Chapter 12
Digital Revolution Advantages: Efficient Processes and Sustainable Feedstock

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12.1 Emergence the Food Value Chains: A Circular and Sustainable Economy Approach

The global economy thus thought so far must change from linear concept "*take-make-dispose*" to the circular concept of bio-economy "*take-make-recycle-reuse*". The linear concept of economy has proved to be unsustainable as well as was has been found to be too resource-intensive – incompatible with our climate change mitigation goals or the earth's finite resources – with consumption nearly twice what the planet can regenerate each year.

There is a huge literature focusing the attention to quantify the total food losses along all the supply chain with providing concrete evidence on the negative impacts (Parfitt et al. 2010; Buzby and Hyman 2012). The UN Food and Agriculture Organization investigated that 1.3 billion food wastes are generated each year along all food chains, amounting to one-third of all food produced globally for human consumption (FAO 2011.1). Notably, the economic impacts of food wastes generated from manufactures industries to catering, from retails to households are roughly around 680$ billion in industrialized countries and 310$ billion in developing countries (FAO 2019). Furthermore, most of food waste and biomass residues generated along the entire food chain are different both as to quality than quantity. From primary production (agricultural residues not exploited) to secondary production or (industrial processing residues or byproducts), and at last, to food wastes generated by household and catering services. In adding to food wastes, their packaging and not consumable material used to support their logistic and shelf-life along all food chain, add pressure on the environment and represent unsustainable costs for the whole community to the international level (Ferreira de Cruz et al. 2012, 2014; Williams et al. 2012). Global manufacturing consumes about 54% of the world's energy and a fifth of its greenhouse gas (GHG) emissions, and Industrial waste makes up to half of the world's total waste generated each year and social

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externalities were also observed, jobs were lost or displaced, and new ones took too long to emerge in multiple markets (EIA 2016).

The food waste valorization and re-use could seem hard especially in a short-time. Despite this negative impact, the food and beverage industry is characterized by a relatively limited number of multinational companies and plenty of small producers from around the world with a different food value chain from country to country (WEF 2018). This represents a facility for improving the efficiency of the food chains internationally, therefore an opportunity for policymakers and industries to collaborate with aim to implement prevention and mitigation measures to reduce by side the food waste and as well as to re-think and replicate good practices for their valorizing into new biobased products (Morone et al. 2019).

Sustainable production is the challenge for the coming years. The aim of the advanced Governments is to accelerate sustainable production projects as well as to leverage renewable resources as a tool for increasing the bioeconomy development based on green-business. Fortunately, several countries are actively implementing prevention and mitigation measures to reduce food waste (FAO 2014). The opportunities for reaching so have expanded with the advent of Fourth Industrial Revolution technology – an ecosystem that holds a dizzying amount of innovation across digital, physical, and biological fields. Examples of the latter technologies include sustainable and integrated technologies that add value of byproducts, considered industrial side streams, by producing marketable biobased products, from chemicals polymers to animal feed, from biofuels to bioenergy by using a new concept of valorization bio-cascading resources, at last (Buzby and Hyman 2012).

The Fourth Industrial Revolution for sustainable growth is already started for several manufacturing industries across major global regions with the aim to give a solid example as well as exploring the innovative pathways from the perspective of productive systems. As the volume of innovation explodes and interconnection among them, the cost of advanced technologies is plummeting (WEF 2018).

The combined effects of technology and its free-falling cost are accelerating progress in several sectors, exponentially. The technological advancements especially applied to the green sectors are being considered as leverage points for achieving sustainable production from cradle to grave. The results emerging for bio-economy is something entirely new – a framework, for the bio-industry, established on interconnected innovation able to grow the Fourth Industrial Revolution.

One of the most important challenges in the coming years will be to fully leverage digital, physical, and biological tech advancements to be able to predict and capture consumer demand, and connect it seamlessly through production operations and materials sourcing in a blueprint that minimizes the environmental footprint, (Mohamed Samir 2018).

Such innovation framework helps quantify the potential for sustainable value creation so that governments, bio-industries, and businesses can “re-design” and “re-thinking” their growth strategies accordingly. It also enables them to scale their bigger contribution towards the Green Agenda for Sustainable Development, thus enhancing economic and industry competitiveness.

Morone *et al*, explains how the development of sustainable industrial processes based on the valorization of non-preventable food waste is dependent on the refinement of the original resource, which produces value-added products. Refinement commences with the pre-treatment and extraction of components (e.g. proteins, lipids, and bio-active compounds) that can be used as value-added co-products in arising sector of Nutraceutical (Morone et al. 2019).

Other valuable components can be extracted, chemical conversion and bioprocessing can be subsequently applied to produce biobased products such as chemicals, polymers, materials, fertilizers, before being used for biofuels and or bioenergetic purposes. Thinking to use Biomass residues exclusively as an energy vector for RES Policies is being considered reductive by now. This new approach of thinking the waste lets drive the industrial community and focus the strategic investments from the Bioenergy Industry toward a more complex model such as Biorefinery.

That model should represent an example of a sustainable industrial implementation for coming years, therefore should be subsequently evaluated via process design and sustainability analysis.

Optimal Biorefinery models should achieve the minimum energy and water consumption, no generation of waste, high biomass to biobased product conversion yield, low production cost with a lowest environmental impact, or even negative cost-effective of the whole process, and at last, high societal acceptance.

Biorefinery concept grafted into the food processes production could bring an innovating production for green growth which can go a long way towards mitigating negative environmental impacts and decoupling the creation of the gross domestic product (GDP), and conserving the natural resources. The OECD Environmental Outlook to 2050 suggests that technological progress can indeed improve the intensity of economies in the coming decades (OECD 2012).

Indeed, developing and emerging economies can be key players, often heightening the importance of sustainability issues, especially for those industries classified as "Energy-intensive manufacturing" (food and beverage, pulp and paper, basic chemicals, refining, iron, and steel, etc.) (EIA 2016).

Furthermore, the food industry is classified as "energy-intensive" to "low-tech" Investment, (according to the OECD's technology classification based on R&D intensity relative to value-added), and could absorb innovations inside of own processes by including new Biorefinery concept with significant upsides. In fact, analysis by the United Nations Industrial Development Organization (UNIDO) claims that the food chain industries can sustain value-added growth across various stages of economic development.

Which then developments of the Fourth Industrial Revolution hold the most promise for accelerating sustainable production by using "*Biorefinery Approach*" especially in food value chains? Not seems to be there a specific technology able to constitute a strategy accelerated for addressing challenges of sustainability production, but the success key seems to be in the connection of the innovations in several sectors with the aim to improve the efficiency of the processes, and at the same time

valorizing the food waste along the chain. Five cross-food industry key trends are emerging with promising impacts among the whole food chain:

New materials from wastes and byproducts (BBPs – Biobased Products): A quarter of all food, measured by energy content, is wasted from "farm to fork", and 8% of the loss occurs both upstream that downstream value chain (FAO 2011; Lipinski et al. 2013). If at this value is also included the potentiality given by using chemical conversion and bioprocessing to produce a platform chemical able to supply new chemical building blocks for new materials (I.e. Biocolourants, Biofertilizers, Bioethanol, composite plastic film, biochar and bioenergy, biofungicides, enzymes) (Morone et al. 2019), the residues value increase fastly due to biomass still not exploited or few valorized to new resources. The biobased materials are poised to play a greater role across industries in the near term. It's expected they can become better than traditional materials, thanks to advances in nano-biotech, green chemistry, and smart lab technology, despite their costs not seems to be cheaper than substituted materials so far. Advances, however, will also depend on the speed with which new materials production and their processing technology can be scaled from research as far as the commercial production by using suitable investments.

Advanced rural systems: The sustainability challenges for food and agriculture in the short and medium-term are particularly acute. Agriculture accounts for 80–90% of freshwater consumption (Ranganathan 2013), and 24% of global GHG emissions (FAO 2013).

Agri-food systems contribute significantly to soil erosion and pollution because of fertilizers, pesticides, deforestation, and over irrigation.

The International Food Policy Research Institute indicates that 5–10 million hectares of cropland are lost annually to severe degradation and that declining yields can be expected over a much larger area (Scherr and Yadav 1996). Notably, Increased demand on land and water for organic feedstock for manufacturing makes agri-food systems a cross-industry issue. Thus, the greatest source of innovation for rural sector is in "precision farming, automated agriculture" and biotech, where the internet of things, data and analytics are coupled with crop science to optimize farming processes, and any decisions on every aspect of the farm, from fertilizer and irrigation to harvesting time, crop selecting and seed spacing. Advances will drive substantial yield gains. Improved planning, could help to address food scarcity, safeguarding human health, the ecosystem rescources, as well as reducing the risk of any investment to be implemented.

Agri-food Factory Efficiency: Agri-food Factory Efficiency: another important issue is factories' automation and their processes, from smart warehousing to advanced biobased products manufacturing by food wastes, to increase resource productivity, shorten supply chains, improving the logistic management, and reduce the energy consumption from non-renewable resources. Improving the efficiency of the factory allows to move closer to demand markets environmentally, but it's necessary don't leave out managing labor market changes.

Traceability: From tracing the origin of byproducts in the food industry, at to trace the food commodities, the technologies such as block chain coupled with sensors and data tags are enabling companies to provide verified information about the materials, processes, and people behind to each single food products and potential biobased products. Building concrete sustainability requires data flows interlinked among food supply chains, eliminating low-value-added processes, ensuring fair earnings for smaller suppliers, and enabling remanufacturing, waste recycling, with exploitation byproducts into new added value biobased products, (WEF 2018).

Digitalization will be always more important moving forward, smart technologies for tracking food quality while also providing healthy choices for consumers are becoming a priority in the near future. But at the single food, several direct and indirect wastes are linked. As household food waste is heterogeneous and thus very complex, artificial intelligence and neural networks are needed to quickly decipher the nature of the waste (or feedstock) so that it can be best used within a Biorefinery. Understanding the nature of incoming feedstock so that follow-on processes can be optimized to deliver the best available output represents one of the maximum priorities for a successful Biorefinery. This could represent a success key for future biorefineries operating by using food waste, working round the clock, envisaging and providing chemicals, materials, and bio-energy, as well as localized employment (Morone et al. 2019).

Forecasts for relating to food consumption to worldwide in 2050 will require a 70% increase in overall food production because of population growth and changes in consumption driven by an expanding middle class (FAO 2012) with demand for red meat and dairy products increasing by up to 80%, therefore of respective food wastes linked to the their production (Searchinger et al. 2013). It's desirable that every opportunity presented by the Fourth Industrial Revolution in a new circular economy context must be used to realize a global food production system that can address challenges with limited environmental impacts, negative cost of processes by valorizing biomass residuals and food waste, with the highest sustainability while harnessing growth, innovation and development opportunities. It estimated that opportunities to create value in agri-food value chains could potentially reach $2.3 trillion annually by 2030 (AlphaBeta 2016).

It will be also necessary to strengthen a key challenge among industry and government so that they working together to promote a strong, risk-based regulatory environment and funding program to encourage the research and commercialization of new technologies and investments among the entire agriculture value chain – from seeds to food packaging and waste" with particular attention to the byproducts valorizing in the view of circular economy (WEF 2018).

Lastly, a holistic systems approach considering prevention and valorization is required, therefore will be essential to stimulate the better connectivity between social scientists, economist, engineers and designers, physical, agronomists, and biology scientists in order to develop integrated strategies for minimizing and valorizing food waste. Such connectivity could minimize the impact of global drivers

and mega-trends. At last, education and awareness of citizens with regard to food waste e potential recycling and valorizing needs to be adopted as 'morally right', rather than 'morally wrong', philosophy with respect to food waste. It is also essential to promote the mentioned concepts since primary education up to tap high-level education with appropriate training programs (Morone et al. 2019).

Recently, data, investigations, and all many evidences collected so far, claim that food waste is a real problem, and visibly actual. Many solutions are ready to be used and promising technologies are commercially available, in both social and scientific realms. The key challenge will be their implementation and connectivity in a new concept of the circular economy.

12.2 Support of the Rural Economy in the Horizon 2020 Framework

In the last decade, the search for innovative pathways towards sustainability has been brought to the forefront of international agenda settings. While international organizations and institutions, such as the United Nations, ADB (Asian Developed Bank), Work Bank Group and the European Union (EU), mobilized around the grand challenge of sustainability to counter the climate change and poverty, on both a local and a global scale. During the latest decades, several policy documents and funding schemes started to consider and consolidate the "eco-innovation" as a key concept (or buzzword).

By focusing the attention at European level, eco-innovation is well-applied to food waste reduction as well as to the valorization of biomass residues, so much that it has been framed by the EU research funding programs, including Horizon 2020.

In particular, the EU program HORIZON 2020 has mostly constructed around the notion of "eco-efficiency" transversely applied to several fields including rural and food sector.

Interesting, in the context of Eco-effectiveness, eco-innovation always appeared in close relation to the terms "circular economy". Eco-innovation, that as a buzzword, has evolved through the years in favour of the new rising concept of the 'circular economy' became imperative in the new framework of Horizon 2020 (Colombo et al. 2019), so much that "systemic eco-innovation" and "circular economy appeared to be considered as synonymous (EU Commission 2018).

In the context of the circular economy, HORIZON 2020 responds to the key challenges our planet is facing for the years to come:

- adapting to and mitigating climate change;
- ensuring food security;
- safeguarding the natural resource base,
- promoting alternatives to fossilbased economies
- sustainably using resources while protecting ecosystems.

In addition, agriculture and food systems, forestry, the marine, and the biobased sectors will be at the very heart of the challenges to be addressed in the coming years.

Regarding the contents of the Work Programme, many of the challenges are addressed to the global nature, requiring the development of global solutions and opening up the innovation process to all active players in international cooperation with third countries and relevant international organizations or initiatives.

In this international perspective, the Work Programme of Horizon 2020 identifies 2 priorities for international cooperation that are focused on:

- *Blue Growth*: which intend to launch a flagship initiative for the South Atlantic Ocean, paving the way towards an 'All Atlantic Ocean Research Alliance', as well as a flagship on the "Future of Seas and Oceans" in line with the G7 Initiative, and at the same time to reinforce cooperation with partners in other regions such as the Baltic Sea and the North Sea, the Mediterranean and the Black Sea.
- *Sustainable Food Security*: with the aim to continue supporting flagships initiatives with China and Africa on Food and Nutrition Security and Sustainable Agriculture (EU Commission (a) 2019b).

Concerning the mentioned challenges applied to the EU Context, the Work program of HORIZON 2020 focuses five priorities:

1. *Addressing climate change and resilience on land and sea*: Climate change is one of the biggest challenges Europe and the world are facing. The primary sectors covered by SC2 (Table 12.1) are among the most important sources of CO_2 emissions and are highly vulnerable to climate change. At the same time ecosystems like forests soils, and oceans are major carbon sequestration reservoirs (i.e. Organic Carbon, and salts of Carbonate). The R&I actions in this work program support meeting the ambitious climate targets calibrated on needs for food, feed, biobased products and energy of 10 billion of the global population by 2030.
2. *Making the transition towards a circular bioeconomy*: R&I actions across all SC2 (Table 12.1) sectors support resource-efficient production and distribution systems, value-chains based on new and more efficient use of wastes, residues, and agroindustrial byproducts, as well as new business models able to enhance the EU natural capital. It is essential, therefore, that European Commission's Circular Economy Package is implemented.
3. *Fostering functional ecosystems, sustainable food systems, healthy lifestyles*: Ensuring long-term food and nutrition security and sustainability of food systems requires sustainable management of Environmental resources (i.e., land, soil, water, biodiversity) as providers of terrestrial and aquatic ecosystem services. These services are key to the basis of the whole food chain, nutrition, lifestyle, and health. The investments in this section of the Work Program focus on future-proof EU food systems to make them more sustainable, resilient, responsible, diverse, competitive, and inclusive.

Table 12.1 Horizon 2020 work programmes, eco-innovation fields applied to the food and rural sectors

Section	Work programme[a]	Number of calls for proposal with keyworkd Eco-innovation in Horizon 2020 (2014–2020) (Colombo et al. 2019)	Number of call for proposal with keyword Eco-innovation applied to food and rural sector and in Horizon 2020 (2014–2020) (2014–2020) (our elaboration)
ES – excellent science	1. General introduction	0	
	2. Future and emerging technologies	0	
	3. Marie Skłodowska-curie actions	0	
	4. European research infrastructures	0	
IL – industrial leadership	1. Leadership in enabling and industrial technologies introduction	1	
	2. Information and communication technologies	0	
	3. Nanotechnologies, advanced materials, biotechnology and advanced manufacturing and processing	4	
	4. Space	0	
	5. Access to risk finance	0	
	6. Innovation in small and medium enterprises: SMEs instrument (phase 1 + 2)	8	4
	7. Biobased industries join undertaking BBJ	0	4
SC – societal challenges	1. Health, demographic change and wellbeing	0	
	2. Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy	**6**	**15**
	3. Secure, clean and efficient energy	1	
	4. Smart, green and integrated transport	0	
	5. Climate action, environment, resource efficiency and raw materials	29	4
	6. Europe in a changing world e inclusive, innovative and reflective societies	0	
	7. Secure societies e protecting freedom and security of Europe and its citizens	0	
	8. Spreading excellence and widening participation	0	
	9. Science with and for society	0	
	10. Communication, dissemination and exploitation	0	

EU Commission (c) (2019d)

4. *Boosting major innovations (inland and sea) new products, value chains, and markets*: Innovation is at the core of EU policies. Demonstrating and scaling up new technologies and business models that create breakthrough innovations are crucial for ensuring the long-term competitiveness in several sectors. But scaling up of innovative new technologies represents a high commercial risk for private investors, especially during development stages. Thus public investment is essential during the early stages, to ensure the creation of sustainable value chains, resulting in new jobs, products, and services in the years to come.
5. *Developing smart, connected territories and value chains in rural and coastal areas*: Helping the rural and coastal areas to meet the wide range of economic, environmental, and social challenges of the twenty-first century is one of the key challenges for Europe. This priority addresses the territorial dimension of Research and Investments actions in primary production, the food and biobased industries, most of which are located in rural and coastal areas. R&I activities aim at the better capitalization of territorial assets, taking account of long-term drivers to open new sustainable avenues for business, services, and value chains in support of rural and coastal communities, promoting new partnerships between producers, processors, retailers, and society.

The Horizon 2020 funding program, therefore, embraces several targets in according with the European policy established. The Rural policy focused on food supply takes into account the typical EU rural structure and its potential network of supply. In fact, rural regions make up roughly half of the territory of the EU-28, with just over one-quarter of the population living in these areas. This background lets to understand how is needed to invest in eco-innovative systems of food chains beginning from the rural sector.

By building innovation capacity and implementing innovative solutions, rural and sparsely populated areas could overcome their inherent challenges and remain viable business locations as well as sustainability centres. There are many aspects of EU rural innovation characteristics of innovation ecosystems, the conditions for the local business sectors, industrial diversity, access to physical and digital infrastructure, relations with urban counterparts for example.

The HORIZON 2020 Platforms and HORIZON EUROPE offer a range of calls, tenders, and prizes aimed to promote inter-projects, international cooperation for several fields, and capitalization services to reinforce the different approaches and identifying synergies and good practices.

Notably, the whole funding program HORIZON 2020 has launched by the EU Commission during the last decade, dedicating part of own Investment Agenda €1.3 billion, and organizing specific opportunities for rural, Agroindustrial, Bioenergy, and Biobased sector, through invitations to submit the innovative proposals in several sections (EU Commission (a) 2019b).

In particular, the Work Programme is structured around four thematic sections:

– "Sustainable Food Security",
– "Blue Growth",
– "Rural Renaissance",

– "Food and Natural Resources"
– "Thematic Investment Platform on Circular Bioeconomy".

Within this thematic-section, a number of topics contribute to the Focus Areas:

– "Low Carbon",
– "Circular Economy"
– "Digitisation".

In particular, the *SC2 section of Work Programme*[1] focuses on the sustainable management of commodities land uses, and water managment, with the aim to secure healthy food as well as to preserve public assets such as biodiversity and clean water.

A specific investigation has been made among several sections and work programs of HORIZON 2020, in order to highlight the funding opportunities relating to eco-innovation, with particular attention to the food and rural sectors, Table 12.1.

EU Commission focused more efforts to counter the food waste along all the chain. Annually in the EU Countries roughly 88 million tonnes of food is being wasted along the whole agri-food value chain, from primary production to final consumer, with consequent high environmental, social and economic impacts (EU Commission 2016). The problem is particularly amped up, and therefore worrying for perishable foods. Reducing food waste, primarily through prevention, efficiency along the chain, recycling, and waste valorization into the new products has enormous potential for ensuring sustainable food and nutrition security, reducing environmental impacts by improved resource use efficiency. Nonetheless, reducing food losses along the agri-food value chain represents a target not straightforward to reach, because it's resulting of many and interlinked factors. Many investigations have been carried out to know the causes, and many innovative solutions are already available. It remains, therefore, urgent need for their demonstration and market replication to different levels, with aims to avoid the burden-shifting of food waste from one stage of the agri-food value chain to another.

Part of the calls focused on food waste in Horizon 2020 aim to identify, validate and demonstrate innovative, effective ways to reduce food losses and waste, all along the agri-food value chain from primary production down to final household consumption and disposal. They should consider diverse forms of innovation, e.g., technological, social, organizational, managerial and institutional, etc. that allow key actors to better organize and coordinate their activities, to monitor conditions, to eliminate causes of inefficiency along the whole chain, and hence, discard as little food as possible without compromising on their quality, including safety, and sustainability.

The call for proposals for food waste reduction and valorization, have to take into account "Sustainable Food System Approaches" to tackle the inherent links between ecosystems, food production, the food chain, and consumer health and wellbeing.

[1] https://ec.europa.eu/programmes/horizon2020/find-your-area

More in detail, EU Commission expects that SFS Projects aim to cover the following thematic actions:

– to deliver diverse and healthy food from land and sea
– to increase resource efficiency and environmental performance of food systems from primary production to consumers
– to understand the impact of climate change on agriculture, resources, food quality and identify options to manage its effects
– to reduce greenhouse gas emissions and emissions of air pollutants from land use and food production taking into account main drivers such as inputs and consumption patterns.

The solutions arising from SC.2 (Table 12.1., Societal Challenges, point n°2) Proposals expected to deliver significant economic, environmental and social benefits. Investments, for example, are focused on healthy and safe food, promotion of biodiversity for agriculture safeguard, on sustainable management of soils, on increasing animal welfare, as well as on the implementation of Food and Blue Clouds. That investments aim to support food production by 2030 with pioneering a digital revolution and new value chains in rural economies.

New ideas, products, technologies, policy recommendations and social innovations are working in tandem to supply a supportive framework for genuine improvements within the way we produce and consume. This is in line with societal expectations for impact-driven research (EU Commission (a) 2019b).

To test and demonstrating efficacy of introduced innovative approaches and to further improve understanding of the root causes behind the current situation, the EU Commission also expects to fund the projects that include tasks to monitor, and valorize food losses and wastes (and associated economic and environmental costs) along the agri-food value chains into new bio-products, (EU Commission (b) 2019c). Any methods used for this purpose should be compatible with several international legislations on measurement and reporting data on food losses and wastes. In addition, the factors enabling and hindering innovative approaches should be taken into consideration. Further targets will be based on setting-up recommendations, best practice guidelines and toolkits for promising innovative approaches to the reduction of food losses and waste shall be developed, taking into consideration the underlying socio-cultural factors and gender aspects.

The coming proposals fall under the concept of the ‘multi-actor approach’ (EU Commission (a) 2019b), ensuring solid collaboration between relevant actors, from farmers or farmers associations, across agri-food industry (including small businesses), wholesalers and retailers, food-related services, until consumers and policymakers. At last, to maximize the concrete impacts, dedicated work packages for international cooperation with no-EU Countries are also encouraged.

In this respect, the EU funding programs like HORIZON 2020 Green Deal and HORIZON EUROPE are demonstrating of being driving-force able to realize the circular economy with involving several key actors, as public institutions, policymakers, SMEs, industries, and researchers, as well as citizenship and their associations. It has developed in order to provide concrete opportunities to embrace more

eco-centric and inclusive approaches to economics, towards stronger sustainability, and the more systematic inclusion opened to plenty of public and private entities and organizations.

The first results of such project activities are actually demonstrating a strong contributor to creating the conditions for dynamic and innovative farming and food sectors managing to turn high-quality products and high environmental standards into a competitive advantage.

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