Deliverable D4.1

Formulation community Value-Chain Maps

AceForm4.0
Activating Value Chains for EU Leadership in FORMulation Manufacturing 4.0

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</tbody>
</table>
# Table of Contents

1. Purpose of this document ........................................................................................................... 4  
2. Executive summary .................................................................................................................. 4  
3. The formulation value chain .................................................................................................. 4  
   Reminder: What is formulation? .............................................................................................. 4  
   Generic innovation value chain for formulated product .......................................................... 5  
4. Toward a Circular innovation value chain for formulation .................................................. 6  
   The use of Circular economy to redesign the value chain ....................................................... 6  
   Different actors of the circular innovation value chain .......................................................... 7  
   How Industry4.0 can accelerate the innovation value chain .................................................. 8  
5. Specific value chains per sectors, actors and challenges ....................................................... 10  
   Formulation sectors within AceForm4.0 .................................................................................. 10  
Value chains actors and challenges per sector .......................................................................... 10  
6. Conclusion ............................................................................................................................... 17  
7. Next steps .................................................................................................................................. 17  
   Appendix A – Call text for H2020 NMBP-30-2016 competition ............................................ 18
1. Purpose of this document

To reach AceForm4.0 objective 4, the deliverable 4.1 aims to identify and map value chains for at least 5 key markets and technological areas in the formulation community. The value chains should be focused on sustainable innovative formulated products including digital technologies for supporting the new products, automation of manufacturing plans and supply chains.

Members of the Aceform4.0 consortium have strong connectivity to stakeholders operating in the innovation and manufacture of formulated products. This connectivity has been used to establish the EU Formulation Interest Group (WP5) and to organise knowledge exchange workshops (WP4). In WP2, the technological and industrial challenges have been identified thanks to a broad online consultation and face-to-face interviews of formulation stakeholders. These activities coupled with consortium connectivity are used in this document to evolve value chain maps and identify players involved in the innovation and manufacture of formulated products.

2. Executive summary

In this document, a generic value chain is modified into a circular innovative value chain. Key players within each of the value chain segments have been identified for each of the six target formulation sectors. These sector-specific value chain maps are expected to allow stakeholders to confirm their position in the innovation process and help them to identify opportunities for cross-sector collaborations. Per sector, challenges are listed and placed in the value chain to highlight cross-sector and global challenges.

The value chains map will help businesses and research communities in their initiatives to find and develop new collaboration partners for strategic cross sector initiatives. This document will be published and made available on the project website via WP5.

3. The formulation value chain

Reminder: What is formulation?

The word “formulation” can be used to refer to different things. First it can be considered as a Recipe. A list of ingredients and detailed processing steps used for the development of a blend displaying well-defined target properties, functionality and performance. It can also defined the act of formulating something. The combination of processes used for mixing and conditioning of ingredients (actives, protective agents and stabilising agents) as well the know-how and technologies that enable selection of ingredients and mixing processes for the production of a blend with specific target properties, performance and functionality. The result of a formulation process can also be considered as a formulation (the actual blend of ingredients).

If a formulation is something easily achievable, it should be differentiated from a formulated product. A formulated product is composed of at least two ingredients which are selected, processed and combined in a specific way to obtain well-defined target properties, functionality and performance. It can exist in liquid, semisolid or powder form. A formulated product has a commercial value and is either meant for direct consumer use or for downstream use in other industrial applications.

The Aceform4.0 project is mainly focused on formulated product.
Generic innovation value chain for formulated product

To keep themselves in a world-leading position, the European formulation community should be able to innovate constantly and bring to the market innovative formulated products outperforming competitor products. Companies usually consider the innovation value chain described on Figure 1.

![Figure 1: Innovation value chain for formulated products](image)

**Raw materials** are considered as the starting point of the innovation value chain. They represent all the possibilities available to create innovative formulated products. At **Process/product innovation** step, the raw materials will be turned into a formulation. With targeted performances, composition and process will be evolved in order to reach defined objectives in term of formulation actions/structure/stability/instability/process robustness/scale-up compatibility (See “More than mixing”). After the innovation step comes the **formulated product production**. The formulation is produced on large scales and faces the “real life” variability like production place specificities/operator/raw material variability (See Turning a ‘Formulation’ into a ‘Formulated Product’). Once manufactured, the formulated product is then **distributed** and sometimes **customised** to meet local constraints (specific packaging, local conditioning need, regulation...). In **use**, the product will deliver its main performance which is the “user experience”. The usage generates the last step of the value chain: **the waste**. For some products the waste step is very limited (e.g. for food, only packaging) but other parameters should be taken in account for this step like the environmental impact or outdated products. In the value chain, there are commonly feedback loops to earlier parts of the chain in order to achieve customer satisfaction, improvements of the formulation or output quality, as well as increased sustainability and less waste.

To keep the leadership, new innovation value chain should be implemented quickly and in a reliable and sustainable way. With the technologies already implemented (like predictive maintenance, on-line quality control...), the linear value chain has reached its maximum performances. In order to find new dynamics and solutions to improve value chain efficiency, the Circular Economy and Industry4.0 mega trends can be used to enable truly disruptive innovations.
4. Toward a Circular innovation value chain for formulation

The use of Circular economy to redesign the value chain

*Circular economy by Ellen McArthur foundation:*

Looking beyond the current "take, make and dispose" extractive industrial model, the circular economy is restorative and regenerative by design. Relying on system-wide innovation, it aims to redefine products and services to design waste out, while minimising negative impacts. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural and social capital. Credit: Ellen McArthur foundation

Circular is a concept that involves maintaining the value of products, materials and resources in the economy for as long as possible, while minimising the generation of waste. EU’s 2015 implementation plan for Circular Economy addresses aspects related to: Production design and process, consumption, waste management and from waste to resources. In the context of these aspects the concepts of "re-use", "resource productivity", “renewable energy” and "down-cycling" play a very important role.

Using the concept of circular economy, it is possible to modify the shape of the innovation value chain into a circular one to minimize the inputs and the outputs (see Figure 2). The introduction of a new step “Re-use/Re-cycle” allows the reintroduction of materials in the value chain (or another one). In addition, a flow of information throughout
the value-chain also needs to be facilitated in order to support the innovation (customer feedback, new ideas for formulation designs, process improvements, optimizations, etc).

![Circular value chain](image)

**Different actors of the circular innovation value chain.**

Based on Aceform4.0 survey outputs (see D2.3) and consortium experience and network, the different categories of actors in the different steps of the values chain have been identified. They can be divided in three different groups:

- **The core actors**: they are the main actors of the innovation value chain. If one of them is missing then the value chain cannot work. They perform usual but key actions in the value chain. Some of them can bring minor innovations in the system like small process or composition modification very often linked to a practical issue in the chain. They answer to the market pressure but their main role is not to bring about major innovations. Their action on innovation may be either in the process so as to reach cost reduction or in the formulation itself by re-formulating an already existing product (modification of available raw material for instance).

- **The innovation enablers**: their action is focussed on research and innovation. They bring new ideas/new concepts/new technologies.

- **The Innovation accelerators**: their role is to facilitate the discovery of innovation and its implementation.

Core actors (represented by the outer links in Figure 3) tend to be active within their own silos. Innovation enablers and accelerators (represented by the links in the inner circle in Figure 3) have the potential to influence activities of all the core actors. Three main groups have been identified: Consumers/Science & Engineering/Policy. Within the innovation process, these three groups’ point of view is always questioned:

- Is it possible (Science)
- Is it feasible? (Engineering)
- Is it allowed? (Policy)
- Is it desired? (Consumer)
How Industry4.0 can accelerate the innovation value chain

What is Industry4.0?

Industry 4.0 is the promise of a 4th Industrial Revolution, in which the integration of various digitalisation technologies (existing and emerging) will enable advanced capabilities to connect, model and automate design, manufacturing and supply chains systems. Thereby this will enable the delivery of products, processes and services in a faster, more efficient and more flexible way.

A term that encompasses different aspects of the optimization through digitalization of process and systems which enables increased connectivity between these. Increased connectivity implies that all production processes, equipment and sensors are integrated and connected all the way to the top of the organisation. All the information (data) generated this way is collected and stored, as well as potentially combined with information from other sources, and then made available for processing by ERP -systems, data mining-tools and other systems. The information should be able to flow up and down and facilitate decision making as well as better control of the processes. For these decisions to be able to reach the production processes and equipment, higher level systems...
are required which in turn have to be integrated with the production processes and the various systems on that level.

For the manufacturing industries, Industry 4.0 offers unique opportunities for attaining:

- Reduced time to market,
- Increased flexibility
- High performance (as high quality as possible)
- Reduce consumption of resources.

For this to happen, all organisations participating in the value-chain should be integrated digitally (i.e. allowing the necessary electronic information to flow in any direction needed). This requires, in turn, for stable ICT-infrastructure, trust, transparency, information security and adequate standards to be in place.

The exact list of specific digitalisation technologies varies by source, but the following slide below provides an interesting coverage of important technologies.

![Industry 4.0 technologies](Credit to LCR4.0)

**The implementation of Industry 4.0 accelerates the innovation**

All the technologies described above could accelerate and improve the value chain of innovation. They bring a better connectivity between the different stakeholders. I4.0 technologies can be used during all the step of the innovation value chain in order to:

- Predict the performance and the impact of the innovation (Virtual Reality/Simulation/Cloud Computing...)
- Support, Accelerate and follow the implementation of the innovation (Industrial internet/Internet of things/System integration/Autonomous systems)
- Analyse the “real life” innovation performance (Big data analytics/Internet of things...)
In this document, some formulation challenges from the formulation industry will be described and classified. We think that some of them could be tackled by use of Industry4.0 technologies.

5. Specific value chains per sectors, actors and challenges

<table>
<thead>
<tr>
<th>Sector grouping</th>
<th>Subsector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Home, Industrial &amp; Personal Care</td>
<td>Personal care – cosmetics, cleaning, well-being, perfumes</td>
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<tr>
<td></td>
<td>Home care – cleaning, laundry, hygiene</td>
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<tr>
<td></td>
<td>Industrial and Institutional cleaning</td>
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<tr>
<td>2. Pharma &amp; Health Care</td>
<td>Pharmaceuticals – small molecule, biologics</td>
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<tr>
<td></td>
<td>Healthcare – hygiene, skincare, pain relief, nutrition</td>
</tr>
<tr>
<td></td>
<td>Medical Devices, Diagnostics, Imaging</td>
</tr>
<tr>
<td>3. Agro Technologies &amp; Plant Protection</td>
<td>Crop Protection</td>
</tr>
<tr>
<td></td>
<td>Agrichemicals</td>
</tr>
<tr>
<td></td>
<td>Seed treatments</td>
</tr>
<tr>
<td>4. Coatings and Surfaces</td>
<td>Paints</td>
</tr>
<tr>
<td></td>
<td>Inks and dyes</td>
</tr>
<tr>
<td></td>
<td>Lubricants</td>
</tr>
<tr>
<td></td>
<td>Adhesives</td>
</tr>
<tr>
<td></td>
<td>Speciality chemicals</td>
</tr>
<tr>
<td>5. Food &amp; Drink</td>
<td>Food – confectionary, processed foods, sauces, animal feed</td>
</tr>
<tr>
<td></td>
<td>Drink – alcohol, soft drinks, coffee</td>
</tr>
<tr>
<td>6. Advanced materials</td>
<td>Composites, polymers, ceramics</td>
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<tr>
<td></td>
<td>Catalysts</td>
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<td></td>
<td>Paper and packaging industry</td>
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<td></td>
<td>Additive manufacturing</td>
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Value chains actors and challenges per sector

To go a step further in the innovation value chain mapping, the generic value chains proposed in section 4 is modified and adapted to each sector. For each sector, some of the value chain steps or actors are modified to provide a more precise description of the value chain components. One can find here again the different stakeholders categories.

For each target sector, a second value chain version is presented to highlight the specific challenges for each steps. A color code highlights the circular economy challenges (green) and the technological challenges (blue) where Industry4.0 could help.
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Home, Industrial & Personal Care

Core actors:<br>• Raw material suppliers<br>• Molecule suppliers<br>• Legislators

Specific to Home, Industrial & Personal Care

• Product designers<br>• Scale-up Team<br>• Internal R&D<br>• Academia<br>• Apparatus suppliers<br>• hTP platform

• Waste Managers<br>• Consumers<br>• Waste valorization companies<br>• Legislator<br>• R&D in recycling

• Production team<br>• Process Innovation demonstrator<br>• Internal research on process<br>• Academia

• Domestic Consumers<br>• Professional Consumers<br>• Downstream formulation industry<br>• Consumption Influencers (e.g. Media...)

• Logistic team<br>• Specialized shop<br>• Superstores<br>• Packaging designers<br>• Marketing

Challenges<br>Specific to Home, Industrial & Personal Care

Variation in raw materials<br>Toxicity levels of different ingredients<br>Sourcing of bio-based ingredients

Simulate consumer use and consumer perception<br>Move to sustainable and circular products<br>Reduce full lifecycle impact<br>Performance/STABILITY (shelf-life)<br>Toxicity levels of different ingredients<br>Retaining/developing skills base

Collection of used/remaining products<br>Recycling of used/remaining products<br>Separate and re-used formulation components

Process robustness<br>Reduce full lifecycle impact (e.g., reduce water consumption)<br>Ingredient traceability<br>Variation in raw materials<br>Sourcing of bio-based ingredients<br>Regional production<br>Retaining/developing skills base

Digitalization customer oriented<br>Performance feedback<br>Ingredient traceability<br>Collect consumer perception<br>Minimize waste during application

New supply chains<br>Digitalization customer oriented<br>Regional supply chain<br>Stability (shelf-life)<br>Retaining/developing skills base
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Pharma & Healthcare

Core actors/Innovation enablers/Innovation accelerators
Specific to Pharma & Healthcare
- Chemical suppliers
- Molecule suppliers
- Legislators
- Waste treatment organisms
- Consumers
- Waste valorization companies
- Redistribution organism
- Pharmacies
- Legislators
- R&D in recycling
- Patients
- Medical staff
- Downstream pharma industry
- Consumption Influences (e.g. Media...)

Production team
- Process innovation demonstrator
- Internal research on process
- Academia

Logistic team
- Government (medicine stocks/vaccination campaign)
- Health professionals
- Packaging designers
- Internal R&D
- Marketing

Challenges
Specific to Pharma & Healthcare
- Variation in raw materials
- Toxicity levels of different ingredients
- Introduce new excipients
- Sourcing of bio-based ingredients
- Collection of used/remaining products
- Redistribution of un-used product
- Recycling of used/remaining products
- Personalized medicine
- Digitalization customer oriented
- Performance feedback
- Feedback from healthcare professionals
- Feedback from patients
- New supply chains
- Digitalization customer oriented
- Regional supply chain
- Stability (Shelf-life)
- Retaining/developing skills base

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Agro technologies & Plant Protection

Core actors/innovation enablers/innovation accelerators

Specific to Agro Technologies & Plant Protection

- Bio-based ingredients suppliers
- Chemicals suppliers
- Legislators
- Waste Managers
- Consumers
- Waste valorization companies
- Legislative
- R&D in recycling
- Gardeners
- Farmers
- Agriculture influencers
- Field performance evaluators (drones/cameras...)
- Product designers/field testers
- Scale-up team
- Internal R&D
- Academia
- Apparatus suppliers
- HTP platform
- Production team
- Process innovation demonstrator
- Internal research on process
- Academia
- Logistic team
- Distributors
- Packaging designers
- Internal R&D
- Marketing

Challenges

Specific to Agro Technologies & Plant Protection

- Variation in raw materials
- Toxicity levels of different ingredients
- Ingredients traceability
- Sourcing of bio-based ingredients
- Performance and stability (shelf life)
- More to sustainable and circular products
- Regulation and customer
- Toxicity levels of different ingredients
- Retaining/developing skills base

- Collection of used/remaining products
- Recycling of used/remaining products
- Minimize waste
- Process robustness
- Ingredient traceability
- Reduce full lifecycle impact (e.g. water contamination)
- Sourcing of bio-based ingredients
- Regional production
- Retaining/developing skills base

- Digitalization customer oriented
- Performance feedback (yield)
- Minimize waste during application
- New supply chains (from production to crop)
- Digitalization customer oriented
- Regional supply chain
- Stability (shelf life)
- Retaining/developing skills base
AceForm4.0 Activating Value Chains for EU Leadership in FORMulation Manufacturing 4.0

Coatings and surfaces

Core actors/Innovation enablers/Innovation accelerators
Specific to Coatings and Surfaces

- Chemical suppliers
- Legislators

- Raw materials
- Process/product innovation
- Policy

- Consumers
- Application
- Removal

- Distribution and local customization

- Formulated product
- Science & Engineering

- Raw materials
- Reuse/recycling

- • Waste Managers
- • Consumers
- • Waste valorization companies
- • Legislators
- • R&D in recycling

• Product designers
- • Scale-up team
- • Internal R&D
- • Academia
- • Apparatus suppliers
- • HTP platform

- • Production team
- • Process innovation demonstrator
- • Internal research on process
- • Academia

• Logistic team
- • Distributor
- • Packaging designers
- • Internal R&D
- • Marketing

Challenges
Specific to Coatings and Surfaces

- Variation in raw materials
- Toxicity levels of different ingredients
- Ingredient traceability

- Collection of used/remaining products
- Recycling of used/remaining products

- Digitalization customer oriented
- Performance feedback
- Collect consumer perception
- Increase lifetime

- Process robustness
- Reduce full lifecycle impact
- (e.g., reduce water consumption)
- Variation in raw materials
- Ingredient traceability
- Regional production
- Retaining/developing skills base

- New supply chains
- Digitalization customer oriented
- Regional supply chains
- Stability (shelf-life)
- Retaining/developing skills base
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Food and Drink industry

Core actors/Innovation enablers/Innovation accelerators

Specific to Food & Drink industry

- Farmer
- Rancher
- Fisherman
- Chemical products suppliers
- Legislators
- Domestic-waste managers
- Local recyclers (garden)
- Waste food managers
- Waste food transformers
- Legislators
- Local institutions
- R&D in recycling
- Processors
- Manufacturers
- Food preparers
- Process innovation demonstrators
- Internal research on process
- Academia

- Product designers
- Scale-up team
- Internal R&D
- Academia
- Apparatus suppliers
- HTSP platform
- Transporters
- Superstores
- Retailers
- Restaurants
- Packaging designers
- Marketing

Challenges

Specific to Food & Drink industry

- Variation in raw materials
- Ingredients traceability
- Toxicity levels of different ingredients
- Minimize food waste
- Collection of used/remaining products
- Recycling of used/remaining products
- Minimize food waste
- Digitalization customer oriented
- Performance feedback
- Ingredient traceability
- Minimize food waste
- Collect consumer perception
- New supply chains
- Digitalization customer oriented
- Regional supply chain
- Stability (Shelf-life/alternative supply chains)
- Retaining/developing skills base
- Safety (expiration)
- Minimize food waste
- Process robustness
- Variation in raw materials
- Ingredient traceability
- Retaining/developing skills base
- Minimize food waste
- Process innovation
- Performance (Stability/Shelf life/alternative supply chain)
- Toxicity levels of different ingredients
- Retaining/developing skills base
- Minimize food waste
Advanced materials

Core actors/Innovation enablers/Innovation accelerators

Specific to Advanced materials

- Upstream formulation supplier
- Raw material suppliers
- Legislators
- Waste Managers
- Consumers
- Waste valorization companies
- Legislators
- R&D in recycling
- Production team
- Process innovation demonstrator
- Simulation software provider
- Internal research on process
- Academia
- Logistic team
- Distributor
- Simulation software provider
- Internal R&D
- Marketing

Challenges
Specific to Advanced materials

- Variation in raw materials
- Toxicity levels of different ingredients
- Ingredients traceability
- Sourcing of bio-based ingredients
- Performance and stability (shelf life)
- More to sustainable and circular products
- (regulation and customer)
- Toxicity levels of different ingredients
- Retaining/developing skills base
- Process robustness
- Ingredient traceability
- Sourcing of bio-based ingredients
- Regional production
- Retaining/developing skills base
- Minimize waste
- Collection of used/remaining products
- Recycling of used/remaining products
- Minimize waste
- New supply chains (from production to crop)
- Digitalization customer oriented
- Regional supply chain
- Stability (shelf life)
- Retaining/developing skills base
- Digitalization customer oriented
- Performance feedback (yield)
- Increase lifetime

AceForm4.0 Deliverable D4.1
6. Conclusion

The deliverable has outlined an innovative generic circular value chain to bring new concepts and ideas to formulation stakeholders. For each steps, actors with different roles have been identified. Looking at these visual representations, stakeholders can easily positioned themselves in the circle but also identified the other actors next to them.

In a second part, more specific value chains are proposed for each sectors considered in the AceForm4.0 project. The content and the actors of value chain steps are then more precise.

For each sectors, specific challenges are precised for each steps. From this mapping, two first observation can be made:

- Several challenges are spread all along the value chain and concerned all the actors (like stability or raw material traceability...)
- Several challenges are shared by different sectors (like sourcing of bio-based ingredients or formulation stability...)

All the value chains proposed in the deliverable represent a working base for formulation stakeholder. Innovation is necessary to stay in business and the innovation place will likely render changes in value-chains where those incumbent to innovation and change slowly will get replaced by others that are able to change and innovate accordingly. New actors will probably appear besides the core actors, although they partly exist today too, such as innovation enablers and accelerators (like stakeholders involved in prediction of properties of formulated products using digital technologies, high throughput metrology, modelling, sensor design...). The deliverable is an important document for new actors because it will help them to target specific part of the value chain where they could act (as main actors or support).

To be implement changes, formulation actors and potential new ones need to meet and brainstorm around these values chains in order to create new synergy. and answer the following questions:

- Where can the innovation occur? Is it needed? Why?
- What are their common obstacles and barriers for the innovation ?
- What are the important common challenges for the innovation value chain? Where are they?
- What are key-enablers for the innovation?

Answering these questions, it will be possible to generate specific cross-sectorial value chains tackling one or several challenges.

7. Next steps

The value chain mapping will be presented to formulation stakeholders during a series of workshops in several European countries (France/Belgium/Sweden/U.K/Germany...). During the session, participant will be able to provide feedback on the value chains. They will use it to positioned themselves and find common synergies with stakeholders from other sectors. New actors, coming from Industry4.0 technology sectors for instance, will use the document to discover actors & challenges, target possible needs for actions and initiate collaborations.
Appendix A – Call text for H2020 NMBP-30-2016 competition

NMBP-30-2016: Facilitating knowledge management, networking and coordination in the field of formulated products

Specific Challenge: Complex formulated products such as pharmaceuticals, medicines, cosmetic creams and gels, detergent powders, processed foods, paints, adhesives, lubricants and pesticides are ubiquitous in everyday life. The design and manufacture of formulated products is a highly significant value-adding step, with a value multiplier ranging from around 3 – 100. There is an estimated emerging global market of around € 1400 bn. The EU has a strong, competitive advantage in formulation and within the EU there are many significant centres for the industrial manufacture and R&D of formulated products.

In order for Europe to avail this opportunity, there is a need to share in a targeted manner, the diverse skills and expertise from different sectors and how this shared complementary expertise can enrich each of the partners’ innovative capabilities through cross-learning and research at the precompetitive level.

Scope: Proposals should focus on and facilitate the exchange of non-competitive “know-how” in formulation technologies which will benefit the innovative potential and capabilities of diverse industrial sectors, relevant in both SMEs and large corporations in the following domains:

- Technologies for better delivery of active ingredients in products through innovative design of combined formulation and high throughput technologies to achieve an optimal use of ingredients;
- State-of-the-art modelling and high throughput metrology methods to better predict, measure, control and at an early stage, optimize the stability of formulated products, leading to higher sustainability, better regulatory compliance, better supply chain management, improved shelf-life properties and an exact correlation between lab-scale and production-scale properties;
- Intensification methodologies for better process design that utilize formulation technologies via a scalable and industrially relevant integrated digital platform in order to reduce the number of steps and use less energy than what is currently employed.

Activities may include the identification of the common scientific and industrial cross sectorial research and innovation challenges through the development of a shared vision and common roadmap.

Priority will be given to proposals involving at least three sectors, such as Chemical, Pharmaceutical, Agrochemical, Food Science and Medical Technology, etc.

Involvement from at least three internationally recognized research establishments within the European Union is encouraged.

The Commission considers that proposals requesting a contribution from the EU between EUR 300 000 to 500 000 would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

Expected Impact:

- Rational development of sustainable developed products and processes;
- Structuring and integration of value chains in the field of design and manufacturing of formulated products as a significant value added step leading to reduction of costs and time to market;
- Mobilisation of European industries to achieve global leadership in delivering innovatively formulated products within the context of Industry 4.0 and the Circular Economy.

Type of Action: Coordination and support action