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Towards bioeconomy development in Latin America and the Caribbean

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The Latin America and the Caribbean region is particularly well placed to both contribute and benefit from the emerging bioeconomy. The region is well known for its immense wealth of natural resources, in terms of land, water and biodiversity, all factors of increasing strategic value for a bio-based world. The rapid agricultural transformation occurring in many countries, and the way that the region has rapidly evolved to become a world leader in the exploitation of the new agricultural technologies and in the bio-fuels markets is a clear sign of this potential. A rapid analysis of supply and demand factors clearly points in the direction that, in any possible future scenario, achieving the needed new global equilibriums, has the LAC region playing a critical role. At the same time, the region has a challenge of its own. Hunger and poverty, although not as dramatic as in other parts of the development world, are continuing preoccupations in the region, especially in the rural areas. These are turning agriculture and biomass production into essential components of any hunger and poverty alleviation strategy. In this context, the bioeconomy in LAC has a dual set of objectives. At the global level, the region has a critical role in contributing to global food, fiber and energy balances, while improving environmental sustainability. And within the region's boundaries, the bioeconomy is a new source of opportunities for equitable growth through improved agricultural and biomass production. In a historical context the transition towards a LAC bioeconomy also offers the possibility of moving beyond the dichotomist vision of agricultural vs. industrial development that has dominated development strategy discussions since the 1950s, as agriculture – industry linkages expand beyond the traditional views to include a much more complex and strategic set of input – output relationships.

Introduction: The concept of the bioeconomy

The bioeconomy represents a vision of a future society much less dependent on fossil resources for its energy and raw materials' needs and where biomass produced in a sustainable way plays a critical role in the production of food, health products, feed, fibres and industrial products and energy. It is a response to at least four major emerging and converging global challenges: (i) the fact that over the next 20-30 years the world population will grow to nine billion people and consequently there will be the need to meet a global food demand, at least 50-70% higher than present, (ii) there is mounting evidence of significant natural resource depletion and, in some cases, exhaustion, (iii) even though we cannot talk about "the end of oil", all available evidence points to the direction that cheap oil is a thing of the past or cheap energy (e.g. shale gas) having incalculable high risks for the environment and (iv) climate change impacts are starting to show at different levels around the world, and are increasingly accepted as major future constraints.

All of these trends are making evident that "business as usual" is no longer an option and major adjustments in social and economic behaviors are in order. Novel approaches are needed to make a chance of seriously addressing the Millennium Development Goals (MDGs) of eradicating hunger and poverty (MDG1) and assuring environmental sustainably (MDG7). The problems are global and certainly not new. They have been there for a long time now. What is new today is the coming together of a better understanding of the problems that need to be confronted, the maturity of national and international political processes, such as those of the United Nations Conferences on Sustainable Development (UNSDC) and the International Panel on Climate Change (IPCC), among others, which provide the basis for the needed minimum political commitment for actions that, given the global nature of the challenge need also to be global. At the same time there is a science and technology base that offers concrete hopes and possibilities of an effective change in the course of action.

In this context, the bioeconomy is increasingly seen as an opportunity – while challenging – to coherently address the complex situation, while at the same time creating new sources for equitable economic and social growth. Its essence has been synthesized with subtle differences as "*the application of knowledge in life sciences in new, sustainable, environmentally friendly, and competitive products"* (EC 2005), as *"the aggregate set of economic operations* *in a society that uses the latent value incumbent in biological products and processes to capture new growth and welfare benefits for citizens and nations"* (OECD, 2006), and more recently as encompassing "…. *the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bio-energy"* (EC 2012) [1] . Irrespective of the emphasis – use of biomass, or the role of the new biology - the common thread in all these concepts is the more efficient use of the natural resources base and the increase of the knowledge intensity of production processes to better capture solar energy and transform it in other forms of energy and products. The sectors and industries associated with the bioeconomy are seen as having a " ... *strong innovation potential due to their use of a wide range of sciences, enabling and industrial technologies, along with local and tacit knowledge"* (EC 2012). Consequently, they show an important potential as a source of whole new value chains, with a reduced environmental impact, with promises for high and low-skilled jobs, helping to reduce poverty and continuing to improve the quality of life for a growing world population. In this sense the bioeconomy is a concept also closely associated to that of the "green economy"(GE) that has been put forward by the United Nations Environment Program (UNEP) in an effort to further operationalize the MDGs and the long standing objective of building a global society that equitably meets the needs and aspirations of the present without sacrificing the rights and opportunities of future generations (UNEP 2011).

Seen in this context, the bioeconomy is that segment (of the economy) building on improved uses of biomass and the opportunities emerging from the new biology and associated sciences. Previous cycles of modern economic organization and growth were dependent on the exploitation of non-renewable sources for the production of energy and chemical building blocks resulting from photosynthesis-based processes that took place millions of years ago. Today's bioeconomy value chains are evolving from renewable processes of what could be called "real time" photosynthesis. This process is already underway and showing impacts in a wide array of sectors, going from food and health to transportation, construction and, even, recreation. The greatest impact has been until now in the pharmaceutical industries, where modern biotechnology is already widely used (and accepted) both in diagnostics as well as in therapeutic applications generating a market that ranges in the tens of billions of US dollars a year (OECD, 2010). Since reaching commercial status 15 years ago, plant biotechnology has become one of the more rapidly adopted technologies in agricultural history, reaching more than 120 million ha of transgenic crops planted each year in more than 20 countries (James, 2010). In spite of the controversy and political discussions, agricultural biotechnology is sustainably evolving to become the standard of agricultural industry rather than the exception. In addition to transgenic approaches, plant biotechnology has gained wide application in non-GMO approaches accelerating breeding significantly. Today mainly by providing new and improved diagnostic tools for the detection of plant pests and pathogens, and in plant tissue culture for mass propagation or for the production of disease-free planting materials. In the future more and more complex traits are required and will become available by improved methods. Industrial biotechnology, ie the use of micro-organisms or enzymes for the processing and production of chemicals, materials and energy, is one of the most promising approaches to produce goods and services with increased economic efficiency and environmental benefits (WWF, 2009).The application of biotechnological knowledge will probably gain even more strength as the idea of a much more diversified biomass-based energy and industrial matrix gets established, linking both current and second generation biofuels to the production of biomaterials including biopolymers and bio-plastics for the chemical, construction and engineering sectors.

Moving towards an economy of new competitive bio-based industries and value chains will not only demand more carbon-efficient and sustainable primary production systems and more productive and resilient food chains, but also more effective innovation capacities and policies to mobilize the required knowledge base. Furthermore, the knowledge base for many urgent changes is already available and will continuously be expanded. The issue seems not to be whether science can deliver; the technical feasibility of the new concepts has been, in most cases, proven. Major limitations appear to be in the present level of understanding of the involved social and economic processes that accompany the emergence of the new sectors and ways of production, and questions regarding their implications, their costs and what are the policies and institutions that are needed to facilitate a rapid and equitable transition. A society less dependent on fossil fuels will be a very different society than the one we know today, more decentralized, less dependent on large scale for efficiency,

[1] Along the same lines the German Bioeconomy Council, defined the bioeconomy as «…. *encompassing all those sectors and their related services which produce, process or use biological resources in whatever form" (*German Bioeconomy Council, 2010)

with significant cyclic processes, with different inter-sector –rural/urban – networks, and with different international trade relations – as a consequence of the changing balance in strategic resources. All this is leading to a new economic landscape (comparative advantages, countries, sectors, products' competitiveness), and is demanding – as any new scenario – new policies, communication with and in societies and institutions to contain, explain and orient actors behaviours, to optimize potential benefits and minimize transitional costs for all involved.

Framed in this emerging context, this paper aims to contribute to the discussion of (i) what should be the objectives of the bioeconomy given the resources and specific conditions, in the Latin American and Caribbean (LAC) region, and (ii) what could be the main items in the discussion agenda "towards a bioeconomy for LAC", with a particular emphasis on the agricultural sector [2]. In pursuing these, this document is organized in five sections additional to this introduction. The second section is a brief discussion on some existing bioeconomy experiences in the LAC region. This is followed by a discussion on food security issues and the connection/relation between the bioeconomy and rural development opportunities (section 3) and a presentation of the alternative pathways that could be part of the building-up of the bioeconomy in the LAC region (section 4). Section 5 discusses briefly the institutional and policy implications required for moving from conventional to bioeconomy approaches, and a summary of some of the constraints that would need to be faced for successful implementation of those strategies. The sixth and final section offers some concluding comments for the paper.

Comparative advantages and pertinent experiences for building LAC's bioeconomy

The Latin American and Caribbean region is particularly well placed to both contribute and benefit from the emerging bioeconomy. Its extensive and diverse natural resource base – land, water, and biodiversity – paired with an emerging economy and growing human resources provides the region with an essential foundation for a solid bioeconomy. As a whole, the region is very well positioned in terms of agricultural land availability with over 50% of its lands classified as having agricultural potential (CEPAL, 2007), a situation only comparable in European dimensions, to East European countries, but more importantly, per capita land availability in the region is significantly above the world average of 0,2 ha/cap[3] According to the International Institute for Applied Systems Analysis (http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm) Latin America has more than 500 million ha in the "best suitability" categories and the largest expansion potential in the categories "very suitable" and "suitable", excluding forests. The projection for 2050 highlights that, even considering a significant population increase, more than 300 million has. could be brought into production without impinging on natural forests, with South and Central America representing about 25% of the land with "very suitable", "suitable" and "moderately suitable" cropping potential for cereals, more than 25% for the oil crops, about 30% for roots and tubers, and more than 35% for sugar crops (all cases for the intermediate and high input technological scenarios). All these figures highlight resource potential for the development of a bioeconomy contributing both to food security, supply of renewables and energy objectives, and with important income generation opportunities, as there are significant yield gaps across almost all product categories. In both sugar and oil crops current utilization vis-à-vis potential is very low and in most diagnostics a poor technological performance can be identified as the most relevant restriction to tackle for improving resource use efficiency[4]. Beyond this, infrastructure limitations are also a big issue, as most of the new areas are not close to existing markets so reducing their potential value.

A second set of key resources for the development of the bioeconomy in the LAC region, is its biodiversity endowment[5]. In this regard, Latin America also is very competitive, as it concentrates a number of the most important biodiversity hotspots of the world; seven of the nineteen LAC countries are considered to be "mega diverse" in terms of biodiversity resources present within their political-administrative frontiers (no other region of the world includes as many countries within this category). The countries of the region in the mega diverse group are Brazil, Colombia, México, Peru, Ecuador, Venezuela and Bolivia, but other three – Costa Rica, Panama, and Guatemala – have important National Biodiversity Indexes (NBI). Even Uruguay,

[2] This focus by no means implies that health and other sectors using or based on biological processes are of lesser importance in terms of their share of the size of the emerging bioeconomy, actually in many cases is just the opposite. The selection of a focus on agriculture related issues, is a reflection of both the need of somehow put boundaries to the discussion and also of the areas of expertise of the institutions participating in the ALCUE-KBBE project.

[3] The main source of information for this section is the FAO /I International Institute for Applied Systems Analysis -IIASA- study on Global Agroecological Zones (GAZ). For more information see http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm

[4] Agriculture for Development, World Development Report 2008, The World Bank, Washington D.C. 2008

[5] Understood as "*the variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it*" (http://cnx.org/content/m12151/latest/)

which has the lowest NBI in the region – 0,487 - ranks over most European countries[6]. The region is also a centre of origin and diversity of a number of species that sustain current world food supply (e.g., potato, sweet potato, maize, tomato, beans, cassava, peanuts, pineapple, cacao, chilli pepper, and papaya). The same applies for a great number of flowering plants with special compounds for food and agriculture, as well as for the biopharmaceutical, nutraceutical, cosmetic, and environmental industries (Roca et al., 2004). These resources offer substantial comparative advantage in terms of opportunities for value adding and sustainable exploitation using new biotechnological tools, an opportunity which is underscored by the dynamism shown by the world market for natural products, which between 2002 and 2008 increased by more than 170% (COMPES 2011).

Regarding water, the LAC region is also a global asset, containing more than 30% of the planet's fresh water (http://www.unep.org/geo/geo3/english/293.htm). This resource however, is somewhat unevenly distributed within the region, but less uneven than in other continents. Some extended areas such as the Pacific Central Plains in Central America, the coastal areas in Chile and Peru, the Patagonia in Argentina, and the Brazilian North East, among others, face either absolute or seasonal restrictions that substantially limit their agricultural production potential, in a context that is expected to evolve with climate change and needs to be monitored and anticipated.

The region's rich resource endowment has already served as a basis for significant developments towards a biobased economy in the region. Strengthening its traditional role in international agricultural and food markets through agricultural transformation processes which has not only touched traditional sectors, such as grains, oilseeds and tropical commodities. The region has made substantial in-roads in developing novel use for biomass e.g. in the biofuels sector as well as in key technologies such as biotechnological applications and eco-intensification practices.

At the present time, Brazil practically dominates the international ethanol trade market and countries like Argentina and others are becoming key players in the development of the biodiesel markets. Based on its strengths as sugar and oil crop producers, almost every country in the region has plans underway to increase its ethanol and / or biodiesel production in the immediate future. Brazil is expected to more than double its biodiesel production by 2011[7]. Argentina has increased its production to more than 3.0 million tons in 2010[8] and Colombia has advanced plans for a 300,000 tons palm oil based refinery, which is expected to enter production during this decade. Biofuel projects are at different stages of completion in Costa Rica, Honduras, Peru and Paraguay, among other countries in the region (IICA 2010). The importance of this potential and their tendencies are reflected in the projections of the role that bioenergy is expected to play in the future demand-supply equilibriums, where LAC appears as the only region in the world that would be able to meet its energy requirements based on "bio" alternatives. According to recent estimates (Gazzoni, 2009), this would require only a relatively minor increase in agricultural land being allocated to bioenergy uses; from 1,3%, currently to about 2,4% by the year 2030. Additionally, there are large and growing number of initiatives to potentiate this situation through small scale energy production either aimed at production in marginal lands in association with food crops (black beans-castor oil beans in the north-eastern Brazilian drylands, *Programa Biodiesel Combustivel Social*, see http://www.mda.gov.br/portal/saf/programas/biodiesel/2286313) or based on different types of agricultural residues and waste (see for instance . http://www.icidca.cu/Red/QueEs.htm).

The region is also a prominent player in the early stages of GM plants biotechnology exploitation. GMO technologies – herbicide tolerant soybeans and insect-resistant and herbicide-tolerant maize and cotton – were introduced in different countries of the region almost at the same time of their commercial availability in the international markets. Out of the more than 30 countries in the world that are using GM technologies at the present, ten are in Latin-America. Brazil, Argentina, Paraguay and Uruguay are currently planting more than a third of the total world area with GM crops, and are among the ten largest producers globally (James 2012). The importance of these advances is not minor. Even though conventional breeding technologies are rapidly evolving, GM technologies are becoming a key component in pursuance of both economic and environmental objectives. From an environmental perspective, GM technologies are already showing significant impacts in terms of Greenhouse Gas (GHG) emission reduction (Brookes and Barefoot 2010). Furthermore, it is estimated that due to the adoption of GM soybeans in Argentina international soybean prices are today 14% lower than they would have been if these technologies were not utilized (Trigo, 2011). Similar impacts have been estimated by Brookes and Barefoot (2010) for other GM crops.

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[6] Note on what is the group of megabiodiverse

[7] www.biodieselmagazine.com/article.jsp?article_id=1064 - 35k

[8] Kerlakian Carlos, "Biocombustibles en la Argentina" ppt, 3ra. Round Table on Responsible Soy, Buenos Aires, Argentina, 23-24 April, 2008.

Latin American countries can also boost internationally recognized experiences in some of the ecological intensification practices, especially "zero-tillage". This practice has been gaining force over the past 20 years and today is widely adopted in Argentina, Paraguay, Uruguay and Brazil, making key contributions to the expansion of agricultural supplies under improved environmental performance standards (Trigo et al., 2009). The net positive environmental impact of this practice has been in terms of retaining in the soil an amount approximately 50 million ton of carbon dioxide, in the case of Argentina and about 0,85 million ton in Paraguay and Uruguay (Brookes and Barefoot, 2010).

These resources and experiences highlight the importance of bioeconomy pathways for the LAC region and the substantive nature of the contributions that they can make both to global equilibriums and to regional challenges. It is of particular importance to point out that all these aspects have evolved out of spontaneous, market-oriented processes and should be carefully monitored regarding their future evolution and how they can be optimized in terms of both regional and global benefits. It is quite clear that whatever future scenario one anticipates for the global bioeconomy, LAC has a distinctive role to play in helping achieve the kind a of global food/feed/fuel balances that will be needed. At the same time, the region has a challenge of its own. Hunger and poverty, although not as dramatic as in other parts of the developing world, are still important throughout the region, especially in the rural areas, making agriculture and biomass production an essential component of any hunger and poverty alleviation strategy. In this regard, the bioeconomy in LAC has a dual set of objectives. At the global level, the region has a critical role in contributing to global food, fiber and energy balances, while improving environmental sustainability. Within the region's boundaries, the emerging bioeconomy is a new source of opportunities for equitable growth through improved agricultural and biomass production and employment opportunities.

In a historical context the transition towards a LAC bioeconomy also offers the possibility of moving beyond the dichotomist's vision of agricultural vs. industrial development that has dominated regional development strategy discussions since the 1950s, as agriculture – industry linkages expand beyond the traditional views to include a much more complex and strategic set of input – output relationships. The next sections of this note look first at two aspects considered critical for the regional discussion. A first aspect deals with food security and rural development opportunities and the policy and institutional situation. Then the discussion moves to presenting what would be the main pathways to consider in the development of the bioeconomy in the LAC region, and a review of what are the main constrains that need to be addressed to make those pathways effective.

Food security and local development opportunities

The bioeconomy concept based on the diversification and sustainable intensification of natural resources use implies a potential competition between food and energy or other uses. This has been a source of concern ever since the concept started to be discussed, but it has intensified in more recent times as a consequence of rising food prices over the last few years and the emergence of social conflicts and food riots in a number of countries (Rulli y Semino, 2007). As oil prices have increased and bio-fuel alternatives have received increased attention throughout both the developed and developing world, the issue of the impact of bioeconomy on food security (access, availability, stability and resource utilisation) has moved to the forefront of the discussion. The importance of the issue is not being questioned. Clearly, food security is closely related to land use and if resources are taken out of food production and allocated to other uses, surely there is basis for the stated concerns.
This potential conflict, however, has to be put in context and there are several issues that need to be put forward for a meaningful discussion. Not all countries are, in this respect, in the same situation.

The "land abundant countries", such as Ecuador, Surinam, Guyana, Paraguay, Uruguay, México, Perú, Venezuela, Colombia, Bolivia, Argentina and Brazil (IICA 2010), are certainly in a different position than smaller food import dependent countries, which are typically the most food insecure, given high dependence on imports of primary staple foods and exports of primary tropical commodities (FAO, 2008). Furthermore, however important biofuels are as demand-shifting parameters, they are not the only factor behind the recent evolution in the agricultural commodities markets, as the combination of a number of poor harvests, stagnant technological change and thus, small yield increases and a structural change in demand from a significant number of emerging countries' consumers, seem also to be playing an important role[9]. Agriculture has been underrated as a source of growth and with regards to its role in poverty alleviation.is reflected in a decline in investments across the board, including R&D, and also in the dynamics of crops' yield change which have decreased from more than 2% a year in the 1980s to less than 1% at present (CGIAR 2011).

[9] See: Trostle, R., 2008

The combination of all these factors should be explicitly brought into play before the final call of judgement in this matter can be made.

But even if the present tensions are to be related to the food *vs.* fuel / energy competition, in a longer-term perspective, the bioeconomy is most likely a positive rather than a negative item in the balance sheet. The essence of the concept as we have indicated above – is about more efficient and effective use of natural resources (biomass, biological processes), through an increased knowledge intensity, leading, eventually, to significant diversification and increases in production levels, making room for both more food and biobased energy alternatives.

A first issue that should be considered is in relation to the income impacts of bioeconomy-based options. These will be two fold. The poverty geography has significantly changed in the last decades, with urban areas concentrating now the largest numbers of poor, but the rural areas still concentrating the worse cases of food insecurity and poverty. Bioeconomy development can help improve both situations. Taking agricultural production to new levels of productivity and production will help improve food supplies to the urban poor, while at the same time improving food security in rural areas, which is mostly a consequence of poverty and lack of opportunities. Thus sustained progress in the agricultural business will also help improve food security for the rural poor through its income and employment linkages (von Braun and Kennedy, 1994; IICA [a], 2007). Bioeconomy opportunities may be linked to nearly any kind of plant material. As such, bio-based industries are well suited for local production, and as both engines for rural development and income generation. In developed countries, most of the available land is already being utilized, but in many of the poorer regions of the world, the proportion of unused land is still significant and that could potentially be used for the cultivation of energy crops (IICA [b], 2007).

Bioeconomy alternatives may offer new ways out of the vicious circle of poverty in which many rural communities find themselves when their land base is not fit for high yield food crop production. The issue is to move the discussion of opportunities beyond the present generation of plant-based energy alternatives, into strategies exploring more aggressively local biodiversity resources, and their relation not only to their direct income effects, but also bringing into play their potential indirect impacts through their beneficial effects on the consolidation of non-agricultural rural employment opportunities. In this sense, Henry and Trigo (2010) and Bruins and Sanders (2012) discussed the potential of small-scale alternatives and found that there is an ample spectrum of relevant opportunities for adding value at the local or on-farm levels related to bioenergy or feed stock production. Lack of electricity, which, in many cases, is one of the critical restrictions for better market access and income generation in isolated rural situations, can be resolved through micro units fed with local biomass primary material, and/or subproducts (cassava, sweet sorghum, sweet potatoes, bananas and plantains, plant and animal residues and waste), thus creating better processing and conservations alternatives. Rural processing for "intermediate" product supply can resolve transportation and logistic restrictions facilitating local production linkages to large-scale factories (i.e. pre-processing of cassava for starch production factories). Beyond the energy link, there also are the biodiversity valorisation opportunities in the form of identification of valuable functional components, as the basis for the development of "appellation of origin" systems that also represent income generation possibilities that should be factored in. These and other alternatives are being successfully explored in different parts of the world. However, they are still highly dependent on different types of "pro-poor (public) policies" (in the form of targeted subsidies, investments, training, information, advice….), or "corporate social responsibility" policies by the private sector, for showing a high degree of insertion of small-scale actors (Henry & Trigo, 2010). The road towards the emerging bioeconomy calls for the mainstreaming of these experiences into poverty reduction and rural development strategies and policies.

Linked to the above, but with an identity of its own, are the potential applications of biotechnology to increase global food supply. Until now, that potential has only been exploited in a very limited way and in relation, mostly, its transgenesis applications and in a handful of crops and traits – soybeans, maize, cotton, canola, herbicide tolerance, and insect resistance, among the most prominent. This is attributable to reasons more related to policy and institutional factors than to the actual lack of technological alternatives. Just as the bioeconomy is more than biofuels, biotechnology is more than transgenesis. Over the last years advances in genomics and other simpler, non controversial, applications of the new biology, have been monumental (see for instance Lusser et.al. 2011). However, they are still not fully incorporated into the toolkit to confront the global sustainability and food security challenges, and there are threads that even when such novel breeding technologies are clearly non-GM that unscientific applications of risk assessment cause significant hurdles to the application of these promising methods.

Fully exploiting these advances in production and post-harvest applications could not only make many of the resource competition issues being discussed today irrelevant, but also contribute to solve the poverty problem behind many of today's food insecurity situations.

Alternative pathways for bioeconomy development in Latin America and the Caribbean

Given the diversity of natural resources, economic and social characteristics and even the nature of each individual country linked to the world economy, there will be not a common pattern for bioeconomy development fitting the whole of the region, but a number of different pathways each reflecting different aspects and comparative advantages. But they all share the same principles aimed at a more effective and efficient use of biological products and processes for achieving specific societal goals. Given the comparative advantages and pertinent experiences in the LAC region relevant to the bioeconomy, as described above, it is possible to identify six distinct pathways, each addressing the common issues and objectives from a different vantage point (remark: this distinction in 6 pathways seems rather arbitrary from my perspective but does make sense from a LAC perspective, hence the adjusted sentence). These six pathways overlap in some aspects, but together offer a holistic approach for achieving the stated purposes in the LAC region. These six pathways include (i) biodiversity resources exploitation, (ii) eco-intensification of agriculture, (iii) biotechnology applications, (iv) biorefineries and bioproducts, (v) value chain efficiency improvement and (vi) ecosystem services.

The potential importance of the bioeconomy for the region becomes evident from some of the benefits associated to the already identified pathways. Biotechnology products have transformed commodity production in many countries of the region and generated billions in increased economic activities as well as significant contributions in terms of employment and other benefits. Bioenergy is a growing sector in most countries

in most countries of the region providing a solid basis for the diversification of the local energy portfolio and also significant contributions in terms of employment generation – mostly in the rural areas. Eco-intensification has made important contributions to agricultural productivity increases as well as a proved a relevant component for climate change mitigation strategies. The above mentioned levels potential loss reduction within existing biomass based value chains make more than evident the need for working at preventing waste and not just focusing in the re-use, or recycling of waste materials. Eco-systems services are by definition essential components of the types of social and economic behavior that will make the new bioeconomy successful, and the importance of biodiversity valorization is beyond argument once the nature of the region's resources is brought to bear.

The remainder of this section presents a brief discussion of each of these pathways as an introduction and guidance for the discussion of the institutional, policy and knowledge generation gaps that need to be addressed for them to effectively contribute to bioeconomy development. These aspects are currently under analysis in other project activities.

Biodiversity resources utilization, covers all scenarios where the differentiating element is the valorization (domestication, transformation, linking to market, etc.) of distinctive biodiversity (discovery of functional traits related to specific uses and sectors, development of new products through innovative transformation, market development for local products, etc.). In Latin America there are many crops that have never been exploited because they were toxic, had low yields, they were hard to get to markets, or just because they were not well known, but certainly given the nature of their components and the kind of scientific tools and infrastructure available today, they can very much contribute to the biobased economy as new industrial feedstocks or basis for new value chains in the phytotherapeutics, cosmetics, or tropical fruits and other areas;

Eco-intensification. Relates to agronomic practices directed to improving environmental performance of agricultural activities without sacrificing existing production/productivity levels. Eco-intensification covers a broad and evolving set of concepts having in common their departure from "business as usual" behavior usually over-focusing on maximizing yields. Eco-intensification aims to achieve a balance of agricultural, environmental, economic and social benefits, seeking more efficient use of energy resources and targeting at reduced use of fossil fuels, pesticides and other pollutants. Examples of specific eco-intensification strategies include no-till agricultural practices, precision agriculture strategies, integrated pest and nutrient management, at the more "production oriented" end of the spectrum and more socially oriented concepts such as that of sustainable land management where a greater emphasis on environmental functions is made. Beyond primary production the eco-intensification pathway is associated to the early concept of the clean technologies, particularly those aspects related to the use of bio-

-logical processes in support of industrial and other activities (waste waters treatments), although the mere use of biological resources or processes in *per se* insufficient, and effective environmental "goods" should be associated to deserve the link.

Biotechnology[10] applications (products, tools and processes), including industrial tissue culture, marker assisted selection in crops and husbandry, GMO seeds/ plants, molecular-based diagnostics, animal reproduction improvement through molecular techniques, modified enzymes, microorganisms and yeasts, etc.. These are applied throughout the whole spectrum of agricultural applications and extending both upstream into natural resources managements and downstream into the food, fiber and chemical industries and in bioenergy supply. Given the magnitude of the demands, modern biotechnology, is called to play a key role in solving the emerging conflicts[11]. Through the opportunities they offer in terms of new options to manage biotic as well as a-biotic limitations to production and productivity, biotechnology is re-setting the "limits" within which biological processes interact with natural resources – soil, water, solar energy – and opening up a whole new range of opportunities not only in food, fibre and energy production, but in almost every sector of the economy, including pharmaceutics and industry in general, triggering both changes in the production function in a number of sectors and products, and also affecting the production function of technology itself, by improving the efficiency and effectiveness of R&D processes. The fields of application are vast, though its becoming evident that substantial investments and institutional adjustments – including an enabling global regulatory environment – are needed to benefit from this potential [12].

Although there is mounting evidence that biotechnology will be in time one of the major elements shaping future technological trajectories, both in agriculture and manufacturing industries (Katz *et al*., 2004), in the more immediate future, however, it is quite unlikely that we can rely only on biotechnology. Thus production and productivity increases will continue to come from conventional animal and plant breeding and improved chemical technologies, with more efficient resource use and agro-ecological considerations becoming increasingly important concerns. Rather than going from a "green" to a "gene" revolution, the more likely situation is one of technological "hybridization" and "blending", with a shift from present day energy-intensive technologies to win-win alternatives that increase productivity while at the same time generating benefits in terms of natural resources management, or conservation technologies that integrally contribute to gains in agricultural productivity, with biotechnology having a much more important role in the tool-kit of research and technology development ("omics" and other molecular techniques), than at the product level. The difference between "traditional" (or conventional) and "modern" technological environments becomes also less relevant as information and management technologies "blend" with biotechnological tools and traditional knowledge on the basis on location-specific requirements. Advances in this direction are already underway with ecological and environmental paradigms being incorporated in the eco-intensification efforts.

Biorefineries and bio-products include the bioenergy sector and processes aimed at the substitution of fossil fuel industrial inputs. Examples are plant ethanol, biodiesel, biogas, and different green chemistry oriented activities. Biorefineries and bioproducts are one of the key components in the bioeconomy concept and, in their essence, are alike the oil refineries, facilities aimed at transforming biomass into a broad spectrum of marketable products and energy. Their importance is related the improvement of the efficiency and the spectrum of bio-based products. Efficiency mainly result from the possibility of decomposing the raw materials into different product chains, and from lowering the cost of the primary products. Biorefinieries open up value adding possibilities of agricultural activities and transforming the nature of its links to the rest of the economy, particularly with the industrial sector. In this sense biorefineries are the cornerstones to the bioeconomy response to high prices of oil and need for capital. Through the better life cycle performance of their products they are also critical in the environmental performance of a number of industrial and consumer products industries. Biorefineires also offer the possibility of a more diversified linkage structure between agriculture and the rest of the economy, and consequently a much more efficient use of biomass resources. A good example of this kind of relations is with animal feed: by biorefining the raw materials for animal feed, one can get a higher quality feed and many by-products not useful for

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[10] Biotechnology it is understood here as *the array of techniques using living organisms or substances derived from these organisms to make of modify a product, improve plants or animals or develop micro-organisms for specific uses* (Cohen 1994).

[11] For an extensive discussion of the role of biotechnology in breaking-up genetic ceiling and improving food security through crop diversification see Gressel, 2008-a

[12] Trade disputes related to GM soybean for feed imports to the EU from GMO exporting countries, are a good example of the problems that will need to be dealt with if the full benefit potential of the technologies is to be realized.

the animal, but useful in other value chains[13]. Additionally, small-scale biorefinery technologies are able to function with different crops feed stocks and require low investment per unit of product and speed-up and multiply impacts at local level. However, current developments in the region are essentially restricted to biofuel production with little further exploitation of the wider potentials, particularly in regards to value adding and local development opportunities. Issues to address in this sense, include a better understanding of the biorefinery concept, alternative biomass production strategies that lower restricting factors. These concepts need to include the nature of the linkages between novel bio-based raw materials and inputs and existing value chains, and the explicit actions that would assure that agricultural producers – particularly the small-scale – and rural communities to not only create but also retain bioeconomy value.

Value chain improved efficiencies, include activities that (i) reduce postharvest losses at whatever level they are occurring, and (iii) aim at developing the needed market links for innovative bio-based products. There is a common mistake in equating the bioeconomy with sustainability concepts. It must be made clear that bio-based options are not *per se* more sustainable. Resource over-use is always a latent issue and resource use efficiency is of no lesser importance in the bioeconomy than in conventional approaches. But the most important issue is related to the potential conflict in achieving the objectives of the bioeconomy to meet increased global food/feed/fuel demands (50-70% over present levels) without further encroachment of forest and marginal lands and at the same time using part of the biomass production efforts to replace present use of fossil resources. How to reconcile these seemingly conflictive tendencies is one of the key challenges in the transition to the bioeconomy, for which there are neither unique nor simple solutions. The final equilibriums will certainly be a complex mix of many new strategies. These will involve, among others, aspects such as the diversifications and expansion of sources of biomass, and more efficient use and processing strategies. Within the latter an immediate challenge in the transition is a more efficient value chain. At present over 40% of what is actually produced is wasted before it reaches its final use (UNEP, 2011). This represents a huge opportunity to start moving into bioeconomy strategies without creating additional conflicts and pressures on the natural resources base. What are the technological, logistical and policy options to improve chain efficiency are questions that need to be addressed. In addition, an aspect, which is often neglected, is the recycling and reuse of nutrients and other resources in agricultural production that have to be regenerated during processing as well as from the bio-based products in the end.

Ecosytem services include the processes by which the environment produces resources utilized by humans such as clean air, water, food and materials[14]. Given the special nature of the relationship and interactions between natural resources and economic and social activities in a bioeconomy approach an ecosystem perspective becomes a strategic component of any sustainable bioeconomy strategy. The bioeconomy is a response to a long period of resource over utilization and an attempt to readapt behaviors in the light of anticipated global challenges. Accordingly, implementation strategies can only succeed if the integrity of the natural environment is recognized throughout the decision making processes and the value of the different flows are appropriately accounted for. Within this general context the development of carbon credit systems, eco-tourism strategies and water management pricing and management mechanisms, are three specific entry points that should be considered in relation to ecosystems services in the framework of a bioeconomy approach.

Promoting the transition to a bioeconomy model

Existing experiences in Europe as well as the USA and several Asian countries, and also in some of the region's countries, such as Brazil in the case of biofuels development and Costa Rica in biodiversity valorization, highlight that policy and institutional dimensions are key elements in the transition from a conventional to a bioeconomy-based perspective.

A more extensive and efficient utilization of biomass based alternatives opens up a wide scope of potential benefits.

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[13] See Matthews and McDonnell (2009), and http://www.feedipedia.org/node/674

[14] According to the the Millenium Ecosystems Assesment (http://www.maweb.org/), ecosystems services can be of the following four types: Supporting services: The services that are necessary for the production of all other ecosystem services including soil formation, photosynthesis, primary production, nutrient cycling and water cycling. Provisioning services: The products obtained from ecosystems, including food, fiber, fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, ornamental resources and fresh water; Regulating services: The benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination, natural hazard regulation; Cultural services: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences – thereby taking account of landscape values

At the same time new issues are raised that need to be clearly incorporated into the policy and institutional environments for those benefits to materialize. Many of these issues related to the particular characteristics of biotechnological applications and how they are perceived, and differ from conventional technology systems. In addition, they arise from the new and different ways in which the output of biomass production processes develop and are integrated into the new value chains. They include aspects related to the comprehensiveness of the policies involved and the role played by policy in the necessary processes, the kind of science on which technology development is based and the type of institutions that are leading the process, the proprietary nature and investment requirements of the new technologies and the new regulatory systems, among other aspects.

The common denominator of the emerging system is the increasing complexity of the new environment when compared to that of existing conventional food/fiber agricultural systems. Table 1 summarizes the main contrasts that need to be considered (for a more comprehensive discussion of these aspects see Trigo, 2002 and Trigo and Henry, 2009)

The main contrast that should be highlighted is with respect to the policy focus and the type of instruments involved. Policy objectives and instruments need to be adapted to the different life cycles implied in the bioeconomy. Conventional policies evolve from "mature" stage situations. In the bioeconomy, most cases are in their early stages of development and in need of, on the one hand, incentive policies to attract and guide investments into the sector. On the other, sustainability instruments to assure best practices in natural resources management and preserve food – energy/other uses balances are needed. A bioeconomy policy environment needs to explicitly consider the natural resources/environment, energy, agriculture, industrial and trade policy domains. The experiences of Brazil, the EU and the US with regulations, taxes and market incentives aimed at the development of modern biofuels, are clear examples of how important the structure of these and other policies are to shape the direction of the new industries and their markets (EU example: Lead Market Initiative). However there are also warning examples, where policy intervention caused serious misconceptions with long-term consequences due to wrongly guided investments. Thus bioeconomy approach requires a more complex and evidence-based policy mix, for central issues, including feedstocks, input diversification, land use planning and industrial and consumer level – fair trade, sustainability and "green" certification, etc. – policies, reaching beyond the energy/transportation sector. In this sense, policies need to consider and promote socially acceptable land use and steer bioenergy development in a sustainable direction to avoid environmental and social damages. At the primary sector level, agricultural policy, including the availability of rural infrastructure, credit and land tenure will determine the scale and distribution of economic benefits. All these policies need to have a regional as well as a global component, as bioeconomy markets will develop in a globalised economy. Beyond the change in focus and scope of the policy environment there are several areas that need to be specifically highlighted for action. These include the science and innovation base, human resources development and social participation, and a number of specific regulations and promotion instruments that become essential for assuring a safe and sustainable bioeconomy development pattern.

Science and innovation

Two dimensions need to be clearly identified and promoted. There is no doubt that, science, new knowledge, is needed to solve the values of the

Table 1: Conventional vs. "Bioeconomy" oriented agricultural systems

Conventional food and fiber oriented agricultural systems	Bioeconomy oriented agricultural systems
Predominance of agricultural and food security policies Predominance of public good / strong participation and leadership from public institutions as drivers of new technological concepts Agronomic and applied sciences R&D most oriented to food production-productivity-quality related issues Relatively low investment requirements "Weak" intellectual property systems Low regulatory intensity Predominance of bulk marketing and logistical infrastructure, low product differentiation except for quality standards.	Policy environment integrating natural resources, food and agriculture, energy and industrial development dimensions Strong participations and leadership from the private sector in technology development Tech. applications closely linked to basic research Horizontal R&D systems ("beyond food"-natural resources use- value chain issues) High investment requirements "Strong" intellectual property protection systems High regulatory intensity Biosafety Consumer protection Increasing importance of value chain integration, product differentiation and standards, and market segmentation issues

Source: The author and on the basis of Trigo (2002) equation of producing "more with less", implied in the concept of the bioeconomy. But new knowledge alone will not do the trick if it is not effectively put to work in transforming existing production patterns; there is also the need to assure appropriate levels of innovative behavior by the relevant economic actors.

In spite of the relatively good performance on key components of the bioeconomy as biotechnology applications and eco-intensification practices, the region´s science and technology infrastructure in the LAC region is relatively weak. The high intensity of use of biotechnological applications in the region's agricultural sector is, indeed, a great advantage, with respect to the logistical and field experience in effective handling of one of the strategic components of the new production strategies. However, a closer look at the situation shows that regional science and technology systems have had little contribution and link to this, as most of the innovations involved have come from outside the region and domestic investments both in science and technology in general and in the biotech related fields in particular are dismally low (Trigo, Falck-Zepeda y Falconi, 2010). Up to 2007, more than 80% of the field trials of GM crops and 100% of the GM varieties in the field were technologies generated outside the region. This reflects not only the low levels of investments in biotechnology research – about USD 130 million for the whole region [15, 16], corresponding to a fourth of the investments of the largest multinational corporation. In addition, significant underinvestment in conventional agricultural research is present in the region, for which the average research intensity index is a litter over 1%, but with a large number of countries (8 in a 15 countries sample, showing negative growth rates during the first part of this decade (2001-2009) (Stads and Beintema, 2009). The extent of the knowledge gaps resulting from this situation emerges from the poor level of scientific production in the region. According to a recent study (Trigo, 2012) the total number of scientific papers published by researchers and institutions from the region in refereed sources during the period 2006-2011, is of the same order as that of countries like Canada or Spain, and only a fraction of Chinese publications in the same field. Furthermore there are large differences within the region, with only Brazil, Mexico, Argentina, Colombia and Chile showing significant figures (Trigo 2012). A similar situation exists in regards to patenting activity in relevant fields related, including the areas of bioenergy crops and processes (CEPAL 2011)

The relative weakness in conventional agricultural research investments is probably more damaging in terms of an immediate strategy for the development of the bioeconomy, than the low levels of investments in biotechnology. It is true that weaknesses in biotechnology capacities lower the potential value of biodiversity resources. But experiences around the world clearly show that a country doesn't need to have the capacity to develop the new technologies in order to benefit from them. Actually, in very few cases the whole cycle is domestic. Most of the successes in GM varieties have strong and significant international technology transfer linkages (Trigo et al., 2002). What is essential is the conventional research capacity to backcross new genes into the commercial genetic pool well adapted to local conditions. Conventional research is also essential as the source of knowledge on soils, pest, and other agronomic information. This provides the basis for novel eco-intensification practices. In fact, in the short / medium term the most likely scenario is the technological "hybridization", where eco-intensification practices and biotechnological approaches share the stage to move production pathways to higher sustainable productivity levels. In the long term, the latter, will however be essential to meet the dual food security-environmental sustainability standards implicit in the bioeconomy concept. (Trigo et.al. 2009).

In the above context, a key set of questions for moving towards a sustainable bioeconomy concerns the priority research areas that should be strengthened in the future (disciplines, type of resources, types of technologies, etc.), and the appropriate investment criteria that should be pursued. Also a closer integration of basic science with technology development and delivery systems, and effective incentive mechanisms for productive actors to assume the risks of mainstreaming the new, is essential and, in most cases, not well attuned. Science and technology investment levels, inter-institutional collaboration, including public-private joint ventures, among others, become key elements that need to be recognized and directly addressed if an appropriate environment for an effective research and innovation system is to be set in place.

Human resources and social participation

A successful transition to the bioeconomy will require both an intensive effort at human resources development and improved mechanisms for social participation.

[15] According to the OECD (2009) the seven largest multinational companies in the field were investing in biotechnology related R&D over USD 1.85 billion, with the largest of them – Syngenta – investing an estimated USD 510 million a year.

[16] The situation is even worse if disaggregated by country. In both cases about 50% of total investments are in Brazil and the five largest countries (Brasil, Argentina, Mexico, Colombia and Chile) account for more than 85-90% of total investments (Trigo, Falck –Zepeda y Falconi, 2010; ASTI)

Bio-based processes require not only a new technological base, which in turns reflects in a rearrangement of the scientific skills base for research and development. They do also need changes at the production and management levels as bio-based strategies, usually, are much more knowledge intensive than conventional approaches. A good example of these tendencies are eco-efficient agricultural approaches, where successful technological innovation is highly dependent both on sophisticated biological sciences capacities and production level human resources (farmers and extension services) able to understand and manage the intrinsic dynamics of biological processes. At a more aggregate level, bio-based strategies also change the established balances within a given society (local, regional, national, international). Access and resource use patterns, benefit distribution and many other aspects of the existing *status quo are changed,* creating the need for better understanding at the community level of the issues involved for decision making processes to evolve in the proper direction. There is need for identifying and managing the emerging trade-offs among the old and the new activities, between the different scales of application, between the short and the long run. At the same time the emerging ideas and processes have to deal to the fact that available knowledge about biological systems is usually low, while mythical, ideological and even religious aspects, are intrinsically linked to biological systems. Improved training at all levels, from primary education upwards, extension programs, the promotion of entrepreneurial capacities, and social communication and decision-making processes are key strategies in this sense.

Supporting new markets development

Future events are already starting to show in current situations, but are still not fully reflected in present market signals. In this context public policy and regulations have a critical role to play in triggering the needed new responses? Topics in need of action include the development of the appropriate metrics for the new processes, so that they can be adequately monitored, the already mentioned integration of policy domains (natural resources, agriculture, rural development, education, science and technology), the reorientation of public investments in infrastructure, education and science and technology together with new incentives to redirect private decision making toward the new areas of economic activity, improved IPR frameworks capable of effectively reflecting the nature of the new scientific and technological parameters as well as the changing role on natural resources in economic processes. All these must go hand in hand with other aspects such as biosafety regulatory frameworks and the development of market standards for bio-based products, among others. Actions regarding incentives and regulations for the bioeconomy should aim beyond traditional economic and science and technology policy instruments. Increased investments and better science focused on appropriate priorities are necessary conditions, but they should go hand in hand with other instruments addressing the human resources issues, IPR and biosafety regulatory systems and other actions directed to promote innovation and the development of the new markets for bio-based products.

(i) The IPR issues, are of particular relevance for LAC. At the general level, the growing relevance of knowledge intensity in production systems and the emergence of biotechnology bring about a noticeable displacement of the "technological space" in the direction of the private sector. Proprietary technologies grow in importance *vis a vis* the public goods dominance in conventionally oriented agricultural. This demands an in-depth and continues review of technology research and development policy and organizational systems, to recognize the more complex management requirements of R&D processes, and to establish adequate conditions for promoting investments and access technologies originally developed for other environments. An indicator of the importance of IP in general and of patents in particular, is what has been occurring in the area of biofuels. During the last 6 years 2,796 biofuel-related patents have been filed world wide, 1047 of them in 2006-2007. At a more specific level, IPR issues are a key aspect for effectively realizing the region's genetic and biodiversity resources potential, especially since to date the framework to regulate access and benefit sharing is still mostly under development. While many countries in LAC are active in the Convention of Biological Diversity and the International Treaty on Plant Genetic Resources for Food and Agriculture, at the national level there still is little in terms of concrete mechanisms needed for the effective transformation of potential into actual benefits. Policies in this respect do not only need to consider the promotion of private involvement in research and development activities. They must also include more global issues related to the creation of the appropriate environment for greater direct domestic and foreign investment biodiversity- valorisation business development activities.

(ii) Biosafety regulations, present a similar picture than IPRs.. From the point of view of the development of the bioeconomy, biosafety is a key issue, not only linked to present day biotech applications.

Future bioeconomy applications of many plant materials – i.e. for biofuel production – are highly dependent on genetic engineering and application of knowledge from modern plant biotechnology for their full exploitation in new uses, or production environments. In addition, one should expect a greater move towards developing, testing, distributing, and cultivating crop species in environments where their potential economic and, particularly, social and environmental benefits are still largely unknown. Working in this field is of particular importance for the smaller countries as it impinges on their ability to free ride on external R&D and capture spill-in benefits. Existing systems also discriminate against national public research institutions and national firms and their ability to become active players in product development – for instance, in biodiversity value adding initiatives. Having, usually, a weaker financial position than large multinational corporations, it is more difficult for them to bear the additional costs involved. An in-depth review and analysis of alternatives is a key issue for the future impact of bioeconomy strategies on the region's social and economic development opportunities

(iii) The development of new product and process standards, is also a key issue for the development of the bio-based products market. Standards are essential elements in aggregating initial demand and allowing effective communication among agents within a given market and across connected markets. They are the basis for market transparency by providing common reference methods and requirements in order to verify claims about these products (e.g. bio-degradability, bio-based content, recyclability, sustainability). They provide guidance to investment and other related economic decision-making. The experiences of the European countries with the Lead Market Initiative and of the US with USDA's Certified Biobased Product label, together with the minimum blend regulations for biofuels in many of the LAC countries clearly proof the importance and effectiveness of this type of incentive/regulatory mechanisms.

Concluding comments

The aspects discussed in this note highlight that even though there may not be yet an explicit discussion and effort directed to explicitly promoting a bioeconomy for LAC, the processes are already present and evolving according to market conditions based on the characteristics of the region's resources and modes of insertion in the international markets. This should not come as a surprise. The bioeconomy is far from an ideal model to be induced in the pursuit of desired objectives. It is rather a needed response to perceived global challenges; it is a process emerging from the need to confront the challenge of dwindling resources, climate change and growing global demand being built on the basis of the extensive and growing knowledge base accumulated over the last decades that make departure from previous behavior, not only desirable but possible.

In this context the LAC region has a critical dual role to play. Because of the weight of its natural resources and in global markets, under any possible scenario, its evolution is a critical component for the needed global food security and environmental equilibriums. At the same time bioeconomy development can be anticipated to make a significant contribution to domestic food security and poverty alleviation objectives at the national and regional levels. In line with this we have identified a set of six pathways, representing potential entry points for the promotion and implementation of the needed changes and also discussed some of the common constrains that need to be confronted for moving forward. The ideas presented do not pretend to be neither exclusive regarding options, nor extensive in the depth of the analysis. Far from this, are only a first approximation conceived to stir further discussion. Nevertheless, we hope to highlight two aspects, which to us are by no means of minor importance. One is that the transition to new situations where biomass and biological processes play a greater and more effective role in meeting the identified challenges will not evolve from a "business and usual" environment. The second, directly related to this, is that for taking advantage of the new opportunities significant policy and institutional changes will have to be mobilized.

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SEVENTH FRAMEWORK PROGRAMME

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