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The origins of the bioeconomy in the European Union[☆]

This article is dedicated to the memory of Dr Stephan Micha (1965–2013), who actively contributed to the development of the Bioeconomy in Germany and in the EU.

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ABSTRACT

This article outlines the context and circumstances that favoured the development of a Bioeconomy Strategy in the European Union (EU) and the role played by the different Framework programmes for Research, Technological Development and Demonstration. Particular attention is given to the biotechnology related programmes and more specifically to the “Cell Factory” Key Action in the 5th Framework Programme (1998–2002). This, together with the parallel development of a Strategy on Biotechnology in 2002, served as a solid foundation for the creation of the, at the time, so-called Knowledge-Based Bio-Economy (KBBE). The KBBE concept emerged in 2005, a couple of years before the launch of the 7th Framework Programme (2007–2013). The experience accumulated over the years and the new societal expectations triggered the EU to launch a Strategy on Bioeconomy in 2012. This article concludes with a brief analysis of the two most important impacts of the EU Strategy on Bioeconomy. One is the Bioeconomy dedicated activity within the Programme Horizon 2020 (2014–2020), and the other the creation of a public-private partnership of bio-based industries. Both the impact of Horizon 2020 on the EU Bioeconomy Strategy and the bio-based industries public-private partnership are analysed in depth in two articles elsewhere in this volume.

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Introduction

The birth of the bioeconomy in the European Union (EU) has been to a large extent the result of chance and necessity. Since 1982, the European Commission (EC) has been in charge of preparing, managing and implementing the EU Framework Programmes in Biotechnology and Life Sciences. Over the years,

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the different research programmes increased in budgetary size, industry participation, number of participants per project, and scientific and technological ambitions of projects, etc. These changes triggered programme managers of the EC to create new managerial instruments to address the increasing size and complexity of the research projects and programmes. Commission staff also needed to take into account the expectations of the Member States' representatives on the programme committees. They managed the programmes in coordination with the EC. Among those instruments that were gradually being developed in the early years were the requirement for transnationality in research projects, the development of the concept of 'European laboratories without walls' [1], the setup of a high-quality method for evaluation of proposals by independent peer-review experts [2], and the development of a number of 'Industry Platforms' associated with some of the most innovative projects [3]. The content of the research programmes was also in permanent evolution to adapt them to tackle the most pressing problems at the forefront of science, technology and society. The overall objectives of EU research programmes were to promote scientific excellence in Europe by bringing together the most dynamic and creative research groups, with the objective of favouring the exploitation of research results for the good of industry and society. When one looks retrospectively, it is easy to realize that the influence of other Community policies, the influence of Member States' representatives at the programme committees and the European socio-economic context of the time, led the orientation of the biotechnology programmes to switch from a more basic and fundamental approach in one programme, towards one more targeted and focussed on a societal or technological programme in the next [4].

The early biotechnology programmes were the managerial and policy frameworks to create solid foundations in European research, such as: European transnationality participation in research projects; an increase in industrial participation, either as partners in projects or as industrial platforms; independent peer-review of proposals; development of solid managerial research tools; and reinforcing excellence in science and promoting industrial exploitation of results. All of the accumulated experience over different Framework Programmes was an essential prerequisite to be able to tackle more ambitious policy initiatives such as the Strategy on Biotechnology in 2002 [5], the concept of the Knowledge-Based Bio-Economy, more commonly known as KBBE [6] and, lastly, the Strategy on Bioeconomy which was adopted in 2012 [7]. As much as 10 years elapsed between the adoption of the Biotechnology Strategy and the Bioeconomy Strategy and 30 years from the first biotechnology programme to the adoption of the Bioeconomy Strategy. This indicates that initiatives like these require not only goodwill but, above all, the development of matching managerial instruments, maturity of sectoral policies and a broad socio-economic consensus. The origin and policy context of these policy initiatives is outlined below. For an insightful analysis of the genesis and evolution of biotechnology research programmes in the EU, see [8].

The "Cell Factory" key action, an early precursor of the bioeconomy

The 5th EU Framework Programme (1998–2002) was a turning point in research policy by creating the so-called Key Actions. It departed from the classical and linear innovation chain, that is to say, from basic to applied research, followed by technological and industrial development and finally ending in industrial exploitation and commercialization. The Key Actions focused on targeted socio-economic needs and on the Community's policy objectives, where European research should make a decisive contribution with innovative products, processes or services.

The "Cell Factory" was one of the six Key Actions identified and its objective was the industrial mastery of the cell as a factory, with the aim of developing new types of drugs, foodstuffs with specific nutritional properties, techniques for biodegradation of recalcitrant compounds, industrial enzymes able to replace less environmentally friendly chemical processes, etc. The overall objective of the Cell Factory, which had a budget of ca. €400 million, was to integrate innovations into living cells (microbial, plant and animal cells) and into their products. Thus, it was expected that they would provide an environment in which results could rapidly be exploited and transformed into products and processes of interest to society. The societal spin-offs were foreseen to be particularly visible in health, the environment, food, agriculture, agro-industries and high value-added products. In contrast with previous Framework Programmes, which were mainly science-driven, the Cell Factory, took a different approach which consisted of putting forward the main socio-economic objectives addressed by the Key Action, together with the anticipated deliverables to society. In order to attain such objectives and deliverables, the Key Action encouraged the mobilisation of any kind of research or technological development, including demonstration activities geared to the maximization of exploitation of research results. In short, from the socio-economic problem, back to basic science and then to exploitation. The challenges that for the first time were addressed in an EU Framework programme by the Cell Factory were:

1. Promoting the development of innovative technologies and mobilising mission- oriented research,
2. Exploitation of results, and
3. Linking the ability to discover to the ability to produce.

These challenges were concomitantly linked to a number of expected deliverables of socio-economic interest. In particular:

1. Improving the diagnostic and therapeutic arsenal for healthcare
2. Improving environmental sustainability, and
3. Improving quality in food, agro-industry and fine chemicals.

Further information on the Cell Factory Key Action objectives, projects, results, exploitation opportunities, etc., can be found in [9,10].

These changes were not cosmetic in Community thinking. They signalled a profound change of paradigm in developing and managing the EU Framework Programmes. At that time the most visible one was the Strategy on Life Sciences and Biotechnology in 2002 [5] adopted towards the end of the Cell Factory. The Biotechnology Strategy marked a turning point for European biotechnology, which went beyond the implementation of the EU Framework Programmes. It triggered structured and interdependent dialogues with industrial, academic and socio-economic stakeholders, where it addressed managerial, policy development, and competitiveness issues, etc. In 2007, on the occasion of the mid-term review of the Biotechnology Strategy, it was mentioned that the latter should make greater efforts to: focus on promoting research and market development for life sciences and biotechnology applications; foster competitiveness by facilitating knowledge transfer and innovation from the science base to industry; encourage informed societal debates on the benefits and risk of life sciences and biotechnology; ensure a sustainable contribution of modern biotechnology to agriculture; and improve the implementation of the legislation and its impact on competitiveness. The communication on the mid-term review also mentioned that the Biotechnology Strategy would provide "an important step towards a competitive and sustainable Knowledge Based Bio-Economy (KBBE)" [11]. Thus, it can be seen that Commission managers and

policy makers picked up the momentum created by the success of the Cell Factory Key Action to develop novel and ambitious policy initiatives reaching beyond its initial topical focus on biotechnology.

In a certain way, it could be thought that the development of the Biotechnology and Bioeconomy strategies and the development of the KBBE was “unavoidable” given the history of the EU. In this perception, as soon as adequate managerial, financial and policy instruments were developed or made available, the blooming of these strategies would take place sooner or later. In this way one could consider that the evolution of instruments and policies is essentially a question of ‘ripeness’. There are many examples in the history of science and technology where scientific discoveries and technological developments were made at the ‘right’ time. However, in this context, where managerial and political decisions played important roles, the human factor in championing one idea was critical. In a similar context, it has been mentioned elsewhere [8], that “European competition and collaboration moves with an engine, which cannot be fuelled with just the right dose of excellence, competence or other resources. Rather, the engine is fuelled by common human values reflecting the European utopia”. Some of these elements will be outlined below.

Pioneer initiatives on bioeconomy

In parallel with the number of bioeconomy-related initiatives triggered by the EU, such as the ones mentioned above, other countries and international organisations developed simultaneously other approaches to the concept of bioeconomy. Here, it is not intended to present a comprehensive review of the origins of the bioeconomy concept, but rather to mention a few examples that in one way or another triggered the discussions and the reflection at the EC level [12]. Thus, in 2002, the Canadian environment think tank ‘Pollution Probe’ issued a document entitled “Towards a biobased economy – issues and challenges” [13] that gave the Commission staff interesting new ideas and a strong impetus to refine and to prepare for a new important pillar and strategic content element for the 7th Framework Programme (2007–2013). Soon afterwards, in 2004, the OECD published a document entitled “Biotechnology for sustainable growth and development” [14], in which for the first time the notion and definition of a biobased economy was spelled out at global level: “A biobased economy is defined as a concept that uses renewable bioresources, efficient bioprocesses and eco-industrial clusters to produce sustainable bioproducts, jobs and income”. This document provided a surprisingly modern vision of what is discussed and defined today worldwide as the ‘bioeconomy’. It introduced novel concepts such as that environmental benefits are a strong motivator for a bio-based economy but not sufficient for a social acceptance of the bioeconomy. It concluded that industry decisions should be influenced by economic considerations. The article considered that biotechnology may not always provide the best technical solution. However, when it does, economic gains and environmental friendliness can go hand in hand. This pioneer document also stressed elements that were completely new at that time in biotechnology and in bioeconomy, such as the revitalization of rural economies, the need for higher degrees of integration, the need to gain new knowledge and the need for a very high degree of policy coordination and convergence across various sectors. These are all details which represent today the basis of most of the different bioeconomy strategies around the world, and in particular the EU Bioeconomy Strategy of 2012. In spite of the seminal concepts introduced in said OECD paper, it became evident that there were no genuine interest or concrete plans within OECD circles to deepen the idea of such a concept but rather to focus on industrial biotechnology. In the following years the OECD

published some of the first thorough studies on the positive impact of industrial biotechnology on reducing environmental impact for a given level of production [15,16].

The Commission services in charge of preparing the programme “Food, Agriculture and Fisheries, and Biotechnology” of the 7th Framework Programme, decided to take the initiative to start the elaboration of a concept, carrying on one side the name of bioeconomy and focused on the increased use of, and processes for, biological resources. Unfortunately, there is no tangible information within the OECD archives of by whom the original idea of ‘biobased economy’, in particular the respective wording in the document, was coming from, or which Member State delegation had prompted or particularly supported it.

How did it come about that within only a few months such a new concept could be developed, introduced to the inner circles of the Commission, discussed with many stakeholders in the academic and industrial communities not only in Europe, but also worldwide? And, likewise, how could this concept be proposed only 20 months later to the general public and then be adopted with a budget of almost €2 billion just one year later in the 7th Framework Programme?

There is a panoply of reasons, in developments in European research and innovation and also because of certain elements of a ‘zeitgeist’ prevailing during these years and of the ‘human factor’. It is really worthwhile to quickly examine this evolution as a kind of ‘model’ of the recent history of European research. However, a deeper insight based on a detailed examination and study of archives, documents, witness interviews etc., is still missing and would require a more profound analysis.

The following factors were of particular relevance for the Commission services to decide to go ahead with this endeavour.

- a) Strong accumulation of new knowledge (DNA sequencing, “omics” developments, etc.) in biological resources (plants, animals, microorganisms), larger and more intensive than at any time before in man’s history, based also on vast gains of knowledge, strongly boosted as well by intensive Europe-wide research during earlier Framework programmes.
- b) Unique chances to combine life-sciences with new knowledge gained from converging areas such as information technologies, nanotechnologies, synthetic biology, cognitive sciences, etc. Particularly important was the integration of this newly gained knowledge for new products and processes, a particular trend during these years at the beginning of the 21st Century under the influence of the ‘knowledge society’ and the ‘knowledge economy’, etc.
- c) The worldwide acknowledgment and expectations that biological resources offer unique features over fossil or other non-fossil resources, such as renewability, carbon friendliness or carbon neutrality, circularity (re- and multiuse in cascade formats) and new functions like multi-functionality, lower toxicity, less resources input, higher stability, endurance, longer life, etc.
- d) Closeness of the bioeconomy to the principle of sustainability. While it is important to remind oneself that a biobased or bioeconomical process or product does not automatically imply that it is sustainable, bio-based processes offer great opportunities towards sustainable use. However, whether a process is sustainable or not is determined over its life cycle, not just by placing a label on a product.

Thus, undoubtedly the *zeitgeist* and streams of ideas, like focusing on knowledge (knowledge society, knowledge economy, Lisbon Treaty, praising integration of various streams of actions, the connection with sustainability, etc.), also played crucial roles. The same applies to the rather recent emerging recognition of the

importance of life sciences, biology and biotechnology to contribute to solving again the so-called 'Grand Challenges'. Another major factor has been the emergence of industrial or white biotechnology in developing economic solutions, as impressively testified in the above mentioned key document of the OECD of January 2004 and others later on. One can legitimately conclude that without the experience acquired in the different Framework Programmes, and in particular in the "Cell Factory" Key Action and the adoption of the Life Sciences and Biotechnology Strategy for Europe of 2002, it would have been much more difficult to convince the many stakeholders in the EU, in particular the European Parliament and Member States, on the adoption of the KBBE concept and later on the EU Strategy on Bioeconomy.

Lateral elements favouring the blossoming of bioeconomy

European technology platforms

Rather helpful in rallying support of this new bioeconomy concept in a foreseeable timeframe were the newly created European Technology Platforms (ETPs), such as "Plants for the Future", "Industrial Biotechnology", "Forestry and forestry based products", "Food for Life", etc. The ETPs are industry-led stakeholder fora recognised by the EC as key actors in driving innovation, knowledge transfer and European competitiveness.

ETPs develop research and innovation agendas and roadmaps for action at EU and national level, to be supported by both private and public funding. They facilitated the efficient build-up of common views, exchange of opinions, setting of priorities among various stakeholders from industry, academia and in some cases even with NGOs, with the aim of mobilising stakeholders to deliver on agreed priorities. ETPs are independent and self-financing entities. They conduct their activities in a transparent manner and are open to new members [17]. This would hardly have been possible in such a short time 5 years before! These ETPs even developed joint activities and strategies beyond their own sector, supporting the emerging integrated views on a KBBE, and were supported in that process by the EC by specific actions such as the BECOTEPS project. [18].

EU-US task force on biotechnology research

Another interesting factor, hitherto largely ignored in discussions, was the work in the joint EU-US Task Force on Biotechnology Research, which triggered a series of high level workshops from 1990. It paved the way, among many other subjects, for new developments in biomaterials and for scientifically based bio-refining. Some of these workshops explored aspects of public perception, bioinformatics, environmental biotechnology, nano-biotechnology, synthetic biology, etc. The discussions between science managers of the EU and US and the thematic workshops organized merit further examination as they anticipated or paved the way, e.g. for certain industrial developments of today [19,20].

Without all these parts of a larger kaleidoscope of developments, the surprisingly quick and efficient strategic outline of the bioeconomy concept as a new stimulus for the 7th Framework Programme would have been an illusion!

Standing committee on agricultural research, SCAR

In mid-2004 the Directorate General of Agriculture offered to DG Research to take over the competence of the Standing Committee of Agricultural Research (SCAR), an internal comitology body of the EC dating from the 1970s. At the Ministerial Council of Agriculture under the Dutch Presidency, this Committee was transferred to the DG Research. During the following years, SCAR emerged in a truly revitalised format to become a very important forum for discussion, not only among the Commission services and Member States, but also the relevant research communities and

stakeholders. The emerging bioeconomy as a research topic was permanently on its agenda. Its strong affiliation with the bioeconomy became visible years later, when in 2015 the SCAR Committee published its 4th Foresight Report on the Bioeconomy [21].

The knowledge based bio-economy and the 7th framework programme

After a careful political and strategic preparation, the 'Conference on KBBE, the Knowledge-Based Bioeconomy in Europe' finally took place on the 15–16th September 2005 in Brussels. In parallel, the first bioeconomy conference ever held in China, took place on the same days [6], jointly planned and staged by Commission services. This unusual and unique event was only possible as the Commission colleagues had intensely prepared this concept in a series of additional bilateral talks and discussions in Canada, the US, Brazil, Argentina, South Africa, India, Russia, Australia and New Zealand. Interestingly enough, these are all countries where the bioeconomy concept is being pursued today, often within the framework of explicit national strategies.

The reaction of the EU Member States to the bioeconomy concept was mixed: general acceptance, but very frequently in a wait and see mode. However, there were exceptions from the very beginning: The Netherlands, Finland, Germany and on industrial scales in France and Italy, the latter however without a strong state interest and involvement at that time. The same applied to the UK, where however British scientists played a very strong role in developing the use of biological resources for new bio-resources in industry.

During the following 14 months until the beginning of the 7th Framework Programme in January 2007, the capital role of Finland must be highlighted, which in the second half of 2006 took over the Presidency of the EU. Likewise, the role of EuropaBio, the European Association of Bioindustries, has to be acknowledged. Both actors were extremely helpful and active. Under the Finnish presidency, through EuropaBio, jointly with the relevant Finnish Minister of Trade and Industry, the ground-breaking document "Knowledge-Based Bioeconomy- a Policy Priority for the EU" [22] was published in November 2006. This document covered for the first time the whole spectrum of potentials of the KBBE as a policy factor, including market incentives for commercialization of bio-based products, the need to lower costs for Intellectual Property Rights (IPR) protection in this area, in particular for small and medium-size enterprises (SME), as well as the potential for a strong mobilization of new investors with increased risk capital. For the first time the potentials for biorefining, inspired by the large wood and forestry-based reservoir of biomass in Finland, were highlighted. However, possibly the most important message was the need for a more coherent political approach towards the build-up of a knowledge-based bioeconomy.

Thus, when the 7th Framework Programme started on January 2007, Europe was the first continent 'owning' an RTD Programme, which emphasized and supported bioeconomy as a strategic goal. During the following years of consolidation until the publication of the first genuine policy strategy on the bioeconomy in February 2012, there were two more important elements that should be mentioned here at European level. Firstly, the publication of the so-called Cologne paper under the German presidency, in which the strategic content of a bioeconomy, including impact on health and medical aspects, were presented in close cooperation among policymakers, industrialists and potential users in an extraordinarily comprehensive way [6]. Secondly, the first bioeconomy stakeholder conference, organized by the Belgian presidency in Brussels, as a way of celebrating the 5th anniversary of the KBBE in autumn 2010. This generated the model for the series of annual

bioeconomy stakeholder conferences in 2012 in Copenhagen, 2013 in Dublin, 2014 in Torino and 2016 in Utrecht and Bratislava.

The rotating presidency of the various Member States turned was used in many cases as the motor or driver to engage in bioeconomy with different emphasis on different aspects or priorities of bioeconomy. Some Member States, such as Finland and Germany have been very active in preparing policies and implementing activities in bioeconomy. In 2009, Germany created its well-known “Bioökonomierat”, a Bioeconomy Council to advise the Chancellor and the Federal Government. Just one year later, in 2010, Germany published its first national Research Bioeconomy Strategy with more than €2,4 billion. The development of the bioeconomy in other EU Member States was led by the Benelux countries, in particular The Netherlands, together with Germany and the Scandinavian countries. Later, these pioneer countries were joined by Ireland, France, Italy, Spain and Austria with regionally differing priorities, approaches and objectives.

The five years from the beginning of the 7th EU Framework Programme and the launch of the first European Strategy on a Bioeconomy “Innovating for sustainable growth: A Bioeconomy for Europe” [7], were marked by multiple, sometimes scattered activities within the EC and the Member States. However, these activities were always pointing into the same direction, that is, to the utmost use of the four unique ‘properties’ of biological resources. These comprise renewability, carbon-friendliness, inherent circularity, – particularly in closing cycles in waste processing, recycling and fostering bio-degradability, mostly in the format of cascades in biorefining activities – and, last but not least, offering new additional and better functions, such as higher stability, longer lifetime, less toxicity, less resources consumption, sustainability, etc.

It was therefore a logical further step forward that, in the context of the elaboration of the EU Bioeconomy Strategy in 2012, the idea of a strong new initiative on larger industrial scales gained momentum, to focus on the development of new bio-based value chains via new biorefining concepts. The model of public-private partnerships became the declared singled out model for such a joint undertaking and funding: the BBI, Bio- Based Industry, initiative became reality, representing the largest industrial and economic cooperation endeavour financially ever undertaken in Europe in the area of industrial biotechnologies, to be the future economic beacon of the bioeconomy. (See the articles by Bell et al. [23], for a more detailed analysis of the developments of the Bioeconomy Strategy in the EU in the Framework Programme Horizon 2020, and Mengal et al. [24], elsewhere in this volume, for the preparation, structure and objectives of the Bio-based industries Joint Undertaking).

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