Towards a European Strategy
for Synthetic Biology

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TESSY Achievements and Future Perspectives in Synthetic Biology

TESSY Final Report

(Deliverable D5.3)

December 2008

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Content

1 Introduction

This final report summarizes the major results of the project "Towards a European Strategy in Synthetic Biology (TESSY)" funded by the European Commission between January 2007 and December 2008 and gives an outlook on future perspectives in Synthetic Biology. The project was carried out by a consortium formed of scientists at the Fraunhofer-Institute Systems and Innovation Research (FH- ISI), the European Science Foundation (ESF), the Albrecht-Ludwigs-University Freiburg, and the company ATG biosynthetics GmbH.
The project consisted of four analytical work packages:

1. Compilation of existing resources for Synthetic Biology
2. Roadmapping
3. Dissemination of TESSY results
4. Sustainable implementation of Synthetic Biology Strategy at Member State and institutional level.

In the following sections the TESSY achievements will be described according to this work package structure. The work packages had a strong focus on integration of the broader community (scientists, politicians, public) by presenting and discussing results on conferences or in bilateral communication mostly by email.

2 Compilation of existing resources for Synthetic Biology

2.1 Workshop with EU projects in the field of Synthetic Biology

Workshop one "Meeting with existing projects" took place on March 13, 2007 in Zurich. In order to gain as much participants as possible it was organized in collaboration with the meeting of the advisory board of the EU project EMERGENCE. Thus, representatives of most ongoing EU projects in the field of synthetic biology (SB) participated (EuroBioSyn, Hylib, CellComput, Biomodular H2, Orthosome, BioNanoSwitch, Synbiosafe, Cobios, Syncells, FuSyMem, EMERGENCE, and TESSY). Altogether 31 representatives of European SB projects attended the meeting. On this meeting first contacts were established for the future

roadmapping core group (see section Draft roadmap, section 3.1). The field delineation of SB was debated in bilateral discussions among participants and the TESSY work plan was reconsidered and anchored within the European SB community. Workshop one was also used to conduct a survey among the European research projects about framework conditions of SB research.

2.2 Scope and Field Delineation of Synthetic Biology and Inventory of EU Synthetic Biology Projects

Synthetic Biology is a term which has been coined several times in the course of the understanding of biological processes. Hence perception of its meaning varies widely. In its latest incarnation Synthetic Biology is seen as an approach to construct biology based on principles developed in engineering disciplines. To cover the various facets of synthetic biology the TESSY consortium proposed the multi-layer definition of Synthetic Biology which has been developed in the EU funded SYNBIOLOGY project. Here the field is not delineated in a classical sense based on the studied material (e.g. genes, organism) rather than by goals and the methodological approach. The final definition applied within the project was

Synthetic Biology aims to engineer and study biological systems that do not exist as such in nature, and use this approach for

- *achieving better understanding of life processes,*
- *generating and assembling functional modular components,*
- *developing novel applications or processes.*

Based on feedback on this definition from the scientific community Synthetic Biology spans broad areas of chemistry (e.g. DNA and RNA synthesis, peptide synthesis, carbohydrate synthesis, lipid synthesis), biology (e.g. genomics, proteomics, metabolomics, systems biology), as well as engineering (e.g. microfluidics) and information technology (e.g. bioinformatics). Looking at this list of potential Synthetic Biology areas explains why it is extremely difficult to list all European activities with potential relevance to Synthetic Biology. It is particularly worth to note that, according to small personal polls, most people doing Synthetic Biology in the broad sense are not yet aware of this fact. Thus, the analysis of EU Synthetic Biology projects was limited to the 18 projects funded under the three NEST

Pathfinder Synthetic Biology calls 2003, 2004 and 2005. The results of this analysis was described in deliverable D1.1.

2.3 Framework Conditions of European Synthetic Biology Projects, Closing Knowledge Gaps, and Integration of Additional Information

Framework conditions of the European Synthetic Biology were a continuing theme throughout work package 1, which aimed at elucidating the actual and desired values for Synthetic Biology research and development. Thus, this topic was dealt with at the kick-off meeting and the workshop in Zurich, it was integrated in the questionnaire, and mentioned in the telephone interviews. Consequently, information regarding framework conditions can be found in the telephone interviews in deliverable D1.1, the questionnaire and the database survey in deliverable D1.3, and last but not least the Synthetic Biology database of deliverable D1.4, which lists original research publications and the respective research groups, funding agencies, companies, and experts.

Interviews with ten prominent European Synthetic Biologists of about 30-45 min each were performed in order to identify fields with substantial potential for further improvement of European SB conditions. In this respect the term "knowledge gaps" is used for the completion of our understanding where decision makers could improve the framework conditions for future continuous improvements.

Funding conditions and organisations, translational money and sources for financing are important factors to design successful projects as mentioned by the interviewees. In addition to these issues legal knowledge gaps became obvious with regard to code of conduct of research biosecurity issues. The latter refers for example to a list of pathogens and genes which have to be screened and declared. More general European law was also mentioned as being of interest e.g. how to deal with recombinant materials in the EU.
A significant number of the interviewed researchers are intending to commercialize their research. Due to this interest in commercialization, knowledge and support regarding intellectual property and IP free space (like open source projects, prior art, free patents) seem to be important prerequisites for the realization of a successful pipeline from basic Synthetic Biology research to commercialization. These contributions were built on the observation,

that bioengineering by SB is application driven as it is the case in other engineering disciplines. The interviewees speculated that after establishing necessary basic research and infrastructure, SB could provide a huge potential for the generation of services and products. This could be exploited by SMEs specialized in this field. With this perspective the interviewees asked for funding of applied research and provision of seed capital in order to support company foundation and bridging to first financing rounds.
Examples for Synthetic Biology tools such as existing literature and IT databases or repositories were listed in deliverable D1.3 and the database of deliverable D1.4.

2.4 Actualisation of inventories

The web data base URL http://www.synthetic-biology.info was used as an informational inventory for TESSY. In order to update the pre-existing state, Synthetic Biology publications from the beginning of 2006 were downloaded from Pubmed (www.pubmed.com) and are presently processed for updating the data base. Exclusively high level papers were selected according to the citation index to be presented to the public. The data was structured by auto-classification software.

Using an internet search an analysis of SB activities was carried out with a focus on Europe. The **research institutions** involved in EU-Nest-SB projects were added as well as 77 member organisations from ESF sources as basis for the further work in this direction. The hits include 27 companies and 112 research institutions. Based on the institutions' self-descriptions, the hits were categorized in high, medium and low relevance for SB according to the SB1-3 categories used in the EU-Nest SynBiology project for its database. The smallest unit in the SynBiology database is a person, therefore it is partially redundant with respect to institutions (more than one person within one institution included). It contains overall 877 datasets and thereof 47 companies and 261 datasets of persons related to SB activities in the European area.

The identified **funding agencies**' programmes were checked for SB-related activities, which were also mapped and integrated in the respective part of the TESSY database. A comprehensive list of the funding organizations and agencies collaborating with the ESF has been included into the database and the current funding situation is described in deliverable

D1.3. At the national level the European Science Foundation currently has 75 member organisations from 30 European countries.

The completion of the database is a work in process as new SB actors enter the field or change their research focus. Thus, all actors (academia, industry, funding agencies) are invited to register in the Synthetic Biology Database which will be a basis for future strategy development and collaboration (http://www.synthetic-biology.info/institutions.html) (Figure 1). The registration procedure can easily started by clicking the "Register" button, followed by the definition of personal activities by expanding the topic-tree and clicking the desired subtopics. The chosen topics will appear in red. To roll back the entries one can click "Clear Tree". The button "Display highlighted" expands the tree up to all the chosen subtopics to make them visible (Figure 2). After the first registration one can supplement the profile by logging in with the personal email address and password. The database can be browsed by clicking the rotating magnifying glass.

Figure 1: Database on Synthetic Biology Actors and Institution; http://www.synthetic-biology.info/institutions.html

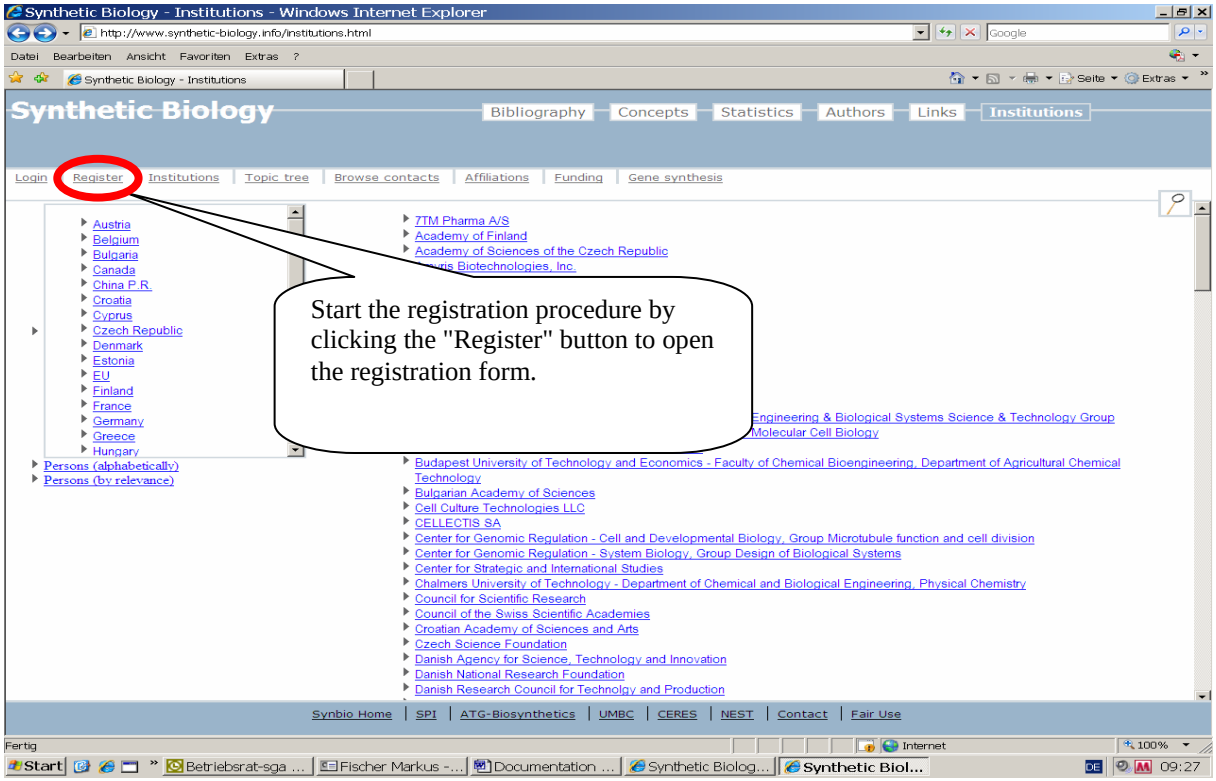
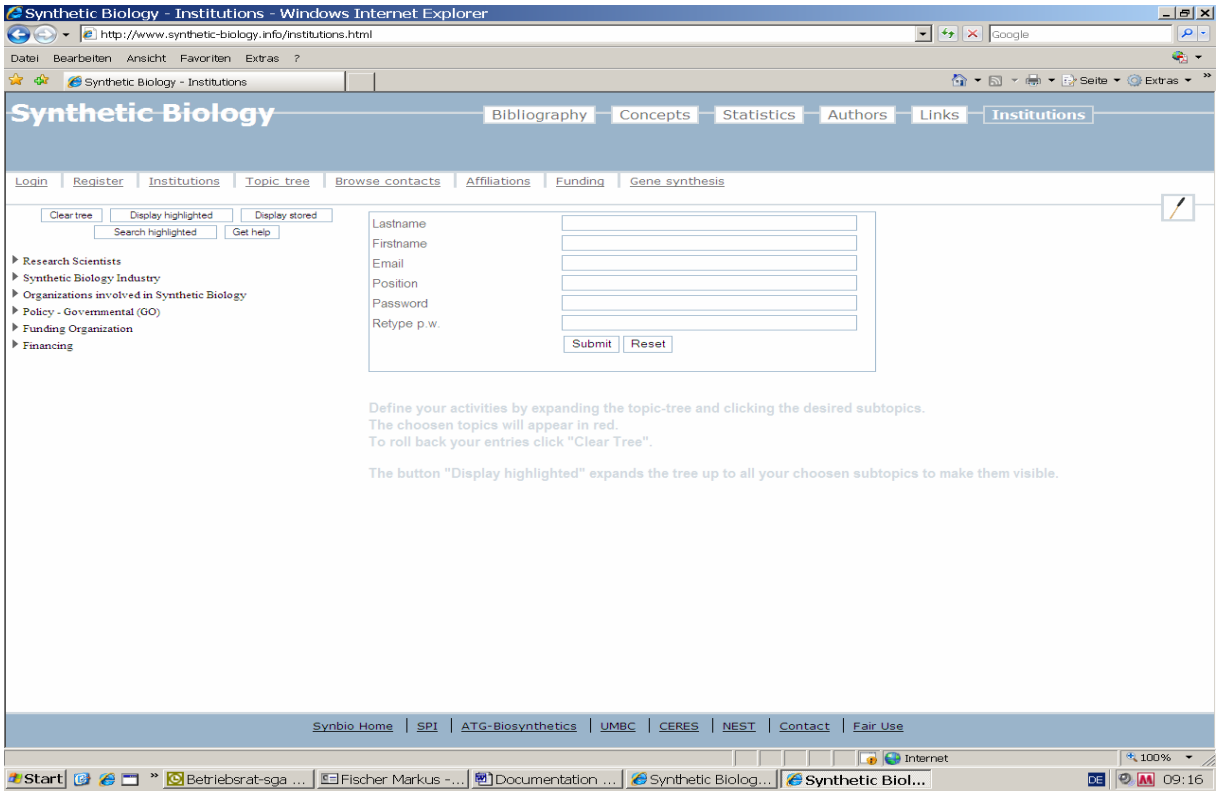


Figure 2: Registration Form

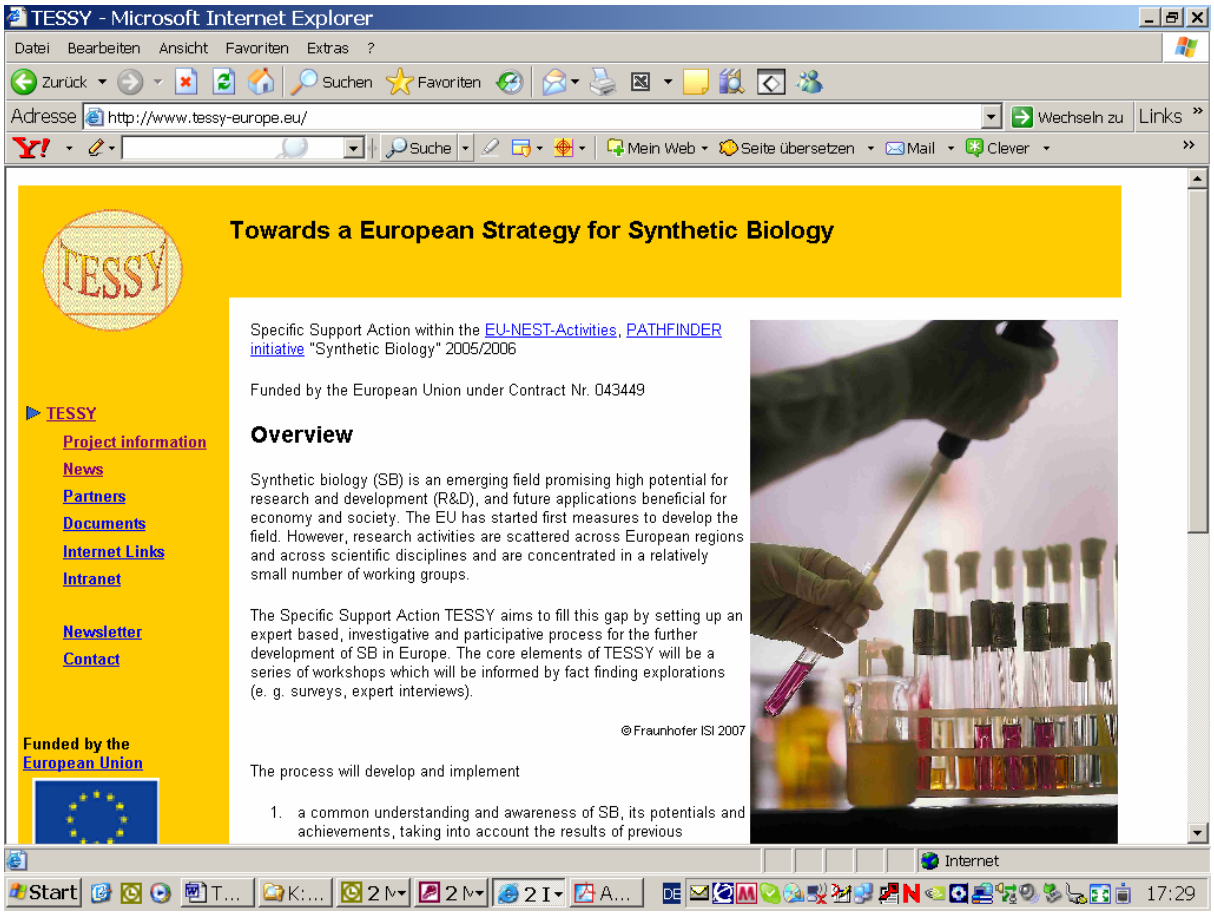


2.5 Communication Tools

2.5.1 TESSY internet platform

In March 2007 the TESSY internet platform was launched under http://www.tessy-europe.eu (MS 1.2; D1.2). The platform contains information about the project and the EU programme responsible for funding, the partners, and background information (Figure 3). Information was included to inform interested parties about how to participate in ESF funding initiatives (Eurocores call for themes in Synthetic Biology and EuroBioFund Call for Expressions of Interest).

Figure 3: Starting page of the TESSY internet platform http://www.tessy-europe.eu



2.5.2 Targeted information: the information leaflet

The TESSY Consortium elaborated a leaflet with general information (Figure 4) and actor specific targeted information on Synthetic Biology (Figure 5). The leaflet was discussed with the advisory board. The consented version was printed (500 coloured copies) and distributed via the TESSY consortium. Especially the European Science Foundation took a lead in its distribution on current and future meetings and workshops of the ESF. A pdf-version of the document was uploaded on the TESSY homepage.

Figure 4: SB Information Leaflet (deliverable 3.1) (page 1)

Synthetic Biology in Europe

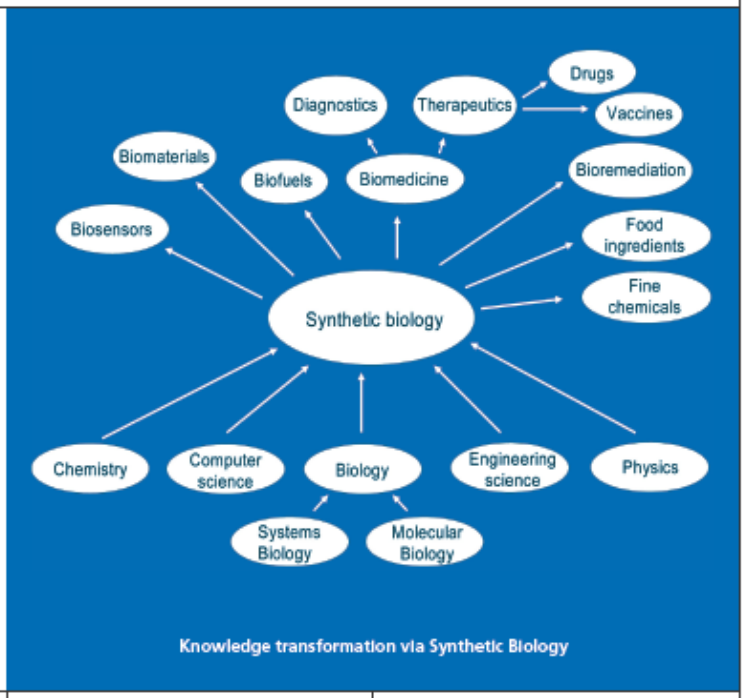
Synthetic Biology is an emerging field at the intersection of life sciences and engineering. It benefits from the output of various disciplines. The field is promoted by the EU to increase collaboration between the European working groups and different disciplines.

What is Synthetic Biology about?

Synthetic Biology uses nucleic acid elements or complex systems that are predefined and chemically synthesised in the laboratory by a modular approach. This approach aims to:

1. engineer and study biological systems that do not exist as such in nature, and
2. use this approach for:
   - achieving better understanding of life processes,
   - generating and assembling functional modular components,
   - developing novel applications on processes.

Registries such as the Registry of Standard Biological Parts hosted at the Massachusetts Institute of Technology, USA (http://partsregistry.org/Main_Page) play an important role in the advancement of Synthetic Biology.



Knowledge transformation via Synthetic Biology

Potential

Synthetic Biology covers the following applications:

1. Biomedicine
2. Cheaper synthesis of biopharmaceuticals
3. Sustainable chemical industry by efficient biotransformation
4. Environment
5. Energy
6. Production of smart materials/ biomaterials
7. Security: counter-bioterrorism

The TESSY process

The goal of TESSY is to develop a European Strategy for Synthetic Biology. This is based on:

- a roadmap with essential steps in regulation, funding, public sector integration and scientific milestones,
- a common understanding and awareness of Synthetic Biology and its potentials and achievements.

TESSY

TESSY-Consortium

Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, Germany; European Science Foundation, Strasbourg, France; ATG biosynthetics GmbH, Merzhausen, Germany ; University of Freiburg, Department of Biology, Freiburg, Germany

ATG:biosynthetics

EUROPEAN SCIENCE FOUNDATION

Fraunhofer Institute Systems and Innovation Research

Figure 5: SB Information Leaflet (deliverable 3.1) (page 2)

What you should also consider...

Researcher

Synthetic Biology opens the horizon for a new research methodology that allows the quick composition of new complex structures and biological applications. The interdisciplinary character of Synthetic Biology creates a high demand for collaboration among different scientific disciplines.

Funders

The truly interdisciplinary nature of Synthetic Biology, together with its emerging character, calls for the rethinking of traditional funding mechanisms. Ways need to be explored to break down the classical disciplinary borders and to maximise the integration of different disciplines, on both a national and a European level. It is desirable to foster community building in each European country and to complement this with European level approaches which aim to integrate research strengths scattered across Europe. The technological component of Synthetic Biology and its high potential for application open up the possibility to strengthen research between academia and industry, thereby striving towards translation of basic science to application.

Industrial Synthetic Biology

The objective of Synthetic Biology is to provide modular molecular tool-boxes applicable for speeding up any R&D in the design of biological systems. The expectation is to reduce costs by marketing these applications earlier, thus achieving early return on investment for life science companies.
This feature makes Synthetic Biology attractive for all industries with high innovation pressure, e.g. the Pharmaceutical Industry; for improving product cycle management; and for filling the product pipeline with new therapeutics and diagnostics.
Synthetic Biology has the potential to create new applications out of all life science fields, including improved healthcare leading to individualized, highly efficient medicine with low side effects; the deployment of Synthetic Biology methodology in environmental technologies; and the design of non-food plants. Synthetic Biology is also a promising avenue for providing a more efficient supply of bio-energy and improve nutrition in quality and quantity.

Public

Synthetic Biology holds a number of promises to secure or improve quality of life. On the other hand there are potential and perceived risks due to deliberate or accidental damage. In addition, ethical issues related to the nature of living beings are arising. In order to ensure the successful development of this new scientific field it is necessary to gather information about its risks and to devise adequate bio-safety strategies to minimize them. The public is encouraged to act as a partner in the development of clear guidelines for Synthetic Biology and to get involved in the respective ethical debates.

Policy

Synthetic Biology raises questions with respect to IP regulation, the guidance and regulation of risk assessment, ethics of life, and the prevention of misuse. These issues need to be taken up by national and international political agendas. Discussions with stakeholders at a European level could form a first step in this policy process.

Further information

TESSY website: www.tessy-europe.eu
Database: www.synthetic-biology.info
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Advisory Board of the TESSY Process

- Dr. Amanda Collis (BBSRC, United Kingdom),
- Prof. Dr. Keith Firman (University of Portsmouth, United Kingdom),
- Prof. Dr. Carlos Gancedo (CSIC, Spain),
- Prof. Dr. Alfonso Jaramillo (École Polytechnique, France),
- Prof. Dr. Sten Jorgensen (Technical University of Denmark, Denmark),
- Dr. François Képès (CNRS, France),
- Prof. Dr. Wolfgang Knoll (MPI for Polymer Research, Germany),
- Prof. Dr. Pier Luigi Luisi (Università degli Studi Roma Tre, Italy),
- Dr. Nikolai Raffler (DFG, Germany),
- Prof. Dr. Jose A. Salas (Ministry of Education and Science, Spain),
- Dr. Markus Schmidt (Organisation for International Dialogue and Conflict Management, Austria).

Previous and ongoing EU activities

- BIOMODULAR H2: Engineered Modular Bacterial Photoproduction of Hydrogen
- BioNano-Switch: A Biological Nanoactuator as a Molecular Switch for Biosensing
- CELLCOMPUT: Biological Computation Built on Cell Communication Systems
- COBIOS: Engineering and Control of Biological Systems: a New Way to Tackle Complex Diseases and Biotechnological Innovation
- EMERGENCE: Coordination puts synthetic biology on firm footing
- EUROBIOSYN: A modular platform for biosynthesis of complex molecules
- FuSyMEM: Functional Synthetic Membranes for GPCR based Sensing
- HYBLIB: Human monoclonal antibodies from a library of hybridomas
- NANOMOT: Synthetic Biomimetic Nanoengines: a Modular Platform for Engineering of Nanomechanical Actuator Building Blocks
- NEONUCLEI: Self-assembly of synthetic nuclei: key modules for semibiotic chemosynthetic systems
- NETSENSOR: Design and Engineering of gene networks to respond to and correct alterations in signal transduction pathways
- ORTHOSOME: An Orthogonal Episome: an Artificial Genetic System Based on a Novel Type of Nucleic Acids
- PROBACTYS: Programmable Bacterial Catalysts
- SynBioComm: Towards a European Synthetic Biology Community
- SYNBIOLOGY: An Analysis of Synthetic Biology Research in Europe and North America
- SYNBIOSAFE: Safety and ethical aspects of synthetic biology
- SYNTHCELLS: Approaches to the Bioengineering of Synthetic Minimal Cells

3 Roadmapping

3.1 Draft roadmap

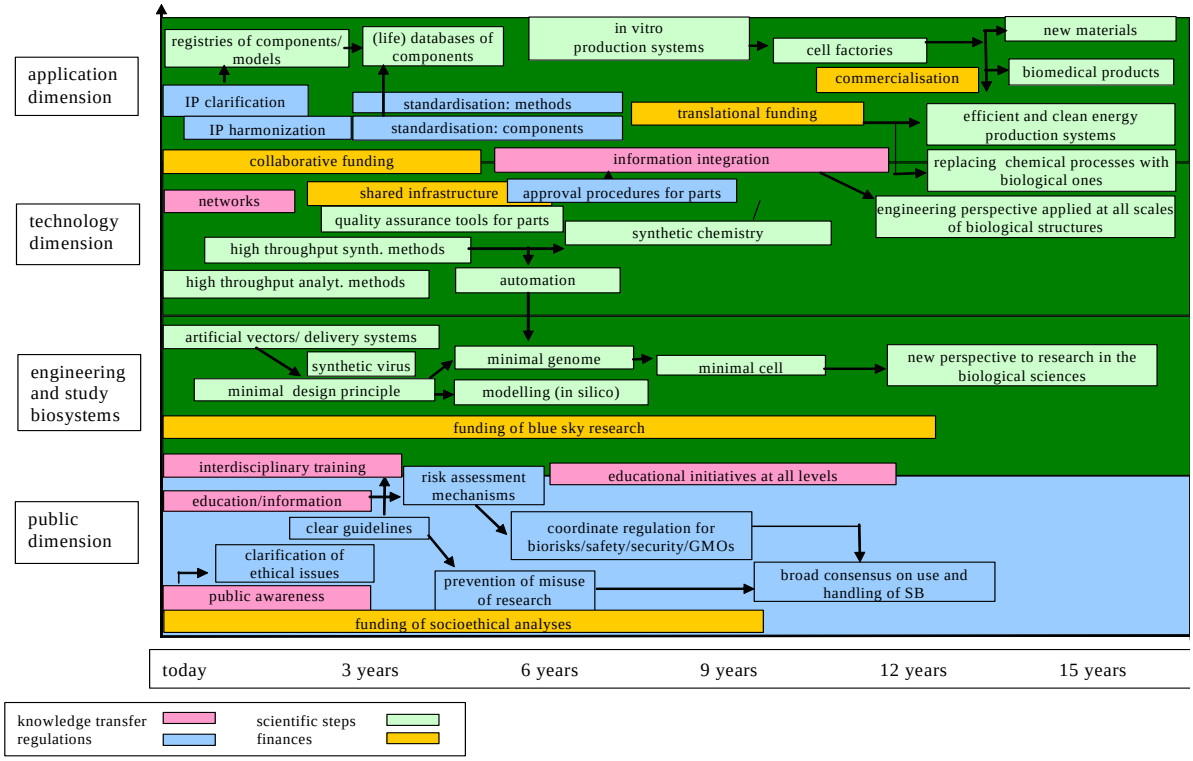
The concept for the whole roadmapping process was developed in the first 4 months of the TESSY project. The first roadmapping workshop was organised to take place as satellite symposium of the SB3.0 conference on 27 June, 2007, in Zurich, Switzerland. In order to have participants from a broad range of research issues and to allow efficient work the participants were invited personally and the number of participants was limited to a maximum of 10 (Table 1). The results of the workshop are documented in deliverable D2.1.

Table 1: External participants of Roadmapping Workshops

Title	Given Name	Family Name	Institution
Prof. Dr.	Keith	Firman	University of Portsmouth, UK
Prof. Dr.	Alfonso	Jaramillo	Ecole Polytechnique, France
Prof. Dr.	José	Salas	Ministry of Education and Science, Spain
Prof. Dr.	Pier Luigi	Luisi	Università degli Studi Roma Tre, Italy
Dr.	Massimiliano	Luchi	Max-Planck-Institut for Polymer Research, Germany
Dr.	François	Képès	CNRS, France
Dr.	Nikolai	Raffler	DFG, Germany
Dr.	Amanda	Collis	BBSRC, UK
Prof. Dr.	Carlos	Gancedo	Instituto de Investigaciones Biomédicas, CSIC, Spain

Based on the results of this Workshop two the TESSY consortium elaborated a draft roadmap. This roadmap was circulated among the advisory board in September and finalised as deliverable 2.2 in October 2007. The roadmap spans a period of time of 15 years and summarizes the activities, milestones and measures in the three dimensions "public dimension", "engineer and study biosystems" and "technology and application dimension" (Figure 6).

Figure 6: Draft Roadmap Version October 2007



3.2 Fact-Finding

Synthetic biology is based on a number of enabling technologies such as the large scale analysis and synthetis of DNA, the deep understanding of biological processes and the ability of in-silico-modeling of biological processes. This requires a close cooperation of researchers with different scientific and cultural background such as biology, chemistry, engineering and computer sciences, physics and electronics. On the other hand SB is still in an early developmental stage with broad industrial applications in a medium to longterm perspective (minimum 10 years). These aspects have strong impact on the type, process and organisation of future funding and stimulating activities in SB. A first concept for such activities as basis for a discourse among public decision-makers, private and public funders scientist and industry was developed in task 2.2 and summarised as deliverable D2.3 in January 2008. Major elements are for example the idea of evolutionary funding which could be helpful in integrating and supporting unexpected methodological approaches in Synthetic Biology research. Evolutionary funding is designed to fund projects that contribute to a certain desired outcome e.g. the provision of efficient energy systems. The selection of projects is carried out

on basis of an assessment of the project's contribution to the out-comes rather than the ex ante assessment of the technology (by an international panel). The advantage of this type of funding is that it supports creativity and helps to draw also conclusion from approaches that do not succeed (tolerance to mistakes).

Additionally, the concept points on the importance of industry in Synthetic Biology. Joint projects between industry and academia could be beneficial for future progress in Synthetic Biology. Another aspect that has to be considered is the interdisciplinary character of Synthetic Biology. This feature confronts funding organisations with new challenges for example with respect to shared budgets across disciplines. It is suggested that an interdisciplinary strategy development could assist to overcome disciplinary borders within funding agencies. In terms of fostering interdisciplinarity it seems also important to develop interdisciplinary criteria for evaluating academic success.

The funding concept emphasizes the need for more European activities. Eurocores and the development of a European consortium in Synthetic Biology that represents an interdisciplinary network of competence and contributes to shared DNA analysis and synthesis capacities, shared computational facilities and a validated registry could be a step in this direction. The required manpower for an accompanying infrastructural measure would be 5-6 persons. Such an infrastructural measure could be attached to a European research institute such as the EMBL. Measures on the legislative and social level could be the establishment of an interna-tional task force to clarify IP issues and the development of a participative process to deal with issues of the public.

3.3 Participatory process

The participatory process was started by the identification of actors from the broader SB community. This was accomplished by a three-step strategy. In a first step search engines were used to identify country-specific internet pages. The second step continued on a URL-specific and country-specific level in order to search in magazines, in the membership lists of national and international associations, publication databases and recent conference documentations. In the third step members of the advisory board were asked to supplement the list of addressees. This resulted in 588 persons who received an invitational letter to participate in the survey.

Additionally the survey used a co-nominate process. By means of this feature the persons that received the invitation to participate in the survey could send an invitation to interested colleagues who could easily gain a personalized access to the survey by sending an email to the survey host.
Thirdly the online-survey was promoted on two international conferences, the SB 3.0 in Zurich, Switzerland and the ESF-Conference on Synthetic Biology in Sant Feliu de Guixols, Spain. Interested persons could join the process via the co-nomination procedure.
In order to grasp the perception of a broad community the draft roadmap was discussed in the web-based survey with two perspectives: it covered the discussion of the already identified aspects of the roadmap both with respect to timing and relevance and allowed the identification of additional topics. A special software tool in the online-version of the survey translated the answers directly into a "personal roadmap". This feature allowed the participants to check their assessment optically.
The total response rate of the survey was 37.6 % (i.e. share of respondents that opened the survey link and filled in at least their personal data). 176 answers could be analysed, which results in a response rate of 29.7 %. The results of the participatory process was analysed and summarized in deliverable D2.4. This information served as basis for the finalisation of the roadmap (section 3.4).

3.4 Final Roadmap

The online survey revealed a distinct opinion within the broader synthetic biology community about the next steps, the requirements and the fostering factors in synthetic biology. The community claimed the need for a number of activities with assessed high relevance (e.g. interdisciplinary training, funding, clear guidelines, IP etc.). There was also high consent about early starting points of many activities (standard deviation ~2 years). On the other hand the time required for each activity (end point) was assessed differently (standard deviation ~ 4.5 years). The survey showed that the perceived relevance of an activity declines if the activity is further in the future. Similarly the consent about the starting point declines if the starting point is further in the future (higher standard deviation) (results of the participatory process are summarized in deliverable 2.4).
The opinion of the need for short-term activities was shared among the advisory board members, however they added a perspective of practicability. Some of the measures with high

relevance and early starting point such as individual and collaborative funding need some (strategic) preparation by funders and/or decision makers; because of that the starting point for these activities was postponed by one year to start in 2009 (results of the second advisory board workshop (WS 3) summarized in deliverable 2.5)

The final roadmap is structured into four fields of activities that represent different groups of actors and targeted milestones (deliverable 2.6) (Figure 7). The four dimensions regulation, funding, knowledge transfer and scientific milestones are assessed as parallel and interacting activity fields. There is a mutual interrelation between the fields; advancement in one of the fields e.g. science can only be achieved based on advancements in the other three fields. On the other hand advancement in e.g. science has also impact on the three other fields. Under these circumstances the activity field "Knowledge transfer" gets an important role in the development of Synthetic Biology for Europe. Activities that are necessary in this field are the set-up of national networks that are linked among each other by a European network. It is essential to integrate SB in existing curricula and develop information material that helps in educational activities at all levels. Emphasized by all experts was the need for increased interdisciplinarity. This should be achieved both on the level of research but also within funding and funding agencies. As it could be learned from previous experience with emerging technologies timely integrated activities among all stakeholder groups are important to raise public awareness and come to a shared understanding of a code of conduct for (Synthetic Biology) Research in Europe. According to the experts' assessment funding for this context activities (ELSI analyses, teaching) should be in the range of 5 – 10 % of total funding. The assessment of the required amount of funding is difficult. Figures may be derived from earlier experience in other emerging technologies. For example development of the emerging field of systems biology was supported with 50 Mio € over 5 years in Germany. On a European level systems biology was supported by 25 Mio € for a joined activity of 6 to 8 countries. This leads to the expert estimate that a total amount of 10- 25 Mio € will be required to start with Synthetic Biology activities in the next two to three years.

The development of a roadmap with scientific milestones revealed a clear chronological order of scientific milestones with enabling technologies such as high throughput synthetic methods among the first essential steps (Figure 8). On the other hand it was emphasized by the advisory board that scientific advancement is a "moving target", as there are currently

extensive research efforts also from private side. This could lead to an accelerated scientific advancement. Thus, the current scientific roadmap is assessed as a guideline for the strategic planning of research focus but it should be updated regularly according to the latest state-of-the art in Synthetic Biology.

Figure 7: Final Roadmap: Measures and Milestones towards a Successful European Synthetic Biology

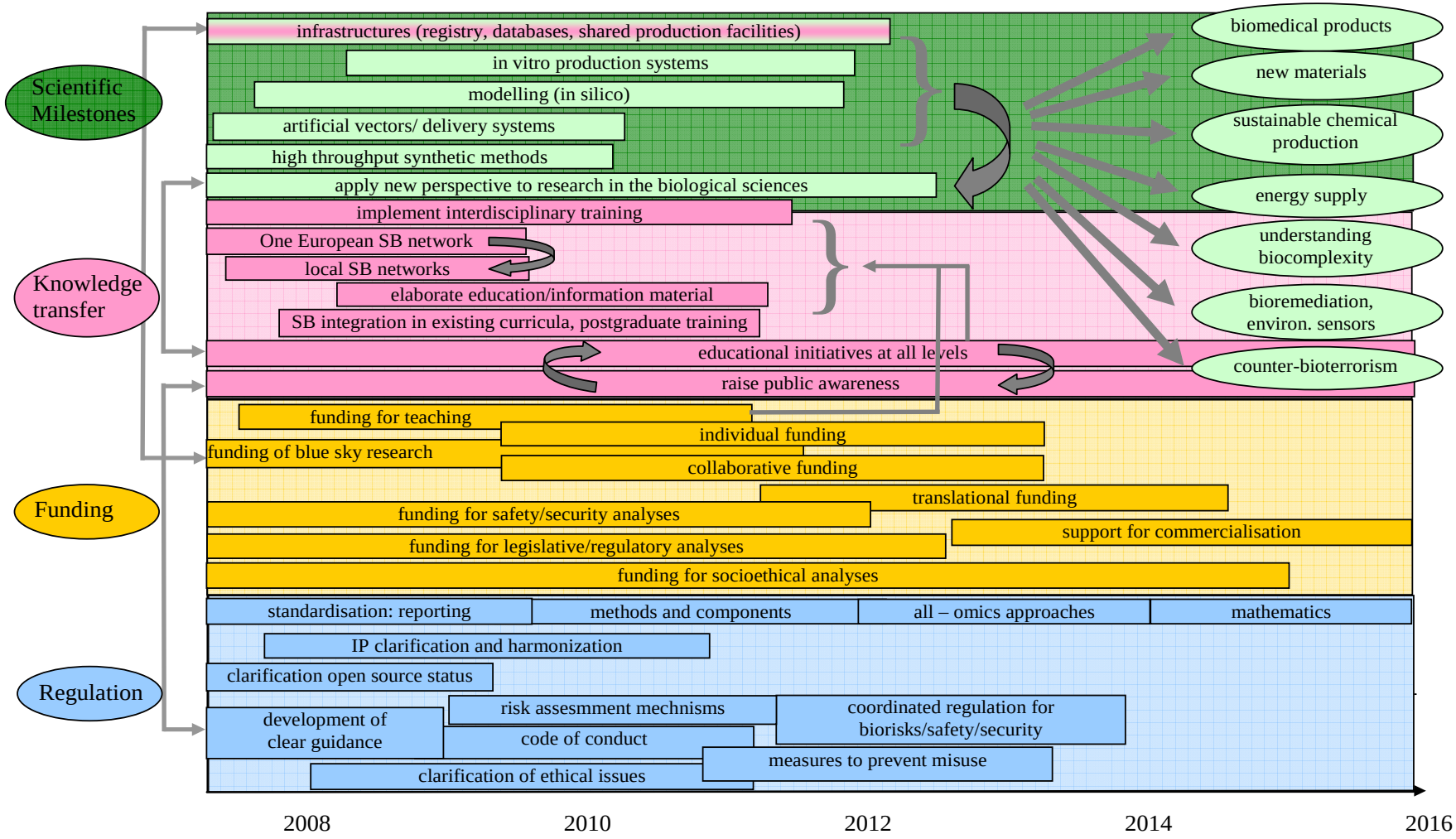
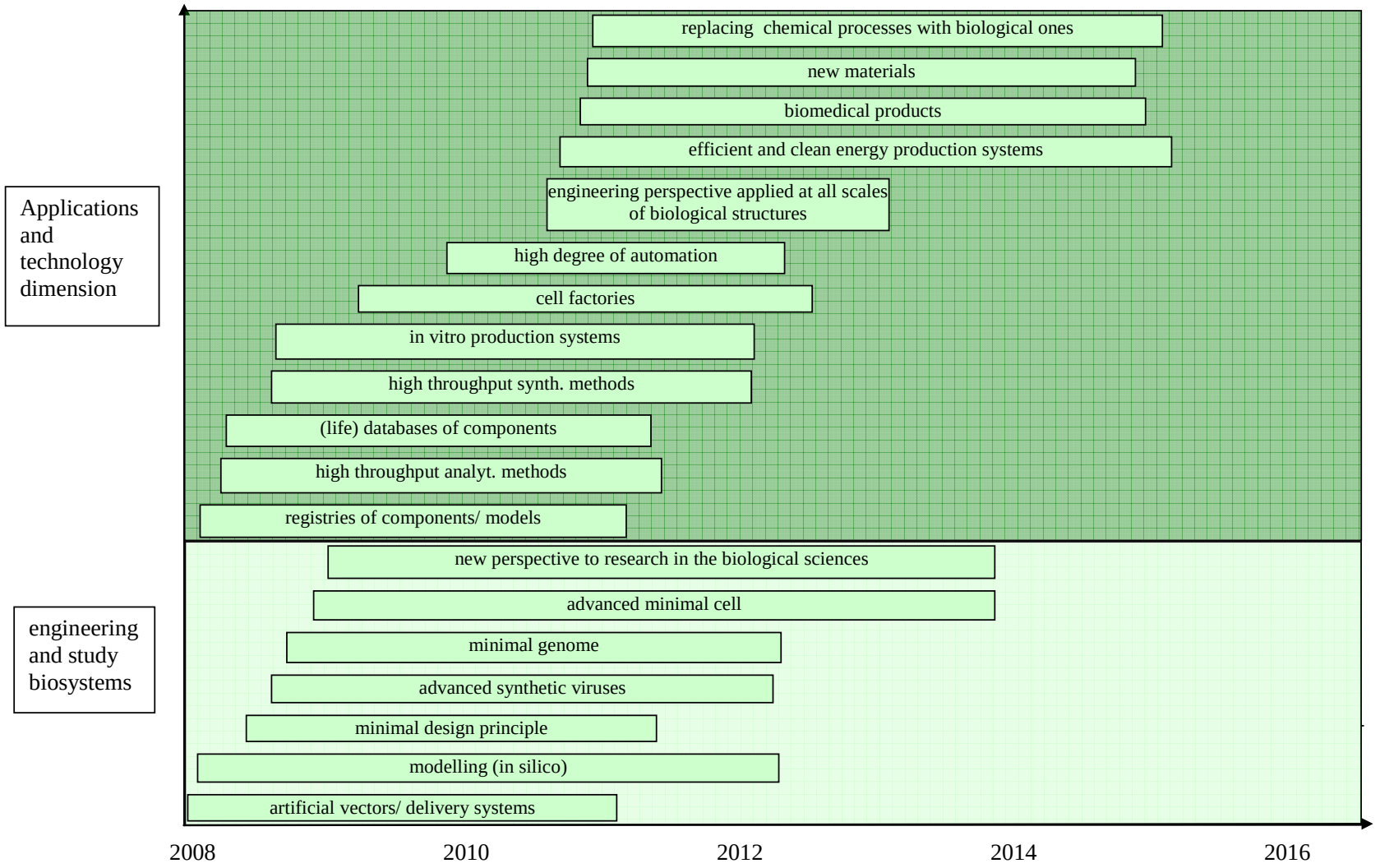


Figure 8: Chronological order of scientific milestones as projected in online survey December 2007



4 Dissemination

4.1 Published materials

All documents compiled within the TESSY project (e.g. analysis, roadmap, information leaflet, etc.) were published on the TESSY homepage. Additionally, the TESSY consortium used the Fraunhofer publication strategy to announce major events and findings via press release[1] and additional articles (e.g. Editorial in BIOforum 6/2008). These activities resulted in a number of articles in printed (e.g. article in the Frankfurter Allgemeine Zeitung 11. November 2008)[2] and online media[3,4] published my external journalist.

4.2 Dissemination event: Opportunities for stakeholders

On 10 June 2008 the TESSY dissemination event "Opportunities for Stakeholders" took place in Brussels. With 54 participants from 14 countries with background in science, funding, politics and industry the meeting provided an excellent platform for the discussion of European and national views on Synthetic Biology. The agenda combined general information from the perspective of science, industry, policy and the public with the dissemination and interpretation of the TESSY roadmap and suggested policy approaches and the discussion of future needs for Synthetic Biology (Table 2). With high level experts and a very interactive and communicative audience the meeting was a successful and motivating signal for future activities in Synthetic Biology. The results were summarized in a documentation (deliverable D3.2), the presentations were uploaded as pdf- documents on the TESSY homepage www.tessy-europe.eu.

It became obvious that Synthetic Biology is a highly interdisciplinary field with a high challenge and potential for knowledge integration. In order to promote the field from a technological perspective, integration needs to be achieved at the intersection of natural science, engineering and industry. Integration of the public in a broader sense i.e. both lay people and decision makers is an additional challenge to develop the field in accordance with public needs and within generally accepted framework conditions. Sustainability in Synthetic

[1] http://www.isi.fhg.de/pr/2008de/pri12/pri12.htm
[2] http://www.faz.net/s/Rub163D8A6908014952B0FB3DB178F372D4/Doc~EA7B28BF578FE4FA1A4FB011BF13B5F74~ATpl~Ecommon~Scontent.html
3 http://www.vbio.de/informationen/alle_news/e17162?news_id=5829
4http://www.jobvector.com/ger_news.php3?news_id=5829&PHPSESSID=jq0q0b7c0gaotm6v2e5jbk5344

Biology could be achieved by involving different (funding) actors on an institutional, national and international level in Synthetic Biology. The adoption of an evolutionary funding strategy that aims at addressing general challenges (e.g. energy requirement of the future) could support creativity and allow the establishment of cross-sectional research alliances. This strategy could stimulate research and funding strategies that integrate complementary skills of the industrial sector and direct research towards future markets. Under this perspective funding organisations should keep in mind the expected need for translational money within the next five years.

Table 2: Agenda of the Stakeholder Meeting, 10 June in Brussels

10:00 - 10:10	**Welcome & Introduction** *Sibylle Gaisser, Thomas Reiss, Fraunhofer Institute, Karlsruhe, DE*
10:10 - 10:50	**Challenges and Perspectives in Synthetic Biology Research** *Vítor Martins Dos Santos, Helmholtz Centre, Braunschweig, DE*
10:50 - 11:25	**Industrial Synthetic Biology – a glimpse on opportunities, challenges and responsibilities of an emergent industry** *Peer Stähler, febit, Heidelberg, DE*
11:25 - 12:00	**Synthetic Biology: responding to the social and ethical challenges** *Paul Martin, University of Nottingham, UK*
12:00 - 12:15	**Synthetic Biology in the EC** *Ioannis Economidis, European Commission, Brussels, BE*
12:15 - 13:15	**Lunch**
13:15 - 13:50	**Roadmap for Synthetic Biology in Europe** *Sibylle Gaisser, Fraunhofer Institute, Karlsruhe, DE*
13:50 - 14:15	**Policy approaches to furthering Synthetic Biology** *Thomas Reiss, Fraunhofer Institute, Karlsruhe, DE*
14:15 - 15:45	**Panel discussion on "Boosting Synthetic Biology in Europe – what is needed?"** The Panel will cover topics such as research funding, interdisciplinary training and academia-industry relationship. Moderator: *Astrid Lunkes (European Science Foundation, FR)* Panelists: *Matteo Bonifacio (Bureau of European Policy Advisers, BE)* *Amanda Collis (Biotechnology and Biological Sciences Research Council, UK)* *Leonard Katz (Synthetic Biology Engineering Research Center, Berkley, US)* *Martin Reddington (Human Frontier Science Program Organisation, FR)* *Luis Serrano (Centre for Genomic Regulation, ES)* *Daniel Vonder Mühll (SystemsX.ch, CH)*
15:45 - 16:00	**Conclusions and next steps** *Sibylle Gaisser, Fraunhofer Institute, Karlsruhe, DE*

4.3 Other dissemination activities

The TESSY consortium contributed to a number of national and international conferences by reporting and discussing the results of the TESSY project. Major contributions were at the following events:

- 24-26 June 2007: Synthetic Biology 3.0 Conference, Zürich, Switzerland
- 24-29 Nov 2007: ESF-UB Conference in Biomedicine: EUROPEAN CONFERENCE ON SYNTHETIC BIOLOGY, Sant Feliu de Guixols, Spain
- 10 April 2008: BioFine Europe Satellite Symposium "Synthetic Biology - Emerging technologies for future biopharmaceutical developments." Freiburg, Germany
- 22 - 24 September 2008: Chemistry in the New World of Bioengineering and Synthetic Biology, Said Buisness School, Oxford, UK
- 22 - 25 October 2008: OECD Planning Meeting "Opportunities and Challenges for the Emerging Field of Synthetic Biology: A Symposium", Bellagio, Italy
- 7 - 8 November 2008: Systems and Synthetic Biology, 9th EMBL/EMBO Science and Society Conference, Heidelberg, Germany
- 12 – 14 December: Projekt Genesis - Wie Naturwissenschaften und Medizin neues Leben konstruieren. Conference of the Evangelischen Akademie Villigst, Schwerte (Ruhr), Germany

5 Sustainable implementation of the SB strategy at Member State and institutional level

5.1 SB Self Assessment Tool (SynBioAssess)

In order to help the development of a sustainable SB strategy the TESSY consortium developed the SB self assessment tool (SynBioAssess) (deliverabel D4.1). SynBioAssess is a set of indicators that illustrate the fields which have an impact on Synthetic Biology and/or are impacted by Synthetic Biology. The tool helps to collect all necessary data in SB and/or identify additional data requirements. It establishes a rational basis for decision-making on future funding and thus increases transparency in decision-making. SynBioAssess allows to contrast the separately evaluated dimensions internal strengths/strengths of resources with the external strengths/ attractiveness of technology in a portfolio approach. An excel spreadsheet facilitates the answering. In this spreadsheet criteria for the internal strengths are clustered according to their contribution to (1) internal organization structure, (2) budget and instruments, (3) internal strategic focus, (4) timing, and (5) internal funding programme with

potential link to Synthetic Biology. Criteria for technology attractiveness are clustered by (1) framework conditions, (2) number of research organisations in country XXX with interest in SB related topics, (3) other funding organisations, (4) SB related trends in country XXX absolute and in comparison to leading competitors, (5) maturity of SB research and development, and (6) expected impact on economy. In SynBioAssess each criterion can be answered in a "facts and numbers" column, followed by a proposal for quantitative assessment. The (weighted) values are summarized in one over-all factor for internal and external strength which is displayed in a chart. For values above a certain threshold a strong investment into SB is recommended, below this threshold a careful consideration of the factors that lead to the observed result is rec-ommended. SynBioAssess can be downloaded from the TESSY homepage and easily adjusted to the individual needs of the user.

5.2 Implementation Workshop: Challenges in Funding Synthetic Biology

The TESSY Implementation Workshop took place on 18 November 2008 in Évry near Paris. It was organised as a platform for knowledge exchange on Synthetic Biology (SB) funding. It aimed at providing an insight into funding needs and funding options. The participants were encouraged to discuss challenges and hurdles in Synthetic Biology funding and analyse approaches for the development of a Synthetic Biology (funding) strategy. Additionally, it was the event to launch the SB Self Assessment Tool (SynBioAssess), which provides a set of indicators to illustrate the fields that have an impact on Synthetic Biology and/or are impacted by Synthetic Biology (Table 3). 16 participants from 9 countries with background in science, funding, and politics participated at the implementation workshop. The results were summarized in a documentation (deliverable D4.2), the presentations were uploaded as pdf-documents on the TESSY homepage www.tessy-europe.eu.

Central results of the workshop are that due to discontinuation of a strong EU support current SB funding relies mainly on a national basis. Some countries are confronted with the situation that they have a huge number of different pots (up to 25 in one country) that could be involved in SB funding which leads to the need of a more centralized administration of money for SB blue sky funding. On the other hand SB has a strong European dimension which led to the question why SB funding was not continued in FP7 on a similar scale as in FP6. It was argued that a continuous support of an emerging field is important and that the strategy of the European Commission to build up and catalyze a certain development without

a sustainable and mid-term strategy would neglect this European dimension of SB, i.e. the funding of SB on a national level would not adequately allow to address the European/international character of SB. Another challenge in SB funding is the perception of the public. It was reported that "synthetic" has a negative connotation and that funding experiences also the challenge to address and convince the public in a certain field.
Thus, the two major hurdles in SB funding are the lack of established systems for communication of scientific success stories (as they are established in the US) and problem for national funding agencies to give money to other countries and thus establish international funding options. The participants concluded that SB funding challenges have to be addressed by a number of measures. It was suggested to invest 5- 10 % of funds into SB communication. Possibilities for bi- or multilateral funding should be determined in more detail, i.e. by addressing political and administrative problems, stimulating Eurocores- and EraNet-activities and checking good practice examples such as a Swiss-German agreement in which one agency has the lead but each country pays its own part in the joint activities. Finally, there was the strong request not to start to reduplicate European activities among national funding agencies but to build on the TESSY results of a high degree of required interaction between disciplines and countries with complementary skills: the need for future European activities on EU level should be communicated to the EC in order to set up further SB activities for example in a large integrated project on Synthetic Biology.

Table 3: Agenda of the Implementation Meeting

Time	Topic	Speaker
9:00 – 9:30	Arrival and Coffee	
9:30 – 9:45	Welcome Address	Françoise Russo-Marie (Head of Genopole Research; France)
9:45 -10:05	Introduction into Synthetic Biology (SB) and the Workshop Goals	Sibylle Gaisser (Fraunhofer ISI; Germany)
10:05 – 10:25	Synthetic Biology funding – the current situation	Astrid Lunkes (ESF, France)
10:25 – 10:45	Coffee Break	
10:45 – 11:15	Synthetic Biology Funding – what is needed from a strategic and educative perspective	François Képès (Génopole; France)
11:15 – 11:45	The UK situation – SB strategy development at the BBSRC	Amanda Collis (BBSRC, UK)
11:45 – 12:15	An overview of Strategy in the UK for SB - implications for Europe and the field internationally	Richard Kitney (Imperial College London, UK)
12:15 – 12:30	Introduction of the self assessment tool	Sibylle Gaisser (Fraunhofer ISI, Germany)
12:30 – 14:15	Lunch Break	
14:15 – 15:15	Working groups: Challenges and barriers in the development of SB strategies	
15:15 – 15:30	Coffee Break	
15:30 – 16:15	Presentation of working group results and plenum discussion	
16.15 – 16.45	International activities in Synthetic Biology: an insight into the OECD approach	Marie-Ange Baucher (OECD, Biotechnology Division, France)
16.45 – 17.00	Conclusions and next steps	Sibylle Gaisser (Fraunhofer ISI, Germany)

6 Conclusions

The TESSY project with its different workpackages started and stimulated a dialogue among different stakeholders on a European and national level that contributed to the development of a common understanding and awareness of Synthetic Biology. By taking into account the results of previous analysis it provided a comprehensive view on the European SB landscape both with respect to involved actors and fields of interest. The database which will be updated by ist users continuously will contribute to further integrate the different actors and disciplines into one Synthetic Biology community.

The roadmap represents the consented perception of the European actors and is a helpful tool for further strategic development of Synthetic Biology. As such, it became a central document for the OECD which started own activities in Synthetic Biology. By inviting a member of the TESSY consortium (Sibylle Gaisser) to the preparatory workshop of the symposium on the policy and political landscape of Synthetic Biology which is going to be held in Washington D.C on 20-21 April 2009, results of the TESSY process will be further discussed and disseminated into the international arena.

Another platform to continue the discussion of the TESSY results will be the upcoming European Conference on Synthetic Biology (ECSB) II: Design, Programming and optimisation of biological systems to be held on 29 March to 3 April in Sant Feliu de Guixols, Spain for which a member of the TESSY consortium (Sibylle Gaisser) was elected as one of the two organising committee chairs responsible to cover socio-economic issues on the conference. On this conference one session will be dedicated to the analysis of political and legal framework conditions. Additionally, the conference "Applied Industrial Synthetic Biology in Europe - Status Quo and Perspectives" which will take place in Freiburg, Germany on 16 and 17 April and which is being organized by a member of the TESSY consortium (Hubert Bernauer) will allow the continuation of the SB dialogue initiated by the TESSY project.

With respect to funding activities the TESSY project contributed to raise the awareness of scientists for the possibility of the EUROCORES funding scheme which finaly led to the submission of a SB proposal to the ESF by a group of SB researchers. Additionally, national and institutional funders became interested in Synthetic Biology and aware of the funding requirements for Synthetic Biology. However, it became obvious that though national funders

can contribute to this highly interdisciplinary field, networking and collaboration of funders and scientists across borders has to remain a strong motivation and driving principle in Synthetic Biology. Against this background future activities in Synthetic Biology on a European level seem to be crucial success factor in Synthetic Biology.

In summary, TESSY made the following main contributions to European Synthetic Biology:

- it developed a common understanding of Synthetic Biology,
- it built awareness for Synthetic Biology among funders and practical support agencies,
- the roadmap established a common way forward in European Synthetic Biology,
- the European visibility in Synthetic Biology was enhanced by an intesive dialogue into the Synthetic Biology community in the US and the European position was strengthened by an active contribution to the ongoing OECD activities.