METRO FOOD

INFRASTRUCTURE FOR PROMOTING
METROLOGY IN FOOD AND NUTRITION

RESEARCH & INNOVATION AGENDA

May 2022

HIGH-LEVEL METROLOGY SERVICES IN FOOD & NUTRITION

www.metrofood.eu

I. PREFACE

Dear reader,
This Research & Innovation Agenda outlines the strategic orientation of the METROFOOD Research Infrastructure (METROFOOD-RI) focusing on Metrology in Food and Nutrition.

METROFOOD-RI is a distributed European Research Infrastructure of global interest, providing various activities to support data collection and measurement reliability as well as basic and frontier research in the field of food and nutrition.

The following Research & Innovation Agenda highlights our research priorities for the first five years of METROFOOD-RI´s operation. It describes how METROFOOD-RI will implement its mission into science and services for the benefit of promoting scientific excellence in providing high-level metrology services and support of the agrifood sector in its different aspects of transformation towards circular bioeconomy. In this regard, the term food integrity is much broader than food quality alone, it also encompasses food safety, traceability, authenticity, and sustainable production.

The rationale for this Agenda derives from a comprehensive analysis of emerging global challenges and needs with respect to the agrifood sector. By adopting a multidisciplinary approach, the wide range of expertise, tools and capacities of the Infrastructure's Consortium members will be used to address key issues related to the food chain. This will both foster the further development of our infrastructure and, in the long-term, increase our operational range and impact.

Our Research & Innovation Agenda provides an overview of all METROFOOD-RI activities and is aimed at a broad audience in general and at stakeholders from the agrifood sector in particular.

Sincerely yours,
The METROFOOD-RI Consortium

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1. VISION & MISSION OF METROFOOD-RI

METROFOOD-RI - *Infrastructure for promoting Metrology in Food and Nutrition* is a distributed Research Infrastructure of global interest aimed to promote scientific excellence in the field of food quality and safety, by means of which it is possible to carry out different activities supporting data collection and measurement reliability, as well as basic and frontier research in food and nutrition. It provides high-quality metrology services in food and nutrition, comprising an important cross-section of highly interdisciplinary and interconnected fields throughout the food value chain.

METROFOOD-RI is aimed to strengthen scientific knowledge, promoting scientific cooperation and encouraging the interaction between various stakeholders, as well as the creation of a common and shared base of data, information and knowledge.

METROFOOD-RI is characterized by a broad multidisciplinary approach with different operational areas including agrifood, sustainable development, food quality and safety, traceability and authenticity of food, environmental safety, consumer sciences, and human health.

METROFOOD-RI VISION:

Strengthening the scientific excellence and scientific cooperation as distributed Research Infrastructure of Global Interest, by means of which it will be possible to find comprehensive, integrated, and reliable measurement data on agrifood products and processes and to carry out different activities supporting data collection and measurement reliability, as well as basic and frontier research in food and nutrition.

METROFOOD-RI MISSION:

Promoting metrology in food and nutrition & harmonization on a European and gradually global scale:

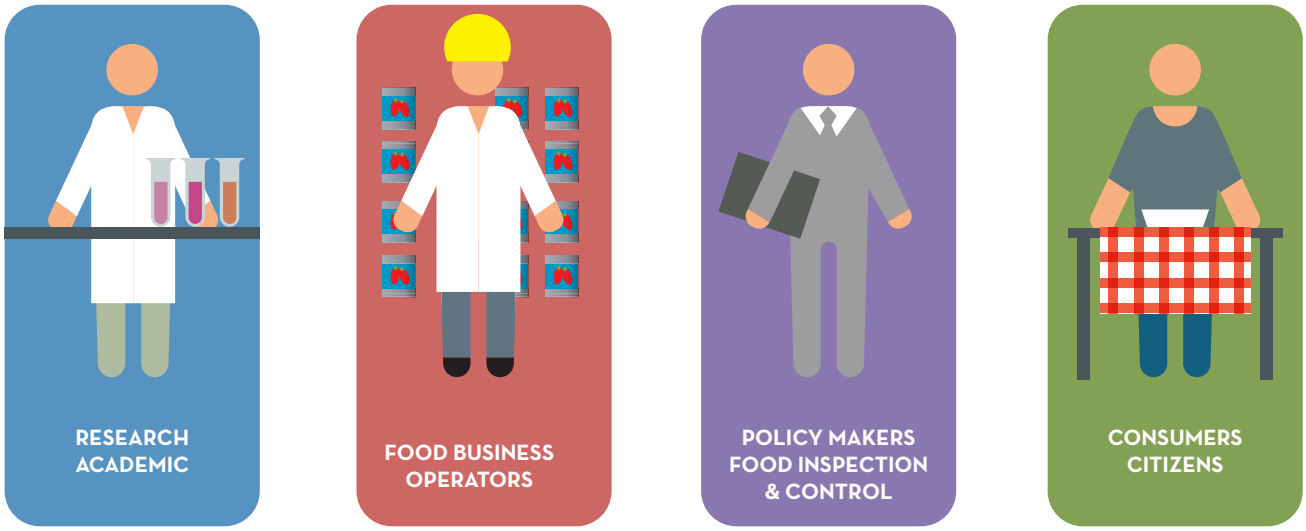
1. To enhance quality and reliability of measurement results
2. To make available and share data, information, and metrological tools
3. To enhance scientific excellence in support to the agrifood system
4. To strengthen scientific knowledge, promoting scientific cooperation and integration.

The Research activities of METROFOOD-RI cover the whole food chain and related services, from agrifood production up to final consumption, in order to:

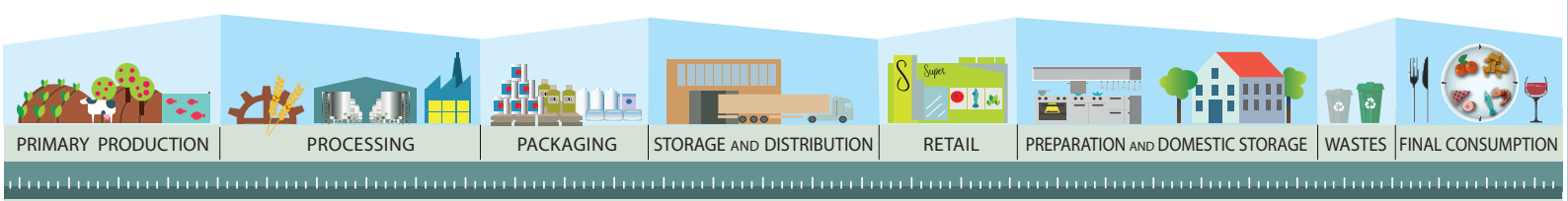
- Support sustainability of food production and consumption;
- Improve food quality and safety;
- Achieve food traceability and authenticity demonstration;
- Optimize all steps *from farm to fork* with a holistic approach.

In harmony with the Responsible Research and Innovation (RRI) principles, METROFOOD-RI will provide distributed high-quality services, acting on the real plan of measurement reliability and procedure harmonization and adoption of the FAIR (*Findable, Accessible, Interoperable, and Re-usable*) principles on data management and service provision.
The scientific and service offering is addressed to a broad set of users and stakeholders, such as:

- Research/Academics, public and private labs and groups engaged in research activities for food data collection and measurement reliability and basic frontier research in food and nutrition;
- Food Business Operators (FBOs) and producer associations;
- Policy Makers and Food inspection and control agencies;
- Consumers/consumer associations and citizens.



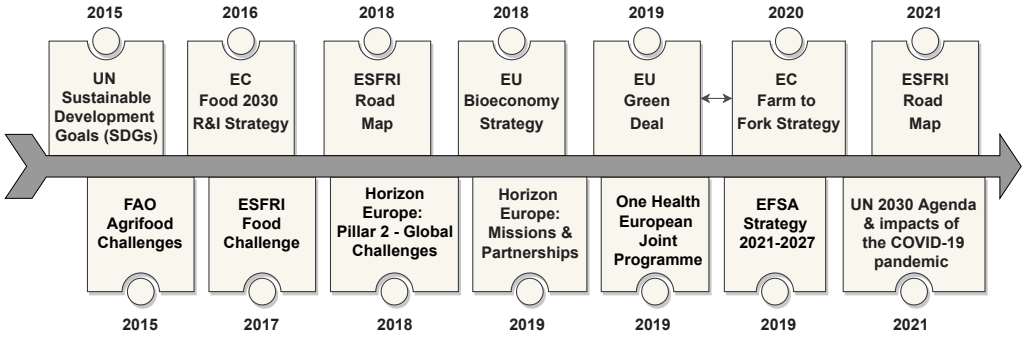
METROFOOD-RI was cited as emerging project in the ESFRI Roadmap 2016 and in 2017 completed its Early Phase upon the EU-funded PRO-METROFOOD project (H2020 GA 739568). Since 2018, METROFOOD-RI is included as "project" in the ESFRI Roadmap for the Domain Health and Food (ESFRI, 2018; ESFRI, 2021). METROFOOD-RI completed its Preparatory Phase under the METROFOOD-PP Project (H2020-INFRADEV-2019-2 GA 871083 - 1 Dec.2019 - 30 May 2022). The METROFOOD-PP Consortium is composed by 48 Institutes (20 Beneficiaries and 28 Linked Third Parties) from the following Countries: Italy (leading Country), Belgium, Czech Republic, Finland, France, Germany, Greece, Hungary, Moldova, Netherlands, Norway, Portugal, Rep. North Macedonia, Romania, Slovenia, Spain, Switzerland, Turkey.



2. OUR MOTIVATION AND CURRENT CHALLENGES

Society faces a number of major global challenges in the 21st century, including environmental, societal, political and economic issues. These grand societal challenges have become the focus of various actors and activities across disciplines pursuing collaborative efforts to address and mitigate them. In this context, policy flagship initiatives and strategies, such as the UN Sustainable Development Goals (SDGs), Horizon Europe Missions and Partnerships, the EU Green Deal or Farm to Fork Strategy, among others, indicate the challenges, gaps and research opportunities within the agrifood sector.

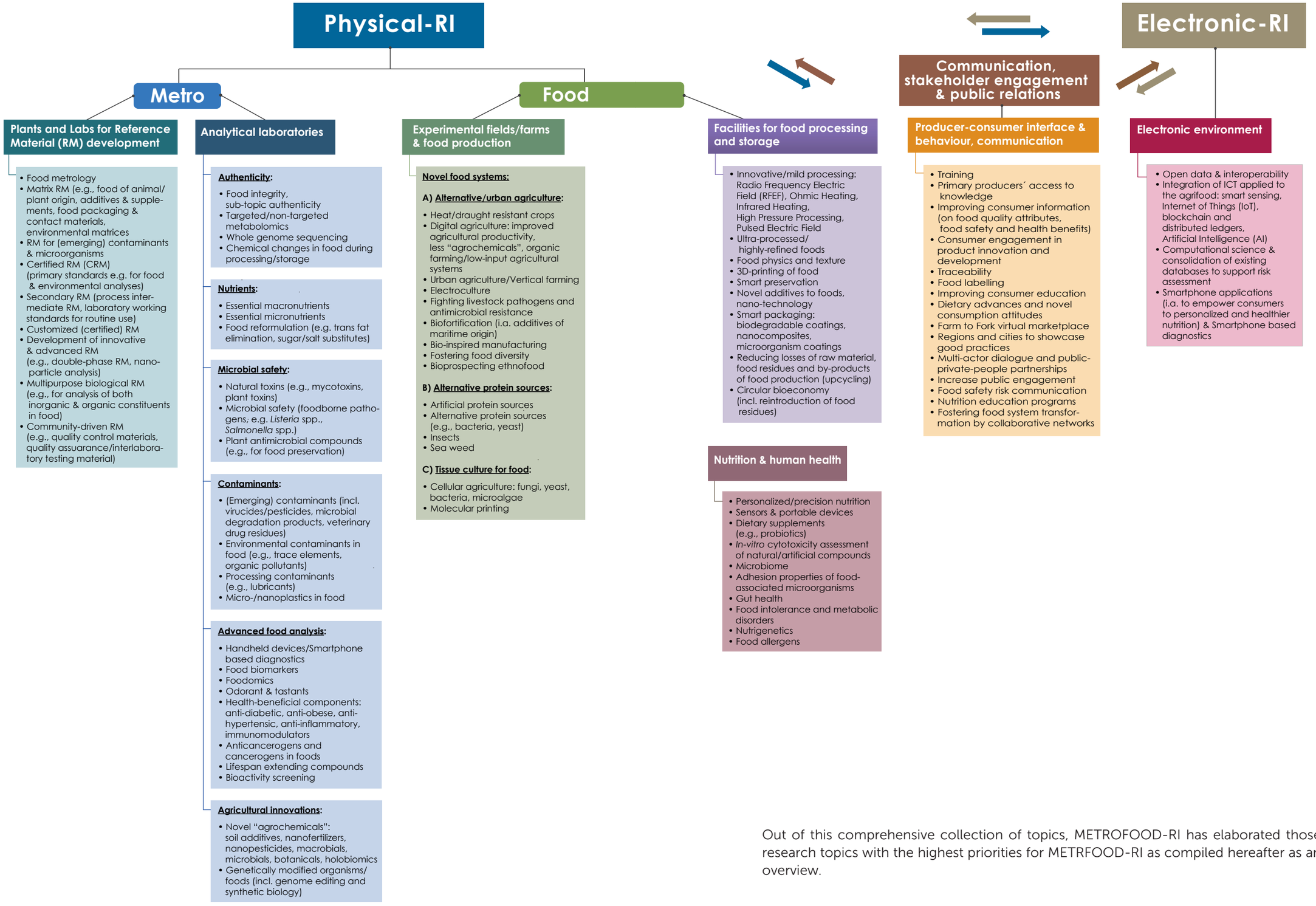
SELECTION OF RELEVANT POLICIES & STRATEGIES IN THE AGRIFOOD SECTOR



These aspects have been analyzed by METROFOOD-RI using a top-down analysis approach. From this, eight main Challenge Clusters (CC) have been defined as core elements to form an integral part of METROFOOD-RI´s future Strategic Research & Innovation Agenda:

- CC 1: Fighting triple burden of malnutrition;
- CC 2: Healthy and safe food for all;
- CC 3: No poverty, viability of farming, livelihood pressure, decent work, migration;
- CC 4: Novel food systems, food systems resilience, food security, climate adaptation;
- CC 5: Environmentally safe production, climate action, green deal, water, soil, fostering biodiversity;
- CC 6: Responsible consumption & production, smart cities;
- CC 7: Democratization, civil security, research/innovation/technology, partnership;
- CC 8: Digitalization.

Based on these clusters, more than 100 research topics in the agrifood field have been elaborated and assigned to the following sections, in which METROFOOD-RI can be structured: *METRO-side* for Metrology, *FOOD-side* for the agrifood chain, *Electronic-RI*, and *Producer/Consumer interface*.



Out of this comprehensive collection of topics, METROFOOD-RI has elaborated those research topics with the highest priorities for METRFOOD-RI as compiled hereafter as an overview.

3. OUR STRATEGIC RESEARCH PRIORITIES

In the framework of this Research & Innovation Agenda, METROFOOD-RI is outlining its research priorities that will direct its initial activities for the first five years of operation as legally mature Research Infrastructure.

The research priorities detailed in the following sections are of overall societal relevance and partially in conformity with the mandate and specific objectives of the World Health Organization (WHO) and the European Union and/or its multiple efforts to bridge existing gaps or (emerging) demands in the European Research Area (ERA).

In this context, METROFOOD-RI´s scope of activities is primarily focused on metrology in food and nutrition and the agrifood sector (with its *METRO-Side* and *FOOD-Side* working in close cooperation), involving physical and electronic infrastructure components, the latter integrating distinct digital technologies and computational resources to foster and support research and innovation (*Electronic-RI*). Beyond research and electronic aspects, the involvement of different stakeholder groups such as consumers or FBO´s represents an important module. METROFOOD-RI´s efforts in this respect are aimed at improving the level and transparency of consumer information on food (Producer/Consumer interface), also to promote healthier eating habits in the general population, as well as providing training and scientific knowledge to farmers and food producers, thereby improving food safety in Europe and beyond in the longer term.

	´METRO´-side	´FOOD´-side	ELECTRONIC-RI	Producer/Consumer Interface
High-Priority Activities	• Food metrology • Food integrity & authenticity • (Emerging) contaminants	• Circular Bioeconomy & Reducing losses of raw material, food residues & by-products of food production	• Open data & interoperability • Integration of ICT applied to the agrifood: smart sensing, Internet of Things (IoT), blockchain and distributed ledgers, Artificial Intelligence • Computational science & consolidation of existing databases to support risk assessment	• Improving consumer information by technology (e.g., on food quality & safety) • Traceability/transparency
Medium-Priority Activities	• Micro-/nanoplastics in food • Natural toxins • Food biomarkers • Foodomics • Nutrients/bioactives incl. anticancerogens in food • Sensors & portable devices	• Alternative protein sources • Personalized/ precision nutrition • Food allergens	• Smartphone applications (i.a. to empower consumers to personalized and healthier nutrition) & Smartphone based diagnostics	• Improving consumer education & awareness • Fostering food system transformation by networking • Training • Food safety risk communication • Food labelling • Dietary advances & novel consumption attitudes

METRO-side

According to the definition of metrology as "the science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology" (BIPM, 2017), metrology provides the tools to make the measurement results reliable and comparable and the most valuable tools are Reference Materials (RM) and standardized analytical methods. Therefore, METROFOOD-RI includes analytical laboratories for the development and validation of new methods for the chemical, physical-chemical and (micro)biological characterisation of foods and any matrix of interest for the agrifood systems.

Due to the importance for metrology, the development of new RM plays an important strategic role with the essential involvement of plants for the production of new RMs for the agrifood sector.

Facing the societal challenge cluster 2 of Healthy and safe food for all, the analytical laboratories within the RI will strategically focus on specific aspects of Food integrity, which is a comprehensive term for sound, nutritive, healthy, tasty, safe, authentic, traceable, as well as ethically, safely, environment-friendly and sustainably produced foods (Elliot, 2012). Therefore, this term encompasses the sub topics authenticity, taste, nutrients, food safety consisting of microbial safety and contaminants, further health-beneficial analytes, genetically modified organisms and novel (smart and rapid) analytical technologies.

FOOD-side

With respect to including the whole food chain from farm to fork, the RI includes, first, facilities for primary production (e.g.: agricultural fields, greenhouses, livestock breeding, aquaculture, agricultural (by)products for bioenergy production, biotechnological production of foods/ingredients, etc.) of food.

Second, experimental plants related to food processing, food storage, food packaging and treatment/reduction of food losses and waste, as well as kitchen-labs, to provide scientific excellence, particularly in the strategic European focus on circular economy.

Electronic-RI

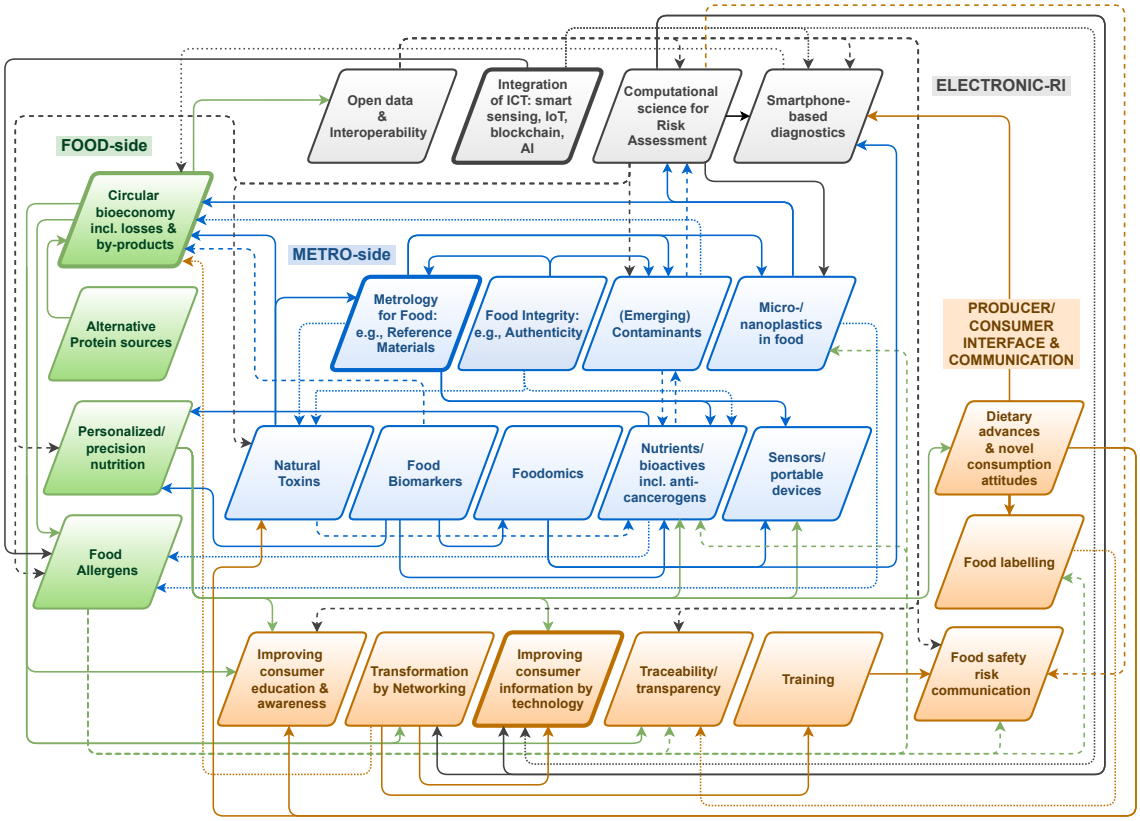
The e-component of METROFOOD-RI consists of a service-oriented architecture providing a platform accessible to the user community (in Europe and beyond) for sharing and integrating data, knowledge and information about food analysis, food composition, nutritional contents, level of contaminants and markers. It will also collect the results provided by the physical component, organizing and complementing them with existing data and providing tools for its uses. The e-RI is being developed by integrating different data sources, and services are being implemented to compare and make interoperable food data and any other data of interest in relation to agrifood and effects on human health, as well as to find out the metrological tools for the analytical purposes related to food and nutrition. These data are analytical results, but include also analytical information and knowledge about methods, standards, best practices and publications. In conclusion, this component will foster the digitalization of the agrifood systems.

Communication, stakeholder engagement and public relations

From Challenge Cluster 7 addressing democratization, civil security, partnership, many aspects at the interface producer/policy makers/consumer interfaces arise. These include strengthening consumer confidence in food products, improving consumer information by different novel technologies (e.g., smart sensors or intelligent packaging) and improving consumer awareness on dietary advances and domestic food processing. Taken together, strengthening a multi-actor dialogue will address all these aspects and, therefore, is also a strategic focus of METROFOOD-RI.

Many of the topics assigned to one of the four METROFOOD-RI sections, however, are also relevant to other sections or other topics thus showing close interconnections between each other and revealing the transversal approach.

NETWORK OF SCIENTIFIC TOPICS



3.1 RESEARCH PRIORITIES *METRO-SIDE*

Strategic Area 1: FOOD Metrology

WHAT IS METROLOGY?

"The science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology" (BIPM, 2017).

These requirements include the (metrological) traceability to internationally accepted units of measurement by assessing uncertainty in relation to national and international reference standards measurements.

As outlined before, the top priority in Food Metrology refers to the tool RM.
Of these, Certified RMs (CRMs) confirm or establish metrological traceability to the International System of Units (SI) and to determine the uncertainty of these results. The traceability to SI is usually conveyed by an unbroken chain of measurements from the sample content to the measurand in SI. In this chain, CRMs along with primary reference and secondary methods play an essential role.

Apart from a set of CRMs available from several providers, there are still major gaps in the supply of RMs, such as *Matrix*-RMs, *Customized*-RM, Innovative and advanced RMs (e.g., double-phase-RMs, RMs for nanoparticle analysis), Multipurpose-RMs, *Community-driven*-RMs (quality control materials, collaborative trial testing material), to name only a few.
Producing and making them available, therefore, is a strategic focus of METROFOOD-RI. This is in line with the Agenda for Metrology in Europe defined by EURAMET, where traceable measurements and the development of RMs is emphasized.

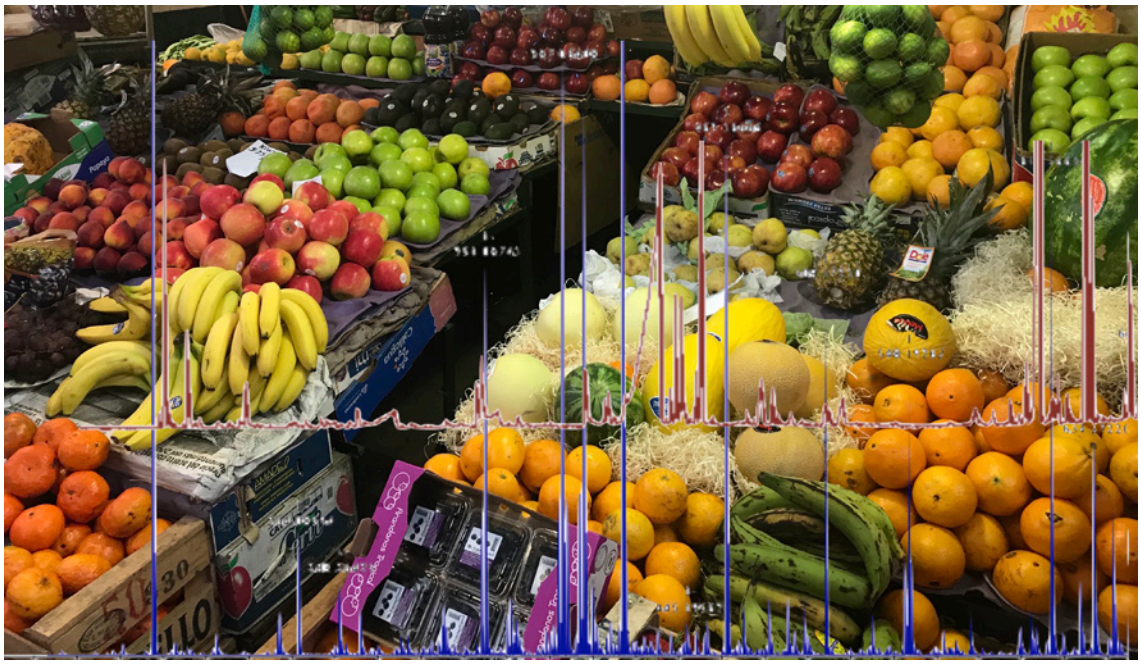
Strategic Area 2: Food Authenticity

There is a growing consumers' awareness of fraudulent food practices including mislabelling, misbranding or misrepresentation of food and food ingredients. In order to maintain consumers' trust and to protect conventional foods and products certified under various labels (regional, geographical indications, organic, etc.) in the EU, verifying authenticity is a top priority of METROFOOD-RI.
Analysing Food authenticity requires (1) novel analytical techniques such as non-targeted metabolomics, (2) rapid technologies (including smart sensor applications) and (3) chemometrics and bioinformatics to process the data comprehensively.

Strategic Area 3: Systemic approach including (emerging) contaminants and beneficial bioactive compounds and nutrients

For assuring Food Integrity and Safety it is essential to integrate harmful as well as beneficial components in view of a systemic risk-benefit evaluation. Among the plethora of substances, *contaminants of emerging concern or emerging contaminants will play an*

increasing role. These terms include compounds with either no defined maximum levels in the EU legislation yet, or having maximum levels, which need to be revised. Among them there is increasing focus on perfluoroalkyl substances (PFASs), emerging mycotoxins such as enniatins or alternaria toxins, nanomaterials and marine biotoxins, to name only a few. In this regard, residues of the new generation of pesticides, antibiotics and coccidiostats have to be addressed.



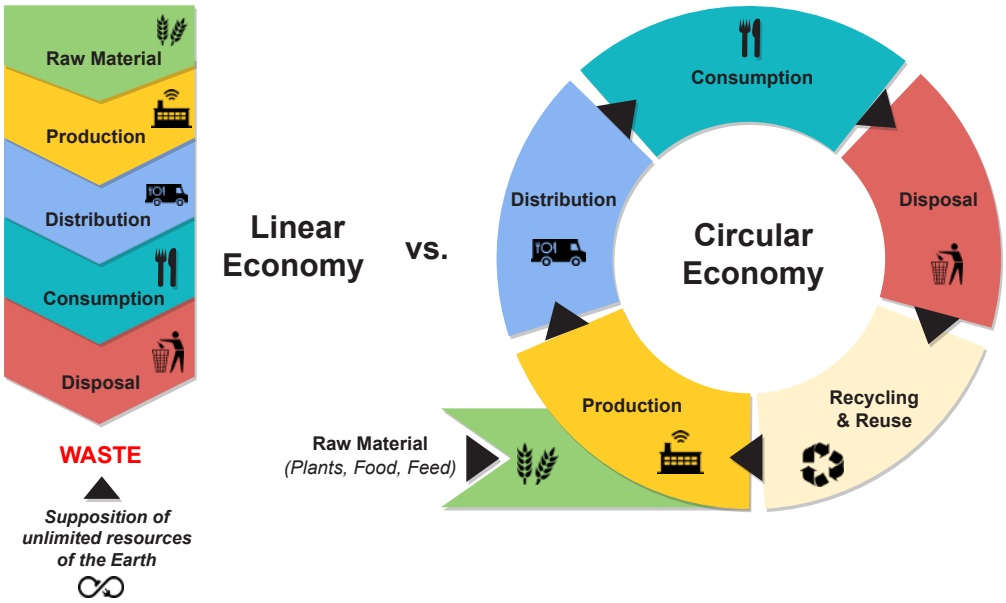
3.2 RESEARCH PRIORITIES *FOOD-SIDE*

Strategic Area 1: Circular Bioeconomy

WHAT IS CIRCULAR ECONOMY?

"Circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended.

In practice, it implies reducing waste to a minimum. When a product reaches the end of its life, its materials are kept within the economy wherever possible. These can be productively used again and again, thereby creating further value." (European Parliament, 2022)



Food is a integral part of our daily lives and essential for all living organisms. Food provides vital nutrients energy and helps the organism to function and stay healthy.
According to Food and Agriculture Organization (FAO) statistics, global food production is performing at high efficiency, producing about 4 billion tons of food annually. At the same time, the FAO estimates that about 30% of the food produced worldwide is lost or wasted each year (FAO, 2011). More specifically, 14% of food is lost between harvest and retail, while significant amounts are wasted at the retail and consumption levels.
Unlike food waste, food loss principally refers to losses that occur between the time of food production to market introduction, attributable to problems ranging from the improper use of inputs to lack of appropriate post-harvest storage, processing or transportation facilities. Wastage of food, a phenomenon nowadays mostly observed in industrialized nations, refers primarily to food that has already reached the stage of marketization (retail and final consumption). Food waste is a frequent result of our throwaway culture, where more food is purchased than can be consumed, overproduction due to over-subsidy by governments, or removal of safe food from market shelves due to strict regulations, such as exceeding the expiration date even though the food has not spoiled.
Given that the resources of our planet are not inexhaustible and in light of a steadily increasing world population to feed and a growing demand for raw materials, the Circular Economy model has triggered a fundamental rethink in society over the last decades. A shift to more sustainable and responsible management of resources, efficient recycling or reuse of materials, as the increase use of renewable commodities is underway. This also moves in tandem with the One Health approach, an integrated concept that seeks to sustainably balance and optimize human, animal, and ecosystem health, and assumes that the health of animals, people, plants, and the broader environment (including ecosystems) are inextricably linked and interdependent.

METROFOOD-RI strives to make a valuable contribution to an agroecological transition, i.e. the transformation of agrifood systems towards greater sustainability, and is committed to the Circular Bioeconomy as top priority. The collaborative and multi-disciplinary activities of the RI strive to transform the consumer model of ´take – make – throw away´ commonly practiced in a Linear Economy system, towards greater sustainability and resilience. During this process, the activities of the RI will be guided by the ´3Rs´ strategy:

1. First ´R´- **Reduce**: Reducing the usage of resources to diminish the amount of waste generated.
2. Second ´R´- **Reuse**: Reusing resources and preserve value & function, or repurposing.
3. Third ´R´- **Recycle**: Recycling of materials into raw materials for renewed usage & resource conservation.

METROFOOD-RI´s scope of action also extends to the agrifood production chain. In the food sector, for example, the industrial processing of raw materials (such as plants, dairy or aquaculture) into food products generates enormous amounts of by-products, most of which are discarded even though the potential for further reuse would exist. It is well known that certain by-products arising from food industry are rich sources of valuable compounds (e.g., nutrients, bioactive phytochemicals), making it worthwhile to extract and reintroduce them into the food value chain as functional value-added ingredients. METROFOOD-RI's efforts are particularly directed towards the valorization and upcycling of by-products and side streams in agricultural and food production to support the United Nations´ Zero-Waste-Strategy (SDG No. 12: Responsible consumption & production).

Strategic Area 2: Alternative protein sources

The world's population is growing steadily and is expected to reach 9.8 billion by 2050, and 1.2 billion in 2100, which will significantly increase the global demand for food (UN, 2017). Given socio-economic transformations and climatic changes, securing sufficient food supplies demands tapping into new food resources. With forecasts indicating that global demand for animal-derived proteins will double by 2050 (Porrit and McCarthy, 2015), this is a particularly relevant issue, as global protein production through large-scale livestock breeding is considered as a major source of greenhouse gas (GHG) emissions and driver of global warming. In the EU member states (EU-27), more than two-thirds of agricultural land is already used for livestock production, and given scarce resources (arable land for feed production and water shortages) and ecological concerns, there is little capacity for expansion left.

Forming the structural elements of our body and taking over vital functions in human biochemistry, proteins – classified as macronutrients – are considered as the building blocks of life. For a healthy adult, the estimated average requirement of protein is 0.66 gram per kilogram of body weight (Health Council of the Netherlands, 2021). Inadequate dietary protein intake can lead to serious health complications affecting physical and emotional well-being.

While plant and animal foods serve as the major dietary protein sources in human nutrition (mainly derived from cows, chickens, soybeans, peas or lentils), certain differences do exist. Divergences primarily relate to the amino acid profile, molecular structure, digestibility, and technical functionality in foods (e.g., water-binding or emulsion capacities) (Day et al., 2022). Also, plant-based proteins are generally considered to be of lower quality than animal-derived proteins.

In the interest of more ethically sustainable production and from an animal welfare prospective, new sources of protein for human consumption have been explored as substitutes for animal agriculture. In particular, the use of microbial protein factories (bacteria, yeast, fungi, and algae) and insects have been reported as extremely promising production systems and resources. Thanks to the advancements in fermentation techniques (microbial/whole-biomass/precision fermentation), some of which are still in early stages but highly efficient, alimentary protein derived from microbes is considered today as the "*third pillar in the alternative protein industry*" (GFI, 2021) alongside plant-based protein or cultivated meat.

Another promising approach is insect farming, which makes a major contribution to the circular economy and climate mitigation efforts. The protein density of edible insects is superior to plant sources or eggs (protein content between 35%-60% dry weight) (Kim et al., 2019; Churchward-Venne et al., 2017), they are easy to breed and raise, and they burn far fewer resources than other agricultural meat production systems.
Over 2000 species of insects are known to date to be used by humans as food, including beetles (Coleoptera), caterpillars (butterfly and moth larvae; Lepidoptera), bees, wasps and

ants (Hymenoptera), grasshoppers, locusts and crickets (Orthoptera) (Jongema, Y., 2015). The majority of insects intended for human consumption are or have been traditionally harvested from wild populations, however the growing trend is moving toward selectively farming insects on a large scale under controlled conditions.

METROFOOD-RI understands alternative protein sources as a key area for action with society-wide relevance, placing it in the focus of its activities. Alternative proteins can help meet the protein demand of our growing population, can improve food security and contribute to building up a more diverse and resilient food system. However, there is still a huge need for research and action to make alternative proteins an integral part of the global food supply. Added to this is the great skepticism of consumers towards alternative protein sources, which is why METROFOOD-RI is also advocating for better education and outreach.

Strategic Area 3: Personalized/precision nutrition

The terms "personalized nutrition" or "precision nutrition" are on everyone's lips in the field of nutrition science today. At its core, it refers to an approach that "*helps individuals achieve lasting and health-promoting changes in dietary behavior*" (Ordovas et al., 2018) by providing nutritional counseling, products or services customized to a specific target audience or person. Although there is currently no universally accepted definition, the two terms are often used interchangeably. In professional circles, however, a distinction is made between the terms in that precision nutrition is more specialized and focused on the individual, and integrates besides dietary habits a comprehensive set of additional parameters, involving genetics and metabolic functions, physical activity, the microbiota, and the metabolome (de Toro-Martin et al., 2017).

Given the epidemiological observation that diet-related non-communicable diseases (e.g., diabetes type 2, obesity, cardiovascular disease, and certain type of cancer) are rapidly increasing worldwide, especially in industrialized countries, personalized nutrition is a promising strategy to counteract this development. In this regards, METROFOOD-RI strongly advocates and supports efforts in personalized nutrition research. The inherent complexity of interactions between human health and nutrition requires multi-level engagement and inter- and transdisciplinary approaches to improve public health on a broader scale, and to alleviate the tremendous burden on the healthcare system and economy in Europe.

Consumers are at the center of the personalized nutrition approach, the success of which requires a deep understanding of the needs, eating habits and food preferences of each target group in order to motivate people to adopt a healthier diet by providing them with tailored dietary recommendations that are fit-for-purpose and implementable in everyday life. From this perspective, METROFOOD-RI's efforts are also aimed to support this process, inter alia, by strengthening the knowledge collated in food composition databases, which serves as an important basis for assessing dietary intake, and by promoting nutritional education in the general population and in vulnerable groups.

Strategic Area 4: Food allergens

Adverse reactions to foods caused by an abnormal immune response, especially to proteins or protein derivatives contained in the food, is globally rising and representing a major public health concern. According to estimates from the European Federation of Allergy and Airways Diseases Patients´ Associations (EFA), 17 million Europeans suffer from food reactions, of which ~20% are under 25 years of age (EFA, 2019). The most common foods evoking allergic reactions are cow´s milk, eggs, wheat, soy, peanut, tree nuts, fish, and shellfish constituents (Nwaru et al., 2014).

As laid down in the Regulation (EU) No 1169/2011 of the European Parliament and Council on the provision of food information to consumers (EU, 2011), the presence of certain substances or products in food causing allergies or intolerances must be indicated in the list of ingredients in pre-packaged foods. Even in the case of unpackaged goods (e.g., food consumed in restaurants), food information about any allergens contained is obligatory towards consumers. Despite stringent legal regulations in food production and package labeling, which are primarily intended to protect consumers from harm to their health, violations are regularly uncovered and the concept of a "food safety culture" is shaken. The underlying reasons for this can be manifold in nature. For example, food hygiene practices at the food production and distribution level are not the same or equally adhered to in all countries. Also, a lack of knowledge in food hygiene and food handling practices, along with deficits of personnel training involved in food production are considered as major entry sources for cross-contamination and food allergens.

Adulteration of foodstuffs and food fraud are other issues that have reportedly increased during the COVID-19 pandemic (Points & Manning, 2020), with allergens having been introduced into our food supply chain without proper declaration (e.g., peanut powder). Ensuring that allergy sufferers have access to safe food without risking an allergic reaction

that could endanger their lives is also a key priority for METRFOOD-RI by combating food fraud and assuring food authenticity and traceability. In this sense, the Research Infrastructure aims to support and strengthen the European food safety system, involving the disclosure of (emerging) food-related risks, such as those posed by allergens or other contaminants with adverse public health implications.

3.3 RESEARCH PRIORITIES *ELECTRONIC-RI*

Strategic Area 1: FOOD Metrology

In the global economic system we live in, the agrifood sector dominates. However, it is subjected to several pressures such as global population growth, climate change, environmental degradation and constantly changing consumer preferences. At the same time, it has the responsibilities of avoiding excessive use of natural resources (soil, freshwater, and others), to avoid misuses of monocultures, excessive food losses and waste (European Environment Agency, 2020).

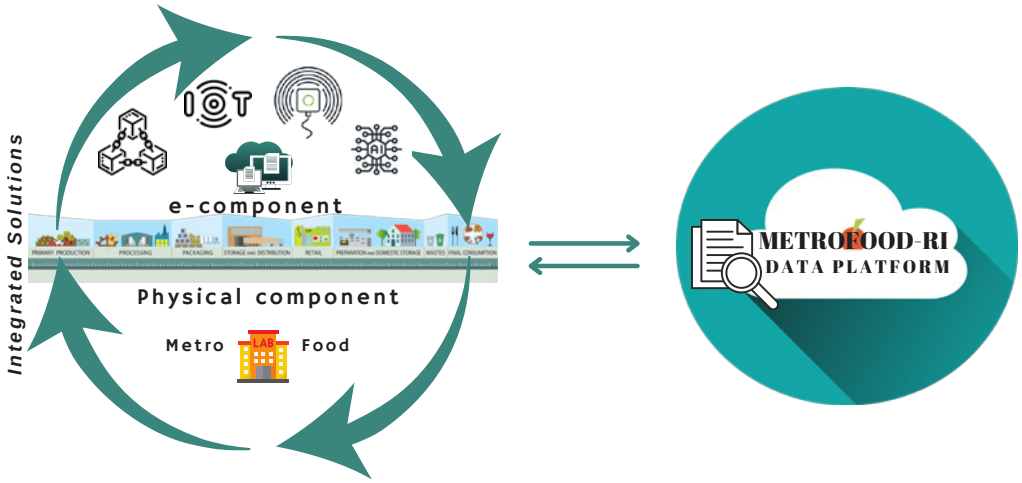
Digital technologies represent an opportunity to solve challenges in the agrifood system at national, regional and international level in areas relating to the environment, the food safety, inclusion, the sustainability and transparency. Combined with data-drive innovation, digital technologies are key in facing these issues. Knowledge innovation and digitalization in food systems can lead to sustainable, resilient, inclusive, safe, and healthy food from farm-to-fork, for all citizens. The application of technology to the "food system", also defined as "foodtech", has become a necessary requirement for becoming competitive in a consolidated and globalized sector.

Furthermore, the digital revolution has involved the agrifood sector in recent years. As a consequence, Industry 4.0 was born, which involves connected systems, also termed as Cyber-Physical Systems, leading to increase automation, better communication, self-monitoring, and deployment of intelligent machines. Industry 4.0 is characterized by a fusion of emerging technologies such as the Internet of Things (IoT), Industrial Robots (IR), Big Data analytics, Blockchain Technology (BT), Artificial Intelligence (AI), and others. The combination of all these components can create significant opportunities, as well as new services or products.

The spread of digitalization and interconnection has led to an increase in the amount of data worldwide. The amount of data generated by humanity in the last two years is equivalent to all data generated in all human history up until two years ago. It is estimated that just 0.5% of the total data is used. For this reason, Big Data today represents an opportunity to create value.

Big Data applications are attempting to address global issues such as food security, safety, and sustainability. In the agrifood sector, Big Data is used or is being researched for various purposes, such as (Wolfert et al., 2017; Tao, Yang and Feng, 2020): the development of predictive models for food safety and risk assessment; new product development and

process innovation (e.g., new flavour combinations) through analysis of multisource data from ingredient lists, sensory results, and consumer preferences; the formulation of classification algorithms to be applied to the identification of chemical or microbiological contaminants (e.g., pathogens, mycotoxins, pesticide residues or veterinary drugs, toxic or potentially toxic elements) and to evaluate their transfer along the production chain; the identification of fraud, adulteration, and defects in products; the compilation of accessible databases, with the possibility of data reuse and interoperability according the FAIR Data Principles and the development of approaches for identifying consumer consumption patterns for improving surveillance of chronic diseases and foodborne outbreaks.
Data driven innovation is quickly reshaping the way we produce and consume food. It enhances the potential to manage natural resources more efficiently and to care for the ecosystems that our food production relies upon without exceeding finite boundaries. It improves the transparency of food systems, processes, and products from farm-to-fork, enabling a more resilient, safe, circular, and customized supply chain, and more personalized diets.



The e-component of METROFOOD-RI consists of a service-oriented architecture that provides a platform accessible to different types of users in order to collect, share and promote the integration of data, knowledge and information about the agrifood system, from "farm to fork". It will also collect the results provided by the physical component and allows access to information on tools for standardization and harmonization of food analysis (RM, reference and official methods, competence testing, etc.); the collection, sharing, analysis and interoperability of data, data link and display (food composition, contaminants, markers; food production and processing; environmental and health impact; etc.); dissemination and training on food and nutritional metrology, food quality/safety/traceability/authenticity; nutrition and information collection on metrology needs in food and nutrition.

METROFOOD-RI fulfills and promotes the implementation of FAIR principles. The resources involved in the RI will allow the development of advanced services such as an ICT infrastructure for food data science to preserve both the data and the results obtained with numerical and predictive models. The sharing of data based on the FAIR principles will facilitate the development of data driven methods and machine/deep learning models based on the availability of data to be analyzed with technologies based on "Big Data" analytics".

Top priority level:

- FAIR data and information management (including big data)
- Integration of systems and data exchange
- Digitalization of the agrifood system and integration of ICT technologies (smart sensing, IoT, block chain, artificial intelligence).
- Artificial intelligence for food research (automatic matching of food databases; automatic recognition of foods or pictures of foods)
- Computational approaches to analyze, aggregate or transform data (algorithms, machine learning, block chain, data pipelines, distributed analysis, etc.)
- Use of computational science and consolidation of existing databases to support risk assessment.

3.4 RESEARCH PRIORITIES *PRODUCER/CONSUMER INTERFACE*

In the last decades food waste has generated, and it's still doing, significant inequity, poverty and important loss for the environment. For these reasons consumer's awareness for responsible production and consumption is increasing and it's important to continue in this way to achieve a long-term sustainability. On the other side, companies and sellers are led, by this trend, to reduce food waste and to increase their responsibility for the best sake of our planet. Following this perspective, consumers are increasingly demanding:

- More product choices
- Additional variations
- Faster availability
- Reliability and traceability of the products

People want to know where their food was grown, harvested, processed, distributed and sold, before it reaches their tables. Transparency and clearness are the keywords to create a new system of consumption and the industry is trying, not only to provide information, but also to create conditions that allow customers to evaluate such information, increasing their level of knowledge/understanding. It will permit to consumers to feel involved in their

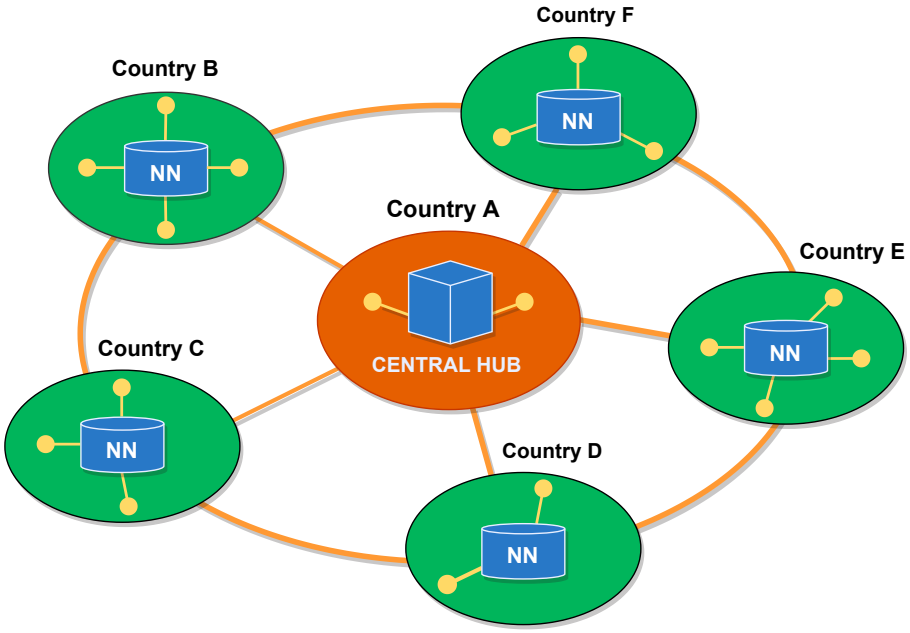
purchasing activities and informed and educated about the expectations and features of services. This approach could create a collaboration from the "bottom" towards service providers and service performance, giving origin to an interactive and transversal system. In this way consumer education became a process through which customers can improve their perceived value, allow them to obtain information/advice, learn how to make rational and efficient future choices, and protect their health and their rights. Furthermore, a digital transformation is taking place in the food industry and the manufacturing models are changing through the use of smart technologies, likewise consumer's attitude. This networking approach emphasizes the interdependencies of actors, resources, and activities as a key component for a major change in the agrifood production system. These aspects are highlighted also by the food processing operations that have benefitted from this new kind of net-industry, by improving traceability, monitoring, control of food quality and safety, automation, and training to predict consumer preferences, reducing losses and wastes at the same time.

Activities that are at the producer/consumer interface are among the priorities of METROFOOD-RI, along with actions for training, education, and knowledge sharing, since they are the backbone of a knowledge-based society. Collaboration with industries (particularly SMEs) and technology transfer are also highly relevant. Particular attention is paid to social engagement and co-creation approaches, even with the implementation of Living Labs (including face-to-face and virtual sessions, as well as demonstrators of the technological services offered) as a tool for open innovation and actual engagement of the agrifood system stakeholders.

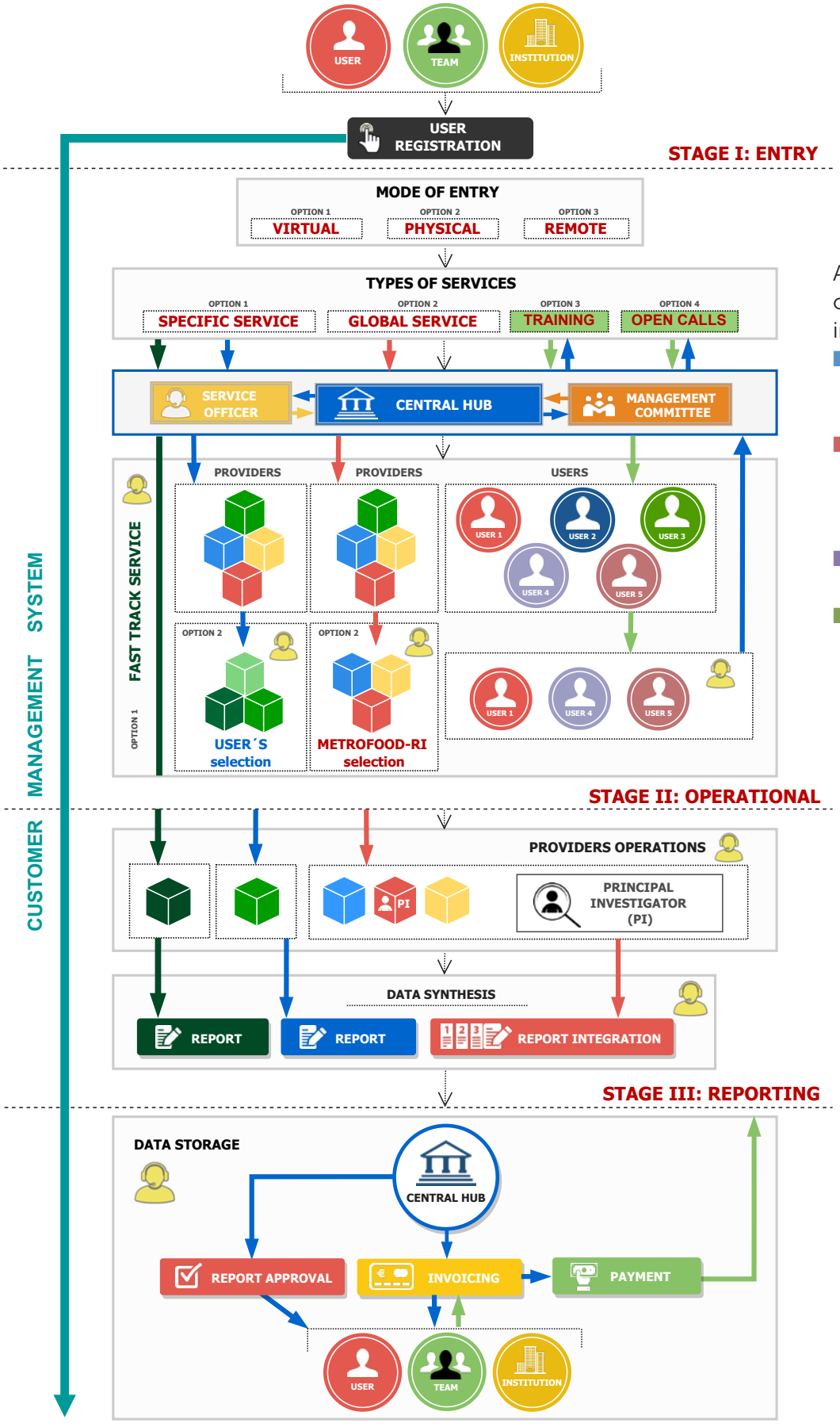
TOPIC PRIORITY LEVEL: HIGH	TOPIC PRIORITY LEVEL: MEDIUM
Improving consumer information (e.g., on food quality & safety)	Improving consumer education
Traceability/transparency	Fostering food system transformation by networking
	Training and education; technology transfer
	Food safety risk communication
	Food labelling
	Dietary advances and novel consumption attitudes

4. OUR MODE OF OPERATING

Being a distributed RI, METROFOOD-RI is organised with a Hub & Nodes structure, which implies the trans-national integration of existing national facilities for supporting metrology in food and nutrition. According to this structure, the future ERIC will comprise a Central Hub (CH), representing the siting of the infrastructure legal entity, and National Nodes (NN), representing the operational sites.



In particular for the services offered by METROFOOD-RI, the Central Hub forms the single access point for the transnational and virtual access. The services will be accessible through different access types - physical access, remote access, and virtual access (for some services, physical or remote access could be even combined with the virtual one) - and different access modes - excellence-driven, market-driven, and open access. The service provision will follow a defined procedural scheme, as illustrated in the given flow chart.



A particular focus will be on the following strategic integrated services:

- Integrated services in support to circular bioeconomy;
- Integrated services in support to food traceability and transparency;
- Organization of Living Labs;
- Integrated virtual access services.

5. IMPACT AND UNIQUE POSITIONING

METROFOOD-RI will promote the acceleration of scientific discovery, innovation and competitiveness, growth and jobs, economic and social cohesion, all representing essential components of sustainable development. It will contribute to a new research approach that allows metrological data flows through networks in a way that will facilitate trade, competitiveness, quality and consumer satisfaction of food and nutrition data at the European level, but also at regional and national level. The RI will foster competitiveness in the Food & Health domain in many ways, especially through its unique technical and scientific offer.

METROFOOD-RI impact can be evaluated considering 7 specific impact areas, namely: scientific, technological, economic, social, educational, and environmental.

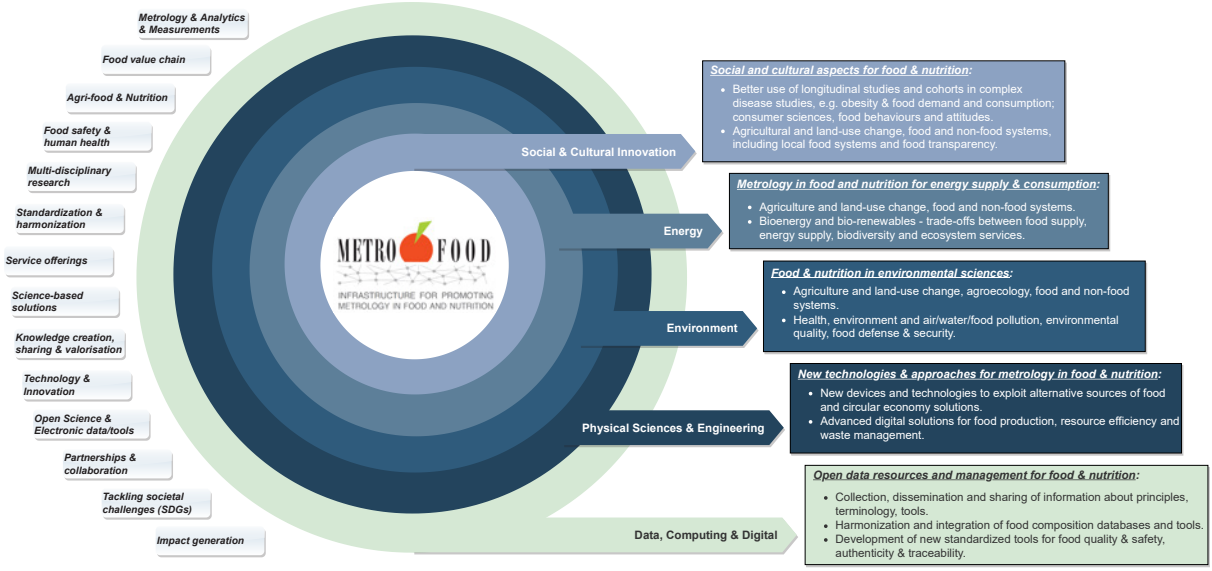
Scientific impact is mostly related to knowledge producing, accumulation and exchange as well as mutual learning at the level of agrifood system stakeholders, research and academia, with added societal value through new services, new products and technologies, and new approaches that could contribute to solve the grand societal challenges.

Economic and Technological & Innovation impacts are related to: i) increased economic activity, not only in the countries where the RI insist, but more widely at the European level; ii) market creation (triggered sales volume) and market expansion (increased sales volume and revenues for agrifood businesses); corporate efficiency gains through data use/application; new technologies and designs developed and transferred; added value of RI-owned patents and other Intellectual Property.

Human Resources (HR) impact is related to: i) scientific attractiveness; ii) increased prestige of the RI as training and education facility; iii) improvement of HR in research in regions/country, iv) improvement of HR in research with training and education facility; iii) improvement of HR in research in regions/country, iv) improvement of HR in research with technical/managerial skills, v) improved job opportunities in the region/country.

Policy impact is related to the effects and changes in regulations, standards, institutions, and science diplomacy, among other policy-related domains. In this context, the RI will implement common cooperation strategies and cohesion policies, as well as to increased trust in science. Food related policy is inevitably evolving, due to the diversity and variability of the new scientific evidence (e.g., introduction of new technologies and use of new materials in production processes, new plant and animal treatments, new emerging contaminants, etc.), as well as the progress of scientific knowledge on the health effects of various already used substances.

One of the important objectives that METROFOOD-RI deals with keeping the environment safety. This means that agroecology, One Health approach, circular economy new approaches will be promoted for: i) reduction of environment pollutants; ii) promotion and characterization of organic food production; iii) assuring the balance between the need for more biological resources and environmental protection and resource sustainability; iv) reduction of food waste throughout agrifood systems, including intelligent packaging materials that prevent early spoilage, protect, and preserve food and innovation technologies could be also used to protect environment.



Cooperation and integration in the landscape is a key asset for METROFOOD-RI. Representing the RI for promoting Metrology in Food and Nutrition, with high-level metrology services for enhancing food quality & safety and supporting the traceability and sustainability of agrifood systems in the view of circular economy, it allows to fill gaps in the Health & Food domain and finds its unique place among the EU Research infrastructures. In particular, it is positioned at the center of the food challenge because of its direct affiliation to "food" comparing to other ESFRI RIs. Thanks to its approach, which consider the whole agrifood system and entire supply chain from farm to fork, METROFOOD-RI can establish strong synergies and complementarities with several ESFRI RIs, and particularly the ones more focused on issues related to "sustainable environment" covering the first stage of a "sustainable food chain", as well as with others more focused on food processing, biotechnologies, and development of bioprocesses. The METROFOOD-RI multi- and trans-disciplinary approach favors collaboration and integration with European, national and supranational organizations and networks focused on metrology (e.g. EURAMET, EU RLs, NRLs) and analytical chemistry (e.g. Eurachem), food safety and risk assessment, food authenticity, but also with the ones focused on biological, biomedical, agronomical, ecological and environmental science, structural biology (considering its potentiality of application to food), as well as on social sciences. Other important areas of collaboration are with EU Technology Platforms (ETPs), Joint Programming Initiatives (JPIs – such as JPI HDHL, FACCE JPI), Horizon European Missions & Partnerships (e.g., EIT-Food), Regional Innovation Smart Specialization Strategies (RIS3, with particular reference to the thematic platform "Traceability and Big Data"), and regional and national technology clusters.

METROFOOD-RI, following the new ERA Policy Agenda objective, pools its members' resources for a better alignment and efficacy of agrifood research and creates a single, borderless market for research, innovation, and technology across the EU in this field, thus contributing to strengthen the European Research Area (ERA), being perfectly aligned with European policy objectives and strategies – specifically the 'European Green Deal' with its main component strategy "Farm to Fork" – and with the Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development of the United Nations. METROFOOD-RI also contributes to the European policy of a 'Europe fit for the digital age', including the European data strategy, high performing computing, digital services, and digital skills and has to work in close connection with the European Open Science Cloud (EOSC).

6. LIST OF ABBREVIATIONS

AI	Artificial Intelligence
BT	Blockchain Technology
CC	cluster challenge
CH	Central Hub
CRM	Certified Reference Material
EIT	European Institute of Innovation and Technology
ERA	European Research Area
ESFRI	European Strategy Forum on Research Infrastructures
ETPs	EU Technology Platforms
EU-27	27 EU Member Countries
EU-RLs	European Reference Laboratories
FAIR	Findable, Accessible, Interoperable, and Re-usable
FAO	Food and Agriculture Organization of the United Nations
FBO	Food Business Operators
GFI	Good Food Institute
ICT	Information and Communication Technology
IoT	Internet of Things
IR	Industrial Robots
JPIs	Joint Programming Initiatives
NN	National Nodes
NRLs	National Reference Laboratories
PFAS	Perfluoroalkyl substance
RI	Research Infrastructure
RIS3	Regional Innovation Smart Specialization Strategies
RM	Reference Material
RRI	Responsible Research and Innovation
SDGs	Sustainable Development Goals
SI	International System of Units
SIDA	Stable Isotope Dilution Assay
SMEs	Small and Medium-sized Enterprises
SRIA	Strategic Research and Innovation Agenda
UN	United Nations
WHO	World Health Organization

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