Chapter 2. Benefits and Challenges of a New Knowledge Based Bioeconomy

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Introduction.

Feeding a world population of well over 9 billion without significantly expanding the land area devoted to agriculture is one of the greatest challenges in this century. Apart from the dramatic increase in global food and feed demand, there is also a rapidly growing demand for non-food, non-feed agro-industrial products for applications spanning many sectors — industry, chemicals and energy. Meeting this demand will be a great test for human ingenuity to drastically increase the productivity on the fertile soils already in production, without causing land degradation. Climate change, water resource scarcity, increased climate variability and geopolitical uncertainties are however already today limiting agricultural production at a global scale. The era of plentiful and under-priced resources is hence slowly coming to an end and agricultural land, biodiversity, terrestrial, aquatic and marine ecosystems and corresponding ecosystem services are under increasing pressure (UNEP, 2014). A key question is therefore how humanity will meet a future massive bioresource demand in a resource efficient, climate smart and sustainable manner?

What today is considered as conventional high-input agriculture has been very successful in meeting an increased food and feed demand in most parts of the world, except in regions such as sub-Saharan Africa. This is largely due to a continuous improvement of crop productivity derived from crop genetic improvements but also through greater use of external inputs such as energy, fertilisers, pesticides and irrigation. This increased use of external inputs is also placing a burden on the environment and contributes to a significant part of global greenhouse gas (GHG) emissions. Agriculture is also the largest consumer of water and the main source of nutrient pollution of groundwater and surface water. Pesticide use is in many places a serious threat to human and environmental health. The increasing costs of inputs such as fertiliser, agrochemicals and energy also account for a large part of total production cost for farmers all over the world. Modern precision agriculture demonstrates promising opportunities to reduce inputs and improve resource and cost efficiency but such technologies are expensive and so far mostly used by farmers in the North.

As a response to high input conventional agriculture, alternative low input agriculture systems, such as organic and agroecological farming, have gained increased attention not least by farmers and consumers in Europe and United States. There is today increasing demand for organically produced food products in advanced economies demonstrating a promising commercial future for these production systems and their products. With particular crops and growing conditions, good management practices, input of nutrients from conventional systems and high labour input, organic farming can nearly match the yields of conventional systems (Seufert et al., 2012). However, for many crops, particularly cereals, organic agriculture results in low yields and would therefore need more land to produce the same amount of food as conventional farms. Such an expansion of land could in many cases result in deforestation and biodiversity loss, which would undermine the environmental benefits of organic practices. When impacts on indirect land use change are taken into account, low-intensity agricultural systems often have higher GHG emissions per unit product and are therefore often less climate smart than high-input agriculture systems (Leifeld et al., 2013;Tuomisto et al., 2012). Low-intensity agricultural systems are therefore deemed by many scientists to be insufficient to sustainably produce the bulk of the globe's cereal based food and feed demand (Seufert et al., 2012). They will thus not be able to provide sufficient agro-based goods and services to fully support the livelihoods of an expanding global population and the accompanying changes in lifestyles of an increasingly affluent world population.

An alternative and additional route to meet the rising demand for agricultural produce in a resource efficient and climate smart manner is to make more use of modern biosciences, including genetic engineering of crops. The benefits of this are exemplified in many chapters in this book, but in essence, through the rapid advances in bioscience it is possible to tailor make:

- Highly productive crops and crop production systems tolerant to biotic and abiotic stress, including disease and drought, and with an enhanced ability to absorb nutrients, limiting the use of pesticides and increasing the efficiency of fertilisers.
- Food and feed with improved nutritional characteristics, improving human health and animal feeding efficiencies reducing waste and livestock related GHG emission and making agriculture more climate smart.
- Productive and resource efficient crop production systems able to efficiently provide ecosystem services, sequester carbon and mitigate climate change.

Advances in biosciences can also result in crops or other biological systems (algae, microorganisms etc.) engineered to produce raw material direct for industry. This is propelling a transition whereby bio-based alternatives for energy, chemical and materials slowly are becoming more economic and mainstream and available in larger quantities. This has led to the development of the term *knowledge based bio-economies or KBBE* (European Commission, 2012). The development of bioeconomies is increasingly seen as a tool for creating sustainable economic growth based on renewable resources and can support a transition away from the fossil fuel economy. The development of KBBEs has also been seen as a tool to revitalise rural communities, supporting job creation and increasing the production base and the opportunities for local value addition and agroprocessing.

Table 1 Table on a selection of national bioeconomy strategies

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Governments around the world are now developing their bioeconomy strategies. A compilation of some recent national strategies related to the development of knowledge based bioeconomies is shown in Table 1. Further information on European bioeconomy strategies is provided in Chapter 16.

This chapter aims to describe the various challenges and issues a KBBE in Europe and Africa has to respond to. The chapter will also try to explain why modern biosciences, resource efficient agricultural production systems, innovative agroprocessing and value chains are important for both Europe and Africa.

What a Knowledge Based Bioeconomy needs to respond to.

Optimizing the Use of Biomass

Ultimately, a KBBE is largely about optimising the production and use of bioresources and biomass. The total annual global primary production of biomass is around 200 billion tonnes (Rosillo-Calle, 2012) and of this roughly some 12 billion tonnes are extracted for human use. Around 58 % of this is used for animal feed, 15 % for direct food consumption, 10 % as bio-based industrial feedstock and 17% as energy carriers (Piotrowski et al., 2015). The most important biobased industrial products are today paper, cellulose, building materials and fuel and to a lesser degree, green chemicals, bioplastics, composites, lubricants, and pharmaceuticals. The demand for the latter type of products may change as industries, not least in the chemical sector, are increasingly looking at phasing out fossil-fuel based raw material in favour of biobased renewables in their future production schemes. Markets for various types of biobased raw material for biofuels will also probably increase in the future. In this context it is however important to add that the world's energy demands cannot be met by biomass alone, but need to rely largely on other renewable energy sources such as hydropower, solar and wind.

In discussing the structure and features of a modern bioeconomy there is an opportunity to address sustainable increase in biomass production at full landscape scale, rather than the common focus on agricultural areas only. This would include discussions on improved, resource efficient and climate smart production under different regimes in different landscapes, including forests, grasslands, aquatic productions systems, and multi-functional landscapes.

Putting the Bioeconomy into a Broader Context

A general goal of a KBBE is to enable economic growth to be combined with ecological and social sustainability. It therefore needs to be a core element of sustainability concepts such as the “green economy”, decoupling economic development from resource use and environmental pressures. It also needs to be a central part of a circular economy, re-using, and recycling existing resources with the aim of reducing waste and closing material loops.

The development of the bioeconomy is indeed receiving increasing attention, and the transition towards a bioeconomy is often associated with increased sustainability (European Commission, 2012). However, there is also a controversy in scientific and public fora on whether or not such a transition necessarily will lead to a better, more sustainable future. Frequently mentioned problems are the competition between food and fuel production and the potential negative environmental and social effects of land use change and intensification (Pfau et al., 2014). It is clear that a KBBE is not a silver bullet solution to food security and increased agricultural productivity and cannot be considered as something self-evidently sustainable. Instead it needs to be designed, planned, regulated and supported in such a way that it effectively functions as a driver of sustainability in the development, use and reuse of bioresources.

There are also a number of other drivers affecting the production and use of biomass besides the continuously growing demand, which interact with the bioeconomy agenda both locally and globally. This includes drivers such as global trade, urbanisation, increasingly complex global food and bioproducts value chains, public debate and political responses on sustainability issues related to agricultural and forestry production regimes.

Lastly, while increasing food production and crop productivity is important, it is also crucial to address the logistical challenges (e.g. lack of storage and agroprocessing facilities leading to post harvest losses) and socioeconomic challenges (e.g. weak markets and poor market access) which currently severely limit access to food for many food insecure.

Biophysical and environmental challenges

Some of the most critical challenges and the potential response not least through using modern biosciences are described below. In a KBBE these challenges will have to be addressed in an integrated manner assessing the potential synergies and trade-offs between the different climate-, land-, water- and ecosystem-related challenges.

Climate change

Climate change is, and will increasingly be a key factor decisive for agricultural production on a global and local scale. Although some agricultural regions will benefit from climate change, negative effects such as droughts, new pests and diseases are expected to dominate on a global level (Foley et al., 2011; Smith et al., 2014). Thus, adapting crop production to a changing climate is imperative for any KBBE to keep providing a growing human population with food, fibre and fuel in the coming decades. The other challenge besides adaptation is mitigation which requires a drastic decrease in GHG emissions. According to the International Panel on Climate Change (IPCC) the AFOLU (agriculture, forestry and other land use) sectors were responsible for approximately 24% of total anthropogenic GHG emissions in 2010 (Foley et al., 2011; Smith et al., 2014).

An important task goal in a KBBE should therefore be to decrease our dependence on fossil energy and decrease GHG emissions. Here, bioscience innovation could help in the development of agro-industrial crop production systems replacing fossil fuel products (described in chapters 8-12 in this book). Modern biosciences could promote land use and agricultural systems reducing agricultural GHG emissions but also more adapted to climate change. In the long run, modern biosciences could promote agricultural systems that even may act as net sinks of CO_2. This would include an increased application of agro-ecological principles, smarter feeding systems for livestock improving livestock productivity or converting annual crops to perennial crops (described in chapters 7, 9 and 12 in this book). However, there remain environmental and socio-economic risks. If biomass is produced and harvested unsustainably, ecosystems will be damaged and potential reductions of GHGs will be reversed.

Increasing the efficiency of nutrient use

Modern agriculture is dependent on fertilisers. Production of nitrogen fertilisers is energy-intensive and results in additional GHG emission. The European fertiliser industry has made significant advances in reducing GHG emissions through minimising N_2O emissions in its fertiliser production processes. Further improvements are possible – although still not commercially viable – by using renewable energy sources in the production process. Phosphorus, a key component in fertilisers, is extracted at few places in the world and is likely to become more scarce and expensive in the coming decades. Fertiliser run-off causing eutrophication and anoxic zones in lakes and the seas is also a problem in many areas of the world. Therefore, it is crucial to develop agricultural systems that minimise nitrogen and phosphorus leaching and recycle nutrients. In large parts of Africa, the problem is the reverse, with nutrient mining and nutrient depleted soils and very limited use of fertilisers. So there is significant potential to improve overall biomass production while respecting the integrity of ecosystems through redistribution of fertiliser use from surplus to deficit regions. In this regard, systems and technologies that recycle nutrients and close nutrient loops between urban and rural farming areas will be important.

An important task in a KBBE is to create crop production systems that assimilate nitrogen and other nutrients more efficiently and hence are able to produce more biomass with less fertilizer input. Such crops are described in more detail in chapter 7 of this book.

Water scarcity

Water is increasingly scarce in many agricultural production areas. Improved irrigation techniques have a high potential for reducing water demand while increasing food production (Jägermeyr et al., 2016). Climate change will however aggravate that trend in many areas of the world, which may be increasingly affected by severe droughts and extreme weather conditions.

A central task in a KBBE is to create crop production systems with reduced irrigation demand which are more tolerant to climate change stresses, including drought, pathogens and new emerging diseases. Modern biosciences can support agroprocessing and agricultural value chains to improve their water and other resource efficiencies and convert agro-waste and urban waste that today pollutes freshwater sources to useful products such as bioenergy and fertilisers. Bioscience based crops tolerant to drought and waste conversion technologies are described in chapters 3, 5, 9, 12 and 15 in this book.

Land scarcity, land degradation and ecosystem services

At the global scale, agricultural land is becoming scarce and ecosystems and their services are under pressure in both Europe and Africa. Land use changes are cumulatively a major driver of global environmental change. The most important form of land conversion is an expansion of crop and pastoral land often at the expense of forests and other ecosystems providing environmental services, resilience and biotic diversity (Lambin and Meyfroidt, 2011). Overexploitation of agricultural and forestry land involves a risk of soil erosion, land degradation and at worst desertification. Converting woodlands, savanna and shrubland to agricultural land often leads to environmental problems such as loss of biodiversity and additional GHG emissions. All this limits the manoeuvring space for expanding and intensifying the use of arable land.

In Europe agricultural productivity and input intensity is very high. Agricultural expansion has mostly come to a halt in Europe, while most natural ecosystems have been modified or converted long ago. The situation is different in Africa, which has been claimed to have more room for agricultural land expansion (Deininger et al., 2011), but where expansion may have associated environmental and socio-economic impacts. Conversion of natural land and land degradation is ongoing in Africa and is in many places accelerating, while input intensity and productivity are still very low. Accordingly, bioresource production solutions have to be adapted to the respective context where inclusive innovation systems, benefit sharing mechanisms, knowledge and technology transfer will be important.

An important task in a KBBE is thus to develop highly productive crops and bioresource production systems which can meet the increasing demands with minimal expansion of agricultural areas, in order to keep ecosystems and their broad range of services intact. It is also equally important to develop bioresource production systems that contribute to preserving existing ecosystem services. A KBBE could also help to rehabilitate degraded land and improve soils. For a more extensive discussion on these tasks see chapters 4 and 6 in this book.

Development Challenges and Opportunities

Broadening the innovation agenda

Today a large part of the funding for bioscience R&D is targeted to the health sector. The promise of a modern bioeconomy is however to a large degree connected to agricultural biosciences supporting sustainable and productive agricultural systems. To realise the potential of a modern bioeconomy, increased public and private sector investments are needed on such things as (i) modern breeding platforms for crops more tolerant to drought, pests or poor soils, (ii) climate smart, environmentally friendly, resource efficient agricultural production systems, value chains and agroprocessing systems.

An important part of the bioeconomy innovation agenda is the potentially increasing role for new types of highly productive and resource efficient production systems for biobased synthetic food and feed (e.g. vegetal, algae, insect or microbial substitutes for meat or other livestock products).

An increasing proportion of bioscience R&D and innovation for a modern bioeconomy is developed in the private sector, and often by large multinational companies. Their primary interest is in developing and marketing bioscience technologies for high profit markets and "global crops" such as maize, soybean and cotton in which they can control parts of the value chain. These multinational companies are, however, often less interested in low profit, bioscience innovations of crucial importance to smallholder farmers. Governments and public sector actors therefore have a crucial role in promoting bioscience innovation in support of a broader innovation agenda.

In knowledge intensive areas such as biosciences, the existence of a strong public sector research base is therefore important to ensure that promising bioscience technologies are made available to a broad set of actors and for the public good. The public sector has a key role in promoting a broad use and uptake of innovations supporting inclusive economic growth and markets for more equal benefit sharing. In Africa in particular, public research organisations and universities are central in adapting modern biosciences to broader societal needs, including the needs of smallholder farming systems and local agro processing actors. Unfortunately, although public R&D is important for inclusive knowledge development, public research organisations and universities have not been effective in moving ideas and technologies beyond research into the market space. Linking public research organisations, universities and market actors is therefore key in improving the chances that the benefits of bioscience innovation also reach smallholder farmers, resource poor communities and a broader set of market actors.

The path from innovation to market is treacherous, and is likely to be even more so with innovations in biosciences. In the case of promoting new bioscience based agro-industrial pathways, current business models, often based on fossil fuel input, need to be altered. The barriers of doing so could be so high that many promising technologies fall by the wayside and fail to deliver their potential. Policies and government support are therefore needed to support the transition to knowledge based bioeconomies. This could be through providing incentives, such as supportive regulations, government procurement regimes, new infrastructures, financing support, tax reductions and business incubation supporting biobased SMEs and start-ups.

New value chains and converting waste to useful products

Modern agroprocessing and value chains are key components of a modern bioeconomy and have the potential to add economic value to primary agricultural production and convert biowaste to useful products, creating new opportunities for farmers and agroprocessing actors.

Bioprocessing and agroprocessing industries are entering a dynamic phase offering new opportunities for a multitude of new value chains, recycling energy and material flows both in Europe and Africa. In both these regions, there are large untapped bioresource production opportunities that offer building blocks for expanded utilisation of bioresources and the growth of agroprocessing industries. This includes the development of new biorefinery industries where modern biotechnology can add value to the primary production and convert agro-waste into valuable products such as feed, enzymes, fuel and at the same time minimise environmental impact.

While traditionally modern biosciences have been developed and implemented by industries, there are opportunities for much more rural participation in the innovation processes leading towards a KBBE. This is particularly true for countries in Africa, with large farming communities in search of new livelihood opportunities. For instance there may well be new products that could be derived through value addition to various horticultural products, traditional grains or natural products.

The European farming sector would greatly benefit from a larger variety of crop alternatives and value chains, which would support crop rotation and new value chain possibilities for farmers and agroprocessing actors. In many parts of Africa there is great need to add value and reduce post-harvest losses by processing and preserving crops of great importance for the smallholder farming sector. This includes crops such as traditional grains, vegetables, fruits, legumes and tubers, staple crops and crops more tolerant to climate variability and change such as cassava, millet and sorghum.

Broadening the value addition opportunities for crops and other bioresources would help revitalise farming communities in both Europe and Africa. Increasing local value addition opportunities to primary production would also be a method to support rural participation in knowledge based bioeconomies. Since it is often inefficient to transport biomass long distances, it should ideally be processed close to the site where it is harvested or acquired. This may in many cases overturn the traditional economy of scale model in favour of economy of numbers where local production plants are integrated with other complementary industries. It is important, particularly in Africa, that a KBBE supports broad based bioresource production and local value addition to primary produce that can be marketed in local, regional and rapidly emerging urban markets.

Resource allocation disputes

The central feature of a KBBE is that agricultural systems are not only producing food and feed but to an increasingly large extent also agro-industrial products in applications spanning many sectors. In the development of new non-food/feed biomass production areas conflicts of interest around resource allocation may arise, such as the food vs fuel disputes. In Europe there is the political debate on a ceiling for crop based biofuels. This debate reflects a fear of increased GHG emissions and negative socioeconomic impacts resulting from indirect land use change that may occur when increased demand for biofuel crops displaces other crops to new areas. Disputes such as these needs to be addressed, assessed and governed in an interdisciplinary manner.

In an African context, it is crucial that the development of agricultural systems producing a wider range of products, including bioenergy, does not negatively affect the ability of Africa to feed itself. Ideally, the development of an African KBBE and a linking of African farmers to a diversity of agri-business opportunities should instead lead to resilient production systems, increased food crop productivity and food production. In the long run this would assist African farmers to be more profitable and able to invest in higher production, increasing supplies of locally affordable food on African markets.

Social, policy and governance issues
Successful development of a sustainable bioeconomy will be determined not only by technical and scientific developments, but also by government policies, public opinion, cultural norms, and perceived social, economic, environmental, health risks and benefits. Ideally, a KBBE should bring prosperity to the parts of the globe where biomass is concentrated.

The KBBE is often connected to new large scale production regimes and foreign direct investment (FDI) in agricultural land. The increase of FDI in agricultural land has caused concerns relating to the perceived negative effects on local food security and livelihoods. International investments may however, if done right, catalyse the development of KBBEs and bring much needed infrastructural investments, technology transfer and new agribusiness opportunities from which all can benefit (Hoff et al., 2012). The question is therefore how investments in large scale land use in a KBBE, including FDI, can be optimised to minimise the inherent risks for all involved and also bring benefits to local communities. Ideally the development of KBBEs and investments in new land use regimes and agrovalue chains should be guided by governance mechanisms taking account of local interests and safeguarding local livelihoods, and food security. Institutions responsible for governing land use should be appropriately resourced for the task of attracting valuable investments whilst simultaneously monitoring and ensuring the interest and rights of those with customary tenure of the land (Fielding et al., 2015). This no small task which may necessitate cumbersome and technical processes such as amending existing and/or developing new regulations to frame monitoring and implementation of activities.

A KBBE requires effective governance of innovation, transparent decision making and coherent well anchored visions and strategies balancing risk and benefits. This includes the regulation of investments and production and trade of biomass and biomass products for inclusive social development and minimised environmental footprints. In the context of biosciences and particularly genetic modification, it will be important to find a balance between public pressure for stringent and demanding regulations and effective regulatory oversight not stifling bioscience innovation. To support such governance, there need to be more interdisciplinary assessments and a consideration of insights from a broad set of scientific disciplines, including environmental, social and economic disciplines, to build up a joint knowledge base and tackle sustainability issues. When measuring success in a bioeconomy it is important that this is not only limited to monetary or production measures. The hope for a bioeconomy is that success can be achieved through a promotion of equitable profit sharing, improvements in access to healthcare, education, and the introduction of social safety nets.

Getting Towards a KBBE in Europe

Europe, with its advanced agricultural, forestry, agroprocessing and chemical sectors has a great potential to become a globally competitive bioeconomy that shares knowledge and technologies with other regions globally, such as Africa. As discussed in other parts of this book, crop productivity growth and food and feed self-sufficiency in Europe are lagging behind many other parts of the world, due to a range of factors, including limited public investments in agricultural innovation and incoherent agricultural policies.

There is at the same time an increasing understanding and also demand within the EU that the high input agricultural system in Europe needs to be made more resource efficient, climate smart and sustainable. Within the European farming community, there is also a demand for a greater diversity of crop alternatives and connected value chains improving crop rotation opportunities and profitability for farmers and agroprocessing actors. The tools of modern biosciences and a modern bioeconomy are well suited to respond to these demands, addressing breeding targets of importance to European farmers, the forestry sector and biobased industries. These include:
- Crops tailored to lower levels of pesticide use and to agricultural practices requiring less energy, water, crop nutrients, and labour input (e.g. low tillage and perennial grains).
- Agro-industrial crops tailor made to enhance the production of certain desirable compounds or renewable components for an expanding biobased industrial sector
-A more productive, sustainable and knowledge intensive forestry sector converting biomass to a range of renewable products.

The development of such bioresource production systems would assist Europe in shifting its fossil fuel dependent economy to one in which health, fibre, industrial products and energy are to a larger degree than today derived from renewable biomass resources. This is also to a large extent outlined in the European Strategy and Action Plan *"Innovating for Sustainable Growth: A Bio-economy for Europe"* (European Commission, 2012).

Bioscience based breeding including genetic engineering is an important part of a KBBE. There is however great political and consumer based resistance in Europe against bioscience based breeding and genetic modification. This together with challenging and costly regulations stifling bioscience innovation have led many European plant breeding, life science and biotechnology companies to move their advanced bioscience innovation to other parts of the world. This has resulted in the interesting dichotomy that while many Europeans want to see a shift towards a biobased economy, Europe is losing some of the key tools in getting towards such a bioeconomy. Converting the promises of modern biology to accepted and widely distributed tools driving the development of a European bioeconomy will therefore be a challenging and long process. The process will require well anchored visions and strategies, political leadership, participatory governance, knowledge driven decision making and transparent systems of weighing risk and benefits with the various technologies and biobased production regimes.

Getting towards a KBBE in Africa

Africa overall is endowed with abundant natural resources, including arable land. These resources are however unevenly distributed, and the variety in agro ecological niches and biomass production conditions (such as availability of water, land, infrastructure, markets etc.) varies widely across the continent. Encouragingly enough, agricultural productivity in large parts of Africa is showing signs of steady improvement (AGRA, 2015), albeit from very low levels. Continued improvements in sustainable agricultural productivity, combined with viable agribusiness that adds value to farmers' production and improved access to markets, can drive broader biobased economic growth across the continent and improve food security across Africa.

In Africa, there is growing recognition that transition into middle-income nations, a key goal for many African countries, can be assisted through investment in and transformation into knowledge based bioeconomies. This is broadly captured by Professor Calestous Juma (Juma, 2011) who argues that modern biosciences can do for Africa what Information Technology has done for India.

Smallholders are the major producer of food in Africa for the foreseeable future. These smallholders, to a large extent both poor and vulnerable, are under increasing pressure to produce more and better quality food, but are facing severe difficulties to do so. African farmers are facing a host of challenges, including a serious lack of improved high quality planting material. African breeding institutions able to adapt modern biosciences to local needs, opportunities and cultivars would thus greatly contribute to food security and improved livelihoods on the continent.

The agroprocessing sector is in many Africa countries a vital part of the economy and also crucial for creating demand and value chain opportunities for African farmers. This sector however runs at a suboptimal level and produces large amounts of waste and severe environmental problems. Transforming the African agroprocessing sector so that it effectively adds value to the primary production and converts waste to valuable products in an environmentally friendly manner will be central in improving agricultural productivity in Africa. A more dynamic, resource efficient agroprocessing sector is also important for creating new jobs and raising profitability for farmers and agribusinesses in the region.

The transition to African knowledge driven bioeconomies will require an increased focus on agricultural innovation in areas such as sustainable agricultural intensification, effective food and agro value chains, resource efficient agroprocessing and market diversification. It would also include agricultural innovation transforming traditional staple crops, livestock, agroprocessing waste and other bio-resources to commercially attractive bio-products. For this to materialise, African countries need to tap into modern biosciences.

Capacities to adapt and use modern biosciences in various sectors are emerging in Africa, such as the Biosciences eastern and central Africa Hub (BecA) in Nairobi, Kenya. For countries in Africa to transform into knowledge-based bio-economies, well developed strategies linked to effective priority setting and targeted efforts are needed. Such efforts include increased funding for research and innovation, business incubation, techno-economic-environment assessment, market creation, policy development, institutional reforms, access to capital and increased international collaboration, not least with Europe. Well targeted funding from European donors and EU could play a catalytic role here. Donor support can also play a role in supporting broad assessments and interdisciplinary analysis supporting African development efforts, stimulating engagement, coherence and collaboration between different sectors (e.g. energy, agriculture and industry).

Collaboration and Joint Efforts

For Europe and Africa there is great potential to foster sustainable intensification of biomass production through increased cooperation. Trade between the two continents could be defined and regulated from a sustainability perspective. This would include the opportunities for sourcing and trading biomass from where its most efficiently produced, which in some cases may be in Europe and in other cases in Africa.

There are promising examples of collaboration between Europe and Africa, which could be nurtured and further developed. Horizon 2020 is a European Commission programme through which research initiatives are being commissioned during the period 2014-20. While Horizon 2020 focuses on European issues and competitiveness of Europe, there are also opportunities for European-African collaboration. Issues central to modern bioeconomies such as clean energy, low carbon economies, linking farmers to value chains, resource efficient agricultural intensification and agroprocessing are part of the Horizon 2020 agenda. Another example of successful collaboration is the Sida supported programmes, BIO-EARN and BioInnovate which are African-European programmes establishing collaborative bioscience innovation platforms in support of modern African bioeconomies (these programmes are described in chapter 15 in this book).

While the European support to build bioscience and technical capacity in the African public R&D sector has been significant, there has been limited support to bioeconomy business development in Africa. The African private sector is still too weak to grasp the opportunities of emerging African markets. The European agroprocessing and biobased private sectors have so far, with some exceptions, made limited attempts to establish themselves in African markets. European-African private sector partnerships are also rare. There are however significant opportunities for increased collaboration. Many countries in Africa are *de facto* bioeconomies but with a highly inefficient production and use of their bioresources and with lots of potential for improvements. Europe has a broad base of advanced life science and biobased companies with a high capacity to develop resource efficient food production and processing, modern value chains and technologies converting agrowaste to useful products suitable for African and European markets. Africa is also endowed with a rich diversity of genetic resources, agro-ecological niches and rapidly growing markets. Thus, the conditions for more investments in Africa by the European private sector, and increased European-African private sector collaboration are becoming increasingly attractive. Efforts towards incubating and supporting European-African private sector partnerships and also broader collaboration engaging public R&D actors in Europe and Africa would therefore facilitate a transition to KBBEs, both in Europe and in Africa.

Concluding Remarks
In this chapter we have discussed the potential of KBBEs to meet a rapid increase in bioresource demand in a resource efficient, climate smart and sustainable manner. We have also discussed the potential for countries in Africa and Europe to transform to KBBEs.

Bioscience innovation systems will be a crucial part of such a transition. In both Europe and Africa there is a multitude of potentially useful bioscience innovations in the public R&D pipeline but also in the private sector. To date the large majority of these R&D efforts have not moved beyond research due to a number of reasons including, weak market demand, negative public opinions, stifling policies and regulations, lack of business incubation, lack of capital and poor market communication.

To unleash the potential of the new biology and the promises of modern bioeconomies in Africa and in Europe, more emphasis needs to be placed on moving innovation from the R&D stage into practical use addressing societal needs.

Throughout this book there are many examples of current or new technology applications and policy measures that could help countries in Europe and Africa to move towards KBBEs.

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