BLUE BIOECONOMY CoLAB

A RETROSPECTIVE FOR DECISIONS — BLUE BIOECONOMY PORTUGUESE PATENT SIGNALS 2004-2024 — OUTLOOK TO 2030

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Glossary

ACTORS AND OWNERSHIP

Applicant — The person or organisation that files a patent application with a patent office.

Inventor — The person(s) who conceived the invention claimed in the patent document.

Assignee (Owner/Holder) — The person or organisation that owns the rights in a patent or patent application (as recorded).

Assignment — A recorded transfer of ownership (e.g., from one assignee to another).

Patent licensing — A contractual agreement granting permission to use patented technology under defined conditions.

FILING, DATES, AND PROSECUTION

Patent — A territorial legal right granted for an invention, providing exclusive rights for a limited period in exchange for public disclosure.

Patent application — The formal request for patent protection submitted to a patent office.

Filing — Submission of a patent application (including national, regional, or international routes).

Filing date — The date a patent application is formally filed at a patent office.

Application date — The date an application was filed (use consistently with "Filing date" to avoid duplication).

Priority application — An earlier filing whose date is claimed to establish priority for later filings on the same invention.

Priority number — The identifier(s) of the priority filing(s) claimed.

Earliest priority date — The earliest claimed priority date across the priority filings for a given invention.

Publication date — The date the patent application is published (often ~18 months after filing/priority, depending on the system).

Claims — Statements defining the scope of legal protection sought or granted.

Examination — The substantive and formal assessment of the application by a patent office (e.g., novelty/inventive step).

Search report — A patent office report identifying prior art relevant to novelty and inventiveness.

Patent prosecution — The process of engaging with the patent office to pursue grant (responses, amendments, decisions).

INTERNATIONAL AND REGIONAL PROCEDURES

Jurisdiction — A country or regional system where patent protection is sought or maintained.

World Intellectual Property Organization (WIPO) — A United Nations specialised agency for intellectual property that supports global IP cooperation, administers international IP services, and provides access to patent information resources.

Patent Cooperation Treaty (PCT) — An international treaty providing a unified filing procedure that can later be pursued in multiple jurisdictions.

PCT application — An international

application filed under the PCT that can later enter national/regional phases in designated jurisdictions.

National/regional phase entry — The step where a PCT application is pursued in specific national or regional offices.

European Patent (EP) — A patent application/grant processed under the European Patent Convention via the European Patent Office, which typically requires validation in selected states for effect.

European Patent Office (EPO) — The regional patent office responsible for search/examination and grant of European patents.

Designated states — Countries in which a European patent application/patent is intended to take effect (subject to validation requirements).

EU IP5 patent families - Group related filings of the same invention or priority, including the five largest patent offices in the world, known as the IP5: Europe (EPO), USA (USPTO), Japan (JPO), South Korea (KIPO), and China (CNIPA).

CLASSIFICATION SYSTEMS

IPC (International Patent Classification) — A WIPO-administered classification system used to categorise patents by technical field.

CPC (Cooperative Patent Classification) — A more granular classification system used to categorise patents by technical field.

Technical field (IPC/CPC frequency) — The distribution/count of patent records assigned to specific IPC/CPC codes in the dataset.

PATENT FAMILY AND IDENTIFIERS

Patent family — A set of related patent filings that protect the same invention across one or more offices, linked via priority and/or procedural relationships (e.g., PCT phase entries, divisionals, continuations).

Kind code — A document-type code attached to a publication number indicating the nature/stage of the document (e.g., application publication vs grant), which can vary by office and impact data harmonisation.

LEGAL STATUS AND LIFECYCLE

Legal status — The current legal situation of a patent/patent application (e.g., pending, active, expired, lapsed, withdrawn).

Pending — The application is under examination and has not yet reached final outcome.

Active (in force) — Rights are currently valid and enforceable (fees paid and no termination event recorded).

Expired — The patent term ended and rights are no longer in force.

Lapsed — Rights became unenforceable before natural expiry, commonly due to non-payment of maintenance/renewal fees.

Discontinued — The application was withdrawn, rejected, or not pursued to grant (depending on the jurisdiction and record).

Public domain — Used in this report to indicate technology not protected (or no longer protected) in the jurisdiction(s) assessed, allowing freedom to operate (e.g., lapsed/withdrawn/refused/expired).

Termination — Loss of validity due to final legal outcome (e.g., expiry, withdrawal, revocation, lapse), without restoration.

Natural term date — The patent term end date calculated without extensions/adjustments.

Patent term — The duration of patent protection counted from the relevant date (varies by jurisdiction and type).

Term extension — Extension of patent term granted under specific legal regimes (e.g., to compensate regulatory delays in some sectors/jurisdictions).

TECHNOLOGY MATURITY

Technology Readiness Level (TRL) — A scale (TRL 1–9) used to describe technology maturity from basic research to market deployment.

TRL Explorer — The tool used in this study to support TRL assessment, followed by author review ("human-in-the-loop"), based on evidence in the patent text.

BRIDGE2HE TRL framework — The TRL self-assessment framework referenced as the alignment basis for the TRL tool used.

EXECUTIVE SUMMARY

This report maps Portuguese inventive activity in the Blue Bioeconomy over the 2004—2024 priority window, using Portuguese priority patent filings as a practical signal of technology direction and investment intent. The most recent search (3rd Oct 2025) yielded 1 985 patent applications, of which 239 were retained as relevant and consolidated into 69 patent families. In terms of where innovation is concentrating, the portfolio is clearly downstream. secondary processing & novel product Production alone represents 46% (32/69 of patent families), and the 2014–2018 cohort shows a clear predominance of health/therapeutic/dermocosmetic applications. However, this strength is paired with strategic gaps that matter for resilience and pipeline replenishment. The report flags gaps upstream and in circularity & resource recovery, and recommends targeted programmes to build these foundations and reduce dependency on a narrow downstream portfolio. When readiness is assessed through TRL, the translation challenge becomes explicit: TRL 4 (33.3%) and TRL 5 (47.8%) make up about four-fifths of families (56/69), while TRL 6 (4.3%) and TRL 7 (1.4%) are rare. This points to a systemic bottleneck between "validated" technologies and those demonstrated at operational scale, which the report treats as the primary competitiveness constraint. That bottleneck sits alongside a "two-track" IP reality. Among applications quantified for legal status, 36% are already in the public domain, 35% pending, 26% active, and 4% unknown, and importantly, public domain cases reflect withdrawal/refusal/lapse, not natural expiry. The report argues that this creates both a signal of fragile execution capacity in some cases *and* a sizeable freedom-to-operate reservoir that can be strategically reused if curated and linked to industrial needs. Therefore, for a mixed audience of funders, policymakers, and industrial partners, the clearest "do next" agenda is dual-track. Public action should prioritise bridging TRL 5→6/7 (shared pilot/demonstration infrastructure, structured regulatory/permitting support, and co-investment/scale-up finance), while also building national capacity for portfolio triage and prosecution and using legal status/retention/TRL shifts as operational indicators to 2030. In parallel, industry can move fastest by partnering around the retained families (where enforceable rights remain), while exploiting the public domain reservoir via a curated toolbox (FTO-screened shortlists + translation notes + matchmaking with testbeds and procurement challenges). Finally, the report warns that concentration is a systemic risk - highlighting strong geographic concentration (~one-third of families in a single hub) - so diffusion mechanisms (regional consortia and industry-anchored platforms) are part of the competitiveness solution, not a "nice to have".

1.

INTRODUCTION

Portugal has been implementing public policies for the Blue Economy since the early 2000s, notably through the ***National Strategy for the Sea 2006–2016***[1]. However, it is only more recently that a specific regulatory and institutional framework for the Blue Bioeconomy has been consolidated, acquiring a clear and ambitious orientation aimed directly at the **sustainable valorisation of marine bioresources**[2].

Building on this policy trajectory, the ***National Strategy for the Sea 2021–2030***[2] stands out, notably through its priority area **AI4 – Blue Bioeconomy and Biotechnology**, which aims to promote the sustainable use of marine bioresources, foster a circular-based Blue Bioeconomy, and stimulate technological innovation. The implementation of this strategy has been operationalised through ***Council of Ministers Resolution no. 120/2021***[3], which approved an Action Plan comprising concrete measures, many of them focused on research, innovation and technological development in the field of the Blue Bioeconomy. In addition, the ***Blue Bioeconomy Pact***[4], financed by the Recovery and Resilience Plan (PRR), establishes a large-scale public–private consortium dedicated to the development of industrial solutions based on marine bioresources, thereby directly contributing to the expansion and consolidation of the sector in Portugal.

Against this backdrop, this report provides a **retrospective analysis (2004–2024)** of intellectual property activity — namely **Portuguese priority patent applications** — in Portugal's Blue Bioeconomy sector, with the purpose of supporting the definition of an **operational indicator** to monitor technological innovation over time. Specifically, the report addresses the following questions: **(i)** how patenting activity evolved between 2004 and 2024, **(ii)** who the main applicants are and how participation

1 – Governo de Portugal, Estrutura de Missão para os Assuntos do Mar. (2006). *Estratégia Nacional para o Mar 2006–2016.* Ministério da Defesa Nacional.

2 – Governo de Portugal. (2021). *Estratégia Nacional para o Mar 2021–2030*. Direção-Geral de Política do Mar.

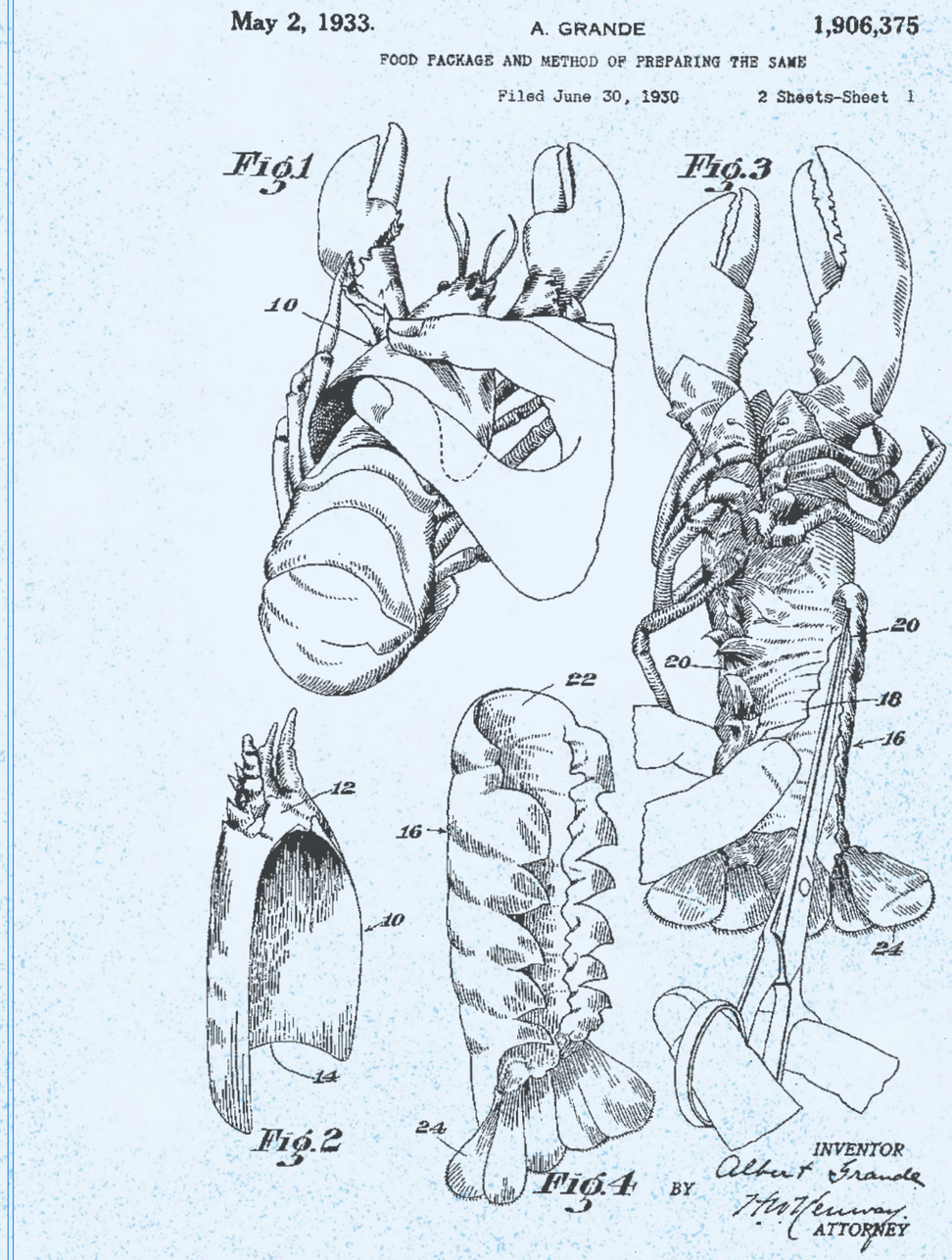
3 – Conselho de Ministros. (2021). *Resolução do Conselho de Ministros n.º 120/2021*. Diário da República, 1.ª série, n.º 170, 1 de setembro de 2021, 2–23.

4 – Pacto da Bioeconomia Azul. (2022). *Ficha de projecto: Pacto da Bioeconomia Azul* [Ficha técnica]. Plano de Recuperação e Resiliência (PRR). Governo de Portugal.

is distributed across the innovation ecosystem, **(iii)** which technological fields and competencies are most represented (e.g., via IPC/CPC classifications), **(iv)** to what extent inventions are internationalised (e.g., through patent-family patterns and filing routes), and **(v)** how inventive activity is distributed across segments of the Blue Bioeconomy value chain.

Patents are widely used as an internationally recognised **proxy for technological innovation** (e.g., Verhoeven *et al.,* 2016[5], Ponta *et al*., 2021[6], Grassano *et al*., 2025[7]), enabling inferences about the extent to which a sector creates, protects, and applies new knowledge. While this approach has known limitations – such as differences between scientific and technological output, variations across patentability regimes, and potential sectorial biases – it provides a consistent and comparable lens for assessing innovation dynamics in the Blue Bioeconomy.

This study contributes an evidence base to support both monitoring and strategic reflection, by providing: **(1)** a structured overview of Portugal's Blue Bioeconomy-related patenting activity (2004–2024), **(2)** a value-chain perspective on where inventive intensity is more concentrated or more limited, **(3)** an identification of dominant and emerging technological fields and competencies, **(4)** an assessment of internationalisation patterns through filing and family-level signals, and **(5)** evidence of concentration and collaboration patterns within the national innovation ecosystem.



5 – Verhoeven, D., Bakker, J., & Veugelers, R. (2016). Measuring technological novelty with patent-based indicators. *Research policy*, *45*(3), 707-723.

6 – Ponta, L., Puliga, G., & Manzini, R. (2021). A measure of innovation performance: the Innovation Patent Index. *Management Decision*, *59*(13), 73-98.

7 – Grassano, N., M'barek, R. and Gonzales Hermoso, H., *Patenting in the Bioeconomy: An Analysis of Trends and Patterns in the EU,* Publications Office of the European Union, Luxembourg, 2025.

2.

METHODOLOGY

2.1. PATENT SEARCH FRAMEWORK

In the present study, patent searches were conducted with time limit of **priority date (01-01-2004 to 31-12-2024), with priority country restriction to Portugal**, using restriction to International Patent Classification/ Cooperative Patent Classification (IPC/CPC) depicted in Table 1.

Table 1 — International Patent Classification/Cooperative Patent Classification (IPC/CPC) used.

IPC symbol				CPC symbol
A01K	A23L	C02F	C12N	Y02A
A01G	A23K	C07K	C12P	Y02P
A01H	A23P	C08F	C12Q	Y02W
A01N	A61K	C08G	G06	
A22C	A61P	C09D		
A23B	A61Q	C11		

2.2. DATA COLLECTION AND PROCESSING

2.2.1. Database

The retrospective **patent application search was performed in free access databases,** PATENTSCOPE [8] from World Intellectual Property Organization (WIPO) and the LENS [9] :

PATENTSCOPE [8] is a free online service for searching patents and patent applications, made available by the WIPO where all published PCT applications as well as patent collections from participating national and regional offices are available. The coverage of the PATENTSCOPE collection allows to search 124,6 million patent documents including 5,2 million published international patent applications. More detailed coverage is available on https://patentscope.wipo.int/search/en/help/data_coverage.jsf.

LENS [9] is an open, integrated knowledge database that unifies scholarly literature and intellectual property data on the Lens.org platform. Built around a MetaRecord architecture, it aggregates, cleans, and normalizes records from diverse global sources to preserve provenance and linkages across identifiers. Its coverage spans 166,5 million patent records from over 95 different jurisdictions.

The use of the above-mentioned databases is limited to their own coverage and high dependence on heterogeneous national sources with uneven coverage and latency. Other databases were used to try to mitigate the naturally occurring differences and confirm regional and national phases as accurately as possible, such as, European Patent Office (EPO Register) [10] , Espacenet [11] , Instituto Nacional da Propriedade Industria (INPI) [12] , and other national offices.

8 – https://patentscope.wipo.int/search/en/search.jsf

9 – https://www.lens.org/

10 – https://register.epo.org/regviewer

11 – https://worldwide.espacenet.com/patent/

12 – https://inpi.justica.gov.pt/

2.2.2. Search Date

The **most recent search was completed on October 3rd, 2025**, and the findings presented in this report reflect the results obtained up to that date. Accordingly, this report does not include events that may have occurred after the search date. At the same time, it is worth remembering that a patent application is first made available to the public, typically 18 months after the filing date or earliest priority date. During this period, patent applications aren't made available, hence it is possible that some patent applications were not identified during the search period.

2.3. DATA WORKFLOW

The patent **search results comprised 1 985 patent applications**, organized into 25 files, one for each CPC or IPC.

2.3.1. Patent Application Analysis Criteria and Selection

The 1 985 identified patent applications were systematically analysed and selected using criteria described in Table 2.

Table 2 — Blue Bioeconomy Selection Criteria

Criteria	Description
1	Applicable to the Primary Production & Biomass Harvesting area of the Blue Bioeconomy Value Chain, including stakeholders such as seaweed and microalgae growers, aquaculture producers of fish, bivalves and crustaceans, feed manufacturers and premix suppliers, commercial fishing fleets and fishers, hatcheries and nurseries, equipment and technology providers (cages, RAS, sensors, feed and harvest systems).
2	Applicable to the Extraction & Bioconversion area of the Blue Bioeconomy Value Chain, including stakeholders such as biorefineries and processing companies, green-extraction providers, membrane/separation companies, enzyme/biocatalysis firms, fermentation platform companies, bioprocess contract development and manufacturing organisations, toll fractionation/purification processors, equipment manufacturer (bioreactors/reactors/centrifuges/dryers/encapsulation), formulation & encapsulation services, and co-product upcycling/valorisation companies.
3	Applicable to the Value-Added Processing & New Product Development/Manufacturing area of the Blue Bioeconomy Value Chain, including stakeholders such as food & beverage manufacturers, nutraceutical and dietary-supplement companies, cosmetic/dermocosmetic firms and formulators, pharma/medtech developers for drug-delivery and biomaterials, biopolymer and bioplastics converters/compounders, coating and antifouling formulators, active/biodegradable packaging manufacturers, contract manufacturers.
4	Applicable to Circular End of Life area of the Blue Bioeconomy Value Chain, including stakeholders such as industrial composting plants and anaerobic-digestion operators, wastewater and nutrient-recovery facilities, biogas/energy-from-waste producers upcycling and secondary-raw-material converters.
5	Contains at least one element of the formulation that was derived, extracted or inspired a marine living bioresources

The rationale for the above-mentioned criteria was operationalised through an analytical process designed to capture patent applications with direct relevance to the Blue Bioeconomy value chain. This process covered the full spectrum of activities, from primary production and biomass harvesting to extraction, bioconversion, value-added processing, and circular end-of-life stages. In doing so, it ensured that the final patent applications set reflected innovations contributing to the sustainable exploitation, transformation, and valorisation of marine biological resources within the Blue Bioeconomy framework.

2.3.2. Data Processing

The selected patent applications were checked for duplicates regarding publication number and title and grouped in patent families.

To further ensure the reliability, consistency, and methodological robustness of the obtained database, a cross-validation analysis was performed against information in the Lens.org[9] platform, EPO Register[10], INPI[11] and other national offices. The verification was carried out on a family-by-family basis, encompassing all international, regional, and national extensions of each patent family. The assessment included a detailed examination of multiple metadata fields: invention titles, publication and priority numbers, jurisdictions, application and publication dates, earliest priority date, applicants, inventors IPC/CPC classifications, and legal status. Throughout this process, potential inconsistencies were assessed, including mismatches between patent identifiers and their respective kind code, as well as discrepancies resulting from linguistic variations or differences in data formatting and presentation between sources. When required, manual curation, adjustments, and data harmonization were conducted to ensure full standardization and comparability of all records.

2.3.3. Data Characterization and Coding

Patent application characterisation was structured using a multidimensional approach comprising three analytical axes. The **first axis** focused on the **general characterisation of patent applications**, aiming to interpret essential information and other relevant attributes. The **second axis** applied the Technology Readiness Level (TRL) framework to assess the **technological maturity of the patented**

inventions, thereby allowing the identification of emerging, developing, and market-ready technologies. The **third axis** introduced a categorical system that enables detailed **mapping of patent families according to their functional roles across different stages of the Blue Bioeconomy value chain**.

For the first characterization axis, categories and data coding were defined from current practice and were transversal to all free patent applications databases and are depicted in Table 3.

The second categorisation axis consisted of the Technology Readiness Level (TRL) (Table 4), which was used to map the technological maturity of the patent families.

However, this assessment was constrained by employing patent applications as the sole source of information. Patent documents do not provide direct evidence of performance, reliability, or testing context, and "prophetic" examples cannot be regarded as validation. Despite these limitations, the present study conducted a qualitative TRL assessment based on the content of the patent application documents.

Table 3 — General Patent Information.

Category	SubCategory	Description		Aim
Actors	Assignees or Holders	Person or company that owns the patent application or the rights to the granted patent.		Identification of the main participants involved in the patenting process, understanding who creates, files, and holds invention rights within the B*lue Bioeconomy*.
	Inventors	Person who designed the invention claimed in the patent or patent application.		
	Applicants	Person or entity that files the patent application with the patent office.		
Legal Status	Unknown (**U**)	The legal status of the patent is not available in the free access databases, or, accurate determination was not possible.		To identify the current legal status of patents, allowing an understanding of whether they are active, expired, under examination, or discontinued – B*lue Bioeconomy*.
	Active	The patent is in force and legally protected; the holder's rights are valid.	A1) Granted at National Level	
			A2) Granted Unitary Patent (uniform protection and centralized legal effect across 18 ratifying EU member states)	
	Inactive	The patent is no longer in force.	I1) A PCT application has officially entered national and regional phases (30/31).	
			I2) The PCT application did not enter national and regional phases (month 30/31).	
			I3) European Patent Application Granted and validated at national level.	
			I4) Either due to non-payment of annual fees or abandonment.	
	Expired (**E**)	The patent has reached the end of its term and is no longer valid; the legal rights have ceased.		
	Pending (**P**)	The patent application has been submitted and is under examination; it has not yet been granted.		
	Discontinued (**D**)	The patent application was withdrawn, rejected, or not pursued by the applicant.		
Jurisdiction	Country or region	Indication of whether a patent application has been extended to regional or national phase of the patent proceedings.		To identify the strategy for protecting the invention in different jurisdictions – *Blue Bioeconomy*.
Technical Field	Frequency of CPC and IPC	Refers to the count or distribution of patents associated with each CPC (Cooperative Patent Classification) or IPC (International Patent Classification) code.		To identify the technological distribution and detect innovation patterns in different areas – Blue Bioeconomy

Table 4 — Technology Readiness Level

Technology Readiness Level	Description
TRL 1 Definition of basic properties	Scientific research that is translated into applied activity, having paper studies of basic properties.
TRL 2 Analytical Study	The resulted applications are mainly speculative, with no proof pf concepts to support assumptions. At this level, technology is limited to analytical studies.
TRL 3 Proof of concept	Active R&D activities, including analytical and laboratory studies to physically validate the previous analytical predictions and assumptions. the first proof of concept.
TRL 4 Technology validation in laboratory	The validation of the technology has been performed at the laboratory level, testing each component so at this point a laboratory prototype is available.
TRL 5 Technology validated in relevant environment	Integration of components with reasonable and realistic supporting elements for testing in a simulated controlled environment (laboratory or industrial settings).
TRL 6 Technology demonstrated in relevant environment	The technology is demonstrated in a real industrial environment.
TRL 7 Prototype demonstrated in operational environment	The technology is demonstrated in a real industrial operational environment.
TRL 8 Product/Process completed and qualified	Technology is ready for implementation, proven to work in its final form and under expected operational conditions.
TRL 9 Product on market	Comercial technology in its actual application, meeting production configuration and marketed.

Source: Developed from EURAXESS [13]

TRL assessment of all patent families in present study was performed in TRL Explorer [14],followed by manual review.

TRL Explorer is an AI-powered evaluation tool aligned with the BRIDGE2HE TRL self-assessment framework. This tool employs a matrix-driven approach that integrates project-specific, in this case, patent-specific, inputs – such as development stage and validation environments – to automatically assign technology maturity levels. To ensure assessment accuracy, results were cross validated within a human oversight review (human-in-the-loop) process. The manual review included analysis by the authors of the patent's claims, description, examples, coding evidence for laboratory, relevant, or operational environments and noting whether examples were working or prophetic. Following best practices, the authors identified critical technology elements, recorded patent passages in an evidence matrix (see Appendix 03).

The third characterisation axis focused on mapping patent families using the categorical system specifically developed for this study. This system was organised into metacategories and categories, providing a coherent framework for classifying technological developments within the Blue Bioeconomy.

The metacategories were defined in alignment with the Blue Bioeconomy value chain [15], ensuring conceptual consistency with established strategic models. The categories within each Metacategory were defined through a human-driven process, based on the specific technical specifications, technologies and products associated with each stage of the value chain (Appendix 04).

Building on the framework described on Table 5, the authors conducted a detailed manual analysis of the information contained in each patent family, systematically classifying and grouping them according to their technological functions within the value chain. The value chain stage corresponding to *Marketing & Distribution* was not considered, as the activities involved are not suited for patent protection.

13 – EURAXESS. (n.d.). *TRL | EURAXESS – Manual on scientific entrepreneurship: Major steps.* Recuperado de https://euraxess.ec.europa.eu/career-development/researchers/manual-scientific-entrepreneurship/major-steps/trl

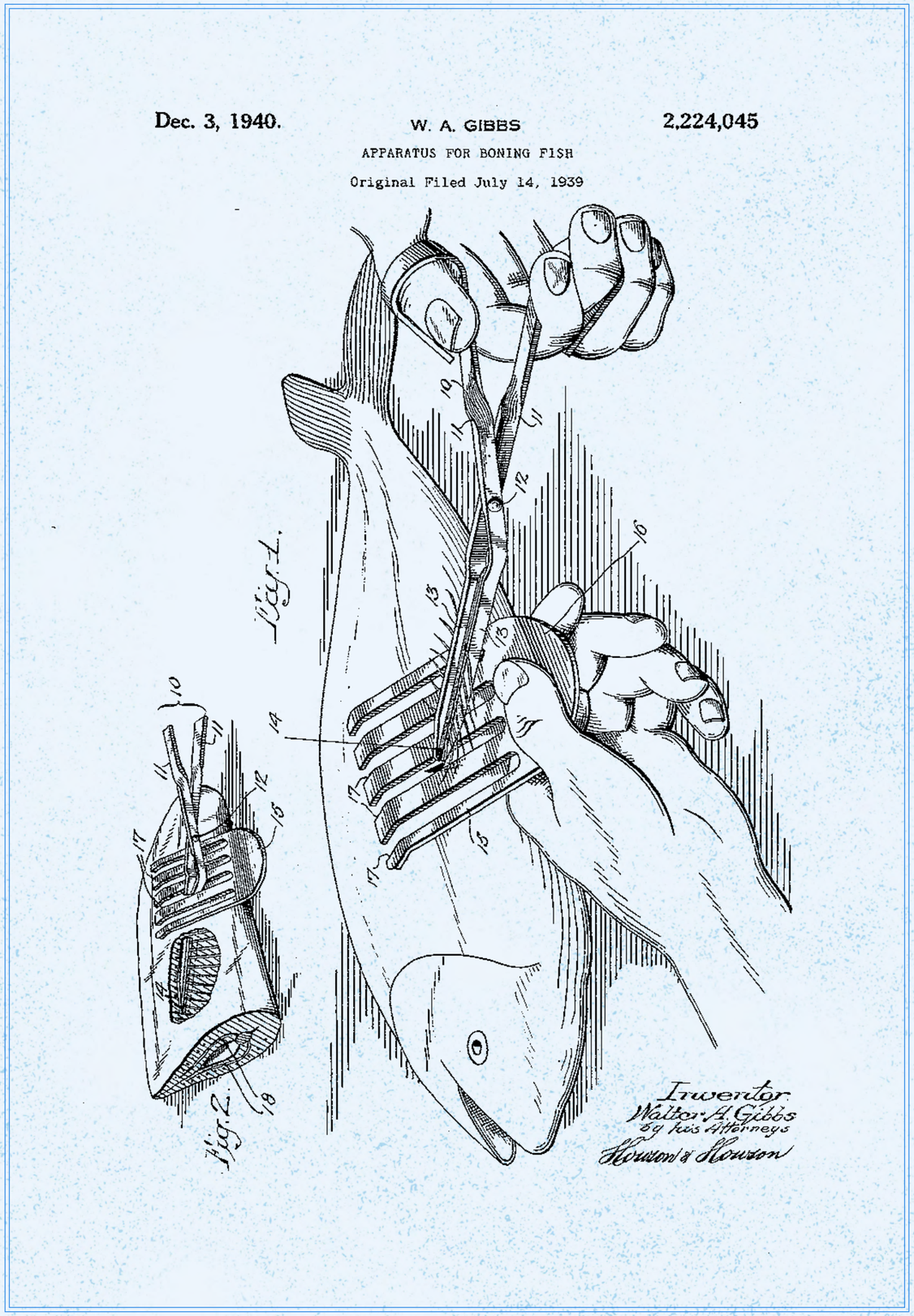
14 – YesChat AI. (2024). TRL Explorer [AI-powered TRL evaluation tool]. Retrieved October 22, 2025, from https://www.yeschat.ai/gpts-2OToJOVVR3-TRL-Explorer

15 – Vasconcelos, V., Moreira-Silva, J. & Moreira, S. (eds) 2019. Portugal Blue Bioeconomy Roadmap - BLUEandGREEN. CIIMAR, Matosinhos, (pub), 68pp.

Table 5 — Blue Bioeconomy Categorical System

Value Chain Position	Metacategory	Category
1	1. Biodiversity & Bioprospecting	1.1 Marine exploration, sampling and enabling technologies
		1.2 Biological and genomic resources (biobanks)
		1.3 Bioprospecting and characterisation of compounds
2	2. Primary Production or Catch	2.1 Aquaculture of fish, molluscs, crustacea and marine invertebrates
		2.2 Algae aquaculture
		2.3 Capture and harvest of wild marine biomass
3	3. Extraction and Conversion	3.1 Processing, extraction and conversion technologies
		3.2 Functional marine bio-based ingredients
		3.3 Platform delivery and engineering technologies
4	4. Secondary Processing & Novel Product Production	4.1 Food & functional food products
		4.2 Feed, additives & animal immunonutrition
		4.3 Health, therapeutic and dermocosmetic applications
		4.4 Advanced bio-based materials and coatings
6	6. Circularity & resource recovery	6.1 Resource recovery and upcycling of products and co-products
		6.2 Effluent treatment, bioremediation and water recirculation
		6.3 Energy, carbon and nutrient recovery technologies

The resulting **Blue Bioeconomy Portuguese Database** consisted in **69 patent families** records, in a total of **239 patent applications (Appendix 02)**.



3.

RESULTS

The present study aimed at determining **the national patent application universe of the last two decades of innovation in the Blue Bioeconomy sector**. Patent applications searches in public databases were completed until **October 3rd, 2025**, and yielded **1 985 patent applications**. The latter were systematically analysed and selected using criteria designed to identify technologies within the Blue Bioeconomy value chain. The resulting **239 patent applications** were subsequently grouped in **69 patent families**.

3.1. PORTUGUESE BLUE BIOECONOMY PATENT APPLICATIONS DYNAMICS

Figure 1 presents the annual evolution of patenting activity in Portugal's Blue Bioeconomy, using the earliest priority year as the timestamp. Two indicators are shown: (i) the total number of patent families, and (ii) the total number of patent applications belonging to those patent-family sets.

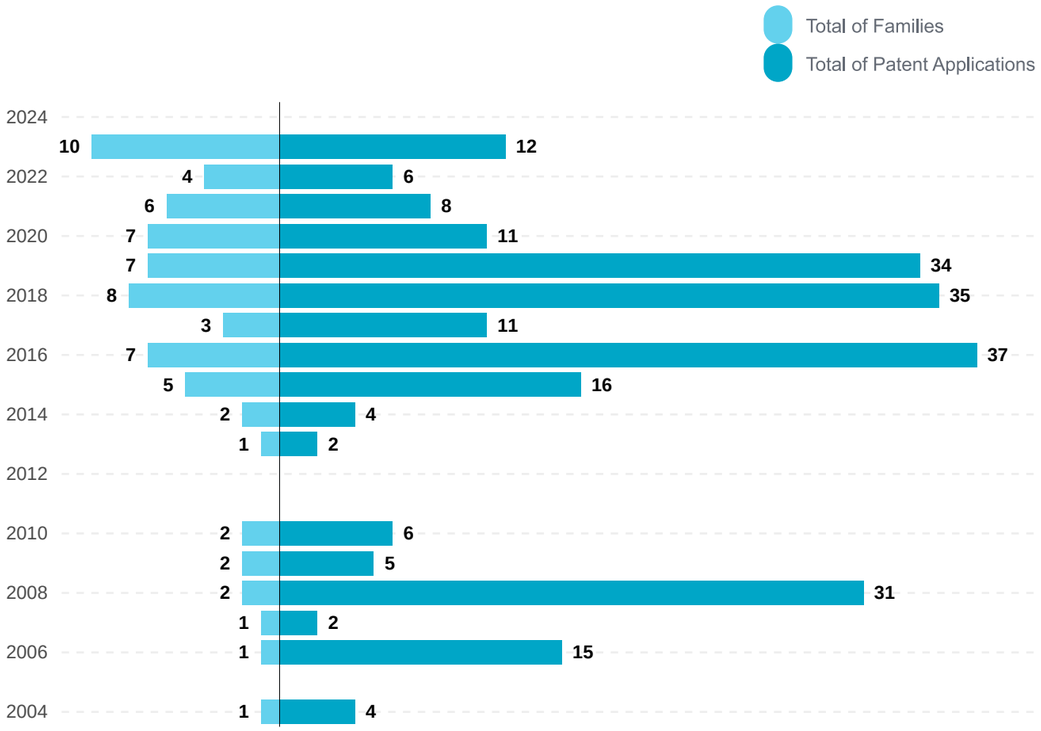


Figure 1. — Early Evolution of Blue Bioeconomy Portuguese Patent Families

Overall, the results reveal a clear shift from **sporadic patenting activity in 2004–2014** to **a marked expansion from 2015 onwards**. During the **first period**, the number of patent families is very limited (typically **0–2 per year**) and several years record no activity. From **2015**, both the number of families and the **volume of patent applications associated with those patent-family sets increase substantially**, indicating not only a higher rate of inventive output but also broader filing activity per family.

The **most pronounced intensity** is observed between **2016 and 2019**. In **2016**, the dataset reaches a peak of **7 patent families**, associated with **37 patent applications**. High levels persist in **2018** (**8 families, 35 applications**) and **2019** (**7 families, 34 applications**), suggesting a phase of strong portfolio building and extensive filing strategies within the sector.

After 2020, the number of patent families remains relatively robust (**ranging from 4 to 10 families per year**), while the total number of associated patent applications declines compared to the 2016–2019 peak, pointing to a lower filing volume per family.

Notably, **2023** records the highest number of families in the **series 10**, corresponding to **12 patent applications**. This confirms sustained inventive activity. However, the associated application volume should be interpreted in light of the **PCT timeline**. **Many of the 2023 families are filed via the PCT route and, at the time of observation, had not yet reached the national and/or regional phases of prosecution**, which typically occur around **30–31 months** after the PCT filing (or priority date, depending on the filing pathway). As a result, the count of applications linked to 2023 families is **temporarily understated** and may increase as those cases enter national/regional stages.

Finally, the **zero value for 2024** most likely reflects the **18-month publication delay** for patent applications rather than a true absence of filings and should therefore be interpreted as a limitation of the present analysis.

3.2. PORTUGUESE BLUE BIOECONOMY APPLICANTS

The distribution of **patent families by top applicants** (Table 6) is highly concentrated and strongly dominated by **portuguese academic and research institutions**, being Universidade do Porto, CIIMAR, Universidade do Minho, Association for the Advancement of Tissue Engineering and Cell based Technologies & Therapies (A4TEC) and Instituto Politécnico de Leiria the top 5 applicants.

Indeed, **Universidade do Porto and CIIMAR** lead the ranking, with **18 patent families** each, however, 13 of these are held in co-titularity between the two institutions. When these jointly owned patent families are consolidated, the combined **Universidade do Porto–CIIMAR portfolio** corresponds to **23 unique patent families out of a total of 69** (i.e. around one-third of all patent families identified in this study). This indicates a strong collaborative dynamic between the two institutions in the development and protection of Blue Bioeconomy technologies.

Table 6. — Top Blue Bioeconomy National Patent Applicants

Top Applicants	No. of Patent Families
Universidade do Porto	18
Centro Interdisciplinar de Investigação Marinha e Ambiental - CIIMAR	18
Universidade do Minho	6
Association for the Advancement of Tissue Engineering and Cell based Technologies & Therapies - A4TEC	5
Instituto Politécnico de Leiria	5
Universidade de Aveiro	4
Instituto de Biologia Molecular e Celular - IBMC	4
Universidade de Évora	3
Universidade Católica Portuguesa - UCP	3
Centro de Ciências do Mar do Algarve	3
Associação Biopolis	2
Stemmatters Biotecnologia e Medicina Regenerativa	2
Faculdade de Ciências da Univerdade de Lisboa	2
Universidade de Almería	2
Instituto Politécnico de Bragança	2

Although the top of the applicant ranking is dominated by academia (universities, research centres and associated laboratories) with limited foreign organizations as co-applicants (e.g., Universidade de Almería) a few private companies (e.g., Stemmatters) are identifiable. The breakdown by applicant organizational type,by legal nature and origin, is depicted in figure below (Figure 2).

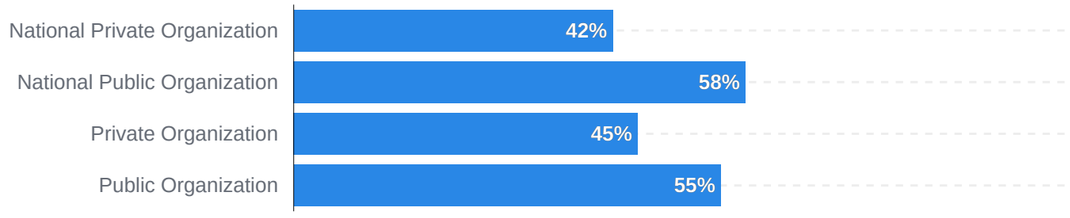


Figure 2. — Applicant Organization type in percentage(%). Individual name applicants were not considered

Public organisations accounted for **55%** of the patent families, while **private organisations** represented the remaining **45%** (Figure 2). Considering only **national applicants, public entities held 58%** of the patent families and **national private organisations 42%** (Figure 2). Taken together, these results indicate that Portuguese innovation in the Blue Bioeconomy is still largely research-driven and anchored in the public science and technology system, but with a significant and growing involvement of private actors.

The ranking of applicants shown in Figure 3 was based on the **number of patent applications filed** and, as such, also reflected the **financial effort invested in intellectual property protection**. Although academic and research institutions occupy most of the top positions – with **Universidade do Porto** and **CIIMAR** clearly standing out – several private organisations also appeared among the leading applicants (e.g., **73100-Stenta e Três Mil e Cem**, **Stemmatters** e **SEA4US**), indicating a growing commitment of both public and private entities to funding Blue Bioeconomy-related innovation.

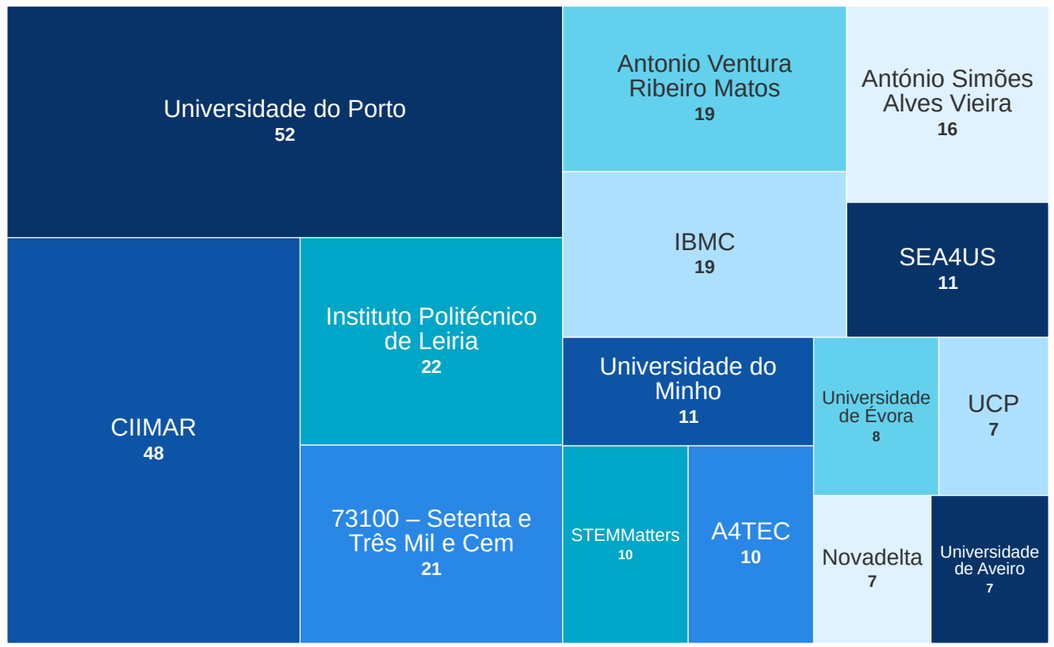


Figure 3. — Applicant ranking by number of filed patent applications.

3.3. PORTUGUESE BLUE BIOECONOMY INVENTORS

Figure 4 presents the **inventor ranking by number of patent families** and current affiliations, according to Open Researcher and Contributor ID (ORCID). The inner ring groups inventors by their present institution, while the outer ring shows individual inventors and the number of patent families in which they appear. The **largest share of inventor activity** is associated with **CIIMAR | Universidade do Porto**, followed by **3B's | Universidade do Minho** and **Universidade do Porto**, with smaller segments linked to Universidade Católica Portuguesa (UCP) and other research organisations. This pattern is consistent with the applicant ranking, where CIIMAR, Universidade do Porto and Universidade do Minho/A4TEC already emerged as the main patent holders, indicating that these institutions not only file the highest number of patent families but also host the most **prolific inventors**, such as **Vítor M. Q. Vasconcelos**, **Pedro N. C. Leão**, **Mariana A. Reis** and **Rui L. G. Reis**, who can be regarded as **leading specialists in Blue Bioeconomy-related technologies in Portugal**.

It should be noted that this identification of "leading specialists" is limited to the subset of inventors with patenting activity included in this study and therefore does not capture all relevant scientific or technological expertise existing in the country.

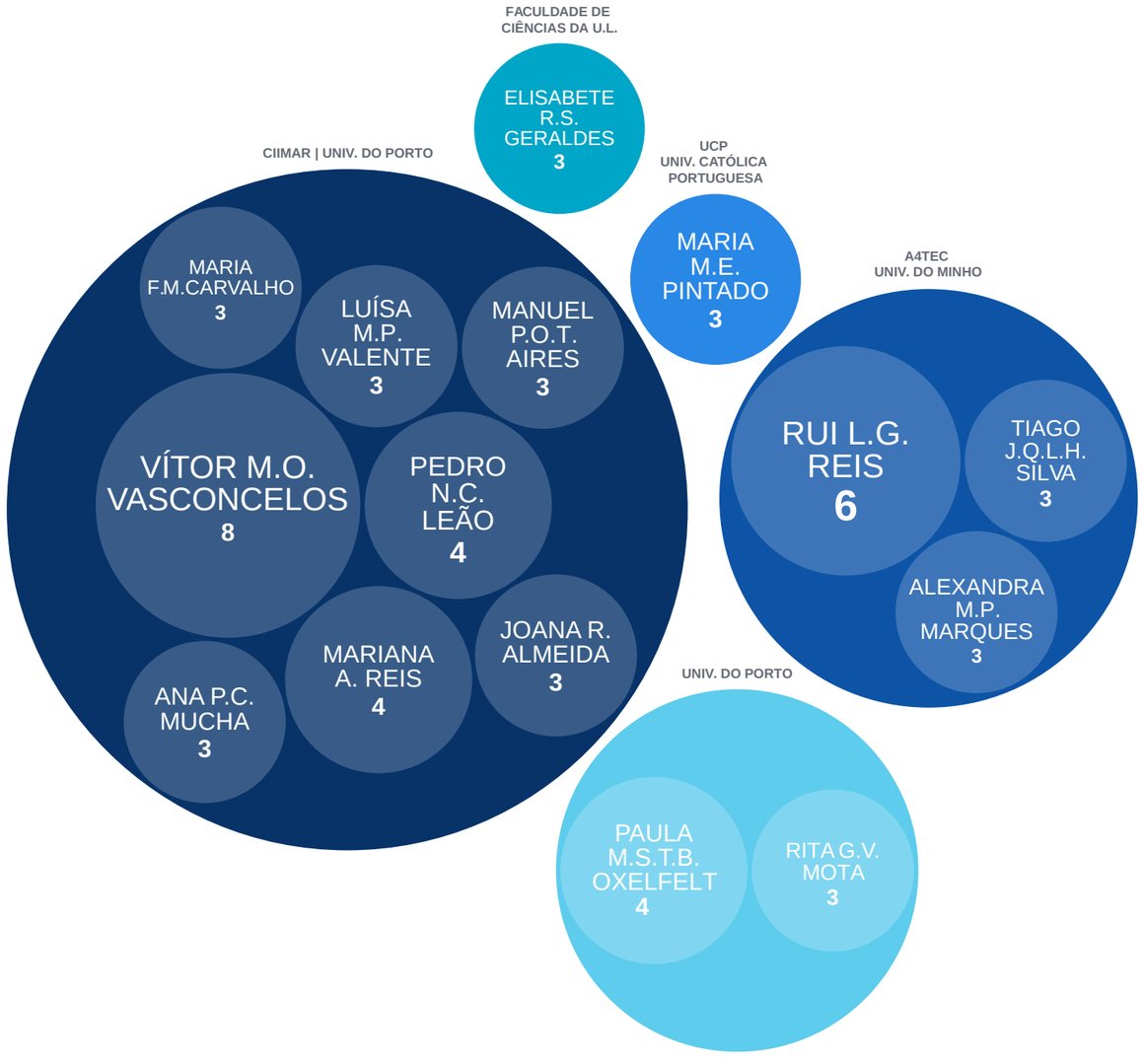


Figure 4. — Inventor ranking by number of patent families and current affiliations according to ORCID.

3.4. PORTUGUESE BLUE BIOECONOMY IPC/CPC

At **IPC level**, the Portuguese Blue Bioeconomy patent portfolio of the last two decades was mainly concentrated in technologies related to **fishing and aquaculture equipment** (e.g., collapsible traps, feeding devices and feeding-stuffs for aquatic animals) and in **chemical/biotechnological classes** focused on **polysaccharides and their derivatives**, **heterocyclic compounds**, **antifouling paints** and **drugs for metabolic or nutritional disorders**. This indicated a dual focus on marine production systems and bioactive or functional compounds.

At **CPC level**, the picture became more detailed and showed a strong dominance of **biochemical classes** linked to **polysaccharides**, **N-glycosides**, **specific microorganisms** such as ***Pichia*** **and yeast isolates**, as well as **carbohydrate preparation**. Additional CPC classes pointed to **applications in metabolic and immune disorders** and to **adaptation technologies in agriculture/aquaculture**, highlighting the importance of marine-derived bioproducts for health and environmental resilience.

Although these results rely on examiner-assigned IPC and CPC classifications, which always involve some interpretative judgement, they are based on formal, standardised systems and therefore provide a robust indication of the main technological fields covered by the patent portfolio. (Figure 5.1 and 5.2).

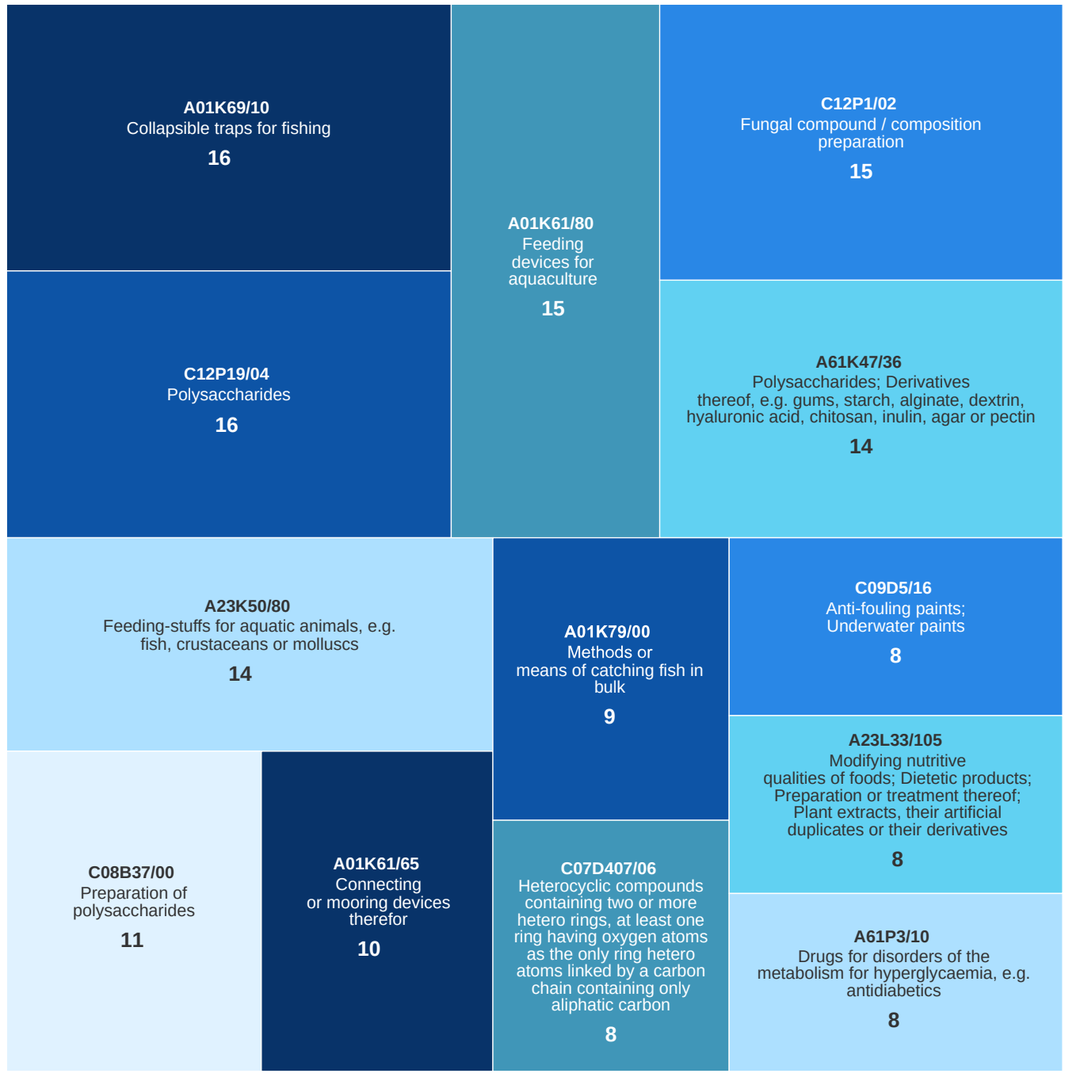


Figure 5.1. — Main IPC

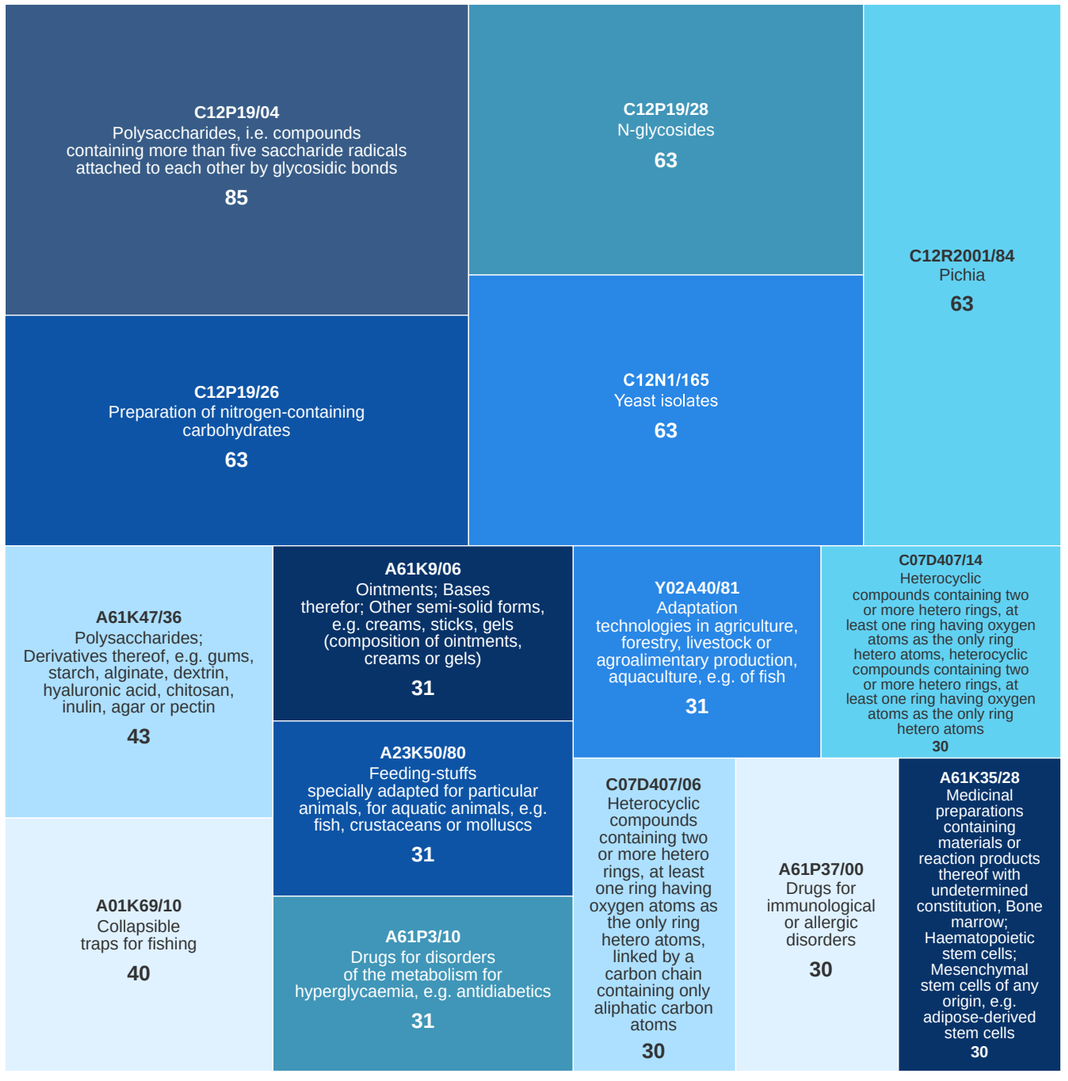
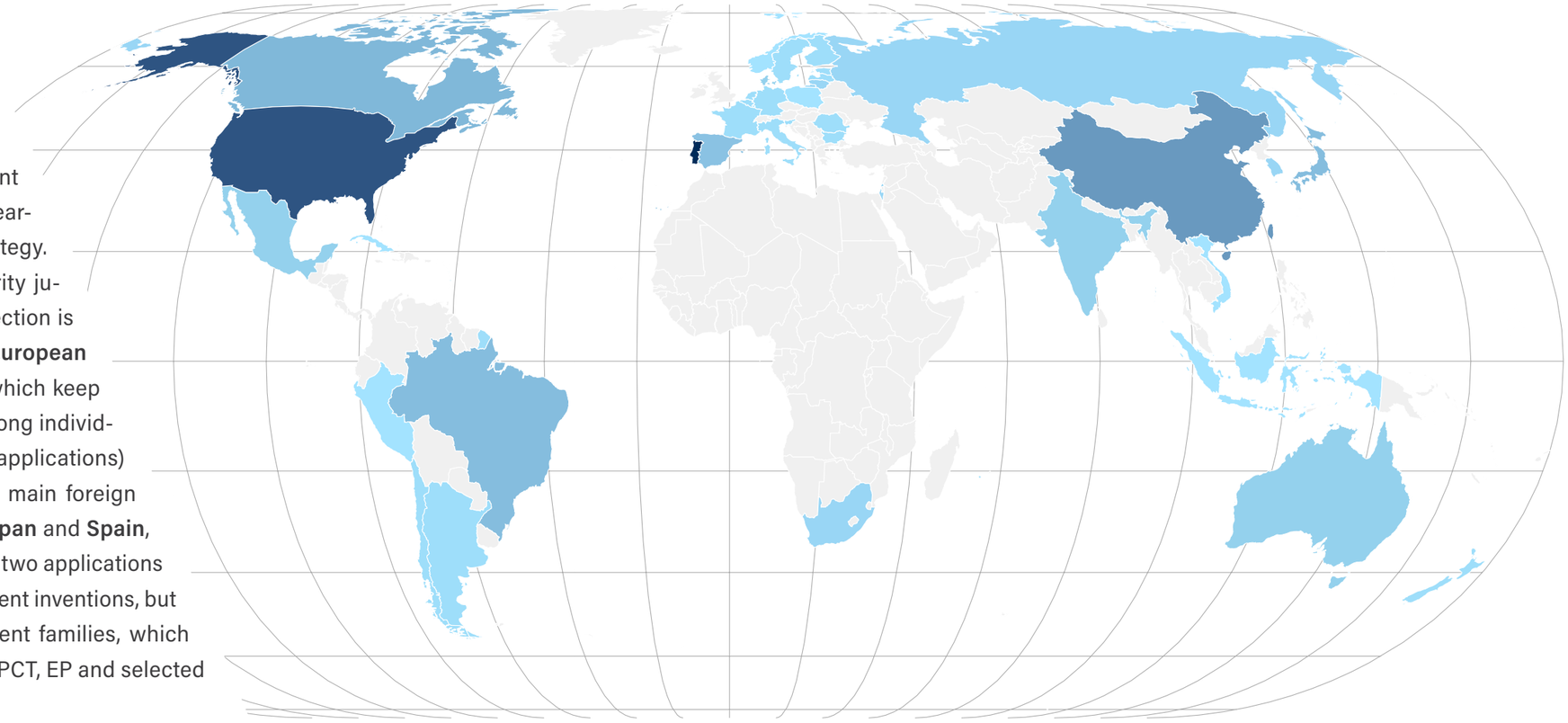


Figure 5.2. — Main CPC

3.5. PORTUGUESE BLUE BIOECONOMY PATENT APPLICATION GEOGRAPHIC DISTRIBUTION



The geographical distribution of patent applications (Figure 6) reveals a clearly internationalised protection strategy. Although **Portugal** appears as a priority jurisdiction (33 applications), most protection is sought via **PCT** (52 applications) and **European Patent** (**EP**) (46 applications) routes, which keep options open for multiple markets. Among individual countries, the **United States** (25 applications) and **China** (13 applications) were the main foreign targets, followed by **Canada**, **Brazil**, **Japan** and **Spain**, with a long tail of countries with one or two applications each. These figures do not reflect different inventions, but the territorial spread of the same patent families, which are often extended in parallel through PCT, EP and selected national offices.

In the Portuguese context, this pattern must also be read in light of the first-filing requirement: applicants based in Portugal are, in principle, required to file their PCT and EP applications initially through the national office, a rule rooted in national-security concerns over potentially sensitive (e.g., military) inventions and which can affect the legal effect of applications in Portugal if not respected. Although the secrecy regime has hardly been applied in practice and case law has already softened its impact in situations of joint ownership, the **strong use of PCT and EP** in the dataset is consistent with a **strategy in which national filings serve as a first step, followed by regional and international extensions to maximise foreign market coverage** for the same underlying inventions.

Figure 6. — Geographic distribution of patent applications.

Portugal	33	Russia	3	Malta	2
USA	25	South Africa	3	Netherlands	2
China	13	South Korea	3	New Zealand	2
Canada	8	Argentina	2	Romania	2
Brazil	7	Belgium	2	Slovenia	2
Japan	7	Bulgaria	2	Sweden	2
Spain	6	Chile	2	Cuba	1
Australia	4	Estonia	2	Hong Kong	1
Denmark	4	Finland	2	Indonesia	1
India	4	France	2	Norway	1
Mexico	4	Germany	2	Peru	1
Austria	3	Italy	2	Poland	1
Israel	3	Latvia	2	Singapore	1
Lithuania	3	Luxembourg	2	Vietnam	1

3.6. PORTUGUESE BLUE BIOECONOMY PATENT APPLICATION LEGAL STATUS

For the quantification of the current legal status of the patent applications considered in this study, those classified with legal status I1 and I3 (see Table 3) were reclassified as not applicable, as they correspond to application temporary stages of prosecution (PCT entering national / regional phases or granted European Patent that was validated in the territories of interest) and therefore were transformed in different patent applications with different legal statuses (e.g., active or pending).

Figures 7.1 and 7.2 show the distribution of legal status for the 239 applications: **28,9%** (n =69) are already in the **public domain**, **27,6%** (n = 66) are **pending**, **20,5%** (n = 49) are **legally active**, and only **3,3%** (n = 8) have an **unknown status**. This indicates a relatively balanced portfolio between patents still under examination, patents with enforceable rights, and a sizeable share of inventions that are now freely available for use.

Of note is the fact that none of the patents in the present study had reached term, all cases classified as being in the **public domain** correspond to applications that were **withdrawn, refused or lapsed before reaching their full patent term.**

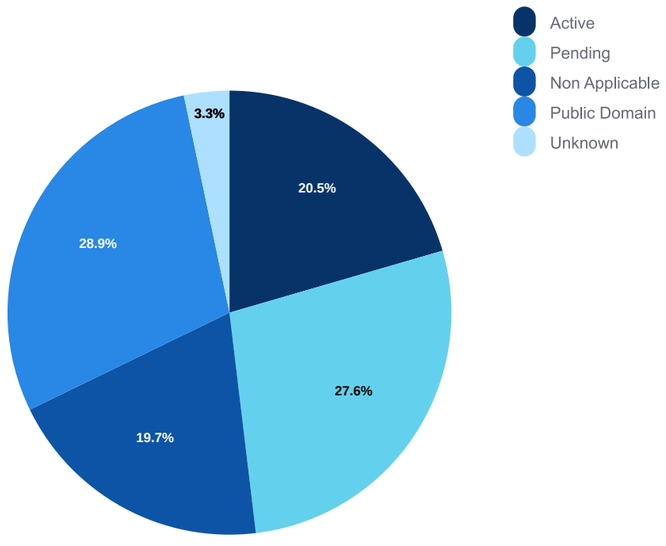


Figure 7.1. — Legal Status distribution of Blue Bioeconomy Portuguese Patent Applications.

A more detailed analysis examined the distribution of legal status by earliest priority date, whereby each year corresponds to the earliest priority of an invention, and the legal status refers to the set of patent applications associated with that priority. When grouped into 5-year cohorts of earliest priority year (2004–2008, 2009–2013, 2014–2018, and 2019–2023), the data reveal a clear evolution of legal status over time.

For **2004–2008 (n = 46)**, **public domain** applications accounted for **50% (n = 23)**, **active** rights for **35% (n = 16)** and **pending** cases for **15% (n = 7)**, with **no unknown** statuses, suggesting that most older applications have already reached a stable outcome. In **2009–2013 (n = 11)**, the profile is even more clear-cut, with **73% (n = 8)** in the **public domain** and **27% (n = 3) active**, and **no pending or unknown** cases.

The **2014–2018 cohort (n = 75)** presented a more heterogeneous distribution with **32% (n = 24)** of **active patents**, **31% (n = 23) pending**, **31% (n = 23)** in the **public domain**, and **7% (n = 5)** having **unknown** status. Finally, for the most recent priorities, **2019–2023 (n = 59)**, **pending** applications dominated (**61% n = 36**), while **24% (n = 15)** were already in the **public domain**, **10% (n = 6) active**, and **5% (n = 3)** were **unknown**, which is consistent with the time typically required for examination and post-grant procedures.

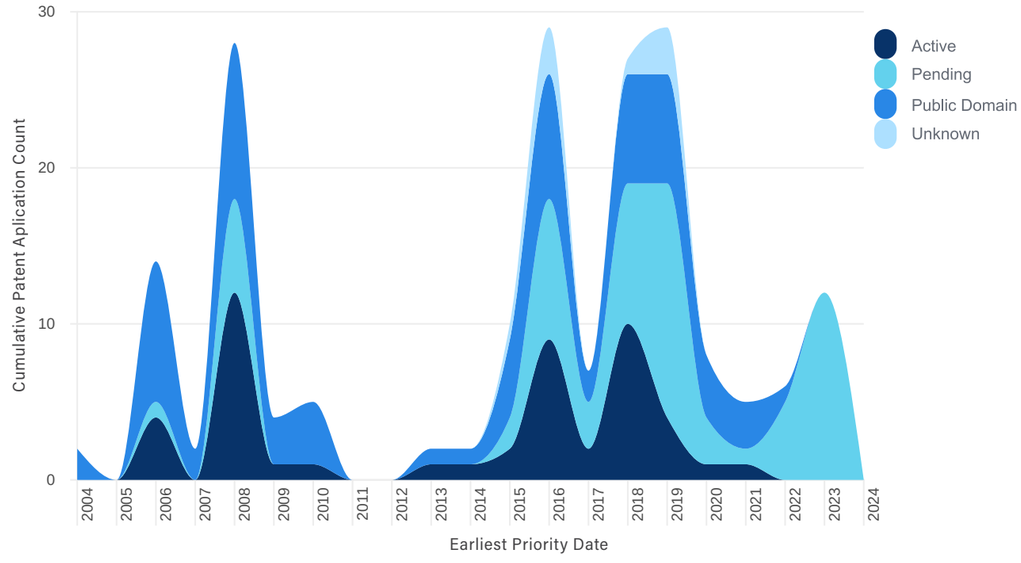
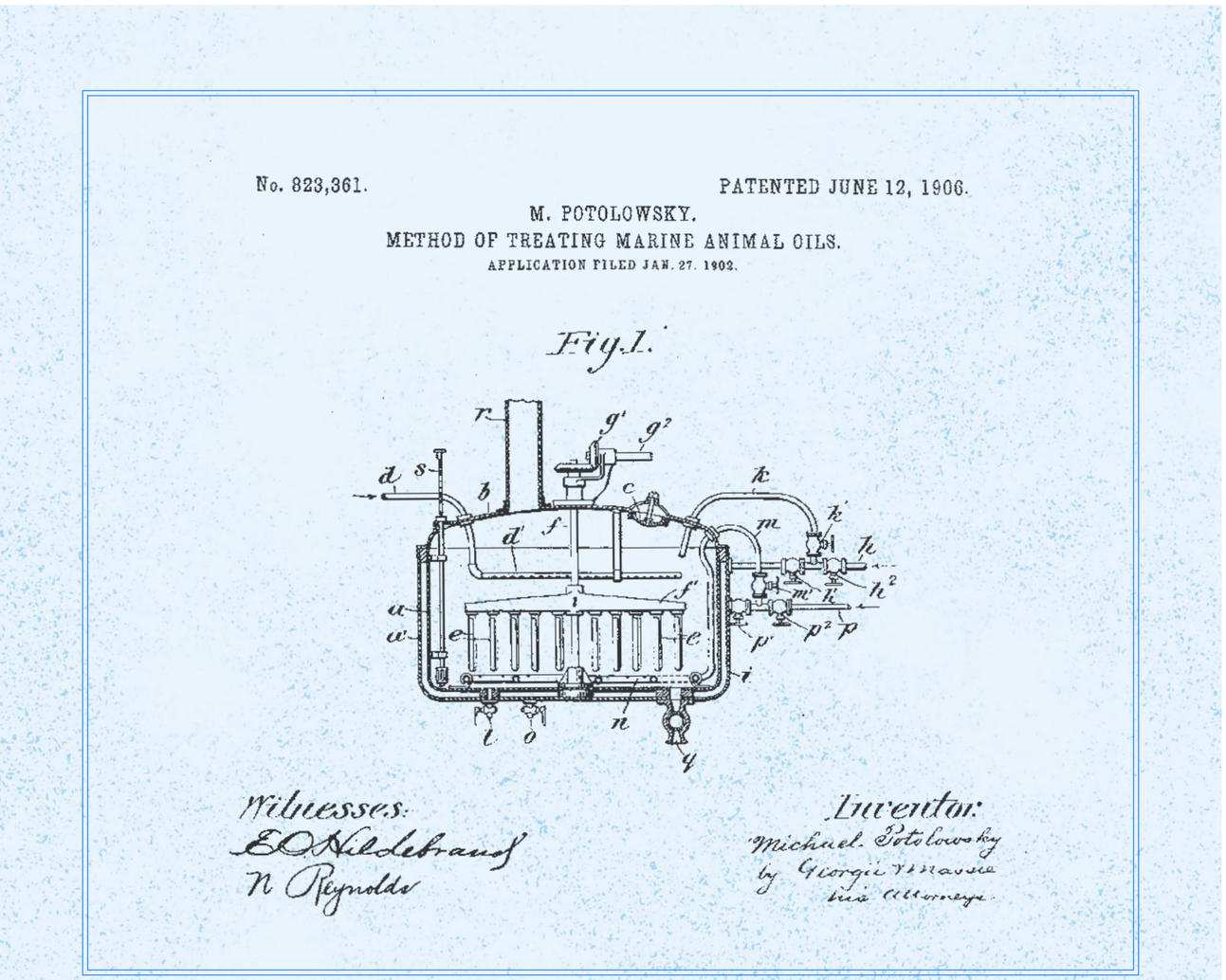


Figure 7.2. — Legal Status yearly distribution of Blue Bioeconomy Portuguese Patent Applications.

Taken together, the coexistence of a non-negligible share of active rights with a substantial proportion already in the public domain suggests a process of selective consolidation of the portfolio over time: applicants appear to file broadly at earlier stages of technological development, but only a subset of inventions is carried through to long-term protection, while many others fall into the public domain and become freely available for use within the Blue Bioeconomy.



No. 823,361. PATENTED JUNE 12, 1906.

M. POTOLOWSKY.

METHOD OF TREATING MARINE ANIMAL OILS.

APPLICATION FILED JAN. 27, 1902.

Fig. 1.

Witnesses:
E. O. Hildebrand
N. Reynolds

Inventor:
Michael Potolowsky
by Georgia Massie
his Attorneys

3.7. PORTUGUESE BLUE BIOECONOMY PATENT APPLICATION INTERNATIONALIZATION STRATEGY

Crossing legal status of patent applications with respective jurisdictions enabled a more granular analysis of the internationalisation strategies of the last 20 years in Portuguese Blue Bioeconomy (Figure 8).The **geographic distribution of patent applications** showed that protection had been structured around a **tiered strategy centred on Europe** and selectively **extended to the Americas, Asia and a small number of other jurisdictions.**

In **Europe**, national filings together with European Patent (EP) designations accounted for **58 active**, **36 pending**, **18 public domain** and only **1 unknown** patent applications, with **Portugal clearly standing out as the core jurisdiction** and a broad set of European Union and of European Economic Area (EEA) states covered through selective EP validation. This pattern might indicate that Europe was intended to function as the primary operating and revenue zone, where applicants maintained dense and relatively recent protection and used the EP route to keep options open for future territorial extensions.

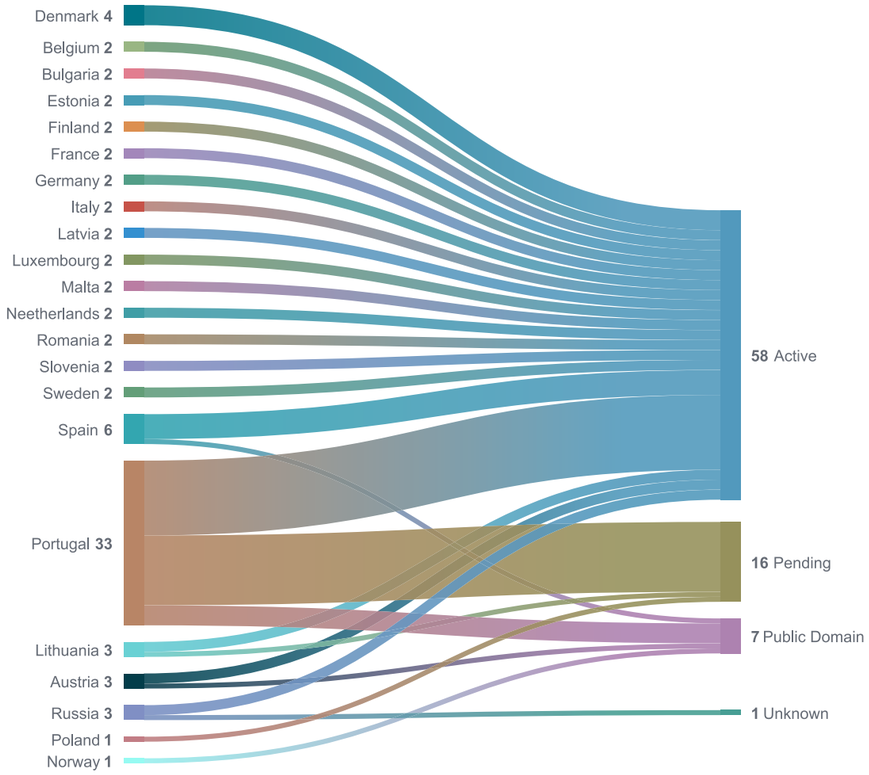
In the **Americas**, the portfolio was more mature and partly historic, with **14 active**, **10 pending** and **24 public domain** patent applications, reflecting long-standing activity in the United States, by far the most represented non-European market, complemented by more targeted filings in **Canada**, **Brazil**, **Mexico** and a few other Latin-American countries.

In **Asia**, protection was focused on major innovation hubs, namely **China**, **Japan** and **South Korea**, which together accounted for **7 active**, **8 pending** and **9 public domain** patent applications, while several other countries only registered applications with unknown or no current status.

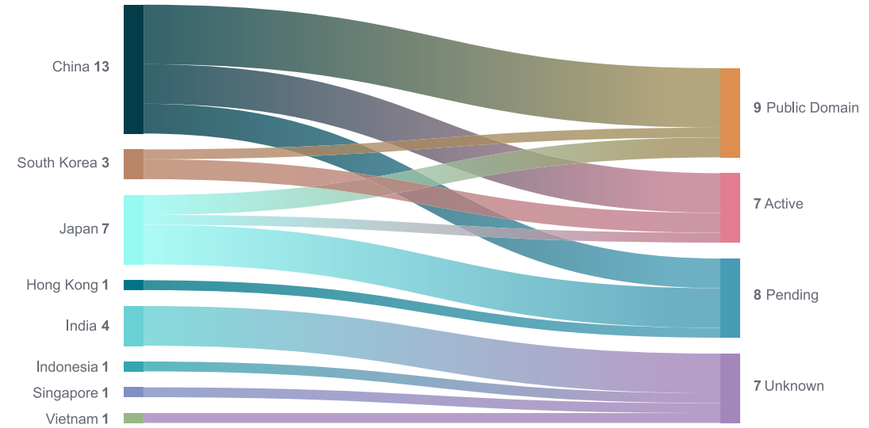
Additional filings in **Israel** and **South Africa** (**3 active** and **3 pending** in total), together with the use of the **PCT system** (**7 pending** and **13 public domain** applications), further illustrated a strategy in which international rights were deployed selectively, following concrete collaboration opportunities and using international and regional procedures to manage timing and cost of national-phase entries.

Taken together with the legal status analysis, this geographic pattern suggested that the portfolio had undergone a process of selective consolidation over time: earlier broad filing, often across multiple jurisdictions, had progressively been **narrowed to a set of families maintained in force in strategically important markets (notably Portugal/Europe, the United States and a few Asian hubs)**, while many other applications were allowed to lapse and moved into the public domain. As a result, approximately half of the distinct inventions mapped in this landscape were already unprotected in at least some, if not all, jurisdictions, creating a substantial freedom-to-operate space and a reservoir of technical solutions for follow-on innovation, whereas the remaining families - still pending or active in key territories – likely concentrated the commercially most relevant and enforceable rights within the Portuguese Blue Bioeconomy.

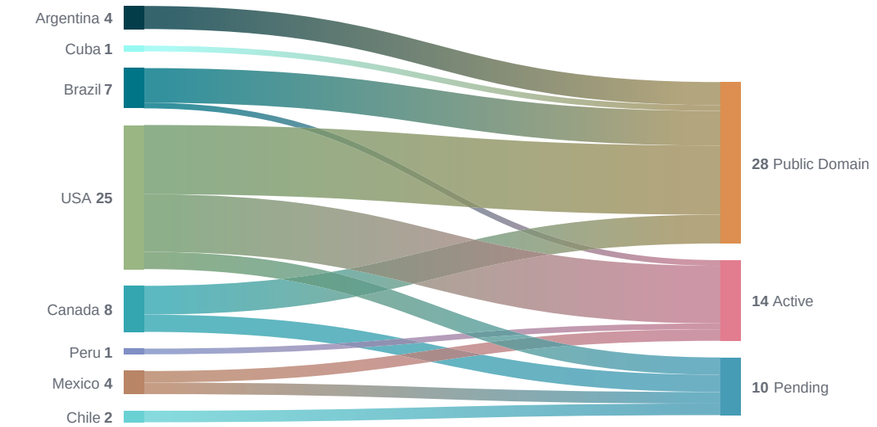
Europe



Asia



America



Other

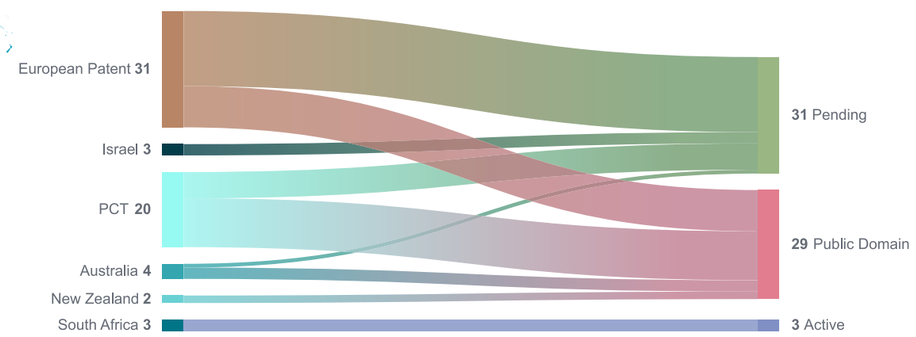


Figure 8. — Legal Status per jurisdiction of Blue Bioeconomy Portuguese Patent Applications.

3.8. PORTUGUESE BLUE BIOECONOMY PATENT APPLICATION TECHNOLOGY READINESS LEVEL

Technology Readiness Level (**TRL**) classification was employed to map the technological maturity of the patent application families (Figures 9.1 and 9.2). Within the subset assessed, most inventions were positioned at intermediate maturity levels: **TRL 4** (**33,3%)** and especially **TRL 5** (**47,8%**) and together accounted for around four fifths of the portfolio (**56 out of 69 patent families**). Earlier development stages were less represented, with **TRL 3** corresponding to **13%** (n = 9), while only a small fraction had progressed towards more advanced stages, with **TRL 6** at **4,3%** (n = 3) and **TRL 7** at **1,4%** (n = 1).

This pattern suggested that most patented technologies in the Blue Bioeconomy were in phases where key functionalities were validated and tested in relevant environments but were not yet fully demonstrated in operational settings or widely deployed in the market. As noted above, these results must be interpreted cautiously, since the TRL classification is based solely on information contained in patent applications, which may under-represent evidence of performance, reliability or real-world testing.

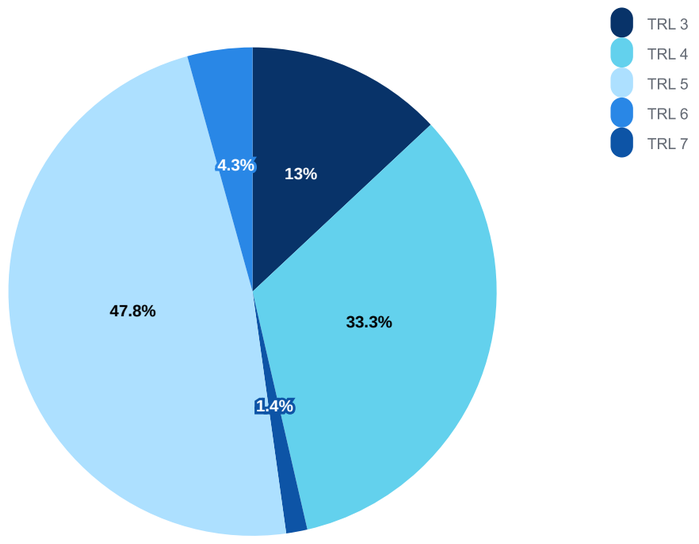


Figure 9.1. — Blue Bioeconomy Patent Application TRL Distribution.

A complementary perspective examined the technological maturity (TRL) of the patent families by earliest priority date. When grouped into five-year cohorts (2004–2008, 2009–2013, 2014–2018, and 2019–2023), the data show a shift from predominantly early-stage inventions towards intermediate maturity levels over time.

For **2004–2008** (n = 5), the portfolio was dominated by **TRL 3** and **TRL 4** inventions, each accounting for **40%** (n = 2), with **no cases at TRL 5 or TRL 6** and a single family at **TRL 7** (**20%** n = 1) – consistent with an exploratory phase centred on proof-of-concept and laboratory validation, with only one fully demonstrated technology.

In **2009–2013** (n = 5), the profile became more mixed: **TRL 3** remained at **40%** (n = 2), while **TRL 4, TRL 5 and TRL 6** each represented **20%** (n = 1), and **no TRL 7** families were observed, indicating the first emergence of pilot/system-validation stages alongside earlier-stage activity.

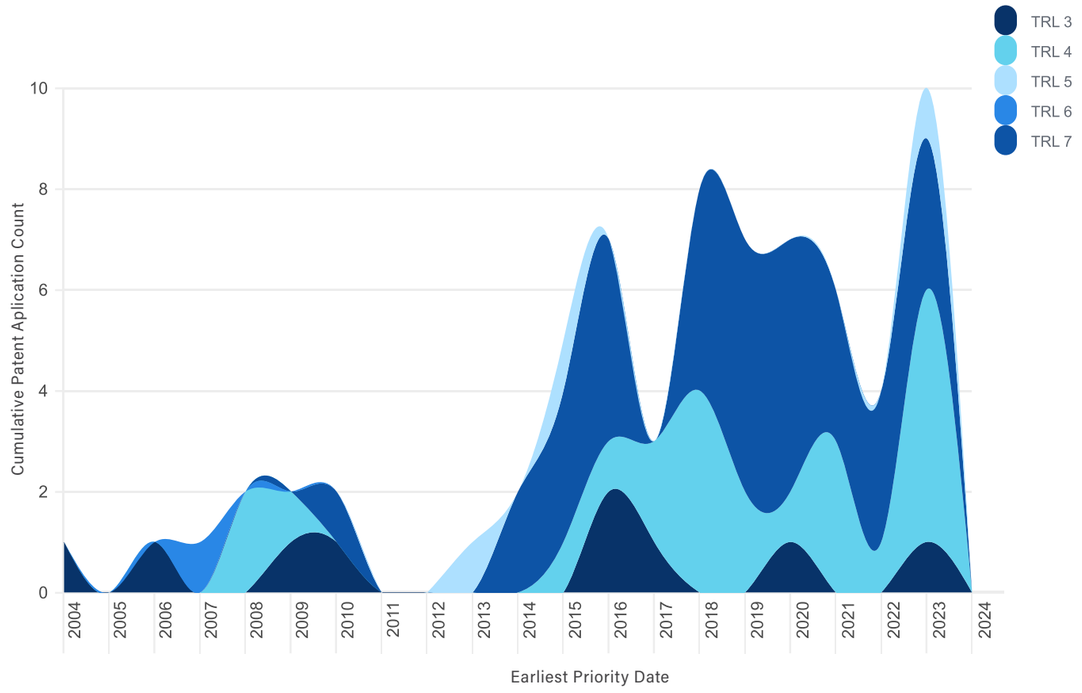


Figure 9.2. — Blue Bioeconomy Patent Application TRL Yearly Distribution.

The bulk of activity occurred from **2014–2018** (n = 25), where **TRL 5** became dominant **(52%** n = 13**)** and **TRL 4** represented **32%** (n = 8), low-TRL inventions (**TRL 3**) declined to **12%** (n = 3) and **TRL 6** appeared only once (**4%** n = 1). A similar but even more consolidated pattern was observed for **2019–2023** (n = 34) with **TRL 5** accounting for **56%** (n = 19) and **TRL 4** for **35%** (n = 12), while **TRL 3** fell to **6%** (n = 2) and only one family reached **TRL 6** (**3%** n = 1).

Taken together, these cohorts indicate both a strong intensification of patenting from **2014 onwards (59 of 69 families fall in 2014–2023)** and a progressive consolidation of technological maturity around **TRL 4–5**. Patents were increasingly filed at pilot-scale or system-validation stages rather than at basic proof-of-concept, while high-TRL solutions remained rare (**TRL 6–7 total n = 4 across 2004–2023**), suggesting movement towards pre-commercial implementation but still limited evidence of widespread large-scale deployment or full market readiness.

No. 709,751. Patented Sept. 23, 1902.

D. W. DAVIS.

PROCESS OF PRESERVING FROZEN FOOD PRODUCTS.

(Application filed May 21, 1902.)

(No Model.)

Witnesses.
Robt Everett.
Witton Coombs.

Inventor
David W. Davis.
By W. A. Ruff
Atty.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

3.9. PORTUGUESE BLUE BIOECONOMY PATENT APPLICATION DISTRIBUTION WITHIN THE VALUE CHAIN

In order to further characterize the technological developments within the Portuguese Blue Bioeconomy, patent applications were classified using a categorical system aligned with Blue Bioeconomy value chain. In this system metacategories were mirroring the main stages of the value chain, and the categories within each Metacategory were defined through a human-driven process, based on the specific technical specifications, technologies and products associated with each stage. This approach allowed for a reading of the patent application portfolio directly in terms of where innovations intervene along the chain, from *biodiversity exploration* to *circularity and resource recovery*. However, the value chain stage corresponding to *Marketing & Distribution* was not considered, as the activities involved are not suited for patent protection.

The resulting distribution (Figure 10) showed a clear concentration of patenting activity in ***Secondary Processing & Novel Product Production*** (Metacategory 4), which accounted for several high-weight categories. In particular, ***health, therapeutic and dermocosmetic applications*** (Category 4.3) alone represented **22%** (n = 15) of all cases, followed by ***advanced bio-based materials and coatings*** (Category 4.4), ***feed, additives & animal immunonutrition*** (Category 4.2) and ***food & functional food products*** (Category 4.1), each contributing **7–9%** of the total. This pattern indicated that much of the technological effort has been focused on transforming marine biomass into higher value-added products for health, nutrition, materials and cosmetics.

Upstream in the chain, ***Primary Production or Catch*** (Metacategory 2) also appeared as a relevant domain, particularly ***aquaculture of fish, molluscs, crustacea and marine invertebrates*** (Category 2.1) with **13%** (n = 9) and ***capture and harvest of wild marine biomass*** (Category 2.3) with **6%** (n = 4), reflecting the importance of securing and managing biological resources. In ***Extraction and Conversion*** (Metacategory 3), patent applications were distributed among ***processing, extraction and conversion technologies*** (Category 3.1) at **10%**, ***platform delivery and engineering technologies*** (Category 3.3) at **9%**, and ***functional marine bio-based ingredients*** (Category 3.2) at **6%**, signalling active development in intermediate technological steps that unlock functional compounds and delivery systems.

By contrast, ***Biodiversity & Bioprospecting*** (Metacategory 1) and ***Circularity & Resource Recovery*** (Metacategory 6) remained comparatively under-represented. ***Marine exploration, sampling and enabling technologies*** (Category 1.1) accounted for only **4%** (n = 3), while categories related to ***effluent treatment and bioremediation*** (Category 6.2) *and* ***resource recovery*** (Category 6.1) together **summed to just 5%**, and some categories (1.2, 1.3, and 6.3) showed no patents at all. These findings suggested that, within the patent application set analysed, innovation was currently more strongly oriented towards downstream valorisation of marine resources than towards early-stage bioprospecting or circularity and energy-recovery solutions, pointing to potential gaps and opportunities for future R&D and policy support along the Blue Bioeconomy value chain.

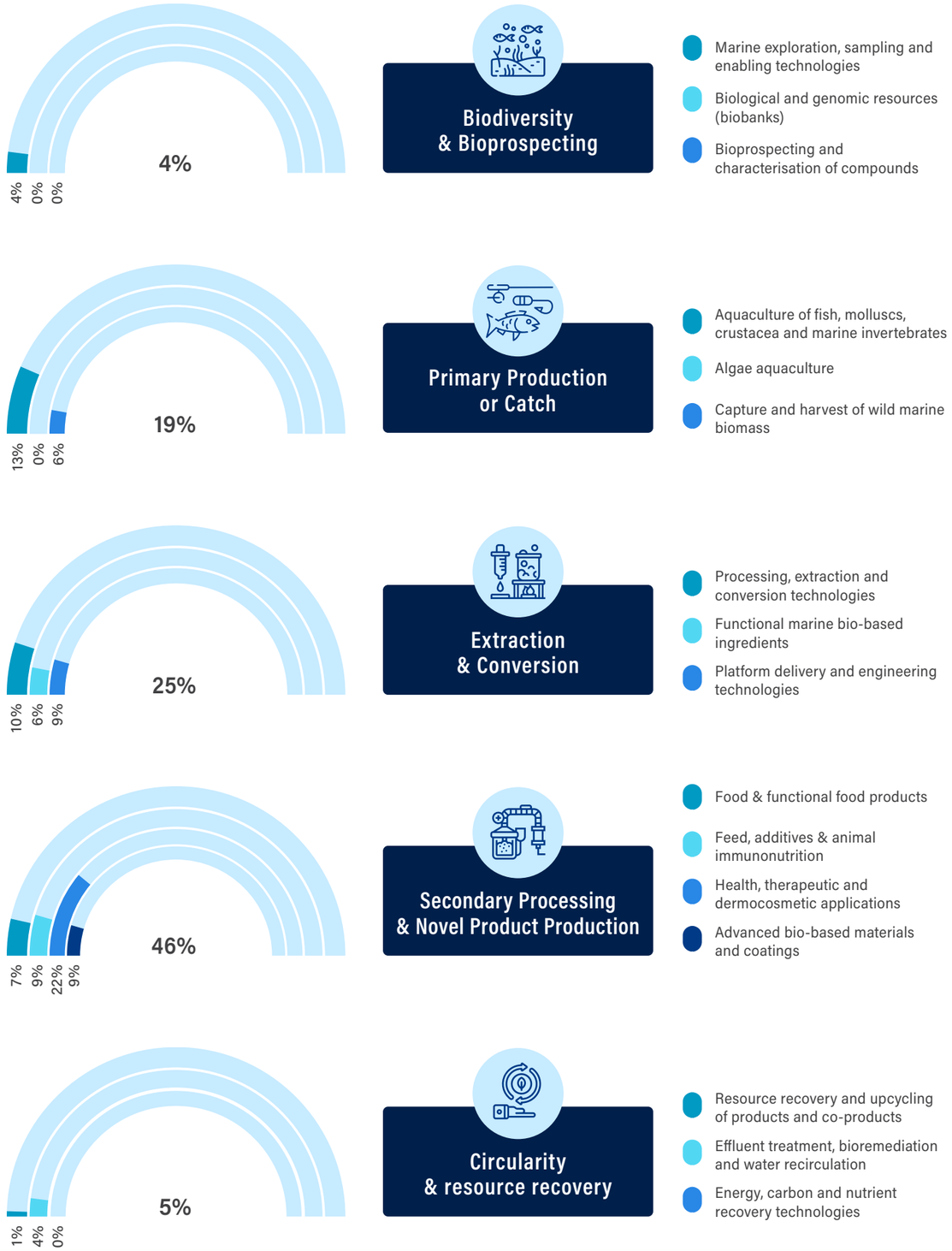


Figure 10. — Distribution of patent families according to their position in the Blue Bioeconomy value chain.

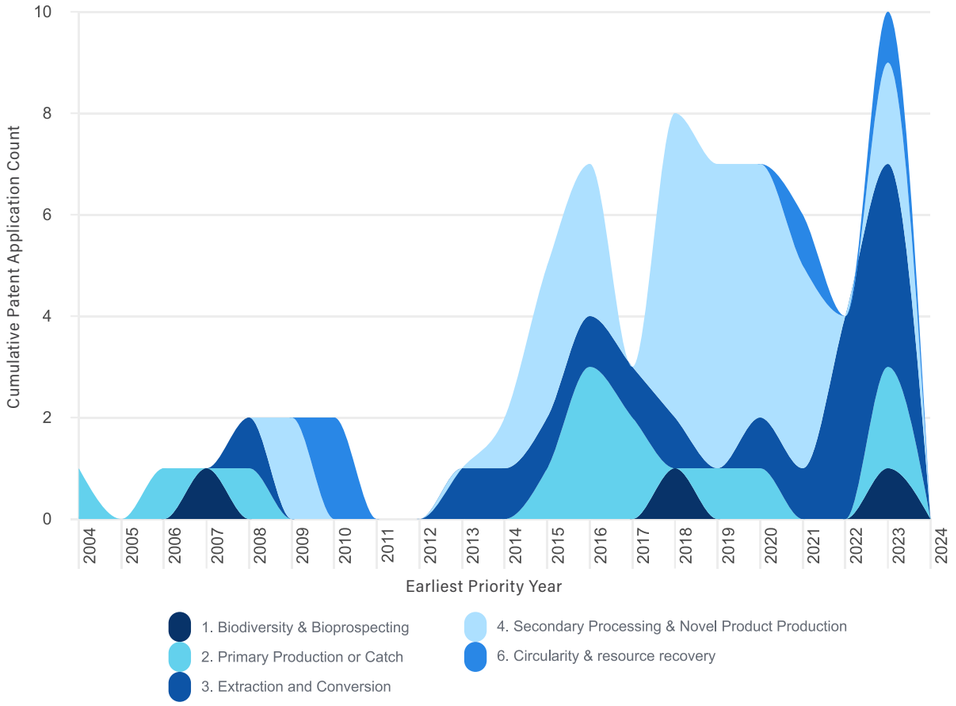


Figure 11.1 — Distribution of patent families according to their Metacategory classifications, by earliest priority year.

Figure 11.2 — Distribution of patent families according to their Category classifications, by earliest priority year.

Figures 11.1 and 11.2 depicts the temporal evolution of the patent family portfolio, showing how patent families were distributed across the Blue Bioeconomy value chain at the Metacategory level and which specific products, processes or services were targeted within each corresponding Category. The 69 patent families were analysed grouped into five-year cohorts according to their earliest priority year (2004–2008, 2009–2013, 2014–2018, and 2019–2023), to identify finer-scale patterns along the value chain.

In the **2004–2008** cohort (n = 5), patenting activity was still modest and primarily oriented towards the upstream and primary-production end of the value chain. At Metacategory level, ***Primary Production or Catch*** (Metacategory 2) dominated with **60%** (n = 3), while ***Extraction and Conversion*** (Metacategory 3) and ***Biodiversity & Bioprospecting*** (Metacategory 1) each represented **20%** (n = 1), **no families** were classified under ***Secondary Processing & Novel Product Production*** (Metacategory 4) or ***Circularity & Resource Recovery*** (Metacategory 6). At Category level, **most applications** fell under ***capture and harvest of wild marine biomass*** (Category 2.3), with a **few cases in *marine exploration, sampling and enabling technologies*** (Category 1.1) and ***processing, extraction and conversion technologies*** (Category 3.1). This distribution reflected an early stage in which innovation focused mainly on accessing and handling marine biomass, rather than on downstream valorisation.

In the **2009–2013** cohort (n = 5), patenting activity remained relatively limited but began to diversify towards mid-chain and downstream functions. At Metacategory level, ***Secondary Processing & Novel Product Production*** (Metacategory 4) and ***Circularity & Resource Recovery*** (Metacategory 6) each accounted for **40%** (n = 2 each), while ***Extraction and Conversion*** (Metacategory 3) represented **20%** (n = 1), **no patents** were classified under ***Biodiversity & Bioprospecting*** (Metacategory

1) or ***Primary Production or Catch*** (Metacategory 2). At Category level, patenting emerged in ***platform delivery and engineering technologies*** (Category 3.3), ***food & functional food products*** (Category 4.1), ***feed, additives & animal immunonutrition*** (Category 4.2) **and** ***effluent treatment, bioremediation & water recirculation*** (Category 6.2). These results indicated the first steps towards developing processing technologies, early product formulations and environmental applications, signalling a gradual shift away from purely resource-oriented innovation.

The **2014–2018** cohort (n = 25) marked a clear acceleration in inventive activity, which became increasingly concentrated in high-value segments. At Metacategory level, ***Secondary Processing & Novel Product Production*** (Metacategory 4) dominated with **52%** (n = 13), followed by ***Primary Production or Catch*** (Metacategory 2) with **24%** (n = 6**),** ***Extraction and Conversion*** (Metacategory 3) with **20%** (n = 5) and ***Biodiversity & Bioprospecting*** (Metacategory 1) with **4%** (n = 1), ***Circularity & Resource Recovery*** (Metacategory 6) was **not represented**. At Category level, a clear predominance of ***health, therapeutic and dermocosmetic applications*** (Category 4.3), complemented by ***food & functional food products*** (Category 4.1), ***feed, additives & animal immunonutrition*** (Category 4.2) and ***advanced bio-based materials and coatings*** (Category 4.4). Upstream innovation persisted through a***quaculture of fish, molluscs, crustacea & marine invertebrates*** (Category 2.1) and a smaller share of ***processing, extraction & conversion technologies*** (Category 3.1). This phase indicated a maturing innovation landscape in which marine biomass was increasingly channelled into functional ingredients and specialised products for food, feed, health and materials.

In the **2019–2023** cohort (n = 34), these trends consolidated and diversified further. At Metacategory level, ***Secondary Processing & Novel Product Production*** (Metacategory 4) remained predominant with **50%** (n = 17), followed by ***Extraction and Conversion*** (Metacategory 3) with **30%** (n = 10). ***Primary Production or Catch*** (Metacategory 2) accounted for **12%** (n = 4), while ***Circularity & Resource Recovery*** (Metacategory 6) represented **6%** (n = 2) and ***Biodiversity & Bioprospecting*** (Metacategory 1) **3%** (n = 1). At Category level, activity again concentrated in downstream applications, led by ***health, therapeutic and dermocosmetic applications*** (Category 4.3) and ***advanced bio-based materials and coatings*** (Category 4.4). The ***extraction and conversion*** domain expanded, with balanced representation across ***processing, extraction & conversion technologies*** (Category 3.1), ***functional marine bio-based ingredients*** (Category 3.2) and ***platform delivery & engineering technologies*** (Category 3.3), suggesting a more sophisticated technological base supporting downstream innovations. **Circularity also re-emerged** through isolated patents in ***resource recovery & upcycling of products and co-products*** (Category 6.1) and ***effluent treatment, bioremediation & water recirculation*** (Category 6.2).

Across all cohorts, some **categories remained systematically absent** or under-represented, notably ***biological and genomic resources (biobanks)*** (Category 1.2), ***bioprospecting and characterisation of compounds*** (Category 1.3), ***algae aquaculture*** (Category 2.2) and ***energy, carbon and nutrient recovery technologies*** (Category 6.3).

Overall, the combined Metacategory and Category-level analyses revealed a clear temporal evolution, from an initial focus on primary production and biomass access, to a strong concentration in downstream value-added products, and, more recently, a growing attention to mid-chain processing and emerging circularity solutions – while early-stage bioprospecting, algae cultivation and dedicated resource-recovery pathways remained comparatively limited across the entire period (2004–2023).

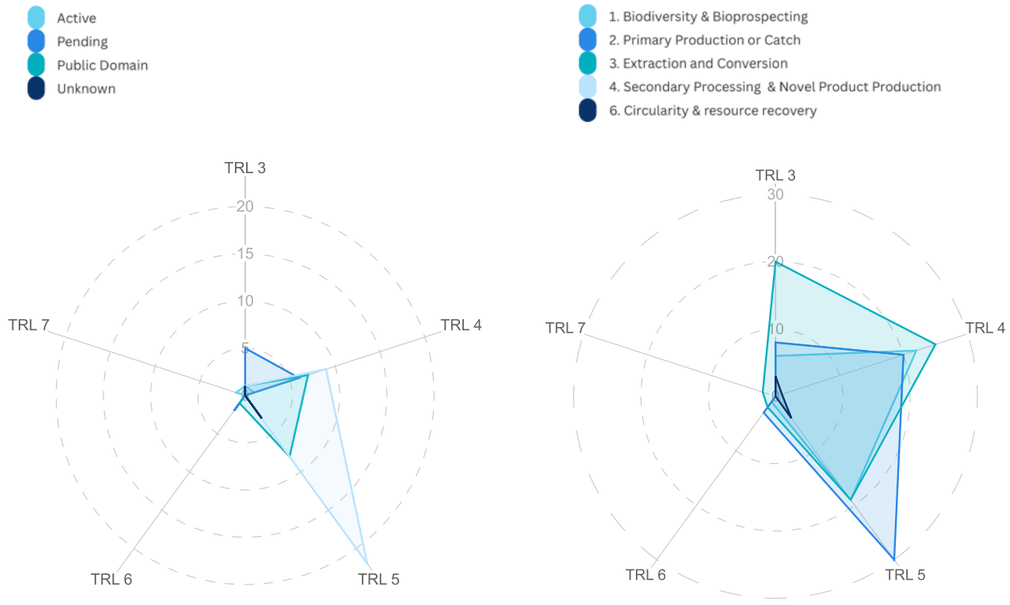


Figure 12. — Distribution of Portuguese Blue Bioeconomy patent families by TRL, value-chain Metacategory and legal status.

When **TRL** was used as the common axis of analysis (Figure 12), the portfolio showed a clear concentration of **inventions at intermediate stages of technological maturity**, and this pattern interacted in a systematic way with both the position in the value chain and the legal status of the underlying patent applications.

Overall, most patent families were located at TRL 4–5, 23 families at TRL 4 and 33 families at TRL 5, whereas only 9 families were at TRL 3, 3 families at TRL 6 and a single family at TRL 7.

At **TRL 3**, the portfolio was clearly dominated by ***Primary Production or Catch*** (Metacategory 2), which accounted for 5 of the 9 families (**56%**), with the remaining four families distributed evenly across ***Biodiversity & Bioprospecting*** (Metacategory 1), ***Extraction and Conversion*** (Metacategory 3), ***Secondary Processing & Novel Product Production*** (Metacategory 4) and ***Circularity & Resource Recovery*** (Metacategory 6) (**each 11%**). In legal terms, as already shown, **more than half of the associated applications at TRL 3** were already in the **public domain** (n = 20), with only **6 patent applications active** and **8 pending**. This suggested that early-stage, upstream developments were frequently allowed to lapse or were discontinued during prosecution, leaving substantial freedom to operate around exploratory concepts in the initial stages of the Blue Bioeconomy value chain.

The technological developments at **TRL 4**, became more evenly distributed within the value chain, with a shift towards mid-chain segments. ***Secondary Processing & Novel Product Production*** (Metacategory 4) represented **39%** of families (n = 9), ***Extraction and Conversion*** (Metacategory 3) **31%** (n = 7) **and *Primary Production or Catch*** (Metacategory 2) **26%** (n = 6), while ***Biodiversity & Bioprospecting*** (Metacategory 1) was marginal (**4%** n = 1) and no families were classified under ***Circularity & Resource Recovery*** (Metacategory 6). The corresponding legal status of technological developments with **TRL 4** was relatively balanced with **26 applications in the public domain**, **42 active** and **20 pending**, with only **one case of unknown status**. This indicated the technological developments with only laboratory validation functioned as a transition stage in which a mixture of upstream and downstream inventions in the value chain coexisted and applicants were likely unsure of which strategy to pursue and actively deciding which projects to maintain, abandon or advance.

The **TRL 5** layer, of inventions validated in relevant environment, where **48% of all families were located** (n = 33), corresponded mainly to downstream, higher value-added stages of the value chain. ***Secondary Processing & Novel Product Production*** (Metacategory 4) dominated with 22 families (**67%**), followed by ***Extraction and Conversion*** (Metacategory 3) with 8 families (**24%**) and ***Circularity & Resource Recovery*** (Metacategory 6) with 3 families (**9%**). **No families in *Primary Production or Catch*** (Metacategory 2) or ***Biodiversity & Bioprospecting*** (Metacategory 1) were observed at this level. From a legal perspective, **TRL 5** showed the highest concentration of pending and active rights with **30 pending patent applications** and **19 active**, while **19** were in the **public domain** and **4 had unknown status**.

Technologies at more advanced stages, TRL 6 and 7, the number of families was very small, but their distribution was informative. At **TRL 6** where inventions were validated in relevant environment, three families were identified, mainly in ***Primary Production or Catch*** (Metacategory 2) (**67%** n = 2) and ***Extraction and Conversion*** (Metacategory 3) (**33%** n = 1). **Three** of the associated patent applications were **pending**, **two** were already in the **public domain** and only **one was active**, indicating that only a limited subset of near-demonstration technologies continued to be prosecuted. At **TRL 7**, a single family was classified, in ***Biodiversity & Bioprospecting*** (Metacategory 1), and **all associated applications were already in the public domain.** Thus, the technology that had reached demonstration of prototype in operational environment was no longer covered by enforceable patent rights.

Taken together, when technology readiness was used as the common reference, legal protection was most heavily concentrated on technologies already validated in the laboratory or in a relevant environment - that is, technologies that had moved beyond simple proof of concept and reached the stages of technology validation in laboratory and technology validated in relevant environment. It was precisely at these levels of maturity that the portfolio shifted from upstream activities towards ***Extraction and Conversion*** (Metacategory 3) and, above all, ***Secondary Processing & Novel Product Production*** (Metacategory 4). In contrast, proof-of-concept technologies - in particular those in ***Primary Production or Catch*** (Metacategory 2) - were more often abandoned and allowed to fall into the public domain, while the very small number of technologies demonstrated in a relevant environment or prototypes demonstrated in an operational environment tended to lose protection as they matured. This pattern reinforced the view that IP management in the Portuguese Blue Bioeconomy preferentially supported mid-chain and downstream technologies at laboratory and relevant-environment validation stages, while leaving both early upstream explorations and a few fully mature solutions as part of the open innovation space.

3.10. PORTUGUESE BLUE BIOECONOMY INTELLECTUAL PROPERTY (IP) RETENTION

Legal status was captured as a time-stamped snapshot at the date of data extraction, reflecting the most recent information available in the consulted patent databases rather than a permanent status. Assessing **IP retention** is therefore critical because it moves beyond simple patent counts to **indicate whether applicants are actively maintaining patent protection, or intent to continue prosecution, across jurisdictions or whether rights have been allowed to lapse/abandoned and the technology has effectively entered the public domain.** This distinction matters for interpretation and decision-making: retention is a proxy for the perceived strategic and economic value of the underlying inventions, supports a more realistic view of the current IP landscape, and helps identify domains where Portugal's Blue Bioeconomy innovations are most durable and investable versus areas where the knowledge base is already broadly accessible for diffusion and follow-on innovation.

To assess IP retention, patent families were classified as Retained, Fully Public Domain, or Indeterminate. This classification was based on a legal status review of each jurisdictional member (i.e., each patent application) using the four previously harmonised categories Active, Pending, Public Domain, and Unknown.

A family was labelled **Retained** if it included **at least one jurisdictional member with legal status Active or Pending**. A family was labelled **Fully Public Domain** only if **all jurisdictional members were classified as Public domain** (that is, with no Active, Pending, or Unknown records). **Families with no Active or Pending members but not meeting the criteria for Fully Public Domain**, typically because they contained Unknown members and/or a mix of Public Domain and Unknown records, were labelled **Indeterminate**.

Five-year cohort, metacategory and TRL-level retention was then reported as the percentage of families classified as Retained, alongside the shares of Fully public domain and Indeterminate families (Tables 7-9).

Table 7. — IP retention by five-year cohort-level.

Time Cohort	2004-2008	2009-2013	2014-2018	2019-2023
No. Patent Families Retained	3	3	21	25
No. Patent Families Fully Public domain	2	2	3	7
No. Patent Families Indeterminate	0	0	1	2
Total No. of Patent Families	5	5	25	34
Patent Families Retained	60%	60%	84%	73%
Patent Families Fully Public domain	40%	40%	12%	21%
Patent Families Indeterminate	0%	0%	4%	6%

Table 8. — IP retention by metacategory-level.

Metacategory	1. Biodiversity & Bioprospecting	2. Primary Production or Catch	3. Extraction and Conversion	4. Secondary Processing & Novel Product Production	6. Circularity & resource recovery
No. Patent Families Retained	2	11	13	24	2
No. Patent Families Fully Public domain	1	2	2	7	2
No. Patent Families Indeterminate	0	0	2	1	0
Total No. of Patent Families	3	13	17	32	4
Patent Families Retained	67%	85%	76%	75%	50%
Patent Families Fully Public domain	33%	15%	12%	22%	50%
Patent Families Indeterminate	0%	0%	12%	3%	0%

Table 9. — IP retention by TRL-level

TRL	3	4	5	6	7
No. Patent Families Retained	5	20	25	2	0
No. Patent Families Fully Public domain	4	2	6	1	1
No. Patent Families Indeterminate	0	1	2	0	0
Total No. of Patent Families	9	23	33	3	1
Patent Families Retained	56%	87%	76%	67%	0%
Patent Families Fully Public domain	44%	9%	18%	33%	100%
Patent Families Indeterminate	0%	4%	6%	0%	0%

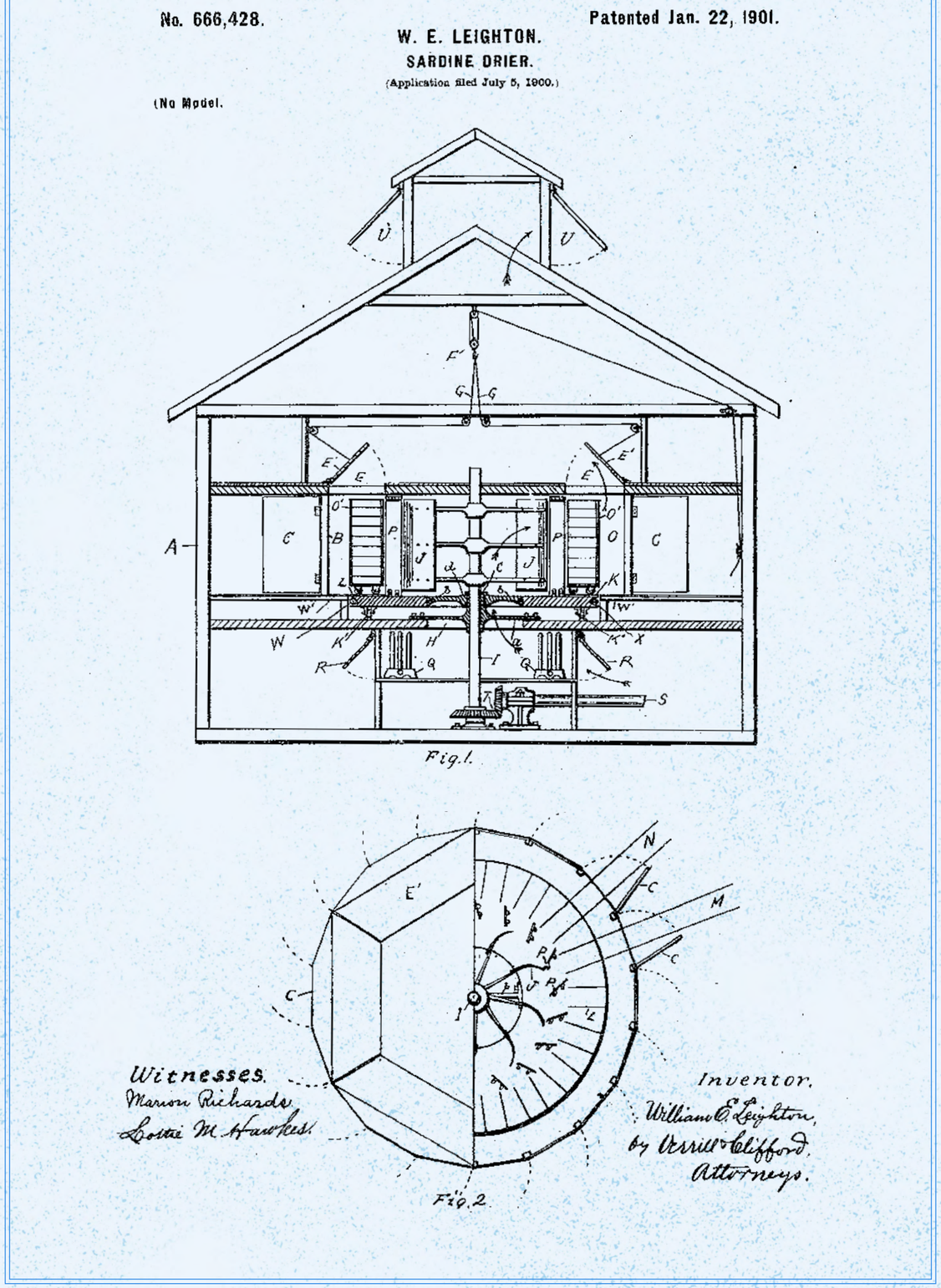
Across the three stratifications (time cohort, value-chain metacategory, and TRL), the patent-family portfolio (n=69) shows overall high retention, but with clear differences in where attrition concentrates.

By **cohort**, **retention is stable but modest in the early periods** (**60%** in both 2004–2008 and 2009–2013, 3/5 each), **rises sharply in 2014–2018** (**84%,** 21/25), and then **moderates in the largest and most recent cohort** (**2019–2023, 73%,** 25/34), where the share **of fully public domain families increases** (**21%**, 7/34) and indeterminate cases are more frequent (6%, 2/34), consistent with greater volatility and/or incomplete legal status visibility in newer filings.

By **metacategory**, the portfolio is strongly concentrated downstream: ***Secondary Processing & Novel Product Production*** alone accounts for 32/69 families (**46**%), followed by ***Extraction & Conversion*** (17/69, **25%**) and ***Primary Production or Catch*** (13/69, **19%**). **Retention is highest in *Primary Production or Catch*** (**85%**, 11/13) and remains broadly strong in the two largest segments (32/69,**75% for *Secondary Processing & Novel Product Production*** and 17/69, **76% for *Extraction and Conversion*** retained) However, attrition is uneven: ***Secondary Processing & Novel Product Production*** **contributes the largest absolute number of fully public domain families** (7), indicating a "selection" dynamic in downstream product-facing innovations, while ***Circularity & Resource Recovery*** shows **the weakest retention** (50% retained, 50% fully public domain, albeit with a small n=4).

By **TRL, retention follows a maturity gradient**. The lowest-maturity group, **TRL 3**, **has the weakest retention** (**56% retained**) and the highest share of families fully in the **public domain** (**44%**), whereas **TRL 4 is the peak-retention band** (**87% retained**). **TRL 5** remains **predominantly retained** (**76%**) but shows a **higher fully public domain share** (**18%**) **than TRL 4**, consistent with selective maintenance as technologies move toward more resource-intensive development and prosecution stages. Higher TRLs (6–7) are too sparsely populated for robust inference.

Taken together, these results indicate that Portuguese Blue Bioeconomy patenting is dominated by mid-maturity (TRL 4–5) and downstream value-chain activity, with generally strong IP maintenance - especially for the 2014–2018 cohort - while attrition (families fully in the public domain) is most evident in early-stage (TRL 3) inventions and in downstream product-oriented segments, and uncertainty (indeterminate status) concentrates in more complex/less transparent legal status contexts and recent filings.



4.

STUDY LIMITATIONS

Patents as an object of study present an inherent limitation because they are generally published only 18 months after the application is filed, creating a systematic time lag that prevents the timely capture of the most recent innovations. This is most likely the reason why 2024 did not retrieve any results.

The present study employed free patent databases that are limited to their own coverage and high dependence on heterogeneous national sources with uneven reporting and latency. Other databases were used to try to mitigate the naturally occurring differences and confirm regional and national phases as accurately as possible.

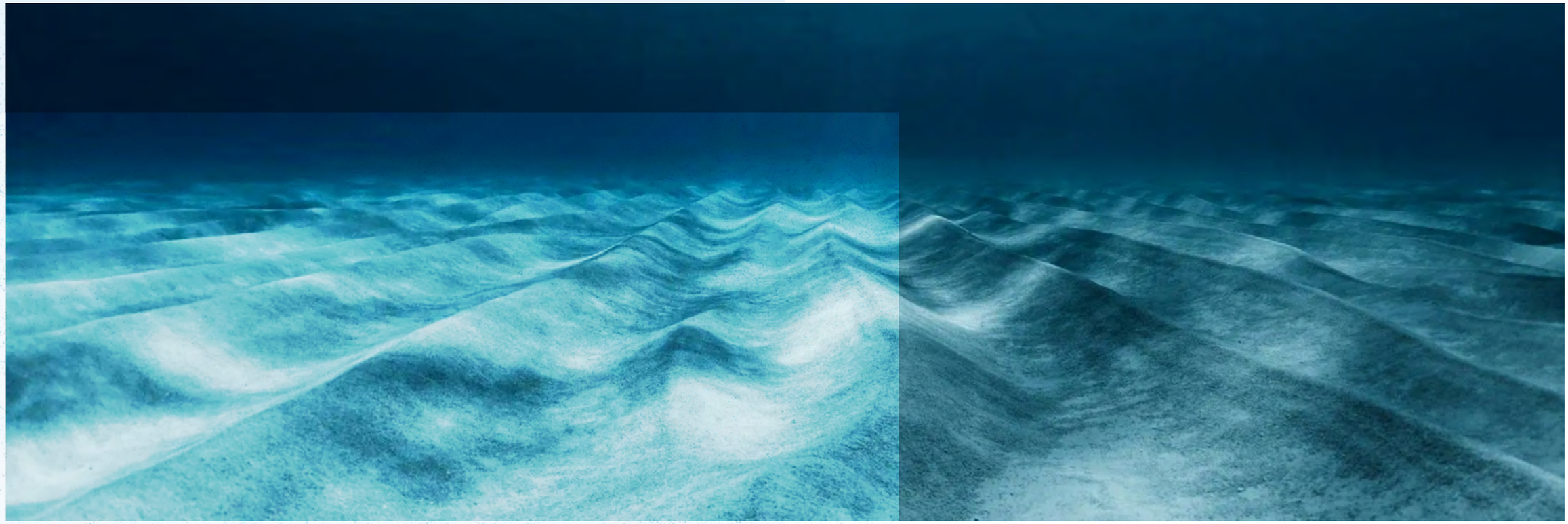
Some local patent offices do not provide online access to patent application data, which means that certain filings cannot be identified or analysed. As a result, the present study necessarily operates under conditions of partial uncertainty regarding the full set of relevant patent activities.

TRL classification solely assessed with patent applications as the sole source of information is subject to important limitations: patent documents often lack detailed evidence on performance, reliability, scale of testing, and operational context, and omit subsequent developments. As a result, the technological maturity of some inventions may be conservatively classified, and the TRL of certain patent families may be under-assessed relative to their actual stage of development.

5.

DISCUSSION AND RECOMMENDATIONS

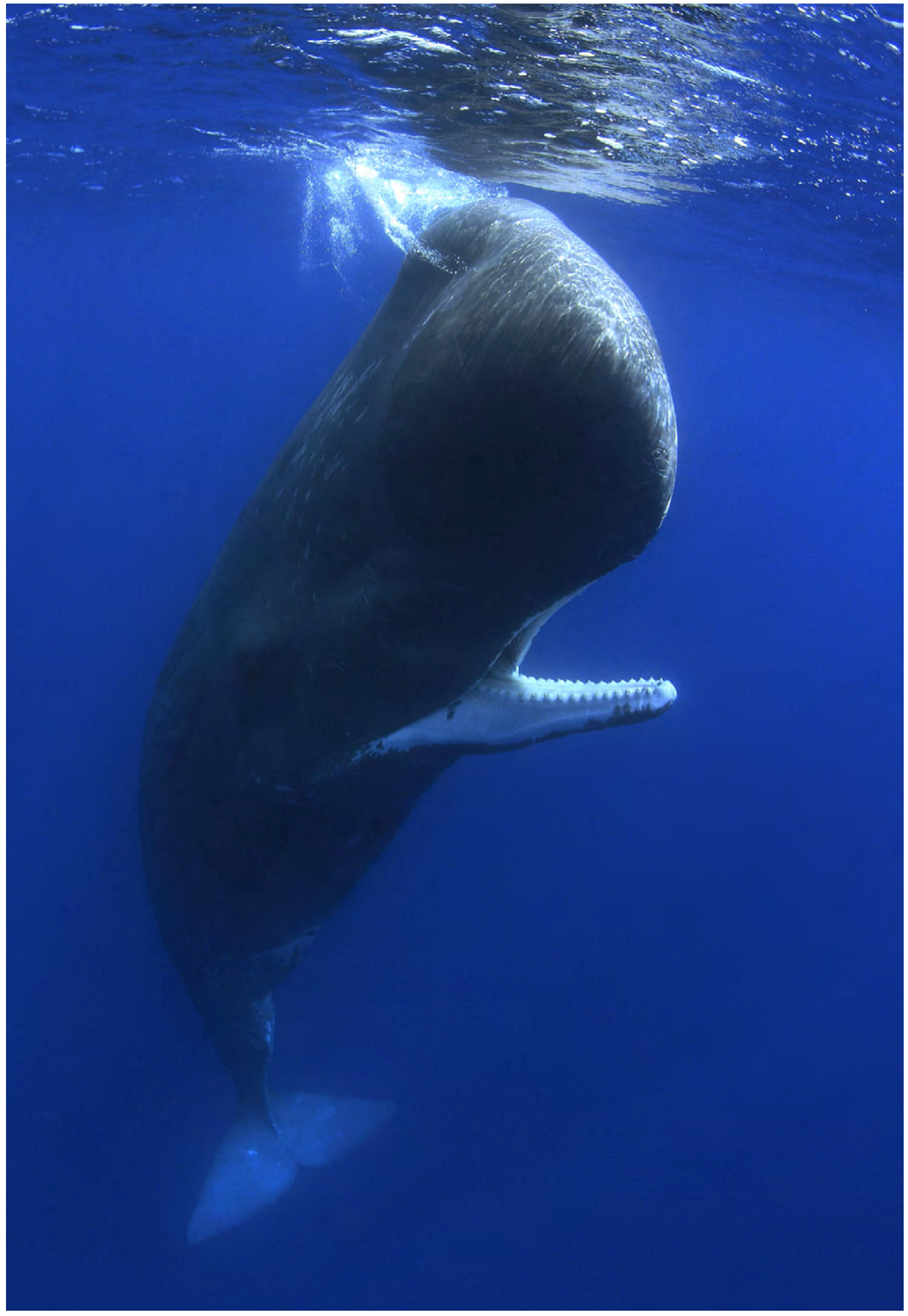
The present report **mapped Portuguese inventive activity in the Blue Bioeconomy value chain over the 2004–2024** priority window, using Portuguese-priority patent filings **as a trace of technological direction and investment intent**. The most recent search (3rd of October 2025) yielded 1 985 patent applications, of which 239 were retained as relevant and consolidated into 69 patent families. The value-chain segmentation of the patent family portfolio followed the structure proposed in the Blue Bioeconomy Roadmap for Portugal (2019)[15]. Of note that interpretation of the most recent priority years must account for procedural lags. Hence, observed zero value for 2024 most likely reflects the 18-month publication delay rather than a true absence of filings, and PCT phase timing can temporarily understate application counts for recent families.



5.1. TEMPORAL DYNAMICS AND ECOSYSTEM STRUCTURE: PIPELINE SCALE, ACCELERATION, AND ACTOR CONCENTRATION

The temporal profile indicated a transition from sporadic activity (2004–2014) to sustained expansion from 2015 onwards, peaking in 2016–2019 and remaining robust after 2020 (with 2023 showing the highest number of families, partly affected by PCT phase timing). **Despite this acceleration, the national pipeline remained relatively small and concentrated in a limited set of applicants**, suggesting that Portugal's innovation capacity is real but not yet broadly distributed across the ecosystem. This concentration is clearest in ownership patterns: Universidade do Porto and CIIMAR lead with 18 patent families each, with 13 families in co-titularity, their total portfolio represents 23 out of 69 families (approximately one-third of the dataset). At ecosystem level, public organizations account for 55% of families and private organizations for 45% (58% *vs.* 42% among national applicants only), indicating a research-driven system with meaningful, yet still secondary, private participation. **Innovation capacity is clustered** in a few hubs (Figure 13) rather than broadly distributed across the ecosystem. **Strong academic teams and established collaborations are producing patentable results, but scale-up, replication across organizations, and industrial uptake are uneven**. This matters because the biggest gains typically depend on coordinated action beyond the lab – notably access to pilots and demonstration facilities, clear regulatory/licensing pathways, and manufacturing partners able to translate validated prototypes into market-ready processes and products.

Figure 13. — Geographic distribution of Portuguese Blue Bioeconomy Innovation Hubs.



5.2. TECHNOLOGICAL POSITIONING ALONG THE VALUE CHAIN: STRENGTHS AND GAPS

Across the full dataset, inventive activity concentrated downstream in ***Secondary Processing & Novel Product Production*** (Metacategory 4). ***Health/therapeutic/dermocosmetic applications*** (Category 4.3) ***alone represent 22% of cases, followed by food & functional food products*** (Category 4.1) ***feed, additives & animal immunonutrition (***Category 4.2) and, ***advanced bio-based materials and coatings*** (Category 4.4) ***(each ~7–9%)***.

Upstream, ***Primary Production or Catch*** (Metacategory 2) remained relevant **(e.g., *aquaculture of fish, molluscs, crustacea and marine invertebrates* at 13%** (Category 2.1)**,** and ***Extraction & Conversion*** (Metacategory 3) contributed a substantive enabling layer (**e.g., *processing, extraction and conversion technologies* at 10%** (Category 3.1), ***platform delivery and engineering technologies* at 9%** (Category 3.3)). However, several capability layers are systematically thin or absent ***biological and genomic resources (biobanks)*** (Category 1.2), ***bioprospecting and characterisation of compounds*** (Category 1.3), ***algae aquaculture*** (Category 2.2), and ***energy, carbon and nutrient recovery technologies*** (Category 6.3) show no patents in the mapped set, and ***circularity categories*** (6.1 and 6.2) are collectively under-represented. **Portugal appears well positioned in downstream, higher-value applications – particularly health/dermocosmetics and materials/coatings – consistent with an EU "centre of gravity" around bio-pharma/bioproducts.** At the same time, thinner upstream discovery/supply and circularity foundations may constrain pipeline replenishment, feedstock resilience, and cost/circularity advantages that often determine competitiveness at scale.

5.3. PORTUGAL WITHIN THE EU BLUE BIOECONOMY CONTEXT

The present report results complement the 2025 EU-level analysis of bioeconomy patenting patterns[7], in which Portugal accounted for 161 (0,6%) of EU IP5 patent families within an EU27 universe of 27 610. At EU scale, bioeconomy-relevant sectors represent only 5,2% of all EU IP5 patent families over 2008–2020, with a decline from 2008–2013, stabilization from 2014–2018, and a moderate increase in 2019–2020. The long-run Compound Annual Growth Rate (CAGR) was slightly more negative for bioeconomy (–0,8%) than for non-bioeconomy patents (–0,4%), reversing in the last five years (+0,8% vs –0,7%). Macroeconomic monitoring further shows marine living resources as a major pillar of the EU blue economy (e.g., €37,9 billion gross value added (GVA) and €209,4 billion turnover in 2022), while blue biotechnology remains smaller but economically visible (€327 million GVA and €942 million turnover in 2022)[16]. **Portugal's downstream concentration in higher-value applications is coherent with EU-wide narratives of where economic value and technological gravity currently sit, while also reinforcing that scaling and translation constraints – rather than invention alone – are likely decisive for competitiveness.**

16 – European Commission (2025). The EU Blue Economy Report. 2025. Publications Office of the European Union. Luxembourg.

5.4. NATIONAL POLICY IMPACT

Portugal has supported the Blue Economy since the early 2000s (e.g., the National Strategy for the Sea 2006–2016[1]). However, a more explicit and consolidated policy cycle focused on the Blue Bioeconomy has only emerged more recently, notably through the National Strategy for the Sea 2021–2030[2] (AI4), the Action Plan under Council of Ministers Resolution no. 120/2021[3], and the PRR-funded Blue Bioeconomy Pact[4].

These policy instruments clearly prioritise industrialisation, technological scale-up, and market creation. Nevertheless, most measures remain in early stages of implementation. For this reason, the 2004–2024 patent portfolio should be interpreted cautiously and within the appropriate timing and policy context. Even so, the **dataset suggests that a mid-level technological maturity pipeline was already consolidating before 2021 - particularly between 2015 and 2020 -indicating that Portugal's scientific and technological base had been strengthening progressively ahead of the current policy cycle.**

By contrast, the relatively incipient context observed for 2021–2024 - when outputs at higher readiness levels (e.g., commercialised products or industrialised processes) might be expected - likely reflects (i) the time-to-impact typical of structurally oriented, recently launched policies, and (ii) patent-related time lags, since delays between filing and publication can under-represent the most recent years.

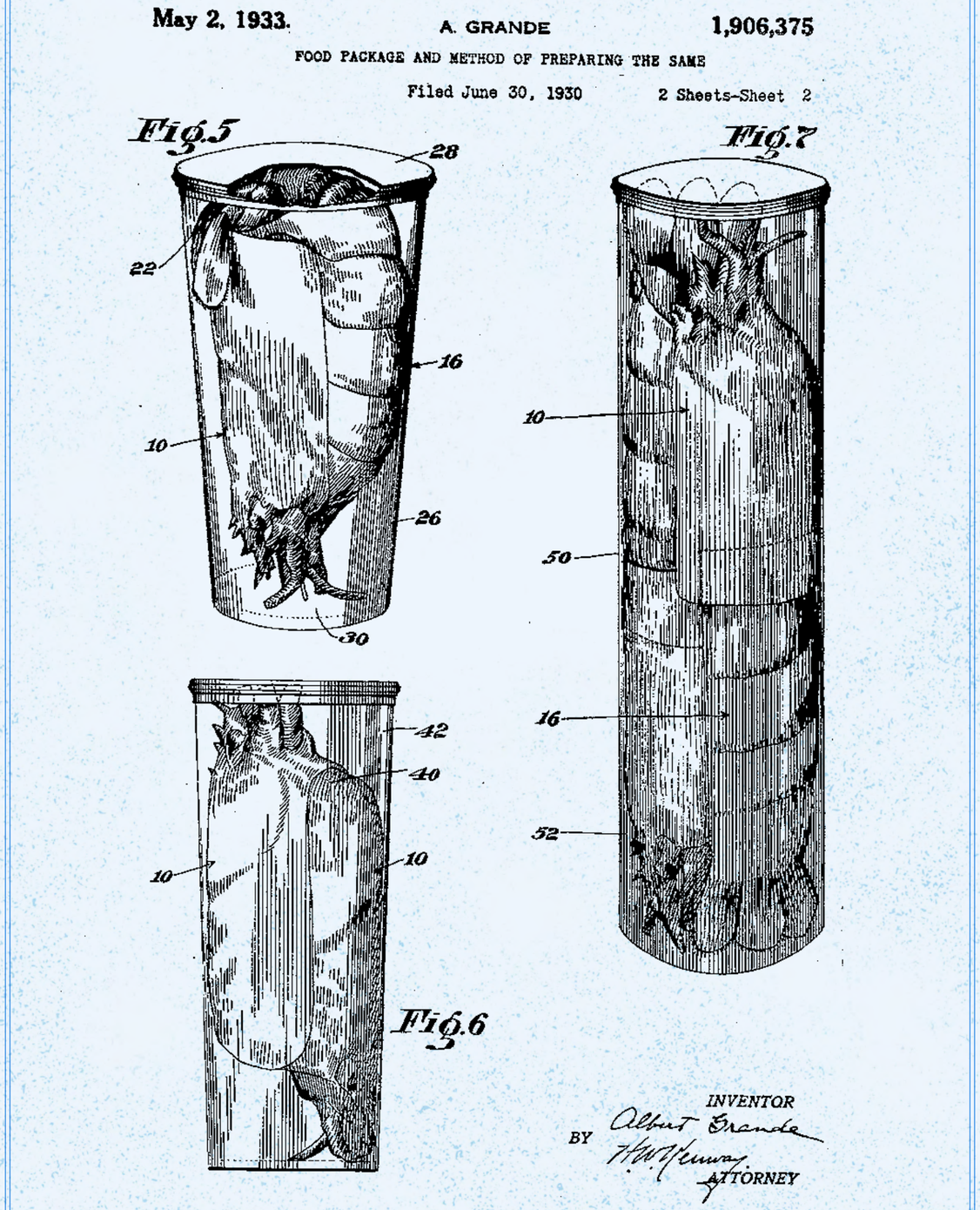
Taken together, this policy and timing context is consistent with the study's maturity profile: the portfolio is heavily concentrated at TRL 4–5, while higher-TRL outputs remain scarce. The following section analyses this TRL distribution as a central empirical signal of where the national innovation pipeline is currently accumulating and where progression constraints appear most pronounced.

5.5. TECHNOLOGY MATURITY AND THE TRL 5 TRANSITION TO TRL 6/7 BOTTLENECK

The TRL distribution reinforces the timing dynamics discussed in Section 5.4. While **recent policy instruments emphasise downstream industrialisation and market uptake, the evidence from the patent portfolio indicates that most inventions are still clustered at intermediate readiness levels** - suggesting that the system is strong in proof-of-concept and technical validation, but less effective in enabling demonstration and deployment outcomes within the period captured by this study. A central finding is the strong concentration of inventions at intermediate readiness levels, with **TRL 5 accounting for 47,8% and TRL 4 for 33,3%** of the sample. Smaller shares are observed at **TRL 3 (13%),** and only marginal representation appears at higher readiness levels **(TRL 6: 4,3%, TRL 7: 1,4%). This pattern is indicative of an innovation system that performs well in laboratory-to-pilot validation, yet faces a pronounced "valley of death" when transitioning from validation (TRL 4–5) to full demonstration and market deployment (TRL 6–7).** Similar dynamics have been highlighted in prior sector assessments, including the Blue Bioeconomy Roadmap for Portugal (2019)[15] and EUMOFA (2023)[17].

These maturity signals should nonetheless be interpreted with caution. TRL assignment based solely on patent documents can under-represent real-world validation, as patent texts often omit operational context, performance data, or subsequent development stages. Even with this caveat, the observed concentration at TRL 4–5 is sufficiently pronounced to justify a strategic emphasis on bridging mechanisms that enable downstream progression, rather than focusing predominantly on upstream R&D.

The binding constraints appear to be concentrated in: access to pilot and demonstration infrastructure, permitting and licensing procedures, regulatory compliance and quality evidence generation, and scale-up financing. **Overall, the pattern suggests that the main barriers to innovation progression are structural and institutional, rather than primarily related to idea generation or early-stage technological capability.**



17 – European Market Observatory for Fisheries and Aquaculture Products (EUMOFA). (2023). *Blue Bioeconomy Report 2023.* Publications Office of the European Union. ISBN 9789276600879. https://doi.org/10.2771/223072

5.6. INTERNATIONALISATION AS A MARKET-INTENT SIGNAL (AND ITS CONSTRAINTS)

Despite the Portuguese-priority focus of the present study, protection was frequently pursued via PCT (52 applications) and EP (46), with the United States (25) and China (13) as key national targets**. This pattern signals international market orientation and competitive intent for at least a subset of inventions.** In the Portuguese context, applicants are generally required to route PCT and EP applications initially through the national office (INPI), which shapes the timing, drafting robustness, and execution of subsequent prosecution steps, without preventing internationalisation. This outward strategy aligns with WIPO's global context: worldwide patent applications reached 3,7 million in 2024 (+4,9%)[18], Europe's share declined from 12,9% (2014) to 9,7% (2024), and patent family data exhibit multi-year lags, with most families filed at a single office. **Multi-office strategies are thus selective and typically associated with higher-value commercial intent. Internationalisation preserves market optionality but elevates capability requirements: prosecution strategy, portfolio triage, freedom-to-operate (FTO) assessment, partnering/licensing pathways, translation financing, and coordination with publications and pilot activities become decisive complements to scientific excellence.** Early and robust first filings are central to cost control, strategic alignment, and successful progression from validated prototypes to investable demonstrations.

18 – World Intellectual Property Organization (WIPO) (2025). *World Intellectual Property Indicators 2025*. Geneva: WIPO. DOI: 10.34667/tind.58959

5.7. LEGAL STATUS, IP RETENTION, AND WHAT IT IMPLIES FOR TRANSLATION DYNAMICS

A related and decision-relevant indicator is patent application legal status. Among applications quantified for legal status, **28,9% were already in the public domain, 27,6% were still pending, 20,5% were active, and 3,3% were unknown**. Notably, **none of the public domain cases reflected natural term expiry. Rather, they correspond to withdrawal, refusal or lapse before full term, suggesting discontinuities in prosecution effort and/or commercial pull**.

When legal status is read through the TRL lens, the translation signal becomes sharper. Early-stage (TRL 3) developments show the weakest retention and a high share of public domain outcomes, whereas protection concentrates most strongly in TRL 4–5 technologies (laboratory validation and relevant-environment validation). Importantly, the few highest-TRL observations did not translate into robust enforceable protection, since the single TRL 7 family was already entirely in the public domain. The report's family-level retention analysis (Retained *vs.* Fully Public domain *vs.* Indeterminate) reinforces this selective-continuation pattern.

Retention rises strongly in the 2014–2018 cohort (84%) and remains high in 2019–2023 (73%), but fully public domain families increase again in the most recent cohort (21%), consistent with volatility and incomplete visibility in newer cases. By metacategory, value chain downstream segments account for the largest absolute number of fully public domain families (a "selection" dynamic in product-facing innovation), while circularity shows the weakest retention (albeit with small number). Legal status and retention patterns jointly suggest a two-track reality: (i) a subset of inventions is actively maintained (pending/active), plausibly representing higher perceived commercial value, and (ii) a substantial open-knowledge reservoir is being created through lapse/withdrawal, particularly in earlier-stage and some downstream segments. This open reservoir can be strategically valuable, especially for SMEs and applied pilots, if systematically curated and connected to industrial needs, while also signalling where execution capacity (prosecution funding, partnering, development finance) may be fragile.

5.8. RECOMMENDATIONS FOR POLICY AND STRATEGY (DUAL-TRACK, BOTTLENECK-FOCUSED)

An integrated set of recommendations focused on critical bottlenecks (see Table 10), combining structural interventions across the innovation value chain with operational actions targeted at the main blockage points identified in this report. The strategic framework recognises that national competitiveness in Blue Biotechnology simultaneously depends on the ability to advance promising technologies toward the market, improve intellectual property management and valorisation, and transform systemic weaknesses - such as upstream gaps and geographic concentration - into strategic assets. Accordingly, the proposed recommendation framework articulates measures aligned with **public policy priorities**, **funding instruments**, **institutional capacity building**, and **ecosystem governance**, aiming to maximise economic impact, resilience, and sustainability by 2030.

Table 10. — Strategic Action Framework for Innovation and IP.

Action Strategy		Focused on	Details of Action Strategy
R1	Bridge TRL 5 Transition to TRL 6/7 (primary competitiveness bottleneck)	Systemic bottleneck where technologies fail to progress due to lack of pilot infrastructure, regulatory readiness, and scale-up finance. **Conclusion:** without targeted intervention at this interface, portfolio growth will continue to stall before market entry, limiting economic impact.	Prioritise: ▪ Shared pilot and demonstration infrastructure. ▪ Structured regulatory and permitting support. ▪ Co-investment and scale-up finance instruments to de-risk first industrial deployment
R2	Professionalise portfolio triage and prosecution for "retained" families	Weak execution capacity in IP management and international valorisation. Need to strengthen positioning in biopharma niches where Portugal can differentiate, demonstrate value, and scale. **Conclusion:** success depends on coordinated support across IP strategy, regulation and partnering.	Build national capacity for: ▪ Prosecution strategy, ▪ Maintenance decisions, ▪ Regulatory and quality evidence planning, ▪ Partnering and licensing strategies, ▪ Special focus on internationally targeted families (PCT/EP/US/CN).
R3	Convert public domain attrition into a structured innovation asset	High share of patent families already in the public domain. **Conclusion:** attrition should be treated as an opportunity (FTO reuse), not as failure.	Establish a curated Portuguese Public Domain Toolbox: ▪ FTO-screened technology shortlists by value-chain need ▪ Technical translation notes for SMEs and pilot users ▪ Matchmaking with testbeds and public procurement challenges ▪ Dual-track IP strategy to enable follow-on innovation
R4	Close strategic gaps upstream and in circularity	Strategic gaps persist in upstream and circular domains (Biodiversity & Bioprospecting, Primary Production or Catch (algae aquaculture). Circularity & resource recovery. **Conclusion:** these gaps limit diversification, resilience and pipeline replenishment.	Launch targeted programmes for: ▪ Biological and genomic resources (biobanks) ▪ Bioprospecting and characterisation of compounds ▪ Algae aquaculture ▪ Energy, carbon and nutrient recovery technologies ▪ Diversify the pipeline, reduce dependency on a narrow downstream portfolio and strengthen system-level competitiveness (supply security, sustainability, cost efficiency).
R5	Reinforce ecosystem	Strong geographic concentration: ~1/3 of patent families in a single hub. **Conclusion:** structural concentration limits territorial diffusion and creates systemic risk.	Reduce systemic risk by: ▪ Enabling additional regional consortia, ▪ Supporting industry-anchored innovation platforms, ▪ Replicating success patterns from leading institutions ▪ Expanding national absorption capacity
R6	Use legal status and retention as operational monitoring indicators to 2030	Lack of systemic performance tracking across the innovation pipeline. **Conclusion:** legal status and TRL shifts should be used as management indicators.	Implement a continuous monitoring of: ▪ Patent family formation by cohort ▪ Retained vs. lapsed share ▪ TRL distribution shifts ▪ Value-chain balance ▪ Public domain inflows as a managed resource

APPENDIX

APPENDIX 01.

IPC AND CPC USED IN THE PATENT SEARCH AND RESPECTIVE TARGETED TECHNOLOGICAL FIELDS

IPC symbol	Title and description	Target Technological Field
A01K	Animal husbandry; Aviculture; Apiculture; Pisciculture; Fishing; Rearing or breeding animals, not otherwise provided for; New breeds of animals.	Fisheries and aquaculture operations (fish, bivalves, crustaceans); Fishing practices.
A01G	Horticulture; Cultivation of vegetables, flowers, rice, fruit, vines, hops or seaweed; Forestry; Watering (picking of fruits, vegetables, hops or the like A01D46/00; Propagating unicellular algae C12N1/12).	Seaweed/macroalgae cultivation; Integrated aquaculture–hydroponics (IMTA); Marine plant cultivation.
A01H	New plants or processes for obtaining them; plant reproduction by tissue culture techniques.	New marine algae/fungi strains and tissue-culture methods (non-GMO).
A01N	Preservation of bodies of humans or animals or plants or parts thereof (preservation of food or foodstuff A23); Biocides, e.g., as disinfectants, as pesticides or as herbicides (preparations for medical, dental or toiletry purposes which kill or prevent the growth or proliferation of unwanted organisms A61K); Pest repellents or attractants; Plant growth regulators.	Biocide/preservation compositions using marine-derived compounds.
A22C	Processing meat, poultry, or fish (preserving A23B, obtaining protein compositions for foodstuffs A23J1/00; Fish, meat or poultry preparations A23L; Disintegrating, e.g., chopping meat, B02C18/00; Preparation of proteins C07K1/00).	Fish and shellfish processing technologies.
A23B	Preservation of foods, foodstuffs or non-alcoholic beverages; Chemical ripening of fruit or vegetables.	Preservation of seafood and aquaculture products and derivatives.
A23L	Foods, foodstuffs or non-alcoholic beverages, not otherwise provided for; Preparation or treatment thereof (preservation thereof A23B).	Marine-origin foods, ingredients and processing (incl. nutrition/functional modifications).
A23K	Feeding-stuffs specially adapted for animals; Methods specially adapted for production thereof.	Aquafeeds and premixes for aquatic species.
A23P	Shaping or working of foodstuffs, not fully covered by a single other subclass.	Forming/structuring of marine-origin food products
A61K	Preparations for medical, dental or toiletry purposes (devices or methods specially adapted for bringing pharmaceutical products into physical or administering forms A61J3/00; Chemical aspects of, or use of materials for deodorisation of air, for disinfection or sterilisation, or for bandages, dressings, absorbent pads or surgical articles A61L; soap compositions C11D).	Pharmaceuticals/cosmeceuticals using marine-derived compounds.

IPC symbol	Title and description	Target Technological Field
A61P	Specific therapeutic activity of chemical compounds or medicinal preparations.	Therapeutic indications of marine-derived actives.
A61Q	Specific use of cosmetics or similar toiletry preparations.	Cosmetic uses of marine-derived ingredients.
C02F	Treatment of water, waste water, sewage, or sludge (processes for making harmful chemical substances harmless, or less harmful, by effecting a chemical change in the substances A62D 3/00; Separation, settling tanks or filter devices B01D; Special arrangements on waterborne vessels of installations for treating water, waste water or sewage, e.g., for producing fresh water, B63J; Adding materials to water to prevent corrosion C23F; Treating radioactively-contaminated liquids G21F 9/04)	Water/wastewater treatment in aquaculture, seafood processing and feed production.
C07K	PEPTIDES (peptides containing β-lactam rings C07D; cyclic dipeptides not having in their molecule any other peptide link than those which form their ring, e.g., piperazine-2,5-diones, C07D; ergot alkaloids of the cyclic peptide type C07D 519/02; single cell proteins, enzymes C12N; genetic engineering processes for obtaining peptides C12N 15/00).	Marine-origin peptides and peptide compositions.
C08F	Macromolecular compounds obtained by reactions only involving carbon-to-carbon unsaturated bonds (production of liquid hydrocarbon mixtures from lower carbon number hydrocarbons, e.g., by oligomerisation, C10G 50/00; fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture C12P; graft polymerisation of monomers containing carbon-to-carbon unsaturated bonds on to fibres, threads, yarns, fabrics or fibrous goods made from such materials D06M 14/00).	Marine-derived polymers/monomers and related syntheses.
C08G	Macromolecular compounds obtained otherwise than by reactions only involving carbon-to-carbon unsaturated bonds (fermentation or enzyme-using processes to synthesize a desired chemical compound or composition or to separate optical isomers from a racemic mixture C12P).	Marine-derived polymers via alternative syntheses.
C09D	Coating compositions, e.g., paints, varnishes or lacquers; filling pastes; Chemical paint or ink removers; Inks; correcting fluids; Wood stains; Pastes or solids for colouring or printing; Use of materials therefor (cosmetics A61K; processes for applying liquids or other fluent materials to surfaces, in general, B05D; staining wood B27K 5/02; glazes or vitreous enamels C03C; natural resins, French polish, drying-oils, driers, turpentine, per se, C09F; polishing compositions other than French polish, ski waxes C09G; adhesives or use of materials as adhesives C09J; materials for sealing or packing joints or covers C09K 3/10; materials for stopping leaks C09K 3/12; processes for the electrolytic or electrophoretic production of coatings C25D).	Marine-derived coatings: antifouling, barrier and protective systems.
C11	Animal or vegetable oils, fats, fatty substances or waxes; fatty acids therefrom; Detergents; Candles.	Marine oils, fats and derivatives (e.g., omega-3).

IPC symbol	Title and description	Target Technological Field
C12N	Microorganisms or enzymes; compositions thereof; propagating, preserving, or maintaining microorganisms; mutation or genetic engineering; culture media (microbiological testing media C12Q1/00).	Marine biotechnology: microbes/enzymes, strains and culture systems.
C12P	Fermentation or enzyme-using processes to synthesise a desired chemical compound or composition or to separate optical isomers from a racemic mixture.	Marine-origin bioprocesses (fermentation/enzymatic synthesis).
C12Q	Measuring or testing processes involving enzymes, nucleic acids or microorganisms (immunoassay G01N33/53); Compositions or test papers therefor; Processes of preparing such compositions; Condition-responsive control in microbiological or enzymological processes.	Assays and analytics for marine microbes/enzymes/nucleic acids.
G06	Computing or calculating; counting.	Digital/AI applications in fisheries, aquaculture and seafood processing.

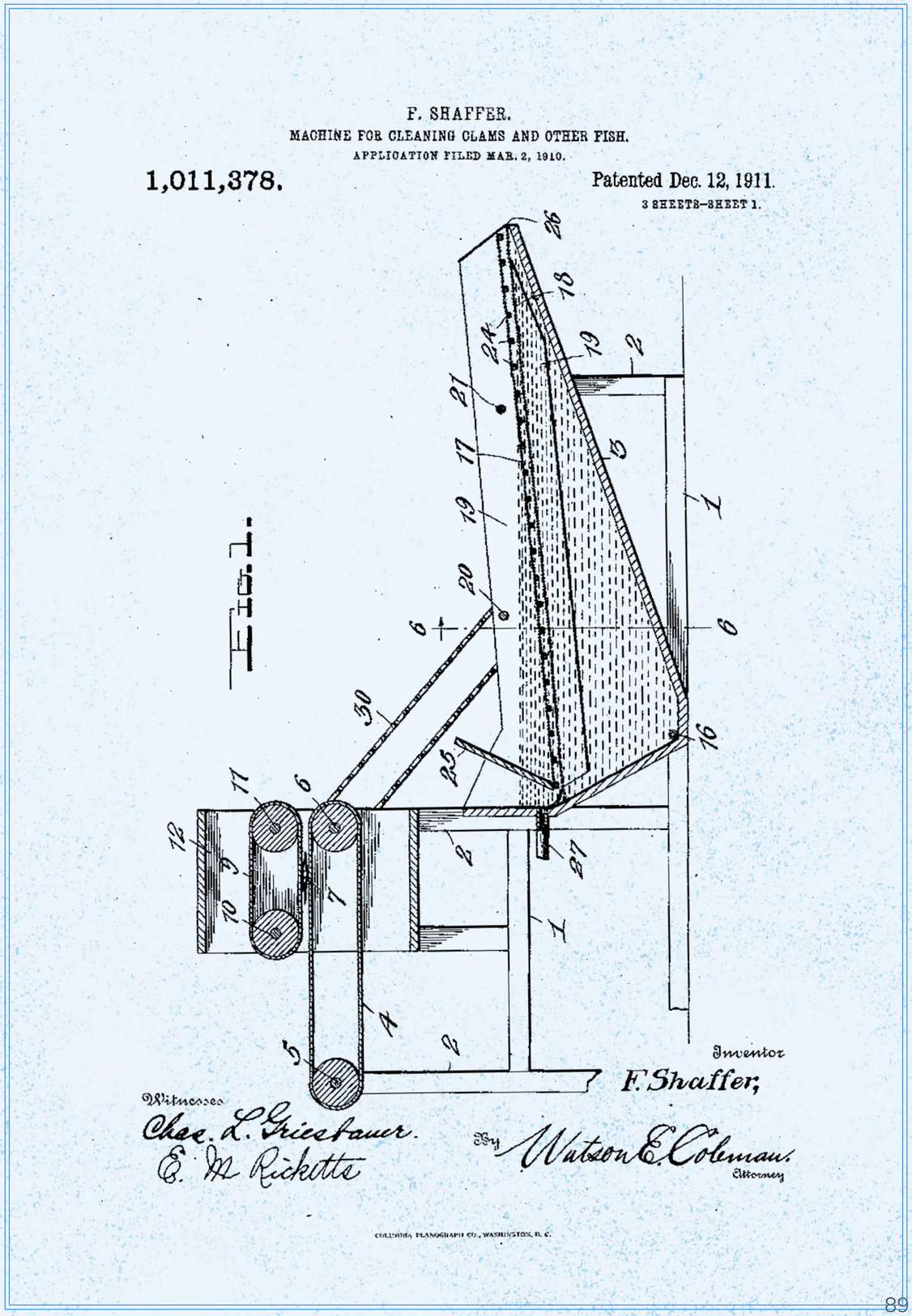
CPC symbol	Title and description	Target Technological Field
Y02A	Technologies for adaptation to climate change.	Climate-adaptation technologies for fisheries, aquaculture and seafood processing
Y02P	Climate change mitigation technologies in the production or processing of goods.	Low-carbon/energy-efficient production in fisheries, aquaculture and seafood processing.
Y02W	Climate change mitigation technologies related to wastewater treatment or waste management.	Wastewater and waste-management mitigation in aquaculture and marine-product processing.

19 – https://worldwide.espacenet.com/classification

APPENDIX 02.

BLUE BIOECONOMY PORTUGUESE DATABASE

Access Database > here


F. SHAFFER.
MACHINE FOR CLEANING CLAMS AND OTHER FISH.
APPLICATION FILED MAR. 2, 1910.

1,011,378. Patented Dec. 12, 1911.

3 SHEETS-SHEET 1.

FIG. 1.

Witnesses
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APPENDIX 03.

TRL CLASSIFICATION

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
1	16/12/2022	Composition to Improve Salt Tolerance in a Plant or Algae and Methods of Production Thereof	4	TRL 4 - The experiments were conducted in a controlled laboratory environment with genetic modifications in Arabidopsis. Knockout plants (AtSEA1) have shown improved salt tolerance under controlled conditions.	"[0047] In an embodiment, it is disclosed the use of a composition that allows to improve a tolerance of a plant to an abiotic stress, in particular high salt concentrations, as compared to a wild-type control plant. It is shown that a nucleotide sequence comprising at least a sequence 90% identical to the sequences (…), or combinations thereof was involved in the above-mentioned characteristic of the plant. In addition, where the expression of said nucleotide sequences was inhibited, genetically modified plants having improved tolerance to a salt stress condition were obtained". **(page 7 and 8)**
2	02/07/2007	Hyperbaric System for the Long-Term Study and Conservation of Intermediate and Deep-Depth Aquatic Organisms	7	TRL 7 - The system is demonstrated in an operational environment, showing that it works in practical settings with minimal supervision. Status for your system: This is where the system currently stands. The prototype has been demonstrated in an operational setting where the system operates autonomously for extended periods (15 days). The operation doesn't require user intervention, and the system meets the operational goals, such as maintaining pressure and water quality.	"A prototype of the system has already been built, with the hyperbaric chamber made of stainless steel, which made it possible to study marine organisms (…) under controlled hydrostatic pressure conditions for 15 days. Operating modes with constant hydrostatic pressures as well as pressure cycles were studied. The maximum hydrostatic pressure that this system can reach is 8 bar (0.8 MPa)."**(page 10 and 11)**
3	23/06/2008	System to Catch Fish and the Respective Method of Use	4	TRL 4 - The patent includes detailed designs for the bubble-making chambers, the mechanism for controlling depth, and fish-catching functionality. While it is unclear whether all components have been integrated into a complete prototype and tested in a controlled setting, the patent suggests the system has passed basic lab validation with the development of specific components (e.g., the compressor, suction pump, and floating tubes).	Detailed description of a preferred embodiment - **paragraphs 51 until 56, page 9 until 10.**
4	31/05/2016	Submersible feeding, control and command platform	3	TRL 3 - The patent provides detailed system designs (including auger screw conveyors, ballasting systems, and the mooring arrangement). However, it's not clear from the patent whether these components have been tested in a lab or pilot environment. It is likely in the design and conceptual phase, so critical components have been validated at a theoretical level.	Detailed description of a preferred embodiment - **page 5 until 11.** "[5] The equipment's housed in the cabins are intended to drive the operating routines of the platfom1, both at the surface and in submersion, namely the ration 5 distribution to the outside of the platform. the collection and treatment of production parameters, and to allow command interventions that overlap to the established routines, whenever the operator, installed in the company's office, so deems it to be necessary, in dialogue, via radio, with the computer system installed on the platform. The routine processing system installed in a cabin (3 l) is not the object of the present invention". **(page 10)**
5	27/06/2023	Monitoring Device for a Marine Animal	3	TRL 3 - The patent describes the functionality of the device in detail, outlining the sensors, positioning system, and other components. However, it is not clear from the patent whether these components have been validated through experimentation. Therefore, while the critical functions are described, there is no clear evidence of a successful proof-of-concept demonstration yet.	"[0027] Figure 1 shows a schematic representation, in a longitudinal cut, of an embodiment of a monitoring device for a marine animal, where: 101 represents a battery, 103 represents an electronic board, 105 represents low density foam, 107 represents a satellite geolocation module, 109 represents an oxygen sensor, 111 represents a coil for inductive charging, and 113 represents an epoxy-filled chamber" **(page 5)**
6	22/11/2004	Multipurpose Trap´s Element, corresponding Fish Trap and Manufacture, Assembly, and Fishing Method Therefor	3	TRL 3 - The design and structure of the trap, including its method of manufacturing (injection molding of plastic), are well-defined, but there is no mention of a prototype or experimental testing in the patent. Critical functions such as the opening/closing mechanism and ease of assembly are described conceptually but not validated through experiments.	Detailed description of a preferred embodiment - **paragraph 36 until 47, page 9.**
7	08/07/2016	Submerged Cage for Flat Fish	3	TRL 3 - The functional characteristics of the cage, such as its ability to submerge and emerge based on water or air filling, and its mooring system, are outlined. However, no experimental or analytical tests of the system in real-world conditions are mentioned, so while the concept is clear, there is no proof of concept yet demonstrated.	Detailed description of a preferred embodiment - **page 7 until page 8.**
8	27/04/2006	Foldable Fish Trap	3	TRL 3 - The critical functions of the fish trap, including its foldable frame, buoyancy system, and adjustable nets, are detailed. However, no specific experimental testing or proof of concept is provided in the patent. The design suggests it works as intended, but it has not been demonstrated experimentally in real-world conditions.	Detailed description of a preferred embodiment- **paragraph 8 until 17, page 10.**
9	25/06/2019	System and Process of Modulating Nutritional Supplementation in Fish for Improving Growth Rate by Using Low-Frequency Ultrasounds	4	TRL 4 - The system has undergone testing in laboratory settings, as indicated by the results shown for zebrafish and gilthead seabream. Experimental results are provided, demonstrating that the system can improve the incorporation of bioactive compounds into fish eggs, with some trials showing statistical differences in growth rates and digestive efficiency. However, additional testing in more controlled environments would be needed to further validate the components.	Detailed description of a preferred embodiment – **paragraphs 49 until 59, page 5.**
10	13/04/2017	Autonomous Aquaculture Fish Feeding System and Operation Method Thereof	4	TRL 4 - The system's components, including sensors for temperature and salinity, are described, and the predictive model has been tested in trials, but laboratory or pilot-scale validation of the entire system (including the autonomous vessel) in controlled environments is not explicitly detailed in the patent. The system is theoretically sound but not fully validated in lab settings.	"[0076] The model was putted under trial and the results indicated that the model was capable of predicting the ration consumption of the D. labrax according to the oscillations in the water temperature and salinity. The predictions ranged from 0.7 to 1.71 g of ration per fish/day. The model also revealed that D. labrax increases its ration consumption in different rates according to the water temperature and salinity, with a slight increase in colder temperatures and a significant rise at warmer waters, leading to a consumption of 26.6 g of ration in 30 days at 21 Q (and 28 psu (Figure 2) "**(page 19).**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
11	30/06/2015	Method and System for Measuring Biomass Volume and Weight of a Fish Farming Tank	6	TRL 6 - The system has been demonstrated in a relevant environment (aquaculture tanks), where it was used to estimate biomass in real-time. The system's prototype has been tested in actual aquaculture settings, but further development is needed to refine its accuracy and efficiency, particularly in large-scale fish farms.	"[0080] For proof concept our system was tested in laboratory experiments, and in these tests we use two different types of fish: flounder and turbot. In laboratory experiments, the results show that our approach has a maximum 8% of relative error in estimating the biomass weight. The fish farming calibration system was also experimented in a live indoor aquaculture farming industry and the results show that our approach has about 15% error in overall biomass weight in real aquaculture environment."**(page 17)**
12	19/05/2020	Underwater Device for Submersible Artificial Fish Habitat and Use Thereof	3	TRL 3 - The patent describes the device in detail, including how the mesh panels and pipe structures simulate natural fish habitats, but no direct experimental data or proof of concept in operational environments is presented. The device's components (circular bodies, mesh panels, support frames) and structure are clearly described, but further validation through experimental testing is not mentioned.	Detailed description of a preferred embodiment - **paragraphs 35 until 45, page 4 and 5.**
13	09/03/2017	Device and Process for Fixation of Larvae and Growth of Juveniles of the Stalked Barnacle Pollicipes Pollicipes	4	TRL 4 - The technology has been validated in laboratory conditions, where it was demonstrated that the device can effectively support larval attachment and juvenile growth. Laboratory trials confirm that the device works as intended in controlled environments. Example: Laboratory tests that show the device's effectiveness in encouraging larval attachment and supporting juvenile growth, with successful development through metamorphosis.	Detailed description of a preferred embodiment - **paragraphs 13 until 34, page 3 and 4**.
14	16/04/2016	A System for Measuring Fish using a Camera and a Structured Light Projector	4	TRL 4 - While the system is described with the necessary components and the process is outlined, there is no mention of a specific laboratory validation or pilot testing. The system's components, such as the projector and camera setup, appear to be ready for validation, but the patent does not provide specific laboratory results or tests confirming their effectiveness in measuring fish.	"Description of figures: Figure 1 shows the different components that comprise the apparatus for obtaining fish measurements. Detailed description: The present invention consists of a method and apparatus for measuring fish. In the preferred configuration of this invention, the method uses a structured infrared light projector (101), an infrared light detecting camera (100), whose observed scene is centred on an ideally planar fish support surface (106), which may be, for example, a scale or a conveyor belt." (Translated from Portuguese **(page 7)**
15	28/07/2023	Polymeric Material for Aquaculture, Production Method and Uses Thereof	6	TRL 6 - The system has been demonstrated in an operational aquaculture environment, specifically in a pilot RAS system with sea bass. This trial confirms that the biodegradable material works effectively in a real-world aquaculture setting, demonstrating its functionality in controlling microbial growth, improving water quality, and supporting fish health in a controlled environment.	"Figure 3: Representation of the mean ± standard deviation (n=4) of survival (%) of sea bass in a pilot system in aquaculture. CTRL: Cultivation in standard system without the addition of porous polymeric mesh. EB: Cultivation in a standard system with the addition of 0.229 g/L of porous polymeric mesh with crude EB extract. SH: Cultivation in standard system with the addition of 0.229 g/L of porous polymeric mesh with powdered HS. MIX: Cultivation in a standard system with the addition of 0.115 g/L of porous polymeric mesh with crude EB extract and 0.115 g/L of porous polymeric mesh with powdered HS".**(page 7)**
16	23/02/2023	Cyanobacteria and Microalgae Plant Biostimulants	4	TRL 4 - The consortium of microorganisms is further characterized using techniques like DNA sequencing and light microscopy. The experimental setup, including hydroponic systems, is used to test the biostimulant's effectiveness on plants. Validation through lab-scale experiments matches TRL 4.	"To establish a consortium that benefits plant growth and/or improve soil characteristics, an initial screening in Petri dishes was performed using exudates from the isolated microorganisms and the isolates selected to integrate the consortium were further characterized by a polyphasic approach. To assess the effects on growth of plant species, as an example two representatives of the Mediterranean flora, Arabidopsis thaliana and Loli um mul tiflorum were tested."**(page 3)** "In terms of the effect of the selected microorganisms' as consortium on plant growth, the six microorganisms selected and characterized were grown independently and then combined according to Table I to be tested as a consortium on plant growth. For this purpose, A. thaliana and L. multiflorum were grown in hydroponic systems, for one month, with nutritive medium (control) or nutritive medium supplemented with the microorganisms' consortium and several biometric and biochemical parameters were evaluated."**(page 6 and 7)**
17	17/12/2018	Xanthonic Compounds and Their Use and Antifouling Agents	5	TRL 5 - The patent details the use of xanthonic compounds in real-world relevant environments, such as marine coatings and leaching tests, suggesting the validation in an operational environment. However, these applications are still at the early stages of field testing.	"1.5 Incorporation of xanthonic antifoulants in marine coatings". **(page 11 and 12)**
18	11/05/2021	Disinfectant Solution Comprising Alcohol and Chitosan	4	TRL 4 - The solution has undergone laboratory testing on various surfaces (e.g., aluminum, plastic, steel) with promising results in terms of both immediate and prolonged antimicrobial activity. The composition is tested against viruses (like HAdV-5), bacteria (like E. coli), and fungi (like Candida albicans), showing effective log reduction. The technology is validated within a controlled environment with reproducible results.	"Example 2 until 6"**(page 8 until 20)**
19	08/03/2018	Uses of Cyanobacterium Extracellular Polymer, Compositions, Coated, Surfaces or Articles	4	TRL 4 - The polymer's anti-adhesive performance has been validated through various in vitro assays (e.g., bacterial adhesion tests, SEM imaging, platelet adhesion studies). The technology is being evaluated under controlled lab conditions, including testing against a range of pathogens and medical materials.	Detailed description of a preferred embodiment – **paragraphs 62 until 74, page 8 until 2**
20	27/04/2018	Edible Food Conditioning Film and Its Manufacturing Process	4	TRL 4 - The formulation for the edible food conditioning film, including the mixing of the seaweed fractions, alginate, glycerol, and water, has been validated in a controlled laboratory setting. Testing shows that the film can act as a protective barrier against oxidation and water loss in food products like fish.	"(0010) It is now important to detail all the processes that gave rise to this innovation, from the production of ethanolic and hydroethanolic fractions to the production of active edible packages and the application of active and biodegradable food packaging in the preservation of frozen fish. **(page 3).** "[0022] It is now necessary to discriminate the steps of transforming the film and its application in foods as active edible packaging, the main function of the present invention, these being the following steps: 1. cutting the film with the necessary measures for the final packaging; 2. applying the film to the food matrix previously frozen or at the time of freezing thereof in order to cover the whole exposed area of the food matrix; 3. rapid freezing of the packaging/food matrix package; 4. Low temperature storage. [0023] With the last step described above it is then possible to preserve frozen fish using an active and biodegradable food packaging.**(page 4)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
21	20/02/2019	Method for Producing and Edible Substance from Halophytc Plants, Use of and System for Corresponding Edidle Products	4	TRL 4 – The process of dehydration and grinding of Salicornia ramosissima into an edible salty substance has likely been tested in a lab setting. Testing would validate that the product maintains its organoleptic and nutritional properties, demonstrating its potential as a salt substitute in food.	"General Description of the Invention"(Translation from Portuguese)**(page 3 and 4)** "It proved to be particularly advantageous when the process also includes a draining step at room temperature, after washing the aforementioned first quantity of halophytic plants, and before drying at a temperature higher than room temperature".(Translation from Portuguese)**(page 3)** "Detailed description of preferred embodiments of the Invention"(Translation from Portuguese) **(page 5 until 8)**
22	18/07/2018	Obtention of a Solution from Extracts of Rosmarinus Officinalis L. for Use as a Food Coating	4	TRL 4 - The document provides detailed descriptions of the process used to create the rosemary extract and the coating solution. It also outlines the use of the coating in food preservation, demonstrating its ability to reduce food spoilage and maintain the freshness of the food. These tests would be conducted in a lab environment with controlled conditions.	"DETAILED DESCRIPTION: The first objective is the obtention of the rosemary extract through an aqueous extraction. For this, the aerial parts are milled to obtain a fine homogenous powder with particle sizes between 0. 5 and 2 µm. Then, the powder is subjected to an extraction with boiling water (85 to 105 °C) for 3 to 10 minutes, filtered through a Whatman filter an lyophilized at a temperature between -30 and -50 °C and 3.5 to 20 Pa of pressure. - The second objective is to obtain the coating solution based on the rosemary extract obtained in the previous objective. The extract obtained in the previous objective is added to distilled water at a concentration between 5 and 15 g/L. After complete dissolution, ascorbic acid is added (1 to 8 g/L), as well as 1 to 8 g/L of a-tocopherol previously dissolved in 10 to 20 mL of absolute ethanol and added to the coating solution until complete dissolution. The last ingredients to be added are calcium chloride (5 to 15 g/L), glycerol (3 0 to 7 0 g /L) , and iota carrageenan at 10 to 15 g/L heating the solution between 20 to 50 °C for 20 to 50 minutes until the solution, forming the coating solution. In one form of preparation, the coating solution is used as a food coating through immersion. In another form of preparation, the coating solution is used as a food coating as an aerosol (spray)".**(page 6)**
23	10/11/2009	Ice Supplemented with Algae and/ or Derivatives, Process for Obtaining Thereof and Applications Thereof	4	TRL 4 - The process of incorporating algae (including freeze-dried algae, algae extracts, or bioactive compounds) into ice is validated in the lab. The technology likely shows efficacy in terms of antioxidant properties, delayed spoilage, and reduced microbial contamination in controlled conditions.	"General description of the invention: [15] Thus, the first step in this process consists of characterizing and quantifying the plant-based products and/or their derivatives to be added to the water to be frozen, in order to obtain a mixture containing this plant material and/ or derivatives in proportions and quantities appropriate for the desired purpose. This mixture may be in solid form, for example in tablets, liquid form, such as in an aqueous solution, or in gel form (Translation form Portuguese)**(page 5)** "Definitions: [26] The application of biotechnological ice has a particular impact on the fishing industry and the marketing of fresh fish, since fish is a product of high commercial value and is highly perishable. Thus, biotechnological ice can be applied to fish throughout the entire supply and marketing chain, i.e. from the moment it is caught at sea to the final consumer (vessel - fish market - transport - trade - final consumer). In this way, the ice of the present invention plays an important role in maintaining the quality of fresh fish, as it prevents the growth of pathogenic microorganisms, the oxidation of polyunsaturated fatty acids and the development of toxins"(Translation form Portuguese) **(page 6)**
24	08/04/2021	Enzyme-Rich Extract and Use Thereof in Pre-Treatment of Plant Feedstuff-based Diets	5	TRL 5 - Laboratory fish growth trials with European sea bass demonstrate that the enzyme-rich extract improves feed efficiency, protein efficiency ratio, nutrient digestibility, and overall fish growth. These results confirm that the technology works in a relevant environment (aquaculture), where the pre-treatment of feed enhances fish performance.	"[0029] European sea bass juveniles (Dicentrarchus labrax) were provided by local commercial aquaculture. After transportation to the experimental facilities, fish were maintained in quarantine for one month and fed with a commercial diet suitable for European sea bass juveniles (AquaGold, Aquasoja; Sorgal, S.A., Portugal). [0030] The growth trial was carried out at the CIIMAR - Interdisciplinary Centre of Marine and Environmental Research (Matosinhos, Portugal) in a thermo-regulated recirculation water system equipped with 15 fiberglass tanks of 100 L water capacity and supplied by a continuous flow of filtered seawater"**(page 7)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
25	17/09/2020	New Hydrolysates to Control Infections, Methods and Uses Thereof	5	TRL 5 - The growth trial with European seabass serves as a relevant environment where the hydrolysate's impact on fish growth, feed conversion, and infection resistance is tested. The results indicate that fish fed diets with NFR hydrolysates had significantly lower mortality rates compared to the negative control, suggesting that the hydrolysate could be a promising feed additive in aquaculture.	"[0044] In an embodiment, juvenile European seabass, reared in a commercial fish farm (Acuinuga, S.L., Spain), were transported to the experimental facility. After 15 days of acclimation, fish were fasted for 24h, then individually weighed and measured and finally distributed into a recirculating saltwater system (RAS) composed of 15 fiberglass tanks of 250 L each, at a density of 3.5 kg m-3. Diets were randomly allocated to triplicate tanks in order to have independent replicates".**(page 8)**
26	26/07/2016	Fedd for Rearing Omnivorous Fish	5	TRL 5 - The feed has been tested in a real-world aquaculture environment. The results show significant growth performance in fish such as Garra rufa, with statistically significant improvements in growth rate, condition index, and other zootecnical parameters when fed this diet.	"Example 2 - Effect of feed on the growth of Garra rufa (Heckel, 1843).The feed of the invention was tested in a growth trial with Garra rufa fish (Heckel, 1843), which lasted for 61 days. This trial compared the effects of two commercial diets - a feed for freshwater ornamental fish (a) and a feed for Discus fish (b) - with those of the feed of the present invention (c). (Translation from Portuguese)**(page14)**
27	26/06/2019	Teleost Fish Larval Diets Supplemented with Natural Extracts for Promoting Fish Growth Performance	5	TRL 5 - The technology has been demonstrated in a relevant environment, i.e., the larval stages of commercially farmed fish like Senegalese sole and gilthead seabream. The natural extracts successfully improved the fish's growth performance, digestive enzyme activity, and immune response under conditions similar to those in aquaculture.	"Trial 1, four marine fish larval diets were tested in Senegalese sole post-larvae, three of them were supplemented with curcumin (CC), green tea (GT) and grape seed (GS) extracts, and a fourth diet (CTRL), without any supplementation of these extracts was a commercial diet. Diets were fed to different group of fish of 45 days after hatching (DAH), for 25 days"**(page 15 until 21)**
28	01/09/2009	Fedd Additives for Aquaculture and Aquariculture and their Respective Use (Translation from Portuguese)	3	TRL 3 - The EOG tests demonstrate that 1-methyl-L-tryptophan can effectively stimulate the olfactory response of fish, confirming the basic biological mechanism for its use as a feeding stimulant. However, no feeding or growth trials have been performed yet to confirm whether these sensory responses lead to actual changes in feeding behavior or growth rates. Example: EOG tests show that the fish can detect 1-methyl-L-tryptophan at very low concentrations, suggesting it could be an effective attractant.	"Detailed description of preferred embodiments of the Invention"(Translation from Portuguese)**(page 5 until 10)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
29	24/10/2018	Sporeforming Probiotic Strains, Methods and Uses Thereof	5	TRL 5 - technology has been validated in a relevant aquaculture environment, specifically through feeding trials with European sea bass juveniles. These trials have shown that the inclusion of these probiotics in plant-based diets (soybean meal, rapeseed meal, and sunflower meal) improves growth performance and feed utilization efficiency, making them a viable alternative to fishmeal-based diets.	"[0049] In an embodiment, the animal experiment was performed at the Marine Zoology Station, Porto University, Portugal, with European sea bass, juveniles obtained from a commercial fish farm (Maresa S.A., Ayamonte, Huelva, Spain). After transportation to the experimental facilities fish were first submitted to a quarantine period of 30 days before transfer to the experimental system where they were allowed to adapt for 15 days. Before the experimental period, fish were fed a commercial diet (48% protein, 11% lipids, 5% starch). The trial was performed in a recirculating water system equipped with 12 cylindrical fiberglass tanks of 100 l water capacity and thermo-regulated to 22.0 ± 1.0 °C. Tanks were supplied with continuous flow of filtered seawater (2.5-3.5 l min-1) of 34.0 ± 1.0 g 1-1 salinity and dissolved oxygen was kept near saturation (7 mg 1-1). Thereafter, 20 European sea bass with an initial mean body weight of 34.4 g were distributed to each tank and the experimental diets randomly assigned to triplicate groups. The trial lasted 45 days and fish were fed by hand, twice daily, 6 days a week, until apparent visual satiation. The experiment was performed by accredited scientists (following FELASA Category C recommendations) and was conducted according to the EU directive 2010/63/EU on the protection of animals for scientific purposes".**(page 9 and 10)**
30	06/03/2018	Method for Obtaining Protein or a Rich-Protein Extract from Algae, Extract and Uses Therefore	5	TRL 5 - The technology has been tested in relevant environments, such as fish feed trials with European sea bass and shellfish species. These trials show significant improvements in digestibility and growth performance when the disrupted algae are included in fish diets.	"[0076] In an embodiment, some of these processed algae (micro and macroalgae) biomass were just included in sea bass dietary formulations as feed ingredients, replacing 30% of a commercial-based formula for this species. These diets were used to an in viva digestibility trial where the capacity of sea bass to digest the algae was evaluated using a classical approach (collection of fish faeces to evaluate the amount of nutrients that were assimilated by the fish). The preliminary results of this trial showed a 14% increase in protein digestibility when Nannochloropsis was included in diets after the application of the vibratory rings mill; and a 36% increase in protein digestibility when the mechanical process was coupled with the enzymatic treatment. The digestibility of the mechanically processed Graci/aria also led to a 30% increase in protein digestibility by European sea bass.**(page 14 and 15)**
31	11/07/2016	Preparation of Cereal Products Suitable for Celiac Patients by the Creation of Supramolecular Structure between Proteins and Chitosan	5	TRL 5 - The detoxification method has been tested on various cereals and their products (e.g., wheat, barley, rye, oats, and their germinated products), confirming its ability to detoxify gluten effectively. The method is shown to significantly reduce the toxic epitopes in both wheat flour and gluten, making them suitable for celiac patients in real-world applications.	"Description of embodiments: The result in terms of the production of products tolerable by coeliac patients is a clear decrease in the digestibility of gluten proteins, namely gliadins, resulting in a product in which more than 65% of the epitopes toxic to coeliac patients are eliminated and the deamidation process conducted by tissue transglutaminase, a key step in the pathogenesis of coeliac disease (11, 12), is inhibited (Figure 3)".(Translation from Portuguese). **(page 15).**
32	12/11/2021	Method for Processing a Protein-Rich Residue and Uses Thereof	5	TRL 5 - The technology has been validated in relevant environments, particularly in processing protein-rich by-products like meat and bone meal. The process has shown success in separating protein and mineral fractions effectively, making them suitable for aquaculture feed, animal feed, fertilizers, and phosphates. Real-world feed trials and product testing are needed to confirm its effectiveness on an industrial scale.	Example 1 until example 8 **(page 8 until 12)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
33	01/03/2019	Hydroxypheophorbide Compounds, Methods and Uses Thereof	5	TRL 5 - The technology is validated in relevant environments such as pre-adipocyte cell models and zebrafish assays. Further studies indicate that these compounds can be effective in reducing obesity-related lipid content and offer a natural solution for weight management in obesity-related disorders like visceral fat obesity and fatty liver disease.	"[0036] This disclosure uncovers compounds with novel lipid reducing activity. It is reported the isolation procedure of two hydroxypheophorbide compounds (hpa and hfa), and the structural elucidation of hfa. Hpa was isolated from Cyanobium sp. LEGE07175 and hfa from Nodosilinea sp. LEGE06001. These marine cyanobacteria are commercially available and can be purchased at http://leqe.ciimar.up.pt/orderinqservices/). Their lipid reducing activity was evaluated using the zebrafish Nile red fat metabolism assay and a 3D cell culture model of murine pre-adipocytes. Furthermore, the production of hpa was evaluated in different materials (Spirulina, microalgae, spinach, cabbage), with GRAS status (generally regarded as safe) for human consumption, to foster the commercialization of the compounds as novel natural products in the form of nutraceuticals or food supplements for the treatment of obesity or related co-morbidities"**(page 11)**
34	01/09/2016	Cyanobacterium Extracellular Polymer, Compositions and Uses Thereof	5	TRL 5 - The RPS has been validated in relevant environments through tests using model drugs and therapeutic proteins for release applications, both in vitro (e.g., with fibroblast cultures) and in simulated physiological conditions. This includes drug delivery experiments in tumor-mimicking pH and other conditions relevant to clinical and pharmaceutical use.	"[0070] In an embodiment, biocompatibility studies were performed. Human dermal neonatal fibroblasts (ZenBio, Inc, USA) were grown in tissue culture flasks at 37 °Cina 5% CO2 controlled atmosphere in Dulbecco's modified Eagle's medium (DMEM, Gibco/BRL, Gaithersburg, MD, USA) supplemented with 10% (v/v) fetal bovine serum (FBS, Gibco). Subculturing was performed by tripsinizing cultures with 0.25% trypsin (Sigma-Aldrich) and 0.05% EDTA (Sigma-Aldrich). Experiments were performed with cells at passage 9. Fibroblasts were seeded at 2.5 x 104 cells per well in a 24-well culture plate and incubated overnight at 37 °C and 5% CO2 to allow cell adhesion. A stock solution of RPS, previously sterilized by autoclaving, was prepared in DMEM with 10% FBS at a concentration of 0.23 mg mL-1. Cell culture medium was replaced by fresh RPS solutions at different concentrations (0, 0.01, 0.03, 0.06, 0.12, and 0.23 mg mL-1), and metabolic activity was assessed by resazurin assay at different time points (1, 2, and 5)".**(page 15 and 16)**
35	13/11/2020	Nanofiber Mesh Comprising Fucoidan, Method and Uses Thereof	5	TRL 5 - The fucoidan-functionalized nanofiber mesh (NFM_Fu) has been validated in relevant environments, with in vitro tests showing a significant decrease in melanoma cell viability while maintaining normal cell viability. This supports its potential as a post-tumor excision therapy for melanoma treatment.	"[0037] In an embodiment, the fucoidan-based system described in the present disclosure was tested over primary human keratinocytes (most common cell type in the epidermis) and fibroblasts (most common cell type in the dermis), as well as, over a representative human melanoma cell line WM-115 (a cell line originated from the primary tumor with competence for metastasis) that has been used in different studies. In vitro results revealed a 50% decrease on melanoma cells' viability while maintain the viability of normal cells, which is an indication of the selectiveness and effectiveness of the developed functionalized nanofibrous membrane or mesh".**(page 6)** "[0055] In an embodiment, the viability of the melanoma cells was lower on the NFM_Fu condition than on the CTR from day 3 onward. At days 3 and 7, NFM_Fu induced a decrease in melanoma cells viability (Figure 4 A). Specifically, at day 3, around 70% of melanoma cells are viable, whereas at day 7 there is a viability of around 50% when compared with the CTR. These observations were corroborated by SEM micrographs (Figure 4 B).Cells were able to colonize the control NFM, covering its surface by showing increasing number of melanoma cells along the course of the 7 days. Oppositely, in the case of NFM_Fu condition this colonization of the mesh was not observed".**(page 12)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
36	22/12/2015	Gellan Gum-based Hydrogels, Methods and Uses Thereof	5	TRL 5 - Technology has been validated in a relevant environment, with hMSC differentiation in gellan gum hydrogels yielding positive outcomes for bone regeneration and other tissue engineering applications. Further studies show its potential for clinical applications such as bone fractures, osteopathies, and osteochondritis.	"Example 6. In vitro tri-lineage differentiation of human adipose mesenchymal stromal/stem cells (hASC) within gellan gum (GG)-based hydrogels." **(page 8)** "[0042] The gellan gum disclose in the present subject-matter is an autonomous biomaterial for human adipose stem cells (hASCs) differentiation in the osteogenic lineage, acting by a mechanism dependent on a mechanotransduction pathway in the absence of any further biological or biochemical cue. It was surprisingly show an autonomous osteogenic activity of a hydrogel based on a gel Ian gum of the present subject matter, preferably a methacrylated gellan, without the modification of the material with cell-adhesive peptides, other celladhesion motifs or mineralization cues."**(page 9)**
37	05/12/2022	New Peptides from Mucus of Halobatrachus Didactylus, Extract from the Mucus of Halobatrachus Didactylus and Uses Thereof	5	TRL 5 - The peptides are tested in relevant environments, such as pharmaceutical formulations, showing significant antioxidant and antihypertensive effects. Further studies are needed to explore their clinical applications in treating diseases like hypertension and diabetes.	Detailed description of a preferred embodiment - **paragraphs 39, page 14 and 15.**
38	21/12/2018	Ultra-Violet Absobing Compounds	5	TRL 5 - The scytonemin analogs have been tested for their effectiveness in sunscreen formulations and cosmetic products, demonstrating their potential for use in protecting against UV-A, UV-B, and blue light. These compounds are now ready for integration into commercial formulations due to their broad-spectrum protection and minimal pigmentation.	"The UV absorption profiles for these molecules and the maximum absorption wavelength can be seen in Figure 7 and table 2, respectively. This data provides an evidence of the complementarity action of the compounds, covering a very broad range of radiation from 293 nm to 500 nm. This indicates that when used as a mixture, they can provide an efficient protection against UV-B, UV-A and blue light. (pg.14) Cytotoxicity tests The pure compounds were also tested in cytotoxicity assays using the MTT assay. Compound 3'-hydroxyscytonemin showed considerable bioacti vi ty, reducing SY-SH5Y (neuroblastoma cell line) viability to 37.8% in 24h and 18.3% in 48h of exposure, at a final concentration of 10 µg mL-1 , as shown in Figure 8.**(page 14 and 15)** "Antimicrobial activity the pure compounds were also tested in antimicrobial assays using the disc diffusion method. Compound 3'- hydroxyscytonemin presented antimicrobial activity against Staphylococcus aureus (ATCC 29213) at a final concentration of 15 µg mL- 1 , as shown in Figure 9. Apart from its sunscreen function, the previously known scytonemins have been associated with anticancer and antioxidative activity, but no antimicrobial activity has ever been reported for any of the scytoneman family of compounds until now.**(page 15)**
39	04/10/2019	Hydrogel-Like Particles, methods and Uses Thereof	5	TRL 5 - The technology has been validated for use in immunotherapy, particularly in cancer treatment. The gellan gum nanoparticles have shown promising results in in vitro settings for stimulating T-cell activation and promoting immune responses against solid tumors. The particles have also demonstrated the ability to deliver cytokines and other therapeutic agents in a controlled manner.	" [0061] In an embodiment, the functionality of the produced anti-CD3 and anti-CD28 to trigger T-cell proliferation was assessed by in vitro CFSE assays with murine freshly isolated splenocytes. Results are shown in Figure 7".**(page 10)** "[0062] Additionally, to the surface conjugation of biologically relevant molecules or the entrapment by soaking of small molecules for latter release, the aforementioned nanoparticles may be used for tracking by means of conjugating a fluorescent dye to the GG structure previous particle fabrication as can be seen in Figure 8."**(page 10)** "[0063] In an embodiment, once the antibody tethering to the GG particles was confirmed, in vitro studies regarding particle and cell interactions were performed. The percentage of CD4+ murine spleen cells which bound to functionalized a-CD3 particles can be shown in the table below (Table 1)."**(page 10)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
40	31/07/2019	Nitenin analogue compounds and their use in the treatment of chronic and acute pain	5	TRL 5 - The technology has been validated in relevant environments, including chronic pain models like chronic constriction injury (CCI) and orofacial pain models, showing effective pain relief with minimal side effects compared to traditional opioid or NSAID treatments.	"EXAMPLES In vivo and ex vivo pain models"**(page 50 until 64)**
41	27/01/2023	Gel Formulation for the Treatment of Drug Intoxication and a Process to Obtain the Same	5	TRL 5 - The gel formulation has been validated in a relevant environment, with results showing that it effectively adsorbs drugs and prevents their absorption through the intestinal mucosa, thus reducing the toxic effects of drug intoxication. Additional tests confirm its stability, pH responsiveness, and ability to handle drug intoxication cases in a clinical context.	Detailed description of a preferred embodiment - **paragraphs 75 until 83, page 8.**
42	25/06/2015	Pyrazinoquinazolinone Derivatives with Antibacterial Activity and Uses Thereof	5	TRL 5 - The compounds have been tested in biofilm models and shown efficacy against multidrug-resistant bacteria. The ability to target biofilms, a critical challenge in treating chronic infections, supports their potential use in clinical settings. Further testing confirms the synergistic effect between fiscalin C and oxacillin against MRSA.	Detailed description of a preferred embodiment - **paragraphs 68 and 69, page 13.** Detailed description of a preferred embodiment - **paragraphs 70 until 76, page 14 until 17.**
43	10/02/2022	Protein Carrier System based on Cyanobacterial Nano-Sizes Extracellular Vesicles	5	TRL 5 - The technology has been validated in relevant environments like fish larvae and mammalian cell cultures. The protein-loaded EVs show a clear fluorescent signal within zebrafish larvae, indicating successful protein delivery. This opens up possibilities for using cyanobacterial EVs as protein carriers in aquaculture to improve nutritional status or immune responses.	"Figure 4. Cyanobacterial extracellular vesicles loaded with sfGFP accumulate in the gastrointestinal tract of zebrafish larvae". **(page 13)** "Figure 5. Synechocystis sp. PCC 6803 extracellular vesicles packaged with sfGFP are internalized by mammalian epithelial cells. **(page 14)**
44	28/02/2022	Bioactive Compounds obtained from Cyanobactera Leptothoe SP. Lege 181152	5	TRL 5 - The compounds have been validated in relevant environments, showing antifouling properties against marine organisms and effective cytotoxic activity against cancer cells. These results suggest their potential for use in cancer therapy and marine biofouling prevention.	"[0046] The cytotoxicity of the fractions A to H2 was tested against the 3D model of the human colorectal carcinoma cell line, HCT 116.**(page 5)** "[0049] The same VLC fractions A to H2 (Table 1) were assessed for their potential antifouling activity using an antisettlement bioassay towards Mytilus galloprovincialis plantigrades, the adhesive stadium of mussel larval cycle". **(page 6)** "[0065] The cytotoxic effect of phormidolide D (3) was tested against HCT 116 human colon carcinoma cells in monolayer (2D) and spheroid models (Figure 11)"**(page 9)**
45	30/07/2021	Method of Obtaining Electromagnetic Frequencies from Aquatic Organisms Bioactivated Fluids for Bioresonance Therapy against a Disease and/ or Pathogen	4	TRL 4 - The integration of real-world biological fluid (bivalve fluid) into the in silico model to simulate and validate immune responses against pathogens (e.g., SARS-CoV) could be happening at this stage. The technology would need to demonstrate that the in silico model accurately reflects human physiological responses when exposed to these frequencies.	"This can, for example, involve the individual to be connected to the Mora®Nova device by the electrodes interfacing or not with liquid medium at different phases for test values readings. In these different situations, the evaluation of human SARSCov virus infection was carried out when respective virus frequency memory was applied in silica by the Mora®Nova device into the human model".**(page 26)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
46	27/09/2017	High Molecular Weight Chitosan, Process for Obtaining and Uses Thereof	3	TRL 3 – The technology has been demonstrated with experimental proof of concept in a laboratory environment. The extraction method has been shown to work, with properties like molecular weight, acetylation, and protein content confirmed through tests like FTIR, NMR, and SEC-MALLS.	Detailed description of a preferred embodiment - **page 10 until 17.** "[0117] In an embodiment, all the drug included within the loading solutions was effectively incorporated by the membranes. Indeed, after the loading the membranes (originally transparent) acquired the same colour as the albumin powder (yellow). This effect can be appreciated in Figure 10. [0118] The release of this protein was also very efficient. Indeed, all the albumin was released after half an hour of study. This is probably due to the high hydrophilicity of albumin. In addition, the experiment was really reproducible, with all the UV spectra overlapping. This indicates a very homogeneous and reproducible arrangement of the chitosan chains during the formation of the membranes."**(page 17)**
47	14/05/2020	Process of Obtaining a Phlorotannin-Enriched Extract having Anti-Enzymatic Action for Use in Dermatology	5	TRL 5 - The phlorotannin-enriched extract has been tested in cell-based models (e.g., keratinocytes and RAW264.7 macrophages) to assess its anti-inflammatory, cytotoxic, and enzymatic inhibition properties. The extract shows promise for wrinkle treatment and skin aging prevention, demonstrating the biocompatibility and anti-aging properties necessary for dermatological products.	Detailed description of a preferred embodiment - **page 5 and 6.**
48	20/12/2010	Hybrid Nanocomposite for Aquatic Media Remediation and Respective Production Method	5	TRL 5 - The hybrid nanocomposite has been tested in relevant environments (e.g., aquatic ecosystems), demonstrating the material's ability to be used as a permeable reactive barrier or in filtering applications. The composite shows good performance in water treatment, with high phosphate removal capacity, and does not cause turbidity or alter the water chemistry significantly.	"The column removal test, Figure 6, performed with particles with a diameter between 100-300 µm, initial phosphorus concentration of 1 mg/L, flow rate of 1 mL/min at 22 ®1 ®C for 30 days, allowed verification of the performance of PNH in removing phosphate ions. The removal capacity of the column was 0.67 g of phosphorus per kg of PNH. The nanocomposite removed all the phosphorus from the phosphate ion in the initial 40-hour period, with the material having a half-life of 134 hours and reaching saturation after 500 hours of testing". (Translation form Portuguese) **(page 9)**
49	24/03/2016	Gellan Gum Hydrogels, Preparation, Methods and Uses Thereof	5	TRL 5 - Preclinical studies demonstrate that modified gellan gum hydrogels can be applied in joint repair procedures like microfracture (MFX) for cartilage lesions in porcine models. The hydrogels effectively retain the blood clot and bone marrow stem cells within the lesion site, promoting the formation of hyaline-like cartilage and improving integration with surrounding tissue. The adhesiveness of the hydrogels eliminates the need for additional fixation aids like fibrin glue.	"[00130] In the human knee joint, the medial femoral chondyle is the most frequent site of deep grade III and IV lesions. Human lesions treated for cartilage repair vary from 0.5 - 12 cm2 in size. In humans, the average articular cartilage thickness over 5 locations ranges from 2.2-2.5 mm, compared to 2-4 mm in pigs. With respect to cartilage thickness for induction of chondral lesions, the porcine model better resembles the scenario in humans. Thus, ex viva conditions similar to those found in humans were used to test fixation of the new modified gel Ian gum-based hydrogels, including: lesion location, size, depth as well as physical stress (gravity and friction)".**(page 29**) "[00135] Both GGp-DOPA hydrogel formulations (GGp-DOPAl and GGp-DOPA3) successfully withstood all stress test conditions, maintaining full integrity within chondral lesions of 2 mm thickness (Figure 10a). In addition, it was possible to remove the 3D GGp-DOPA hydrogels fully intact from the lesion after fixation tests. On the contrary, only partial fixation of GGp and GG-MA formulations was observed within the same testing system, and hydrogel fragmentation was also observed".**(page 30)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
50	24/01/2020	Antibiofouling Device for Optical Sensors, Methods and Uses Thereof	5	TRL 5 - The electrolytic cell has been tested in real-world marine conditions, with successful demonstration of biofouling prevention on optical sensor windows. The system maintains effective chlorine production and sensor transparency during continuous submerged operation, with low power consumption (0.5-1.75 mW), ideal for autonomous underwater devices.	Detailed description of a preferred embodiment - **paragraphs 57 and 58, page 9 and 10.**
51	19/05/2010	Apparatus for the retention of (bio)solids and a method for the treatment of a waste material using said apparatus	3	TRL 3 - This TRL might apply to early experimental validation, particularly if small-scale testing or lab simulations were conducted on the apparatus to show that the theoretical design works in practice. The document discusses some design features, such as the gas lift action, sludge collection hoods, and effluent discharge, suggesting early testing might be involved	Detailed description of a preferred embodiment - **paragraphs 10, page 3.** Detailed description of a preferred embodiment - **paragraphs 12 until 14, page 3** Detailed description of a preferred embodiment - **paragraphs 22 until 24, page 5.**
52	30/06/2023	Synergistic Bioremediation Composition	5	TRL 5 - The composition has been demonstrated in relevant environmental conditions (i.e., marine environments). Field trials or pilot-scale tests may be conducted in areas affected by oil spills or marine fuel contamination to assess the effectiveness of the bacterial consortia in real-world conditions.	Detailed description of a preferred embodiment - **Examples 1 and 2, page 7 until 12.**
53	31/03/2014	Method to Obtain Collagen/ Gelatin from Marine Sponges	5	TRL 5 - The method has been tested in real-world environments where marine sponges are sourced from wild and cultivated sources. Field tests with various sponge species have shown consistent results in extracting collagen with high yields. The extraction process has also been compared to traditional methods, confirming that it is more efficient and sustainable.	Detailed description of a preferred embodiment - **paragraphs 13 until 26, page 4 until 8.**
54	30/09/2021	Antifouling Compound, Method and Uses Thereof	5	TRL 5 - The compounds were incorporated into polyurethane-based coatings and tested for their ability to prevent biofilm formation by marine bacteria and the settlement of mussel larvae. The coated surfaces demonstrated effective antifouling properties, and the incorporation of these compounds into coatings showed sustained antifouling efficacy.	"[0059] In an embodiment to assess the AF effectiveness and toxicity of the synthesized derivatives of compound 1, in viva bioassays using adhesive larvae of the most common macrofouling species, Mytilus galloprovincialis/ were conducted and the ECso and LCso were further calculated for the most potent compounds. After the selection of the most promising AF compounds, putative AF target mechanisms were studied through the evaluation of acetylcholinesterase (AChE) and tyrosinase (Tyr) activities. Studies concerning the antimicrofouling activity, namely the antibiofilm activity using Pseudoalteromonas tunicata/ were also conducted for one of the disclosed AF compounds. In a further embodiment, ecotoxicity for two non-target marine organisms, nauplii of the crustacean Artemia salina and the marine microalgae Phaeodactylum tricornutum, was evaluated. At last, a polyurethane (PU)-based marine coating comprising one of the disclosed AF compounds was conceived to evaluate its ability to reduce the settlement of mussel larvae and biofilm formation by a marine bacteria after incorporation in a coating formulation"**(page 10 and 11)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
55	12/12/2014	Functionalization Process for Biocide Immobilization in Polymer Matrices	5	TRL 5 - The biocide-immobilized polymeric coatings have been tested in real-world environments, such as aquaculture systems and marine infrastructures. The functionalized biocides demonstrate long-lasting antifouling performance without significant degradation or leaching, confirming their suitability for marine applications.	"[5 until 10] The functionalized biocides prepared in accordance with the conditions described in examples 1 and 2, were tested in marine real environment, as antifouling additives in polyurethane based polymeric matrices (antifouling paints with two components). The used components for the Hempel´s paint Polibest 55551 formulation preparation, by white colored were: a resin or base (Reference: 55559, Hempel A/S) and the suitable during agent (reference 95370, Hempel A/S19. Rge proportions by volume of the components used were those recommended by the supplier (2/1 of base/curing agent) **(page 35)**
56	23/11/2020	Gellan Gum based Inks, Methods of Obtaining and Uses Thereof	5	TRL 5 - The bioinks have been validated for bioprinting 3D structures with embedded cells, showing promise for use in tissue repair, wound healing, and skin regeneration. These inks were tested in relevant environments like bioprinting platforms and 3D printers, demonstrating their compatibility with extrusion techniques and their ability to form hydrogel structures.	Detailed description of a preferred embodiment - **paragraphs 38 until 40, page 9.** Detailed description of a preferred embodiment - **paragraphs 68 and 69, page 12.** Detailed description of a preferred embodiment - **paragraphs 51 and 52, page 10.** Detailed description of a preferred embodiment - **paragraphs 70 and 71, page 12.**
57	25/06/2015	Antimalarial Agent, Methodsand Uses Thereof	4	TRL 4 - The bioactivity of hierridin C has been validated in laboratory conditions, with in vitro testing showing low micromolar IC50 values for both sensitive and drug-resistant malaria strains. Further chemical synthesis methods for hierridin C have been developed, ensuring the availability of this compound for larger-scale testing."	"[0065] In an embodiment, hierridin B and hierridin C were tested for in vitro activity towards the P. falciparum strains, in particular P. falciparum 3D7 strain and the multidrug-resistant Dd2 strain to verify whether the chlorine atom featured in hierridin C affects the activity of the compound, in particular the antimalarial activity. Furthermore, the results for hierridin Band hierridin C were compared (table 1)".**(page 13)** "[0070] In an embodiment, several cell lines were exposed to hierridin C, in particular to a concentration of hierridin C up to 30 µg mL-1 (75.2 µM). The cell lines exposed to hierridin C, were in particular the cell lines of hepatocellular carcinoma HepG2, colon adenocarcinoma HT-29, neuroblastoma SH-SY5Y, breast carcinoma T47D, normal prostate cell line PNT2, breast adenocarcinoma, RKO colon carcinoma and MG-63 osteosarcoma. No cytotoxicity was observed in any of the cell lines tested"**(page 15)**
58	19/06/2015	A Construct, a Vector and a Method of Production of a Target Molecule in a Cyanobacterium	5	TRL 5 - Initial Testing in Relevant Environment: The technology has been validated further in Synechocystis under different growth conditions, demonstrating that the neutral sites do not interfere with the bacterium's basic cellular functions, such as growth and viability. Example: The testing of Synechocystis strains transformed with the plasmids containing GFP under different conditions (light, temperature, glucose) to measure growth curves and expression levels.	Detailed description of a preferred embodiment - **paragraphs 56 until 65, page 15 until 17.**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
59	07/11/2013	Method to Produce a Recombinant Collagenase to Digest Collagens	6	TRL 6 - Demonstration in Relevant Environment: Further refinement and validation of the recombinant collagenase in more complex biological systems (e.g., animal studies or initial clinical trials) to demonstrate its efficacy in treating diseases like Dupuytren's disease or its use in biotechnological applications. Example from the document: The enzyme's use in medical or research applications, showing its ability to be stored effectively, its stability, and its safe use in a therapeutic context.	Detailed description of a preferred embodiment - **paragraphs 63 until 71, page 20 until 23**
60	30/08/2019	Halogenated Compounds, Process and Uses Thereof	5	TRL 5 - A relevant environment for testing has been used, with the compounds demonstrating antimicrobial properties against clinically relevant strains and showing potential for real-world healthcare application.	"[0043] The methanolic extract was submitted to solid phase extraction (Waters Sep-Pak®Vac 35cc 10 g C18 Cartridges) using mixtures of water/methanol (4:1 to 1:4; 4 to 8 column volumes each), yielding an enriched fraction free of chlorophylls and other pigments. The fraction was then chromatographed using semi-preparative HPLC conditions with a gradient of water/acetonitrile 19:1 to 0:1 (both with 0.1% of formic acid) as mobile phase. Fractions were collected every 30 s (total run time of 70 min) and 140 fractions were collected into 96-well deep well plates, and a 25% of a 67 mg 140-well fractionation was tested against Staphylococcus aureus S54F9. In order to carry out this broth microdilution antibiotic susceptibility test, 50 µL of each HPLC fraction resuspended in 14% MeOH in water were mixed with 50 µL of the 5. aureus suspension at 106 CFU/ml in 2x MHB in a microtiter plate (final desired inoculum = 5.105 CFU/ml, final concentration of MeOH in bioassay plate= 7%, final volume per well = 100 µL). The microtiter plate was replicated onto a selective/differential solid medium (Manitol Salt Agar) in order to distinguish between bacteriostatic and bactericidal activities. Growth controls (broth with bacterial inoculum, no bioactive molecule) as well as sterility (broth only) and solvent controls (broth with 7 % MeOH in water) were included [7]". **(page 7 and 8).** Detailed description of a preferred embodiment - **paragraphs 52 until 55, page 12.**
61	08/02/2021	Variants of Hyperthermophilic Carboxylesterase for Polymer Systhesis	4	TRL 4 - The technology has been validated in controlled laboratory conditions. This includes successful protein engineering and testing, confirming the ability of the carboxylesterase variants to catalyze polymer synthesis with improved yields and molecular weights. Example: The detailed laboratory tests described in the patent document, where enzymatic variants of AfEST are engineered to enhance product yields and polymer sizes. Reaction conditions such as temperature and time were optimized, and the products were characterized using methods like FTIR and NMR.	"To test the performance of these mutants, PCL eROP reactions were carried out with E-CI and the mutant dissolved in toluene at 70 °C and 90 °C for 72 hr. In 30 the case of the assays for PCL-PEG synthesis, PEG4000 were added as well. To evaluate the remaining E-CI, Gas Chromatography (GC) was applied to the isolated product samples. Furthermore, the synthesized PCL and PCL-PEG copolymers were extensively characterized by means of Attenuated total reflectance Fourier transform infra red (ATR FTIR) spectroscopy and by Proton Nuclear Magnetic Resonance (1H NMR) to assess their 5 main structural features".**(page 7 and 8)**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
62	27/08/2020	Process for the Production of Xylan and Xylan Products from Algae Products and their Uses	4	TRL 4 - The technology has been validated in laboratory settings. This includes aqueous extraction of xylan from Palmaria palmata, endoxylanase hydrolysis of the xylan fraction, and the successful isolation of xylo-oligosaccharides free from xylose contamination. The process also yields a protein-rich fraction. Example: Laboratory validation has been performed to prove the efficient extraction and hydrolysis processes, with products characterized by specific molecular weights and degrees of polymerization.	"[0072] The present invention refers to a process for the production of xylo-oligosaccharides, soluble xylan and an insoluble protein-rich fraction from marine biomass, in particular algae. Specifically, said process is a simplified and ecofriendly process, based on aqueous extraction of washed, dried, milled algae and highly efficient enzymes, highly active at low to moderate temperatures. Surprisingly, the disclosed process resulted in a xylo-oligosaccharide composition free of xylose"**(page 7)** Detailed description of a preferred embodiment - **paragraphs 84 until 88, page 8 until 9.**
63	30/11/2018	Device for Capturing in Situ Aquatic Microbiomes	4	TRL 4 - The technology is validated in a laboratory setting. This includes testing the device's individual components such as the filtration system, pump, sensors, and microcontroller. The device has likely been tested for its functionality and reliability under controlled conditions. Example: The device's filtration and DNA preservation processes have been compared to standard methods, showing comparable results for DNA recovery and community diversity.	Detailed description of a preferred embodiment - **paragraphs 54 until 56, page 9.** Detailed description of a preferred embodiment - **paragraphs 59 until 61, page 9 and 10.** Detailed description of a preferred embodiment - **paragraphs 71 until 74, page 12 and 13.**
64	24/10/2023	Fishing Twine	4	TRL 4 - The technology has been validated in a laboratory setting, and the twine structure has been shown to improve the mechanical properties and reduce coating material requirements. The laboratory validation likely includes mechanical testing, durability testing, and perhaps marine resistance testing. Example: Testing of the twine's mechanical properties, such as stiffness, and the reduced need for coating materials, as well as its performance in lab-based durability tests.	Detailed description of a preferred embodiment - **example 1, page 14.**
65	24/11/2023	Process for Producing Hydrolysed Protein	4	TRL 4 - The process has been validated in a laboratory setting. The hydrolysis process is tested for protein extraction, digestibility, and encapsulation properties. The results indicate that the process yields proteins with digestibility above 90% and functional properties like encapsulation capability. Example: Laboratory-scale validation of the enzymatic-free hydrolysis process, demonstrating the advantages in terms of digestibility, water solubility, and the ability to encapsulate active compounds.	Detailed description of a preferred embodiment - **example 1, 2 and 3, page 8 until 12.**

Family Ref	Earliest Priority Date	Title	TRL	TRL Justification / Analysis	Extract Patent
66	11/12/2023	Method for Obtaining and Stabilising Mycosporines-Like Amino Acids and Phycoerythrin from Biological Matrices, Composition and Cosmetic Composition Thereof	5	TRL 5 - Here, the technology is tested in an environment that mimics the intended operational conditions. This could involve testing the stabilization process and PE extraction in an industrial or semi-industrial lab, possibly with different species or larger volumes of Palmaria palmata. Activities: Scaling up the process to pilot-scale trials, testing under more relevant environments (such as small pilot plant settings).	Detailed description of a preferred embodiment – **paragraph 110 until 124, page 13 until 15.**
67	29/11/2023	Composition for Waterproofing Coating of Cork Substrates and Respective Application Method	4	TRL 4 - Laboratory tests are conducted to confirm that the composition works as intended. Tests would include measuring the effectiveness of the barrier in preventing tannin migration, its mechanical properties, and its performance under different application conditions (e.g., temperature, humidity). Example: Validations in laboratory conditions showing that the waterproofing composition prevents tannin migration and has antifungal and antibacterial effects.	"[0067] To measure whether a cork has been well impregnated, especially in contexts like that of the present disclosure, the following methods can be used: Weighing (measuring the weight of the stopper before and after the composition application process. A significant increase in weight indicates absorption of the liquid); Microscopy analysis (scanning electron microscopy (SEM), to visualize the penetration of the liquid into the internal structure of the stopper); Spectroscopy (Using techniques such as infrared spectroscopy (IR) or nuclear magnetic resonance (NMR) to analyse the chemical composition of the stopper before and after impregnation, verifying the presence of the impregnated composition); Mechanical Tests (Performing compression and flexion tests to verify changes in the mechanical properties of the stopper, which may indicate an adequate level of impregnation)."**(page 6)**
68	13/07/2023	Marine Streptomyces as Natural Antifungal Agents to Combat the Brown Rot Fungus Gnomoniopsis Smithogilvyi	4	TRL 4 - The technology has been validated in laboratory conditions, with further optimization of extraction and cultivation processes for the Streptomyces spp. strains. The antifungal activity has been confirmed in lab settings with quantitative results. Example: Extraction and bioassay testing of the Streptomyces spp. strains confirm that the antifungal agents are effective against Gnomoniopsis smithogilvyi and have potential for agricultural applications.	Detailed description of a preferred embodiment - **example 1, page 4.**
69	30/07/2008	Process for the Co-Production of Chitin, its Derivatives and Polymers Containing Glucose, Mannose and/or Galactose, by the Fermentation of the Yeast Pichia Pastoris	4	TRL 4 - Technology validated in laboratory environment (Current TRL) Description: The process has been validated in laboratory conditions, with tests confirming that Pichia pastoris produces chitin and other polysaccharides efficiently. The glycerol byproduct from the biodiesel industry has been successfully used as the primary carbon source. Example: Laboratory-scale production of chitin and polysaccharides from glycerol byproducts, demonstrating the feasibility of using a low-cost carbon source for high-density fermentation.	Detailed description of a preferred embodiment - **example 1, page 9.**

APPENDIX 04.

BLUE BIOECONOMY CATEGORICAL SYSTEM

Value Chain Position	Metacategory Designation	Definitions	Categories Designations	Definitions
1	Biodiversity & Bioprospecting	First Stage: Comprises the sustainable exploration of marine biodiversity, aiming to identify, isolate and characterize biological and genetic resources with economic, scientific or ecological potential.	Marine exploration, sampling and enabling technologies	Technologies for the systematic collection of organisms and environmental samples (water, sediment, biofilms, invertebrates) for biological, genetic and chemical analysis, as well as sensors, underwater vehicles (ROVs/AUVs), samplers, mobile laboratories and bioinformatics tools for screening and analysis.
			Biological and genomic resources (biobanks)	Infrastructures and databases that store samples, genomes, strains and marine lineages for research and industrial use.
			Bioprospecting and characterisation of compounds	Technologies aimed at the screening and identification of metabolites, enzymes, peptides and other biomolecules with bioactive, industrial or therapeutic properties.
2	Primary Production or Catch	Second Stage: Corresponds to the production or capture of marine biomass. This stage forms the basis of the production system, providing the biomass required for the subsequent phases of the Blue Bioeconomy value chain.	Aquaculture of fish, molluscs, crustacea and marine invertebrates	Technologies for larviculture, grow-out and health management in hatcheries, nurseries, RAS systems and cages, including genetics, welfare and biosecurity, as well as cages, platforms, feeding and harvesting systems, aeration, sensors, robotics/autonomous vessels and the cultivation of filter-feeding organisms (molluscs, crustaceans and marine annelids) for biofiltration, biomass and co-products.
			Algae aquaculture	Technologies for the cultivation of macro- and microalgae in onshore and offshore systems (photobioreactors, raceways, tanks), including associated operations such as inoculum preparation, primary harvesting and dewatering, and their monitoring and control.
			Capture and harvest of wild marine biomass	Technologies for the sustainable wild capture and harvesting of marine biomass (fish, crustacea, invertebrates and seaweeds), including selective fishing gears and harvesting devices, vessels and platforms, and digital monitoring and traceability systems that improve safety, efficiency and environmental performance.
3	Extraction and Conversion	Third Stage: This stage covers the primary processing and conversion of marine biomass into raw materials, biological inputs and semi-finished products that feed the production processes of Blue Bioeconomy sectors, bridging biomass extraction/production and industrial transformation.	Processing, extraction and conversion technologies	Technologies for green extraction, fractionation, purification, fermentation/bioconversion and encapsulation/stabilisation/drying of marine-derived compounds, including enzyme-based processing, to generate stable, high-value intermediates for downstream use.
			Functional marine bio-based ingredients	Marine-derived functional ingredients such as lipids and omega-3s, hydrocolloids and polysaccharides, proteins and peptides, pigments and antioxidants, and bio stimulant formulations for applications in nutrition, health, materials and agriculture.
			Platform delivery and engineering technologies	Biogenic delivery platforms (vesicles, EVs and related systems) and genetic/metabolic engineering platforms (vectors and optimised production strains) that enable targeted delivery and efficient, scalable production of marine bio-based molecules.
4	Secondary Processing & Novel Product Production	Fourth Stage: Encompasses the secondary processing and transformation of raw materials, biological inputs and semi-finished or semi-manufactured products derived from marine resources into high-value-added final products and services, including novel foods and feeds, bio-based materials, health and wellbeing ingredients and other Blue Bioeconomy applications.	Food & functional food products	Secondary processing of marine-derived ingredients into foods and beverages for human consumption, including functional products with health claims, natural technological ingredients and preservation/packaging solutions.
			Feed, additives & animal immunonutrition	Development of marine-based feeds, premixes, additives and immunomodulatory solutions that improve performance, health and resilience in aquaculture and animal production.
			Health, therapeutic and dermo cosmetic applications	High-value health, medical and skin-care products from marine resources, including therapeutic actives, advanced delivery systems, biomaterials for wound healing and dermo cosmetic/photoprotection formulations.
			Advanced bio-based materials and coatings	Marine-derived biopolymers, composites, coatings and nanomaterials that provide biodegradable packaging, antifouling/anticorrosion protection and enhanced functional properties for industrial and environmental applications.
6	Circularity & resource recovery	Sixth Stage: Involves the reuse, recycling, revalorisation and reintegration of products, co-products and residues into the production system, including the bioremediation and valorisation of effluents and waste streams using marine-derived biological systems. This stage closes the Blue Bioeconomy cycle, promoting resource efficiency, waste reduction and the transition towards circular and sustainable models, in line with the principles of the circular economy and environmental neutrality.	Resource recovery and upcycling of products and co-products	Technologies that convert solid residues, end-of-life products and co-products (e.g., shells, trimmings, biomass side-streams) into new bio-based ingredients, materials, fertilisers, adsorbents or other value-added products.
			Effluent treatment, bioremediation and water recirculation	Biological, physicochemical and nature-based technologies for treating and bioremediating effluents and process waters (e.g., using micro/macroalgae, filter-feeders, biofilms, specialised reactors), enabling water reuse, nutrient recovery and reduced discharge impacts.
			Energy, carbon and nutrient recovery technologies	Processes and systems that transform marine-derived wastes and emissions into energy carriers and circular resources, including anaerobic digestion and other waste-to-energy routes, biochar and carbon sequestration, CO□ capture and utilisation (e.g., via algae), and nutrient recovery into concentrated fertiliser/bio stimulant products.

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