SOMMERRUST

Plants for the Future
European Technology Platform

CropBooster-P

June 2019

CropBooster-P: Scenario Analysis

Documentation

About this documentation

This documentation describes the approach and the results of the CropBooster-P Scenario Analysis project. The purpose of the Scenario Analysis is to provide **novel perspectives** for the work of other work streams and should serve as a means of communication to facilitate a **common understanding of possible future challenges** both within CropBooster-P workstreams and towards external stakeholders.

In our Scenario Analysis we created **four learning Scenarios** to facilitate the development of the roadmap towards *„[...] sustainably doubling Europe's crop yields by 2050 and preparing these crops for the needs and the future climate of Europe"* (Proposal Submission Form, p. 2/59). More specifically, the Scenario Analysis provides insights about (a) which crops and plant species should be in focus, (b) what technical possibilities will be available to adapt future plants & which ones should be considered, and (c) what the crop traits are that need to be engineered into plants to meet the needs of future society.

In this context, this documentation aims to serve as a future reference for CropBooster-P project members by providing answers to the following questions:

1. **What future scenarios should we consider for CropBooster-P?**
2. **What implications may these scenarios have for my work?**
3. **How did the team arrive at these particular scenarios?**

The last point will help team members who want to further elaborate on the scenarios and stay consistent with the original thinking of the scenario team. Elaborating the scenarios is strongly encouraged and can be useful, for example, to explore specific challenges that will arise at a later point in time but that have not yet been covered during the initial scenario exercise. While this documentation describes the status of the scenarios at the conclusion of the initial Scenario Analysis, there is a separate document intended to be updated continuously in order to describe and compare the latest version of the four scenarios.

Executive Summary

1. In total, **34 stakeholders participated in the Scenario Planning exercise**: 12 core team members from the plant science domain, 20 external stakeholders from science, politics and the food industry and two facilitators.

2. The Scenario Exercise resulted in **four learning scenarios**[1] **for agriculture in the EU in 2050:**
   (1) "Plantovation": innovation solutions are intensively used, providing steady and high-quality food in a sustainable way as well as large volumes of feedstock for a thriving bioeconomy.
   (2) "Your Food. Your Health. Your Choice": health and sustainability concerns drive agriculture & food businesses towards being diverse and transparent, meeting the needs and preferences of individuals.
   (3) "Foodmergency": the EU is struggling to fulfill basic food demand due to severe environmental degradation. In response to this, the EU has seen the introduction of a large-scale and technology-driven agricultural system to mitigate the most dire consequences.
   (4) "REJECTech": consumers have little trust in politicians, scientists and big industry. Society is highly polarized and rejects new food-related technologies – despite dissatisfaction with the current state of affairs like limited food choice and high prices.

3. Each scenario has a different kind of **impact on the key activity fields within CropBooster-P:**
   - **Yield** is most important for scenario 1 (demand from bioeconomy) and 3 (satisfying basic needs)
   - **Nutritional quality** is most relevant in scenario 2 (to meet individual dietary needs/preferences)
   - **Sustainability** is most important in scenario 3 (maintaining the ability to meet food demand in the future) and scenario 4 (avoiding technologies/practices deemed "unsafe" for humans and ecosystems)

[1]Learning scenarios serve as general frameworks for contemplating future worlds. They illustrate possible strategic directions and highlight important areas for further exploration. In contrast to more elaborate decision scenarios, however, they usually lack the detail and depth of analysis to derive specific decisions (see also p. 9).

The Scenario Core Team

Not in the pictures, but part of the Preparation Workshop team: Mathias Pribil.

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2. Trend Research

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1. Scenario Building
2. Explaining Scenarios to Stakeholders
3. Scenario “Prototyping”
4. Impact Assessment
5. Conclusions and Next Steps

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Why Scenario Analysis?

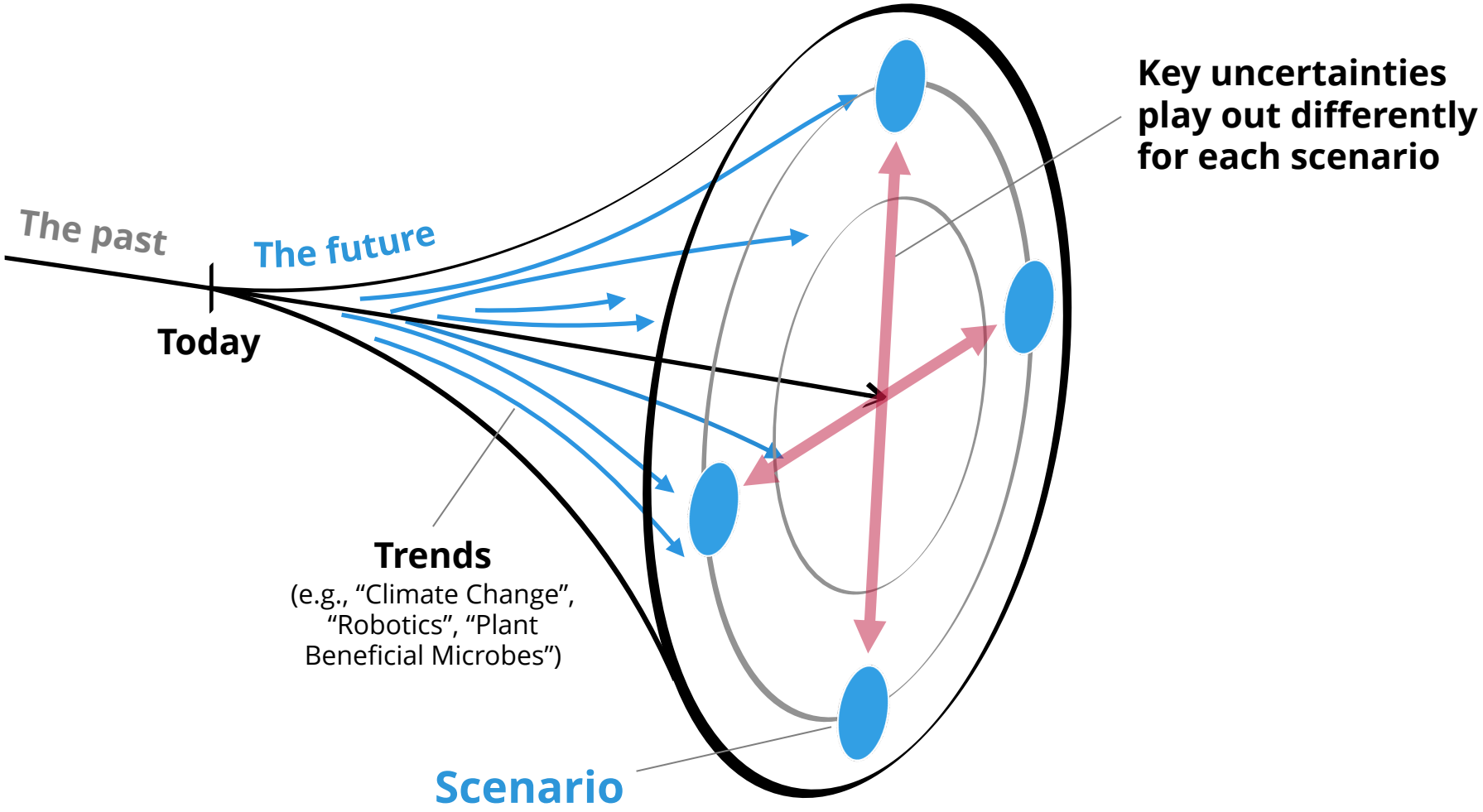
The outcome of the scenario planning exercise are **learning scenarios** that

… provide **new perspectives** about the trends and topics affecting CropBooster-P

… help to make our results **more robust** against the influence of key uncertainties

… facilitate a more **proactive** stance towards future threats and opportunities

Based on trends and uncertainties, specific scenarios can be constructed



Criteria of good (and bad) learning scenarios

Learning scenarios serve as a general framework for contemplating future worlds. They cover the most relevant aspects and areas of interest. In order to advance learning scenarios into decision scenarios, a greater depth of analysis and data is usually needed, potentially even requiring quantitative models.

Don't

Confuse scenarios with predictions (one can't predict complex (social) systems in the long-term; however, possibilities – incl. discontinuities – can be imagined in the form of scenarios)

Create implausible scenarios e.g., based on an inconsistent combination of outcomes or based on extremely unlikely events like a major asteroid collision

Exclude scenarios just because they are inconvenient or **"ought not to be"**

Do

Create scenarios that are different from each other to cover a **wide range of possibilities** (key uncertainties play out differently)

Create scenarios that are internally consistent

Create scenarios that are unlikely but plausible

The scenario analysis process featured three major workshops

PART I

1. Preparation
(1-day)

- Definition of **scenario scope** (e.g., timeframe, domains, ...)
- Discussion and selection of relevant **trends and uncertainties**
- Decision on **"proxy variables"** (specific aspects of future worlds) to use for scenario building

PART II[1]

2. Scenario Building
(1-day)

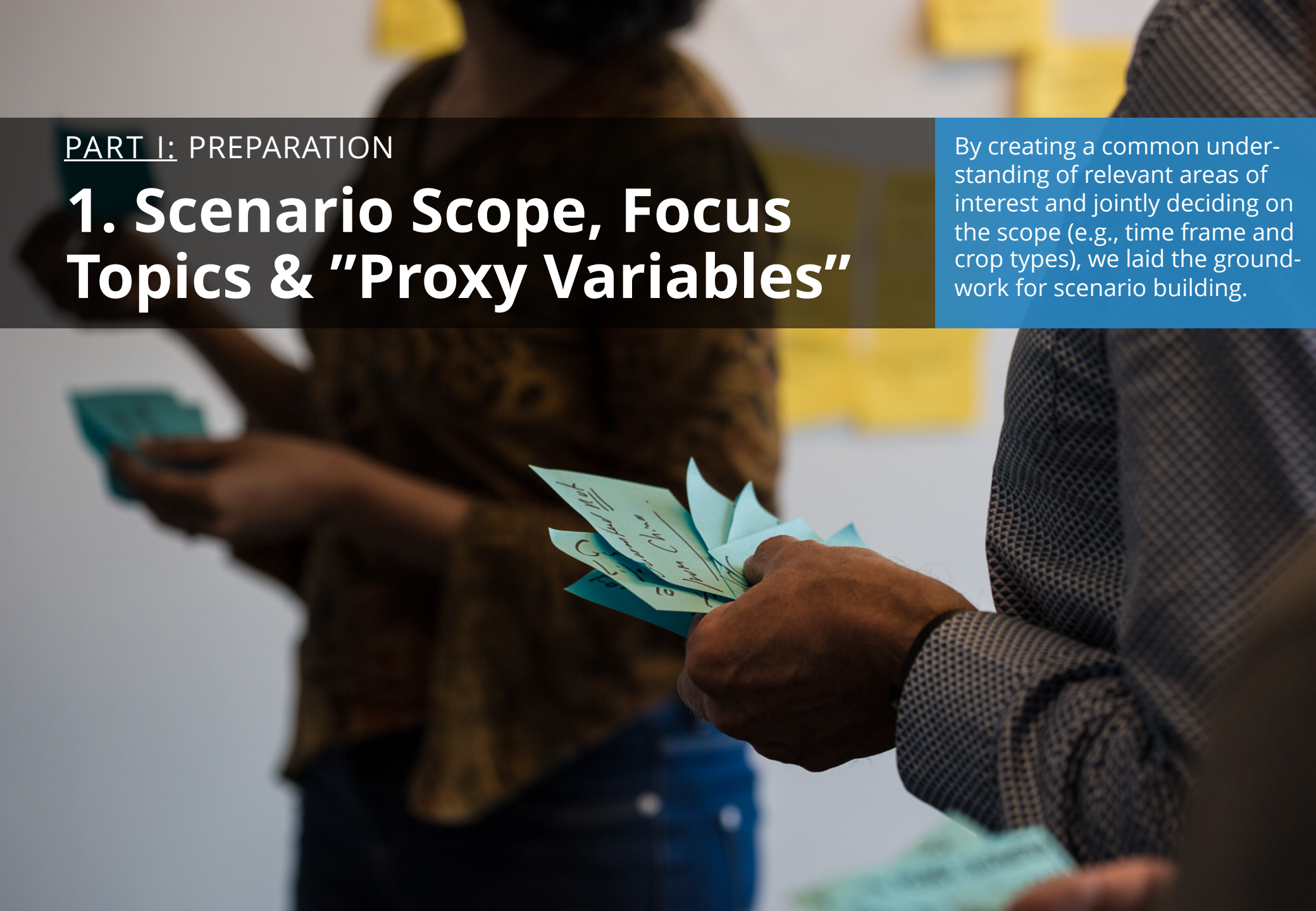
- Presentation of **trend research**
- Creation of **3-5 specific scenarios**
- Development of **vivid descriptions** and catchy names for scenarios to make them easy to relate to

3. Impact Assessment
(1-day)

- **Presentation of scenarios** to stakeholders from politics, science and food industry
- **Prototyping session** in small groups to familiarize with the scenarios
- Deriving relevant **potential implications for future work**

[1] "Scenario Building" and "Impact Assessment" have been conducted in two consecutive workshop days

Content

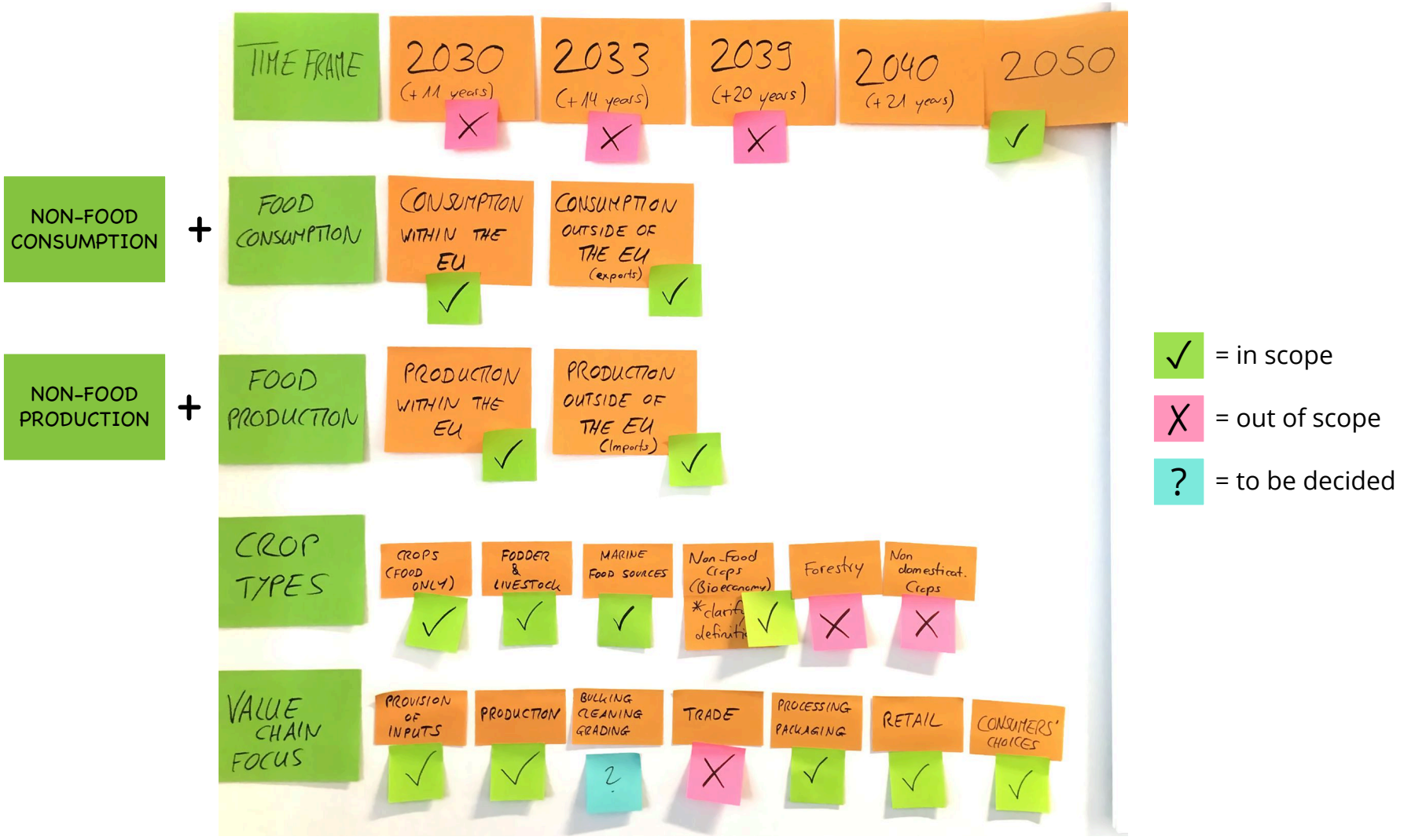


PART I: PREPARATION

1. Scenario Scope, Focus Topics & ”Proxy Variables”

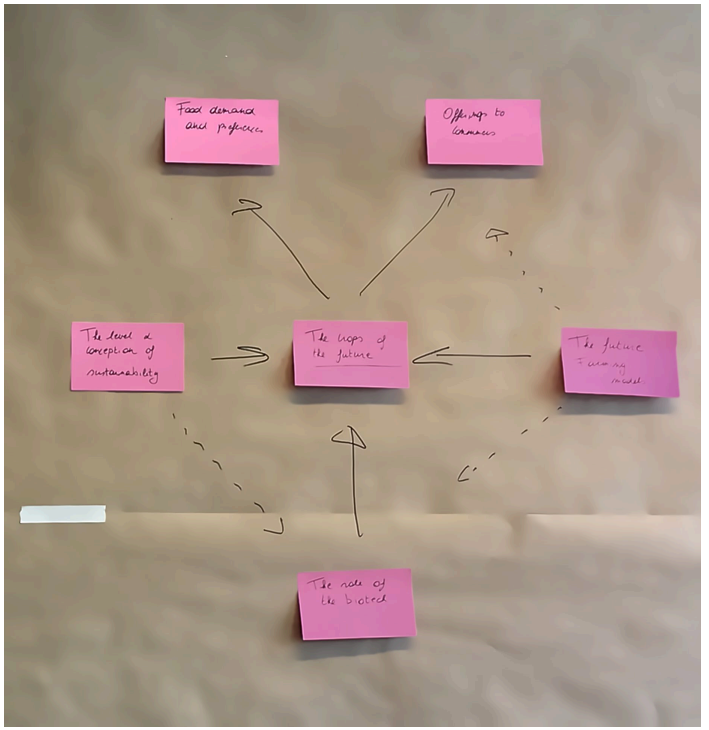
By creating a common understanding of relevant areas of interest and jointly deciding on the scope (e.g., time frame and crop types), we laid the groundwork for scenario building.

Scenario Scope – creating a common understanding of the project focus



Six overall outcome themes emerged during the project

1. **Food and non-food demand and preferences**
   (e.g., what nutritional qualities are a priority?)
2. **Offerings to consumers**
   (e.g., what kind of food labeling will be put into place?)
3. **The crops of the future**
   (e.g., what are the priority crops?)
4. **The role of biotech**
   (e.g., what biotech tools will be available?)
5. **The future farming model**
   (e.g., what production practices are in place?)
6. **The level and conception of sustainability**
   (e.g., what sustainability factors do we need to consider?)



Outcome themes describe the areas of interests that should be explored by the scenarios and serve as a framework for selecting relevant Proxy Variables.

Seven Proxy Variables were selected to represent future worlds

Proxy Variables describe specific aspects of future worlds (i.e., details of society, politics, supply, demand). Covering relevant areas of interest and overall outcome themes, they make scenarios more tangible and allow direct comparison between them. The concreteness of the Proxy Variables facilitates building powerful scenarios and makes it easier to communicate them to a larger audience. The following seven Proxy Variables were selected for this project:

#1 What kind of protests are taking place by NGOs about food production in the EU in 2050?

#2 What are the main topics/files discussed in the European Parliament concerning bioeconomy and what will the debate be like in 2050?

#3 What education/training will be required to become a farmer in Europe in 2050?

#4 What crops will a European farmer grow in 2050, and what will be the specific traits of these crops?

#5 What does a typical dinner look like in a French middle-class family in 2050?

#6 What does the most popular cereal box in Europe look like in 2050?

#7 What will be the cover story on European bioeconomy of the Harvard Business Review in 2050?

PART I: PREPARATION

2. Trend Research

Trends help us understand in which direction future worlds could develop. Therefore, we carefully selected the most relevant ones and explored their potential impact.

Overview of the approach to trends for our scenario building project

A: Creation of long list of trends until first workshop

1. Collection of 96 trends from core team members
2. Consolidation to 35 proposed trends by SOMMERRUST
3. Proposal of 16 additional trends by SOMMERRUST
4. Review of long list of 51 proposed trends by core team

B. Completion and use of Trend Cards

5. Selection of 45 final trends during Preparation Workshop
6. Completion of Trend Cards (one-page summaries)
7. Use of Trend Cards during Scenario Building Workshop

List of trends considered for scenario building

Trends (in alphabetical order):

1) Aging Population
2) AI & Big Data
3) Altered Genetic Resources Circulation
4) Alternative Nutrition Sources
5) Animal Welfare
6) Biofortification
7) Biotech
8) Blockchain
9) Cheaper Food
10) Circular Bioeconomy
11) Climate Change
12) Cultivar / Species Mixtures
13) Decline of Pollinators & Biodiversity
14) Declining Chemistry for Pest Control
15) Diet-related Chronic Diseases
16) Do-it-Yourself
17) E-Commerce
18) Economic Pressure on Farms
19) Electrification
20) Environmental Concerns
21) Fair Trade
22) Globalization
23) Healthy Lifestyle
24) ICT on the Rise
25) Increased Mechanisation
26) Intellectual Property
27) Land-Use Pressure
28) NBTs & Genetic Modification
29) Offering of Meat Alternatives
30) Organic Farming
31) Plant Beneficial Microbes
32) Population Growth
33) Power of the Online Public
34) Product & Research Regulation
35) Public Engagement in Research
36) Renewable Energy
37) Resource Scarcity
38) Rising Disposable Income
39) Risk Sensitivity
40) Robotics
41) Self-Tracking / Quantified Self
42) Sustainability
43) Transparency
44) Urban Farming / Greenhouses
45) Urbanization

Trend Card

Plant Beneficial Microbes

Example of Trend Card

Description

As the discovery of new synthetic pesticides has become increasingly costly, the biopesticide market has been growing, including the exploration and use of plant beneficial microbes. These can act preventatively, suppress diseases, enhance the availability of nutrients and promote plant growth and rooting.[1]

Facts & Figures

- Increasing investment of agri start-ups in microbiome[2]
- Ca. €400M spent on "microbiome related research" in the first 2 years of H2020 (EU), investment up to €130M foreseen until 2020[3]
- The global human microbiome market would be worth USD 0.3 billion by 2019, and reach USD 0.7 billion by 2023[4]
- Rising number of scientific papers on microbiome research (2769 [2012] to 8431 [2016][5]

Stakeholders & Influencers

- Researchers/startups (seek funding, innovate)
- Consumers (demand)
- Farmers (supply)
- Supermarkets/retail (promotion)
- Government (regulation)
- NGOs (certification)

Related (Sub-)Trends

Pesticide free agriculture, Sustainable agriculture, Bio Boom

Relevancy: CropBooster-P

- Influence on land use, crop sustainability and productivity
- Reduced acceptance of conventional CPM
- Influence on food prices
- Enable new business models
- Certification and regulation (synthetic pesticides/fertilizers vs. biologicals)

Sources: [1] Poleatewich, A. (2018), "Utilizing beneficial microbes in a systems approach to plant disease management". [2]Waltz, E. (2017), "A new crop of microbe startups raises big bucks, takes on the establishment", Nat Biotechnol. 8;35(12):1120-1122. [3]EU MICROBIOME R&IMAPPING, DG RTD presentation. [4]OECD (2017), "The Microbiome, diet and health: Towards a science and innovation agenda", OECD Science, Technology and Industry Policy Papers, No. 42, OECD Publishing, Paris. [5]European Commission, Directorate-General for Research and Innovation (2018) Study on mission-oriented r&i on food system microbiomes by A. Małyska.

Content

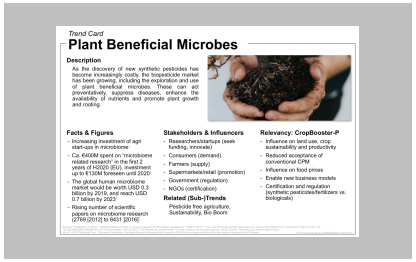
PART II: SCENARIO BUILDING & IMPACT ASSESSMENT

1. Scenario Building

We constructed four diverse learning scenarios by detailing out specific aspects of possible future worlds and making them as concrete and vivid as possible.

Overview: from trends to scenarios

1. Recap of the 45 Trend Cards



Team members presented their prepared Trend Cards as inspiration for the Proxy Variable ideation

2. Ideation: Proxy Variables

In small groups the core team ideated on how exactly specific details (Proxy Variables) of possible future worlds could play out

3. Identification of scenario themes

The best ideas were clustered and common themes were identified to build scenarios around

4. Quality check of the scenarios

Based on an “uncertainty grid”, we discussed the consistency and diversity of the developed scenarios

Eventually, we arrived at four learning scenarios

Key Uncertainties we used to assess our scenario quality

Note: Outcome alternatives describe the two most extreme ways the uncertainties could play out. As a set, scenarios should cover a wide range of outcomes; individual scenarios should be internally consistent and not too similar.

	Uncertainties	Outcome alt. 1	Outcome alt. 2
Need for adaptation		low	high
	Impact of environmental changes[1]	limited impact on current form of farming	heavy negative impact on current form of farming
	Development of demography[2]	healthy, small population	large, unhealthy population
	Development of the economy[3]	stable, prosperous economy	poor, volatile economy
	Development of the political environment	collaborative, open markets	isolationism
Chosen priorities in farming		less challenging	more challenging
	Importance of sustainability in farming / the value chain[4]	sustainability not important: main focus on yield (and price)	sustainability important & relevant across the entire value chain
	Role of the bioeconomy: food vs. non-food	focus on food (little competition from feedstock)	strong additional demand for non-food/feedstock
Science: solution or problem		solution	problem
	Development and adoption of advanced biotech/GM/NBTs	Breakthroughs & widespread adoption, science-friendly regulation	Ban of wide range of biotech methods, complex & restrict. regul.
	Development and adoption of non-biological technology[5]	Breakthroughs and widespread adoption	Large scale failures and abandonment
	Influence, competency and reputation of scientists	very high	very low

[1] e.g., climate change, resources scarcity, development of pests, loss in biodiversity
[2] e.g., size of population, age, chronic diseases
[3] e.g., prices, income, equality
[4] e.g., environmental concerns, animal welfare, organic farming
[5] e.g., robots, AI, VR/AR, blockchain

Quality check led to diverse set of four scenarios, covering all major uncertainty outcomes

UNCERTAINTY GRID:

2. Scenarios / Scenario themes
that have emerged from ideation on Proxy Variables

1. Key Uncertainties and how they could play out
(less challenging = green, more challenging = red)

3. Evaluation of the uncertainties for each scenario
(intermediate outcomes = yellow)

4. Comparison of the scenarios
Scenario 4 was added after quality-checking scenarios 1 to 3 — realizing that one key uncertainty outcome had not been covered so far

PART II: SCENARIO BUILDING & IMPACT ASSESSMENT

2. Explaining Scenarios to Stakeholders

We introduced our scenarios to external stakeholders by narrating mini-stories on how they may become reality. That way, they could jointly work on them and derive potential impacts.

Overview of the four presented scenarios

Scenario 1

Innovation solutions are intensively used, providing steady and high-quality food in a sustainable way as well as large volumes of feedstock for a thriving bioeconomy.

Scenario 2

Health and sustainability concerns drive agriculture and food businesses towards being diverse and transparent, meeting the needs and preferences of individuals.

Scenario 3

Due to severe environmental degradation, the EU is struggling to fulfill basic food demand. In response to the crisis, the EU has seen the introduction of a large-scale and technology-driven agricultural system to mitigate the most dire consequences.

Scenario 4

Consumers have little trust in politicians, scientists and big industry. Society is highly polarized and rejects new food-related technologies – despite the dissatisfaction with the current state of affairs like limited food choice and high prices.

“Plantovation”:

A success story of innovation in agriculture

Note: Storylines are not predictions but rather possible yet uncertain paths of development

From today to 2050 — how the scenario may become reality:

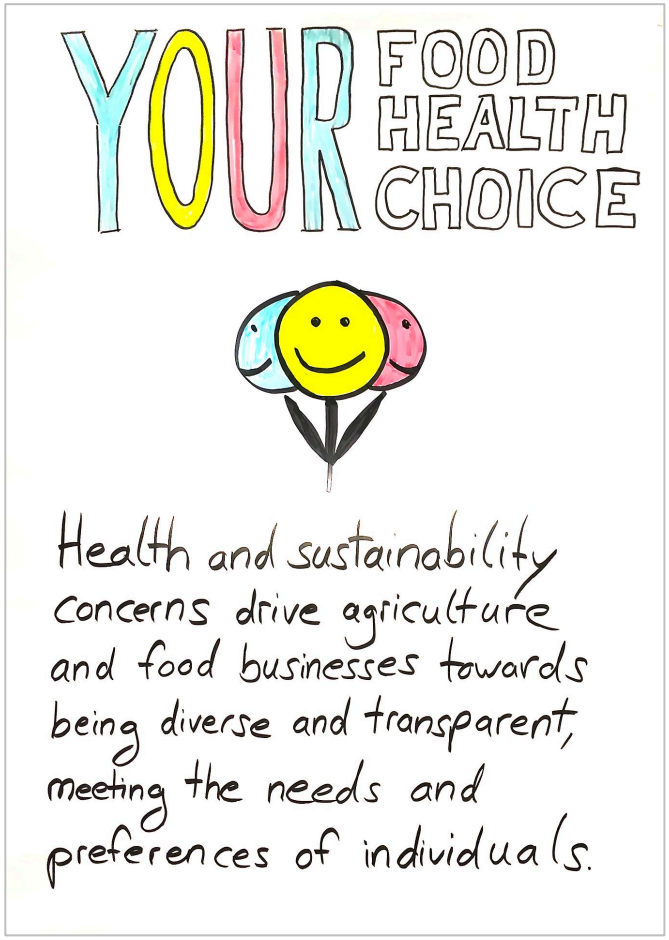
- A technology revolution is already under way today:
  - Artificial intelligence beats the best Go players[1] and creates artworks people can’t distinguish from human-made ones
  - New gene editing technologies make things possible that seemed like science fiction just a while ago
- At the same time, we need to fix our CO_2 problem — and biomass provides a feasible, relatively cheap solution
- In the coming years, more and more entrepreneurs will be applying revolutionary technologies of the next generation to grow crops for food and non-food applications
- The reservations against certain plant technologies visible today quickly fade as startups celebrate breakthroughs and spectacular results — pleasing both consumers and investors
- The increasing flow of venture capital into this domain eventually leads to big, multinational “agritech” companies
- As a result, the next generation of multi-billionaires will not be in software — they will be in “agritech”

[1] Go is considered as one of the most complex strategy board games in the world.

Your Food. Your Health. Your Choice:

How consumers became king

Note: Storylines are not predictions but rather possible yet uncertain paths of development



From today to 2050 — how the scenario may become reality:

- Already today, one can buy a Coke with one's name printed on it or mass customize muesli to satisfy individual preferences
- Data as a resource and the ongoing digitalization will continue to enable new business models and societal opportunities
- By gathering and analyzing data, health will move from curing to preventing disease. Personalized medicine will take off in the coming years increasing focus and efficacy — which is urgently needed to contain civilization diseases like diabetes that are otherwise spreading quickly
- At the same time, the actual impact of diet on our health will become more and more transparent, leading to a convergence of medicine and nutrition
- Visionary entrepreneurs will be quick to seize the emerging opportunities and give consumers what they want: their food, their health, their choice
- As a result, a new class of billionaires and successful food companies emerge that generate vast profits — not from crop production, but from a relentless focus on consumer needs and highly sophisticated supply chains that make it possible to satisfy these diverse needs efficiently

Foodmergency:
A cautionary tale about food security

Note: Storylines are not predictions but rather possible yet uncertain paths of development

From today to 2050 — how the scenario may become reality:

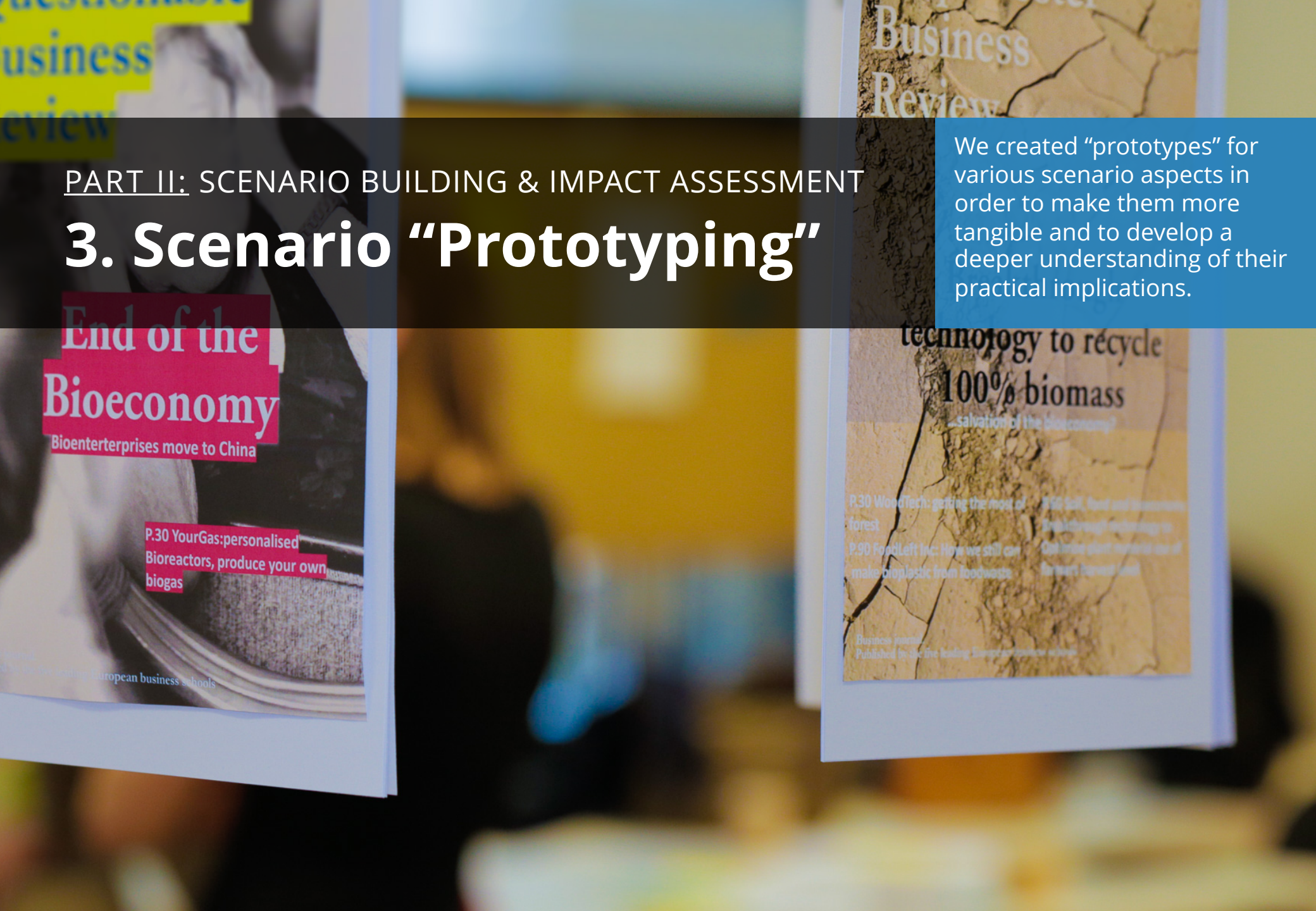
- The warnings from scientists against climate change and its potential impact on agriculture are loud and clear
- Unfortunately, the pessimistic views turn out to be correct: the EU — like many other countries around the world — faces a series of severe environmental crises. As a result, the EU experiences dramatic food security challenges
- Globally, the situation is even grimmer in some cases. The global economy suffers and international food trade collapses due to global shortages
- As food security can no longer be taken for granted, the EU and national governments take radical steps to increase the production of food crops: this includes regulation that favors yield-oriented biotech and drastic market interventions to increase European production capacities for food
- Over the course of just a few years before 2050, a government-directed, large-scale agricultural system is created
- Society backs these policies because they seem to be without alternative. However, the widespread use of advanced biotech, instances of public mismanagement and personal restrictions are seen critically

REJECTech:
When science lost the people

Note: Storylines are not predictions but rather possible yet uncertain paths of development

From today to 2050 — how the scenario may become reality:

- Skepticism, fake news, and heated discussions in the (social) media have become a global phenomenon. This development also affects agricultural topics as the use of glyphosate illustrates. Europe becomes particularly precautionary
- As the possibilities from technologies like gene editing, A.I. and robotics increase, so does the probability of failed experiments
- A steady stream of food scandals and examples of scientific misconduct also do its share to further erode European society's trust in science, industry as well as in the institutions that are supposed to supervise them
- Over the years, sustainability becomes synonymous with the absence of advanced biotech. Eventually, the EU enacts strict regulation to please skeptical voters and large agri companies lose their license to operate
- The rejection of technology has its price, however: growing challenges from climate change and low productivity in agriculture result in supply problems and increasing prices. As agriculture develops significantly slower in the EU than abroad, trade imbalances arise and force EU agriculture to find alternative value adding activities



PART II: SCENARIO BUILDING & IMPACT ASSESSMENT

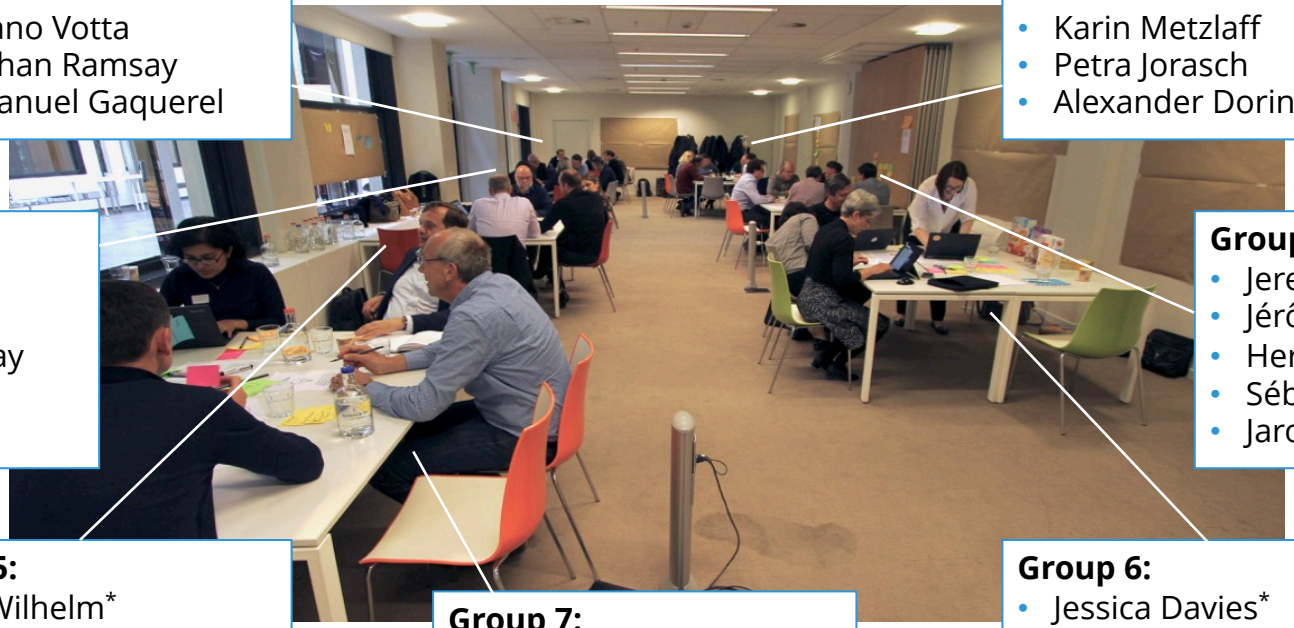
3. Scenario “Prototyping”

We created “prototypes” for various scenario aspects in order to make them more tangible and to develop a deeper understanding of their practical implications.

Overview of stakeholder teams on day 2

Group 1:
- Aleksandra Malyska*
- Norbert Rolland*
- Mariano Votta
- Jonathan Ramsay
- Emmanuel Gaquerel

Group 2:
- Marc Cornelissen*
- Marios Markakis
- Karin Metzlaff
- Petra Jorasch
- Alexander Doring



Group 3:
- Bertrand Muller*
- Martin Parry*
- Anja Krieger-Liszkay
- Erik Murchie
- Marina Korn

Group 4:
- Jeremy Harbinson*
- Jérôme Enjalbert*
- Hervé Dupré de Boulois
- Sébastien Thomine
- Jaroslav Salava

Group 5:
- Ralf Wilhelm*
- Alexandra Baekelandt*
- Gert Meijer
- Timothy Lefeber

Group 7:
- Rene Klein Lankhorst*
- Vandasue Lily Rodrigues Saltenis*
- Nan-Dirk Mulder
- Jean-Charles Deswarte

Group 6:
- Jessica Davies*
- Jose Vogelezang
- Ana Atanassova
- Erik Alexandersson

*Core team members

The task: creating “exhibits from the future”

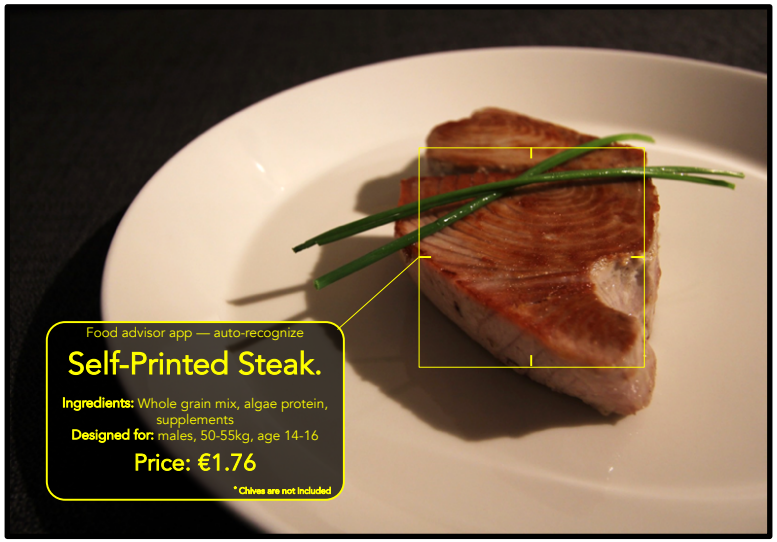
Prototyping: How and why

The teams were asked to imagine going on an archaeological expedition to the future and bringing back evidence.

Each team built four prototypes for their assigned Proxy Variable (one per scenario).

→ Prototyping helps building up an intuitive understanding of the designed future worlds and facilitates detailed discussions on specific scenario aspects.

Example of a possible “prototype” shown to participants for inspiration



Fictitious augmented reality image of a typical dinner from the year 2050

The teams created highly diverse prototypes for each Proxy Variable — one per scenario

Proxy Variables	Prototype concept and medium
#1 What kind of protests are taking place by NGOs about food production in the EU in 2050?	three protest banners, one mock-up web campaign
#2 What are the main topics/files discussed in the European Parliament concerning bioeconomy and what will the debate be like in 2050?	four fictional interview snippets with members of the European Parliament (acted out in a live-performance)
#3 What education/training will be required to become a farmer in Europe in 2050?	four fictional audio recordings with farmers
#4 What crops will a European farmer grow in 2050, and what will be the specific traits of these crops?	four flyers and live sales pitches/presentations
#5 What does a typical dinner look like in a French middle-class family in 2050?	two mock-up food ordering webpages, one dinner plate, one print-out
#6 What does the most popular cereal box in Europe look like in 2050?	four cereal boxes with different design, labeling and packaging
#7 What will be the cover story on European bio-economy of the Harvard Business Review in 2050?	four covers of the fictional *CropBooster Business Review*

#1 – Protests about our food production

Prototypes: three protest banners, one mock-up web campaign

SCENARIO 1

PLANTOVATION

Physical protest has become uncommon. Instead an online petition demands "**We want REAL food**!" — as opposed to the synthetic (e.g., 3D-printed) food which is prevalent in the Plantovation scenario.

SCENARIO 2

YOUR FOOD HEALTH CHOICE

To effectively personalize food, citizens had to become completely transparent. The slogan "**NO SPY FOOD**" and the image of someone tracking the consumption of a barcoded burger refer to the disapproval of tracking and poor data privacy.

SCENARIO 3

FOODMERGENCY

A banner with the slogan "**FEED US FIRST. THIS IS OUR FOOD!**" depicting a wall with the word "out!" on it hints towards strong isolationism and towards a strong rejection of non-food crops due to food shortages/limited resources.

SCENARIO 4

REJECTech

"**SAFE CHEAP FOOD. A HUMAN RIGHT**" is the slogan the NGO puts on their banner, together with a "safe food" label and a scale representing that right. The protest emphasizes the charged, moral dimension of access to "safe" food.

#2 – Bioeconomy: Discussions in the EP

Prototypes: four interview snippets w/ MEPs (acted out in a live-performance)

SCENARIO 1

PLANTOVATION

Staying internationally competitive by **protecting innovation** is an important topic. At the same time, the benefits from sharing technology in order to increase global wealth and progress is recognized.

SCENARIO 2

YOUR FOOD HEALTH CHOICE

Data is a big topic: protecting private data on the one hand while unlocking the value that new types of data streams can offer. Success factors include **better food education** and the overall **decommoditization** of the market.

SCENARIO 3

FOODMERGENCY

Production first, sustainability second: absolute priority of food crops over non-food crops in order to meet the basic food demand and to prevent social unrest and major R&I efforts to revert to the 2020 situation.

SCENARIO 4

REJECTech

Major trade balance issues due to superior agricultural products produced outside the EU. Loss of consumer trust, **food frauds** & increasing food prices are discussed. Intensified police actions deemed to be necessary to secure the functioning of food value chains.

#3 – The training of a farmer in 2050

Prototypes: four fictional audio recordings with farmers

SCENARIO 1

PLANTOVATION

A young farmer highlights the importance of **automated sensing technology**, **precision agronomy** and **biotech** in his curriculum and how esp. a "**coding for farmers**"-class helped him growing his farm as a successful business.

SCENARIO 2

YOUR FOOD HEALTH CHOICE

To grow specialized crops to meet the nutritional needs of a specific group of people, this farmer wants to go to university for training in **plant quality**, **biotech**, **diets** and **medicine** but also in **marketing** and **consumer relations**.

SCENARIO 3

FOODMERGENCY

This farmer went to the *European School of Farmers for Food Security* and learned how to breed **climate resistant plants**, **risk management** as well as **modelling techniques** to ensure at least a limited yield.

SCENARIO 4

REJECTech

To provide healthy food in an organic way, this farmer wants to learn more about **traditional farming methods**, **climate development**, as well as **abiotic** and **biotic stress tolerance** of varieties. She is in a network of local farmers.

#4 – Crop types grown in 2050

Prototypes: four flyers and live sales pitches/presentations

SCENARIO 1

PLANTOVATION

The mega corporation *C4 supercrops*, a subsidiary of *Apple Foods and Industrial Innovations* pitches its new **Super Sugar 6®** crop which is praised for its high, guaranteed return on investment.

SCENARIO 2

YOUR FOOD HEALTH CHOICE

The farm network **Your.Food.Org** offers eco-friendly, high-quality crops and is connected to Your.Health.org. One gets a new food basket every week and the promise is to accommodate consumers' personal needs (age, cholesterol, ...).

SCENARIO 3

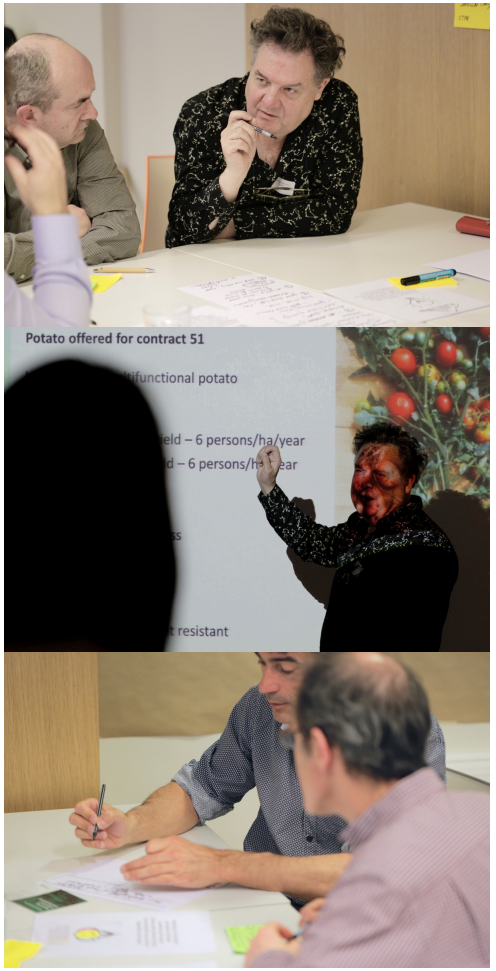
FOODMERGENCY

A bid to a meet an **Urgent Crop Plant requirement** by *The EU Central Authority in Food Resource Management*. It describes a new high-yielding, multifunctional, disease & stress resistant GM diploid potato producing both potato tubers & "pomatoes" (tomatoes above ground).

SCENARIO 4

REJECTech

The *Ministry of Agriculture* of Northern Italy, Independent Republic issues a **Mycotoxin Alert** announcing the Hygiene Department will collect and destroy all rye production of the area. Certain cultivars are forbidden. Bread shortage is expected.



#5 – A typical family dinner

Prototypes: two food ordering webpages, one dinner plate, one print-out

SCENARIO 1

There is **high variety** on a dinner table in the Plantovation scenario. The **plate is biodegradable** and any waste can be transferred into the circular bioeconomy. Food is **high quality**, there's both meat and meat alternatives.

SCENARIO 2

You can **order your customized dinner online** and determine the delivery point, method and time. As an input you can upload e.g., your **food preferences** or **health profile** and get **personalized meal recommendations.**

SCENARIO 3

You can order your dinner online, but **choice is very limited** to **basic staple food** such as potatoes. However, there is also **nutritionally optimized** food, both GM and non-GM (more expensive). You have a limited amount of **food stamps** you can pay with.

SCENARIO 4

The family eats **healthy, well-labeled food**: organic carrots, eggs from free running chicken, a glass of organic red wine. The decision for **natural products** comes with the trade-off **low productivity, low meat consumption** and **limited choice** of food variety.

#6 – The most popular cereal box

Prototypes: Four cereal boxes with different design, labelling and packaging

SCENARIO 1

PLANTOVATION

"Tech Flakes!", designed by *iGEM* are advertised "100% GMO, robofarmed, new triple helix shape, now with algae protein boost". The box design focuses on tech, science and GMO implying that those are positively connotated in this scenario.

SCENARIO 2

YOUR FOOD HEALTH CHOICE

"My Choice. There's only one you." puts the individual in the center of the attention. The box has detailed nutritional information and information on sustainable/ethical origin tailored to individual's nutritional needs and preferences.

SCENARIO 3

FOODMERGENCY

"FLAKES" are provided by the EU as the only available product. A very reduced and simple design with an EU flag and the image of some flakes point towards shortages and a planned economy.

SCENARIO 4

REJECTech

"Golden harvest" is advertised to be "As nature intended, 100% natural grains" and as being free of additives. The very traditional design features an old, wooden hay wagon. It showcases the importance of naturalness to consumers.

#7 – Cover story on bioeconomy

Prototypes: four covers of the fictional *CropBooster Business Review*

SCENARIO 1

PLANTOVATION

The title story "**Europe 100%** - How FLYBIO birthed the insurgence of an entirely biofuel-run energy sector" hints at the widespread success of the bioeconomy.

SCENARIO 2

YOUR FOOD HEALTH CHOICE

"**Fully traceable bio-packaging solutions** – SealedAir offers online tracking and tracing solution for sustainable biopackaging": The cover shows bioeconomy solutions reflecting consumer demands for transparency & sustainability.

SCENARIO 3

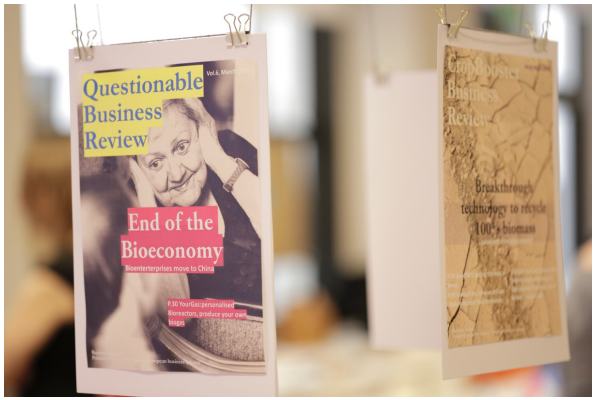
FOODMERGENCY

"**Breakthrough technology to recycle 100% biomass** - …salvation of the bioeconomy?": This story implies that only by using left over biomass from food production, bioeconomy has a chance to thrive at all and can generate some revenue.

SCENARIO 4

REJECTech

The *Questionable Business Review* features a critical story on the "**End of the Bioeconomy** – Bioenterprises move to China". It implies a loss of the European bioeconomy's competitiveness due to a very small-scale agricultural system.



PART II: SCENARIO BUILDING & IMPACT ASSESSMENT

4. Impact Assessment

We discussed the potential impact of the scenarios for CropBooster-P in small teams. Each team focused on one of three topics: sustainability, yield, or nutritional quality.

Scenario impact — focus on yield

High-level summary based on discussions in groups 1, 2 & 5

Created for external version of the documentation

Yield is to be addressed in multiple crops, including scenario-specific crops for different use purposes and under different regulatory conditions. Consequently, preparatory work for yield improvement should offer a broad range of biological starting points and be achievable through different technical approaches.

SCENARIO 1

Major yield improvements for a flourishing B2B environment will drive welfare and wellbeing of society and Europe; **multi-purpose crops for bulk production and specialties** will dominate a circular bio-economy; yield improvement should seamlessly work in conjunction with **acquisition of new product functionalities**. **IP** and **value share** are core success factors.

SCENARIO 2

Heterogeneous food preferences will be requiring **smaller scale production chains**. The yield of an **increasing range of crop varieties** cultivated with agricultural practices agreeable to the end consumer will be critical to keep costs of EU food production within a realistic range. The ecological impact may be positive and part of the value equation. Key is that consumer choice translates into proper pricing and value share across the EU ag chain.

SCENARIO 3

The prime scope is to accomplish a sufficient level of global food production, which may include diet shifts. To achieve yield under **volatile and new weather conditions**, it will be necessary to upgrade all biological processes linked to **energy management** and **abiotic stress handling**. R&D costs will be high, as will be the cost of cultivation that will **require optimized agricultural practices for planting, rotation, nutrient input**, etc. Few crops will qualify for this. This immediately poses sustainability issues.

SCENARIO 4

The inability to tackle crop yield within Europe with the same approaches as outside Europe implies that options for damage control need to be considered at policy level. In the background, yield improvement needs to be achieved through **exploring novel knowledge-based breeding workflows** that do not rely on GMO or gene editing, yet deliver a competitive annual yield gain.

Scenario impact — focus on yield (group 1)

— Internal version only —
Based on direct workshop results

Solutions should 1) meet needs 2) reduce our footprint 3) be measurable 4) be non-discriminatory. Only by combining aspects of scenario 1 & 2 (tech development accompanied by customer orientation) it will be possible to achieve sustainable yield growth.

Plantovation:

- Is compatible with a circular economy
- Allows to preserve biodiversity
- Comes with high IP issues
- Favors yield improvement

Your Food. Health. Choice:

- Yield becomes less important
- More natural resources pressure
- Lack of predictability (consumers)
- Increasing costs
- Ecological impact hard to predict
- Need to adjust breeding program (yield as pot. trade off)

Foodmergency:

- Decreasing sustainability
- Increase of monoculture
- Conflicts between social actors
- Favors yield improvement (high cost/low sustainability)

REJECTech:

- Yield limited
- Life expectation decrease
- (overall not favorable)

Scenario impact — focus on yield (group 2)

— Internal version only —
Based on direct workshop results

Scenario 1 (Plantovation) is about a flourishing B2B environment offering welfare and wellbeing to society and planet.

Scenario 2 (Your Food. Your Health. Your Choice.) and 4 (REJECTech) are driven by impact of the consumer on how the Ag value chain operates and what it produces (e.g., crops are grown)

Scenario 3 (Foodmergency) is driven by a global human failure and will affect all aspects of society including C2B and B2B.

Each scenario will trigger its unique land use for agricultural production and offers other options for R&I. Yield improvement is key across the scenarios and depending on the scenario other crops and traits should be developed. Furthermore, depending on the scenario the way how the traits are developed, would differ.

Scenario impact — focus on yield (group 5)

— Internal version only —
Based on direct workshop results

Develop more diverse crop varieties.
For scenario 2 *(Your Food. Your Health. Your Choice)* and 3 *(Foodmergency):* varieties with different/personalized overall nutrient composition (energy intake and minerals/vitamins) and/or containing more protein/less starch.

Develop multipurpose crops.
Especially in scenario 1 *(Plantovation)* they are needed for both food and non-food/bio based production to support the circular economy.

Develop a higher stress tolerance.
In scenarios 1 *(Plantovation),* 2 *(Your Food. Your Health. Your Choice)* and 3 *(Foodmergency)* this could be done by using biotech, however scenario 4 would be biotech-averse, so alternative options would need to be explored.

Scenario impact — focus on nutritional quality

High-level summary based on discussions in groups 3 & 7

Created for external version of the documentation

Nutritional quality plays different roles across the scenarios and offers both commodity and specialty crop differentiation opportunities.

SCENARIO 1

To meet the (global middle-class) consumer demand for sustainable and supplement-free products, **advanced breeding approaches for high quality food and feed** are economically justifiable. Both commodity and specialty crops will undergo rounds of improvements balancing with improvements made for co-product and biorefinery strategies.

SCENARIO 2

Customer demand drives the development in food and feed. To meet expectations on nutritional quality, taste and other sensory qualities, the core causative biological processes in crops and livestock need to be understood and converted to **advanced breeding approaches**. As consumer demand also includes a **heterogeneous choice**, a multitude of commodity and specialty crops need to be upgraded.

SCENARIO 3

The challenge to deliver food in sufficient quantity leads to **nutritional quality not being a primary target**. A lobby for diet shift may affect the ratio feed: food production thus reducing the pressure on land use. To incentivize consumers shift diet, timely availability of food with improved nutritional quality, taste and other sensory features could be key. This requires know-how similar as in scenario 2, yet with a key requirement that such improvement doesn't bring along any penalty in yield and abiotic stress handling.

SCENARIO 4

In the absence of competitive yield and volume-based off-farm prices, **farmers may seek differentiation in quality** including nutritional quality, taste and other sensory features of interest to the consumer. The know-how requirement will be similar to that in scenario 2, but as in scenario 3 improvements may not jeopardize yield. Moreover, it must be possible to develop the improvements through workflows **not using GMO or gene editing methods**.

Scenario impact — focus on nutritional quality (group 3)

— Internal version only —
Based on direct workshop results

Plantovation:
Great opportunity for innovation → monitoring and quantifying quality

Your Food. Health. Choice:
Quality, nutritional and health aspects are most important but/and depend on constantly changing consumer needs

Foodmergency:
Nutritional quality is not the target of plant production. (Food processing could correct it?)

REJECTech:
Nutritional Quality can be high but harvestable amount may be low

Scenario impact — focus on nutritional quality (group 7)

— Internal version only —
Based on direct workshop results

Plantovation:
- Breed for high quality/against anti-nutritional quality
- Breed for improved feed (dual purpose crops)

Your Food. Health. Choice:
- Breed for high quality/against anti-nutritional quality
- Fix problems due to processing (food industry)

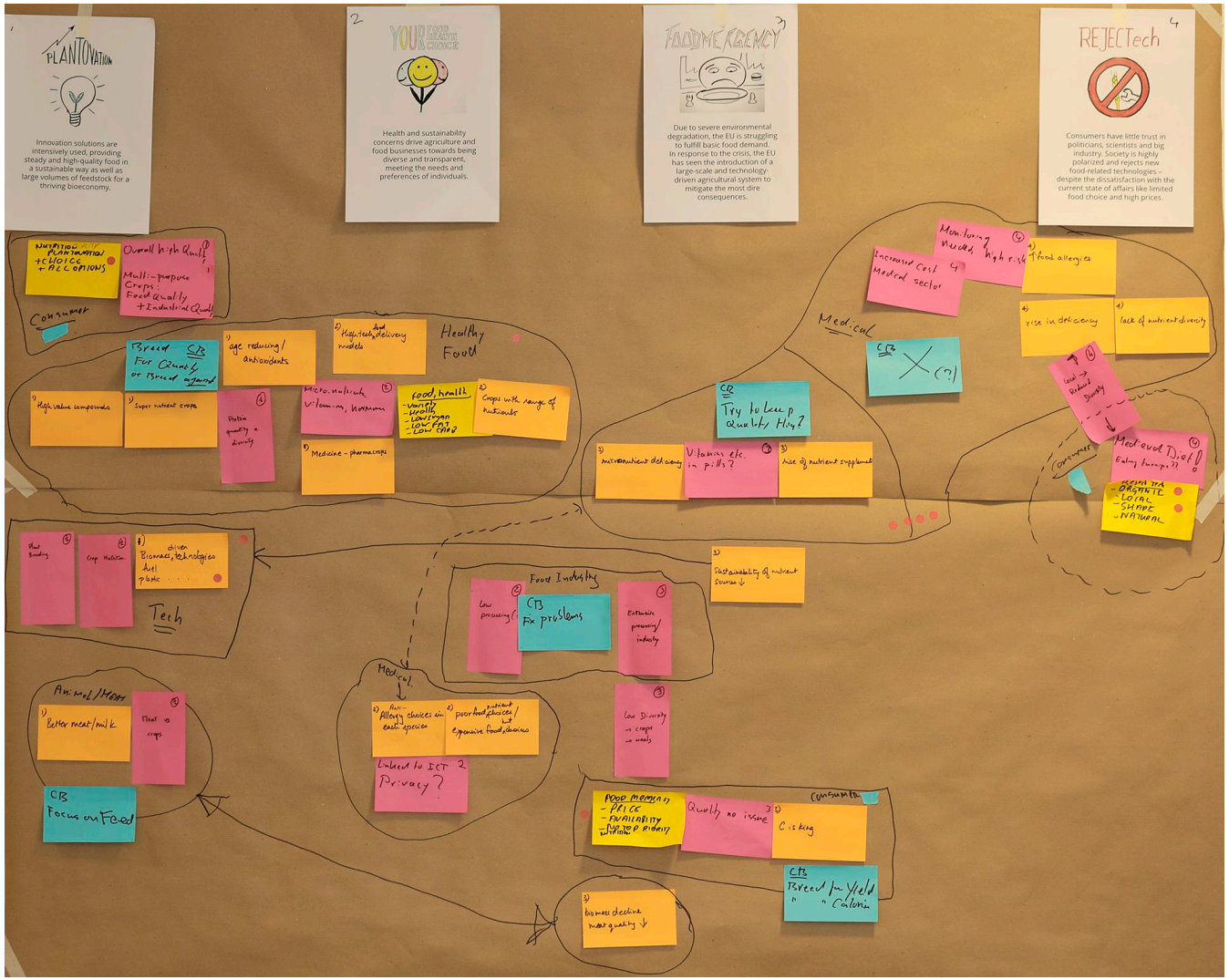
Foodmergency:
- Breed for high yield; high calories
- Best effort to maintain quality

REJECTech
- No action space

Categories:
- Consumers
- Healthy Food
- Animal/Meat
- Technology
- Food Industry
- Medical Issues

Details of scenario impact — focus on nutritional quality (group 7)

— Internal version only —
Based on direct workshop results



Scenario impact — focus on sustainability

High-level summary based on discussions in groups 4 & 6

Created for external version of the documentation

Sustainability in agriculture is core across all scenarios. However, whereas sustainability opens up many opportunities in scenarios 1 and 2, it is rather a necessity due to environmental crises in scenario 3 in particular. Moreover, the meaning of the concept of sustainability and corresponding agricultural practices will differ significantly between scenarios. Sustainability requirements for crops include optimized production of biomass and harvestable product, suitability for co-product strategies, minimal requirements for land use, disease and pest treatment, nutrient input as well as tolerance to weather fluctuations, soil-friendly cropping needs and good rotation compatibility.

SCENARIO 1

This scenario envisages the **largest growth of productivity**. Embracement of the **bio-economy** is foreseen. From a know-how perspective, this scenario puts the highest urgency on incorporating and testing **different sustainability features**. From a know-how development perspective it implies that the biology underpinning these different features should be **tackled in parallel**. This may require international cooperation.

SCENARIO 2

Customer demand for healthy and **sustainable food produced in a transparent manner will open markets** where the sector needs to prove its capability of meeting the specific emphasis points of customers related to sustainability. This may imply **"chemical free" production procedures, no tilling, limited nutrient (N) supply**. Know-how development should therefore focus on addressing these topics first, and have it seamlessly incorporated with the elevated requirements for nutritional quality and yield in the different crops.

SCENARIO 3

Society and governments across the globe are expected to agree to any proposal from the Ag value chain that would help **stabilize or revert the situation**. As in scenario 1, a broad repertoire of sustainability options needs to be investigated in parallel, but with some key differences. It is likely to **that disease and pest management as well as nutrient supply** are tackled by **integrated crop–chemical approaches**. Furthermore, improvement on those sustainability traits should not create any yield penalty.

SCENARIO 4

In the absence of competitive yield and volume-based off-farm prices, **farmers may seek differentiation towards end customers by being a leader in sustainable agricultural practices**. This would require know-how to create "sustainability traits" that **do not rely on GMO and gene editing technology**.

Scenario impact — focus on sustainability (group 4)

— Internal version only —
Based on direct workshop results

1. Roots architecture and physiology (especially Carbon exudates) are affecting globally all nutrient use efficiencies (N, P, …) and WUE
2. Improvement of N fixation is a target for most scenarios, using tools available within each scenario.
3. Necessary adaptation to climate change, using tools available within each scenario.
4. Improving response of crops to natural defense stimulants and soil fertility stimulants (most scenarios)
5. Water stress tolerance; improvement of stomatal closure, C3 vs C4…
6. Improvement of interactions with bacteria (PGPR) and mycorrhizae can contribute to most nutrient uptake.
7. Bet-hedging: species/variety diversity is critical in risk management

Scenario impact — focus on sustainability (group 6)

— Internal version only —
Based on direct workshop results

1. **Considering climate change & crop resilience is key to be fit for many futures**
   - Considering high plasticity crops that can adapt to changing climate
   - Consider water-logging as an issue, as this may be missed with a focus on drought

2. **Consider double-benefit options, e.g. food & bio-based value**
   - Engage with circular economy players to understand opportunities
   - Suggest policy incentives for enabling food+bio crops

3. **Consider the land take / space for nature effects**
   - Beware of global externalities when considering Europe scope
   - Alternatives for feed and meat are important as these are major sustainability issues

4. **Resource efficiency is important to consider**
   - Is there an opportunity for collaboration with microbiome experts?
   - Take care that some issues have high variation across Europe e.g. water

5. **Beware of over-focusing on "wrong" technology-bias**
   - Don't dismiss alternatives. Keep listening to each other and respect other perspectives and approaches
   - Technology neutral regulation. Focus on goals, not on technology

Details of scenario impact — focus on sustainability (group 6)

— Internal version only —
Based on direct workshop results

PART II: SCENARIO BUILDING & IMPACT ASSESSMENT

5. Conclusion & Next Steps

In this last session, external stakeholders provided their perspective on what priorities CropBooster-P should consider for the project work going forward.

Workshop take-aways regarding yield

Toolbox Format

- Flexible and evolving database that can be extended/updated throughout time
- A database where data related to specific traits/genes/species/technologies can be easily extracted e.g., by generating pivot tables
- Presenting the toolbox as an encyclopedia consisting of PDF-written chapters is less relevant as this is difficult to access and highly likely to be outdated soon

Priority Crops

- The proposed list of crops should contain a more extended list of vegetables and fruits
- Focus rather on minor/new/niche crops to unlock their potential, e.g., to not focus too much on maize, but rather on largely underexplored crops such as Miscanthus, Quinoa, Forage crops, Cannabis, Millet (C4), Sorghum (C4) etc.

Crop Traits

- Crops resistant to extreme climates e.g. able to cope with flooding (anaerobic stress)
- More diverse crop varieties e.g., w/ increased protein/decreased starch content or with a different nutrient composition
- Multipurpose crops allowing a circular bio-economy (e.g., crops with valuable traits relevant for both food and non-food industries/applications)
- Increased importance of not only biomass yield, but also seed yield, root mass… etc.

Techno-logies

- Include also enabling technologies (e.g., related to tissue + cell culture) as these may be extremely important in the process of CRISPR-mediated gene editing
- Include also genomic selection and classical breeding
- Modeling approaches should be predominantly present in the CropBooster-P outcome
- Include the contribution of epigenetics on yield

Workshop take-aways regarding nutritional quality

Toolbox Format

- Favor a searchable database as output, that can be updated as new information/technologies arise
- Compiling the toolbox into an encyclopedia format was thought to be unnecessary (as this could go out of date)

Priority Crops

- The suggested list of priority crops to be considered in the database should include vegetable and fruit examples
- Niche crops could be considered in separate category from priority crops to ensure important information is preserved

Crop Traits

- Consider bio-digestability and protein availability as a trait
- Consider specialized traits for specific nutritional requirements, e.g., gluten-free wheat
- Dealing with nutritional tradeoffs (starch/protein partitioning within a crop)

Techno-logies

- Post harvest technologies to ensure optimal nutrient quality during crop storage
- Stress induced transposable element mobilization (could also be relevant for sustainability)

Workshop take-aways regarding sustainability

Toolbox Format

- Database: searchable, by traits/genes/species/technology
- Should allow to draw the simple summary graph highlighting links between Traits/Species/Technologies (Dots scheme of the proposal, presented by Axel)

Priority Crops

- Additional crops: pearl millet, sorghum (drought resistant and high nutrition quality), grapevine, sunflower, lucerne, key horticultural species, as bean, broccoli, cabbages, miscanthus...
- Many minor crops are essential for sustainability, requiring specific breeding efforts (little work performed so far), and should be listed somewhere ("core species" vs species benefiting from translational biology?).

Crop Traits

- Flooding (anaerobic stress)
- Importance of Carbon storage in the soil, through root exudates/root biomass (Climate mitigation: carbon capture)
- Dual usage of crops: fruits/seeds/tuber harvest + plant residues used for non food

Techno-logies

- Reference to classic breeding methods (but out of CropBooster scope)
- Transposable Element based breeding
- Biofuels and other non-food use (fibers) of crop parts non harvested for food use

Conclusion

Over the course of the CropBooster-P Scenario Analysis, the project team explored a wide range of trends and uncertainties that are directly or indirectly related to the future of agriculture in Europe. The process resulted in four learning scenarios:

(1) Plantovation

(2) Your Food. Your Health. Your Choice

(3) Foodmergency

(4) REJECTech

By design, the four scenarios are plausible but unlikely. Hence, reality in the year 2050 will probably include aspects from each of the learning scenarios as well as some unforeseen outcomes. The set of scenarios covers a broad range of outcomes related to major uncertainties about EU agriculture. As the project was only a starting point, we recommend proceeding with further impact analysis to reach an even broader understanding of the diversity of possible future(s). This will provide new perspectives that make CropBooster-P's project results more robust and facilitate a more proactive stance towards future threats and opportunities.

Within Work Package 1 of CropBooster-P, the four scenarios frame the option space regarding three key topics: (1) yield, (2) nutritional quality, and (3) sustainability. In the context of the overall project, this initial Scenario Analysis provides the reference point for a multidimensional assessment including the economic, social and environmental impact (Work Package 2), societal needs and expectations (Work Package 3), international cooperation (Work Package 4), and finally strategy development (Work Package 5).

The proposed next steps to best support these activities as well as a summary of the project context are therefore outlined on the next two pages.

Proposed next steps

Our scenario project provides the starting point for further exploration and for taking specific measures towards more desirable future outcomes. In order to maximize the value generated by the Scenario Analysis, we recommend the following steps:

Detail the scenarios

Additional value can be captured from the scenarios by further elaborating on some particularly interesting aspects. This may include additional research on important trends and uncertainties

Prepare for the future

Develop a CropBooster-P roadmap balancing opportunity, need and risk by appreciating the spread and commonalities of desired outcomes under different scenarios

Identify early warning signals

Before any of the scenarios fully materia-lizes, there will be weak signals that can be picked up if one looks for them. By identifying these signals now and incorpo-rating them into the road-map, CropBooster-P can minimize risks, increase chances of success and deliver on time

Create the future

Don't just wait and see how the future unfolds: take specific measures today to prevent undesirable outcomes or scenarios from happening

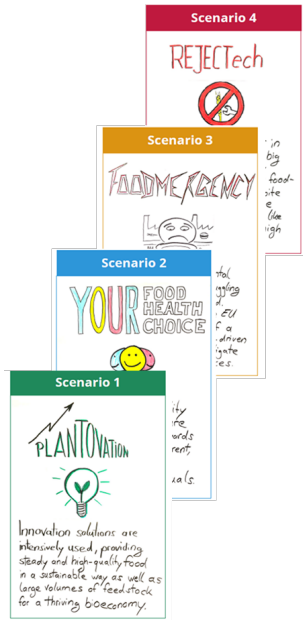
CropBooster-P: A high level view of how the roadmap is being developed

Setting the option space for yield, nutrition and sustainability

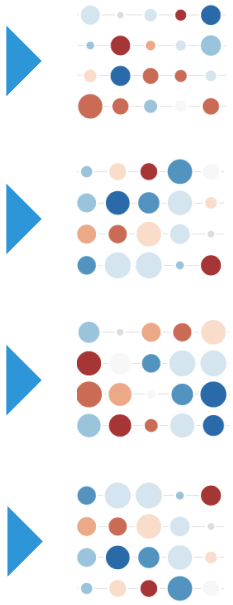
CropBooster "As is" 2019

EU crops technologies

Future worlds 2050



Alternative CropBooster outcomes



WP 1

Multidimensional assessment of the option space

WP 2
Economic, Social and Environmental Impact

WP 3
Societal Needs and Expectations

WP 4
International Cooperation

Strategy Development

WP 5

- Roadmap to future proof the EU crops
- Improved societal awareness and enegagement
- Taking into account how the future may develop
- In depth anticipation of economic, social and environmental impacts

About CropBooster-P and the Scenario Analysis project partners

The **CropBooster-P** Consortium brings together some of Europe's most prestigious plant science institutions and stakeholder organizations who jointly will develop the blueprints for the crop varieties of the future. It is the answer to the Horizon 2020 call future proofing our plants.

Representing the whole plant innovation chain from fundamental research to crop production and food processing, **Plant ETP** is committed to stimulating research and innovation in plant science and agriculture as a joint basis between industry, academia and the farming community, to the benefit of the growers and the final consumers.

SOMMERRUST is an innovation consultancy that helps companies improve their innovation capabilities, and design and introduce new business models. SOMMERRUST was responsible for planning, conducting and facilitating the Scenario Analysis process. For more information contact info@sommerrust.com

CROPBOOSTER-P SURVEY

PLEASE NOTE: Data collected until 15.09 2019 will be used in the primary analysis. However, the survey will remain active after 15.09 2019. Data collected after this may be used for supplementary analysis, you are welcome to add entries after this period. The updated entries will be made available periodically on the database update folder.

* Required

CROPBOOSTER-P SURVEY

Partners Information- This section is for INTERNAL USE only, to make certain all partners (and consequently, fields of expertise) are represented in the data collection.

1. **Name** *

2. **Affiliation** *

Description of entry- general survey

(This section is common to all 3 subtasks, and forms a common information base for the data collected. Subsequent sections will be specific to the respective subtask you choose.)

3. **Is this entry documenting a review?** *
   Mark only one oval.
   - ◯ Yes *After the last question in this section, stop filling out this form.*
   - ◯ No

4. **Title of publication** *

5. **Author List** *
   Recommended format: Doe J., Taylor E., etc

6. **Year of publication** *

7. **Abstract / Summary** *

8. **Bibliographic reference/ PMID/ DOI/ Other identifiers** *
   Please use other identifiers (such as URLs) only in cases where no standard identifiers are available.

9. **Gene/ Protein /QTL involved** *
   Provide standard accession numbers/ identifiers. You can enter multiple genes separated by (;). For reviews with multiple genes of varying degrees of priority, this question may be skipped.

10. **Biological pathway (eg. Photosynthesis)**

11. **Technologies and Methods**
    Select the technologies and methods that are relevant and have been utilized in the study of this gene/ trait. If you would like to add a physiological trait without/ with yet unknown genetic basis please select not known/ not yet identified. Include a description in the relevance to CropBooster descriptive answer for ranking / qualification purposes.
    Check all that apply.

- [ ] Conventional Breeding
- [ ] Conventional GMO
- [ ] Epimutation
- [ ] Gene Editing
- [ ] GWAS
- [ ] MAS
- [ ] Metabolic design
- [ ] Modelling
- [ ] Mutagenesis
- [ ] Mutant Populations
- [ ] Phenotyping
- [ ] Plastid transformation
- [ ] Populations/Mapping, Magic, Diversity Sets
- [ ] Speed Breeding
- [ ] Synthetic Biology
- [ ] Tagged populations
- [ ] TILLING
- [ ] Transposon mobilisation
- [ ] Other
- [ ] Not known/ not yet identified

12. **If other, specify**

13. **Crop category / group** *
    Check all that apply.

- [ ] Algae
- [ ] Fibres/ Lignocellulose
- [ ] Forage grasses
- [ ] Grain staples
- [ ] Model Plants
- [ ] N2 fixers
- [ ] Oilseed
- [ ] Root staples
- [ ] Vegetables / fruits
- [ ] Other:

14. **If other, specify**

15. **Species** *

Species marked with asterisk (*) are of particular relevance to this survey. Other species may also be selected, but only in the case that gene/ trait under consideration is not studied in the asterisked species.
Mark only one oval.

- Arabidopsis*
- Alfafa*
- Barley
- Brassicas
- Carrot
- Citrus
- Clover
- Douglas
- Durum wheat
- Eucalyptus
- Field bean
- Grape*
- Sunflower*
- Hemp
- Laminaria*
- Lettuce*
- Lupin
- Maize*
- Millet
- Miscanthus*
- Oat
- Olive
- Onion
- Parsnip
- Pea*
- Pome*
- Poplar*
- Porphyra*
- Potato*
- Rapeseed*
- Raspberry
- Rice
- Ryegrass*
- Saccharina spp.
- Sitka
- Soybean*
- Sorghum
- Spinach
- Spruce
- Strawberry
- Sugarcane
- Sugarbeet*
- Tomato*
- Switchgrass
- Ulva*
- Wheat*
- Tobacco*
- Willow
- Other

16. **If other, specify**

17. **Scale/ geographical region**
Mention the regions the species is cultivated in. (This is relevant for the final report and analysis)
Check all that apply.

- [ ] Mediterranean
- [ ] Humid subtropical
- [ ] Marine
- [ ] Humid continental
- [ ] Subarctic/ Tundra
- [ ] Highland
- [ ] Oceanic
- [ ] Other / do not know/ multiple regions

18. **If other/ multiple regions specify**

19. **Orthologues in other species**
Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other:

20. **If yes, specify**

21. **Bibliographic references for orthologues (PMID/ DOI/ Other identifiers)**

22. **Transferability potential/ existing examples of transferability?**
Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other:

23. **If yes, specify**

24. **Bibliographic references for examples of transferability (PMID/ DOI/ Other identifiers)**

25. **Subtask** *
Mark only one oval.

- ◯ Yield *After the last question in this section, skip to question 103.*
- ◯ Nutritional quality *After the last question in this section, skip to question 30.*
- ◯ Sustainability *After the last question in this section, skip to question 149.*

26. **Relevance to subtask** *
How does this example fit into the subtask (yield, nutrition or sustainability)? Short description for qualification purposes.

_____

27. **Does this gene/ trait involve or affect other subtasks? If yes, state which one(s):** *
Check all that apply.

- ☐ Yield
- ☐ Nutrition
- ☐ Sustainability
- ☐ No, it does not

28. **If yes, how?**

_____

29. **GENERAL COMMENTS**
Please include any comments that might be relevant to this entry. If documenting a review, please emphasise the pathways reviewed , relevance to cropBooster-P

_____

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Subtrait Nutrient Quality

30. **Nutrient Class** *
Mark only one oval.

- ◯ Protein *Skip to question 31.*
- ◯ Carbohydrate *Skip to question 39.*
- ◯ Oils and fats *Skip to question 46.*
- ◯ Minerals *Skip to question 65.*
- ◯ Vitamins *Skip to question 72.*
- ◯ Specialized metabolites *Skip to question 55.*
- ◯ Antinutrients *Skip to question 83.*
- ◯ Toxic compounds *Skip to question 90.*
- ◯ Fibre/feedstock *Skip to question 97.*

Protein

31. **Protein Category** *
Check all that apply.

- ☐ Amino acids
- ☐ Peptides
- ☐ Enzymes
- ☐ Storage proteins- gliadines/ glutenines
- ☐ Storage proteins- general
- ☐ Other

32. **If other, specify**

33. **Type of amino acid**
Check all that apply.

- [ ] Isoleucine
- [ ] Leucine
- [ ] Lysine
- [ ] Methionine
- [ ] Phenylalanine
- [ ] Threonine
- [ ] Valine
- [ ] Argenine
- [ ] Tryptophan

If other, specify

34. **Factors affecting nutritional quality** *
Please select the nutritional quality factors affected/ modified by the current entry
Check all that apply.

- [ ] Sulfur deficiency
- [ ] Nitrogen deficiency
- [ ] Digestibility
- [ ] Heat stress
- [ ] Drought stress
- [ ] Fermentation properties
- [ ] None of the above/other factors/don't know, can't say

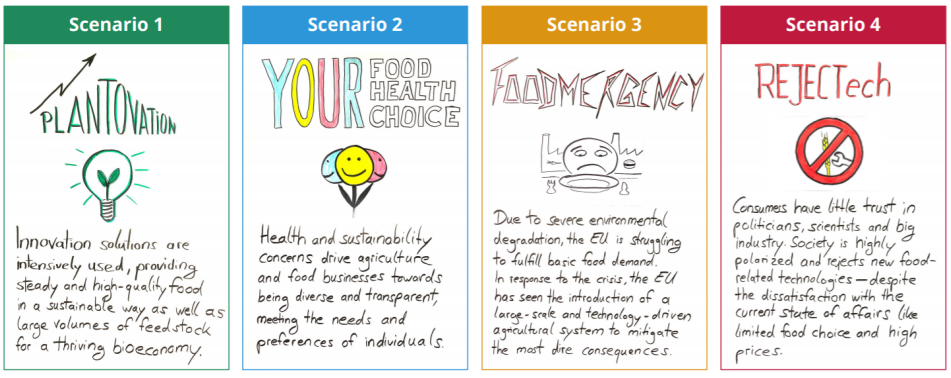
35. **If other, specify**

36. **Comments**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



37. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

38. **Comments to the scenarios**

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Stop filling out this form.

Carbohydrate

39. **Carbohydrates** *
Check all that apply.

- [ ] Sugars
- [ ] Oligosaccharides
- [ ] Polysaccharides

40. **Type of nutrient** *
Check all that apply.

- [ ] Monosaccharides
- [ ] Disaccharide
- [ ] Polyols
- [ ] Starch
- [ ] Non- starch polysaccharides
- [ ] Non- starch glycogen
- [ ] Other: _____

41. **Factors affecting nutritional quality** *
Please select the nutritional quality factors affected/ modified by the current entry
Check all that apply.

- [ ] Stress - UV radiation
- [ ] Stress - light intensity and photoperiod
- [ ] Stress - Water high or low
- [ ] Stress - heat
- [ ] Stress - high nitrogen
- [ ] Genetic variation
- [ ] Genes affecting biosynthesis/regulation/transport/
- [ ] Metabolism
- [ ] Biomass allocation
- [ ] Sulfur deficiency
- [ ] Nitrogen deficiency
- [ ] Digestibility
- [ ] Fermentation properties
- [ ] Stress - other
- [ ] None of the above/other factors/don’t know, can’t say

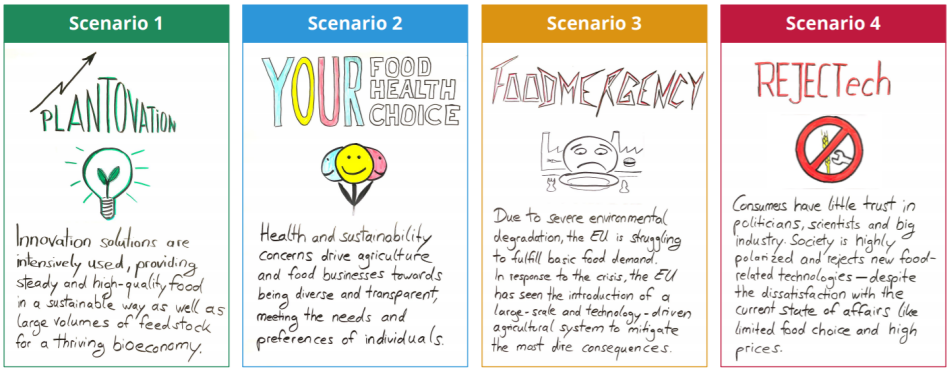
42. **If other, specify**

43. **Comments**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



44. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

45. **Comments to the scenarios**

Stop filling out this form.

Oils and Fats

46. **Type** *
Check all that apply.

- [ ] Sterols
- [ ] Saturated fatty acids
- [ ] Unsaturated fatty acids
- [ ] Long chain polyunsaturated fatty acids
- [ ] Monohydroxy fatty acid derivatives
- [ ] Crude extract
- [ ] Other

47. **If other, specify**

48. **Fatty Acid type**
Check all that apply.

- [ ] Myristic
- [ ] Palmitic
- [ ] Stearic
- [ ] Oleic
- [ ] Linoleic
- [ ] α linoleic
- [ ] Other

49. **If other, specify**

50. **Factors affecting nutritional quality** *
Please select the nutritional quality factors affected/ modified by the current entry
Check all that apply.

- [ ] Structural characteristics - Stability - heat
- [ ] Structural characteristics- Stability - light
- [ ] Structural characteristics Stability - humidity
- [ ] Molecular characteristics - Antioxidant capacity
- [ ] Accumulation - storage root
- [ ] Accumulation - seed
- [ ] Accumulation - shoot system
- [ ] Accumulation - root system
- [ ] None of the above/other factors/don't know, can't say

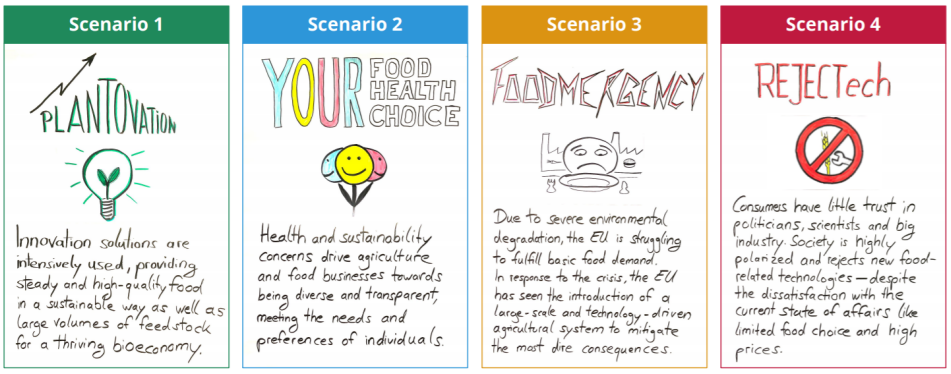
51. **If other, specify**

52. **Comments**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



53. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

54. **Comments to the scenarios**

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Stop filling out this form.

Specialized metabolites

55. **Secondary metabolites-**
plant based compounds that play a potentially nutritive role / in the prevention and treatment of disease
Check all that apply.

- [ ] Organic acids
- [ ] Bioactive compounds
- [ ] terpenoids
- [ ] glucosinolates
- [ ] phenolics

56. **If other, specify**

_____

57. **Low molecular weight antioxidant**
Check all that apply.

- [ ] glutathione
- [ ] ascorbate
- [ ] Other: _____

58. **If other, specify**

_____

59. **Comments to entry**

_____

60. **Factors affecting nutritional quality**
Please select the nutritional quality factors affected/ modified by the current entry
Check all that apply.

- [ ] Stress - UV radiation
- [ ] Stress - light intensity and photoperiod
- [ ] Stress - flood
- [ ] Stress - drought
- [ ] Stress - heavy metal
- [ ] Stress - high nitrogen
- [ ] Biostimulants
- [ ] Microbes in rhizosphere
- [ ] intra/inter-species variation
- [ ] Genes affecting biosynthesis/regulation
- [ ] None of the above/other factors/don't know, can't say

61. **If other, specify**

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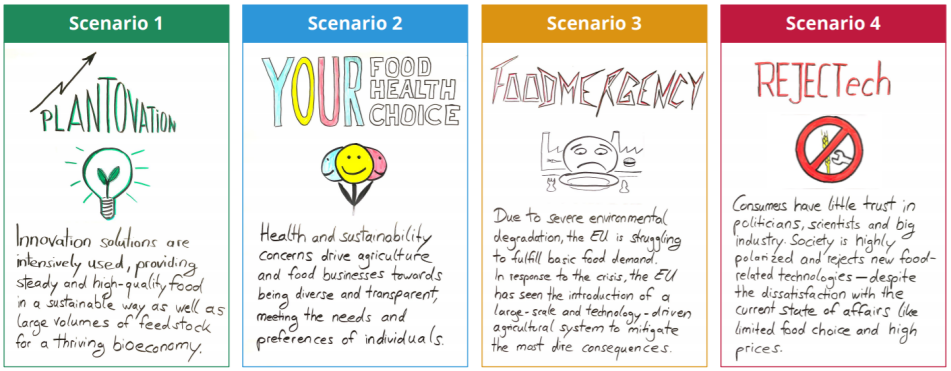
62. **Comments to entry**

_____

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



63. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

64. **Comments to the scenarios**

Stop filling out this form.

Minerals

65. **Macronutrient**
Check all that apply.

- [ ] Nitrogen
- [ ] Phosphorous
- [ ] Potassium
- [ ] Calcium
- [ ] Sulfur
- [ ] Magnesium

66. **Micronutrient**
Check all that apply.

- [ ] Iron
- [ ] Chloride
- [ ] Potassium
- [ ] Manganese
- [ ] Zinc
- [ ] Iodine
- [ ] Selenium

67. **Factors affecting nutritional quality** *

Please select the nutritional quality factors affected/ modified by the current entry
Check all that apply.

- [ ] Stress- heat
- [ ] Stress-cold
- [ ] Stress- high humidity
- [ ] Stress- flood
- [ ] Stress- drought
- [ ] Stress-salinity
- [ ] Stress-toxicity
- [ ] Stress-other
- [ ] Stress- nutrient overload
- [ ] Stress- Nutrient deficiency
- [ ] Stress- soil toxins
- [ ] Stress- soil composition
- [ ] Stress- pH
- [ ] Fertilizer- form
- [ ] Fertilizer-quality
- [ ] Biostimulants
- [ ] Geographical factors
- [ ] Bioavailability
- [ ] Microbes- in rhizosphere
- [ ] Microbes-fertilizer use efficiency- nitrogen fixation
- [ ] Sulphur nutrition
- [ ] Pathogen toxins
- [ ] Intra species cultivar- specific variation
- [ ] Uptake and allocation to edible organs
- [ ] Membrane transporters
- [ ] Efflux proteins
- [ ] Organic molecule synthesis
- [ ] Stress- transposable elements
- [ ] None of the above/other factors/don't know, can't say

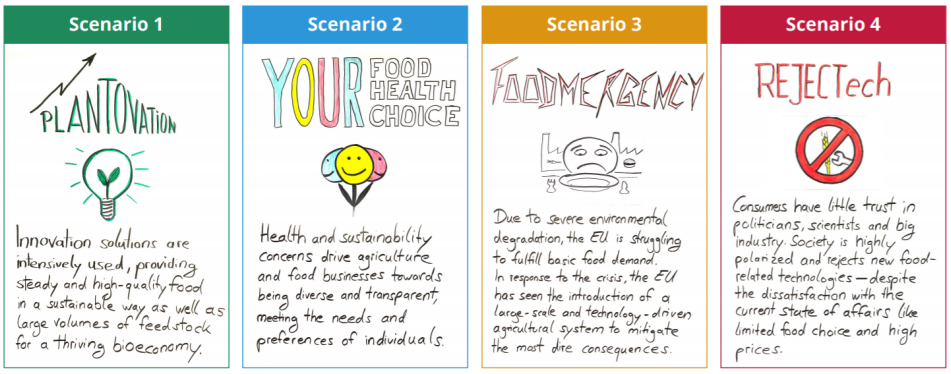
68. **If other, specify**

69. **Comments to entry**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



70. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

71. **Comments to the scenarios**

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Stop filling out this form.

Vitamins

72. **Vitamin A**
Check all that apply.

- [ ] α-Carotene
- [ ] β-Carotene
- [ ] β-Cryptoxanthin

73. **Vitamin B**
Check all that apply.

- [ ] Thiamine
- [ ] Riboflavin
- [ ] Niacin
- [ ] Pantothenic acid
- [ ] Pyridoxal
- [ ] Biotin
- [ ] Folates
- [ ] Cobalamin

74. **Vitamin C**
Check all that apply.

- [ ] Ascorbate

75. **Vitamin E**
Check all that apply.

- [ ] Tocopherols
- [ ] Tocotrienols

76. **Vitamin K**
Check all that apply.

- [ ] Phylloquinone

77. **If other, specify**

_____

78. **Factors affecting nutritional quality**
Please select the nutritional quality factors affected/ modified by the current entry
Check all that apply.

- [ ] Antioxidant potential
- [ ] Enzymatic cofactor
- [ ] Redox chemistry
- [ ] Enzyme protection
- [ ] Enzyme precursor
- [ ] Biosynthesis of enzymes
- [ ] Root uptake
- [ ] Membrane transporters
- [ ] Nitrogen fertilizers
- [ ] Oxidative stress
- [ ] Component of biological pathway
- [ ] Application of polyamines
- [ ] Stress-temperature
- [ ] Stress-other
- [ ] Pathogen toxins
- [ ] Bioavailability
- [ ] Digestability
- [ ] None of the above/other factors/don't know, can't say

79. **If other, specify**

_____

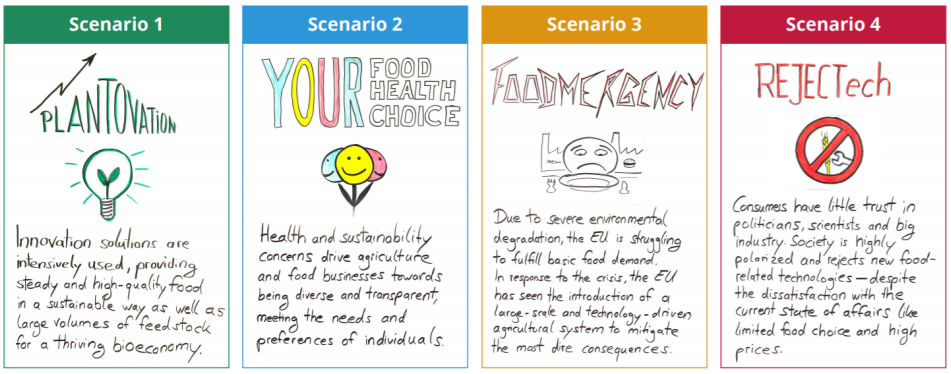
80. **Comments to entry**

_____

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



81. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

82. **Comments to the scenarios**

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Stop filling out this form.

Antinutrients

83. **Category** *
Check all that apply.

- [ ] Proteinaceous antinutrients
- [ ] Non proteinaceous antinutrients

84. **Types** *
Check all that apply.

- [ ] Protease inhibitors
- [ ] Amylase inhibitors
- [ ] Lipase inhibitors
- [ ] Lectins
- [ ] Ribosome Inactivating Proteins
- [ ] Phytate
- [ ] Oxalates
- [ ] Phenolics (tannins, gossypol, other phenolics)
- [ ] Glucosinolates
- [ ] Dietary fibre

85. **Factors affecting nutritional quality** *

Please select the nutritional quality factors affected/ modified by the current entry
Check all that apply.

- [ ] Intra-species variation
- [ ] Inter-species variation
- [ ] Genes affecting biosynthesis
- [ ] Genes affecting regulation
- [ ] Exogenous factors affecting synthesis and stability
- [ ] Genes affecting biosynthesis/regulation
- [ ] Genes affecting transport/metabolism
- [ ] Transport/competition with mineral nutrients
- [ ] Enzyme inhibitors
- [ ] None of the above/other factors/don't know, can't say

86. **If other, specify**

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87. **Comments to entry**

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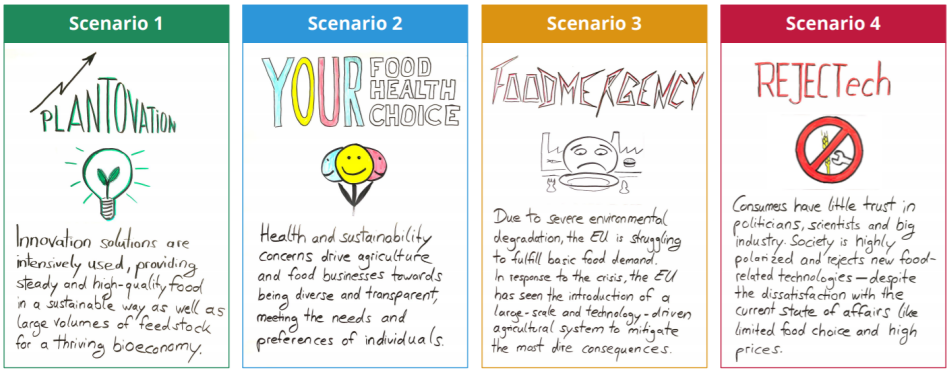
Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



88. **Under which scenarios would this entry have special relevance?**

Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

89. **Comments to the scenarios**

Stop filling out this form.

Toxic compounds

90. **toxic compounds**
Check all that apply.

- [ ] Elements
- [ ] Metabolites

91. **Type**
Check all that apply.

- [ ] Nitrate
- [ ] Heavy metals- Arsenic
- [ ] Heavy metals-Lead
- [ ] Heavy metals- Cadmium
- [ ] Cyanogenic glycosides
- [ ] Saponins
- [ ] Alkaloids
- [ ] Coumarins

92. **Factors affecting nutritional quality** *
Please select the nutritional quality factors affected/ modified by the current entry
Check all that apply.

- [ ] Intra-species variation
- [ ] Inter-species variation
- [ ] Genes affecting biosynthesis
- [ ] Genes affecting regulation
- [ ] Exogenous factors affecting synthesis and stability
- [ ] Genes affecting biosynthesis/regulation
- [ ] Genes affecting transport/metabolism
- [ ] Transport/competition with mineral nutrients
- [ ] Enzyme inhibitors
- [ ] None of the above/other factors/don’t know, can’t say

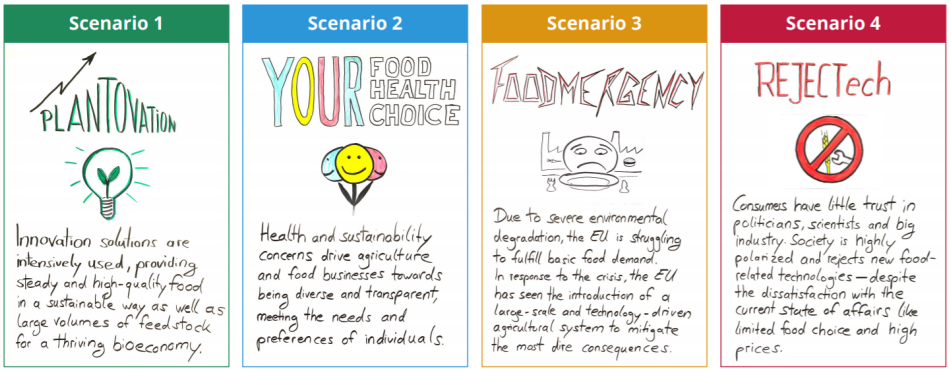
93. **If other, specify**

94. **Comments to entry**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



95. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

96. **Comments to the scenarios**

Stop filling out this form.

Fibre/ feedstock

97. **Type** *
Check all that apply.

- [ ] Ethanol content
- [ ] Digestibility
- [ ] Lignin content
- [ ] Lipid content
- [ ] Fatty acid content
- [ ] Fatty acid composition
- [ ] Alkyl ester content
- [ ] Butanol content
- [ ] Nutrient use efficiency (s)
- [ ] Water use efficiency (s)
- [ ] Acid detergent fibre
- [ ] Neutral detergent fibre
- [ ] Total dietary fiber

98. **Factors affecting nutritional quality** *
Please select the nutritional quality factors affected/ modified by the current entry
Check all that apply.

- [ ] Soluble/insoluble ratio
- [ ] Polymeric structure
- [ ] Protein content
- [ ] None of the above/other factors/don't know, can't say

99. **If other, specify**

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100. **Comments to entry**

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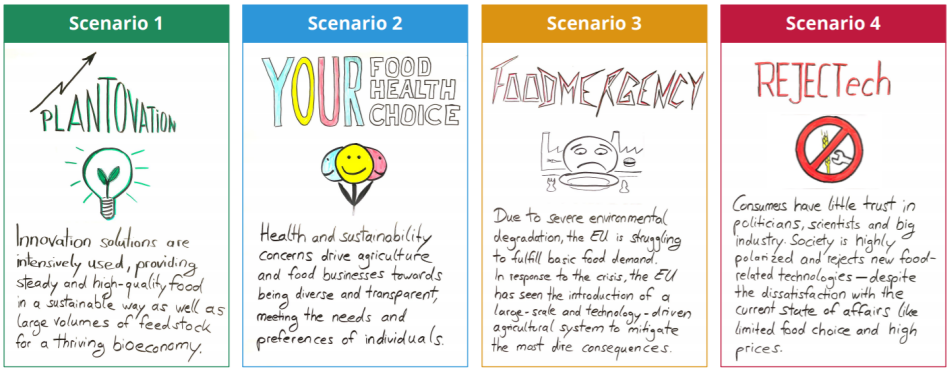
Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



101. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

102. **Comments to the scenarios**

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Stop filling out this form.

Subtrait Yield

103. **Class** *
Mark only one oval.

- ◯ Photosynthesis - photochemistry and biochemistry *Skip to question 104.*
- ◯ Uptake and spatial management of resources *Skip to question 114.*
- ◯ Sink/source activity *Skip to question 126.*
- ◯ Plant growth, architecture and phenology *Skip to question 134.*

Photochemistry and Biochemistry

Select relevant subtrait. Choose ONE option from the drop- down columns below that fits gene/ trait best.

104. **Photochemistry**
Check all that apply.

- ☐ Light harvesting
- ☐ Light capture optimisation
- ☐ Pigment composition
- ☐ Light use efficiency (electron transport)
- ☐ Other

105. **If other, specify**

106. **Biochemistry – Carbon assimilation**
Check all that apply.

- ☐ Stomatal aperture
- ☐ Rubisco and other Calvin cycle enzymes
- ☐ Photosynthetic limitations (cofactor, TPU)
- ☐ Chloroplast - cytosol transporters
- ☐ Sucrose - starch balance
- ☐ Photorespiration
- ☐ Dark (mitochondrial) respiration
- ☐ Photosynthetic pathway (C4, C3, CAM, C3-C4 intermediary)
- ☐ Sugar pathways
- ☐ Photoacclimation
- ☐ Photosynthetic induction
- ☐ Other

107. **If other, specify**

108. **Biochemistry - Photoprotection**
Check all that apply.

- ☐ NPQ
- ☐ Mehler reaction
- ☐ Repair pathways (Oxidative stress)
- ☐ Photosynthetic by-products
- ☐ Protective molecules
- ☐ Sugars and osmolytes
- ☐ Photosynthetic antioxidants
- ☐ Other

109. **If other, specify**

110. **Factors affecting yield**

Please select the yield factors affected/ modified by the current entry
Check all that apply.

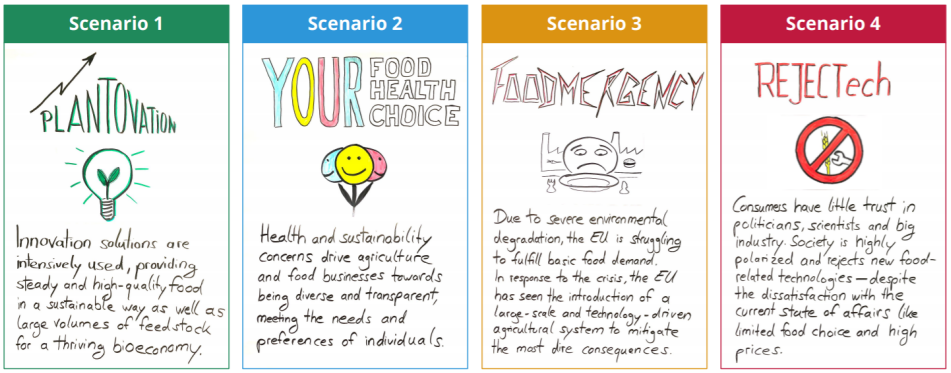
- [ ] Stress - Nutrient deficiency
- [ ] Stress - Nutrient overload/form/quality
- [ ] Stress - Drought
- [ ] Stress - Flood
- [ ] Stress - Heavy metals
- [ ] Stress - Salinity
- [ ] Stress - Heat
- [ ] Stress - Cold/frost
- [ ] Stress - pH
- [ ] Stress - O3, UV, oxidative
- [ ] Stress - Light
- [ ] Stress - Photoperiod
- [ ] Stress - Physical constraints (soil compaction, hail, wind, sun…)
- [ ] Stress - High humidity
- [ ] Stress - Soil composition
- [ ] Stress - Bio-stimulants
- [ ] Stress - Microbes in the rhizosphere
- [ ] Stress - Toxicity
- [ ] Stress - Soil toxins
- [ ] Geographical factors
- [ ] None of the above/other factors/don't know, can't say

111. **If other, specify**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



112. **Under which scenarios would this entry have special relevance?**

Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

113. **Comments to the scenarios**

Stop filling out this form.

Uptake and spatial management of resources

Select relevant subtrait:

114. **Water and Nutrient uptake/assimilation vs use**

Check all that apply.

- [ ] Water and Nutrients uptake (transporter channel regulators…)
- [ ] Other:

115. **If other, specify**

116. **Primary and secondary metabolism**

Check all that apply.

- [ ] Osmolites
- [ ] Proteins
- [ ] Metabolic compounds accumulation
- [ ] Other:

117. **If other, specify**

118. **Nutrient use efficiency (NutUE)**

Check all that apply.

- [ ] Local Water and Nutrients transport (root, stem and leaf tissues)
- [ ] Long distance Water and Nutrients transport (xylem)
- [ ] Nutrient metabolism
- [ ] Nutrient partitioning
- [ ] Nutrient storage
- [ ] Nutrients recycling
- [ ] Alternative metabolic pathways
- [ ] Ion homeostasis
- [ ] Other

119. **If other, specify**

120. **Heavy metals and salt**

Check all that apply.

- [ ] Uptake (transporter channel regulators…)
- [ ] Local and long distance transport metabolism
- [ ] partitioning
- [ ] storage
- [ ] Alternative metabolic pathways
- [ ] Ion homeostasis
- [ ] Other:

121. **If other, specify**

122. **Factors affecting yield**

Please select the yield factors affected/ modified by the current entry
Check all that apply.

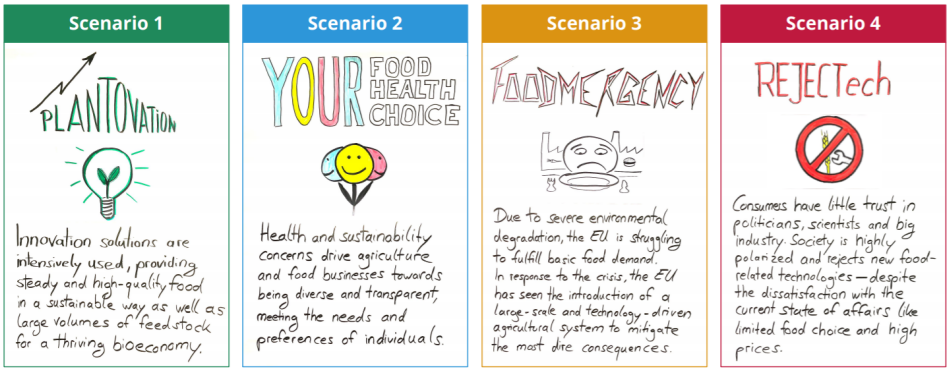
- [ ] Stress - Heat
- [ ] Stress - Cold
- [ ] Stress - High humidity
- [ ] Stress - Flood
- [ ] Stress - Drought
- [ ] Stress - Salinity
- [ ] Stress - Toxicity
- [ ] Stress - Nutrient overload
- [ ] Stress - Nutrient deficiency
- [ ] Stress - Soil toxins
- [ ] Stress - Soil composition
- [ ] Stress - pH
- [ ] Geographical factors
- [ ] None of the above/other factors/don't know, can't say

123. **If other, specify**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



124. **Under which scenarios would this entry have special relevance?**

Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

125. **Comments to the scenarios**

Stop filling out this form.

Sink/ source activity

Select relevant subtrait:

126. **Nutrient metabolism, transport, remobilization and partitioning**
Check all that apply.

- [ ] Sucrose metabolism (source)
- [ ] Nutrient metabolism (source)
- [ ] Water and nutrients storage
- [ ] Storage compound metabolism (source)
- [ ] Carbon transfer
- [ ] Nutrient transfer
- [ ] Coordination of C and Nutrient assimilation
- [ ] Other micronutrients
- [ ] Other

127. **If other, specify**

128. **Source sink balance**
Check all that apply.

- [ ] Sink to source feedback
- [ ] Source to sink feedforward
- [ ] Senescence of source organs
- [ ] Sink/grain development
- [ ] Seed filling
- [ ] Sensescence of sink organs
- [ ] Other

129. **If other, specify**

130. **Factors affecting yield**
Please select the yield factors affected/ modified by the current entry
Check all that apply.

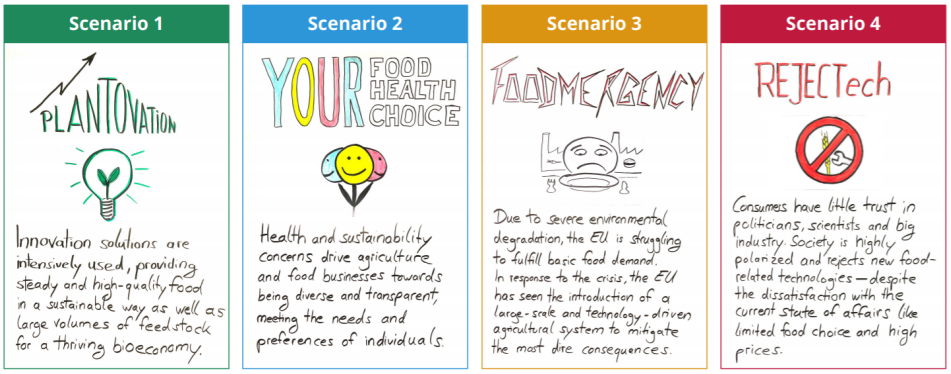
- [ ] Stress - Heat
- [ ] Stress - Cold
- [ ] Stress - High humidity
- [ ] Stress - Flood
- [ ] Stress - Drought
- [ ] Stress - Salinity
- [ ] Stress - Toxicity
- [ ] Stress - Nutrient overload
- [ ] Stress - Nutrient deficiency
- [ ] Stress - Soil toxins
- [ ] Stress - Soil composition
- [ ] Stress - pH
- [ ] Geographical factors
- [ ] None of the above/other factors/don’t know, can’t say

131. **If other, specify**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



132. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

133. **Comments to the scenarios**

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Stop filling out this form.

Plant growth, architecture and phenology

134. **Shoot architecture anatomy and canopy profile**
Check all that apply.

- [ ] Phyllotaxy
- [ ] Self - shading
- [ ] Compactness
- [ ] Stem anatomy and composition
- [ ] Shoot and canopy hydraulics
- [ ] Vascular tissues anatomy (density, structure) and functionning
- [ ] Profile of photosynthetic resources
- [ ] Leaf angle (erectness)
- [ ] Leaf morphology/shape
- [ ] Organ length/width/strength
- [ ] Wound healing
- [ ] Other

135. **If other, specify**

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136. **Leaf anatomy and activity**
Check all that apply.

- [ ] Cuticular thickness
- [ ] Wax/cutin ratio and content
- [ ] Stomatal properties (morphology, densities, distribution, location and resistance)
- [ ] Mesophyll thickness
- [ ] Mesophyll conductance
- [ ] Mesophyll resistance
- [ ] Mesophyll structure
- [ ] CAM/C3/C4 intermediary structure
- [ ] Vascular tissues anatomy (density, structure) and functionning
- [ ] Leaf hydraulics
- [ ] Stomatal aperture and functioning regulation
- [ ] Organelle properties (density, positioning and movement)
- [ ] Cellular subcellular and Ultrastructural adaptations
- [ ] Wound healing
- [ ] Other

137. **If other, specify**

138. **Growth rate**
Check all that apply.

- [ ] Meristem activity
- [ ] Cell division
- [ ] Growth mechanics
- [ ] Cell expansion
- [ ] Cell wall composition
- [ ] Cell turgor
- [ ] Other

139. **If other, specify**

140. **Root architecture, anatomy and activity**
Check all that apply.

- [ ] Root length
- [ ] Root number (lateral, seminal, adventitious)
- [ ] Root growth angle
- [ ] Root density
- [ ] Root plasticity
- [ ] Root competition ability
- [ ] Root hydraulics
- [ ] Cell layer number
- [ ] Cells layers structure
- [ ] Aerenchyma (PCD)
- [ ] Cell division/elongation
- [ ] Cell wall composition
- [ ] Lignification, Suberisation
- [ ] Cellular subcellular and Ultrastructural adaptations
- [ ] Wound healing
- [ ] Storage capacity
- [ ] Respiration
- [ ] Exudation
- [ ] Other

141. **If other, specify**

142. **Root/shoot coordination**
Check all that apply.

- [ ] Root/shoot ratio
- [ ] Root/shoot transport and signalling
- [ ] Other

143. **If other, specify**

144. **Phenology**
Check all that apply.

- [ ] Reproductive switch
- [ ] Flower development/abortion
- [ ] Flowering time
- [ ] Flower number
- [ ] Fertilization and seed set efficiency
- [ ] Seed number/abortion
- [ ] Seed filling rate
- [ ] Inflorescence plasticity
- [ ] Early vigour
- [ ] Ageing/senescence/juvenility
- [ ] Plastid/chloroplast lifetime
- [ ] Stay-green
- [ ] Other

145. **If other, specify**

146. **Factors affecting yield**

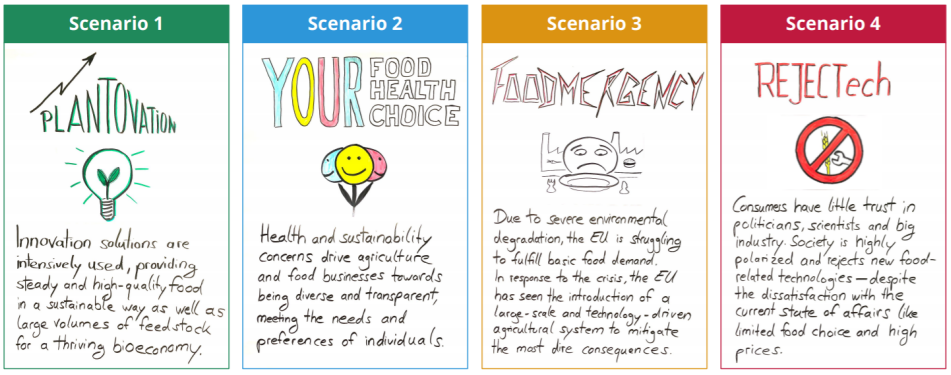
Please select the yield factors affected/ modified by the current entry
Check all that apply.

- [ ] Stress - Heat
- [ ] Stress - Cold
- [ ] Stress - High humidity
- [ ] Stress - Flood
- [ ] Stress - Drought
- [ ] Stress - Salinity
- [ ] Stress - Toxicity
- [ ] Stress - Nutrient overload
- [ ] Stress - Nutrient deficiency
- [ ] Stress - Soil toxins
- [ ] Stress - Soil composition
- [ ] Stress - pH
- [ ] Geographical factors
- [ ] None of the above/other factors/don't know, can't say

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



147. **Under which scenarios would this entry have special relevance?**

Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

148. **Comments to the scenarios**

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Stop filling out this form.

Subtrait Sustainability

149. **Class** *

Mark only one oval.

- ◯ Photosynthesis - photochemistry and biochemistry *Skip to question 104.*
- ◯ Uptake and spatial management of resources *Skip to question 114.*
- ◯ Sink/source activity *Skip to question 126.*
- ◯ Plant growth, architecture and phenology *Skip to question 134.*

Photochemistry and Biochemistry

Select relevant subtrait:

150. **Photochemistry**

Check all that apply.

- ☐ Light harvesting
- ☐ Light capture optimisation
- ☐ Pigment composition
- ☐ Light use efficiency (electron transport)
- ☐ Other

151. **If other, specify**

152. **Biochemistry – Carbon assimilation**

Check all that apply.

- ☐ Stomatal aperture
- ☐ Rubisco and other Calvin cycle enzymes
- ☐ Photosynthetic limitations (cofactor, TPU)
- ☐ Chloroplast-cytosol transporters
- ☐ Sucrose - starch balance
- ☐ Photorespiration
- ☐ Dark (mitochondrial) respiration
- ☐ Photosynthetic pathway (C4, C3, CAM, C3-C4 intermediary)
- ☐ Sugar pathways
- ☐ Photoacclimation
- ☐ Photosynthetic induction
- ☐ Other

153. **If other, specify**

154. **Biochemistry - Photoprotection**

Check all that apply.

- ☐ NPQ
- ☐ Mehler reaction
- ☐ Repair pathways (Oxidative stress)
- ☐ Photosynthetic by-products
- ☐ Protective molecules
- ☐ Sugars and osmolytes
- ☐ Photosynthetic antioxidants
- ☐ Other

155. **If other, specify**

156. **Factors affecting sustainability**

Please select the sustainability factors affected/ modified by the current entry
Check all that apply.

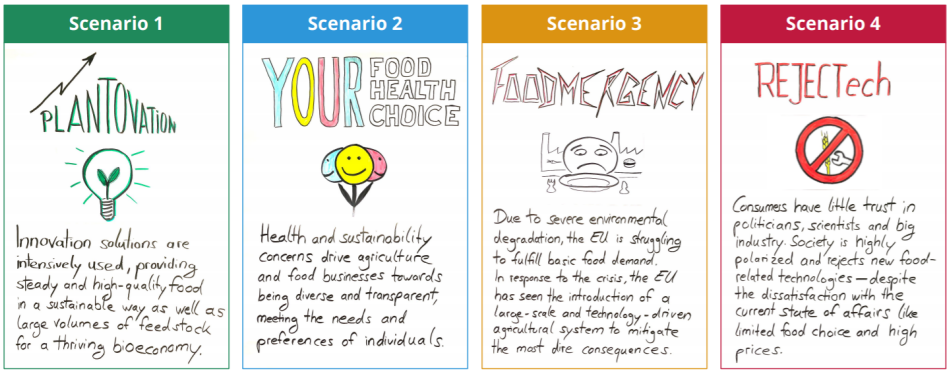
- [ ] Stress - Nutrient deficiency
- [ ] Stress - Nutrient overload/form/quality
- [ ] Stress - Drought
- [ ] Stress - Flood
- [ ] Stress - Heavy metals
- [ ] Stress - Salinity
- [ ] Stress - Heat
- [ ] Stress - Cold/frost
- [ ] Stress - pH
- [ ] Stress - O3, UV, oxidative
- [ ] Stress - Light
- [ ] Stress - Photoperiod
- [ ] Stress - Physical constraints (soil compaction, hail, wind, sun…)
- [ ] Stress - High humidity
- [ ] Stress - Soil composition
- [ ] Stress - Bio stimulants
- [ ] Stress - Microbes in the rhizosphere
- [ ] Stress - Toxicity
- [ ] Stress - Soil toxins
- [ ] Geographical factors
- [ ] None of the above/other factors/don't know, can't say

157. **If other, specify**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



158. **Under which scenarios would this entry have special relevance?**

Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

159. **Comments to the scenarios**

Stop filling out this form.

Uptake and spatial management of resources

Select relevant subtrait:

160. **Water and Nutrient uptake/assimilation vs use**

Check all that apply.

- [ ] Water and Nutrients uptake (transporter channel regulators…)
- [ ] Other:

161. **If other, specify**

162. **Primary and secondary metabolism**

Check all that apply.

- [ ] Osmolites
- [ ] Proteins
- [ ] Metabolic compounds accumulation
- [ ] Other:

163. **If other, specify**

164. **Nutrient use efficiency (NutUE)**

Check all that apply.

- [ ] Local Water and Nutrients transport (root, stem and leaf tissues)
- [ ] Long distance Water and Nutrients transport (xylem)
- [ ] Nutrient metabolism
- [ ] Nutrient partitioning
- [ ] Nutrient storage
- [ ] Nutrients recycling
- [ ] Alternative metabolic pathways
- [ ] Ion homeostasis
- [ ] Other

165. **If other, specify**

166. **Heavy metals and salt**

Check all that apply.

- [ ] Uptake (transporter channel regulators…)
- [ ] Local and long distance transport metabolism
- [ ] Partitioning
- [ ] Storage
- [ ] Alternative metabolic pathways
- [ ] Ion homeostasis
- [ ] Other:

167. **If other, specify**

168. **Factors affecting sustainability**

Please select the sustainability factors affected/ modified by the current entry
Check all that apply.

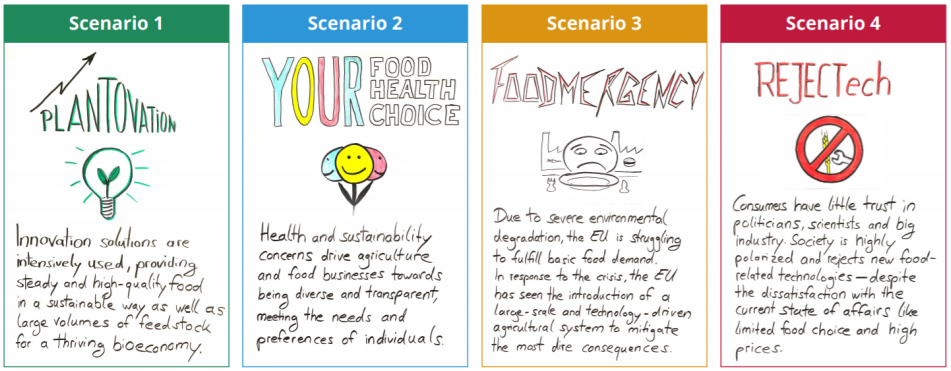
- [ ] Stress - Heat
- [ ] Stress - Cold
- [ ] Stress - High humidity
- [ ] Stress - Flood
- [ ] Stress - Drought
- [ ] Stress - Salinity
- [ ] Stress - Toxicity
- [ ] Stress - Nutrient overload
- [ ] Stress - Nutrient deficiency
- [ ] Stress - Soil toxins
- [ ] Stress - Soil composition
- [ ] Stress - pH
- [ ] Geographical factors
- [ ] None of the above/other factors/don't know, can't say

169. **If other, specify**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



170. **Under which scenarios would this entry have special relevance?**

Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

171. **Comments to the scenarios**

Stop filling out this form.

Sink/ source activity

Select relevant subtrait:

172. **Nutrient metabolism, transport, remobilization and partitioning**
Check all that apply.

- [ ] Sucrose metabolism (source)
- [ ] Nutrient metabolism (source)
- [ ] Water and nutrients storage
- [ ] Storage compound metabolism (source)
- [ ] Carbon transfer
- [ ] Nutrient transfer
- [ ] Coordination of C and Nutrient assimilation
- [ ] Other micronutrients
- [ ] Other

173. **If other, specify**

174. **Source sink balance**
Check all that apply.

- [ ] Sink to source feedback
- [ ] Source to sink feedforward
- [ ] Senescence of source organs
- [ ] Sink/grain development
- [ ] Seed filling
- [ ] Sensescence of sink organs
- [ ] Other

175. **If other, specify**

176. **Factors affecting sustainability**
Please select the sustainability factors affected/ modified by the current entry
Check all that apply.

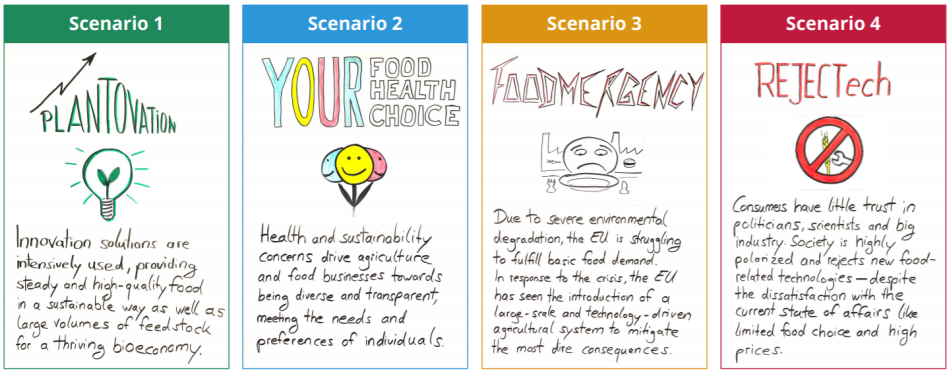
- [ ] Stress - Heat
- [ ] Stress - Cold
- [ ] Stress - High humidity
- [ ] Stress - Flood
- [ ] Stress - Drought
- [ ] Stress - Salinity
- [ ] Stress - Toxicity
- [ ] Stress - Nutrient overload
- [ ] Stress - Nutrient deficiency
- [ ] Stress - Soil toxins
- [ ] Stress - Soil composition
- [ ] Stress - pH
- [ ] Geographical factors
- [ ] None of the above/other factors/don’t know, can’t say

177. **If other, specify**

Application to Scenarios (WP 1.1)

Please share your thoughts about the scenarios under which the listed example is relevant. Subjective opinions are accepted here

Scenarios from the outcome of WP 1.1



178. **Under which scenarios would this entry have special relevance?**
Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

179. **Comments to the scenarios**

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Stop filling out this form.

Plant growth, architecture and phenology

180. **Shoot architecture anatomy and canopy profile**
Check all that apply.

- [ ] Phyllotaxy
- [ ] Self-shading
- [ ] Compactness
- [ ] Stem anatomy and composition
- [ ] Shoot and canopy hydraulics
- [ ] Vascular tissues anatomy (density, structure) and functionning
- [ ] Profile of photosynthetic resources
- [ ] Leaf angle (erectness)
- [ ] Leaf morphology/shape
- [ ] Organ length/width/strength
- [ ] Wound healing
- [ ] Other

181. **If other, specify**

_____

182. **Leaf anatomy and activity**
Check all that apply.

- [ ] Cuticular thickness
- [ ] Wax/cutin ratio and content
- [ ] Stomatal properties (morphology, densities, distribution, location and resistance)
- [ ] Mesophyll thickness
- [ ] Mesophyll conductance
- [ ] Mesophyll resistance
- [ ] Mesophyll structure
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- [ ] Vascular tissues anatomy (density, structure) and functionning
- [ ] Leaf hydraulics
- [ ] Stomatal aperture and functioning regulation
- [ ] Organelle properties (density, positioning and movement)
- [ ] Cellular subcellular and Ultrastructural adaptations
- [ ] Wound healing
- [ ] Other

183. **If other, specify**

184. **Growth rate**
Check all that apply.

- [ ] Meristem activity
- [ ] Cell division
- [ ] Growth mechanics
- [ ] Cell expansion
- [ ] Cell wall composition
- [ ] Cell turgor
- [ ] Other

185. **If other, specify**

186. **Root architecture, anatomy and activity**
Check all that apply.

- [ ] Root length
- [ ] Root number (lateral, seminal, adventitious)
- [ ] Root growth angle
- [ ] Root density
- [ ] Root plasticity
- [ ] Root competition ability
- [ ] Root hydraulics
- [ ] Cell layer number
- [ ] Cells layers structure
- [ ] Aerenchyma (PCD)
- [ ] Cell division/elongation
- [ ] Cell wall composition
- [ ] Lignification, Suberisation
- [ ] Cellular subcellular and Ultrastructural adaptations
- [ ] Wound healing
- [ ] Storage capacity
- [ ] Respiration
- [ ] Exudation
- [ ] Other

187. **If other, specify**

188. **Root/shoot coordination**
Check all that apply.

- [ ] Root/shoot ratio
- [ ] Root/shoot transport and signalling
- [ ] Other

189. **If other, specify**

190. **Phenology**
Check all that apply.

- [ ] Reproductive switch
- [ ] Flower development/abortion
- [ ] Flowering time
- [ ] Flower number
- [ ] Fertilization and seed set efficiency
- [ ] Seed number/abortion
- [ ] Seed filling rate
- [ ] Inflorescence plasticity
- [ ] Early vigour
- [ ] Ageing/senescence/juvenility
- [ ] Plastid/chloroplast lifetime
- [ ] Stay-green
- [ ] Other

191. **If other, specify**

192. **Factors affecting sustainability**

Please select the sustainability factors affected/ modified by the current entry
Check all that apply.

- [ ] Stress - Heat
- [ ] Stress - Cold
- [ ] Stress - High humidity
- [ ] Stress - Flood
- [ ] Stress - Drought
- [ ] Stress - Salinity
- [ ] Stress - Toxicity
- [ ] Stress - Nutrient overload
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- [ ] Geographical factors
- [ ] None of the above/other factors/don't know, can't say

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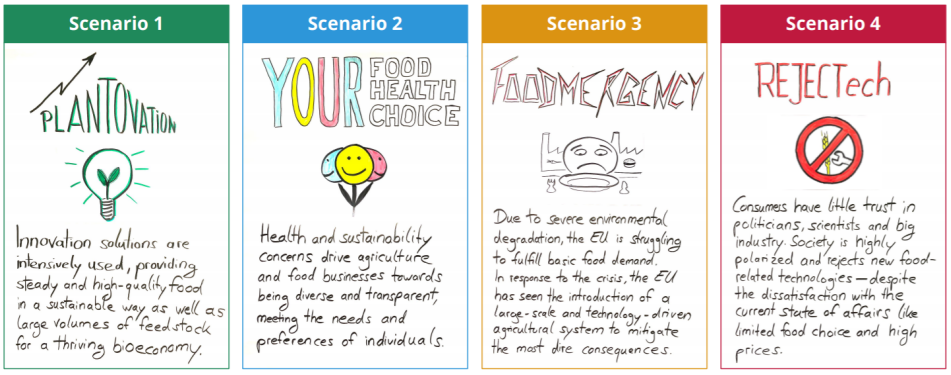

193. **Under which scenarios would this entry have special relevance?**

Check all that apply.

- [ ] Scenario 1
- [ ] Scenario 2
- [ ] Scenario 3
- [ ] Scenario 4

194. **Comments to the scenarios**