SUSTAINABLE, BIO-BASED AND NON-CONVENTIONAL

ADDITIVES FOR HIGH VOLTAGE INSULATION SYSTEMS

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supported by
Visegrad Fund

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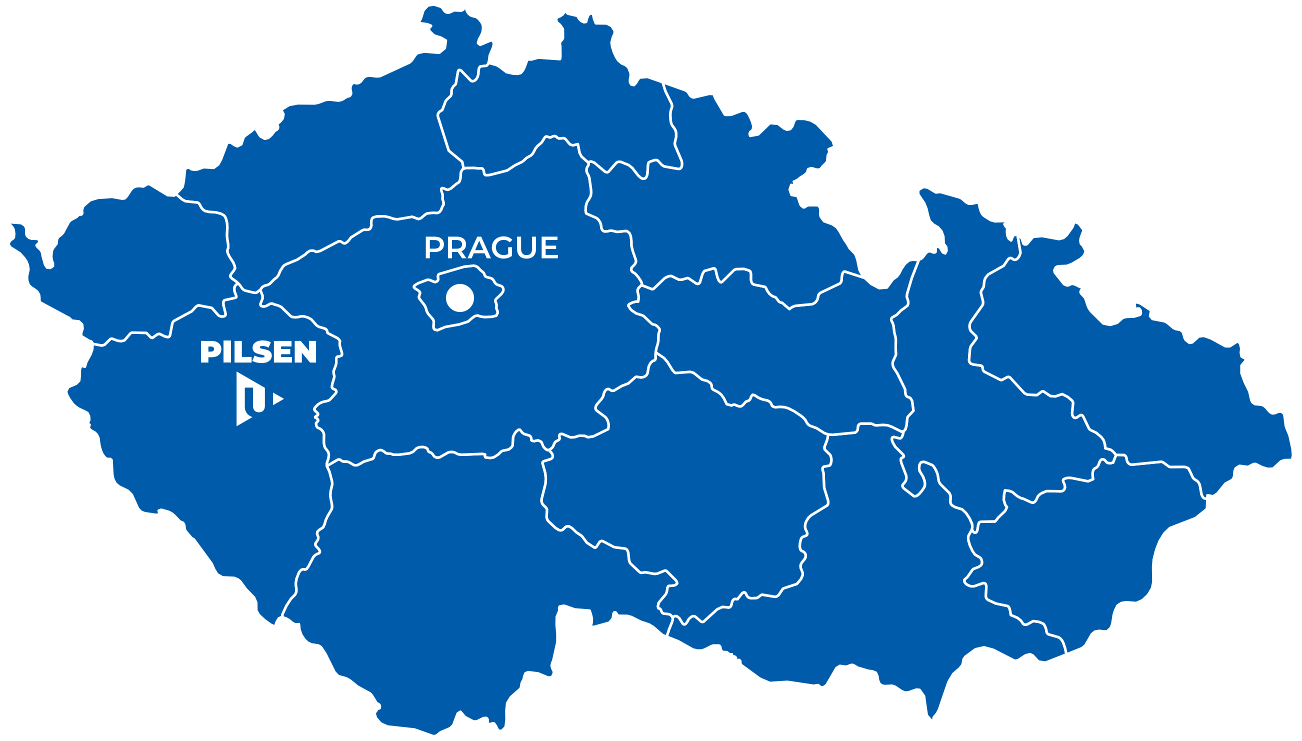
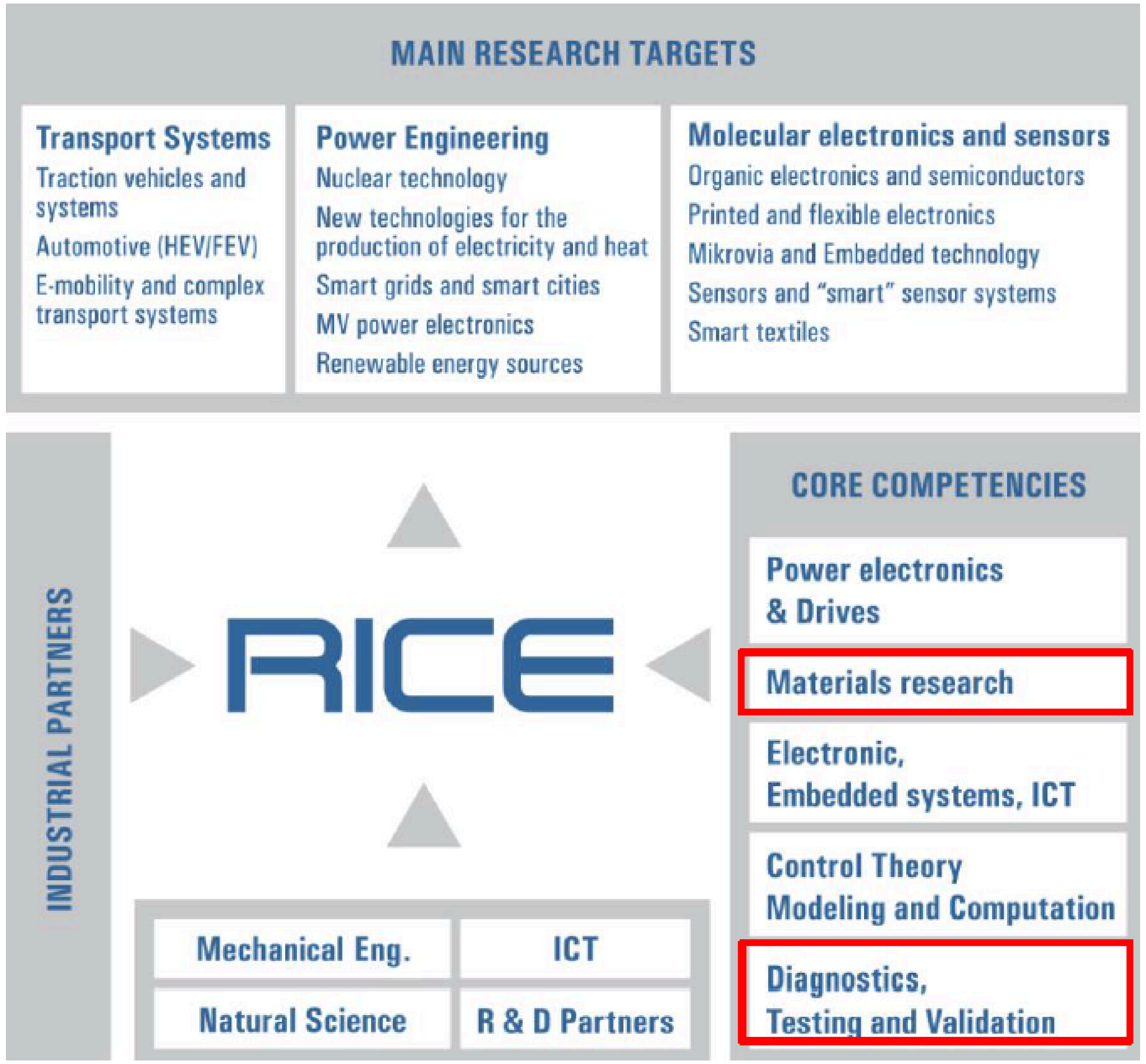
UNIVERSITY OF WEST BOHEMIA

- **Founded 1950 (VŠSE), 1991 (UWB)**
- **Total number of students - 12 000**
- **Number of Ph.D. students - 800**
- **Total number of staff - 2 000+**
- **9 faculties**
- **2 institutes**
- **4 research centers**



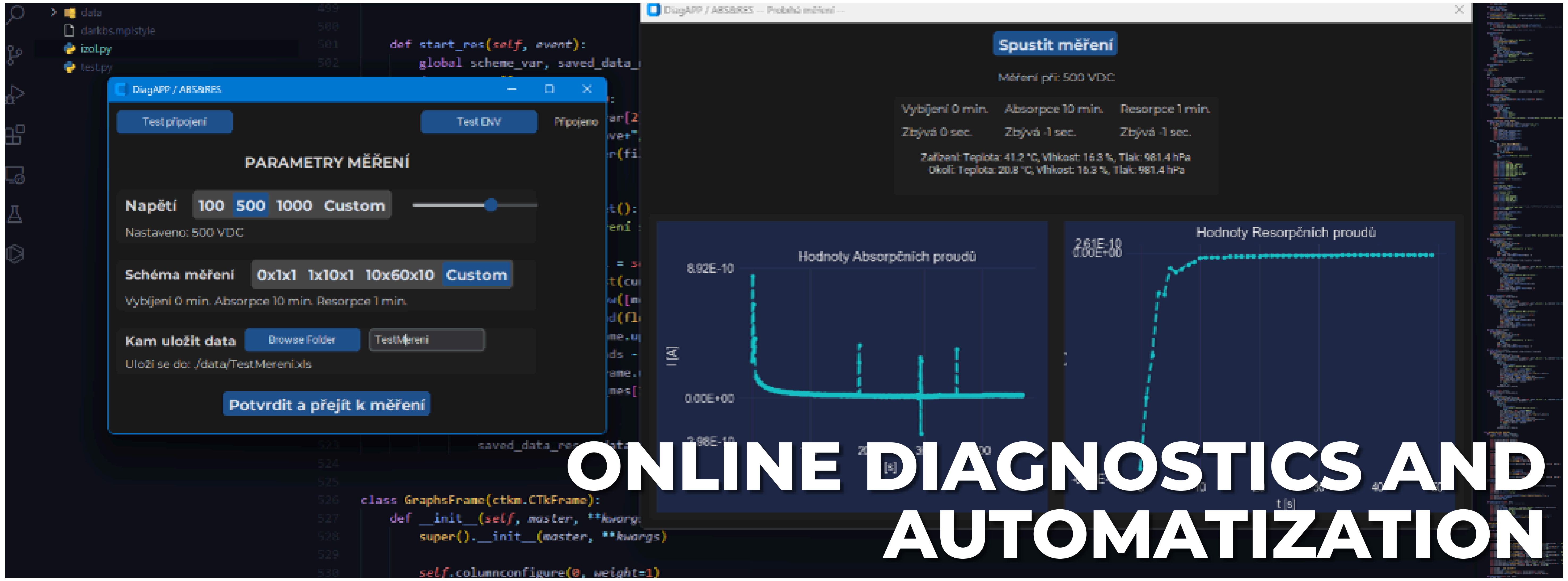
FEE AND RICE



MAIN RESEARCH TARGETS
Transport Systems
Traction vehicles and systems
Automotive (HEV/FEV)
E-mobility and complex transport systems
Power Engineering
Nuclear technology
New technologies for the production of electricity and heat
Smart grids and smart cities
MV power electronics
Renewable energy sources
Molecular electronics and sensors
Organic electronics and semiconductors
Printed and flexible electronics
Mikrovia and Embedded technology
Sensors and "smart" sensor systems
Smart textiles
INDUSTRIAL PARTNERS
RICE
Mechanical Eng.
ICT
Natural Science
R & D Partners
CORE COMPETENCIES
Power electronics & Drives
Materials research
Electronic, Embedded systems, ICT
Control Theory Modeling and Computation
Diagnostics, Testing and Validation


Diagnostics
Process engineering
High Voltage
High-Bay Warehouse
KET
Acoustics
Electronics
Sensors
Printed electronics
Smart Textiles

NEW HV DIELECTRIC MATERIALS



DiagAPP / ABS&RES
Test připojení
Test ENV
Připojeno
PARAMETRY MĚŘENÍ
Napětí
100
500
1000
Custom
Nastaveno: 500 VDC
Schéma měření
0x1x1
1x10x1
10x60x10
Custom
Vybíjení 0 min. Absorpce 10 min. Resorpce 1 min.
Kam uložit data
Browse Folder
TestMereni
Uloží se do: ./data/TestMereni.xls
Potvrdit a přejít k měření
Spustit měření
Měření při: 500 VDC
Vybíjení 0 min.
Absorpce 10 min.
Resorpce 1 min.
Zbývá 0 sec.
Zbývá -1 sec.
Zbývá -1 sec.
Hodnoty Absorpčních proudů
Hodnoty Resorpčních proudů
ONLINE DIAGNOSTICS AND AUTOMATIZATION

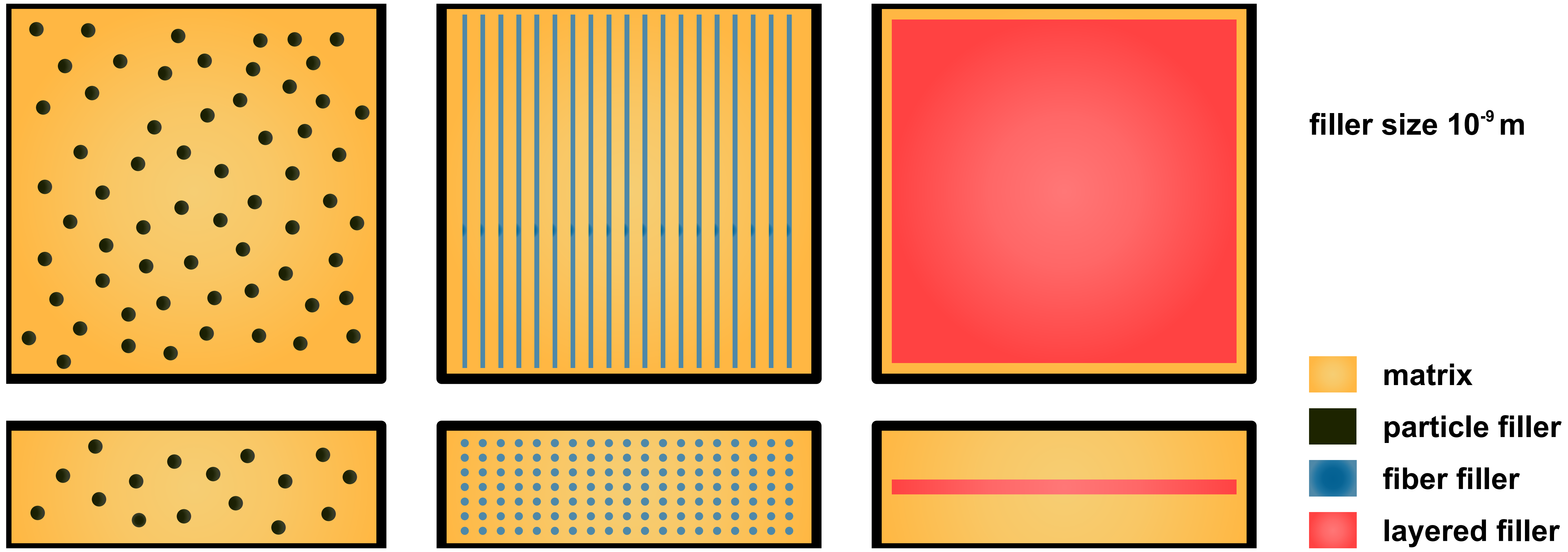
Tektronix
SPACE CHARGE

MATERIAL DIAGNOSTICS

APPLIED RESEARCH PROJECTS

CURRENT STATE OF SOLID NANOCOMPOSITES

CURRENT STATE OF NANOCOMPOSITES



COMMONLY INVESTIGATED NANOFILLERS

METAL OXIDES (SiO_2, MgO, TiO_2, Al_2O_3, Fe_3O_4....)

LAYERED NANOCLAYS (MMT....)

CARBON-BASED (CNT, GRAPHENE....)

Material	Dielectric constant
SiO_2 (silicon di oxide)	3.5–4.5, 3.9
Al_2O_3 (aluminium oxide)	8.5–9
Si_3N_4 (silicon nitride)	6.2
HfO_2 (hafnium oxide)	22, 25
MgO (magnesium oxide)	9.8
ZrO_2 (zirconium dioxide)	25, 17.5
TiO_2 (titanium dioxide)	80–100
Ta_2O_3 (tantalum pentoxide)	26

WHY NANOFILLERS?

MECHANICAL PROPERTIES

DIELECTRIC PROPERTIES

CONDUCTIVE PROPERTIES

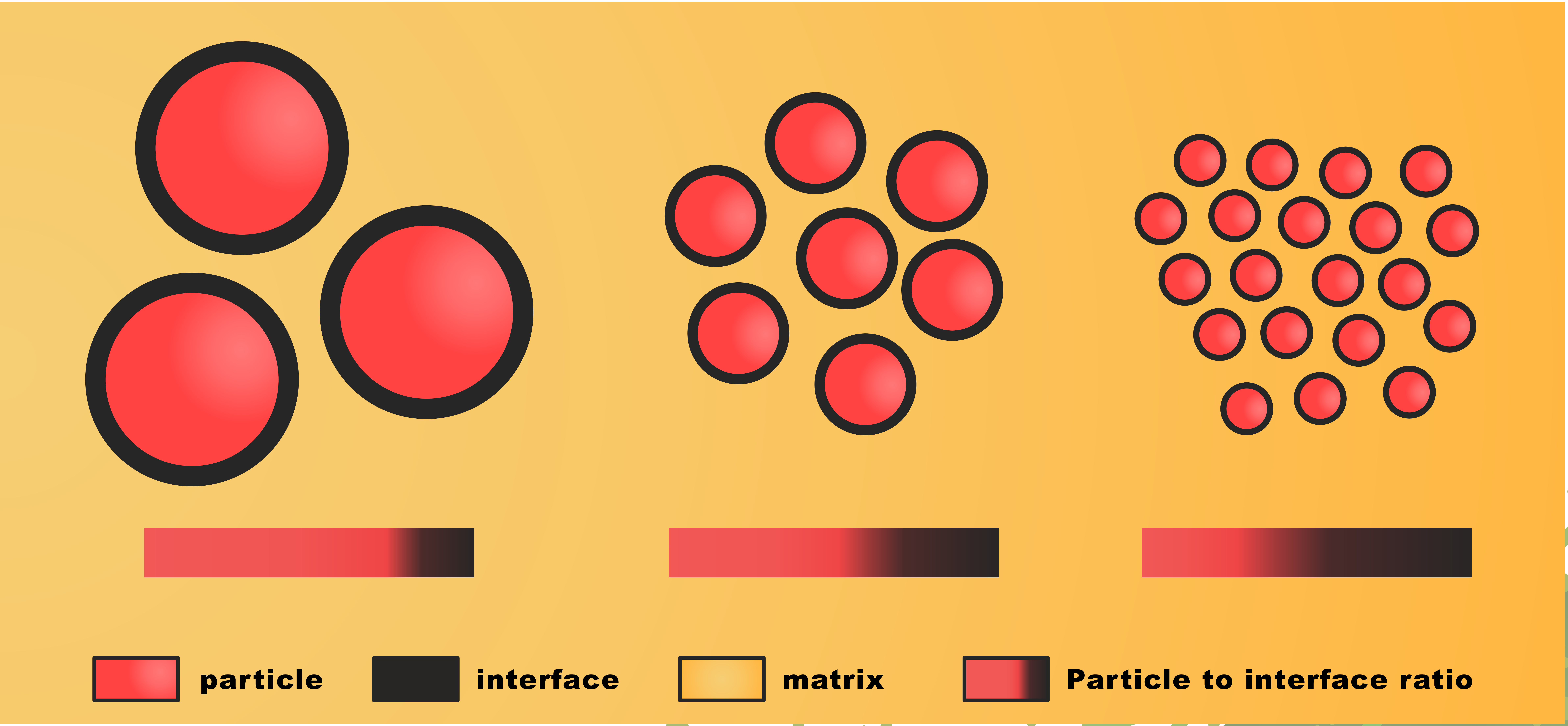
ENERGY STORAGE

FIRE RETARDANCY

Adding a few wt. % enhances desired properties.

Kumar, Brijesh & Kaushik, Brajesh Kumar & Negi, Yuvraj. (2014). Perspectives and challenges for organic thin film transistors: Materials, devices, processes and applications. Journal of Materials Science: Materials in Electronics. 25. 10.1007/s10854-013-1550-2.

CURRENT STATE OF NANOCOMPOSITES



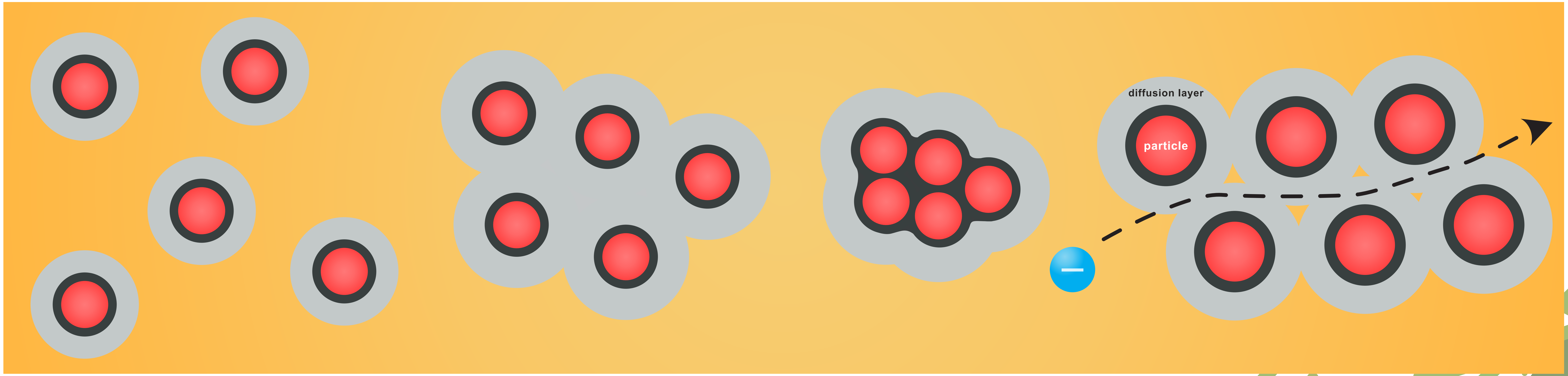
CURRENT STATE OF NANOCOMPOSITES

CHALLENGES WITH NANCOMPOSITES

AGGREGATION VS DISPERSION -> SPACE CHARGE -> DIELECTRIC PROPERTIES

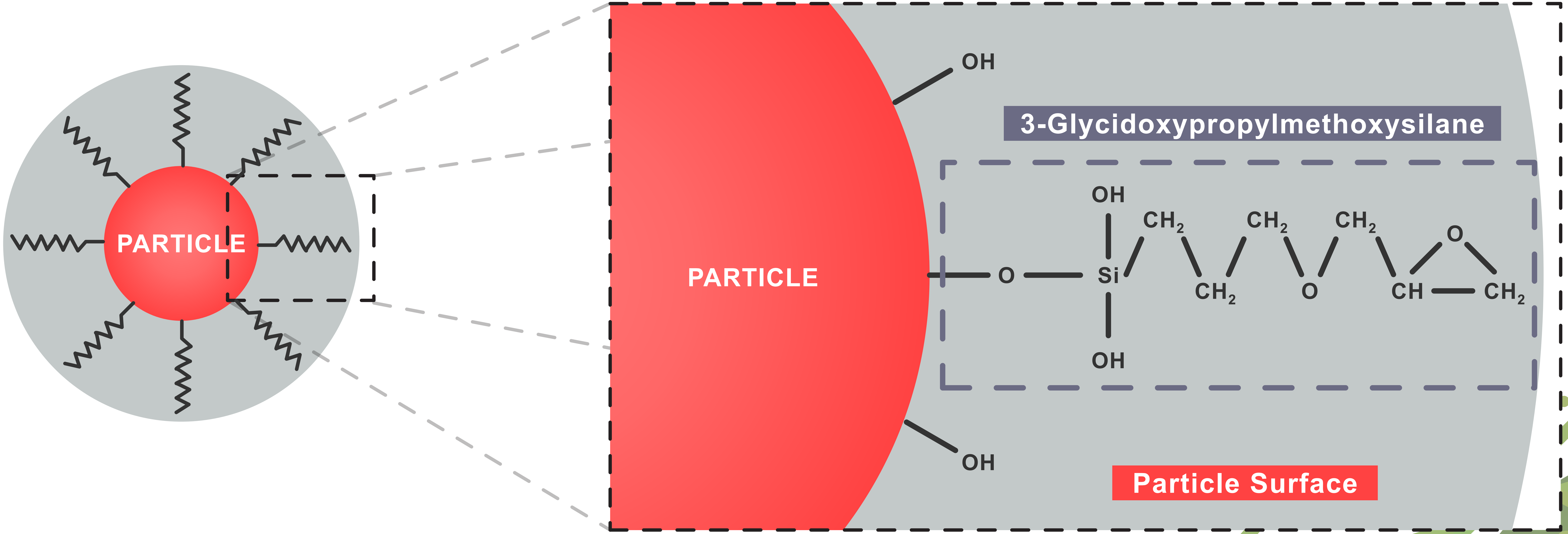
HIGH COST - CERTAIN NANOFILLERS -> USE OF HYBRID FILLERS

BALANCE (MATERIALS AND WT. %) - THERE IS NO FILLER THAT IMPROVES EVERYTHING



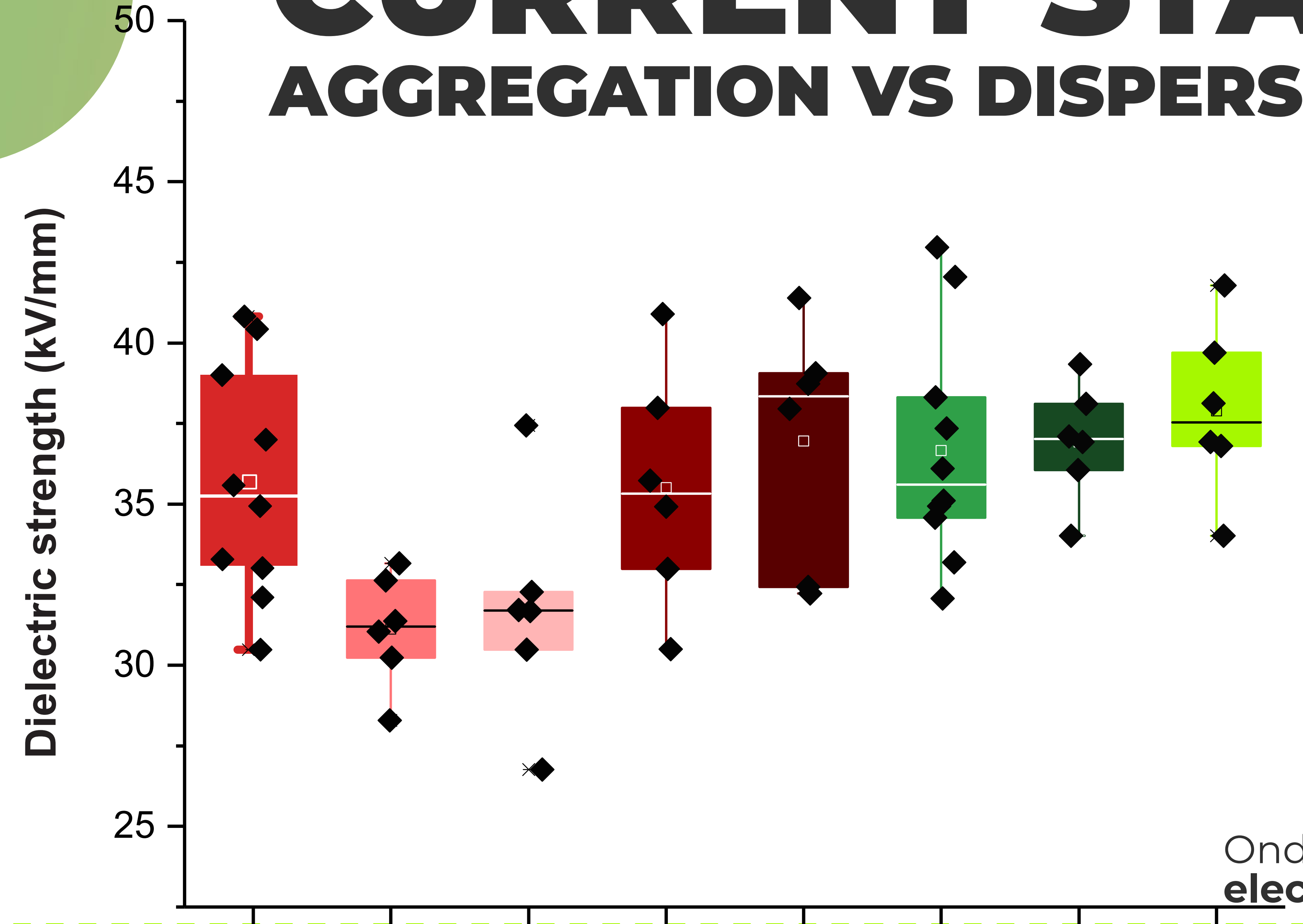
CURRENT STATE OF NANOCOMPOSITES

AGGREGATION VS DISPERSION

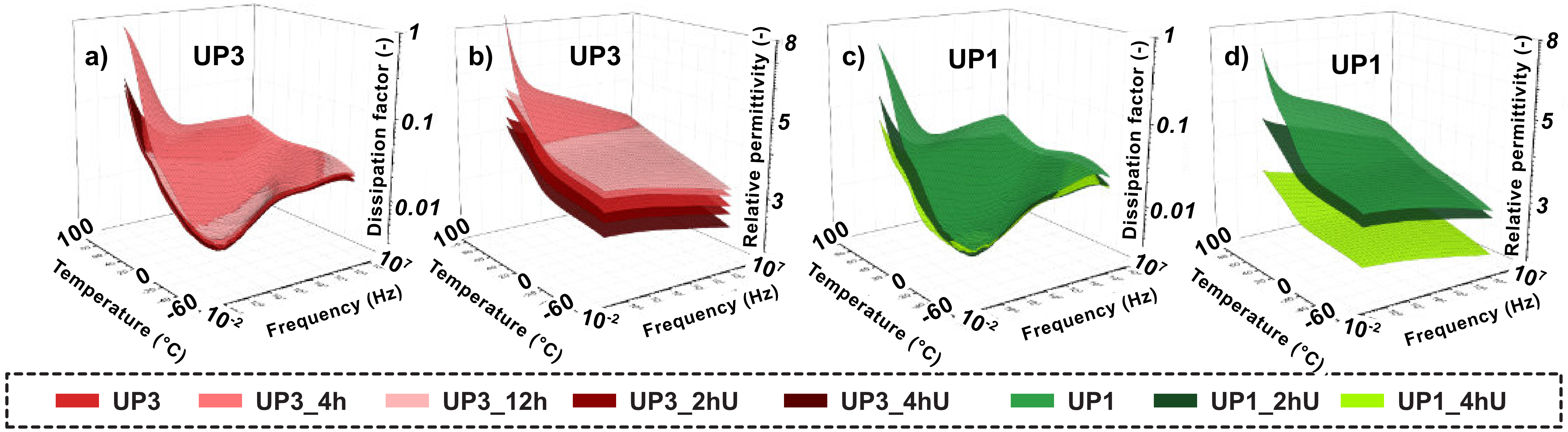


CURRENT STATE OF NANOCOMPOSITES

AGGREGATION VS DISPERSION



functionalized SiO_2 nanoparticles (1 wt. %, 10 nm)



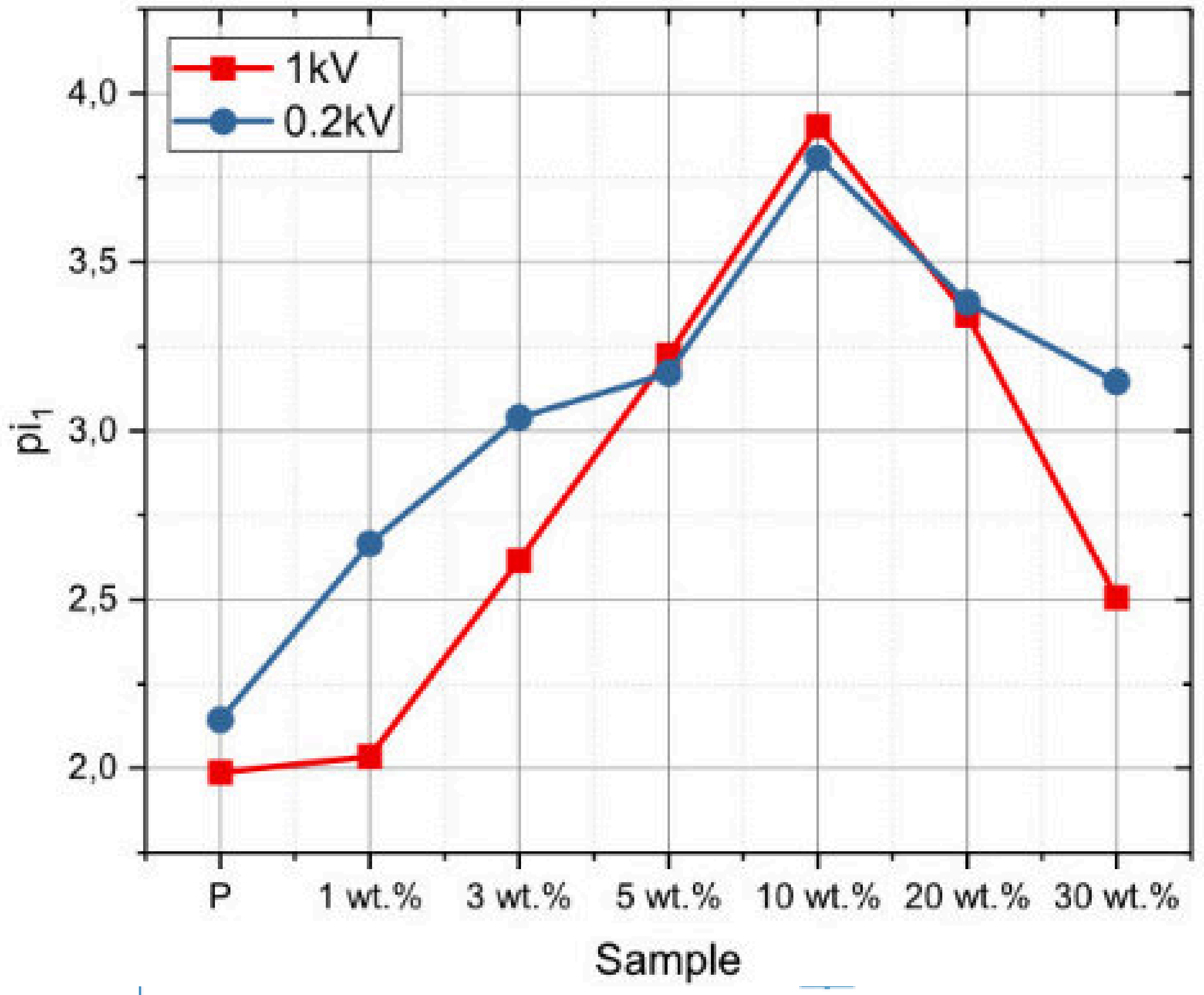
Ondrej Michal, Václav Mentlik, Jaroslav Hornak; **Influence of prolonged mixing of silicon dioxide nanoparticles on the electrical properties of resin nanocomposites**. AIP Conf. Proc. 5 May 2023; 2778 (1): 040018. https://doi.org/10.1063/5.0135871

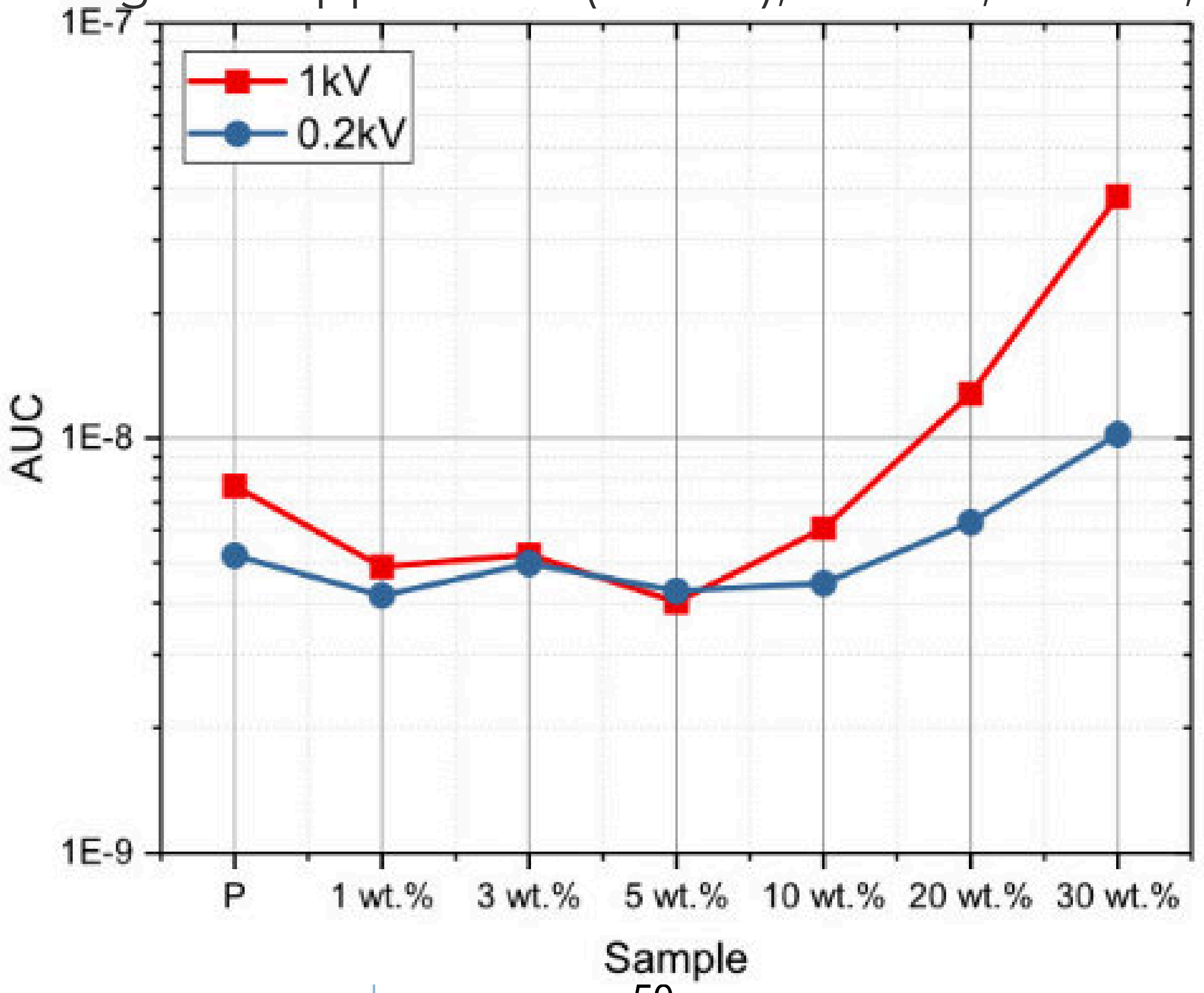
CURRENT STATE OF NANOCOMPOSITES

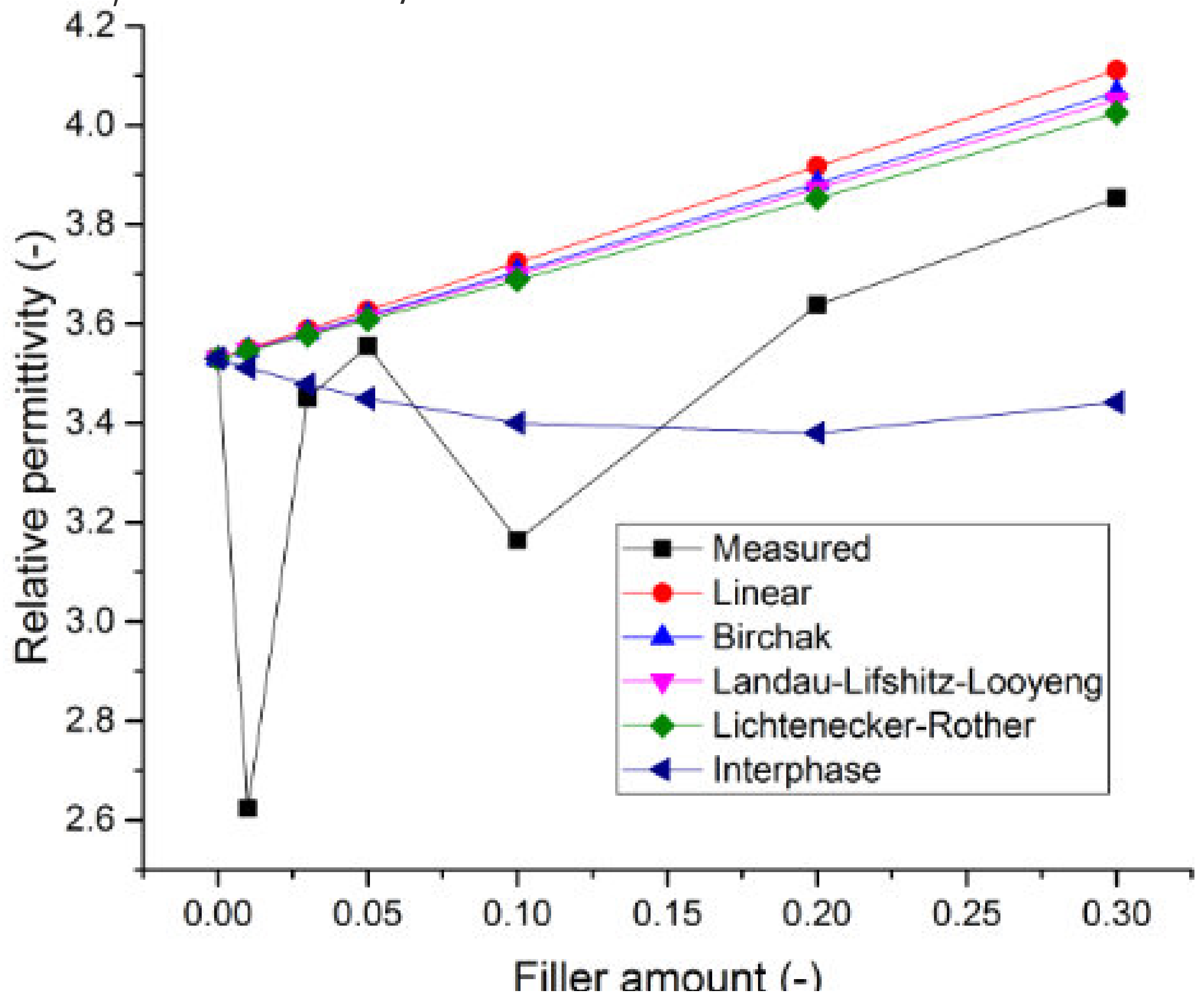
BALANCE IN WT. %

J. Hornak et al., "**Current and Voltage Response Measurements on Nanodielectrics**," 2020 IEEE 3rd International Conference on Dielectrics (ICD), Valencia, Spain, 2020, pp. 285-288, doi: 10.1109/ICD46958.2020.9341970.
J. Hornak, O. Michal, P. Trnka, P. Kadlec, V. Mentlík and P. Totzauer, "**Verification of Relative Permittivity Models for Composite Nanodielectrics at Elevated Temperatures**," 2018 IEEE International Conference on High Voltage Engineering and Application (ICHVE), Athens, Greece, 2018, pp. 1-4, doi: 10.1109/ICHVE.2018.8642034.

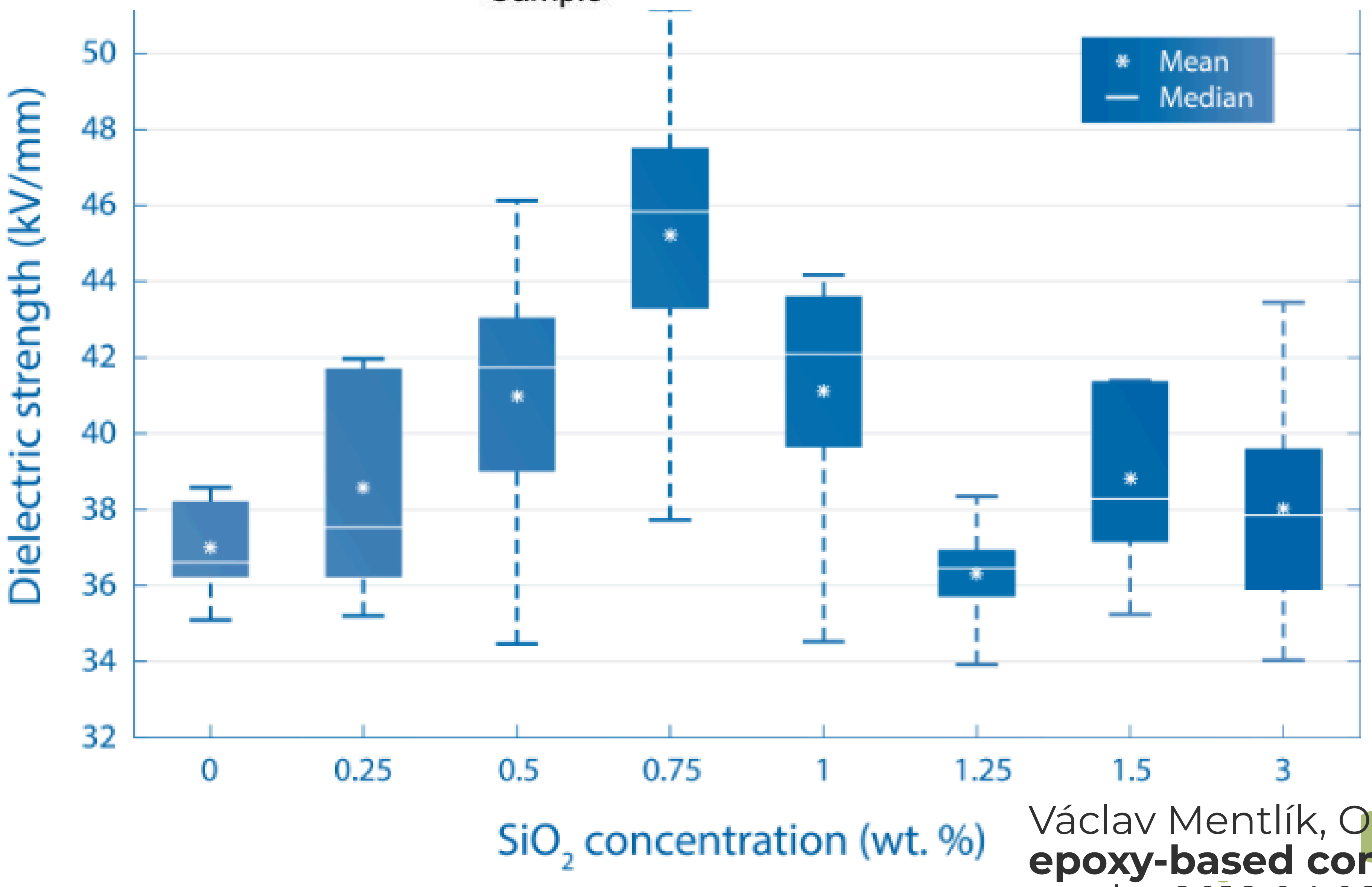
MgO

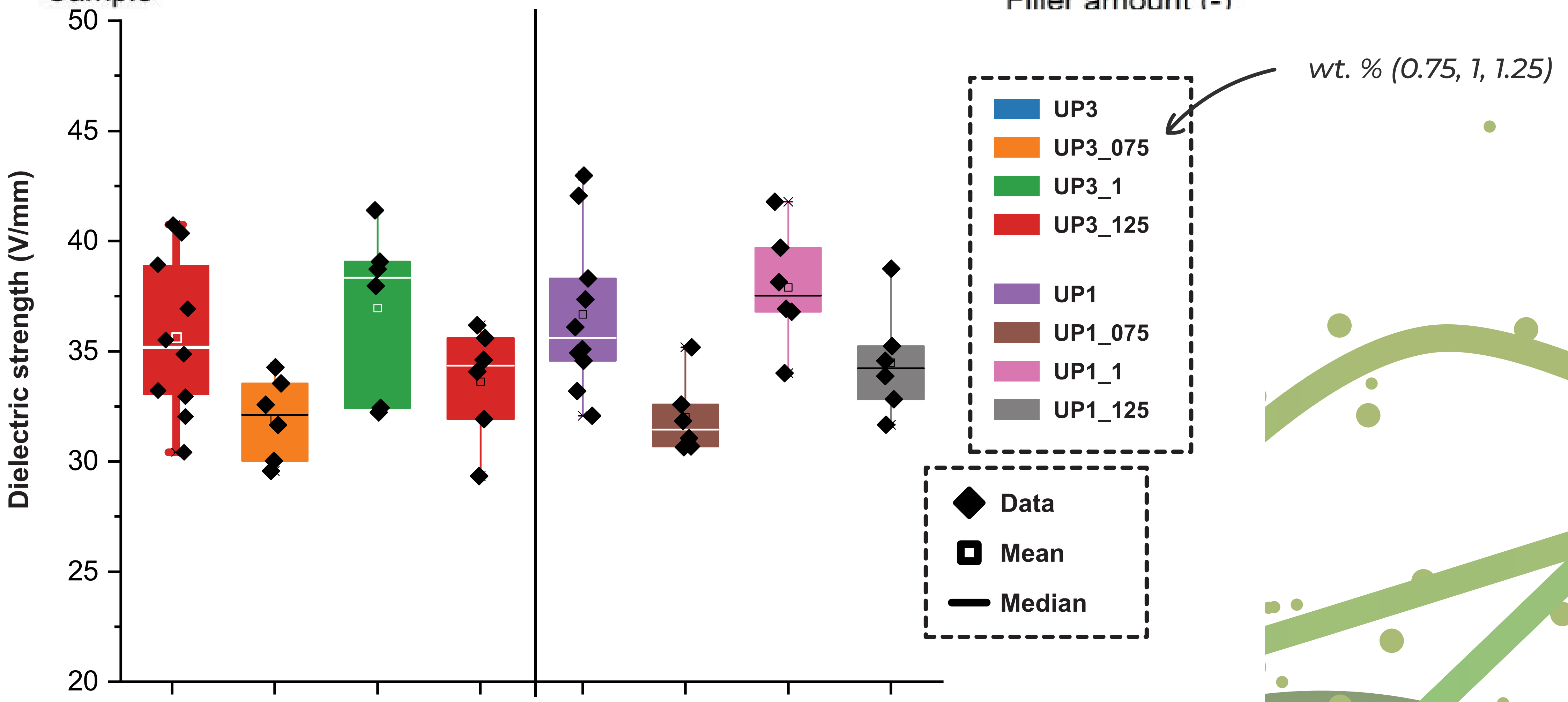






SiO_2





Václav Mentlík, Ondřej Michal, **Influence of SiO2 nanoparticles and nanofibrous filler on the dielectric properties of epoxy-based composites**, Materials Letters, Volume 223, 2018, Pages 41-44, ISSN 0167-577X, https://doi.org/10.1016/j.matlet.2018.04.021

SUSTAINABILITY IN NANO ADDITIVES

SUSTAINABILITY IN NANO ADDITIVES

WHAT IS THAT EVEN MEANS?

REDUCING ENVIRONMENTAL IMPACT

Nanofillers that are dispersed within a *polymer* matrix, improve their mechanical, thermal, and dielectric properties. However, the sustainability of these materials depends on various factors, including the **source** of the nanofillers, their **lifecycle**, and the potential for **recycling** or **biodegradability**.

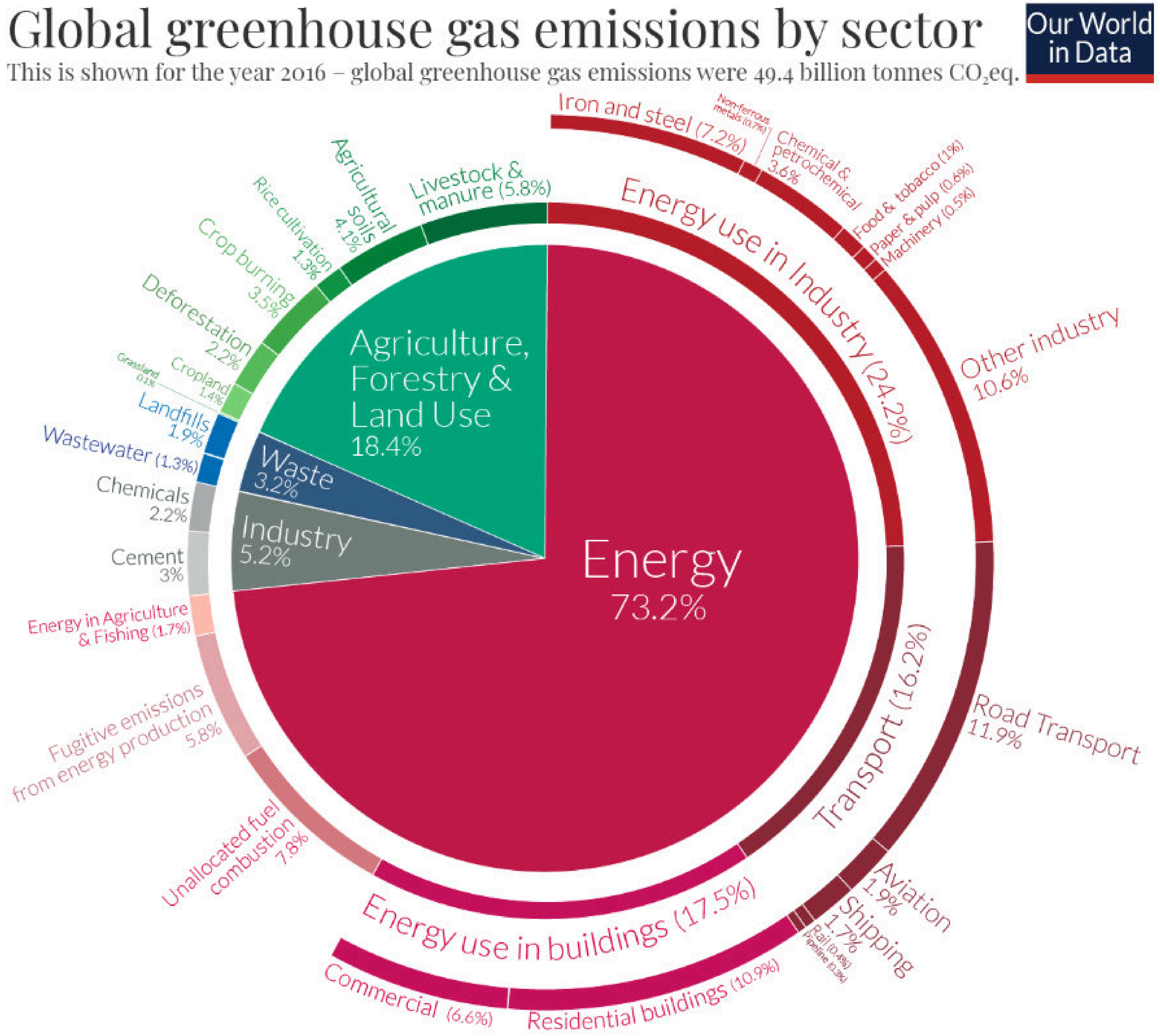
ECO-FRIENDLY SOURCES AND SYNTHESIS

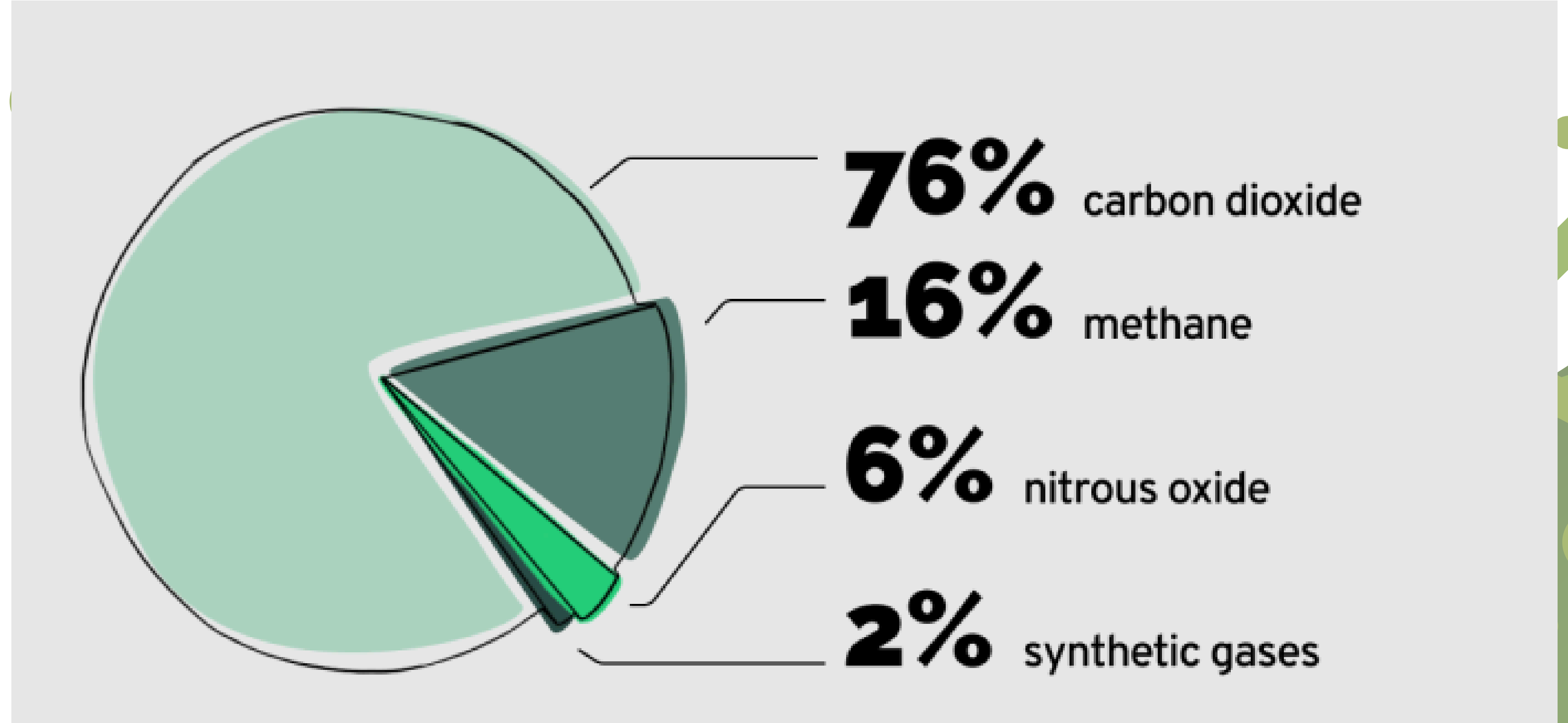
LIFECYCLE ASSESSMENT AND END-OF-LIFE STRATEGIES

BIODEGRADABILITY AND ENVIRONMENTAL DEGRADATION

SUSTAINABILITY IN NANO ADDITIVES

ECO-FRIENDLY SOURCES AND SYNTHESIS



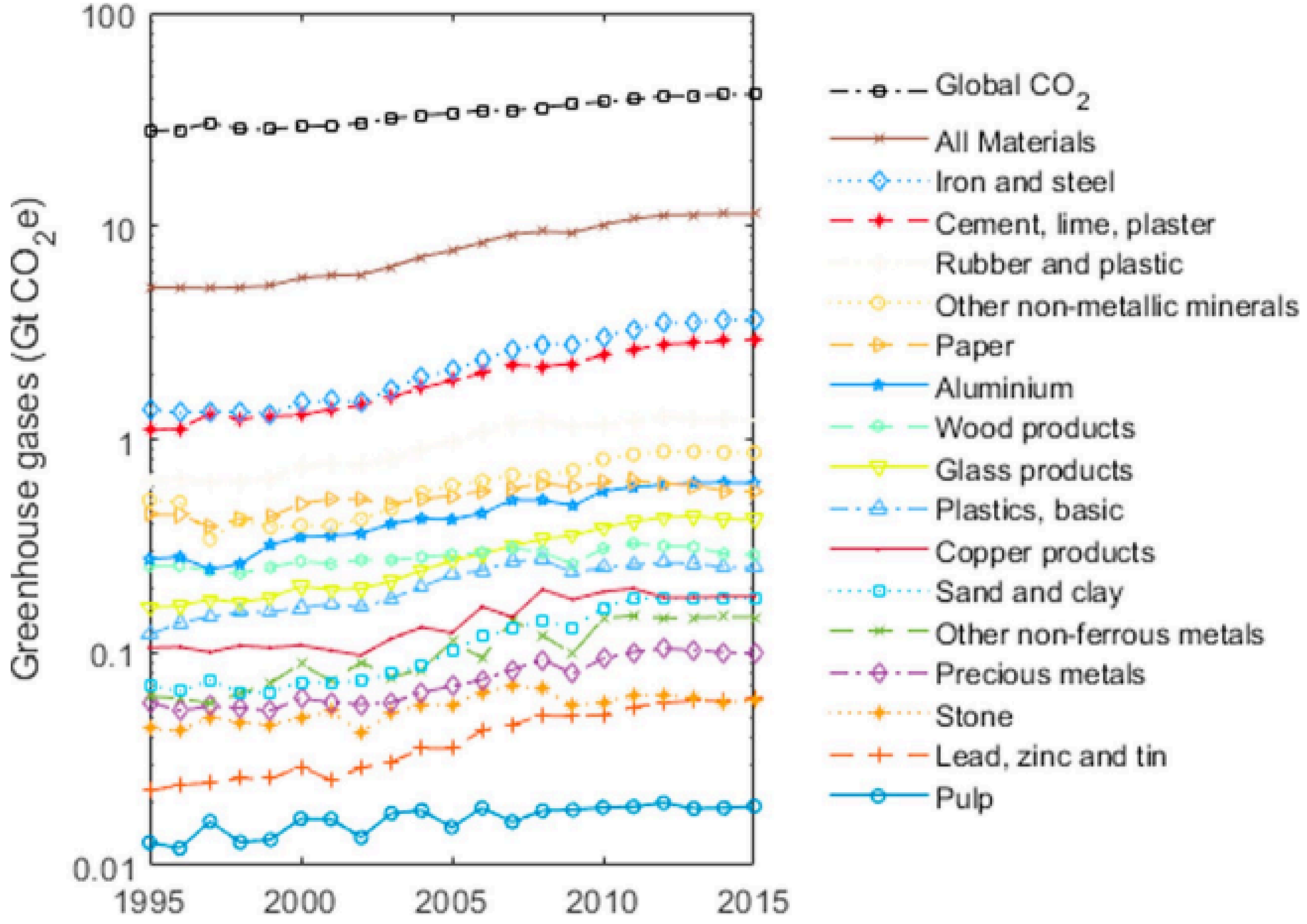


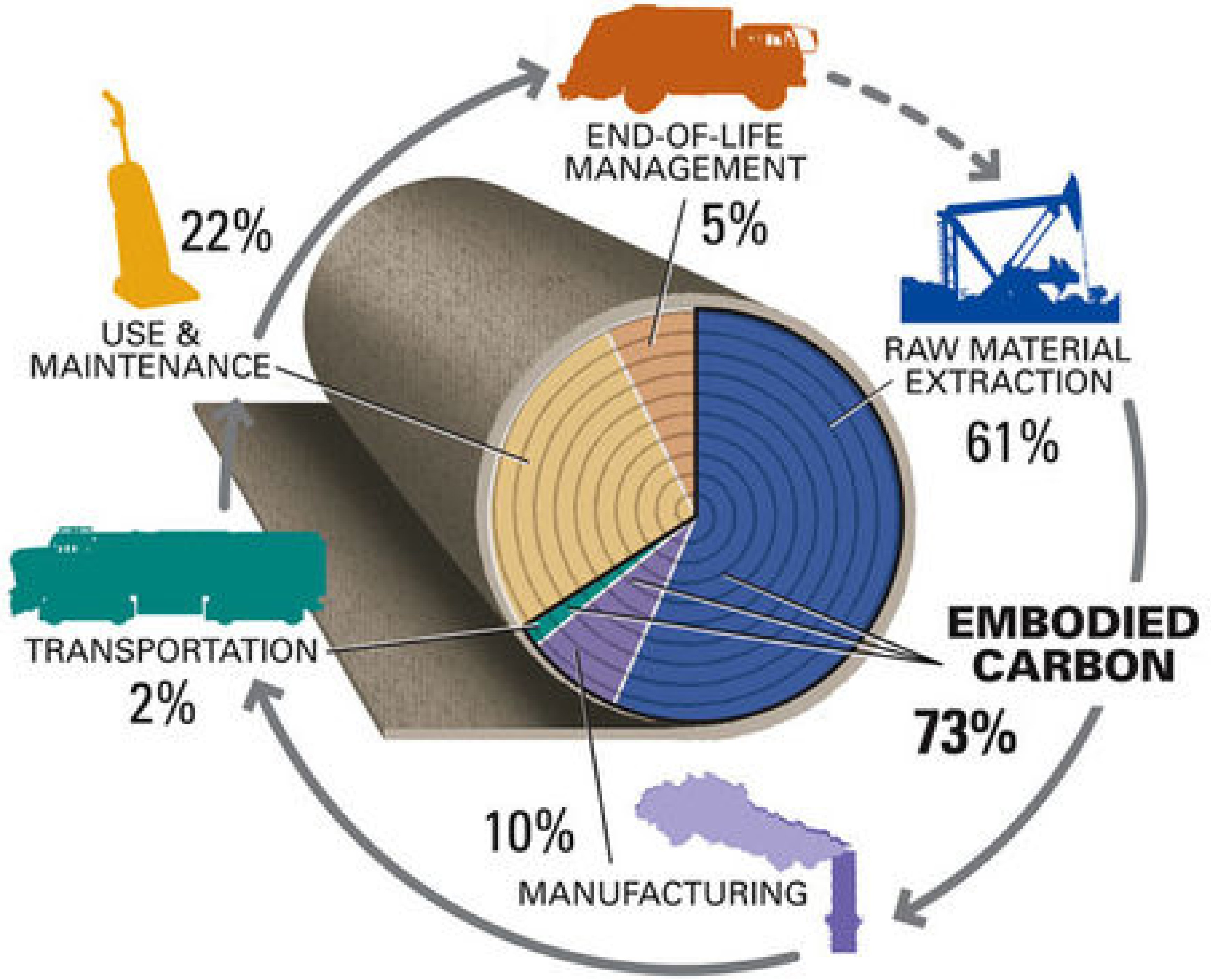
GLOBAL GREENHOUSE GAS EMISSIONS PER TYPE OF GAS. SOURCE: EPA.

Hannah Ritchie (2020) - "**Sector by sector: where do global greenhouse gas emissions come from?**" Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/ghg-emissions-by-sector' [Online Resource]

SUSTAINABILITY IN NANO ADDITIVES

ECO-FRIENDLY SOURCES AND SYNTHESIS



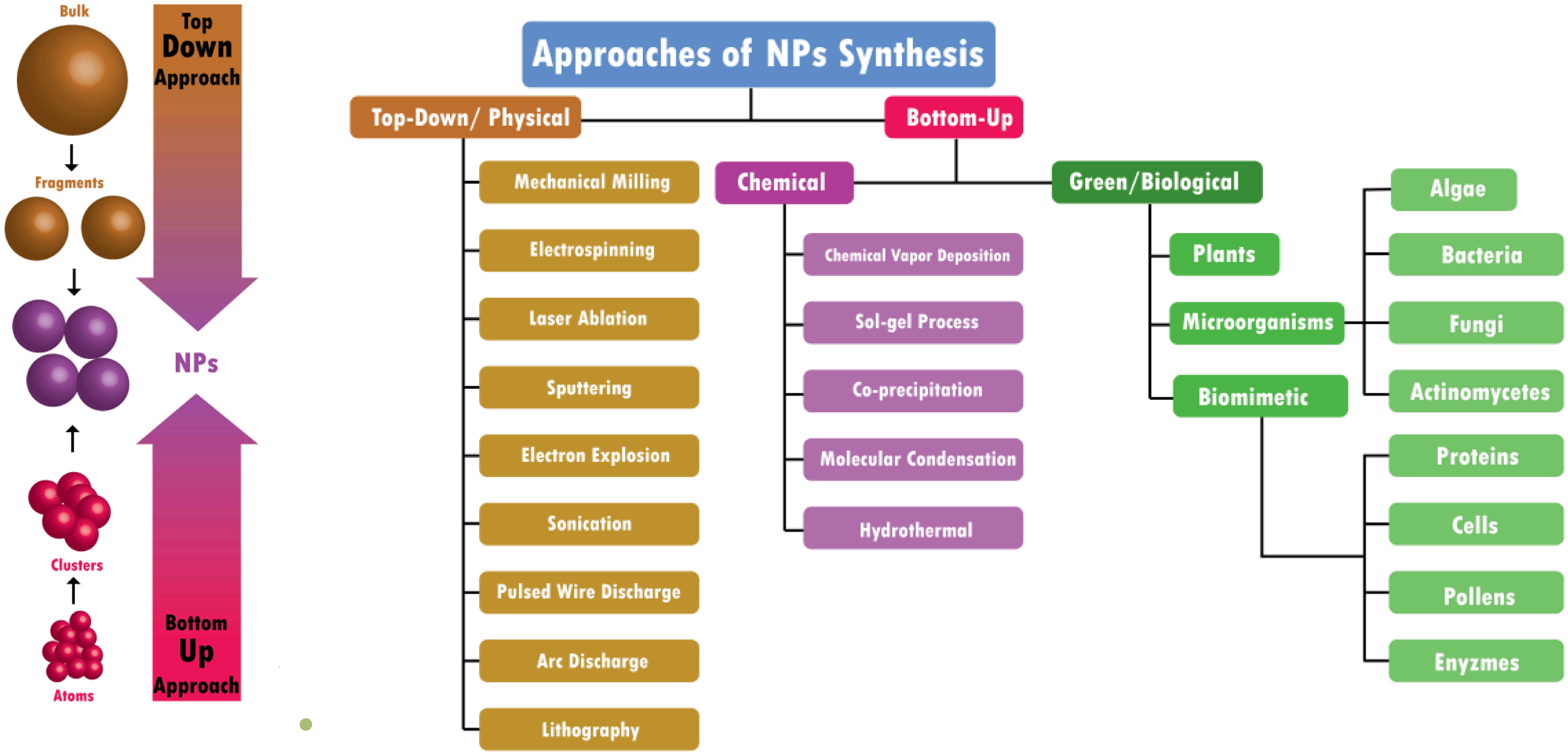


LIFE CYCLE EMISSIONS OF FOSSIL FUEL-BASED MATERIALS FOR CONSTRUCITON APPLICATIONS

Hertwich, E.G. **Increased carbon footprint of materials production driven by rise in investments**. Nat. Geosci. 14, 151–155 (2021). https://doi.org/10.1038/s41561-021-00690-8

SUSTAINABILITY IN NANO ADDITIVES

ECO-FRIENDLY SOURCES AND SYNTHESIS



Altammar KA (2023) **A review on nanoparticles: characteristics, synthesis, applications, and challenges**.
Front. Microbiol. 14:1155622. doi: 10.3389/fmicb.2023.1155622

SUSTAINABILITY IN NANO ADDITIVES

ECO-FRIENDLY SOURCES AND SYNTHESIS

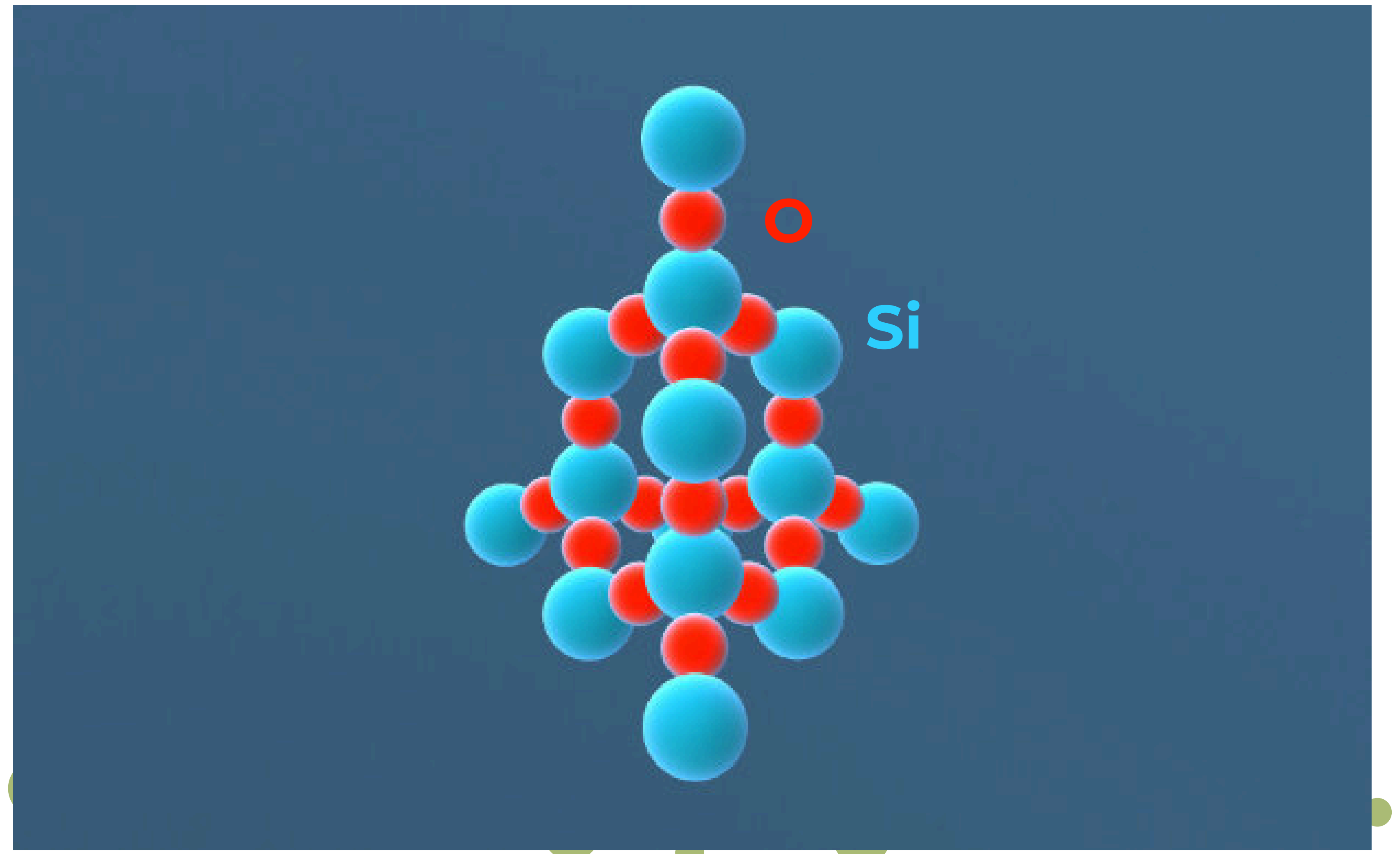
SILICON DIOXIDE (SiO_2)

COMMONLY KNOWN AS **SILICA**

FOUND IN NATURE AS **QUARTZ (MOST ABUNDANT MINERALS ON EARTH)** AND A MAJOR COMPONENT OF **SAND**

RECOGNIZED FOR ITS **BIOCOMPATIBILITY**

NATURAL AND SYNTHETIC SOURCES



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SUSTAINABILITY IN NANO ADDITIVES

ECO-FRIENDLY SOURCES AND SYNTHESIS

*1 - aqueous alkali metal silicate solution -> melted quartz sand with soda (Na_2CO_3) at about 900-1300 °C

CHEMICAL SYNTHESIS OF SiO_2

PRECIPITATED: WATER GLASS*1(**$Na_2O \cdot nSiO_2$** ; n = 2–4)) IS NEUTRALIZED WITH ACID (e.g., **H_2SO_4**) RELEASING **SiO_2** AND **nH_2O** (FINAL NPs FILTERED AND DRIED)

PYROGENIC/FUMED: REACTION OF SILICON TETRACHLORIDE **$SiCl_4$** WITH **O** AND **H** IN A FLAME

INDEPENDENT/STÖBER METHOD: ADDING PRECURSOR (MAINLY SILICON ALKOXIDE **TEOS**) (0.1–0.5 M) IN **ETHANOL** IN THE PRESENCE OF AMMONIUM HYDROXIDE (**NH_4OH**) (0.5–3 M) AND **H_2O** (0.5–17 M) AT 25 °C. MODIFIED VERSIONS FOR BETTER DISPERSED NPs OF THIS METHOD USING CTAB (REPLACEMENT ALCOHOLS WITH ALDEHYDES)

NEGATIVES

HAZARDOUS CHEMICALS HARMFUL TO THE ENVIRONMENT (CTAB, SOLVENTS...)

COSTLY TECHNIQUES (BY THE USE OF TEOS, SPECIFICALLY)

Rodriguez-Otero, A.; Vargas, V.; Galarneau, A.; Castillo, J.; Christensen, J.H.; Bouyssiere, B. **Sustainable Harnessing of SiO2 Nanoparticles from Rice Husks: A Review of the Best Synthesis and Applications**. Processes 2023, 11, 3373. https://doi.org/10.3390/pr11123373

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SUSTAINABILITY IN NANO ADDITIVES

ECO-FRIENDLY SOURCES AND SYNTHESIS

GREEN SYNTHESIS OF SiO_2 (biomass and agricultural waste)

CURENTLY DISCUSSED TOPIC OF RESEARCHERS

IMPORTANCE OF PRETREATMENT OF WASTE

HIGH IMPURITY CONTENT, SUCH AS METAL OXIDES LIKE IRON OXIDE (Fe_2O_3), OBSTRUCTS THE PROCESS OF OBTAINING SILICA WITH AN ACCEPTABLE HIGH PURITY. ACID LEACHING (H_2SO_4) IS REQUIRED TO RETAIN THE BIOGENIC STRUCTURE OF SILICA WHILE REMOVING IMPURITIES. REPLACEMENT FOR ECO-FRIENDLY LEACHING AGENT (LIKE CA -> $C_6H_8O_7$)

TABLE: ASH AND SiO_2 CONTENT OF SOME PLANTS

Plant	Part of plant	Ash%	Silica%
Cane	Husk	—	08.00
Coffee	Husk	—	12.00
Bagasse	—	14.71	73.00
Bamboo	Nodes (inner portion)	1.44	57.40
Bread fruit tree	Steam	8.64	81.80
Corn	Leaf sheath	12.15	64.32
Lantana	Leaf and stem	11.24	23.38
Rice husk	—	22.15	93.00
Rice straw	—	14.65	82.00
Sorghum	Leaf sheath epidermis	12.25	88.75

TABLE: SILICA COMPOSITION OF VARIOUS AGRICULTURAL WASTES

Agricultural waste	Silica content (%)
Sugarcane bagasse ash	55–88.7
Bamboo lead ash	49.9
Rice husk ash	86–97
Rice straw	84.6
Wheat husk ash	40.5–59.7
Palm oil ash	45.5

Rodriguez-Otero, A.; Vargas, V.; Galarneau, A.; Castillo, J.; Christensen, J.H.; Bouyssiere, B. **Sustainable Harnessing of SiO2 Nanoparticles from Rice Husks: A Review of the Best Synthesis and Applications**. Processes 2023, 11, 3373. https://doi.org/10.3390/pr11123373

Muhammud AM, Gupta NK. **Nanostructured SiO2 material: synthesis advances and applications in rubber reinforcement**. RSC Adv. 2022 Jun 23;12(29):18524-18546. doi: 10.1039/d2ra02747j. PMID: 35799930; PMCID: PMC9218877.

September, Lyle & Kheswa, N. & Seroka, Ntalane & Khotseng, Lindiwe. (2023). **Green synthesis of silica and silicon from agricultural residue sugarcane bagasse ash -a mini review.** RSC Advances. 13. 10.1039/d2ra07490g.

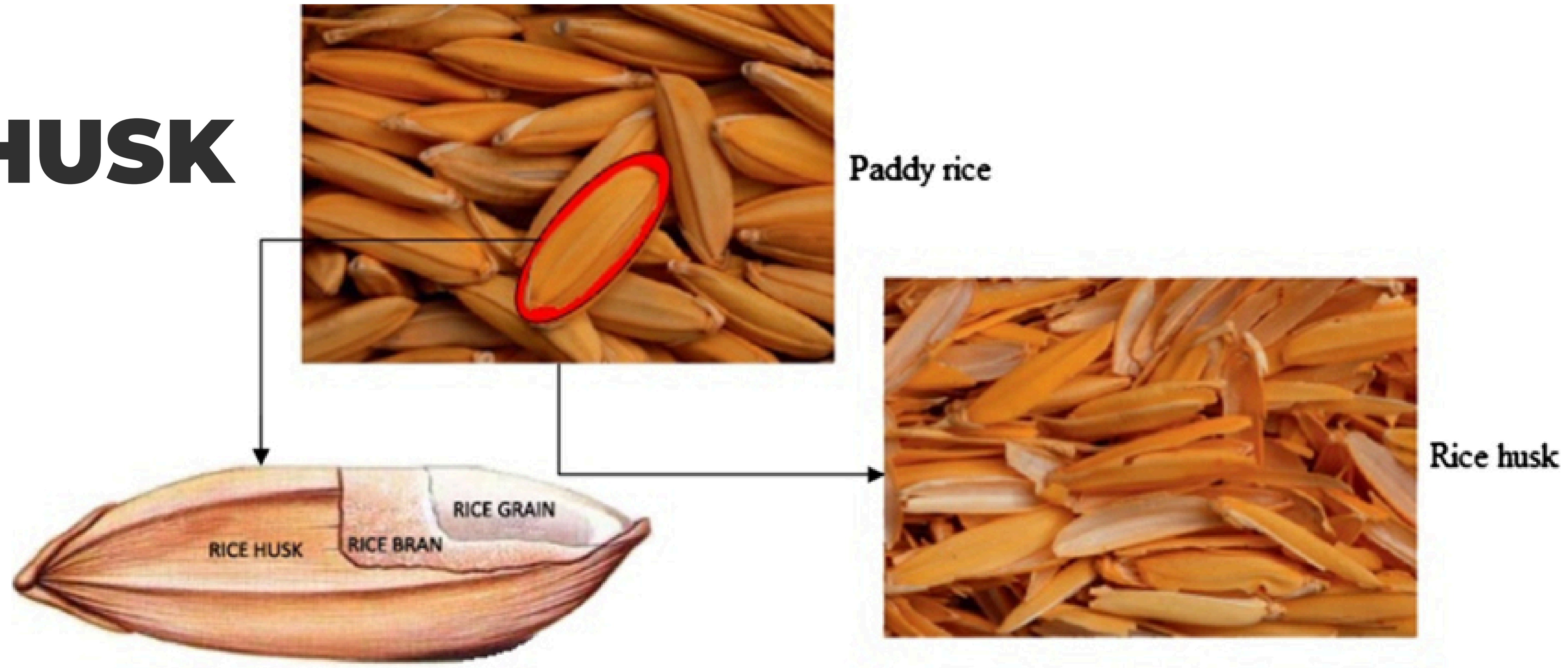
SUSTAINABILITY IN NANO ADDITIVES

ECO-FRIENDLY SOURCES AND SYNTHESIS

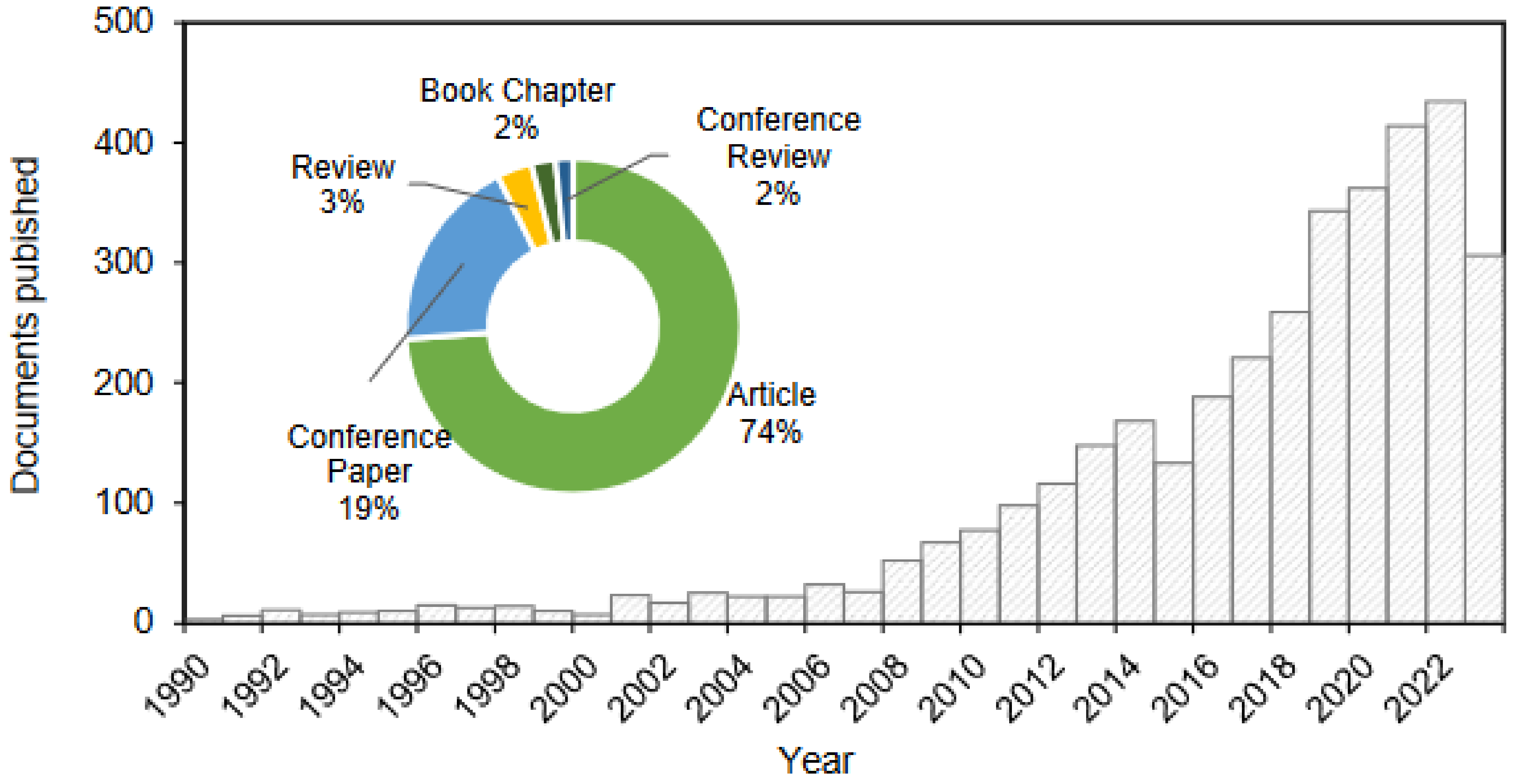
SYNTHESIS OF SiO_2 FROM RICE HUSK

COMBUSTION METHOD (WITHOUT PRETREATMENT -> NO PURE SILICA)

ACID LEACHING (PRETREATMENT BEFORE CALCINATION) - FINAL QUALITY DEPENDS ON RICE HUSK ORIGIN, TEMP. AND HEATING RAMP OF CALCINATION.



PUBLISHED DOCUMENTS OF NPs FROM RICE HUSK



EVOLUTION AND DISTRIBUTION OF PUBLISHED PAPERS ON SILICA EXTRACTION TECHNIQUES INVOLVING RICE HUSK DURING THE LAST DECADE (SCOPUS)

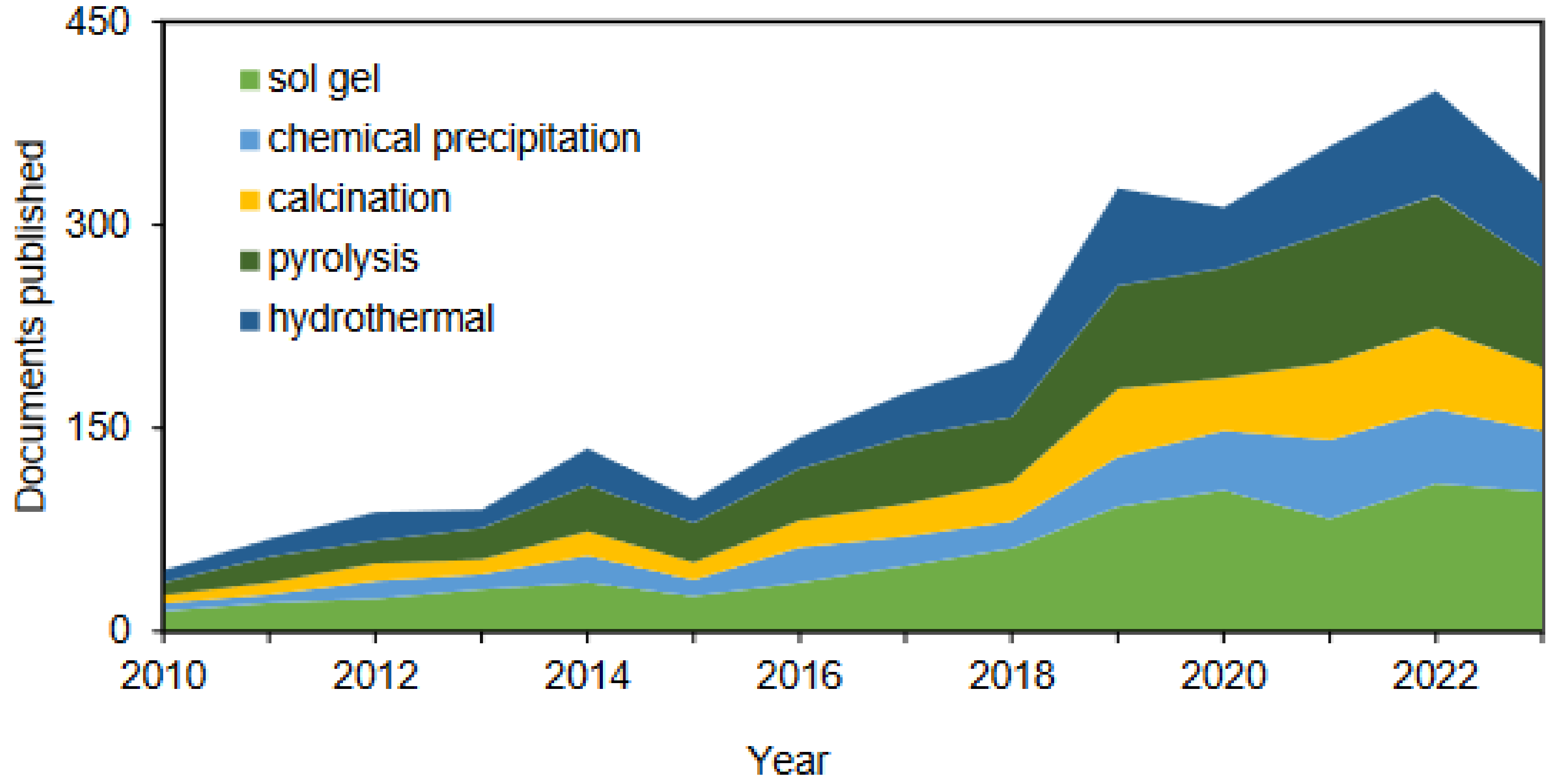


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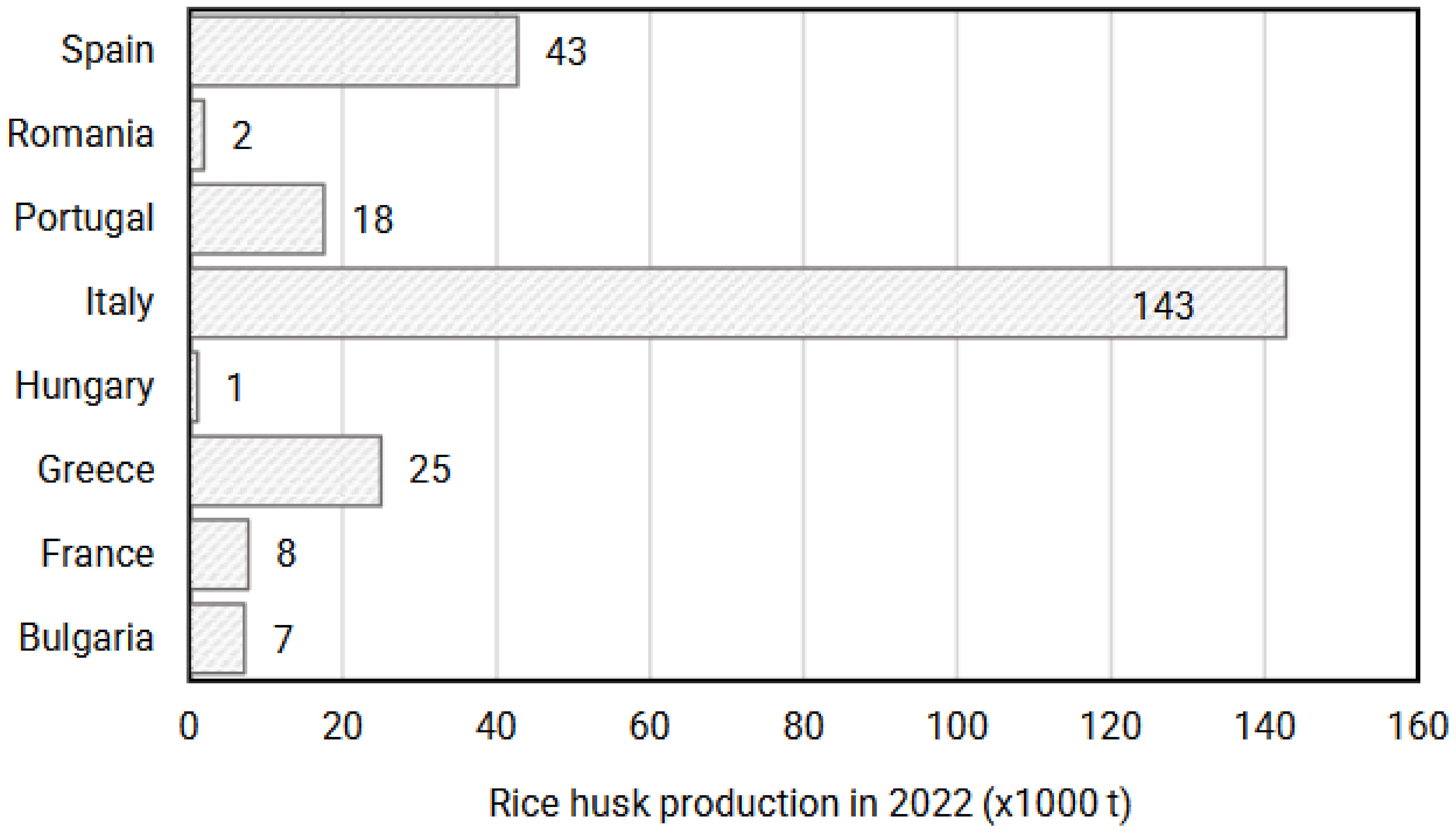
TABLE: INFLUENCE OF RICE HUSK ACIDIC PRETREATMENTS AND CALCINATION PROCEDURES ON SPECIFIC SURFACE AREA OF BIOGENIC SILICA.

Country	Pretreatment	Acid Washing	Calcination	S_{BET} (m^2/g)
China	Drying at 105 °C for 2 h	HCl 0.7 M for 1 h at RT (better than acetic acid) H_2SO_4 0.7 M for 1 h at RT	600 or 700 °C for 0.5 h Oven directly set to 600 or 700 °C	210 240
Malaysia	$C_{12}SO_4Na_2/H_2O$ H_2O Drying at 110 °C	HCl 0.5 M at 60 °C for 0.5 h of stirring H_2SO_4 0.5 M at 60 °C for 0.5 h	600 °C for 2 h	218 208
Venezuela		HCl 4 M for 24 h	Sequential: 350 °C for 3 h, 550 °C for 2 h, 700 °C for 3 h Grinding for 12 h	234
China		HCl, H_2SO_4, HNO_3 1,2,3N at RT for 1 or 2.5 h of stirring (best to remove K: HCl 1N)	600 °C for 2 h (test: 600–1200 °C for 0.25–2 h) Grinding for 10 min	248
India	H_2O	H_2SO_4 1 M	700 °C for 6 h	220
Egypt	H_2O Drying at 110 °C Milling	Citric acid (5wt%) 50 °C 3 h + 80 °C 1 h	Sequential (10 °C/min) 310 °C for 1 h, 400 °C for 2 h, 510 °C for 5 h, 600 °C for 0.5 h	313
Turkey	H_2O Drying at 110 °C for 24 h	Boiling for 2 h HCl (3%*v*/*v*) reflux	600 °C for 4 h (10 °C/min)	321
France	H_2O	HNO_3 2 M 100 °C 1 h, washed at pH 7, dried at 100 °C for 12 h	700 °C (5 °C/min)	330
China	H_2O Drying at 110 °C Pulverized in 10–60 Mesh	HCl 8 wt% of 1 g/10 mL at 120 °C for 4 h, washed at pH 7, dried at 110 °C for 3 h	300 °C for 0.5 h N_2 (1 L/min) (20 °C/min) 610 °C for 3 h O_2 (1 L/min) (10 °C/min)	352

Rodriguez-Otero, A.; Vargas, V.; Galarneau, A.; Castillo, J.; Christensen, J.H.; Bouyssiere, B. **Sustainable Harnessing of SiO2 Nanoparticles from Rice Husks: A Review of the Best Synthesis and Applications**. Processes 2023, 11, 3373. https://doi.org/10.3390/pr11123376



RICE HUSK PRODUCTION IN EUROPE (EU-27) BY COUNTRIES (MODIFIED DATA FROM EUROPEAN COMMISSION REPORT ON RICE PRODUCTION ACCESSED IN AUGUST 2023), WITH RH ESTIMATED TO BE 20% OF THE WEIGHT OF THE RICE PROCESSED AT MILLS.

Rodriguez-Otero, A.; Vargas, V.; Galarneau, A.; Castillo, J.; Christensen, J.H.; Bouyssiere, B. **Sustainable Harnessing of SiO2 Nanoparticles from Rice Husks: A Review of the Best Synthesis and Applications**. Processes 2023, 11, 3373. https://doi.org/10.3390/pr11123373

SUSTAINABILITY IN NANO ADDITIVES

ECO-FRIENDLY SOURCES AND SYNTHESIS

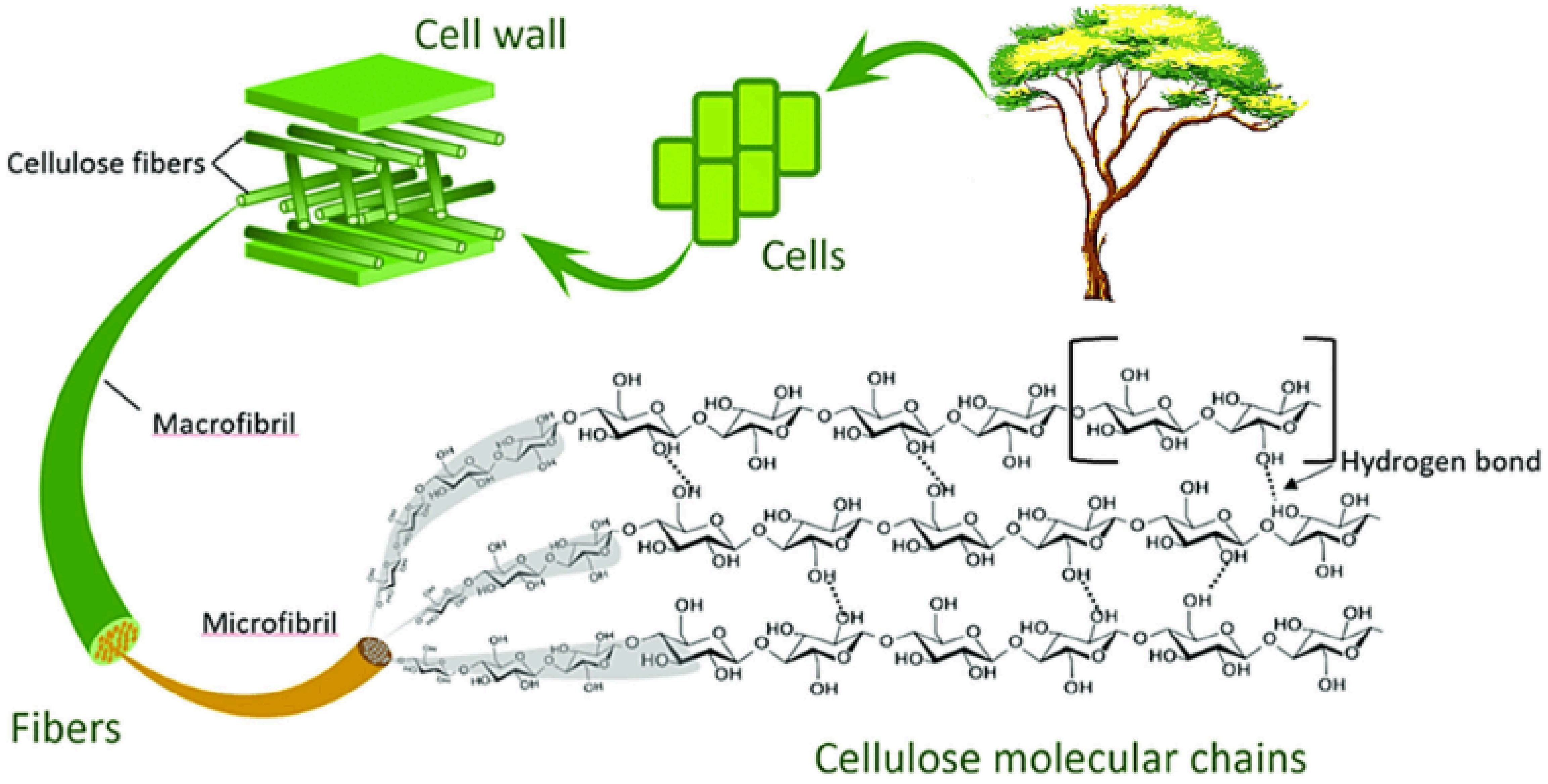
NANOCELLULOSE

NANO-STRUCTURED **CELLULOSE**, NANOCRYSTAL VS NANOFIBRILS

LOW CARBON FOOTPRINT, SUSTAINABLE, RENEWABLE, RECYCLABLE AND NONTOXIC

CALLED ONE OF THE POSSIBLE REPLACEMENT FOR PLASTICS -> **BIOPOLYMER**

ABUNDANT MATERIAL -> TREES, WASTE FROM AGRICULTURAL CROPS AND OTHER BIOMASS



Li, T., Chen, C., Brozena, A.H. et al. **Developing fibrillated cellulose as a sustainable technological material.** Nature 590, 47–56 (2021). https://doi.org/10.1038/s41586-020-03167-7

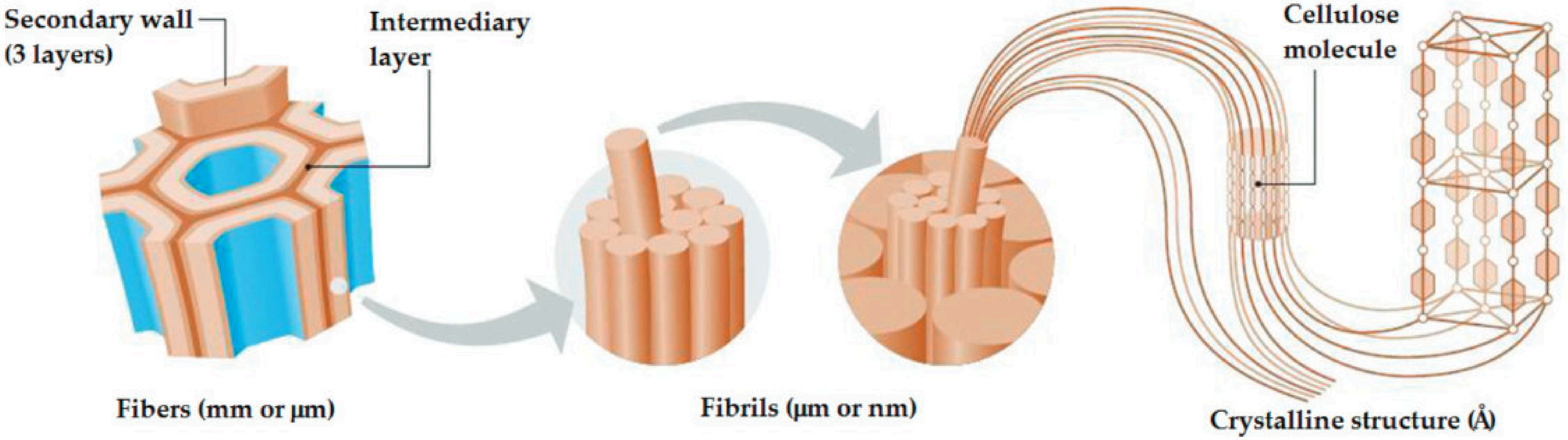
Owonubi SJ, Agwuncha SC, Malima NM, Shombe GB, Makhatha EM and Revaprasadu N (2021) **Non-woody Biomass as Sources of Nanocellulose Particles: A Review of Extraction Procedures.** Front. Energy Res. 9:608825. doi: 10.3389/fenrg.2021.608825

SUSTAINABILITY IN NANO ADDITIVES
ECO-FRIENDLY SOURCES AND SYNTHESIS

CELLULOSE NANOFIBRILS

PROCESS OF SYNTHESIS: TOP/DOWN - **MECHANICAL SHEARING** (HOMOGENIZER, MICROFLUIDIZER OR ULTRA-FINE FRICTION GRINDER)

W: 3-100 nm L: > 1 μm



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SUSTAINABILITY IN NANO ADDITIVES

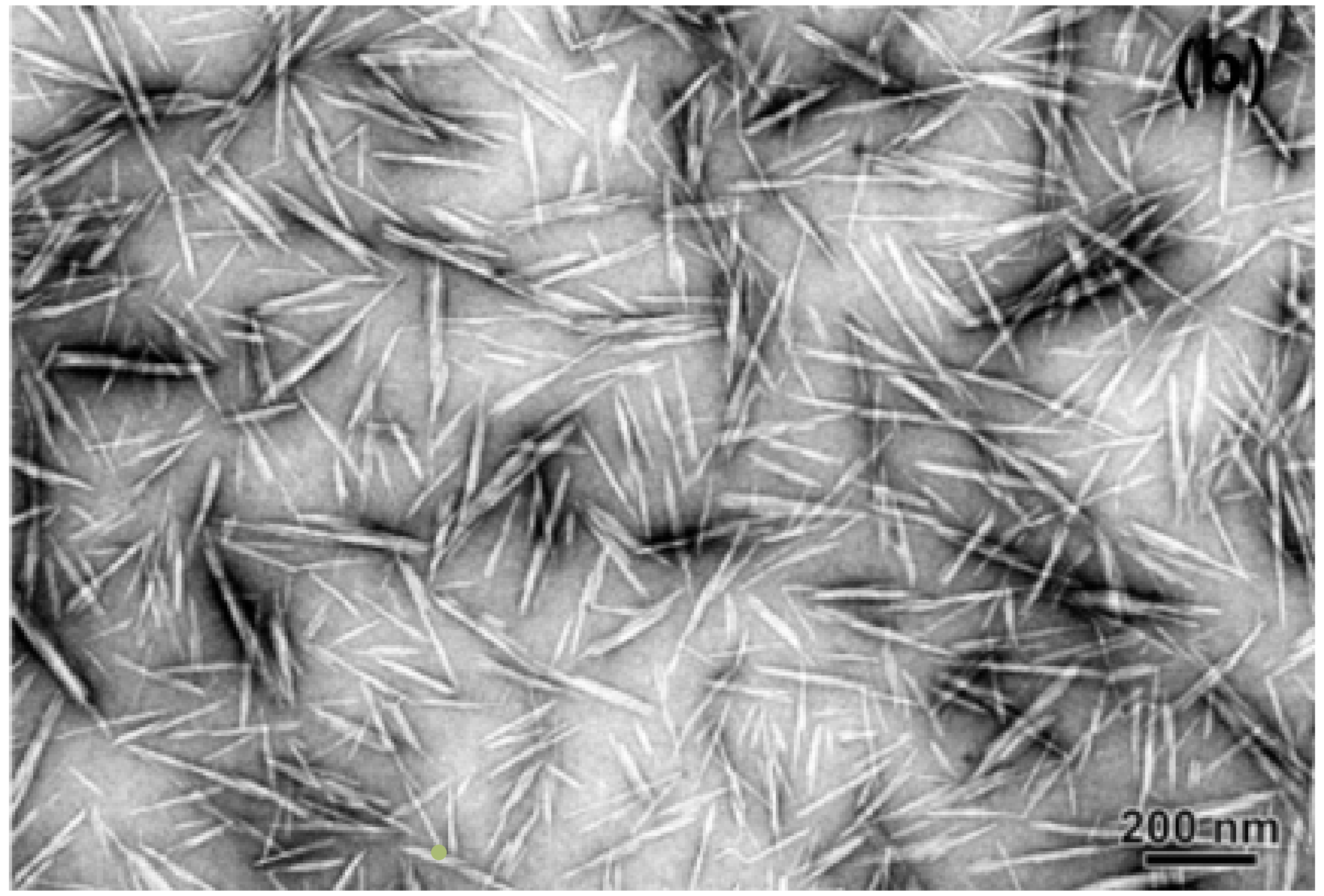
ECO-FRIENDLY SOURCES AND SYNTHESIS

CELLULOSE NANOCRYSTALS

CONTROLLED STRONG ACID HYDROLYSIS TREATMENT (SULFURIC ACID - $\mathbf{H_2SO_4}$) TO CELLULOSIC FIBERS ALLOWING DISSOLUTION OF AMORPHOUS DOMAINS AND THEREFORE LONGITUDINAL CUTTING OF THE MICROFIBRILS

GEOMETRICAL DIMENSIONS DEPEND ON THE ORIGIN

HIGH ASPECT RATIO ROD-LIKE NANOCRYSTALS (WHISKERS)



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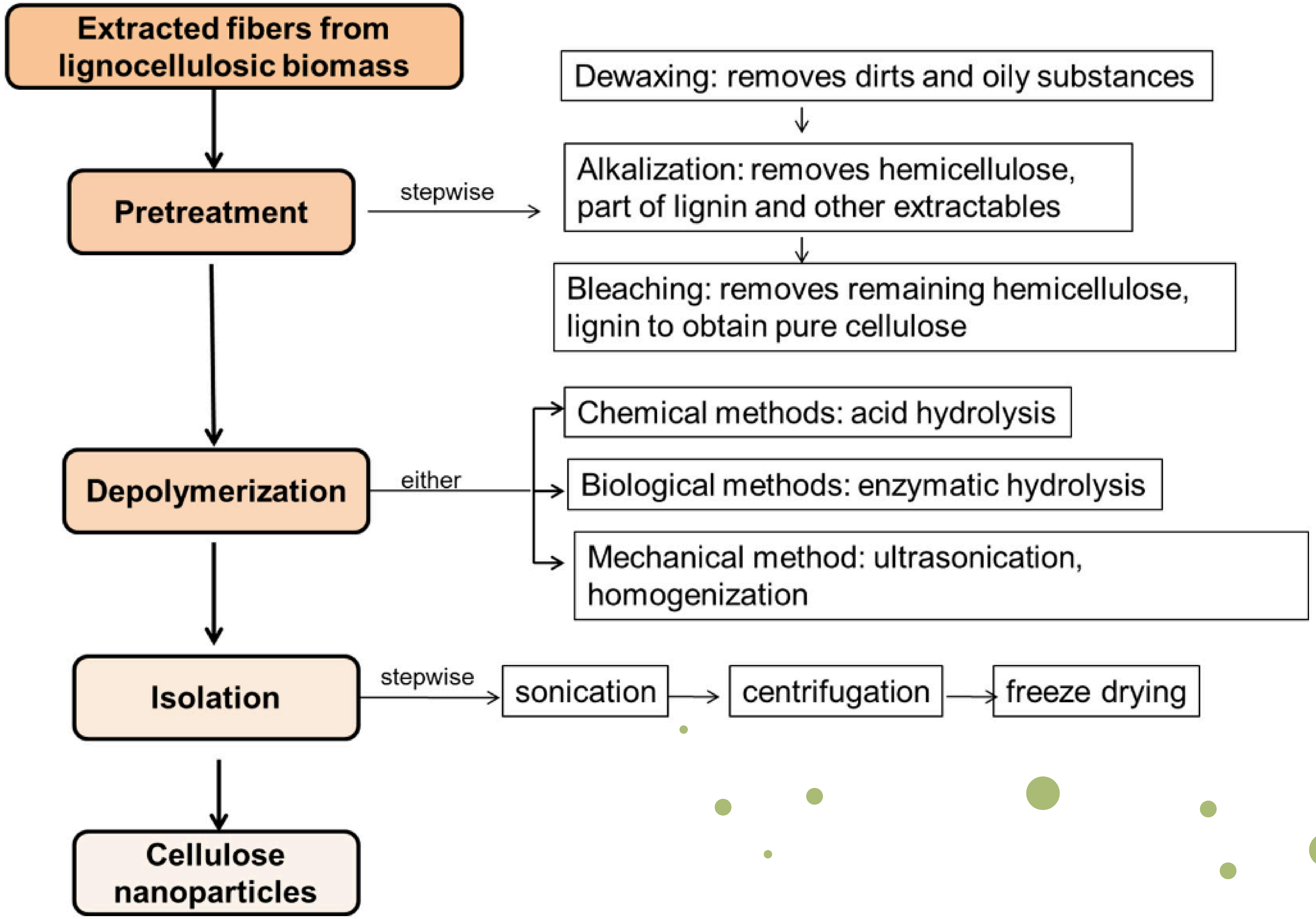

SCHEMATIC SHOWING THE CHEMICAL PROCESSES INVOLVED IN THE EXTRACTION OF NANOCELLULOSE STARTING WITH UNTREATED FIBERS.

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TABLE: PERCENTAGE COMPOSITION OF SELECTED LIGNOCELLULOSE BIOMASS AND PROCEDURES USE TO OBTAIN HIGHER CELLULOSE CONTENT.

	Lignocellulose biomass	Cellulose (%)		Hemicellulose (%)	Lignin (%)	Pretreatment carried out		
		B	A			Dewaxing	Alkaline	Bleaching
1	Passion fruit peel	29	80	23	36	No	Yes	yes
2	Wood	46	80	27	25	yes	yes	yes
3	Bamboo	42	84	27	23	Yes	Yes	Yes
4	Wheat straw	40	84	34	20	Yes	Yes	Yes
5	Flax	75	89	13	3	Yes	Yes	Yes
6	Grape pomace	19	80	7	16	Yes	Yes	Yes
7	Groundnut shell	38.31	83	28	21	Yes	Yes	Yes
8	Sugarcane bagasse	45.0	87	30	21	Yes	No	yes
9	Tea leaf	16.2	83	68.2	19	No	Yes	Yes
10	Hemp	70.6	–	15.6	4	Yes	Yes	Yes
11	Sisal	62.6	–	12.5	8	Yes	Yes	Yes
12	Flax	66	–	18	2	yes	yes	yes
13	Bagasse	72	–	16	< 1	No	No	Yes
14	Banana fiber	64	96	19	5	no	yes	yes
15	Coconut	35	65	25	36	Yes	Yes	yes
16	Jackfruit peel	20	–	24	2	Yes	Yes	Yes
17	Soy hull	48	–	24	6	No	Yes	Yes
18	Alfa fiber	46	87	26	–	No	Yes	Yes
19	Sugar palm fiber	44	82	7	33	yes	yes	yes
20	Pineapple leaf	81	99	12	3	no	yes	yes
21	Banana stem	24	93	26	–	yes	no	yes
22	Fique tow fiber	52	83	24	24	yes	no	yes

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SUSTAINABILITY IN NANO ADDITIVES

NON CONVENTIONAL FILLER TYPES THAT DIDN'T FIT INTO PRESENTATION

HALLOYSITE NANOTUBES

NATURALLY OCCURRING ALUMINOSILICATE MINERALS THAT ARE SIMILAR IN STRUCTURE TO CARBON NANOTUBES AND CAN BE USED TO IMPROVE MECHANICAL AND BARRIER PROPERTIES.

METAL-ORGANIC FRAMEWORKS

CRYSTALLINE COMPOUNDS CONSISTING OF METAL IONS OR CLUSTERS COORDINATED TO ORGANIC LIGANDS TO FORM ONE-, TWO-, OR THREE-DIMENSIONAL STRUCTURES. MOFS ARE EXPLORED FOR THEIR POROSITY AND POTENTIAL IN GAS STORAGE, SEPARATION, AND CATALYSIS WITHIN COMPOSITES.

LAYERED DOUBLE HYDROXIDES

INORGANIC MATERIALS WITH A LAYERED STRUCTURE THAT CAN IMPROVE FLAME RETARDANCY, THERMAL STABILITY, AND MECHANICAL PROPERTIES OF POLYMERS.

CHITIN AND CHITOSAN NANOFIBERS

DERIVED FROM THE SHELLS OF CRUSTACEANS AND OTHER SOURCES, THESE BIOPOLYMERS OFFER BIOCOMPATIBILITY AND BIODEGRADABILITY, SUITABLE FOR MEDICAL AND FOOD PACKAGING APPLICATIONS.

SUSTAINABILITY IN NANO ADDITIVES

NON CONVENTIONAL FILLER TYPES THAT DIDN'T FIT INTO PRESENTATION

BASALT FIBERS

MADE FROM BASALT ROCK, THESE FIBERS PROVIDE EXCELLENT THERMAL STABILITY, MECHANICAL STRENGTH, AND CHEMICAL RESISTANCE.

BIOCHAR

CHARCOAL USED AS A FILLER FOR ITS HIGH SURFACE AREA AND POROSITY, WHICH CAN ENHANCE THERMAL, MECHANICAL, AND ELECTRICAL PROPERTIES.

QUANTUM DOTS

NANOSCALE SEMICONDUCTOR PARTICLES THAT HAVE QUANTUM MECHANICAL PROPERTIES. THEY CAN BE USED IN POLYMER COMPOSITES FOR OPTICAL APPLICATIONS, INCLUDING DISPLAYS AND SENSORS.

AEROGELS

EXTREMELY LIGHTWEIGHT MATERIALS WITH HIGH POROSITY AND LOW THERMAL CONDUCTIVITY, USEFUL FOR THERMAL INSULATION APPLICATIONS.

IN POL

THANK YOU!

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