STAKEHOLDERS' CONSULTATION 2014

HORIZON 2020 SOCIETAL CHALLENGE 2

Food Security, Sustainable Agriculture, Marine, Maritime and Inland Water Research and the Bioeconomy

Please consider the following questions, referring specifically to the Horizon 2020 Specific Programme for Societal Challenge 2 'Food Security, Sustainable Agriculture, Marine, Maritime and Inland Water Research and the Bioeconomy'[1].
Please quote where relevant any available evidence such as foresight and other assessments of research and innovation trends and market opportunities.
Replies to each question should be limited to 815 words.
Thank you for your kind collaboration

Information on the submitting organisation:

Plant ETP, the European Technology Platform 'Plants for the Future', is a stakeholder forum for the plant sector with members from industry (European Seed Association and individual companies), academia (European Plant Science Organisation) and the farming community (Copa-Cogeca). It offers its stakeholders a platform to provide their views and to represent their interests in an open discussion process. It provides a 20-year vision and a short-, medium- and long-term Strategic Research Agenda (SRA) for Europe's plant sector setting out a consensus on the research needed to fulfil the vision. In addition, the platform brings key issues to the attention of European bodies. These issues include the growing importance of plants and plant sciences to tackle the future challenges for our societies and the crucial support for efforts to give plants an adequate standing and importance in the public view and the political perception.

***ESA, the European Seed Association*,** is the single voice of the European seed industry, representing the totality of the European seed sector active in research, breeding, production and marketing of seeds towards the EU institutions and relevant national and international bodies. It is a growing association, attracting a steadily increasing and diverse membership from European seed industry and beyond. Today, ESA represents more than 35 national seed associations and more than 60 direct company members

***EPSO, the European Plant Science Organisation*,** is an independent academic organisation that represents more than 223 leading academic research institutes, universities and departments from 31 countries. Together they represent over 28000 plant researchers and staff. In addition, EPSO has over 3.000 personal members. The mission of EPSO is to promote plant science and plant scientists, to represent plant scientists in discussions about future plant science programme priorities across Europe, to provide an authoritative source of independent information on plant science, and to promote training of plant scientists to

[1] Pages 54-59 of http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0811:FIN:en:PDF

meet 21st Century challenges in breeding, agriculture, horticulture, forestry, plant ecology and sectors related to plant science.
Copa-Cogeca is the united ***voice of farmers and agri-cooperatives*** in the EU. Together, they ensure that EU agriculture is sustainable, innovative and competitive, guaranteeing food security to half a billion people throughout Europe. Copa represents over 13 million farmers and their families whilst Cogeca represents the interests of 38,000 agricultural cooperatives. They have 72 member organisations from the EU member states.

In addition, this input is supported by ***EuropaBio*** is the European Association for BioIndustries. Its members are involved in research, development, testing, manufacturing and commercialization of biotech products and processes in human and animal healthcare, diagnostics, bioinformatics, chemicals, crop protection, agriculture, food and environmental products and services. EuropaBio also counts a number of National Biotech Associations in its membership who in turn represent more than 1800 biotech SMEs operating in Europe.

Identifying the challenges

1) In the framework of the Horizon 2020 Societal Challenge 2, what are the most **important specific challenges** which require immediate actions in order to achieve smart, sustainable and inclusive growth?

Sustainable plant production is the basis to address a wide range of societal challenges including food security, production of high-value bio-based products as well as bulk materials and bioenergy. In order to utilise the full potential of bio-based solutions for these targets, a new focus area “Sustainable growth: unlocking the potential of living organisms” should be defined. Based on targeted research and innovative implementation of scientific results this sector has a very high potential to address major societal challenges as well as generating jobs and creating value.

The **food security** challenge manifested as more and more volatile food prices affecting the poor and triggering social unrest, necessitates immediate solutions. At the same time long-term perspectives need to be developed to address issues related to the fact one-quarter of all agricultural land is highly degraded, yet over the next 40 years, agricultural production must increase by 60%, sustainably and with fairer distribution, to provide global food security, a major contributor to social stability (FAO). In addition, Europe is increasingly dependent on imports, sourcing for instance an annual £37.6bn of food, feed and drink from overseas. It is not, however, only a matter of producing greater biomass, but also a matter of improving nutritional quality of food and feed for healthier diets, which would ameliorate the increasing burden of diet-related chronic disease. Global demand for meat will also increase, mainly in developing countries. Rising incomes will shift food demands from cereal-based to meat and dairy products. Therefore, the demand on protein crops for both human and animal food may be overall increased, exacerbating the conflict between environmental concerns and increased land competition.

Chapter 7 of the 5th Assessment Report by Intergovernmental Panel on **Climate Change** (IPCC) Working Group II states that the effects of climate change on crop and food production are evident in several regions of the world, and negative impacts of climate trends have been more common than positive ones. Studies have documented a large negative sensitivity of crop yields to extreme daytime temperatures around 30°C for several crops and regions.
In the event of local temperature increases in excess of about 1°C above pre-industrial, with or without adaptation, negative impacts on average yields become likely from the 2030s with median yield impacts up to 2% per decade projected for the rest of the century, and after 2050 the risk of more severe impacts increases. These impacts will occur in the context of rising crop demand, which is projected to increase by about 14% per decade until 2050. Under scenarios of high levels of warming, of 3-4°C or higher models suggest large negative impacts on agricultural productivity and substantial risks to global food production and security.
Changes in climate and CO_2 concentration will enhance the distribution and increase the competiveness of agronomically important and invasive weeds and evidence points to changed geographical ranges of pests and diseases. Changes in temperature and precipitation, without considering effects of CO_2 will contribute to increased global food prices by 2050, with estimated increases ranging from 3-84%.
The average benefit, as yield difference between the adapted and non-adapted cases, of adapting crop management is equivalent to about 15% to 18% of current yields.

Increasing yield in a sustainable way is one important approach to overcome the bottleneck of biomass availability. Since 1982, at least 88% of yield increases for the major cereal crops and oilseed rape in the UK are estimated to have arisen through plant genetic improvement. This overarching challenge is compounded by the need to improve resilience of crops to increasingly variable and fluctuating conditions in the future as a consequence of climate change, and the expansion of agricultural production into less fertile lands. This will require improvements in stress tolerance, particularly to combined abiotic and biotic stresses together with the development of novel agricultural techniques that address both future production needs and the narrowing of existing yield gaps. At the same time, there is a requirement to reduce loss of biomass during production, along the entire value chain, while adapting plant production to novel challenges and pests that may arise from changing conditions and production scenarios. The use of biomass for non-food purposes offers significant potential for sustainable chemistry and medical applications. Plants offer a significant potential to produce bioactive green molecules. Therefore, major fields of research in Societal Challenge 2 need to be:

- Improved resource use efficiency and resource stewardship
- Yield and yield stability - increased resilience towards dynamic and adverse environments
- Enhanced plants for healthy human nutrition & animal feed
- Resilient plants – improved plant health in dynamic and adverse environments
- Improved composition and performance of plants for non-food products

The **global dimension** of these challenges needs attention: food security and resource management are global issues with different facets in industrialised regions like Europe

(including the diversity of aspects within our continent) and internationally. Food security is a known driver of social turmoil and migration in developing countries including neighbouring countries in Europe. Thus, increasing food security in these countries as well as options for value creation in these countries that often have a good potential to develop agriculture, would also reduce the pressure for migration.

Developing an open-minded **dialogue with the society** will be important to explain to the citizens of Europe the demand of research in this field and the potential to address the societal challenges. Within such a discourse, all stakeholders will have the opportunity to exchange their views and perspectives with other participants in the discussions. This should be the basis of a better understanding of risks and benefits linked to the topics of societal challenge 2.

2) What **key research and innovation areas** need to be addressed in order to tackle these specific challenges, and meet the specific objectives of Societal Challenge 2?

All key research topics mentioned below address the focal topics "Sustainable Food Security" or the wider approach of "Sustainable growth: unlocking the potential of living organisms".

Immediate action is needed in the following key research topics:

- **Crops tolerant to abiotic stress** including genetics and breeding of agricultural crops and **forest trees** with high yield, quality and resilience against climate change
- Addressing **emerging and increasing risks in plant health** in Europe introduced to Europe due to global trade and climate change
- **Plants for human nutrition and health** by providing tailored raw materials for specific health benefits and for reducing risks of chronic disease
- Plants for more **sustainable feed** – specifically improving feed quality ad energy consumption **in aquaculture**
- **Green bioactive molecules** – including small molecules effective in human health and proteins for molecular farming
- **Outreach and engagement** - Outreach to policy and society; Engagement in global actions in the Global Plant Council and with developing countries (incl. FAO)

3) What are the **key assumptions** underpinning the development of these areas (research & innovation, demand side and consumer behaviour, citizens' and civil society's concerns and expectations)?

While Europe has a strong research and industry basis in all of the above research topics, there is a strong demand in addressing these topics at the level of H2020 for their pan-European dimension and importance. Climate change impact (see Q1 IPCC quote) or increasing risks of spreading of **plant pests** through globalised trade do not stop at state borders; adaptation strategies to these challenges are thus most efficiently addressed in pan-European research and implemented by public-private partnerships in plant breeding and production. **Healthy diets** are increasingly important to prevent explosion of cost for medical treatment and to allow for better health in the aging societies of Europe. The demand for tailored plant biomass to improve food quality is increasing, while still significant

research questions have not been addressed in the interaction between plant raw material supply, food processing and impact on human health. With an increasing protein gap in human nutrition globally **aquaculture** becomes a very important sector for economic as well as health reasons in many countries in Europe. It is foreseen that optimised plant-based feed in aquaculture will increase quantity and quality as well as sustainability of aquaculture farming.

For non-food applications in the medical and industrial fields, plants provide a significant potential by providing **bio-active small molecules** that have already proved their potential for medical purposes. **Proteins** produced in molecular farming can be used to support biorefinery as well as medical applications. State-of-the-art molecular farming practices will thus address the demand for better and green medical products as well as reducing the cost for industry in emerging biorefinery concepts. Also less than 10% of the plant kingdom's biodiversity has been chemically and biologically investigated and as such, new discoveries are expected when the plant biodiversity is explored.

Outreach and engagement in global activities are key to the support of European citizens for the technological basis of the bioeconomy as well as realising the responsibility of Europe in a globalised world. Many of the societal challenges mentioned have to be addressed outside of Europe to reduce or best avoid impact on European societies (e.g. the link of food security and migration or the low resilience of agriculture to climate change especially in developing countries). By acting in global dimensions in the mentioned research topics Europe does not only accept and fulfil its global responsibilities, but at the same time reduces risks for European societies and develops opportunities for European industries. European citizens that visited the interactive events got highly interested in plant sciences and their use for addressing these challenges as shown by the repeated success of the global Fascination of Plants Day (FoPD), which generated a wide range of events (1032 events in 2013) reaching a huge number of participants in over 54 countries around the world.

Tackling bottlenecks & gaps

4) What are the **bottlenecks** – in practices and research – in addressing these areas, and what are the inherent risks and uncertainties, and how could these be addressed?

- **Crops tolerant to abiotic stress** including genetics and breeding of agricultural crops and **forest trees** with high yield, quality and resilience against climate change
  While there is increasing knowledge at individual scales like e.g. the genome, the upcoming challenge is to utilise this knowledge for improving predictive power by deciphering the role of interactions of scales (e.g. between genome and the performance in the environment, stand and population towards management or raw material quality to processing). Improving knowledge focussed to achieve prediction will improve the speed of breeding of crops for adaptation to climate change and of adjusting management practices.

- Addressing **emerging and increasing risks in plant health** in Europe introduced to Europe due to global trade and climate change

Global trade activity includes the risk of transporting novel pests into European agriculture for which essential crop varieties are not resistant. This poses a similar risk as already developed during the avian flu crisis with significant potential for entire loss or significantly reduced yields (up to 30%-40% losses in developing countries annually from 'field-to-fork') of European agriculture, sometimes including risks for human health (e.g. fungi such as mycotoxins). Already today the location and area, in which major crops are exposed to major pests and diseases is strongly increasing. Therefore, societies and economies must anticipate, so that they can prevent and control new emergent diseases as well as sudden spread of diseases in order to avoid major social, economic and ecological crises. Major knowledge and technology gaps are present in diagnosis of pathogens, in integrated pest management and in plant genetic resistances.

- **Plants for human nutrition and health** by providing tailored raw materials for specific health benefits and for reducing risks of chronic disease
  In 2005, the World Health Organisation (WHO) projected that mortality from chronic disease would increase by 17% world-wide in the decade 2005-2015, due to longer average lifespan, tobacco use, decreasing physical activity and, perhaps most importantly, the increasing consumption of unhealthy foods. Because socio-behavioural risk factors significantly contribute to the incidence of and mortality from chronic disease, science and public policies need to be re-oriented towards prevention rather than only cure as well as towards improvement of the impact of chronic diseases once contracted. The nutrigenomics and nutraceutics areas will greatly benefit from the collaborative efforts of academia and industry in the creation of plant-based biofortified food with scientifically established functional and disease-risk reducing effects. This is in accordance to the scientific substantiation of health claims on food products requested by EFSA. Developing and applying model foods for phytochemical bioactive compounds to reduce the risk of chronic non-communicable diseases has a great potential to improve health benefits.

- Plants for more **sustainable feed** – specifically improving feed quality ad energy consumption **in aquaculture**
  This topic is also addressing the social challenge "Blue Growth". The aquaculture sector (specifically farmed fish sub-sector) experiences a lack of fish meal and fish oil and therefore already today most aqua-feed formulations contain significantly less fish oil and meal than 3-4 years ago. Thereby the beneficial content of omega-3-polyunsaturated fatty acids (O3FAs) in farmed fish and in the human diet has been reduced too. The aquaculture companies call upon the plant sector to develop plants supplementing in terms of O3FAs and fish meal. In addition, the production of required pigments (e.g. Astaxanthin) for colour and health benefits can be facilitated in plants. This will be crucial to replace the unsustainable use of fish oil for provision of omega-3-polyunsaturated fatty acids and fish meal as protein source. However, complex bioengineering of plant biochemical pathways to generate these complex oils is the major research bottleneck as are current GM regulations.
  In addition to production in higher plants, research addressing growth rates, oil content and required pigments (e.g. Astaxanthin) of algae will be pursued.

- **Green bioactive molecules** – including small molecules effective in human health and proteins for molecular farming
  Molecules derived from plants make up a sizeable proportion of the drugs currently available on the market. These include a number of natural, small-molecule compounds (secondary metabolites), the monetary value of which is very high. New pharmaceuticals often originate in nature. During the past 30 years, 1355 new drug entities (NDEs) were introduced to the market, 27% of which were either natural products or were derived from natural products as semi-synthetic derivatives. In addition, 20% of the drugs were synthesized after the molecule was first discovered from natural resources. Approximately 50% of new drug entities against cancer and microbial infections are derived from nature. Undoubtedly the chemical diversity of plants is much larger than any chemical library made by humans and thus the plant kingdom represents an enormous reservoir of pharmacologically valuable molecules just waiting to be discovered. It is estimated that reducing the incidence of flu by just 1% would save for instance the UK economy £13.5m per year.
  Economy of scale and the biotechnological production of high-value plant secondary metabolites in cultivated cells is potentially an attractive alternative. However, compared to microbial systems eukaryotic organisms such as plants are far more complex, and our understanding of the metabolic pathways in plants and their regulation at the systems level has been underestimated and much fewer resources have been directed towards this research. Similarly, plants offer several advantages for the production of recombinant human proteins as drugs and cosmetic ingredients, including the speed and scale of production at relatively low costs compared to fermenter systems, and the intrinsic safety of using organisms that do not support the growth of human pathogens. It is also possible to 'fine tune' the structure of biopharmaceuticals produced in plants in ways that cannot be achieved in microbial or mammalian cells.

- **Outreach and engagement** - Outreach to policy and society; Engagement in global actions in the Global Plant Council and with developing countries (incl. FAO)
  Outreach: Significant activities have evolved in the past years opening new options of discourse with society and politicians. Specifically the report of the Working Group "Plant Breeding" of the European Parliament provides a balanced view and thus a good basis for further discussion between all stakeholders supporting the EP in its function.
  The often limited understanding of economic and ecological reality, of global interrelations and the basis of technical solutions limit today´s willingness of our societies to support plant sciences and agriculture. Thus, an open and fact-oriented discussion with society and direct involvement in societal and political decision making is required. The Fascination of Plants Day attracts every second year thousands of citizens globally to learn about plant science and discuss with scientists and industry about risks and benefits. It is a very successful format of the discourse between plant and agricultural research and the civil society.

Global engagement: Global effort addressing the societal challenges mentioned above are initiated and coordinated by the Global Plant Council (e.g. Digital Seed Bank; Biofortification).
Regarding collaboration of European and African scientists and companies towards sustainable intensification of agriculture, the bottlenecks are the restrictions to e.g. CGIAR Research programmes from which European scientists networking with African partners are excluded as submission has to come from a CGIAR centre.

5) Is there evidence for any **major gap** (knowledge, science and technology, markets, policies, competences, skills)?

- **Crops tolerant to abiotic stress** including genetics and breeding of agricultural crops and **forest trees** with high yield, quality and resilience against climate change
  Abiotic stress is already responsible for major economic (and social) losses. DARA calculates in its Economic Stress Monitor[2] that the global climate economic stress impact burden will increase by 150% from 2010 to 2030 with still more than 90% due to impact on land. DARA also lists several economic assessments on the impact of drought incidences for individual countries ranging up to 3.3 billion US$ (US 2002 drought). It is alarming, when DARA expects "tripling of the price of wheat due to the decline of agriculture due to climate change". This dramatic scenario is supported by Wheeler and von Braun (2013, Nature; Climate change impact on global food security) causing significant further risks of affecting food security globally. Therefore, research should address the following major gaps: lack of understanding of heat, salinity and drought tolerance in plants, lack of genetic variation in major crop germplasm for thermotolerance during grain development, lack of thermostability in rubisco reducing biomass/ yield.
  In forest, genetic resources are not yet at the same state – even with respect to conservation. FAO, in its 2014 report "The state of the world´s forest genetic resources", analyses that "half of the forest species reported by countries are threatened or subject to genetic erosion" and that only "10% of the world´s wild plants are conserved in seed banks". Genomics provide powerful tools for answering crucial questions (e.g. adaptation and applications (e.g. breeding, conservation). The development of forest trees has lagged behind that of model and agricultural systems. Thanks to the rapid development and accessibility of new generation sequencing and genotyping technologies, genomic research in forest trees is now capable of entering into an important and productive phase.

- Addressing **emerging and increasing risks in plant health** in Europe introduced to Europe due to global trade and climate change.
  No critical mass action at European level exists to anticipate emerging and suddenly spreading plant disease.

[2] http://daraint.org/wp-content/uploads/2010/12/CVM_Economic-Stress-Monitor.pdf

- **Plants for human nutrition and health** by providing tailored raw materials for specific health benefits and for reducing risks of chronic disease
  First activities at national and European level exist, however, not yet at critical mass to address the urgent challenge of food and nutritional security in Europe and globally.

- Plants for more **sustainable feed** – specifically improving feed quality ad energy consumption **in aquaculture**
  There is a pull from the aqua-feed industry for alternative sources of their most expensive inputs (i.e. fish meal FM, fish oil FO and also the pigment/antioxidant astaxanthin):
  FO and FM are their primary costs, trending ever upwards. To deal with this, most aquafeed formulations now contain significantly less FO and FM than 3-4 years ago, meaning that ultimately the consumer is getting less omega-3 in the end product.
  This downward trend cannot continue, since FO and FM in the fish diets are essential for the health and growth of the fish.
  Thus, there are big pressures on diminishing natural resources of FO and FM and companies would bit their hand off for someone to produce an alternative, sustainable economically viable source of these two inputs.

  Using algae to produce replacements is theoretically possible, but costs too high unless for very specific (and small scale) applications like feeding fish fry/larveae.
  Thus, this is persued as 2nd route: microalgae are a highly valuable resource as illustrated in the 2014 JRC Scientific and Policy Report on "Microalgae-based products for the food and feed sector: an outlook for Europe"[3]. For example, the production volumes of poly-unsaturated fatty acids (DHA/EPA) from micro-algae are only 240 tons/year, but the market value of this production (mostly extracted from ocean fish) is estimated to be higher than $300 Million/year. JRC reports that most experts consulted estimate that Europe can become market leader in micro-algae based products for the food and feed markets in the next decade. The two most important factors that may contribute to the expected European market position are scientific and technological developments in the field of micro-algae research and in the food and feed market.

- **Green bioactive molecules** – including small molecules effective in human health and proteins for molecular farming
  Many small molecule compounds have already been identified for specific uses, but there is a gap in translational research funding to take them further.
  Similarly, translational projects are needed to bring plant-derived proteins through clinical trials and to the market.
  GMP-compliant process development is necessary to get products to the market, focusing on regulatory principles such as DoE in the development stages and PAT during production so that quality-by-design principles are built in.

[3] https://ec.europa.eu/jrc/sites/default/files/final_version_online_ipts_jrc_85709.pdf

- **Outreach and engagement** - Outreach to policy and society; Engagement in global actions in the Global Plant Council and with developing countries (incl. FAO)
  Outreach: There is a gap in terms of European support to sustain coordination and free material provision at European level for the Fascination of Plants Day. This has been covered by the EPSO reserve so far, which can't continue at this level. This is crucial e.g. as consumers have become more and more detached from the production of food. E.g. in a Eurobarometer survey 2009[4], a large proportion of consumers indicate that they know little or nothing about the environmental impacts of food.
  In addition, there is a need to complement the new inter-parliamentary Working Group on Plant Breeding (in the European Parliament) by one of stakeholders including science, industry and farmers.
  Engagement: There is a lack of European level engagement in the Global Plant Council first two pilot initiatives (Digital Seed Bank; Biofortification).
  Regarding collaboration of European and African scientists and companies towards sustainable intensification of agriculture, there is a gap and thus A need for open competitive research and innovation programmes in which European scientists networking with African partners can participate, as well as a network among the European scientists engaging with Developing countries on agriculture.

Defining opportunities

6) What are the **emerging opportunities** for advances in the areas tackled by Societal Challenge 2, taking into account the EU position in research and innovation?

The excellent plant science base has been evaluated in terms of articles appearing between 2005 and 2011 in 'plant sciences' journals as listed by SCImago and Thomson Reuters' Web of Science. The citation numbers are accurate as of May 2013. The short outcomes are over 617.000 citations of European scientists vs e.g. 385.000 from the USA and 133.000 from China.
This combined with a strong plant breeding and farming sector (in the Plants for the Future ETP) cross-sectorial co-operations are a prime opportunity for Europe.

- **Crops tolerant to abiotic stress** including genetics and breeding of agricultural crops and **forest trees** with high yield, quality and resilience against climate change
  The rapid advancement in understanding the basis of plant productivity and options to accelerate progress in breeding open new routes to increase and stabilise yield, quality and resilience against climate change impact. In the past years, an increasing percentage of crop genetic resources including wild relatives have been conserved in global efforts (e.g. Svalbard). These hitherto untapped (only conserved) genetic resources need and can be mobilised specifically to improve crop resistance against stresses.

[4] http://ec.europa.eu/public_opinion/flash/fl_256_en.pdf

One the one hand, forest geneticists and ecologists are turning to genomics to elucidate the mechanistic bases of the variation their research tries to understand. On the other hand, more and more genomicists are keen to better connect the basic principles of cellular functions they observe in their model organisms to insights from forest ecology. So there is great potential for interactions.

- Addressing **emerging and increasing risks in plant health** in Europe introduced to Europe due to global trade and climate change.
  The EU's stringent regulatory process for plant protection products has had an especially severe impact on the availability of products for specialty crops and minor uses. The lack of proper plant protection solutions compromises not only the competitiveness of the entire agri-food chain – the EU being the second largest producer of fruit and vegetables in the world with value exceeding €70 billion per year and also the second largest importer – but it also compromises the sustainability of the sector to prevent and control new emerging pests, the employment generated within the sector, and more importantly the diversity of high quality agri-food products in Europe. Therefore, this minor use and specialty sector (incl. fruit and vegetables, cereals, including rice, seeds, hops, flowers) is of huge importance in Europe; it represents 18% of the agricultural value on just 3% of the land. In order to ensure long term solutions for all the minor use and speciality crops in the EU, a more permanent research and innovation programme should be developed on minor uses and specialty crops within a smart, sustainable and inclusive growth policy in line with Europe 2020 objectives. Only in this way will we address all problems by ensuring common solutions for all minor use and speciality crops in accost effective manner. A similar programme is already in place in the USA, and for each dollar spent on that programme, it has been calculated that there is an economic benefit of $500 (Annual spending of $14 million providing an annual economic benefit of $7.7 billion).

- **Plants for human nutrition and health** by providing tailored raw materials for specific health benefits and for reducing risks of chronic disease
  The emerging opportunity for advance in this area is the development and use of model foods for phytochemical bioactive compounds to reduce the risk of chronic non-communicable diseases. It has been well recognized that food components need to be studied on the context of complex foods and not as purified compounds, since other metabolites, enzymes, fibre etc with which they are normally ingested may modify the bioavailability and bioactivity of specific phytonutrients. Hence there is a need to design a limited number of model foods (near-isogenic plant-based foods that vary only in the quantity of the bioactives under analysis) that can be used in all research activities on bioactives to establish scientifically the relationship between food and health.
  Identifying and enhancing beneficial compounds in plants for human health opens the opportunity to improve human nutrition (in foods people like/ are used to eat) and health status. This leads to a better health status of our population.

- Plants for more **sustainable feed** – specifically improving feed quality ad energy consumption **in aquaculture**
  Create a sustainable source for farmed fish feed by improving / modifying plant secondary metabolites to benefit fish nutrition and human nutrition - directly as food-additive; indirectly via fish consumption.

- **Green bioactive molecules** – including small molecules effective in human health and proteins for molecular farming
  The successful launch of the first plant-derived pharmaceutical product in 2012, plus the increasing pipeline of plant-derived pharmaceuticals in clinical development, indicates that the time is right to seize the initiative and provide incentives for both researchers and industry to invest in molecular farming.

- **Outreach and engagement** - Outreach to policy and society; Engagement in global actions in the Global Plant Council and with developing countries (incl. FAO)
  Outreach:
  - A Participatory process of stakeholders, citizens and policy towards innovation driven agriculture to increase productivity and sustainability.
  - Further increase the spread and thus impact of the Fascination of PLANTS Day, which already attracted a great audience with its interactive mode.

  Engage in global actions/
  - Link to and engage in the Global Plant Council's first initiatives (Digital Seed Bank; Biofortification)
  - Support European/African projects in sustainable intensification of agriculture towards longer term partnerships in food and nutritional security – e.g. on the pilots: Underutilised fruit and vegetable crops; Cassava value chain

7) In which areas is the strongest potential to **leverage innovation** and, in particular, ensure the participation of **industry including SMEs**?

- **Crops tolerant to abiotic stress** including genetics and breeding of agricultural crops and **forest trees** with high yield, quality and resilience against climate change
  Breeding companies are often SMEs, while having an exceptionally high innovation need and willingness. The "social welfare gain" of the German plant breeding was estimated to be between 9 and 12.5 billion € in the years 1991-2010 (Noleppa/ Witzke (2013) Die gesellschaftliche Bedeutung der Pflanzenzüchtung in Deutschland). ESA – the European Seed Association – reports that the European plant breeding and seed production industry is at the forefront of R&D and innovation and is committed to pursue its high rates of investments of up to 20% of its annual turnover on further R&D.
  In the forest sector, delivering of improved varieties will be raised/multiplied in private nurseries for deployment on large scale, enabling numerous SMEs to participate.

- Addressing **emerging and increasing risks in plant health** in Europe introduced to Europe due to global trade and climate change.

Markets primarily addressed here are the Plant Health and the Seeds markets. Both have globally great economic importance. Europe is well positioned in these markets, with a good number of companies ranging from large multinational to SME-nation based companies. Small, technology-based companies are a more and more important source of high quality employment and a vital source of technology for larger companies. Emerging and increasing risks of plant diseases represent a serious threat to agriculture and to the environment, providing a clear niche to be filled by small technology-based companies, particularly if EU provides support. There is a strong strategic added value for actions aiming to reinforce the sustainability and resilience of basic productive sectors providing sources of high quality and safer food for the population.

- **Plants for human nutrition and health** by providing tailored raw materials for specific health benefits and for reducing risks of chronic disease.
  This action will benefit many SMEs as well as some large industries from the plant breeding, processing and food sectors bringing a unique competitive advantage to European industries in the global market.

- Plants for more **sustainable feed** – specifically improving feed quality ad energy consumption **in aquaculture**
  The aquaculture industry defined the urgent need for alternative sources of their most expensive inputs (i.e. fish meal FM, fish oil FO and also the pigment/antioxidant Astaxanthin). A solution with plant compounds (secondary metabolites) will boost their competitiveness in terms of food quality, sustainable production and lower price of production.

- **Green bioactive molecules** – including small molecules effective in human health and proteins for molecular farming
  The provision of translational funds that include incentives to (a) engage the regulatory authorities; (b) build in the quality –by-design principles that are mandatory in the industry; and (c) provide impetus for clinical development will help to leverage innovation in this area. Importantly, many of the original waves of molecular farming SMEs ceased trading within 5 years of start-up because there was no sustainable way to fund clinical development.

- **Outreach and engagement** - Outreach to policy and society; Engagement in global actions in the Global Plant Council and with developing countries (incl. FAO)
  Bringing stakeholders, policy and citizens together in a participatory process ensures long-lasting solutions benefiting society, environment and industries.

8) How could Horizon 2020 Societal Challenge 2 best contribute to **EU policies**, and leverage and **complement Member States'** efforts for growth and job creation?

- **Crops tolerant to abiotic stress** including genetics and breeding of agricultural crops and **forest trees** with high yield, quality and resilience against climate change

Breeding is a highly job-intensive sector and investment in this sector will deliver additional employment in research as well as in seed industry. According to a recent report about the economic value of plant breeding in Germany (Noleppa/ Witzke 2013), the German breeding sector consists of about 60 SMEs with more than 3300 employees in research and development. The entire German seed industry has 130 companies with more than 12.000 employees. Thus, investment in this sector will generate new jobs (at all levels of qualification) in research, development and the seed industry. At European level, the European Seed Association represents the totality of the European seed industry (more than 7000 companies, 90% of which are SMEs with more than ca 50.000 employment) active in research, breeding, production and seed marketing, usually located in rural areas. Thus, they help to boost rural development by attracting highly skilled workers to these regions.
In the forestry sector, a domino effect is seen in (By helping developing varieties that will fit future abiotic and biotic stresses) e.g. one job in forestry leads to 4.4 jobs in forest processing sector in Western Europe. Thus it is important to ensure the sustainability of the first step of the forest tree wood chain.

- Addressing **emerging and increasing risks in plant health** in Europe introduced to Europe due to global trade and climate change.
  Disease emergence is clearly a transnational problem. For example, global trade has a fundamental role in this phenomenon; global trade and its corresponding regulations cannot be addressed at national levels. Similarly, climate change and the predicted expansion of pathogens and vectors beyond their natural limits of spread require an international response and the coordination of European-wide efforts.
  This will support policy implementation: May 2013 legislation by DG SANCO.
  In addition, intrinsic solutions in plants to be more tolerant / resistant to pathogens, enable us to use less pesticides in agriculture, another European goal.

- **Plants for human nutrition and health** by providing tailored raw materials for specific health benefits and for reducing risks of chronic disease
  Along the ideas of the JPI Healthy Diet for Healthy Life, more investments in nutritional studies dealing with prevention of diet-related diseases and involving both academia and industry, will fully respond to the Europe 2020 challenge of promoting healthy aging and will contribute to create novel functional food products with potential world-wide exploitation.

- Plants for more **sustainable feed** – specifically improving feed quality ad energy consumption **in aquaculture**
  This action is crucial to achieve sustainable farmed fish production. First national efforts are starting (e.g. in the UK), which need a boost at European level.

- **Green bioactive molecules** – including small molecules effective in human health and proteins for molecular farming
  This theme will benefit from helping to harmonise the regulations for plant breeding technologies across the EU. Efforts will be starting to discus with Member States to

provide matching funds for clinical development if produces developed under H2020 funding look promising in preclinical development.

- **Outreach and engagement** - Outreach to policy and society; Engagement in global actions in the Global Plant Council and with developing countries (incl. FAO)
  Outreach:
  - **FoPD**: All organisations of the over 1.000 events in 2013 generated local or national funds for supporting their events. Thus, a European contribution to the coordination and free material provision is appropriate and needed.
  - **EP**: several Member States already expressed their interest to engage in the new process on plant breeding with stakeholders and the European Parliament.

  Global engagement:
  - **GPC**: Some Member States already contribute to GPC pilot actions.
  - **Developing countries**: Several Member States appreciate a more open, competitive process for R&I collaborations.

9) What types of **cross-cutting and trans-disciplinary activities** would best tackle these challenges/opportunities based on the first experience of Focus Areas such as Blue Growth or Sustainable Food Security[5]?

Overall a much closer interaction of all life sciences is needed to use the immense opportunities in bioeconomy and beyond. Therefore, we propose an umbrella (could be a focus area) 'Sustainable growth: unlocking the potential of living organisms'. This will foster establishing and strengthening the links 'Plants – human food – nutrition – human health; plants – medicine – human health; plants – sustainable farmed fish feed – human health; etc.
In addition, links with manufacturing (e.g. agricultural engineering, process optimisation, good manufacturing practices), meteorological / climate sciences, IT, will be crucial.

- **Crops tolerant to abiotic stress** including genetics and breeding of agricultural crops and **forest trees** with high yield, quality and resilience against climate change
  In order to achieve the efficient and quick advancements, it is necessary to integrate all technological options for plant breeding. This includes, besides the improvements in genetics and molecular understanding of genetic resources and stress responses, the physiological analysis and screening technologies increasingly getting available in national phenotyping centres and by cooperation between countries in Europe. This integrated approach of genetics, molecular sciences, physiology and breeding is a stronghold in Europe, which gives a competitive advantage to European breeding companies in the global competition. In addition, on-farm demonstration and linking experimental farms are needed across Europe to provide farmers the possibility to get closer to plant breeding and to varieties with specific characteristics (that are not

[5] Horizon 2020 Work Programme 2014-2015 on Societal Challenge "Food Security, Sustainable Agriculture and Forestry, Marine and Maritime and Inland Water Research and the Bioeconomy"
http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-food_en.pdf

always part of the criteria for recognition of a breed, but of great relevance for farmers). This allows also showcasing suitable rotations and agricultural practices.
Forest tree breeding for sustainable forest production, adapting forest to climate change and added-value wood products will benefit from trans-disciplinary work of biologists (genotype, phenotype characteristics suitable to tolerate / use environmental changes, entomology), forest management experts (sylviculture), manufacturing experts (wood scientists and economists) to develop the required knowledge and use this to develop and test in practise flexible multidimensional models.

- Addressing **emerging and increasing risks in plant health** in Europe introduced to Europe due to global trade and climate change.
  Factors influencing disease emergence / sudden increase include: global trade and travel ('import' of diseases to Europe caused by human activity), external changes e.g. climate change, and biological changes - evolution. The analysis of all three causes needs to interact with biological sciences (from the molecular genetics of the interactions between plant pathogens and their hosts and vectors determining host and vector ranges, to the genetic variations of pathogens, plant and vector populations, and to the ecology of these populations and their interactions), management of agricultural practices and of international trade etc. An important output of the proposed research theme will be the elaboration of protocols for rapid response in the case of new and increasing emergences that could support policy making.

- **Plants for human nutrition and health** by providing tailored raw materials for specific health benefits and for reducing risks of chronic disease
  Food including nutritional security requires rethinking for the entire bioeconomy net linking up with human health. Preventive of ameliorative measures for diet-related chronic diseases would provide a widespread benefit both for the costs of public health and from the socio-economic perspective, if one considers that about 80% of the people over 65 years are suffering from at least one chronic disease, while about 50% suffer from two or more chronic conditions.
  To analyse, improve and utilise plant compounds beneficial for human nutrition and health, a substantial collaboration across the areas of plant biochemistry, functional plant genomics, food science (nutritionists), and health research (incl. clinicians), communication and behavioral studies, legal experts (functional food, novel food regulation) from academia as well as industry is necessary.

- Plants for more **sustainable feed** – specifically improving feed quality ad energy consumption **in aquaculture**
  This gap needs aquaculture experts (on farmed fish) to collaborate closely with plant biologists (metabolomics, molecular biology, physiologists) & plant sector, fish and human nutritional scientists, and processing experts & aquaculture and food sectors.

- **Green bioactive molecules** – including small molecules effective in human health and proteins for molecular farming

This is becoming increasingly important and requires collaboration of clinicians with plant biologists (physiologists, metabolomics, plant molecular biology), processing and manufacturing experts (GMP), legal experts and as appropriate development aid experts. This fosters a close collaboration between the plant, pharmaceutical and well-being (fragrances, cosmetics) sectors.
Examples would include trans-disciplinary activities joining plant biology, biotechnology, process engineering and medical sciences to (i) identify target molecules that would benefit from molecular farming (i.e. in terms of demand/scale, structure, speed of production, oral delivery etc, that would not be satisfied by current production platforms) or that (ii) have not been produced successfully using alternative platforms (e.g. because they are biologically active in mammalian cells, whereas this might not be the case in plants). This would identify targets that would satisfy niche markets.

- **Outreach and engagement** - Outreach to policy and society; Engagement in global actions in the Global Plant Council and with developing countries (incl. FAO)
  It is of crucial importance to provide a sound scientific basis to decision makers. In addition, the urgently required dialogue between academia, industry, politicians and civil society about the future of European agriculture and breeding is a must. Academia (from universities and research institutes) and industry (from SMEs as well as large companies) are ready to engage much more in such collaborations with policy (European Parliament, European Commission, Member States) in and beyond Europe (with FAO, African countries), as well as society involving communication and social sciences experts. European organisations can play an important role to widen participation beyond currently engaged institutions, be information multipliers and foster long-term strategic thinking towards longer term partnerships.

Output and impacts

10) What type of **output** could be foreseen and what could the **impacts** (on science and technology, innovation, economy, environment and society) be based on your identification of priority areas for action? What would success look like? How would you measure it?

- **Crops tolerant to abiotic stress** including genetics and breeding of agricultural crops and **forest trees** with high yield, quality and resilience against climate change.
  Crops (incl. forest trees) with improved resistance against abiotic stress will reduce the significant losses in agricultural production due to abiotic stresses (see above), thus increasing yield stability in changing environments. In addition, crops with increased resource use efficiency will reduce the ecological footprint of agriculture and also reducing emission of greenhouse gases. The reduced fertilizer input will be economically and ecologically beneficial.

- Addressing **emerging and increasing risks in plant health** in Europe introduced to Europe due to global trade and climate change.
  An important output of the proposed research and innovation theme will be the elaboration of protocols for rapid response in the case of new and increasing

emergences that could support policy making. In this way enormous losses of crops / harvest will be significantly reduced or completely avoided. E.g. a virus attacking citrus plantations could eliminate all such plantations in Spain, Italy and Greece.

- **Plants for human nutrition and health** by providing tailored raw materials for specific health benefits and for reducing risks of chronic disease.
  Novel functional food products with specific health benefits would represent a short-term measurable output, whereas a significant reduced incidence of chronic conditions could be a long-term measurable output. In this way the health status of the population will be significantly increased, so that medical treatments will be reduced and working power increased (fewer sick leaves).

- Plants for more **sustainable feed** – specifically improving feed quality ad energy consumption **in aquaculture**
  Sustainability for the farmed fish sector in Europe will increase, as well as the quality in terms of healthy compounds in fish and in the human diet. In addition it will reduce production cost of farmed fish.

- **Green bioactive molecules** – including small molecules effective in human health and proteins for molecular farming
  Launch of more approved products that are plant-derived pharmaceutical proteins, mirroring the success enjoyed in the cosmetics industry; (ii) New pipelines of plant-derived pharmaceuticals coming through; (iii) Establishment of mainstream production platforms based on plants; (iv) Plants considered on an equal footing to other production platforms.

- **Outreach and engagement** - Outreach to policy and society; Engagement in global actions in the Global Plant Council and with developing countries (incl. FAO)
  Outreach:
  - Better dialogue participatory culture in Europe, sustaining new technologies and approaches to address societal challenges and goals.
  - Stabilise the plant and food sector, thus attracting more VC, students and employees.

  Global engagement:
  - Help advancing global issues and lead some of the actions, increasing European competitiveness and implementing a responsibility from Europe

11) Which related innovation aspects could reach **market deployment within 5-7 years**?

- **Crops tolerant to abiotic stress** including genetics and breeding of agricultural crops and **forest trees** with high yield, quality and resilience against climate change
  Crops with reduced water use and higher efficiency of nitrate and phosphate acquisition.
  Genomic selection provides breeding values comparable to that based on pedigree and phenotypes, but by reducing breeding cycle by half would increase genetic gain per time unit by 2.

- Addressing **emerging and increasing risks in plant health** in Europe introduced to Europe due to global trade and climate change.
  High-throughput, efficient and cheap detection and diagnosis methods are already set-up for human and, to a lesser extent, for animal pathogens. Translating this technology to Plant Health and setting up efficient networks to use this technology in the most efficient way would be a significant achievement in this theme.
  Concerns about the indiscriminate use of chemical treatments to deal with agricultural pests, and the public awareness of the risks posed by the abusive use of pesticides is paving the way for alternative products and control strategies to be incorporated into Integrated Pest Management IPM programmes to prevent or ameliorate emergent plant diseases. The regulatory limits reinforced at European level are contributing to a shift in the cultural practices, the adoption of new standards, and the public acceptance of cleaner technologies in agribusiness. Also, a new market for beneficial organisms is emerging, with an associated demand for knowledge-based methodologies. Restrictions in the number of chemicals available for pest control forces to develop novel tactics and alternative strategies to combat new emerging pests and vector-borne diseases. Among these, manipulation of insect vision by selectively reflecting or absorbing solar radiation and exploiting narrow-band light emitting diode (LED) sources are promising strategies to interfere with insect vectors of plant diseases.
  Efficient identification and/or design of new resistance alleles are major challenges to the seed industry. Not less important is forecasting durability of resistances when deployed in the field.
  Ideally, combinatorial actions of the above mentioned examples are also envisaged: diagnostic methods can be instrumental to deploy effective IPM programmes and for the identification of beneficial genetic traits.

- **Plants for human nutrition and health** by providing tailored raw materials for specific health benefits and for reducing risks of chronic disease
  Plant-based biofortified food and related functional food products with scientifically demonstrated disease-risk reducing effects, (plant products like anthocyanin derived from purple corn and purple tomato are ready to reach the market)

- Plants for more **sustainable feed** – specifically improving feed quality ad energy consumption **in aquaculture**
  The beneficial omega-3-polyunsaturated fatty acids (O3FAs) produced in modified higher plants supplement fish oil and meal for fish and human consumption. Time frame is subject to a concerted effort of all stakeholders (for deregulation in the public sector and public benefit). The benefit for the citizens is clear as today most aquafeed formulations contain significantly less fish oil and fish meal than 3-4 years ago, meaning that ultimately the consumer is getting less omega-3 in the end product.

- **Green bioactive molecules** – including small molecules effective in human health and proteins for molecular farming

New enabling technologies (several examples of companies that provide technologies to assist other companies producing recombinant proteins), new pharmaceutical proteins (see examples on the market already in the attached file) and new production platforms.

- **Outreach and engagement** - Outreach to policy and society; Engagement in global actions in the Global Plant Council and with developing countries (incl. FAO)
  Outreach:
  - FoPD: Established as global bi-annual event bringing citizens and policy makers closer together with science, industry and farmers
  - EP: Established working partnership between stakeholders and European parliament towards innovation driven agriculture for productivity and sustainability

  Global engagement:
  - GPC: First two pilots materialised in global projects with strong European involvement and lead in one
  - Developing countries: Underutilised Fruit and Vegetable Crops first long-term partnerships between European and African scientists, companies, extension services are successfully improving African agriculture