Circular and digital **Bioeconomy**

Opportunities for the Transition and Sustainable Development of the Portuguese Economy and Industry

COTEC Portugal

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Autores

Leitão, Alexandra (coordinator)
Degree in Economics and MSc in Finance from Faculdade de Economia, Universidade do Porto. PhD in Economics, specialization in Environmental Economics, from Nova School of Business and Economics. Assistant Professor at Católica Porto Business School and CEGEA consultant in projects in the field of Environmental Economics.

Pintado, Maria Manuela Estevez (coordinator)
Degree in Pharmacy from the Faculty of Pharmacy, University of Porto (1991) and PhD in Biotechnology from the Catholic University of Porto (1999). Manuela Pintado is Associate Professor, Head of the Center of Biotechnology and Fine Chemistry (CBQF), an Associate Laboratory, and Deputy Director of the Faculty of Biotechnology. She is the Leader of Biomedical and Biobased Products group and coordinates the Bioactives and Bioproducts Research Laboratory. The focus of her research has been on the valorisation of agro-food by-products into value-added products. Manuela Pintado has extensive experience in collaboration with the industry, mainly the agro-food sector.

Rebelo, Francisco
Invited Assistant at Católica Porto Business School. Master in Economics and International Management from Faculdade de Economia, Universidade do Porto.

Ribeiro, Tânia
Tânia Ribeiro, degree in Biochemistry from the Faculty of Sciences, University of Porto. Master in Food Technology and Safety. Currently, PhD student in Biotechnology at Faculty of Biotechnology of the Catholic University of Porto in cooperation with BLC3 to develop new bioactive and functional ingredients from the olive oil industry by-products. Over her career has been involved in food technology and by-products/endogenous resources valorisation projects, including the validation of its bioactivity and functionality.

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Porto, 30th December 2019

Alexandra Leitão

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Portugal and Europe are currently experiencing two major developments - the creation of a circular economy and a digital revolution - with the capacity to transform our economy and society. This study analyzes **the circular economy as a lever for the growth and development of the Portuguese economy.** Particular emphasis is placed on circular bioeconomy, as a new economic paradigm with the potential of replacing materials and products based on fossil fuels by renewable materials and products with greater potential for use in closed-loop cycles. It also intends to highlight the **crucial role of digitization to support and enhance the desired transition**. Both agendas must be managed simultaneously, with the ultimate goal of contributing to long-term sustainable prosperity, in its economic, social and environmental dimensions.

After a brief clarification of the circular economy and bioeconomy concepts, their relationships and overlaps (section 2), the study characterizes their importance in the national productive structure and analyzes the Portuguese business activity regarding the implementation of the circular economy model (section 3). Section 4 estimates the macroeconomic potential of circular economy within the Portuguese economy and section 5 focuses on the central role of forests for the circular bioeconomy. Bioproducts from forest biomass with high potential and very attractive markets are identified. Moreover, the implications of environmental sustainability arising from the diffusion of these new biomaterials are highlighted, specially focusing on the decarbonisation of the economy. Section 6 addresses the role of digital economy in the desired transition and, finally, there are several recommendations to promote the circular bioeconomy.

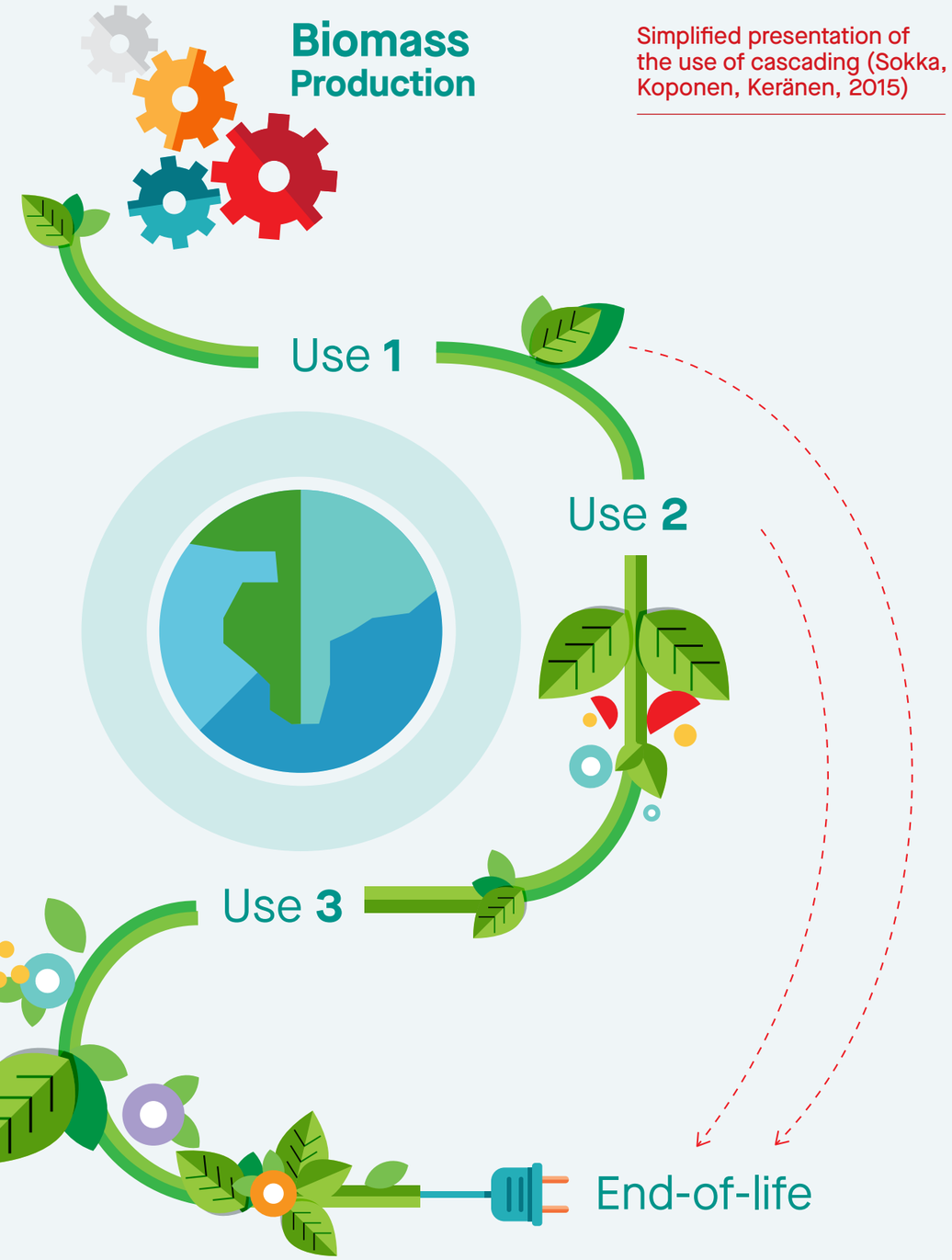
The bioeconomy and the circular economy share the common goal of a more sustainable and resource-efficient world with a reduced carbon footprint. Both seek to avoid using fossil fuels to achieve climate goals and to decrease pressure on virgin raw materials. The concepts overlap to some extent, but neither concept is fully part of the other concept.

The bioeconomy encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products. It replaces fossil carbon with renewable carbon from agriculture, forests and the marine environment biomass, including by-products and waste.

The circular economy is a restorative and regenerative model by design where nothing is lost and everything feeds a new cycle, and which aims to keep products, materials and resources in the economy with the greatest utility and greatest value, for the longest possible period of time. At the same time, it allows the minimization of waste and it postpones new production, therefore saving on virgin raw material and additional energy. Extending the life cycle of products and materials, retaining their value and functionality for longer periods of time, requires systemic approaches such as ecodesign, sharing, reuse, maintenance, repair and recycling. Also, changing from non-renewable resources to biomaterials is an important aspect of the circular economy's agenda.

The principles of a circular economy must be applied to the bioeconomy. The use of cascading biomass strongly overlaps with the concept of circular economy and is an integral part of the concept (circular bioeconomy). It is a core strategy to maintain the value of biomass in material applications with high added value in the economy, for as long as possible, before sending it for energy recovery, while guaranteeing the preservation of natural capital.

A more ambitious vision for the circular bioeconomy is the transformation of the main economic sectors, leveraging and maximizing the potential of digital technologies, biotechnologies and nanotechnologies to transform biomass into advanced biomaterials, products and services, minimizing the use of non-renewable resources.



Simplified presentation of the use of cascading (Sokka, Koponen, Keränen, 2015)

Bioeconomy and Circular Economy in Portugal

Bioeconomy and Circular Economy in Portugal

In general, the most recent years have shown a growth trend in indicators such as value added, turnover and productivity both in the bioeconomy and in the circular economy in our country.

In 2017, the bioeconomy represents approximately 7% of the Portuguese value added, corresponding to around 12 000 million euros, which reflects a positive trend since 2011. In the European Union, its share in the total economy is only 4.9%. **It employs around 602 thousand workers, corresponding to 13.3% of the total employment in Portugal.**

In terms of turnover, Portuguese companies in the bioeconomy are responsible for more than 43 000 million euros in 2017, corresponding to about 12% of the total turnover of the economy, reflecting a growth rate of around 17% compared to 2011.

Between 2011 and 2017, bioeconomy productivity (value added per worker) in Portugal rose by 54.3%, currently standing at 19.7 thousand euros per worker. Nevertheless, it only corresponds to approximately half of the Portuguese economy average productivity (37.6 thousand euros per worker). There are, however, some categories that stand out: bioenergy; manufacture of pulp, paper and paperboard; bio-based chemicals, pharmaceuticals, plastics and rubber; forestry and logging. These categories have productivity levels above the average productivity of the economy as a whole.

Despite the positive evolution, the comparison with the European Union shows that the productivity of the Portuguese bioeconomy only represents 52.2% of the European Union bioeconomy productivity (37.7 thousand euros per worker).

Regarding the circular economy in Portugal, its value added has grown substantially since 2014. It is estimated to exceed 7 000 million euros in 2017, corresponding to 4.21% of the national value added. Despite the limited weight of the circular economy in the Portuguese economy, it is still higher than that in the European Union (3.45%). Between 2014 and 2017, the pace of growth in the value added of the circular economy in Portugal was nine percentage points higher than that registered in the European Union (20.7% compared to 11.7%). **It employs approximately 280 thousand workers, corresponding to about 6.21% of the total employment in our country, and employment has been growing since 2011.**

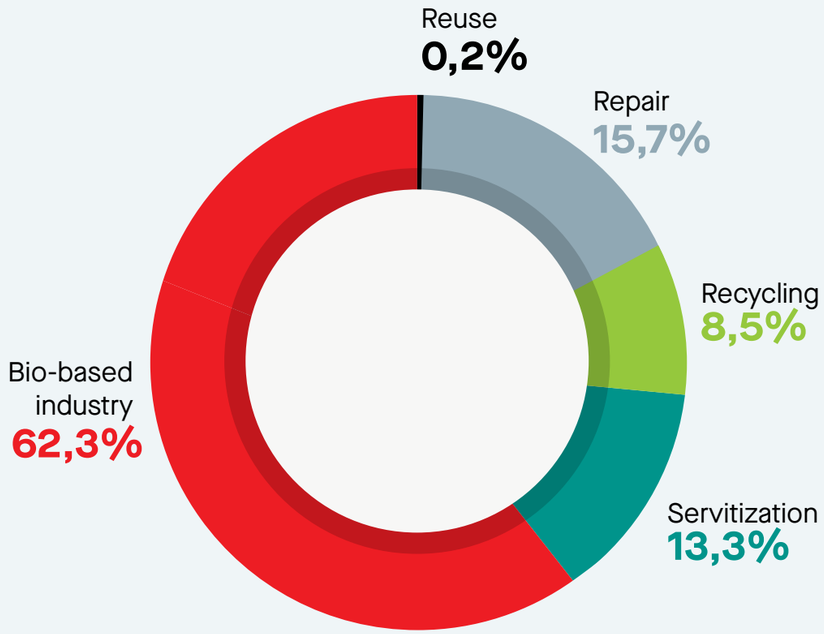
The major contribution to the circular economy comes from the bio-based industry, which represents 62.3% of the total value added generated by the circular economy in our country (which compares with 41.1% in the European Union), followed at a long distance by repair and servitization.

The turnover of companies in the circular economy has been increasing since 2012, with particular emphasis in 2017, approaching 25 000 million euros. This trend is similar to that observed in the European Union, however, once more, it is worth mentioning the higher growth rate in Portugal (21.4% compared to 13.1%).

The average productivity of the circular economy in 2017 is 25.5 thousand euros per worker, reflecting a positive trend since 2011. Although higher than the bioeconomy productivity in Portugal, it only represents 68% of the average productivity of the Portuguese economy. The most productive category is servitization, followed by recycling, albeit far away. The productivity of the bio-based industry, 25.1 thousand euros per worker, is very close to the average productivity of the circular economy.

The comparison with the European Union shows that the productivity of the Portuguese circular economy only represents about 46% of the productivity of the circular economy in the European Union (55,700 euros per worker).

Value added of the circular economy in Portugal, by category, 2017



7 000 M€

Value Added of the Circular Economy in Portugal (2017)

280 000

Workers of the Circular Economy in Portugal (2017)

25 000 M€

Turnover of the Circular Economy in Portugal (2017)

As mentioned above, another of the objectives of this work is to understand, within the Portuguese business activity, the stage of implementation of the circular economy model and its importance in the companies' strategy.

The firms participating in this study incorporate environmental and sustainability concerns into the organization's strategy and are already looking to the specific model of the circular economy.

Many of the companies follow a narrow view of circularity, motivated essentially by waste reduction and efficiency in the use of resources. There are a significant number of initiatives underway in the production cycle, with a strong emphasis on waste reduction and greater material and energy efficiency of the products and production processes, and a smaller number of initiatives to transform products, with value retention and creation, or to develop innovative proposals for customers that allow the use of products for longer periods of time, which will allow a new type of relationship with the customer, both crucial for companies to maximize the benefits from the circular economy model.

Therefore, **although circular thinking is on the companies' agenda, they are still at different stages of strategic thinking.** There are companies still focused essentially on operational benefits. As they become more familiar with the concept, they also find the opportunity to create competitive advantage through new products, new product models and access to new markets and customers. They see circularity as an important factor in future competitiveness, keeping ahead of disruptive trends.

Since this is a new concept, companies are aware of the challenges to be faced in the adoption of such model. The successful implementation of circular models depends heavily on the rethinking of supply chains. **Understanding the value of collaboration is crucial as circular economy is not something that can be achieved alone.** It is necessary to build relationships along the supply chain. Companies recognize the importance of ensuring transparency in the circular processes of supply chain partners, the need for them to be aligned with the organization's sustainability standards, ensuring the continuous supply of material flows. Also, most companies recognize the importance of digital in the implementation of fundamental operational changes for the development of a circular economy model.

> "…although **circular thinking** is on the companies' agenda, they are still at different stages of strategic thinking."

The Macroeconomic Potential of the Circular Economy

The Macroeconomic Potential of the Circular Economy

Based on input-output matrices, that describe the interactions of the circular economy sectors with the rest of the economy, **the macroeconomic potencial of the circular economy in our country is estimated. In particular, in terms of gross value added and employment creation.**

It is estimated that each million-euro increase in the final demand will result in an increase of gross Portuguese value added between a minimum of 880 thousand euros and a maximum of 1.438 million euros, depending on the category of the circular economy to which demand is directed (bio-based industry or reuse, respectively). Concerning the bio-based industry, this is an average value of the different sectors of activity considered, which reveals large disparities: the wood and cork industries and the bio-based manufacture of wooden furniture have the largest impact on gross value added (1.013 million euros for each additional million of final demand), while liquid biofuels have the lowest impact (595 thousand euros). The sectors' imported content is a determinant factor explaining the differences. The important role of pulp, paper and paperboard manufacturing in the creation of wealth in the Portuguese economy, beyond the sector itself, should also be highlighted, through the relationships established with other businesses.

Moreover, in terms of job creation, significant disparities between sectors are visible. Reuse and repair activities are more labor intensive than the bio-based industry. In the bio-based industry there is evidence of high spillovers in terms of job creation by the rest of the economy, in the case of pulp, paper and paperboard manufacturing, wood and cork industries and bio-based manufacture of wooden furniture and production of bioelectricity.

Regarding the Portuguese circular bioeconomy in particular, it can be concluded that, generally, **bio-based activities generate more wealth in the input supply chain than in the downstream product and material application chain. Moreover, this potential for wealth creation in the upstream chain is always greater than that for the average of the Portuguese economy. Also, the potential for wealth creation compared to the average of all economic activities, is more significant in Portugal than in the EU28, both upstream and downstream.**

Wood products (in the broad sense) and bio-based textiles stand out from the other national economic activity sectors due to their ability to create wealth, both upstream in the supply chain and in the downstream user chain. They are therefore classified as 'key sectors'. The promotion of these sectors is thus highly recommended from an economic perspective given their high potential for value creation.

For example, **a unitary increase in demand for wood products generates value added in the upstream supply chain 2.33 times the average effect generated by all sectors of the national economy**. On the other hand, a unitary increase in the supply of output of wood products generates value added of 1.21 times greater than the average effect generated by all sectors of the economy with regard to the downstream user chain.

The found evidence that the output of bio-based activities is limited in terms of alternatives of use and applications and with low value added is of great concern. In this sense, this work aims to show the economic potential of advanced biomaterials and bioproducts originating from forest biomass, with high value added compared to traditional applications, that are still under-exploited by the market.

Forests and the Circular Bioeconomy

Forests and the Circular Bioeconomy

The forestry sector is of strategic importance for the sustainable future of modern society. **Forests play a leading role as suppliers of bio-based products, more resource-efficient with competitive and low-carbon supply chains that allow to accelerate the transition to a sustainable European bioeconomy.**

Regarding new biomaterials and bioproducts, the potential of forest resources for the implementation of circular bioeconomy and competitiveness in key sectors such as Construction, Textile and Plastics should be highlighted. The new biomaterials, in addition to being produced using biological raw materials, are obtained through more ecological processes, thus allowing to significantly reduce carbon emissions.

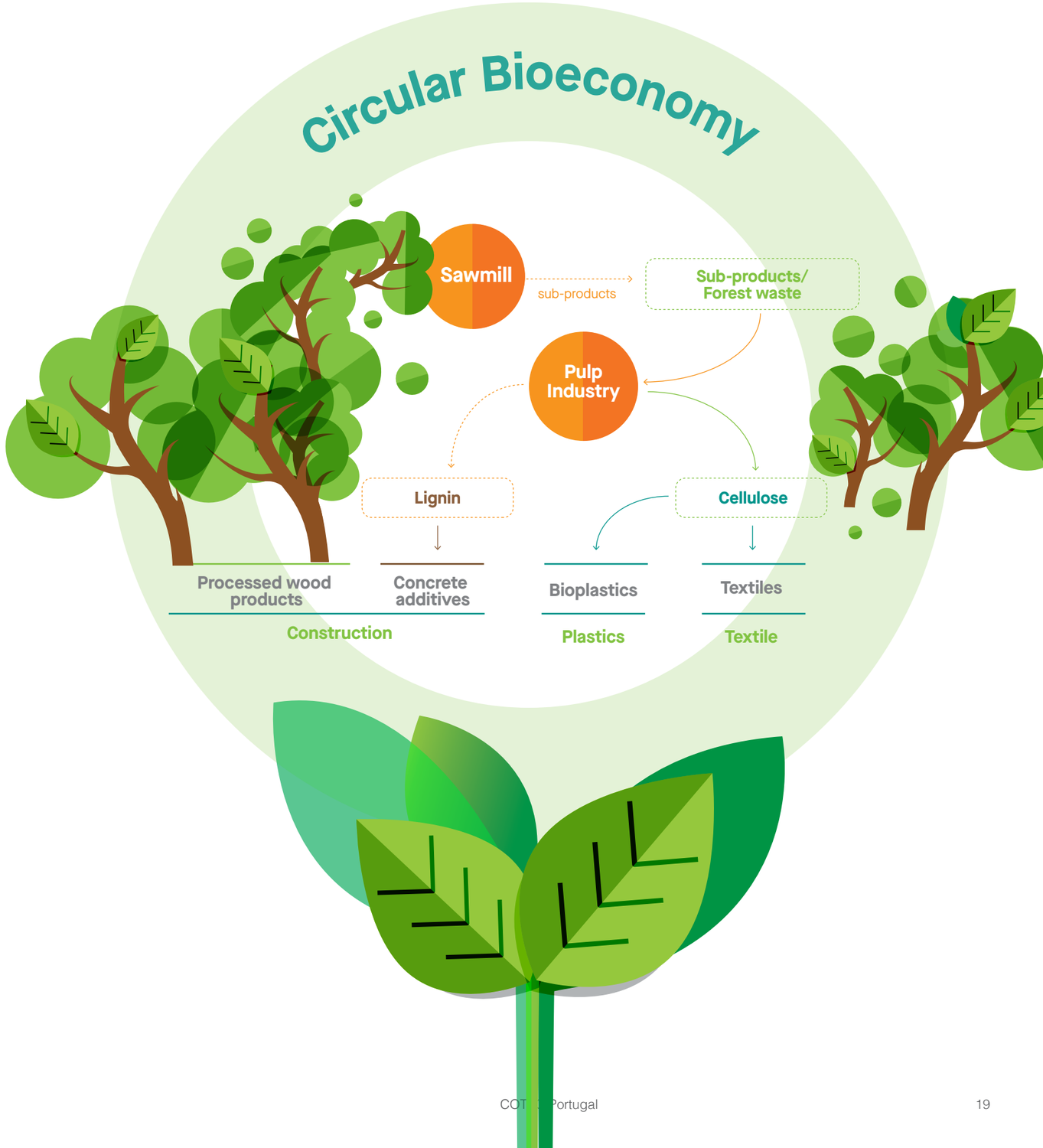
The construction sector has a high environmental impact. In the last decade, the concept of "green building" has become more popular due to the current global challenges in relation to greenhouse gas emissions and climate change. **A more sustainable construction sector requires greater use of materials with low incorporated energy, such as wood and cork, as well as better environmental performance in new buildings and extensive renovations in old buildings.**

The textile sector is one of the largest industries in the world and the second most polluting on the planet. The demand for textile fibers is growing rapidly due to the growth of the global population. Lignocellulosic biomass is already well positioned to replace textiles based on fossil resources because of the quality of its fibers and due to its smaller environmental footprint. Its environmental performance depends heavily on the biomass source and the production process.

Finally, most plastics on the market are synthetic, usually derived from fossil fuels. The production and use of petrochemical plastics are linked to the main challenges of environmental sustainability: greenhouse gas emissions, disturbance in ecosystems (for example, oceans) due to the increase in non-biodegradable plastic waste and waste problems. These make it essential to find alternatives to this material. The immediate action is to increase the recycling and reuse of plastics. **However, it is also necessary to gradually replace plastics with materials that are less harmful to the environment. A promising solution is to use bioplastics based on forest biomass.**

In short, forest biomass from sustainable forest management is an excellent source of wood for new low-carbon building materials, but also as a leading source of cellulose for new and greener biotextiles and bioplastics. Lignin is another significant component of wood that has shown enormous potential in obtaining new and more sustainable materials. Between all the lignin applications, lignin incorporation in concrete can be emphasized.

Selection of biomaterials based on forest biomass with potential contribution to the Circular Bioeconomy >



However, forests are not the only source of lignocellulosic biomass whose potential has not been properly valued. The amount of biomass waste generated by agricultural activities, food processing and other industry sectors has been increasing considerably as a result of population growth and the expansion of industrialization. **Agri-food waste and by-products are great sources of biological compounds that can be exploited as raw materials to replace fossil fuels, complementing the use of forest biomass and being an asset in obtaining new, more versatile and sustainable bio-based materials.** There are great economic and social opportunities, in addition to environmental benefits, in the transformation of biological by-products/waste into renewable and profitable raw material to obtain new products in sectors such as Construction, Textiles and Plastics.

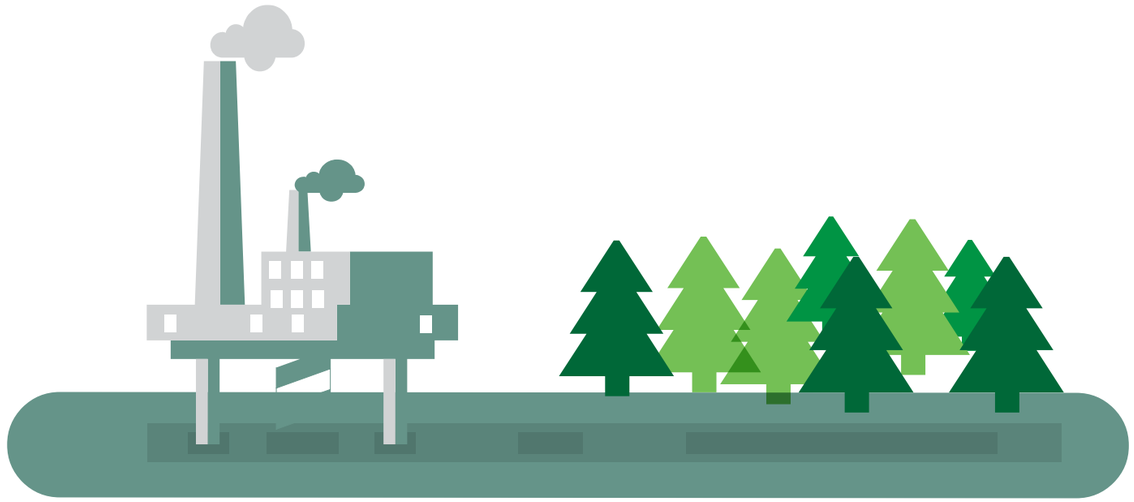
In addition to these sectors, other promising applications to forest biomass have also emerged in the food and cosmetics industry.

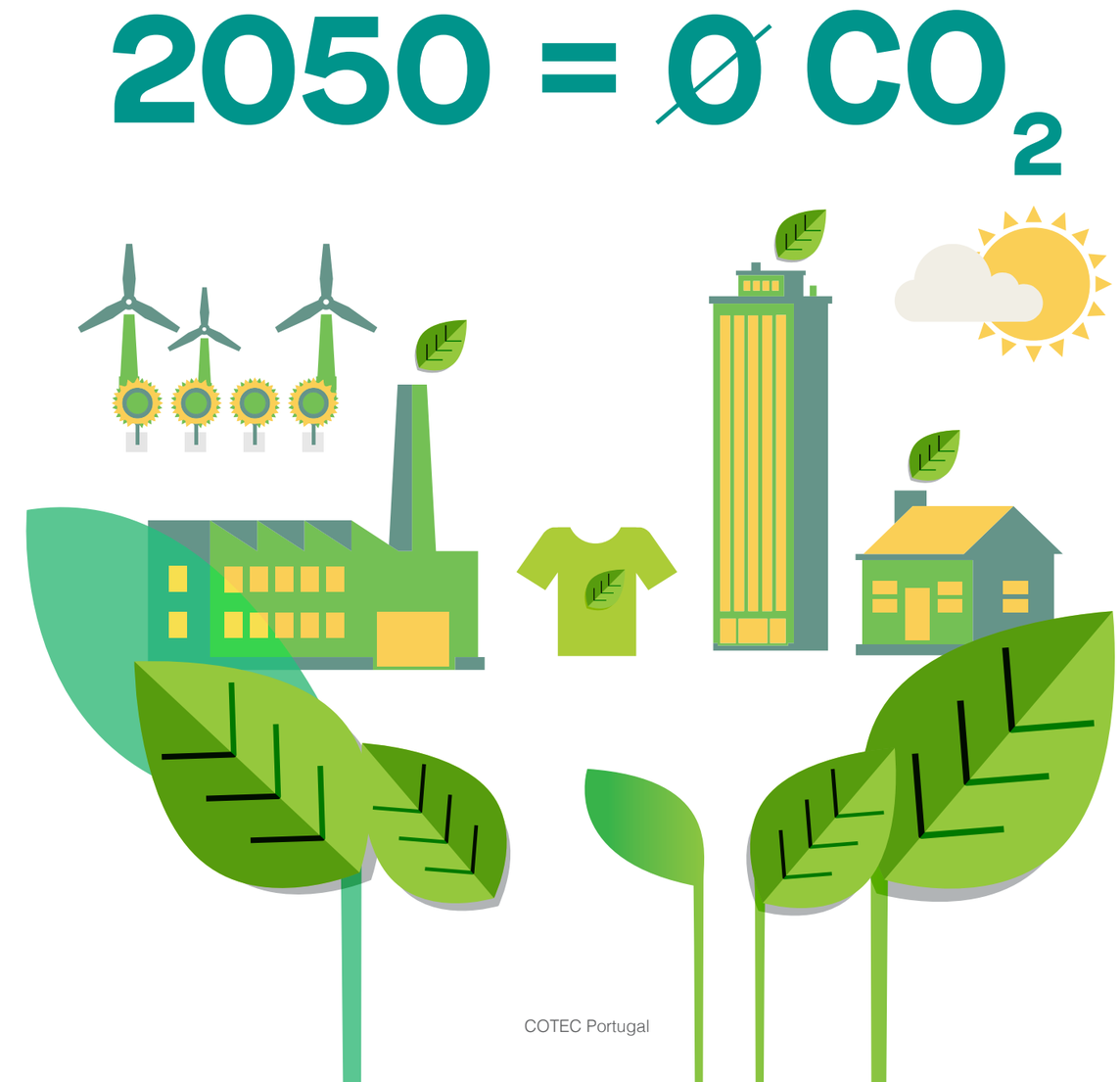
The new bioproducts identified have high potential and attractive markets. **It is estimated that a 5% market share of these bioproducts in the global Construction, Textiles and Plastics markets in 2030 corresponds to an aggregate increase in revenues of € 260-579 million per year in Portugal.** The analysis clearly shows the potential for creating value in high value added and differentiated products.

In addition to the economic dimension, the implications of environmental sustainability arising from the diffusion of these new biomaterials are highlighted, specially focusing on the decarbonisation of the economy.

The environmental externalities associated with conventional products used in the Construction, Textiles and Plastics sectors and the corresponding bioproducts are estimated. Particular emphasis is placed on greenhouse gases emissions given the current climate emergency context that will very easily have an impact on more demanding environmental regulation in the near future, particularly in the European Union, given the goal set by the European Commission for Europe to become the first continent carbon neutral in 2050.

The externalized environmental costs of conventional products are significantly higher. The differences are very relevant in a context of internalization of environmental externalities through environmental regulation and cannot be neglected by producers.





Digitalization

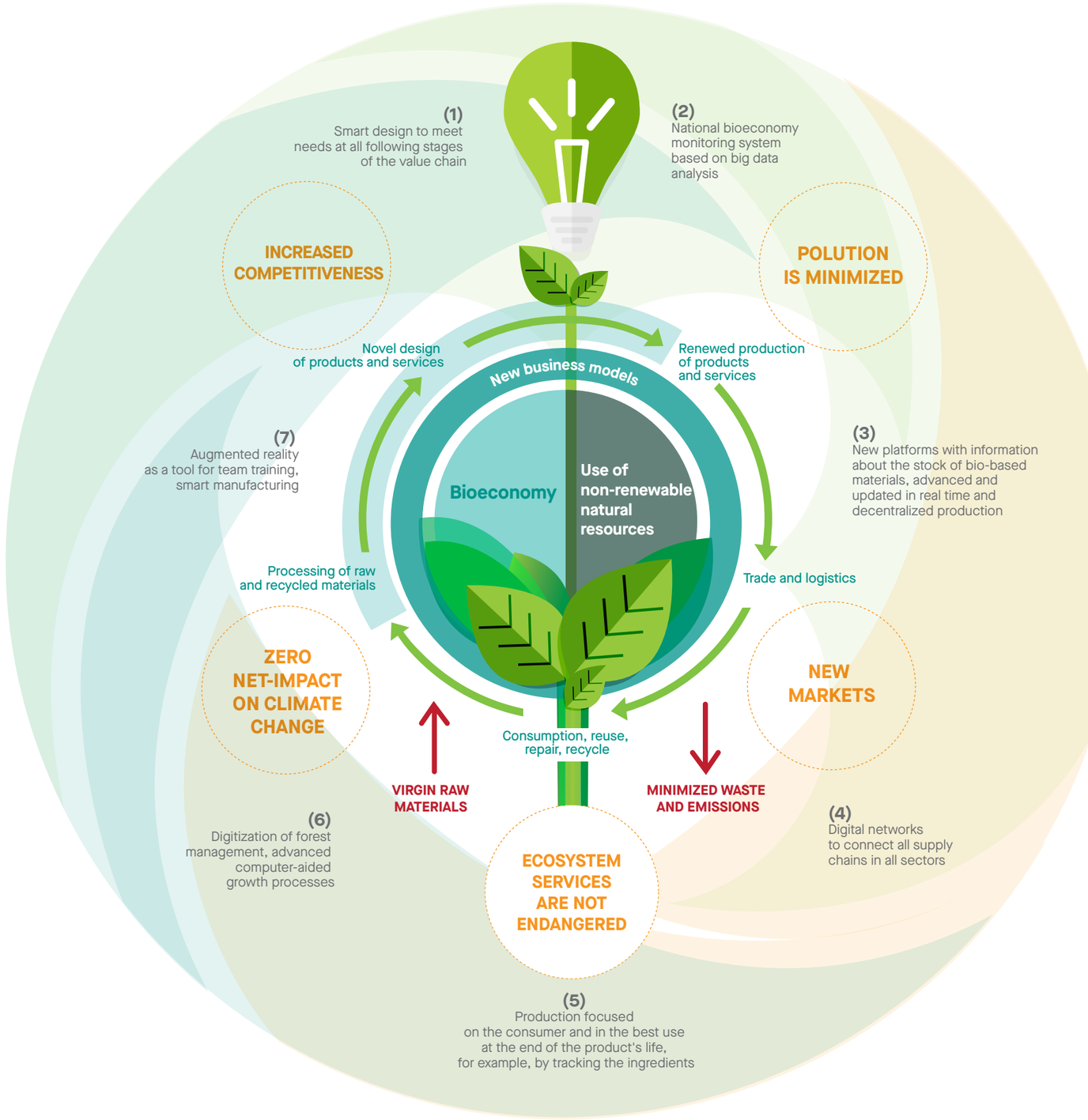
Digitalization

The adoption of digitization can be the best strategy to move definitely from a linear fossil economy to a circular bioeconomy. **Combining the principles of circular bioeconomy with the benefits and potential of digital and information technologies is the key to making production and biomass collection processes more efficient, reducing waste and increasing the applicability and use of new biomaterials by the consumer at the end of the chain.** Digitization can be a key element and facilitator of all stages involved in the development and commercialization of new bio based solutions.

In general, data, information and digitally activated solutions such as digital platforms, smart devices and apps, digital services and emerging technologies such as artificial intelligence, Internet of Things and blockchain are key to addressing and overcoming some of the key barriers to the implementation of a circular economy and accelerating the desired transition. **There are three main approaches to how digitization can be used in this transition: improving the collection and management of data and information and increasing connectivity and information sharing; make products, processes and services more circular; influence mindsets and empower citizens and consumers to contribute to the transition.**

In particular, for new products derived from forest biomass, digitization offers tools and technologies, such as radio frequency identification (RFID), DNA marking and blockchain technologies, to support the development of traceability systems to secure the chain-of-custody throughout the value chain of the new products. Traceability is a competitive advantage, which can also encompass the circularity, and for this, digital tools are essential, to develop holistic systems that include standards for the traceability of virgin and recycled raw materials. Another essential point in which digital systems can play a fundamental role is in the standardization and certification of new products obtained from forest biomass. Standardization and certification are fundamental for the market penetration of these new biomaterials to be enhanced and/or at least comparable to the oil products already established.
Other advantages associated with the implementation of digital solutions in the forest circular bioeconomy are: (i) Smart design to meet subsequent needs at all stages of the value chain; (ii) Systems for monitoring the bioeconomy, allowing the assessment of trends, the potential of different production processes or the calculation of saved emissions, for example; (iii) New platforms with information on the stock of bio-based materials updated in real time, allowing to increase the availability and supply of larger volumes of bio-based materials; (iv) Digitization of forest management and advanced computer-aided growth processes, in order to guarantee sustainable forest management that makes the ecological, economic and social functions of forests compatible; (v) Autonomous and/or electrified systems for harvesting forest resources (which increase accuracy and productivity) and transport (to improve efficiency and reduce environmental impact); among others.

Application of digitization to the concept of circular bioeconomy in the RECIBI project)



Recommendations

The study concludes with several recommendations to promote and implement a circular bioeconomy definitely and efficiently, where digitization plays a crucial role:

- **Ensure the availability of forest biomass** by improving its mapping and by sustainable forest management is essential to ensure the competitive production of new biomaterials and bioproducts.

- **Implement the principle of cascade use**, ensuring the assessment of the environmental impacts of products throughout their life cycle, as well as the reduction of by-products.

- **Develop industrial symbioses** that will increase the security of raw material supply and generate the transition to a sustainable circular economy.

- **Innovate in methods and technologies to optimize biomass flows and production processes** and reduce gaps in the industrial production chain such that the possible higher cost of bioproducts due to the complexity of production processes are offset.

- **Improve the standardization and certification of new products obtained from forest biomass,** to increase market confidence in products.

- **Improve traceability and the chain of custody throughout the value chain** to obtain competitive advantages.

- **Invest in consumer awareness to increase market penetration of new products.**

The transition will not happen on its own and if this is left to the market alone. The Government has a crucial role to play in identifying areas where incentives can help unlock the necessary private sector investment.

New policies and legislation are required to create a regulatory and supportive framework in order to stimulate the forestry sector towards a circular bioeconomy, namely:

- Climate mitigation policies, which include policies to increase the use of forest territory, avoiding bushes and wasteland without agricultural or forestry functions;

- Sustainable forest management policies aimed at protecting and improving biodiversity through policy instruments such as standards and certifications, as well as policies aimed at increasing the availability of biomass;

- Bio-based content policies and the development of indicators and targets related to the bio-based content of products;

- Waste and recovery policies to promote the cascade use of forest biomass overcoming current barriers;

- R&D policies to increase investment, both public and private, in research and development in the area of forest bioeconomy;

- Policies to support investment in the area;

- Market support policies aimed at driving a greater market need for sustainable forest-based products, including public purchasing and procurement policies;

- Awareness-raising policies designed to improve society's understanding of the social, economic and environmental benefits of bio-based products.

The combination of a regulatory and supportive framework, adequate environmental prices and public investment should guide the creation of a circular bioeconomy based on forest biomass.

COTEC Portugal

HEADQUARTERS
Edifício Porto INOVA
Rua Eng.º Ferreira Dias, n.º 728, sala 1.05
4100-246 Porto
T. +351 226 192 915
F. +351 226 192 919

BRANCH
Avenida Eng.º Duarte Pacheco,
n.º 19 - 12.º Esq.
1070-100 Lisboa
T. +351 213 183 350
F. +351 213 183 359

geral@cotec.pt

cotec.pt

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