Chapter 4
Strategies for a Rapid Transition to a Circular, Biobased Society

Lene Lange

Abstract Rapid transition towards circular, biobased economy includes upscaling current knowledge/technologies *and* at the same time investing in public/private collaboration for developing biobased technologies. What is ready to be done and where investment is urgently needed can be summarized as follows: Reduction of emissions through improved resource efficiency by upgrading waste; stopping loss of biodiversity by reducing pesticides and land-use; hereby strengthening industrial competitiveness, creating jobs of many skills and improve rural livelihood. An analysis is given for so far too slow implementation: Global climate agenda focuses on energy/transport, where CO_2 reduction is easily calculated, while indirect, but huge effects of improved resource efficiency are neglected. A strategy for rapid transition is outlined: unlocking full potential of the biomass, upgrading all components to the highest level. Upgrade all types of biomass – including industrial side streams and organic wastes. Communicate that biobased solutions address many societal challenges. Highlights are given of promising emerging bio-based technologies: negative emission technologies, circular textile industry technologies, BioAg, substituting pesticides, biological soil improvement and food and feed ingredients for improved health. Instruments and drivers are described, embracing that societal changes do not come from technology alone: Incentive structures, building markets; knowledge dissemination; transforming EU subsidies to drive implementation of greener solutions; international biobased collaboration to gain priority, including win/win strategy for growth economy collaborations; and dedicated bioeconomy alliance between Africa and Europe.

Keywords Circular biobased economy · Transition strategies · Valorizing industrial side streams · Upgrading organic wastes · Upscaling technologies · Public/private synergies · Emerging biobased technologies · Global climate change agenda · International cooperation · New alliance · Strengthening African biobased economy

L. Lange (✉)
BioEconomy, Research & Advisory, Karensgade 5, Valby, Copenhagen, Denmark

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1 Introduction

The first step forward, implementing the biobased society, is to use the knowledge, knowhow and technologies we already have to upgrade the biological resources, producing value added products from what now goes wasted. Societal drivers for doing this are many. Improved use of the biological resources already produced in agriculture, forestry and aquaculture contributes to reducing emissions contributing to climate change mitigation; strengthening industrial competitiveness, hereby creating more jobs for many types of skills and competences; stimulating rural development by developing local biobased activities; as well as giving more room for biodiversity, by producing more animal feed as well as non-food products with no use of land and pesticides. However, in spite of the many value adding societal upsides, implementing new and more responsible use of the biological resources is still moving too slow. The primary three reasons for this are as follows: The climate agenda is still, also globally, focused on energy and transport, which can be easily calculated in CO_2 Excel sheets, while effects of more responsible consumption are much more complex to calculate, but not less important. The concepts of biology, plant biomass structures, enzymes and microbial conversion are not easily communicated in one-liners. Lastly, we need to attract much more public attention to our messages. As scientists we are often so enthusiastic about the new possibilities, just opened for new frontier research that we forget to tell enough about all the knowledge we already have, ready for use. This chapter aims to provide a background for empowering many more (scientists as well as informed laymen) to communicate the message about what can be done much better already now, hereby advancing responsible consumption of the local and global biological resources, along with communicating the next opportunities that are ready for implementing in only a few years.

2 Unlock the Full Potential of the Biomass by Upgrading All Components to the Highest Level

The first and foremost thing to do to forward a rapid transmission to a circular, biobased society is to recognize biomass as a precious and finite resource, which should be used primarily when upgraded to its full potentials. Exploiting only the energy content of the biomass, by, e.g. combustion of wood chips or conversion of the biomass to energy only, biofuel will in the future most probably not be seen as sustainable in a resource efficiency perspective; the long term most precious in the biomass is the structures, not the energy, as we in the future can get ample supply of truly emission-neutral, renewable green energy from wind, sun and geothermy. The following example illustrates how structures of the biomass can be used for making higher value products: It is possible to produce prebiotic, gut-health-promoting xylan oligoes (XOS) from the hemicellulose fraction of wheat straw

(Dotsenko et al. 2018). Thus, higher value feed and food ingredients can be recovered first from the wheat straw biomass, and the residual cellulose fibres can be used as basis for making cellulosic biofuel or maybe even used for producing higher value products, by using the fibres, upgraded to new types of textile fibres. Another example is to substitute the current practice of converting a full crop or biomass into biogas only, a common practice in many parts of EU where biogas prices are subsidized (as the only type of biobased product). New innovations allow for making much higher value instead of using the biogas directly as bioenergy. Biogas can be upgraded to higher value products, separating biogas into CO_2 and methane, using the methane as building block for a new technology platform, and producing biobased jet fuel by a GTL (Gas2Liquid or PtX) approach. In this process, naphtha will be produced as a side product in big volumes, constituting a large supply of new raw material for producing bioplastic (reference, H Wenzel, SDU). Furthermore, biogenic CO_2 (as well as atmospheric CO_2) can be hydrogenated by splitting water (using affordable surplus windmill electricity) into hydrogen and oxygen. Also the residual bacterial biomass from anaerobic digestion can be developed into valuable, precisely administrated, soil improvement products. The press pulp after production of plant oils can be used as basis for producing protein-rich food or animal feed; and the press pulp after juice production can be used for making textile fibres or higher value antioxidant-rich health-promoting products (e.g. from black berries). The new type of grass biorefineries can produce alternative, local protein to substitute for non-sustainable soy protein, imported from South America. The classical exploitation of sugar polymers from seaweed can be developed into modern seaweed-based blue biorefineries, in which an entire spectrum of components can be valorized. Not the least are the highly interesting, almost totally, unexploited unique marine, health-promoting products with documented anticancer effect, as well as prebiotic effect, or polymers with wound-healing potential, of relevance for the growing issue of diabetes-related not easily healing wounds. The examples are legio.

The first products in the new biomass conversion bioeconomy are built on the following process: using plant cell wall-degrading enzymes to break plant polymers completely down to short sugar oligoes or even to monomeric sugars. Such simple sugars were then used to grow microbes (bacteria or fungi), which then produced fuel (e.g. bioethanol by fungal yeast), organic acids from filamentous fungi or building blocks for chemicals and materials (primarily produced by bacteria). Notably, with the emerging technologies in sight, it is obvious that we right now are facing a paradigm shift in bioeconomy. Fuel, materials and chemicals will in the future be possible to make from atmospheric CO_2 by a carbon capture and use approach (see Sect. 6.1). With this in mind the next level of bioeconomy approach is expected primarily to follow a new biorefinery approach: to valorize the biomass through biorefining technologies where nature's complexity is kept intact and used as basis for production of higher value products for health, food and feed ingredients, as well as circular use of fibres (e.g. textiles) and polymeric building blocks. One of the first examples of such a biorefinery was the Green Biorefinery introduced above. Here it is the primary product. The protein content of the green grass is recovered by a simple screw press treatment, separating the grass into juice and a fibrous pulp. The protein is recovered from the juice by precipitation. From the hemicellulose of the residual side stream, the fibrous pulp, higher value animal feed additives can be made in the following way: By enzyme treatment, the hemicellulose fibres are broken down to short xylan oligoes (XOS), documented to have prebiotic effect, improving gut health of non-ruminant animals and people.

Also animal-derived complex molecules are upgraded in next level biorefineries. Excellent examples of this new trend are that all parts of the milk feedstock or all components of a potato feedstock can be upgraded to higher value such as food and feed ingredients (link to Arla and KMC to be inserted). Next in line could be full valorization of the press pulp after olive oil, sunflower oil or rape oil, full valorization of by-products from flourmills and full valorization of higher value products from innards of pigs, cattle and chicken as well as from keratinaceous by-products such as chicken feather, fish skeleton and fish skin, pig bristles, etc.

Thus, for a rapid transmission to a more biobased society, it is important to introduce a cascading, holistic integrated approach to the biomass conversion processes. Utilizing all components of the biomass to their full potential is called the cascading principle. It provides basis for more responsible consumption, contributing significantly to climate change mitigation and climate change adaptation, using the harvest fully instead of letting 30–50% be wasted as is currently done globally. In a future perspective of planet health as well as from an economic point of view, it makes good sense to use the raw material as efficiently as possible. In Denmark, we have several examples of full industrial upgrade of all side streams of a given feedstock, which have been developed and commercialized and only built on business-targeted investments. Return of investments was secured by delivering highly positive business opportunities, providing for expanding business and improved international competitiveness.

3 Upgrade All Types of Accessible and Sustainably Sourced Biomass – Not Just Crop Residues – But Also Industrial Side Streams and All Types of Organic Wastes

In the next era of biobased industries, we expect many new feedstocks to be included, processed by many new even more efficient and cost-conscious bio-processing regimes. Further, new products, with new user-friendly functionalities will be developed, addressing a broader spectrum of societal challenges (see Sect. 4 below). In order to unlock the full potential and optimized valorization of conversion of all these types of biomass, it is essential to distinguish and address separately the three major types of biomass feedstock: residues from primary production, industrial side streams and wastes (mixed, wet and dirty).

Residues from primary production: Forestry residues can be upgraded to a higher level than hitherto pursued. Bark holds a high content of antioxidants and oils, as well as nutritional components. New initiatives have been taken, e.g. in Africa to make upgraded use of bark Thorben G. Nielsen, Pesitho, pers.com. Historically, in the Nordic countries a food security tradition existed, when the harvest failed: bark was mixed into bread and porridge. This practice is even included in poetry in the text of one of the most famous Norwegian songs (quote in Norwegian: "Frosten tock vor grannes aker; vi får atter blande bark i brodet"; in English: "The frost took our neighbors harvest; we will again have to mix bark in our bread"). However, new technologies have taken valorization of forestry residues into new levels: converting wood paste into a substrate for fungal growth. By adding a source of nitrogen, e.g. seaweeds, it is possible to produce single cell proteins for animal feed, simply by growing the highly nutritious fungal yeast on the N-enriched wood paste. The resulting product is not only protein-rich; it is also rich in vitamins (B12). And the fungal cell wall materials are documented to have prebiotic, gut health-stimulating effect. The evidence for such claims are very solid: For more than a decade the fungal yeast biomass, left after production of human insulin, was used as animal feed for very successful large scale production of pigs. The pig farmers reported on healthy, fast-growing pigs.

In fishery a new challenge, which can also be seen as an opportunity, is emerging. EU has passed a new directive, banning dumping of by-catch at sea; the by-catch must be landed along with the primary catch product. This directive has the effect that a new fish-based protein- and oil-rich feedstock will become available for upgrading. Such upgrading may even reach high-priced gourmet level products, made from parts of hitherto unexploited fish species. Furthermore, harvesting of invasive species and species which by climate change has started occurring in ecologically unbalanced volumes can provide a new short cut for making higher value products from aquatic animals (e.g. protein-rich sea stars, chitosan-rich medusas, or (farmed?) invertebrates such as sea cucumber). Also for agricultural residues, a lot of additional steps can be taken to ensure improved bioresource efficiency. The following example illustrates the unexploited potential: Discarded, odd-sized and odd-shaped vegetables and fruits along with foliar parts of (also higher value organics) vegetables can be upgraded to new types of salted, dried or microbially fermented vegetables inspiring high gourmet grade in Japanese cuisine as well as leading to more, locally, produced nutritious animal feed.

4 Upcycling of the Biorefinery Concept to a New Level by Growing Heterotrophic Organisms on Residual Streams, Creating a New Protein-Rich Biomass

The available and sustainably accessible biomass cannot deliver to all the needs of a more biobased society. The bioresources are finite. Therefore, biobased products will be in higher demand than what we can deliver by even upgraded use of all sustainably sourced biomass components through optimized biorefining. This is due to the fact that biobased products will be needed for fulfilling many purposes, addressing an entire range of societal challenges. The most ambitious, among the current generation of biorefineries, applies a cascading principle to valorization of biomass. It produces several types of biobased products, all in all making optimized use of each of the components of the biomass. However, heterotrophic organisms like bacteria, fungi and insects can be grown also on biomass residues with a low level of proteins (if nitrogen of other sources are supplied). This enables us to get more protein out of the biomass than the protein present in the biomass itself, achieved by producing, e.g. single cell bacterial, fungal or insect protein. And it also opens for the opportunity to produce more essential and nutritional food and feed ingredients beyond proteins, such as lipids, vitamins, antioxidants, etc. in large scale. This is doable because the heterotrophic organisms (bacteria, fungi or insects) secrete enzymes for breakdown of the residual plant biomass-derived side streams. For insects it is the bacteria in the insect gut which break down plant cell wall materials.

Another sustainable approach to produce higher volumes of compounds found in nature is by making microbes, grown in a fermenter that produces the compound for us, with no requirement for land use, with minimal level of emissions and no harm done to the organisms, which produce such materials in nature. One example is to produce higher volumes of new types of antibiotics and other health-promoting compounds found in nature, e.g. from rare plants or extremophilic microorganisms. For doing this we need even more research on heterologous expression of both small peptides and complex secondary metabolites. Another fermenter-based fungal production of essential molecules is to produce different kinds of milk protein and different kinds of meat proteins. This represents a new approach to contributing to meeting the global demand for meat and milk without burdening the climate with emission of the highly potent greenhouse gas methane. Also production of specialized molecules, such as flavours or pigments, can be done in fungal or bacterial strains, optimized for microbial fermentation. All in all, growing microbes in fermenters is expected to be one of the most important approaches to providing for global supply of sustainably produced food and also new types of natural products (including new antibiotics) produced for the health of man and animals by pharmaceutical industries.

5 Develop Biobased Products, Addressing a Whole Spectrum of Societal Challenges

The first bioeconomy era was totally dominated by making biobased substitutes for fossil-based products such as fuels, chemicals and materials based on upgrading/refining crude oil to a wide spectrum of products. This focus was developed to address the most burning global issue: how to switch from fossil based to bio-based. This approach – for short described by one line, “from biomass to biofuel” – has been so well communicated that it shadowed for the many other approaches for valorizing biomass including the approaches, where much higher economic and societal value could be generated than just making low-priced bio-energy. Now the trend is to develop a wide spectrum of biobased products. Products which together are addressing many societal challenges, as well as contributing to meeting several of the UN Sustainable Development Goals: More responsible consumption, achieved by using all parts of the biomass improved health of man, animals and plants, achieved through smart and affordable technologies; upgrading biorefinery side streams for combating lifestyle diseases and improving gut health; clean and safe drinking water through cutting down use of pesticides, achieved through the development of new BioAg products, which strengthen resilience and robustness of the plants, instead of killing the intruders, diseases and pests; giving more room for biodiversity, by making smarter circular uses of cotton fibres and by producing animal feed from upgrading of side streams and by producing animal proteins (milk and meat protein) for the future in fermenters, viz. with no use of land; and not the least to improve social inclusiveness by creating jobs and stimulating rural and coastal development, just to mention a few of the very wide spectrum of advancements, which can be delivered by the next generation of microbial production, providing many new products for the biobased and bio-produced bioeconomy.

6 Invest in Emerging Biobased Technologies, Taking Leapfrog Steps Towards a Biobased Society

6.1 Negative Emission Technologies

Seen from a global resource-approach, the emissions now leading to the serious threat of climate change can also be seen simply as “misplaced resources”. By capturing and upgrading such misplaced carbon resources, we can contribute to both reduction of climate change and resource efficiency. New negative emission technologies (NET) are going beyond the current focus on Carbon Capture and Storage. Captured carbon should of course preferably be used instead of just stored, making no value and with inherent risk of future leaks being harmful to climate. Biobased feedstocks, undergoing chemical and/or biological processing, can lead to new, highly needed NET innovations. Many such innovations can be embraced under the heading “Carbon Capture and Use, CCU”. The last few years of research have shown that this can be done, making significant value from such emissions and hereby providing routes for producing useful products, which have a negative carbon footprint. An innovation, which is much needed to be recognized, up-scaled and commercialized, is the following case: biogenic biogas can be split into CO_2 and methane. Such biobased methane can subsequently (by Gas2Liquid or Power2X, PtX technologies) be used as building block to produce liquid e-fuels. This process is enabled by using electricity (low-priced and zero emission energy) from windmills, made affordable especially in the periods where the windmills produce surplus of electricity. Even more methane can be produced from biogas if also the CO_2 from the biogas is converted into methane (viz. hydrogenated by splitting water into hydrogen and oxygen). Such methane-based e-fuel is especially suitable as substitute for the currently used fossil-based jet fuel, bunker oil and diesel for heavy transport vehicles (flights, ships and trucks), where no other sustainable energy resource exists today (batteries will be too heavy with current battery technology). From this process, making higher value from biogas, another useful compound (Naphtha) is produced as a large volume side stream. Notably, Naphtha is a promising building block for making both bio-plastic and new types of biobased synthetic textile fibres (see Sect. 6.2 below).

6.2 Circular Technologies for a More Sustainable Textile Industry (Re-use Textiles and Fibres)

The paramount challenge: Textile industry is the most environmentally burdensome industry next only to the oil sector, not just by emissions but also by taking land from food production and biodiversity and being amongst the largest consumers of water and pesticides. Circularity in the textile sector is a necessity! Opportunity: The textile sector is aware of its burning platform and ready for change. Ambitious goals have over the last few years been expressed by a broad spectrum of players in the fashion and textile sector, indicating that access to more sustainably-produced fabrics and materials is a necessity for the sector to meet their sustaníability targets. Further, EU has taken drastic steps to ban combustion of textile (from 01.01.2025), hereby, de facto creating big volumes of used textiles ready for upgrade. The Danish Bioeconomy panel recommended the Danish government to give priority to developing upgrade technologies for discarded textiles. Technical options for textile circularity: (1) use and re-use cloths; (2) downgrading outsorted textiles to carpets, stuffing, etc.; (3) circular, upgraded use of discarded textiles as raw materials for new textiles; and (4) cleaning and re-using fibres of outsorted textiles (Fig. 4.1).

6.3 BioAg Products, Substituting for Pesticides Through Improved Plant Robustness

BioAg products are a highly interesting and promising part of the biobased era. Biobased BioAg products (microbes, microbial enzymes or metabolites) can be used for addressing essential challenges, such as strengthening the crop plants (adaptation to climate change), as substitutes for pesticides, to improve soil fertility, and contributing to global food security as well as – most importantly – leaving more room for biodiversity.

Fig. 4.1 Danish Marine Proteins: Sea stars, when appearing in invasive amounts can be processed into protein-rich animal feed

Pesticide use is a threat for drinking water quality and safety as well as for biodiversity and health of man. The new era of BioAg products has already started. A fungus (a species of the mould genus *Penicillium*) has been developed into an already commercialized product, “Jump Start”. This type of fungus is known for having nutrient resource efficiency improvement effect by mobilizing otherwise for the plants inaccessible bound phosphorus from soil. A further effect of this microbial product is to give more robustness to newly germinated crop plants in case of spring draught. Other products, already available or being close to commercialization, have the effect of making the crop plants more robust to attacks of pests and diseases. Further, other microbially derived products can improve soil fertility by stimulating the soil microbiome, including a positive effect on the rhizosphere microbiome. The entire BioAg area is a very complex area as beneficial effects can be difficult to provide evidence for and therefore the mode of action being difficult to elucidate and document. The perspective for positive development of the BioAg product area is to be leveraged by improved understanding of microbiome composition and function, including the microbiome of the phyllosphere, rhizosphere or seed surface; all types of microbiomes are interacting with pests and diseases, being either soil-, wind- or seed-borne.

Finding substitutes for chemical pesticides is urgent. New very disturbing developments of fungal infections of (especially immuno-compromised) humans are taking place in growing frequency as we speak. Non-curable fungal infections are caused by fungal isolates (especially of species of the fungal mould *Aspergillus*) which have acquired resistance towards the rather few efficient fungal drugs we know of. Notably, the antibiotic resistance in the mould is not developed due to overuse of fungal drugs for treating humans. Research results point towards such resistant fungal strains that are developed as a response to frequent use of fungicides in rather high doses on agricultural crops. The world is in dire need for being able to reduce our use of pesticides, not the least fungicides. Examples have been recorded, where the patient survived leukaemia (or other types of cancer), but subsequently died from a non-curable fungal infection, invading the brain or the lungs.

6.4 New Biological, Soil Improving Products

Soil improvement has so far not been in focus for developing the biobased economy. However, selected side streams of next generation biomass conversion can through targeted processing be developed into optimized soil improving products (biochar and fibre-rich products). Notably, while we are getting closer to having a good overall grip on the carbon cycle on the planet, terrestrial as well as marine, we are slowly encountering that there might be new and unpleasant surprises in the nitrogen cycle. It has recently been shown that climate change may lead to a higher risk of nitrous oxide to be produced. Notably, laughter gas, N_2O, has approx. 300 times the greenhouse effect as compared to CO_2. More specifically, N_2O can be produced as an indirect effect of use of inorganic N-holding fertilizers. Another source of nitrous oxide is being produced by big container ships. It comes from N being present in the "dirty" bunker oil. N_2O is also produced in hitherto non-disclosed amounts by airplanes. Further, emission of nitrous oxide is also occurring, when low lying and wet agricultural soil is attempted cultivated.

Use of inorganic phosphorus as fertilizer constitutes another burning platform: inorganic P is getting close to being depleted. However, interesting new technologies have been made for recovering phosphorus by biological means: bacterial biomass from anaerobic digesters (AD for waste water treatment) are upconcentrating P in their bacterial cells. Such occurrence of phosphorus can be recovered from the AD bacterial biomass, hereby providing a new biogenic source of phosphorus for soil improvement, present in a form, which can be administrated precisely so that overdosing does not take place – as is the risk for both N and P from animal manure. A method for achieving circularity of nutrients by "Nutrient Capture and Use (NCU)" will most likely be the approach used already in the rather near future. Hereby two things are achieved in one go, rescuing resources, which are useful for improved soil fertility and being possible to administrate in correct doses; as well as reducing pollution of the nearby waters, by avoiding excess of run-off nutrients from agricultural fields; excess nutrients which could harm biodiversity. Nutrient Capture and Use (NCU) can be used in many parts of EU, where agricultural land is close to the sea as occurring, e.g. in the Baltic countries, Ireland, Sweden and Denmark. It is to be expected that such countries in the coming years will develop new Nutrient Capture and Use technologies. This could also be highly relevant for many other parts of the world, e.g. New Zealand, Bangladesh, African continent, China, Indonesia, the Philippines, etc. Overall, new types of biomass-derived or microbially derived soil improvement products are relevant for many parts of the globe, however especially a crucial need for tropical soils. Such soil types are under climate change challenged conditions under threat for being even faster depleted of soil nutrients. Sustainable and affordable, locally accessible soil improvement products are one of the single most important efforts for improving agricultural yields in Africa. Shortage of especially P but also N is one of the single most important reasons for lower yields in sub-Saharan African agriculture.

6.5 Climate-Friendly Food and Feed Ingredients for Improved Health of Animal and Man

A new generation of health-promoting, biobased products is emerging, different from, but supplementary to, pharma and drugs. Such new products are being developed based on increased knowledge and understanding of microbiomes: knowledge, not just about organismal composition but also insight in the functional role of the different groups of organisms in the microbiome and not the least, based on this gaining insight into how such composition and function can be modified by external interventions. The product candidates for such external interventions are gut health-promoting food ingredients and feed additives, stimulating the healthy part of the gut flora, hereby inhibiting the unhealthy part of the microbiome flora, to be used for one stomach as well as for ruminant animals and likewise, for new products for improved skin microbiome, as well as for improved, healthy microbiome composition and function in the respiratory track system. The next ambitious step to take (an emerging new innovation) is to develop biobased (probiotic or prebiotic) products, which can be documented to inhibit the replication of antibiotic resistance genes and a-biotic resistant microorganisms.

6.6 Biobased Public Health-Promoting Products

Valorization of marine products seems to have overall higher potential for health-promoting effects than the terrestrial products, e.g. for skin care, wound healing and protection against infections, microbiome boosters (in gut, skin and respiratory track system). A third biobased aspect, with strong upside for new health-related innovations to be gained, is to make new health-directed bioprospecting activities in the marine biosphere, to be applied for supporting both public health and the new generation of blue biorefineries. There is so much more to be found!

6.7 Improved Health of the Planet and Protection of Biodiversity by Biobased Products

Geoengineering efforts of relevance for the future health of our planet are currently taking place notably much below the public radar. The little, which is exposed or published, indicates a disturbing trend. Almost no biological expertise is involved. Therefore, possible risks to the biosphere are not fully taken into account. Further, on the other hand, the potential positive effect of new bio-relevant geoengineering mechanisms on the health of our planet is not included. Hopefully, action is taken to involve public researchers (here including biological expertise) also from Europe in the area of Geoengineering. 360-degree thinking and transparency are needed!

7 Instruments and Drivers for Speeding Up Transitions

7.1 Incentives for and building the market

(carbon tax, directives for responsible consumption, public procurement). Recently EU directives, aiming at improved circularity, improved resource efficiency and reduction of waste, have been decided upon in EU. To take full advantage of these new directives, upgrading technologies are needed to be ready for the new era of resource circularity. It is expected that there will be more such directives, taking EU towards more responsible use of natural resources also in the upcoming decades. However, no operational connection has been established between introducing new EU directives and ensuring that upgrading technologies will be among the priorities for the common EU research and innovation agenda. This dilemma has led to at least two burning platforms, where immediate follow-up R&D actions are needed: the directive for compulsory outsorting of textiles from waste (meaning that textile can no longer be burnt) and the directive on compulsory landing of fish by-catch (meaning that such fish can no longer be dumped at sea). Both of these examples of directives will lead to significant amounts of available and accessible feedstocks, with huge potential for valorization through circular upgrade. For the textile area, the challenge now is to asap develop new technologies for re-use of especially cotton fibres, hereby reducing the need for land, water and pesticides used for production of virgin cotton fibres; for making new types of fibres from leftover biomass from, e.g. the green biorefinery, or from leftover product from forestry and wood processing; and for using new alternative and local, sustainably produced plant fibres. The magnitude of making the textile sector more sustainable is put in perspective by the mere fact that textile industry globally is the most burdensome on global resources and climate, next only to the oil industry.

7.2 Transition through knowledge dissemination, public schools, life-long learning

To understand the basic concepts of a biobased society, you need to understand the basics of biology, microbes and plants. But more than that is needed. Also the microorganisms, forming microbiomes in your gut and on your skin, are of importance for nutrition, health and hygiene. However, biology does not have sufficient space and attention in the public school curricula to cover also such topics. This could be about to change! Corona epidemic brought hygiene into every people's home, work places and schools. Another sign of change was the message from IPCC, in fall 2019, that food practice (eating primarily meat based and wasting more than needed) is of significant importance for the climate. This was followed closely by alert warnings from experts and organizations that we lose biodiversity in a speed never seen before. Connecting excess in meat consumption with biodiversity loss is essential. Feed production takes up around 3/4 of the total arable land. Producing more feed from upgrade of residues and side streams can free land and space for biodiversity. Next came the message from industry that they need more bio-skilled people; and the message from the unions that their members need new skills and competences. Together this calls for concerted action, starting in public schools, to be given priority in higher education and offered broadly in life-long learning. The Danish Workers Union, "3F", took the initiative of making a folder communicating the basics of the "Biobased Society", written for their members, but used much more broadly by politicians and opinion makers and in schools. It is now translated into eight languages (Lange and Lindeblad 2016).

7.3 New, more resource-efficient and climate- and environment-friendly agriculture, forestry and fishery are an option within reach

Directives have been made in EU to introduce circularity as mentioned above, for plastic and textiles, and making landing of by-catch of fish compulsory. Next could be an obligation to adhere to resource efficiency like the already introduced industry regulation by Best Available Techniques (BAT, OECD) concepts. The BAT concept is already in operation and used as key policy tools for Pollution Prevention and Control in EU. The possible gain by introducing BAT concepts for improved resource efficiency can be illustrated by examples: Scientists at Wageningen Research Center, The Netherlands, and at Aarhus University, Denmark, have provided evidence for that changing from growing cereal (wheat and barley) to growing grass, to be converted in the green biorefinery into protein-rich animal feed, substituting for imported soy. This practice can lead to double yield of biomass per hectare as well as to reducing the excess run-off of nutrients with 50%, which again means reducing the pollution of the surrounding waters, currently threatening biodiversity. In fishery, in general only 50% of the total fish biomass is used for consumption. The other half is wasted. The cooperatively owned Codland Fish processing plant in Iceland has been able to increase this fraction to around 80 or even >90% being used for food purposes. Similarly, the Norwegian company Biomega has introduced technologies for upgrading of fish-cut-offs to higher value food ingredients, including fish proteins and fish oils (reference to NCM publication). For forestry, NGOs are arguing, evidence based and convincingly, for more untouched forest areas, while on the other side urge for phasing out fossil coal for electricity and heat has drawn forestry plantation practice in direction of producing wood chips for combustion, not just wood chips from forestry residues but downgrading entire trunks into wood chips. We need a new type of forestry: the climate- and biodiversity-friendly forest, from which can also be produced higher value products, upgrading wood biomass in much smaller volumes per hectare, but to much higher prices, providing also beauty for public recreational activities.

7.4 EU subsidies of primary production in the future linked to more green practices?

Subsidies especially for agriculture occupy a very large share of the total EU common budget. This harbours in itself a highly interesting opportunity. If for receiving EU subsidies it is required that you change agricultural practices, reduce GHG emissions, CO_2 and methane, cut down run-off of fertilizer to surrounding waterways, improve resource efficiency and/or protect environment and biodiversity, it can be the most potent driver for change in direction of a more sustainable Europe.

7.5 Social inclusiveness, creating jobs and rural development

Bioeconomy, new value chains and efficient upgrade of primary production are the strongest card on hand for stimulating rural development. Many societal and socio-economic challenges in our society are connected to the growing social and economic distance between urban and rural areas. This is of concern across the political spectrum and across the EU member states. The positive societal aspects of strengthening the biobased society have so far not been communicated broadly and in clear terms. We can and have to do better.

8 International Win/Win Collaboration, Contributing to a More Sustainable Planet

Opportunities for contributing more to both global sustainability and to EU competitiveness through international collaboration are almost not touched upon in recent high-level papers for Horizon Europe, HEU development. During most of Hor2020, two formal/informal drivers were prevalent for setting the scene for most of the international, third country collaboration activities in EU: A series of earmarked calls where international partners from specific countries were compulsory to include, in order for EU applicants to qualify and EU Commission (EC) bilateral initiatives based on opportunities identified during EC visits to such countries. However, during the last few years of Hor2020, interesting new international collaboration has started emerging, e.g. the portfolio of the EU Joint Undertaking, public private partnership, Bio-Based Industries (BBI) now includes a handful of interesting international win/win partnerships, reflecting growing interest in international RDTI investments in EU, creating hope for turning the trend prevalent for decades, where R&D investments in EU to a high degree led to business investments and establishment on other continents. Notably, new businesses are created based on advancements in research and technologies, funded by European RDTI investments. It is of utmost importance to continue and strengthen such development. Hopefully, the new EU common Research collaboration program, Horizon Europe, HEU, must include a strategically well-thought-through international RTDI strategy. To exemplify, two building blocks for such a strategy could be:

A dedicated bioeconomy alliance between Europe and Africa is timely and very important to have established as soon as possible, to work alongside with the already ongoing food-security collaboration programs between EU and Africa. If we do not expand from focusing only on food security, not on upgrading of residues, side streams and wastes, we risk in a few years to be in the situation that severe malnutrition and hunger is a reality in several parts of Africa – at the same time as 30–50% of all agricultural, forestry and aquatic production are still going wasted. We can help this not to happen by timely sharing knowledge and building partnerships in an alliance between Africa/EU for developing the African biobased bioeconomy.

Well-thought-through technology protection strategies and policies within the biorefinery area could pave the way for a highly interesting development: Noteworthy, a huge cumulative platform of biorefinery technologies are already published, in the form of scientific peer-reviewed papers, placed in the public domain. In the new biobased circular bioeconomy, common efforts could be invested into making such an open access technology platform more accessible for newcomers, including an overview of characterized commercialized enzymes and microbes and of open access microbial host systems (with no strings attached), developed for production of proteins in fermenters and of biorefinery technologies such as fermentation, product recovery and recirculation of processing water, etc. Such a platform of accessible knowledge, enzymes and microbes could serve several purposes: to function as an easy guideline to follow (for both academia and industries), when entering into international collaboration with, e.g. the BRICK countries, or highly industrialized countries like Canada, the USA and Australia making sure you are on safe ground in collaboration within the open access public domain. Further, such a platform would also be relevant for lowering the entrance threshold for new biobased EU companies to enter into the biorefinery/biobased area, hereby, paving the way for a more equal distribution of biobased industries in all regions of Europe.

9 Future Perspectives

Rapid transition to a more biobased society depends on decision-makers to see the societal value and opportunities in producing value adding products from the one third to half of all harvest, which now goes wasted, and on the establishment of integrated bioresource research collaboration throughout the entire knowledge- and value-chain, hereby opening for fast and efficient use of new knowledge and for combining known and novel technologies. For this to happen it is essential to relate the broad spectrum of biobased technologies to the wide range of societal needs: climate change mitigation and adaptation; feeding a growing population also under climate change challenged food production conditions (e.g. shortage of rain combined with high temperatures in Southern Europe and general climate change challenged conditions for agriculture in many parts of Africa); exploiting the new public health-relevant opportunities for making affordable gut-health-promoting food and feed ingredients from conversion of plants, fungi and algae and seaweed biomass; making building blocks for biobased materials and chemicals to substitute for fossil-based, through biorefinery and negative emission technologies (NET); making new, low-emission biomass derived soil improvement product; and making biosubstitutes for pesticides and building new knowledge for fighting the threat of growth in antibiotic resistance. Last but not the least, successful, just and timely transition of a sustainable, circular and biobased global society depends on that we stimulate international collaboration, promoting socially inclusive and responsible win/win knowledge sharing (Figs. 4.2, 4.3, and 4.4).

Fig. 4.2 Locally produced protein powder made from the juice of a screw press processing in the Green Grass Biorefinery. Production of the feedstock, perennial green grass or clover grass, as compared to growing, e.g. cereals, has an environmentally friendly profile: it can be cultivated without the use of pesticides, and it gives (under Danish conditions) twice as much biomass and only half the run-off of surplus nutrients per hectare. (Photo: Ida Marie Jensen, Aarhus University, Denmark)

Fig. 4.3 Seaweed, *Saccharina latissima*, cultivated in the deep and clean fjords of Faroe Island. The feedstock for making a cascading of products, including higher value gut-health-promoting feed and food products

Fig. 4.4 Small scale production of nutritious food in the form of oyster mushrooms, grown on the household's own coffee ground, otherwise wasted. (Photo by René Georg)

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