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Forest industry clusters as innovation systems: analysing innovation support frameworks in five European regions

Die Analyse von Forst-Clustern aus Innovationssystem-Perspektive: Wie unterschiedliche Rahmenbedingungen in fünf europäischen Regionen Innovationen unterstützen

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Schlüsselbegriffe: *Sektorale Innovationssysteme (SIS), Bioenergie, Holzbau, biobasierte Produkte, sektorübergreifende Offenheit, institutionelle Rahmenbedingungen*

Abstract

This paper develops and applies a comprehensive model for characterising regional forest-sector innovation systems. With this approach, we aim to describe and compare regional forest industry clusters across Europe and to assess how well their innovation systems are developed and how strongly they support innovations. By looking at a range of framework condition factors we also aim to explain the strengths of these sectoral innovation systems.

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We apply our model empirically to five regional forest-sector clusters, which were studied in a European research project, focusing on three particular forest-related innovation fields: energy, wood construction and bio-based products. We found strong sectoral innovation systems in three regions: North Karelia (FI), Baden-Württemberg (DE) and Aquitaine (FR). While the forest-sector innovation system in Catalonia appears to have an industry gap, in the Basque Country there is a strong industry but weak public policy support.

We find that strong resource base and forestry tradition are important framework conditions and that specifically a high relative economic importance of the forest sector in the region is supportive for a strong innovation system. Such regions offer strong institutional support, have advanced and specialised technological systems, and a particular openness towards cross-sectoral relations.

Zusammenfassung:

Dieser Artikel entwickelt ein umfassendes Modell zur Beschreibung regionaler Innovationssysteme für den Forstsektor. Dieses Modell zielt darauf ab, regionale Forstcluster in Europa zu beschreiben und zu vergleichen sowie zu bewerten, wie gut die jeweiligen Innovationssysteme entwickelt sind und wie stark sie regionale Innovationen unterstützen. Weiters soll dieser Ansatz verwendet werden, um die Stärken dieser sektoralen Innovationssysteme mit einer Reihe von Rahmenfaktoren zu erklären.

Unser Modell wird in fünf regionalen Forstclustern empirisch getestet. Diese wurden in einem europäischen Forschungsprojekt untersucht, das sich auf drei forstliche Innovationsfelder konzentrierte: Energie, Holzbau und bio-basierte Produkte. Die Cluster in den drei Regionen Nordkarelien (FI), Baden-Württemberg (DE) und Aquitaine (FR) können demnach als entwickelte forstliche Innovationssysteme angesehen werden, während die anderen Cluster Defizite aufweisen. So findet sich in Katalonien ein starkes institutionelles System, aber eine schwache Forstindustrie, im Baskenland hingegen eine ausgeprägte Industrie, aber eine schwache öffentliche Unterstützung durch die Politik.

Der Artikel kommt zum Schluss, dass eine starke Ressourcenbasis und forstliche Tradition wichtige Voraussetzungen für ein starkes Innovationssystem darstellen, dass aber insbesondere die relative ökonomische Bedeutung des Forstsektors in den Regionen sich positiv auf die Entwicklung eines starken Innovationssystems auswirkt. Solche Regionen bieten dann ausreichend institutionelle Unterstützung, verfügen über entwickelte und spezialisierte Technologien und besitzen eine besondere Offenheit für sektorübergreifende Kooperationen.

1. Introduction

1.1 Background

The forest sector is a typical example for a labour intensive "mature" SME-sector with often small and family-run companies (Jenssen and Nybakk, 2013; Ollonqvist, 2011; Weiss 2013). Notwithstanding, the sector has high economic development potentials, due to the growth of timber demand and the use of sustainable products in Europe in combination with a recent hype for using bio-technology, bio-energy and building with wood for climate change mitigation (bio-economy). Such factors render it a valuable case for an analysis of innovations and the role of innovation systems in their support. Innovations are understood as both product and process innovations (Borràs and Edquist, 2013, p. 1513). Most commonly, the innovation systems approach (Lundvall, 1992) is used for technology intensive production with its typical corresponding bigger-sized firms. Following Hirsch-Kreinsen et al. (2008), we argue here that the same is valid for the less technology intensive forest sector. Innovation systems in short are defined as systems supporting innovations in a sector or region, respectively, and consisting of institutions, actors and their interrelations. Institutions comprise of administrative structures, policies as well as informal societal norms, relevant for doing business and innovations. Innovation policies are programmes and/or actions, which have both intentional and unintentional impacts on innovation. In the broadest sense the notion of relevant actors applies to governments, their representatives and their administrative bodies, economic sector organisations and groups, and also individuals. Industry, research and governments are considered to be the most important types of actors ("triple helix" model; Etzkowitz and Leydesdorff, 2000). More recent studies put also the users or the society as a whole in to focus, for instance, through the concepts of a quadruple helix (Carayannis and Campbell, 2009), open innovation (Chesbrough, 2003) or social innovation (Murray et al., 2010). Leydesdorff (2012) argues for a potential N-tuple of helices corresponding to our society's specialised functionalities. The authors of the quintuple helix innovation model argue for the media-based and culture-based public and civil society as the fourth helix, and the natural environment of society as the fifth (Carayannis and Campbell, 2010). The quadruple helix represents our knowledge society but the quintuple helix recognises the need for a socioecological transition and makes the innovation model ecologically sensitive. In the quintuple helix model, the helices are rather seen as innovation drivers than societal actors (Carayannis and Campbell, 2010).

Actors and policies are driving forces within the system that hinder or support the development of innovations. Innovation systems have territorial and technological dimensions: They may be of supra national, national or local scope, and they may be non-sector specific or sectorial. Such territorial and/or sectoral systems are, however, not autonomous: In reality, the different territorial levels may be interconnected through multi-level governance systems (Kaiser and Prange, 2004) and sectors are interlinked. Sectoral innovation systems are characterised by the sector's technolo-

gies (Malerba, 2005) which – certainly in the case of the forest sector – have to include ecological aspects. The issue of the natural resource and the environment are included in studies on sustainable innovation (Rennings, 2000; Carayannis et al. 2012) and its relevance was shown in detail for the case of the wood filiere in Aquitaine (Bélis-Bergouignan and Levy, 2010). The specific boundaries of the sectors may vary across regions.

Within the forest sector we look in our study at sustainable forest management and the forest-based industries. More specifically, for the potentially prosperous fields where innovative activities are assumed to happen, we include bio-energy production, wooden construction and bio-based materials. All three fields had been identified by the EC as potential future "lead markets" (Lead Market Initiative; EC, 2007) and play a central role in current bio-economy strategies and platforms (e.g., the EU Bio-economy strategy; EC, 2012). The data used in our study have been collected between 2010 and 2012 in the frame of the European research project RoK-FOR "Sustainable forest management providing renewable energy, sustainable construction and bio-based products". They stem from five European regions: Baden-Württemberg (Germany); North Karelia (Finland); Catalonia (Spain); the Basque country (Spain); and Aquitaine (France). These five case study regions have been selected as regions with research driven clusters in the forest sector, but with different framework conditions and development potentials. They were examined with regard to the forestry tradition in the region, economic framework conditions and their regional systems of policies and actors that influence research and innovation. External factors may be forest resources and support measures, internal factors may be numbers and characteristics of SMEs in combination with attitudes and behaviour of entrepreneurs and decision-makers (Nonic et al. 2012).

It is a misconception of low and high-tech sectors to assume that only the latter were a source for economic growth and innovation; studies show that – although low- and medium technology sectors invest less in research and development – they are still relevant for innovation and economic growth (Hirsch-Kreinsen and Jacobson, 2008). Specifically, for the forestry sector, we know from an extensive study in Central-Eastern European countries (Rametsteiner et al., 2005) that larger forest holdings (>500 ha) are as dynamic as an average SME in the EU manufacturing sector. Unfortunate framework conditions such as the fragmentation of forest ownership or small forest-based companies hinder innovativeness in the sector. From the same study, we also know that not only these are structural problems in the forestry sector, but also that the innovation systems are not well prepared to support innovations in forestry. Rametsteiner et al. (2005) find a range of weaknesses: The forestry sectoral innovation systems are disconnected from the national innovation systems and cross-sectoral interrelations between forestry and relevant other sectors such as energy, tourism or environmental services do hardly exist. This problem was recently confirmed with a similar innovation system analysis design for the non-timber sector in an Austrian case study (Weiss et al., forthcoming) and case studies in other European regions

(Ludvig et al., 2016a, b; Zivojinovic et al., forthcoming). Also within the sector, there are usually no comprehensive innovation policies formulated. Quite similar difficult conditions exist also in forest-based industries (Ollonqvist, 2011). There are specific needs and challenges for innovation governance in this low-and medium-tech traditional industry sector with very often family-run small businesses, located in rural areas, and limited R&D capacities. Wood value chains are often dependent on external knowledge and competence services which, for instance, may be supported through cluster structures (Rimmler et al., 2011). The concept of industry clusters in its original meaning refers to regionally clustered companies of a sector and complementary structures such as R&D, educational and training organisations (Porter, 1998). Cluster policies very often install so-called cluster organisations with the aim to support networking among regional firms, facilitate knowledge exchange and cooperation, improved access to investments or subsidies as well as access to training and R&D services. As such, they fulfil innovation system functions (Weiss et al., 2011: p. 312). Cluster organisations, by linking and supporting related industries, companies and R&D institutions, have become an increasingly important instrument for developing entrepreneurship, competitiveness and innovation (Glaeser et al. 2010; Ketels et al. 2008). In the regions of our study, clustered forest industries, cluster policies, and/or cluster organisations exist in varying combinations.

The aim of this study is ambitious: We develop and test a comprehensive model for assessing regional innovation systems, including internal and external elements and factors. The model shall be able to characterise industry clusters including qualities such as their strength and openness, and to relate their innovativeness to internal and framework conditions.

1.2 Conceptual and methodological approach

In this paper, we test the applicability of an innovation system approach to assess regional forest clusters on the example of five selected regions. We use the term "cluster" in a Schumpeterian (Schumpeter, 1934) meaning to describe the empirical phenomenon of collocated firms with more or less developed institutional support organisations (Porter, 1998). We use both concepts, "innovation systems" and "clusters", in a strict empirical understanding. In this way, we are able to characterise and compare the forest-based sector related innovation systems in the regions: We aim to assess how well developed they are, and how they differ from each other. It will be important to describe not only the internal structure of the innovation systems but also their connectedness to outside - to national or regional innovation systems and to other sectors that represent new societal demands and developments (openness). Since the concept for this study was developed in 2008/2009, it used the then prominent triple helix model as one important reference. However, based on the state-of-knowledge in innovation research, it took a broader approach including also further

societal and institutional dimensions (e.g., openness) as well as ecological aspects (regional forest resources) – aspects that had been taken up in innovation research later, such as in the quintuple helix model.

In our conceptual model we describe the specific regional framework conditions and capacities in order to explain how the described innovation systems (policies and actors and their interrelations) differ. For the regional framework conditions we consider the general economic strength of the region (GDP) as well as the forest sector share therein as relevant factors, the abundance and productivity of the forests as well as the forestry tradition and the specialisation and advancement of the forest-based industries in the region.

Actors are an important part of innovation frameworks as they are the agents that can support or hinder innovations (Buttoud et al., 2011). Specific beliefs, expectations, goals, competences and levels of "organisation" (institutionalism) characterize them. Actors are constantly engaged in processes of learning and knowledge accumulation (Malerba, 2005). In congruence with the policy framework conditions, we will distinguish the relevant actors in the five regions into sector specific ones on the one hand and general research, development and innovation organisations on the other. Sector specific ones are usually the interest groups in agriculture, forestry and the wood industry, including bio-energy or other biomass associations. They are active in networking, consultation, lobbying and fundraising activities, provide for expertise for the production and marketing, and help in financing under agricultural, forestry, renewable energy or other sectoral and non-sectorial budgets. Specific authorities implement relevant laws but have also consultancy functions and offer subsidies. Regions may have sectoral R&D and training institutions. The general research, development and innovation organizations are non-sector specific R&D support institutions (providing for technical advancement and know-how) as well as governmental and non-governmental actors in innovation and start-up support as well as in rural and regional development programmes.

Our survey was carried out in 2010 and mapped the key actors to support innovations in forest management, bio-energy production, wood construction and bio-based materials. We specifically assess the strength of sectoral actors in the region, in how far the three spheres of the triple helix are covered and how well the forest sector actors have cross-sectoral relations.

Institutional framework conditions affect the forest sector, both in terms of their direct impact on the way the forests are managed and their indirect impact on the sector through alterations to the markets for forest products and services (Pelli et al, 2017). The question in this respect is which kinds of policies are relevant: Is it the forest sector specific policies or is it the non-sectorial innovation and rural/regional development policies? We ask in our analysis which types of policies are relevant in the case study regions.

Important characteristics of the innovation systems include their inclusiveness in terms of the triple helix actors, their sectoral strength, but also their cross-sectoral interrelations. In order to characterise their innovativeness, we look at their openness towards new directions, in our study being specifically defined as bio-energy, wood construction and bio-based products.

Our conceptual model thus includes basic ecological, economic and institutional framework conditions and describes the innovation system elements and characteristics of the regional industry clusters. We hypothesize the framework conditions as factors explaining the structures and innovativeness of the analysed clusters (Figure 1). Knowing about the complex interlinkages and circular interrelations between those elements, we can also ask how ecological or economic preconditions impact on the institutional framework and prior sectoral development ("advancement"), or how certain innovation system features influence on the innovativeness of the clusters.

Ecological, economic and institutional framework conditions	Regional industry clusters	
	Innovation system elements	Innovation system characteristics
• Forest resource • Forestry tradition • Technological advancement • Economic framework conditions • Sectoral innovation policies • General innovation policies	• Actors • Institutions (policies)	• Sectoral strength • Systemic character • Non-sectorial support • Inter-sectoral connection (openness)

Figure 1: Conceptual model

Our data are based on literature and document analysis in combination with two questionnaires that were sent to local contact points, who then distributed the questionnaires in their regions. The first questionnaire focused on the relevant policies and programmes in the regions. It was sent to key administrative authorities in the regions that deal with forest-related policies and policy programmes. For each region we used one information source. The second questionnaire was distributed to

all administrative actors that work in forestry and forest-based industry policies or coordinate forestry and forest-based industry policies in the regions, including interest groups, education and training centres, as well as forest administration offices. This second questionnaire focused on mapping the actors and organisations of the region, and their role in supporting innovation in the three areas. Altogether, we received 54 answers, of which five provided information on policies and programmes in the regions (questionnaire 1), and 49 on organisations and actors in the sector and the three innovation fields in the regions (questionnaire 2). Overall, the study has a comparative case study design and the data were collected by a purposeful sampling technique (full response from the relevant actors).

The results of our analyses are presented in section 2 (economic framework conditions) and section 3 (innovation system analysis of the regions). The comparative analysis is done in section 4 (discussion) along the three main questions of the article: to characterise the SIS in the regions, to determine the explanatory factors, and to assess the role of the ISs' external openness.

2. Economic framework conditions: the forest-based sector in the five case study regions

The five case study regions of our research are characterised here by their sectoral and regional economic key indicators (Table 1) and their forest-technological development (advancement). The detailed data presented here will be used for a summary assessment of the explanatory factors later in section 4.2. and as described in Figure 1

Table 1: Economic framework conditions in the case study regions (data sources: MCPFE State of Europe's Forests, 2007; EUROSTAT)

	Forest area in the case study region		**Regional annual fellings** (million m3/yr)	**Regional GDP** (PPS 2006, EU27=100)	**Forest sector share in country's GDP** (% of gross value added)	**Forest-based industry sector (FBI) jobs in regions/** inhabitant (%)
	ha (% of land area)	ha/ inhabitant				
North Karelia (FI)	1 490 900 (89.7%)	8.98	5.5	89	5.4	3.01
Baden Württemberg (DE)	1 362 229 (39%)	0.13	7.6	129	1.0	1.95
Catalonia (ES)	1 214 664 (38%)	0.17	0.6-0.8	123	0.9	0.02
The Basque Country (ES)	396 000 (55%)	0.19	1.2	134	0.9	0.16
Aquitaine (FR)	1 822 000 (44%)	0.58	8.5	99	0.8	1.07

The abundance of forests per inhabitant is highest in North Karelia (FI), yet lowest in Baden-Württemberg (DE): in the former it is 8.98 ha per inhabitant, in Baden-Württemberg it is 0.13 ha per inhabitant. Measured by relative economic contribution, the Finnish 5,4% share of the national GDP renders its forest based sector most eloquent in comparison to the other regions. It outdistances Germany (1%), Spain (0,9%) and France (0,8%) by more than 3 (MCPFE, 2007). In some cases, regional sector GDP data are missing and this is why we had to rely on the national data. In terms of the distribution of forest area as share of the total territory, Finland is on the first place (90%) followed by the Basque country (55%). The distribution of forest-based industry sector (FBI) employment rates show North Karelia (FBI employment per inhabitant 3.01%), Baden-Württemberg (1.95%) and Aquitaine (1.07%) the strongest.

The distribution of work force in the sector mirrors to some extent the general economic and labour market situation in the regions as well as the abundance of forests. Baden-Württemberg has, despite its lowest share of forestland per inhabitant, more labour force in the sector per inhabitant than for instance Aquitaine (FR). In sum, the "strongest forest region" is by far North Karelia, followed by Baden-Württemberg and Aquitaine.

The main products of the FBI sector in the regions are as follows (figures are based on the MCPFE (2007) incl. ISIC/NACE 02, 20, 21 in 2005):

• North Karelia (FI): products from sawmills (a pulp, a plywood, a particle board mill), several wood products companies (components for wood construction, floorings, thermowood), forest technology and machinery, forest inventory technology (laser scanning), wood energy.

• Baden-Württemberg (DE): sawn timber (mainly spruce, beech), timber for construction, e.g., cladding, decking, engineered wood joist; glulam, solid wood components; finger jointed components, external and internal wall; floor system; roof systems windows, doors), panels, furniture components, furniture.

• Catalonia (ES): sawmill products (e.g. pellets and construction wood); panel industry; bio-energy (small role in pellets and woodchips production); cork-oak (app. 2,700 tonnes manufactured per year from Catalonian cork-oak bark).

• Basque Country (ES): pulp and paper, sawmill products, pellets, wood construction.

• Aquitaine (FR): nurseries, logging, sawmill products, glulam, charcoal, pellets, construction (traditional carpentry and new panel based systems), green chemistry, furnishing, packaging, panels and paper.

We can cautiously defer here that the economic relevance of the forest sector in combination with the woodland available is a precondition for the innovative activities

in the sector in the respective regions. In what concerns the main products there is clearly a focus on low-processed wood products (sawn timber), followed by some components for bio-energy (pellets). Particularly innovative products can be found in examples for more advanced production from the list above: thermowood, machinery or laser scanning in North Karelia, glulam, wood as construction material (roof, windows, furniture etc.) in Baden-Württemberg, or green chemistry or furnishing in Aquitaine. In Catalonia, there is a special tradition of cork production.

3. Innovation system analysis of regional industry clusters

The five case study regions are described here by their main innovation system elements – the most important public and private actors and the relevant policies for innovation support in the fields of forestry, bio-energy, wood construction and bio-based products. We look at general innovation policies as well as sectoral actors and programmes for innovation support. On the basis of this information we assess the clusters' characteristics as defined in the conceptual model (Figure 1) to be used in the analysis (section 4.1).

3.1 North Karelia (FI)

North Karelia is a remote, rural area in Finland in which the forest sector is one of the most important economic sectors – a fact that is actually true for whole of Finland. The sector has therefore a visible role and there are extensive forest-related research and development activities in North Karelia covering forest management broadly (e.g. planning, technology, biodiversity, protection of natural resources and life span studies) and various wood chains.

The survey respondents mention a list of sector specific influential actors: The main public administration actors of relevance are the Regional Council of North Karelia, regional Forest Centre, regional Forest Management Association, the State Forest Enterprise (Metsähallitus), and the Centre of Economic Development, Transport and the Environment for North Karelia. Key forestry specific research and development centres in this region are the Finnish Forest Research Institute (METLA, Joensuu unit [7]), University of Eastern Finland (School of Forest Sciences), European Forest Institute (EFI), North Karelian University of Applied Sciences, and Joensuu Science Park. With all this, – although remote – there is a considerable accumulation of education, training, research and development expertise in the region. The largest forest industry unit in the region is the pulpmill Enocell (Stora Enso Ltd.). There are strong forest technology and machinery companies with economic impact. Overall, we find a pronounced cluster-like accumulation of forest industry in the region including connected

[7] In 2015 METLA was merged with other state research institutes in the field of agriculture, game and fisheries to form the Natural Resources Institute Finland (LUKE). Also other forest administrative structures are currently under revision and re-organisation.

sectors such as forest machinery or chemistry and including research, consultancies and other services providers. Although there is no formalised cluster structure, there are established platforms and networking contacts among the various players, we do find organisations that actively fulfil networking functions and there have been relevant cluster programmes at the Joensuu Science Park - at the time of investigation the Forest Industry Future Cluster Programme), including the following partner organisations: the North Karelian Regional Council, the national Forest Cluster Ltd., the Centre for Economic Development, Transport and the Environment for North Karelia, and the North Karelian Biosphere Reserve.

There is a range of specific forestry-related policies on national and regional levels[8] that deal with forest management, sector development, nature conservation and partly enclose bio-energy (North Karelia Regional Forest Programme 2015).

Since forestry and the forest-based industries play an important role in the region, the sector is specifically perceived also in non-sector specific policies such as in innovation, rural and regional development as well as sustainable development policies[9]. As an example, in the regional Forest Strategy 2010 which was developed with involvement of multiple stakeholders following the triple helix principle, the region was coined "European Forest Province".

The North Karelian Forest Industry Future Cluster underlines the sector specific attempts for an integrative sectoral policy for fostering the forest sector capacities. It illustrates how strongly the sector specific as well as national and regional innovation policies are interconnected in this "forest region".

There is an exceptionally strong attention on the development of forest-based bio-energy in Finland and in the region in particular, the strongest from all sectoral and non-sectorial policies that we have examined[10].

The Regional Council of North Karelia has a vision to become a fossil-oil-free region by 2030 and in the North Karelian Regional Development Programme 2014 it lays down the aim for long-term development of bio-energy.

Using wood in construction is a renewed trend in Finland. Finnish regulations had restricted the use of wood in large units due to fire hazard. Current global trends (i.e. climate change, requirements of carbon sequestration, energy saving and life span

[8] National Forest Programme 2015; North Karelia Regional Forest Programme 2015; North Karelia Environmental Programme 2010; Forest Strategy of North Karelia 1998-2010: European Forest Province 2010; Biodiversity Programme; The Forest Industry Future Cluster Programme.

[9] Government's communication on Finland's national Innovation Strategy; Strategy for Centres for Economic Development, Transport and the Environment; National Programme for Development of the Mainland Finland Rural Areas 2007-2013; Wood construction programme; Natural Resource Strategy for Finland.

[10] On national level, the Finnish National Programme for Development of the Mainland Finland Rural Areas 2007-2013 (Ministry of Agriculture and Forestry) includes the development of bio-energy and Finland promotes renewable energy through subsidies for research and investments – e.g., for biomass-based district heating systems, and specific feed-in tariffs for electricity from renewable sources (OECD, 2012a). The Regional Development Policy Programme for North Karelia has initiated wood energy projects (in the University of Eastern Finland) that have a great importance for the development of bio-energy in the region: the North Karelia Regional Plan 2030 and the Regional Land Use Plan 2020. Starting in the 1990's, three regional bio-energy programmes have been implemented in North Karelia (1992, 1998 - upgraded in 2001 - and 2007). Bio-energy programmes have introduced multi-faceted participatory approaches and gained substantial visibility in the region. In 2007, the current North Karelia Bio-energy Programme 2015 was approved. Before its approval, its programme draft was reviewed by around 100 organisations and enterprises.

analysis of buildings) change the attitudes towards the use of wood as a construction material also in extensive buildings. Construction sector businesses are developing their activities in North Karelia. Present development aims includeto make it possible to use more wood in multi-storey buildings.[11]

In comparison to the other sub-sectors of this report, the bio-based materials are least visible in policy programmes in the region. They are also less influenced by sectoral but rather from non-sectorial innovation policies and climate change mitigation policies. At present, the bio-based sector is in a development stage and quite fragmented, consisting of small units of research and production. National government programmes create a favourable background for innovative development actions.[12]

In sum, in the region of North-Karelia, we see a strong connection of the forest sector with general innovation support, very active and well connected sectoral actors from public administration, industry and research sides (triple helix), lively interaction with other relevant sectors (openness) as well as a pronounced advancement and specialisation of R&D in the sector, including even the new field of bio-based products.

3.2 Baden-Württemberg (DE)

Baden-Württemberg is an industrially strong and innovative German federal State with a strong forestry tradition. Forest sectoral organisations and policies are well established. Since Germany has a pronounced federalist constitution, the major legislative power for forestry is not on the national but on the State level.

The most important public administration actors are at State level and include the Ministries of Science, Research and Art; of Finance and Economics; Rural Areas and Consumer Protection (with the attached Agency of Renewable Resources); and Environment, Nature Conservation and Nuclear Safety . Besides the State Ministries of Baden-Württemberg, there is an important role for the State Forest Enterprise, which not only manages the State forests, but also carries out supervision of non-state (i.e. municipal and private) forests, and offers consulting and promotion of non-state forests. There is a range of relevant interest groups on the level of the State (forestry, forest industry, renewable energy and nature conservation), and strong research, training and education centres (universities, training institutes and the State Forest Research Centre which also hosts the European Forest Institute Regional Office for Central Europe EFICENT). Forest-sector companies primarily belong to the woodwor-

[11] One of the central policy documents relevant for the revival of wood in construction is the North Karelian Regional Development Programme 2014. While designing the Regional Development Programme, regional land-use plans, national objectives concerning regional development, administrative regional strategies and other legally binding programmes related to the region were taken into account. Furthermore, various climate change mitigation policies have been influential, including the Regional Climate and Energy Programme 2020 or the Climate Strategy of Joensuu Region.

[12] National policies include the Government's communication on Finland's National Innovation Strategy to the Parliament and strategies of the ministries, e.g. the Ministry of Employment and the Economy: Strategy for Centres for Economic Development, Transport and the Environment. There have been specific programmes for innovation and development of wood-based bio-products (see, http://www.woodwisdom.fi/en/). The Finnish Innovation Fund, has lined bio-based production as one of the main fields in future sustainable development (A Natural Resource Strategy for Finland, Sitra 2009).

king industries (including construction and building components such as floors, windows, doors as well as furniture) plus biomass. Through a number of organisations, the region has a leading role in Germany in utilising renewable energies in general.

The most important policy fields for the forest sector in Baden-Württemberg are forestry policies (particularly for forest management), sectoral industry policies (for the forest-based industries), innovation policies (especially for bio-energy and bio-based materials) and sustainable development policies (with regard to rules on nature conservation but also for the promotion of renewable energy and materials, among others, from a climate change mitigation perspective). According to the German federal structure, the Federal Forest Act (Bundeswaldgesetz) only gives an umbrella, the specific regulations are found on State level, in this case in the State Forest Act of Baden-Württemberg. In addition, forest sector related research and development is strongly governed on provincial level.

Promotion and support of horizontal cooperation activities, along the forestry-wood chain, are done by both innovation and sectoral industry policies. The Cluster Initiative on the Forest-Wood Sector is done by the Baden-Württemberg Ministry of Finance and Economics, a promotion programme on industrial use of wood by the Ministry of Rural Areas and Consumer Protection. Innovation policies are influential in promoting Baden-Württemberg as an environment with perfect economic, scientific and cultural conditions for innovative business ideas, as well as having direct subsidies, funding and tax incentives by the state.

For forest management, forest policies (most strongly) and nature conservation policies are particularly relevant, on both the national and more specifically on the State level. Because of the great importance of community forestry in Baden-Württemberg, there are detailed legal provisions for the cooperation between the state forest administration and the communities.[13] However, none of the forest management or nature conservation laws is specifically targeted towards innovation in the sector.

Baden-Württemberg has a leading position within Germany in the field of renewable energy, which, besides biomass from forests also includes solar energy, wind energy and hydropower.[14]

[13] National level laws include the Federal Forest Act and the Federal Act on Nature Conservation, State level laws are the Forest Act for Baden-Württemberg (Landeswaldgesetz 1995) and the Nature Conservation Act of Baden-Württemberg (Gesetz zum Schutz der Natur, zur Pflege der Landschaft und über die Erholungsvorsorge in der freien Landschaft 2005). The most important sources of information about legal provisions drawn on here are the State Forest Act (Landeswaldgesetz) and an administrative regulation for community forests (Körperschaftswaldverordnung 1978). There are a few more specific forest related policy documents and laws such as a National Forest Programme (1999-2006), an Act on Forest Propagation Material (2003), a Forest Damage Compensation Act (1969) and an Act on Classification Scales for Raw Timber.

[14] According to the Baden-Württemberg state energy policy, an extension of bio-energy is planned ("Energy Concept for Baden-Württemberg 2020") and this will account for at least 20% of energy production and at least 16% of heat provision by 2020 (Wirtschaftsministerium Baden-Württemberg, 2009). According to the plan, the share of renewable energy in primary energy consumption is set to reach at least 12% by 2020. There is a specific Law on the Use of Renewable Energy on Heat production Baden-Württemberg (2008) and a regional biomass action plan for Baden-Württemberg There is also a tendency to support "sustainable mobility" a sector with research in the field of alternative propulsion systems, such as, electric and hybrid vehicles and fuel cell technologies.

In support of the implementation and development of renewable energy in Baden-Württemberg, forest policies address relevant topics.[15] On national level, innovation policies[16] as well as electricity related regulations are relevant[17]. In sum, the bio-energy programmes are strongly defined within the general energy policies and from national as well as provincial levels.

There are policies that drive wood construction at the national and State levels.[18] Sustainable construction policies in Germany very much tackle the energy level for energy efficient housing. Forestry comes into play on a secondary place, when it comes to use of construction materials (wood) and the use of woodchips and saw mill products for energy production. None of these policies, however, specifically integrates the forest sector.

For the development of bio-based products, a number of relevant policies exist.[19] Those policies are coordinated at the national level, only one regional level policy was initiated by Baden-Württemberg in 2002 (Kaiser and Prange, 2004; p. 402). All in all, it is interesting to see that national innovation policies have identified bio-based materials as an important future market.

In sum, there are strong sectoral organisations from all triple helix spheres although there seems to be a tendency for a dominating role of public organisations. Although support comes from various policy fields, actors and policies rather seem to be isolated from each other, intersectoral cooperation and integrated policies being rare.

3.3 Catalonia (ES)

Due to the autonomous status of Catalonia, the relevant public policies and actors are largely from the regional level, which applies also to industry and research. Typical for the region are multifunctional oak forests that have been traditionally used for grazing and for producing cork, but hardly for timber.

In Catalonia, professional organisations related to the forest sector, private and public forest owners, forestry companies, forest products manufacturing industries and tho-

[15] such as funding of research projects on agroforestry and bioenergy in the Centre for Renewable Energies (Freiburg) and a cross-faculty center of the University of Freiburg, which engages in research and education on renewable energy, as well as to promote horizontal cooperation activities of forest owners by the state forest administration of Baden-Württemberg.
[16] including the promotion of renewable raw materials (bio-based products and bio-energy) by the Agency for Renewable Resources (FNR), and a framework programme on innovations in new materials for industry and society by the Federal Ministry of Consumer Protection, Food and Agriculture.
[17] National Regulation on the production of Electricity from Biomass (2005); National Biomass Sustainable Electricity Regulation (2009).
[18] The Guideline on Sustainable Construction (Leitfaden Nachaltiges Bauen, 2013 www.nachhaltigesbauen.de/) by the German Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety as well as the Research Initiative „Future Construction" (Forschungsinitiative Zukunft Bau), a national research initiative on the future potential of the civil construction sector. The German Regulation for Reduction of Energy Consumption in Buildings (Energiesparverordnung 2014) is explicitly dealing with the use of pellets and woodchips for energy saving measures in buildings. At the regional level, the Guideline on Sustainability in Public Construction for Baden-Württemberg is important. Finally, there exist low rate loans for energy-efficient residential buildings (for new buildings and for rehabilitation measures of old buildings) by the Bank of Baden-Württemberg (KfW) (OECD 2012b).
[19] including the "Federal action plan for the industrial use of renewable resources (2009)", a promotion programme for bio-based products, the "Framework Programme Biotechnology", and more indirectly the Framework Programme on Innovations in New Materials for Industry and Society and the Research Framework on Sustainability.

se using forest by-products, representatives of agrarian organisations as well as the public administrations, form a Forest Intersectoral Council (Dominguez and Plana, 2002).

Catalonia has a regional cluster support organization that does not focus on traditional sectors but on emerging societal trends and needs. One relevant cluster is formed in the field of biotechnology, called BIOCAT, which also covers bioenergy. There is also a territorial cluster formed by local (supra-municipal) entities whose aim is to make the low-value wood market (forest biomass) more dynamic. There is a clustering trend around biofuels and biomass but less in the other sectors of our study.

Within the fields of forestry and bio-energy, a range of R&D, education and training organisations are found, including universities and other public and private research centres.[20] Various relevant bio-energy companies exist which often but not exclusively produce pellets and a number of bio-energy interest groups are active.[21]

In the field of forestry, forest and rural development policies are most important in Catalonia. For renewable energy-related issues, also regional and sustainable development policies are considered important. Wood construction and bio-based materials are rather poorly addressed by policies. Cork is a highly important product for which specific regulations exist.

Within forestry, there are subsidies and grants to promote the mobilization of wood, maintenance of jobs, carrying out forest fire prevention tasks, disaster repairs, and other goals prioritised in Catalonia.[22] In practice, our respondents report that there is a lack of resources on the side of the authorities, which is why the procedures can take many months and only around a third of the forest area of Catalonia has a management plan at all.

Within the fields of our study, the highest amount of relevant policies and programmes in the region relate to the bio-energy sector.[23] Even if bio based energy was identified as important on the political level and subsidies are offered for their use and for R&D activities, the survey respondents report of little impact on innovation in bio-based energy in the region[24].

In the field of wood construction, the only identified document is the policy paper

[20] CTFC (The Forest Science Centre of Catalonia) seems to be the most active, locally and internationally visible regional sectoral R&D organisation. It is a reference centre with high capacities for research and the mission of enhancing the sectoral development in the region.

[21] including associations of professionals and producers of renewable energies (incl. APERCA (Associació de Professionals de les Energies Renovables de Catalunya), APPA (The Spanish national renewables lobby group, Asociación de Pequeños Productores Autogerneradores), or CFC (Consorci Forestal de Catalunya, it is the Forest Owners Association of Catalonia – L`Associació de Propietaris Forestals de Catalunya).

[22] The regulations for forest management are given in the National Forest Law (Ley de Montes 43/2003) and the more specific Catalonian Forest Law (Llei 6/1998). They provide that for the realization of harvests, a management-planning document is necessary. For forest properties smaller than 25 hectares the requirements are simplified ("small management plans" - Plans Simples de Gestió, PSGMF). Companies acting in the sector need to be accredited by the Ministerial Department of the Environment and Housing (DMAiH) as first-stage processing industry by means of a document that proves their entrepreneurial qualification (Law 6/1988).

[23] On national level, under the Renewable Energy Plan of the Spanish government, the Biomcasa Programme establishes a funding system for using biomass for heating and air conditioning of buildings. Relevant regional level energy-related policies are the Energy Plan and Climate Change in Catalonia 2012-2020 and the Strategy to Promote the Energy Use of Forest and Agriculture Biomass 2020.

[24] Cp. Generalitat de Catalunya 2012; 2014.

from 2014 on Building with Wood ("Construir con Madera"), coordinated at the national level in frame of the EU Programme ESFRI (the European Strategy Forum on Research Infrastructure, formerly Roadmap 2010). According to the responses, wood construction has a rather small importance for the region because there is no tradition of timber built houses. The risk of fire in the long dry season has significant influence on decisions to build with wood.

Also bio-based products are reported to have very small importance in the region. The regionally coordinated "Annual Plan for Technology Transfer" (coordinated by the Department of Agriculture) is the only relevant policy document. To some extent, bio-based products are covered by the concept of "white biotechnology" or "industrial biotechnology" which is included in the Catalonian R&D cluster BioRegió.

Overall, the forest sector is economically not very significant in Catalonia, which implies limited institutional capacities, especially in the industry. Consequently, the existing small policy support can also hardly be taken up actively by practice.

3.4 The Basque Country (ES)

The Basque Country is a highly industrialised, autonomous region in Spain, with high forest coverage and relevant companies, universities and research centres working in the forest sector.

Governmental actors seem to be very weak when it comes to innovation support in the sector. Experts report in our survey that the administrative system is very complicated and that there is a lack of trust and co-operation between the stakeholders, which is a severe obstacle for developing a support system in the sector. While forestry actors seem to have hardly any relevance, the forest industry has some significance, in particular the bio-energy sector.

An important public administration body is Etorlur, a public company to manage rural land for supporting small municipalities in their management, which belongs to the Provincial Council of Gipuzkoa.

Governmental organisations are hardly active in sectoral R&D and innovation support. Besides of the University of the Basque Country (UPV/EHU), research and development is strongly driven by private companies, often of international relevance, and even training is offered by the industry.[25]

A range of companies act in the field of renewable energy.[26] Important interest groups are forest owner associations and in the field of renewable energies and wood

[25] e.g., ItsasMendikoi, which is a centre for training, insertion and rural development relevant for renewable energy, or Arizmendi Ikastola, belonging to the Mondragon Corporation and offering all levels of education including a professional training centre that is relevant for wood construction.

[26] including Bioforest-bost, Smurfit Nervión, Celulosas Zubialde, Celulosas Zikuñaga, Enerpellet, and many more.

construction (e.g. the Basque Timber Industries Association MIME/EZM). Industries have often a strong international connection or to the neighbouring regions in Spain (Valladolid) and France (Aquitaine).

For the Basque Country our survey respondents judge renewable energy and wood construction more strongly addressed by policy than forest management. Biobased products are not supported so far. Innovation policies, forest policies and sectoral industry policies are reported to be the most relevant.[27]

According to our respondents there seems to be some reluctance in the Basque Country towards the use of forest biomass for producing bio-energy in the region. In theory, there are manifold policies which could be used for promoting the development of bio-energy[28], however, according to our expert respondents, these policies are "only on paper" without real impact on developing the bio-energy sector. They even see barriers against the use of forest biomass to produce energy because it is seen as a competitor to wind power, which is strongly developed in the region.

Wood construction is seen to have strong potentials for the region. There are number of policies and programmes that are relevant such as the Rural Development Plan of the Basque Country, which supports the improvement of the competitiveness of the forest sector and promotes innovation in the sector.[29] These policies and agreements, however, have not had strong implementation effects in practice yet.

Although in the field of bio-based products there are hardly any relevant policies, a few companies and research institutes from the region have jointly applied for the research project "White catalogue of products elaborated with radiata pine wood to be used in Architecture" to the ETORTEK programme. This project on technological solutions for the enhancement of the wood of radiata pine aims to develop technological solutions to be used in construction, on one hand, and to the development of processes to extract and produce bio-products from wood residues, on the other.

Overall, the Basque survey respondents report that despite the significant forest resources and the fact that there are relevant programmes there is a complicated administrative system and a lack of trust and co-operation among the various sta-

[27] Relevant innovation programmes are IKERKETA - a Grant Programme on the Investment in Innovation, and with a special sectoral focus, LEHIATU - Grant Programme for Initiatives of Basque agricultural companies to renew activities. The most important forest policy programmes are the Provincial Law on Management of Forests and Natural Protected Areas (1994/2007), the Forest Plan of the Basque Country (1994-2030), which includes a Strategy for Sustainable Development, Conservation of Forests and Indicators of Forestry and Environment; as well as the Regional Rural Development Programme (2007-2013) that promotes rural development and the use of resources in the area and which establishes a funding plan for the development of sustainable forest management. Other relevant programmes are the Regional Plan for Agroforestry and a Regional Programme for the Funding of R&D (Provincial decree for sustainable production 97/2004).

[28] For instance, the grant programme "EVE-IDAE Programme" provides subsidies for machinery to transport biomass and for thermal or electric energy production from biogas or biofuels. From the Department of Environment, Spatial Planning, Agriculture and Fisheries of the Basque Government, public support is offered for research, development and innovation of the sectors of agriculture, fisheries and food (Ikerketa and Lehiatu programmes and the so-called Mugarri Plan).

[29] Further specific programmes are: the Territorial Plan for the Agroforestry Sector of the Basque Country, the Forest Plan of the Basque Country (1994-2030), the "Basque Environmentally Sustainable Building Plan", the Basque Eco Design label, the R&D project "White catalogue of products elaborated with radiata pine wood to be used in Architecture", the "Strategy of Development: Initiative of thermal-treated wood", and an agreement to promote the use of wood that comes from certified sustainably managed radiata pine as well renewable material, which was agreed between (i) EUDEL (Association of Basque Municipalities; 23/03/2005), (ii) Basque Parliament (29/12/2008), (iii) Parliament of the Provincial Council of Araba (16/03/2009), (iv) Parliament of the Provincial Council of Bizkaia (23/03/2009), and (v) Parliament of the Provincial Council of Gipuzkoa (24/04/2009).

keholders, which hinders innovation in the sector. Public programmes have little direct effect on the sector development but innovations are strongly driven by private companies.

3.5 Aquitaine (FR)

The historical background of Aquitaine's forestry is large-scale afforestations on agricultural and non-productive land (wetlands and sand dunes) more than 150 years ago. Low quality timber is used for pulp and paper industry. There is a growing need for bio-energy today and attempts to develop also more high quality uses for timber.

A central actor in forestry is the regional service of agriculture "Direction Régionale de l'Alimentation, de l'Agriculture et de la Forêt (DRAAF) Aquitaine" and the departmental services on shore and sea of Gironde "Direction départementale des territoires et de la mer de la Gironde (DDTM)". These local agencies of the ministry manage and distribute all national and EU agricultural and rural development subsidies, including the Rural Development Programme and the grants for cleaning and planting after storm. Further support structures are the Forest Productivity Center of Aquitaine (Centre de Productivité Forestière d'Aquitaine, CPFA) and the Regional Centre of Forest Property (Centre Regional de la Propriété Forestière CRPF) which supports the forest owners and validates management plans for all private owners with more than 25 ha of forest property. The National Forests Office (Office national des forêts ONF) is mainly active in the management of state forests and in less productive areas with dunes and in mountain regions. A regional body is in charge of coordinating certification schemes.

An important interest group is the Federation of Wood Industries Aquitaine (Fédération des Industries du Bois d'Aquitaine FIBA) which gathers all the industry from harvesting to wood processing, disseminates technologies and promotes the use of regional wood. Further interest groups are the Union of South-Eastern Foresters (Syndicate des Sylviculteurs du Sud Ouest http://maisondelaforet-sudouest.com/) with more than 6000 members and the National Union of Furniture Industries (Union des Industries Francaises de l´Ambeublement, UNIFA).

The region of Aquitaine has created the regional cluster "Industrie et Pin Maritime du Futur" (IPMF) in 2005, renamed "Pole de Compétitivité XYLOFUTUR" in 2008. It includes all enterprises, research and training organisations of the wood processing industry and has a specialisation on paper and chemicals (http://xylofutur.fr/le-pole/nos-objectifs/). Their strategy includes a "roadmap on plant chemistry and bio fuels 2014-2016" (Conseil Regional d´Aquitaine, 2013). The projects in Xylofutur also benefit from support via the EU regional development funds.

In Aquitaine, industry and innovation policies are most relevant for construction and

bio-based products.[30] Regional and sustainable development policies are important in the fields of forestry, renewable energy and wood construction.[31] Forest and rural development policies are most important for forestry.[32]

The use of wood for bio-energy generation traditionally has not been a highly developed area in Aquitaine. At the time of the survey, a Regional Plan for Climate and Energy, conducted by the regional council of Aquitaine and the regional services of the Ministry of Environment and Energy, was assessing the available resources, needs and options for energy supply.[33]

In the field of wood construction, there are dedicated R&D funds at the national level and in Aquitaine.[34] One of the leading French wood construction firms (Arbonis) has a branch in Aquitaine and is a member in the Xylofutur cluster organisation.

For supporting the development in bio-based products, the same policies have importance as in renewable energy and wood construction. Remarkably, the Xylofutur cluster includes wood chemistry in its scope.

In sum, we find the relevant sector and non-sector organisations actively included in the sectoral development, from all three segments of the triple helix model. This is specifically seen in the cluster organisation, which connects all three spheres and outreaches across sectoral and regional boundaries (Belis-Bergouignan and Levy, 2010; Conseil Général des Landes, 2014).

[30] Important overarching policies include the French Strategic Research Programme that includes topics in the forest, wood and paper sector with around 14 priority areas and which follows the objectives defined in the Strategic Research Agenda of the European Forest-based Sector Technology Platform (FTP). Important policy instruments are also the Regional Intervention Regulations (Règlement d'Intervention Régional). The Regional Intervention Regulation for the Forest Sector seeks to promote the development of a competitive, environmentally friendly and innovative forestry sector, focused on added value of its products through the protection of forest resources, mechanization of forest operations and innovation, research and training in the wood processing industry. The Regional Intervention Regulations for Enterprises supports enterprises in the wood processing industry just as in other industries of Aquitaine.

[31] including climate change policies and the Grenelle Environment Round Table.

[32] The European Agricultural Fund for Rural Development is especially relevant for forest management and bio-energy. Among others, it funds innovation in forest related enterprises as well as the defence against forest fires. Aquitaine is a LEADER region with specifically targeted regional programmes including an innovation focus and used for a number of forestry-related as well as bio-energy-related projects. The LEADER objectives for Aquitaine include "Meeting the challenge of climate change and energy" with the aim of developing renewable energies (biomass from agriculture and forestry as well as solar energy). As an example, the company SMURFIT which is associated to DELKIA took advantage of these grants to build a biomass (cogeneration) plant of 124 MW using 500 000 tonnes of wood and wastes. Under INTERREG, cross-border programmes with Spain are carried out. Within forestry, the key policy documents are the national Forest Law (Code Forestier), and the Regional Forest Management Scheme, the latter being developed by the regional commission for forests, including stakeholders and the administration. The Regional Centre of Forest Property (CRPF, 2005) disseminates it. The forest policy aims to ensure sustainable management of forests, producing goods and services through two major operative modes, which relate to cultivated forests for wood production, and protective forests where wood production is not the priority. For multiple purpose forestry, also Natura 2000 and the PEFC Regional Scheme are relevant.

[33] Further relevant programmes are the Heating Fund of the Agency for the Environment and Energy Management and the Development Plan of Renewable Energy in France.

[34] At national level there exists a National Plan for Wood in Construction 2010, the target was to have 12 % of wood in construction in 2010 instead of 10% in 2000 (CNDB, 2010) according to a French regulation on this (décret n° 2010-273 de mars 2010). Relevant research funds are offered through the Agence Nationale de la Recherche (ANR). The Regulation of Regional Response (RIR) sets out for the improvement of energy consumption in construction. Under this regulation, currently a grant is prepared and one of the criteria is the selection of appropriate material. Wood is considered as an ecological material in this respect.

4. Comparative analysis

4.1 Types of innovation systems – how to characterise the regional forest SIS

From the case study descriptions, we can characterise the present sectoral innovation systems and how they differ from each other. By looking at the relevant actors, policies and their interrelations we assess the following aspects (Table 2): How strong the sectoral actors and policies in the regions are in supporting the sector development (sectoral strength); in how far the three spheres of the triple helix are present (systemic character); how strongly other actors and policies from national innovation systems or from other sectors are integrated (non-sectorial support); and to what extent the various sub-sectors are covered (inter-sectoral connection).

Table 2: Characterisation of the SIS in the regions

Region / Characteristics	North Karelia (FI)	Baden-Württemberg (DE)	Catalonia (ES)	The Basque Country (ES)	Aquitaine (FR)
Sectoral strength	strong	strong	weak	weak	strong
Systemic character	triple helix	triple helix	industry gap	government gap	triple helix
Non-sectorial support	strong (national/regional)	strong (regional)	poor	poor	strong (regional)
Inter-sectoral connection	strong	moderate	weak	weak	strong

First of all, by assessing the sectoral strength in innovation support, we found congruence among actors and policies: Regions with strong sectoral actors also have strong and specific policies in place. At the same time, the regions with strong sectoral actors have all three triple helix spheres present and with lively interactions through which they can be characterised as systemic support structures. Such strong SIS are found in North Karelia, Baden-Württemberg and Aquitaine whereas they were characterised as being weak in Catalonia and the Basque Country – with a more public dominance in Catalonia and an industry dominance in the Basque Country.

Non-sectorial support from NIS or RIS is strongest in North Karelia, which is situated in a country where the forest-based sector receives high attention on the national level with strong initiatives for new sub-sector developments. Also on regional level, integrated innovation and development policies exist which offer strong support for the forest industries. In Aquitaine, a high attention for the sector particularly exists on

regional level. In Baden-Württemberg, the main support also stems from the regional level. Poor support in Catalonia seems to be the case because of low capacities within the forest industries, whereas in the Basque Country it seems that the government system does not offer strong support.

Inter-sectoral connections appear to be strong in North Karelia and Aquitaine, both among the sub-sectors of our study and even beyond the forest-based sector. For Baden-Württemberg, cross-sectoral policy initiatives exist, their implementation, however, is hampered by the sectoral administrational structure which is strongly oriented at the traditional sector boundaries. In Catalonia and the Basque Country, intersectoral connections are only weakly established.

In summary, we find fully developed SIS in North Karelia, Aquitaine and Baden-Württemberg where active and well connected sectoral actors from all triple helix spheres support innovations. In addition to their systemic character they also show good external integration and openness as they receive support from non-sectorial actors and are rather open for cross-sectoral connections. The weaker SIS with industry gap in Catalonia and government gap in the Basque Country are less supported by RIS or NIS and have weaker inter-sectorial relations.

4.2 Explanatory factors – how framework conditions explain the strength of the innovation systems

According to our conceptual model we include a number of ecological, economic and institutional features as possible explanatory factors for how the innovation systems of the regions differ (Table 3). By using the figures from chapters 2 and 3, we compare the regional forest resources (forest area and fellings), the sector tradition (historical development of forestry and forest-based industries), the specialisation and advancement of the forest-based industries, the economic framework conditions (economic strength of the region, the forest sector share therein, forest industry jobs in the region) and institutional characteristics (innovation support through sectoral and general innovation policies).

Table 3: Framework conditions in the regions

Region / Characteristics	North Karelia (FI)	Baden-Württemberg (DE)	Catalonia (ES)	The Basque Country (ES)	Aquitaine (FR)
Forest resource	+ Strong	+/- Medium	- Poor	+/- Medium	+/- Medium/strong
Established tradition of forestry and forest industries	+ Strong	+ Strong	- Poor	+/- Medium	+ Strong
Advancement/ specialisation of forest sector	+ Advanced	+ Advanced	- Less advanced	- Less advanced	-/+ Medium advanced
Economic framework conditions	+ Strong	+ Strong	- Poor	- Poor	+/- Medium
Sectoral policies on innovation	+ Many	- Few	+/- Some	+/- Some	+/- Some
General innovation policies	+ Many	+ Many	- Few	- Few	+ Many

When looking at possible explanatory framework conditions, we realise that a strong resource base as well as a high relative importance of the forest sector support the development of a strong innovation system. North Karelia harvests much less timber than Baden-Württemberg or Aquitaine harvest but given the low population rate in North Karelia this still makes the forest sector one of the most significant ones. In North Karelia this is the case on both national and regional levels (being mirrored by the fact that the policy support is strong from both levels as well), in Baden-Württemberg and Aquitaine more on regional level. In Catalonia and the Basque Country the forest sector is significantly smaller, particularly when looking at the GDP contribution of the sector or its employment opportunities.

It can be assumed that a long sectoral tradition such as in North Karelia and in Baden-Württemberg helps building the sectoral institutional framework. The more than 150 years of forestry history in Aquitaine also allowed the development of strong institutional capacities in the region. The cork industry in Catalonia was apparently not strong enough to support a strong forest sector. Cork is furthermore often perceived as a separate sector based on an agroforestry production system and not so fully integrated into the forestry sector. In the Basque Country, the forest sector plays a role but is not so significant in the overall economy.

How specialised the sectoral technologies are, seems to be a summary result of the forest resources and tradition in the regions, including the broad range of specialised production in Baden-Württemberg, the strong machinery focus in North Karelia and

the pulp and paper and chemicals focus of Aquitaine. The Catalonian cork industry seems the only regional specialisation in the regional forest sector and also in the Basque Country it is not very specifically developed.

In sum, it seems that it is particularly the relative economic importance of the sector determining the institutional support. In absolute numbers, the Baden-Württemberg forest sector is a few times bigger than that of North Karelia or Aquitaine, but the strongest policy support is present in North Karelia. At the same time, Baden-Württemberg has the lowest share of forests per inhabitant but a significant contribution to sectoral jobs. The mere forest area in the regions (in absolute or relative terms) is not able to explain a strong or innovative forest sector.

4.3 Openness – how new directions are supported

The openness of the innovation systems towards new products and towards links outside the established sectoral boundaries is an important indicator for its effective innovation support. As shown in 4.1, the openness of the SIS (inter-sectoral connections) goes along with other strengths (sectoral strength, systemic character and non-sectorial support). We examine more specifically now, how strongly the regional innovation systems support the three innovative sub-sectors in our case studies (Table 4). Our specific interest is to examine which explanatory factors (section 4.2) seem to be the crucial ones for supporting the new products and more radical innovations (such as bio-based materials). The resulting "openness" in the innovations fields as given in the table is a summary evaluation of provided support. Stronger innovation support is thus assessed as greater openness towards the new activity in the sector.

Table 4: Openness of innovation systems for new directions/products

Region / Openness for	North Karelia (FI)	Baden-Württemberg (DE)	Catalonia (ES)	The Basque Country (ES)	Aquitaine (FR)
Bio-energy	great	great	moderate	poor	moderate
Wood construction	great	moderate	poor	moderate	moderate
Bio-based materials	great	moderate	poor	poor	great

Bio-energy is the field with the strongest support in all regions of our study. Although the impulse for the policy support comes strongly from the EU level, the concrete support takes quite different forms. Whilst in North Karelia, bio-energy is strongly fostered within the designated (national and regional) rural and regional development policies, in Baden-Württemberg the policy focus is specifically defined and designed in energy regulations and policies. In Aquitaine, bio-energy is fostered by the EU LEADER programme within the European regional development programmes and through the regional cluster. In Catalonia, the implementation of the policy support is hampered by the weak forest industry and in the Basque Country it seems that the hindering factors relate to the weak institutional support.

Wood construction has gained support due to its mitigation potentials for climate change. In many countries, the use of wood for building has long been restricted by law because of the presumed fire risk. Particularly in North Karelia and Baden-Württemberg, regions with a certain tradition in wood construction, the sector has initiated a new boom in wood construction and pushed for policy changes. Policy support is given in North Karelia, Aquitaine and the Basque Country where programmes support an increase of wooden construction (building with wood). In Baden-Württemberg the policy focus particularly aims at the higher energy efficiency in buildings and facades.

The most recent innovation field of our study are bio-based materials. This topic is in an emerging phase in Europe in general, with research impulses from innovation and climate change mitigation policies and new companies, and newly pushed through the concept of the bio-economy. The most specific support from policy side is found in North Karelia and Aquitaine. Both are also those regions with the greatest openness across sector boundaries. North Karelia effectively supports the topic through integrated development policies, in Aquitaine the traditional pulp and paper focus of the industry is opened up towards new chemicals. In Baden-Württemberg, a certain support exists but in so far mostly initiated through national level policies that do not have such a specific impact on regional level so far.

Overall, we see two major factors relevant for the openness of the sector: The high relative importance of the sector (as shown in 4.2) as well as the institutional structure: It seems that the non-sectorial regional governance structure in North Karelia and Aquitaine allows them to react more quickly to new trends than the more sectorally decentralised structure in Baden-Württemberg.

5. Conclusions and outlook

In the forest sector, currently, the impulses in fact come from outside the sector – such as from sustainable development and climate change policies that call for an increased use of bio-based energy and materials. Can we explain, why and how regions pick-up and are able to develop new technological trajectories? From the analysis of the five regions of our study, it seems that a necessary precondition is an existing strong sectoral innovation system on regional level such as in North Karelia, Baden-Württemberg and Aquitaine. Only if strong sector actors exist, policy support such as the offer of R&D grants or the demand for new solutions can in fact be utilised. This result confirms what the triple helix model postulates: the presence and interaction of governments, industry and research (Etzkowitz and Leydesdorff, 2000). Formalised or informal clusters are supportive for a triple helix innovation structure in practice. The existence of rich forest resources which make up for a significant contribution to the regional GDP seems to be a necessary precondition, but it seems to be the relative economic significance of the sector in the region that is the strongest factor.

It furthermore seems that openness across sector boundaries strongly helps in translating policy goals and market opportunities into action – through this creating a quadruple innovation system structure (Carayannis and Campbell, 2009). In this regard, the regional governance structure seems of importance: while the provincial administration of North Karelia and Aquitaine seem better suited for cross-sectoral development programmes, such integrated approaches and inter-sectoral linkages are hindered by the strong sectoral organisation of the state of Baden-Württemberg. Our results put in question if forest resources as such work as an ecological innovation driver and thus add up to a quintuple structure (Carayannis and Campbell, 2010) because they become only relevant if they are able to translate into economic figures.

According to the surveys in course of the project, a lack of cooperation was identified as an important hindering factor for the support of new innovations. The reasons for lacking cooperation may lie in a strong sectoral separation of the public administration such as in Baden-Württemberg or in fragmented bureaucratic systems and lacking trust between public and private actors in Catalonia and the Basque Country. Policy support may be difficult to put in practice when capacities are lacking on the side of the public administration (Basque Country) or the sectoral industry organisations (Catalonia).

The European forest sector is currently influenced by bigger societal and economic changes: most importantly growing demands for recreation, growing demands for sustainable "niche products", growing demands for health care and natural products stemming from forests on the one hand and on the other with Kyoto goals for mitigating climate change as well as more resource efficient energy consumption. A booming support through bio-economy strategies and policies has the potential to benefit most of these product fields.

All these products go beyond the hitherto traditional forest products and they require external public support by public and semi-public organisations as well as the interest groups in concern. It is notable that in all the above-analysed cases wood construction based in wooden products is much less developed than bio-energy. The bio-energy policies under examination here are much driven by established policies on energy effectiveness and sustainable energy consumption. Relatively little still is to be found in biodiversity conservation, carbon sequestration, sustainable building with wood, chemical products from forests or health products and food from forest resources (Rametsteiner et al., 2005; Weiss et al., 2011; Weiss et al., forthcoming). The regions under examination here all have different contextual factors and conditions. However, there are some common features, which show to be fruitful for innovation in the forest sector: firstly, a tight cooperation between all forestry actors within a triple helix structure, secondly, cross-sectoral openness with general innovation support and, thirdly, political framework conditions which also target sectoral specific developments. It can be foreseen that regions will only be able to utilise the top-down push for a bio-economy if they have strong and openminded actors and networks on the ground.

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References

Bélis-Bergouignan, M.C., Levy, R. 2010. Sharing a common resource in a sustainable development context: The case of a wood innovation system. Technological Forecasting and Social Change 77(7), 1126-1138. DOI: 10.1016/j.techfore.2010.03.009

Buttoud, G., Kouplevatskaya-Buttoud, I., Slee, Bill, Weiss, G. 2011. Barriers to institutional learning and innovations in the forest sector in Europe: Markets, policies and stakeholders. Forest Policy and Economics 13, 124–131.

Borrás, S., Edquist, C. 2013. The Choice of Innovation Policy Instruments, Technological Forecasting and Social Change, 80, 1513-1522.

Carayannis, E. G., Campbell, D.F.J. 2009. 'Mode 3' and 'Quadruple Helix': toward a 21st century fractal innovation ecosystem. International Journal of Technology Management, 46(3), 201-234.

Carayannis, E. G., Campbell, D. F. J. 2010. Triple Helix, Quadruple Helix and Quintuple Helix and How Do Knowledge, Innovation, and Environment Relate to Each Other? International Journal of Social Ecology and Sustainable Development, 1(1), 41-69.

Carayannis, E.G., Barth T.D., Campbell, D.F.J. 2012. The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. Journal of Innovation and Entrepreneurship, 1:2.,12 p.

Chesbrough, H.W. 2003. Open Innovation: The New Imperative for Creating and Profiting from Technology. Boston, MA: Harvard Business School Press.

CRPF, 2005. Schéma Regional de Géstion Sylvicole, SRGS Aquitaine, Centre Régional de la Propriété Forestière-CRPF, Bordeaux (http://www.crpfaquitaine.fr/docs/srgs_bd.pdf (13 January 13, 2015)).

CNDB, 2010. Le Plan Bois Construction Environment. Committee National pour le Developpment du Bois-CNDB (http://www.bois-construction.org/?p=plan_construction_bois (13 January 2015)).

Conseil Général des Landes, 2014. La filière de transformation du bois dans le département des Landes: état des lieux et perspectives 2014, Direction des entreprises et initiatives économiques, Mont-de-Marsan, Novembre 2014.

Conseil Regional d´Aquitaine, 2013. Feuille de route régionale "Chimie du végétal et biocarburants", Orientations 2014-2016 (http://les-aides.aquitaine.fr/IMG/pdf/feuille_route_chimie_du_vegetal_et_biocarburants.pdf) (13 January 2015).

Dominguez, G., Plana, E. 2002. The Status of Intersectoral Coordination in SFM in Catalonia-Lessons learnt from an experimental qualitative design, In: Tikkanen, Ilpo; Glück, Peter, Pajuoja, Heikki (eds.): Cross-Sectoral Policy Impacts on Forests, EFI-Proceedings No. 46, Savonlinna, Finland.

EC, 2007. A lead market initiative for Europe. COMMUNICATION FROM THE COMMISSION TO THE COUNCIL, THE EUROPEAN PARLIAMENT, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. COM(2007)860

EC, 2012. Innovating for Sustainable Growth: A Bioeconomy for Europe. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. COM(2012) 60.

Etzkowitz, H., Leydesdorff, L. 2000. The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. Research Policy, 29 (2).

Generalitat de Catalunya, 2012. El Pla de l'Energia i Canvi Climàtic de Catalunya 2012-2020 (http://icaen.gencat.cat/ca/pice_l_institut/pice_funcions_i_memoria/pice_pecac/ (13 January, 2015)).

Generalitat de Catalunya, 2014. Estratègia Per Promoure L'aprofitament Energètic De La Biomassa Forestal I Agrícola, Grup de treball de biomassa de la Generalitat de Catalunya, February 2014, 106 p., (http://icaen.gencat.cat/web/.content/08_institut/documents/arxius/140207_estrategiabiomassadef.pdf (13 January 2015)).

Glaeser, E., Kerr, W., Ponzetto, G. 2010. Clusters of entrepreneurship. Journal of Urban Economics, 67, 150-168.

Hirsch-Kreinsen, H., Hahn, K., Jacobson D. 2008. The low-tech issue. Innovation in Low-

Tech Firms and Industries. Cheltenham, Edward Elgar.

Jenssen, J.I. & Nybakk, E. 2013. Inter-organizational networks and innovation in small, knowledge-intensive firms: A literature review. International Journal of Innovation Management 17(02): 27 pp.

Kaiser, R., Prange, H. 2004. The reconfiguration of national Innovation Systems – the example of German biotechnology. Research Policy 33, 395-408.

Ketels, C., Solvell, O., Lindqvist, G. 2008. Clusters and Clusters Initiatives. Center for Strategy and Competitiveness, Stockholm School of Economics.

Leydesdorff, L. (2012). The Triple Helix, Quadruple Helix,…, and an N-Tuple of Helices: Explanatory Models for Analyzing the Knowledge-Based Economy? Journal of the Knowledge Economy, Volume 3, Issue 1, pp 25–35; doi: 10.1007/s13132-13011-10049-13134.

Ludvig, A., Corradini, G., Asamer-Handler, M., Pettenella, D., Verdejo, V., Martínez, S. and G. Weiss (2016a): The practice of innovation: The role of institutions in support of Non-Wood Forest Products. BioProducts Business 1(6), pp. 73-84.

Ludvig, A., Tahvanainen, V., Dickson, A., Evard, C., Kurttila, M., Cosovic, M., Chapman, E., Wilding, M. and G. Weiss (2016b): The Practice of Entrepreneurship in the non-wood forest products sector: Support for innovation on private forest land, in: Forest Policy and Economics, Vol 28, pp 31-37.

Lundvall, B.Å. 1992. National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning. London, Pinter Publishers.

Malerba, F. 2005. Sectoral systems: how and why innovation differs across sectors. In: Fagerberg, J., Mowery, D.C., Nelson, R. (eds.) The Oxford handbook of Innovation, Oxford University Press, Oxford, 380-406.

MCPFE, 2007. State of Europe's Forests 2007. The MCPFE report on Sustainable Forest Management in Europe Jointly prepared by the MCPFE Liaison Unit Warsaw and UNECE/FAO, p. 247.

Murray, R., Caulier-Grice, J., Mulgan, G. 2010. The Open Book of Social Innovation. London: The Young Foundation and Nesta.

Nonic D., Nedeljkovic J., Rankovic N., Marinkovic M., Glavonjic P., Weiss G. 2012. Analysis of factors influencing cluster establishment in the Timok forest area in Serbia. Austrian Journal of Forest Science 129 (3-4), 202-227.

OECD, 2012a. Linking Renewable Energy to Rural Development. OECD Green Growth Studies. DOI:10.1787/9789264180444-en

OECD, 2012b. Towards a Green Investment Policy Framework - Case Study Series. Climate And Energy Policy In Germany: Mechanisms To Encourage Private Sector Investment/Participation In Low-Carbon Development. A case study of Germany's Building Sector. German Federal Environment Agency and KfW, OECD Environmental Directorate, (http://www.oecd.org/env/cc/Case%20study%20Germany.pdf (18 January 2015)).

Ollonqvist, P. 2011. Innovation in Wood-based enterprises, Value Chains and Networks: an Introduction. In: Weiss, G., Pettenella, D., Ollonqvist, P., Slee, B. (eds.): Innovation in Forestry: Territorial and Value Chain Relationships. CABI International, Oxfordshire; 189-203 (ISBN 978-1-84593-689-1).

Pelli, P., Haapala, A., and J. Pykäläinen (2017): Services in the forest-based bioeconomy – analysis of European strategies, Scandinavian Journal of Forest Research, DOI: 10.1080/02827581.2017.1288826

Porter, M.E. 1998. Clusters and the new economics of competition, Harvard Business Review, 76:6, 77-90.

Rametsteiner, E., Weiss, G., Kubeczko, K. 2005. Innovation and entrepreneurship in forestry in central Europe. EFI Research Report 19, European Forest Institute, Joensuu, Finland.

Rennings K. 2000. Redefining innovation - eco-innovation research and the contribution from ecological economics. Ecological Economics 32, 319–332.

Rimmler, T., Coppock, R., Oberwimmer, R., Pirc, A., Posavec, S., Weiss, G., 2011. How to Support Firm competitiveness in Timber Industries? Clusters as Policy Means in Four European Countries. In: Weiss, G., Pettenella, D., Ollonqvist, P., Slee, B. (eds.): Innovation in Forestry: Territorial and Value Chain Relationships, CABI International, Oxfordshire; 101-117 (ISBN 978-1-84593-689-1).

Schumpeter, J.A. 1934. The Theory of Economic Development. An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle. Harvard University Press, Cambridge, Massachusetts.

Sitra, 2009. Natural resources strategy for Finland (http://www.sitra.fi/en/natural-resources-strategy (13 January 2015)).

Weiss, G. 2011. Theoretical approaches for the analysis of innovation processes and policies in the forest sector. In: Weiss, Gerhard, Davide Pettenella, Pekka Ollonqvist and Bill Slee (eds.): Innovation in Forestry: Territorial and Value Chain Relationships. Innovation in Forestry: Territorial and Value Chain Relationships, CABI International, Oxfordshire; 10-33 (ISBN 978-1-84593-689-1).

Weiss, G., Ollonqvist, P., Slee, B. 2011. How to Support Innovations in the Forest Sector: Summary and Conclusions. In: Weiss, Gerhard, Davide Pettenella, Pekka Ollonqvist and Bill Slee (eds. 2011): Innovation in Forestry: Territorial and Value Chain Relationships, CABI International, Oxfordshire; 303-319 (ISBN 978-1-84593-689-1).

Weiss, G. 2013. Innovation in Forestry: New Values and Challenges for Traditional Sector. In: Carayannis E.G. (ed.): Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship, 964-971.

Weiss, G., Ludvig, A., Zivojinovic, I., Asamer-Handler, M., Huber P., 2017. Non-timber innovations: How to innovate in side-activities of forestry – Case study Styria, Austria. In: Austrian Journal of Forest Science, 134 (Special Issue 1a), pp. 231 – 250.

Wirtschaftsministerium Baden-Württemberg 2009. Energiekonzept 2020, Abteilung 4: „Energie und Wohnungsbau", Referat 41: „Grundsatzfragen der Energiepolitik" (http://www.wee100prozent.de/wp-content/uploads/2013/07/Energiekonzept_2020-Baden-W%C3%BCrttemberg.pdf (13 January 2015)).

Živojinović, I., Nedeljković, J., Stojanovski, V., Japelj, A., Nonić, D., Weiss, G., and A. Ludvig, 2017. Non-timber forest products in process of transition: Innovation cases in selected SEE countries. Forest Policy and Economics 81: 18-29.