A forest-based circular bioeconomy for southern Europe: visions, opportunities and challenges

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SYNTHESIS REPORT

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Reflections on the bioeconomy

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EFI

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Reflections on the bioeconomy
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Foreword

The Basque Country, like the rest of the world, is facing paramount environmental, social and economic challenges. Increasing human wellbeing, prosperity and social justice, while ensuring the lasting protection of the planet and its natural resources is the great endeavour of our times, one that is challenging and fascinating in equal proportions. It requires fundamental changes to our economic model, and to current patterns in the production and consumption of goods and services. Like other regions of the world, Southern Europe needs to find new ways to remain competitive in the global economy. This shift relies heavily on our ability to make the most of the ongoing digital and biotechnological revolutions, create a new generation of industrial capacities, decarbonise the economy and decouple economic growth, environmental degradation and consumption of raw materials. This, in turn, requires three important socio-economic transitions: the transition towards renewable energies and energy efficiency to tackle climate change. The transition towards a circular economy, to reduce material intensity *making more with less* and finally, a biological transition towards renewable, indigenous raw materials produced sustainably from our territories to preserve and restore our natural capital. The concept of circular bioeconomy presented in this report can be a decisive development to make these transitions possible. Furthermore, it holds the promise to reconcile economic development with environmental protection in a post-oil era. Forests are a key component of our landscape and forestry is deeply rooted in our culture. We are very happy to have supported the European Forest Institute in the compilation of this report, which shows how forests can better contribute to the emerging bioeconomy, highlighting the opportunities lying ahead and the hurdles to overcome. We hope this work will generate further social debate, increase trans-regional cooperation and stimulate positive action at multiple levels.

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Executive Summary

Addressing the societal and environmental challenges presented by *global change* requires fundamental changes to the way our society produces and consumes goods and services. Securing prosperity for a growing population, dealing with resource scarcity and mitigating climate change and environmental degradation will require an increased reliance on nature-based solutions, renewable energies and materials used in highly efficient and innovative closed material loops. That is what the circular bioeconomy can help to achieve.

Each city, region and country will need to find new ways to remain competitive and will need to develop a specific location-based approach to the bioeconomy, adapted to existing biogeographical, economic and social specificities to maximise economic, social and environmental benefits. Success will depend on the ability to take advantage of the opportunities emerging from ongoing technological revolutions (e.g. bio- and nanotechnologies, digitalisation) to transform industry (new feedstocks, chemicals and materials, advanced manufacturing) into circular business models that leverage the potential of the sharing, platform and performance economies. But, it is not enough to develop a strong bio-based sector. It is necessary to create a biological framework for the economy, essentially to *biologise* the economy, from construction, to transport and tourism. Ecotourism, wood construction, bio-based packaging and aviation biofuels are all examples of how forest goods and services can transform major economic sectors.

This report analyses the challenges and opportunities to develop a forest based bioeconomy in southern Europe. Forest can play a fundamental role in boosting the regional bioeconomy. They have expanded substantially over the last century and have again become a dominant land use. They are the largest source of land-based biological resources, not competing with food production. They are the largest green infrastructure of the region, provide a large array of ecosystem services and play a significant but undervalued, role in the economy. The utilisation rate of these forest resources is very low in most regions and this contributes to high forest fire risks. Significant synergies can be achieved through increased management, including reduced wildfire-risk, provision of the bioeconomy with high-value molecules and materials, and supply of relevant regulating services (e.g. erosion control, water regulation, drought mitigation).

There is already an important forest-based sector in place that can play a key role in developing a forest-based bioeconomy, if it is able to overcome its fragmentation and technological limitations that especially affect domestic wood working industries, which are generally in low-value commodity market segments and generally disconnected from higher added value segments (e.g. wood construction) that typically dependent on imported wood and engineered wood products. The region also has strong agro-food chains that produce large amounts of organic residues, which are today underutilised. These are important for the bioeconomy, which cannot rely only on limited forest resources. Mixed feedstock biorefineries and a closer cooperation between forestry and agriculture is needed to advance the bioeconomy agenda.

Current bioeconomy strategies of southern European countries focus on developing bio-based sectors, especially agriculture, with no clear connection to related environmental or industrial policies. They lack a transformational ambition and fail to set overarching objectives in terms of climate change mitigation, material resource intensity, etc. They fail to identify the opportunities to co-develop the circular economy, leveraging the synergies between biotechnologies and digitalisation. In these strategies, forests are mainly seen as sources of biomass. However, biomass availability, mobilisation potentials and the possible conflicts or trade-offs with other ecosystem services are treated superficially. Excepting the French strategy, sustainability is taken for granted and the strategies provide little guidance on how to maximise economic, social and environmental impacts implementing principles such as hierarchy of uses, optimal fractionation and cascade use. Local development strategies that leverage the potential of non-wood forest products are generally ignored. These shortcomings should be addressed in a new generation of strategies, with more ambitious implementation plans. Forests in relation to the bioeconomy are present in a significant number of regional smart specialisation strategies, but generally with a strong focus on bioenergy or disconnecting advanced uses of wood from regional supply chains. Nature-based tourism, short value chains and valorising ecosystem services have enormous potential to contribute to economic development in many regions and are frequent priorities in Mediterranean regional smart specialisation strategies. They should also receive greater attention in the national bioeconomy strategies.

The production of advanced, high-value bio-based products and materials, timber construction and leveraging the hidden potential of non-wood forest products represent key opportunities to develop the forest-based bioeconomy in southern Europe. There is a wealth of knowledge and relevant developments that can help the transition from a niche to the norm. Each sector faces specific hurdles that must be identified and systematically removed, so the critical question is not what can be made of forest biomass, but rather what will be made, on what scale, where, and what will drive it? While private actors must respond to market conditions, it is the responsibility of governments and societal actors to develop the framework conditions that will facilitate and guide the developments in the desired directions.

Key elements of such enabling environment are: i) an engaged well informed society; ii) strong, reassuring sustainability schemes; iii) adequate research, development and innovation capacities; iv) improved access to finance and risk-taking capacity; v) favourable regulatory evironment able to correct current perverse subsidies and market externalities; v) increased collaboration along the value chain and across sectors; vi) sustainable and well functioning supply of biomass; and vii) a regional approach able to create economies of scale, making the best of available natural resources and reflecting people's drives and regional competitive advantages. Some of the elements that require specific and urgent attention in Southern Europe are:

Sustainable supply of biomass and ecosystem services

• Acknowledge the potential trade-offs and synergies between the different bioeconomy objectives and environmental sustainability and identify specific policy actions needed to enhance the synergies and minimize the trade-offs.

• Analyse, document, monitor and inform about biomass availability and potential, taking into account economic, social and environmental constraints. Monitor and account for the current and potential supply of ecosystem services, its respective beneficiaries and their value.

• Coordination and integration of currently fragmented forest management to secure economic, environmental and social sustainability of forest management. In regions with limited mobilisation capacity, local bioenergy supply chains can provide the needed leverage for take-off.

Adequate research development and innovation capacities

• Increase the investment in research development and innovation combining supply and demand side policies and balancing the attention of social, managerial and technological innovations.

• Focus attention on bridging the research innovation divide by supporting pilot plants and upscaling facilities, but also meeting the need for basic knowledge such as wood properties of southern hardwood and softwoods.

• Secure skilled professionals in the interface of life sciences and forestry with engineering and entrepreneurship, economy and social sciences.

Favourable regulatory framework, access to finance and risk-taking capacity

• Develop specific drivers for clean technologies that are flexible enough to avoid technological lock-ins through elements such as: a high enough carbon tax, setting mandatory targets for bio-based products and banning harmful non-biodegradable products.

• Give special attention to funding start-up initiatives and late-stage scalable production. A portfolio of tools will be necessary from public, private partnerships, joint ventures, deferred tax policies, purchase agreements and debt financing.

• Reduce volatility through smaller scale multi-feedstock bio-refineries and industrial symbiosis, building on residues and side streams of existing forest and agro-food industries.

Increase collaboration along the value chain and across sectors

• Create opportunity for forest owners to participate in downstream value chains securing adequate benefit sharing and promote long-term supply agreements.

• Create cross-sectoral bioeconomy clusters and engage actors in systematic business discovery processes, encouraging the creation of new partnerships and industrial ecosystems.

Engage society

• Generate consensus on the use of forests focusing on the promising synergies that can be created through a combination of management intensities at the landscape level, including the capacity to better adapt to climate change.

• Promote informed public debate at multiple levels, from local to global, to define a common vision on desirable and feasible bioeconomy futures. This can include, developing regional bioeconomy strategies, focusing on the potential role of a full range of goods and services of forested landscapes, rather than only on the traditional forestry sector.

• Keep the public informed through adequate product standardisation and labelling schemes, including elements related to the environmental and social footprints of imported feedstocks.

• Address the Euro-Mediterranean dimension, as climate change and the sustainable management of natural resources might have game-changing implications for the social and political stability of the region.

Introduction

Crossing the planetary boundaries

By 2050, the Earth's population will reach 9.7 billion, with 66% of the population living urban lifestyles in cities and megacities (United Nations, DESA 2015). Production of goods, trade, capital, technology and information flows have rapidly expanded and lead to a globalised, urban and digital economy that has affected Earth's functioning. This unprecedented period of human development is still dependent, to a great extent, on fossil fuels, finite biophysical resources, and a linear pattern of production-consumption-disposal. As a consequence, society is facing unprecedented interconnected challenges in trying to ensure human development and wellbeing within our planet's boundaries (Steffen *et al.* 2015). Four of these boundaries might already have been crossed:

- accelerated climate change
- loss of integrity of the biosphere
- intense land-use change
- altered biogeochemical cycles

Therefore, Earth's systems could already be entering a state that cannot sustain the current economic development model (Steffen *et al.* 2015). Air and water pollution, soil degradation, freshwater salinisation and hyper-accumulation of waste are severe externalities that jeopardise human development gains and that could aggravate social inequalities.

The pace of change will accelerate over the next two decades. Developing countries will lead economic growth and will account for an increased share of the economy. Two billion people will enter the global middle class and will adopt western consumption patterns. To satisfy increasing demands, the world will need to produce, for example, 50% more food, 45% more energy and 30% more fresh water (United Nations 2012), while reducing negative environmental impacts. This represents an enormous challenge for society and technology, and it is clear that we need a new economic paradigm to achieve these in a way that would be also in accordance with the Paris Agreement and the SDGs targets.

Currently, globalisation, urbanisation and technological development are changing the economic landscape, and are destabilising many traditional economic sectors and shifting the competitive balance within and across regions. Emerging economies are increasing their share of both manufacturing and consumption. As Europe's technological and competitive advantage narrows, it needs to find new avenues to create wealth and wellbeing. Countries, regions and cities need to remain competitive in the global landscape, generate jobs and livelihood opportunities for all and invent new ways of approaching development in the rest of the world.

The current fossil-fuel based, resource intensive, linear economic model seems to have reached its limit. The delicate balance of economic benefits and costs, including environmental and social externalities, seems to have lost its equilibrium. Most, if not all, economic sectors must be transformed to address the urgent need to de-carbonise and de-materialise the economy, to reduce pollution, water consumption and generally reduce negative environmental impacts, while at the same time, increase competitiveness, equity and wellbeing.

Success will greatly depend on the ability to transform consumption and production patterns in order to increase energy and material efficiency, taking advantage of the emerging opportunities offered by technological and societal developments in such diverse field as the bio-based economy, the circular economy, the digital society and the biological and nanotechnological revolutions, that are the source of a new generation of materials, renewable energies, clean production systems and business opportunities.

An emerging paradigm: the circular bioeconomy

Recently an European Forest Institute's (EFI) report analysed the context in which the circular bioeconomy strategies should be developed in Europe (Hetemäki et al. 2017). Based on this, we outline here some of the key features that need to be taken into account

The circular economy paradigm seeks to use materials and services efficiently and to produce zero waste through redesigning how products are built and used, minimising their environmental footprints through sharing, reusing, repairing, recycling and ensuring that any unavoidable residues are biodegradable, allowing for close biogeological material cycles. The bioeconomy proposes a shift towards using renewable biological materials to create a new generation of goods and related services that can replace and upgrade what today is being created by using fossil fuels and non-renewable materials. It also proposes a greater reliance on nature-based solutions to replace the built infrastructure (e.g. procuring clean water through watershed management instead of through a depuration facility, increasing resilience to floods by planning for controlled flooding areas instead of using costly artificial levees, embankments and post-disaster management). Both the circular and bioeconomy concepts complement each other in important ways. Bio-based materials often have greater potential for recycling and biodegradation and are better adapted to circular designs and closed material loops. Nature-based solutions and the circular economy can help reduced total material needs, maximising the capacity of bio-based products and services to satisfy human needs. This is very important as the

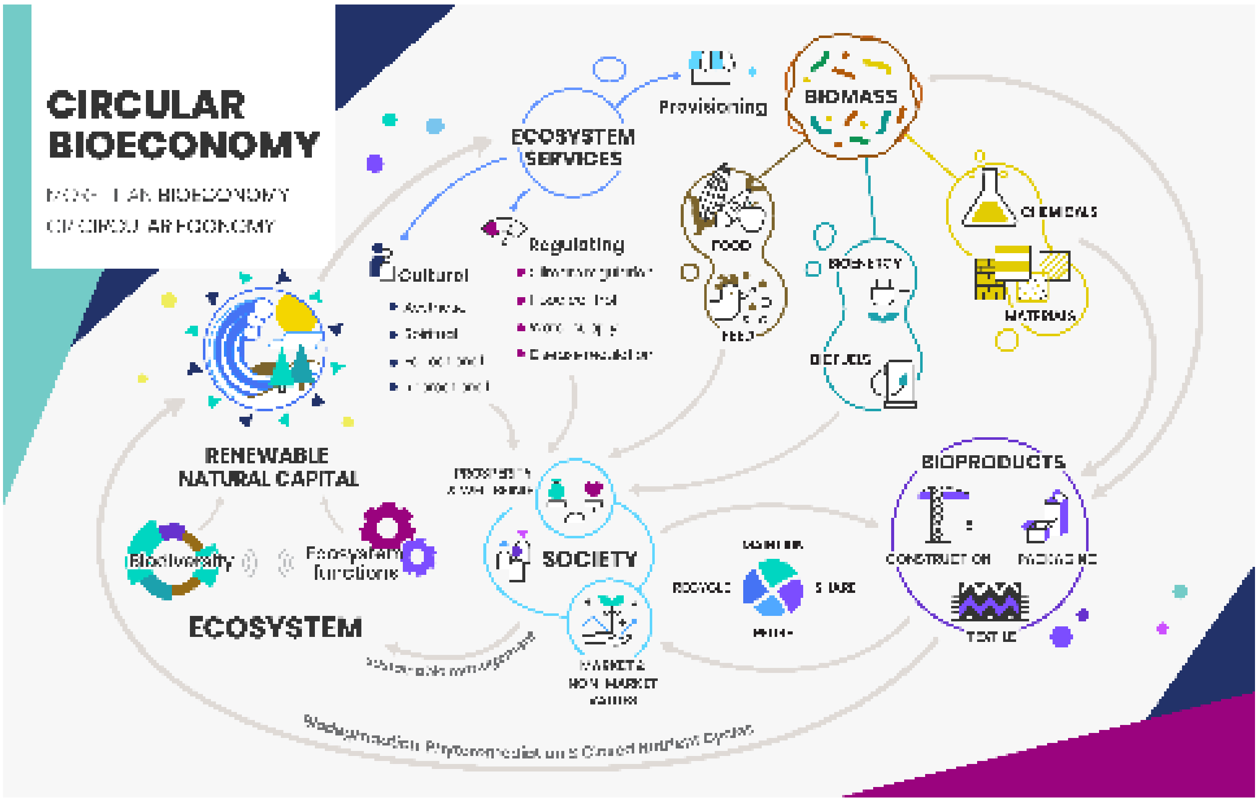


Figure 1. Illustration of circular bioeconomy flows, based on Hetemaki *et al.* 2017

bioeconomy, as frequently defined (e.g. as defined in the European Bioeconomy Strategy), does not embrace new patterns of consumption and the reduction of raw material needs.

The circular bioeconomy is a new economic paradigm that increases reliance on renewable, biological resources with increased resource efficiency and circular material loops. It has the potential to substitute fossil-based, non-renewable and non-biodegradable materials with renewable, re-usable, recyclable and biodegradable products. It must be seen as a whole (Figure 2): on the one hand natural resources such as carbon, water, solar energy and soils provide the needed background for biodiversity and ecosystem functioning, which in turns provides goods and services for nature and society in a continually changing but resilient balance. If wisely developed, the circular bioeconomy can help reconcile economic development with environmental protection.

In a narrow sense, the circular bioeconomy can be seen as an emerging sector. It is the sum of all activities that transform biomass into different product streams, including materials, chemicals, biofuels and food and animal feed. It includes processes and products of the traditional industries in the forest sector (pulp and paper, timber, cork, etc.), the agri-food sector along with new biorefineries[1] that are producing a new range of products from

[1] According to the International Energy Agency, a biorefinery is a facility that combines biomass transformation processes to produce a spectrum of bio-based products (food, feed, chemicals, materials) and bioenergy (biofuels, power and/or heat). See: http://www.ieabioenergy.com/

biofuels to speciality chemicals, fibres and composites for manufacturing, energy, food and feed. It also includes the many ecosystem services that provide societal well-being and are necessary for well-functioning of ecosystems. See for example Hetemäki *et al.* (2017) and the *European Union bioeconomy report 2016* (Ronzon *et al.* 2017).

In a more ambitious sense, the circular bioeconomy is the biologisation of the economy, which means a transformation of the main economic sectors from construction to transport and even to fashion, by leveraging and maximising the potential of emerging digital bio and nanotechnologies to transform the different fractions of biomass into advanced biomaterials, products and services, reducing non-renewable resources to a minimum (Schütte 2018). Wood construction, bio-based packaging, bio-textiles, nature based tourism or advanced aviation fuels are examples of how the circular bioeconomy can transform the main economic sectors. This vision, however, faces some major challenges. For example, there are limits to the amount of biomass that can be produced, and maximising the production and collection of the necessary biomass can conflict with other social or environmental goods and services. For this reason, the transformational bioeconomy must fully develop circularity principles and support an array of renewable energies. For this reason, the transformational bioeconomy must be environmentally sustainable, fully develop circularity principles and relay also on non biobased renewable energies.

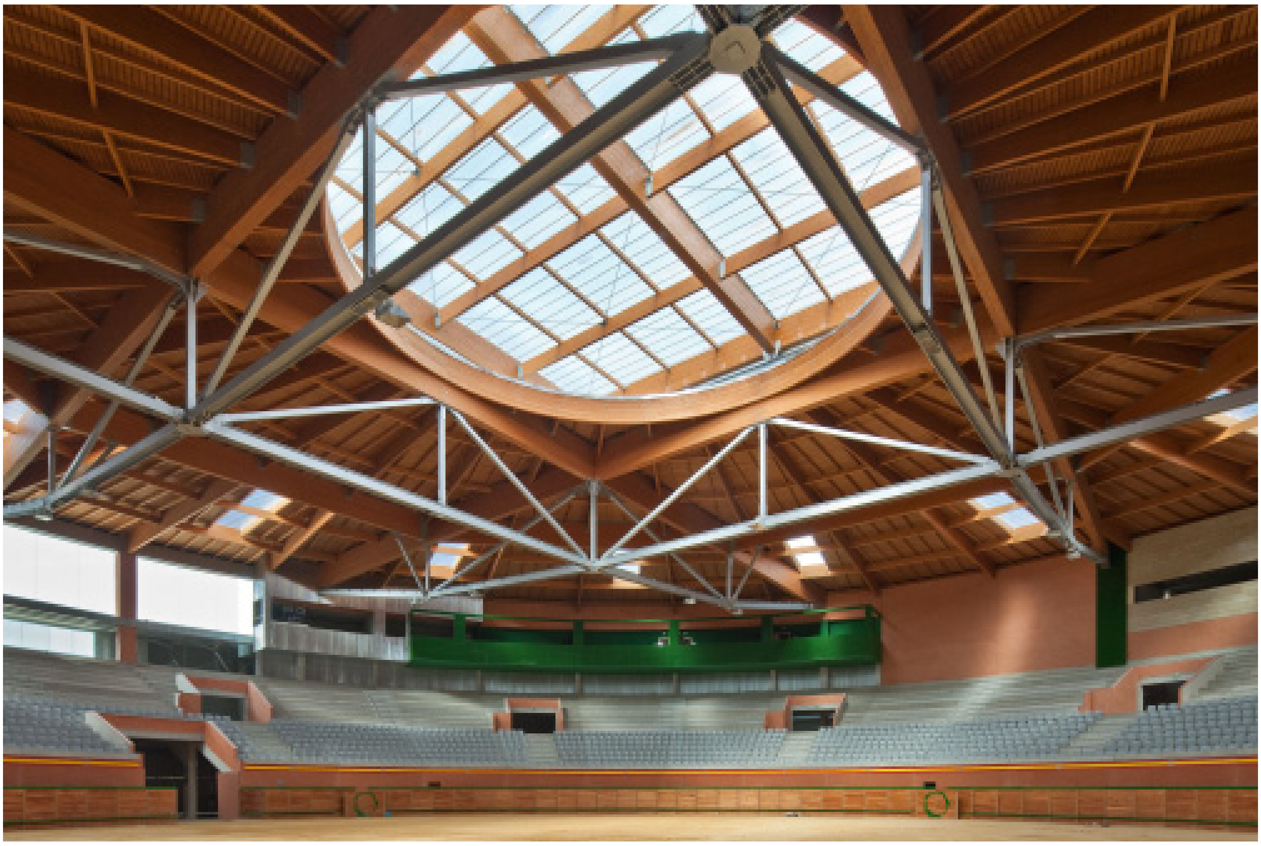


Table 1. Economic sectors that require an urgent transition towards sustainability

Sector	Relevance (in 2011)	Main options
Natural capital (ecosystems and agro-ecosystems)	• natural and agro-ecosystems provide the underpinnings of life and feed humanity • 4 billion people work directly in agriculture, forestry and fishery sectors	• secure and monitor sustainability • reverse critical negative externalities reducing policy and market failures • improve management and circularity for food security and sourcing the bioeconomy
Energy	• 80% of final energy consumption is based on fossil fuels • global energy demand growing at 1.5% yr^{-1} • 60% of renewable energy based on inefficient traditional biomass • 2.5% of world diseases caused by burning fuel	• renewables (solar, wind, marine, geothermal, biomass, hydro, etc.) • energy efficiency, including improved use of biomass universal access to electricity as a condition to access green energy
Manufacturing	• 20% of greenhouse emissions • 25% of resource use • 23% of jobs • 17% of pollution-related health problems	• increase water energy and material efficiency • substitute non-renewable and high-energy footprint materials for low-footprint biomaterials • circular economy, eco-design, bio-mimetics
Waste	• 11.2 billion tonnes of solid waste generated per year • organic decay equals 5% of total emissions • marine litter • soil and water pollution	• circular economy (reduce, re-use, recycle, biodegradable) • new bio-based products from organic waste (e.g. degradable biomaterials) • waste to energy conversions
Construction	• 10% of global GDP • 33% of GHG emissions • 33% of all material use • 40% of waste • 12% of fresh water	• revert to timber and bio-materials for sustainable construction • passive house standards • water efficiency, collective renewable heating • retrofitting buildings for improved environmental performance
Transport	• 50% of liquid fuel consumption • 25% of energy-related GHG emissions • 80% of atmospheric pollution in cities • 1.3 million fatal accidents per year • global Automobile fleet to grow 300% by 2050	• landscape and urban planning • enhanced public transport • digital economy (i.e. virtual meetings) • sharing economy, shared transport • renewable electric and lighter, more efficient vehicles (i.e. bio-based carbon fibre cars) • aviation advance biofuels
Tourism	• 5% of global GDP and 8% of global jobs • 6% of total exports, first export sector for 150 countries • 5% of global GHG emissions, relevant local pressures on water and waste and nature	• green transport • green construction • nature- and heritage-based tourism • increased resource efficiency
Cities	• 50% of global population, increasing rapidly • up to 80% of energy consumption and GHG emissions • consumption and waste generation centres	• leverage high density population to increase energy, water efficiency to reduce waste • improve urban-rural links • nature-based solutions for human health, risk mitigation, urban farming, etc.

Source: adapted from UNEP 2011

Building blocks to realise the circular bioeconomy

Southern Europe is the region with the largest diversity in Europe also in landscapes and patterns of land use. Each city, region and country will need to develop a specific and tailored approach to the circular bioeconomy, adapted to existing biogeographic, economic and social situations. For example, they will have to consider the availability and types of biomass, existing industrial capacities, societal preferences, and they will need to find adequate strategies to maximise economic, social and environmental benefits.

The bioeconomy, relies heavily on biological resources though the capacity to produce them might be insufficient to supply their already existing needs (Global Footprint Network 2015). For this reason, reduced material intensities and closed material loops are necessary to maximise positive environmental and social impacts. In this respect, the traditional local knowledge of ancient systems were implicitly based on bioeconomy criteria. Old innovations can be re-discovered, adapted, improved and spread, as is the case of agroforestry systems and the use of non-wood forest products (NWFPs). Yet, to transition the local economy to circularity is not always simple. It might even be viewed as daunting by local and regional private and public actors who are often constrained not only because they lack an adequate framework (e.g. lack of financial resources, skills and specific competencies) but also because there is confusion about circularity means and confusion about the necessary steps to achieve it. To partially solve the problem, scholars from the Centre for European Policy Studies and the Stockholm Environment Institute recently created a modular framework called Circular Economy Progress for Stakeholders (Taranic, Behrens and Topi, 2016). This framework divides the circular economy into eight building blocks. To achieve circularity, these blocks or modules can be implemented by public and private actors, either independently or in any possible combination. The framework can be extended and expanded to include any new technology or approach that becomes available. Table 2 briefly summarises their characteristics.

Table 2. The eight building blocks of the Circular Economy Progress for Stakeholders framework

Bio-based products	Substitute synthetic, non-renewable products with biological products. This requires re-thinking product and process design to use biological feedstocks and reusing by-products from agri-food and forest industry processes. Also, it requires sustainable and efficient biomass supply chains, deployment of biotechnologies and hybridisation with nanotech-nologies and material sciences, eco-design, etc.
Industrial symbiosis	This is the "physical exchanges of materials, energy, water, and by-products" between different co-located industrial facilities: the waste / by product of one facility is used as a resource by another. It requires appropriate framework conditions and intense facilitation.
Material resource efficiency	Material resource efficiency is the process of reducing the amount of material resources, e.g. raw materials or intermediate products, needed to produce one unit of a product or service. It can be summarised as "doing more or the same with less."
Renewable energy and energy efficiency	Renewable energy is the production of energy in its various forms from resources that are naturally renewable over the lifetime of the power plant. Energy efficiency equates to reducing the amount of energy necessary to produce the unit of product. In economies constrained by natural boundaries, they should always be used together.
Product lifecycle extension	This consists of designing, producing and delivering products, services and processes with prolonged life spans, i.e. made to: • serve longer • be easily repaired • be easily upgraded • be easily serviced and maintained • be easily recombined into something new, reused and recycled at later stages of the life cycle It requires realistic future scenarios and a vision of the future. It moves the focus of the economy from production to maintenance, servicing and upgrading, and to some extent, from manufacturing to services. It favours long lifespan material uses over short lifespan material and energy uses.
Performance economy	In essence, it consists in providing products as services, both for B2C and B2B. It requires changes to consumer behaviour from purchase to rent or lease.
Sharing economy	It relays on the consumers sharing the access to goods and services, and in some instances sharing the process of obtaining and disposing of the goods and services. It may be sup-ported by online platforms, but this is not necessary. It is typically used C2C (consumer to consumer) but can be used B2B (Business to Business).
Platform economy	It relays on the direct interactions between buyers and sellers on different scales. It may use online platforms, but this is not necessary. It may make the economic roles fluid, consumer and producer. It is not intrinsic to the Circular Economy as such, but it enables other building blocks (e.g. the performance economy and the sharing economy) and it can accelerate the adoption and the scaling up.

The eight building blocks of the framework could be integrated with the bioeconomy to produce a novel approach to local economic development, i.e. the circular bioeconomy.

What is the role of the forest-based sector in the circular bioeconomy

The role of forests and the forest sector is often viewed through a very traditional lens as providers of timber, pulp, paper and some bioenergy, accounting for a small percentage of global GDP and as providing employment. However, new technologies, business models and consumption patterns are creating opportunities allowing for the forest-based sector to make a much greater contribution to sustainable development. The forest sector is already undergoing major structural changes and diversification and in producing advanced materials that can help transform main economic sectors such as energy, construction and manufacturing (textiles, plastics, pharmaceutics, cosmetics,...). This knowledge-intensive portfolio of current and future products will require specialized services (design, research and development, consulting, marketing, sales, etc.) that further multiply its economic impact and its capacity to generate employment (Hetemäki et al 2014).

Moreover, forests provide key ecosystem services to society, such as cultural services (recreation, ecotourism, hunting, health), regulating services (clean air, erosion control, climate mitigation), and provisioning services (clean drinking water, non-wood forest products like mushrooms and berries). At the global scale, the total value of the ecosystem services provided by forests has been estimated in the trillions of dollars, which is two orders of magnitude above global GDP (UNEP 2011). Tourism already represents 10% of global GDP (2017) and, in many regions, the nature-based tourism is the most dynamic segment (and forest resources are a key component there). Yet, forests can only produce goods and services for the bioeconomy if extreme climatic events or unsustainable management does not alter their biological integrity. This double-sided contribution of forest to the bioeconomy and its feedback loops must be a relevant element when designing the circular bioeconomy (Kleinschmit *et al.* 2017).

The forest-based circular bioeconomy in southern Europe as examined in this synthesis report

Southern Europe has biophysical, economic and cultural specificities as well as particular challenges and opportunities. Describing and identifying them is the main goal of this synthesis report that reviews existing scientific knowledge. Chapter 1 outlines the major environmental and societal challenges, as well as the most relevant characteristics of forests and the forest-based sectors. Chapter 2, analyses the role of the bioeconomy in existing national bioeconomy strategies and regional smart specialisation strategies. Chapter 3 explores the opportunities ahead in the main bioeconomy sectors. Chapter 4 examines the options to overcome crosscutting hurdles in areas that require urgent attention from science and policy. Finally, chapter 5 summarises the messages and makes recommendations for action.

The report concentrates on forests and acknowledges the relevance of agro-ecosystems and other sources of biomass, from land and sea, as well as biological waste. It takes a broad look at the bioeconomy beyond the supply and transformation of biomass, to address other opportunities linked to other types of goods and ecosystems services.

Southern Europe is understood in this report as the Mediterranean and Atlantic climate regions of the Iberian Peninsula and Southern France (former regions of Aquitaine, Languedoc-Roussillon and Provence, Alps and Côte d'Azur), the Italian peninsula, Greece and the Mediterranean climate areas of southeast Europe. It does not cover the continental climate areas of South Eastern Europe and the Balkans, unless when specifically mentioned.

1. Setting the scene: Drivers, enablers and barriers in southern Europe

Developing a circular forest-based bioeconomy in its broad sense requires a clear understanding of the overall environmental, social and economic context and its likely evolutions. What is the situation of the forest-based sector and how can it face this new context and adapt to it? This chapter addresses the drivers, opportunities and barriers in southern Europe that will help or limit the capacity of the forest-based sector to play an increased role in the circular bioeconomy.

1.1. Social and environmental challenges

Southern Europe has undergone strong population growth, urbanisation and economic development in the last century. It is today a net importer of fossil- and bio-based primary resources, notably fossil energy carriers, food and wood. A relatively recent scenario analysis (World Economic Forum 2011) has identified three key long term challenges for the Euro-Mediterranean region:

A. the scarcity and fragility of natural resources, exacerbated by climate change and changing consumption patterns;
B. structural unemployment and weak competitiveness, in a context of diverging demographic trends (e.g. rapidly aging population in Southern Europe versus young and rapidly growing population in neighbouring Mediterranean and Near East Countries; and
C. the degree of political integration in which these issues will be addressed.

The World Economic Forum (WEF) argues that these interconnected challenges are binding together Southern Europe and the larger Mediterranean Region in a "community of shared destiny", as "no country or individual actor can control the final outcomes". The bioeconomy, as the key element of a new development paradigm, lies at the core of these challenges and must be addressed, consequently in its larger regional dimension, as has already been recognised in the Partnership for Research and Innovation in the Mediterranean Area initiative.[2]

Sustainable management of scarce natural resources

The Global Footprint Network estimates that southern European countries have already surpassed their biocapacity four to five times (Figure 2, Global Footprint Network 2015). This means that the region's consumption of biological resources largely surpasses their production capacity.

Water resources are especially limited and unevenly distributed in location and time. The Mediterranean region already hosts the largest share of the world's population living underwater stressed conditions (UNEP/MAP-Plan Bleu 2009) and demand is increasing. The population in the region is estimated to grow an additional 7% in the next decade to reach 560 million people in 2030, up from 280 million in 1970 (CIHEAM 2015). Tourism, industry and agricultural irrigation are putting additional pressure on water resources and are generating competition across economic sectors and land uses. This creates significant long-term challenges related to the water-food-energy nexus with the potential to generate social distress and political instability. In this context, the bioeconomy must be able to sustainably increase the productivity of biological resources, decouple economic growth and material use, reduce water and carbon footprints and contribute to food security, among other positive social and environmental impacts.

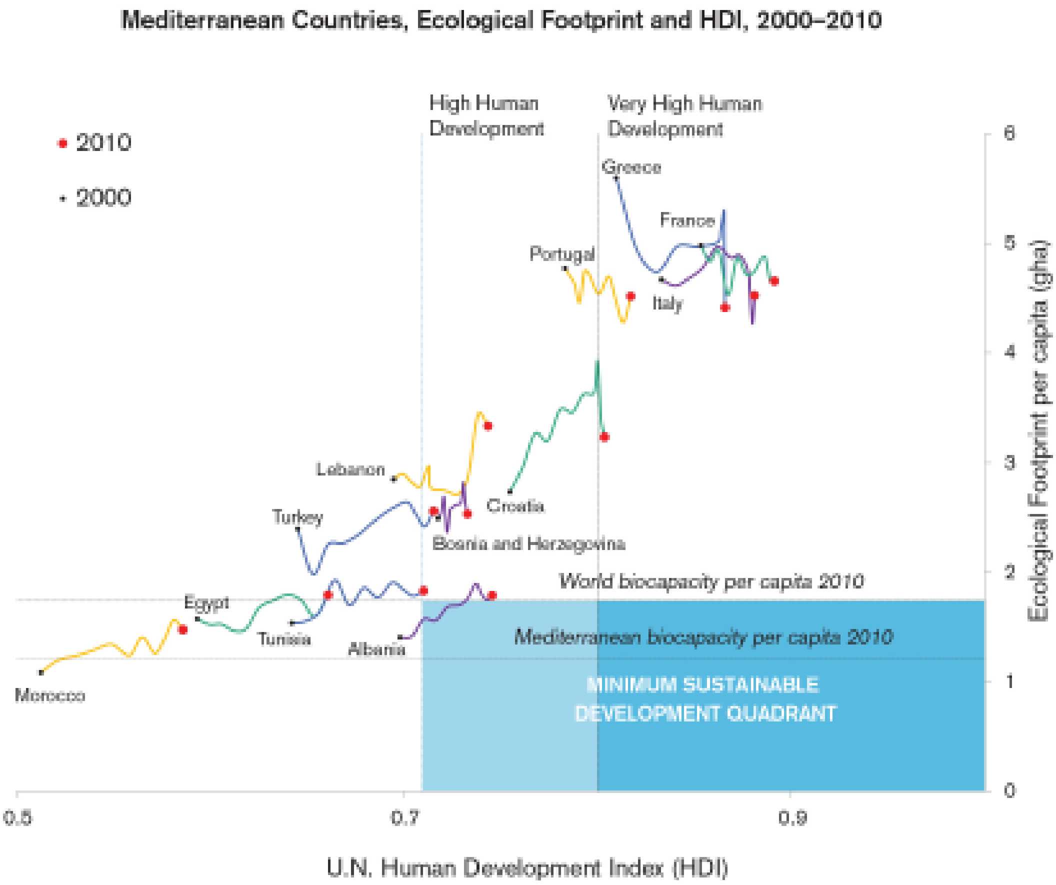
Despite the existing ecological constraints, the share of biomass in total domestic material use is relatively high in southern Europe (Eurostat 2017). This is a direct consequence of a generally lower material intensity[3], as corresponds to less industrialised and more service-oriented economies. This lower material intensity, high relative share of biological resources and a high potential for solar, wind and geothermal energy offers great opportunities for a fossil-free circular bioeconomy.

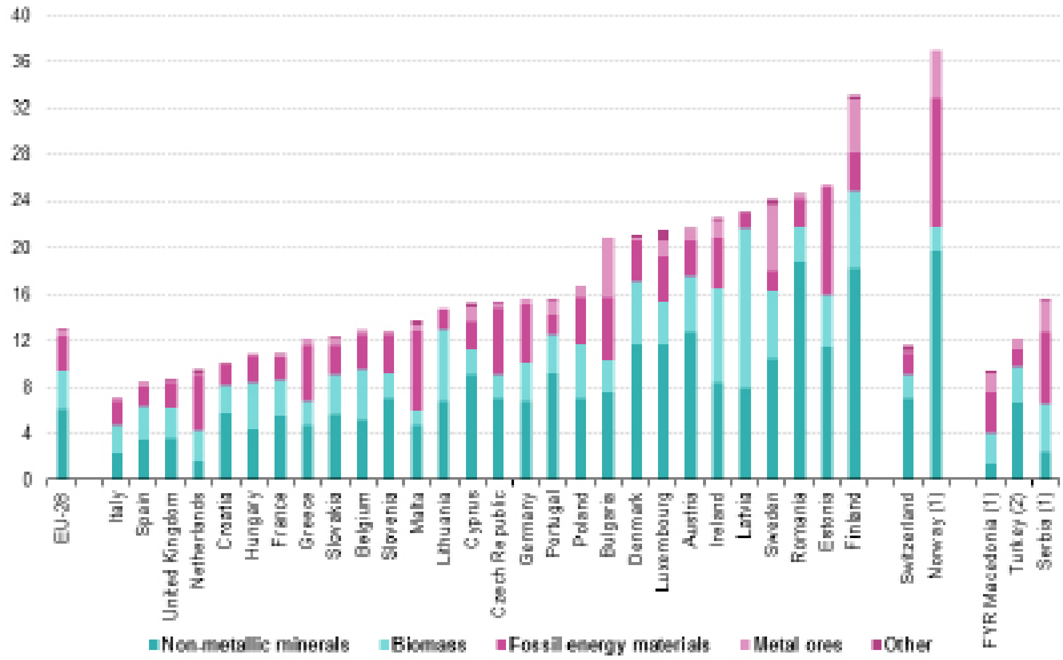
Increased innovation capacity and employment as top priorities

In comparison with other advanced economies in North America and Asia, the European Union (EU) performs relatively well in social inclusion and environmental sustainability but underperforms in relation to a knowledge -based economy that can help

[2] PRIMA is set up "to develop knowledge and common innovative solutions for water management and provision and agro-food systems in the Mediterranean region, … to contribute to solving water scarcity, food security, nutrition and physical activity, health, wellbeing and migration problems upstream". https://ec.europa.eu/research/environment/index.cfm?pg=prima

[3] Domestic Material Consumption is in the range of 7 to 11 tonnes per capita in Italy, Spain and France, with a share of biomass in the range of (29%-34%), which compares with 16 tonnes per capita in Germany (22%), 17 in Poland (28%) or 21 in Austria (22%) and are significantly lower than the 24 tonnes per capita of Sweden (24%) and the 33 tonnes per capita of Finland (20%) (EUROSTAT, 2016).





Note: 'Other' includes 'Other products' and 'Waste for final treatment and disposal'
(¹) 2015
(²) 2014
Source: Eurostat (online data code: env_ac_mfa; demo_gind)

◀

Figure 2. Trends in Ecological Footprints and the Human Development Index in Southern Europe and the larger Mediterranean region (Global Footprint Network 2015)

Figure 3. Average per-capita omestic Material Consumption in European countries (EUROSTAT, 2017)

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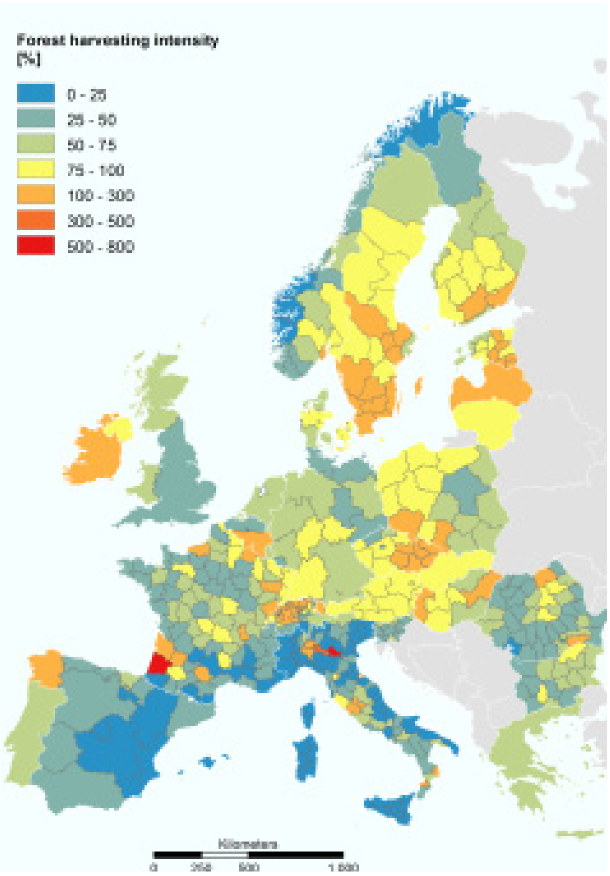


facilitate the transition to higher value-added, more productive activities (WEF 2014). This gap between the EU and other advanced economies is especially notable in southern and eastern Europe. Key elements explaining the divide are: lower research and development expenditures (less than 1% of GDP in southern Europe), less capacity to translate research into marketable solutions (e.g. fewer number of patent applications) and slower implementation of the European Digital Agenda (European Commission 2017). Innovation capacity is an important element of what has been called bioeconomy readiness. Other relevant aspects are the existence of bioeconomy strategies and of bioeconomy-related clusters signalling business cooperation (Spatial Foresight, SWECO, ÖIR, t33, Nordregio, Berman Group, Infyde 2017).

A weaker innovation capacity, among other factors, is reflected in structurally high unemployment rates and extremely high youth unemployment rates, which are among the highest in the world reaching 24% in France, 28% in Portugal, 38% in Italy, 44% in Spain and 47% in Greece (OECD 2016). These trends are exacerbated in rural areas, where a strong exodus has led to large areas being abandoned, creating some of the lowest populated rural areas in Europe (e.g. the Iberian Lapland). Paradoxically, southern European countries have aging populations, a shrinking workforce and increased difficulty in finding citizens willing to work in certain segments of the labour market, generally

Figure 4. Regional innovation scoreboard 2017 (left) and bioeconomy readiness (right). Source: European Commission 2017, Spatial Foresight, SWECO, ÖIR, t33, Nordregio, Berman Group, Infyde 2017

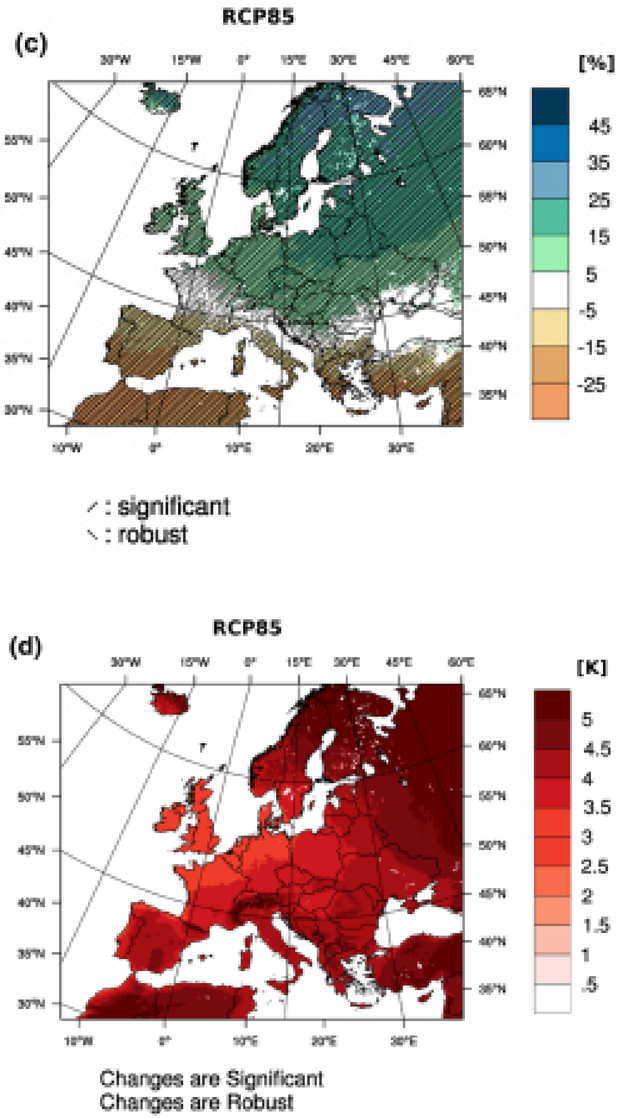


Figure 5. Projected changes of total annual precipitation (%) (left) and annual mean temperature (K) (right) for 2071–2100 compared to 1971–2000, for RCP8.5 (c, d) scenario. Source: EURO-CORDEX: new high-resolution climate change projections for European impact research, Jacob D. *et al.* 2013

in the primary sector. Creating quality employment, also in rural areas, is both a major challenge and one of the most relevant opportunities for the bioeconomy in southern Europe. Youth unemployment is also high in southern Mediterranean countries (average of 23% in 2015) where national labour markets have been unable to absorb the rapid growth among educated youth, and this is creating a lost generation. Addressing the problem of unemployment at the Mediterranean level is a key challenge that will shape the future of both Europe and Northern Africa (WEF 2011).

Climate change is a game changer for nature and people

Forecasts indicate a Mediterranean temperature increase between 2° and 4°C and a decrease in rainfall between 4% and 30% by 2050 (Figure 5, Jacob *et al.* 2014). Increased drought can have major impacts on agriculture, water and food security, affecting crop yields and soil sustainability. There is increased scientific evidence on the links between environmental distresses, climate change, political instability and migration in Mediterranean Africa and the Middle East Temperature fluctuations alone have been shown to significantly affect migrant flows into Europe (Missirian and Schlenker 2017). The potential impacts of biophysical triggers on migration fluxes cannot be overestimated (see Ahmed 2017).

On the other hand, many studies on cultivated or close to nature ecosystems have shown that changing climatic conditions alter communities of animal, plant and microbial species, their phenology, physiology and their productivity. In some areas, for example, some tree populations have already become extinct. Higher temperature and water stress are behind these changes. In addition to these steady trends, extreme climatic events such as heat waves and long dry spells play a major role in reducing the resilience of ecosystems. Mediterranean climate patterns are predicted to expand, causing tree species to change across Europe, with potentially severe economic impacts on forestry (Hanewinkel *et al.* 2013). This will result in new questions regarding agri-food systems, forestry, risk management strategies and land use planning (Fitzgerald and Lindner 2013). In France, for example, recent investigations have shown that by 2060 the risk of forest fire could increase in Mediterranean areas and be extended to a large fraction of the national territory.

Urbanisation affects lifestyles, societal perceptions and priorities

The rapid increase of urban populations and urban lifestyles constitutes one of the major changes of our times (Seto *et al.* 2011). Almost three quarters of the EU-28's population live in cities, towns and suburbs. Cities are responsible for 80% of the energy consumption in the EU; buildings alone are responsible for 42% of total energy consumption, 50% of all material uses, 30% of all waste and 35% of all carbon emissions (EUROSTAT 2016). It is difficult to see how the circular bioeconomy could succeed without contributing to more sustainable cities and without engaging urban citizens. On the other hand, urban lifestyles and reduced access to natural and rural areas are generating a disconnection from nature, and changes in social perception on rural activities, including agriculture and forestry. Forest management and forest issues are not well understood outside the small forestry community and, in many cases, there is a significant gap between reality and people´s understanding. Urban perceptions, generally reinforced in school systems (Pergams and Zaradic 2008), can end up having an important effect on decisions affecting the management of natural resources, shaping policies, approaches and even financial frameworks for the forest bioeconomy (Farcy *et al.* 2016). European citizens, especially in southwestern Europe, value the public goods provided by forests (e.g. biodiversity, protective functions) over the supply of raw materials and are, as a consequence, suspicious of forest management oriented to wood production (Rametsteiner, Eichler and Berg 2009). New ways of developing cities must be based on circular approaches to consumption and mobility, on renewable energies and on an increased reliance on bio-based solutions (e.g. in construction, textiles, packaging) and through an increased reliance on nature-based solutions, green infrastructures and biomimicry. Such social transformation must be sustained in shared understandings of plausible, sustainable and desirable futures, scientifically sound and appealing to both rural and urban citizens (Costanza 2014).

1.2. Strong bio-based sectors that can lead the bioeconomy transition

The bio-based sectors, including food and agro-food industries have a turnover in the EU-28 in the order of EUR 2 trillion (JRC 2016). Southern Europe, including all of France, contributes 40%. In absolute terms, France, Italy and Spain are the main southern contributors with a 15%, 13% and 9%, respectively, share of the EU's bioeconomy. Southern European countries are among the three top contributors in primary production (agriculture, fishing and aquaculture), manufacturing (bio-textiles, wood products and wooden furniture, paper and bio-based chemicals) and energy (bio-fuels and bio-electricity) as shown in Table 3.

Table 3. Turn-over (left) and contribution to employment (right) of several bioeconomy sectors in Europe (2014). Only the three largest EU contributors are listed. Based on Ronzon *et al.* 2017. *missing data for several countries

	Highest contribution	Turnover Billion EUR	Most specialised	Jobs (%)
Agriculture	France	68.4	Romania	27.7%
	Germany	55.0	Greece	13.0%
	Italy	45.0	Poland	11.0%
Forestry	Germany	8.8	Latvia	1.6%
	Sweden	8.4	Estonia	0.9%
	France	6.1	Lithuania	0.9%
Fishing and aquaculture	Spain	2.4	Greece	0.8%
	France	2.1	Portugal	0.5%
	United Kingdom	1.7	Croatia	0.4%
Agri-food	Germany	210	Croatia	4.1%
	France	186	Bulgaria	3.3%
	United Kingdom	132	Lithuania	3.3%
Bio-textiles	Italy	50.0	Portugal	2.6%
	France	11.8	Bulgaria	1.8%
	Germany	11.0	Romania	1.4%

	Highest contribution	Turnover Billion EUR	Most specialised	Jobs (%)
Wood products	Germany	40.3	Estonia	3.7%
	Italy	27.8	Latvia	3.6%
	France	17.5	Lithuania	3.4%
Pulp and paper	Germany	39.8	Finland	0.9%
	Italy	21.9	Sweden	0.7%
	Finland	19.1	Slovenia	0.5%
Green chemistry	Germany	33.5	Denmark	0.8%
	France	20.8	Czech Republic	0.4%
	Italy	11.3	Slovenia	0.3%
Liquid fuels	Germany	8.4	Belgium	0.1%
	France	4.5	Denmark	0.1%
	Italy	2.5	Germany	0.1%
Bio-electricity	France*	2.3	Cyprus	0.3%
	Spain*	1.4	Bulgaria	0.2%
	Italy*	1.2	Romania	0.2%
Total	Germany	407	Romania	33.1%
	France	337	Greece	17.3%
	Italy	293	Lithuania	16.8%

Agriculture and the agro-food sectors dominate the bioeconomy, while forests and forest related value chains represent more over 50% of the non-food bioeconomy of southern Europe (Ronzon *et al.* 2017). As a consequence, there is higher diversity of biomass sources with a greater relevance of agricultural residues and dedicated agricultural crops. Nevertheless, lignocellulosic biomass and, specifically forest primary and secondary biomass (residues and side-streams), are the most significant sources of non-food biomass in southern Europe (Table 4, Figure 6).

Clearly, there is a need to better understand, monitor and communicate biomass availabilities, to facilitate business discoveries and investment decisions. In general terms, Southern European bioeconomy will need to stay away from a model based in large scale bio refineries centred in bulk products and commodities. Instead it will need a greater focus on specialised, smaller scale facilities producing higher added-value bio-products. Even then, achieving the necessary economies of scale might require mixed feedstock conversion processes and, distributed pre-treatment facilities. This represents a significant technological challenge.

Table 4. The contribution of the forests-based sector to the current bioeconomy in southern European countries. Based in JRC (2016) and S2Biom project

	Turnover			Biomass			
	Billion EUR 2014	% non-food bio-economy	% of forest in non-food	Total potential 2020	Forest biomass %	Forest biomass /non-food	Forest & lignocel-lulosic crops
Croatia	10.1	26%	65%	6 749	57%	85%	58%
Cyprus	2.3	12%	67%	679	10%	10%	52%
France	337.1	23%	52%	124 786	40%	59%	47%
Greece	27.1	12%	54%	9 025	29%	41%	43%
Italy	293.1	28%	74%	50 831	32%	40%	52%
Malta	0.3	37%	100%	130	7%	7%	15%
Portugal	38.6	39%	56%	17 592	76%	79%	84%
Slovenia	6.5	47%	69%	6 063	89%	90%	90%
Spain	191.3	22%	53%	67 910	24%	32%	55%

Source: S2Biom project[4]

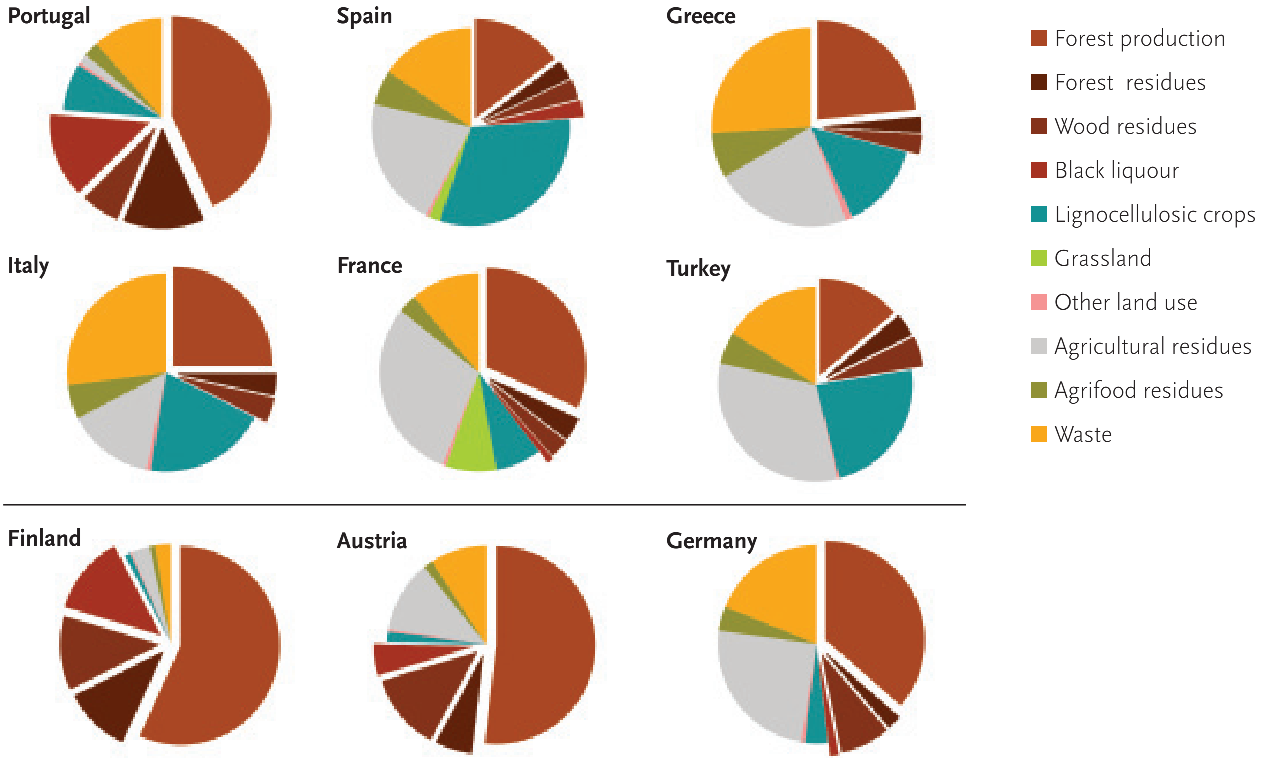


Figure 6. Relative availability of biomass types. Brown colours represent different types of forest biomass.

Source: S2Biom project[4]

The marine environment also offers great potential for the bioeconomy. Southern Europe has the longest coastlines of all Europe. This creates opportunities for aquatic activities, including fisheries aquaculture and offsite biomass production. Five of the top seven fishing fleets of the EU are from southern countries (Spain, France, Italy, Portugal, Greece)[4]. In spite of this, marine biomass represents a low share of the total biomass (25kg per capita per year in Spain, the country with the biggest fishing fleet in the EU). As traditional fisheries decay, aquaculture and offshore biomass cultivation and transformation (micro-algae) appear as to be a promising opportunity.

Although small in volume, fish biomass sustains very relevant food and tertiary sectors (restaurants, tourism, etc.). Even so, marine bioeconomy opportunities go beyond biomass. The coastline, the landscape, the rich cultural heritage and the climate are important factors explaining why southern Europe are the destination for 30% of the world's tourism. The Mediterranean, however, is one of the most polluted seas on Earth, with surface plastic concentration as high as the better known Pacific gyres (Cózar *et al.* 2015). The potential economic and social impact has not received enough attention. Reducing marine litter and marine pollution must be a key policy, economic and societal driver of the bioeconomy, and it must be at the centre of relevant regional initiatives. The opportunities of the marine bioeconomy are not further discussed in this report.

[4] http://ec.europa.eu/eurostat/statistics-explained/index.php/Fishery_statistics

1.3. Forest and forest-based sectors in southern Europe.

Southern European forests and forest-based industries are highly diverse. In order to understand the current situation and the main trends of forest and forest-based industries in southern Europe, it is useful to distinguish between two main forest regions. The humid forests of the Atlantic rim and continental piedmonts that are frequently dominated by planted forest and the low management Mediterranean forests that dominate most of central and southern Portugal, southern France and most of Spain, Italy, Greece and the Adriatic coast of the Balkan region.

For historical reasons, the humid and temperate forests of the Atlantic rim are dominated by plantation forests with a significant share of exotic species. Maritime pine and eucalyptus are the main species in this region amounting to 4 million ha of forested area. Radiate pine and Scotch pine are also important, mainly in northern Spain. With average growth rates typically in the range of 10–20 m^3/ha, this relatively small region produces around 30 million cubic meters of roundwood. This includes over 75% of the Portuguese and Spanish wood production and 42% of the total French softwood production. Harvest intensity is typically around 50% to 70% of the total growth and is mainly based in plantations that provide over 95% of all wood produced. Management intensity and wood production is very low in the remaining semi-natural forests present in the continental piedmonts and mountain regions. The productive commercial forest plantations are mainly privately owned, as much as 90% in Portugal and Galicia. Average ownership size is very small, around 1 ha in northern Portugal and western Spain, and up to 6 to 9 ha in the Basque Country and Aquitaine. Forest owners are quite elderly, and new owners are inheriting their forests typically at ages between 60 and 65 years old. Consequently, this generational change is bringing new urban forest owners, but not necessarily younger ones. Contrary to the situation in Nordic countries, forest owner organisations are rather new and, with some exceptions, generally weak. Also, with the exception of France, forest cooperatives are mainly non-existent. Moreover, in contrast to some central European regions, the public forests do not play as active a role in wood production. The predominance of fragmented, private and aging ownership, weak producer organisations, and sometimes a lack of infrastructure in rough terrains results in major wood mobilisation difficulties. This also complicates information flows and the uptake of technological and managerial innovation (see Martinez de Arano and Lesgourgues 2014 and references therein).

In contrast to the Atlantic region, the Mediterranean climate areas of southeast and southwest Europe are characterised by less productive, highly biodiverse forests, including a large share of non-commercial species. In these forests the climate is dryer, the canopies less dense the canopies are less dense but the brush is thicker, which contributes to high forest fire risk. Non-wood forest products are relatively more important in forest economies. Forest industries, outside niche markets (e.g. cork, poplar or resin) are fragmented or based on imported wood resources (Nilsson 2007).

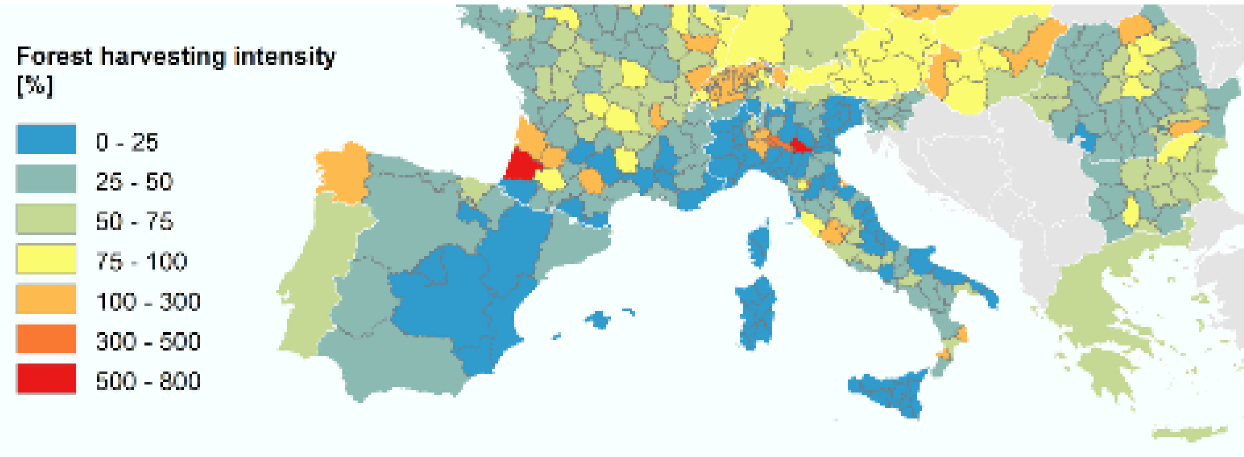


Figure 7. Average harvest intensity in southern Europe for 2000–2010

Source: Levers *et al*, 2014

Expanding forests, low utilisation rates

Over the last 70 years, southern Europe has witnessed of one of the most impressive forest increases ever recorded. Forest cover that had fallen well below 10% in the first half of the XX century is now reaching averages of 39% in Italy and 50% in Spain and in Mediterranean France. In Spain, forests have expanded by 4 million ha in the last 20 years. In certain regions, the expansion of forests is even more intense. Catalonia, for example, is approaching the highest forest cover it has had in the last 1 000 years. In Italy forest cover doubled in the last 50 years. This expansion is a result of spontaneous afforestation of abandoned agricultural lands and pastures. Planned afforestation has only occurred in some regions mainly for timber production. Outside the most productive planted areas, utilisation rates are fairly low (Figure 7), as wood-based value chains are generally weaker (see below). Rural abandonment and the expansion of forests have multiple consequences. On the one hand, there is an opportunity to restore the ecosystem and conserve biodiversity. On the other, these areas are producing untapped biomass resources for the bioeconomy. Currently, the landscape is increasingly dominated by continuous, high-density, young forests with high fuel loads, which present a great risk for high-intensity fires, especially since the climate is becoming increasingly hotter and dryer. The very high cost of fighting fires is a key element of southern forest policy, even though the capacity of current fire suppression systems is under question.

The estimated spatial distribution of the availability of biomass in the region is shown in Figure 8 and expressed per unit of land area. The estimated amount of biomass available varies strongly across southern Europe. The forest biomass potential per unit of land is generally highest in plantation dominated areas (southwest France, central Portugal) and where there is a higher forest cover ratio. The estimated biomass available from forests represents the potential availability and considers various technical and environmental constraints that could reduce availability.

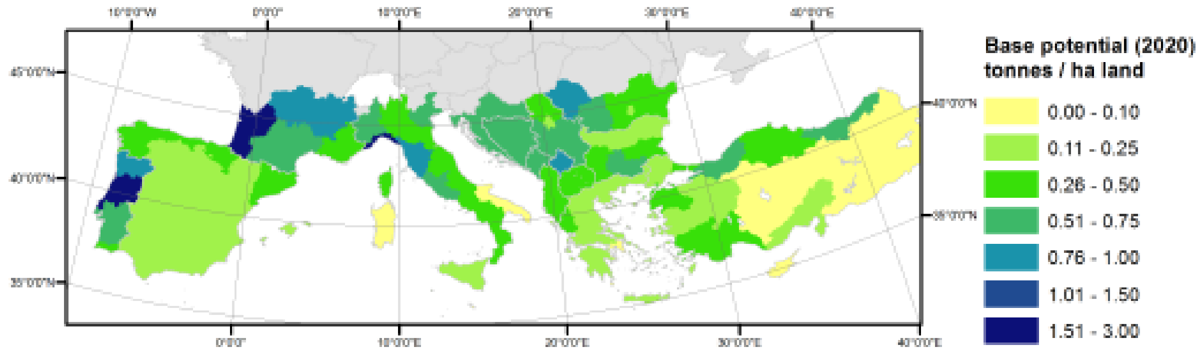


Figure 8. Distribution of potential forest biomass availability per hectare of land (including primary residues from forests)

Source: Base potential in 2020 in Dees et al, (2017)

Using this biomass would require a significant change in the way these forests are managed and could have varying effects because of the many other benefits forests provide to society. A key issue in mobilising the potentially available biomass in the region will also be whether private and public forest owners can be motivated to bring their wood to the market. Survey results suggest that private forest owners in Portugal might not contribute large amounts of stem wood for energy purposes (Blennow *et al.* 2014), but it is unclear whether private owners would be willing to supply it for material uses. The survey results contrast with findings from the southeastern European countries, showing a relatively high degree of willingness on the part of forest owners to manage their forests with the intention of producing woody biomass for energy purposes (Stejpan *et al.* 2015). Southern European citizens are among those who are most clearly in favour of managing forests mainly for conserving biodiversity and for protective functions and are less interested in forests being used for commercial wood supply (ECORSYS 2010). This represents an additional hurdle for wood mobilisation.

Forest extension and biomass potential per capita is in range with continental regions in Europe but is far below the boreal regions (Table 5). The Nordic bioeconomy is based on an average of 9 $m^3ha^{-1}yr^{-1}$ (average harvest in 1990–2000) and 4 ha of forest per capita, while in southern Europe those values are below 0.5 $m^3ha^{-1}yr^{-1}$ and 0.5 ha of forest per capita. In relative terms, in the Mediterranean region there are more forests but less mobilised biomass (always per capita) when compared to the Atlantic region (or even to central European regions). The transformational capacity of a forest-based bioeconomy will depend on its capacity to maximise environmental and social benefits per unit of biomass processed and per hectare of forest managed, while also including the value of the ecosystem services that are now market externalities into the economy.

Table 5. Availability of Forest Resources in different biogeographical regions. Values represent the average of NUT2 Regions

	Forest ha $inhab^{-1}$	Std.	Harvest m^3 $inhab^{-1}$ yr^{-1}	Std.	Increment $m^3 ha^{-1} yr^{-1}$	Std.
Atlantic	0.11^{a}	0.22	0.35^{a}	0.74	5.16^{a}	0.69
Boreal	4.17^{b}	5.06	9.04^{b}	8.08	3.06^{b}	0.56
Continental	0.29^{c}	0.2	1.08^{c}	1.00	4.14^{c}	0.61
Mediterranean	0.43^{d}	0.44	0.42^{ad}	0.65	3.73^{cd}	0.78

Source: Verkerk *et al.* and S2BIOM project

Box 1. Why is forest biomass not just another feedstock? Why must the supply be addressed in its full complexity?

In contrast to other raw materials, biomass production is intimately related to the landscape, its people and nature. This obvious statement has multiple consequences:

• Production practices must maintain or restore the natural capital (soil, water, biodiversity). There are multiple examples of negative impacts. Intensification is not always the right answer.

• In any given region, supply depends on thousands of individual farmers, forest owners and land managers. Changes in the supply chains must deal with the ideas, wills and perceptions of multiple stakeholders and with property structures that have strong regional variations. Consequently, there will never be a one size fits all approach to improving biomass supply.

• The capacity to supply biomass can be greatly affected by climate change, with especially negative consequences in southern Europe. Adaptation requires action at multiple levels High fragmentation of forest ownerships is a major hurdle for climate change adaptation and the sustainable supply of biomass and all other ecosystem services.

In addition, biomass is a relatively bulky material with high water content and low energy density, which can have many alternative uses.

• Costs of production and harvest are generally high in Europe due to high environmental standards and high labour and other operating costs. This complicates cost-competitiveness, both compared to fossil alternatives and to equivalent products from elsewhere in the world.

• The cost of transport is high over long distances, requiring localised processing or pre-processing facilities for cost-effective production. In mountain areas, predominant in southern Europe, limited accessibility and lack of transport infrastructure is an additional limitation.

• A high diversity in biomass types, typical of southern Europe, possesses additional technological challenges and increased costs. Niche differentiation and higher added-value products need to replace economies of scale.

• Since mobilising biomass is difficult, making the best of by-products (e.g. sawdust, bark or lignin rich liquors) offers a clear opportunity to develop the bioeconomy while also helping to improve the profitability of existing industries. The limited size of many industrial plants, especially in the sawmilling sector, could require innovative approaches to secure, or compensate for the lack of economies of scale.

• Cost and availability issues can be exacerbated by resource competition among different potential uses of biomass. High demand or subsidies in one market (e.g. energy) can lead to price increases for other uses.

• However, in areas with weak forest industries, as in the Mediterranean, the availability of cost-effective side streams is limited. Local bioenergy value chains can be the lower hanging fruit that can help activate forestry. The carbon balance of bioenergy will greatly depend on the characteristics of the supply chains and the conversion technologies.

1.4. Forest-based industries in southern Europe

In Portugal the forest industry represents 2.1% of the country's GDP, 8% of the industrial GDP, and 10% of total exports. The contribution to the national economy is much lower in other Mediterranean countries where is generally around or below 1% of the GDP.

With few exceptions, southern Europe's forestry faces high harvest and logging costs, highly heterogeneous and dispersed supply and a large array of different regulations and market arrangements. Southern Europe hosts world class capacities and global players in the wood panels industry (e.g. Arauco Sonae, Garnica plywood, Fantoni group, Gruppo Mauro Saviola…). Leading companies are present or actively entering high added value markets in construction (e.g. structural and specialty panels), furniture or wood based chemistry. The situation of the sawmilling sector is somehow different. There are significant capacities in wood-working industries, wood architecture, furniture and wood design. Italy is Europe's first and world's third furniture exporter and is also Europe's 4th largest market for wood construction. However, in general terms, high added-value engineered wood industries relay on imported wood. With some notable exceptions the sawmilling sector is still comprised of small companies producing low added-value products for commodity markets. Competitive position is weak. Counter intuitively for an industrialised country, France, for example, exports roundwood and is a net importer of elaborated products. The lack of more sophisticated and profitable solid wood value chains puts downward pressures on the price of the raw material, as cost reduction is the key strategy to stay in commodity markets. This in turns jeopardises wood mobilisation capacities and the long term engagement of forest owners.

Pulp capacities in Atlantic areas are quite significant, hosting some global players such as Spanish ENCE, Portuguese Navigator and global companies like Smurfit Kappa. Profitability is tight, and industries are focused on costs contention. While Eucalyptus pulp will retain competitive advantages and will benefit from strong demands in the tissue segments, there are less competitive advantages for softwood pulp, but it benefits from strong demands in the packaging sector due to the expansion of e-commerce. In general, pulp mills have entered the bioenergy markets, but there have not been significant developments towards the biorefinery concept, with some exceptions like Tembec's pulp mill in Aquitaine.

In Mediterranean areas wood value chains remain week and dominated by energy uses. Bioenergy. This consumption is less visible and badly recorded in official statistics. Available data shows that residential consumption of fuelwood and pellets is high in Italy, as high as some 20 to 22 million tons per year. It is growing remarkably Spain and is expected to increase significantly in the Balcans region. In general terms, however, the development of the bioenergy sector is facing significant barriers. These are partially related the characteristics of the energy demand and the structure of the energy sector, which is much less reliant on district heating and associated combined heat and power (CHP) production (for example district heating is not well developed in France, where it only meets 6% of the demand). Also, a weak solid wood sector means less forest residues, limiting bioenergy uses because of the low profitability of pure energy value chains.

In summary, despite industrial and technological capacities, high-end/high added-value solid and engineered wood products rely mainly on imported wood, while local resources are linked to lower value commodity value chains. While pulp& paper and panel segments are dominated by large global players, the sawmill segment is occupied by traditional small and medium-size enterprises. Sustained efforts will be needed to support the transition of local sawmilling industries towards higher added-value, longer lifespan engineered wood products and timber construction.

1.5. High biological diversity: what is at stake?

The Mediterranean Basin is a biodiversity hotspot with exceptionally high plant endemism, and one of the lowest percentages of natural vegetation remaining in pristine condition (no more than 5%) in the world. The Natura 2000 network is well developed in southern Europe,[5] especially in the Mediterranean climate regions covering above 30% of the lands in Croatia and Slovenia, over 25% in Cyprus, Greece and Spain and is also above the EU28 average (18%) in Portugal and Italy. Only France and Malta, with some 13% of land under Natura 2000, are below the average in values similar to central European

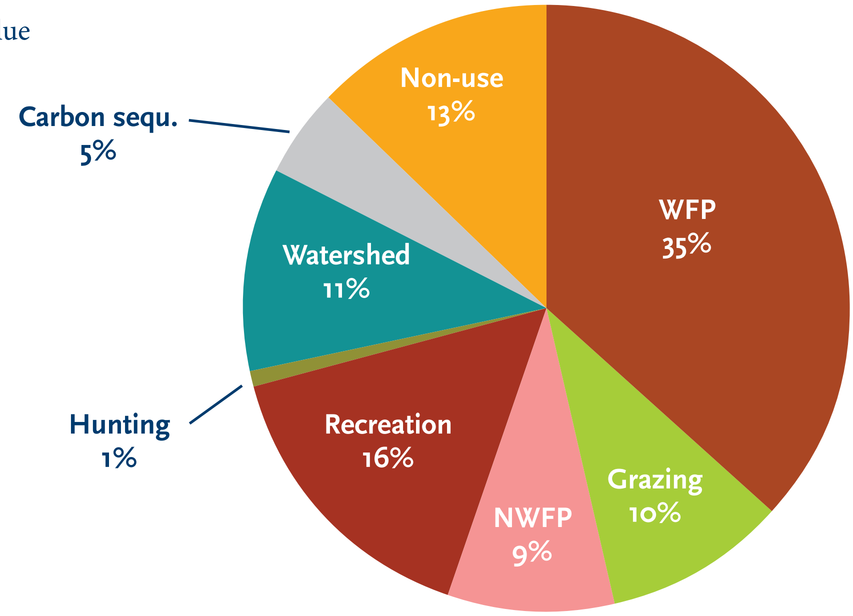
[5] http://ec.europa.eu/environment/nature/natura2000/barometer/index_en.htm

and Nordic countries, that are typically between 12% and 15%. Yet, land area on strict natural reserves is limited to around 4% and erosion of biodiversity continues with threats from climate change, catastrophic fires, new pest and diseases and land use changes. In the Atlantic regions, forestry is mainly based on monoculture plantations of native or introduced species. In recent decades, these man-made forests have been observed to be fragile in relation to abiotic or biotic phenomena such as windstorms (Aquitaine, 1999 and 2009), fire (Portugal, Spain), pest and disease (Portugal, France). As conservation areas prove insufficient, a dynamic conservation approach is required urgently. It should be based on active management to sustain the natural processes responsible for maintaining biodiversity (natural disturbance, gene flows, regeneration) and increase the capacity to adapt to climate change. The Atlantic region will require innovative plantation forestry approaches based on a mix of species at the stand and landscape levels. This is extremely important as biodiversity is not only an assemblage of elements (from gene to ecosystems), it also has a functional role in sustaining complex processes and interactions within the ecosystem, which in turn supplies a broad range of goods and services to society. A number of studies have shown that biodiversity is linked to the capacity of ecosystems to adapt to evolving environmental conditions (van der Plas *et al.* 2017) . When measured, the economic value of non-marketed ecosystem services has been shown to be much higher than the value of marketed biomass (see Box 1). But there is, nevertheless, the need for more tangible valuation methods that are scientifically and politically acceptable.

Box 2. The values of Mediterranean forests

Non-wood forest products (NWFP) such as, cork, fodder, mushrooms, fruits, medicinal and aromatic plants, together with services like soil protection, watershed management, water quality, biodiversity enhancement and climate change mitigation or micro-climate amelioration contribute significantly to the local or national economies of the Mediterranean region. Merlo and Croitoru (2005) presented an average total economic value of Mediterranean forests of about EUR 133 per hectare of forests (in 2001 prices), or almost EUR 50 per capita per year. On average, only around 35% of this value can be attributed to wood forest products, 9% to non-wood forest products and remaining to livestock (grazing) and other ecosystem services. (see Fig. 9). More recently, Masiero *et al.* (2016) have estimated the value of NWFPs in south west Europe at EUR 16.5 per hectare of forests. In Spain and Italy, they represent over 20% of the value of timber. These are probably underestimations, due to lack of reliable and consistent data. Acorns and nuts, cork, animal products, mushrooms and truffles and honey are the main NWFPs, although with great regional differences. Non Wood Forest products can contribute to a more significant and stable flows of incomes, increasing the capacity to sustainable manage and protect forests securing in addition a fundamental set of public non-market services and social values to both local people and the whole community.

Fig. 9. Composition of the total economic value of Mediterranean forests
NWFP: non-wood forest products
WFP: wood forest products;
Non-use: bequest and existence value



Source: Merlo and Croitoru (2005)

Key messages

• The European Mediterranean region is facing major challenges related to the scarcity and fragility of natural resources, notably water, exacerbated by climate change but also by structurally high unemployment rates in a context of diverging demographic trends (e.g. rapid growth in southern countries, rapid aging in northern countries. The circular bioeconomy, as a new economic paradigm must help address those challenges, placing renewable natural capital at the core of economic activities and finding new sources for prosperity and wellbeing.

• Contrary to popular belief, forests in southern Europe have been rapidly expanding in the last century and are still expanding today, even if at a slower rate. Forests are also gaining biomass, as management intensities are generally very low. Except for some Atlantic areas, wood extraction is typically below 50% the biological growth. This has many positive consequences such as increased carbon sequestration, soil restoration and habitat that is available for forest specialists. However, high biomass and forest continuity leads to more megafires. It can also reduce the availability of open habitats and reduce water yields because of increased evapotranspiration. A dynamic conservation approach is urgently required. It should be based on combining management intensities at the landscape level. The bioeconomy can provide the required economic engine.

• Southern Europe has a diversified typology of non-food biomass, with greater relevance of dedicated agricultural crops, agricultural residues and food waste. One possible implication is a greater need for mixed feedstock biomass conversion processes and bio-refineries, distributed pre-treatment facilities and/or a focus on low-volume high-value specialties. There is a clear need to better understand, monitor and communicate the availability of biomass in order to help businesses to know about it and to make their investment decisions.

• Non-wood forest products such as cork resin and nuts are also a relevant resource that requires specific and well-tailored approaches. In general terms, the relevance and potential contribution of non-wood forest products and ecosystem services must be better understood and better reflected in economic and policy decision making.

• The existing forest-based industries are an important instrument in moving towards the bioeconomy. While the pulp, paper and panel sectors, relevant in Atlantic regions, are dominated by transnational, global players, the sawmill product segment consists of small, rather traditional, small and medium-size enterprises locked in low-value commodities. The existing capacities are far from negligible (furniture, timber construction), but the business generally relies on imported wood. Sustained efforts will be needed to support the transition towards higher added value, longer lifespan engineered wood products and timber construction.

2. Forests and forestry in southern European bioeconomy strategies

The EU and 15 member countries have developed bioeconomy strategies (See Hetemäki *et al.* 2017). Although not among the front runners, some Southern countries have developed their own strategy, as is the case for Spain, Italy and France. These national strategies are analysed in this section, along with Portugal's green growth commitment, which has a strong bioeconomy component. Virtually all countries and regions have sectorial bioeconomy related policies or strategies or, for example, renewable energy action plans. Those are not analysed here as they fail to provide a coherent and holistic vision of the potential and challenges of the bioeconomy.

2.1 The European Union strategy: A bioeconomy for Europe

In the EU, the concept of a knowledge-based bioeconomy was first officially introduced in 2005 with an emphasis on biotechnologies and sustainability, for transforming life sciences knowledge into new, sustainable, eco-efficient and competitive products. In 2007, the EU adopted the declaration: *En route to the bio-based economy*, putting the focus on biotechnologies for increased crop production and biomass transformation especially in the health, energy and food sectors. The Seventh Framework Programme (2007–2013) devoted EUR 1.7 billion to a programme called Knowledge Based Bioeconomy that included biotechnologies along with agricultural, fisheries and forest research. In parallel, it launched in 2007 the Lead Market Initiative to stimulat3 six promising and sustainable sectors (including renewable energies, biomaterials and sustainable construction) leveraging public procurement and other demand side measures to foster innovation and market uptake. At the same time, the European Commission launched the Climate and Energy package with the goal of reducing carbon emissions by 20% for 2020, and which included mandatory targets for increased efficiency and a 20% share of renewable energy (later increased to 27% of emission reduction and 27% of renewable energies by 2030). In this context, and as a reaction to the economic downturn, the European Commission launched the 2020 strategy for smart, sustainable, inclusive growth with a clear focus on economic development, competitiveness and jobs. It included a flagship initiative to help decouple economic growth from the use of resources, by decarbonising the economy, increasing the use of renewable sources, modernising the transport sector and promoting energy efficiency. This was followed two years later by the EU's bioeconomy strategy called *Innovating for Sustainable Growth: A Bioeconomy for Europe* (European Commission 2012) with the objective of encouraging policy coherence, innovation and social acceptance. Interestingly, the EU bioeconomy strategy's main focus is on sourcing and producing biomass instead of on the industrial biotechnologies and pharma that have dominated recent Organisation for Economic Co-operation and Development bioeconomy strategies, setting a trend followed in most EU national strategies (McCormick and Kautto 2013).

Box 3. The EU Bioeconomy strategy in a nutshell

Definition: The bioeconomy is an economy that uses biological resources from the land and sea, as well as waste, as inputs for food and feed, industry and energy production. It also covers the use of bio-based processes for sustainable industries.

Main focus: The bioeconomy aims to create policy coherence across research and innovation, agricultural and rural development, environmental, industrial, energy and other policies.

Drivers: Emission reduction, better resource efficiency and an increased competitiveness are expected to be reconciled with food security and the sustainable use of renewable resources for industrial and environmental purposes.

Goals: 1) Ensuring food security; 2) Managing natural resources sustainably; 3) Reducing dependence on non-renewable resources; 4) Mitigating and adapting to climate change; and 5) Creating jobs and maintaining European competitiveness.

Priority sectors: The bioeconomy works in agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries.

Priority lines for action:

- Investment in knowledge, innovation and skills; expanding support for knowledge networks, advisory and business support services; increasing the share of multi-disciplinary and cross-sectoral research, facilitating the development of new bioeconomy curricula and vocational training schemes; increasing coordination of national research agendas; and partnering with the private sector notably through EIPs and bio-clusters

- Participative governance and informed dialogue with society; creating a bioeconomy panel to enhance synergies and coherence between policies; encourage similar panels at Member States and at regional levels; create a bioeconomy observatory to assess progress and promote adoption of national and regional strategies

- Enhance markets and competitiveness in the bioeconomy, communicate the benefits of bio-based products and support the expansion of markets through standards and standardised methodologies for sustainability assessment

Gaps: Several key areas of the bioeconomy are not dealt with or assumed to be dealt with in other policies. This is the case for resource competition, resource efficiency and, in general, sustainability and social issues.

2.2 A bioeconomy strategy for France (2017): Putting photosynthesis at the core of the economy

The Ministry of Agriculture and Forestry has prepared a bioeconomy strategy (Republic of France 2016) based on a public debate. It includes a parliamentary report entitled: *From biomass to bioeconomy: A Strategy for France*[6]. The strategy builds upon previous work, as The new industrial France (2015) and the National Strategy for Ecological Transition Towards Sustainable Development (2015–2020) focuses on the bio-based sector. It is intended to make sectorial policies related to agriculture, forestry and urban waste, among others, more coherent. The bioeconomy is understood as the photosynthesis economy, and, more generally, as the living world economy. It encompasses all biomass production and processing activities, whether in forestry, farming or aquaculture, directed at the production of food, feed, bio-based products and renewable energy.

Drivers and focus, including relation to other technology trends

Key drivers identified in the French strategy are:

• the need to implement the Climate Agreement reached at COP 21;
• the surge in demand for protein because of population growth and changes in consumer habits; and
• the opportunity to gain efficiently, creating more value from the available bio-resources, including current side products.

[6] http://www.senat.fr/rap/r15-380/r15-380.html

The strategy aims to leverage existing bio-based industrial capacities and research excellence to provide "innovative, effective and affordable solutions able to meet the diversity of human needs." Main challenges are related to creating markets for bio-products, supporting the industrial transition in key sectors, up-scaling pilot and lab scale solutions, achieving a smooth supply of biomass, ensuring sustainability all along the value chain, promoting social acceptance through informed dialogue and stimulating technological, social and environmental innovation. The strategy acknowledges the need to adapt to regional differences, but does not further explain. Synergies with nanotechnologies and information and communication technologies (ICTs) are not identified.

Sustainability and social issues

In contrast with other strategies, the French strategy does not assume that the bioeconomy is necessarily sustainable, nor universally acceptable. Specifically, it identifies several threats, and presents strategic approaches to overcome them (Table 6).

While the circular economy and resource efficiency principles are described (and set to be further developed in the forthcoming National Strategy for the Mobilisation of Biomass) the connections to the digital economy are weak and are mainly focused on new technologies for resource assessment and precision farming.

Table 6. Challenges and approaches for sustainability according to the French strategy

Challenges	Strategic approach
Degradation of natural capital	• Ecosystem services are a key element
Unsustainable primary production	• Sustainable practices, soil as an ecosystem • Avoid soil losses to urbanisation and infrastructures
Increase demand of biomass	• Sustainable intensification also by intercropping, organic agriculture and confined production (i.e. micro-algae) • Better mobilisation of existing resources • Better foresight and modelling • Increased efficiency and reduced material use
Secure positive environmental and economic impacts	• Hierarchy of biomass uses, develop life cycle analysis • Fractionation, for optimal use of biomass • Cascade use and circular economy
Social integration	• Promote change in consumption patterns • Address legitimate reluctance • Public debate at multiple scales • Information and pedagogy

Innovation, research, training and education

The French strategy recognises that innovation processes in the bioeconomy are complex as they occur at the interface of natural processes, technology and social systems, with multiple and diverse actors involved along divergent value chains. The strategy suggests departing from current research and development practices and giving more relevance to transdisciplinary and socio-economic research in living labs. It also advocates for increased links between research, vocational training and education, focusing on the regional scale as proximity is a key success factor.

The role of forests

The forest sector is recognised as one of the pillars of the French bioeconomy and such bioeconomy developments offer new opportunities for the wood-based industry. It places the focus on the sustainable supply of biomass, also reflecting on the needs of non-traditional sectors (such as chemistry). There are no clear orientations in relation to forest industries. Energy, including biofuels, is highlighted and there are references to intermediate and specialty molecules. Notably, there is no strategic orientation on forest bio-refineries or engineered wood, although it states that material uses of wood should be prioritised over energy uses. It advocates for increasing transparency on resource availability, but it does not suggest how resource efficiency principles (e.g. hierarchy, fractionation and cascading) could be implemented. The role of ecosystem services in regional development is acknowledged (e.g. through green tourism) and states that ecosystem services must not be left out of socioeconomic models, even if how to include them is yet unclear. These issues should be addressed in an action plan to implement this strategy that is still to be developed.

2.3 Bioeconomy in Italy (2017): A unique opportunity to reconnect economy, society and the environment

The Italian bioeconomy strategy, (Republic of Italy 2016) was led by the president of the council on ministries and co-coordinated by the ministry of economic development. The text was prepared by an inter-ministerial working group with the participation of the committee of regions and the clusters for agri-food, green chemistry and blue growth. Public consultation was limited and had little influence in the final text.

Drivers and focus including relationships with social trends

The bioeconomy comprises those parts of the economy that use renewable, biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy. These are the agri-food, forestry and marine sectors, along with the industries that depend on them. The main driver for the strategy is to leverage existing capacities in those sectors to reduce dependency on fossil fuels and finite materials. This will be achieved through a circular approach that puts the focus on longer, more sustainable and locally routed value chains. Contrary to other strategies, the Italian bioeconomic strategy identifies the key challenges of the larger Mediterranean region such us: i) high hydric stress and climate change affecting agriculture, food and water security; ii) social and economic stress creating instability; and iii) strong migration from rural to urban areas and from other countries into Europe.

Sustainability and social issues

Sustainability is, in general terms, taken for granted, although some challenges in relation to loss of soil organic matter and increased hydric stresses are identified. Resource competition, resource efficiency, carbon and water balances of bioeconomy value chains are examples of important issues not clearly addressed. The need for life cycle analysis (LCA) and voluntary certification schemes are mentioned as relevant tools to gain social support. Using marginal land is seen as a main approach to increase the biomass supply. The bioeconomy, through valorisation of side streams, is seen as an opportunity to reverse land abandonment and to help attract new actors to rural areas. Interestingly, the opportunities derived from expanding forests are not evaluated. Green chemistry, next generation plastics and agricultural biorefineries receive most of the attention. Although Italy is a global leader in green chemistry, this sector is currently 30 times smaller than the combined furniture and pulp and paper sub-sectors.

While mentioning the need for a participatory and place-based approach, which conveys the territory as a source of endogenous materials and ecosystem services, the Italian strategy emphasises that citizens are consumers, and that there will be a need to raise awareness to promote more responsible purchase choices that will create stronger bioeconomy markers.

Innovation and digital economy

No clear guidance is provided on how to better structure the research and innovation system, although there are mentions of technological and social innovation, industrial symbioses, training in entrepreneurship and demand side innovation through, for example, standardisation. Similarly, digitalisation is solely addressed as an opportunity for increasing agronomic techniques and productivity, although there is one mention to smart manufacturing or industry 4.0.

Role of forests

Forests are seen in the Italian strategy as a relevant carbon reservoir, a high biodiversity ecosystem and as the source of biomass. The balance among them and the new opportunities and challenges that the bioeconomy presents are not discussed. Sustainability, for example, is linked to certification.

Lack of forest management, the negative impacts of climate change, a high dependency on imported wood (and the associated risks of illegal timber), low competitiveness and the lack of a business mentality in the local forest sector are seen as major hurdles. In fact, the furniture and paper sectors generate 420 000 jobs and a turnover of EUR 60 billion. However, 80% of the wood demand is satisfied through imports. Local production is marginal and oriented to low-value products and energy. The weak integration of Italian forests into the industrial value chains is a major challenge but also an opportunity. However, no orientations is given for the future development of forest industries other than a desired increase in the use of wood in sustainable construction and general advocacy for high-value new wood products, wood-based materials, composites and bioenergy. This is probably because forest biomass is seen as a companion of agricultural biomass. Value chains on non-wood forest products are barely mentioned and neither is the role of ecosystem services.

2.4 Portugal's green growth commitment

Portugal does not have a bioeconomy strategy, but it is developing a long-term development model that first took shape in the Green Growth Commitment that was adopted in 2014, and was led by the Portuguese Ministry of Environment, Spatial Planning and Energy with over 100 organisations that participated in a significant consultation process (Governo de Portugal 2015).

Drivers and focus, including other technology trends

The Green Growth Commitment is an agenda for long-term environmental sustainability, growth and employment incorporating circular economy and bioeconomy approaches and targets across sectors including the construction, agriculture, forestry and waste management industries. The main drivers are: climate change and its related challenges (biodiversity, water, etc.) in the context of increased demands for food, energy and water; the mismatch between the value and the management of natural resources; and the need to create green jobs through green growth, building on existing strengths. The

Green Growth Commitment has 14 objectives and 114 actions addressing stimulus for green sectors, the efficient use of resources, the energy transition towards renewables and biodiversity improvement. Some interesting objectives for a circular bioeconomy are:

• Increasing the productivity of materials (from EUR 1.14 of GDP per kg of materials consumed in 2013 to EUR 1.17 in 2020 and 1.72 in 2030).

• Increasing the use of waste and by-products as raw materials in the economy (from 56% in 2012 to 68% in 2020 and 86% in 2030).

• Increasing the ratio of building renovations to new buildings (from 10.3% in 2013 to 17% in 2020 and 23% in 2030).

• Increase the share of renewable energy (from 25.7% of final energy consumption in 2013 to 31% in 2020 and 40% in 2030) and reduce CO_2 emissions (from 87.8 tonnes of CO_2 in 2012 to 68.0-72.0 tonnes of CO_2 in 2020 and 52.7-61.5 tonnes of CO_2 in 2030).

• Valorise biodiversity (from 81 species and 46 habitats with favourable conservation status per bio-geographic region in 2012, to 96 species and 53 habitats in 2030, while ensuring that in 2020 all existing species and habitat retain or improve their conservation status).

Sustainability and social issues

Green economy principles (resource efficiency, reusing, recycling) and reducing carbon and material intensity are key elements of the Green Growth Commitment. Contrary to other strategies, it does have quantifiable targets in relation to carbon emissions, material intensity, condition of water bodies, use of waste in the economy, biodiversity conservation and natural capital accounting. Reducing the risk of soil degradation is a specific target for the agricultural and forest sectors. When it comes to using biomass, it provides no guidance on how resource efficiency will be achieved (e.g. cascade use, hierarchy of uses and biomass fractionation, etc.). Social issues are not directly addressed although it emphasises public participation through a *green coalition* that a consultative body open to civil society representatives.

Innovation and digital economy

Research and innovation is one of the catalysers for green growth, along with green tax reform, public procurement, access to funding, and social awareness and participation. Research and development priorities are cross-sectoral, focusing on developing and upscaling technological and business model eco-innovations. The Green Growth Commitment does not identify links with the digital economy or with nanotechnologies.

Role of forests

Forests and forests-based industries represent 2.1% of GDP and 10% of national exports. The Green Growth Commitment also recognises the social, cultural and ecological value of forests, acknowledging the existence of different social perceptions and attitudes towards forests and forestry. Targets in relation to forests include:

A. support for creating innovative, low carbon, forest-based products and placing on them on the market;
B. improving forest management and productivity;
C. increasing forest certification; and
D. making joint management more dynamic.

Forests are also relevant in relation to quality and quantity, biodiversity conservation, green tourism, and to healthy cities where the role of forests as green infrastructure is being promoted. Additional targets in reference to forest industries address improving the use of waste streams, energy efficiency and self-dependency through bioenergy. Crosscutting actions such as improved national cadastre and tax reform, also target sustainable forest management, which would benefit from resources collected through green taxes on carbon, vehicles, plastic bags and waste. Finally, forest fires are recognised as the most relevant threat to forests in the green economy. Proposed actions include a 17% increase in fire suppression budgets and enforcing the *Plano Nacional de Defensa da Floresta contra Incêndios.*

2.5. Spanish Strategy on Bioeconomy 2030

The Spanish bioeconomy strategy, adopted in 2016 (Gobierno de España 2016), was led by the State Secretary for Research and Innovation with a limited consultation process. It includes a definition of the bioeconomy, objectives and concrete measures to be updated in annual work plans. A bioeconomy observatory was presented in September 2017 with the intention of adopting and promoting the action plans.

Drivers and focus

Key drivers identified are:

1. Change in global consumption patterns due to population growth, urbanisation and broadening of the global middle class.
2. Climate change that will impact primary production and biodiversity and that requires increased water efficiency and more sustainable production systems.
3. Increasing the competitiveness of the bio-based sectors, with a strong focus on agro-food.

The bioeconomy is defined as "the sustainable transformation of biomass from agriculture, forestry, fisheries and waste."

Sustainability and social issues

Sustainability is a commonly used keyword but the Spanish bioeconomy strategy does not elaborate on its meaning. There are some concrete explanations of sustainability only in relation to agro-food systems. These are described as:

- the need for new varieties resilient to environmental stresses;
- increasing efficiency in the use of water and fertilizer;
- reducing negative environmental externalities; and
- reducing waste all along the agro-food chains.

In relation to waste, the strategy prioritises re-use and recycling and advocates for cascade use. The positive environmental and social impacts of the bioeconomy are taken for granted, though the importance of building social support is highlighted. The Spanish strategy recommends using a tailored communication strategy, and it recommends creating a stakeholder panel to engage multiple actors through existing bioeconomy-related online platforms.

Innovation, research, training and education

Authored by the State Secretary of Research, the Spanish bioeconomy strategy emphasises research and innovation as well as existing financial means. It advocates for increased cooperation between research, industry and society, but does not explain how to go about creating such relationships. It also proposes specific measures to create training materials at multiple levels, to increase capacity and skills within new bio-technologies.

Role of forests

Forest and forest industries are one of the target areas of the bioeconomy along with, agro-food chains, fisheries and aquaculture, and waste. The emphasis is placed on improving the efficiency of traditional value chains and adapting forest production to climate chain. The strategy mentions the existence of opportunities to develop new bio-based products and materials but does not elaborate on them. It hints at a potential role for bio-refineries but without further elaboration on feedstock sources or on the role of existing forest industries. The economic role of non-wood forest products, nature-based tourism and leisure activities are also acknowledged, but without proposing specific actions.

2.6 Main gaps in national bioeconomy strategies

A bio-resource perspective

The following are the three main approaches to the bioeconomy described by Bugge, Hansen and Klitkou (2016):

1. bio-technology vision that emphasises the importance of research and the development application of bio-technologies in different sectors of the economy;
2. bio-resource vision that focuses on processing and upgrading biological raw materials and their supply chains; and
3. bio-ecology vision that highlights sustainability, ecological processes and place- based development.

Like the EU bioeconomy strategy, southern European bioeconomy strategies adopt a bio-resource approach. They strongly emphasise the industrial transformation of biomass and pay much less attention to place-based development strategies or to other portions of the bio-technology sector, notably pharmaceuticals. Consequently, the links between the bioeconomy and social agendas are weak. While technological innovation is seen as a key driver, social innovation is generally ignored. However, the role of social innovation in innovation generally and in wellbeing is increasingly recognised elsewhere. It is understood as a new mode of governance where citizens are actively involved. It has been effective in addressing the challenges of climate mitigation, social justice, aging populations, etc., but also the culture of trust and risk-taking that is needed to promote scientific and technological innovations (BEPA 2010). Social innovation could be critical to address biomass-fire-water nexus hurdles in resource mobilisation that are emerging from fragmented forest ownerships, missing owners and the relatively weak presence of cooperatives.

A lack of transformational ambitions

The reviewed bioeconomy strategies share a sectoral approach. They focus on developing biomass transformation sectors but are not ambitious when it comes to the transformational potential of the bioeconomy. There are no overarching goals or targets in relation to sustainability (e.g. reducing material intensity, avoiding carbon emissions, etc.) nor are there targets for biologising key economic sectors (e.g. construction, textile, etc.) this is dealt with in other sectoral policies (i.e. climate change mitigation, renewable energy, etc.). Notably, the strategies do not delve into what the bioeconomy can do for more sustainable and liveable cities, nor do they go into how to bring the bioeconomy to cities. The Portuguese Green Growth Commitment represents a notable exception. It is a very different type of document and is not directly comparable with the bioeconomy strategies of other countries. It departs from a sectoral view (and addresses, even if partially, the potential contribution of bio-based and renewable industries to the greening of main economic sectors, including water, energy and cities. It is also closer to an action plan with concrete actions and targets.

Sustainability as driver and expected outcome

The need to create sustainability is the motivation for the strategies, however the concept, as it is considered in most european bioeconomy strategies, is either taken for granted or is only addressed in general terms (Staffas, Gustavsson and McCormick 2013). Intense climate change and water scarcity are identified as key environmental challenges in all reviewed strategies, while the tensions caused by migration in the Mediterranean are directly acknowledged only in the case of Italy. The French strategy is notable, as it identifies sustainability challenges across the value chain, including aspects such as the risk of degradation of natural capital, unsustainable primary production practices, resource competition, negative environmental impacts and a lack of social integration. It also proposes strategic approaches to minimise those risks (e.g. improve production practices, resource efficiency, hierarchy of uses, cascade use, etc.) as well as through public debate at multiples levels to address the legitimate reticence of different societal actors. In this way, it covers most of the sustainability concerns of the research community identified by (Pfau *et al.* 2014). None of the strategies addresses the potential negative impacts in third countries, as for example through induced land use change.

Resource efficiency, hierarchy of uses and cascade use are generally endorsed, with no reference to possible hurdles in implementation. The draft French strategy on mobilisation of biomass under development[7], proposes a pragmatic approach. It makes material uses of wood, including engineered wood products, a policy priority, meaning that energy uses would not receive public support. However, it admits that there is not enough market pull to absorb all the available wood supply. It then considers energy uses of biomass as a good transitional solution. All the strategies propose a life cycle analysis as a relevant tool to guaranty sustainability, but they offer little detail on how to embedded it in a future policy framework. It remains to be seen how complex resource use challenges will be inserted into future bioeconomy policy frameworks.

A directional narrative to engage consumers

All strategies acknowledge the need for social support. The French strategy gives quite a lot of attention to defining the themes that require public debate and the territorial scale (e.g. lo-

[7] http://www.consultations-publiques.developpement-durable.gouv.fr/projet-de-strategie-nationale-de-mobilisation-de-a1719.html

cal, regional, national, global) that might be more adequate. This debate should help to overcome different views on the bioeconomy and secure a more equitable share of benefits and burdens. The Portuguese Green Growth Commitment also acknowledges the existence of different legitimate views on the use of natural resources. These two documents were based on more comprehensive public and/or parliamentary debate. Social aspects are given weak consideration in other strategies, where citizens are mainly seen as consumers whose purchase patterns need to be well understood and steered towards the bioeconomy. These strategies follow a European trend where strategies propose a governmental rather than a governance approach (Pülzl, H. *et al.* 2017). Costanza (2014) proposes a participatory vision of plausible and desirable futures as a more effective way to engage different societal groups in developing a paradigm shift.

Fragmentary consideration of the necessary framework conditions

Access to finance, the capacity for risk, the regulatory environment and public-private collaboration, and the connections between research, innovation and training are all relevant aspects of a bioeconomy framework (Hetemäki *et al.* 2017). They are acknowledged in the strategies, but they are dealt with in a fragmentary way. In addition, the links between the bioeconomy and the circular economy are not addressed in any detail, nor are the opportunities or challenges related to the digital economy or nanotechnologies. A more comprehensive approach to these relevant aspects of the bioeconomy is needed.

2.7 Approaches to the bioeconomy in smart specialization strategies

Regional Innovation Smart Specialization Strategies, also called RIS3s, are place-based economic transformation agendas that identify key priority areas for policy support, innovation and investment. They must leverage regional strengths, competitive advantages and potential for excellence. RIS3 strategies are bottom-up business discovery processes promoted by the European Commission and are a requirement for receiving funding from the European Regional Development Fund (ERDF). They should provide the strategic framework to align actors and policies. Through their bottom-up, participatory approach and their direct links to the ERDF, the RIS3 strategies provide an opportunity to understand how the bioeconomy is being implemented in regional development policies.

According to a recent study (Spatial Foresight, SWECO, ÖIR, t33, Nordregio, Berman Group, Infyde, 2017) most EU regions have at least some bioeconomy-related approach in their RIS3 strategies. Table 7, summarises the main priorities in relation to production and processing of biomass for the EU28 and, specifically, for southern regions. Agriculture and agro-food chains are the most common priorities for biomass production in the EU and particularly in southern Europe. There, forests and forestry are a priority in 38% of the regions, which compares with 45% of RIS3 strategies addressing marine biomass and 28% focussing on waste.

In relation to products and services, bioenergy is the most frequent non-food value chain present in 70% of all strategies. Bioenergy is frequently the only forest-related priority, even in regions with significant forest industry, as is the case of Spanish Galicia. Although relevant, wood construction and advanced uses of solid wood receive far less attention, despite the larger potential for positive environmental and economic impacts. The predominance of bioenergy could be the result of the relatively lower complexity of bioenergy value chains, but it is probably also related to generalized existence of renewable energy action plans and policy targets derived from mandatory European targets (i.e. defined in the European Climate and Energy package). It is tempting to think about what such policy targets could do to boost other bioeconomy sectors. In very general terms, except for the sophisticated agro-food value chains, southern European regions seem to be placing less attention on higher added value bio-based sectors such as pharmaceuticals and cosmetics, bio-materials, sustainable construction and advanced bio-refineries than the central European and Nordic regions.

Table 7. Bioeconomy priorities of European Regions. Percentages reflect the proportion of regions adressing each priority in their RIS3 Strategies

Biomass production	EU-28	Southern Europe
Agricultural biomass	57%	71%
Marine and aquaculture biomass	29%	45%
Forest biomass	38%	38%
Waste	31%	28%
Bio-based products and services		
Food and beverages	64%	83%
Biorefineries	31%	22%
Bio-based chemicals and plastics	40%	28%
Pharmaceuticals and cosmetics	26%	12%
Timber and bio-construction	29%	22%
Bioenergy and bio fuels	70%	70%
Water and other natural resources	12%	14%

Source: Spatial Foresight, SWECO, ÖIR, t33, Nordregio, Berman Group, Infyde 2017 and the eye@ris3 data base (http://s3platform.jrc.ec.europa.eu/)

Forests in French Smart Specialisation Strategies[8]

There are five regions in southern France that have some forest-related priority in their RIS3 Strategies (Table 8). There is a large diversity of approaches. In Aquitaine, sustainable management and wood mobilisation are considered along with new high-end uses in the green chemistry and engineered wood products. The neighbouring Midi-Pyrenees focus on industrial biotechnologies and advanced materials for aerospace, transport and packaging, from renewable carbon, not addressing forest-related issues or value chains. In the Mediterranean region (Languedoc-Roussillon, Provence-Alpes-Côte d'Azur and Corsica) forest biomass seems to be a companion of agro-food biomass for the high-end transformation of bio-energy. The energy transition is a priority in Provence-Alpes-Côte d'Azur and Corsica with renewable energy and sustainable building and retrofitting as key priorities. However, neither forest biomass nor engineered wood products are emphasised. Except for Aquitaine, where forest-based industries play a significant role in the regional economy, the potential of forests seems to be underestimated. In some cases, forests seem to be considered more of a problem than an opportunity (e.g. Provence-Alpes-Côte d'Azur).

[8] French, Italian, Spanish and Portuguese regions with forest-related priorities where scanned in the eye@ris3 database. Sixteen regions where selected and their RIS3 Strategies downloaded and analysed between June and September 2016. The RIS3 Strategies are available in this repository and are not individually cited in this report.

Table 8. Forest bioeconomy priorities in French southern regions (NUT2 regions before the administrative reform)

NUT2	Forest bioeconomy priorities	Comments
Aquitaine	• Mobilisation of biomass and biorefineries • Wood-based sustainable construction and energy efficiency in buildings • Digital technologies for sustainably managing natural resources • Cross fertilisation, material sciences with ICTs and life sciences	Aquitaine has extensive softwood resources, pulp and paper industry, and biorefinery. The saw milling sector is atomised and dominated by low added value products. Planted forests shape the landscape and contribute to an important tourism sector.
Midi-Pyrenees	• Industrial biotechnologies for the non-food bio-based value chains. Focus on: 1) developing biotechnology assets (enzymes, microorganisms, etc.) and new technologies for synthesising valuable molecules and polymers; and 2) advanced and functional materials for aerospace, transport and packaging, including nano/ bio-materials	The region has a strong focus on advanced products from "renewable carbon". It does acknowledge the relevance of its forest resources, but does not address forest, forestry or forest based industries. Forestry is neither considered in the priority: "innovation of territorial agro-food systems".
Languedoc Roussillon	• Valorising agricultural (and forest) production through bioenergy, but also construction materials, biopolymers and active biomolecules e.g. food additives • Health, pharmaceuticals and related biotechnologies • Water cycle, although with little emphasis on watershed management	Energy transition is centred on solar energy. Bioenergy is a complement for the efficient use of agricultural products despite a regional target of 2436 GWh/yr. of bioenergy for 2020. The region as cross-cutting priorities in digitalisation, metrology, entrepreneurship and social innovation.
Provence-Alpes-Côte d'Azur	• Energetic transition with a focus on renovating buildings (no mention of wood construction), smart grids and renewable energies, among which biomass is barely considered • Health and nutrition are key, including nutraceuticals and natural cosmetics	The region produces only 10% of its total primary energy demand distributed as: 54% hydro, 39% forest biomass, 4% waste, 2% solar and 1% wind. The only mention of *forests* is in relation to forest-fire risk under the priority related to defence technologies.
Corsica	• Valorisation of natural and cultural resources includes consolidating the wood-value chains. Emphasis is on the agro-food sector • Energy production, distribution and management with an emphasis on sustainable construction, solar energies, smart grids and ICT applications	Sustainability and bio-construction are key elements of energy production and are not necessarily linked to existing wood or cork value chains. Bioenergy is considered among the renewable energies with a lesser role. Tourism is seen as a cross-cutting sector that needs to be better integrated with forest and agro-food value chains.

Table 9. Forest bioeconomy priorities in Italian RIS3 strategies

NUT2	Forest bioeconomy priorities	comments
Valle d'Aosta	• Agro-wood value chain, sustainable construction and renewable energies are prioritised under *Sustainable Mountains*, with digital and biotechnologies as KET • Tourism is a cross-cutting priority including nature-based enological and eco-tourism	The RIS3 says nothing about how to develop the wood-value chain, the role of timber in green building or the role of biomass in renewable energies.
Calabria	• Sustainable construction is one of the five pillars, with a clear focus on wood construction based on local resources • Sustainability of forestry and other primary productions • Diversification of tourism towards nature and rural tourism	Construction represents 20% of the regional economy. Sustainable building is strategic and includes domotics, energy efficiency, quality, reduced waste and anti-seismic properties. While ICT are cross-cutting, biotechnology is linked to pharmaceuticals and health. Forest fires as risk.
Lazio	• Biosciences linked to pharmaceuticals and clean energies in confluence with ICT and nanotech • Green economy priority considers decarbonisation of the energy utilities, energy efficiency in buildings (timber construction not directly mentioned), and active forest management of ecosystem services (water, tourism)	Agri-food priorities include cross-fertilisation with biotech/nanotech for new advanced materials, etc. Public procurement and industrial ecosystems are key approaches.
Veneto	• Furniture and sustainable construction are priorities under sustainable living. Nanotech, ICT and material science are key KETs • Biofuels from biomass and biogas are an element of Smart Agri-Food. • Functional and bio-based materials are a relevant element of creative industries	Silviculture as a cross-cutting sector linked to sustainable living is the only hint of a local wood value chain. ICT, nanotechs, biotechnologies and fast prototyping are cross-cutting KETs.

Forests in Italian smart specialisation strategies

Many Italian RIS3 strategies have cross-cutting priorities that could be related to forestry but have not made the relationship explicit, as is the case in Sardinia (renewable energy, eco-tourism). Table 9, presents a summary view on the role of forests in four Italian RIS3 strategies that do have forest or timber priorities. Sustainable construction and furniture are the most prominent forest-related priorities (Veneto, Lazio, Calabria, Valle d'Aosta, etc.) and the emphasis on timber is significant. Energy efficiency, waste reduction, seismic behaviour and niche markets are seen to be key drivers for wood construction, while changes in consumer preferences are challenges for timber furniture. Both sectors currently depend on imported wood (see chapter 3.2). Advocacy directed at substituting timber imports with national wood can be read in the Italian bioeconomy strategy but is not reflected in the regional priorities. Only in some cases (e.g. Calabria) a forest value chain perspective emerges. Energy transition is also a frequent priority, but with less emphasis on forest biomass and its specific challenges and opportunities. This contrasts with the relatively high use of forest biomass for energy in Italy, the existence of relevant industrial and technological capacities and the high bio-electricity feed in tariffs. Interestingly, some regions (e.g. Veneto, Calabria) identify opportunities to create a biological framework for the economy, essentially to biologise the economy (fashion, advance materials for automotive, aerospace, mechatronics, construction) combining the potential of bio-technology, nanotechnologies and ICTs. Finally, eco-tourism and its links with local food-chains and non-wood forest products are a frequent priority.

Forests in Spanish and Portuguese smart specialisation strategies

Table 8 summarises the role of forests and forest-based industries in selected Spanish and Portuguese RIS3 strategies. There are big differences in how the bioeconomy is addressed. A relevant group of regions (not shown in Table 10) put the focus on nature-based tourism and local agro-food products (e.g. Castilla la Mancha and many other regions not shown in Table 10 as Madeira (PT), Canary Islands (ES), Cantabria (ES). Frequently, RIS3 strategies fail to analyse the potential of biotechnologies and endogenous biomass sources to transform key and emerging economic sectors (automotive, housing, aerospace, textile, etc.). As a result, the potential contribution of forest bioeconomy is either totally ignored, limited to health and pharmaceuticals (e.g. Basque country) or focused on biomass supply for bioenergy (e.g. Galicia, North Portugal). Some regions (e.g. Portugal Centro (PT), Castilla y Leon (ES)), however, have a more integrated vision of the potential for advanced forest-based bioproducts.

Table 10. Forest bioeconomy priorities in Portuguese and Spanish RIS3 strategies

Region	Priorities	Comments
Galicia (ES)	• Modernisation of primary sectors. The focus on forestry emphasises sustainable intensification, improved profitability of biomass production and bioenergy. Rural tourism is also considered, with a focus on ICTs • Industrial competitiveness focusing on automotive, shipbuilding and fashion through KETs (nanotechnology, advanced materials, biotechnology, etc.) with a priority on ICTs and advanced manufacturing • Healthy lifestyles with a focus on technologies for active aging and functional food	Galicia produces 45% of Spanish timber and its forest industries represent 2% of the regional industrial GDP. However, there are no priorities for engineered construction or advanced forest bio products or for the improved use of side steams. The potential of lignocellulosic biomass to transform key and emerging economic sectors (textiles, automotive, aerospace) seems to be underestimated.
Basque Country (ES)	• Advanced manufacturing, focusing on automotive, aeronautics, machine tooling, and deploying digital technologies and material science, photonics, micro-electronic and nanotechnology • Energy, with a focus on oil and gas, wind, marine, thermos-solar, smart grids and new business models • Health, with a strong focus on pharmaceuticals and medical technologies	A second-level priority encompasses several territorial opportunities, including agro-food and environmental protection. Forests over 50% of the region and forest-based industries represent 1.5% of the regional GPD. The application of biotechnologies is focused on health. The potential role of bio-materials to transform key economic sectors is not considered.
Castilla y León (ES)	• Environmental sustainability and the maintenance of natural and cultural heritage through sustainable innovation • Advanced wood and recyclable materials • ICT solutions for forestry and other primary sectors	Castilla y Leon has a regional forest plan to host relevant forest research centres, bioenergy international fairtrades and is active in international forestry issues and leads, for example, the Mediterranean Model Forest Network
Castilla la Mancha (ES)	• Game industry as part of the agro-food and tourism value chains • Local products with regional labels, as those coming from traditional agro-forestry • Biotechnologies	The region has extensive traditional agroforestry areas (*dehesas*) but very little active forestry. It has a significant forest fire problem that absorbs most of the regional rural development funds devoted to forestry.

Region	Priorities	Comments
Portugal Norte (PT)	• Creative industries and fashion, with a focus on textiles, shoes, furniture and apparel. Advocates for better inclusion of cork, but otherwise little emphasis on biomaterials • Mobility and environment. New materials for transport and aeronautics and biofuels. The potential of cork is mentioned along with cross-cutting nanotechnologies and ICTs • Agro-environment and food, with a focus on sustainable forest and agricultural practices, the expansion of functional food products (wine, oil, chestnuts), local specialities and smart packaging	Other specialisation areas are i) life science and health, with a focus on pharmaceuticals, ii) marine economy, including marine energies and naval construction, iii) specialised services, with a focus on ICTs iv) heritage and tourism, with strong links to food specialities. North Portugal has significant forest resources and forest-based industries. The potential synergies with priority areas are not addressed.
Centro Portugal (PT)	• Sustainable industrial solutions, based on smart manufacturing, new materials including forest based • Efficient use of regional, natural resources, including renewable solar energies, the sea and biomass; value chain approach from production to markets, also including nature-based services • Technologies for quality of life with a focus on medical technologies and active aging • Territorial innovation, including cross-cutting approaches to rural development, sustainable cities and tourism	Forests receive special attention along with agriculture, ICTs, biotechnologies and tourism. They are relevant for the regional economy, contributing up to 40% of Portuguese forest GDP. Key challenges for sustainable production are identified. The potential contribution of new materials and renewable energies are addressed.
Alentejo (PT)	• Agro-food and forestry, with a focus on agro-industries and cork and the multi-functionality of agro-food systems through agro-tourism • Economy of natural and environmental resources, with a focus on mining and quarrying resources, but also water services linked to biodiversity • Key technologies, energy and mobility, with an emphasis on solar energy, traditional energies and smart grids a subsidiary role for biomass. Advocates for efficiency and use of agro-waste streams in bio-refineries	The region prioritises i) heritage, creative industries and tourism, which includes eco-tourism; and ii) advanced services for the social economy, with a focus on new business models, the digital economy, wellbeing, active aging and smart cities. Alentejo is highly specialised in agriculture and forestry (14% of regional employment and 42% of research capacities). The potential of biotechnologies is almost totally ignored.

Overview of the role of forests in southern smart specialisation strategies

The general picture that emerges from the analysis of RIS3 strategies in southern Europe is one of incremental innovation focused on existing sectors, with limited scope for disruptive innovation. This can be seen in Galicia's focus on forest bioenergy or the Basque Country's emphasis on oil and gas. More disruptive and longer-term approaches could give the bioeconomy a chance to effect change. In general terms, RIS3 strategies have a strong component of technological innovation to achieve economic goals and to create wealth. Many RIS3 strategies capture the transformational potential of digitalisation across sectors, from tourism to mobility, pharmaceuticals or health. This is not well addressed in the national strategies. The potential of biotechnology is generally linked to the pharmaceutical and health sectors or to the transformation of waste. While biosciences are recognised as necessary to improve primary production, much less attention is paid to biotechnologies in relation to forest biomass and industrial waste streams. There are, of course, exceptions, as in the Midi-Pyrenees where they emphasise biotechnologies for developing biomaterials for advanced industrial sectors such as aerospace. Biosciences are viewed as a key for improving primary production in agriculture and forestry in many regions with significant academic and research capacities in biology, agronomy, geology and/or forestry. But, much less attention is paid to social innovation, governance and policy issues.

Another interesting element in the strategies is their frequent consideration of environmental sustainability as a necessary driver or component of regional specialisation. This is reflected in their emphasis on bio energies and on sustainable construction as elements of the energy transition. In this respect, timber construction is a priority in 22% of all southern regions and is important in Italy and France (see Tables 8 and 9). But, the principles of the circular economy (e.g. share, re-use, recycle) and resource efficiency (e.g. cascade, hierarchy of use) receive little attention, which is perhaps because of the nature of the analysed documents. Interestingly, waste as a material is only a priority in around 30% of southern regions, similar to the EU28 (see Table 7).

Another significant element of the strategies, when it comes to forest biomass, is the frequent disconnection of the forest value chains. While some regions emphasise the supply of forest biomass with little thought for developing potential new uses beyond bioenergy (e.g. Galicia), other regions focus on advanced uses of biomass with no, or very little, consideration for regional supply chains (e.g. Midi-Pyrenees). Notable exceptions are found in all countries, particularly in Aquitaine (FR), Castilla y Leon (ES), Calabria (IT) or Alentejo (PR). The lack of strong forest-related interest groups has fractured public perception on the use of forest resources. The relatively weak contribution of forests to the regional GDPs and the short-term focus of RIS3 strategies are possible causes for the general lack of a comprehensive approach to forest value chains.

Finally, a significant number of regions are making it a priority to capture the value of nature, forests and agro-ecosystems through eco-tourism and other territorial approaches based on commercialising local productions and the *mise en valeur* of their natural and cultural heritages.

3. Potential contribution of forests to a circular bioeconomy in key sectors and different regions

This section discusses the potential contribution of forests and forestry to the circular bioeconomy, sustainability and competitiveness in three key sectors: i) advanced forest-based bio-products; ii) building with wood, and iii) non-wood forest products. It presents market foresight, technology trends, economic drivers and barriers. It also highlights some specific cases and examples. This section does not address the challenges and opportunities related to the use of forest biomass for energy.

3.1. Advanced bio-products: emerging products and technologies

An important market pull for bio-based materials

Throughout the twentieth century, the development of petro-chemical technologies, the low cost of feedstocks and a lack of consideration for potential negative externalities led to a general application of fossil fuels and materials in all types of economic activities. Today fossil energy meets over 80% of total energy demand. Fossil-based fibres represent 70% of all textiles (90 million tonnes in 2015) and 98% of all plastics are fossil based. Plastics are at the core of modern manufacturing industry. Over 300 million tonnes of plastic polymers were produced in 2016, fulfilling needs in all sectors of the economy from ephemeral packaging to high-value applications in the medical or aeronautical sectors. These textile and plastic economies work in an almost totally linear mode. In 2015, the textile industry consumed 98 million tonnes of oil, produced 2% of total carbon emissions and shed half a million tonnes of microfibers into the oceans, being responsible for 20% of industrial wastewater pollution. Only 12% of textile fibre is recycled, and even that is only for generally low-value products (e.g. isolation material). The majority (73%) is incinerated or thrown into landfill after being owned by a single user. Some 90% of all plastics are produced with virgin feedstock accounting for 6% of total oil consumption. Globally, the plastic recycling rate is merely 14%, the majority (54%) is in landfill or is incinerated after being owned by a single use, but over 30% leaks into oceans and terrestrial ecosystems (Ellen MacArthur

Foundation 2017, World Economic Forum 2016b). Current trends are not viable. By 2030 demand for textiles will grow 44% and will double for plastics, multiplying fossil fuel demands and negative externalities. A new plastic and textile economy requires a circular approach based on renewable feedstocks, and a new generation of fibres and polymers that are highly reusable, recyclable and biodegradable (Soetaert and Vandamme 2009, CIRCFS 2017, Baskar *et al.* 2012, World Economic Forum 2016). The biotechnological revolution and the need to address climate change, pollution, and hyper accumulation of waste and marine litter are creating momentum for a new generation of bio-based materials that will redefine the characteristics and boundaries of current forest-based sectors (Soetaert and Vandamme 2009, Kant 2012). Opportunities for bio-based products are not limited to textiles and plastics. A relatively reduced set of petrochemical platform molecules (e.g. ethene, propene, benzene, methanol, etc.) are used to produce a large array of products such as rubbers, nylons, solvents, latex, dyes, emulsifiers colourants, etc. Bio-based building blocks are gaining market traction as drop-in replacements of fossil counterparts or as the basis for new chemical pathways and new products to use in all types of applications from construction to agriculture, food and feed (Farmer and Mascal 2015).

Emerging opportunities for wood and other lignocellulosic biomass

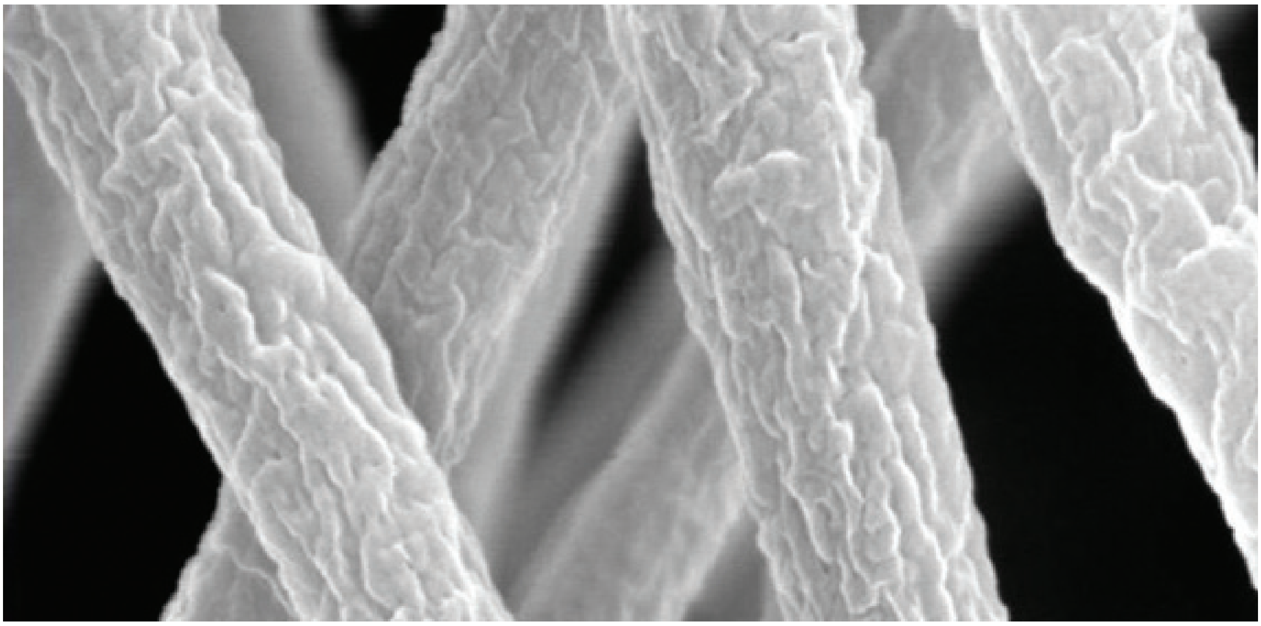
The main components of wood, cellulose (35%–50%), hemicelluloses (20%–35%) and lignin (5%–30%) are the most abundant natural polymers on Earth. In addition, wood (and lignocellulosic tissues in general) have other extractable compounds (1%–1 0%) that provide valuable molecules. With different degrees of engineering, solid wood can be used as a manufacturing material and an energy feedstock. Its components can also be separated and processed independently through different chemical pathways. There are many ways to separate and extract those components and different biomass types have specific characteristics (e.g. chemical composition, anatomical and structural characteristics). Selecting fractionation, product recovery, purification and conversion depend on the type of biomass and on the targeted products. It can have decisive impacts on yeilds, qualities and economic viability. Once fractionated, the original cellulose fibres can be preserved to a certain degree to produce paper, textile fibres or cellophane. Cellulose and hemicellulose components can be completely hydrolysed into basic sugars to produce ethanol and platform molecules that enter into the sugar processing routes. The lignin fraction can then be processed independently. Specific molecules and essential oils can be extracted through different processes. These four main streams are described bellow.

Cellulose fibres

Lignocellulosic biomass is well placed to play a significant role in replacing fossil-based textiles because of the quality of the fibres that can be produced and because its environmental footprints is much less than cotton (e.g. water, pesticides, competition for agricultural land). Cellulose textiles are already 7% of all fibres. The demand will increase significantly in the next few decades (Hämmerle 2011). Viscose is the main artificial bio-based textile. It can be produced from many lignocellulosic materials, including bamboo and agricultural waste, but currently it is mainly produced from dissolving pulp, a specialty highly pure (more than 90%), bleached cellulose, the production of which has more than doubled over the last few years representing 3.5% of all cellulose production (FAOSTAT). It can be produced in sulphite pulp mills or in Kraft pulp mills with an acid pre-hydrolysis. However, traditional viscose uses carbon disulphide, a toxic chemical. Pour-safe measures and wastewater treatment have serious human health and environmental effects (Changing Markets Foundation 2017). Safer technologies (e.g. Spinnova) and alternative processes based on less hazardous chemicals (e.g. Lyocell, Modal) are emerging but still need to gain increased market share (see section 4.2). Solving these environmental issues will create new opportunities for the forest sector, also in southern Europe. While converting current pulp capacities in the Atlantic regions can be relatively straightforward (e.g. the case of Tembec in Aquitaine), developing a new textile sector based on European dissolving pulp will continue to be a challenge as most of it is currently exported to Asia for further processing. Outside pulp-producing regions, additional challenges relate to developing and or adapting emerging technologies to available lignocellulosic sources.

Sugar streams

Currently, most bio-polymers and building blocks are made from plant sugars and plant oils (first generation feedstocks), sourced from dedicated crops and, to a lesser extent, from agricultural or post-consumer-residues. Agricultural land, however, is limited and food production (e.g. food first) is a well stablished policy priority in most bioeconomy strategies (see chapter 2 in this report). For this reason, lignocellulosic, or second generation, feedstocks, are a promising source of sugars (cellulose, hemicellulose) for their abundance and because they might compete less with food production. However, lignocellulosic industrial technologies still need time to mature in order to compete with better established sugars, starches and oils. Notably, the recalcitrant nature of lignocellulosic biomass limits the conversion of cellulose and hemicellulose to sugar streams, and thus pre-treatment and extraction technologies become determinant in terms of yields and costs (Carus and Dammer 2013). New optimized fractionation methods can maximize sugar yields for specific chemical pathways and can also reduce environmental footprints, increasing the competitiveness of lignocellulosic sugar streams (Werpy and Petersen 2004). Promising technologies include different mixes of organic solvents (Organosolv) or ionic liquids (ILs), which can effectively recover over 90% of the cellulose and hemicelluloses in moderate temperatures and pressures (reducing energy needs, carbon footprints and required capital investments). Once extracted, celluloses and hemicelluloses can be hydrolysed rendering fermentable sugars that can replace first generation sugar feedstocks (e.g. corn, sugar cane, etc.) in the production of biofuels, polymers, bioplastics and chemical building blocks. A second very active area of interest is micro-organism engineering to design fermentation routes tailored for specific feedstocks and end-products, which will open new markets for highly specialised knowledge providers. High synergies between different research



fields are expected. The combination of these biotechnologies with process engineering, information and computing technologies and nanotechnology represents a new technological paradigm with the potential to create a new generation of high performance biomaterials.

Lignin stream

Lignin comprises up to 30% of the mass and 40% of the energy content of agricultural and forest biomass. Lignin is a by-product of pulp mills and lignocellulosic sugar streams. Lignin is complex and chemically and physically very robust. In addition, contrary to what happens with cellulose and hemicellulose, its structure varies among species (e.g. softwood vs. hardwood) and is also changed during the fractionation (Holladay *et al.* 2007). This means that lignin extracted in Kraft pulp miles is basically a different feedstock from lignin extracted in sulphite mills. For those reasons, the main use of lignin is for energy. Generally, lignin is burnt in mill operations or, much less often, sold for low value applications. In some cases, electricity is generated through combined heat and power (CHP) installations. This contributes to energy self-sufficiency and has a positive effect on the mill operations. Other viable options are based in complete depolymerisation. Lignin can be gasified to produce syngas (a mixture of H_2 and CO_2). Pure hydrogen can be fed into fuel cells for energy or it can undergo a different chemical process. It can be converted to methanol and biogasoline or transformed into biodiesel through the Fischer-Tropsch technology. Total depolymerisation of lignin means using energy to deconstruct what biosynthesis has produced. Arguably, the process will have to become more efficient if more complex molecules are to be obtained. However pyrolysis or chemical hybridisation are energy intensive and produce complex mixes of molecules that require costly purification, rendering them uncompetitive (Farmer and Mascal 2015). For this reason the most promising short-term alternative to energy uses relies in finding applications to essentially unmodified forms. There are, in fact, niche markets for many unaltered forms. Lignosulfonates produced in the pulping process are used as dispersants, emulsifiers, binders, sequestrates and adhesives (Jong *et al.* 2011). These are relatively low value and have low-volume applications. In the midterm, although there continue to be significant obstacles, lignin represents a potentially low-cost source of carbon polymers such as polyacrylonitrile (PAN) suitable to produce carbon fibre (Meek *et al.* 2016) at significantly lower costs (Mainka *et al.* 2015). Required lignin grades can be obtained from the regular Kraft pulp side stream (Norberg 2012). Diverting ten per cent of the lignin that is potentially available in the United States could produce enough carbon fibre to displace about half of the steel in domestic passenger vehicles (Holladay *et al.* 2007) This could lead to significant weight emission reductions in the automotive industry. The Swedish research centre RISE is working towards developing commercial grade lignin-based carbon fibres by 2025[9].

Valorising extractables

Extractable compounds represent (1%–10%) of lignocellulosic biomass. Interestingly, extracts are often obtained from unused parts of trees or from the bark and can contain active and useful ingredients that are currently underexploited. These components (e.g. secondary metabolites) include alkaloids, carotenoids, flavonoids, phenols, resins, sterols, tannins, terpenes and waxes. This group of phytochemicals is responsible for a variety of biological actions, both *invitro* and *in-vivo*, for example as antioxidants, insecticides and as antimicrobial and antifungal agents. From an application point of view, preparations containing one or more phytochemicals could be used in the agro-food chain as natural crop protection or food preserving agents. Technologies like supercritical CO_2 and superheated water extraction, ultrasound and microwave assisted extraction, extraction with deep eutectic solvents and ionic liquids and steam explosion are very efficient and cost-effective methods of extracting bioactive components with high added value for cosmetics and pharmaceutical applications. Extracting low-volume, high-value molecules from rich and diverse forests could be an important opportunity for the bioeconomy in southern Europe.

Moving forward

"The critical question does not appear to be what can be made of forest biomass, but rather what will be made, on what scale, where, and driven by what?" (Hetemäki and Hurmekoski 2016). Southern Europe is active in the bio refinery arena. France, Italy and Spain alone account for one-third of all bio refineries (77 out of 224) recorded by the Nova Institute and the Europa-bio, although with very few wood-based or lignocellulosic bio refineries (figure 10). Given the limited, if any, premium price for biopolymers and fibres, policies and regulations will play an important role in directing market developments (Carus *et al.* 2013). As an example, the ban on supermarket plastic bags has helped to make Europe one of the leading producers of highly-degradable, starch blends (Aeschelmann *et al.* 2016). Unfortunately, until recently, the EU lacked a favourable policy framework, as only bioenergy and biofuels have mandatory targets, incen-

[9] http://www.innventia.com/en/Our-Expertise/New-materials/Carbon-fibres/Swedish-lignin-based-carbon-fibre/

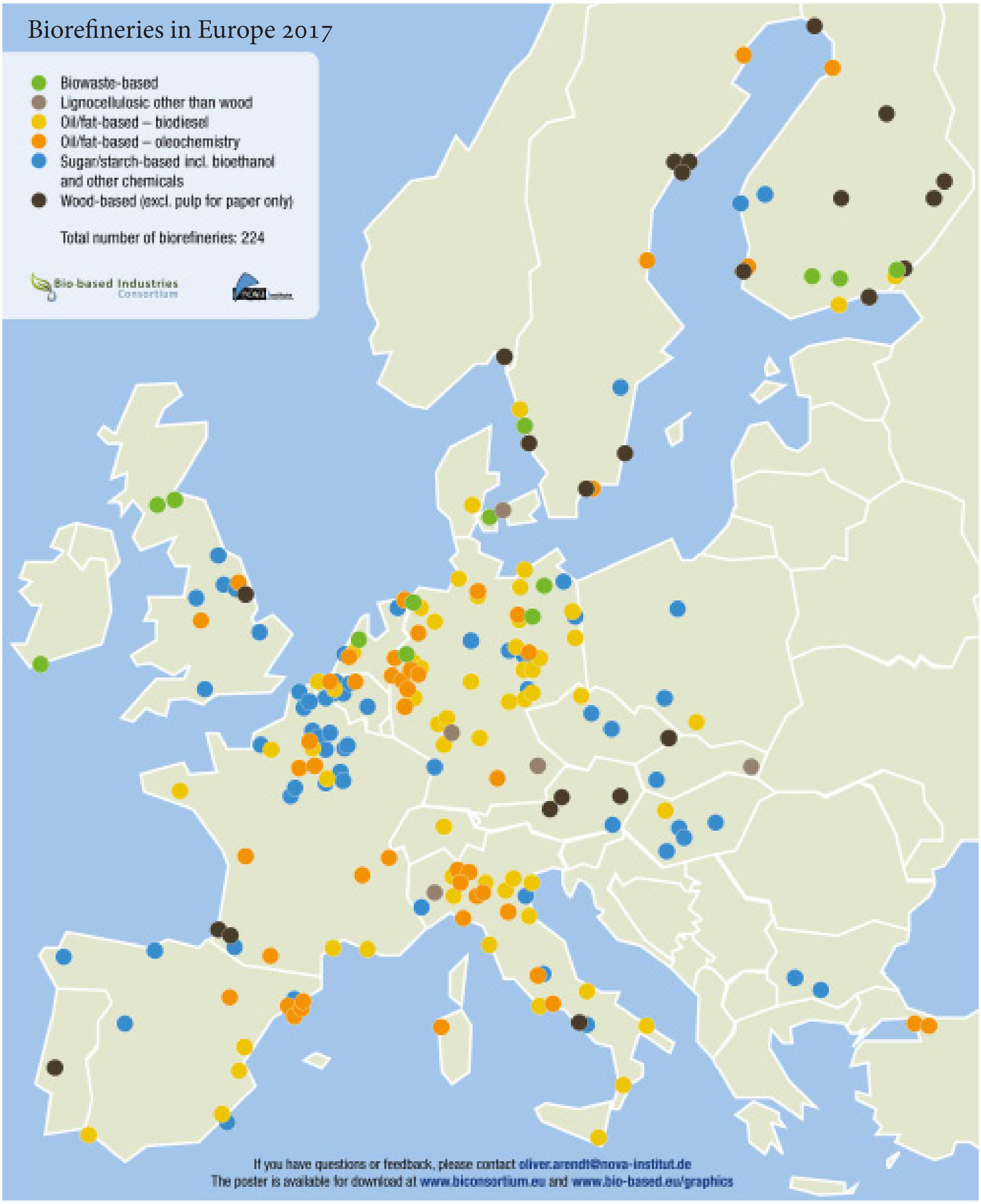


Figure 10. Biorefineries in Europe, 2017

Source: Bio-based Industries Consortium (BIC) and nova-Institute (http://bio-based.eu/markets) tives and feed-in tariffs. Without comparable support, bio-based chemicals and polymers will continue to suffer from underinvestment by the private sector. But policies will not be enough. It will be necessary to create the conditions that facilitate the emergence of new bio-based solutions; among them, special attention should be given to the supply and availability of wood and other lignocellulosic biomass.

3.2 Building with wood: current situation and future prospects

Greening the construction sector is a key challenge for sustainable development (UNEP 2011). In the EU28, the construction sector represents 35% of all greenhouse gas emissions, 50% of extracted materials, 30% of all water use and generates some 40% of all waste. It is also quite relevant in economic terms and adds up to around 10% of GDP while employing 12 million people (Hurmekoski 2017). Compared to many manufacturing industries, there have been few major improvements over the past few decades in the productivity, profitability, or the environmental impact of construction in the sector. A more sustainable construction sector requires increased use of materials with low embodied energy, like timber and cork, as well as improved environmental performance (e.g. passive house standards) in new buildings and extensive retrofitting of older construction. There are some key drivers pushing a renewal of timber building:

• There is strong policy momentum for developing a more sustainable construction sector in general as part of the energy transition. Overall, 22% of the southern regions have included sustainable construction as a priority in their smart specialisation strategies (29% in the EU28). Regions with significant woodworking industries have specifically identified timber construction as a priority. This trend is especially obvious in France and Italy, over, Spain, Portugal and Greece.

• Timber has intrinsic advantages. It has been estimated that every tonne of wood used to replace other materials (concrete, steel, etc.) implies a reduction of 2.1 tonnes of carbon emissions (Sathre and O'Connor 2010). In addition, it has good thermal insulation properties and can deliver highly efficient and cost-effective building and retrofitting solutions. It reacts well in case of fire, when used for structural purposes, as it does not collapse under high temperatures and, when used in interiors, it can positively influence indoor air quality and human health (buffers humidity, softens acoustics, creates a stress-relieving atmosphere). In addition, the high seismic resilience of timber buildings is an important advantage in earthquake-prone countries as Italy, Greece or Turkey (UNECE 2017).

• The emergence of new engineered wood products (EWP) has greatly enhanced the possibility of prefabricating structural components giving architects greater flexibility in construction modes, opening new markets in large-scale construction like multi-storey residential and collective buildings (e.g. offices, schools, hospitals, industrial and sports halls, etc.). Lightweight, high prefabrication, dry construction materials are easier to use, lighter to transport and produce less waste. The largest construction markets in southern Europe, however, is related to the retrofitting, renovation and re-structuring of existing buildings. This brings the challenging opportunity of developing site-specific, high quality designed engineered structural and non-structural (e.g. windows, doors, …) building components.

• Timber construction requires relatively low quantities of wood, and new EWPs can be developed based on many different species and wood qualities. It has been estimated that reaching a 20% market share of timber construction in the EU will only require 10% of today's European wood production. New markets for EWPs can activate significant side-streams based on wood residues (e.g. chips, sawdust and bark, which can be used for producing wood-based panels, composites, bioenergy and biochemicals) improving the economic viability of forestry (Humerkoski and Hetemäki 2017).

The case of Italy

Developing timber construction in southern Europe faces some specific challenges that are illustrated in analysing the Italian case. Italy has a long tradition of using wood for structural purposes in historical buildings, mainly for roofs and floors in old masonry buildings and churches. Despite that, timber was little used in new construction in Italy until about 10 years ago when ideas of sustainability and eco-efficiency in building started to play a key role in the housing policies of most regional and municipal public organisations. In Italy the building sector is responsible for 30% of total energy consumption and 25% of CO_2 emissions, therefore, it is easy to see why policies aimed at encouraging energy efficiency and using technology and natural materials in the construction sector are now necessary and are not simply an intellectual or ideological choice. Today, sustainable construction is a key priority for many Italian regions (see section 2.7).

Recent trends in wood construction

According to Centro Studi Federlegno Arredo Eventi SpA (2017), in 2015 Italy comes fourth in Europe for constructing residential timber buildings with a share of 7% of the whole residential building market. The growing diffusion of timber structural systems in Italy is also due to improvements gained in the automation process and performance of Computer Numerical Control (CNC) machinery, as well as in advances in the gluing process of wood-based products, which led to developing new engineered wood products. The introduction of new types of mechanical fasteners, especially self-drilling screws, have greatly enhanced the possibility of prefabrication of structural components and has made the construction process easier and faster.

Recently, important research projects, via both full-scale tests on entire multi-storey buildings and numerical investigations, have been conducted in Italy on using wood for residential construction, mainly focused on cross-laminated timber (X-Lam or CLT) technology. The seismic and fire performance of multi-storey buildings were of great interest and were investigated via shaking table and fire tests of three- and seven-storey, full-scale buildings in Japan. Noteworthy are: the SOFIE Project (2005–2007) conducted by CNR-IVALSA Italy, NIED, BRI and University of Shizuoka Japan on the seismic performance of multi-storey CLT buildings (Ceccotti and Follesa 2006) and the SERIES Project (2010–2013) conducted by the University of Trento, Italy, Graz University of Technology, Austria and University of Minho, Portugal on the seismic performance of multi-storey CLT, log house and light frame buildings (Tomasi and Piazza 2013).

The excellent fire and seismic performance, together with the great speed of construction due to an almost completely dry construction process, can explain the steady market gains, especially in constructing new residential and school buildings. An additional driver was the construction of several pioneering multi-storey buildings ranging from four to nine stores in different Italian regions with different levels of seismicity. The tallest buildings were erected in Milan, where four nine-storey, CLT residential buildings were built in 2012.

A wood-based sector depending on imported resources

Wood processing in the timber construction and furniture sectors is performed by 77 000 companies. Timber construction represents around 43 000 small and very small companies, spread almost uniformly throughout the country, employing around 179 000 employees (Federlegno 2008). Along with the pulp and paper industry and forestry activities, the total number of employees is around 300 000, producing roughly 1% of Italy's GNP (MCPFE 2007).

Italian wood satisfies only around 20% of total demand from the construction and furniture sectors (Berti *et al.* 2009), despite large forest resources. Most of the wood used for timber construction in Italy is imported from central and northern countries of Europe, especially Austria and Germany, which represents a missed opportunity for greater economic, social and environmental gains. Currently, Italy uses only a fraction of its native wood resources. Its total annual increment is estimated at 37 million m^3 (INFC 2007). Its annual harvest amount is estimated at approximately 12 million m^3 per year (MCPFE 2015) or one-third of the annual increment. Firewood is the main use, representing about 60% of national wood production. The remaining 40% volume is mainly used in the furniture sector and, in a smaller percentage, the construction sector. These figures have remained stable over the last few decades, despite increasing demand, because of agricultural and forestry activities in many mountainous areas being gradually abandoned. Wood plantations contribute 1 million m^3 to the annual growth, and they cover 122 250 ha (INFC 2007), 70% of which is represented by poplar. Poplar alone supplies almost 40% of Italian wood-based products for the construction sector. Despite its relevance, the number of plantations has reduced by 50% since the 1970s due to low profitability for forest owners, tighter environmental regulations and a lack of perception of positive externalities (Coaloa and Nervo 2011).

Forests in Italy constitute a valuable resource for the environment and the tourism industry, providing many valuable services including reducing landslide hazards, which are quite significant in many parts of the country. Forest resources have the potential to also be used as valuable structural material for timber construction and the furniture industry. There is much to be gained by with better integrated, higher added-value supply chains. Using wood could create a clear benefit in terms of local economies and employment, as well as an incentive to protect forested areas and, therefore, safeguard the local environment for future generations.

Developing local supply chains

Engineered wood products represent a new opportunity to use locally-grown timber in the construction sector. Cross laminated timber (CLT or X-Lam) panels are particularly suitable for this use. CLT are prefabricated panels made by gluing cross layers of small timber boards. CLT panels are structural elements that are strong and stiff and have good overall dimensional stability (e.g. the don't expand or shrink due to changing temperature or humidity) and can be used for walls, floors and roofs in multi-storey buildings. Since defects are less critical compared to other wood-based products such as glue-laminated timber that require larger defect free pieces of wood, lower-quality timber boards can also be used. CLT is particularly suited for regions facing the Mediterranean basin, where trees might be smaller and the quality might be lower compared to northern Europe.

The short procurement chain of wood for structural use has been tested in two different Italian regions. In Tuscany, a region with over 1 million ha of forests, a project started in 2009 that selected wood species best suited for structural purposes (locally-grown Douglas fir). Next, the mechanical properties of the different timbers and timber boards was researched and rules for visually grading locally-grown Douglas fir were derived. In 2010, a pilot plant for producing CLT structural panels made with locally grown timber was installed in Tuscany using some European and regional grants. In 2011, a two-storey public building was constructed in Florence using the CLT panels made of locally-grown Douglas fir produced in Tuscany. The whole project was completed in only three years (Borsi *et al.* 2011). In 2013 in Sardinia, a region with approximately 585 000 ha of forest covering 24% of the land area, the University of Sassari and involving the University of Cagliari and the IVALSA Trees and Timber Institute completed a similar research project. Visual and machine grading rules for local maritime pine wood were derived, and CLT panels made of maritime pine were produced and tested, leading to a full mechanical characterisation of such panels (Trulli *et al.* 2017, Concu *et al.* 2016, Fragiacomo *et al.* 2015).

These experiences show that although technically feasible, strong and firm support by the local public authorities and the national government is crucial to establishing a short procurement chain of timber in the Mediterranean basin that can be economically competitive with the stronger and more organised producers in Scandinavia, Austria and central and eastern Europe. Within the framework of EU regulations, local and national authorities should promote the use of locally-grown timber, with tangible benefits for the users complying with these guidelines.

Opportunities for market development

The construction sector suffers from inertia. It is considered more risk-averse and path dependent than most other sectors due to existing norms, expertise, large capital invested in machinery and the large number of small actors in the construction value chain. Normally, cost is the main differential factor in the market and this does not encourage radical innovation. With the exception of northern Italy and some French regions, timber construction has a very low market share in southern Europe. This means a weaker industrial ecosystem and a generalised lack of perception of wood construction as a technically and economically credible alternative. Moreover, the contribution of the forest sector to local communities and the economy is generally underestimated. The lack of well-organised advocacy groups also means less favourable regulations and awareness-raising activities. Consequently, in the short term, the market potential of wood construction in Europe by 2030 appears to be region-specific, with greater potential in the Nordic countries, followed by central Europe, northern Italy and France and finally southern Europe (Hurmekoski 2017). Its success will, however, greatly depend upon green building regulations and public procurement policies. Linking the woodworking industry to local resources is a priority in the Italian Bioeconomy Strategy and makes sense for other countries that have significant wood-working capacities built upon imported wood resources (e.g. Spain). To overcome existing hurdles, decisive action will be needed, especially in regions with the lowest timber construction levels.

• The first step should be to create a level playing field for construction markets, by removing the unnecessary hurdles from national construction regulations. Although timber construction can be directly sustained (e.g. stablishing mandatory targets), perhaps there is more to be gained from a stricter environmental performance regulation for buildings (e.g. energy efficiency, circularity) as this would render timber construction cost-completive without dislodging other existing technologies and materials. It would be useful to share and expand existing experiences in this respect.

• Attention must be paid to developing efficient supply chains, in some cases upgrading the technological capacities of sawmills and in other cases facilitating investments in advanced EWPs. It might also be necessary to actively search for potential private investors and to encourage new partnerships to develop saw mills and EWP manufacturing plants.

• Increased research and development and innovation will be needed to link existing and new woodworking capacities to the use of local wood resources. Local wood species and their products must be characterised. Southern European softwoods can perfectly fulfil the technical requirements for modern engineered wood products. While their case can be relatively straightforward, more challenging is the development of new products from Mediterranean native and planted hardwoods (e.g. Eucalyptus spp., Mediterranean oaks, etc.). The successful cases of poplar wood and cork can be inspirational. Advancing in this direction will help sawmills gain a better competitive position outside the low-cost commodity market segments that are currently dominant.

• Involve local communities with the aim of illustrating the progress and benefits achieved in the areas and regions where the availability of local wood could justify starting a short procurement chain of wood for structural purposes. Informing both public and private forest owners on how to generate profit through sustainable forest management is crucial.

• Liaising with public authorities at different levels (local and regional councils, public housing authority, etc.) is also important for developing a common, multi-level strategy involving forestry management, production of structural timber components, production of energy, promotion of timber as a structural material in public buildings, etc. This strategy should be supported in existing tools such as the rural development plans and the smart specialisation strategies.

Expected benefits from timber construction

The positive effects of developing a new way to build in towns and cities based on timber resources will go well beyond the expected environmental gains. It can tangibly improve rural welfare, generate local revenues through timber production and develop energy or bio-material value chains from residues. Active rural areas will be able to generate additional income in the tertiary sector through such things as natural tourism, and this can be an incentive to expand and protect forested areas. Increased reliance on high added-value products can help secure the future of the woodworking industries. This will in turn benefit public and private forest owners securing markets for their timber and offering room for more profitable forest management. It can also represent an opportunity for private construction companies, which can upgrade their expertise from traditional reinforced concrete and masonry to new sustainable timber systems. Municipalities, public agencies for social housing and other contractors will benefit from the high sustainability of buildings, the speed of construction through an entirely dry process, increased safety on the building site due to the prefabrication process and the absence of wet components, and the structural safety especially in earthquake prone regions.

Box 4. Building with wood: A snapshot of southern European countries

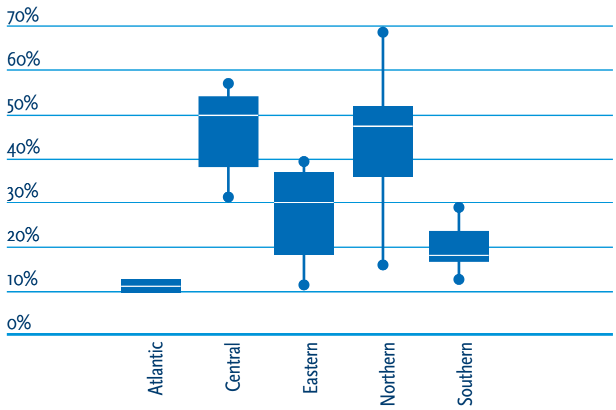
In southern Europe, wood construction has been growing over the last few decades, particularly for individual houses and public buildings. In France, for example, 2016, almost 2000 companies were involved in timber construction. They are generally small (60% have less than 10 workers) and represent 3% of the residential building sector. Timber construction represents 9% of all individual houses (-7% since 2014) and 4% of all collective houses (+72% since 2014). In the large majority of the cases (84% of the turnover) wood is used as solid or laminated beams for structural purposes. Construction based on CLTs and other advance EWPs represents only 3% of total timber construction (Observatoire National de la Construction Bois 2017). The growing interest of architects and designers for engineered wood products such as laminated timber (glue lam) and more recently CLT, has stimulated the emergence of new markets, including the construction of multi-storey buildings. The CLT technology has also paved the way for using local tree species. French production of CLTs is rather recent and is linked to existing sawmills, or to a laminated timber plant. SACBA in Aquitaine produces CLT from local maritime pine wood, as well as Norway spruce and has promoted the association France-CLT, which gathers eight CLT manufactures along with other agents in the construction ecosystem. CLT is also produced in Spain and Italy. The Basque company EGOIN (Spain) offers multi-story timber buildings and houses made with the CLT and glue-lam the produce. In the last decade, they have adapted products and processes to use locally sourced radiata pine wood, transitioning from central European and Nordic softwoods. XLAM Dolomiti is a European leader in CLT production and uses, wherever possible, locally-sourced spruce to supply the active markets in northern Italy. As happens elsewhere, few developments were made for using hardwoods in structural solutions, but there are some interesting cases. The Spanish company Garnica plywood, for example, has developed structural insulated poplar panels for the construction market. Beyond wood, the Portuguese Corticeira Amorim, offers digitally printed panels, different flooring solutions and external coatings based on cork composites that are marketed across the globe. There is good potential for developing CLT and laminated timber production in southern Europe. The existence of sawmills and laminated timber plants is a good asset, and partnerships between these two industries should be encouraged. Experience shows there is a need to increase the technological capacities and service quality of sawmills, so they can satisfy the more sophisticated demands of engineered wood producers. Also, it takes special effort to overcome the reluctance of clients who are used to well-establish species (e.g. spruce CLTs). Using new forest resources such as chestnut or eucalyptus could be envisaged in, for example, mixed hardwood-softwood panels, but this requires technological research and developments (pilot phase) before going to the industrial phase, keeping in mind the necessary competitiveness, and thus the economic feasibility.

3.3 The hidden potential of non-wood forest products

Non-wood forest products are products of biological origin other than wood derived from forests, other wooded lands and trees outside forests (e.g., forest fruits, mushrooms, cork, pine nuts, acorns, chestnuts, resin, medicinal herbs, essential oils, honey, etc.). Although not always well known, they play an important role in rural economies (FAO 2015). The latest report on the *State of Europe's Forests* (Forest Europe 2015) estimated the total value of NWFPs extracted annually from European forests at EUR 2.3 billion. This represents around 10% of the value of round wood and is a very significant figure. Because of the relatively weaker wood value chains, these NWFPs represent a larger share of forest production in the Mediterranean region. The relevance of NWFPs, however, goes beyond the direct economic value, as they are strongly connected to cultural heritage and territorial identity.

Mediterranean NWFPs include a large variety of products from those used in mass markets (cork, chestnuts, resin), to specialties (wild mushrooms, truffles) and various products for niche markets (e.g. *P. Pinea* seeds). Looking at their economic life cycle, and therefore to their market development, some are old, declining products (spontaneous aromatic plants that tend to de domesticated). Wild medicinal plants still represent a relevant source of genetic material for developing the pharmaceutical, chemical, cosmetic and food industries. Others are new, emerging products like new sap drinks or new (at least for the European market) edible plants and insects. In addition, changing market conditions are re-opening opportunities for old, almost abandoned products, like resin and chestnut tannin. Some NWFPs are produced through dedicated forest management, albeit with a range of management intensities (e.g. cork, resin, as well as chestnut and pine nuts in certain regions), while others, generally called wild forest products, are collected but not actively managed. This is the case of many mushrooms and berries, but also for some honeys and medicinal or decorative plants. Both types of NWFPS have significant potential to contribute to the bioeconomy, even if they require very different approaches and strategies.

In the case of wild forest products, two opposite trends are in place in the same time even for the same categories of products. There is a trend towards domestication, as in the case of berries and nuts. In many European countries these products are taking advantage of the image of forest products, but they are cultivated like the most intensive farm products (strawberries, hazelnuts, etc). There is also another interesting trend towards re-wilding, in search of products that are more natural, tasty, rich in some micro-elements and/or more socially and environmentally acceptable products in terms, for example, of animal care standards and non-polluted sources of production. This is the case of re-wilding game animals and aromatic herbs or plants used in cosmetics. The search for old products connected with traditional knowledge in the use of forest products is still present in many rural areas in the Mediterranean region (chestnut beer, baskets made with willow branches, strawberry tree root - *Arbutus unedo* – or pipes, the manna drug from ash - *Fraxinus ornus*).



Source: Based in Prokofieva *et al.* 2017.

Figure 11. Percentage of households engaged in NWFP harvesting activity in 2015 in different European regions. (Southern countries include France, Italy, Spain, Portugal, Greece and Turkey.)

Leveraging the potential of wild NWFPs

From the bioeconomy perspective, one main and distinct role of wild NWFPs is their potential to bring socio-economic wellbeing and a more balanced rural-urban relationship (Vidale and Petenella 2014). This potential should not be underestimated. A household survey on wild NWFP consumption habits, which was answered by close to 17 000 citizens in most of the EU28 and some neighbouring countries, found that over 90% of Europeans consumed some type of wild forest product during 2015 (Lovric *et al.* 2017). More importantly, 35% of rural and 22% of urban respondents picked or harvested products themselves during the year, although with big regional differences, and with relatively more people picking the products themselves in Nordic and central Europe and fewer in southern and Atlantic countries (see Figure 11). Over 70% of these people who pick products go to the forest more than three times a year.

The positive effects of forest outdoor activities on human health are attracting increased attention and could prove to have significant economic effects on healthcare savings. Moreover, the data indicates strong potential for wild, non-wood forest products to encourage nature-based tourism and generate income in rural areas, leveraging existing social trends. According to Prokofieva *et al.* (2017), forest potential could be leveraged in the following ways:

• Build on experiential economy approaches where consumers' feelings are the essential to the value. In marginal, inner, Mediterranean areas an indirect economic role is played when NWFP are used as iconic products in territorial marketing initiatives for branding a geographic area and networking its actors (e.g. the *Strada del porcino*, the *Route del la châtaigne*, etc.). Mycological tourism, showing traceability of wild food from the forest to the restaurant, mushrooms picking courses, etc., are central to some nature-based tourism strategies. In these cases, the economic role of the NWFPs is more connected to social innovation, that is to coordinating all actors under the same vison and rules to promote a local development strategy.

• Build on the growing trend towards a greater appreciation and use of locally-sourced, natural, traditional and wild resources, as seen in the increased use of wild and traditional products in quality restaurants and health foods, artisanal brewed beverages, jams and sweets, as well as natural cosmetics and natural medicines. Short value chains and direct sales of NWFP products can represent good opportunities for diversifying income sources and providing seasonal employment.

These approaches are affecting the role of NWFP in rural development in terms of direct and indirect effects on income generation and are not only being used for personal consumption and a subsistence income. Linking NWFPs with tourism and short value chains can greatly contribute to rural economies. However, not all set-ups guarantee that the value generated will be captured locally.

The NWFP economy faces constraints and structural limitations that need to be overcome such as the previously noted issue of seasonality, which affects the availability of particular NWFPs and limits opportunities for specialization. The lack of a continuous flow of fresh products means it is impossible to reach a minimum, stable critical mass of products to place on the market. The problem of a reduced amount of NWFPs is exacerbated by the difficulties connected to the atomisation of supply and a frequent lack of vertical and horizontal integration among the actors of the value chain. This is one of the reasons why many NWFPs are sold by individuals to middlemen. Collectors are normally price takers with little power over the market and they are unable to take advantage of the potential for adding value along the value chain. NWFP property rights are often not designed to actively and easily promote commercial value chains (e.g. in Greece and Turkey all NWFPs are owned by the state, while in many regions in Spain mushrooms can be collected for free). Small-scale activities frequently based on the work of individuals picking the products are associated with informal markets, i.e. markets where transactions and actors are not registered, where tax evasion is a common practice, where minimum standards for product storage and health standards are not considered (e.g. fresh, wild mushroom in many Balkan countries).

These quite common conditions have at least three direct negative effects:

• The market is not transparent, statistics are not kept or they are unreliable, public authorities tend to underestimate the economic and social role of the sector, the social perception of the importance of NWFPs is misunderstood and, ultimately, the sector is kept in the margins in terms of decision makers' initiatives for defining regulations and providing incentives.

• In a context based on informal rules, with frequent incidents of illegal behaviour, professional operators face problems consolidating their market position, investing in supply chain organisation and modernising the sectoral economy.

• Tracking the products from their origin to where they are sold to the consumer is difficult. When transactions are not transparent and property rights and fiscal regulations are not implemented, it is impossible to trace the products. This is an important constraint in trying to develop the market for some NWFPs, especially in the case of food products.

To improve supply chain arrangements, it is particularly important to regulate harvesting rights and modalities, allowing for products to be traced (extremely important for edibles), avoiding unfair employment conditions, and balancing the rights of the local population and hobbyist with the needs of more professionalised operators. Although direct producer-to-consumer approaches are always possible, benefits will be achieved, in many cases, with better cooperation among producers and/or vertically along the value chains. In this respect, Internet-based portals and social networks have become relevant as commercialisation channels and a great opportunity for NWFPs. One example is a high-quality brand for wild mushrooms developed in the Spanish region of Castilla y Leon that integrates interested agro-food operators, guaranteeing consumers the geographic origin, sustainable picking, safety, and high visual and culinary quality, while also establishing economies of scale and joint marketing efforts. The brand builds upon a comprehensive effort that includes awareness and marketing campaigns, new picking regulations and a network of ICT enabled mobile selling points where people who have picked the products can sell their daily harvest with full web-based traceability and transparency[10].

Leveraging the potential of industrial NWFPs

The opportunities offered by non-wood forest products go well beyond niche markets, small-scale activities and heritage, especially when considering industrial products such as cork, resin and other extracts. Southern Europe hosts some global leaders in several markets. The Italian company SILVATEAM with production facilities in Italy, China and Latin America is a global leader in chestnut and other natural tannins for the leather industry and also produces wine additives, animal feed and other industrial applications. Italian Vegetable Tanned Leather is a quality brand for the fashion and apparel industry, key for Italian leather competitiveness in global markets, that shows how the importance of NWFPs go beyond their monetary value. The Portuguese iconic company Corticeira Amorim is the global leader in cork products. Intensive investments in research and development have led to an extended portfolio of products that include bottle stoppers for all market segments (including screwable cork stoppers!), also innovative construction materials such as digitally printed housing panels, waterproof and scratch resistant flooring, furniture sold at IKEA and other top-notch products such as advanced race-horse shoes and specialty components for industrial or aerospace applications. In this way, residues from stopper production that were being burnt for energy, have found new and higher added-value applications. In the sector of medicinal herb-based products for health care the Italian company Aboca is the precursor and an international benchmark company with 1 100 employees, 77 natural herb species employed, more than 3 000 different products put on the market. In recent years, Spain has reactivated the production of natural resins, replacing imported resins from China, to reach 15 000 tonnes per year and contributing to new investments in processing facilities. With over 800 000 ha of favourable pine forests, resin production represents a significant opportunity for the post-oil era in southern Europe, even if the cost of labour is a major limitation in current market conditions. The French company DRT, with over 1 000 employees, began by processing the once very important Aquitaine resin. It still produces derivatives from natural and tall oil resins, but it has also expanded to include specialty extracts from pine bark, grape seeds and olive leaves, while supplying polyphenol- and phytosterol-based products to the health, nutraceutical and cosmetic industry worldwide. Essential oils and natural extracts are among the hidden treasures of the diverse southern forests, one that offers many opportunities for new entrepreneurial adventures, as shown by the Galician start-up Hifas da Terra that develops innovative fungus extracts for oncological and other applications. In the case of well-established value chains (cork, resin) the ability to supply the raw-material in quantity and quality is a limiting factor. It is, of course, a multifaceted problem that might require new sustainable intensification management practices, new approaches to achieve profitability, combining for example NWFP

[10] https://www.setasdecastillayleon.com

production with wood and other goods or services supported with Payments for Ecosystem Service type of schemes (e.g. as in *dehesas* or *montados*) and might require managerial or social innovations to improve the value chains efficiency and equitability. In addition, realising the potential for new products and business models will require sustained efforts in research and development, increased entrepreneurial skills and improved access to venture capital for bioeconomy start-ups.

Concluding remarks

When compared with wood products, NWFPs, as a branch of the Mediterranean forest economy, are underestimated and consequently are underused and underfinanced. Still in many contexts NWFP are secondary forest products, for which the *Kielwasser* or Wake Theory, is considered a guiding principle in forest management. This assumes that sustainable production of wood is the primary objective of sustainable management, as it guarantees at the same time all other functions, goods and services (Rupf 1960). Few forest managers realise that in oak forests the annual production of some hectograms of white truffles per hectare can potentially generate much more income than wood production and that forest management practices could be adapted to optimise growing truffles growing rather than focusing on the annual increment of wood (Barreda 2011, Reyna and Pérez-badia 2015). Similarly, silvicultura treatments in Mediterranean pines can be optimised for producing mushrooms or pine honeydew, which have great potential to increase economic and/or social outcomes (de Miguel *et al.* 2014a, de Miguel *et al.* 2014b).

Considering the potential and the problems this branch of the Mediterranean forestry sector, it's clear that the high internal demand and the EU's strong position on international markets for several NWFPs represent a significant opportunity for the Mediterranean bioeconomy and offers a chance to enhance internal NWFP supply supporting income generation in rural areas. While it is unrealistic to cover the internal EU demand for all NWFPs from European forests, enhancing production of NWFPs could be a key aspect of future forest policies to reduce dependency on international trade and re-establish economic bridges between largely urban NWFP consumers and producers located in remote rural areas.

4. Unleashing the potential for the forest-based bioeconomy in southern Europe

As shown in previous sections, the forest bioeconomy must create prosperity and wellbeing while, at the same time, reduce environmental footprints. It has significant potential in southern Europe where it benefits from important social and economic drivers. It will require technological, social and policy innovations to develope new value chains based on forest goods and forest services (section 4.1) and a strong sustainability framework (section 4.2) to protect and increase the natural capital, with a specific focus on climate change adaptation and mitigation (section 4.3). The bioeconomy can create a strong market pull for forest goods and services. This demand must be matched by adequate supply, though active management at the landscape level to create resilient and thriving landscapes, balancing the provision of multiple ecosystem services (e.g. wood, water, non-wood forest products, pasture). Many southern regions have low forest management activity, weak forest value chains and most of them lack organisational structures capable of overcoming the structural fragmentation of forest ownership. A recent work has identified the most relevant barriers for wood mobilisation in Europe and has extracted lessons learnt from different initiatives and projects across the continent[11]. This report emphasises the need to overcome fragmented ownerships (section 4.4), as this is a critical hurdle not only for wood mobilisation but also for climate change adaptation, forest fire prevention and for providing other ecosystem services.

4.1 Creating innovative bio-based products and services

The European Forest Institute (Hetemäki *et al.* 2017) has identified the required framework conditions that will make it possible to develop the potential of bio-based products and services. These can be summarised as:

• Strong sustainability schemas. There are multiple pathways to develop the bioeconomy, and not all have the same sustainability potential. As it relies on biological systems, the bioeconomy must be sustainable.

[11] Orazio,C.; U Kies and D. Edwards (2017) *Wood mobilisation in Europe*. European Forests Institute. 116 pp ISBN number: 978-2-9519296-4-9

• Engaged societies. Developing shared visons of sustainable, desirable and plausible futures through scientifically informed societal debate is a possible way forward.

• Knowledge, innovation and skills. Create circular bio-based products and services. Research, development and innovation should not be restricted to technologies, as social, managerial and policy innovations are also crucial for the circular bioeconomy. In addition, new ways to teach and train are needed as existing skills do not match the requirements of the bioeconomy.

• Risk-taking capacity. It is essential to facilitate investments in pioneering but possibly risky initiatives. This can be achieved creating markets for innovative bio-products (e.g. through public procurement) and increasing the public-private and private-private cooperation, also between global companies and small and medium-size enterprises.

• A common and stable regulatory framework. This could speed up development of the circular bioeconomy for bio-based products and services, reducing the risks for business and consumers and assuring sustainability. Biomass comes from the land and the sea and its production has many social and environmental implications.

Developing this framework will require strong private-public collaboration and strong government-to-government collaboration at multiple levels (e.g. cities, regions, member states and the EU).

At a more operational scale, Europabio (Dupont-Inglis and Borg 2018) in the framework of the BioTIC project (Bio-TIC 2015) [12] has identified the main barriers for deploying in industrial biotechnologies in Europe:

• markets barriers, such as the lack of public awareness and unclear product standards;
• biomass supply barriers, such us, high and volatile costs, fluctuation in quality and price, unsecure supply and competition from frequently subsidised energy uses; and
• technological barriers, which can be very process specific.

In France, Italy and Spain, barriers related to public awareness, access to finance for pilots and upscaling and difficulties establishing partnerships along bioeconomy value chains and across sectors are highlighted.

To overcome those barriers they propose 10 key areas for action, related to securing biomass supply (1), innovating in products and process of available biomass (2, 8), facilitating cross-sectoral connections (7–10), increasing research capacities, skills and upscaling of technological solutions (2, 3, 6), developing a favourable policy environment and access to finance (4, 9) and engaging society (5).

1. improving opportunities for feedstock producers within the bioeconomy;
2. investigating the scope for using novel biomass;
3. developing a workforce that can maintain Europe's competitiveness in industrial biotechnology;
4. introducing a long-term, stable and trans-

[12] They refer specifically to the Industrial biotechnology understood as the thermo-chemical and biological transformation of biomass. It is a central element of the bioeconomy, even if it does not include solid uses of wood or cork or other biomaterials such as cotton or flax, nature-based tourism or other services.

parent policy and incentive framework to promote the bioeconomy;
5. improving public perception and awareness of industrial biotechnology and bio-based products;
6. identifying, leveraging and building upon EU capabilities for pilot and demonstration facilities;
7. promoting the use of co-products from processing;
8. improving bioconversion and downstream processing steps;
9. improving access to financing for large-scale biorefinery projects; and
10. developing stronger relationships between conventional and non-conventional players.

Analysing the innovation environment for the bioeconomy in southern Europe is beyond the scope of this report. Overall innovation capacity is analysed in the European Innovation Scoreboard (European Commission 2017). For the specific bioeconomy innovation environment, the performance of southern countries in the Global Cleantech Innovation Index provides important insight, as the bioeconomy makes a relevant share of the clean technology sector, with some 33% of the 2018 Global Cleantech 100[13] companies using biomass as feedstock or providing solutions for biomass processing.

Table 11 summarises several Global Cleantech2017 country profiles (Clean Tech Group and WWF 2017). Overall, southern countries performed lower than Nordic or central European countries and, also, lower than other OECD countries. Countries like Italy and France have above average general innovation capacities and strong specific cleantech innovation drivers because of favourable policy environments (regulation) and relatively high public investments in clean tech research and development. Access to early stage venture capital and green bonds help France perform much better than Italy, where the lack of start-up funding is a major impediment. Spain and Portugal can be placed in a second group. They have significantly weaker research and development investments and weaker overall innovation capacity. However, they rank much worse on the policy environment, which explains their low scores. In those sectors with more favourable regulation (wind energy in Spain, for example), deployment of clean technologies has been significant. Finally, Greece performs below average in all index areas and notably in general innovation drivers, specifically clean tech innovation drivers and early stage business opportunities. The case of Turkey is interesting, as it scores better than average on overall innovation capacity but fails in specific drivers for clean tech.

Table 11. Clean technology Innovation profiles of southern European countries, summarised from the Global Clean-tech Innovation Index (GCII). Ranking refers to the position among the 40 countries analysed in the GCII. The index has four components. General innovation drivers; Specific innovation drivers refers to the policy environment, cluster activity and access to finance; Emerging cleanTech refers to early stage investments, patents, high impact start-ups, etc.; and Commercialised Cleantech refers to the size current markets (imports, exports, employment, etc.).

▶

[13] https://i3connect.com/gct100/the-list

Table 11.

	Ranking	General Innovation	Specific Innovation	Emerging cleantech	Commercialised cleantech
France scores around the mean in general innovation drivers, even if quite low for perceived entrepreneurial opportunities and early-stage business activity. It scores, slightly higher than the mean in specific clean tech innovation drivers due to the policy environment and higher investments in research and development. Emerging cleantech in France is strong, backed by the high availability of early-stage venture capital in the sector and the recent issuing of EUR 7.5 billion in green bonds. Renewable energy consumption and clean tech imports and exports are relatively low and that explains the low clean tech commercialisation score.	13	🟡	🟢	🟢	🟡
Greece scores well below the mean on general innovation drivers and very low in perceived entrepreneurial opportunities and early-stage business activity. The unattractiveness for renewable energy investments and low clean tech research and development expenditure (even if larger than Bulgaria or Romania) hinders specific drivers. Emerging clean tech is low.. Venture capital investment and patent activity also rank low. Commercialised clean tech in Greece suffers from an underdeveloped investment environment and reduced clean tech business activities (mergers, acquisitions, IPOs, etc.).	34	🟡	🟡	🔴	🟡
Italy's score for the Global Innovation Index is quite low. It scores slightly above the average in specific-cleantech divers despite a friendly policy environment, due to an underdeveloped early-investment landscape. It takes last place for early-stage entrepreneurship. Emerging clean tech is quite low, mainly due to low venture capital investment. Italy leads other southern European countries in clean tech mergers and acquisitions.	26	🟡	🟢	🟡	🟡
Portugal scores below average in general innovation drivers due to a weak entrepreneurial culture innovation ecosystem. However, it scores above average in clean tech supporting policies and cluster activity. It has relatively low public research and development investments and lacks access to start-up finance. This explains why emerging clean tech innovation is the weakest pillar. Commercial clean tech activity (e.g. clean tech commodity trade) is low, except for consumption of and employment in renewable energies. Portugal's overall performance lies well below the average for all the European countries analysed.	27	🟡	🟡	🟡	🔴
Slovenia scores below the global-average in general innovation drivers, clean tech specific drivers and emerging clean tech. It has great potential to improve its innovation ecosystem and embedded national entrepreneurial culture. It has a top score for clean tech cluster development and supportive government policies. Strengtheners that are overrun by a total lack of start-up access to private finance and low investment attractiveness for renewable energies. This translates to low emerging clean tech, with a particular weakness, again, in the lack of early-stage financing. Despite these weaknesses, Slovenia manages to score 16th place in commercialised innovation, with strong clean tech commodity exports and imports.	21	🟡	🟡	🟡	🟢
Spain Scores below average (also below Portugal) in general and specific clean tech innovation drivers. Particular weaknesses are: lack of a clean tech-supportive policy environment, and low research and development expenditure on clean tech, especially compared to other European nations. Emerging clean tech is low, due to the low number of clean tech start-ups and environmental patents. Spain does better in commercialised cleantech. It shows evidence of late stage private equity deals, successful public clean tech companies, strong exports of clean tech commodities and above average use of renewable energy.	25	🟡	🟡	🟡	🟢
Turkey's clear strength lies within general innovation drivers, scoring high in entrepreneurial culture indicators and giving evidence of an active early-stage innovation ecosystem. It performs much weaker in clean tech-specific drivers because of the lack of supportive policy environment, reduced access to private finance and weak cluster organisation. Consequently, it has one of the lowest scores in emerging clean tech. While still well under the global average, it shows some evidence for commercialised clean tech due to clean tech commodity imports and above-average use of renewable energy.	33	🟢	🟡	🟡	🔴

Source: Cleantech Group and WWF 2017

In summary, improving entrepreneurial culture, risk taking capacity and access to early-stage and late stage finance are common challenges in southern Europe, along with societal awareness and engagement. These barriers must be overcome to strengthen the innovation systems and bridge the academia-business divide. Entrepreneurial skills can be introduced in the life science and biotech curricula along with improved access to early stage funding. Support to pilot plants and upscaling is necessary. Making new businesses creating on current side streams a priority, existing industries can help overcome limitations in the biomass supply, while also helping to strengthen, rather than to compete with, traditional bioeconomy enterprises. This can be achieved through more systematic business discovery processes and by promoting cross-sectoral interactions and partnerships between established companies and innovative start-ups to create new industrial ecosystems. The World Economic Forum (2016a) also stresses the need for increased cross-sectoral collaboration and public-private partnerships in order to advance towards climate friendly industrial systems. In addition, distributed pre-processing to aggregate biomass and a priority on value over volume, reducing the needs for economies of scale are possible ways forwards (Bio-TIC 2015). Attention must also be paid to improved collaboration and benefit sharing along the biomass value chains to guarantee the long-term engagement of producers.

On the other hand, an improved policy framework to facilitate access to markets, de-risk investments and secure sustainability and societal support (e.g. green public procurement, environmental taxation, product and process standards, etc.) seems to be of special urgency in countries like Greece, Portugal, Spain or Turkey.

Cross sectoral links and public private partnerships will also be necessary to develop and scale-up placed-based approaches to realise the potential of non-wood products and the soft values of forests and forested landscapes (e.g. linking ecotourism and health, water provision with fire prevention, developing synergies between wood and non-wood forest products, etc.). Greater emphasis on socio-economic research and social innovation might be required in addition to technological innovations. Finally, the social economic sector can make significant contributions.

4.2 The bioeconomy needs to be sustainable

The bioeconomy relies on natural resources for energy, material production, nature-based solutions and green infrastructure. For the bioeconomy to succeed, nature, the environment, must be at the core of the economic development model, supporting the economy and human wellbeing. This is implicit in the motto of the French bioeconomy strategy, which placing photosynthesis at the core of the economy, and also in the Italian strategy, which speaks of a unique opportunity to reconnect the economy with society and the environment (see section 2.1). For this to be possible scientists call for a nested, strong approach to sustainability recognising that nature and the environment are the basis for economic development and social wellbeing. Natural capital cannot be traded-off for human constructed capital as both are complementary and synergic. This departs from weak sustainability that sees social, economic and environmental elements as independent pillars. Accepting trade-offs between natural capital and economic development makes sense in a fossil-based economy, where economic growth is mainly fuelled by non-renewable fossil resources and materials accumulated during millions of years of the Earth's history. It certainly makes less sense in an economic paradigm that depends on the capacity of nature to provide goods and services. The bioeconomy must identify and realise synergies between environmental protection and human development. A worst-case scenario for the European Mediterranean region emerges precisely from accepting excessive trade-offs between economic development and environmental sustainability, in a context of climate change (World Economic Forum 2011).

What are the sustainability risks and opportunities of the bioeconomy for southern Europe?

The bioeconomy holds a promise to sustain wealth creation while reducing or reversing current environmental effects. Positive effects are related to the environment (e.g. climate change mitigation, reduced use of materials and waste) and wellbeing (e.g. increased energy security, employment, rural livelihoods and economic growth), as can be read, for example, in the drivers for bioeconomy strategies. This improved environmental performance requires reduced material intensity and reduced carbon, water and other ecological footprints or, more in general, maximising the ratio between the benefits and the impacts derived from every unit of resource used (Sfez *et al.* 2017).

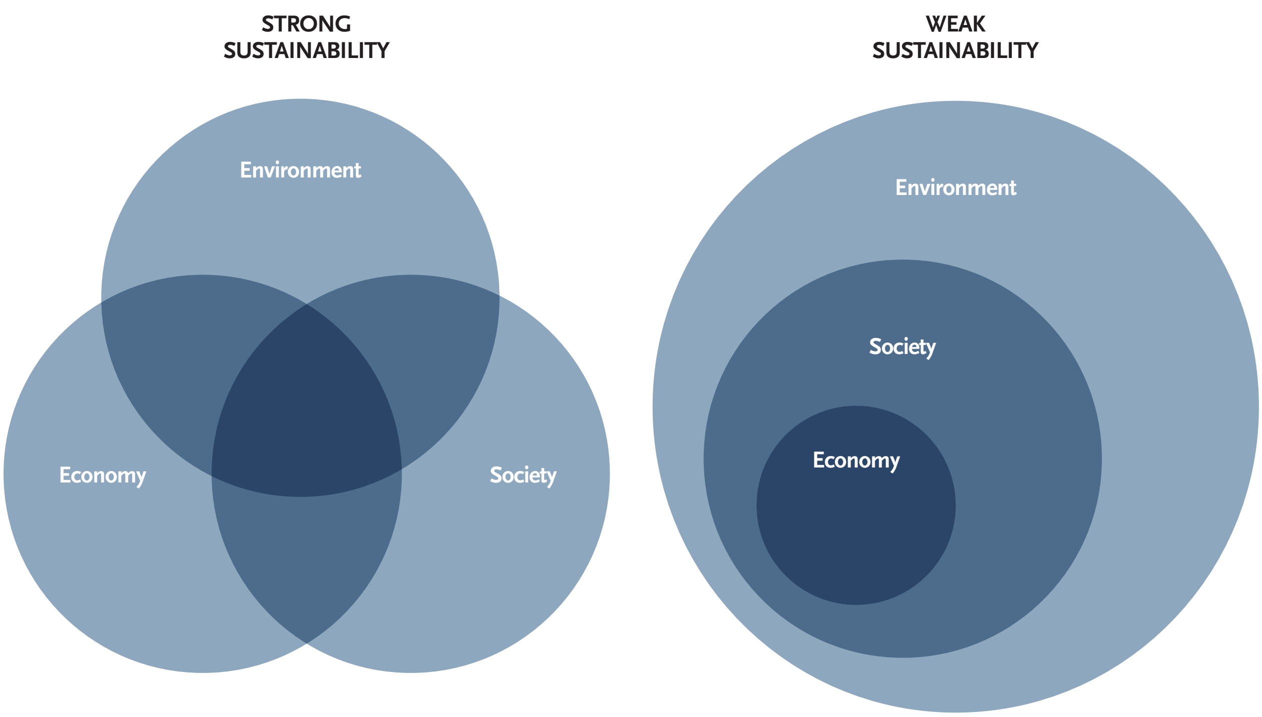


Figure 12. Strong vs weak sustainability approaches.

There is a generally positive attitude towards the potential of science, technology and industry to create new, more sustainable products from biomass (Pfau *et al.* 2014). It is acknowledged that, generally, bio-based products have clear advantages over those based on fossil fuels and non-renewable materials. They tend to have reduced carbon footprints and are usually less toxic and more biodegradable, which make it easier to re-use, recycle and dispose of them. In their analysis of current wood flows in Switzerland and using a Live Cycle approach, Suter, Steubing and Hellweg (2017) found an average positive impact of 0.5 tonnes of carbon dioxide equivalent per cubic metre of wood used to replace other materials, but with large differences for different uses. This is in line with research findings done in other countries with a variety of methodological approaches (see Sathre and O'Connor 2010, for a literature review). In general terms, the substitution effects are bigger when solid materials are used to replace high embedded energy materials such as concrete or steel, and when combined with bioenergy use at the end of the product life cycle.

Bio-plastics and bio-textiles that can replace their fossil-based counterparts are gaining traction and can contribute to reducing carbon footprints, marine litter, hyper-accumulation of waste and pollution. Research shows that they hold great potential, but also that they are not the panacea (World Economic Forum 2016). Among the bioplastics that can directly substitute for plastic, for example, bio-ethanol based polyethylene terephthalate (PET) can be used to replace current plastic bottles. Although PET is durable and recyclable, it is not biodegradable. For this reason, PET will have a limited positive environmental effect, especially if collection and recycling rates are not radically improved. Other bio-plastics such as Polylactic acid (PLA) bioplastics are biodegradable and are more promising, although they do not fit all applications. Reducing plastic use through changes in consumer behaviour and improving circularity will need to work in parallel with developing a new generation of bio-based biodegradable plastics (World Economic Forum 2016). The textile sector, dominated by fossil-based materials, is also a relevant source of waste and pollution. As bio-textiles gain traction, their environmental performance is increasingly being examined. Some bio-based textiles can have high water footprints (e.g. cotton), require toxic chemicals in their production (e.g. traditional viscose), or use toxic elements in tinctures, imprints and/or functional additives (e.g. alkyl phenols, phthalates, etc.), creating negative environmental impacts and also making them less recyclable (Shen *et al.* 2010). In a recent LCA analysis conducted by SCS Global Services[14], it was concluded that the environmental performance of a cellulose based bio-textile will heavily depend on the source of biomass and the production process along complex global value chains. For example, viscose produced from recycled clothing has a much better performance than average Asian production based on European or Canadian boreal forest pulp or Indonesian rainforest pulp. New technologies are improving the environmental performance of cellulose-based textiles, reducing water footprints and the need for toxic chemicals and increasing recyclability (e.g. Lyocell, Spinnova). The take-home message is that assuring sustainability goes beyond the bio-based origin

[14] https://www.scsglobalservices.com/new-study-reveals-lighter-environmental-footprint-for-fibers-sourced-from-flax-and-recycled-clothing

of products. Lignocellulose-based textiles can greatly contribute to a new textile economy, if circular economy principles are applied from cradle to cradle. In this process, well-designed LCAs should track environmental and social impacts in globalised value chains.

Greater concerns, even sceptical views, arise in relation to the capacity to sustainably supply increased demands of biomass (Pfau *et al.* 2014, Robledo-Abad *et al.* 2017), and have to do with the potential negative effects on the natural capital and the social fabric of biomass producing regions and communities. They can be summarised as:

• Risks associated with intensification. Breeding, fertilisation and improved forestry practices can significantly increase productivity but can also have negative effects (e.g. biodiversity, soil or water quality). In some cases, when forest governance is weak, increased demand for biomass can lead to resource depletion (e.g. overharvesting, illegal logging, etc.) or to unsustainable practices (e.g. soil degradation). This in turn can affect primary productivity, creating a negative feedback loop, and affect other components of the ecosystem (e.g. carbon balance, water quality).

• Risks associated with land-use change. Most, if not all, EU bioeconomy strategies embrace the principle of food-first. It places the focus of the bioeconomy on non-food biomass (e.g. agro-food waste streams and forestry). Nevertheless, EU imports of biomass could still increase competition for land-use in third countries. Increased demand of biomass can also lead to conflicts between nature protection and biomass production. In regions with a high utilisation rate of forest resources (e.g. central and Nordic Europe) the debate about land-use impacts in forestry is dominated by two contrasting approaches to sustainable land management, called land sparing and land sharing (Phalan *et al.* 2011). According to the land-sparing approach, productive areas are segregated from conservation areas. Part of the land is set aside for conservation, while the rest is dedicated to intensive forest production (e.g. industrial plantations). The land-sharing approach advocates for multifunctional management of all forests, modulating management intensity through, for example, close-to-nature and retention forestry (Gustafsson *et al.* 2012), in order to supply multiple ecosystem services along with wood and non-wood products.

• Risks associated with social exclusion and resource grabbing. The larger proportion of EU forests are owned by families, municipalities and governments, so there is a large social base supporting the forest bioeconomy. Nevertheless, unequal participation in the value chains and unequal sharing of the nuances and benefits of bioeconomic activities are still relevant issues. Effective public participation at local, regional and national levels and maintaining the local control of natural resources are seen as a necessary condition for mitigating these risks. At the global level, the risk of land grabbing, displacement of small-scale farmers, deterioration of food security leading to rural poverty and increased inequalities remain a significant concern.

In relation to these risks FSC and PEFC schemes are quite active in many southern european countries. Moreover, through participatory processes (not very frequent in the Region) they have developed country or regional certification schemes suited, to the much diversified local conditions. Standards have been developed also for some NWFP and FSC is now testing new indicators for the certification of the sustainable supply of ecosystem services, using also Mediterranean case study areas.

How can the bioeconomy live up to its sustainability expectations?

A first essential element of the sustainable bioeconomy derives from its intimate dependence on the Earth's natural capital and its ecosystem services. Researchers (Costanza *et al.* 2014) have estimated the value of global ecosystem services as USD 125 trillion (in 2011), with a loss of between USD 4.3 trillion and USD 20.2 trillion per year between 1997 and 2011, equivalent to some 6% to 27% of global GDP. These figures, no matter how big, underestimate the relevance of ecosystem services the same way that the value of agriculture for human wellbeing goes far beyond its generally low contribution to the GDP. They are mainly useful to raise awareness and to better guide political and economic action. An essential element of the bioeconomy must be to monitor and account for natural capital and ecosystems services and to set up policies to avoid unwanted market externalities, also creating the appropriate economic drivers needed to support sustainable value chains.

A second element is the landscape/territorial approach. The bioeconomy needs certain dimension and economies of scale. Direct farmer-to-market approaches have shown their limitations even for high-value agricultural products. A territorial dimension is needed. Different land uses provide direct sets of ecosystem services that must also be balanced at the landscape level. In this respect, there is increasing scientific evidence that a considerable amount of land, globally and regionally, needs to have a predominantly unmanaged status, ensuring biodiversity conservation, e.g. space for conservation and evolution of the crop's wild relatives, which is essential for the bioeconomy (Lefèvre *et al.* 2014), and global ecosystem services like climate stabilisation and rainfall recycling over land (Ellison *et al.* 2017). Set-aside policies can constrain the biomass supply. In a sustainable bioeconomy, this is not to be considered lost land as it contributes highly to the Earth's resilience to the benefit of all. These areas can provide also local economic benefits as through nature based tourism. In fact, the value of these benefits can exceed that of biomass in many regions (Croitoru 2007). Also, set-aside policies can be combined with intensive management in other areas, securing efficient biomass supply. Forestry in many Atlantic regions is close to this approach, as production is concentrated in planted areas, while semi-natural forests sustain much lower management intensities and productions. There are, however, concerns on the sustainability of these large, planted monocultures for a number of reasons (e.g. higher incidence of pest outbreaks, more vulnerability to climate stress), and also concerns about soil degradation in forestry operations and, also, negative societal perceptions (Valero *et al.* 2014). In addition, protected areas could prove to be too small to halt biodiversity loss, if not surrounded by suitable land uses (DeFries *et al.* 2007). Increasing the multi-functionality of planted and other managed forests through, especially in ecological corridors, connecting conservation areas, can contribute to greater system stability. In contrast, in Mediterranean regions, land abandonment and low management intensities are leading to rapid forest expansion and biomass gains. This has positive consequences for soils, climate change mitigation and forest dependent biodiversity. However, forest continuity and biomass accumulation increases the risks of catastrophic fires, also heavily affecting protected areas (San-Miguel-Ayanz *et al.* 2012), it represents a threat for species depending on open spaces (Ostermann 1998, Plieninger *et al.* 2006) and can also have an effect on available water due to the higher evapotranspiration (del Campo *et al.* 2017). Increased management intensity seeking multifunctional and resilient landscapes can make an important contribution to the sustainability of Mediterranean forests.

Overall, southern Europe has a fantastic opportunity to combine set-aside strategies with different intensities of forest management, including agroforestry systems and open areas. There are many potential synergies between reduced fire risk, increasing water flows, reduced hydric stress, biodiversity protection and the creation of wealth and rural livelihoods. The bioeconomy can provide the economic engine to activate sustainable management (Corton *et al.* 2013). Knowledge on fire behaviour, forest dynamics, tree physiology and the functional role of biodiversity needs time and focus to further develop from fundamental research to viable land management systems (Liang *et al.* 2016, van der Plas *et al.* 2016, van der Plas *et al.* 2017).

A third critical element of a sustainable bioeconomy is circular economy thinking. Positive environmental and social impacts (e.g. employment) should be maximised along the whole life cycle of products and services, from resource extraction over the production process to the use phase, and eventually the multiple re-use of recycled resources in new products. At the end of life, waste is minimised through energy use and recuperation of ashes as a fertilizer, for example, or as building material. Unavoidable waste can be dealt with through phytoremediation further closing nutrient cycles. Life-cycle thinking can be mainstreamed by policies stimulating industrial symbiosis, giving value to waste, and putting a high price or ban on disposal. Well-designed Life Cycle Assessment (LCA) eco-design and environmental screening of new products and business models at the design phase become essential tools for the bioeconomy. There is a wealth of knowledge, from research and experience, that must be incorporated into the bioeconomy, reducing material intensity through resource efficiency, higher product longevity , hierarchy of uses of biomass (e.g. material uses vs. energy uses), biomass partitioning (e.g. optimal use for each biomass fraction), cascade use (sequential recycling for material uses before final energy use and disposal) (Brunet-Navarro *et al.* 2016) and use of waste streams (e.g. side products of one process as inputs of another process) in industrial symbiosis and also through new business models linked to the sharing, performance and platform economies (see Table 2 in the introduction).

A fourth key element of the sustainable bioeconomy is the need to address both production and consumption patterns. As an example, one of the reasons for increased water and energy footprints in the region is the shift away from the more sustainable and healthy Mediterranean diet as increased consumption of meat and dairy products replace olive oil, unrefined cereals and legumes (Global Foot Print Network 2015), increasing obesity (Papandreau *et al.* 2008)[15]. A general concern comes from the fact that expected environmental gains (e.g. resource efficiency, waste reduction, carbon emissions, etc.) can be reduced and even reversed by a concomitant increase in consumption rates as the current dominant consumerist world view maximises growth of the economy (GDP) as the primary path for solving societal challenges (Constanza *et al.* 2014). This is known as the rebound effect (Brookes 1990) that was formulated for energy efficiency but that can also be applied to material efficiency. This needs to be address with economy-wide measures. Overarching targets to reduce material, water and carbon intensities must guide the bioeconomy along with developing bio-based sectors. This will require strong societal engagement and shifting the focus from economic growth to human wellbeing (UNU-IHDP and UNEP 2014)[16]. Activating societal change will require acting on multiple levels of the social-ecological system, from changing mindsets (visions, values) to developing new rules (standards, incentives, punishments, constraints) and adjusting economic parameters (i.e. taxes, subsidies) and also unleashing the creative potential of people (Meadows 2010). The role of mind-sets in shaping human action cannot be easily overestimated, as mental models and images directly influence human behaviour (Smajgl and Ward 2013). Unlocking society from the current consumption and production patterns requires a positive engaging narrative (EFI 2017). Society needs to visualise sustainable and desirable futures, because negative messages will not function. Costanza (2014) proposes participatory scenario planning at multiple scales as a tool to develop common desirable futures across societal groups.

In summary, the main sustainability issues of the forest-based bioeconomy are related to sustainable production, biodiversity, conservation, social justice and equity. Its main sustainability benefits are bio-production, climate mitigation and water management. There are plenty of opportunities to find synergies between them. How these are identified and given value, monitored and steered will be key for a successful bioeconomy. They will require a combination of improved management of natural resources (at multiple scales, from the genome to the landscape) and a strong focus on maximising environmental and social benefits produced per unit of biomass used or hectare of land managed (Sfez *et al.* 2017), with an increasing reliance on natural-based solutions. This, in turn, will be based on technological, managerial and social innovations for efficient transformation, use, re-use, for sharing, recycling and disposing of biomass and bio-based products and creating wealth from the ecosystem services and soft values of forests.

[15] Papandreou, C., Mourad, T.A., Jildeh, C., Abdeen, Z., Philalithis, A. and Tzanakis, N. 2008. Obesity in the Mediterranean region (1997–2007): a systematic review. *Obesity Reviews*, 9: 389–399. doi: 10.1111/j.1467-789X.2007.00466.x

[16] UNU-IHDP and UNEP. 2014. Inclusive Wealth Report 2014. *Measuring Progress toward Sustainability*. Cambridge University Press, Cambridge.

4.3 Adapting to and mitigating climate change

Adaptation is necessary and requires economic support

Climate change is particularly challenging for the forests in southern Europe that are already experiencing harsh conditions. Different climate scenarios in this region predict increased summer temperatures and reduced annual precipitation (Jacob *et al.* 2014), leading to severe heat shocks and drought events, further leading to increased hydric stress, greater potential susceptibility so some pests and diseases and forest dieback. In addition, favourable conditions for catastrophic fires will extend both temporally (i.e. extended fire season) and spatially, reaching new areas to the north and east.

Forest policy makers and managers need to be proactive and reactive in facing these challenges. Anticipatory adaptive strategies are aimed at reducing the risks, to increasing forest resistance and resilience, to fostering forest adaptation, and to preserving multiple options to cope with huge uncertainties in future scenarios. Nevertheless, precaution and prevention strategies will not prevent all catastrophes and, in many cases, healing and restoration measures will be needed. Proactive and reactive measures have a cost (e.g. thinning too dense forests, increasing agroforestry practices, changing species composition, converting coppices to high forests, regenerating ageing unstable forests,...); they also produce different types of products that could feed the bioeconomy. Here, we question the potential qualitative match between the products of adaptive practices and the circular bioeconomy. The latter could bring support to adaptation and forest restoration depending on climate change and socio-economic scenarios. The quantitative assessment of this support is beyond the scope of this report.

How adaptation strategies and the bioeconomy can support each other

Adaptation of Mediterranean Forests to climate change can be operationalised through three objectives:

- attenuation of risk
- increased resilience
- support for restoration

Table 12 summarises management measures to address these objectives as proposed by Birot *et al.* (2011).

Table 12. Tentative list of specific measures to adapt or restore forests in the context of climate change beyond normal practices and materials potentially provisioned for bioeconomy sectors

▶

Objective	Measure	Material produced	Frequency per site
Fire prevention	Fuel breaks and wildland urban interface (WUI): establishment	Large and small lumber, logs, fire wood, wood scraps, wood waste, green waste	Once, scheduled
	Fuel breaks and wildland urban interface (WUI): Maintenance	wood chips, wood waste, green waste	every 2 to 4 years, depending on site productivity
	Open areas and agroforestry schemes: Establishment	Large and small lumber, logs, fire wood, wood scraps, wood waste, green waste	Once, scheduled
	Open areas and agroforestry schemes: Maintenance	Pasture, livestock, small logs, fire wood, NWFPs (aromatic plants...), crops	Nested cycles, depending product and on products and site productivity
Drought tolerance	Additional thinning to reduce Leaf Area Index. Conversion of coppice to high forests. Change is age structure	Small lumber, logs, fuel wood	Every 15 to 25 years, depending on tree species and site quality
Attenuation of risks	Shorter rotation	Large and small lumber	Once, scheduled, less than every 50 years, generally
Restoration	Post-fire salvage logging	Burnt logs, fuel wood (woodchips), wood scraps (particle boards), wood waste	Occasional, unscheduled
	Clearing after storm	Logs, fuel wood (woodchips), wood scraps, wood waste	Occasional, unscheduled
	Clearing after mortality events (dead trees)	Fuel wood (woodchips), wood scraps, wood waste	Occasional, unscheduled
	Sanitary clearing (infested trees)	Wood scraps, wood waste	Occasional, unscheduled

In the erosion-prone climate and orography that is predominant in southern Europe, soil organic matter and soil physical structure play a central role in soil resilience, productivity and water reserve. Protecting soil condition, especially during forest operations and in post-fire restoration activities, must be a clear priority. In addition, provenances better adapted to future climates can be gradually introduced in existing stands, facilitating what could be a natural, but slower, migration of genes and species. Eventually, species shifts can be facilitated in semi-natural forests or directly established in plantation forestry. This, however, could require a mental shift, since regeneration and restoration with local genetic material is generally advised now when not explicitly enforced with regulation. A common argument is that promoting mixed stands can reduced the risk of dieback due to environmental conditions, pest and diseases. Radical changes in forest composition (e.g. species shifts) or conversion to new forest systems, could have complex and indirect effects on sustainability and markets and should be carefully considered, including by evaluating the adaptation capacity of existing populations. At the landscape level, the combination of dense forests with agro-forestry systems and open areas (e.g. pasturelands) could contribute to more resilient territories. There is more knowledge on the effect of landscape structures on fire-spread speeds, water production or biodiversity. There is much less capacity to create the governance and economic frameworks to make these smart landscapes a reality, especially in the context of fragmented ownerships (see chapter 4.4).

Planned proactive measures aimed at reducing risks and increasing resilience to drought can be designed to produce materials in certain quantities, qualities and timing, and they are clearly better than imposing reactive measures. New models and guidelines are emerging to better incorporate forest fire risk and water balances in Mediterranean forestry (e.g. Piqué *et al.* 2017). These new approaches look for synergies between adaptation to climate change and the supply of different types of biomass that can match bioeconomy developments. Certain sectors (e.g. engineered wood) are more demanding in terms of quality and dimensions than timber with certain dimensions and mechanical properties. Other types of materials (e.g. composites) and uses of solid wood (e.g. wood-based panels) can benefit from lower quality, raw material. At the extreme, bioenergy could potentially use all types of biomass qualities from harvest residue to shrubs and lignocellulosic mixtures all the way to post-consumer wood. It is important, therefore, to develop a product mix (and downstream value chains) that can secure the profitability of biomass extraction. The viability of biomass as feedstock and raw material depends heavily on the amount produced and on the cost of extraction and transport to destination. Policy, social, managerial and technological innovations are needed to reconcile climate change adaptation priorities with biomass supply in quality, quantity and cost. Finally, well developed forest value chains can be instrumental in mitigating the negative impacts of large catastrophes (e.g. storms, fires) when responses to mobilise and transform huge amounts of damaged timber become necessary.

How can forests support climate change mitigation?

The essence of climate change mitigation is reducing carbon emissions or compensating for them with increased carbon sinks in natural or artificial reservoirs. The contribution of forests can be enhanced through two approaches:

1. Increasing carbon stocks in different forest reservoirs (trees, deadwood, litter and soil): increasing these stocks can be achieved by expanding forest areas, increasing biomass and

replenishing carbon in soils. Generally, this approach is favoured by fast growing species, high density plantations and reduced management intensities (reduced wood extraction) to speed up biomass build-ups. This enhanced sequestration approach has several limitations. As forests mature, carbon is stocked at decreasing rates, as decomposing dead wood and litter, compensates for new growth. As the expansion of Mediterranean forests in recent decades shows, forest continuity and high biomass loads increase the risk and rate of catastrophic fires, generating uncontrolled carbon emissions, economic losses and even cause the loss of human lives.

2. Reducing emissions through increased substitution of fossil fuels and high carbon footprint materials with forest-based products that generally have lower carbon footprints (e.g. wood, cork, natural resins): this approach focuses on carbon flows from the atmosphere to forest products and requires increased productivity and more intense management. As discussed briefly in the preceding section, measuring substitution effects requires a life-cycle approach and case by case analysis. In general terms, the substitution effect is greater when forest-based materials (e.g. engineered wood products, cork) substitute energy intensive materials (e.g. concrete, steel, plastics) in long life-span uses (e.g. timber construction, Roux *et al.*, 2017, Keegan *et al.* 2013) and where cascade approaches are implemented. This is partly due to the carbon stored in the harvested wood products, but mainly due to the very low energy embedded in wood and cork-based materials. In this respect, priority should be given to the wood construction and engineered wood sector, then to the advanced bio-products sector and, ultimately, to the bioenergy sector (Ciccarese *et al.* 2014). This hierarchy of uses must be implemented through cascade approaches (e.g. giving priority to long-life material uses, re-using, sharing, recycling, while restricting bioenergy uses to end of life uses as an alternative to disposal) and through optimal partitioning of biomass (e.g. using each portion of biomass for its most valuable possible use). As competition among different uses and market conditions will drive the system, it is important to create adequate policy frameworks for maximising positive climate effects.

In this respect, the carbon balance of energy-only approaches has received great scrutiny in recent years (Berndes *et al.* 2016, Brack 2017; Robledo-Abad *et al.* 2017). Bioenergy is generally considered carbon neutral, which means that its emissions are re-absorbed by the regrowth of the harvested stand over time. However, as woody biomass is less energy dense than fossil fuels, and contains higher quantities of moisture and less hydrogen, burning wood for energy usually emits more greenhouse gases per unit of energy produced. The final carbon balance of wood bioenergy must be calculated case by case as it depends on several factors, such as (EASAC 2017):

• The source of biomass (plantation, short rotation coppice, waste), the intensity of operations, the emissions produced during forestry operations, harvesting and transport, and changes in forest dynamics.

• The regrowth period depending on site productivity, forest operations and harvesting intensity, as this can affect in different ways the growth rates of the remaining forest and reduce or increase its susceptibility to forest fires, storms, pests and diseases.

• The alternative use for biomass. If the biomass will decompose anyway (forest residues), the impact will tend to be positive; if the alternative is long-term carbon storage in the forests or in wood products, the impact will tend to be negative.

• The technology, size and efficiency of the energy conversion, ranging from individual boilers to industrial power plants and from heat, CHP electricity or biofuels.

• The energy mix that will be substituted. As the share of renewables increase (wind, solar), comparing biomass emission with fossil fuel emissions makes less sense.

Generally, bioenergy is and can be produced in combination with other forest products and services, contributing to their economic viability (e.g. in factory bioenergy consumption or based in residues, bioenergy linked to fire-prevention). Even more, every single stem produces different qualities of wood that enter different material and/or bioenergy value chains. In some cases, notably in the Mediterranean region, bioenergy can be the only economically viable alternative, and is the economic engine needed, to manage the forests, reduce fuel loads, encourage forest continuity and prevent megafires (Verkerk *et al.* 2018). In these cases, bioenergy should be a tool to improve forest conditions, to increase the value of managed stands, and to increase the sustainability and resilience of the landscape, and not as a long-term solution in itself. For the above reasons, the carbon balance of biomass should consider together the full set of forest-based products and services that are and will be co-produced (Berndes *et al.* 2016).

Conclusion: conditions for the best match between bioeconomy and adaptive measures

• Adaptation to climate change requires developing adaptive management strategies[17]. Active, adaptive management can alleviate hydric stress and the risk of forest fire, while also increasing water availability downstream. The circular bioeconomy can provide economic support to adaptive measures, and there are some emerging examples. But, the bioeconomy can also become a driver of global change when the demand reaches the point of disruption of ecosystem functions. Climate change adaptation can benefit from different management intensities in the landscape, including agro-forestry approaches. Policy, social and technological innovation is needed to link adaptation priorities with biomass markets and the bioeconomy, creating more resilient landscapes.

• There are significant synergies between adaptation and mitigation to climate change. Forests managed for adaptation will maintain significant carbon stocks above ground and, especially, in soils as carbon depleted after centuries of agricultural use is replenished. Increased carbon stocks in soil, will improve productivity and will help reduce water stress, as soil organic matter plays a key role in both processes. Managed forests can supply low-carbon-footprint raw materials and feedstock reducing unwanted carbon emissions in uncontrolled forest fires. Due to the huge diversity of local forestry contexts and scenarios of change, and due to the importance

[17] A clear conceptual scheme of adaptive management strategies is given by the California Department of Fish and Wildlife: http://www.dfg.ca.gov/erp/adaptive_management.asp

of transport costs, good synergies between a circular bioeconomy and adaptive measures are more likely to be seen at the local geographic scale, while large-scale bioeconomy sectors are expected to be more distant from local requirements.

• Coping with multiple uncertainties, adaptive measures are, by definition, flexible and regularly adjusted. Therefore, matching bioeconomy and adaptation requires flexibility in both domains. Preserving this flexibility while progressing jointly in both directions is a challenging matter of innovation.

Box 5. The bio-economy as an opportunity to tackle wildfires

The Mediterranean basin is a global wildfire hotspot and wildfires in just five Mediterranean countries (France, Greece, Italy, Portugal and Spain) currently have an effect on approximately 450 000 ha per year, representing annual economic damage of about EUR 1.5 billion, just considering forest losses as perceived by stakeholders. A much larger figure will be obtained if direct and indirect damages to ecosystem services and property are accounted for (San Miguel and Camia, 2010). To tackle wildfires, these five countries invest approximately EUR 2.5 billion annually on prevention, mostly on suppression. Despite a decline in the number and area affected by wildfires in Europe and globally, the damage from wildfires (expressed in the volume of wood that is lost) increased over the twentieth century. Moreover, this trend is expected to continue in the next decades due to global climate change, which requires rethinking how to effectively tackle wildfires in the future. In a context of climatic conditions favouring wildfires, the changing forest resource - in terms of area, growing stock and structure - has been a key factor in the increased frequency and effect of wildfires in the European Mediterranean region. Forest resources have greatly expanded in the region due to active afforestation and to natural vegetation encroachment after agricultural lands have been abandoned. Wood extraction represents a small fraction of the increment and low active forest management generally characterizes Mediterranean forests. Consequently, the young, expanding and largely unmanaged forests contain high fuel loads and favourable conditions for rapid and large spread of wildfires. Basic forest management practices can contribute to reducing wildfire risks by reducing fuel loads and altering fuel continuity at the landscape level. Forest and fire management could be integrated to jointly reduce wildfire risk and to supply high-quality timber or biomass, as well as other ecosystem services, in the context of urbanisation, globalisation and climate change. Human actions are the main cause of wildfires as ignition is mostly due to runaway agricultural fires, negligence and arson, indicating a perceived low value of forests. Therefore, to effectively address the problem of wildfires, a new paradigm is needed that recognises forests as a valuable resource that provides important, renewable, biological resources and other ecosystem services. A transition towards a bioeconomy will offer opportunities to finance and operationalise long-term, landscape-scale management strategies. Adequate policy frameworks and policy incentives are crucial to attract the necessary investments and support the structural development of specific Mediterranean value chains and infrastructures. These investments are needed to finance and develop sustainable, integrated forest and fire management activities that can help to ensure the resilience of the Mediterranean forests - and ultimately society - to confront the problem of wildfires. For more information, see Verkerk *et al.* (2018) and references therein.

4.4. Defragmenting forest ownership

Southern Europe needs to overcome the problems caused by extreme fragmentation in forest ownership and management to secure the benefits from ecosystem services. Research findings on the effects of fragmentation and abandonment are summarised. New governance approaches and institutional arrangements are presented. Some initiatives are highlighted.

Introduction

In Europe, forests cover 215 million ha, accounting for 33% of the total land area (Forests Europe 2015). Of these, about 50% are privately owned and mostly small scale with less than 5 ha (Schmithüsen and Hirsch 2010). According to Živojinović *et al.* (2015), the diversity of forest owner types in Europe has been increasing in the past years. Lahdesmaki *et al.* (2016) demonstrated significant demographic changes in the forest ownership structure in northern Europe, namely more non-farming, female and elderly owners. Several studies (e.g. Hugosson and Ingemarsson 2004, Ingemarsson *et al.* 2006, Karppinen and Tiainen 2010) consider that the increasing number of new forest owners and the consequent demographic changes in the ownership structure are reflected in the values and objectives of forest owners by making them more versatile. This might affect the quantity and quality of ecosystem services provided increasing the challenge for policy-makers who must consider a broader range of private forest owners for policy development (Bengston *et al.* 2010).

The increasing diversity of forest owners in Europe has resulted from ownership fragmentation which occurs when an area of forest is divided, or fragmented, into several smaller patches of forest habitat (Wilcove *et al.* 1986, Collingham and Huntley 2000, Fahrig 2003). The main cause of ownership fragmentation is inheritance, with the land being distributed among all heirs instead of being inherited by only one child, as in some regions in the German legal framework) (Sklenicka 2016). The distribution of land by all heirs can happen physically, i.e. the unit of land is divided in smaller plots or into co-ownership, where all heirs share the property rights over the land (Noev *et al.* 2003). Ownership fragmentation can be the result of various other institutional, political and sociological factors such as urbanisation, property restitution, transaction costs in land markets, expropriation from the original owners and dividing the land among new owners (King and Burton 1982, Blarel *et al.* 1992, Sklenicka *et al.* 2014). According to Latruffe and Piet (2014), ownership fragmentation is a multifaceted concept that encompasses five dimensions: (1) number of plots; (2) plot size; (3) the shape of plots; (4) distance of the plots from the farm buildings; and (5) distances between plots (or plot scattering).

Ownership fragmentation can lead to negative externalities, such as problems of economic efficiency in forest management (higher harvesting and transaction costs), disincentives for investment in forest practices, and greater management problems related to providing ecosystem services, including wildlife, water, recreational opportunities and soil security (Hatcher *et al.* 2013). Stoddard (1942) found that the size of a forest holding influenced the behaviour and management objectives of non-industrial private forest owners. Muench (1965) found that the size of a forest holding and its associated characteristics, namely, occupation, education, and land tenure, were positively related to landowner adoption of incentive-based forestry practices. Nybakk *et al.* (2009) established that forest size moderates the effects between forest owners' innovation and economic performance, suggesting that large-scale forest owners benefit more from the innovative use of forest land for economic purposes. Stanislovaitis *et al.* (2015) found that pursuing income from forest management is strongly linked to the size of forest holdings and that only larger private forest owners regard income as a top priority. More recently, Feliciano *et al.* (2017) concluded that the size of the property influences private forest owners' conceptualisation of management when age and education of forest owners are considered. In addition, new owners usually have different management objectives from older forest owners (Weiss *et al.* 2017). This chapter focuses on ownership fragmentation related to the decrease of plot size and consequently, small scale forestry. It presents problems and opportunities associated with fragmenting forest holdings and, consequently, small scale forestry, giving the example of a country in southern Europe – Portugal - where the phenomenon of small scale forestry is very marked, especially in the north and central regions.

Governance approaches to mitigate the negative externalities associated with small-scale forestry

Securing the provision of forest based goods and services requires a landscape approach that negotiates the various trade-offs among different goods and services reconciles stakeholders' multiple needs, preferences and aspirations and minimises the negative externalities associated with small-scale forestry and land fragmentation and (Sayer *et al.* 2013).

Joint forest management and joint forest ownership are examples of landscape approaches. The inherent aim of jointly owned forestry is to make forest management easier for the forest owners and simultaneously create more efficient and larger areas to increase the profitability of the forest economy (Korhonen 2010). Several European countries report cooperation in forest management. This can take various forms such as forest owners associations, cooperatives and associations for joint management. In some countries (Balkan countries, Romania, Portugal, Baltic countries), joint forest management is a recent approach to managing forests, in others (Austria, Norway) it was introduced long ago. In addition, advisory, consultancy and managerial services targeted to forest private owners can help reduce some of the negative impacts of land fragmentation. A good example is the French Centre National de la Propieté Forestiere and its network of regional centres.

Table 13. Examples of landscape approaches in forestry across Europe

Name	Definition	Type	Countries
Municipal forest ownership	These are claimed to be distinct from public ownership because of the closeness of the management (municipalities, communities) to the multiple local beneficiaries (citizens). More than 10% of all public forests in Europe are in municipal ownership.	Joint ownership	Several European countries
Common property regimes (CPRs)	"Commons" are forests owned by a group (co-owners) who hold exclusive rights and share duties towards that resource. It is perhaps better understood as a group-owned private forest. This type of property exists in several parts of Europe, such as Italy, Sweden, Portugal and Switzerland. Communal forest properties have several advantages: they keep large resource systems intact without having to divide them into small pieces. Community-owned or -managed forests were established as an outcome of land reforms in the 18th and 19th centuries.	Joint ownership	Italy, Poland, Hungary, Slovakia Sweden, Spain and the United Kingdom.
Forest cooperatives and forest associations	Their scope and objectives depend on their individual statutes, but mostly the cooperation itself provides opportunities for knowledge exchange among the members, more efficient and effective forest management, and facilitates implementation of policy programmes. In these countries, forest owner associations are seen as promising organisational structures to channel state support with the aim of technology transfer towards sustainable and profitable forestry under the new regime.	Self-organised management for the benefit of the members - not joint ownership	Several countries in Europe (north, south, southwest) and former socialist countries
Jointly owned forest	As a potential means of preventing fragmentation and improving the effective utilisation of the forest resource, Finnish forestry has introduced the idea of an investor-based, jointly-owned forest (JOF). A JOF can be defined as an area of combined holdings intended for the practice of sustainable forestry for the benefit of the shareholders. The first JOFs were established in Finland in the late 19th century, primarily by the authoritative orders. (Source: Lahdesmaki *et al.* 2016).	Joint ownership and joint management	Finland
ZIFs – Zones of forest intervention	ZIFs are a combination of voluntary collective action of forest owners with public authority established in Portugal. Around 20 700 forest owners are members of ZIFs, covering an area of about 846 137 ha. The ZIF approach is considered promising for managing small-scale forest holdings by technical and political stakeholders. The first ZIFs were implemented in Portugal in 2006. The main objectives of the ZIFs are to mitigate the risk of forest fires and to cut the costs of wildfire prevention.	Joint management but not joint ownership	Portugal

A Case study: Portugal

In Portugal, about 93% of the forest is private (Mendes 2005). The area under private ownership is 3 129 000 ha. There are about 400 000 private forest owners in Portugal and 6.5 million of forest holdings. In the north and centre of the country, most of the forest holdings have less than 0.5 ha and are populated by maritime pine and eucalyptus. While there is no quantitative data available about the size distribution of forest holdings in Portugal, the contrasting regional differences in property size are well known. Small scale forestry predominates in the northern and central regions with about 50% of the forest land concentrated in holdings of an area up to 10 ha. In the southern regions, more specifically in the Alentejo, the property size is large scale with most forest holdings of an area larger than 100 ha.

Forest Owners' Associations

Even though there is in Portugal a high percentage of highly fragmented forestland under private ownership, the phenomenon of collective organisation of private forest owners began only approximately 30 years ago. These organisations appeared with rather minor involvement of the forest services in promoting forest owners' associations. The state only played an indirect, but rather important, catalysing role mainly due to grant-driven afforestation programmes and other incentive schemes that were implemented after Portugal entered the EU. This funding helped to support the implementation and operating costs of forest owners' associations and encouraged forest owners to ask for technical advice about the grant schemes and other services (e.g. mapping properties).

Torrijos *et al.* (2003) notes several advantages of forest owners' associations, namely for promoting action among small-scale owners, improving the profitability of non-industrial private forestry, promoting forest multi-functional uses and promoting the sustainable use of forest resources.

The following is a non-exhaustive list of services provided by forest owners' associations in Portugal:

- information about the public incentive schemes for forest investment;
- preparation of forest plans to apply for funds from those programmes;
- monitoring forest plans and afforestation works carried out by private contractors;
- technical information about forest management operations;
- training courses for forest owners;
- certification advice; and
- forest works such as shrub cleaning and forest fire prevention actions undertaken by forest sappers, who are trained and coordinated by the forest owners' associations.

In economic terms, the range of services provided by forest owners' associations falls in the following categories (Mendes 2006):

- private services: e.g. technical advice, harvesting, or marketing services provided to each individual member;
- club goods: e.g. implementing forest certification schemes; and
- public goods: e.g. contributing toward reducing the risk of forest fires or to providing more positive forest externalities such as landscape quality, climate regulation or recreation.

There seems to be a positive correlation between the number of members and the diversity of services provided. This implies circular causation, i.e. on the one hand the increasing number of members generates a higher demand for the provision of services, and on the other hand, the increasing number of services provided by forest owners' associations attracts more members (Feliciano and Mendes 2012).

Forest fires and ZIFs

Forest fires are an old phenomenon in Portuguese forests. What is new, and has become more frequent, is the scale reached by these forest fires in 2003, 2005, 2016 and especially in 2017 when more than 100 people died and approximately 500 000 ha of area were burnt (Figure 13). For many years, the cork oak forests in the south were not affected and the eucalyptus forests, mostly managed by the pulp and paper industries, were usually less affected by forest fires. More recently, forests burn everywhere, including the highly managed forests such as eucalyptus forests. After the big fires that occurred in 2003, the Portuguese Government approved a Permanent Forest Fund to support forest expansion, protection of existing forests and provision of forest public goods and services. Later, the Government recognised that forest fires were a complex problem and approved a new instrument to tackle the problem. This instrument is called ZIF – *Zonas de Intervencao Florestal* (Zones of Forest Intervention) and its main objective is to reduce ownership fragmentation and to cut down wildfire prevention costs.

The ZIFs emerged in 2005 (Law-Decree no 127/2005 from 5 August) as a proposal for the organisation of the Portuguese non-industrial private forest owners. The ZIFs are areas of continuous forest managed under the same forest management plan. The forest holdings covered by ZIFs can be owned by different types of forest owners: private (e.g. individual, industries), state, commons. The management entity of ZIFs oversees implementing the forest management plan. The ZIFs aim to provide effective and suitable management of forests to overcome the constraints of small-scale forest holdings, and, in addition, to reduce the risk of forest fires and to promote the recovery of burnt forest areas. Currently, these zones have a national distribution and occupy a total area of about 8% of the country's mainland. ZIFs usually have a management entity (*entidade gestora*) that is often a forest owner organisation. Forest owners with forest stands within the perimeter of a ZIF are obliged to follow a forest management plan, which had to be approved beforehand by the general assembly of the ZIF (Fernandes 2008, Marques 2011, Valente 2013). Around 20 700 forest owners are members of ZIFs, corresponding to an area of

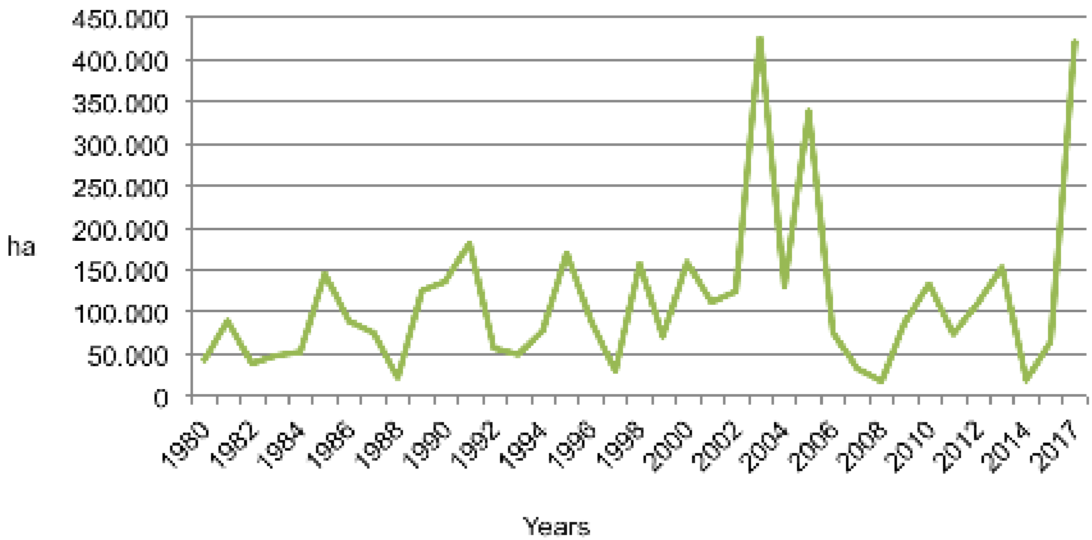


Figure 13: Area burnt in Portugal between 1980 and 2017 (Source: PORDATA[1] and ICNF[2])

[1] https://www.pordata.pt/Portugal/
[2] http://www.icnf.pt/portal/florestas/dfci/relat/rel-if/2017

846 137 ha (Valente 2013). ZIFs provide a good opportunity for forest owners who have inherited their forest holdings but live in the city or in other countries and have no capacity to manage the forests by themselves, to outsource forest management to the ZIF management entity. The objectives of ZIF are to allocate concrete responsibilities to the management entity, to structure the territory, to homogenise local and regional policies and to integrate different angles of the local and regional policies. The advantages of this joint management mechanism for the forest owners are: mitigating transaction costs, having political representation (lobby), coping with free-riding problems, claiming for compensation for the public goods and services provided, and as a framework to exchange knowledge and to promote social cohesion. The ZIF approach is considered promising for managing small-scale forest holdings by technical and political stakeholders.

ZIFs are organised by:

1. internal regulation, which defines the objectives of the ZIF and the power and duties of members;
2. forest management plan (PGF), which defines the areas for production, protection and forest work; and
3. specific plan of forest intervention (PEIF), which defines the actions for preventative forest works (e.g. forest fire protection plan, pest and diseases protection plan).

The forest owners' associations located in the regions of small-scale forestry in northern and central Portugal have been the most active players in establishing and managing ZIFs and in preparing and implementing the forest management and fire protection plans. Despite the successful participation of forest owners and forest owners' organisations in implementing ZIFs, early enthusiasm has faded in the last few years because measures and actions were not effectively implemented (Valente *et al.* 2013). Several problems might have contributed to this situation. Mendes and Fernandes (2008) pointed out the high level of bureaucracy associated with implementing ZIFs and the lack of financial incentives to help forest owners who were undertaking the actions required by the approved forest management plan. The financial incentives were to be delivered through the Permanent Forest Fund (*Fundo Florestal Permanente*) and the, now extinguished, PRODER (Portuguese Rural Development Programme), but the money was not always transferred to the management entity on time, and this constrained the forest work. With high management costs, the failure of financial incentives is a shortcoming for implementing ZIFs. Other barriers are issues related to property rights. Because a ZIF has no juridical capacity to intervene in the forest holdings, some of the necessary forest works are difficult to undertake. The council of Mação, one of the Portuguese councils with ZIF approval since 2005, was in 2017 still seeking funding to implement the actions described in the ZIF management plan, including joint forest management and maintenance and construction of fire breaks. In 2017, it was estimated that 80% to 90% of the area of Mação was burnt[18].

In 2008, Mendes and Fernandes made some recommendations for successfully implementing ZIFs, but these were never fulfilled:

[18] http://observador.pt/2017/08/17/incendios-autarca-diz-que-80-a-90-do-concelho-de-macao-ardeu/ (Accessed 30/01/2018)

1. public funding should be given in the medium-term and with a cap;
2. management entities should be given freedom to set objectives to accomplish the management plan and should be evaluated for effectiveness by independent entities;
3. eligibility of public funding should be linked to the effectiveness of the management entities; and
4. management entities should be severely punished in cases where the managers take advantage of the public funding provided.

As described above, the development of the ZIFs has shown some promises but also significant limitations and highlights the need for policy innovation to address forest ownership fragmentation and its related challenges (e.g. forest abandonment). The long standing *associations foncières* in France, their recent Italian incarnation in *Associaizoni Fondiarie* or the Galician *Sociedad de Fomento Forestal* (SOFOR) can provide important lessons and can help provide relevant solutions for other territories.

Conclusion

Innovative methods for forest management can mitigate some of the problems associated with small-scale forestry and ownership fragmentation. In Portugal, the ZIF approach has been recognised as a promising for managing small-scale forest holdings by a wide range of stakeholders (policy makers, forestry engineers, researchers). However, the barriers for implementation have contributed to the failure in delivering the main objectives, mainly preventing forest fires and contributing to sustainable forest management. Until 2017, numerous ZIFs (150 in 2013) have been approved and management plans have been designed, but there has not been money to implement the planned actions. Due to the enormous fires in 2017, forest policy has been discussed and is now being reformulated. It is crucial to allocate a percentage of the permanent forest fund to managing ZIFs, to revise this at least every second year, and also to undertake the forest holding mapping (cadastre) for Portugal so the planned actions can be enforced. Decision-making regarding ZIF management should be an inclusive process, taking into consideration the views of the wide range of local and regional stakeholders. This would reduce any existing prejudices and scepticism about ZIFs, and it should contribute to increasing the social legitimacy of the management entity of ZIFs to pursue sustainable forest management. Public campaigns should be organised to increase the public's awareness about the importance of forests in providing ecosystem services for human wellbeing and the advantages of joint management approaches for maintaining those services.

5. Concluding remarks

Forests have rapidly expanded in southern Europe over the last decades. They offer a large and diverse portfolio of ecosystem services ranging from provisioning services (wood, lignocellulosic biomass, non-wood products), regulating services (preventing soil erosion) to cultural and immaterial services (recreation, mental health, cultural identity). All these forest services will play a significant role in the bioeconomy. This reporthas explored some of the most relevant challenges and opportunities ahead to realise their potential, considering the ecological, economic and social specificities of southern forests. The following paragraphs summarise the key findings and recommendations for action.

Shared visions for a bioeconomy in southern Europe

The circular bioeconomy is crosscutting in nature. It requires a deep transformation in the way we manage and use natural resources and the way in which we design, produce and consume goods and services. This is only possible though the concerted action of multiple actors in the private and public spheres, from corporations to social entrepreneurs, from biomass providers to industries and distribution networks, and from governments to citizens. A positive, shared vision on sustainable, feasible but also desirable futures is needed. These futures must be co-created through systematic, informed participation and envisioning exercises at multiple scales, from local to regional and global. A critical element will be to move away from considering growth as the solution for all economic problems and instead focus in the content and quality of economic growth, in order to achieve social and environmental sustainability. The principles elaborated on in the context of the circular economy are pertinent because they emphasise sharing, reusing, recycling, resource decoupling and zero waste. Trade-offs between economic growth and environmental protection will become less and less acceptable and a stronger focus must be placed on identifying and realising promising synergies. Avoiding environmental degradation must become a shared objective across societal actors. Environmental accounting can help visualise the real value of natural capital and improve policy and economic decisions. Only through engaged citizens, cities and regions will the bioeconomy become a thriving reality.

A stable enabling environment

Transforming the current petrochemical sector will take decades and requires a long-term enabling environment that takes the specificities of the bioeconomy into account. The bioeconomy is characterised by a large divergence of value chains, in which a given batch of biomass can be used for multiple products and can follow many possible technological pathways. In a context of emerging technologies, evolving markets and fierce competition with non-bio-based products and materials, it is often difficult to foresee which technologies or products will succeed. Moreover, with few exceptions, it will be difficult to match the economies of scale typical of the petrochemical industry and will require smaller bio-factories, closer to source areas. These competitive disadvantages and increased uncertainties are the main obstacles in the way of expanding the bioeconomy and must be overcome through:

• A favourable policy environment that offers security to investors. It must be technology neutral to avoid bottlenecks and technological lock-ins and to favour innovation. It should include product standards and regulation to set up a predictable playing field, improving societal awareness and securing positive environmental and social impacts. A high enough carbon tax, reducing perverse subsidies on fossil fuels and product regulations (e.g. mandatory targets to reduce or substitute certain products or processes) are frequently considered as necessary game-changing initiatives.

• Improved access to finance and reduced risks through, for example, public-private partnerships, long-term loan guaranties and green bonds in which a third party shares the risk of the project with the actual investors that might not have that capacity. Targeted instruments for the early stage and up scaling are required.

• Integrated industrial ecosystems. One-feedstock-one-product approaches will be subject to high technical and market volatility that can be overcome through multi-feedstock bio refineries producing a larger set of products in a regional industrial complex. Combining high-value specialty products with larger volume commodities and the ability to shift to the best available feedstock, responding to seasonality in supply, can reduce risks. It has, however, significant technological challenges and requires decisive action to bring multiple actors together in value chains that are separate today.

• Exploiting the intrinsic quality and properties of forest biomass (e.g. cellulose fibres, solid and engineered wood or cork materials. etc.) will contribute to a long-term competitive advantage as those products and materials will be less easily replaced in a very dynamic technological and market landscape. They will also provide a good basis for a larger portfolio of products based on side streams.

• Innovation capacities must be overhauled. Investments in research and development must be increased to catch up with efforts being made by other European regions, but special attention should be given to bridging the knowledge innovation divide. The lack of funding and adequate facilities to test and upscale research results is considered one of the main hurdles in the way of developing the industrial bioeconomy in southern Europe. The technological push (supply side policies) needs to be better coordinated with the market pull or demand side policies (e.g. innovative green public procurement). In addition, cross-sectorial connections should be encouraged to help businesses discover the bioeconomy, developing, cross-sectorial bioeconomy clusters and implementing niche innovation approaches (e.g. through living labs and co-creating solutions along and across value chains). At the same time, more emphasis will needed in social and managerial innovation as a necessary complement to technological innovation. New sets of skills might be required, notably those emerging from a cross-fertilisation between biology, engineering, entrepreneurship and social sciences. At this early stage, increased cross-regional cooperation might be needed to set up required training programmes in a cost-effective way.

• Securing the supply of biomass and ecosystem services. Ensuring an adequate supply of quality biomass is frequently identified as one of the most critical barriers in the way of the bioeconomy, and it is extremely relevant in southern Europe where biomass resources are diverse, and where there is, in many regions, limited wood mobilisation capacity. It is important to better understand and characterise available biomass (e.g. which agro-residues and agro-food wastes are produced in very significant quantities along with forest biomass) and to better estimate the future availability of forest biomass considering not only physical availability but also regrowth rate, mobilisation costs, and environmental and social implications of its mobilisation. It is important to communicate findings transparently to allow public and private operators to make sound investment decisions. As has happened with wood, cork or resin, mobilisation efforts will frequently not be enough and broader strategies for biomass production might be needed (e.g. expanding the resource base, sustainable intensification). Frequently, bioeconomy activities are based on imported resources and it is important to set up well recognised standards to assess their environmental and social footprints.

• Forests and agro-ecosystems provide much more than biomass and frequently the economic relevance of natural and cultural heritage can surpass that of material value chains. These ecosystem services must be well understood and monitored, including its differential beneficiaries and economic relevance. They must be considered and integral part of bioeconomy strategies.

• Overcoming the fragmented nature of forest ownerships is a necessary condition to securing the long-term provision of biomass and other ecosystem services, and it requires urgent political attention.

A regional approach and location-based strategies

The bioeconomy could take completely different shapes in different regions. At any given location, it will require an innovative combination of biotechnological approaches, biomass processing capacities and agro-ecological developments, including local supply chains and nature-based-tourism-type strategies. In this sense, a focus on the goods and services of forested landscapes rather than on traditional forestry will be needed. The regional dimension is necessary to be able to create industrial ecosystems and the adequate economies of scale. Each regional approach will need to make the best of available natural resources, building on regional competitive advantages and reflecting policy and societal choices. It must also address the deep social and economic transitions induced by the urbanisation and the tertiarisation of the economy, with the related displacement of the centre of gravity from rural areas to cities and from goods to products and services. These location-based, regional bioeconomies will require increased policy coherence and can probably be better embodied in a next generation of rural development plans and regional smart specialisation strategies.

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