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Evaluation of the impact of projects funded under the 6th and 7th EU Framework Programme for RD&D in the area of non-nuclear energy

Final report

Final Report

FP6/7 Energy projects, Mid-term Evaluation

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Executive Summary

History and budgets

The Framework Programme has funded projects on energy since the beginning. After strong support for energy in the first four FPs both the relative importance of energy (as related to the total FP volume) as well as the absolute budgets for energy research decreased sharply in FP5. This was not in line with the political urgency of climate change (e.g. Kyoto protocol, 1998) at the time.

During FP6, energy was mainly supported under the sub-priority "Sustainable energy systems" that had a budget of around €700m, only 3.7% of the budget of FP6. The attention and budget for energy research were, in absolute and relative terms even at an historical low. In FP7, a total of 2,350 M€ (for 7 years, compared to 5 years in previous FPs) was reserved for the sub-programme 'Energy' within the "Cooperation" programme of 32,413 M€ (therefore 7.3% of total was spent on energy). With this budget FP7 was in absolute terms again almost at the level of FP4, but in relative terms the importance was still lower than in the early FP years (15-20%).

Objectives

The objectives of FP6 and FP7 energy research are a mixture of research goals and energy policy goals. From the energy perspective goals are: secure energy supply, sustainable energy supply and enhanced competitiveness of European energy industry. From research policy perspective the four relevant goals are: sustainable development, enhanced competitiveness of Europe, a knowledge based economy and contribution to other policy goals (i.e. energy policy). The mix of demonstration projects and research projects reflects this dual goal setting. With the SET plan in 2008 a more coordinated approach of energy research in Europe was strived for. In practice the focus on climate change goals became stronger. The goals are at the heart of European policy and the relevance of these goals does not need further discussion.

FP6 supported projects research on energy on very different technologies with the objective to increase technological maturity of each technology. In comparison with FP5, FP6 supported larger projects with multiple participants, whereas FP5 projects dealt with one issue at a time. The larger scale of the FP6 projects was not as productive as the more focussed nature of FP5. FP7 came back to the logic that prevailed prior to FP6 and progressively gave up large projects that were designed to involve the whole value chain of the technologies from the research and technology providers to the industrial end users.

Despite clearly defined high-level, strategic and operational objectives for energy research, the intervention logic of the European Commission suffers from an explicit vision at the programme level of the distribution of funding among the different areas in order to reach the high-level objectives. It is unclear on what criteria the distribution of research funds over the various research areas was determined.

Project portfolio

More than 600 non-nuclear energy projects were supported in FP6 and FP7. FP6 supported the implementation of 266 non-nuclear energy-related projects, while 376 projects have been promoted under FP7. The success rate for proposals was around 20% both in FP6 and FP7, indicating that there were five times more projects than EU funding. While in FP6 demonstration projects received 45% of the total EU contribution to projects this share increased to 54% in FP7.

Bioenergy was the area with the largest EU support under FP6 and FP7, receiving a combined total of 517 million Euro in FP6 and FP7. Energy Efficiency and Smart Grids received 461 and 394 million Euro, respectively. CCS/CCT received 271 million Euro, PV 251 million and FCH 198. At the other end, Socio-economic (47 million Euro), Future Emerging Technologies/ Materials (82 million Euro), Other Renewables (109 million Euro), Concentrated Solar Power (112 million Euro), Renewable Heating

& Cooling (131 million Euro), as well as Wind Power (179 million Euro) received the lowest EU contributions. Socio-economic research actually declined in budget between FP6 and FP7, while some other areas such as Bioenergy, Energy Efficiency and PV benefitted less from the increase in overall budget than the other areas.

From FP6 to FP7, the EU funding share has increased from 48% to 58%. This is in part due to increased maximum funding rates for certain types of legal entities, e.g. SMEs, for which maximum funding rates increased from 50% in FP6 to 75% in FP7. Another factor may be changes in participation patterns. Unfortunately, data for FP6 are not sufficiently detailed to allow for an analysis of the evolution of the participation by type of organisation.

Funding rates do not vary greatly between areas with two exceptions: Future Emerging Technologies/Materials and Socio-economic show higher funding shares, and lower project total costs, which is due to a higher participation of research organisations eligible for higher funding rates.

Project participants

In FP7, almost half of the participants are private companies, another almost half are research organisations (with equal shares for higher education and scientific institutes on the one hand and research centres on the other hand); 6% are public organisations and 3% are other organisations. For many areas, distributions reflect this overall picture. A noticeable difference exists for Energy Efficiency. Here, the participation of both types of research organisations is very low indicating perhaps the stronger demonstration focus in this area and/or a certain lack of research activity. In this area, the share of public organisations is very high. Because of the lack of data on FP6 participants it is not possible to identify how industry participation developed between FP6 and FP7.

The average number of participants by project has decreased from 14 in FP6 to 11 in FP7, which is a reflection of progressively giving up very large and complex projects in FP7.

78% of the organisations participating in FP6 and FP7 energy research participated in one project only. This suggests that the FPs are open for participation of new organisations.

While 38 out of 4,615 organisations participated in 15 or more projects, on average each organisation participated in 1.7 projects, and 78% of the organisations participated in one project only. 63% of the participations in FP7 were by participants who had not been active in FP6. This clearly indicates that the FPs allowed new organisations to join and receive funding for their activities. The renewal rate is below average in the small area Socio-economic (43%), but also in the large areas Carbon Capture and Storage/Clean Coal Technologies (51%), PV (56%), Smart Grids (59%) and Wind (59%). Renewal is above average in the areas Concentrated Solar Power (64%), Bioenergy (68%), Other Renewables (70%), Heating & Cooling (74%) and Energy Efficiency (84%).

Participation in FP energy research projects is strongest in metropolitan areas in (North) Western Europe. In FP7 Spain, Portugal and UK increase their participation (compared to FP6), while the 13 new Member States decrease participation.

The geographic distribution of participations is most suitably described relative to the national GDP. Participation is unevenly distributed including differences between Member States, and between regions. Averaged over FP6 and FP7, the Netherlands and Spain participated very strongly relative to the national GDP, while the participation of France and the United Kingdom was very low. A certain tendency towards lower participations can furthermore be found in those countries that have become EU Member States since 2004 as well as in southern Europe as well as in northern Scandinavia. Central Eastern and most of Central Western European participation lost ground from FP6 to FP7, while Spain, Portugal and the UK increased. Participation by Non-EU countries increased from FP6 to FP7. Some regional hot spots are created by the location of administrative seats of research organisations and companies, while the project work may actually be conducted in other regions.

Project budget and EC contribution

The average EU contribution per project increased from FP6 to FP7, suggesting larger, more capital intensive projects closer to commercialisation, esp. in the Bioenergy and Smart grid areas. While in FP6 the average project total budget was 6.5 million Euro with an average project EU contribution of 3.1 million Euro, these figures increased in FP7 to 8.8 and 5.1 million Euro, respectively. As on the other hand the number of participants per project decreased, this is a clear indication that the nature of the projects has evolved towards larger, more capital intensive projects. The largest projects in terms of total budget mainly have demonstration character (although for many projects there was no indication of the formal type of projects). This shows that certain technologies have come closer to commercialisation. Bioenergy and Smart Grids are the most prominent areas in this regard.

Outcomes&impacts

FP6 and FP7 pursued objectives at different levels. These objectives have been presented in Section 1.1. We identified in particular different levels of objectives:

Programme level results

At the level of the programme, both were aimed at increasing efficiency of the energy European system and at mitigating global change. These two objectives are long-term objectives and are difficult to assess.

Besides, the FPs were expected to structure and provide guidelines for the future of the EU energy policy on the one hand and of the EU energy research policy on the other hand. To that regards, the FPs have fulfilled their commitments: the FPs have permitted to elaborate the long-term strategy of the EU. Even though socio-economic projects for instance suffered from insufficient interactions between the participants with the EU officials and industry representatives, the projects have produced valuable tools, models and knowledge on energy.

The FPs has also the duty to establish the Europe Research Area. As far as energy is concerned, the FPs have strongly contributed to the expansion of regional, national or trans-national existing networks. Participants in the projects consensually underlined how they benefited from the programme to start working with new partners from other countries. Projects had strong impacts to what regards transnational cooperation, networking and collaboration within the value chain. The most tangible and remarkable result of the FP6 and FP7 projects is related to the construction of the European Research Area.

Area level results (technological)

At the level of the areas, both FP6 and FP7 aimed at increasing the reduction of cost of technologies (by increasing efficiency of technologies). The state-of-the-art of technology was very heterogeneous across areas, implying different objectives. Sometimes, FP was aimed at developing a second generation of technology (e.g. bio-fuel) or improving existing plant (small hydropower) or buildings (refurbishment for Energy Efficiency), while in other cases, state-of-the-art at the start of FP6 was fragmented basic knowledge and the objective was to take stock of existing knowledge (e.g. socio-economic research).

FP6 was sometimes an opportunity to identify research challenges/bottlenecks that were further investigated during FP7. In other cases, FP6 supported a large variety of technologies in order to identify later on the most promising ones. From that perspective, FP6 projects paved the way for further research in the subsequent FP.

Overall, FP7 was much more focused than FP6 in the sense that fewer technologies were supported and fewer projects were funded within each area. The analysis shows that whatever the level of maturity of technology prior to the start of the FPs, the programmes have enabled an improvement of the technologies. At the level of the areas, FP6 and FP7 have thus permitted outstanding progress.

Impacts on participants

At the level of the participants, a number of conclusions emerge:

- Projects in general reach their technological and scientific objectives. Most project participants (70%) indicate that the project has or will reach or exceed its objectives. A further 20% to 25% indicates that the project largely achieved its objectives. Only a small minority (around 10%) indicates that the objectives were only reached partly, and only 1% indicates that the project failed.
- Scientific outputs of FP participants have been substantial. Scientific organisations reported on average around 8 scientific publications per participation, half of which were published in high impact journals. A (rough) extrapolation for (almost) finished projects shows that in total around 18,000 articles and 8000 articles in high impact journals have been published so far. Just over 11% of participants indicate that their participation is associated with at least one patent application or grant.
- Participants indicate that their participation has led to substantial organisational impacts, especially in terms of improved networks and knowledge position. For all these measures more than 50% of participants indicate that there is more than a small effect on their organization for these two aspects. In terms of economic organisational impact so far, around 20-25% of participating companies see a substantial improvement of more than 5% for turnover and profit. The large majority (76%) of companies indicate that there has been an increase in their general competiveness. However, for only around 2% of participants their participation has had very large effects of more than 25% increase in turnover. profit, FTE or market share.
- The Framework Programme results in a large number of concrete outcomes in terms of potential innovations. Two-thirds of participants see a concrete marketable outcome, now or in the future. These innovations are roughly equally divided across products, services and processes (each around 20%), with business models only around 6%.
- Participants have high expectations regarding the potential turnover and impacts on energy savings, renewable energy generation and CO2 reduction, but uncertainties are high and the road to impact long. Concrete economic and energy impacts are at this moment still limited, but not absent. The aggregate expected annual turnover by participants related to these innovations, taking into account the probability of market entry, amounts to €18 billion - €75 billion by 2020. Note that these impacts will only take place under the condition of substantial additional private and/or public investment and no major negative shifts in policy and market conditions.
- In total 18% of participations indicate to have had an impact on national policy making. Areas with particular high impact were Smart Grids, Other Renewable Energy sources and
- A first exploration of the efficiency of the Framework Programme in terms of scientific outputs, shows that the FP is delivering value for money in technological and scientific terms. A full assessment of efficiency was not possible due to lack of

complete bibliometric data, counterfactual information, and appropriate benchmark programmes.

European Added Value

Although European Added Value is not yet a very well operationalised concept, and EAV is hard to measure it can be concluded that the FP energy programmes permitted the creation and organisation of activities (e.g. research clusters) that would have not been possible at the national level. The FP energy investments have clearly promoted transnational cooperation and networking, improving the Union's research position on a global scale and improving businesses competitiveness in renewable energy technologies. Both FP6 and FP7 have supported the emergence of global research champions and allowed the EU to take or maintain a leadership position in certain areas such as biofuels, wind and smart grids. The energy research in FP6 and FP7 has therefore certainly contributed to the creation of European Added Value.

However, there are still things than can improve.

- ***Fragmentation:*** Both programmes have performed quite well in creating new networks, they have been less successful in promoting actual cooperation and concrete alignment between national and EU research policies. They have also been less successful in closing knowledge gap between the old and new Member States. This has resulted in a a large number of projects, sometimes relatively small, rarely related to each other even within the same area. Interviewees also lamented that there has been little effort from the Commission services to promote interactions between projects and avoid overlaps, which should be one key advantage in terms of EAV and a priority for the European Institutions. There seems to be a lack of concrete instruments or a structured approach aimed to achieve this very purpose.
- **Clusters of excellence and barriers to new entrants**: over time research financing through FPs has promoted the creation of research agglomerates with specialised research institutions that have professionalised project proposal preparation and submission; making it harder and harder for new entrants and smaller players to participate successfully.
- **Additionality**: While it is clear that most projects would not have not been carried out without EU financing, it is not possible to determine yet if these projects truly contributed to the development of research excellence in the EU and have had a strong impact in terms of turnover and profit for the individual company participating. The proper analysis of EAV would strongly benefit from a counterfactual analysis of the real impact of FP6 and FP7 programmes, looking at what would have been the outcomes in the absence of the intervention. This would be possible through a dedicated analysis on the follow-up of FP6 and FP7 rejected proposals (which was not done in this evaluation because data on these projects were not supplied by the EC for.

Conclusions

1. The budgets for FP6 and FP7 for energy are not in relation to the political importance of energy and climate change (Kyoto agreement, 1998) and the public debate on climate change at the time of the conception of the plans.
2. Despite clearly defined high-level, strategic and operational objectives for energy research, which show the relevance of the FP energy research, the intervention logic of the European Commission suffers from an explicit vision at the programme level of the distribution of funding among the different areas in order to reach the high-level objectives. It is unclear on what criteria the distribution of research funds over the various research areas was determined.
3. There were significant differences in organisational set-up between FP6 and FP7. These differences seem not to have led to large differences in participation,

appreciation and impact between FP6 and FP7. Differences in timing and the lack of information on a large part of FP6 projects make direct comparison however difficult.

4. The FPs have contributed to the (further) construction of the European Research Area in the field of energy. The energy research in FP6 and FP7 can be considered scientifically successful.
5. The energy research in FP can be considered technologically successful.
6. Before the cost reduction that is aimed for is achieved in the market, further development of FP results is generally necessary. Economic impacts were not as high as expected.
7. The potential and expected future impacts on energy savings, renewable energy production and CO2-emission reduction are substantial, but measurable impacts so far are limited (but not negligible)
8. It is too early to tell whether the main objectives of FP6 and FP 7 at the programme level with respect to energy (increasing efficiency of the energy European system and at mitigating global change) have been met. These two objectives are long-term objectives and are difficult to assess.
9. Furthermore the FPs have permitted to elaborate the long-term energy strategy of the EU
10. The energy research in FP6 and FP7 has therefore certainly contributed to the creation of European Added Value.

Recommendations

1. It is recommended to continue investments in energy research. This is already part of Horizon2020.
2. It is recommended to develop a more systemic vision on the role of various technologies in achieving the higher level goals of the FP energy research in order to determine the distribution of funding among the different areas (including new, upcoming areas).
3. It is recommend to maintain a broad portfolio of support instruments to suit the varying project needs.
4. The European Commission services are advised to strengthen their program and project management processes, and add a project portfolio management approach comparable to what is being done in the private sector.
5. It is recommended to have more systematic attention for valorisation of research results and capitalisation of results from demonstration projects from the EC, as part of the FP (i.e. Horizon2020) to increase economic and societal impact.
6. Regulation and (energy) policies should be used to support the successful application of research results (and research results should be used to determine optimal policies.
7. Specific attention for reducing administrative burdens and support possible new entrants is recommended.
8. In order to improve future evaluation and monitoring data management at the EC must improve and evaluators must get access to all data available.
9. It is recommended that the EC, in future Terms of Reference does not describe methodology in detail but will give more freedom to evaluators to develop optimal evaluation strategies.

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Glossary

Abbreviation	In full
BIO	Bio energy
CA	Coordination of network actions
CCS/CCT	Carbon Capture and Storage / Clean Coal Technologies
CSP	Concentrated Solar Power
DG RTD	Directorate-General for Research and Technological Development
DG ENER	Directorate-General for Energy (since 2010)
DG TREN	Directorate-General for Transport and Energy (until 2010)
EAV	European Added Value
EC	European Commission
EE	Energy efficiency
EU	European Union
ETP	European Technology Platform
ERA	European Research Area
FCH	Fuel Cells and Hydrogen
FETm	Future Emerging Technologies & Materials
FP	Framework Programme
IEE	Intelligent Energy Europe
IP	Integrated projects
JTI	Joint Technology Initiative
MS	Member State
NOE	Network of excellence
OthRen	Other renewable energy sources
PV	Photo voltaic energy
(R)HC	(Renewable) Heating & Cooling
SA	Support Actions
SE	Socio-economic
SET-plan	The European Strategic Energy Technology plan
SG	Smart grids
STREP	Focused projects
TRL	Technology Readiness Level
Wind	Wind energy

1. Context of this mid-term evaluation and this report

1.1 Background of this mid-term evaluation

The **Framework Programme for Research and Technological Development (FP)** has been the main instrument of EU policy in the field of research. It defines the objectives, priorities and conditions of the research funding of the European Commission. It was the most important instrument for the implementation of the Innovation Union strategy. This flagship initiative, which has been the part of the Europe 2020 Strategy aimed to strengthen Europe's ability to compete and promote sustainable growth.

This study was launched to investigate the scientific, technological and innovation impact of **energy research projects** funded under FP6 and FP7. As mentioned in the Tasks Specifications, the study was aimed at assessing the use of projects results, the impact of the projects on the participants and the European dimension of the projects.

The objectives of the study were three-fold:

- At the **project level**, the objective was to determine the economic and scientific impact of the projects on the participants;
- At the **area level**, the objective was to assess the advancement of scientific and technological knowledge due to the projects;
- At the **programme level**, the objectives were:
  - To assess the contribution of the EU intervention for achieving the FP6/7 objectives and the objectives of EU energy and research policy (in particular the SET-Plan);
  - To analyse the complementarities and synergies between research and demonstration activities supported by FP6 and FP7;
  - To analyse the structuring and leveraging effect of EU supported activities towards activities carried out within the Member States.

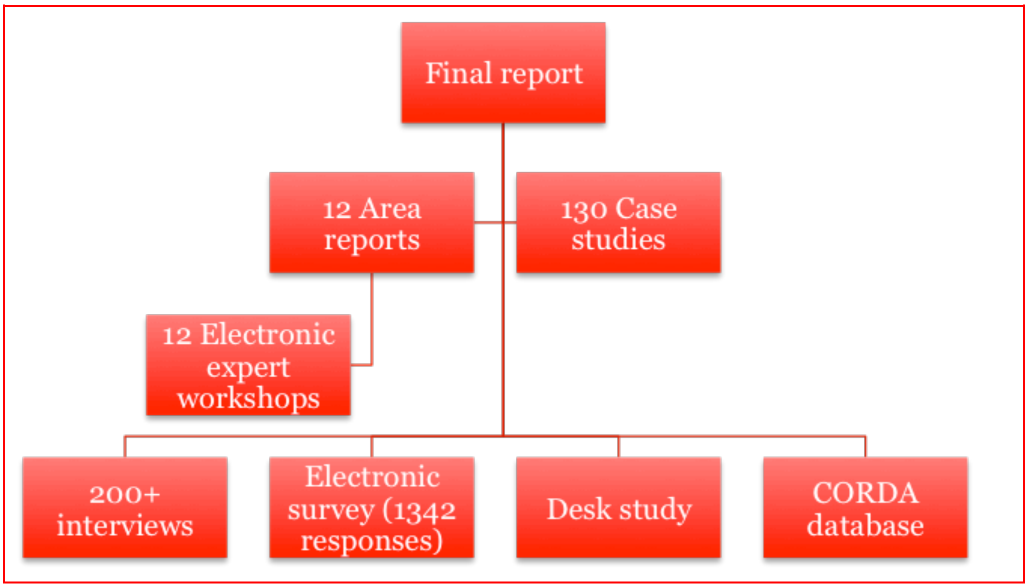
1.2 Methodology and approach

This final report is the synthesis of a large amount of empirical work that underpins this report. The figure below gives an overview of the data collection and analysis that is the foundation for this report. A combination of qualitative (such as interviews for case studies) and more quantitative methods (electronic survey) were used in an integral manner:

- Desk study, both on programme level (e.g. policy documents), area level (e.g. technological road-maps) and project level.
- The CORDA database and EC monitoring information provided information on the background details of projects and their participants. Limited additional monitoring information was available (such as progress reports), especially for FP6 projects.
- Interviews with 200+ participants, from all technological areas, national and organisational backgrounds. Include both project coordinators as well as participants. Additional interviews were held on the programme- and area-levels, such as with EU and MS policy stakeholders, key experts and EC representatives.
- An electronic survey sent to all FP6 and FP7 participants of which email addresses were available through the CORDA database, resulting in 1342 responses (18%).

- Electronic workshop with policy stakeholders and technical experts were held on the basis of draft area reports. These online discussions (one for each area) delivered valuable contextual interpretation and served to validate conclusions on the area level.

Figure 1 Data sources



These tools were used to produce three main types of outputs:

- 130 case studies of individual FP projects. After a careful portfolio analysis the number of case studies were distributed across the different areas, type of sub-technologies and type of funding instruments. These case studies describe the background of the project and its participants, results and impacts (scientific, technological, economic and energy-related).
- 12 area reports of technological areas[1], based on case studies and information from the electronic surveys, with additional desk work and interviews, discuss the main impacts on the technology field and its constituents (companies, research institutes, universities, public organisations). The are reports have been validated in the electronic workshops
- This final report

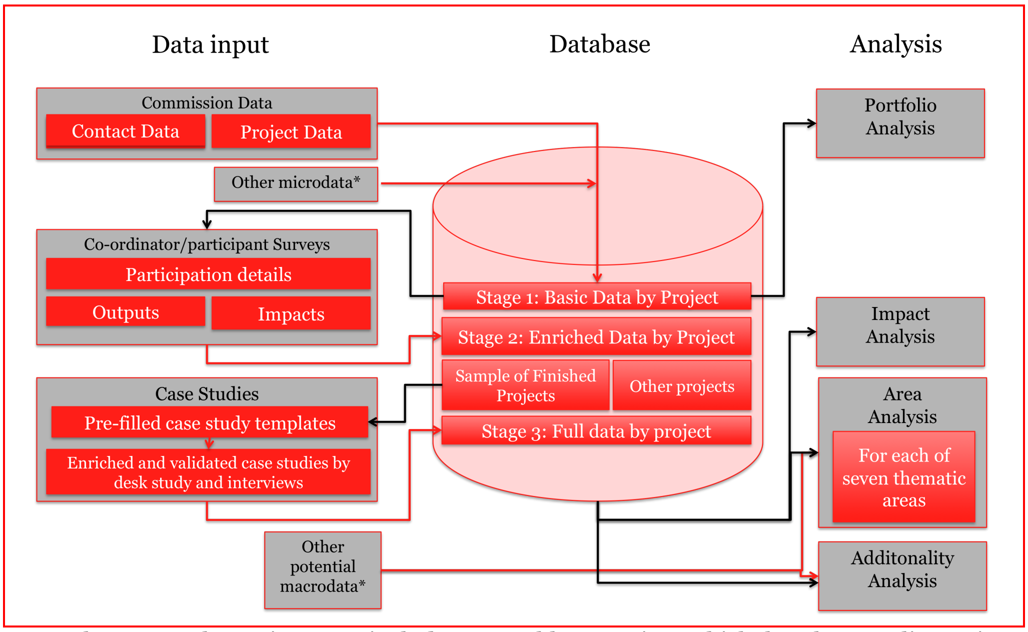
This main report is focused on the level of the Framework Programmes, but uses examples and evidence from the area and project level extensively. Both the area reports and the main reports make extensive used of the integrated data from the electronic survey and the case studies – which in turn rely mostly on interviews with FP participants.

All data sources above were analysed in an integral manner through our evaluation database. An overview of this database is presented in the figure below. As such, the selection and implementation of case studies were informed by the information from the electronic survey, but the case studies also served as validation with individual participants. This cross-validation has improved the reliability of the results. The final

[1] Bioenergy; Carbon capture and storage & clean coal technologies; Concentrated solar power; Energy efficiency; Fuel Cell and Hydrogen; Future & Emerging Technologies materials; Heating and cooling; Photovoltaic energy; Socio-economic; Smart grids; Wind energy; Other renewable energy sources

qualitative and quantitative analyses are based on the integrated and validated evaluation database.

Figure 2 Evaluation database



Note: the seven thematic areas include renewable energies, which has been split up in 6 individual areas.

1.3 Data issues

The execution of project was seriously hampered by various data-issues.

- Files on individual projects at the European Commission were not made accessible for the evaluators. Applications, progress reports, final reports and other communication between the project participants and EC officials could only be used by the project team if made public by the project partners themselves (in practice this meant that only final reports that were published on the internet could be used).
- In addition the CORDA database that contains data on the contracted projects for the Framework Programme turned out to be incomplete and not up-to-date. As a consequence a large part of FP6 projects could not be taken into account in the analysis and many FP6 project coordinators and project participants could not be surveyed (because even names and contact data were unavailable). Contract data that were mentioned in CORDA referred to the original contracts that had been closed between the consortia and the EC, and project changes that occurred during the projects were not conveyed to the evaluation team. Unambiguous characterisation of the projects (e.g. demonstration or research project; thematic area) was missing.
- With a referral to privacy legislation contact data of unsuccessful applicants were not provided to the evaluation team. This meant that the intended survey among this group (in order to e.g. provide counterfactual information that could be used for determining additionality of the FP) was not possible.
- The ToR for the project indicated that additional data (on energy research in FP7) were available by way SETIS, the Strategic Energy Technologies Information System. The data-collection within SETIS on FP7 (by means of the Energy

Research Knowledge Centre (EKRC) had however not progressed to such an extent that the information could be already used for this evaluation.

In order to overcome these issues large efforts were made by the evaluation team, especially in retrieving e-mail addresses of coordinators for FP6 projects. Most of these were found, but many participant addresses remained unknown. As a consequence FP6 projects are somewhat underrepresented in the survey, and for some issues no conclusions could be drawn about FP6. Overall however the use of various methods during the evaluation (triangulation) makes that this final report presents a broad overview and analysis and robust conclusions on the FP energy projects.

More detailed information on the methodology is presented in the Appendix.

1.4 Structure of this report

The report is structured around the following main sections:

- Policy background of FP6 and FP7
- Implementation of the FPs: Portfolio Analysis
- Effectiveness, Efficiency and Impacts of the FP6 and FP7
- European Added Value
- Conclusions and Recommendations

2. Policy background of FP6 and FP7, programme goals

2.1 The EU Framework Programme

The **Framework Programme for Research and Technological Development (FP)** is the main instrument of EU policy in the field of research: it defines the objectives, priorities and conditions of the research funding of the European Commission. In practice, the FP is the primary instrument for funding research in Europe. It is also considered the most important instrument for the implementation of the Innovation Union strategy. This flagship initiative, which part of the Europe 2020 Strategy aims to strengthen Europe's ability to compete and promote sustainable growth. According to the principle of subsidiarity, FP co-finances the development of cross-border research projects.

2.1.1 Framework programme historical background

EU Research framework has evolved and developed constantly throughout the past 30 years, according to the needs EU of innovation policy and the creation of the internal market. The first step taken towards an integrated EU research approach goes as far as the 21st December 1982, when the Council approved a preparatory phase for a Community Research and Development Programme in the field of Information Technologies[2]. EU-wide research was promoted at the time in order to reduce a perceived gap between the EU industries and their biggest competitors, mostly from the US and Japan. The first Framework Programme, commonly known by the acronym "FP1", was launched in 1984 and run for a period of 4 years, with an allotted budget of 3.27 billion ECUs[3], it covered a limited number of activities and was more reactive than proactive. It is only since the launch **Lisbon Strategy** in 2000, that Research policy has become one of the key elements of European policy to promote economic growth and the creation of new jobs. Precursor to Europe 2020 strategy, the Lisbon strategy was a development plan, whose main scope was to create in the EU *'the most competitive and dynamic knowledge-based economy'*[4] in the world and to lay down solid basis for the creation of the single market between 2000 and 2010. Another important goal of the Lisbon Strategy was also the creation of new jobs and the improvement of labour skills across the EU. The EU launched the **European Research Area (ERA)** in 2000 as a key element for implementing the Lisbon strategy. ERA comprehends three major aspects:

- The creation of a EU internal market for research, where people, ideas and technologies can circulate freely,
- EU-wide coordination of all research activities
- The implementation of "ERA instruments", such as the Framework Programme to promote cross-country research

The establishment of ERA was followed by the pledge of increasing R&D national spending up to 3% of GDP during the summit of Barcelona in 2002. These policy actions led to major changes to the structure of the programme, which are particularly noticeable from FP6 onward. According to Andrée 2009, during the FP1 – FP5 (1984

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[2] Andrée D. 2009, "Priority-setting in the European Research Framework Programmes", VINNOVA, Swedish Governmental Agency for Innovation Systems.

[3] Development of Community research – commitments 1984 – 2013 (current prices), European Commission: http://ec.europa.eu/research/fp7/pdf/fp-1984-2013_en.pdf

[4] Lisbon European Council 23 and 24 March 2000, Presidency Conclusion, http://www.europarl.europa.eu/summits/lis1_en.htm

– 2002) **there was very little interaction between FP and national programmes**, national authorities were not engaged heavily in the preparation of research priorities and the various FPs were perceived as additional tools to national research activities, rather than as an integral part of them. However since 2002 FP has become the most important financial and legal tool for the implementation of ERA priorities, therefore both FP6 and FP7 have interacted more with national programmes and private investments than any predecessor. As a consequence of the growing interest in EU-wide research, the budget of the FP has increased steadily since its start and stands at around EUR 54 billion for FP7, making of it the world's largest research programme as well as the largest budget administered directly by the European Commission. Figure 1 below shows clearly the constant increase in budget dedicated to the FP from 1984 until nowadays.

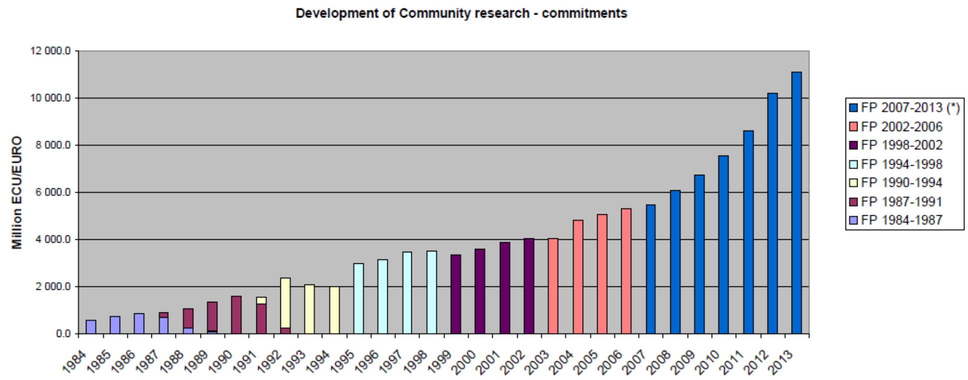

Figure 3 Development of Community research committed (current prices) from 1984 till 2013[5]

2.1.2 FP6 and FP7 basic features

The core structure of the FP remained unchanged between FP6 and FP7 (see figure 2).

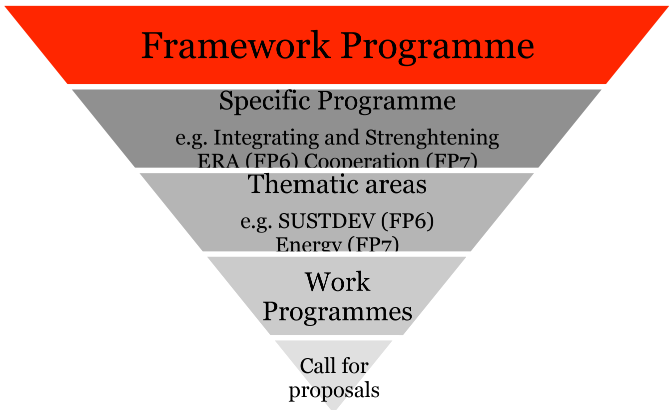

Figure 4 FP proposal framework

The FP is composed of many sub programmes addressing different themes and associated goals. The overarching specific programme defines the overall objectives of the programme throughout its duration. The specific programme is then divided into "Thematic Areas" (e.g. Energy), which are implemented through annual "Work Programmes" elaborated by the Commission and consented by Member States.

5 Development of Community research – commitments 1984 – 2013 (current prices), European Commission: http://ec.europa.eu/research/fp7/pdf/fp-1984-2013_en.pdf

Finally, call for proposals are published each year, proposing specific topics for research in the different areas of interest.

The **6th Framework Programme for Research and Technological Development of the European Union (FP6)** represented a deliberate break with the previous Framework Programmes, presenting more ambitious and innovative means of implementation. For the first time, FP6 was also the result of intensive preparation and consultation activities among the scientific and industrial community and public authorities at different levels. FP6 major goal was to reduce EU Research fragmentation by introducing innovative features to promote the implementation of innovative projects:

- Concentrate EU financing on a limited number of key priorities for Europe
- Foster the creation of network groups of researchers across Europe
- Promote greater mobility of researchers and more attractive place for foreign researchers

FP6 also introduced new funding instruments such as Integrated Projects and Networks of Excellence, and attempted to simplify the administrative procedures, these have been again modified in the following programme FP7. The total budget for the period 2002-2006 amounted to 17,500 million Euros (excluding nuclear research), roughly 4% of EU Member States expenditure on Research and Development activities[6]. The largest bulk of the FP6 budget allocated to the Programme "Integrating and strengthening the European Research Area", divided into seven thematic priority areas.

While building up on the basic structures of the FP6, **the 7th Framework Programme for Research and Technological Development of the European Union (FP7)** aims to achieve several new goals, such as strengthening the scientific and technological bases of industry, promote the international competitiveness and promote research activities in the European Community[7]. It is a multiannual program (2007-2013) with a structure based on four specific programs:

- **Cooperation**: aims to promote cooperation and to strengthen the ties between industry and research within a transnational framework. The goal is to build and strengthen European leadership in the areas most important research. The program is divided into nine themes, self-management, but complementary in terms of the implementation:
- **Ideas:** foster the dynamism, creativity and excellence of European research at the frontier of knowledge in all scientific and technological fields, including engineering, science socio-economic and humanities. This action will be supervised by the European Council research.
- **People**: increasing the quantity and quality of human resources in research and technology in Europe by fostering the movement of researchers across Europe especially through a set of Marie Curie actions.
- **Capacity**: The objective of this action is to support research infrastructures, research in benefit of SMEs and the research potential of European regions (Regions of Knowledge) encourage the realization of the full potential of search (convergence regions) of the Enlarged European Union and to build a European knowledge society effective and democratic.

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[6] http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/fp6_ex-post_evaluation_expert_group_report.pdf#view=fit&pagemode=none

[7] "FP7 in Brief How to get involved in the EU 7th Framework Programme for Research" EC: http://ec.europa.eu/research/fp7/pdf/fp7-inbrief_en.pdf

The overall FP7 budget, by far the largest until now, is of €50 521 M for a period of 7 years. Figure 3 below represents the FP7 breakdown according to the different thematic areas.

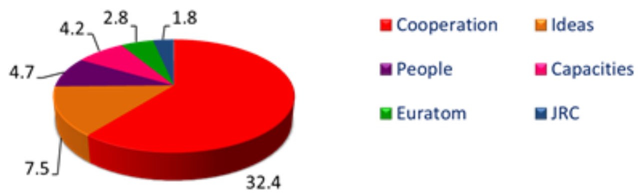

Figure 5 FP7 breakdown Euros according to the different thematic areas

2.2 Energy in FP

2.2.1 Historic overview investments in energy research in FP

The Framework Programme has funded projects on energy since the beginning. Energy has even always been a pillar of the Framework Programmes[8]. The first Framework Programme (1984-1987) forecasted almost one half of the total budget (47.2%) for the improvement of energy resources (nuclear and non nuclear), which represented €1.8b. The share of the budget devoted to energy decreased during the second Framework Programme (1987-1991) and the third Framework Programme (1990-1994), with respectively 21.7% and 15.9% of the budget oriented towards energy. In terms of absolute budget, energy received a slightly decreasing amount of EC funding during FP2 and FP3: respectively around €1.2b and around €1b.

The fourth Framework Programme (1994-1998) increased the budget devoted to non-nuclear energy which was supported by the programmes JOULE and THERMIE embedded in the first activity of the FP. In total, energy research received €2.1b during FP4. The fifth Framework Programme (1998-2002) supported non-nuclear energy with the programme "Energy, Environment and Sustainable Development" (EESD) that had a budget of €1.0b[9] that is to say close to the budget of FP2 and FP3.

After the strong support for energy in the first four FPs both the relative importance of energy (as related to the total FP volume) as well as the absolute budgets for energy research decreased sharply (which is strange considering the Kyoto-protocol that was drafted in 1997). In the fifth Framework Programme (1998-2002) energy was mainly supported by the programme "Energy, Environment and Sustainable Development" (EESD). €1.0b was devoted to non-nuclear energy[10](8.0% of the budget).

During FP6, energy was mainly supported by the Priority 6 "Sustainable development, global change and ecosystems" (SUSTDEV) for which 12.1% of the budget of FP6 and €2.3b were targeted. Priority 6 was divided into three sub-priorities, of which "Sustainable energy systems" that had a forecasted budget of around €700m. The budget available for (non-nuclear) energy therefore represented only 3.7% of the budget of FP6, the lowest budget ever for energy during the history of the Framework Programmes.

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[8] http://earma-vienna-2013.book-of-abstracts.com/fileadmin/earma2013/presentations/03-07_HORVAT_EARMA_2013-30thEURTD-PS-72.pdf

[9] http://cordis.europa.eu/eesd/

[10] http://cordis.europa.eu/eesd/

In FP7, a total of 2,350 M€ (for 7 years, compared to 5 years in previous FPs) was reserved for the sub-programme 'Energy' within the "Cooperation" programme of 32,413 M€ (therefore 7.3% of total was spent on energy).

In FP7 the budget in absolute terms was again almost at the level of FP4, but in relative terms the importance is still lower than in the early FP years:

2.3 The FP6 objectives

The strategic objectives of FP6 in the energy area addressed the reduction of greenhouse gases and pollutant emissions, the security of energy supply, the increased use of renewable energy as well as to achieve an enhanced competitiveness of European industry. There were two parts to energy RTD in FP6:

- Research activities having an impact in the short and medium term (265 M€). These activities were managed by DG TREN in order to bring innovative and cost competitive technological solutions to the market as quickly as possible through demonstration. The areas covered: Clean energy, in particular renewable energy sources and their integration in the energy system, including storage, distribution and use; Energy savings and energy efficiency, including the use of renewable raw materials and Alternative motor fuels.
- Research activities having an impact in the medium and longer term (436 M€). DG RTD led this action with a view to developing new and renewable energy sources, and new carriers. The goal was to foster further reduction in greenhouse gas emissions beyond the deadline of 2010. Research topics were structured as follows: Fuel cells including their applications; New technologies for energy carriers/transport and storage, in particular Hydrogen; New and advanced concepts in renewable energy technologies and Capture and sequestration of CO_2, associated with cleaner fossil fuel plants.

2.4 Green Paper on Energy, SET-Plan, FP7

2.4.1 2006 Green paper on Energy

At the end of FP6 the 2006 Green Paper on Energy concluded that:

> "The EU needs to consider ways to finance a more strategic approach to energy research, taking further steps towards integrating and coordinating Community and national research and innovation programmes and budgets. Building upon the experience and output of European technology platforms, high-level stakeholders and decision-makers need to be mobilised to develop an EU vision for the transformation of the energy system and to maximise the efficiency of the overall research effort"[11].

The 2006 Green Paper on Energy is also very clear on the need to better link the EU energy research policies with the EU energy policies. R&D is taken into account and considered as a way to make EU policy on renewable energy more effective:

> *The Renewable Energy Road Map would cover key issues for an effective EU policy on renewable energy among which: "Research, demonstration and market replication initiatives to bring clean and renewable energy sources closer to market"*

[11] European Commission (2006), *A European strategy for sustainable, competitive and secure energy*, [COM(2006) 105]

"A resourced strategic energy technology plan to accelerate the development of research in promising energy technologies. "Research in areas of high energy use, housing, transport, agriculture, agro-industries, and materials should also be addressed. (...) The plan should strengthen the European research effort to prevent overlaps in national technology and research programmes (...)"

"The EU needs to consider ways to finance a more strategic approach to energy research, taking further steps towards integrating and coordinating Community and national research and innovation programmes and budgets. Building upon the experience and output of European technology platforms, high-level stakeholders and decision-makers need to be mobilised to develop an EU vision for the transformation of the energy system and to maximise the efficiency of the overall research effort."

Besides, one objective identified in the Green Paper was to provide a common framework for national energy policies. The strategy was to better articulate national energy policies by providing tools to support the set-up of a European grid, investments in infrastructure and in generation capacity and by defining a common approach for energy mix, energy efficiency and use of renewable energy sources.

2.4.2 The SET plan

In order to realise a transformation of the entire energy system and make low-carbon technologies affordable and competitive in 2008 the Strategic Energy Technology Plan (SET-Plan) was launched. The EU's approach in the SET Plan focuses on the European Industrial Initiatives (EII). Industry-led, the EIIs aim to strengthen industrial participation in energy research and demonstration, boost innovation and accelerate deployment of low-carbon energy technologies. EIIs target sectors in which working at EU level adds most value, and technologies for which the barriers, the scale of the investment and the risk involved can be better tackled collectively. There are EIIs for the main areas of sustainable energy: Bioenergy, Fuel Cells and Hydrogen, Solar and Wind. Other EIIs are aiming at providing good framework conditions for sustainable energy (The European Electricity Grid Initiative) or making non-renewable energy systems more sustainable (in the areas Nuclear and Energy Efficiency (Smart Cities)).

The *Review of the SET- Plan Implementation Mechanisms for the period 2010 – 2012*[12] reported:

EIIs even at this embryonic stage are proven unique mechanisms for industrial-driven research and innovation. The Teams that are leading and coordinating these however, do not fully meet their foreseen mission and key objectives. They mostly miss a balanced and representative group of industries and often of Member States with clear commitment to strategic planning, investment and coordinated implementation. Supported by the European Technology Platforms, whose contributions have been valuable, they have demonstrated capacity to prioritizing and planning of actions. However, it is their decision making and ability to putting into 'operation' the implementation plans that are limited.

The SET plan strongly affected the set up of FP7, a.o. by a number of roadmaps that were developed within the EIIs, and that determined the topics for research under FP7.

[12] http://setis.ec.europa.eu/system/files/SET-Plan_%20Review%20of%20Implementation%202010-12.pdf

2.4.3 FP7 objectives

The European Commission defined the objectives of FP7 for energy as follows:

- To improve energy efficiency throughout the energy system;
- To accelerate the penetration of renewable energy sources;
- To decarbonise power generation and, in the longer term, substantially decarbonise transport;
- To reduce greenhouse gas emissions;
- To diversify Europe's energy mix[13].

A broad portfolio of technologies was supported for two main reasons:

10. The recognition that none of the technologies being developed can make a sufficient difference on their own and that their commercialisation will take place over differing time horizons; and
11. In order reduce the risk and potentially the costs, if one or more technologies fail to make the expected progress[14].

2.4.4 Differences in focus between FP6 and FP7

Between FP6 and FP7, there are furthermore large differences in organisational focus. FP6 supported projects research on energy on very different technologies with the objective to increase technological maturity of each technology. The Evaluation and Impact Assessment of the European Non Nuclear Energy RTD Programme carried by EPEC in 2009 underlined that the main difference between FP5 and FP6 was that FP6 supported larger projects with multiple participants, whereas FP5 projects dealt with one issue at a time. The conclusion was that the larger scale of the FP6 projects was not as productive as the more focussed nature of FP5[15].

FP7 came back to the logic that prevailed prior to FP6 and progressively gave up large projects that were designed to involve the whole value chain of the technologies from the research and technology providers to the industrial end users.

This is visible from the evolution of the calls during FP7. To that regards, Ecorys (2010) noted that FP7 was characterised by "fewer projects, with fewer partners[16]." from the second call onwards and by a "major reduction in the number of topics open per call".

2.5 Logical Framework Analysis for FP6/7 energy support

FP6/7 energy projects therefore have, as has been discussed above, two different policy backgrounds: research policy as well as energy policy. Based on the midterm evaluation of energy projects in FP7 by Ecorys and earlier work on the objectives of the Framework Programme (Technopolis 2011), four links can be identified between the rationales of energy and research policy at the high-level objectives:

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[13] http://www.transport-research.info/web/programmes/programme_details.cfm?ID=46221

[14] http://cordis.europa.eu/fp7/energy/

[15] EPEC (2009), *Evaluation and Impact Assessment of the European Non Nuclear Energy RTD Programme*, report for DG RTD.

[16] Ecorys (2010), *FP7 Energy Mid-Term Evaluation*, report for the EC/DG Energy

- Both rationales include explicitly the high-level objective to 'Enhance Europe's competitiveness'
- 'Support other Community Policies' is an explicit FP rationale, therefore including energy policy (implementation of SET-plan)
- The high level objectives 'Ensure sustainable development & economic growth' (from FP) and 'Environmental sustainability of energy supply' (SET-plan) show much overlap.
- A 'knowledge based economy' contributes directly to an 'enhanced competitiveness of Europe'.

In Figure 6 this combined rationale for the energy part of FP is present in a simplified form, focused on the (energy) cooperation projects in FP.

At the highest level objectives, the three goals of the SET plan (secure energy supply, sustainable energy supply and enhanced competitiveness of European energy industry) combine with the four relevant goals of FP research (sustainable development, enhanced competitiveness of Europe, a knowledge based economy and contribution to other policy goals (i.e. energy policy).

Strategic and operational perspectives cannot be clearly separated: strategic objectives for the FP may be operational objectives for the energy research, since from the perspective of energy policy, research is a means to generate innovation that will lead to impacts in the energy field while from the perspective of research policy, energy is a market for application for the results of research, in order to create research impact.

Apart from the very energy-specific 20-20-20 goals, the energy research policy goals and FP goals are very much in line and consisting of:

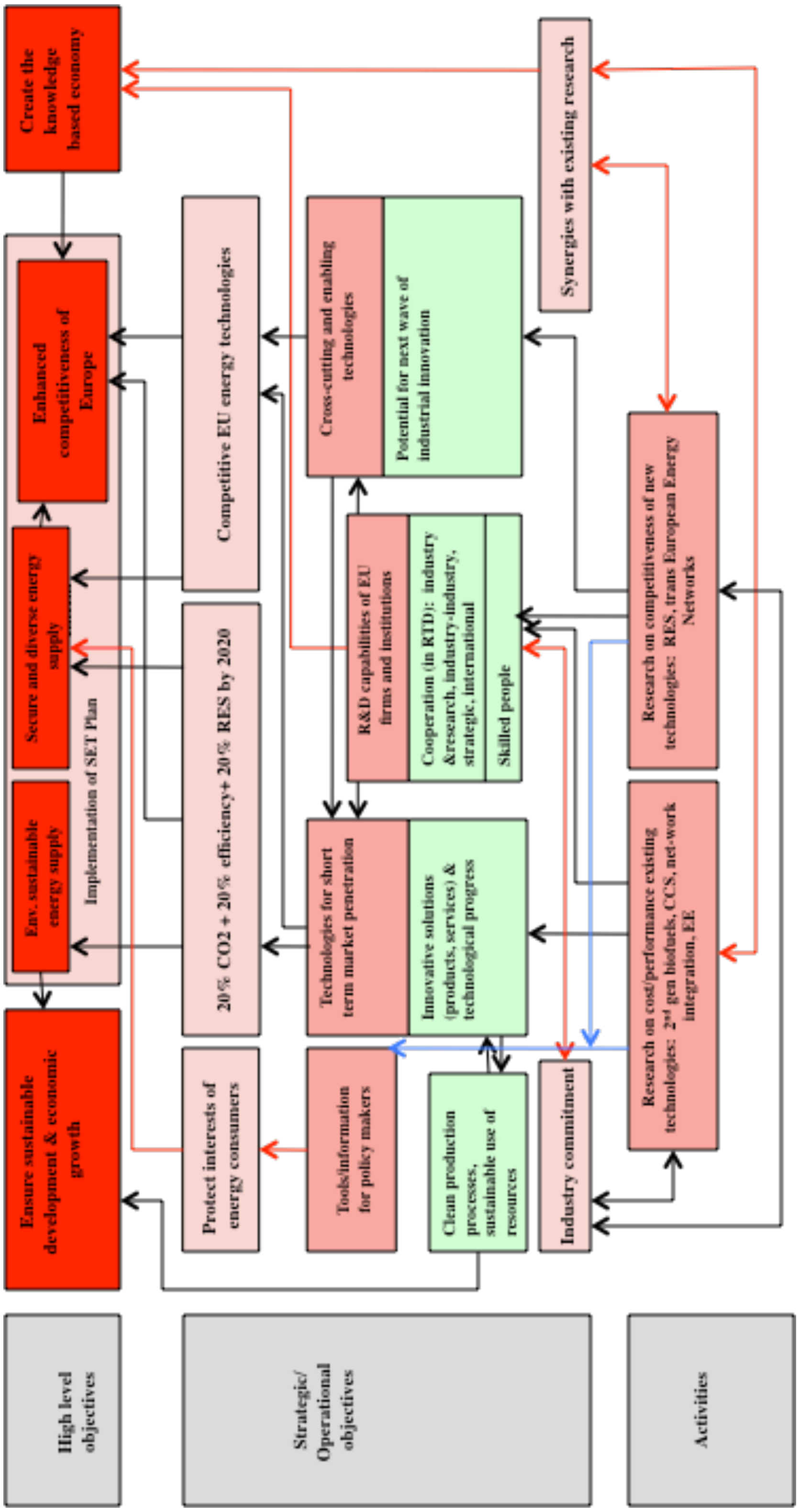
- Goals related to innovation (technology development leading to market implementation)
- Goals related to research (enabling technologies for longer term renewal of industry)
- Goals related to R&D capabilities and competitiveness of firms (at highest level: knowledge based economy)
- Goals related to knowledge for policy making

'Industry commitment' (and financial contribution) and 'Synergies with existing research' (from other EU/MS programmes like IEE, JTIs, but also as done in settings like EERA or EIIs) are amongst the operational objectives, but these can also be considered inputs for the research programmes on energy in the FPs by providing ideas, knowledge, skills and networks.

Main activities are the research programmes in FP6 and FP7, including, in line with the 'dual' goals in energy and innovation (and therefore showing direct relevance) , more demonstration oriented short term projects (focused on improving the cost-performance of existing technologies like energy from biomass, and energy efficiency) and longer term oriented research projects on the competiveness of new technologies (with more emphasis on e.g. Renewable Energy Sources).

Despite clearly defined and relevant high-level, strategic and operational objectives for energy research, the intervention logic of the European Commission suffers from an explicit vision at the programme level of the distribution of funding among the different areas in order to reach the high-level objectives. In FP6 the breakdown of EC funding into the different areas could only be made after the calls had been closed and the selection of projects had been made. In FP7 the calls were more thematically oriented, and although it is obvious that in the distribution of funds between long- and short-term and over the various research areas the (environmental and economic) potential of technologies played a role, it is not very explicit why the distribution of research funds over the various research areas is as it is.

Figure 6 Simplified intervention logic for energy research in FP6 and FP7



Technopolis, for this study

2.6 Conclusions

The political urgency of climate change (e.g. Kyoto protocol, 1998) was not reflected in budget and relative importance of energy research in FP6, in absolute and relative terms the attention for energy research was at an historical low. In FP7 the budget in absolute terms again almost at the level of FP4, but in relative terms (7.3%) the importance still lower than in the early FP years (15-20%).

The Framework Programme has funded projects on energy since the beginning. After strong support for energy in the first four FPs both the relative importance of energy (as related to the total FP volume) as well as the absolute budgets for energy research decreased sharply (which is strange considering the Kyoto-protocol that was drafted in 1997) in FP5 and even further in FP6.

During FP6, energy was mainly supported under the sub-priority “Sustainable energy systems” that had a budget of around €700m, only 3.7% of the budget of FP6.

In FP7, a total of 2,350 M€ (for 7 years, compared to 5 years in previous FPs) was reserved for the sub-programme ‘Energy’ within the “Cooperation” programme of 32,413 M€ (therefore 7.3% of total was spent on energy).

In FP7 the budget in absolute terms was again almost at the level of FP4, but in relative terms the importance is still lower than in the early FP years (15-20%).

Goals of FP6 and FP7 energy research are a mixture of research goals and energy policy goals. Combating climate change becomes more and more important over time.

From the energy perspective goals are: secure energy supply, sustainable energy supply and enhanced competitiveness of European energy industry. From research policy perspective the four relevant goals are: sustainable development, enhanced competitiveness of Europe, a knowledge based economy and contribution to other policy goals (i.e. energy policy). The mix of demonstration projects and research projects reflects this dual goal setting. With the SET plan in 2008 a more coordinated approach of energy research in Europe was strived for. In practice the focus on climate change goals became stronger.

Despite clearly defined high-level, strategic and operational objectives for energy research, the intervention logic of the European Commission suffers from an explicit vision at the programme level of the distribution of funding among the different areas in order to reach the high-level objectives. It is unclear on what criteria the distribution of research funds over the various research areas was determined.

FP7 has stronger focus than FP6 with more calls on smaller topics, and smaller more focused projects with on average a smaller number of partners.

FP6 supported projects research on energy on very different technologies with the objective to increase technological maturity of each technology. In comparison with FP5, FP6 supported larger projects with multiple participants, whereas FP5 projects dealt with one issue at a time. The larger scale of the FP6 projects was not as productive as the more focussed nature of FP5. FP7 came back to the logic that prevailed prior to FP6 and progressively gave up large projects that were designed to involve the whole value chain of the technologies from the research and technology providers to the industrial end users.

3. Implementation of the FPs: Portfolio Analysis

3.1 Implementation

The European Commission manages and implements the Framework Programmes by elaborating and publishing annual work programmes including the schedules of calls for proposals. These calls, which are announced in the EU's Official Journal as well as on the CORDIS and Participants Portal's website dedicated to EU-supported research, usually cover specific research areas for which funding is made available under the call. The 642 energy projects funded under FP6 (266 projects) and FP7 (376 projects) were funded under 55 individual calls, of which 15 in FP6 and 40 in FP7. The strongly increased number of calls in FP7 shows the new approach of more specific and detailed calls compared to the more generic calls in FP6.

Applicants submit their proposals after the launch of a call and before the deadline specified in the call. All proposals submitted are evaluated by a panel of independent experts who are acknowledged specialists in their respective field. The proposals are evaluated against a set of predefined criteria, for which minimum requirements (thresholds) are defined. All proposals within a certain field passing these thresholds are ranked according to their quality. The best proposals are then retained for funding based on the pre-defined budget for that call and the EU funding requested by these proposals. The European Commission enters into financial and scientific/technical negotiations with each project consortium, and, if successfully finalised, draws up grant agreements with the project participants.

In general, more proposals are submitted than funded. In FP6, the overall success rate was 18%[17]; within *Sustainable Development* including *Energy*, the success rate was 17.6% (based on the number of proposals), and 21.9% (based on the number of applicants)[18]. In FP7, the overall success rates slightly increased for the period of 2007 to 2012 to 19% (based on the number of proposals), 22% (based on the number of applicants) and 19% (based on the EU funding). For *Co-operation* including *Energy* the success rates correspond to the overall numbers, except for a 21% success rate based on the EU funding[19].

While participants indicate a certain improvement in the administrative burden related to project administration in FP7 compared to FP6, many indicate that national funding schemes put lower administrative burden on them than the framework programmes.

3.2 Analysis of R&D versus demonstration projects

In FP6 and FP7, energy projects are not systematically classified as R&D or demonstration projects in the available data. As a rough estimate, projects administered by DG ENER (formerly by DG TREN) can be taken to have a demonstration character, while projects administered by DG Research have a research focus. Based on this approximation, the number of demonstration projects slightly increased from 126 in FP6 to 135 in FP7, while R&D projects strongly increased from 140 in FP6 to 241 in FP7. The associated EU contribution to demonstration projects

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17 Expert Group (2009), *Ex-post Evaluation of the Sixth Framework Programmes*, Report for the European Commission.

18 European Commission (2008), *FP6 Final Review: Subscription, Implementation, Participation.*

19 European Commission (2013), *Sixth FP7 Monitoring Report.*

increased from 374 million Euro (FP6) to 1,029 million Euro (FP7) for demonstration projects, while for R&D projects the EU contributions increased from 461 to 886 million Euro. In relative terms, the demonstration share of the EU contribution increased between FP6 and FP7 from 45% to 54% while the R&D share decreased from 55% to 46%. On average, demonstration projects received 3.0 million Euro per project in FP6 strongly increasing to 7.6 million Euro in FP7; R&D projects slightly increased from 3.3 to 3.7 million Euro on average between FP6 and FP7.

Figure 7 Aggregate of projects and costs

	FP6	FP7	Change (%)
#Demo projects	126	135	7%
Demo EU contribution	374	1029	175%
EU contribution per project	3.0	7.6	156%
#R&D projects	140	241	72%
R&D EU contribution	461	886	92%
EU contribution per project	3.3	3.7	12%
Total #projects	266	376	41%
Total EU contribution	835	1915	129%
Total EU contribution per project	3.1	5.1	62%

Ecorda. Financial figures in million Euro

3.3 Distribution of EU contributions by area

Figure 8 EU contributions by area (million Euro) and number of projects

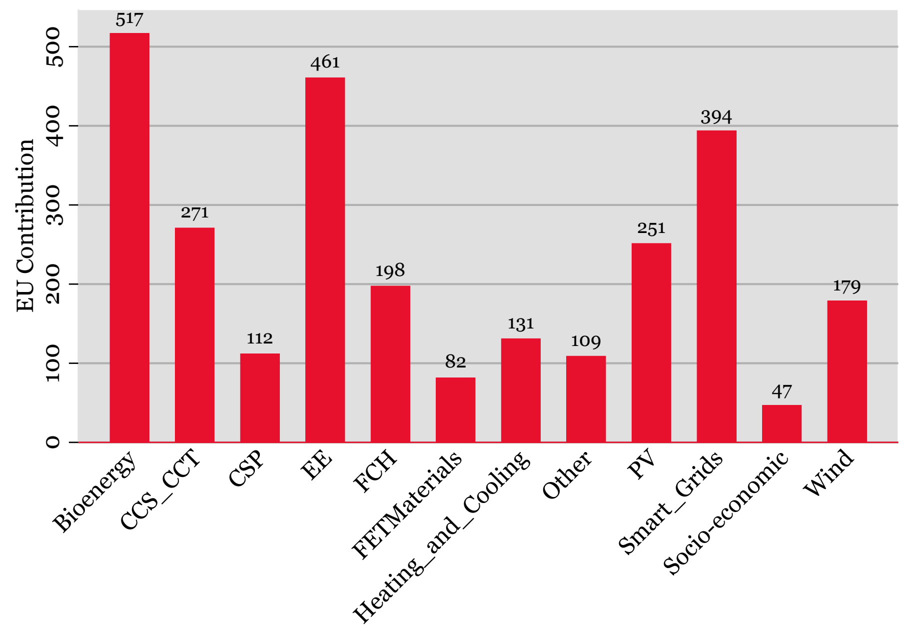
	FP6		FP7	
Area	**EU contri-bution (k€)**	**# projects**	**EU contri-bution (k€)**	**# projects**
Bioenergy	170	46	347	55
CCS/CCT (Carbon Capture and Storage/ Clean Coal Technology)	67	20	204	48
CSP (Concentrated Solar Power)	4	3	108	18
EE (Energy Efficiency)	166	35	295	41
FCH (Fuel Cells and Hydrogen) [20]	174	40	24	8
FET/Mat (Future Emerging Technologies/Materials)			82	32
(Renewable) Heating and Cooling	23	16	108	25
Other (ocean energy, hydro power, knowledge building/ co-ordination activities)	22	17	87	26
PV (Photovoltaic)	83	26	168	38
Smart Grids	63	26	330	52
Socio-economic	29	27	18	10
Wind (Power)	33	10	146	23
Total	**836**	**266**	**1,915**	**376**

[20] Of the 48 projects included in the present analysis, 40 are FP6 projects. More FP7 projects have been funded through the FCH Joint Undertaking; these projects are excluded from the present analysis.

Figure 8 provides an overview of the budget and the number of projects in FP6 and FP7 that were supported in non-nuclear energy, at programme level as well as at the level of technological programme areas.

The total FP6 plus FP7 EU funding contributions to projects by area are presented in Figure 9 below. Bioenergy projects received a combined total of 517 million Euro in FP6 and FP7. Energy Efficiency and Smart Grids received 461 and 394 million Euro, respectively. At the other end, Socio-economic (47 million Euro), received the lowest EU contributions and saw its budget halved between FP6 and FP7. Smaller shares of budget ware also dedicated to Future Emerging Technologies/ Materials (82 million Euro), Other Renewables (109 million Euro), Concentrated Solar Power (112 million Euro), Renewable Heating & Cooling (131 million Euro) as well as Wind Power (179 million Euro). The budget for Other Renewables include projects in three costly areas (ocean energy, hydropower and "other"). The contribution of the EC accordingly differed as well. Overall, the EC contributed around €76.6m in ocean projects, around €13m in hydro projects and around €19m in other projects in this area.

Figure 9 FP6 plus FP7 EU funding contributions by area (million Euro)



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Overall, the most obvious change from FP6 to FP7 is the strong increase in total EU contribution from 836 million to 1.915 billion Euro (excluding the FCH area in FP7). This is partly explained by the longer duration of FP7, but represents a 64% increase of the annual budget[21]. The area Future Emerging Technologies/ Materials was created in FP7 and Concentrated Solar Power only saw 3 projects funded in FP6 with a combined EU contribution of 4 million Euro, while in FP7 18 projects were funded with a combined EU contribution of 108 million Euro, representing a 25-fold increase. In CSP, the major goal of a roadmap study in FP6 was to identify key areas of necessary technological progress to be addressed in future research programmes;

[21] The EU contribution increase is 104% on an annual basis if the FCH area is excluded for both FP6 and FP7.

these recommendations were adopted in FP7, which is reflected in the strong budget increase.

The differences in budget share across areas is based on the process that was followed for the previous FP. Following a public consultation, the European Commission carries out an internal discussion with the Programme Committee (composed of representatives of national authorities) and gather inputs from various expert advisory groups. Budget allocations are still strongly influenced by national policies and along with European energy goals. In the case of bio-fuels for instance, the large share of budget is in line with a strong growth in the production of biofuels in the last decade, which in turn can be related directly to high oil prices. National developments within this field have been driven strongly by governmental policies aimed at replacing fossil by renewable sources, which was reflected in the FP programmes. A strong increase of some 400% can be seen in Smart Grids between FP6 and FP7, indicating the growing importance of this field in relation to the deployment of renewable energy and the integration of the energy markets. In this case, both national (renewable integration into the network) and European (market integration) concerns have equally influenced the evolution in this area. All other areas increased by typically between 100% and 200% with the exception of Socio-economic research, which actually declined from 29 million Euro EU contribution in FP6 to 18 million Euro in FP7. This may be partly explained by the fact that projects financed in the socio-economic area focus in particular on the analysis of socio-economic, geo-political and environmental aspects related to the production and use of energy and do not involve technology development, which usually entail higher costs. Also, during FP7 the European Commission integrated more socio-economic research into other areas. There also seems to be a general evolution by EC services to push forward a bilateral contracting approach to addressing socio-economic issues of key importance in European policy making in a more prescriptive manner, for example by contracting consultants and researchers directly through service contracts. This type of activities though, do not act as substitute to the research carried out in the socio-economic area with regards to energy externalities, security of supply and energy modelling forecasts.

Excluding the FCH area, which in formal terms is funded by the FCH-JU in FP7 rather than by the European Commission directly[22], the areas Bioenergy, Energy Efficiency and PV saw a below-average increase in overall EU funding contributions from FP6 to FP7; this needs to be seen against the fact that notably Bioenergy and Energy Efficiency already received major budgets in FP6. As mentioned above, Socio-economic decreased by half, in comparison with other areas saw above-average increases in EU funding. PV (as part of solar energy including CSP) and Bioenergy are among the areas for which the Strategic Energy Technology Plan (SET-Plan) in 2009 proposed to launch European Industrial Initiatives or for which joint initiatives already existed in 2009[23]. Furthermore, the SET-Plan included the Smart Cities Initiative in the Energy Efficiency area, which focused on the deployment of energy efficiency measures in urban areas. As mentioned above, these areas have benefitted less from increased EU funding than other areas such as Wind, CCS, Smart Grids, which are also included in the SET-Plan in the form of European Industrial Initiatives. The SET-Plan provides stakeholders, particularly industry representatives, with a platform for open discussion on research issues, indirectly influencing budget shares. Industrial initiatives are important instruments for the European Commission to evaluate the state of the art of the technology and market changes.

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[22] The FCH-JU is funded by the Commission in FP7; most of the FCH JU contribution actually comes from the FP7 Energy Theme.

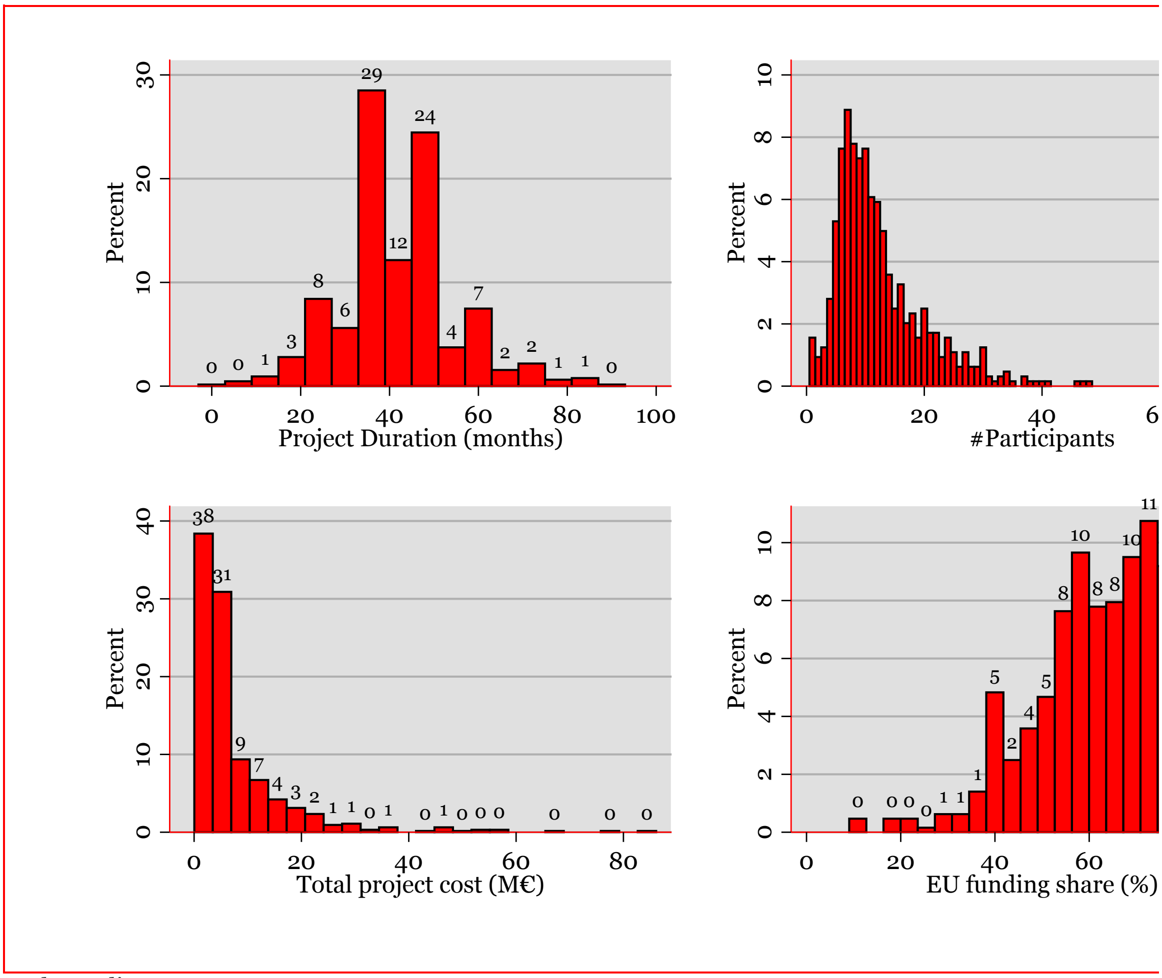
[23] European Commission (2009), *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Investing in the Development of Low Carbon technologies (SET-Plan)*, COM(2009) 519 final.

3.4 Project characteristics

The projects in the non-nuclear energy FP6 and FP7 portfolio in general last for 3 or 4 years and have around 6 to 10 participants. The majority of projects has received an EU contribution of less than 7 million Euro in total. The EU funding share is 54% to 80% for most projects; half of all projects have a funding share of above 67%. On average, funding shares have increased from 63% in FP6 to 67% in FP7, calculated as average of all projects independent of the project total budgets. Funding shares calculated as total EU contribution divided by total budget results in an average funding share of 48% in FP6, and of 58% in FP7.

Main project characteristics are displayed in Figure 10.

Figure 10 Histograms describing the main parameters



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3.4.1 Project duration

The median project duration of all areas is around 40 months, or just over 3 years. Bioenergy has significant outliers towards longer projects whereas Other Renewables have the largest spread. Longest projects take up to seven years. Most projects have a duration of between two and four years.

The median project duration has increased from 38.5 months in FP6 to 42 months in FP7. The spread in project durations has significantly decreased, which is more relevant than the small overall increase. The bigger and more comprehensive *integrated projects* (IP) in FP6 have an average duration of 58 months compared to 40 months for the smaller and less complex *specific targeted research projects*

(STREP). The IPs have been discontinued in FP7; *collaborative projects* (CP) in FP7 have an average duration of 44 months, which explains the reduced spread in project durations in FP7.

Specific support actions (SSA) and *co-ordination actions* (CA) (in FP6) or *co-ordination and support actions* (CSA) (in FP7) in general have shorter project durations compared to STREPs and IPs (both in FP6) or CPs (in FP7). Figure 11 and Figure 12 show the project durations by area for IP/STREP/CP projects and for SSA/CA/CSA projects separately with coordination and support type projects having shorter durations by around 18 months on average. However, individual coordination and support type projects take up to 60+ months.

Project durations are rather evenly distributed over the areas with the exception of Socio-economic research, which has shorter projects because of the lack of hardware elements.

Figure 11 Duration of IP/STREP (FP6) or CP (FP7) projects by area (months)

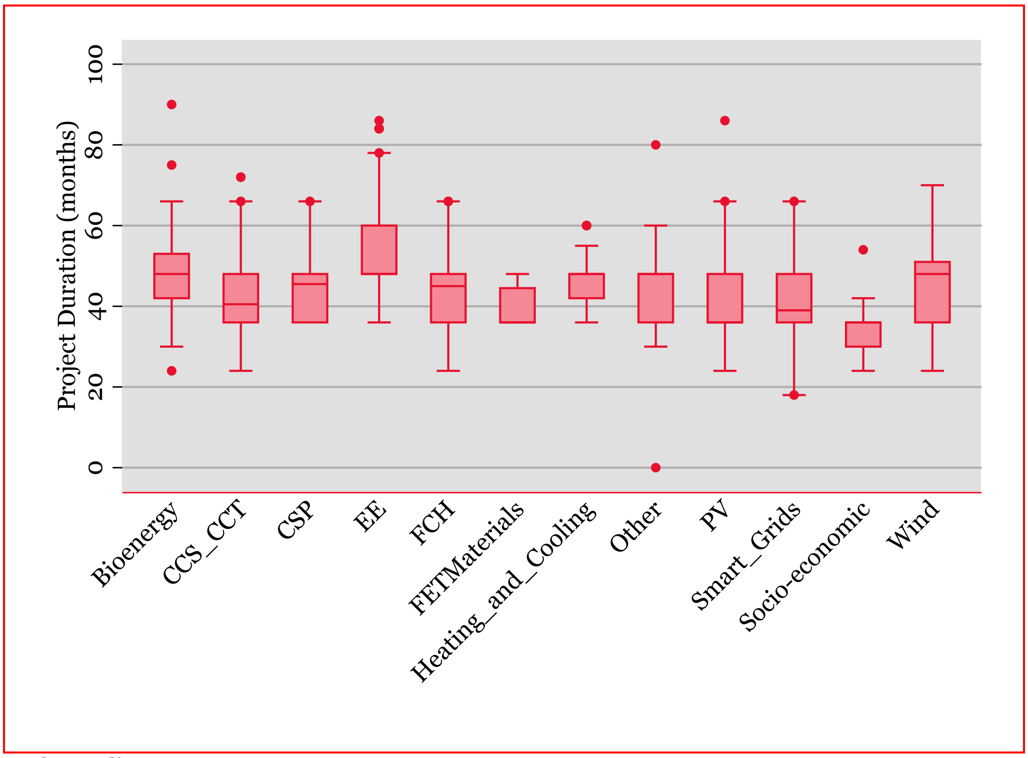

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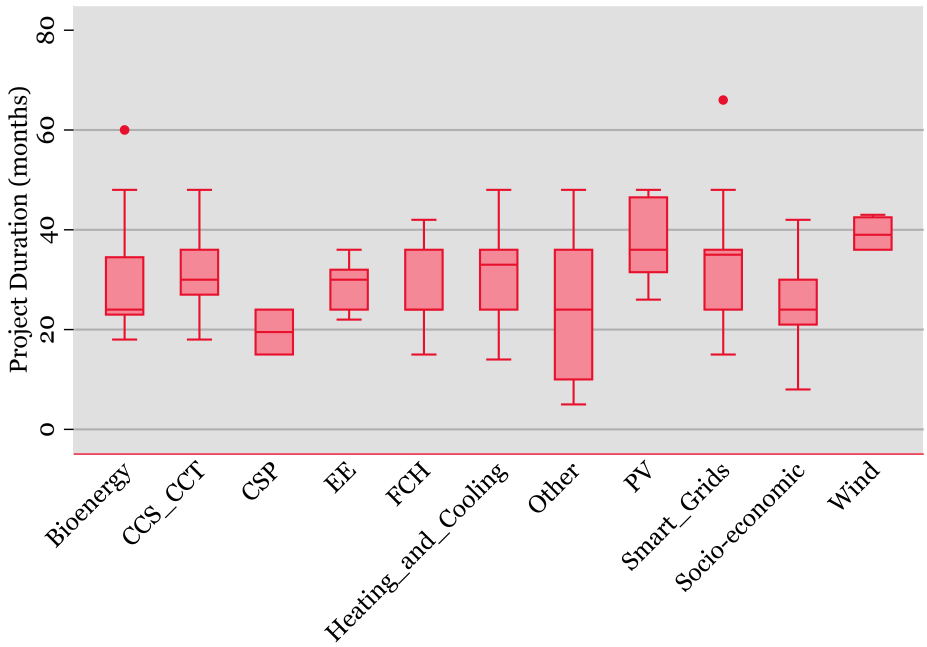
Figure 12 Duration of SSA/CA (FP6) or CSA (FP7) projects by area (months)



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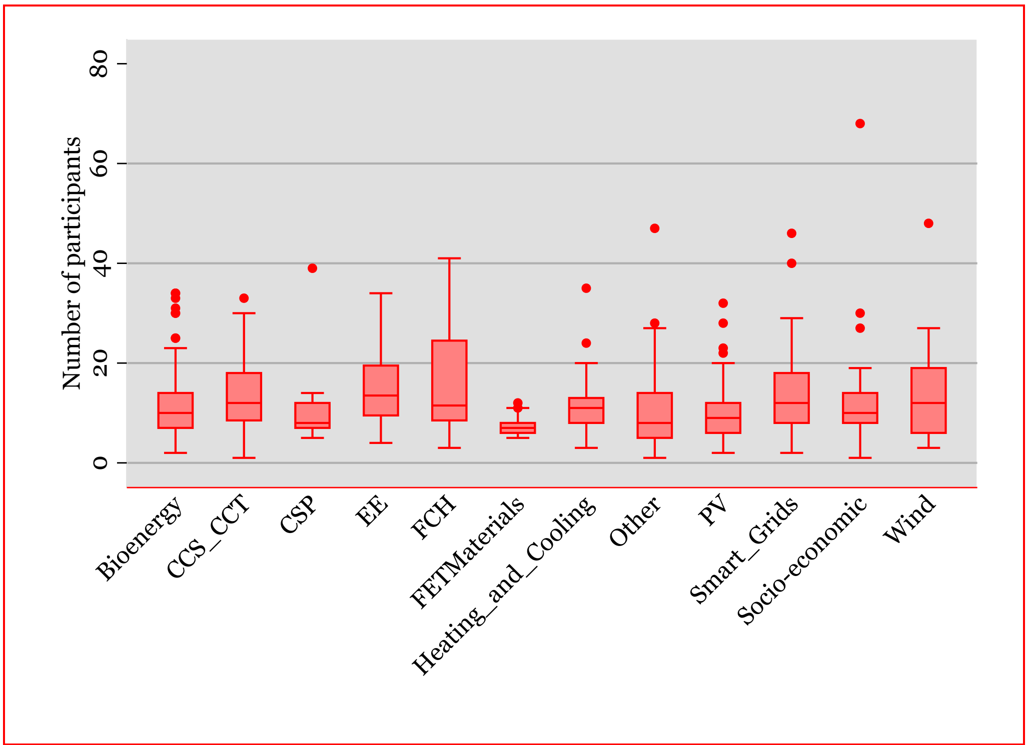
3.4.2 Number of participants per project

The average number of participants per project has decreased from 14 in FP6 to 11 in FP7; the median has decreased from 11 in FP6 to 10 in FP7. This is a reflection of the fact that the very large and complex Integrated Projects in FP6 were progressively given up in FP7.

Most areas have their median around ten participants. Variation is largest in Fuel Cells & Hydrogen, Energy Efficiency, and Wind Power. The largest projects in terms of number of participants are found in Socio-economic, Wind Power, Other Renewables, and Smart Grids with a few outliers up to 68 participants. Almost all areas have single projects beyond 30 participants.

The number of participants does not differ noticeably between IP/STREP (in FP6) or CP (in FP7) on the one hand and SSA/CA (in FP6) or CSA (in FP7) on the other hand. However, the latter often have very small and very large projects in terms of the number of participants.

Figure 13 Number of participants by area



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3.4.3 Project size and EU funding

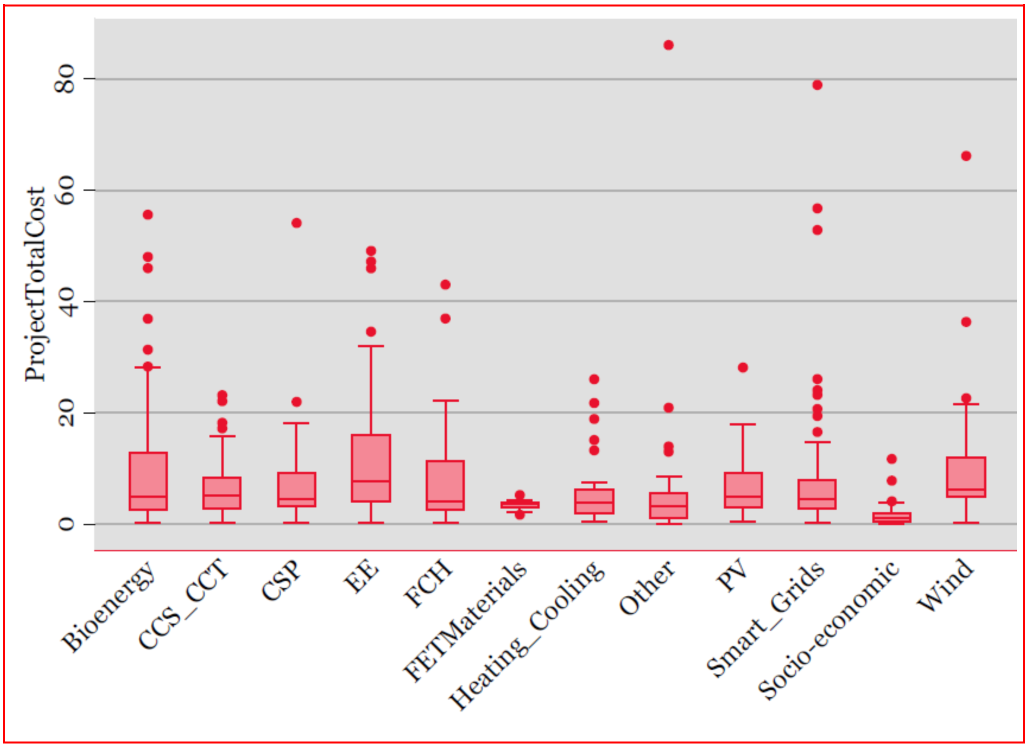
The projects vary considerably in size. While in FP6 the average project total budget was 6.5 million Euro with an average project EU contribution of 3.1 million Euro, these figures increased in FP7 to 8.8 and 5.1 million Euro, respectively.

SSA/CA/CSA projects in general have low budgets compared to STREP/IP/CP projects. While the former in general cover actions such as studies, collaboration of expert groups or dissemination with a budget of typically below one million Euro, the latter cover research, development and demonstration activities typically above a few million Euro.

All areas include both types of projects leading to a significant spread in total project costs[24] starting from "zero" as shown in Figure 14. The boxes (in which 50% of the project population resides) are usually close to the lower end of the spectrum; most research, development and demonstration projects are in the range of a few to 15-20 million Euro. There are, however, some expensive outliers, especially in Smart Grids, Bioenergy and Wind Power, going up to 200 million Euro. The greatest variation in project costs can be found in the Energy Efficiency area. Participants are able to reorganize the work to be performed and reallocate budget during the course of the project either among partners or tasks, although this usually implies a certain administrative burden for the coordinator. Budget overrun are rare, however a certain level of flexibility with budget allocation at the project level is important for project participants, particularly for large projects or projects that extend over long period of times.

[24] Total project costs include the EU funding and the costs borne by the project partners.

Figure 14 Project total costs by area (excluding one Bioenergy project of around 200 million Euro)



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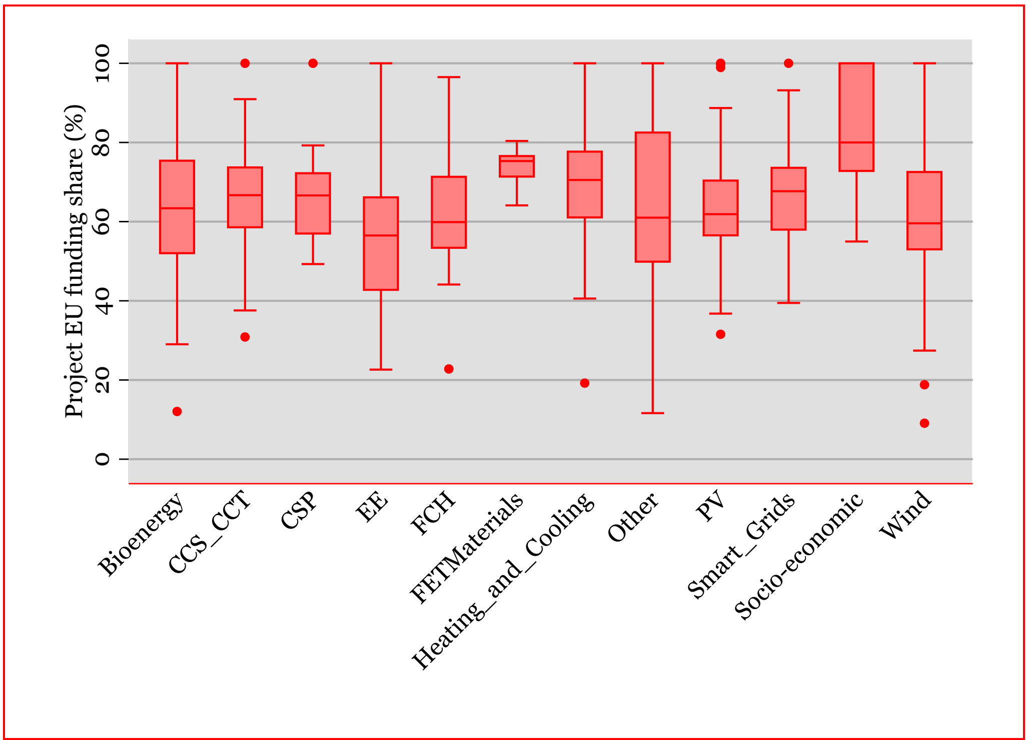
The EU funding contribution to the projects shows a similar pattern. The very expensive projects, however, sometimes have a low funding rate. On the other hand, Smart Grids, Bioenergy and other areas show typical funding rates of 50-60% also for the very expensive projects. This is the case where typically budgets are rather evenly distributed among project partners requesting similar funding shares.

The EU funding share as shown in Figure 15 is typically around 60% or slightly above. 100% funding is restricted to co-ordination and support actions with smaller budgets, while in general 50% funding applies to industrial project partners. In FP7, funding rates of 75% became available to Small and Medium-sized Enterprises (SMEs). Unfortunately, data available for this evaluation are not sufficiently detailed to allow analysing the effect of this on average funding shares. Funding shares do not vary greatly between areas with two exceptions: Future Emerging Technologies/Materials and Socio-economic show higher funding shares, and lower project total costs related to the stronger academic character of participants.

Figure 15 Project EU funding share by Area



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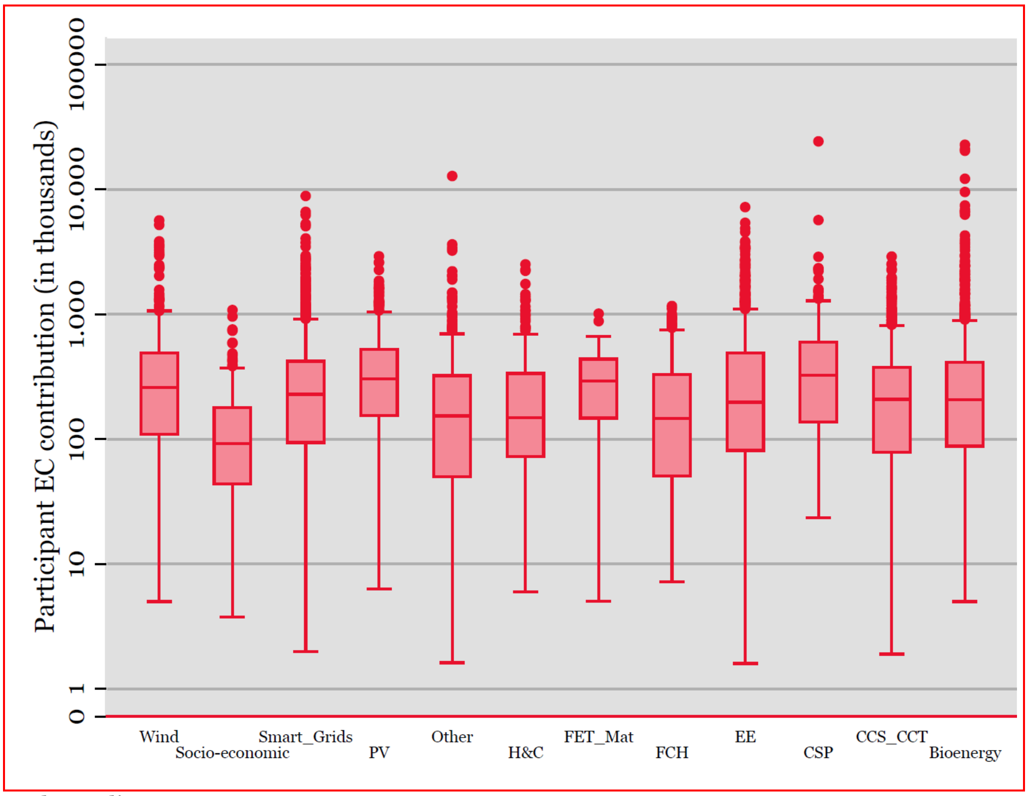
The financial contributions participants receive from the EU vary over a very wide range. Minimum EU contributions start from a few thousand Euro, and go up to 24 million Euro for individual participants in single projects. The median EU contribution is around 200,000 Euro, varying by area between 100,000 Euro for the Socio-economic area and 320,000 EUR for Concentrated Solar Power. While some areas such as Socio-economic, Future Emerging Technologies/Materials as well as Fuel Cells and Hydrogen have low maximum participant EU contributions of up to one million Euro, most areas have a number of outlier EU contributions of several million Euro. Highest single EU contributions are in Bioenergy with several contributions of 10 million Euro and beyond, and one in Concentrated Solar Power, Other Renewables and Smart Grids, respectively.

Figure 16 Participant EU contributions (log scale), thousand EUR



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3.4.4 Correlations between project characteristics

In the following, correlations between the characteristics discussed above are described. Most indicators are only weakly correlated as can be seen in Figure 17.

Figure 17 Correlations between the indicators

	Total cost	Duration	Participants	EC Contribution
Total cost	1			
Duration	0.36	1		
Participants	0.37	0.16	1	
EU Contribution	0.88	0.39	0.50	1
EU funding share	-0.42			

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Total project costs and project EU funding are strongly correlated as (in general) EU funding is granted as a percentage of the total costs. However, EU funding shares depend on a number of aspects, including the funding scheme, the type of activity and the legal status of the organisation requesting funding: non-profit public bodies, SMEs, research organisations and higher education establishments can receive up to 75% (in FP6 funding for SMEs was limited to 50%), while other legal entities can receive funding shares up to 50%.

Average EU funding shares for private companies (including SMEs) increased from 57% in FP6 to 61% in FP7, for higher education and scientific institutes they decreased from 95% to 75%, for research centres they increased from 64% to 75%, and for public organisations they remained rather constant at 74% and 72% in FP6 and FP7, respectively[25].

Furthermore, certain project types receive lower funding shares than research & development projects, while others receive higher shares. For activities such as consortium management, networking, training, coordination, dissemination, etc., the reimbursement can be up to 100% of the eligible costs; this is typically done in co-ordination and support type actions. The 100% rate applies also to frontier research actions under the European Research Council.

For demonstration activities, the reimbursement rate may reach 50%. The latter, however, is difficult to assess for the FP6/7 energy projects because projects are not systematically classified as demonstration in the available data. As a rough estimate, projects administered by DG ENER (formerly by DG TREN) can be taken to have a demonstration character, while projects administered by DG Research have a research focus. Based on this approximation, demonstration projects in FP6 had an average funding share of 41.4% increasing to 51.3% in FP7. In contrast, research projects in FP6 had an average funding share of 56.2% increasing to 67.3% in FP7. Average EU shares above 50% for a project are mainly explained by the participation of entities eligible for funding shares above 50%, most notably research and higher education institutions. Obviously, the latter have a tendency to participate preferentially in research projects, which may at least partly explain the higher funding shares in these projects compared to demonstration projects.

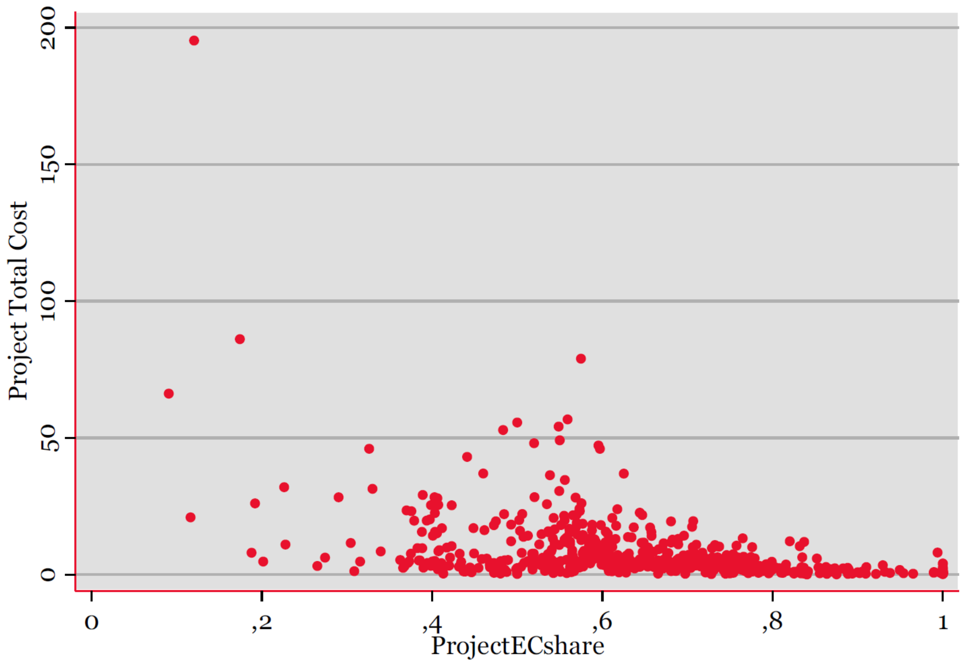
Funding shares below 50% are granted to single projects where individual participants claim high total costs while only requesting low funding shares.

A weaker yet still relevant correlation exists between project size and EU funding share with larger (more expensive) projects receiving lower funding shares. This trend is displayed in Figure 18. Projects above 50 million Euro total costs receive funding shares of less than 60%, some as low as below 20%. In the inverse perspective, projects with funding shares above 60% have total costs of below 25 million Euro; above 70% funding share, projects have below 14 million Euro total costs. The average funding share of the EU to projects is about 66%[26].

[25] It should be noted here that for more than half of the projects in FP6, the legal status of the participants is not available for the present analysis.

[26] Calculated as average of all projects independent of the project total budgets.

Figure 18 Total cost vs. EU funding share



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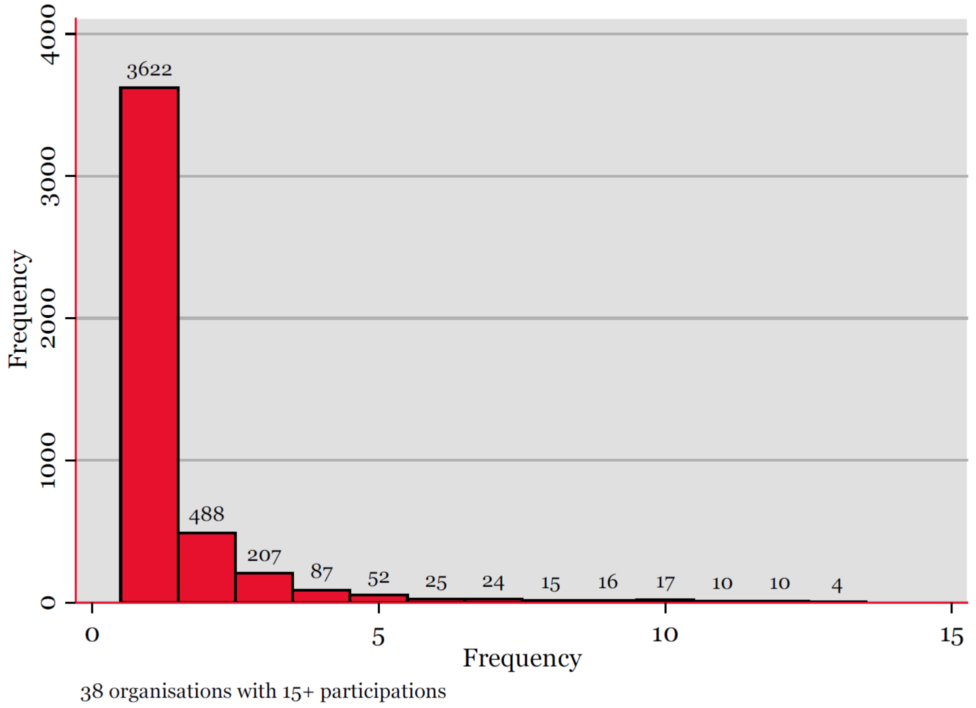
The correlation between project cost (or EU contribution) and project duration is also weaker but still relevant with longer projects having higher costs (and higher EU contributions). More interestingly the spread in project total costs increases with the project duration.

The number of participants in a project does not show clear correlations to the EU funding share. However, it has a weak correlation to the total project costs, and a medium correlation to the EU contribution.

3.5 Participation characteristics

A 'participation' is defined as the participation of one organisation in one project. There were 7,919 participations in total over 4,615 unique organisations, meaning that each organisation on average participated 1.7 times, although 78% of the organisations only participated once (see Figure 19 below). Organisations with a very high frequency in participation, however, are often very large research organisations with many affiliations where EU projects are administered centrally, while the actual research entities are independent of each other in scientific terms. The process of consortium building seems to be quite efficient, with the majority of partners being able to include in the consortium all relevant partners, on the basis of the survey results only 16% of participants believe they were missing a key partner in the consortium. In some cases, partner realise that certain specific partners are missing only during the project implementation and it is usually representatives of specific industries or equipment manufacturers that were unknown to the partners at the inception of the project. In most cases surveyed participants indicated that the missing partner could have brought added value by providing access to certain technology to test a new technology.

Figure 19 Number of participations by organisation



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Of the total 7,919 participations, 3,634 were recorded in FP6 and 4,285 in FP7, representing an increase of 18%. 63% of the participations in FP7 were by participants who had not participated in FP6. Broken down by area, this renewal rate is below average in the small area Socio-economic (43%), but also in the large areas Carbon Capture and Storage/Clean Coal Technologies (51%), PV (56%), Smart Grids (59%) and Wind (59%). Renewal is above average in the areas Concentrated Solar Power (64%), Bioenergy (68%), Other Renewables (70%), Heating & Cooling (74%) and Energy Efficiency (84%).

3.5.1 Participations by type of organisation

Project data allow distinguishing the following types of actors:

- HES: Higher Education and Scientific Institutes
- PRC: Private Companies (large, SME)
- REC: Research Centres
- PUB: Public Organisations
- OTH: Other Organisation

Unfortunately, data for FP6 are not always complete resulting in about two thirds of organisations being classified as "Other", which in this case means that they are undefined (see Figure 20). For FP7, the number of participations is equally distributed between Higher Education and Scientific Institutes (22.9%) and Research Centres (24.1%), and almost double as many participations are by Private Companies (43.5%). In other words, research organisations participate as frequently as industry. Public Organisations (6.1%) and Other Organisations (3.4%) play minor roles.

Figure 20 Participations by type of organisation in FP6 and FP7

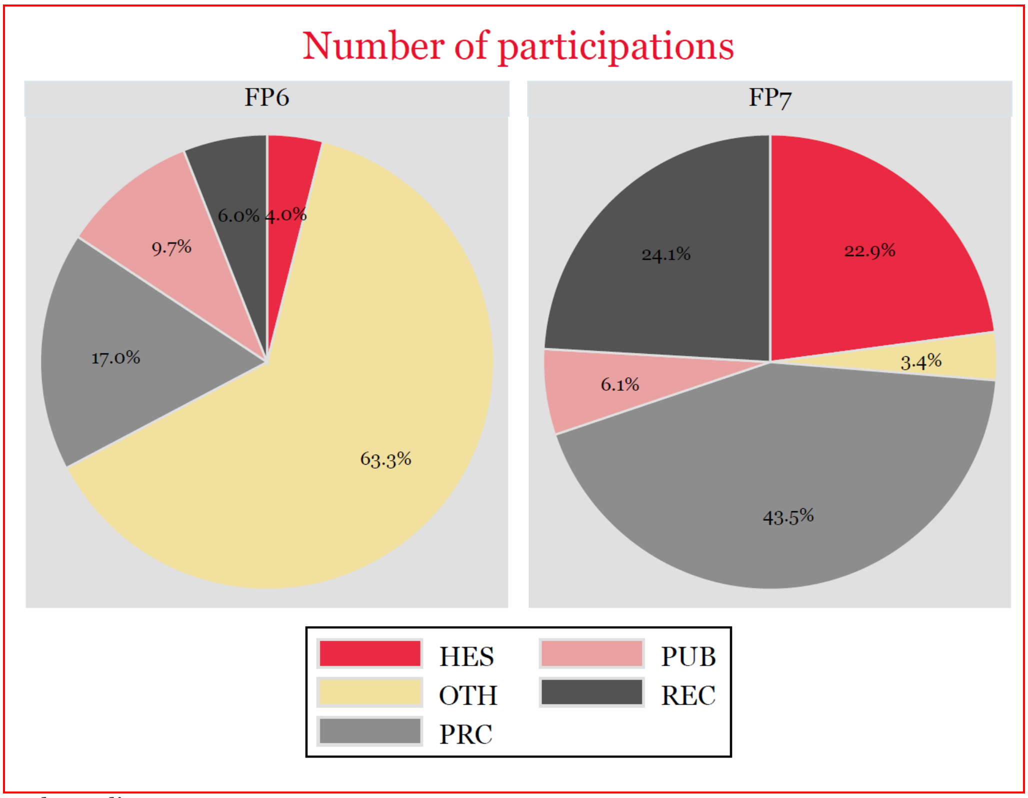

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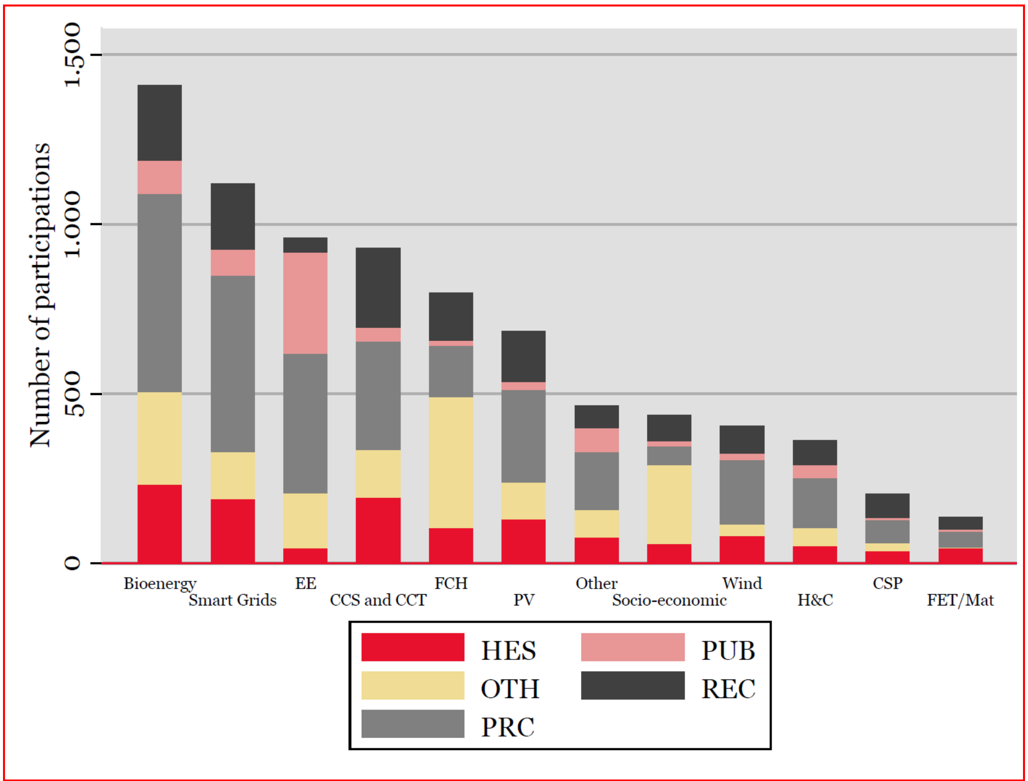
Figure 21 breaks participations down by area. For many areas, distributions reflect the overall picture described above. A noticeable difference exists for Energy Efficiency[27]. Here, the participation of both types of research organisations is very low, which may indicate a lack of research activity in this area. On the other hand, the share of Public Organisations is very high. This is due to Initiatives within FP6 and FP7 specifically aimed at communities such as the CONCERTO initiative, or the European Smart Cities and Communities initiative.

[27] In Fuel Cells & Hydrogen, the distribution is probably distorted by the fact that most FP7 projects are excluded from the present analysis. Similarly, in Socio-economic many Other Organisations are recorded because 27 out of 37 projects are FP6 projects where organisation data are mostly unavailable.

Figure 21 Number of participations by type of organisations, by area



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With respect to SME participation, limited data are available for the present analysis. For 2,038 participations out of a total of 7,919 participations, the SME status is available; for these, an average of 26% are SME participations. SME participation is very high at 40% in Future Emerging Technologies/ Materials, at 38% in Bioenergy and at 35% in Other Renewables. On the other side, SME participation is particularly low at 14% in Fuel Cells & Hydrogen[28], at 16% in Carbon Capture and Storage/ Clean Coal Technology and at 18% in Smart Grids.

3.5.2 Large participants

There are two distinct groups of organisations receiving large EU contributions: On the one hand there are private companies, which participate in very few (down to 1) projects with very high EU contributions to individual project participations (see Figure 22), while on the other hand there are large research organisations which participate in many projects leading to large cumulative EU contributions. Some of these research organisations are located in one place and have a major energy focus. Others have a larger number of sub-entities located in different places with a central administration handling all administrative issues with the EC, in which case they are counted as one organisation and the project participations are geographically assigned to the administrative seat; Appendix C lists the TOP 50 participants by participations. The first 26 are research centres or higher education and scientific institutes with 21 to 77 participations. The strongest private company records 19 participations.

Private companies having received high EU contributions are from the chemical, energy, bioenergy or other industry sectors and participated in the large Bioenergy projects (see section 3.4.3). Other participants with large individual EU contributions

[28] FCH is only partly represented in the present analysis, with a very low coverage of FP7 due to funding through the FCH Joint Undertaking rather than the EC. This may influence the SME participation result.

are from the energy sector participating in Concentrated Solar Power, Smart Grid or Ocean Energy (Other) projects (see Figure 22).

Figure 22 Top private companies by EU contribution (million Euro)

Organisation Legal Status	Participant EU Contribution	Participations
Private Company (chemical sector)	> 30	4
Private Company (energy sector)	> 20	2
Private Company (chemistry sector)	> 20	1
Private Company (bioenergy sector)	> 20	1
Private Company (energy sector)	> €10	10
Private Company (energy sector)	> €10	21
Private Company (industry)	> €10	1

3.5.3 Geographic distribution of participations

Project participations are unevenly distributed geographically. These differences can partly be explained by the differences in Gross Domestic Product (GDP) and Population between the countries.

A linear regression analysis predicts with good certainty the number of participations in FP6/7 Energy as a function of GDP and population[29]. The relation between GDP and the number of participations is positive, so countries with a higher GDP tend to have more participations in the FP6/7 energy programme. Population, however, is a much worse predictor on participations, i.e. the correlation between participations and population is rather weak.

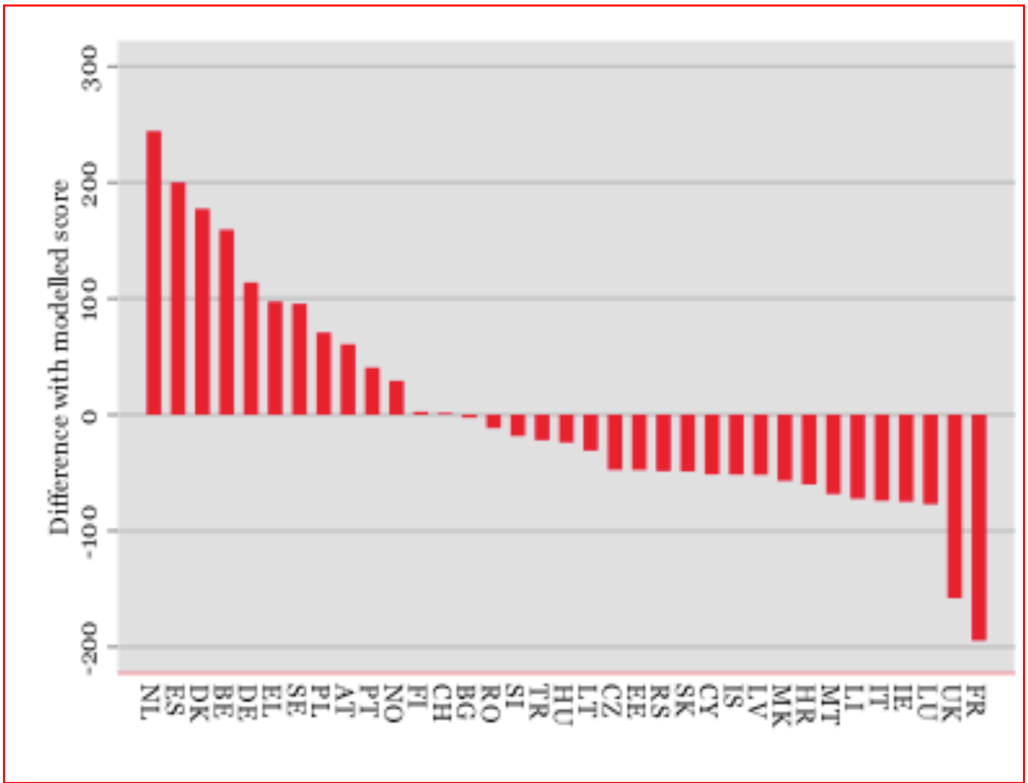
The figure below shows how countries actually perform compared to the model. A positive difference (such as for the Netherlands or Spain) implies that the country has more participations than the model predicts. In other words they perform above what could be expected from the national GDP. Countries with a negative difference underperform such as France or the UK; judging by their GDP, one should expect more participations than actually found.

The 13 countries having become EU Member States in the course of 2004-2013[30] accounted for 362, or 10.0% of participations in FP6. However, their participation has decreased to 311 in FP7, or 7.3%. The share of EU-15 participations has remained constant from FP6 to FP7 at around 67% (2,422 in FP6, 2,900 in FP7), while the participations of other countries have increased from 23.4% to 25.0%.

[29] Data for GDP and population are taken from Eurostat, averaged over 2004-2012.

[30] 2004: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia; 2007: Bulgaria, Romania; 2013: Croatia.

Figure 23 Differences between countries' actual and modelled participation counts[31]



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In addition to national differences there are also strong regional differences within the Member States. There are hotspots of very strong participation alongside regions with practically zero participation.

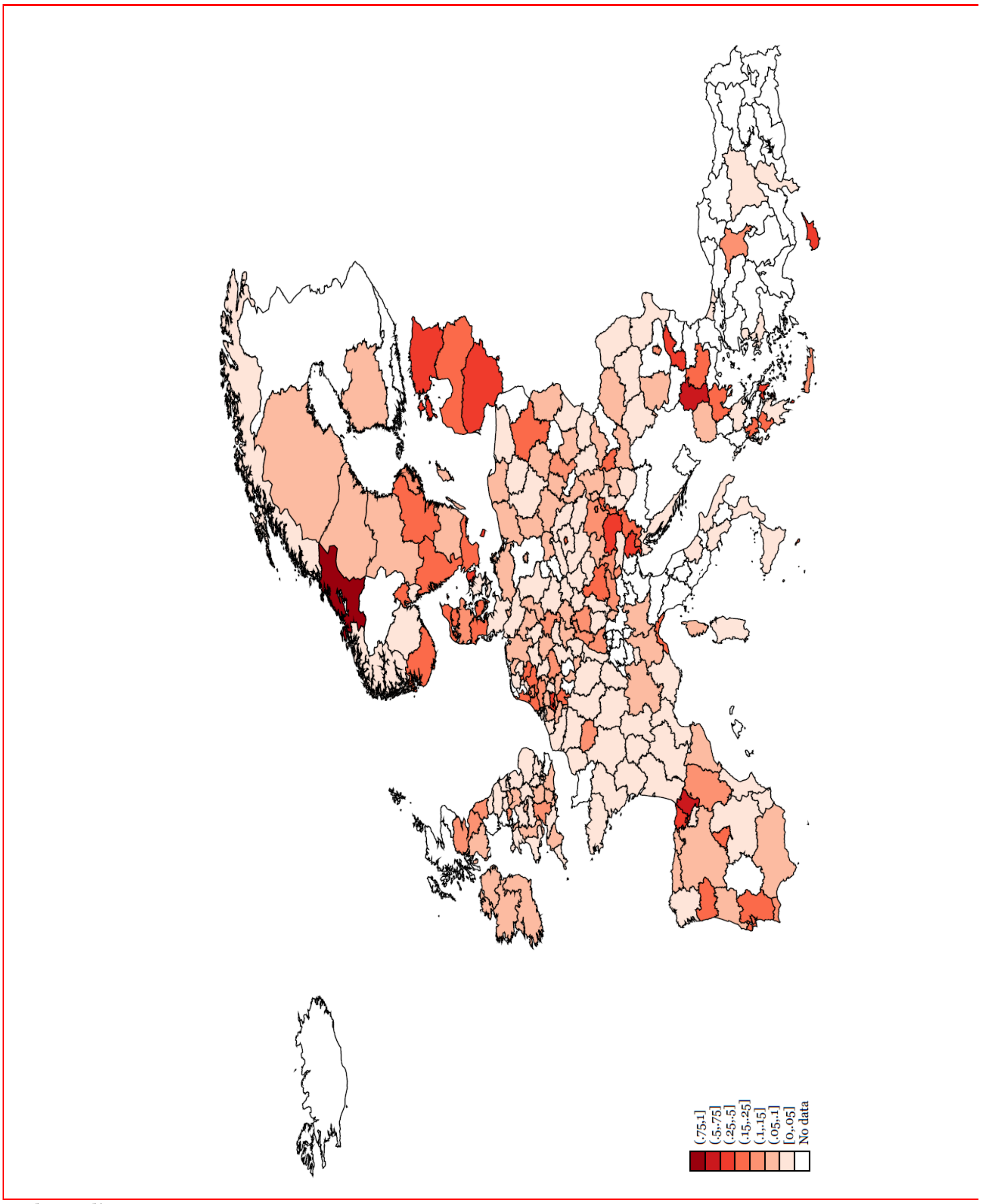
A certain tendency towards lower participations can be found in eastern and southern Europe, in certain areas of France and the UK as well as in northern Scandinavia. High participation can be found in densely populated areas including large metropolitan areas as well as generally in central Western Europe. Some of these hotspots can be explained by a few research centres whose administrative centres are located in one city while the research is carried out in a number of different sub-entities located in different regions; in these cases all participations are geographically assigned to the seat of the central administration. Also research organisations located in one place and with a high number of participations are producing hotspots while the relevance of these organisations is at national level.

Normalising participations to the gross domestic product (GDP) in the region gives a more meaningful picture as shown in Figure 24. The figure thus shows regions with higher and lower levels of EU funded activities relative to the region's economic strength. This reduces the differences compared to the absolute differences in participation levels. However, the qualitative patterns of high or low participations described above mostly remain valid. However, Central Eastern European participation by GDP is more comparable to Central Western Europe than in the absolute perspective.

Qualitatively, Central Eastern and most of Central Western European participation lost ground from FP6 to FP7, while Spain, Portugal and the United Kingdom increased.

[31] The graph includes the 28 EU Member States as well as 7 associated countries.

Figure 24 Indexed participations by GDP[32] by region (NUTS 2 level)[33]



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[32] GDP figures are averages over the 2007 to 2011 timeframe based on data by Eurostat.

[33] Participations by GDP are divided by the overall maximum number achieved, giving a range between zero and one for the index.

3.6 Conclusions on Implementation of the FPs

More than 600 non-nuclear energy projects were supported in FP6 and FP7. The success rate for proposals was around 20%.

FP6 supported the implementation of 266 non-nuclear energy-related projects, while 376 projects have been promoted under FP7. The success rate for proposals was around 20% both in FP6 and FP7, indicating that there were five times more projects than EU funding.

The importance of demonstration projects relative to R&D projects increased significantly from FP6 to FP7.

While in FP6 demonstration projects received 45% of the total EU contribution to projects this share increased to 54% in FP7. The average EU funding of demonstration projects increased strongly from 3.0 million Euro per project in FP6 to 7.6 million Euro in FP7; in contrast average R&D project EU contributions only increased slightly from 3.3 to 3.7 million Euro.

Bioenergy was the area with the largest EU support under FP6 and FP7, followed by Energy Efficiency and Smart Grids.

Bioenergy projects received a combined total of 517 million Euro in FP6 and FP7. Energy Efficiency and Smart Grids received 461 and 394 million Euro, respectively. CCS/CCT received 271 million Euro, PV 251 million and FCH 198. At the other end, Socio-economic (47 million Euro), Future Emerging Technologies/ Materials (82 million Euro), Other Renewables (109 million Euro), Concentrated Solar Power (112 million Euro), Renewable Heating & Cooling (131 million Euro), as well as Wind Power (179 million Euro) received the lowest EU contributions. Socio-economic research actually declined in budget between FP6 and FP7, while some other areas such as Bioenergy, Energy Efficiency and PV benefitted less from the increase in overall budget than the other areas.

From FP6 to FP7, the EU funding share has increased from 48% to 58%.

This is in part due to increased maximum funding rates for certain types of legal entities, e.g. SMEs, for which maximum funding rates increased from 50% in FP6 to 75% in FP7. Another factor may be changes in participation patterns. Unfortunately, data for FP6 are not sufficiently detailed to allow for an analysis of the evolution of the participation by type of organisation.

Funding rates do not vary greatly between areas with two exceptions: Future Emerging Technologies/Materials and Socio-economic show higher funding shares, and lower project total costs, which is due to a higher participation of research organisations eligible for higher funding rates.

In FP7, almost half of the participants are private companies, another almost half are research organisations (with equal shares for higher education and scientific institutes on the one hand and research centres on the other hand); 6% are public organisations and 3% are other organisations.

For many areas, distributions reflect this overall picture. A noticeable difference exists for Energy Efficiency. Here, the participation of both types of research organisations is very low indicating perhaps the stronger demonstration focus in this area and/or a certain lack of research activity. In this area, the share of public organisations is very high. Because of the lack of data on FP6 participants it is not possible to identify how industry participation developed between FP6 and FP7.

The average number of participants by project has decreased from 14 in FP6 to 11 in FP7, which is a reflection of progressively giving up very large and complex projects in FP7.

78% of the organisations participating in FP6 and FP7 energy research participated in one project only. This suggests that the FPs are open for participation of new organisations.

While 38 out of 4,615 organisations participated in 15 or more projects, on average each organisation participated in 1.7 projects, and 78% of the organisations participated in one project only. 63% of the participations in FP7 were by participants who had not been active in FP6. This clearly indicates that the FPs allowed new organisations to join and receive funding for their activities. The renewal rate is below average in the small area Socio-economic (43%), but also in the large areas Carbon Capture and Storage/Clean Coal Technologies (51%), PV (56%), Smart Grids (59%) and Wind (59%). Renewal is above average in the areas Concentrated Solar Power (64%), Bioenergy (68%), Other Renewables (70%), Heating & Cooling (74%) and Energy Efficiency (84%).

The average EU contribution per project increased from FP6 to FP7, suggesting larger, more capital intensive projects closer to commercialisation, esp. in the Bioenergy and Smart grid areas.

While in FP6 the average project total budget was 6.5 million Euro with an average project EU contribution of 3.1 million Euro, these figures increased in FP7 to 8.8 and 5.1 million Euro, respectively. As on the other hand the number of participants per project decreased, this is a clear indication that the nature of the projects has evolved towards smaller consortium but more capital intensive projects. The largest projects in terms of total budget mainly have demonstration character, which shows that certain technologies have come closer to commercialisation. Bioenergy and Smart Grids are the most prominent areas in this regard. Although the internal record were lacking clear information on the formal type of project, for future evaluations projects type must be clearly categorised in order for the European Commission to evaluate the relative impact and differentiate across projects.

Participation in FP energy research projects is strongest in metropolitan areas in (North) Western Europe. In FP7 Spain, Portugal and UK increase their participation, while the 13 new Member States decrease participation.

The geographic distribution of participations is most suitably described relative to the national GDP. Participation is unevenly distributed including differences between Member States, and between regions. Averaged over FP6 and FP7, the Netherlands and Spain participated very strongly relative to the national GDP, while the participation of France and the United Kingdom was very low. A certain tendency towards lower participations can furthermore be found in those countries that have become EU Member States since 2004 as well as in southern Europe as well as in northern Scandinavia. Central Eastern and most of Central Western European participation lost ground from FP6 to FP7, while Spain, Portugal and the UK increased. Participation by Non-EU countries increased from FP6 to FP7. Some regional hot spots are created by the location of administrative seats of research organisations and companies, while the project work may actually be conducted in other regions.

4. Effectiveness, Efficiency and Impacts of the FP6 and FP7

4.1 Introduction

This chapter discusses the outputs, outcomes and impacts of the FP6/7 Energy Programme, its effectiveness (to what extent the policy goals were achieved) and the efficiency (whether these results present the best value-for-money). Our analysis will provide insights into impacts for the participants in the projects and for the European energy systems.

This chapter is based on a synthesis of quantitative and qualitative evidence. The most important sources are the participant survey, 130 case studies of individual projects, over 200 interviews and desk research. Detailed information on the methodologies involved can be found in the appendix.

Although analysing the outputs and outcomes from Framework Programme *projects* will be of high importance to get a good idea of the impacts of the FP, the principal unit of analysis for most impacts are on the *participant*-level. There are two main reasons for this approach. First of all, projects are not entities that submit publications, apply for patents, generate turnover or improve their competitiveness. Any lasting concrete impacts can almost by definition only take place through the participating organisations and people. Secondly, all data is collected on the level of participants, as participants can only reliable give answers regarding their own situation and not on the collective level. Translating and aggregating these data to project-level may result in a loss of information.

An important methodological note for the quantitative methodologies used in this section with implications for the interpretations of the results is the issue of additionality. As the Commission could not give us access to data of applicants whose projects were not granted due to data privacy restrictions, it was not possible to collect a counter-factual (control group) in order to assess net-impacts. This limitation was addressed by exploring additionality in other ways (see also Chapter 6), but also by formulating all survey questions in an 'attributive' mode (What were the (impact/results) *as a result of your participation in the project)*. However, especially the attribution of future further in the causality chain (e.g. turnover from new innovations) is likely to be not only caused by the FP, but from various factors in which the FP was an important component. For these indicators, it is better to speak in terms of associated impacts.

4.2 Overview of outcomes and impacts of the projects

We will discuss different kinds of outcomes and impacts of the Framework Programme:

- Scientific outcomes/impacts: publications, PhDs and scientific excellence in general
- Technological outcomes/impacts: improved technological readiness levels
- Organisational outcomes/impacts: impacts on the capacities and competitiveness of organisations
- Impacts on innovation: new products, services, processes and business models
- Economic impacts: e.g. turnover from these new innovations
- Energy impacts: impacts on (future) renewable energy generation, energy savings and CO_2 reduction
- Impacts on policymaking

Methodological note on extrapolation and imputation[34]

The Framework Programme aims to achieve a wide range of impacts, from capacity building for R&D&I, to development of new technologies, improving the competiveness of Europe and the building of sustainable networks. Many of these aspects cannot be covered in simple quantitative indicators and are covered in a qualitative way (through the case studies, interviews and qualitative survey questions).

However, a number of aspects are more easily covered by quantitative indicators, such as publications, PhDs, expected turnover, new products etc. In our participant survey we have collected data on participants' estimates of these indicators.

In order to provide rough estimates of the *total* mid-term impacts associated with participation in the Framework Programme, sticking to just the survey data is not enough as our 1300+ responses only represent 18% of total participations. Simply aggregating the totals from our survey would therefore be a large underestimation of the total impacts so far.

In order to generate rough estimates of total impacts, imputed values have been generated on the basis of a custom multiple imputation model. This model imputes the values of missing respondents by looking at similar participations. Similarity is defined on the basis of a number of background characteristics of a typical participation:

- Thematic Area (e.g. Wind, PV)
- Type of project (e.g. IP, STREP, NoE)
- Framework Programme (e.g. FP6, FP7)
- Type of organisation (e.g. Research Centre, Company)
- Size of contribution (in euro EC contribution)

On the basis of these background characteristics, a sample of the most similar participations (at least 10) were identified. The missing response was imputed as the typical value of this sample (median).

For certain variables with large variances (such as turnover, energy impacts), the custom imputation model results in too low estimations since extreme large values are almost never assigned to missing responses (since the imputation model is based on medians). For these variables, a more straightforward extrapolation, which uses sample means, has also been used. However, given the fact that there is a likely positive response bias due to the fact that less successful participants are less likely to report, these figures are probably too optimistic. The best estimate is likely to be somewhere in between the imputed and extrapolated values.

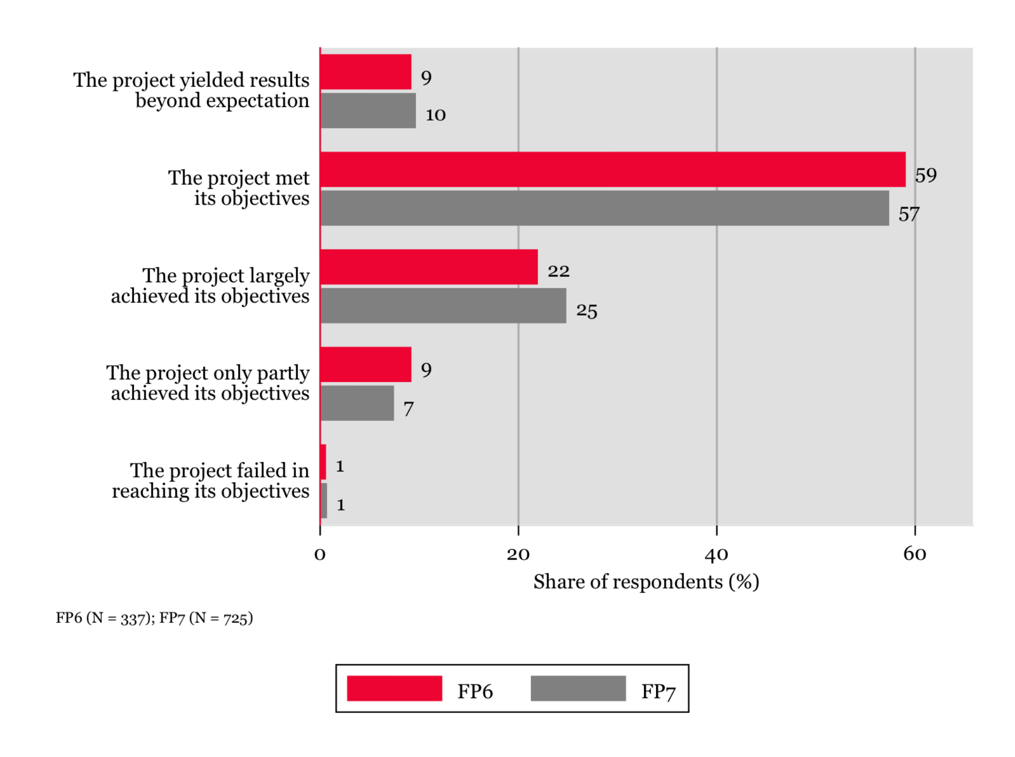
For both methods, uncertainties are high, and the responses for many questions show large variations. It should therefore be stressed that these results should be interpreted with care, and that these estimations should be seen as ranges of likely values, not as absolute measures of impact.

[34] The extrapolations are still subject to a final sensitivity analysis and may still undergo minor changes.

4.3 Achievement of project objectives[35]

Although the routes of technological, scientific and economic impacts can be complex and convoluting, it is not unreasonable that projects that reached their objectives are more likely to generate impact than those who did not. A programme is hardly likely to be successful if its basic components are failing to reach their objectives.

Figure 25 Achievement of project objectives



Technopolis 2014, based on participant survey

The figure above shows that most project participants (70%) indicate that the project has or will reach or exceed its objectives. A further 20% to 25% indicates that the project largely achieved its objectives. Only a small minority (around 10%) indicates that the objectives were only reached partly, and only 1% indicates that the project failed.

[35] Methodological note: All graphs in this entire chapter include all relevant responses from the electronic participant survey. Out of a total of 7919 participations in 642 projects, the survey included 1340 valid responses. However, the quantitative analyses include only the projects that are finished before the end of 2015, reducing the number of participations included to 6627 (542 projects), for which we have 1166 valid survey responses.

Figure 26 Successfulness of the projects[36,37]

	Survey N	Mean	Survey total	**Significant group differences** *Projects in these groups score less/more (mean)*
Participants indicating that project objectives achieved or exceeded	796	69%	549	SA more (89%) Bio less (60%), SG more (79%) PRC less (62%), DEMO more (74%) RES less (67%)

Technopolis 2014, based on participant survey

In general, this leads to the conclusion that participants **generally indicate that project objectives are largely or fully achieved.** Support action projects are rated much higher on average (almost 90% reached or exceeded objectives), although arguably the uncertainty and risks in this type of project is lower. Projects in the Smart Grid area are considered relatively successful by their participants, while Bioenergy lags behind in this respect. Overall, private companies are slightly less positive than other types of participants, but the differences are relatively small. The differences between demonstration projects and research projects were also investigated. Here we see that participants in demonstration projects (supported by DG ENER / DG TREN) are generally more positive about the extent to which objectives have been achieved or exceeded compared to research projects.

4.4 Scientific outcomes and impacts

Scientific results are an important part of the objectives of the Framework Programmes. Scientific outcomes, such as scientific publications, are the major driver for Higher Education Institutions (mainly universities) and research institutes to participate in the Framework Programmes. These types of organisations were asked to provide estimates of the scientific impact related to their participation in an FP6 or FP7 Energy project. In our survey, a scientific organisation reported on average around 8 scientific publications, half of which were published in high impact journals. An extrapolation for (almost) finished projects shows that in total around 18,000 articles and 8000 articles in high impact journals have been published so far. Note that across the board FP6 has more articles per participant and FP7 less. This could be partly due to the fact that publications continue to be written also after the project, but also to a slightly different focus. Networks of Excellence were particularly successful in publishing. It is no surprise that participants who receive more funding also publish more. The differences between demonstration and research-oriented projects also confirm expectations. Demonstration project result in less scientific publications in general compared to the more basic research projects.

Research projects are also an important way to train new scientists, and FP project often provide a good platform for training PhDs. A typical participant in a project trains one PhD, but on average this results in around 3000 PhDs trained in the 542 projects includes in the analysis. Integrated Projects have a much higher average of 2.4 PhDs per participation, demonstration projects train on average about half as many PhDs per participation compared to the more research-oriented projects coordinated by DG RTD.

[36] Abbreviations are listed in the Glossary at the beginning of the document

[37] The tables in this chapter are based on the electronic survey excluding projects that were not finished at the time and for which participants indicated that results were still too uncertain (28%). The charts in this chapter are however based on all the data from the survey to give a broader overview. This may in some cases reflect a difference in the N value.

Figure 27 Scientific output

	N	Mean (Median)	Survey sum	Imputation	**Significant group differences** *Projects in these groups score less/more (mean)*
Number of scientific publications[38]	349	7.87 (4.5)	2747	±18,000	FP7 less (6.46), FP6 more (8.96) NOE more (16.59) Wind more (12.9) Funding more (+) DEMO less (5.15), RES more (7.8)
Number of scientific publications In high impact journals[39]	330	4.07 (2.5)	1343	±8000	FP7 less (3.01), FP6 more (4.87) DEMO less (1.7), RES more (4.1)
Number of PhDs[40]	306	1.59 (1)	487	±4000	IP more (2.36) OthRen more (4.17) DEMO less (0.82), RES more (1.78)
Number of participants with at least one patents applied for or granted[41]	749	0.1 (0)	75	±500	CA less (0.02) EE less (0.03), FCH more (0.23), PV more (0.18), SE less (0) Funding more (+) DEMO less (0.07), RES more (0.12)
Number of participants with at least one patents applied for or granted by consortium partners[41]	749	0.11 (0)	82	±500	CA less (0), IP more (0.15) Bio more (0.18), CSP more (0.25), SG less (0.05), SE less (0) HES less (0.20) Funding more (+) DEMO less (0.07), RES more (0.12)

Technopolis 2014, based on participant survey

The involvement of PhD students in FP projects is an important outcome since it gives them the opportunity to learn and to develop expertise on topics that are considered important by the research community, the industry and the EC. Interviews show how important it is for the research organisations to ensure that PhD students are active in FP projects.

Finally, the survey investigated the number of associated patents, but for research institutions, higher education institutions and private companies. We found that 1 in 10 participations results in at least one patent application or grant, this number is consistent whether we asked participants regarding their own patents or those of their consortium partners. Around half of those have already been granted, while the other half is still in the application phase. The figure below shows that, when we include all projects, a further 6% - 12% expects to apply for a patent in the near future. Just like the other scientific outputs, demonstration projects generate fewer patents than their research counterparts. Often, demonstration projects involve the further development and scaling of technologies that have already been patented in an earlier stage. It is noteworthy that the participants in the FCH area are much more likely to apply for a

38 This question was only asked to public & private research institutes or higher education institutions. This explains the lower number observations

39 ibid

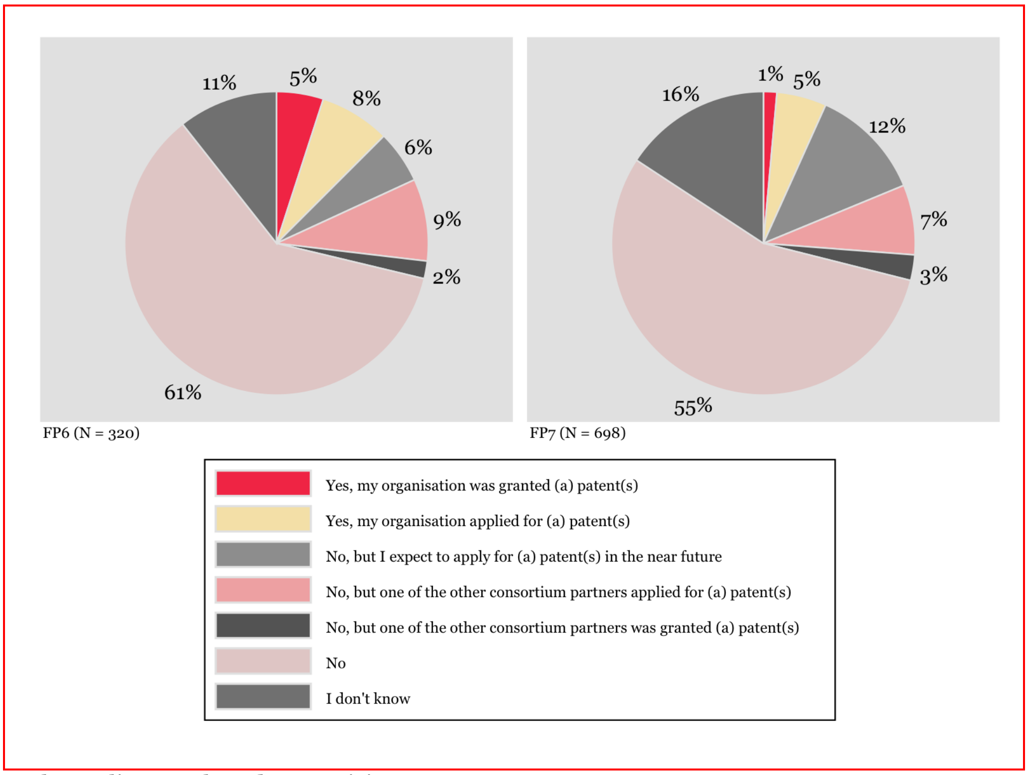
40 ibid

41 These figures exclude "I don't know" answers (14%).
This may reflect a lower N value in comparison to charts including this category.

patent (23%), the same is true for the PV area (18%). There is also evidence that the Bioenergy and CSP areas have higher patenting rates, while smart grids has much lower patenting rates.

Overall, this result is in line with the scope of FP, which has focused mostly on early stage research and only more recently on later stage developments. Also, the FP has the tendency to promote strongly public academic research, which does not favour patent acquisition.

Figure 28 Patent output



Technopolis 2014, based on participant survey

4.4.1 Effects by area

In general, projects succeeded in increasing scientific knowledge and in levelling up the scientific capability of participants. FP projects often provided the participants with the possibility to keep the distance from the technological leaders and to escape from falling behind them. This said, the technological impacts on participants strongly differ across areas depending on the average technological knowledge maturity of the areas:

- CCS/CCT: FP6 projects (focused on research) generated more patents than FP7 projects (that focused on testing and scaling up the developed methodologies and technologies.) Projects have strongly impacted on the technological position of participants;
- CSP: FP6 had almost no influence on the technological position of participants. FP7 helped various organisations to improve their technological position;
- Energy Efficiency: The largest majority of the FP7 projects did not engender patent application or patent grant. This point is coherent with the fact that some

projects were demonstration projects with an application of existing technologies where improvement of the technologies was very incremental;

- FCH: The enhanced R&D capability, the increase of R&D investments and staff show that the implementation of FCH projects not only results in new products, processes and services, but also strengthens the organisations taking part in the projects;
- RHC: The focus of both framework programmes in the RHC area was on demonstration, system integration, cost reduction, performance and reliability, and market introduction of existing concepts and products.
- PV: Collaborations, especially those that targeted the whole production chain of PV, have made researchers more aware of challenges and requirements for their products later on in the chain. One notices a significant number of patents. This may be caused by the slightly higher TRL and application focus of PV projects. However, it appears that only a minority of these patents is a broadly enforceable patent such as an EPO or USPTO patent;
- Socio-economic research: Few to none technological impacts are to be expected from these projects;
- Smart Grids: Projects financed in this area have directly contributed to initial design, development and testing of innovative technologies. Few patents but a slight increase in the number of patents in between FP6 and FP7, which confirms a certain progress in terms of concrete technological outputs. Most outputs are used by project participants, such as research centres and universities, for further research or consulting services;
- Wind: The enhanced R&D capability, the increase of R&D investments and staff shows that the implementation of wind-projects not only results in new products, processes and services, but also strengthens the organisations taking part in the projects;
- Other renewable sources: Only a small number of projects resulted in patents, probably related to the fact that this area also includes a number of network support actions.

Other factors, including the national research framework and policy development, may also have influenced the technological development with respect to others.

4.5 Technological outcomes and impacts

One of the key aims of the Framework Programme is the development of new and better technologies within the Energy domain. The effects on technology development can be assessed at two primary levels:

- The participant & project level, discussing individual (sets of) technologies (micro-perspective)
- The European energy (technology) system, the effects of the FP as a whole on the different broad technology fields (macro-perspective)

4.5.1 Impacts on the level of participants and individual technologies

A useful way to look at whether projects improved technologies, is to use the system of Technological Readiness Levels (TRLs). Technological readiness is a measure of how far a new technology is from application. Although it implies a rather linear perspective of technology development and innovation, it provides a useful way too make rough comparisons before and after projects, and between different technology areas. The scale starts with TRL1, which is scientific fundamental research, and ends at TRL9, which corresponds to the pre-commercialisation step. It should be stressed that none of the FP projects were intended to reach commercialisation within the scope of the project, as the FP is limited to pre-commercial activities. However, especially in large integrated projects, several components or supporting tools (such as models) do reach a very developed stage, as this is required to advance the technology as a whole.

Exhibit 1 Definition of TRL as developed by the NASA[42]

TRL 1 Scientific research begins translation to applied R&D: Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.

TRL 2 Invention begins: Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.

TRL 3 Active R&D is initiated: Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.

TRL 4 Basic technological components are integrated: Basic technological components are integrated to establish that the pieces will work together.

TRL 5 Fidelity of breadboard technology improves significantly: The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.

TRL 6 Model/prototype is tested in relevant environment: Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.

TRL 7 Prototype near or at planned operational system: Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment.

TRL 8 Technology is proven to work: Actual technology completed and qualified through test and demonstration.

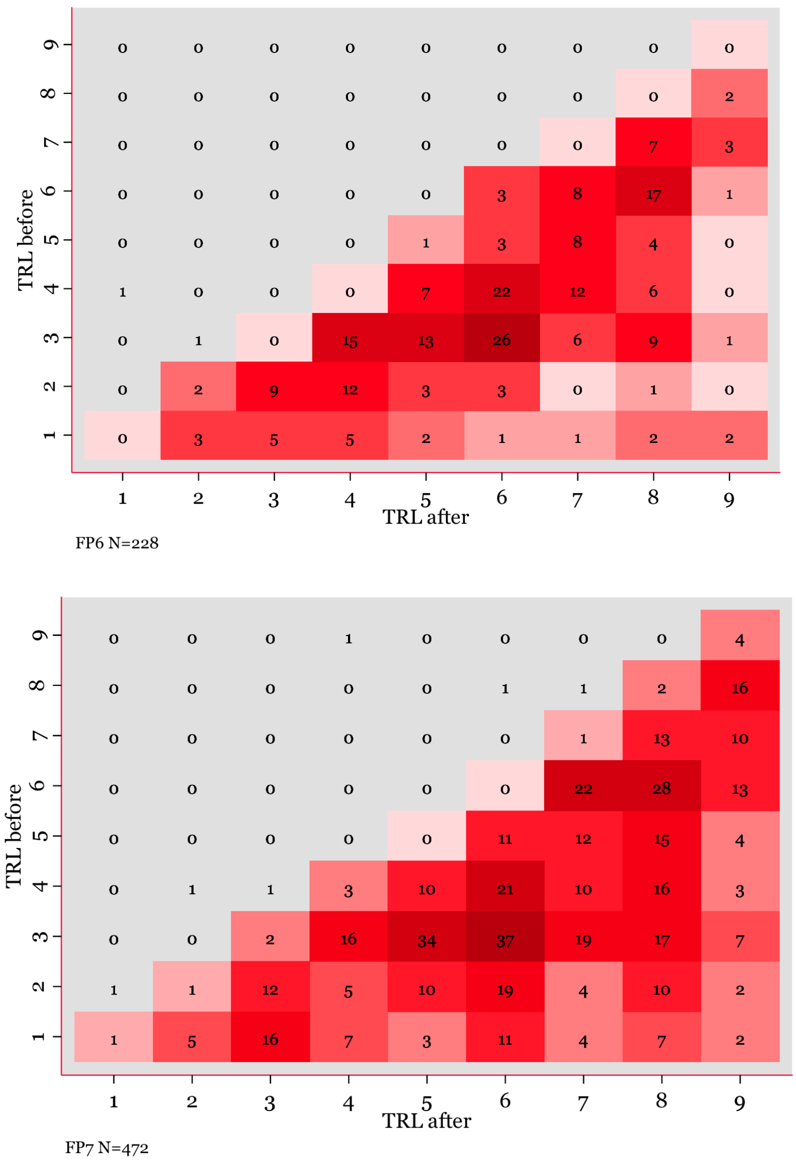
TRL 9 Actual application of technology is in its final form: Technology proven through successful operations.

Figure 29 gives an overview of the main effects on Technology Readiness Levels reported by participants. From this figure, it becomes clear that the most typical developments in FP6 are from TRL3 to TRL6 (and from TRL6 to TRL8). In FP6, projects are rarely brought until the final stage of actual application in the final form. This is quite different in FP7, where a fair share of projects reports a technological readiness level of TRL9 by the end of the project (probably related to the stronger demonstration character of FP7[43]). Another striking difference is the large increase in projects that start at a later Technology Readiness Level (7 or 8). This reflects the increased focus on demonstration projects in FP7.

[42] http://www.nasa.gov/content/technology-readiness-level/

[43] The FP programme does in principal not support market application of project results. This is not necessarily in contradiction with projects having results at TRL9. As part of larger projects often development of components is necessary, and while these components are ready to be brought on the market (TRL9), the main project result may still be in the research phase.

Figure 29 Shift of Technological Readiness levels due to participation in project, FP6 and FP7



Survey

The results are further detailed in Figure 30 below. In total, 75% of participants in a project with a technology development goal indicated that the technological readiness level of the technologies they worked on during their project improved. Coordination of network actions, support actions therefore score relatively low on this, while Focused Projects score very high.

The average project starts at TRL 3.75 (median 3), and finished at 6.12 (median 6). A typical project therefore brings a technology from the validation phase to a model/prototype being tested in a relevant environment. This is true in particular for the projects dealing with energy efficiency, FET and RHC.

As could be expected, demonstration projects start with a higher TRL at the start of the project (TRL 4/5) and also end later (TRL 7). A TRL 7 indeed corresponds with the goal of a demonstration project: i.e. the development of a prototype near the operational system. Demonstration projects make slightly more progress on average in

TRL terms, although the difference is small. However, this would not lead to a conclusion that demonstration projects would be more successful than research projects, as TRL steps are hardly equidistant in terms of the required resources and time involved.

Integrated Projects start on average a bit earlier in the TRL.

As could be expected, projects in the Future Emerging Technologies / Materials area start at an earlier phase (and finish also earlier). Heating and Cooling projects start later and end later.

Figure 30 Technology readiness level (TRL)

	N	Mean (Median)	Survey Total	Significant group differences *Projects in these groups score less/more (mean)*
TRL improved during the project *(yes/no)*	798	75%	599	CA less (40%), SA less (44%), STREP more (84%) Bio more (82%), CCSCCT more (88%), FCH more (85%), HC more (88%), OthRen less (60%), SE less (19%) HES more (84%), PRC more (82%), PUB less (56%), OthOrg less (69%) Funding (+)
TRL before the project *(Scale 1-9)*	530	3.75 (3)	-	IP less (3.35) CCSCCT less (3.14), FETm less (2.29), HC more (4.67) PRC more (3.98), PUB less (2.62), REC less (2) DEMO higher (4.6), RES lower (3.4)
TRL after the project *(Scale 1-9)*	536	6.18 (6)	-	FP7 more (6.41), FP6 less (5.88) CCSCCT less (5.11), EE more (6.93), FCH less (5.63), FETm less (5), HC more (7.21) PRC more (6.46), OthOrg less (5.57) Funding (+) DEMO higher (7.3), RES lower (5.7)
TRL improved during the project *(Scale 1-8)*	521	2.48 (2)	-	FP7 more (2.60) FP6 less (2.32) CA less (1.6) CCSCCTless (2.06), EE more (3.05) HES more (2.75) Funding (+) DEMO higher (2.7) RES lower (2.4)
TRL 9 within next 12 months *(Likely 0% - 100%)*	541	49%	265	CCSCCTless (34%), FCH less (36%), FETm less (28%), HC more (68%), Wind more (70%) DEMO higher (63%) RES lower 43%)
TRL 9 by 2020 *(Likely 0% - 100%)*	540	77%	416	CCSCCT less (68%), FCH less (71%), FETm less (63%), HC more (85%), SG more (85%), Wind more (86%), HES more (80%) DEMO higher (86%), RES lower (74%)

Technopolis 2014, based on participant survey

The figure also shows the average progress in terms of Technology Readiness Levels. Here we see that the average project improved by 2.5 TRL. FP7 projects show slightly more improvement than FP6 projects, but the difference is small. Projects which had more funding available, improved their TRL more. Participants were also asked to indicate the likelihood of the technologies to enter the application phase (TRL 9) in the next year or by 2020. Half of the relevant respondents indicate that they expect that the technologies will be at the application phase within the next year. This is much lower for those projects in the Carbon Capture and Storage & Clean Coal Technologies, Fuel Cells and Hydrogen and Future Emerging technologies. In general, a picture emerges that most FP projects that aim to improve technologies are rather successful in doing so. In terms of focus, the FP is located exactly on the nexus of fundamental science and applied R&D, being in the position of stimulating the flow of knowledge from ideas (in science) towards practical application (in industry).

Figure 31 Examples of projects that generated strong technological impacts for the participants

Name of project	FP	Area	Technological impact	Appendix
THATEA	FP7	FET	After the project was finished, the participants developed the following applications: industrial waste heat transformer, industrial linear motor driven heat pump and high-temperature driven heat pump for industrial and domestic/office applications	D.12.6
SafeWind	FP7	Wind	Forecasting has improved site selection, making wind farm management more efficient. Improved models and tools have created worldwide business opportunities for European technology and the partners involved in the Anemos system are already using the new knowledge acquired to provide forecasting services.	D.11.3
Super 3C		SG	The Super Coated Conductor Cable (Super 3C) project is an example of how European research may support the development of new technologies and products. Super 3C was the first project in Europe to test the feasibility and functioning of a low-loss High Temperature Superconducting (HTS) energy cable using Coated Conductor (CC) tapes. The project oversaw the complete cable design process, the manufacturing of the components and final testing of 30-meter cable system. The consortium leader obtained a patent for the product delivered and so did one of the project partners for the CC tape.	D.10.1

4.5.2 Impact on the European energy systems

Beyond the participants in the projects, the assessment should also focus on the technological impact of the projects on the energy systems.

First it is worth noticing that the FP6 sometimes enabled the identification of technologies that were further developed during the course of FP7:

- CCS: all technologies were assessed against each other during FP6 and provided baseline for further research in FP7;
- CSP: a roadmap was supported (project ECOSTAR) to identify key research topics (collector concepts, cooling systems, heat storage and molten salt fluid);
- PV: OrgaPVNet was a coordination action that brought stakeholders in organic PV (OPV) throughout Europe, from fundamental research to chemical companies, together. The coordination action has produced a roadmap;
- Smart Grid: The project RELIANCE provided an in-depth analysis of the knowledge gap in terms of RTD requirements in the transmission system. This analysis was complemented by four possible scenarios for energy demand in Europe and for each scenario, detailed project roadmaps were prepared.

As regards the increase in the maturity of the different technologies during FP6 and FP7, the situation is very different across areas as well as within areas in some cases.

The analysis[44] shows however that the FPs have been successful in enabling advancement of technology, whatever the start-of-the-art of the technologies at the beginning of FP6 was:

- Bio-energy: Projects covered almost the whole chain from mock-up to exploitation. The projects have led to considerable progress in R&D and innovation. In particular, significant progress has been made towards sustainable liquid biofuels and efficient, flexible and clean stationary bio-energy for a wide variety of biomass feedstock.
- CCS/CCT: Projects covered a spectrum from upstream research to part-scale prototype as far as CCS is concerned. FP6 objectives were to diminish the cost of CO_2 capture. No specific technologies were envisaged but rather the aim was to review and assess the range of possible CCS solutions. For instance, one objective of the project ENCAP was to identify the most-suited pre-combustion technology out of four technologies: OxyFuel, Chemical Looping, High-Temperature Oxygen production technologies and technologies found among the Novel Pre-Combustion capture concepts. The FP6 projects did succeed in improving technology. FP7 objectives were to carry on diminishing the cost of capture. The target was 10 to 12 large-scale demonstration projects across Europe. Despite impressive steps towards this objective, the technological objective has not been reached because the cost of CO_2 capture remained dramatically higher than the price of Certified Emission Reductions (CER) preventing the actual set-up of these large-scale demonstration projects. For CCT, projects covered the whole spectrum;
- CSP: The last decade has seen the CSP becoming more mature with a huge step made towards commercialisation. At the end of FP7, the phase of market introduction had started already;
- Energy Efficiency: Maturity of technologies increased from mock-up to pre-commercial for polygeneration and from mock-up to commercial for eco-buildings. For transport and mobility, maturity of the technology was high already prior to FP6 (at the commercial stage);
- FCH: Projects covered a spectrum from mock-up to part-scale prototype. The developments are however below expectations in spite of good projects like HySYS (FP6) which ended up with an improved system components and sub-systems that can be used as a basis for future fuel cell and ICE-vehicles;
- FET: Projects started (by definition) from upstream research and some of them resulted in the design of mock-up. Projects started from ideas explored prior to the projects and developed basic research in order to prepare a second phase dedicated to prototypes tested in labs. For instance, the project THATEA tested two applications, one to generate heat at 80°C and one for cooling at -40°C). It achieved around 40% of the Carnot efficiency – the maximum theoretical limit of efficiency for the conversion of heat to work and vice versa. Although this had been achieved in heat engines it had never been done with heat pumps or in an integral system for heating;
- RHC: Projects did not focus on a single technology but used a wide range of totally different technologies and technology combinations (heat pumps, solar collectors, absorption chillers, geothermal equipment, heat exchangers, combined systems, control units, heat storages, desalination systems, etc. Before FP6, the readiness of the various technologies in this area varied significantly between basic concept

[44] For the analysis that is presented below, a broader typology of technology development was used. The reason is that it is sometimes difficult to precisely assess the TRL of the technologies: Upstream research (concept design); Development (mock-up, part-scale prototype, full-scale prototype); Demonstration (pre-commercial); Exploitation (commercial)

design and pre-commercial demonstration. For example, the project EU-ULTRALOWDUST (FP7) developed and demonstrated new ultra low emission small-scale biomass combustion stoves and boilers as well as an electrostatic precipitator system that can be used to retrofit old boilers and stoves;

- PV: Both FP6 and FP7 have had a clear impact on the state of the art of PV knowledge and methods in Europe. Some projects attained world records in cell efficiency in a number of technologies such as thin film cells, tandem cells, organic cells and overall module efficiency. Projects related to conventional PV dealt with commercialised products and remained in the stage of exploitation. Projects on thin film went from part-scale prototype to pre-commercial while projects on organic film started from mock-up and ended-up at the stage of demonstration;
- Smart Grids: Projects covered a spectrum from upstream research to part-scale prototype as far as transmission networks and distribution networks are concerned and from mock-up to part-scale prototype as far as energy storage is concerned. The project ADDRESS has permitted an increase in hosting capacity of distributed energy resources and on the Advanced Metering Infrastructure (AMI), with a range of technologies already near standardization;
- Wind: Projects started from part-scale prototype and ended-up at the stage of pre-commercialisation (in particular as far as LIDARs and technologies for remote sensing are concerned). The project UPWIND (FP6) is a good example of such projects since it developed tools and specified methods to enable large wind turbines and to improve reliability of current products. The project demonstrated that a 20 MW design is feasible. The project resulted also in the specification of mass/strength ratios for future very large blades securing the same load levels as the present generation wind turbines;
- Other renewable sources: Projects covered a spectrum from upstream research to pre-commercialisation as far as ocean energy is concerned while projects remained in the latter stage (exploitation) as far as hydropower is concerned (the reason is that plants existed already and FP projects were aimed at increasing their efficiency).

The figure below shows examples of technological impacts on the European energy systems resulting from FP6 and FP7 projects.

Figure 32 Example of projects that generated strong technological impacts on the European energy systems

Name	FP	Area	Technological impact on the European energy systems	Appendix
HySYS	FP6	FCH	The improved system components and sub-systems developed in the project could be used as a basis for future fuel cell and ICE-vehicles. Systems are being deployed in the HyCOM initiative and the Lighthouse projects, and research is being continued in EU projects HiCEPS and FUEREX. Coordinator Daimler is in discussions with some partners for future common projects	D.6.3
EU-Ultralowdust	FP7	RHC	The EU-ULTRALOWDUST project developed and demonstrated new ultra low emission small-scale biomass combustion stoves and boilers as well as an electrostatic precipitator system that can be used to retrofit old boilers and stoves. From the experiences gained in this project, products could be developed further towards market readiness by identifying and implementing product improvement and cost reduction potentials. Those products now define the new state-of-the-art in ultra-low particulate matter (PM) emissions. A broad market introduction of these systems can significantly improve air quality by reducing PM and other emissions. Within the project it was e.g. estimated that in Germany PM emissions can be reduced by up to 25% if all old stoves are retrofit with the system developed in the project.	D.1.2

ADDRESS	-	SG	Project partners developed equipments (e.g. washing machine, network management software) to be used as demonstrators in pilot projects. Overall, the greatest achievements have been gained in increasing the hosting capacity of distributed energy resources and on the Advanced Metering Infrastructure (AMI), with a range of technologies already near standardization.	D.9.8
THATEA	FP7	FET	The two applications tested (one to generate heat at 80°C and one for cooling at -40°C) achieved around 40% of the Carnot efficiency – the maximum theoretical limit of efficiency for the conversion of heat to work and vice versa. Although this had been achieved in heat engines it had never been done with heat pumps or in an integral system for heating.	D.12.6
AER GAS II	-	Bioenergy	The project showed that the production costs of the gasification process are in the same range as the production costs through fermentation processes, but the gasification process is somewhat more expensive. Demonstration projects should be done to optimise the specific components of the process in order to make it cheaper.	
UpWind	FP6	Wind	The project developed tools and specified methods to enable large wind turbines and to improve reliability of current products. The project demonstrated that a 20 MW design is feasible. The project resulted also in the specification of mass/strength ratios for future very large blades securing the same load levels as the present generation wind turbines. Thus, in principle, future large rotors and other turbine components could be realised without cost increases for the industry, assuming the new materials are within certain set cost limits.	D.11.4

4.6 Organisational outcomes and impacts

Just looking at the concrete outputs and outcomes of Framework Programme projects would give a too narrow picture of the benefits of a joint research and development programme. By participating in Framework Programme projects, organisations build capacity to engage in R&D in the future, build networks with relevant partners and increase competitiveness and profitability. Moreover, an innovation instrument may cause 'behavioural additionality', meaning in this case that organisations' strategies are permanently changed towards an increased focus on R&D and innovation. In our analysis of the magnitude of these impacts, we have distinguished between participants with a for-profit motive (i.e. mostly companies), and those with a non-profit objective (research institutes, higher education organisations, public organisations).

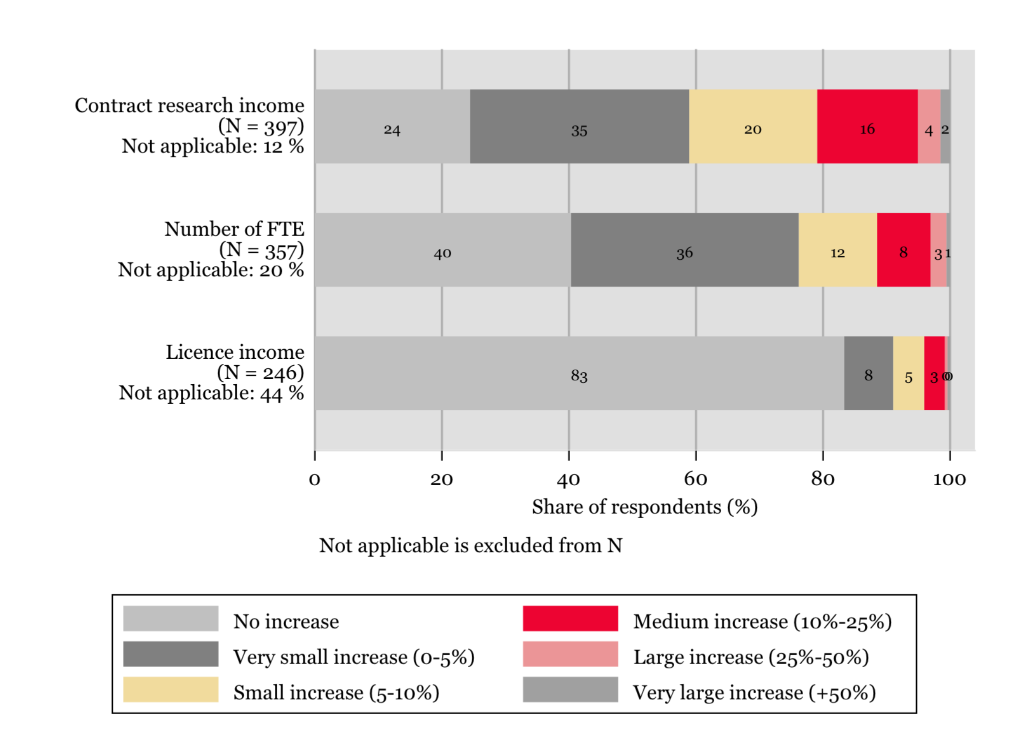
4.6.1 General economic organisational impacts

Figure 33 shows an overview of key indicators for economic organisational impact for non-profit organisations.[45] Even though a typical research institute is not-for-profit, generating revenue through contract research and licensing is a key objective to realise new investments in upcoming research. Also, contract research and licenses are indicators of generated knowledge from research project actually being used in practise, thereby generating added value for society as well. Although only 6% of participants in projects indicate that they have seen a large effect (>25%) on their contract research income, 42% indicates to see at least some small effect of more than 5% increase. This indicates that a large share of participating organisations use the new knowledge in practice, but for only a small share of participants this has had an

[45] This section concerns a general discussion financial and economic organisational impacts. The direct (expected) results from new innovations realised through the FP are discussed in the next sections.

effect that it really changed their sources of income. License income, has increased for more than 5% for 9% of participants, but did not change for the large majority (83%). Given the fact that license income often first needs intellectual property (mostly patents in this case), it is not a surprise that only a small proportion of participants register any impacts. Still, virtually no one indicated that their license income has substantially increased, even though many projects have finished relatively long ago. This shows that – at least for knowledge institutions – profitable patents resulting from FP participation are only present in a limited number of cases (which is in line with the skewed-ness of patent income in general: only a very small number of patents is responsible for a large part of worldwide licensing income).

Figure 33 Project's impact on organisation (knowledge institution)[46]

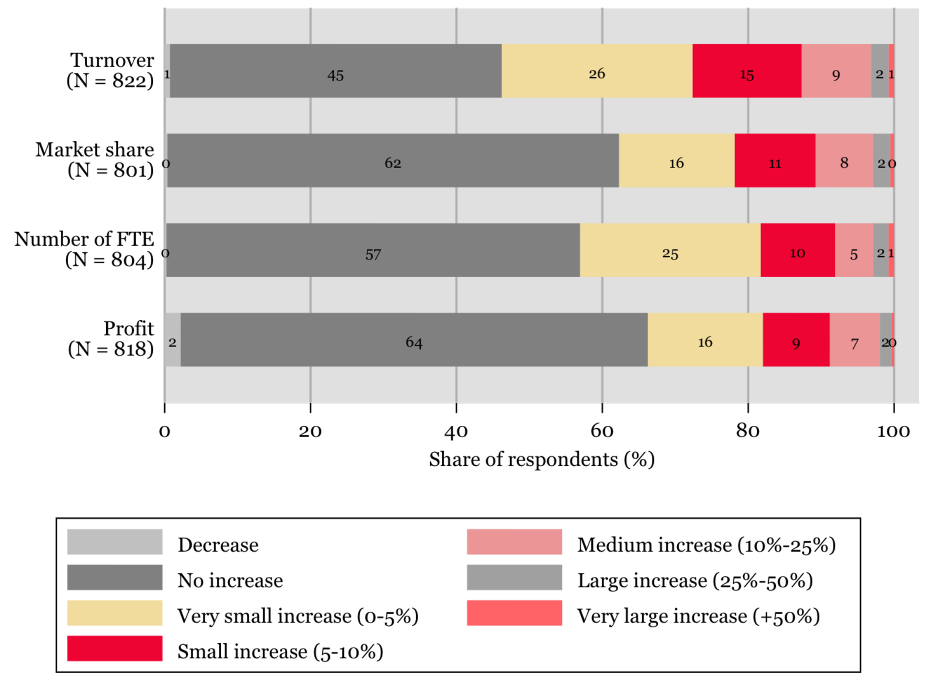


Technopolis 2014, based on participant survey

Similar economic effects on organisations were investigated for companies or research organisations with a for-profit objective. The results are presented in the figure below. For all indicators around 20-25% of participating organisations see a substantial improvement of more than 5%. For only around 2% of participants their participation has had very large effects of more than 25% increase in turnover, profit, FTE or market share. Demonstration project have more turnover increase and profit increase (6.2% vs 4.1%, and 4.1 % vs 2.3%) also Market size (5.8% vs 2.8%). There is no strong evidence that the effects differ substantially between the areas.

46 FTE = full time equivalent

Figure 34 Project's impact on the organisation's economic performance

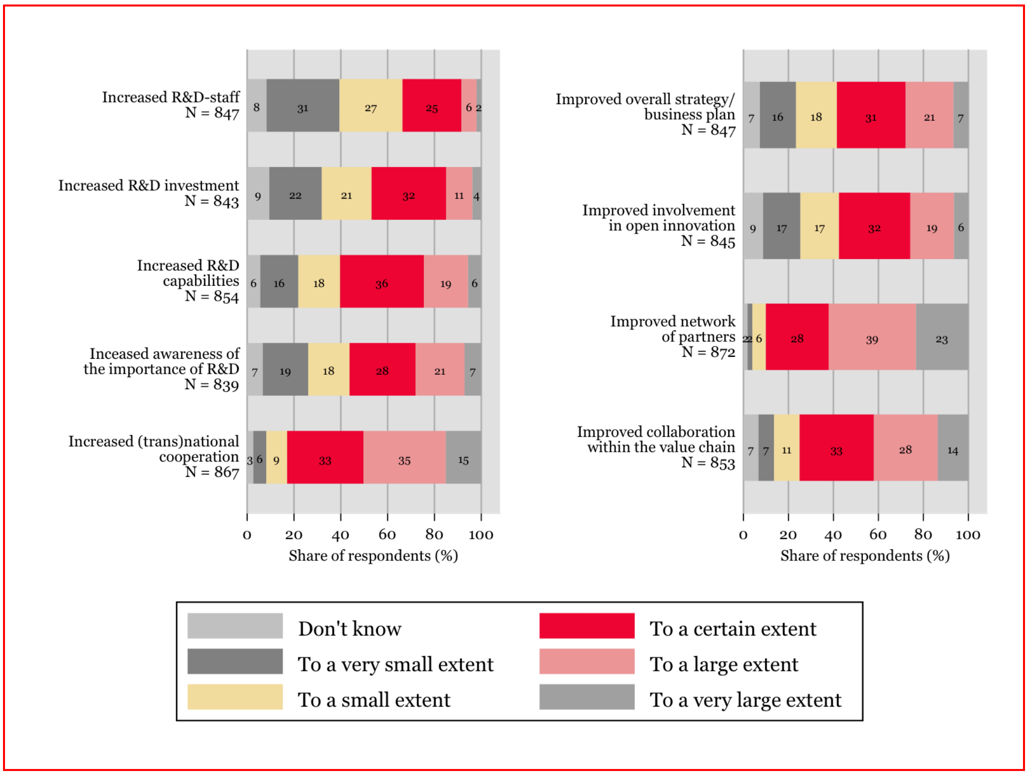


Technopolis 2014, based on participant survey

4.6.2 Behavioural additionality

We also investigated more qualitative measures of effect on organisations with a profit motive. Figure 35 gives an overview of such impacts, including some aspects of behavioural additionality. As is apparent from this figure, a majority of participants indicate that their participation had a large or very large effect on transnational co-operation and an improved network of partners. Other effects are less pronounced but still significant, such as an effect on improved R&D-capabilities, improved awareness of the importance of R&D, improved collaboration in the value chain and an improved overall strategy. For all these measures more than 50% of participants indicate that there is more than a small effect on their organisation. For increased R&D-investment and increased R&D-staff, the effects are relatively smaller, as around 10% of organisations indicate that their participation has had a large effect on these aspects. Participants with larger budget shares report more effect on all categories.

Figure 35 Qualitative measures of organisational impact

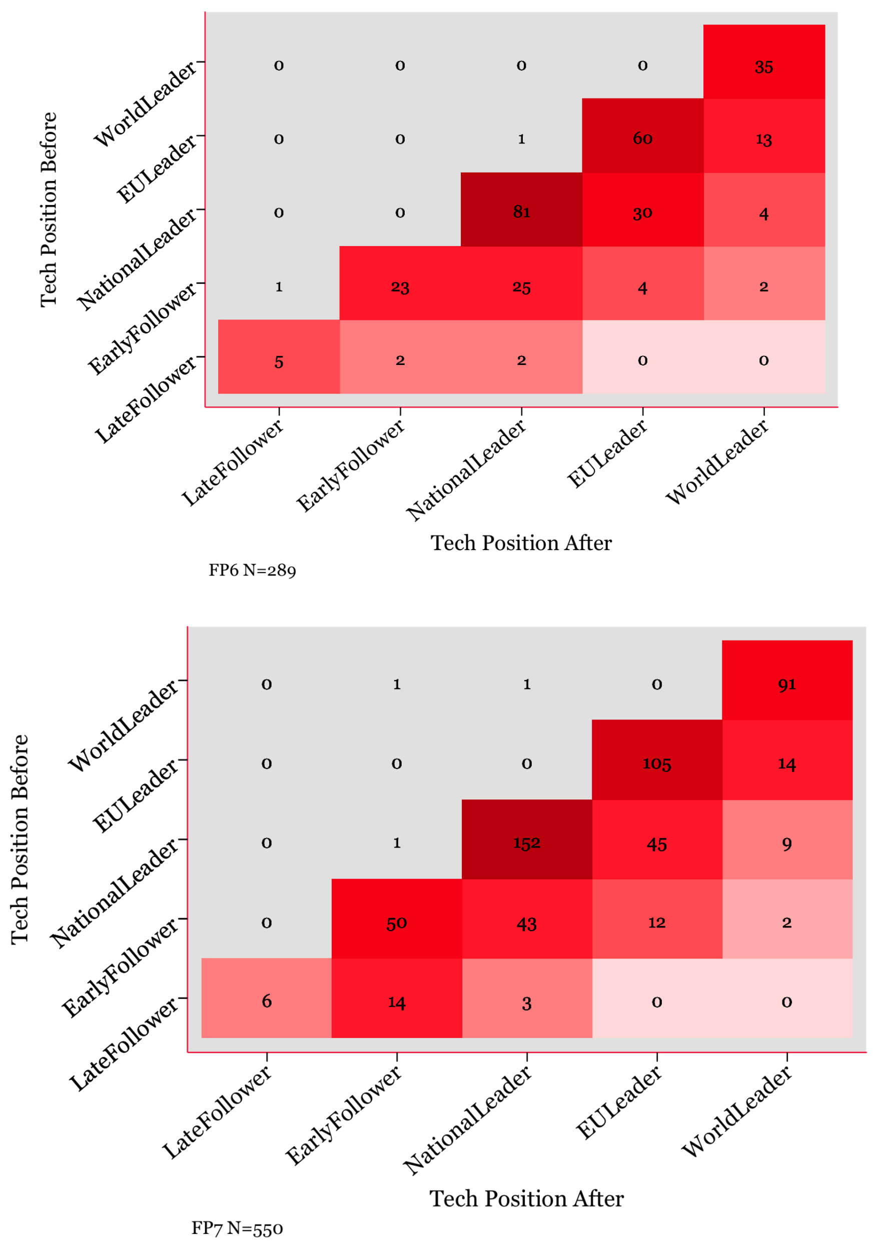


Technopolis 2014, based on participant survey

4.6.3 Technological competitiveness position

An important objective of the Framework Programme is to contribute to a more competitive European industry. An important part of competitiveness is to have a leading technological position. Naturally, the competitive nature of the FP application procedure, which is focused on excellence, will already attract organisations with a good technological position. However, improving the technological positions of companies as a result of a participation in the Framework Programme would be very much a desirable impact. Participants were asked to rank their technological position before and after the project, the results are presented in Figure 36. Organisations were asked whether they were among the national, European or world leaders in their field. The majority of firms that participate in the FP are already in the position of national leadership or even EU leadership at the start of the project. Around 10% of organisations shift from the national leadership category to the EU leadership position, around 3% shifts from the EU leader position to World Leadership position. Of course, there are a lot of autonomous developments as well, so this change cannot directly be attributed completely to the FP participation. However, given the fact that virtually nobody decreased in technological leadership position shows that there is likely to be at least some positive effect.

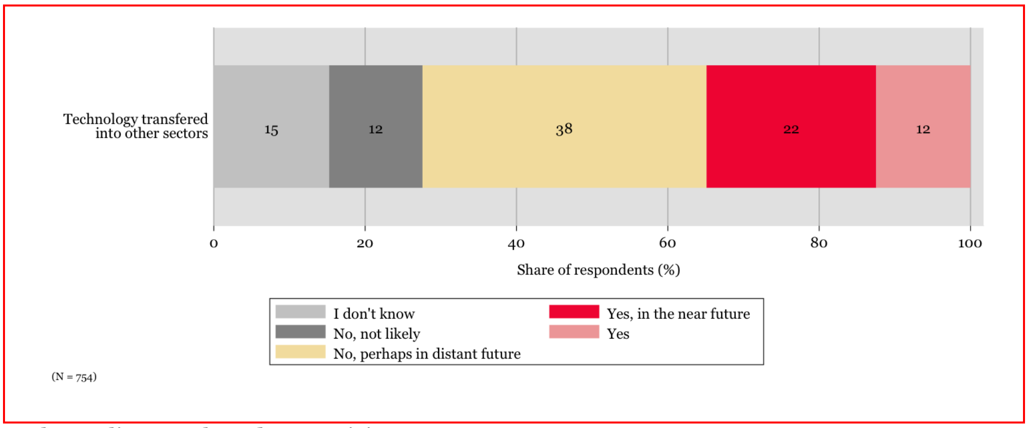
Figure 36 Technological position



Technopolis 2014, based on participant survey.

An important potential effect of working in joint R&D projects across value chains and also across narrow sectors is the flow of knowledge from one sector to the other, creating knowledge spill-overs. An example could be a newly developed process for Bioenergy, which also boosts the use of biomaterials for non-energy use (e.g. fibre materials). Or a new or improved semiconductor materials developed within the area of PV or FET could also be applied in computer chip manufacturing. The fact that science and technology is unpredictable clearly does not only have downsides, but also upsides as technologies may find applications for which they were not developed initially. Figure 37 shows that for 12% of participants such technology transfers have already occurred, while a further 22% expects this to happen in the future.

Figure 37 Technology transfer between sectors

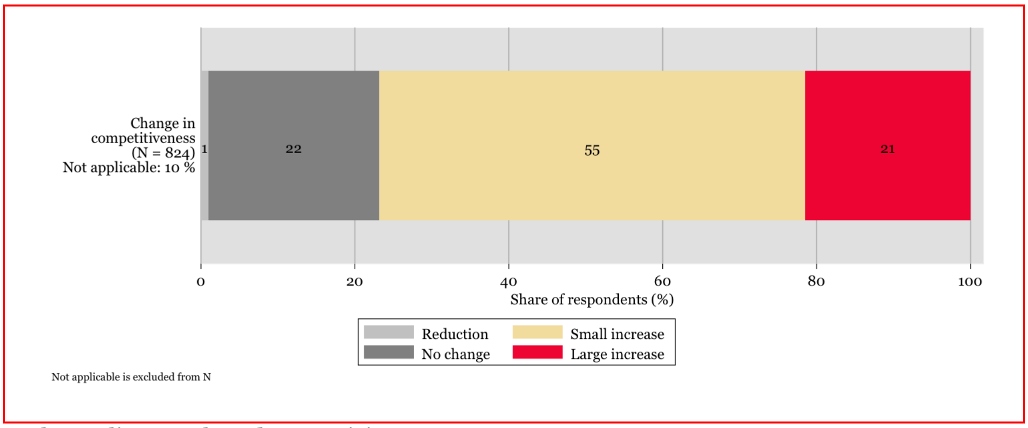


Technopolis 2014, based on participant survey

4.6.4 General Competiveness

Companies were asked specifically whether they also perceived an improvement of general competiveness in the global market place due to their participation. Figure 38 shows that the large majority (76%) of companies indicates that there has been an increase in their general competiveness. One in five companies indicate a large increase in competitiveness.

Figure 38 Change in competitiveness as result of the projects



Technopolis 2014, based on participant survey

4.6.5 Examples from projects

The table below shows example of organisational impacts resulting from FP6 and FP7 projects.

Figure 39 Examples of projects that generated strong organisational impacts for the participants

Name	FP	Area	Organisational impact
IRED	-	SG	The participants in the project highlighted that the project was very successful to bring stakeholders together and creating networks that help them in pooling resources and that provided them with access to expertise from the other actors of the networks.
SESSA	-	SE	SESSA created the first European forum for discussion of regulatory issues in European electricity markets. SESSA provided the participants in the project with a place where to discuss for the first time electricity regulatory issues in a systematic way. Participants now benefit from this platform.
NANOPEC	FP7	FET	The Coordinator (U. of Lausanne) was able to set up further significant initiatives on Photoelectrochemical Water Splitting at National level leveraging on the results of NANOPEC (PECHouse 2).
INNOVASO L	FP7	FET	Research partners benefited from the cooperation with Industrial partners both on the development of prototype materials for solar cells and their applications (automotive industry).
HAWE	FP7	FET	The coordinator Omnidea was capable to enter the field of High Altitude Wind Energy. The project allowed to recruit partners developing the technical components and other aspects like wind forecasting and business strategy.
Biosynergy	-	Bioener gy	The overlap between research institutes in this field decreased, due to this project. Research institutes are now more focusing on their own specialities and can now devote all their efforts to what they are the best at.

4.7 Innovations from the Framework Programme and their effects

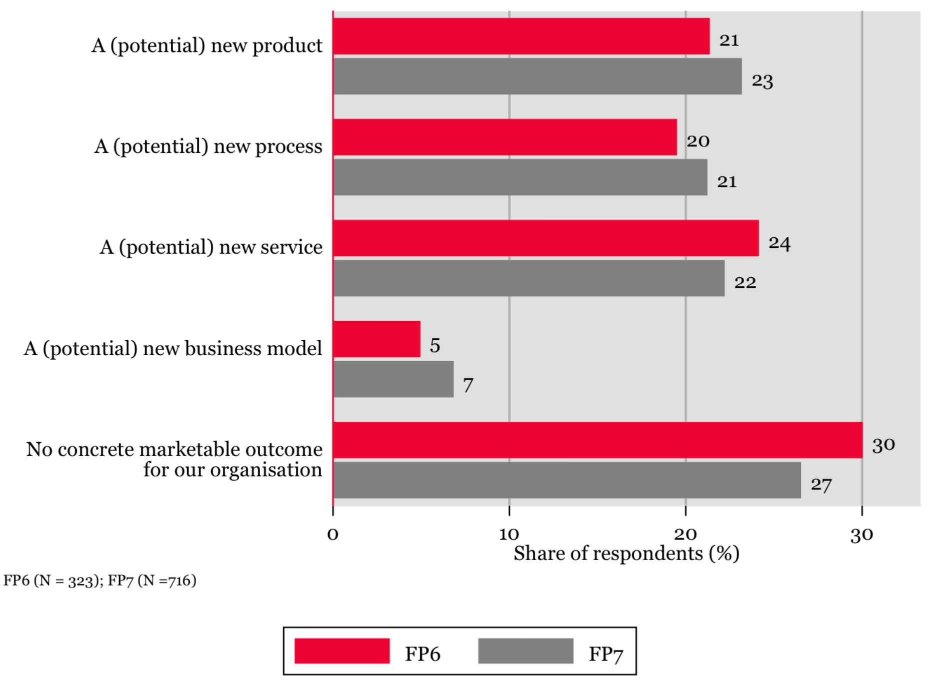
An important outcome - which is a prerequisite for any further economic or energy impact - is that the project resulted in or directly contributed to a concrete marketable outcome. Four different types of marketable outcomes are generally identified when we talk about an innovation:

- A new product
- A new service
- A new process
- A new business model

Project participants were asked whether their participation in a project led or is expected to lead to a potential marketable outcome. Two-thirds of participants do indeed see a concrete marketable outcome, now or in the future. These innovations are roughly equally divided across products, services and processes (each around 20%), with business models only around 6%. In total 487 concrete innovations were reported, which translates to around 3500 new potential innovations in the total FP6/7 sample of (almost) finished projects.

Of course, real economic and societal impact will only occur if these innovations enter the market. Participants expect in total 55% of concrete outcomes to enter the market within five years, meaning around 1100 new innovations are expected to have entered the market in five years, although such expectations tend to be somewhat optimistic in general. On average, companies assign higher probabilities for market entries than Higher Education Institutions.

Figure 40 Main marketable outcomes of the projects



Technopolis 2014, based on participant survey

In total 68% of participants indicate that their participation resulted in a concrete outcome. As could be expected, companies report more concrete outcomes than higher education institutions. Coordinated actions also report less concrete outcomes in terms of innovations, whereas IP and STREP projects result in more concrete outcomes. The differences between areas are relatively small, although heating and cooling quite clear performs better in terms of concrete outcomes. This is mainly due to the fact that the H&C projects are in general aimed at more mature technologies.

When we compare the type of innovation across technology areas, we see that Bioenergy projects on average have more process-innovations and less product-innovations; PV, Heating & Cooling, Fuel Cells and Hydrogen have more product-innovations on average; while socio-economic projects score very low on all accounts (as can be expected). Projects from the Energy Efficiency area show relatively many new business models as outcomes of projects.

Figure 41 Concrete outcomes[47]

	N	Mean	Survey total[48]	Impu-tation	**Significant group differences** *Projects in these groups score*
Has the project led to a concrete outcome	760	68%	487	±3500	CA less (42%), IP more (77%), STREP more (74%) HC more (82%), PV more (78%), SE less (41%) HES less (61%), PRC more (80%), PUB less (39%)
Project led to a new product	760	22%	153	±1200	CA more (2%), STREP more (30%) Bio less (13%), CCSCCT less (14%), FCH more (31%), FETm more (48%), HC more (35%), PV more (32%), SE less (4%) HES less (14%), PRC more (33%)
Project led to a new process	760	20%	152	±1000	CA less (7%), IP more (27%) Bio more (39%), CSP more (40%), SG less (9%), SE less (6%), Wind less (3%) Funding more (+) DEMO less (15%), RES more (22%)
Project led to a new service	760	23%	175	±1000	FETm less (5%), SG more (32%) PRC less (18%), REC more (32%) DEMO more (28%), RES less (21%)
Project led to a new business model	760	6%	46	±200	EE more (13%) DEMO more (10%), RES less (4%)
Probability to be marketed by 2020	518	55%[49]	NA	NA	EE more (67%), Wind more (74%) HES less (47%), PRC more (59%) Funding more (+) DEMO higher (62%) RES lower (51%)
Realised market introductions	518	11%	56	56 – ±200[50]	Sample too small

Technopolis 2014, based on participant survey

Interestingly, demonstration projects show relatively less new processes, but more new services and business models.

The market probability by 2020 is an important measure to get more insight into the potential future economic and energy impacts, as these will not take place when new innovations do not enter the market. Of those participants with a concrete outcome, the average probability of market entry is 55%. However, there are of course large variations between the innovations. Just under 10% indicate that their innovation has 0% market probability, while 28% expects that the probability is less than 40%. Most

[47] All participants were asked to report the information for their most important concrete outcome with the highest potential. These figures therefore do not include information about other products developed on the basis of a FP participation. However, from the case studies we have seen that only a small minority of participations leads to multiple concrete innovations with a large potential (the work is generally rather focused for each individual participant).

[48] The survey total only includes projects finished before the end of 2015

[49] This figure is calculated for all participants *with* a concrete outcome.

[50] This figure is an extrapolation (see methodology section at the start of this chapter)

people indicate that it is still quite uncertain but definitely possible with a probability between 40% and 60% (31%). One quarter of respondents expect that it is highly likely (>80% probability) or certain (as it has already entered the market)

Naturally the types of innovations vary wildly within, but especially across areas. The table below shows examples of innovation impacts resulting from FP6 and FP7 projects.

Figure 42 Example of projects that generated concrete innovations

Project	FP	Area	Innovation impacts
GenHyPEM	FP6	FCH	Project outcomes were the development of low-cost fabrication techniques for components and the design, construction and testing of a prototype electrolyser. After the project, consortium partner CETH has proceeded to gain funds from the private sector, and continued the development, increased the capacity of their PEM water electrolyser systems and put the systems on the market.
Bionicol	FP7	RHC	In the BIONICOL project, a new type of solar absorber was developed. An aluminum roll-bond absorber featuring bionic channel structures that reduces the pressure drop in the absorber was developed. The main innovation was to use the roll-bond process for the absorber production and to use aluminium instead of copper as material to pipe the heat transfer fluid. This could be achieved by identifiying a heat transfer fluid that prevents aluminium corrosion inside the absorber. This innovation can potentially lead to less costly absorbers due to not using expensive copper. The first solar thermal collectors featuring aluminum roll-bond absorbers will soon be available on the European market.
THATEA	FP7	FET	The initial area where the technology is likely to be used is in developing a thermoacoustic heat transformer for industry. Other applications could include using heat pumps for domestic applications, solar driven cooling systems and conversion of waste heat to electricity.
Biocard	-	Bioenergy	A static system was developed for fractioning the biomass from bales to seeds and lignocellulosic biomass.
Optfuel	-	Bioenergy	It was for the first time that a company took the responsibility to make contracts with farmers for large-scale short rotation plantation of wood as bio-energy plants (200 hectares were planted in Germany and Poland). This can be seen as a business model innovation.
EU Agro Gas database	-	Bioenergy	The EU Agro Gas database is intensively used; users are found all over the world. Also it was the basis for the formulation of technical standards for biogas plants in Europe, as best available technique. The demonstration plants have resulted in commercial production plants. Based on the project results, Gejenbacher developed a steam turbine principle product that is now sold worldwide.
TOPFARM	FP6	Wind	In order to achieve the optimal economic output from a wind farm during its life time, an optimal balance between – on the one hand – capital costs, operation and maintenance costs, costs related to component fatigue lifetime consumption and – on the other hand – power production output is to be determined on a rational basis. The project addressed this problem. The different methodologies developed by the project are in use by research institutes and universities, inside and outside the consortium, as well as on the way of being commercialised by the industry. The commercialisation potential is mainly due to the prospective the methodology has in increasing the accuracy of offshore wind measurements.
NORSEWInD	FP7	Wind	The project was developed to reduce uncertainty regarding offshore wind development, and to provide more efficient data. The dataset is available on the project's webpage along with a reliable GIS tool, modelled data and satellite derived wind atlases. During the project some 12 years of LiDAR data has been acquired, collated, quality controlled and analysed. This is the largest single

			wind LiDAR dataset in the industry.

4.7.1 Economic impacts

In order to get a more detailed quantified estimates of the economic return to these new products, processes, services and business models, several questions in the survey were asked which together form a basis for an informed estimate of these impacts. The Figure 43 shows an overview of these estimates, along with an extrapolation of the results from the survey for the entire population of participants. Participants were asked to provide low, mean, and high estimates of the potential turnover of these new innovations, *assuming they reach the market*. Additionally, the probability of reaching the market was identified and used to calculate a figure for expected annual turnover. Finally, the annual turnover of projects that are already on the market are presented separately. Note that these figures are estimations based on a sizable but not complete sample, and include only projects that finish before the end of 2015 and for which participants indicated that it was already possible to identify impacts with at least a reasonable level of confidence. Because the FP7 is still running, a final evaluation will have to shed more light on the total impact of the FP6 and FP7 combined.

Figure 43 Associated economic output[51]

	N	**Mean (Median)**	**Survey total[52]**	**Imputation (**Conservative estimate**)**	**Extrapo-lation (**Optimistic estimate**)**	**Significant group differences** *Projects in these groups score*
Hypothetical potential annual Turnover *low estimate*	294	€24.9 million (€0.075m)	€5.6 billion	± €10 billion	±€40 billion*[53]	SE less (€0.062m) REC less (€0.840m) Funding more (+)
Expected future annual turnover *low estimate*	294	€4.5 million (€1.5k)	€2.4 billion	± €4 billion	±€15 billion	
Hypothetical potential annual Turnover *average estimate*	314	€73.7 million (€0.375m)	€23.1 billion	±€39 billion	±€100 billion	SE less (€0.470m), Wind less (€0.460m) REC less (€25.4m) Funding more (+)
Expected future annual Turnover *average estimate*	314	€16 million (€11k)	±€10 billion	±€18 billion	±€75 billion	
Hypothetical Potential Turnover *high estimate*	271	€138 million (€1.75m)	€32.4 billion	±€80 billion	±€150 billion	SE less (€3.8m), Wind less (€4.1m) REC less (€39.2m) Funding more (+)

[51] Potential turnover refers to the estimations of turnover when their product, service, process or business model will have entered the market (which may take still a long time) . Expected turnover takes into account the probability of market entry.

[52] All individual high values which have a high impact on the total figure were manually checked by the area experts.

[53] For indicators with large variances, such as turnover, our imputation method gives a rather conservative estimate, as it is based on median values for similar participations (based on type of organisation, area, size of funding and type of project). Rare values (very large turnover figures, or 100% market probability) are underrepresented. We therefore added another more optimistic estimate using a more simple linear extrapolation method based on sample means. However, this figure is likely to be somewhat on the high side given a likely positive non-response bias due to bad cases being less likely to respond (e.g. bankruptcies). See also the methodological note on imputation and extrapolation (beginning of this chapter)

	N	Mean (Median)	Survey total[52]	Imputation (Conservative estimate)	Extrapo-lation (Optimistic estimate)	Significant group differences *Projects in these groups score*
Expected future annual Turnover *high estimate*	271	€28 million (€4k)	±€13 billion	±€37 billion	±€70 billion	
Realised turnover	41	€13 million	€510 million	±€ 750 million	±€2.5 billion	Sample too small

Technopolis 2014, based on participant survey

From the figures it becomes clear that the reported potential future turnover is very large, ranging from 10 – 35 billion euro a year in a low scenario and 80 – 150 billion euro a year in a high scenario. This amounts to an average of €24 million (low) to €124 million (high), although the median figures show that the economic impact is very skewed: there are many (potential) innovations of which the market potential is very small and a few products, processes, services or business models that have a high potential turnover. A more detailed discussion on this skewed-ness of results is presented in the section on drivers and barrier at the end of this chapter. Larger FP projects in terms of funding generally result in a higher expected turnover. Innovations emanating from the socio-economic and wind area show lower turnover potential.

However, in order to provide a more realistic estimate it is necessary to take into account the probability that these innovations enter the market. This significantly reduces the expected turnover, to €4.5 – 10 billion in a low scenario to €37 - 70 billion annually in a high scenario. Note that it can take up to 2020 before these turnover figures are realised, and it could be likely that participant overestimate the probability of market entry as they may not have full information on competing technologies. In total, out of around 1300 respondents in the survey, 41 organisations (3%) reported improved revenue at this moment already from these new products, services, processes or business models. Note that of course many more companies have improved turnover through other means than these new products (see also section on organisational impacts). The current realised annual turnover of new innovations amounts to around €500 million in the sample we have, which can be extrapolated to ±€1.6 billion to the entire group of participants in the Framework Programme.

An expected annual turnover of €18 billion - €75 billion by 2020 translates to an economic return in terms of turnover of ± 10 – 40 times the initial EU investment. However, in order to investigate a hypothetical '*return' on investment* figure, it is necessary to translate this to actual returns (profits). Taking a hypothetical – but not entirely unrealistic – long-term profit rate of 10%, the economic annual 'return' in the long run is around 1-4 times the EC contribution. Naturally, companies themselves will have to invest significant amounts to achieve these turnovers (most likely many times the EC contribution), just as organisations themselves in many occasions already invested in new innovations before the FP project itself.

There are six projects in which participants have indicated expected turnovers for 2020 of more than 500 million euro. These are BIOASH (Bioenergy), EQUIMAR / WAVE DRAGON (WAVE), INTEGRAL (Smart Grids), LARGE-SOFC (FCH), MOVECBM (CCS/CCT) and BIODME (Bioenergy). However, for some of these projects the expected impact is likely to be very uncertain: the most likely scenario is that a product is either quite successful, or it is not at all (e.g. will hydrogen break through as a transport fuel?). When looking at realised turnover, examples of projects that show current turnovers of >1 million euro, these are CO2SINK (CCS/CCT), FLEXCELLENCE (PV)[54], EU-DEEP (Smart Grids) and HIGHSPEEDCIGS (PV),

[54] The results of the project have been implemented in practise, but turnover ceased due to bankruptcy of the main private partner

although also here participants indicate that turnovers are still to increase by 2020. Most of the above examples of concrete (expected) economic impact are coming from either large-scale demonstration projects (or projects related to demonstration projects). Unfortunately, the small number of observations on products already on the market inhibit further detailed analysis on the type of projects that are economically successful (or not). However, a general picture emerges of a situation where very few participants already indicate to have major economic returns at this moment combined with a large number of participants with high but uncertain expectations.

The economic benefits of a new innovation are not always directly translated to turnover in the participating organisations, moreover turnover estimates from surveyed participants can partly be misleading. In some case, especially higher education institutes opt to establish a spin-off company, which is to bring a new innovation to the market. For organisations with a non-profit motive, 11% has established a spin-off as result of the participation in the FP project. The result is not to be considered fully satisfactory, this would translate to around ±130 spin-off companies which were founded as a result of the FP6 and FP7 energy projects over the past 12 years. The number of spin-offs resulting from research projects is considered as an important results in terms of economic output and is an aspects that may be able to positively impact economic growth and technology transfer.

The table below shows concrete examples of economic impacts resulting from FP6 and FP7 projects.

Figure 44 Example of projects that generated economic impacts for the participants

Project	FP	Area	Economic impact
INTEGRAL	-	SG	The project INTEGRAL created the baseline version for commercialisation of the software system "PowerMatcher Agent core 3.0", which allows residential devices and appliances to communicate and negotiate over the internet as a Virtual Power Plant (VPP). Hence network devices are able to optimise their performance on the basis of energy consumption and production. The software is currently being further developed by the research institute TNO Netherlands, who owns a patent over the technology. A considerable up-scaling is being carried out through the project ECO-GRID, where the application will be tested with 700-2000 households.
BIOSYNERGY	-	Bioenergy	Avantium (Dutch chemical company) picked up one of the results of BioSynergy project (chemical conversion of cellulosic into FDCA and the production of polymers based on this) and has commercialised it. Abengoa worked on a demonstration project for cellulosic ethanol (based on wood, straw). They further improved it and also gained more knowledge about possible by-products, such as surfactants.
DOMOHEAT	-	Bioenergy	Based on the results of the Domoheat project, KWB adopted their boilers to the new substrate fuel (olive kernels). Now KWB has about 10-20% of the annual sold boilers running on olive kernel. The annual turnover with olive kernel was ca 0.2 M€/Year.
SAFEWIND	FP7	Wind	The Anemos system is being continuously developed by partners, and already commercialized in existing products.

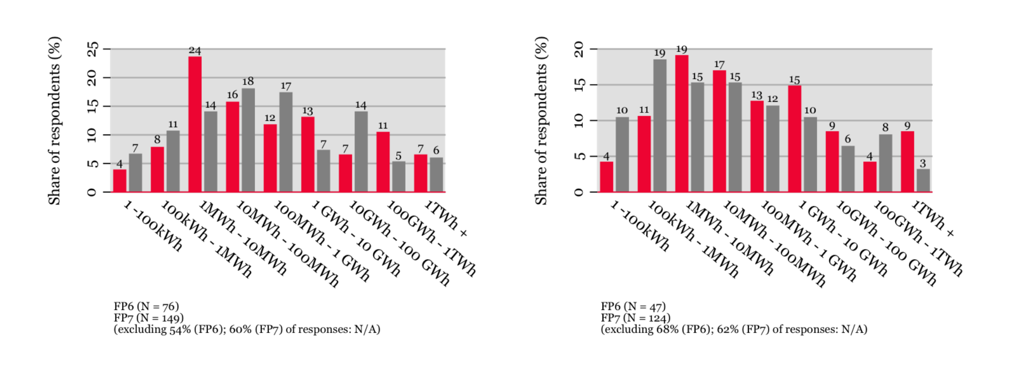
While as shown in table 5, participation to certain projects meant concrete positive outcomes for project participants, it has to be noted that both FPs focused mainly on fostering innovation and technology through a project based approach, highly promoting the dissemination of project results in the academic world, leading to less importance given to concrete economic outputs and full support to the value chain. The European Commission that must ensure an "unbroken chain of support from low to high TRL levels for an efficient and successful development of technologies from early stage research to full market deployment. Moreover, in order to ensure economic benefits for individual participant's stronger mechanisms for the protection of IPR should be ensured.

4.7.2 Impacts on renewable energy generation and energy efficiency

The Framework Programmes are not just aimed at improving economic benefits for European companies, but intend to serve important societal causes as well. For the FP projects in the Energy area, the FP is a major tool in generating the new innovations that will help European countries in increasing their renewable power generation, improve energy savings and reduce CO_2 emissions.

Figure 45 shows the main outcomes from the survey questions on potential power generation, savings and CO_2 reduction, for those participants indicating that participation has or will lead to a concrete innovation.

Figure 45 Associated power generation, power savings & CO_2 reduction (red = FP6, grey = FP7)



Technopolis 2014, based on participant survey

Around 40-45% of participants with a concrete outcome indicate that their potential product may result in concrete power generation. The total scope of annual power generation varies widely, from 1MWh per year to over 1 TWh a year. Around 35% of those with a concrete outcome indicate that they expect potential power savings as a result from their innovation. Around 55% indicates that they expect potential CO_2 reduction.

Just like for economic impacts, a quantitative analysis has been carried out to explore the magnitude of these effects. The results are presented in Figure 46. For annual potential power generation, we see that the potential is estimated at ±17 TWh (conservative estimate) to 80 TWh (optimistic estimate). Taking into account the probability of entering the market, this is reduced to ± 6.4 TWh – 30 TWh. This still presents a large future expected impact of the Framework Programme on the renewable power generation in Europe. For reference, the total wind power electricity production in Germany in 2010 was 36 TWh[55], and the total energy consumption of Germany is around 600 TWh in 2012[56]. However, it may require a lot more time before this expected potential has materialised. Looking at realised annual power generation, we see that the figure is somewhere between 1.2 TWh and 4TWh, roughly the annual generation of a small to medium sized power plant. Potential, expected and realised power savings show a similar picture, although potential and expected are about half of power generations, while realised power savings are actually already

55 "Spain becomes the first European wind energy producer after overcoming Germany for the first time". Eolic Energy News. 31 December 2010.

56 http://www.bdew.de/internet.nsf/id/DE_20120111-PI-Wachstum-der-Erneuerbaren-erhoeht-Handlungsdruck

higher. The impact on CO_2 generation is in line with the effects of renewable power generation and energy savings.

In conclusion, it appears that the potential and expected future impacts are substantial, but measurable impacts so far are limited (but not negligible).

Note that the total results are largely driven by a few examples of very high impact, which is representative of the skewed nature of renewable energy technology. This skewedness makes the extrapolations relatively uncertain, as even one very successful innovation could dominate the total impact of all the other new products combined. Examples of projects of which the participants have high expectations regarding energy impacts are BIODME (Bioenergy), BIGPOWER (Bioenergy), CO2SINK

on later TRLs have a higher chance of getting concret(CCS/CCT), DYNAMIS (CCS/CCT), 7MWEC (Wind), ALONE (H&C). There is a clear relationship between projects with a substantial economic impact (in terms of turnover) and those projects with a substantial impact on energy savings and renewable energy generation. This is quite a logical relationship, as market introductions of innovation are a precondition for energy impacts.

The table below shows whether there are any statistical differences between participations with different characteristics. Besides differences between areas, there are few clear patterns. Bio energy project participations have lower expectations for power generation on average, in particular if ones takes into account that the largest share of budget was dedicated to such activities. Clean Coal, Wind and other renewable show higher than average expected impacts. Unfortunately, as the sample with clear energy impacts with higher market probabilities is relatively small, it is difficult to assess whether there are clear patterns that explain why projects are successful or not. However, more qualitatively it can be seen that projects with strong industry partners, well-aligned and/or focused projects and a focus e results in terms of impact on energy generation and savings.

Figure 46 Power & CO2 reduction[57] [58]

	N	Mean[59] (Median)	Survey total[60]	Imputation	Extra-polation	Significant group differences *Projects in these groups score*
Potential annual Power generation	161	110 GWh (55 MWh)	±16 TWh	±17 TWh	±80 TWh	Bio less (47 GWh) Clean coal and carbon capture and storage more (417 GWh) OthRen more (220 GWh) Wind more (143 GWh)
Expected annual Power generation	161	18 GWh	6.4 TWh	±6.4 TWh	±30 TWh	

[57] For indicators with large variances, such as the indicators in this table, our extrapolation method gives a rather conservative estimate, as it is based on median values for similar participations (based on type of organisation, area, size of funding and type of project). Rare values (very large generation figures, or 100% market probability) are underrepresented. We therefore added another more optimistic estimate using a more simple extrapolation method. However, this figure is likely to be somewhat on the high side given a likely positive non-response bias due to bad cases being less likely to respond (e.g. bankruptcies). The best estimate is somewhere in the middle between the conservative and optimistic estimate.

[58] The data on CO_2 emissions gathered in the survey proved not reliable enough, as respondents were not familiar enough with the units. The conversion calculator from the EPA (epa.gov) was used instead, based on the sum of renewable power savings and renewable power generation.

[59] Not counting zeros

[60] All individual high values which have a high impact on the total figure were manually checked by the area experts.

	N	Mean[59] (Median)	Survey total[60]	Imputation	Extra-polation	Significant group differences *Projects in these groups score*
Realised annual Power generation	17	46 GWh	800 GWh	± 1.2 TWh	±4TWh	
Potential annual Power savings	123	76 GWh (55 MWh)	9.3 TWh	±9.4 TWh	±45 TWh	
Expected annual Power Savings	123	15 GWh	4.8 TWh	±4.9 TWh	±23 Twh	
Realised annual Power Savings	14	150 GWh	2.2 TWh	± 2.2 TWh	±10 Twh	
Potential annual CO2 reduction	217	NA	± 17 million tonnes	± 17 million tonnes	± 85 million tonnes	
Expected annual CO2 Reduction	217	NA	±7 million tonnes	±7 million tonnes	40 million tonnes	
Realised annual CO2 reduction	19	NA	±180 million tonnes	± 2 million tonnes	±10 million tonnes	

Technopolis 2014, based on participant survey

The figure below shows example of energy generation/savings resulting from FP6 and FP7 projects.

Figure 47 Example of projects that generated strong energy generation/savings

Project	FP	Area	Energy generation/savings
Groundhit	FP6	RHC	The most important outputs from the project are three ground source heat pumps (HP) which have significant advantages over existing heat pumps. One HP has an improved efficiency which is about 10-20% above available HP. The second HP is able to deliver hot water at 80°C instead of 40°C, which is usually delivered by heat pumps. The third HP is very efficient when it comes to utilizing warm ground water of up to 40°C as heat source. The newly developed HPs enlarge the possible field of application of heat pumps (e.g. now being able to retrofit old buildings which need hot water of 80°C) and thus can contribute to reducing CO_2-emissions and the consumption of fossil fuels. Heat pumps powered by the European electricity mix can cut the CO_2-emission down to 35% compared to heating with oil.
Biolive	-	Bioenergy	The main breakthrough made in the project was the viscosity reduction - by using improved enzymes - which made that the biomass pulp was easier to handle and also the transportation and mixing was easier and took less energy. Another important result was the higher yield of the end product. The company patented the finding. The pre-treatment is only with water and physical treatment through steam explosion. However, the most important result of the project is the building of the industrial-scale second-generation bioethanol production plant with an output of 40,000 tons ethanol per year. The biorefinery was opened in October 2013
ENERCOM	Append	EE	Started in 2008, the ENERCOM project has been developing high-efficient polygeneration of electricity, heat, solid fuels and fertilisers from sewage sludge and greenery waste mixed to biomass residues, thereby offering a new and safe environmentally friendly and cost-effective path for the

			disposal of sewage sludge, maximising energy output, greenhouse gas reduction, cost-effectiveness and new chances for SME. The exploitation plan includes the creation of two SMEs for heat delivery and worldwide planning and marketing of similar plants. The company SYNERCO is the result of a joint venture between partners Bisanz Anlagenbau GmbH, LEE SARL and Soil-Concept SA. SYNERCO provides the know-how and expertise in the areas of fluidised bed combustion technology pyrolysis/thermolysis, gasification, anaerobic digestion and composting. The creation of another company is expected until the end of the project. The participants of the ERNERCOM project have applied three patents' application in the domain of biomass, wastewater and new energies. With the creation of the prototype, a decrease of 2,000 tons of CO2 per year is expected. Replication of the concept in the 3,000 compost plants in the EU would allow additional generation of at least 56TWh of electricity, heat and solid fuels.

4.7.3 Impacts on policymaking

The section analyses the impact of the FP programmes on policy-making, particularly at the national and local level (see Figure 48 below). Based on the survey results, policy impact at the national and regional level is perceived as moderate, 18% and 15% respectively. Policy impact is difficult to estimate for participants, as it is often only an indirect consequence of the project activities and it is not easy traceable unless a proper follow up is made, which is not the case for most project financed. For the socio-economic research theme though, the main objective of the projects analysed was to create knowledge in support of policy making activities. The aim was to develop "tools, methods and models to assess the economic and social issues related to energy technologies and to provide quantifiable targets and scenarios for medium and long term horizons"[61]. The scope of such activities was targeted though at supporting European policy-makers with less focus on national and local issues (see also chapter 6). In the case of smart grids and energy network research activities, some of the projects financed focused on supporting the integration of regional energy markets and energy infrastructures, fostering the development of tools and data sharing across borders, which was clearly perceived as having an impact on decision-makers. The stronger effect on local policy-making is found in the Other Renewable Energy area, a small theme in comparison to others that funded a number of ocean energy, projects with communication and dissemination activities led by and targeted at local stakeholders.

Figure 48 Impact on policy-making at the local and national level

	N	Mean (Median)	Absolute	**Significant group differences** *Projects in these groups score*
New/modified policy framework *National level*	630	18%	113	FP7 less (17%) FP6 more (20%) Photovoltaic less (17%) SG more (32%) PUB more (30%)
New/modified policy framework *Local level*	591	15%	89	NOE more (20%) Bio less (10%) OthRen more (34%)

61 http://www.transport-research.info/web/programmes/programme_details.cfm?ID=46221

From Figure 48 it is possible to observe that the policy impact at the national level is perceived as higher during FP6 than FP7. As seen in section 5.4, projects during FP6 focused more on early stage research rather than demonstration with the opposite true for FP7. Early stage research activities seems therefore to have had a stronger impact on decision-makers with respect to later stage research, which develops in parallel to industrial policies already established.

The table below shows example of financed projects that had concrete impacts on policy-making resulting from FP6 and FP7 projects.

Table 1 Example of projects that generated strong impacts on policy

Project	FP	Area	Impacts on policy
SESAC	-	EE	At the policy level, the results of the project were used by the technical services of each local council to start a dialogue with elected officials on the possibility to set ambitious targets for energy production and energy efficiency. The methodology for measuring energy efficiency was also used by local policymakers. At the EU level, the two European networks, ECLEI and Energy Cities, disseminated the results to their members through newsletters and other communications.
THINK		SE	THINK was designed as a a Think Tank facility to provide advice to DG Energy units on a diverse set of energy policy topics. In close collaboration with the EC staff, the THINK project team has provided DG Energy with precious insights on energy issues, which has been directly reflected in the work carried out by the different units. THINK experts were also invited to present their results directly to national governments.
Bionorm	-	Bioenergy	The two BioNorm projects contributed to the development of EU standards within the field of solid biofuels, covering the whole range of aspects needed to build the foundation for the development of the market for solid biofuels in Europe.
Cane Biofuel	-	Bioenergy	The CaneBioFuel project created a lot of attention in Latin America for 2nd generation biomass fermentation. The Brazil government has funded a 17 M€ research programme 'BioFuel Research' with the goal of bringing the research on cellulosic-based ethanol also in Brazil to a next level.
SafeWind	FP7	Wind	In particular in countries where the market for renewable energy is rapidly developing, e.g. in North America, the interest for the project's technologies is big. Several consortium members have been invited to a number of conferences and workshops outside Europe to present the European know-how on wind power forecasting.

4.8 Efficiency

The aspect of efficiency can refer either to *process efficiency* or cost-benefit *efficiency*. The first refers to an analysis of how efficient the implementation of a programme has been in terms of processes such as administrative requirements, effective selection procedures, good guidance, monitoring and control etc. The second aspect refers to the cost-effectiveness, i.e. whether the invested means have resulted in an optimal level of effects. Process efficiency will be mostly discussed in the Chapter 3 (implementation) and Chapter 6 (European Added Value). This section will focus on the cost-effectiveness only.

The costs[62] of the Framework Programme are relatively straightforward – these are the contributions from the European Commission to the individual project participations for their participation in the Framework Programme. These amount to €2.5b in total, with €1.6 billion for projects finished by the end of 2015. Of course,

[62] The analysis in this paragraph is presented from the perspective of the programme / government intervention.

roughly only half of the project costs were covered by the European Commission, but as this evaluation is focused on the effect triggered by the EU investments in R&D&I, we take this figure as the main reference point.

The previous sections have shown that the Framework Programme has a broad range of impacts, from scientific publications to increased R&D capacities and from technological breakthroughs to better networks. It is extremely difficult – if not impossible – to quantify all these impacts (let alone aggregate the different types of impacts). However, some indicators presented before are of a quantitative nature and can be translated to a 'bang-for-buck' figure. The result –for (almost) finished projects) - is presented in Figure 49.

Figure 49 Estimates of measurable value for money indicators

Indicator	Extrapolated value	Average per project	Average per 1m euro EC Contribution	Reference value (EPSRC 2012/2013)[63]
Total number of publications	±18,000	±32	±11.25	8.1
Total number of publications in high/impact journals	±8000	±12	±5	4.5
Number of PhDs	±4,000	±7.4	±2.5	±2.1
Number of Patents[64]	±500	±0.9	±0.3	0.22
Number of spin-outs				0.03
Potential new innovations	±3,500	±6.5	±2.1	NA
Expected new innovations	±2000	±3.7	±1.25	NA
Expected annual turnover (after innovation has reached the market)[65]	±€18 billion - €75 billion	±€33m – €138m	±€11m – €45m	NA
Realised annual turnover	±€ 750 million - €2.5 billion*	±1.4m - ±4.6m	±0.47m - ±1.5m	NA
Expected annual power generation	±4.9 TWh - ±23 Twh	±9GWh – ±42GWh	±3GWh – ±15 GWh	NA
Realised annual power generation	± 1.2 TWh – 4TWh	±2.2GWh - ±7.4GWh	±0.8GWh – ±2.5GWh	NA
Expected annual Power Savings	4.9 TWh - ±23 Twh	±9GWh – ±42GWh	3GWh – 14GWh	NA
Realised annual Power Savings	± 2.2 TWh – 10 Twh	±4GWh – ±18GWh	±1.4 GWh - ±6.3 GWh	NA

Survey and statistical analysis

[63] Research Performance and Economic Impact Report 2013, EPSRC

[64] This is a minimum, as participants may have applied for multiple patents.

[65] This figure could take a long time to materialise, as some innovations will take at least until 2020 to enter the market.

In terms of direct STI outputs, we see that a typical projects results in ±24 papers (of which half in high-impact journals), ±7.4 PhDs, 1 patent, and almost 4 expected new innovations. In order to have a better insight in whether these values present value for money, reference values for the UK Engineering and Physical Sciences Research Council have been added to the table. Unfortunately, past FP evaluations have not estimated total impacts, and it is therefore difficult to benchmark these indicators. The UK Research systems has the best data available for comparison, and the EPSRC's field are closest to the research fields in the Energy FP. We see that the indicators per million euro of the EPSRC and the estimates of FP are very close together, with the FP performing slightly better than the EPSRC. An important note is that the EPSRC's funding is aimed at research projects that have a very high public funding percentage and are generally of a more fundamental character. Still, it shows that the Framework Programme can definitely compete with national targeted programmes on scientific outputs, despite its broader scope in terms of the research to innovation chain.

Easier to compare are the monetary values of expected and realised annual turnover. The value for expected future annual turnover resulting from the new innovations – taking into account the likelihood of market entry – are between 11 and 45 times the initial investment from the EC. Of course, many other investments (co-funding from participant, follow-up R&D, marketing, setting production lines, etc.) are required before this turnover will materialise in the future, so these figures cannot be interpreted as return on investment (especially since turnover does not equal profits). Still, the potential economic return is still relatively high in comparison with the investments made. This is also shown by the fact that there are a substantial number of new (potential) innovations that are developed as a result of participation in the Framework Programme. However, the current levels of turnover are still relatively low – though not negligible. Many economic impacts (even those of early FP6 projects) still need to materialise, a minimum of five to ten years is needed for such development to take place. The same is in general true for impacts on energy generation and savings, as these – almost always – go hand in hand with impact on turnover. Since the sections above have shown that effectiveness for economic and energy system impacts are not always optimal due to specific barriers, efficiency can by definition not be optimal.

In conclusion, the results show that the Framework Programme is delivering value for money in technological and scientific terms, and can be considered efficient in that respect. However, whether the programme is optimally efficient is hard to assess without good reference data on similar programmes; and without good access to counterfactual data. It is clear that if the economic – and energy – impacts will indeed materialise to a great extent, the programme will have delivered excellent value for money. However, the extents of these effects are still very uncertain.

4.9 Drivers and success factors and barriers

In this section, we present the main drivers and success factors on the one hand and the barriers for further development on the other hand.

4.9.1 Drivers and success factors

The capacity of the projects (in particular the demonstration projects) to engender impacts depends on several factors of different types:

- Internal factors of the projects depending on the partners and on the consortium;
- External factors due to the policy support of the technologies and to the economic conditions.

When analysing drivers and success factors, it is important to take into account the skewed nature of the impacts associated with research and technological development projects in general.

Skewed impacts

Scientific, technological and potential innovations as outputs and outcomes of projects have been relatively widespread, with large shares of participants indicating that they did indeed associate their participation in the Framework Programme with these outputs and outcomes. A large share of project participations (68%) resulted in a concrete potential innovation outcome. However, when we move from 'potential innovation' to actual market implementation and the size of market impact (measured in turnover, but also energy impacts such as power savings and renewable power generation), a big divide occurs between those innovations with a large impact and those with very little or no impact. Only a small number of innovations manage to offer major added value, but when they do their impact is indeed can be very large. This skewed-ness in impacts is caused mainly by external reasons (although internal reasons in terms of technological success, and more soft aspects as an entrepreneurial spirit are of course preconditions), especially in terms of market conditions, such as

- Competition with other technologies

-Available capital for the final steps of development, production scaling and marketing & sales

- Regulation (as a driver, such as feed-in tariffs, or a barrier, such as a ban on CCS)

This skewed-ness is also evident in our sample. Only a handful of companies already report concrete impacts in terms of turnover at the moment (±1% of our sample), although many more have (uncertain) expectations. Looking at expected turnover, we see that 10% of participants are responsible for 90% of expected turnover.

This skewed-ness has a large impact on the possibilities of predicting and evaluating impacts of such large research programmes. Clearly, extrapolation and imputation become more and more difficult the smaller the 'high impact' sample becomes. This is one of the reasons why the uncertainty bands in the impact tables above are relatively large, but is also means that the survey sample of 'high impact' projects is so small that it becomes difficult to discern concrete success factors from a quantitative perspective.

4.9.1.1 Internal factors

A quantitative analysis of internal factors has been carried out to see which background factors are associated with more concrete technological outcomes and outputs and economic impacts. Although these have also been presented integrally in the analysis in the chapter above, the table below gives an overview of the main findings from these background analyses.

Figure 50 Tests for internal explanations of impact

Hypothesis / background factor	Evidence	Explanation
Industry involvement: Projects led by a private company compared to other projects	Higher TRL levels at the start, higher TRL levels at the end (around 1 TRL level difference). No other significant effects.	Private companies more often in charge of demonstration projects, which have higher TRL levels. So while it is clear that demonstration projects
Demonstration projects have more impact than research projects.	Demonstration projects have higher TRL levels at the start and at the end (see also section 5.3), and respondents report a higher probability of market entry for new innovations.	Demonstration projects are aimed at a later phase of technology development.

Hypothesis / background factor	Evidence	Explanation
Co-funding rates	Lower co-funding rates are related to more concrete innovations	See above – lower co-funding rates are also associated with demonstration projects and with company participations in general.
Project size	Larger projects (in terms of funding) result in more TRL improvement and market probabilities, as well as higher expected turnover rates, even when accounting for the type of project.	Larger projects can invest more in technological development, resulting in more progress and therefore higher expected market impacts.
Project Type	The results above have shown that integrated projects (and STREP projects to a lesser extent) are generally more associated with concrete technological and innovation outcomes than other types of projects.	The reasons that IPs and STREPs have higher associated technological outputs and outcomes is related to the design of these projects.
Organisation Type	Higher education institutions and Research Centres are clearly more successful in terms of scientific outputs. Companies are most successful when it concerns concrete innovations, although research centres have similar expectations regarding turnover as companies	These differences are quite inherent in the different roles and objectives of the organisations themselves.

Survey and Technopolis statistical analysis

The effects in the table are actually all consistent with expectations as they are directly related to the design of the Framework Programme. Clearly, demonstration projects have a higher TRL and therefore a higher market probability, and the fact that projects which are designed to generate integrated technological progress (IPs) also do so is no surprise either. However, the positive conclusion emerging from this analysis is that the programme is working as designed on these aspects. This is likely also related to the fact that the Framework Programme is highly competitive and therefore in general will feature projects that are likely to at least reach the objectives set within the scope of the Framework Programme conditions in general and the project in particular.

Of course, it is desirable to have a deeper understanding how the background factors work together, and whether outputs, outcomes and impacts can be explained by a combination of background factors (rather than one – by – one). In general, it can therefore be useful to analyse the background factors together in a multivariable regression model.

An exercise where these multiple variable regressions models where tested to associate outcome and impact indicators with background variables showed that the total predictive value of such models is very low. The only clear pattern is the difference between demonstration projects versus more research-oriented projects, where the first have more innovation outputs, and the latter have more scientific output. The limited explanatory power beyond these factors has a number of reasons:

- The fact that most impacts are actually expected in the future and have an inherent uncertainty in them, even for participants themselves. This is inherent in research and technological development in general, also in the Energy area.
- The large heterogeneity of project objectives and outcomes, as the Energy area includes 12 very different technology areas
- The skewed-ness of impact indicators (see box)
- Since the only major source of quantitative data (the survey) is based on self-reporting, there may be variations in how respondents are able to assess certain (expected) impacts themselves, even with careful instructions.

- The incomplete background information from the CORDA database, limiting the possibilities for statistical estimation and testing

From a more qualitative perspective, the analysis of case studies and area reports shows that most often, the projects that are the most successful in generating outcomes and impacts have certain characteristics in common:

- The most successful projects were often based on existing networks of core partners who had worked together already and who had already shared knowledge. Several examples of successful projects have been organised around a core group of partners that had worked with each other already in the context of projects with public support from national authorities. Some projects proposed for the FP gathered partners from different countries that were involved in a previous project. From that perspective, in order to increase the potential success of the projects, it is important to ensure that the partners know each other, trust each other and are willing to share knowledge and know-how.
- The most successful projects were also often thus based on project managers who already had experience in RTD projects. The interviews show that FP projects request specific competences to make the consortium function during the course of the project in order to achieve the objectives.
- As was clear from the statistical analysis, another important success factor on the economic part of the projects is related to the role and weight of the industry in the projects. The demonstration projects were driven by the industry. This is a necessary condition for success (but not sufficient) since the industry will ensure that the outcomes of the projects can be translated into commercialised products or services put on the market.

4.9.1.2 External factors

External factors, such as market conditions, can also serve as drivers of impact. This is especially the case when a developed technology is close to market-ready at just the right time from a policy or market development perspective. An innovation that is launched in a positive market and policy environment has in general more opportunity to generate impacts.

Policy can be a major driver of innovation impacts, either by creating demand-side factors (regulations that require the implementation of new technologies), or by creating supply-side support (such as subsidies for the final phases of development, or seed capital for start-ups). The effects of supply side policies are often quite clear, the most obvious example is the German *Energiewende* which led to large public investments in renewable energy technologies and power infrastructure that is a prerequisite for a new energy mix (e.g. improved electricity grids).

An example of demand-side factors are the requirements in certain countries to increase the share of biofuels in the total fuel mix, which has spurred the demand for new biofuel solutions. However, demand-side factors depend heavily on the market conditions, as increased demand could also lead to investment in scaling older generation technologies and lead to an 'infant industry vs. incumbent' problem. The latter example has been the case in the PV-sector, where demand side policies (mainly feedback-tariffs) have led to large investments in economies of scale in older generation technologies (crystalline silicon), leading to a very cost-effective incumbent industry. Even though new technologies clearly have the *potential* to be competitive, substantial investments in economies of scales are required first before the new technology can be competitive (this is the classical 'infant industry' argument). When capital markets (or governments) are not willing or able to invest large amounts to reach the competitive point, the effect could be an economic lock-in.

Just like policies, market factors can also play a positive role in driving impacts. New (renewable) energy technologies are in competition with conventional technologies in the entire energy mix. For instance, the price of oil (itself often influenced by political events), and especially the medium to long-term expectations of the oil price have an effect on private investments in the energy sector.

4.9.2 Barriers

Despite a noteworthy overall increase in the technology maturity of energy technologies during FP6 and FP7, the road to full deployment is still long. There are a number of reasons that explain this difficulty in reaching full deployment.

A first group of barriers is related to the **economic lock-in** for further development. Many interviewees and respondents to the survey have highlighted the fact that additional huge investments are sometimes still needed to further develop the technology and to embed technology progress into commercial products. For instance, full-scale prototypes required high investments whereas payback investment is still too long. This has been pointed out in particular for the following areas: CCS/CCT, Concentrating Solar Power (CSP) or Renewable Heating and Cooling. In other cases, the market for products embedding the technologies developed by the FP6 and FP7 projects is not there (CCS, RHC) is not enough mature (CSP) for absorbing sufficient quantities of products. Therefore, the production of such products would not benefit from economies of scale. Another type of economic lock-in is when global developments have eroded the industrial base (such as happened with the PV production in Europe). Here the main observation is that public R&D-policies can have limited effects when they are not properly aligned with other policy areas such as trade, industrial, energy and fiscal policies.

Another barrier hindering the economic impact of the projects is much more SME-specific and can be seen for the areas where the market structure is made of SMEs. For such areas, the SMEs which participated in the project cannot fund the next steps in the technology development.

A second group of barriers is imputable to the **initial set-up of the consortiums** during FP6 and FP7. Many interviewees have underlined the fact that the commercialisation of products was not sufficiently thought and designed beforehand and too often, partners left the project with their own IP and without a full product with shared IP. We have identified numerous examples of projects without new products put on the market in spite of technologies developed for these projects already on the market or close to the market. The examples has shown that there is not always enough incentive to continue co-operation in creating innovations together after the end of a project. Especially in the energy efficiency and wind technology areas (but also others), this has reduced the impact of innovations .

A third major barrier for impacts are changing political and policy frameworks. Many FP areas were strongly supported in FP6 and FP7 but have encountered a policy shift just as potential innovations became ready to enter the market. A clear example here is the paradigm shift in the mobility sector. Whereas initially the policy goals were aimed at stimulating fuel cells and hydrogen as the future main solution, this was later shifted to a focus on biofuels. Even more recently, electric cars and by extension smart grids are coming up as the main solution, decreasing the demand and interest for biofuels. This has hampered the uptake of the innovations that came from the Bioenergy area (for more discussion see area report summary).

4.10 Conclusions on Effectiveness and Efficiency

FP6 and FP7 pursued objectives at different levels. These objectives have been presented in Section 1.1. We identified in particular different levels of objectives:

At the **level of the programme**, both were aimed at increasing efficiency of the energy European system and at mitigating global change. These two objectives are long-term objectives and are difficult to assess.

Besides, the FPs were expected to structure and provide guidelines for the future of the EU energy policy on the one hand and of the EU energy research policy on the other hand. To that regards, the FPs have fulfilled their commitments: the FPs have permitted to elaborate the long-term strategy of the EU. Even though socio-economic projects for instance suffered from insufficient interactions between the participants with the EU officials and industry representatives, the projects have produced valuable tools, models and knowledge on energy.

The FPs has also the duty to establish the Europe Research Area. As far as energy is concerned, the FPs have strongly contributed to the expansion of regional, national or trans-national existing networks. Participants in the projects consensually underlined how they benefited from the programme to start working with new partners from other countries. Projects had strong impacts to what regards transnational cooperation, networking and collaboration within the value chain. The most tangible and remarkable result of the FP6 and FP7 projects is related to the construction of the European Research Area.

At the **level of the areas**, both FP6 and FP7 aimed at increasing the reduction of cost of technologies (by increasing efficiency of technologies). The state-of-the-art of technology was very heterogeneous across areas, implying different objectives. Sometimes, FP was aimed at developing a second generation of technology (e.g. bio-fuel) or improving existing plant (small hydropower) or buildings (refurbishment for Energy Efficiency), while in other cases, state-of-the-art at the start of FP6 was fragmented basic knowledge and the objective was to take stock of existing knowledge (e.g. socio-economic research).

FP6 was sometimes an opportunity to identify research challenges/bottlenecks that were further investigated during FP7. In other cases, FP6 supported a large variety of technologies in order to identify later on the most promising ones. From that perspective, FP6 projects paved the way for further research in the subsequent FP.

Overall, FP7 was much more focused than FP6 in the sense that fewer technologies were supported and fewer projects were funded within each area. The analysis shows that whatever the level of maturity of technology prior to the start of the FPs, the programmes have enabled an improvement of the technologies. At the level of the areas, FP6 and FP7 have thus permitted outstanding progress.

At the **level of the participants, a number of conclusions emerge:**

- **Projects in general reach their technological and scientific objectives.** Most project participants (70%) indicate that the project has or will reach or exceed its objectives. A further 20% to 25% indicates that the project largely achieved its objectives. Only a small minority (around 10%) indicates that the objectives were only reached partly, and only 1% indicates that the project failed.
- **Scientific outputs of FP participants have been substantial.** Scientific organisations reported on average around 8 scientific publications per participation, half of which were published in high impact journals. A (rough) extrapolation for (almost) finished projects shows that in total around 18,000

articles and 8000 articles in high impact journals have been published so far. Just over 11% of participants indicate that their participation is associated with at least one patent application or grant.

- **Participants indicate that their participation has led to substantial organisational impacts, especially in terms of improved networks and knowledge position**. For all these measures more than 50% of participants indicate that there is more than a small effect on their organization for these two aspects. In terms of economic organisational impact so far, around 20-25% of participating companies see a substantial improvement of more than 5% for turnover and profit. The large majority (76%) of companies indicate that there has been an increase in their general competiveness. However, for only around 2% of participants their participation has had very large effects of more than 25% increase in turnover. profit, FTE or market share.
- **The Framework Programme results in a large number of concrete outcomes in terms of potential innovations.** Two-thirds of participants see a concrete marketable outcome, now or in the future. These innovations are roughly equally divided across products, services and processes (each around 20%), with business models only around 6%.
- **Participants have high expectations regarding the potential turnover and impacts on energy savings, renewable energy generation and CO2 reduction, but uncertainties are high and the road to impact long. Concrete economic and energy impacts are at this moment still limited, but not absent.** The aggregate expected annual turnover by participants related to these innovations, taking into account the probability of market entry, amounts to €18 billion - €75 billion by 2020. Note that these impacts will only take place under the condition of substantial additional private and/or public investment and no major negative shifts in policy and market conditions.
- **In total 18% of participations indicate to have had an impact on national policy making.** Areas with particular high impact were Smart Grids, Other Renewable Energy sources and
- **A first exploration of the efficiency of the Framework Programme in terms of scientific outputs, shows that the FP is delivering value for money in technological and scientific terms.** A full assessment of efficiency was not possible due to lack of complete bibliometric data, counterfactual information, and appropriate benchmark programmes.

5. European Added Value

5.1 EU Added Value and FP6/FP7 energy research

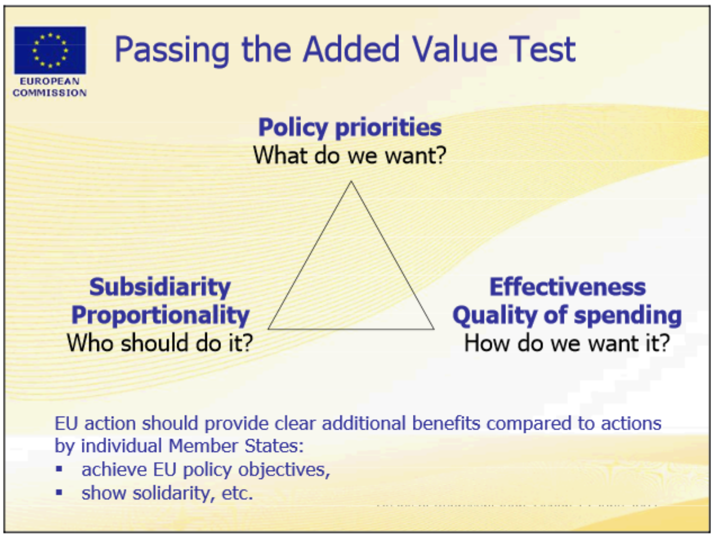
5.1.1 Brief introduction to the concept of EU Added Value

The European Commission defines EU Added Value ("EAV") as:

"The value resulting from an EU intervention which is additional to the value that would have been otherwise created by Member State action alone"[66].

Within the context of a heated discussion on the EU budget, the European Parliament defined EAV as the "*little sister*" of the principle of subsidiarity[67]. The principle of subsidiarity is an integral part of the Treaty of Lisbon (article 5), its main objective is to guide Member States and the EU in shaping the level of intervention of the EU with respect to specific fields that are shared between the Union and the Member States[68]. In terms of EAV this should imply that European budget and incurred expenses are justified only if directed towards actions that cannot be better implemented at the national level. The concept of EAV has therefore often been used in relation to the Union spending in order to justify policies and public intervention that would be better accomplished at the EU level rather than at the national one.

Figure 51 EU Added Value



European Parliament

[66] European Commission "The added value of the EU budget" Commission Staff Working Document, Brussels, 29 June 2011, (SEC(2011) 867 final) http://ec.europa.eu/budget/library/biblio/documents/fin_fwk1420/working_paper_added_value_EU_budget_SEC-867_en.pdf

[67] European Parliament, "Reflection paper on the concept of European Added Vakue", 21 September 2010, Rapporteur Salvador Garrida Porredo, http://www.europarl.europa.eu/meetdocs/2009_2014/documents/sure/dv/sure_20100923_4garr_/sure_20100923_4garr_en.pdf

[68] Europa.eu "The principle of subsidiarity", Summary of EU legislations.

The European Commission proposes an "*EU added value test*" (Figure 51), suggesting that EU spending and policy-making should fulfil three basic conditions[69]:

- Policy relevance: the action must address key Union's objectives;
- Subsidiarity principle: the action must entail transnational or cross-border alternative objectives and should deliver economies of scale;
- Proportionality: the action must deliver results in an efficient and effective manner.

Given the comprehensive bulk of existing literature on EAV, the concept has taken many forms and may vary according to the stakeholder involved and the context within which it being implemented[70]. Certain definitions refer to the general value simply relating it to public policies, in other cases it is related to economic theory and the measurement of economic growth, whereas it may also be related to political theory[71]. According to Medarova-Bergstrom et al. there are two main perspectives on EAV: economic and political. In economic terms, EAV refers not only to the delivery of public services and goods to European citizens, but also to the internalisation of positive and negative externalities, quantitative accounting of EU policies benefits and achievement of economies of scale[72]. A political perspective on EAV implies that EU actions should actively promote high level political priorities enshrined in EU policies objectives[73]. In the case of EU energy, the EAV of EU policy making relates to the achievement of renewable energy and energy efficiency goals, the creation of the internal energy market for both gas and electricity through for instance increased infrastructure interconnections, security of supply and the development of policies to fight climate change and environmental degradation related to the use of energy.

5.1.2 EAV in FP6 and FP7

EAV has been embedded in EU research policies since the inception of the FP programmes, it has evolved and gained importance along with the programmes, till becoming a recurrent theme of impact assessment and analysis of EU research programmes and policies. The EU right to act in this area is recognised in the Treaty on the Functioning of the European Union where specific goals are defined. Article 179 establishes the creation of the European Research Area, promoting the strengthening of the Union's scientific and technological research capacity and freedom of movement for scientific knowledge and technology while promoting internal competition[74]. In addition Article 180 stresses the importance of transnational cooperation to achieve

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[69] European Parliament, "Reflection paper on the concept of European Added Vakue", 21 September 2010, Rapporteur Salvador Garrida Porredo,

[70] Yellow 2000 "Identifying the constituent elements of the European Added Value (EAV) of the EU RTD programmes : conceptual analysis based on practical experience", Study commissioned by: European Commission, DG Research, 20 November 2000 http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/fp5_monitoring_eu_added_value_of_rtd_programmes.pdf

[71] D. Tarschy "The Enigma of European Added Value", Swedish Institute for European Policy Studies 2005:4 http://www.sieps.se/sites/default/files/45-20054.pdf

[72] Medarova-Bergstrom et al http://www.ieep.eu/assets/888/IEEP_-_EU_value_added_and_climate_change_March_2012.pdf

[73] Ibid

[74] European Commission, "Commission staff working paper: - Impact Assessment Accompanying the Communication from the Commission 'Horizon 2020 - The Framework Programme for Research and Innovation", http://ec.europa.eu/research/horizon2020/pdf/proposals/horizon_2020_impact_assessment_report.pdf

such objectives[75]. The fundamental idea is that FPs contribute further to promote excellence in European research, without simply duplicating national efforts.

At the inception of the FPs, during the 1980s, the concept of EAV was generally seen as an important justification for EU expenditures on research by promoting collaboration across Member States and knowledge sharing. Hence, the first interpretation of EAV and research related mostly to the promotion of transnational cooperation and knowledge sharing. Over the years, further advantages were added, including synergies and avoidance of overlaps, financing of very large projects and overcoming of cross-borders and intra-national issues for the development of infrastructures. Since FP5, EAV is used for the selection of projects and partly contribute to the definition of high-level programme objectives, rather than having a direct influence on the thematic objectives and programmes' composition. This conception of EAV is then loosely based on the definition below:

"The value resulting from EU support for RTD activities which is additional to the value that would have resulted from RTD funded at regional and national levels by both public authorities and the private sector"[76]

During FP6, EAV influenced the development of overarching goals such as the creation of the European Research Area (ERA) and the development of specific instruments like Networks of Excellence (NoE) and Integrated Projects (IP). Promoting EAV was the main rationale for the strong promotion of cooperation across the EU, and in particular the integration of new Member States. As a consequence, a key element of FP6 was the financing of larger multidisciplinary projects such as IPs and NoEs. Supporting the development of very large projects though not always delivered the expected results in terms of EAV. Participants found themselves forced in pursuing too many objectives, without clear-cut vision on the true added value component of European research and were discouraged by the difficulty of coordinating large multinational consortia. In the end, participants seems to consider as a European additionally the simple fact of being part of a multi-national consortium, without proper consideration for other impacts.

During FP7, the European Commission defined more clearly the importance of EAV behind the programme clearly stating that

"Activities funded from FP7 must have a "European added value". One key aspect of the European added value is the transnationality of many actions [...]. Indeed, many research challenges (e.g. fusion research, etc), are so complex that they can only be addressed at European level."[77]

In specific calls and topics participants were requested to indicate the impact of their project in terms of EAV. Though in most cases participants were neither required to define specific criteria for the measurement of EAV nor to elaborate on actual EAV value of their project. In the latest FP is therefore possible to identify and measure EAV on two levels, as a reflection of trans-national cooperation and knowledge-sharing or through raised competition across the EU between individual scientists.

[75] Ibid

[76] Yellow 2000 "Identifying the constituent elements of the European Added Value (EAV) of the EU RTD programmes : conceptual analysis based on practical experience", Study commissioned by: European Commission, DG Research, 20 November 2000 http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/fp5_monitoring_eu_added_value_of_rtd_programmes.pdf

[77] European Commission "New Practical Guide to EU Funding Opportunities for Research and Innovation – Annex 1", ftp://ftp.cordis.europa.eu/pub/fp7/docs/practical-guide-rev3_en.pdf

5.1.3 Measuring EAV

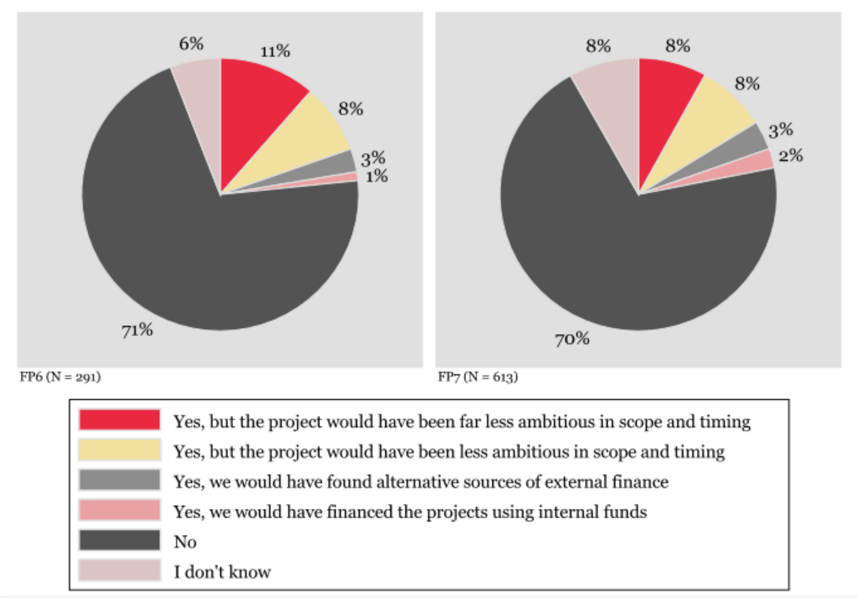
Measuring the impact of FP6 and FP7 programmes and projects in quantitative and even qualitative terms can prove relatively tricky, mostly because of the uncertainty surrounding the application of EAV's definition and evaluation criteria. In the end, the concept does not appear to be mature and specific enough to be applied in a consistent manner by the different stakeholders, as much depends on issues at stake and the origin of the stakeholder. Moreover, the EAV objectives established at the beginning of the programme are high-level and difficult to be measured in quantitative terms. The main obstacles to measuring of EAV is therefore finding a set of "SMART" KPIs that can demonstrate if and how EAV is actually been achieved, both at the programme and project level. At the project level, EAV can be assessed through different methods, for instance by measuring the scoring of projects with respect to specific KPIs or by providing a qualitative assessment of the project performance through the impressions and experiences of the stakeholders involved.

In order to quantitatively estimate the EAV of FP6/7 programmes, the report will first look at the survey results, focusing on specific questions on EU additionality and policy impact (section 5.1.4) and the assessment of FP research with respect to national funding (section 5.1.5). Secondly, on the basis of the survey results, 130 case studies and area reports it will identify key parameters to critically evaluate the EAV of individual projects (section 5.1.6). In such a manner, thematic area results can be partially compared and ranked according to the results per project, while a partial quantitative estimation of EAV is achieved.

5.1.4 Survey results

The current section presents the results of the assessment of EAV elaborated directly from the results of a survey to FP6 and FP7 project participants. A whole section of the questionnaire was dedicated to the evaluation of EAV. Project participants were asked a number of multiple-answers questions and one question with the freedom to answer freely.

Figure 52 EC funds additionality: Would the project be executed without EC funding?

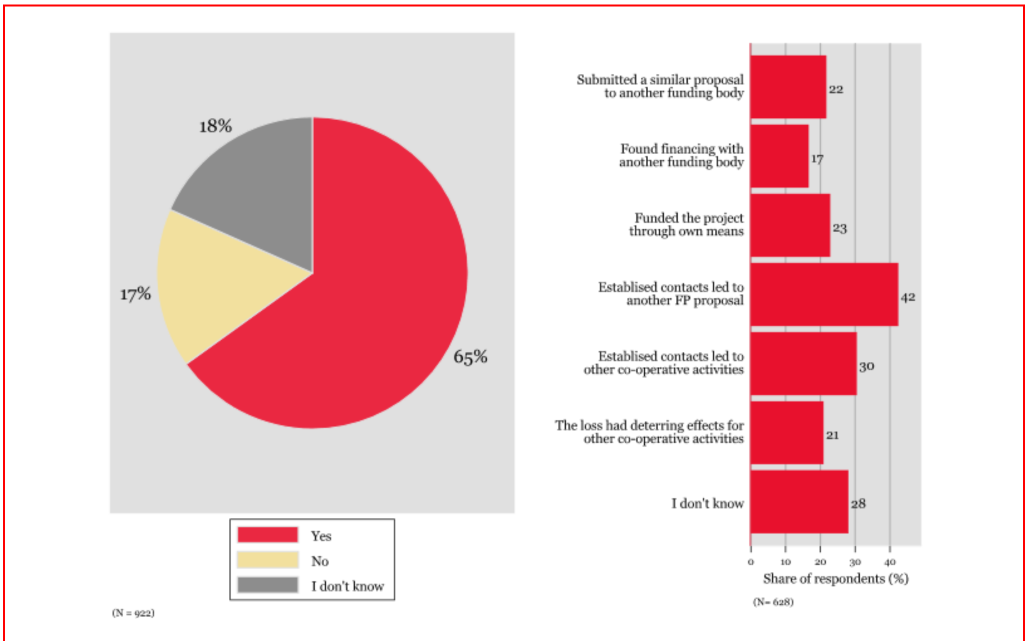


Technopolis survey

Project participants largely reported that their project would not have been carried out without EU funding (71% for FP6 and 70% for FP7). Only 1% for FP6 and 2% of FP7 respondents declared that the project would have been financed with internal funds or that would have been much less ambitious in scope (11% of FP6 and 8% of FP7 respondents). Figure 52 tells us that the majority of projects financed could only be executed thanks to the provision of European funding.

Respondents were also asked whether they had been part of an unsuccessful bid and how activities were followed-up after rejection. In total 65% of respondents declared that at least one unsuccessful project proposal had been submitted by their company or institute. When asked on how they follow-up on the proposal rejection, in at least 42% of the cases respondents declared that the unsuccessful proposal led to the establishment of business contacts leading to another FP proposal or cooperation activities (30%). In 21% of cases though the loss had a deterrent effect on future cooperation (Figure 53).

Figure 53 Follow-up on rejected proposals



Technopolis survey

These are both important indicators of the relative importance of EU financing to support activities that would not be pursued otherwise. Although, they cannot be considered as direct indicators of the relevance of the actual projects financed, for which the reader should refer to previous chapters.

Overall, it can be concluded that the process of submitting an FP project proposal, even if unsuccessful, already entails a positive EAV in providing stakeholders with a possibility to know each other and form research or business partnerships. The percentage of participants seeking other forms of financing is not very high (21%), implying that project participants tend to develop research projects and ideas that are strictly pertinent to FP programmes rather than seeking financing for own research activities only (also confirmed from the analysis above).

Figure 54 below presents more results elaborated from the participants' survey for both programmes that relate to EAV:

- On a scale from 1-5, the FP scores relatively well (3) in terms of improvement of technical know-how for the EU. With respect to specific technologies, energy efficiency scores better than the average (3.05).
- In total, 39% of surveyed participants believe that technology transfer has taken place in their field, with Heating and Cooling with a much higher

percentage (69%). However the results are less satisfying for integrated projects (IPs) and private companies.

– Overall 21% of participants believe that their project had an impact on EU policy-making, the percentage is higher for FP6 but lower for FP7, showing that there has been a partial decline with respect to this aspect. With respect to the different thematic areas, the impact is much lower for photovoltaic (8%) but higher for smart grids (34%) and socio-economic (38%). The latest result is not surprising as it precisely the scope of this area of research to provide decisional support to policy-makers at the EU level. This is slightly higher than the perceived impact at the national and local level, validating the assumption that FP projects and projects' results are directed at European issues rather than national ones.

As mentioned in chapter 5, research activities in the socio-economic area were defined in particular to provide EU policy-makers with the necessary knowledge to promote the implementation of sustainable energy policies through the analysis of environmental and social impacts related to the use of new technologies. This area of research is particularly relevant to EU policy making since for decades it has contributed to the development of evidence-based policy promoted by the European Commission.

Figure 54 Impacts with respect to EAV

	N	Mean (Median)	Absolute	**Significant group differences** *Projects in these groups score*
Improvement technical know -how EU *(Scale 1-5)*	665	3.29 (3)	-	CA less (2.95) SA less (2.82) EE more (3.05) SE less (2.65) Funding more (+)
Technology transfer to other sectors[78] *(Yes/no)*	545	39%	213	IP less (27%) HC more (61%) PRC less (34%)
Increased awareness energy challenges[79] *(Scale 0-5)*	591	2.68 (3)	-	STREP less (2.35) Bio less (2.4) OthRen more (3.22) SG more (2.91) HES more (2.94) PRC less (2.55)
New/modified policy framework *EU level*	616	21%	129	FP7 less (18%) FP6 more (25%) CA more (47%) STREP less (18%) EE less (9%) FETm less (3%) Photovoltaic less (8%) SG more (34%) SE more (38%) PRC less (15%) OthOrg more (35%) Funding less (-)

Technopolis 2014, based on participant survey

[78] These figures exclude "I don't know" answers (15%).
This may reflect a lower N value in comparison to charts including this category.

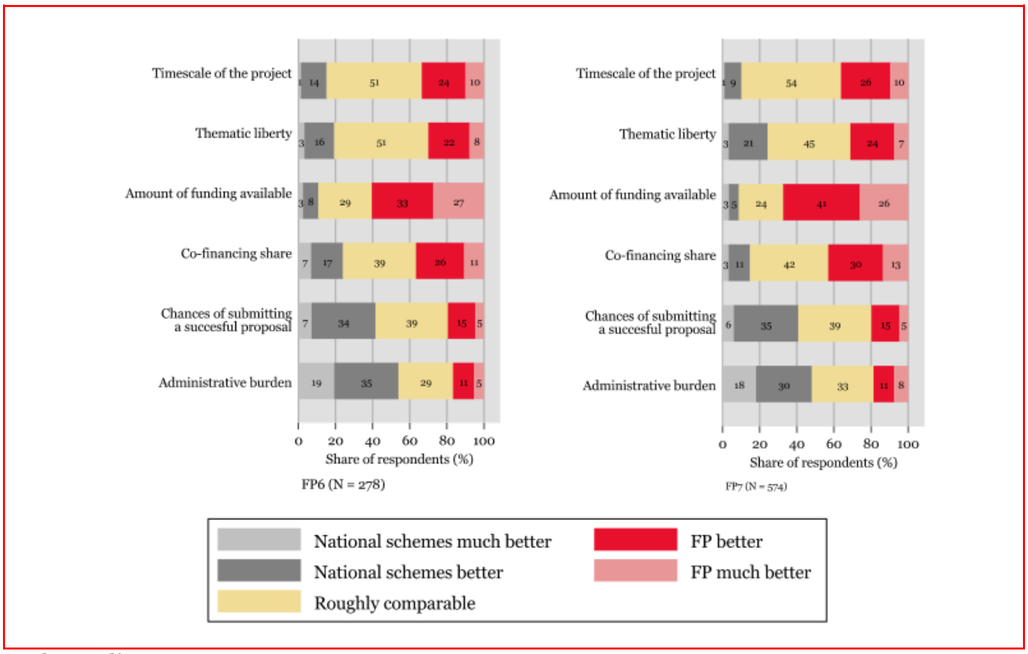
[79] These figures exclude "I don't know" answers (12%).
This may reflect a lower N value in comparison to charts including this category.

5.1.5 EU Research Comparison of the FP to national policies

Public funding, either at the European, national and local level, represents an important source of financing for research and innovation. Public intervention is justified according to the principle that individuals and private organisations will not necessarily pursue research activities to the benefit of the majority of individuals. As seen so far, European action in this area is enshrined in a number of treaties and justified on the basis of the principle that it strengthens the scientific and technological basis of EU research and allows for the implementation of larger projects, in terms of size and scope than national financing alone.

It is interesting to see how, in practical terms, project participants perceive EU financing in comparison with national sources. Participants surveyed were presented with a series of qualitative statement to compare national and EU funding is presented in Figure 55 below.

Figure 55 Comparison between national funding and EU FP funding



Technopolis

The following opinions were found

- *Timescale of the project*: half of both FP6 and FP7 respondents find project timelines in EU and national MS funding two roughly comparable. Roughly a third of both categories believe FP to be better in this respect.
- *Thematic Liberty*: Roughly 50% of project participants for both FP6 and FP7 find that both funding levels are roughly comparable in terms of thematic liberty.
- *Amount of funding available*: 33% of FP6 and 41% of the FP7 believe that the amount of EU funding is more adequate than national financing, a third of both categories actually stated that FP is much better (27% for FP6 and 26% for Fp7).
- *Co-financing share*: 39% (FP6) and 42% (FP7) find the co-financing share is roughly comparable between the two funding schemes. Roughly 40% of respondents reported that FP co-financing is either better or much better than the national one.

- *Chances of submitting a successful proposal*: More than a third of respondents from both programmes believe that chances of submitting a winning proposal are higher at the national level than with FP, 39% believe the two are roughly comparable.
- *Administrative burden*: Roughly 50% of respondents declared that at the national level administrative burden scores better (+/- 30%) or much better (+/- 20%) than FP.

Even when looking at individual thematic areas, the results on the comparison of FP with national funding are very similar. For the majority of surveyed participants, FP funding scores better than national funding on various aspects apart from administrative burden, which seems to be still the main complaint for participants also from the analysis of case studies. Also, national funding is partly favoured due to higher changes of submitting a successful proposal. This provides a strong indication for the European Commission particularly with respect to the administrative burden. In particular, the coordination of large projects is seen as a daunting task in terms of administrative requirement and interviewees lament the total lack of flexibility in this respect. Interviewed participants have lamented strict observance of administrative rules by the project officer, with little involvement in the project content. The European Commission should be able to maintain a strong grasp on the administrative and financial aspects of the project implementation while ensuring that project officers have a throughout understanding of the project. Proper follow-up measures should also be included in the inception of the project, participants themselves should be asked to provide quantitative KPIs to measure project performance concretely.

The figures presented so far provide a partial indication of the impact of FP in terms of EAV. As mentioned in section 1.1.3, measuring EAV is challenging given the lack of clear identifiable EAV objectives at the start of the programme and for individual projects. In order to be able to provide a more comprehensive picture, in the following section the report presents an overview of EAV by thematic areas partly based on the results of the survey and a qualitative assessment of the individual area reports.

5.1.6 Results from individual thematic areas

From the analysis of specific areas of research, based on the survey results and case studies, it is possible to provide a general overview of the main results in terms of EAV aggregated for both FP6 and FP7. Here below we provide a few examples of identified EAV by thematic area.

In the field of bioenergy both FP programmes led Europe to become a leader in the field of research for lignocellosic to ethanol processes. According to our results, at the time of FP6 Europe was lagging far behind in research on second generation biofuels, FP research promoted in particular the research position of the EU with respect to cellulosic ethanol research. The main success factors were the creation of large consortia with many partners through IPs and budget availability that permitted to address considerable parts of the innovation and value chain, including demonstration/pilot plants.

In the case of CCS, FP have been the driving force behind the possible development of the sector in Europe. The programmes sustained large projects with a large number of stakeholders involved, creating strong collaboration links across Europe, particularly among companies and researchers highly specialised in the area. Large projects have permitted to broaden the scope of research for many of the participants involved, this has been particularly advantageous for smaller players.

RTD activities promoted by the two FP programmes in the Smart Grids and Energy Networks have clearly contributed to the shaping of future research activities in the area at the national and European level. Thanks to FP, this area of research has seen collaboration for the first time among network operators, energy producers and regulators. The area is also seen as key for the future implementation of a decarbonised European Union, leading to a huge increase in financing and projects financed between FP6 and FP7. Some difficulties still exist though, as competing national interests, particularly for large players, are pursued within financed projects.

With respect with renewable energy technologies, for both area of photovoltaic and wind FPs had a positive impact in promoting transnational cooperation in such a way to allow for the most renowned experts in Europe to work together, which is usually not allowed with national financing sources. Based on the feedback from participants, these two areas are also expected to positively contribute to the achievement of European energy targets. An important aspect of these two areas is that they have achieved important results with respect to the cost-efficiency and performance of technologies for European businesses, enhancing competitiveness at the European level.

However, to ensure an appropriate assessment of EAV based both on the survey results and analysis of specific thematic area, the report attempts to quantitatively evaluate EAV at start by looking at specific parameters that have been identified as the most relevant in relation to EAV through the analysis of the case studies and interviews with project participants. We evaluate the relative impact of FP6/7 on these parameters by looking at survey responses in some cases and by providing a qualitative estimate in others. The EAV impact for each parameter is categorised as:

- 1: No impact or very low impact
- 2: Low impact
- 3: Medium impact
- 4: Considerable impact
- 5: Very large impact

Here below we provide the description of the individual criteria and survey indicators that have been matched to them. At this stage no difference is made between the two programmes.

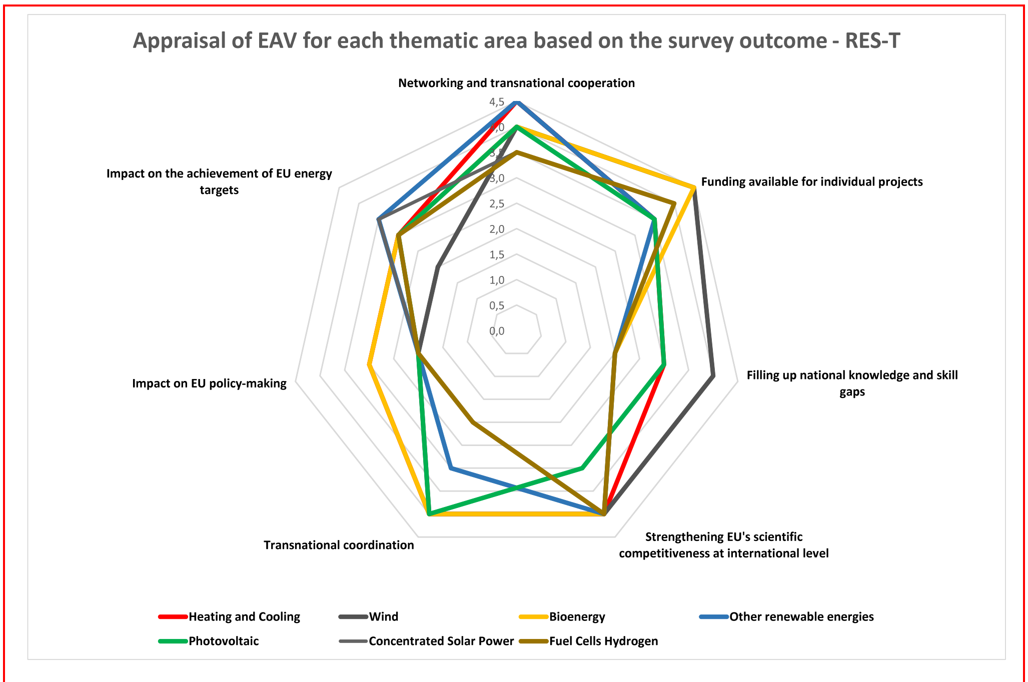
- *Networking and transnational cooperation:* One of the key factors representing the EAV of FP programmes is the promotion of networking and knowledge sharing across the EU. In all area reports FP are found particularly successful in promoting cooperation between participants and long-lasting business relationships. The evaluation is based on the survey responses. Participants surveyed were asked to assess the extent to which participation to the FP had contributed to increase national and transnational cooperation and if it has contributed to improve their network of partners.
- *Funding available for individual projects*: larger amounts of funding available for individual projects allowed the financing of larger projects, with a great number of partners that allows to cover a broader scope of research. Average project size and number of participants is taken as an indicator of the relative impact of EAV in this aspect.
- *Filling up national knowledge and skill gaps*: collaboration across borders fosters the assembly of the best expertise available in the area of research, while creating critical mass at the national level. Participants have the possibility to select and collaborate with partners with specific skills that may not be available in their own country. This promotes the reduction of existing knowledge and skills gaps between Member States. Geographical spread of participations and in particular, participation from New Member States is considered as a partial indicator of this along with considerations from the project team based on the area thematic area reports.
- *Strengthening EU's scientific competitiveness at international level*: EAV lies also in the promotion of EU researchers at the international level, promoting

excellence and reducing the gap between the EU and other countries such as the US and Japan. Participants also believe that participation to FP programmes provide extra visibility of results acquired and that in general, EU financed projects hold more credibility than projects financed at the national level, possibly having a larger impact on policy-making. Responses to the survey question on project contribution to European position in the field is taken as an indicator.

- *Transnational coordination*: Both FP programmes consistently backed up the achievement of European policy goals, such as the achievement of renewable energy targets, in doing so they partly help to reduce national research fragmentation as these started to align with their own research policies with the European one. This also related to the creation of the ERA, which began at the inception of FP6. Networks creation and spread of initiative is taken as a qualitative indicator to measure impact in this aspect.
- *Impact on EU policy-making*: FP programmes provide policy-makers with important scientific knowledge for the making of EU energy policies, in particular with respect to innovative technologies. Survey responses on FP impact on EU policy is taken as an estimate of the relative impact.
- *Impact on the achievement of EU energy targets*: FP programmes may provide direct support to the Union and Member States for the achievement of established renewable energy targets. The appraisal is based on survey responses (estimates on renewable power generation, power savings, CO2 reduction and individual case studies analysis).

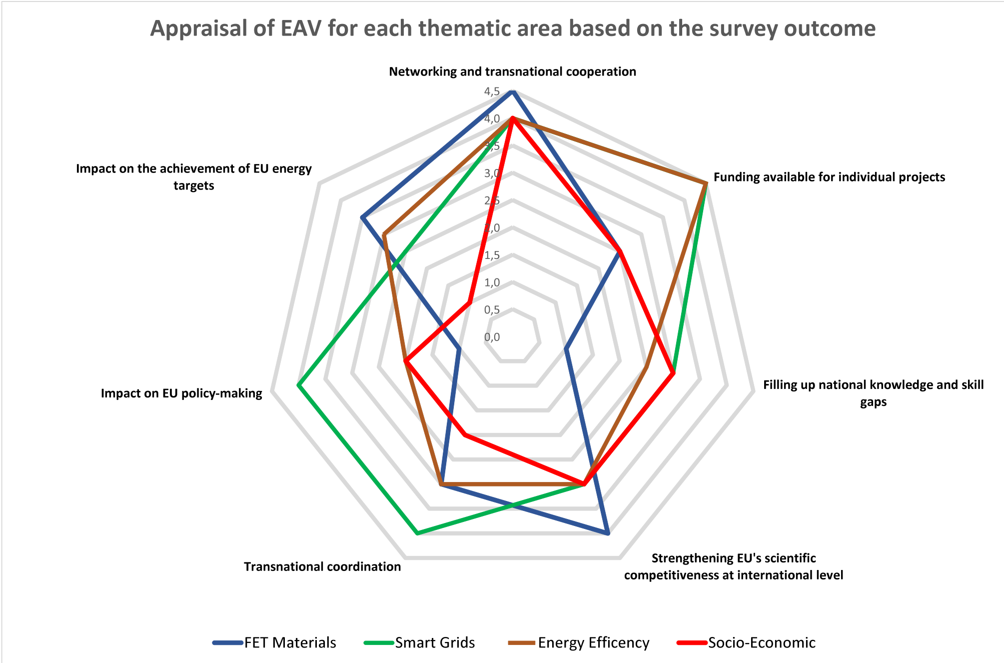
The present evaluation only provides a partial estimate of EAV of FP projects, which is limited to the results of the participants' survey and analysis of case studies. The advantages of such analysis lay in the possibility to identify shortcomings for specific thematic areas and also provides an indication of the specific targets and objectives that should be set at the project level in order to be able to measure EAV. The results of this analysis are presented in Figure 56 and Figure 57 below. The same criteria could be adapted as quantitative measures to be used for the evaluation of EAV impact at the project level.

Figure 56 Appraisal of EAV for different thematic areas based on survey and area report (renewable energy technologies)



Hinicio analysis

Figure 57 Appraisal of EAV for different thematic areas based on survey and area report



Hinicio analysis

From the analysis provided it is possible to observe that FP impact is high in terms of network development, supporting the development of transnational partnerships, providing funding on a large scale, particularly for infrastructures development missing at the national level and strengthening competitiveness of the Union as perceived by participants. The analysis however finds that the programmes have a moderate impact on the achievement of renewable energy, energy efficiency and emissions reduction targets. With respect to this last parameter, it has to be observed that there are large discrepancies between areas, with some scoring much better than others. In general, in line with the analysis provided so far, the impact on filling knowledge gaps between Member States and avoiding overlaps between research at the national and European level is quite low. In certain areas, participants also perceive a moderate impact on EU policy-making.

5.2 Conclusions on EAV

In conclusion we can state that FP financing has permitted the creation and organisation of activities (e.g. research clusters) that would have not been possible at the national level. It has clearly promoted transnational cooperation and networking, improving the Union's research position on a global scale and improving businesses competitiveness in renewable energy technologies. Both programmes have supported the emergence of global research champions and allowed the EU to take or maintain a leadership position in certain areas such as biofuels, wind and smart grids.

It is undeniable that FP programmes have led to important results and partly contributed to the creation of EAV, however a number of shortcomings have also been identified through our analysis:

- ***EAV Measurability***: Given the objectives and criteria established during both FP6 and FP7, it is very challenging to measure EAV at the programme or project level in concrete terms. The attempt made above has to be considered even given its obvious limits. This is mostly because, EAV considerations arise only at the latest stage of the preparation of programmes and given the broad definition presented above, in the end all results were somehow branded as holding a certain EAV, although no objective "SMART" KPIs were applied. Individual calls and projects lacked specific and clear EAV KPIs, and guidance for project consortia to apply these criteria, making it difficult for participants to establish EAV objectives and clearly identify the real EAV of their project once completed.

- European Commission management: Interviewees also lamented that there has been little effort from the Commission services to promote interactions between projects and avoid overlaps, which should be one key advantage in terms of EAV and a priority for the European Institutions. There seems to be a lack of concrete instruments or a structured approach aimed to achieve this very purpose. *Note: In this respect, European Commission services could be advised to add to their program and project management processes, a project portfolio management approach comparable to what is being done in the private sector.*
- ***Fragmentation:*** Both programmes have performed quite well in creating new networks, they have been less successful in promoting actual cooperation and concrete alignment between national and EU research policies, having a little impact on know-how gaps between different European regions. Partly, this should not be seen as a failure given that the programme is supposed to promote excellence across Europe and worldwide. However, in order to ensure a level-playing field for all, particularly researchers, the European Commission should consider to foster the movement of researchers, particularly PhDs, for longer period of time and within projects.
- **Lack of clarity**: in general there is a perceived lack of clarity as to the real objectives that FP tries to achieve in terms of EAV, with respect to research (e.g. ERA) and policy-making (e.g. energy targets). This lack of clarity, implies primarily a lack of focus for the specific objectives related to EAV.
- **Clusters of excellence and barriers to new entrants**: over time research financing through FPs has promoted the creation of research agglomerates with specialised research institutions that have professionalised project proposal preparation and submission; making it harder and harder for new entrants and smaller players to participate successfully.
- **Additionality**: While it is clear that most projects would not have not been carried out without EU financing, it is not possible to determine yet if these projects truly contributed to the development of research excellence in the EU and have had a strong impact in terms of turnover and profit for the individual company participating. The proper analysis of EAV would strongly benefit from a counterfactual analysis of the real impact of FP6 and FP7 programmes, looking at what would have been the outcomes in the absence of the intervention. This would be possible through a dedicated analysis on the follow-up of FP6 and FP7 rejected proposals.

One solution to these issues would be to provide stakeholders with clear-cut methodologies to evaluate EAV, mainly through SMART qualitative and quantitative evaluation criteria, which could be evaluated ex-ante and ex-post. If deemed important, the EAV concept must be taken into account at an earlier stage of programme design. EU research programmes should promote solutions to concrete problems at the EU level, instead of "serving" the interest of multiple stakeholders while achieving little in concrete terms. These should consist of concrete indicators related to project implementation at the European level. For instance European integration and worldwide outreach could be partly quantified through the number of stakeholders involved across Europe, number of papers and presentations given outside Europe.

EAV could also be fostered through a direct intervention from EC services beyond programme and project level intervention, through a project portfolio management approach with EC staffs responsible for identifying, triggering and enabling further interactions and cross-fertilization between projects of a common portfolio, and consistent knowledge management beyond project closure and throughout the FP lifecycle. This in return would enable project portfolios to address EAV through clusters of complementary projects which cannot individually capture EAV as a whole.

Now that research facilities are also more integrated, the Union could also consider other forms of public financing such as the US system, where research activities organised at the national level are promoted through public procurement rather than co-financing; with lesser and larger projects.

6. Conclusions and recommendations

6.1 Conclusions

1. The budget for energy projects in the framework programme was in FP6 at an historical low, both in absolute as well as in relative terms. The increase in budget in FP7 was significant, but the budget was still not as high as it used to be in former FPs. **The budgets for FP6 and FP7 for energy are not in relation to the political importance of energy and climate change (Kyoto agreement, 1998) and the public debate on climate change at the time of the conception of the plans.**

2. The objectives of FP6 and FP7 energy research are a mixture of research goals and energy policy goals. From the energy perspective goals are: secure energy supply, sustainable energy supply and enhanced competitiveness of European energy industry. From research policy perspective the four relevant goals are: sustainable development, enhanced competitiveness of Europe, a knowledge based economy and contribution to other policy goals (i.e. energy policy). The mix of demonstration projects and research projects reflects this dual goal setting. With the SET plan in 2008 a more coordinated approach of energy research in Europe was strived for. In practice the focus on climate change goals became stronger. **Despite clearly defined high-level, strategic and operational objectives for energy research, which show the relevance of the FP energy research, the intervention logic of the European Commission suffers from an explicit vision at the programme level of the distribution of funding among the different areas in order to reach the high-level objectives.** It is unclear on what criteria the distribution of research funds over the various research areas was determined.

3. **There were significant differences in organisational set-up between FP6 and FP7** (e.g. more targeted calls in FP7; other (smaller) type of projects supported in FP7). **These differences seem not to have led to large differences in participation, appreciation and impact between FP6 and FP7.** Differences in timing and the lack of information on a large part of FP6 projects make direct comparison however difficult.

4. Around 13,000 articles and 6,500 articles in high impact journals have been published so far; 3000 PhDs have been trained and 500 patents has been applied for. Most projects state that they achieved their objectives. The FPs have furthermore strongly contributed to the expansion of regional, national or trans-national networks, amongst research partners and within the value chain. An improved scientific competitiveness of Europe in various areas is recorded. **The FPs have** therefore c**ontributed to the (further) construction of the European Research Area in the field of energy. The energy research in FP6 and FP7 can be considered scientifically successful.**

5. At the level of the areas, both FP6 and FP7 aimed at increasing the reduction of cost of technologies (by increasing efficiency of technologies). The FPs have booked outstanding progress in the development of knowledge that has potential to contribute to this goal. Most projects achieved the goals. This evaluation shows that whatever the level of maturity of technology prior to the start of the FPs, the programmes have enabled an improvement of the technologies. Almost all participants have sustained their competitive technological position in the past years, about one-third of participants has improved it's competitive position because of FP participation. **The energy research in FP can be considered technologically successful.**

6. FP6 and FP7 have not succeeded in achieving the level of commercialisation yet that was expected. **Before the cost reduction that is aimed for is achieved in the market further development of FP results is generally necessary.** Although participants did benefit from improved lasting networks and building R&D capacities, and to a large extent indicate that their technological and general competitiveness have improved, **economic impacts were not as high as expected.**
7. The current realised annual turnover of new innovations as a consequence of FP-participation amounts to around €500 million in the sample we have, which can be extrapolated to ±€1.6 billion to the entire group of energy participants in the Framework Programme. This translates to an expected turnover, to €4.5 – 10 billion in a low scenario to €37 - 70 billion annually in a high scenario (in 2020, based on possibly optimistic participant estimations). For organisations with a non-profit motive, 11% has established a spin-off as result of the participation in the FP project, resulting in roughly 130 spinoffs.
8. **The potential and expected future impacts on energy savings, renewable energy production and CO2-emission reduction are substantial, but measurable impacts so far are limited** (but not negligible: annual power generation is between 1.2 TWh and 4TWh, roughly that of a small nuclear power plant).
9. **It is too early to tell whether the main objectives of FP6 and FP 7 at the programme level with respect to energy (increasing efficiency of the energy European system and at mitigating global change) have been met. These two objectives are long-term objectives and are difficult to assess.**
10. **Furthermore the FPs have permitted to elaborate the long-term energy strategy of the EU**
11. **FP7 managed to support demonstration projects** that is to say projects that, according to the EC definition, "demonstrate and validate, at industrial scale, new technologies, concepts and systems, in order to test and assess the technological and economical feasibility of innovative energy solutions[80]". But the programme did not manage to support projects that would be replicable and replicated, or if one uses the EC definition, projects for which "demonstrated technologies would quickly lead to market deployment".
11. Although European Added Value is not yet a very well operationalised concept, and EAV is hard to measure it can be concluded that the FP energy programmes permitted the creation and organisation of activities that would have not been possible at the national level, promoted transnational cooperation and networking, improving the Union's research position on a global scale and improving businesses competitiveness in renewable energy technologies. Both FP6 and FP7 have supported the emergence of global research champions and allowed the EU to take or maintain a leadership position in certain areas such as biofuels, wind and smart grids. **The energy research in FP6 and FP7 has therefore certainly contributed to the creation of European Added Value.**

Recommendations

12. In line with the continuing importance of CO2 emission reduction, the needs in society for energy at acceptable costs and the security of energy supply and the

[80] http://ec.europa.eu/energy/technology/projects/projects_en.htm

geopolitical considerations about this supply and the related innovations in the energy area that are necessary to achieve these goals **we recommend continued investments in energy research**. This is already part of Horizon2020, where energy research budgets will increase again and will be higher than ever before in absolute terms and (in relative terms) back at the level of FP3 and FP4.

13. In line with conclusion 2 **we recommend to develop a more systemic vision on the role of various technologies in achieving the higher level goals of the FP energy research** with the objective to promote "excellence" in European research worldwide. This vision should form the basis for a transparent set of criteria **to determine the distribution of funding among the different areas** (including new, upcoming areas). Consideration on the European Added Value of programmes should also be taken into account at an early stage during programme preparation, ensuring that national interests play a secondary role with respect to European ones.

14. The fact that the differences in set-up between FP6 and FP7 have not led to large differences in effects suggests that the portfolio of instruments in both programmes has been able to cater for many different needs. The case studies for this evaluation suggest that the very large integrated projects from FP6 and Networks projects that bring many players together on a topic that requires international coordination may have had a stronger impact on policy-making at the national level. Smaller targeted research projects in which concrete technologies are developed are obviously more effective in developing concrete outcomes for project participants. We therefore **recommend to maintain a broad portfolio of support instruments to suit the varying project needs.**

15. Both programmes (FP6 and FP7) have achieved good scientific and technological results and have performed quite well in creating new networks. They have been less successful in promoting actual cooperation and concrete alignment between national and EU research policies.. This has resulted in a large number of projects, sometimes relatively small, rarely related to each other even within the same area. Sometimes projects that are not delivering what has been agreed seem to go on for too long, there is a general feeling that the European Commission services at time lack a suitable understanding of the actual project content and technical aspects, with too much focus on the other hand towards administrative details. In addition to this there has (as was indicated by interviewees) been too little effort from the Commission services to promote interactions between projects and avoid overlaps. There seems to be a lack of concrete instruments or a structured approach aimed to achieve this very purpose. **The European Commission services are advised to strengthen their program and project management processes, and add a project portfolio management approach comparable to what is being done in the private sector.**

16. Both programmes have shown to be open to new participants entry, however based on geographical spread of participants, there is still quite a gap between old and New Member States that the programmes were not able to close. To ensure a level-playing field for all European regions and possibly reduce the existing knowledge gap, the European Commission should consider to strengthen researcher mobility within projects, rather than focusing on participation of companies only from new Member States. This should be achieved by promoting the individual training of researchers, particularly PhDs candidates, for long period of time and within projects.

17. The road from technological success to commercial application is generally long and risky. This is confirmed by this evaluation. Since the energy research in FP has not only economic goals, but also other societal goals there is (even) more rationale for support for this difficult phase than in other fields of technology. This is at present not provided for tin the FP. **We recommend more systematic**

attention for valorisation of research results and capitalisation of results from demonstration projects from the EC, as part of the FP (i.e. Horizon2020) **to increase economic and societal impact.** The European Commission that must ensure an "unbroken chain of support from low to high TRL levels for an efficient and successful development of technologies from early stage research to full market deployment. This support should then be fully integrated with other European instruments. Moreover, in order to ensure economic benefits for individual participant's stronger mechanisms for the protection of IPR should be ensured.

18. The valorisation of research results is not only determined by technological success of economic developments. Regulation and energy policies can play an important role as well. In these times where energy (and materials related to energy production and consumption) becomes more and more a competition determining **factor regulation and (energy) policies should be used to support the successful application of research results, in turn research results should be used to determine optimal policies.**

19. Over time research financing through FPs has promoted the creation of research agglomerates with specialised research institutions that have professionalised project proposal preparation and submission; making it harder and harder for new entrants and smaller players to participate successfully. High administrative burdens (that are considered the main disadvantage of the FP over national programmes) increase this entrance barrier. **Specific attention for reducing administrative burdens and support possible new entrants is recommended.**

20. As sketched in chapter 2.2 this evaluation has encountered various difficulties in the data-availability. **In order to improve future evaluation and monitoring data management at the EC must improve and evaluators must get access to all data available.**

We recommend that:

- The content of CORDA is improved, so that the information is complete (involves all projects supported), up-to-date and accurate (gives insight in the actual situation), provides structured information in relation to policy goals (including unambiguous characterisations of projects in relation to these policy goals).
- Contracts with project are drafted in such a way that evaluators are allowed to access project files at the EC
- Project application forms are drafted in such a way that all applicants (including unsuccessful) ones consent in making their e-mail addresses available to external parties for evaluation purposes
- To facilitate future evaluations and assessment of project results, participants, should be required to present a follow up plan and update the European Commission with the results after the end of the project up to x years after the end of the project. For instance an account of all publications, spinoffs and their estimated turnover, could be asked for depending on the project content and scope. Quantitative indicators such as number of jobs, spinoffs created and capital invested should be considered first. In relation to point 8 above, any additional administrative burden should be easy to follow and kept at a minimum, the format through which such information be provided be standardised for all participants.

21. As part of the evaluation almost 130 case studies were drafted. This number of case studies was set in the Terms of Reference for the evaluation. Although the drafting of the case studies provided very useful insights in results, impacts and

management issues of the FP6 and FP7 energy projects, the number of case studies was far larger than methodologically necessary. As a consequence the attention for broader analysis (e.g. other methods) and comparison was although more than minimal, less than optimal for this evaluation. **We recommend that in the EC, in future Terms of Reference does not describe methodology in detail but will give more freedom to evaluators to develop optimal evaluation strategies.**

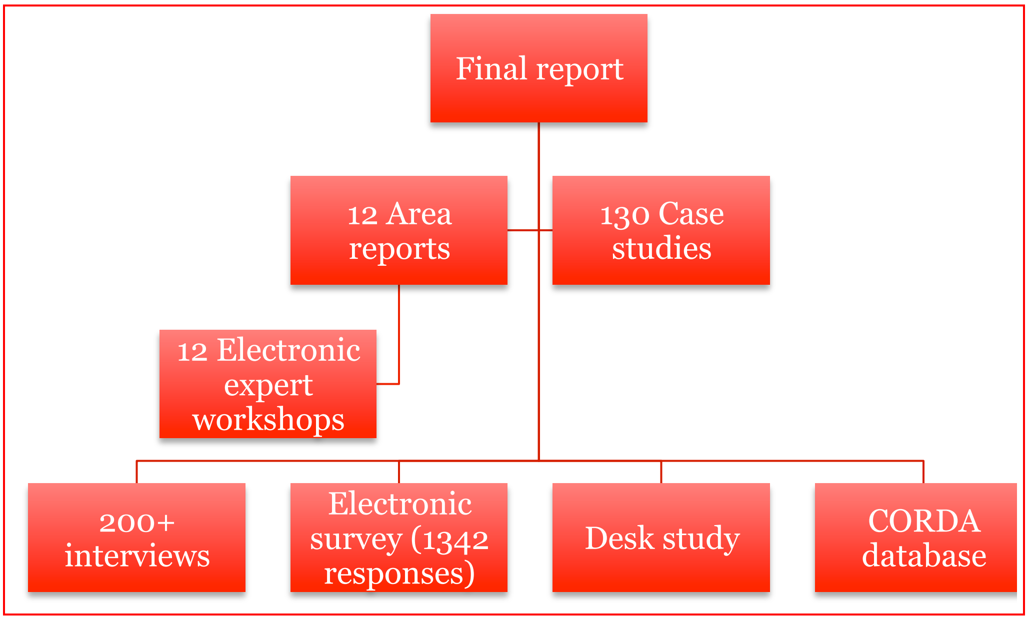
Appendix A Notes on methodology and information sources

A.1 Methodology overview

This final report is the synthesis of a large amount of empirical work that underpins this report. The figure below gives an overview of the data collection and analysis that is the foundation for this report. A combination of qualitative (such as interviews for case studies) and more quantitative methods (electronic survey) were used in an integral manner:

- Interviews with 200+ participants, from all technological areas, national and organisational backgrounds. Include both project coordinators as well as participants. Additional interviews were held on the programme- and area-levels, such as with EU and MS policy stakeholders, key experts and EC representatives.
- An electronic survey sent to all FP6 and FP7 participants of which email addresses were available through the CORDA database, resulting in 1342 responses (18%).
- Desk study, both on programme level (e.g. policy documents), area level (e.g. technological road-maps) and project level (e.g. available project reporting).
- The CORDA database and EC monitoring information provided information on the background details of projects and their participants. Limited additional monitoring information was available (such as progress reports), especially for FP6 projects.
- Electronic workshop with policy stakeholders and technical experts were held on the basis of draft area reports. These online discussions (one for each area) delivered valuable contextual interpretation and served to validate conclusions on the area level.

Figure 58 Data sources



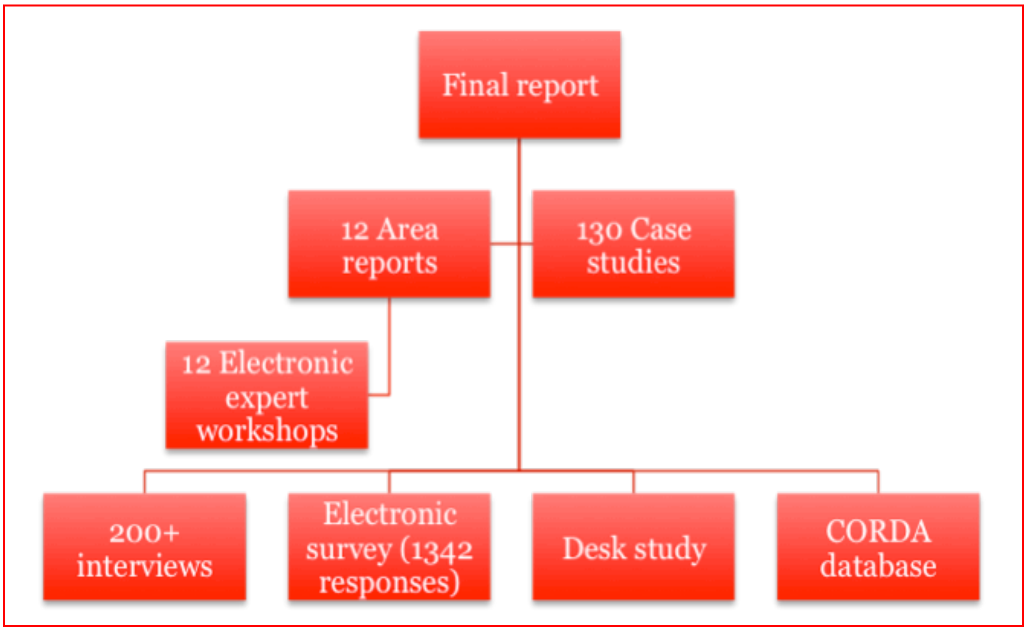
These tools were used to produce three main types of outputs:

- 130 case studies of individual FP projects. After a careful portfolio analysis the number of case studies were distributed across the different areas, type of sub-technologies and type of funding instruments. These case studies describe the background of the project and its participants, results and impacts (scientific, technological, economic and energy-related).
- 12 area reports of technological areas[81], based on case studies and information from the electronic surveys, with additional desk work and interviews, discuss the main impacts on the technology field and its constituents (companies, research institutes, universities, public organisations). The are reports have been validated in the electronic workshops
- This final report

This main report is focused on the level of the Framework Programmes, but uses examples and evidence from the area and project level extensively. Both the area reports and the main reports make extensive used of the integrated data from the electronic survey and the case studies – which in turn rely mostly on interviews with FP participants.

All data sources above were analysed in an integral manner through our evaluation database. An overview of this database is presented in the figure below. As such, the selection and implementation of case studies were informed by the information from the electronic survey, but the case studies also served as validation with individual participants. This cross-validation has improved the reliability of the results. The final qualitative and quantitative analyses are based on the integrated and validated evaluation database.

Figure 59 Evaluation database



[81] Bioenergy; Carbon capture and storage & clean coal technologies; Concentrated solar power; Energy efficiency; Fuel Cell and Hydrogen; Future & Emerging Technologies materials; Heating and cooling; Photovoltaic energy; Socio-economic; Smart grids; Wind energy; Other renewable energy sources

Note: the seven thematic areas include renewable energies, which has been split up in 6 individual areas.

A.2 List of case studies

This report draws much of its materials from 129 case studies that have been carried out in the course of this evaluation. The projects were selected in close discussion with the European Commission according to a number of selection criteria:

- Due to the need to focus on measuring impacts of the FP, a focus on finished or almost finished projects was chosen.
- A balance between the FP6 (67%) and FP7 (33%),
- A balance between the 12 research areas covered in this evaluation, with a slight overrepresentation of small areas (such as the Other area) in order to have enough material for each area
- A focus on projects that are likely to be successful, by analysing the first responses of the survey for 'potential high-impact projects'. For this purpose 20% of case studies were selected later after the survey response was available.
- In some case discussion with the European Commission led to include particular projects of high interest

An overview of all case studies is given in the table below:

Figure 60: Overview of case studies

Area	Project	Author
Bioenergy	AER-GAS-II	Christien Enzing
Bioenergy	BIOCARD	Christien Enzing
Bioenergy	BIOLYFE	Christien Enzing
Bioenergy	BIOSYNERGY	Christien Enzing
Bioenergy	BIONORM-II	Sebastian Stålfors
Bioenergy	BIO_MGT	Sebastian Stålfors
Bioenergy	BIOCOUP	Sebastian Stålfors
Bioenergy	BIODME	Sebastian Stålfors
Bioenergy	BIOGAS CHCP	Christien Enzing
Bioenergy	BIGPOWER	Christien Enzing
Bioenergy	CaneBioFuel	Christien Enzing
Bioenergy	DOMOHEAT	Christien Enzing
Bioenergy	EU-AGRO-BIOCASE	Christien Enzing
Bioenergy	HYVOLUTION	Christien Enzing
Bioenergy	NEXTGENBIOWASTES	Sebastian Stålfors
Bioenergy	NILE	Christien Enzing
Bioenergy	OPTFUEL	Christien Enzing
Bioenergy	RECOFUEL	Sebastian Stålfors
Bioenergy	SUPER METHANOL	Christien Enzing
Bioenergy	UNIQUE	Malin Jondell Assbring
Other	NEREIDA MOWC	Matthias Altmann
Other	ORECCA	Matthias Altmann
Other	WAVEDRAGON MW	Matthias Altmann
Other	WAVESTAR	Matthias Altmann
Other	CORES	Andrej Horvath

Other	EQUIMAR	Andrej Horvath
Other	HYDROGENIE	Andrej Horvath
Other	SHAPES	Helena Kovacs and Andrej Horvath
Other	ABC-OF-TRI-GEN	Jerome Treperman
Other	EERASE	Jerome Treperman
Other	MESOR	Jerome Treperman
Other	SURGE	Matthias Altmann
EnergyEfficiency	BUILD HEALTH	Olivier Mallet, Patrick Eparvier
EnergyEfficiency	BRITA IN PUBS	Patrick Eparvier
EnergyEfficiency	ENERCOM	Agathe Bouffet, Patrick Eparvier
EnergyEfficiency	HEGEL	Francie Sadeski
EnergyEfficiency	LOWEHOTELS	Patrick Eparvier
EnergyEfficiency	NANOSTIR	Patrick Eparvier
EnergyEfficiency	POLYSMART	Léonor Rivoire, Patrick Eparvier
EnergyEfficiency	SESAC	Olivier Mallet, Patrick Eparvier
EnergyEfficiency	SETATWORK	Francie Sadeski
EnergyEfficiency	RENAISSANCE	Léonor Rivoire, Patrick Eparvier
EnergyEfficiency	SOLBIOPOLYSY	Patrick Eparvier
FCH	GENHYPEM	Malin Jondell Assbring
FCH	HYSIC	Malin Jondell Assbring
FCH	HYSYS	Malin Jondell Assbring
FCH	METSOFC	Malin Jondell Assbring
FCH	NESSHY	Malin Jondell Assbring
FCH	STORHY	Malin Jondell Assbring
CSP	DISTOR	Werner Zittel
CSP	E2PHEST2US	Werner Zittel
CSP	ECOSTAR	Werner Zittel
CSP	MED-CSD	Werner Zittel
CSP	SOLHYCO	Werner Zittel
Smart Grids	ADDRESS	Paola Trucco
Smart Grids	EU-DEEP	Paola Trucco
Smart Grids	EWIS	Paola Trucco, reviewed by Jean-Christophe Lanoix
Smart Grids	GROW-DERS	Tommy Jansson
Smart Grids	INTEGRAL	Paola Trucco
Smart Grids	IRED	Paola Trucco
Smart Grids	MERGE	Paola Trucco
Smart Grids	MORE MICROGRIDS	Tommy Jansson
Smart Grids	NIGHT WIND	Tommy Jansson
Smart Grids	OPEN METER	Paola Trucco
Smart Grids	REALISEGRID	Tommy Jansson
Smart Grids	RELIANCE	Paola Trucco
Smart Grids	SUPER 3C	Paola Trucco
Smart Grids	SUSPLAN	Paola Trucco
Smart Grids	PEGASE	Daniele Benintendi
Smart Grids	TWENTIES	Daniele Benintendi
Smart Grids	FENIS	Daniele Benintendi
CCS CCT	CEASER	Francie Sadeski
CCS CCT	CAOLING	Francie Sadeski
CCS CCT	CESAR	Olivier Mallet, Patrick Eparvier

CCS CCT	CO2 REMOVE	Francie Sadeski
CCS CCT	CACHET II	Patrick Eparvier
CCS CCT	CASTOR	Patrick Eparvier
CCS CCT	CO2 SINK	Francie Sadeski
CCS CCT	DECARBIT	Patrick Eparvier
CCS CCT	DYNAMIS	Patrick Eparvier
CCS CCT	ECCO	Patrick Eparvier
CCS CCT	ENCAP	Patrick Eparvier
CCS CCT	EU GEOCAPACITY	Patrick Eparvier, Leonor Rivoir
CCS CCT	RISCS	Patrick Eparvier, Flore Vaucelle
CCS CCT	FLEXIBURN CFB	Francie Sadeski
CCS CCT	H2-IGCC	Francie Sadeski
PV	CRYSTAL CLEAR	Joost van Barneveld
PV	FULL SPECTRUM	Joost van Barneveld
PV	HIGHSOL	Joost van Barneveld
PV	MOLYCELL	Joost van Barneveld
PV	ORGA PVNET	Joost van Barneveld
PV	PV-MIPS	Joost van Barneveld
PV	ULTIMATE	Joost van Barneveld
PV	UPP-SOL	Joost van Barneveld
PV	METAPV	Matthias Ploeg
PV	ATHLET	Matthias Ploeg
PV	FLEXCELLENCE	Matthias Ploeg
PV	APOLLON	Matthias Ploeg
PV	HIPOCIGS	Matthias Ploeg
PV	SOLSILC DEMONSTRATOR	Matthias Ploeg
FETMAT	SOLHYDROM	Daniele Benintendi
FETMAT	EFFIPRO	Daniele Benintendi
FETMAT	HAWE	Daniele Benintendi
FETMAT	INNOVASOL	Daniele Benintendi
FETMAT	NANOPEC	Daniele Benintendi
FETMAT	FETHATEA	Daniele Benintendi
SocioEconomic	CASES	Paola Trucco
SocioEconomic	LETIT	Paola Trucco
SocioEconomic	NEEDS	Paola Trucco
SocioEconomic	REACCESS	Paola Trucco
SocioEconomic	SECURE	Paola Trucco
SocioEconomic	SESSA	Paola Trucco
SocioEconomic	THINK	Paola Trucco
SocioEconomic	WETO-H2	Paola Trucco
Wind	DOWNWIND	Sebastian Stålfors
Wind	NORSEWIND	Sebastian Stålfors
Wind	SEEWIND	Sebastian Stålfors
Wind	TOPFARM	Sebastian Stålfors
Wind	UPWIND	Sebastian Stålfors
Wind	SAFEWIND	Malin Jondell Assbring
Wind	POWWOW	Malin Jondell Assbring
HeatingCooling	ALONE	Jan Zerhusen
HeatingCooling	BIONICOL	Jan Zerhusen

HeatingCooling	GROUNDHIT	Jan Zerhusen
HeatingCooling	HIGHCOMBI	Jan Zerhusen
HeatingCooling	HITI	Jan Zerhusen
HeatingCooling	MEDIRAS	Jan Zerhusen
HeatingCooling	SOLERA	Jan Zerhusen
HeatingCooling	ULTRALOWDUST	Jan Zerhusen

A.3 Survey

An electronic survey was sent to all participants and coordinators in FP6 and FP7 Energy projects. A recommendation letter from the European Commission was attached to the invitation. The electronic survey was developed and collecting using the Surveymonkey software. Data collection took place from the end of October – mid January. Our evaluation team provided support to dozens of participants via email or telephone. A copy of the electronic survey questions is available in the annex.

The invitation to participate in the survey was sent to the main contact person (where possible not the administrative contact person but the contact person involved in the content of the project). People were requested to forward the email to the most senior researcher/manager who was (is) involved in the project, should they themselves not be that person. All respondents received personalised invitations to participate as well as customised reminders depending on the number of projects contacts were responsible for. Participants received up to three reminders All surveys were linked to the specific projects using our evaluation database and statistical software package Stata.

During the case studies, interviewees were encouraged to also take part in the electronic survey. Additionally, key indicators were reviewed or collected for a large share of interviewees.

Figure 61 Overview of response rates

	Number	Percentage	Notes
Total number of participants in FP6/7	7919	100%	
Available contacts	6849	86%	
Available email addresses	5808	73%	A large number of contact details from FP6 were not available in CORDA. All coordinators of these projects were manually identified and invited.
Working contact data	5388	68%	Around 400 email addresses in the CORDA database were not valid
Response rate	1330	17% (total) / 25% (received invitations)	
Fully completed surveys	927	11.7% (total) / 17.2% (received invitations)	Note that a large number of respondents did fill in significant parts of the survey
Total number of available participations with data	1342	19.7% (total) / 25% (received invitations)	This includes the data collected through the interviews. In total data was updated or added for 42 participations through the interviews.

These 1342 responses cover 573 projects in total, which means that the analysis includes at least 1 response for 89% of projects. The typical FP project therefore had 2.4 survey responses on average to inform the quantitative analysis and case studies. For at least 75 projects the coordinator was one of the survey respondents, although this is likely to be higher since a number of responses cannot be traced back to the specific participant (only to a specific project).

The division of responses shares across areas was relatively uniform. The lowest response share was in the Bioenergy area (16%), while the highest was in the FET/Materials area (34%). The latter is also explained by the fact that there are no FP6 projects in these areas and therefore only includes relatively recent projects.

The division of response shares across organisation types was also analysed. Here we see that 22% of responses comes from higher education institutions, 34% of private companies, 5% of public organisations, 21% of research centres and 17% of other (or unknown organisations). Compared to the actual distribution, HES and REC are slightly overrepresented, while other and public organisations are slightly underrepresented. In our statistical analysis we have tested for differences between organisation types in order to account for these small variations.

Note that for the quantitative analysis in chapter 5, the indicator tables were calculated only for those projects which are finished before the end of 2015. Also, respondents who indicated that they themselves were not able to provide realistic estimations of outputs, outcomes and impacts were excluded. The total number of responses for this analysis was therefore reduced to 964.

A.4 Involvement of experts

A number of high-level experts reviewed this final report, and their input was used to produce this final version.

Figure 62 Expert reviewers final report

Name	Position	Country	Role
Jørgen Kjems	independent consultant	DK	Advisory Group on Energy (E00785)
Marko Topic	Professor University of Ljubljana	SL	Advisory Group on Energy (E00785)
Ulrich Wagner, Jörg Nellen,	DLR/German Aerospace Center	DE	
Gianni Operto	independent Consultant (formerly Emerald Technology Ventures, CEO Elektrizitätswerke Zürich)	CH	Advisory Group on Energy (E00785)
Koen Schoots	ECN	NL	ERKC Report manager

Note that for each of the 12 area reports an online expert workshop was held with over 100 participants in total. Experts were selected from academic experts, national and European policy stakeholders, industry representatives and FP participants. The feedback from these electronic workshops was integrated in the final version of the area reports. The individual area reports include the list of the participants in the electronic workshops.

We are especially grateful to the researchers of the European Research Knowledge Center (part of SETIS), many of whom have reviewed individual area reports.

A.5 Interviews

Note that a large number interviews was carried out for case studies totalling over 200 individual interviews with FP participants. Additionally, policy stakeholders and academic experts were consulted for the individual area report. For this final report itself, a number of preparatory interviews were held:

Figure 63: Overview of pilot interviews

European Commission/DG Ener	**Programme officer/ DG Ener**	**Philippe Schild (RTD/K3)**
European Commission / DG RTD	Programme officer/ DG RTD	Roberto Gambi (ENER/C2)
Research	EERA executive committee	Massimo Busuoli (ENEA)
Joint Research Centre: Energy Systems Evaluation Unit, Institute for Energy and Transport	Scientific Officer	Roberto Lacal-Arantegui
European Industrial Research Management Association (EIRMA)	Secretary General	Michel JUDKIEWICZ

A.6 Use of Database

Technopolis has used Filemaker, a database development and publishing package, to facilitate effective collaboration among the four Technopolis offices and three partner organisations. This database combined the information delivered by the EC's directorates of Energy and Research, and enabled the project team to view and edit the information simultaneously in one central environment. The basis for this database were CORDA tables containing contact, project and organisation information related to 642 FP6/7 energy projects. The information in these tables contained information on the projects themselves such as total costs, time span and project description. Linked to each project was information on the organizations that participated, their roles and financial contributions. It contained all the contact details for interviewees and whether the project itself was selected for a case study. In addition, thousands of survey responses were added to the data set, linked to projects and their participants. For a limited set of projects, information on publications and patents was also available, which was linked to the projects. This environment enabled the consultants to have all the relevant information for the projects they reviewed in one place, without the risk of using unsynchronised information. Additionally, they could verify and comment on the key indicators that were given by survey respondents to add to the integrity of the survey.

The environment was accessible through any standard internet browser through its web interface. A screenshot of the environment is given below:

Figure 64 Database web interface

Technopolis

Appendix B Area Report Summaries

B.1 Bio-energy

The FP6 and FP7 Energy programme's main goals are accelerating the development of energy technologies towards cost-effectiveness for a more sustainable energy economy for Europe (and world-wide) and ensuring that European industry can compete successfully on the global stage.

Bio-energy is a field of growing importance; especially new developments in biotechnology/life sciences contributed to this. In FP6 in total 46 bio-energy projects were selected for funding (total budget of 329.99M€ and EC contribution of 170.30M€). While in FP5 priority was given to thermal processes, in FP6 the focus moved towards biofuels. In FP7 55 bio-energy projects were selected for funding (total budget of 777.75M€ and EC contribution of 346.56M€); now with second-generation biofuels as the main focus of the programme.

Overall the programme has led to considerable progress in the Bio-energy field. The FP6/7 Bio-energy projects have been very effective in terms of direct project results, outcomes based on these results and their scientific-technological, economic and ecological impacts.. Most projects met their objectives. Results were published and patents based on these results have been applied/being granted or will be applied for. The Technology Readiness Levels of the technologies developed in the Bio-energy projects have increased.

The Bio-energy projects had a considerable effect on the R&D resources: (staff, investments and capabilities), on the organisation's strategy and increased the awareness of the importance of R&D within the participating organisations. The projects led to an improvement of the network with project partners and to more collaboration within the value chain and to more open innovation. This is especially valuable for the integrated approach that was used in many of the bio-energy projects, covering large parts of the biomass well-to-wheel chain.

The FP6/7 Bio-energy projects contributed to new processes and products. Three-quarter of the projects have a marketable outcome, for about half of the projects these are (potential) new processes. In the FP6-funded projects, the technological position (national, European, world leader) of the participants in the bio-energy projects has stayed the same for more than half of the respondents, the rest improved their position. For the FP7 participants the change in position was (still) less significant. About two third of the participants indicated that they will continue to work on the technology developed in the project.

Companies involved in the projects report the largest impact of the projects' results on turnover, and less on market share and on employment. Public research organisations mention the largest impact on contract research income, followed by growth in number of employees, and less on income from licenses. The projects are expected to contribute to renewable power generation, power savings and CO2 reduction and through this to the realisation of the EC energy and climate policy goals.

There is great European added value of FP funding in bio-energy research, technical development and innovation. About two third of the respondents stated that their projects would not have been carried out without the FP funding. FP6/7 has played an important role in getting Europe high on the lignocellulosic-to-ethanol research agenda. At the time of FP6, Europe was lagging far behind in the second generation and bio-refinery research field and the US was far ahead. Now Europe has a rather good position in this field, especially cellulosic ethanol. Also FP6/7 funding stimulated cooperation in this field. This also resulted in less overlap between research groups as research groups are now more focusing on their specialities. Finally, many projects are expected to contribute to the realisation of Europe's energy and climate policies and the transfer to a bio-based economy.

Important factors that have stimulated these developments are first of all that European researchers were very eager to get involved in the second-generation biofuels development and made progress in this field as fast as possible. European transport fuel policies, energy and climate policies also stimulated these developments. The involvement of companies, especially in the role as project coordinator, could also be an important factor for the effectiveness of the FP6/7 programme. Programme effectiveness and especially the implementation of project results was hindered by the economic and financial crises, by fluctuations in market prices of biomass feedstock and by alternative technological routes and change in policies.

Main drivers for future bio-energy technology policies - aiming at both stationary and transport bio-energy - are reduction of CO_2 emissions and independency of imported energy. Such policies can only be implemented in a successful way in case national and European policy makers fulfil a coherent and consistent policy over a long period of time (also securing the availability of enough biomass). This will also persuade industry and investors to stay/become active in this field.

B.2 Smart Grids

This area report presents the findings of the analysis on the area of research for smart grids and energy networks carried out within the 6th and 7th Framework Programmes coordinated by the European Commission. The results presented in this report are based on information and data provided by the European Commission, existing literature review, a survey of all FP participants and the detailed analysis of 17 projects ("case studies") carried out by the project team. Interviews with project officers were also carried out in the context of this analysis.

In terms of general context, the European electricity network infrastructure did not drastically change in the past century and was built to cope mostly with a centralised energy system, which requires minimal intervention from network operators and no participation from end-users. The acceleration of the penetration of intermittent renewable energy capacities, , decentralized energy capacities that could be intelligently controlled though information and communication systems, the liberalization of energy markets and the query of resource efficiency gains through the optimal matching of offer and demand, generated a number of technical challenges on existing networks having an impact on technology requirements, as well as opportunities for end-users to become "pro-sumers". The smart grid concept emerged as an integrative concept able to bring a solution to some of these challenges. Smart grid represents a concept encompassing a broad range of technical and regulatory solutions to the challenges posed by the transition from a traditional energy system to a more sustainable and decentralised one, where new market players (such as pro-sumers) do appear. As a result, developments in the area are overwhelmingly concerned with the integration of existing technology blocks rather than the development of particular technologies Also, in line with the provisions of the Third Energy Package and the creation of the internal energy market, it was also necessary to create a pan-European electricity grid infrastructure able to interconnect national electricity markets and integrate large quantities of renewable electricity.

Detailed analysis of projects financed within the 6th and 7th Framework Programmes presents an interesting picture on the evolution of research activities in this area. A deep increase of activities in the smart grids area can be observed between FP6 and FP7. Indeed, the number of projects financed doubled and total investments increased with more than 500%. FP7 clearly built on the achievements of FP6, however while for FP6 there was no specific research activity dedicated to smart grids, during FP7, Activity Area 7 enabled a more structured approach in this field, which was reaching more maturity. Moreover during FP7, individual topics were specifically designed to as developed in the R&D Roadmap of the SET Plan European Electricity Grids Initiative (EEGI) and meet the needs of industrial stakeholders, through the contribution of the European Technology Platform (ETP) for SmartGrids. A large number of stakeholders was involved in this area of research, with network operators taking the lead in many projects, particularly from 2009.In terms of project outcomes and results (chapter the area report finds that the majority of projects financed, especially during FP6, focused on the analysis of a system-wide approach rather than the development of individual technology components. This somehow reflects the very nature of smart grid projects in the business world: smart grid innovation throughout the world is more driven by the enabling role of intelligent networks, examplified by IT platform-based service layer value creation, rather than innovation on hardware technologies as is the case in other (renewable) energy areas, especially in the production field. Concrete outputs vary greatly, from technical reports and simulations to grid management tools and cabling equipment. From the analysis of the survey results, it is apparent that as research activities have progressed, a partial shift has taken place between FP6 and FP7, where technological outputs, such as the design, validation and testing of new technologies is more pronounced. Also, while objectives and outcomes were quite broad during FP6, and only became clearly defined and focused during FP7. We could observe that research activities during FP6 have directly contributed to the delineation of research activities for FP7. Also thanks to the launch of the SET-Plan and the EEGI, projects have produced more concrete results in FP7, aligned with requirements better specified by business stakeholders. However, while technological developments has certainly increased in particular during FP7, most stakeholders are still largely dependent on public financing for the development of intra-national projects. This is particularly true for regulated network operators that are often missing the right incentives to invest adequately in smart grids projects.

With respect to the relevance and effectiveness of projects financed in this area, both programmes achieved large outreach across stakeholders and promoted collaboration, cooperation and the uptake of multidisciplinary issues. Long-terms impacts with respect to utility are more difficult to evaluate since smart grid technologies are still at an early stage of development, with most projects focusing on activities that did not entail an immediate commercial value creation: business models in the smart grid sector are only now starting to appear. The network operators, as main actors in this field, have the mission to enable the development of businesses for the electricity market actors and are hence not primarily involved in the development of new businesses themselves. The smart grids research area clearly presents a pan-European component that can help overcome main challenges faced by the EU, such as the integration of European energy markets and grid operation across Member States. This area report finds that FP projects allows participants to broaden the scope of their research from a national perspective to a European and even global one. The complex multi-disciplinary research work is enriched thanks to the variety of methodological approaches, national experiences and analysis of specific situations.

On the basis of the results of our analysis, it is possible to identify a number of specific recommendations for future research activities in this area:

- Key performance indicators (KPIs), focusing on relevant technical aspects should be set to evaluate project performance and potential value creation. Project participants should be encouraged to elaborate on the future scope and use of the technology or product developed following the end of the project, in order to get more traceability of the real direct and indirect business impacts, which might take some time to materialise after the project;
- Participants should also be required to prepare a follow up plan on the concrete use of results, to avoid that project results (e.g. prototypes, models, databases or tools) are left unused following the end of the project;.

- Research priorities should start focusing on commercial impacts and market uptake of the solutions provided, while encouraging harmonization of all options provided to ensure a system-wide approach;
- The European Commission services should encourage more exchanges between running projects to identify and build on overlaps and in particular, enable exchanges with related areas of research (e.g. ICT, renewable technologies). This is a role European Commission services should actively play, since it is the only structure in place able to identify those projects and overlaps in a timely manner (meaning very early in the project awarding process);
- The participation of a variety of stakeholders currently underrepresented (ESCOs, service and IT consulting firms, "pro-sumers") should be strongly encouraged since they are very active in the field of smart grids, and key players able to push innovative technologies to markets.

On the policy side, a pan-European approach is needed to deal with regulatory and (pre)-normative aspects and accelerate the implementation of pan-European technology platforms, able to compete against non-European (US-based but with growing competition from Asian economies) solutions. Even if beyond the scope of the FP programme, it is expected that in the future the regulatory framework will be adapted to the needs of regulated stakeholders to ensure they have the right incentives to invest into new technologies. This should also reduce the dependency on public financing for project development.

B.3 Socio-economic

This report presents the result of the analysis carried out in the context of the "*Mid-term Evaluation of FP6 FP7 projects in the energy area*" on the background, impacts and main results of FP6 and FP7 projects financed within the socio-economic area. The results of this area report are based on a survey of all project participants, the detailed analysis of 8 project Case Studies (see Appendix) and existing literature review, particularly past evaluations of the FP6 programmes.

The report presents the general context and policy background of research in this area. Socio-economic research in the field of energy encompasses a broad spectrum of research topics, focusing in particular on the analysis of socio-economic, geo-political and environmental aspects related to the production and use of energy. Projects financed in this area generally focus on the design or upgrade of quantitative modelling tools, analysis of costs externalities and security of supply. More recently, the research area focus shifted more prominently to the analysis of issues related to the transition from a traditional energy system to a more sustainable one. The overarching objective of this area of research is to assist policy-makers and improve existing knowledge of the implementation of sustainable energy systems through the analysis of environmental and social impacts related to the use of new technologies. This area of research is particularly relevant to EU policy making since for decades it has contributed to the development of evidence-based policy promoted by the European Commission. In particular it has an important impact on the delineation of different policy options in the long-term, for instance through the establishment of quantitative targets and quotas, and methodologies to develop such tools. On the contrary our analysis shows that this research area is much less useful to the business community.

The analysis carried out in this report draws attention to important differences between FP6 and FP7 programmes, in particular with respect to the level of resources dedicated to each programme. When comparing descriptive analysis of FP6 and FP7 projects, it is found that the number of projects financed during FP7 was less than half of the ones financed during FP7 and total investments in projects decreased by 57%. Partly this might be due to the fact that during FP7 socio-economic research has been progressively integrated in other areas of research. Another reason is certainly that

European Commission services rely more heavily on bilateral contracting with experts through other channels, such as Framework Contracts, to request support for specific socio-economic analysis within a short time framework. Indeed such contracting process seems more adequate, also because attracting business investments into these research areas is proving difficult, and not always very relevant.

Overall, due to their very nature, projects in this areas are smaller, both in terms of budget and size of consortium, than the average FP project and the total project investments represents only 1.26% of the total budget. The average EC financing share is also higher than for other areas (83% in comparison with an average of 66%). With respect to the topics analysed, thematic priorities remained somehow similar and in some cases FP7 projects were financed as follow up activities to FP6 projects. Most project participants are universities, research institutes and specialised consultancies, with a very low share of industry representatives.

Analysis of concrete project impacts and outcomes has revealed to be quite challenging given the nature of the projects and their outputs The most relevant project outputs relate to the creation of new knowledge and modelling tools, which tend to be more beneficial for individual participants, who are able to consolidate their main competencies, increase their knowledge and gain insights into this area of research beyond their national borders. In particular, FPs have proven very effective in promoting collaboration across the EU and knowledge sharing among stakeholders, even if some knowledge gaps remain between Member States. In terms of actual impacts to EU policies, it was possible to identify a few concrete impacts, but for most projects these remain vague. Interviews suggest that this is partly due to a lack of interactions between EU institutions and project consortia throughout project cycle. Also, participants surveyed or interviewed find it difficult to follow up on the use and uptake of project results, which is not made easier by the fact that it is not possible to keep track of the use of scientific reports throughout the legislative procedures and that final legislative documents rarely quote such scientific work.

In terms of relevance projects financed are well in line with energy policy priorities. However the limited use of project results raises concerns with respect to the long-term efficiency and utility of this area of research. Again, this is partly due to a certain mismatch between the objectives and goals set at the inception of the projects, the parallel evolution of EU policy-making and the lack of perceived commercial relevance to the business community. The evaluation of the short term impact of socio-economic research projects has proved to be somehow difficult, using the existing set of KPIs. Policy impacts may not necessarily derive from the direct use of project results as participants would expect, but rather on the uptake of the models that have been developed through the project. This is the case of many models, such as PRIMES and POLES that have been used as scientific references and in support of various legislations and were developed and upgraded through FP projects. In the past these tools played a key role in setting up targets and promoting certain policy options with respect to others.

On the basis of the results of our analysis, it is possible to identify a number of specific recommendations for this area of research to ensure stronger impact and efficiency of projects financed in this area.

- The European Commission must ensure a thorough follow up of research activities before, during and after the project.
- The European Commission may evaluate the possibility of transferring more of this research activity, either through:
  - The integration of non-transversal socio-economic research into specific thematic areas and projects,
  - Topic specific tendering contracts ran by the relevant ETPs
  - Research tenders directly contracted by European Commission services, for example through Framework Service Contracts.

- A wider array of stakeholders must be included in the preparation of socio-economic priority research areas in order to identify topics of further relevance to the business community. This will generate further participation in projects and the transferability of project results to the business world. The participation of industry stakeholders should therefore be promoted through the SET-Plan, ETPs and sectoral industry associations. The European Commission should also ensure that national stakeholders are aware of research activities in this area through targeted communication activities.
- The relevance of developing specific instruments (such as quantitative models or toolkits) in the context of FPs, , must be assessed both from a FP programme management standpoint (do they meet the objective to bring the industry community at the core of EU research activities?), as well as a EU policy-making (is the FP funding approach the most suited manner to obtain scientific inputs in a timely and subject/objective-driven manner for European Commission services, or should they use more direct contracting means).

B.4 Concentrated Solar Power

The potential impact of Concentrating Solar Power technologies (CSP) is huge: When the technology is mature and competitive, it could cover double digit shares of electricity production in Europe with further impacts on world markets as geographic areas with high direct solar radiation between 20° south and north are potential target markets. This would have significant impacts on greenhouse gas reductions, stable electricity production from renewable energy and on dispatchable power as well as on the market relevance of the corresponding European industry.

Today, the technology is in a status between research and the early phase of market introduction. Only a limited number of projects (about 40) have been constructed mainly in Spain in recent years and are operated under favourable economic conditions (cost covering feed-in tariff). Since the economic crisis these conditions have worsened and new projects lack cost competitiveness, which has almost stopped further project development. The cumulative sales volume is still too low and has not yet achieved a significant cost degression.

Within FP6/7 a total of 20 projects on CSP were funded with a total funding volume of 110 million Euro and total project costs of 183 million Euro. Due to the (pre-)industrial status of the technology, projects focussed on roadmapping, market assessment and feasibility studies. Additional funding was given to projects aimed at optimizing system concepts or at developing and improving specific technologies such as storage, heat transfer fluids, electricity generation by thermionic devices, sterling engines or microturbines etc.

Consequently, most projects resulted in scientific output (PhD studies, patent applications, scientific publications etc.) which have the potential to be converted into commercial products later.

The major goal of the roadmap study under FP6 was to identify key areas of necessary technological progress which should be addressed in future research programmes. These recommendations were adopted in FP7.

According to survey results most respondents indicated that the projects met the project objectives or yielded results beyond expectation. Projects improved the technology readiness level (TRL) of the technology covered by about 3 on average. 15 per cent of respondents indicated a patent grant or application, 50 per cent indicated at least 1 PhD from project participation, and almost 90 per cent indicated at least one scientific publication. No direct investment volumes triggered by project participation were mentioned although some projects resulted in follow-up projects applying the outcome of the earlier project. More than 80 per cent of respondents indicated that with an 80 per cent probability no commercial product would be market ready within one year after project end.

Most of respondents indicated an increased (trans-)national co-operation and an improved network of partners. While due to the character and limited number of projects FP6 had almost no influence on the technological position of the involved institutes/companies, FP7 project participation helped various organisations to improve their technological position either from “Late Follower” to “Early Follower”, from “Early Follower” or “National Leader” to “National Leader” or “EU Leader”, respectively, or from “National Leader” to “World Leader”.

More than 80 per cent of respondents indicated no or a very small increase on turnover and of market share due to FP6/7 participation. The overwhelming majority of respondents indicated that CSP plants have a huge potential impact on renewable power generation, and CO_2 reduction. All respondents indicated a continuation of their work after the project had finished.

As EU and national funding were offered in parallel, one cannot analyse the relevance of FP6/7 in isolation. However, most respondents indicated that EU and national funding should be co-ordinated in order to improve programme efficiency. The co-financing share was seen to be better or much better at EU level by 60 per cent of respondents in both, FP6 and FP7.

The main challenges to the development of CSP technologies at industrial scale are the high costs which need to be brought down in order to develop a mass market.

Future funding should focus on:

- Priority to internal storage and dispatchable power supply in order to tap the advantages of CSP against PV to its full extent;
- Better integration of the pathway from research to a 10 to 30 MW first-of-its-kind commercial system;
- Capacity building in EU Member States and Mediterranean countries;
- Development of harmonized regulations, codes and standards which are essential for the market penetration of the technology;
- Technology transfer to potential target markets by co-operations in order to stimulate markets and to promote technologies made in Europe.

Besides research, a market introduction programme with corresponding incentives to operators aimed at reducing costs through economies of scale would be necessary in order to solve the “chicken and egg” problem of missing markets due to high costs and high costs due to missing industrial markets.

B.5 Photo Voltaics

This area report describes the effects of the European Commission’s support to the Photo Voltaic (PV) sector in Europe within the 6th and 7th Framework Programme (FP6/7) and the context influencing the effects of this support.

The European PV sector is a term used to describe the set of actors that are involved in the production chain for producing PV modules. Actors include research institutions and universities, production companies and equipment manufacturers, parts of the semi-conductor industry and many more such as enterprises involved with the silicon (Si) feed stock and micro-electronics companies.

The global as well as the European PV sector have experienced volatile developments during FP6 and FP7 (2002 – 2013). Whereas in the early 2000s the amount of electricity produced by PV technology was very modest, the production has grown exponentially towards the end of the decennium such that it is a serious component of the European (renewable) energy mix. PV generation capacity has increased 160-fold during the period 2002-2011. This tremendous growth has been driven by supply side policy, such as many European member state regulations on feed in tariffs, as well as an aggressive policy approach towards reducing production costs and increasing production capacity of PV modules and related technology. These national regulations were for a great part driven or inspired by the European Commission's requirement for National Renewable Energy Action Plans (NREAP) and the 20/20/20 objectives. Arguably, another major driver for the rapid application of PV in Europe was the price reduction realised by Asian producers by increasing the production scale around 2008.

At the time of the start of FP6, the most important challenges were to further increase the energy output of PV-systems, while decreasing the costs of the PV cells contained in a PV module as these cells were the main contributors to the costs of a PV module. Important challenges were to be found in the lifetime of the systems, the efficiency of the cells and lowering of the (industrial) production costs. At the start of FP7, the most important challenges were again to further increase the energy output of PV-systems, while decreasing the costs of the complete system. Also, increasing the sustainability of the PV-modules was identified a challenge. Sustainability was related to the required material input and the availability of rare metals but also to the environmental footprint of module production.

Several external developments with a high impact to the European PV industry have taken place in this period. The economic crisis of 2008 is certainly important to mention but has not been decisive. The availability and price of Si have had a strong influence on the cost effectiveness of Si based PV but even more so on the viability of alternatives to silicon. Finally, manufacturers of Si-based PV modules have been seriously impacted by imports and 'price dumping' from the Asian market with which they could not compete. This latter phenomenon had also been stimulated through aggressive production capacity expansion of PV components in Asia.

Within this context, the FP programme has delivered numerous outputs. Consortia of research institutions and enterprises have generated demonstrable knowledge in the form of patents, peer-reviewed publications and PhD's. Several projects have established world records for cell efficiency. Some projects led to spin-off activities and while other projects have generated knowledge and practices that have spilled over to other sectors. These results have led to favourable outcomes for the European PV industry.

Participants in FP projects have been able to keep up with or advance global PV developments as is indicated by our survey. The FP has had positive effects on employment as well as turnover in the PV sector – mostly with those involved in research. FP projects have yielded results that many participants expect to see in the market before 2020 in some form. Most importantly, the 6th and 7th framework programme have given the PV sector the support, in both financial as well as political terms, to continue performing world-class research, development and demonstration.

This is also where the majority of the FP's impact takes place. Due to the external developments, most of Europe's PV manufacturing capacity has gone out of business. The ones that do exist either face serious financial difficulties, or they have been able to survive due to cost effectiveness and continuous process improvement. Nonetheless, the uptake of all the fruitful results from the FP is limited because of this missing link in the value chain. This implies that the economic effects of employment, turnover and self-sufficiency in production remain largely absent as of yet. Most of the impacts of the FP can be found at research institutions, the European state of the art in PV knowledge and with equipment manufacturers – enterprises that design and deliver equipment to produce PV modules and cells. Roughly said, this is the high-tech domain of the PV industry.

The presence of this globally competing, high-tech sector is important for Europe, not only in terms of employment or other economic activity. State of the art knowledge and capacities on the topic of micro-electronics in general and PV as an energy technology in particular are of strategic importance for Europe's energy independence and continued availability.

The European added value of the FP in the area of PV is clear. Few Member States within the EU contain all the parts of the PV value chain, such that European PV efforts are de facto international as it has been for decades. National research support usually excludes foreign parties from participation, and as such the EC is one of the few European funding bodies that is able to safeguard the European perspective and they have done so very well.

With FP support, the European PV sector has been able to perform integrated projects with public-private partnership from feedstock to module manufacturing, an approach that has been used as an example the world over. This has enabled the PV sector to maintain a systems perspective and focus research towards the most relevant challenges. In addition, the FP support has enabled the formation of several technology platforms, such as the EU PV platform and OrgaPVNet. These bodies have issued roadmaps and long-term development plans that have been instrumental in gaining industrial as well as national funding support.

Overall it can be concluded from the evidence presented in this report that research in the area of PV in FP6 and FP7 has been scientifically and technologically successful. This is shown by world records in PV cell efficiency, both directly and indirectly due to FP6/7 participation. Other indicators for the scientific success are patents applied for by participants in the FP6/7 PV area and numerous publications. We conclude therefore that in relevant areas for solar research work has been done that has increased the level of scientific and technological competence in Europe, and in the world.

However, direct economic effects on European enterprises have been limited. Due to economic developments and competition from Asia, the sector of solar cell manufacturers in Europe has virtually been wiped away. Indirect economic effects too are not easily attributable. The EU and global solar market have boomed over the period of the evaluation and the worldwide innovation leading to significantly lower cost prices per Wp installed power has been crucial in this (besides market stimulation esp. in Germany). These cost reductions (from €4 to €1.2 between 2000-2011) are mainly attributable to scale-up effects and maturing of technology that has been developed before FP6/7. It is therefore hard to say that FP6/7 have contributed to the rapid adoption of PV in Europe or worldwide. Beneficial economic effects remain to surface in future years as the technology developed in FP6/7 dissipates throughout the PV sector.

A future strategy of supporting PV R&D would benefit from a focus on those parts of the value chain where Europe can find a definitive sustainable competitive advantage (or at least level playing field). At the moment the EU is very competitive in manufacturing of high-tech components and PV manufacturing equipment, but less so on the large scale production of more standardized technology such as the PV panels themselves. A new strategy could focus on this competitive edge in high-tech equipment manufacturing, combined with a push for new (high-tech) second/third generation technologies where the EU could become competitive in the (near) future. However, competitiveness cannot be guaranteed by leading the technological development, as has been shown for the case of Silicon-PV. If Europe wants to be competitive through second/third generation PV, all its other policy domains (energy, trade, fiscal) need to be aligned.

B.6 Renewable Heating and Cooling

Renewable heating and cooling (RHC) is of great importance for the European energy policy. Heat alone accounts for almost half of the European final energy consumption. The share of renewables in this sector steadily increased in recent years reaching 15.1%

in 2011. RHC is expected to significantly contribute to the EU 20 20 20 targets. About 40% of the CO2 reductions and 45% of the renewable energy consumption targets are estimated to come from RHC applications by 2020.

Before the start of the sixth Framework Programme (FP6) the main challenges in the RHC area were to go from scientific concepts and early stage technical development to market ready solutions. The main goals of both framework programmes were therefore to bring various technologies closer to the market by increasing efficiency and reliability, reducing cost, increasing the field of application and demonstrating the technology concepts in real world conditions.

A total of 41 RHC projects were funded during FP6 and FP7. The average total project cost was €5.4m with an average EU contribution of €3.2m resulting in an average EU funding share of 59%. The average total project investments as well as the EU share were significantly higher for FP7 than for FP6. The size of the project consortia varied between 3 and 35 participants averaging 11.3 participants. Project durations were on average 41 months (min. 14, max. 60 months). The great majority of the projects met or surpassed the project objectives and only a small number of projects only partly achieved their objectives. Almost every project achieved some kind of marketable outcome (e.g. a new product, a new process or a new service).

The projects had a great impact on the directly involved organisations and on the RHC sector in general. Participating companies and research organisations were able to consolidate or improve their technological position in the European and the international context. The projects supported under both framework programmes also contributed to Europe's technical position in this field. The positive impact was not limited to scientific and technological aspects, but also included economic aspects such as increased turnover, increased profits, increased market share and an increased number of full time employees for a large number of involved companies and research organisations. Other areas also benefit from the RHC research and development efforts. A technology and know-how spill-over to other areas already happened or is expected in the near future from about half of the projects.

Funding RHC projects on a European level had some additional positive aspects that go beyond the pure funding of technology development and knowledge generation. These added values include the establishment of new contacts to potential business partners and the extension of networking contacts within the project consortia, the great visibility and very good reputation of projects supported under the framework programmes as well as the comprehensive scope of the projects. This includes aspects beyond technological development such as developing market studies, roll-out strategies and market introduction plans. The timescale of the projects and the available funds were estimated to be better than in comparable national programmes. However, the total amount of available funding was considered too low by the project participants compared to the importance of this area for the European energy policy.

The total EU contribution to FP6 and FP7 RHC projects amounts to €131 million. This amount represents 4.8% of all available NNE (None-nuclear Energy) funds in both programmes. Taking FP6/7 nuclear energy R&D funds into account this percentage is a lot lower. The share of RHC applications in Europe's final energy consumption is about 14%. The important role of RHC in Europe's final energy consumption and its expected major contribution to the EU's 20-20-20 targets was not reflected in the available funds in FP6 and FP7.

B.7 Wind

Although the wind energy capacity has experienced an extensive growth in Europe as well as worldwide during FP6 and FP7, the EU as a whole appears not to be successful in reaching its targets for wind power by 2020. The main explanation given is the economic crisis as well as a hesitation to invest.

Despite this, the present evaluation shows that the framework programmes have succeeded in their primary objectives; to increase wind power capacity and to contribute to a cost reduction in the wind energy production. A range of different indicators presented in the study points towards this conclusion.

Perhaps the most important indicator of a successful project implementation is the commercialisation of the output. The evaluation shows that approximately 80% of the project participants expect this to be realised, even though they are unsure when this will be. Given this sector´s extensive investment lead times – a major factor of uncertainty – this might not be a surprise.

The commercialisation of the technology developed during project implementation is not the only aspect when assessing the impact of the projects. The effects on the participating organisations seem to be of high value as well. For example, improvements have been noted in an increase of R&D capability, more involvement in open innovation as well as an increase of network of partners – all of which are promising signs for future expansion of wind energy. Still, the technological competition in the wind energy sector appears to be challenging as only a limited number of the project participants assess their technological position to have improved due to project participation.

Although FP6 and FP7 seem not to have led to an increase in turnover for the participating organisations, the participants experience their organisations' competitiveness to have been strengthened on a general level due to project activities. The extensive collaboration and networking between the participants in the projects, the mixture of high-tech industry and research organisation constituting the project consortia, give the impression of a powerful arrangement, forceful enough to reach the programmes´ objectives.

B.8 Fuel Cells and Hydrogen

The results presented in this evaluation indicate that the framework programmes have had a clear impact on the FCH field. The project activities appear to have strengthened the participating organisations themselves, as shown in enhanced R&D capability and increased R&D investments and R&D staff. There are a number of possibilities of new products, processes or services reaching the market as a consequence of FP project participation. The programmes have provided good conditions to publish the results, often in high-impact journals. In general, the evaluation shows a positive impact on an organisational level. The FP6 and FP7 projects have been effective in reaching their core objectives.

To some degree, the programmes have contributed to boost the project participants' technology level. The evaluation indicates that 19 organisations have improved their technological position due to FP (mainly FP6) participation. Many have moved from being an early follower to become a national leader in their technology, but there are also some examples of organisations moving from national leader to EU leader, and from EU leader to world leader. This is a promising development, since one of the critical challenges for this area is the competition with other regions (in particular, USA and Japan). The fact that many organisations have strengthened their competitiveness does not, however, necessarily have an immediate impact on their technological position in a comparative global outlook (since competitors are developing as well). Nor does it automatically lead to an increase in turnover for the organisations. The extent to which Europe's competitiveness in this specific sector has increased also needs to be compared to the money invested in this area in FP6 and FP7.

FP6 focused on initiatives for a transition from a fossil fuel-based economy to a hydrogen-based one. The "European Growth Initiative" earmarked public and private funding for partnerships for a large scale "Quick Start" initiative for hydrogen production and use in order to accelerate the commercialisation of hydrogen technologies. With the creation of the FCH JTI – an outcome of the results of FP6 - at the start of FP7, the European Commission to a certain extent has handed over the initiative to the industry, and development in the FCH area is now to a larger degree than before left to the industry.

The development in the FCH area has, in general, been slower than hoped for. The evaluation results show that this is the case also for the FP6 and FP7 projects. The evaluation shows that the share of respondents that indicate that their project is aimed at improving their Technology Readiness Level (TRL, as a measure used to assess the maturity of evolving technologies during their development) is markedly higher for this area than the average for all energy research areas, but that the TRL did not increase as much as the average for all energy research projects. That is, the high hopes of improving a TRL were met, but to a lesser degree than is the case for the FP6/7 energy research projects in general. Very few participants in the FCH area expect their technology to be market ready within one year, and this is well below most other technology areas covered by this evaluation. This is in itself not surprising, as the FCH market is still building up and the infrastructure is still to a large extent missing. Furthermore, the share of respondents indicating that their projects have no concrete marketable outcome for their organisation has increased in FP7 compared to FP6.

It can be concluded that the impacts on society of the projects carried out in this area in FP6 and FP7 have been limited. This could be said to be particularly true for FP7 activities apart from the JTI initiative; these other FP7 research initiatives have not added very much to the JTI as they have been limited in scope. Many projects have proven successful from a technical point of view, but are still not ready for market. This, of course, is not the case only for the Fp6 and FP7 FCH projects, but it can be observed that the EC funding (that is, outside of the significant contribution the FCH JTI has made) has not significantly altered the situation; commercialization still depends on infrastructure availability. These technologies are still generally in an earlier stage, which means that the economic effects and the effects on CO2 reduction are largely missing

B.9 Energy Efficiency

This report is the mid-term evaluation of projects funded under FP6 and FP7 work programmes, in the area of energy efficiency.

It considers the challenges in the field of energy efficiency, reviews the policy means and details the specificities of the projects of both programmes. The evaluation is based on literature review, FP data analysis, a survey to FP project participants and a selection of case studies.

This report is organised as follows: a description of objectives, outputs and impacts of the projects, and an analysis of the effectiveness (matching of outcomes to programme objectives), relevance (matching of programme objectives to identified challenges) and efficiency (matching of outputs to inputs) of the programme. The added value for participants to take part in European-funded projects is also assessed, to find out what are the benefits for their organisations.

Overview of the projects

Energy efficiency is defined by the International Energy Agency as "a way of managing and restraining the growth in energy consumption[82]". Energy efficiency deals with buildings, appliances, transport, industry and end-use applications.

Energy research funded under FP6 had been supported by several thematic programmes and sub-priorities, the most important being the programme SUSTEDV. Under FP7, different programmes funded energy efficiency which is something specific to energy efficiency.

Energy efficiency's projects funded by FP6 and FP7 dealt with eco-buildings, polygeneration and cities/transport.

75 projects have been funded by the FP6 (2002-2006) and the FP7 (2007-2013). During 11 years, the EC invested €450m during this period for a total of €874m of research carried out.

Main findings

The perception of the interdependence between the technological challenges and the non-technological challenges related to the implementation of energy efficiency measures was rather weak at the beginning of FP6. This perception grown up during FP6 and become clearer in the definition of energy efficiency roadmaps for the preparation of the Energy efficient Buildings (EeB) Public Private Partnership (PPP) which focused on energy performance measurement, environmental issues, materials, ICT, etc. During the course of FP6 and FP7, the attention put on impacts measurement and potential market penetration of technologies and solutions progressively increased over time.

Two third of participants in the projects noticed that the projects did not engender patents. Instead, knowledge has been diffused in scientific publications and has been codified in specific leaflet, brochures and technical reports.

Energy efficiency has strongly benefited from the research and innovation projects which were funded by the FP. Research and innovation at the beginning of FP6 suffered from a fragmentation of actors and the projects have participated in the structuration of the actors.

Impacts of FP projects for the participants

For projects participants, there is a significant added value to take part to FP-funded projects. The amount available for the implementation of the project is very large, and consortia are often rather broad (in particular for the FP6 projects since it was how the programme was designed). Even the organisations that state that they would have carried out of the project even without the EC funding recognise that the FP allows to reach a European scale, and to team with partners that would have been outside of their usual scope. There is a high benefit for smaller players in terms of networking. The participation in FP project is regarded as increasing the capacity-building, credibility and track-records of smaller institutions.

Conclusion

The main conclusions of this evaluation are as follows:

- The programmes were well conceived to meet the challenge to increase energy efficiency. Over time, the European Commission set up a policy framework in

[82] http://www.iea.org/topics/energyefficiency/

order to address energy efficiency with research and innovation projects as well as with policy measures;

- The programmes supported projects likely to impact the economy and meet the set objectives of increasing energy efficiency;

However, the support was designed to end-up with outcomes supposed to be replicated. As far as polygeneration is concerned, this replication is highly questionable. For transport and buildings, a considerable amount of knowledge on practices, experiences, measures and results have been produced which are increasingly diffused across cities.

B.10 Carbon Capture and Storage and Clean Coal Technologies

This report is part of the mid-term evaluation of projects funded under FP6 and FP7 work programmes, and presents the analysis of activities in the area of carbon capture and storage (CCS) and clean coal technologies (CCT).

It considers the challenges in the field of energy and CO2 emission in the EU, reviews the policy means and details the specificities of the projects of both programmes. The evaluation is based on literature review, FP data analysis, a survey to FP project participants and a selection of case studies.

This report is organised as follows: a description of objectives, outputs and impacts of the projects, and an analysis of the effectiveness (matching of outcomes to programme objectives), relevance (matching of programme objectives to identified challenges) and efficiency (matching of outputs to inputs) of the programme. The added value for participants to take part in European-funded projects is also assessed, to find out what are the benefits for their organisations.

Main findings

The main findings of this evaluation are as follows:

- The programmes were well-conceived to meet the challenge to reduce CO2 emissions in a fossil fuel-based economy, although potentially ambitious on the timeline;
- The programmes supported projects likely to impact the economy and meet the set objectives of reducing the costs of CO2 capture;
- However, the support was designed in the context of CO2 prices around €30-40/tonne. When the Emissions trading system (ETS) was launched, the limit of the total number of emissions allowances was supposed to ensure they would keep a value. But, the price of one tonne of carbon has plummeted from €30 in 2007 to €4 today. With such levels, the financial support in favour of CCS was not adequate anymore and the economic operators had no interest to keep investing in CCS technologies and demonstration projects.

Evolution of EC policy focus during the 2000's

Under the FP6, a broad range of CO2 capture and storage technologies were reviewed and assessed. It allowed the identification and first demonstration of some technologies, which were further examined under in the following programming period. The FP7 built upon this "pilot phase" to focus on promising technologies and try to demonstrate their viability at a large-scale. However, it never proved possible to reach the objectives of reduction of the costs of CO2 capture.

With such a drop in the likely marketability of projects' results, the policy focus evolved as of the middle of the FP7 implementation period. This is reflected in the programming documents of the Horizon 2020 calls on energy. Despite a limited public acceptance - which might have been underestimated in the first years of FP support - efforts on storage are pursued. For carbon capture, however, a shift is visible: the focus is given on the uptake of low-carbon-technologies by industrial applications (other than power generation sector, which are not supported anymore). This implies that research goes back to laboratories, and large-scale demonstration projects are unlikely to be pursued, at least few of them with public funding.

Technological outcomes and sustainability

It is important to underline that the projects funded under the FPs generated a considerable amount of knowledge, and allowed bridging many technological gaps. First generation CO2 capture technologies, like amines, have been improved and the energy penalty has been reduced. Several next generation capture technologies have been investigated and improved such as membranes, chemical looping combustion and adsorbents. In addition, although the focus in both FPs has been on power generation industries (coal/gas) did not allow sufficient large-scale implementation, the knowledge generated and technologies developed may be beneficiary to other sectors: the progresses made are transferable to cement or steel and may be replicable in these sectors.

However, the original ambition of drastically cutting the costs of carbon capture could not be reached. The set objective was to reach cost of €15/tonne of CO2, compared to prices between €40-70 at the beginning of FP6. Pre-combustion capture seems to be the most promising technology, with improved sorbents that allowed prices to drop to €25-30/tonne, and CO2 capture rates close to 100%. Nevertheless, these amounts remained too high to be attractive enough at a commercial scale. In addition, the large-scale demonstration of projects at an intermediate scale between pilot and full industrial scale could not be implemented. The technology developments had taken longer than initially foreseen, and these large demonstrators also proved too costly, even with significant public funding.

These factors caused several industrial stakeholders to turn away from CCS and research to go back to laboratories.

Impacts on society

For civil society, impacts of the CCS-CCT FP-funded projects are not visible yet. The technologies could not be implemented further than at pilot scale. As regards storage of carbon, both on-shore and off-shore, knowledge has significantly increased but the legal and legislative aspects, related to risks implied, are not advanced enough. The societal barrier, together with the lack of adapted regulation, are currently the main hurdles to the development of storage sites in Europe.

Impacts of FP projects for the participants

For projects participants, there is a significant added value to take part to FP-funded projects. The amount available for the implementation of the project is very significant, and consortia are often rather broad. Even the organisations that state that they would have carried out of the project even without the EC funding recognise that the FP allows to reach a European scale, and to team with partners that would have been outside of their usual scope. For the smaller players, FPs are also a unique chance to work with sector leaders. There is a high benefit for them in terms of networking, but also for their image. The participation to FP project is regarded as increasing the capacity-building, credibility and track-records of smaller institutions. According to participants, in order to be successful, future public support should take place in the frame of international agreements, preventing industries from relocating to countries where there is no emissions' regulation. The funding mechanism shall also be more attractive to industrials in order to limit financial risks of large-scale demonstration projects: for participants, the reference is feed-in tariffs in the renewable energy sector.

B.11 Future Emerging Technologies / Materials

The Future Emerging Technologies (FET) and materials area is not dedicated to any specific technology. Rather, it is a programme for the financing of high risk/high reward ideas. The programme commenced in FP7 and to date has financed 32 projects. At the time of publication, few projects have completed their full remit and few have full disclosure of results. As such, this report should be considered an initial assessment.

The FET process was set up by the EC on "bottom up" principles, with no limitations in terms of technology; only guidelines on the type of ideas that would be considered eligible. The similarity of calls in the different years allows us to extract four principles to illustrate EC expectations:

- **Novelty**: the quest for breakthroughs and not simply incremental research;
- **High-risk**: a principle justifying the intervention of public funds.
- **Interdisciplinarity**: this is required to overcome the inherent limitations of academic research and to push for results oriented initiatives.
- **Purpose driven**: there was an explicit request to deal with advanced topics while aiming at concrete objectives. For this reason the participation of companies and especially SMEs was a high priority.

In terms of the level of funding, projects were relatively homogeneous, with budgets of around €3 million, with an average of 6 to 8 partners. The projects are significant and elaborate initiatives that maintain a manageable and flexible structure. This was essential as projects were set up to be able to adapt their progress with the findings. For example, during the first phase, there were studies to select the best materials for prototypes; then, according to the type of materials chosen, tasks were redistributed according to the partners' expertise.

In the document we provide some brief summaries of projects in order to demonstrate the different types of technologies developed. There are examples of Photovoltaic, Hydrogen, Waves, High Altitude Wind and Thermoacoustic technologies and projects.

The main observation from the programme is the quality of participation. From the first batch of projects (18 out of 32 of those completed or having passed the midterm review) there are a large number of publications and high level of participation in scientific events (both in absolute terms and per project). Also, 24 patents have been filed with an average of 1.3 patents and 38 publications per €10 million. The composition of consortiums shows that major European research centres were often active in several projects.

Industry participation was undertaken either via the research centres at large companies or through SMEs specialising in R&D. Even although the larger share of budget was on average allocated to research centres, we could notice that companies played a key role, as they were heavily involved in the final results. Also as some of the projects analysed have had immediate follow up, it was clear in these new initiatives that companies were increasingly involved as ideas moved closer to deployment. Another aspect of the importance of the programme has been the recognition, by both scientists and industry, that these types of ambitious projects cannot currently be funded at either national level or by the private sector. The role of the EC is thus essential in pushing high-risk innovation in Europe. The European dimension is necessary as it is extremely difficult, if not impossible, even for large countries, to find all the adequate skills and equipment for many projects.

The EC in Horizon 2020 will continue financing this type of initiatives with a larger budget. The new programme will finance the same type of projects with the difference that the calls will be open to all FET technologies not just Energy. The management of the calls has also been transferred to DG Connect.

The recommendations that we can give are sort of straightforward or to look at past projects to improve the selection process and to try to guarantee a follow up to the successful ones. What was clear is that on average it will take time before the Industry will be interested to start to directly finance the follow up of these projects and then it should be expected that they will require at least a second cycle supported by public funds.

B.12 Other Renewable Energies

This report examines the research and demonstrator projects under FP6 and FP7 in the area of 'other renewable energy sources'. The area other renewable energy sources encompasses three different subareas: ocean energy, hydro energy, and other activities such as knowledge building or coordination activities.

- Ocean energy can take several forms, with wave and tidal energy being the most common and the most mature technologies.
- Hydro energy refers to 'falling water'. Hydropower uses the kinetic energy and pressure freed by falling water (rivers, canals, streams and water networks). Water reservoirs serve as energy storage and make this form of energy very flexible.
- Other types of projects concern a variety of activities such as coordinating and connecting organisations, disseminating knowledge throughout Europe, as well as preparatory activities, such as conferences and events.

In total, there are 43 projects in the 'other renewable energy sources' area with an average of 10 partners per project. The overall budget going to these projects amounts to €109m. With an average duration of 36 months, projects in this area were ca. 6 months shorter than the average project across all areas.

For the following analysis, most emphasis will be put on the subareas of 'ocean energy' and 'other types of projects' and less on 'hydro energy'. There are two reason for this focus: one the one hand, there have only been five hydro project in total; on the other, the response rates to our survey and workshop have been rather low.

With this in mind, the following findings can be summarised:

- For the majority of respondents the FP6 and FP7 projects were satisfactory in the sense that the projects achieved their objectives.
- The scientific and technological impacts of the FP6 and FP7 projects can overall be considered to be positive.
- In sum, respondents perceive a positive impact through project participation on their TRL as well as on the European technology level in general.
- On the other hand, several commercial indicators such as turnover or profit do not reflect this observation.
- Overall, a large majority of respondents stated that they intend to continue working on the technology after the project finished.
- The large majority of projects would not have been carried out without FP funding, both in FP6 and FP7.
- FP6 and FP7 seem to support the establishment of a research and development community that aims at collaborating in their specific technological field.
- The programmes resulted in a number of improvements for the organisations involved as well as the EU in general.
- The FP6 and FP7 projects were considered of significant European added value.

A recommendation concerning ocean energy projects which can be generalised is that the European Commission should strengthen its competences to perform due diligence prior to providing funding to a company.

Appendix C TOP 50 organisations by number of participations in FP6 and FP7

Organisation name	Country	Participations
ECN	NL	77
FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V	DE	69
DANMARKS TEKNISKE UNIVERSITET	DK	57
COMMISSARIAT A L'ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	FR	56
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	FR	47
UNIVERSITAET STUTTGART	DE	45
NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK - TNO	NL	38
TEKNOLOGIAN TUTKIMUSKESKUS VTT	FI	37
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE	UK	35
DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV	DE	33
FUNDACION TECNALIA RESEARCH & INNOVATION	ES	33
RICERCA SUL SISTEMA ENERGETICO - RSE SPA	IT	31
ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	CH	28
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE	IT	26
FORSCHUNGSZENTRUM JUELICH GMBH	DE	25
KENTRO ANANEOSIMON PIGON KE EXIKONOMISIS ENERGEIAS (CENTRE FOR RENEWABLE ENERGY SOURCES AND SAVING)	EL	25
CONSIGLIO NAZIONALE DELLE RICERCHE	IT	24
THE UNIVERSITY OF MANCHESTER	UK	24
JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION	BE	23
CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS-CIEMAT	ES	23
SINTEF ENERGI AS	NO	23
EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZURICH	CH	22
IFP Energies nouvelles	FR	22
STIFTELSEN SINTEF	NO	22
NATIONAL TECHNICAL UNIVERSITY OF ATHENS	EL	21
TECHNISCHE UNIVERSITEIT DELFT	NL	21
KATHOLIEKE UNIVERSITEIT LEUVEN	BE	19
VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.	BE	19
Karlsruher Institut fuer Technologie	DE	19
CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS	EL	19
AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS	ES	19
ELECTRICITE DE FRANCE S.A.	FR	19
NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU	NO	19
FUNDACION CENER-CIEMAT	ES	18
KEMA NEDERLAND BV	NL	18
AIT Austrian Institute of Technology GmbH	AT	16
POLITECNICO DI TORINO	IT	15
CHALMERS TEKNISKA HOEGSKOLA AB	SE	15
KUNGLIGA TEKNISKA HOEGSKOLAN	SE	15
VATTENFALL RESEARCH AND DEVELOPMENT AB	SE	15
BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES	FR	14
TECHNISCHE UNIVERSITAET WIEN	AT	13
INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM VZW	BE	13
RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN	DE	13
LUNDS UNIVERSITET	SE	13
EIDGENOESSISCHE MATERIALPRUEFUNGS- UND FORSCHUNGSANSTALT	CH	12
AALBORG UNIVERSITET	DK	12
UNIVERSIDAD PONTIFICIA COMILLAS	ES	12
ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS - ARMINES	FR	12
L'AIR LIQUIDE S.A	FR	12

Appendix D Examples of successful projects by area

In this appendix, readers will find short presentations of successful projects.

D.1 Heating and Cooling

D.1.1 Bionicol

The aim of the BIONICOL project was to develop a solar collector with a new solar absorber featuring a bionic channel structure in order to obtain a uniform flow distribution, a low pressure drop in the absorber as well as a high thermal efficiency. The construction, production and design of these absorbers display major differences compared to existing products. In the course of the project major obstacles such as corrosions problems were overcome and relevant know-how e.g. regarding the roll-bond production method was created. As a direct consequence of the project, these high-tech absorbers can be mass produced now. In 2013, contracts were signed to deliver bionic absorbers to a European company that will use them in their solar collectors. Solar collectors with this new technology will soon be available on the European market.

D.1.2 ULTRALOWDUST

The ULTRALOWDUST project focused on the development, improvement and field testing of technologies capable of significantly reducing the carbon monoxide, organic gaseous carbon and particulate matter emissions from small-scale biomass combustion. In the course of the project it was possible to have extensive field tests of the technologies, which enabled the participants to identify weak points and cost reduction potentials in their systems. As a consequence, the systems' reliability was increased while production costs were reduced significantly. For one technology it was possible to reduce the system costs by 50% with additional cost reduction potentials identified.

D.2 Energy efficiency

D.2.1 BUILD HEALTH

BUILD HEALTH was a FP6 funded project that focused on energy efficiency in hospitals. The main objective of the project was to develop energy design strategies before the construction of buildings and monitor the performance of the buildings, in order to prove that energy design strategy could result in important energy savings. The project involved 3 hospitals: one in the UK, one in Italy and one in Moldova.

For the coordinator, the project helped to gain visibility in the market. After the project, the coordinator was contacted to be part of consortium participating in hospital buildings. The project (couple with the HOSPITALS project) helped the coordinator to secure a high-profile position at the national and EU level.

D.2.2 ENERCOM

Started in 2008, the ENERCOM project has been developing high-efficient polygeneration of electricity, heat, solid fuels and fertilisers from sewage sludge and greenery waste mixed to biomass residues, thereby offering a new and safe environmentally friendly and cost-effective path for the disposal of sewage sludge, maximising energy output, greenhouse gas reduction, cost-effectiveness and new chances for SME.

The exploitation plan includes the creation of two SMEs for heat delivery and worldwide planning and marketing of similar plants. The company SYNERCO is the result of a joint venture between partners Bisanz Anlagenbau GmbH, LEE SARL and Soil-Concept SA. SYNERCO provides the know-how and expertise in the areas of fluidised bed combustion technology pyrolysis/thermolysis, gasification, anaerobic digestion and composting. The creation of another company is expected until the end of the project.

The participants of the ERNERCOM project have applied three patents' application in the domain of biomass, wastewater and new energies.

D.2.3 BRITA in PUBs

BRITA in PUBs was a FP6 project that started in May 2004 and finished in April 2008. The EC contribution for this project was €3.5m for an overall budget of €7.7m. The main budget was for the demonstration/construction.

The project had three pillars:

- The first pillar was the actual retrofit of eight demonstration public buildings. The idea was to work on different types of buildings in order to end up with a whole set of recommendations to enable the highest possible diffusion.
- The second pillar consisted of socio-economic research. Each demonstration buildings had its own socio-economic research report focused on barriers and needs of users/public.
- The third pillar corresponded to dissemination.

The project has led the City of Stuttgart to define higher requirements in energy efficiency, which implies in turn an actual reduction of energy consumption of public buildings. The project has also given examples to show how public buildings can be more efficient in their energy consumption. For instance, SINTEF was regularly invited to present the results of the project in different countries. The head of the school in Asker was also invited to present the school at a conference in Edinburgh, arranged by the organisation Children in Scotland.

D.2.4 SESAC

The SESAC project aimed at enhancing the role of sustainable local energy management; promoting energy- and cost efficient eco-buildings; increasing the share and integration of a renewable energy supply locally; ensuring widespread dissemination and training, also using local case studies and guidelines; exchanging experiences and expertise, with the transfer of know-how through workshops and study tours – among others.

Outputs of the project are mainly the multiple demonstration projects carried out by the partners in Växjö, Grenoble and Delft. Overall, the three main cities performed 21 case studies. The main results of the projects were:

- The partners performed inventories of existing energy management system elements to improve the cities' energy policies;
- The partners supported the building of a number of new infrastructures, with energy ratios of 20-40% below current and applicable national indices and standards;
- The project helped to carry out renewable energy sources conversion in 370 dwellings and 1 school;
- The project led to the installation of 402.5 kilowatt (kW) distributed PV, 880 kW distributed combined heat and power (CHP) and 5 kW wind energy.

The project led to the production of 4,300 kW RES-absorption cooling, 6912 kW district heating and 820 kW polygeneration from organic.

At the policy level, the results of the project were used by the technical services of each local council to start a dialogue with elected officials on the possibility to set ambitious targets for energy production and energy efficiency. The methodology for measuring energy efficiency was also used by local policymakers. At the EU level, the two European networks ECLEI and Energy Cities disseminated the results to their members through newsletters and other communications. For the three partner cities, the project was also a way to gain visibility at the national level and further develop efficient energy management.

D.3 Bioenergy

D.3.1 The Biolyve project

The main breakthrough made in the project was the viscosity reduction - by using improved enzymes - which made that the biomass pulp was easier to handle and also the transportation and mixing was easier and took less energy. Another important result was the higher yield of the end product. The company patented the finding. The pre-treatment is only with water and physical treatment through steam explosion. However, the most important result of the project is the building of the industrial-scale second-generation bioethanol production plant with an output of 40,000 tons ethanol per year. The biorefinery was opened in October 2013 and is situated in Crescentino, Italy. This 150M€ capital investment is owned by Beta Renewables, a joint venture between Biochemtex, Mossi Ghisolfi Group engineering company, American fund TPG (Texas Pacific Group), and Novozymes. The facility has a production capacity of 75 million liters a year of second-generation bioethanol intended for the European market.

D.4 Carbon Capture and Storage & Clean Coal Technologies

D.4.1 ENCAP

The project was a FP6 project that started in 2004 and lasted five years (plus a one-year extension). ENCAP started with a budget of €22.1m and an EC contribution of €10.7m. It involved 24 organisations.

The objective of the project was to develop new combustion CO2-capture technologies and processes for power generation based on fossil fuels. A first step aimed at identifying the most-suited pre-combustion technology out of four technologies: OxyFuel, Chemical Looping, High-Temperature Oxygen production technologies and technologies found among the Novel Pre-Combustion capture concepts. A second step had the objective to test the technology at a large scale in order to end up with recommendations for the set-up of a large-scale demonstration power plant.

During the project, several novel capture concepts were assessed and classified. The project focused initially on different technologies. Even if the project enabled progress on pre-combustion technologies during the first phase, ENCAP focused for the second phase only on OxyFuel combustion and post-combustion. The results obtained on pre-combustion were actually further investigated in other projects (in particular in FP7 DECARBIT project)

The most outstanding output of the project is related to OxyFuel combustion. A low combustion turbine was produced which was tested during the project. This turbine was the start for further research activities (some of them carried out after this project).

ENCAP reviewed a wide-range of technologies and paved the way for further research on some of them in follow-up FP projects.

D.4.2 FLEXI BURN CFB

FLEXI BURN CFB project under the FP7 aimed to develop and demonstrate a power plant concept based on the Circulating Fluidized Bed (CFB) technology combined with Carbon Capture and Storage (CCS). This project combined the CFB's intrinsic advantages (fuel flexibility and low emissions) with oxygen-firing for carbon capture and storage (CCS). The EC contributed for 6,41m€ over 10,85 m€ total budget.

The overall result of this project was a power plant design based on the FLEXI BURN CFB concept, ready for demonstration of high efficiency large utility-scale power plant with CCS burning a large variety of indigenous and imported coals from lignite to anthracite as well as co-firing biomass. Demonstration tests with different coals at a first-of-its-kind 30 MWth air-oxygen-flexible CFB pilot facility and validation tests at the world's first and largest supercritical once through CFB (460 MWe Lagisza in Poland) were essential elements in the project to ensure the efficient, reliable and safe design of the commercial scale FLEXI BURN power plant.

New simulation tools were developed to support the Flexi-Burn CFB and the concept was successfully demonstrated at 30MWth scale.

The partners having being part of the project considers themselves as world leaders in Oxy-fuel technology. Some embarked into another project to further develop the technology. Nevertheless, no significant economic breakthroughs were obtained, and the new technology did not reach public acceptance.

D.4.3 CaOling

The CaOling project was a FP7 project with an EC contribution of €3,73 m. It was aimed at the scaling-up the post combustion carbonate looping systems, which was to reduce the cost of carbon capture, one of the most promising concepts for CO2 capture from coal power plants. In this process, the efficiency penalty for the capture of CO2 is drastically reduced because it is possible to generate additional power from the various high-temperature sources in the system unlike a wet chemical absorption process.

This project focused on the experimental pilot testing and scaling up of the process at scales in the 1 MW range. A 1MW carbonate-looping pilot was to be built in the Hunosa 50 MWe CFB (circulating fluidized bed) coal power plant of "La Pereda", using a side stream of flue gases of the commercial plant. This was the largest pilot facility of this type in the world and was expected to enter operation in the summer of 2011. The research programme at the pilot included research activities at lab-scale and fundamental knowledge on sorbent properties.

While the CaOling project demonstrated a proof of concept of post-combustion Ca-looping, CO2 capture efficiencies over 90% achievable and SO2 capture in the CFB carbonator over 95%, this very technology success depends on the success of all CCS technologies in the world. It is assumed by consortium partners that before reaching the commercial stage, there is a need for 2 more steps to demonstrate the technology at full scale, notably at the size of 20-30 MW. However, as of today, the post-combustion carbonates looping systems are not yet interesting at a commercial point of view.

D.4.4 EEPR

The European Energy Programme for Recovery (EEPR) was set up in 2009 to address both the economic crisis and support energy policy objectives. €4billion were allocated to mature projects in 3 fields: Electricity infrastructure, Off-shore wind energy and Carbon capture and storage. CCS received €1bn on six projects.

D.4.5 NER300

NER300 is a financing instrument managed jointly by the European Commission, European Investment Bank and Member States aimed at supporting the demonstration of environmentally safe CCS and innovation renewable energy technologies. It is funded from the sale of 300 million emission allowances from the new entrants' reserve. Funding is paid retrospectively on the basis of energy generated over a five-year period. No CCS demonstration projects have qualified for funding under the first call of this programme in 2012.

D.4.6 DECARBIT

DECARBIT was a large scale-integrating project under FP7. It started in 2008 and lasted four years. It had a budget of €15.5m. 16 core partners from 8 countries constituted the consortium in addition to an industrial contact group of 5 large energy companies in order to ensure industrial interest and involvement from technology end users.

The project focus was to pursue the search for improved and new pre-combustion technologies in order to reach the cost target of €15 per tonne of CO2 captured. The aim of DECARBIT was to reduce the energy needed for the separation of CO2 and oxygen in pre-combustion power plants or similar industrial processes.

The project demonstrated that the micro-porous membranes were not promising. But research on the dual-phase membranes was carried out by SINTEF and enabled significant progress.

The impact of the project is still limited, since pre-combustion technologies are not operational nowadays due to the energy needed for the capture of CO2 and the additional cost that this consumption implies. Interviewed participants underlined the fact that would not have implemented the project without FP support and would not be able to pursue it without public funding.

D.4.7 CO2 ReMoVe

The CO2 ReMoVe project was a FP6 six-years project of €15m, about 8 of which was granted by the Commission. CO2 ReMoVe project aimed to prove the short and long term reliability of geological storage of CO2, and to undertake the research and development necessary to establish scientifically based standards for monitoring and verifying future CCS operations. The main achievements were considered to be in the new monitoring technology for observation CO2 leakage and quantification of CO2 plumbs in the reservoir (risk assessment).

The project developed 3 patented performance assessment tools (Quintessa, TNO and BRGM) and about 12 monitoring methods and tools (BGR, BGS, OGS, SSR, BRGM) and several hundred publications were produced.

The project developed activities on seven active injection operation sites. Four of them were the largest demonstrations of CO2 injection and storage in the world: Sleipner (Norway), In Salah (Algeria), Snøhvit (Norway) and Weyburn (Canada). The three other sites (Ketzin in Germany, K12-B in the Netherlands offshore, Kaniow in Poland) provided an adjunct to the large-scale industrial sites, as they were ideal for monitoring CO2 behaviour in, and close to, the borehole environment and for testing down-hole and surface tools without interrupting industrial operations.

The development of performance assessment and monitoring methodologies led to the establishment of safety and security guidelines for CO2 underground storage operations that were used for the EU CO2 storage directive. Performance Assessment tools as well as tools for risks identification of CO2 storage have already been deployed to commercial scale projects. The large developed data sets are available for the research community to do future research.

In onshore areas, there is still a high level of public resistance against CO2 storage, notably in the Netherland and Germany. Even though the attention for CCS is diminishing now in Europe, The project coordinator TNO still considers this field as important and intends to work in implementing the new developed technology. A €100m project is foreseen and funds are to be collected among partners and public funds. TNO also intends to apply for funding under HORIZON 2020.

D.4.8 CESAR

The project CESAR was a three-years project (Feb. 2008 – April 2011) that aimed to reduce the cost of post-combustion CO2-capture technology down to €15/tonne Co2. The project builds on the research outcomes of CASTOR (FP6 2004-2008), which aimed at developing and validating innovative technologies to capture CO2 at post-combustion stage and store it. CESAR received €3.99 million from the European Commission, and consortium partners contributed €2.70 million. The 22 partners focused on the following activities: research on the most cost effective solvents for post-combustion CO2 capture; modelling of the CO2-capture processes based on the property of the solvents and testing the new solution on a pilot power plant.

The partners of the project analysed several solvents and tested two on a pilot power plant. The use of most performing solvent integrated into a complex system led to a reduction of cost of 20% (around €35) in comparison with the baseline solvent: still significantly above the set objective of €15/tonne of CO2.

Even though the results of the project were promising, the support from policy-makers and policies for post-combustion CCS dramatically changed by the beginning of the 2010's and a significant number of private projects that started based on the results of the CESAR projects had to be abandoned.

The results of the project have been used in another FP7 project (OCTAVIUS) with some of the same partners. This project aims to demonstrate integrated concepts for zero emission power plants covering all the components needed for power generation as well as CO2 capture and compression.

D.5 Concentrated Solar Power

D.5.1 ECOSTAR

The major objectives of the ECOSTAR co-ordination action were to:

- identify the European innovation potential with the highest impact on CSP cost reduction,
- focus the European research activities and the national research programmes of the partners involved on common goals and priorities, and
- widen its basis of industrial and research excellence, capable to solve the specific multidisciplinary CSP problems.

High level commitment of six large research centres from Germany (DLR), Israel (WIS), France (CNRS-IMP), Spain (CIEMAT), Switzerland (ETH) and Russia (IVTAN) each with long-year experience in the subject and most of them conducting a significant programme on concentrating solar technologies and operating their own facilities, combined their national expertise to achieve these goals. This group had teamed up with the international association of power and heat generation (VGB PowerTech), which includes many of the European players in the power sector, to ensure through an independent industry assessment that the identified innovation pathways are feasible from an industry perspective, to disseminate them to the power sector, and to support the identification of further expertise needed.

For the seven technologies (trough using oil, trough with direct steam generation, CRS[83] Salt, CRS steam, CRS atmospheric air, CRS hybrid gas turbine and Dish concentrators) the state-of-the-art was reviewed, research priorities were identified and proposals of how to achieve the goals of the roadmap were developed.

This joint roadmap was adopted by the EU. Its proposed research areas are the basis of present and future Research Framework Programmes of the EU in this area. Indeed, many of the topics are addressed in the individual projects being carried out under FP7. The research addressed in this roadmap was partly performed during FP7 and, in total the state of the industry was shifted from an early uncommercial level (TRL3-TRL4 level) to an early commercial level (TRL 7 to TRL 8 levels) for all technologies except the Stirling, which still lags behind (TRL 4-5).

D.5.2 SOLHYCO

The project aimed at adapting a small commercial standard turbine of 100 kW to solar-hybrid operation. For this purpose, the turbine had to be adapted to biofuel use on the one hand and to solar operation (adapted to a special receiver) on the other hand.

The development of some key components such as the solar receiver with profiled multi-layer tubes and a heat rejection system was successfully performed. During the experimental phase experience was gained which resulted in further modifications to improve turbine efficiency.

Besides the technical demonstration of the first solar hybrid micro turbine – temporarily powered by pure solar radiation – able to operate at 100% renewable energy (combination of solar radiation and biofuels), further important aspects of the project included cost estimates of a commercial turbine and the possible market size in various target regions, namely, Mediterranean countries with special focus on Algeria as well as Brazil and Mexico.

D.5.3 E2PHEST2US

The project E2PHEST2US (Enhanced Energy Production of Heat and Electricity by a combined Solar Thermionic-Thermoelectric Unit System) aimed at designing and realizing innovative and scalable components for solar concentrating systems that generate both electricity and heat and work efficiently at high temperatures (800-1000°C). The proposed concept included the design, realization and testing of several new component technologies. A high-temperature receiver was developed providing the heat input to the converter unit. A conversion module based on a new concept was developed for electrical and thermal energy production based on thermionic and thermoelectric direct converters, thermally combined in series to increase the efficiency, which at project start was estimated at 35%. Detailed calculations during the project resulted in 30% theoretical efficiency. A heat recovery system was designed to collect waste heat (standard efficiency of 65%) and provide it as additional energy product (co-generation). Innovative hybrid wirings for transporting fluid and electricity were designed, realized and tested. The benefit associated to a single hybrid cable able to carry both relatively high-temperature fluids and electricity, was analysed and demonstrated (e.g. the simple handling and reduced space need). A laboratory scale demonstrator in the Watt range was successfully tested with radiation from a solar simulator as a proof of the theoretical concept.

A small-scale prototype solar system was realized, tested under ambient solar conditions and evaluated with respect to the real impact of the new components. This

[83] CRS = Central Receiver System

was the first realization of a new conversion concept, which was successfully tested during project duration. The measured thermal-to-electrical efficiency was 6%. However, several improvements were already realized during the test phase, which might increase the efficiency by a factor of two to three. Various patents were filed. Presently, the core partners prepare a follow-up project with the goal to construct and operate a first commercial prototype plant.

The main impacts of the E2PHEST2US project are:

- Direct conversion of solar power to electrical energy exploiting thermionic and thermoelectric processes,
- Design and preparation of highly engineered solar radiation absorbing thermionic and thermoelectric materials,
- Electrical conversion efficiency of the module is potentially higher than standard PV semiconductor modules,
- High working temperature operations with the possibility to provide also residual thermal energy as an output.

D.6 Fuel Cell and Hydrogen

D.6.1 GenHyPEM

The main objective of the FP6 project GenHyPEM was to develop an efficient PEM water electrolyser for direct storage of gases in pressurized vessels. All basic research efforts were devoted to the optimization of already existing electrolysers of industrial size, in order to facilitate the industrial introduction. The final outcome was the development of low-cost fabrication techniques for all components and the design, construction and testing of a prototype electrolyser:

- Significant results in the development of cheap non-noble electrocatalysts, which can be used in place of conventional platinum-family materials, thus enabling significant cost reductions. The electrocatalysts were identified and stable performances obtained during operation at high (1 A cm-2) current density, paving the way to substantial cost reductions.
- Prototype electrolysers producing from 0.1 to 5 Nm3 H2/h were successfully designed and constructed. An automated GenHy®100 PEM water electrolyser can be used for laboratory applications, and an automated GenHy®5000 unit can be operated between 600 and 1000 mAcm-2 and can deliver gases up to 6 bar. The electrolysis unit is remotely controlled from a personal computer and dedicated software.
- Simple electrolysers specifically designed for educational and exhibition purposes. Prototype systems have been exhibited in various international conferences.
- GenHyPEM interacted with EU H2/FC Technology Platform, and followed up the developments of the platform. The project also provided and exchanged information in view of steering the work and aligning the deliverables with the priorities and targets of the platform to the extent possible.

D.6.2 NessHY

NessHy was an FP6 project dedicated to medium to long term research and development in the field of hydrogen storage in solid materials. NessHy was the first European attempt to adopt a holistic multidisciplinary approach, addressing key issues related to hydrogen storage in solids, such as new materials, and novel analytical and characterisation tools.

The project produced a vast amount of publications: About 250 refereed journal articles, 4 book chapters, 185 conference presentations, 115 presentations in workshops, seminars and summer schools, 30 invited lectures, 15 presentations in industry forums, and 2 press releases. Seven PhD dissertations were produced within the project.

Eight patent applications have been filed by specific patterns on issues related to material synthesis, characterization, up-scaling and storage system (tank) development.

D.6.3 HySYS

The objective of the FP6 HySYS project was the research on low-cost components for fuel cell systems and electric drive systems. The focus was on components, which have a high potential of significant cost reduction by decreasing complexity and choosing innovative approaches to support a future mass production.

The improved system components and sub-systems could be used as a basis for future fuel cell and ICE-vehicles. Systems are being deployed in the HyCOM initiative, which aims to develop hydrogen communities and stimulate growth in hydrogen technology markets, as well as the Lighthouse projects where new technologies can be assessed and demonstrated under pseudo-commercial conditions. Research is being continued in EU projects HiCEPS and FUEREX, amongst others.

As a result of the project, Daimler is in discussions with some partners for future common projects, although not in the exact same area as HySYS. Cooperation with many partners is considered an advantage for understanding needs and future trends of partners involved in the development and production chain.

D.6.4 StorHy

The FP6 project StorHy focused on automobile hydrogen storage, with the aim of developing robust, safe and efficient on-board vehicle hydrogen storage systems suitable for use in hydrogen-fuelled fuel cell or internal combustion engine vehicles.

The project background was the need for new technologies, which satisfy all of the hydrogen storage attributes sought by manufacturers and end users. Hydrogen storage is a key enabling technology for the extensive use of hydrogen as an energy carrier. At the start of the project, none of the current technologies satisfied all of the hydrogen storage attributes sought by manufacturers and end users. Therefore, the state-of-the-art called for efforts focusing on improving existing commercial technologies, compressed gas and liquid hydrogen, and exploring the higher risk technologies involving advanced solid materials. The main objective of StorHy was to provide economically and environmentally attractive solutions for three storage options: Storage as gas under high pressure (up to 700 bar); Solid storage; Storage as liquid at very low, cryogenic, temperatures (-253°C).

The project included sub-projects for three different technologies for hydrogen storage: improving existing commercial technologies for compressed gas and liquid hydrogen, and exploring the higher risk technologies involving solid materials. There were also sub-projects for dissemination activities, safety aspects and evaluation. Solutions were aimed at transport applications and reinforcing the competitiveness of the European car industry.

There have been breakthroughs beyond StorHy targets in terms of physics, safety and cost constraints. StorHy is deemed to have paved the way for market entry of both liquid and compression storage, which are ready for small series development. Consortium members and other industry have shown interest in the new generation of cryogenic storage.

D.6.5 METSOFC

The objectives of the FP6 project METSOFC were to develop the next generation stack technology based on metal-supported cells to improve robustness, cost efficiency and functionality, as well as to reach a robustness of SOFC stacks which fulfils the requirements defined by the transportation sector. In general, the manufacturing processes of the metal supported fuel cell components are still in the development stage and have not yet had any large impact. Nevertheless, METSOFC has shown the potential of the metal supported SOFC in future SOFC products.

The project had not been possible without EC funding. With continued work in future projects, the impact in society is expected to be seen in a faster and solid opening of the market of SOFC systems for many applications, such as micro combined heat and power in single houses, distributed generation of power and heat in apartment houses, hospitals, banks and office buildings, and APUs for the transport sector (trucks and ships). This will result in much more efficient and clean means of utilizing fuel resources for the production of electricity and heat. Successful integration of SOFCs on the market would thus bring EU one step closer to achieving the targets for 2020.

These potentially more robust, reliable (and cheaper) SOFC systems will create important high-tech, clean-tech jobs in Europe with sales on the global market. As the evolution of the SOFC technology is moving from pilot and demonstration into commercialization and mass production the cost and availability of materials will dominate cell and stack production. Due to the significant lower cost of iron and chromium used in ferritic stainless steel, compared to the cost of nickel and zirconia used in Ni/YSZ anode-supports cermets, the METSOFC concept offers some promising economic advantages.

D.7 Other Renewable energy sources

D.7.1 WAVESTAR

The WAVESTAR is a system of floats that transform the mechanical energy of waves into electricity in a hydraulic system connected to a power generator. The objective of the WAVESTAR project was to design, construct, install, optimize and document the operation of a 500 kW (scale 1:2) wave energy converter in the North Sea. During the project the plans were adapted to install a test section of a 600 kW system with 4 instead of 20 floats; the installed capacity of the test section was 110 kW. In order to protect the system, the floats are lifted out of the water when the waves exceed a specified height.

Prior to the WAVESTAR project, the technology was developed in a scale 1:40 model with more than 50 different model tests carried out in 2004, and in a scale 1:10 machine launched for sea test in the fjord Nissum Bredning, Denmark, in January 2006.

Within the WAVESTAR project, the test section of a 600 kW Wave Star machine was installed at Hanstholm, Denmark, in 2009, and connected to the grid in 2010. Until May 2013 electricity was produced and delivered to the grid. The efficiency of the system was significantly improved.

The Wave Star machine will be extended and updated with a new power take-off system, and will be reinstalled in 2015. Hybrid systems in combination with off-shore wind are planned.

D.7.2 SHAPES

The SHAPES project was developed with an aim to facilitate and strengthen the co-operation between EU Small hydro power Research and Market actors. The consortium was based on connections between very strong partners who already collaborated before and had the chance through SHAPES to fully develop the potential of previous synergies. One of the main outputs of the project was the "Guide on How to Develop a Small Hydropower Plant", published by the coordinating organisation, the European Small Hydropower Association (ESHA). The most evident impact of this study was a successful translation of the developed concepts into the policy level in some countries and formation of good evidence-based cases for developing legislation on renewable energy. Furthermore, the communities outside Europe, especially in Africa and South America, had been extremely interested in these developments, too. Another direct output of the project, the Inventory of Research Bodies active in SHP, is still being used on a regular basis for a number of purposes such as data collection and the development of new partnerships.

The main impact of the project was widely recognised in terms of knowledge sharing and information dissemination. It is remarkable to conclude that 50% of the visits and downloads from the site are done by parties outside Europe, mainly from South-east Asia, America and Africa.

D.8 Photo Voltaics

D.8.1 FullSpectrum

The FullSpectrum project (FP6 project# 502620) included participants from manufacturing to fundamental research that performed R&D towards a broad selection of distinct PV technologies. The collaboration was very successful and led to world-record PV efficiency, publications, patents, spin-offs and follow-up projects. The project also led to an FP follow up and the project's design has been used as an example throughout the world, including countries as the USA Japan.

The following world record efficiencies have been achieved:

- concentrator GaAs cell (28.6 % @293) by FhG- ISE
- dual-junction cell (32.6 %@500-1000) by IES-UPM
- triple-junction cell at high concentration (37.6 %@1700) by FhG-ISE
- fuel-fired TPV system (3.96%) by PSI
- luminescent solar concentrator (7.1%) by ECN

Other achievements were:

- The principles of operation of the IBSC have been experimentally demonstrated using QD prototypes (IES-UPM, UG) and a bulk IB material based on a transition-metal-doped sulphide has been synthesized (CSIC, IES-UPM).
- The first hybrid solar/fuel-fired TPV system has been built.

Industrial products developed:

- triple-junction cells with efficiencies ~35% (AZUR)
- compact high concentration modules (Isofoton)
- concentrator characterization tool for mass production (IES-UPM)

D.8.2 UPPSOL

The UPP-SOL project (FP6 Project# 38386) pursued the development of urban polygeneration photovoltaic devices. Curved mirrors focus a concentrated beam of sunlight onto an efficient and small multi-junction cell. The heat generated at the module is higher than in other concentrated PV (CPV) applications and allows for application in absorption cooling, desalination and industrial processes. The concept reduces material consumption and costs and can capture over 64% of incident energy.

Two different working demonstration models were developed but have limited uptake nowadays because the technology is not competitive with conventional PV, largely due to the price drop of this technology.

D.8.3 Crystal Clear

CrystalClear (FP6, project# 502583) was a comprehensive technology development and demonstration project that focused on crystalline silicon PV panels. Sub projects ranged from feed stock input to life cycle analysis. Crystal Clear has delivered many results that last until today: Knowledge about Si impurity tolerance for PV Cells, new methods of growing and processing larger (+130%), Si ingots and world records in efficiencies for cells (16% at 120 μm and 16.4% at 160 μm thickness). An novel method of applying MWT technology was also developed by using a new production process, yielding a cell efficiency of 15.9%.

D.8.4 FLEXCELLENCE

FLEXCELLENCE was an FP6 research project (2008-2010) that contributed to the development of a mode of production in Photovoltaic Energy based on silicon-based thin-film roll-to-roll technology. The project had several successful knowledge outputs and led directly to a new FP7 project. Unfortunately, direct economic implementation results were limited due to bankruptcy of the main industrial partners. Key technological results in interconnection processes are now taken further by a participating knowledge institute in non-silicon technologies such as CIGS and organic PV.

D.8.5 MolyCell

The Molycell project focused on demonstrating the feasibility of PV devices with organic- and dye-sensitised components, and hybrids thereof. The project had a demonstrable effect on the technology readiness levels of several factors in organic PV (OPV). It achieved its objectives, most milestones and led to follow-up projects, a European OPV roadmap, industrial interest, publications and a patent. The most important result of Molycell is said to be the inception and organisation of a European community around OPV.

D.8.6 OrgaPVNet

OrgaPVNet was a coordination action that brought stakeholders in organic PV (OPV) throughout Europe, from fundamental research to chemical companies, together. The coordination action has produced a roadmap that received significant attention and led to successful FP proposals for further research on OPV related topics. It has had a structuring and organising effect on stakeholders involved in OPV in Europe and has also brought about a cultural change for OPV, that made research more application oriented. This has aided in positioning OPV as the preferred technology for building integration efforts.

D.9 Smart Grids

D.9.1 Super 3C

The Super Coated Conductor Cable (Super 3C) project is an example of how European research may support the development of new technologies and products. Super 3C was the first project in Europe to test the feasibility and functioning of a low-loss High Temperature Superconducting (HTS) energy cable using Coated Conductor (CC) tapes. The project oversaw the complete cable design process, the manufacturing of the components and final testing of 30-meter cable system. The consortium leader obtained a patent for the product delivered and so did one of the project partners for the CC tape. The project lasted for a period of four years, from 2004 till 2008 and saw the participation of leading research structures and manufacturing industry.

D.9.2 NIGHT WIND

The project NIGHT WIND demonstrated the use of a refrigerated warehouse as a giant battery for storing wind energy. The objective of the project was to store electricity produced during night-time by windmills, releasing this energy again during peak electricity demand hours in daytime. The project created a useful process and service to thermally store night energy from renewable sources thereby reducing the running costs for cold chain operators.

D.9.3 INTEGRAL

The project INTEGRAL created the baseline version for commercialisation of the software system "PowerMatcher Agent core 3.0", which allows devices and appliances to communicate and negotiate over the internet as a Virtual Power Plant (VPP). Hence network devices are able to optimise their performance on the basis of energy consumption and production. The tool operability was tested throughout at the "Powermatching City" pilot in Hoogkerk a small village in the Netherlands.

D.9.4 RELIANCE

The project RELIANCE provided an in-depth analysis of the knowledge gap in terms of RTD requirements in the transmission system. This analysis was complemented by four possible scenarios for energy demand in Europe and for each scenario, detailed project roadmaps are prepared. A detailed RTD roadmap focussing on the network system, detailing 128 projects, of which 76 considered to be of high strategic importance for a total budget of 2000 M €. Many of the projects identified were carried out by ENTSO-E.

D.9.5 MICROGRIDS

The scientific and technical work carried out within the project MICROGRIDS led to the development of new hardware prototypes, models, algorithms and processes. At least one organisation was granted a patent. All deliverables are available for external dissemination via the project website. A book on the subject, edited by the coordinator was released in 2014. A very important output from the project consisted in the large numbers of data collected. This made it possible to actually quantify benefits with this method, compared to strictly qualitative and theoretical measurements that were done before.

D.9.6 IRED

The project IRED (Integration of Renewable Energy Sources and Distributed Generation into the European Electricity Grid) is a good example of the impact of the FP6 programme in terms of strengthening cooperation and coordinate research activities at the European level. IRED was a large European Cluster of FP5 and FP6 projects funded in the area of integration of Distributed Energy Resources (DER) and management of the electricity grid. The main objective of the project was to provide stakeholders with a platform to promote knowledge-sharing and good practices by improving links between relevant research institutes. Therefore, the main outcomes of the project are not measurable in terms of concrete outputs but rather on its success to bring stakeholders together. Project stakeholders, all participating to different projects, contributed by identifying achievements and shortcomings of existing projects and activities, providing concrete suggestions for priority research areas. The inputs provided by IRED participants were partly reflected in the ETP vision. Participants have shown great enthusiasm for the project, which resulted in the better pooling of resources and expertise and enabled the undertaking of more substantial and more rewarding research initiatives.

D.9.7 SUSPLAN

The project SUSPLAN "Development of regional and Pan-European guidelines for more efficient integration of renewable energy into future infrastructures" main objective was to deliver a set of recommendations for an efficient integration of Renewable Energy Sources (RES) RES into network infrastructures. The main concrete outputs of the project are the datasets developed, the results of the analysis and the policy recommendations. However, the project fostered collaboration among participants both at the national and European level. Most participants pursued further research in the area of energy networks made use of the project results in similar EU projects.

For instance, the results of SUSPLAN fed directly into the work of the European projects TWENTIES, E-HIGHWAYS through the project coordinator and other participants also involved in these projects. The project GRIDTECH, financed through Intelligent Energy Europe (IEE), also made use of SUSPLAN. The results of the regional report on Outer Hebrids became an important reference tool for local policy-makers. Some of the data and results from SUSPLAN were subsequently used in the HIGHPACT, a national project on deployment of renewable energy in Scotland.

D.9.8 ADDRESS

The project "Active Distribution networks with full integration of Demand and distributed energy RESourceS" (ADDRESS), was a large-scale Integrated Project financed under the FP7 framework programme. The project was developed also thanks to the smart grid technology platform and its main objective was to develop innovative technical and commercial framework for the enabling of Active Demand. A number of partners were involved since 2005 in the work of European technology platform for the electricity networks of the future (ETP SG) and actively contributed to the drafting of two key documents that set the main guidelines for future research in the area. ADDRESS was one of the first project to be developed according to the requirements expressed by the ETP SG.

D.10 Socio-economic

D.10.1 WETO H2

The WETO-H2 report, commissioned by the European Commission and published in January 2007 developed a reference projection of the world energy system in 2050 focusing on two varying scenarios: a carbon- constraint scenario and a hydrogen economy based scenario. The project was based on complex quantitative models, developed through POLES modelling. The concluding report's main objective was to be a guiding reference document for the European energy industry and EU policy-makers. The Joint Research Centre also participated in the project and ensured that the model and tools developed were reiterated by the Institute for Prospective Technological Studies IPTS and were operable by its staff. For this reason, it was possible for the JRC to work directly with the POLES model and related databases developed through WETO-H2, such as TECHPOL. These tools were used for research activities, mostly on behalf of the Directorate General Climate Action (DG Clima), in particular for the development of energy emission scenarios and impact of EU climate change policies.

These sorts of important indirect added values were difficult to grasp in the project evaluation and direct valorisation of results.

D.10.2 NEEDS

The objective of the project NEEDS was to evaluate the full costs and benefits (i.e. direct and indirect) of energy policies and of future energy systems, both for individual countries and for the enlarged EU as a whole. The project saw the participation of 66 partners, representing 26 different countries. It is to date the largest project ever financed in the area of socio-economic analysis for energy. The most significant impact of the project however is the creation for the first time of a pan-European "engineering" model that paved the way for future model design at the EU level. The upgraded MARKAL-EFOM model developed within NEEDS has influenced the development of countless European models of energy systems, and was taken up by various partners as their main tool for analysis. The direct impact to EU and national policy making has however somehow been weaker and more difficult to grasp. Interviewees noted that despite the great potential and impact the project could have had on the work of the European Commission (EC), there was little involvement of EC services into the project content. During its four years of existence nine project officers had been appointed to follow the project, thus leading to little continuity and ownership. This also had a negative impact onto the project as it lead to continuous delays and little concrete support and guidance for content development. But it has also to be seen as negative for the EC that ended up not having any real insight into the project and was unable to benefit appropriately from the results and tools developed during the project, contrary to project participants, as explained earlier.

D.10.3 THINK

THINK was a Coordination Action designed to advise directly DG Energy individual units on a diverse set of energy policy topics. The project was carried out by a small team of experts working full-time on the project supported by leading academics and experts from all across Europe. In total, the project delivered 12 reports and two booklets that integrate policy recommendations in different fields of energy research. In terms of impact to EU policy making here below we present some of the instances in which THINK individual reports have been used and quoted for the preparation of key policy documents. Two reports on transition towards a low carbon energy System (Topic 3) and on infrastructure cost-benefit analysis (topic 10) were mentioned as relevant documents in the context of the European Commission DG Energy's Roadmap 2050. The report on offshore grid (topic 5) was thoroughly evaluated by the European Coordinator whom referred to it in the Fourth Annual Report "Connection to off shore wind power in Northern Europe (North Sea Baltic Sea)". The report on electricity storage (topic 8) resulted in the drafting of the EC working paper "The future role and challenges of Energy Storage". The report has been discussed and evaluated by members of the European Commission, including the Head of Unit, Energy Efficiency at DG ENER and two Deputy Heads of Unit (Internal Market II: Wholesale markets; electricity & gas at DG ENER and State aids at DG COMP). The report on energy technology (topic 9) greatly contributed to the drafting of the communication on "Energy Technologies in a future European Energy Policy" and was mentioned in the context of the EC Technology and Innovation strategy. The Irish government also requested a presentation of the results of the report on energy infrastructure cost-benefit analysis (topic 10), while ACER and ENTSO-E the report in their proposals. The 2050 report (topic 3) and the report on EU energy technology policy (topic 9) were mentioned as relevant documents in the context of the Commission's Roadmap 2050 and the Technology and Innovation Strategy.

D.10.4 SESSA

The project "Sustainable Energy Specific Support Assessment" (SESSA) created the first European forum for discussion of regulatory issues in the energy market, focussing in particular on electricity reforms. The key impact of SESSA was to bring together for the first time academics, policy-makers and business representatives to discuss electricity regulatory issues in a systematic way. The project initiated a tripartite dialogue among these key stakeholders, which continues to this day through different platforms. Furthermore, SESSA encouraged the translation of academic analysis into policy making, creating a direct link between research on regulatory issues and decision-making at the EU-level. Moreover, the project promoted for the first time coordination and integration of European research in this field, bringing together key national experts also involved in the shaping of national regulatory frameworks. Many of these stakeholders continued working together following the end of the project and are still collaborating at the EU and national level nowadays. This appears as an excellent achievement. Also, the project indirectly contributed to the launch of the Communication "Prospects for the internal electricity and gas markets" [COM (2006) 841], which was prepared on the basis of the 2006 review of the energy market.

D.11 Wind

D.11.1 POW'WOW

The purpose of the FP7-project POW'WOW was to coordinate activities in the field of short-term forecasting of wind power, offshore wind and wave resource prediction, and offshore wakes in large wind farms. The aim was to spread the knowledge gained from these projects among the partners and colleagues, and to start the work on a roadmaps for the future.

The major outputs from this project are two virtual laboratories (ViLabs; the ViLab for offshore wake modelling, and the ViLab for short-term predication of wind power), as well as workshops, and a position paper on wind and wave resource integration. The ViLab for offshore wake modelling was developed to overcome some of the difficulties wind farm modellers face in obtaining data sets with which to develop or evaluate models. The lab emphasises models and evaluation results reported in the bibliography and from national or EU research projects. The idea behind the second ViLab was to take some of the cumbersome work of data acquisition out of research projects and put it in the lab, and to be able to compare research with a number of leading models in the field. However, the lab did not receive the attention expected despite large efforts on the consortium part.

The seven workshops held by the project were largely seen as successful. Two of them focused on the integration of wind and wave resource calculation, two on best practice in the use of short-term forecasting, one on optimal use of information for wind power forecasting, one on the special situation in short-term forecasting in Brazil and the last one on wake modelling.

The position paper produced by the project discussed wind and wave resource integration, which had not been done previously. The paper was produced partly as an output of the workshops on wind power forecasting.

Finally, two expert groups for waves and for short-term prediction were formed, mainly from within the consortium.

D.11.2 NORSEWInD

NORSEWInD was a FP7-project designed to provide a wind resource map covering the Baltic, Irish and North Sea areas. The aim was to acquire highly accurate, cost effective, physical data using a combination of traditional Meteorological masts, ground based remote sensing instruments (LiDAR & SoDAR) and Satellite acquired SAR winds. The vertical resolution of the ground based instruments will be used in the future to calibrate the satellite data to provide hub height, real world data.

The project produced a vast amount of publications, thus being one of the major contributors to the scientific outputs produced by the two framework programmes. The publication lists consist of 35 articles in peer-review journals; one book chapter and one PhD (in addition to 71 conference papers and 8 reports). The range of different scientific journals consortium participants have been published in as a direct result of the project covers methodological as well as pure technological and energy related issues. Some examples from the list are Journal of Methodology and Climatology, Wind Energy Journal, Quarterly Journal of the Royal Meteorological Society, and Journal of Atmospheric and Ocean Technology.

The PhD thesis, "Offshore Wind Energy and Sea Surface Temperature from Satellite Observations", was produced by a PhD student at the department of wind energy of the Technical University of Denmark (DTU Wind Energy).

D.11.3 SafeWind

The ambition of this FP7 project was to improve predictability and treat the issue of extreme conditions concerning various temporal scales – from very short-term to long-term horizons and for local, regional and European scale.

Since SafeWind is a continuation of two other FP projects. ANEMOS and the parallel ANEMOS.PLUS, it is difficult to determine the impact of SafeWind alone. However, there are several examples of impact from the projects combined. A pilot tool for extreme event predictions was developed and evaluated within the project. The tool was first developed in the ANEMOS project but was extended with new models for extreme conditions developed in SafeWind. The Anemos system is a spin-off of the prediction tool, which has been commercialized by a consortium member.

The Anemos system is being continuously developed by partners, and commercialised. There is interest from consortium members in continuing research in a new project. The large number of PhDs and MSc's in the project is considered to form a solid basis for future R&D within the field. Moreover, consortium members continue to attend and organise conferences together. The last one was in Rotterdam in 2013 in collaboration with the European Wind Energy Association.

The project also worked at developing new forecasting methods focusing on uncertainty and challenging situations, models for alarming as well as for warning.

Forecasting the power output of wind farms is a means to facilitate large-scale integration of wind generation, in line with the EU goals for 20% of renewables by 2020. Previous R & D efforts on wind power predictions focused on "usual" operating conditions, which often resulted in errors. SafeWind satisfied end-users' need for specific approaches that improved wind power predictability by reducing large errors, and by predicting extremes.

The consortium had 23 partners from 9 countries that worked in close relation to industry. The role of the industrial partners was crucial since they provided real-world data that were used for the validation of the developed models.

Models and tools developed in SafeWind have helped maintain excellence of European R&D and created worldwide business opportunities for European technology. There are large environmental impacts as project outputs ease the integration of wind power, corresponding to the 2020 and 2030 targets.

D.11.4 UpWind

The rationale behind the FP7 UpWind project was to design new huge wind turbines that would be able to stand in future on- and offshore wind farms. The project aimed to develop the accurate, verified tools and component concepts the industry needed to design and manufacture this new type of turbine.

As the UpWind project‘s scope was very wide and the project laid the basis for essential future strategies for decreasing cost of energy, UpWind contributed considerably to the recommendations of the European Wind Energy Technology Platform and the foundation for the European Wind Initiative. UpWind will help European Wind Energy companies maintain their favourable position in the global market, reach EU renewable electricity targets, and to attain the main objectives.

It is clear from the conclusions of UpWind that the European Wind Initiative‘s research agenda is both feasible and necessary and should therefore be financed without delay by the European Commission, national governments and the European wind energy sector.

D.12 Future & Emerging Technologies materials

D.12.1 INNOVASOL

INNOVASOL aimed at developing radically new nanostructured materials for photovoltaic (PV) excitonic solar cells (XSCs) in order to make them competitive with traditional energy sources.

The target was to overcome current limitations of third-generation PV devices through an improvement of the materials used for assembling XSCs. Taking into account that the state of the art DSSC (Dye-Sensitized Solar Cell) device has 11% efficiency, INNOVASOL XSC device target was to reach 11-15% efficiency.

The project screened particularly four classes of XSC materials: i) quantum dot light absorbers (QD), ii) molecular relays, iii) hole transport materials, iv) mesoscopic electron transport materials.

The optimization of core materials was done aiming at the enhancement of PV device lifetime and at decreasing cost production of materials.

Concerning the target proposed in INNOVASOL, the Consortium succeeded in the preparation of XSC on glass and thin glass substrates, with a power density of 13 mW/cm2 (proposed target 10-15 mW/cm2). Spot cells (0.1 cm2) with 13% efficiency have been prepared by using the most promising project materials. Furthermore, XSC modules of 65 cm2 with efficiency of 6.4% were fabricated. Degradation of overall cell efficiency less than 2% was reached.

The technology has several long term applications of the technology such as automotive roof panels, transparent windows and civil/industrial buildings requiring stringent performances (long lifetime, high stability, high efficiency and high relative humidity resistance). Through the research centre of FIAT the project tested automotive applications.

D.12.2 GO NEXT

Thin film photovoltaic cells based on organic semiconductors have attracted interest as a possible alternative to conventional, inorganic photovoltaic technologies. The following is a list of the main advantages of organic photovoltaic (OPV) devices:

- Low weight and flexibility of the PV modules

- Semitransparency
- Easy integration into other products
- New market opportunities, e.g. wearable PV
- Significantly lower manufacturing costs compared to conventional inorganic technologies
- Manufacturing of OPV in a continuous process using state of the art printing tools
- Short energy payback times and low environmental impact during manufacturing and operations.

The main disadvantages associated with organic photovoltaic cells are low efficiency, low stability and low strength compared to inorganic photovoltaic cells.

Out of several types of OPV, bulk heterojunction polymer solar cells (BHJ-SCs) represent a promising route to scalable, economically viable, energy conversion technologies when compared with conventional solar cells thanks to the potential for the development of low-cost, large-area cells and modules.

The project aims at developing efficient bulk heterojunction solar cells (BHJ-SCs), with graphene electrodes. In order to show it many questions remain open like the degree of interaction of graphene with the polymeric layer, which could degrade the outstanding graphene electron conductivity, as well as the graphene/polymer electron affinity, which plays an important role in the overalls solar cell efficiency.

The project will leverage the combination of two different fabrication processes, and in particular the doping of the graphene, to obtain semi-transparent electrodes as well as the texturing of the electrodes. This approach, which has never been proposed before, is high-risk and high-impact. If successful, it should lead to strong improvements in solar cell efficiency. Furthermore, all the technologies proposed are suitable for large area realization paving the way for scalable, economic fabrication technologies on low cost flexible substrates.

D.12.3 NANOPEC

Sustainable, cost-efficient large-scale production of hydrogen can, in principle, be established by solar photoelectrochemical (PEC) water splitting, where semiconductor electrodes absorb sunlight to drive water electrolysis.

NanoPEC employed innovative concepts and new methods, enabled by nanotechnology, to design nanocomposite photoelectrodes for solar water splitting, where each component performs specialized functions to overcome intrinsic limitations of single phase materials.

The final objective, was to develop a 1 square-centimetre test device that converts solar energy to hydrogen energy with a sustained 10% efficiency and a maximum performance decay of 10% over the first 5,000 hours of operation and a 100 square-centimeter test device with a sustained 7% efficiency. The first objective was accomplished, not the second one as the solar-to-hydrogen (STH) efficiency was 6 % and the size of the prototype 63cm2.

It has to be remarked that besides contributing to the development of prototypes, the presence of the research centre of Eni was key to set up an Internal Panel Review with the following companies:

Fiat, PSA Peugeot-Citroën, Total, Solaronix, Solvay, Belenos (Swatch Group), Granit Technologies, HySyTech, Hydro2Power.

This kind of collaborative approach among companies was possible given the pre-competitive level of the technology, which induces firms to be willing to exchange experiences and opinions on future potential applications.

D.12.4 POLYWECS

The project studies Wave Energy Converters (WEC) and specifically introduces Polymeric WECs (PolyWECs), characterized by the employment of Electroactive Elastomer (EE) transducers.

PolyWecs differ from previous solutions as they integrate in one deformable lightweight and low-cost polymeric element the three components of WEC (mechanical wave absorbers, mechanical transmission, power take-off system).

Preliminary studies on energy generation through EEs demonstrated their great potential in terms of cost effectiveness, efficiency and reduced complexity. Due to their intrinsic low mass, flexibility and resilience, as well as their capacitive nature and high voltage operation, EE technology perfectly matches the requirements of WECs.

The objectives of the project can be summarized in the following points:

- Optimisation of DE materials for WEC applications;
- Conceiving new electro-mechanical configurations for PolyWECs;
- Study of the fluid-DE interaction through numerical simulations;
- Performing wave-tank tests of small scale prototypes;
- Development of techno-economical models for assessing the economic potential of EE-based WECs in given wave-climates and for evaluating their energy-carbon sustainability.

D.12.5 HAWE

The focus of the project is to develop an efficient technology to capture high altitude wind. Traditional wind installations (low altitude) present several limitations: they have to be located where wind conditions are favourable and not close to the end users; the intensity of wind is low and intermittent. High altitude wind does not have these problems as wind intensity is much higher and constant. Also the transport costs are much less than traditional wind towers as there is no need of special vehicles.

Moreover Europe is at a latitude range where wind energy is available with high density levels, in particular the southernmost European countries; these are located in latitudes where very high wind energy densities are available at altitudes ranging from 4000 to 15000m.

HAWE consists of a buoyant, rotating, cylinder shaped airship, anchored to a ground station by a tether cable. A production cycle is divided in two phases. A power phase (rising phase) in which the Airborne Module increases its altitude pulling up the tether cable which drives the alternator at the ground station, producing electrical power. During the recovery phase, an electrical motor, installed at the winch, rewinds the cable to its original position, consuming power in order to do so but much less than that produced during the power phase due to the reduced pull force.

The project has the aim to study the multiple components of the technology through a series of prototypes increasing in the dimension (from 4 to 24 meters of wingspan) of the cylinder. OMNIDEA is an SME responsible for putting together the technology and the rest of the partners had tasks in developing the different components.

The project had a complete overview on the technology with studies on wind forecasting and a business plan developed by the Portuguese utility EDP.

D.12.6 THATEA

Thermoacoustics utilizes the rich interactions between thermodynamics and acoustics. In any sound wave, there exist coupled pressure, displacement, density, and temperature oscillations. The pressure oscillations induce temperature oscillations which in turn cause heat transfer to or from nearby solid surfaces. The combination of these oscillations and the placement of enough solid walls at the proper position in the acoustic wave, close enough to the heated or cooled areas in the gas, produce a rich variety of thermoacoustic effects.

Using acoustic wave motion eliminates mechanical friction and wear, and therefore drastically increases lifespan and minimizes maintenance. Because of the lack of moving mechanical parts in the thermodynamic process the construction tolerances and material requirements are relaxed allowing for (potential) low production and investment costs.

THATEA main experiments were carried out on heat pumps: two different types of thermoacoustic heat pumping devices have been constructed and tested. These two differ with respect to the temperature level on which they operate. The first application consists of a simulation of a gas driven thermoacoustic system to pump heat from 10 to 80°C; a thermoacoustic combination that has not been seen before. The second application concerns a waste heat driven thermoacoustic chiller producing cold at a temperature of -40°C, with a tripled efficiency than previously measured.

The key outcome of the project was that the two integral systems that were built prove that thermoacoustic technology is a feasible technology that can be applied in a number of energy related applications.

Applications of the technology can be: thermoacoustic heat transformers for industrial applications, heat pumps for domestic applications, solar driven cooling systems and conversion of waste heat to electricity.

The technology has a wide-reaching potential because the practical embodiment is relatively simple. The systems are housed in a structure similar to a tube and contain no moving parts. This gives it a high reliability and a long life span, making it more economically feasible than some other energy technologies.

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