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Top emerging bio-based products, their properties and industrial applications

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Fraunhofer ISI

Mapping innovation in the field of:

- NATURAL RUBBER
- LIGNINS
- RENEWABLE OILS AND FATS
- VEGETABLE FIBRES

LARGE VOLUME
BIOMASS COMPONENTS

- TERPENES
- NATURAL POLYELECTROLYTES

LOW VOLUME – HIGH VALUE
BIOMASS COMPONENTS

- URBAN WASTE

OFMSW
SLUDGE FROM WASTE WATER TREATMENT

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THE STARTING POINT: BUILDING A COMPREHENSIVE DATABASE

A **database** was built to collect the following information for each of the BBPs identified under current development from the above mentioned biomass categories:

- biomass feedstock
- maximum TRL achieved
- number of active firms
- production facilities
- leading actors
- estimated market size
- non bio-based or traditional alternatives
- innovation highlights
- applications
- selected sources of information

biomass components	Number of innovative BBPs mapped
natural rubber	5
vegetable fibres	17
renewable oils and fats	19
lignin	23
terpenes	18
polyelectrolytes	6
urban biowastes	19

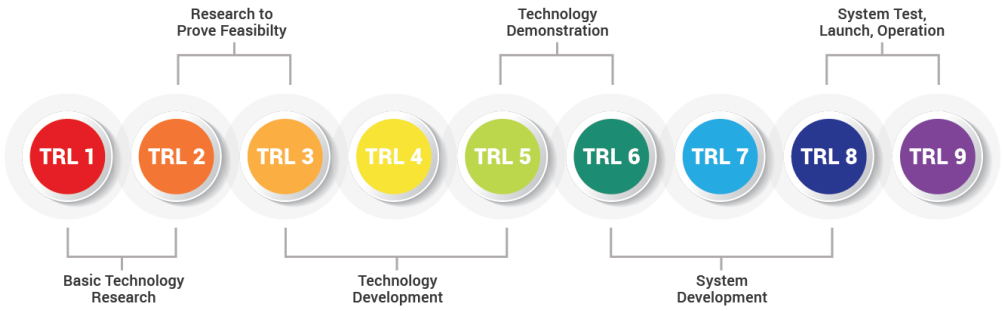
PRODUCT	MAX TRL	# ACTIVE FIRMS	PRODUCTION FACILITIES		LEADING ACTORS
			EUROPE	REST OF THE WORLD	
LIGNIN					
vanillin	9	>10	10	3	Borregaard; Rhodia; Takasago International Corporation; Jiaxing Zhonghua Chemical Co., Ltd.; IFF Inc. New York; Advanced Biotech. Inc.; Comax Flavors; BASF; De Monchy Aromatics
lignin-based thermoplastic biocomposites	9	1	1	0	Tecnaro GmbH
lignosulfonates	9	>10	6	>5	Sappi Europe Domtar; Green Agrochem-Lignin Unit; Borregaard LignoTech; Changzhou Shanfeng Chemical Industry; CIMV; Asian Lignin Manufacturing India Private Limited (India). Tembec (Canada). MeadWestvaco (USA), Georgia Pacific (USA). Northway Lignin Chemical. KMT Lignin Chemicals. LignoTech Ibérica SA. BIOTECH Lignosulfonate Handels GmbH (Czech Rep.)
bio-phenolic resins	8	>20	16	1	Tecnalia; VTT; Collanti Concorde Srl; Foresa Industrias Quimicas Del Noroeste Sa; Rampf Eco Solutions Gmbh & Co. Kg; Bio Base Europe Pilot Plant ; Novamont Spa; Biochemtex Spa; Biosyncaucho SL; Avantium. Akzo Nobel Coatings International B.V. Chimar Hellas S. A.; AVALON Industries AG. Biophenolix
organosolv lignins	7	>5	2	2	Borregaard, Chempolis, American Sc Techn, Lignol Innovation Corp.
BTX aromatics (benzene toluene xylene)	6	>10	2	5	Biochemtex; Anellotech Inc.; FPInnovations; Lignol; Weyerhaeuser; Alberta Pacific Forest Industries Inc. The Biomaterials and Chemicals Research Network (or Lignoworks) . Biorizon (TNO, VITO, ECN and the Green Chemistry Campus).
phenol and alkylphenols (coniferyl, sinapyl, p-coumaryl compounds)	5	13	9	4	Biorizon (TNO; VITO;Covestro). Avantium. Chemelot InSciT. Bio Base Europe Pilot Plant. DSM ChemTech Center. FPInnovations; Lignol; Weyerhaeuser; Alberta Pacific Forest Industries Inc
lignin bio-oil	5	>20	14	>5	Lantmännen, SP Processum AB, SP SverigesTekniska Forskningsinstitut AB, StichtingWageningen Research(WFBR), Cooperativas Agro-alimentarias de España, CREA (Italy), CERTH (Greece), Nutria S.A., ; Shell Oil Company; Honeywell UOP. Total Raffinage Chimie SA; Italian Bio Products SRL; Metgen; Bio Base Europe Pilot Plant. Biorizon. Metgen.Tecnalia (Spain). Foresa (Spain). Vertoro BV

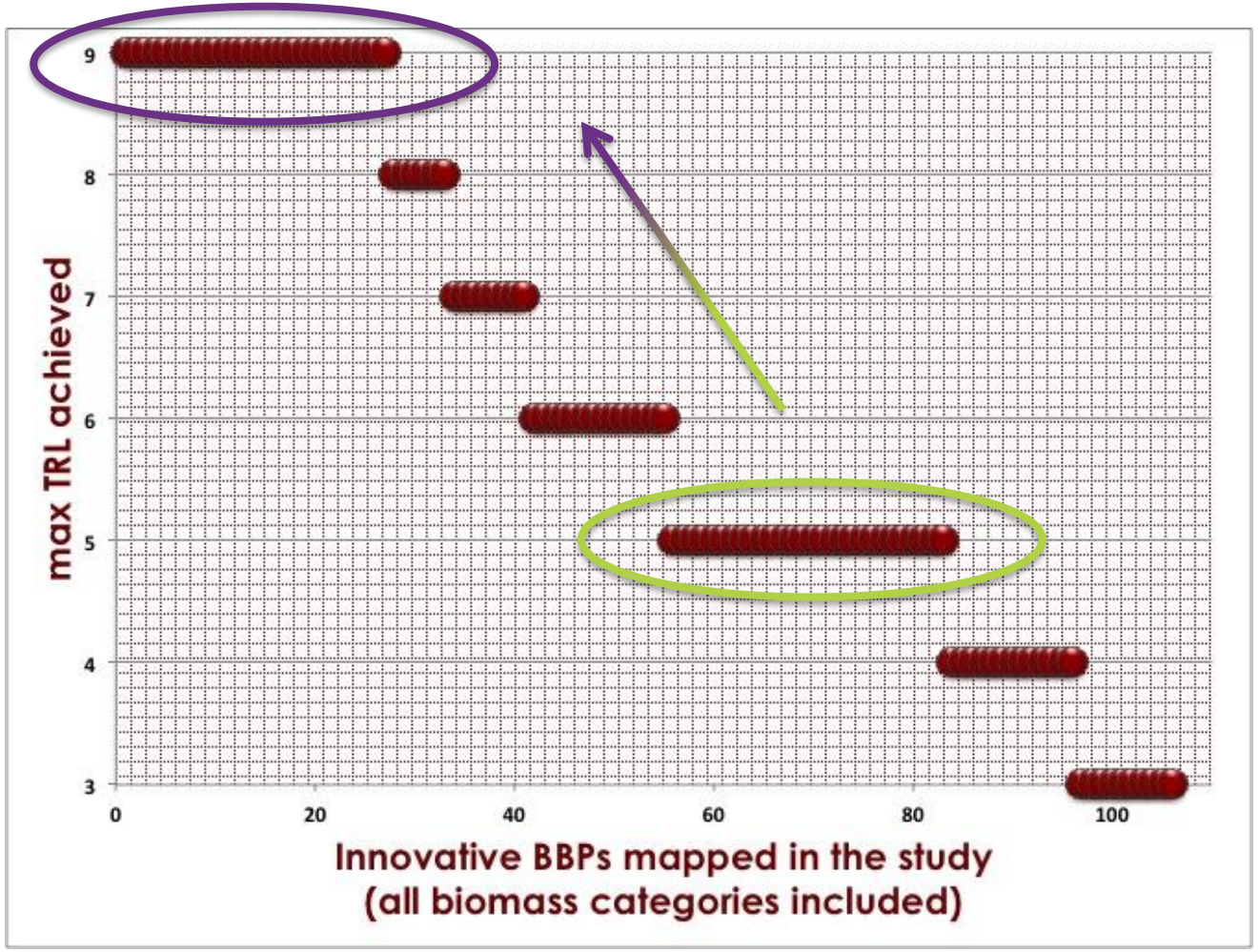
107 innovative BBPs mapped in this study

Technical advancement of innovation in BBPs

Spread of TRL values achieved by the products included in the database:

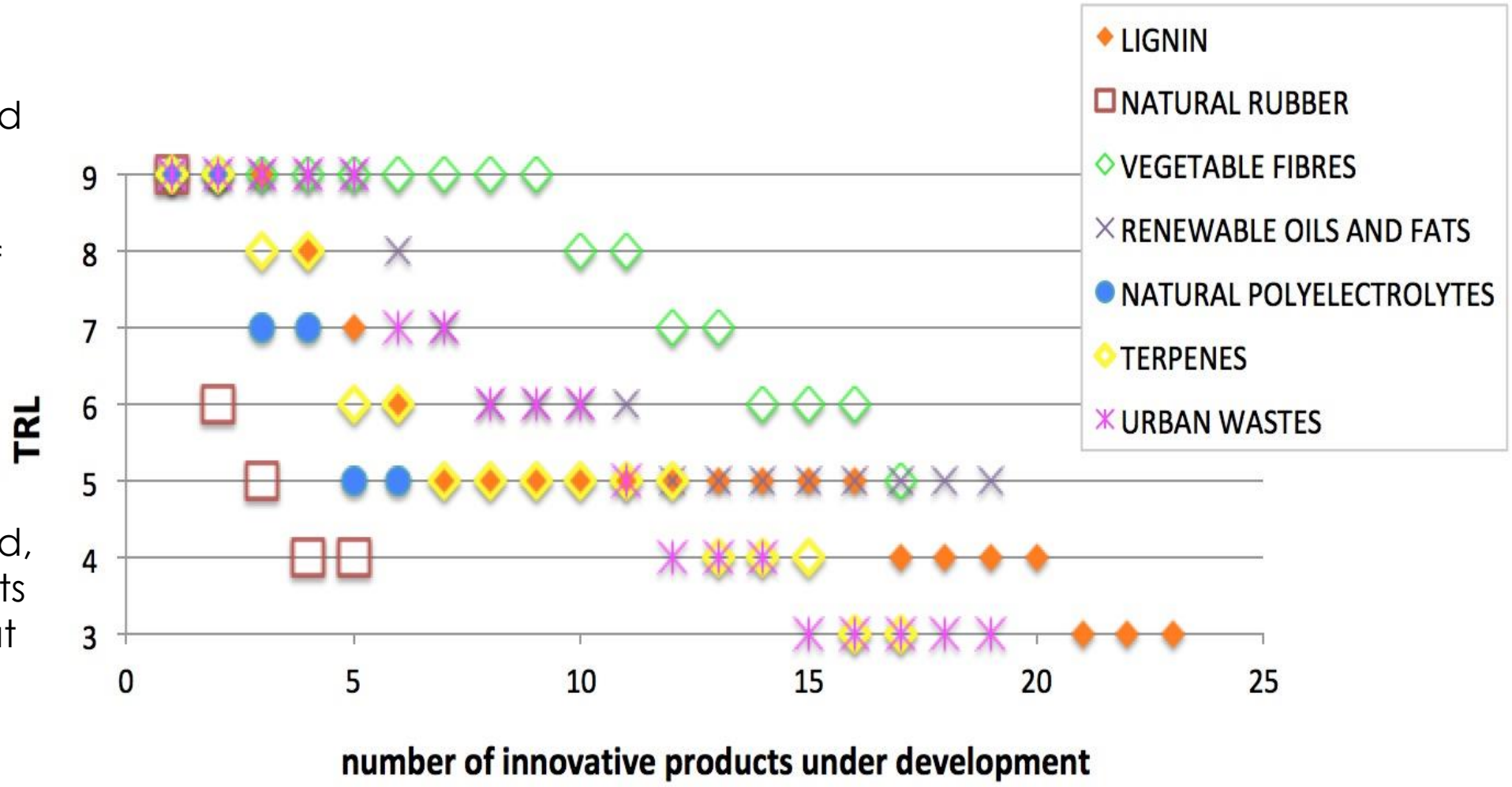
- approx. 30% BBPs at TRL 9
- approx. 30% BBPs at TRL 5
- rather empty gap in between





Technological advancement in every biomass category

- **lignin** is the most intensively investigated source of innovative BBPs at current
- the highest number of new products next to commercialization actually derives from **vegetable fibres**
- **urban wastes** are also intensively investigated, and there are products under development at all stages of technical advancement.



Key markets and main applications of the TOP 20 BBPs

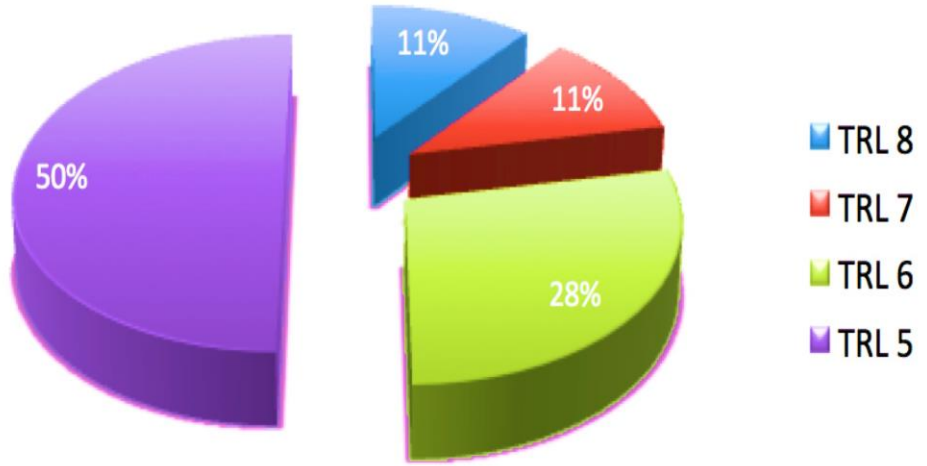
assessment based on: active marketplace, EU-based development, innovation degree, market potential

Biomass category	TOP BBPs under development	Key markets and applications
Natural rubber	• **Guayule rubber**	• substitute of natural rubber from Hevea Br. in all rubbery goods. Automotive. Biomedical items.
Vegetable fibres	• **Lignin biocomposites reinforced with natural fibres** • **Microfibrillated cellulose** • **Thermoplastic biopolymers reinforced with natural fibres** • **Natural fibres reinforced bioresin pre-pregs** • **Self-binding composite non-woven natural fibres**	• injection molding of plastic items • rheology modifier, reinforcing filler, emulsions stabilizer, filtering media, biomedical field. • alternative to glass or carbon-fibres reinforced plastics • alternative to glass or carbon-fibres reinforced pre-pregs • plastic paper
Renewable oils and fats	• **Biolubricants** • **PHAs** • **Biobased polyamide 12**	• automotive and industrial field • biodegradable plastics • technical plastics

Biomass category	TOP BBPs under development	Key markets and applications
Lignin	• **Lignin-based carbon nanofibres** • **Bio-BTX aromatics** • **Lignin bio-oil** • **Lignin-based phenolic resins** • **High-purity lignin** • **Biobased phenol and alkylphenols**	• alternative to PAN-based carbon fibers. Composites • bio-based raw chemicals • green chemicals and biofuels • alternative to phenolic resins. Constructions. • thermosets. Composites. Additive for plastics. • aromatic chemicals and monomers
Terpenes	• **Limonene-based engineering polymers**	• bio-based polyurethanes, polyamides, polycarbonate
Polyelectrolytes	• **Bacterial biosurfactants (sophorolipids and rhamnolipids)** • **Biotechnological chitosan**	• medical and pharmaceutical formulations, cosmetics, personal care, food industry
Urban biowastes	• **PHAs from urban wastes** • **volatile fatty acids (VFAs) mixtures**	• biodegradable plastics • raw chemicals to produce esters, solvents, polymers.

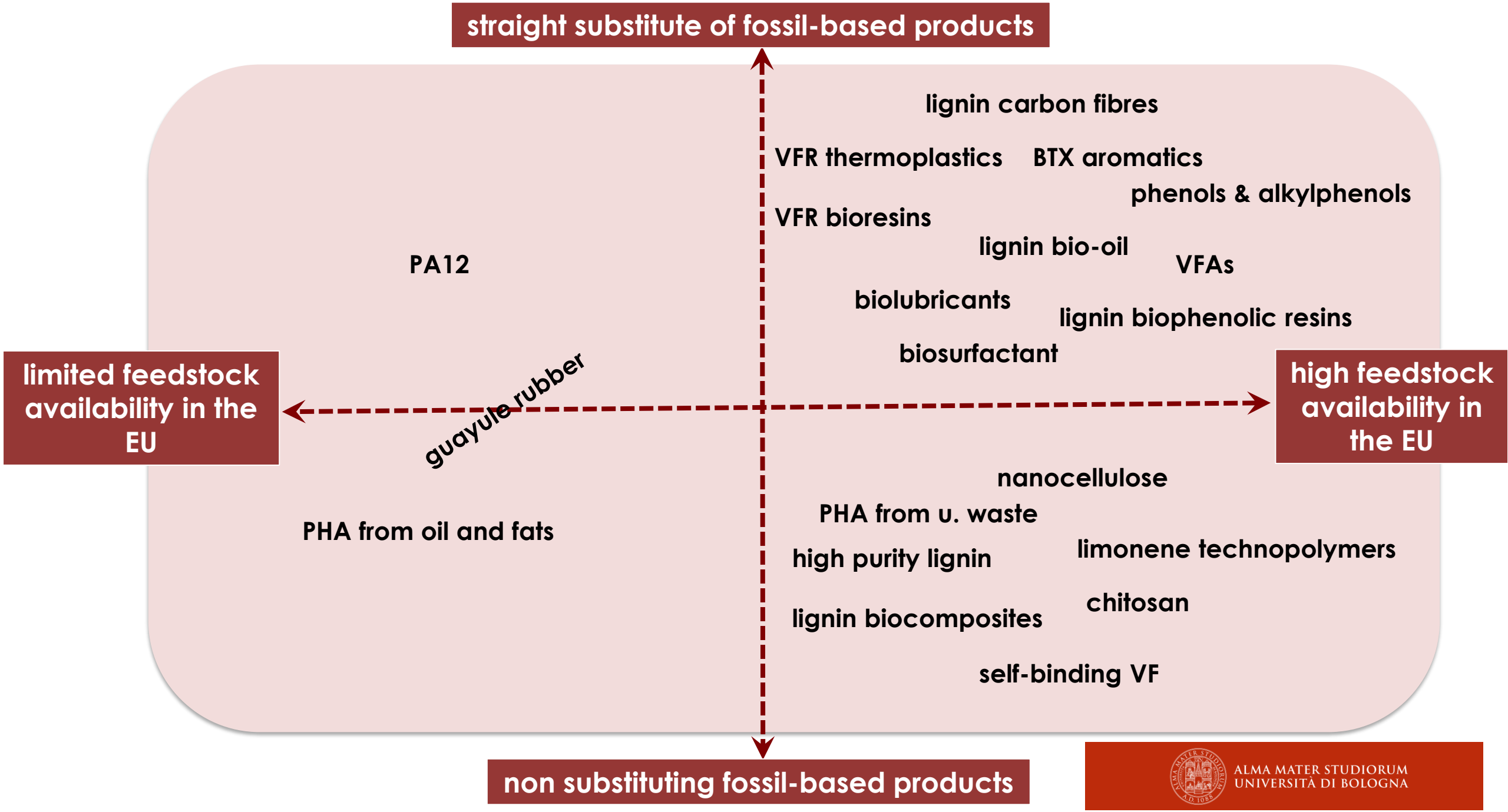
TRL distribution of the TOP 20 innovative BBPs

TRL	5	6	7	8	9
	pilot	demonstration		commercial	
Key for categories		guayule rubber			
				nanocellulose	
		composite non woven veg fibres			
natural rubber		lignin biocomposites reinforced with veg fibres			
vegetable fibres		veg fibers bioresin prepregs			
	veg fibres reinforced biopolymers				
lignin				bio-phenolic resins	
		bio-BTX aromatics			
renewable oils and fats	phenol and alkylphenols				
terpenes	lignin bio-oil				
natural polyelectrolytes	thermoplastic lignin polymers				
	high purity lignin				
urban wastes					
	lignin carbon fibres				
		PHAs from renewable oils and fats			
	polyamide 12				
	biolubricants				
	limonene-based engineering polymers				
			bacterial biosurfactants biotechnological chitosan		
			VFAs mixture		
		PHAs from urban wastes			



What are the trends actually??

- to be bio-based in no more enough!
- advanced materials whith improved technical performances
- innovative solutions for high added value niches, such as biomedical items
- valorization of wastes
- increasing opportunities for the plastics sector
- lignin is the new oil (?)
- forward-looking management of critical raw materials


straight substitute of fossil-based products
lignin carbon fibres
VFR thermoplastics
BTX aromatics
phenols & alkylphenols
VFR bioresins
lignin bio-oil
VFAs
PA12
biolubricants
lignin biophenolic resins
biosurfactant
limited feedstock availability in the EU
guayule rubber
high feedstock availability in the EU
nanocellulose
PHA from u. waste
PHA from oil and fats
high purity lignin
limonene technopolymers
chitosan
lignin biocomposites
self-binding VF
non substituting fossil-based products

Market and scenario analysis

- Relatively high costs: 1,5-5 time competing products
- But interesting Compound Annual Growth Rate (CAGR): 2-12%

Opportunities from alternative scenarios:

- Fossil fuel depletion
- Sustainability concerns
- Climate concerns

R&D gaps

- Importance of research:
  - Yields & technologies
  - Feedstock availability
  - Quality and stability, batch-to-batch consistency
- But key role of:
  - Policy
  - Awarness

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