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Grant Proposal

B-GOOD: Giving Beekeeping Guidance by cOmputatiOnal-assisted Decision making

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Abstract

A key to healthy beekeeping is the Health Status Index (HIS) inspired by EFSA's Healthy-B toolbox which we will make fully operational, with the active collaboration of beekeepers, by facilitating the coordinated and harmonised flow of data from various sources and by testing and validating each component thoroughly. We envisage a step-by-step expansion of participating apiaries, and will eventually cover all EU biogeographic regions. The key to a sustainable beekeeping is a better understanding of its socio-economics, particularly within local value chains, its relationship with bee health and the human-ecosystem equilibrium of the beekeeping sector and to implement these insights into the data processing and decision making. We will fully integrate socio-economic analyses, identify viable business models tailored to different contexts for European beekeeping and determine the carrying capacity of the landscape. In close cooperation with the EU Bee Partnership, an EU-wide bee health and management data platform and affiliated project website will be created to enable sharing of knowledge and learning between scientists and stakeholders within and outside the consortium. We will utilise and further expand the classification of the open source IT-application for digital beekeeping, BEEP, to streamline

the flow of data related to beekeeping management, the beehive and its environment (landscape, agricultural practices, weather and climate) from various sources. The dynamic bee health and management data platform will allow us to identify correlative relationships among factors impacting the HSI, assess the risk of emerging pests and predators, and enable beekeepers to develop adaptive management strategies that account for local and EU-wide issues. Reinforcing and establishing, where necessary, new multi-actor networks of collaboration will engender a lasting learning and innovation system to ensure social-ecological resilient and sustainable beekeeping.

Keywords

Environment, resources and sustainability, Business models, Apiculture, Animal health, honey bee, health status index, beekeeping management, decision making, indicators, factors, IT-application, data flow, database platform, multi-actor approach

List of participants

You can find an overview of all B-GOOD beneficiaries in Table 1.

Table 1.
List of Beneficiaries.

No.	Name	Short name	Country	Project entry month	Project exit month
1	UNIVERSITEIT GENT	UGENT	Belgium	1	48
2	STICHTING WAGENINGEN RESEARCH	WR	Netherlands	1	48
3	DALL'OLIO RAFFAELE	BSOUR	Italy	1	48
4	PENSOFT PUBLISHERS	PENSOFT	Bulgaria	1	48
5	INSTITUT NATIONAL DE LA RECHERCHE AGRONOMIQUE	INRA	France	1	48
6	MARTIN-LUTHER-UNIVERSITAET HALLE-WITTENBERG	MLU	Germany	1	48
7	UNIVERSITATEA DE STIINTE AGRICOLE SI MEDICINA VETERINARA CLUJ NAPOCA	UCLUJ	Romania	1	48
8	AARHUS UNIVERSITET	AU	Denmark	1	48
9	UNIVERSIDADE DE COIMBRA	UCOI	Portugal	1	48
10	THE NOTTINGHAM TRENT UNIVERSITY	TNTU	United Kingdom	1	48

No.	Name	Short name	Country	Project entry month	Project exit month
11	FRIEDRICH LOEFFLER INSTITUT - BUNDESFORSCHUNGSINSTITUT FUER TIERGESUNDHEIT	FLI	Germany	1	48
12	UNIVERSITAET BERN	UBERN	Switzerland	1	48
13	STICHTING BEEP	BEEP	Netherlands	1	48
14	SUOMEN MEHILAISHOITAJAIN LIITTO SMLRY	SML	Finland	1	48
15	UNIWERSYTET JAGIELLONSKI	UJAG	Poland	1	48
16	SCIENSANO	SCIEN	Belgium	1	48
17	SCIPROM SARL	SCIPROM	Switzerland	1	48

Table 2.
B-GOOD's specific objectives.

WP1	To facilitate and standardize large scale data collection on honey bee health indicators and genepool charateristics across the EU, preferentially in an automated or semi-automated way and integrated with the EU Bee Partnership;
WP1	To combine ad hoc data input and laboratory analyses in a comprehensive pilot study in different representative EU member states;
WP2	To develop and test innovative technologies for monitoring honey bee colonies;
WP3	To enable data collection on external factors underpinning the landscape, land-use practices and environmental drivers in apiary localities, preferentially in an automated or semi-automated way;
WP3	To obtain insights into the apiculture-ecosystem equilibrium and to determine the carrying capacity of the environment;
WP4	To map the business environment and identify key socio-economic components of healthy and sustainable beekeeping in the EU;
WP4	To investigate how stakeholders and beekeepers assess and may overcome the business environment's complexity;
WP4	To assess production efficiency, (health) management decisions by beekeepers, and their personal, environmental and managerial determinants as the key to identify viable business models for sustainability of EU beekeeping;
WP5	To utilize past and present data and machine learning to identify correlative relationships in complex data, and between real world descriptive data and aspects of the Health Status Index;
WP5	To use and expand simulation tools developed by EFSA to make holistic assessments of the impacts of multiple stressors and drivers on bees;

WP5	To identify key risks and validate the various HSI components and to identify the most promising and relevant ones;
WP5	To perform context dependent risk assessment for bee colony management and to give guidance in decision making;
WP6	To develop and update an IT-application to streamline the incoming and outgoing data flow to support various functionalities (e.g. digital logbook, data progress report and decision making support);
WP7	To plan stewardship with, and communicate and disseminate the project results to, a dedicated group of actors, stakeholders and the public at large;
WP8	To facilitate multi-level and cross-sector actor/stakeholder partnerships and networks for beekeeping within Europe;
WP8	To engage multiple actors, from within diverse beekeeping systems, in collaborative research and development activities to ensure the resilience and sustainability of beekeeping in Europe;
WP8	To generate collective learning and establish a durable learning system that promotes creative thinking and multi-directional knowledge exchange for developing innovative beekeeping tools and business models;
WP9	To efficiently manage the project and ensure compliance with all EC requirements.

1. Excellence

1.1. Objectives

Overall aim – The overall aim of the 4-year B-GOOD project is to pave the way towards healthy and sustainable beekeeping within the EU. A key to healthy beekeeping is the Health Status Index (HSI), inspired by EFSA's Healthy-B toolbox. Honey bee health can be assessed by 'indicators' associated with colony attributes (e.g. amount of brood, disease load) and colony outputs (e.g. pollination service, honey harvest), and 'factors' associated with external drivers (e.g. resource providing units), which will be extended with a fourth set of components related to the honey bee gene pool (e.g. local adaption, subspecies, ecotype). We will make this enhanced HSI operational by working together closely with the EU Bee Partnership towards an automated or semi-automated data flow from various sources into a common EU-wide bee health and management data platform, and by testing and validating (or discarding) each component thoroughly, eventually leading to the objective selection of the most promising and relevant components. A key to sustainable beekeeping is interdisciplinary problem-solving research by integrating socio-economics and the human-ecosystem equilibrium of beekeeping with bee health, and to implement these insights into a dynamic learning and innovation system (LIS) to support beekeeper decision making.To reach this overall aim, B-GOOD will address the following specific objectives (Table 2) that are presented according to the work package framework of the project proposal:

1.2. Relation to the work programme

This B-GOOD project proposal fully addresses SFS-07-2018: *Making European beekeeping healthy and sustainable.* B-GOOD meets the specific challenges and scope of that topic as demonstrated below (Table 3) Note: the right-hand column can be read as a single piece of prose.

1.3. Concept and methodology

1.3.1. Concept

Overall concept – The B-GOOD project is in line with the vision, strategy and recommendations of the European Food Safety Authority (EFSA) and takes forward earlier initiatives from its internal and multidisciplinary task force (i.e. the Bee TF) and the Working Group (WG) MUST-B (EU efforts towards the development of a holistic approach for the risk assessment on MUltiple STressors in Bees) of the Scientific Committee for Emerging Risks (SCER). The latter highlighted the importance to EU risk assessment of greater harmonised data collection and data reporting and the need for enhanced dialogue and data sharing with stakeholders, EU Member States and institutional partners. This culminated in the launching of the EU Bee Partnership in November 2017. This new network will be directly involved in the execution of the B-GOOD project through partners within our team (partner 12) and EFSA MUST-B (partner 8). In harmony with these approaches, the B-GOOD project has identified five gaps that are currently hindering a cohesive and collaborative development of a holistic approach to improve the health of honey bee colonies and the sustainability of EU beekeeping. *Gap 1: Health Status Index* – A viable and practical HSI is needed. Beekeepers can estimate the health status of their colonies by visual inspection, but this is time consuming and disturbs colonies (causing behavioral stress and reduction of their social immunity). An improved approach (data model) is needed to share and standardise this information and maximise its usefulness. Semi automated and/or automated monitoring will add to its utility by reducing workload and colony disturbance. A common index for measuring and reporting honey bee health status, developed from the HEALTHY-B toolbox, will aid risk assessors, authorities and the plant protection and veterinary medicines industries, measuring health status in real time and across geographical locations, as well as measuring the effect of (beekeeping) management decisions and actions. It is an essential building block for the development of targeted guidance for healthy and sustainable beekeeping. *Gap 2: Socio-economics of beekeeping* – The socio-economics underpinning beekeeping must be better understood and form the basis of guidance. Studies on the socio-economics of beekeeping are scarce and mostly focused on single countries or regions. Determinants of economic performance differ substantially depending on the country, region, beekeeper and beekeeping characteristics, but systematic and consistent analysis integrating health and environmental characteristics is lacking. Beekeepers fall into two broad categories: professionals deriving their main income from the bees, and amateurs (the majority) with a small home apiary. Characteristics, values, interests, motives, business models and beekeeping management styles of these two groups differ, and a single professional business model and advice system may not benefit all beekeepers. Understanding their respective socio-economic goals and drivers of performance is therefore essential for deriving tailored advice and business models for beekeepers. These factors need to account for local and regional contexts in the development of blueprints for viable and sustainable business models. *Gap 3: Sustainable beekeeping* – The need for beekeeping to be sustainable involves both the development of management strategies to maintain bee health (correct identification and treatment of problems, and correct beekeeping practices) and understanding of the ecological balance between bees and the environment while safeguarding economic viability. Intensive stocking rates will decrease bee health during critical environmental resource bottlenecks. Integrating the approach of ecological balance with efficient data transfer and advice on bee health will maximise the sustainability of beekeeping. *Gap 4: EU-wide database platform* – Data access and sharing must be facilitated. Standardised data models derived from the HSI will provide the basis for quick and efficient data sharing across the EU. This provides benefits for beekeepers who can track bee health issues geographically close to them and apiculturally close to theirs. Optimised data sharing will also assist in testing hypotheses using observations from the wider network. This platform should integrate information available at the EU level, including information on farming, environment and socio-economics, to provide all relevant data for guiding decision making at local, regional and international scales. *Gap 5: Guidance in decision making* – Targeted guidance for beekeepers is needed, as neither they nor policy makers can be expected to sift through all the relevant information in the data platform and come to an informed decision. This guidance needs to be targeted towards the aims and motivation of the actors, it must be easily accessible, and it should be supported by detailed analysis protocols to provide information on recommended actions for beekeepers and other actors at local and regional scales.

Table 3.

Relation to the work programme.

<table>
<tr><td>Specific challenges in the work programme</td><td>How the B-GOOD research programme addresses them</td></tr>
<tr><td>Lack of a holistic approach</td><td rowspan="2">B-GOOD paves the way towards healthy and sustainable beekeeping, by following a collaborative and interdisciplinary approach, merging data from multiple sources, from in and around beehives as well as wider socio-economic conditions. This approach will identify correlative relationships, to perform risk assessments and provide guidance for beekeepers to make more informed and better decisions in various contexts.</td></tr>
<tr><td>Key factors for healthy and sustainable European beekeeping are determined by what happens in or around hives</td></tr>
<tr><td>Proposals will develop ready-to-use tools for operationalising the 'Health Status Index'</td><td rowspan="2">A key to healthy beekeeping is the Health Status Index inspired by EFSA’s Healthy-B toolbox which we will make fully operational, with the active collaboration of beekeepers, by facilitating the coordinated and harmonised flow of data from various sources and by testing and validating (or discarding) each component thoroughly.</td></tr>
<tr><td>To develop and implement an action plan for a coordinated and harmonised approach to the collection of related data and information</td></tr>
</table>

Pilot study in different representative European countries to test, standardise and validate methods for measuring and reporting selected indicators and factors affecting bee health	We envisage a step-by-step expansion of participating apiaries, calling successively on our research partners, selected beekeepers and the broader beekeeper community, related stakeholders and networks. In a pilot study, we will combine field observations with laboratory analyses across EU regions covering the North-South and East-West axes.
Exploring the various socio-economic and ecological factors beyond bee health to provide comprehensive blueprints of successful business model(s) of European beekeeping	The key to sustainable beekeeping is a better understanding of its socio-economics, particularly within local value chains, its relationship with bee health and the human-ecosystem equilibrium of the beekeeping sector and to implement these insights into the data processing and decision making. We will fully integrate socio-economic analyses, identify viable business models tailored to different contexts for European beekeeping and determine the carrying capacity of the landscape.
To create an EU platform to collect and share knowledge of science and practice related to honey bees, their environment and agricultural and beekeeping practices Organising and coordinating data sets and standards relating to the environment and agricultural and beekeeping practices relevant to the monitoring of honey bee health and giving all relevant stakeholders access to such information.	In close cooperation with the EU Bee Partnership, an EU-wide bee health and management data platform and affiliated project website will be created to enable sharing of knowledge and learning between scientists and stakeholders within and outside the consortium. We will utilise and further expand the classification of the open source IT-application for digital beekeeping, BEEP, to streamline the flow of data related to beekeeping management, the beehive and its environment (landscape, agricultural practices, weather and climate) from various sources.
Interactions of stressors affecting honey bees and their relative contribution to colony losses emerging risks or pathogens (e.g. the small hive beetle, *Aethina tumida*, and the Asian hornet *Vespa velutina*)	The dynamic bee health and management data platform will allow us to identify correlative relationships among factors impacting the HSI, assess the risk of emerging pests and predators, and enable beekeepers' to develop adaptive management strategies that account for local and EU-wide issues.
A multi-actor approach bringing together beekeepers, bee inspectors, other stakeholders (e.g. plant growers) and scientists (including social scientists) is required	Using existing partnerships and networks, we will fully engage with a wide range of actors to share and integrate their expertise and interests. Reinforcing and establishing, where necessary, new multi-actor networks of collaboration will engender a lasting learning and innovation system (LIS) to ensure social-ecological resilient and sustainable beekeeping in Europe.
To give appropriate feedback to beekeepers both through dissemination and training	A targeted communication strategy for exploitation and dissemination will be created, helping maximise the uptake and impact of the project results, which will include usage of a language familiar to stakeholders.

	We make use of traditional printed media, tailored training workshops/programmes, as well as web-based platforms (project website and bee health and management web portal, BEEP) to create a dynamic LIS.
To minimise the impact of biotic and abiotic stressors	The LIS will enable fact-based decision-making, based on real-time data inputs, for beekeepers and other stakeholders. Threshold values will be set in order to determine when a decision needs to be communicated to the end-user, through 'alerts'. This will enable adaptable and timely mitigation actions aimed at alleviating the impact of different stressors to which bees are exposed and tailored to local contexts.

Multi-actor approach (MAA) – B-GOOD will integrate the expertise and interests of a wide range of relevant actors to shed light on the context and circumstances (apicultural, environmental and socio-economic) under which the beekeeping sector operates in the EU. This will be achieved by instigating a multi-actor approach that fully engages with a wide array of actors. The identification and active involvement of actors from the start of the project will ensure relevant input in: 1) determining crucial objectives (research and bee management); 2) generating creative and innovative solutions to achieve these objectives; 3) facilitating vertical and horizontal collaboration for knowledge development and learning; 4) ensuring evaluation of outcomes by actors and scientists, fostering value focused innovations; 5) establishing a durable and adaptable innovation platform and learning system that is strengthened by multi-actor partnerships/networks. The B-GOOD MAA is as an overarching framework for collaboration and learning, detailed in WP8, that links multiple work packages. The foundations for the B-GOOD MAA is our strong consortium, which comprises of a rich mix of universities and research institutions, National Reference Laboratories for Bee Health (NRLs), a beekeepers' association, beekeeping practice centres and several Small and Medium-sized Enterprises (SMEs), including one apicultural consultancy body. Consortium partners are based in 13 EU Member States and cover the entire EU and beyond through their extensive networks. These partnerships and networks form the backbone of our MAA. They will be fully engaged in the co-creation of solutions, strengthened throughout the project's lifespan and, where necessary, new partnerships/ networks will be encouraged. Establishing multi-actor and multi-scale networks of collaboration will engender a lasting learning and innovation system to ensure social-ecological resilient and sustainable beekeeping in the EU.

Multi-disciplinarity – B-GOOD brings together highly-qualified scientists, who are recognised experts in the fields of apiculture, bee physiology and pathology, assay development, ecology, agricultural science, socio-economics, engineering, modelling and data mining, from both the public and private sector, and also five SMEs and one non-profit organisation. The combined expertise of the consortium partners will help deliver the holistic approach and impact for which we aim.

From 'idea to application' / From 'lab to market' – B-GOOD has identified a provisional list of targeted indicators and factors, classified on the basis of the current Technology

Readiness Levels (TRL) with their explicit data type (Aut = automated data collection; Man = manual data collection; Lab = data obtained from laboratory analyses) (Table 4). The subdivision in 'colony attributes', 'external drivers' and 'colony outputs' refers to the Healthy-B study ('gene pool' is novel). Those with a High relevance, High technical feasibility and High priority (H-HH) score, mainly corresponding to a TRL higher than 6, are considered 'ready-to-use' in WP1; those still 'under development' (TRL below 6) will be tested and validated within WP2/3/4.

Table 4.

Classification of indicators and factors based on Technology Readiness Levels (TRLs).

I. Colony attributes					
Definition	Ready-to-use = TRL > 6		Under development = TRL < 6		
	Description	Type*	Description	Type	WP
Presence of a queen	Visual verification	Man			
Potential fecundity	Presence of brood	Man	Vibration monitoring	Aut	2
Queen longevity	Queen marking	Man			
Colony size	Visual estimation	Man	Bee counter	Aut	2
Presence of brood	Visual estimation	Man	Vibration monitoring	Aut	2
Type of bee bread	Visual verificationPalynological techniques	ManLab			
Pesticides in bee matrices	Multi residue analysis	Lab	lateral flow device	Man	2
Metabolic activity			Gas analysis	Aut	2
Atypical worker behaviour	Visual identification	Man	Vibration monitoring	Aut	2
Thermoregulation	Remote sensing	Aut			
Colony foraging activity	Bee counter	Aut			
Clinical signs of diseases	Visual verification	Man			
European/American foulbrood	Microbiology	Lab			
Virus infection	Molec. fingerprinting	Lab	Lateral flow device	Man	2
Mite *Varroa destructor*	Visual verification	Man			
Small hive beetle *Aethina tumida*	Trapping	Man	Vibration monitoring		
Asian hornet *Vespa velutina*	Trapping	Man	Acoustic monitoring	Aut	2

II. External drivers					
Landscape features			GIS analysis	Aut	3
Farming practices			GIS analysis	Aut	3
Floral diversity/abundance			GIS analysis	Aut	3
Climate			Climate data	Aut	3
Colony management			Survey	Aut	3
III. Colony outputs					
Honey harvest	Hive/harvest weighing	Aut			
Pollination supply/demand	Field work	Man			
IV. Gene pool					
Subspecies/ecotype	MorphometryGenetic barcoding	LabLab			
Local adaptation	Pedigree	Man			
Disease tolerance/resistance	Mite population dynamicsMite reproduction	ManMan	Genetic footprinting	Lab	2
* Aut = automatic data collection; Man = manual data collection; Lab = laboratory analyses					

Ongoing EU projects – To ensure synergies with ongoing EU activities, the B-GOOD consortium contains leading scientists involved in key EU-funded and EU-led projects/ initiatives on risk assessment, bees and sustainable pollination (Table 5).

Table 5.

Former and ongoing EU projects with a link to B-GOOD.

Acronym (period)	Title (funding); function of B-GOOD partner(s)	Partners
POSHBEE (2018-2022)	Pan-European assessment, monitoring, and mitigation Of Stressors on the Health of BEEs (H2020); as members	5, 6, 8, 12
ECOSTACK (2018-2022)	Stacking of ecosystem services: mechanisms and interactions for optimal crop protection, pollination enhancement, and productivity (H2020); as deputy coordinator and WP leaders	8,9,15
MUST-B (2017-2021)	Holistic approach to the risk assessment of multiple stressors in honeybees (EFSA); as coordinator	8
SUPER-B (2014-2018)	Sustainable pollination in Europe (COST); vice-chair and members	2, 6, 12
SWARMONITOR (2013-2015)	Provide automated assessment of honey bee colony swarming status (FP7); as members	5, 10
EPILOBEE (2012-2014)	A pan-European epidemiological study on honey bee colony losses (EURL Bee Health); as partner	1

Acronym (period)	Title (funding); function of B-GOOD partner(s)	Partners
BEE-DOC (2010-2013)	Bees in Europe and the decline of honey bee colonies (FP7); as WP-leaders	1, 5, 6, 12
STEP (2010-2013)	Status and Trends in European Pollinators (FP7); as partners	4, 12
COLOSS (2008-2012; 2013 onwards)	Prevention of honey bee COlony LOSSes (COST); initially as chair, now as COLOSS president	1, 5, 6, 12
(since 2017)	EU Bee Partnership (Discussion Group under EFSA's new Stakeholder Engagement Approach framework); as invited member	12
(since 2018)	EU Pollinators Initiative	12

1.3.2. Methodology

Overview – B-GOOD encompass a very wide range of methodological approaches and domains, from detailed in-hive measurements and the development and application of technology to support it (WP1 and WP2), to stakeholder and beekeeper interviews and surveys (WP4) and policy assessment via the multi-actor approach (MAA) (WP8).

All work packages are linked with data-flows representing the key processes of data generation and transfer (see Fig. 3.1-6 and full details in all WP descriptions: Section 3.1 work plan).

Key aspects of these linkages are the generation of in-hive measurements and hive performance (WP1), which is supported by technological developments (WP2). These are facilitated by WP6's web-based tool development, which also provides direct linkages between data collection and analysis (WP5), dissemination, communication and the MAA (WP7 and WP8). This online innovation platform is provided for knowledge transfer to the stakeholders to develop viable and sustainable business models for beekeeping in different EU contexts (WP4). The platform is fed by data analysis, building on simulation modelling and machine learning. The simulation component is state-of-the-art honey bee modelling developed for EFSA, with scenarios and simulations developed in WP3, WP4 and WP5. However, this link is bi-directional, also feeding from the MAA to inform the analysis and modelling. Thus, B-GOOD develops not only an information flow from data to decision, but also incorporates value positions, actor and stakeholder objectives as integral components for defining its aims and activities, and evaluating progress.

Unique aspects of B-GOOD are:

- The wide spatial network of bee colony data collection, as well as close linkage to existing bee data networks;
- Development of autonomous hive-monitoring technologies and techniques using unique approaches such as accelerometers;
- The use of machine learning to identify relationships between the HSI and colony state;

- The simulation modelling that links data from the bee networks, B-GOOD data collection and socio-economic analyses to the MAA and desired outcomes of the actor networks and stakeholder groups, with unprecedented coverage over most of the EU;
- The utilization of the MAA as an integral part of the approach to the project, not simply to gather stakeholder input but as an interactive and iterative process of co-creation and co-development to agree on objectives and achieve realistic solutions for stakeholders, beekeepers, and policy makers;
- The development of a learing and innovation system for knowledge transfer, both to and from B-GOOD data collection and analysis and the MAA, involving and targeting EU beekeeper networks as a whole;
- B-GOOD's ambition to create a lasting impact by instilling collaboration and learning as an adaptive co-development system to sustain progress long beyond the timeframe of the project.

Outline of work packages

WP1: Beekeeping and Health Indicators; Lead partner: 2; major involved: most others

WP1 will provide the main infrastructure to collect data for bee health assessment and validation at the colony and apiary level, including different beekeeping business models. At the same time this infrastructure will disseminate knowledge from researchers to beekeepers, using a learning-by-doing approach. Learning-by-doing is known to be highly effective, and the best people to validate methods are the actual end-users. The WP1 infrastructure will consist of a step-by-step expansion of participating apiaries, calling successively on partner research institutions (Tier 1), selected beekeepers (Tier 2) and the broader beekeeper community (volunteers, Tier 3). Our goals are:

1. to develop a B-GOOD monitoring approach, for harmonized data collection,
2. to collected high quality data for HSI validation, and
3. to assess bee health in ample colonies of beekeepers to give them hands-on experience at B-GOOD monitoring.

Involving beekeepers will also lead to (indirect) publicity of B-GOOD monitoring to pan European beekeeping communities and networks, benifical for after the project ends.

Within each Tier, bee health will be assessed by:

1. systematically monitoring colony health indicators (colony attributes and colony outputs),
2. gaining insight in geographic genepool differences of colonies, and
3. to a more limited extend, by monitoring colony health factors (external drivers).

Monitoring will occur preferentially in an automated or semi-automated way, requiring the installation of different registration devices (remote sensing, bee counters, vibration monitoring). Each Tier will be a filter to the next Tier. Researchers in Tier 1 will collect data on indicators with high scores for relevance, technical feasibility and priority (H-HH in the Healthy B Toolbox). Novel health tools will be added that emerge from WP2, when the developmental stage was a success. This Tier execution by researchers will be complex and labour intensive, but lead to insight in the set of indicators that is most essential for bee health assessment and at the same which monitoring tools and protocol are the most bee- and user-friendly for the next Tier. The latter will be especially important for the installment and use of novel protocols and tools in every colony such as the BEEP Sensor System and electronic devices emerging from WP2. The insights obtained in WP2 will be matched with stakeholder views and opinions on what characterizes a healthy bee colony (WP4). Beekeepers in Tier 2 and 3 help validating the B-GOOD monitoring approach, while adding data on the most essential indicators. With each Tier the apiaries will cover more of European territory. Whereas in Tier 2 experienced beekeepers using pre-determined business models will be selected from a North- South axis, in the final Tier (Tier 3) volunteers from across EU regions (North-South and East-West axis) using any business model will participate.

In order to obtain high quality data collected, monitoring will be done in a harmonized and optimized way. A separation will be made between beekeeper and laboratory protocols. Beekeeper protocols will be used by beekeepers, e.g. for doing an observation or collecting a sample. At the end of the project these protocols will be validated by researchers for effectiveness and by beekeepers for self-explanatoriness and user-friendliness. Professional laboratory protocols, e.g. to determine disease load in a sample taken by a beekeeper, also need to be standardized, harmonized, and optimized. Outcomes need to be repeatable and of high quality, which can be obtained by accredited laboratories or by means of proficiency testing to allow laboratories to demonstrate or upgrade their performances. All data obtained will be transmitted to the EU-wide bee health and management data platform for validation of HSI and the decision making process for health assessment.

WP2: Beekeeping and Innovation; Lead partner: 10; major involved: 1, 2, 5, 8

WP2 will explore and develop innovative ways of monitoring honeybee hives, manually, semi-automatically, and automatically. Not all methods will necessarily help the colony health status assessment, but by feeding data acquired from WP2 into WP5, any new parameters that are important will be identified and clarified. The techniques investigated in WP2 have different Technology Readyness Levels (TRL); some will provide data within a month after the project start, others only by the end of the project.

All research work undertaken in WP2 has the potential

1. to rapidly benefiting a very large network of honeybee hives thanks to the expansion mechanism inherent in the B-GOOD three tier process described in WP1, and
2. to resulting in high impact scientific publications.

Whenever an exciting discovery is made in WP2, B-GOOD has all in place to promote it rapidly to maximum usefulness in practice, including:

1. possible IP protection under the supervision of the exploitation manager,
2. implementing on an existing commercial platform such as the BEEP hardware,
3. validating on a large array of honeybee hives exhibiting a statistically relevant distribution of climates, environments and bee strains,
4. self-sustained exploitation of the benefit by feeding it into the European Bee Partnership.

Most importantly, any research in WP2 may end up in directly (by providing a new important parameter) or indirectly (by demonstrating the importance of a previously known parameter) complementing the HSI.

The development required will occur in the existing laboratory/apiary of the leading partner(s), guaranteeing rapid progress and minimal additional investments, where electricity and internet is readily available.

Six major innovations, leading to a cascade of possible beneficial discoveries, will be investigated in depth in WP2, specifically the use of:

- in-hive accelerometers to produce long terms statistics of a range of honeybee pulsed waveforms;
- in-hive gas and spatially resolved temperature measurements, quantitating physiological activity and brood;
- bee counters providing outside-hive mortality rates, pollen flow, drone/worker discrimination;
- lateral flow devices to detect pesticide residues, outside and inside the hive;
- lateral flow devices to detect honeybee viruses of high health relevance;
- TaqMan Assays for genetic footprinting.

The FP7 project 'Swarmonitor' has shown that vibration monitoring by accelerometry is capable of sensing

1. the deterioration of the strength of a colony in winter,
2. the brood cycle on any frame of interest, indicating queen residence and laying, and
3. the presence of virgin queens.

It has also demonstrated potential in sensing the colony's intention to swarm (work in progress). In very recent studies, the method has been extended by recording raw vibrational traces in order to log individual honey bee vibrational pulses, four of which we can already be automatically discriminated (whooping, worker piping, queen piping). Because some of these pulses are intentional, and because they have a broad and finite repertoire, the monitoring of their long-term trends promises the development of a tool highly specific to any changes in the physiological status of the colony. In particular, we have strong evidence suggesting that we are detecting the density of laying workers in the colony, as both the previously published acoustic and body behaviours of this signal match our observations; simple and short manipulative experiments will allow us to test this. We have multiple lines of evidence that bees working on the wax honeycomb generate ultra-high vibrational pulses that we also detect. This strongly supports the concept of detecting the presence of small-hive beetles working in the honeycomb, either as larvae or adults hiding in empty cells, although it remains to be seen whether this can be discriminated against similar pulses from wax moths.

Entire honeybee colonies overwinter, allowing them to exploit early foraging opportunities in spring. This, however, comes at the cost of consuming honey reserves to maintain a minimum temperature in winter. The colony must balance the need for numerous workers against the cost of feeding them through winter. The food vs. temperature equation is a significant health status indicator, and we also suspect that the behaviour of individual bees is strongly dependent on the external temperature. This is modelled as part of WP5 in B-GOOD with the ApisRAM code, where every bee in a colony is individually tracked in time within a dynamic, spatially explicit thermal model. A 3D grid of temperature sensors in the brood box will provide the spatially resolved measurements that we need to optimise the model.

Another innovation is INRA's optical bee counter to record the real-time traffic of honeybees at the hive entrance (in- and out- activity of every single bee), thereby giving an absolute measurement of the within-colony mortality rate (subtracting exits and entrances). This tool was successfully used for analyzing bee activity and survival in response to different stressors in controlled conditions, and will be incorporated into B-GOOD automated monitoring. By carefully listening at the hive entrance, it is clear that the acoustic signature of a flying worker bee is easy to discriminate from that of

- a drone,
- a wasp, and
- a hornet such as the invasive Asian hornet (*Vespa velutina*).

We therefore also envisage integrating the use of a landing board microphone into recording of hive entrance flight activity as a means to detect the instantaneous density of bees and their pests at the hive's entrance.

Neonicotinoids are the insecticide class most used in agriculture, they are highly soluble in water and therefore have systemic action in plants. Because of this, they spread in the environment to contaminate entire eco-systems. Through its cooperation with a Chinese partner, RIKILT (a subdivision of WR) has access to a non-commercial dual Lateral Flow Device (LFD) that was designed to detect the neonicotinoids imidacloprid and acetamiprid. The dual LFD allows easy and fast detection of these molecules in plant materials within 10 minutes after a simple sample extraction and dilution in boiled water, does not require expert use, is inexpensive (11 € per assessment), has potential for rapid on-site detection, has been validated in cut flowers at concentrations ~1ng/mL, and shows relevant cross-reactions to thiacloprid, clothianidin, nitenpyram and imidaclothiz. However,

1. validation and relevance is required in plants foraged by honeybees,
2. two more neonicotinoids must be implemented in the test to cover the full range of globally available neonicotinoids,
3. it would be desirable for the system to work on bee matrices (e.g. honey, pollen or bee body),
4. improvements in sensitivities (e.g. for honey) are desireable and
5. it may be possible to extend the LFD detection to viruses.

Bee paralysis symptoms, trembling and crawling bees, and high honeybee mortalities (e.g. in front of the hive) can be caused either by pesticides or by viruses such as Chronic bee paralysis virus (CBPV) and the Acute bee paralysis virus (ABPV) - Kashmir bee virus (KBV)- Israeli acute paralysis virus (IAPV) complex, which are highly prevalent accross Europe. LFD is already used to detect several plant and animal pathogens and we will develop a novel LFD method to improve the diagnosis of viral disease in bees and discriminate it from pesticide intoxication, resulting in a useful tool for beekeepers or veterinary inspectors when observing such symptoms in this field.

Several European honey bee populations now exhibit resistance against varroatosis, evolved through natural selection. Recently, three such bee populations from Gotland (Sweden), Toulouse (France) and the Amsterdam Water Dunes (AWD; The Netherlands) were genetically fingerprinted and, from the latter two, the genetic variants associated with the resistant phenotype were identified (partner 1 and 6; papers submitted to *Nature Communications* and *Nature*, respectively). Partner 1 already studied the allelic frequencies of the AWD-specific footprint in the general bee population in Belgium by traditional Sanger sequencing. The study revealed a widespread distribution of all variants throughout bee colonies, indicating that they are not colony specific, which facilitates their use in centrally coordinated population-wide selection programs. Furthermore, on average, risk-causing mutations were found in more colonies (89%; 41/46 colonies) relative to protective mutations (43%; 20/46 colonies). In order to allow screening for protective SNPs (Single Nucleotide Polymorphisms) on a much larger scale (pan-European level; in WP1), we will develop in WP2 TaqMan Mutation Detection Assays (TaqMan MDA).

WP3: Ecology and Environmental Drivers; Lead partner: 9; major involved: 8, 15

WP3 will provide a dynamic landscape model across the EU, capturing the major floral resources for bees, considered a key driver influencing bee health status and crucial for a sustainable beekeeping. The model will be incorporated into the ApisRAM model (WP5) to predict changes in bee health status. This flower resource model will incorporate information on climate and management practices to create digital phenological maps of pollen and nectar resources for major land-use types important for bees across the EU. The model will be created by adopting a top-down approach by first identifying the major agricultural, forest and semi-natural landscape elements important for bees using advanced remote sensing tools and existing EU databases on crop and forest mapping and statistics (e.g., EUROSTAT, JRC MARS bulletins, Agri4Cast, and CAP crops statistics for crop areas, and EAFTS, EUFORGEN and EUFGIS for forest and semi-natural areas). Afterwards, an extensive assessment of floral phenology and their nectar and pollen resources at each major landscape element across the EU will be done using several floral databases (e.g., Pan European Phenology, ECOFLORA, Agriland database, International Phenological Gardens of Europe), complemented with experimentation for those key species where those values do not exist. The model will translate the phenological stage of each key species, their density and coverage, into daily nectar/pollen estimations for each typology of landscape element; these bee foraging activities are important to understand and model in ApisRAM. A bottom-up approach will then be used to calibrate and validate the model on eight different landscape scenarios in selected partner countries. The landscape scenarios will be built on 100 km2 landscape windows using detailed GIS data and management information from each landscape element obtained from national agricultural registers holding annually updated information on crop types, livestock and farm ownership. At each landscape window, a field assessment of flower resources in each landscape element type will be conducted using a detailed protocol applied on a short temporal scale (e.g. once a month) during the flowering season. For model validation, the data obtained from the field floral resource evaluation at the testing landscapes will be crosschecked with the data predicted from the phenology of floral resources model. After validation, the flower resource model will be tuned and upscaled to different countries representative of the major edaphoclimatic regions across the EU where an EFSA ApisRAM scenario is existing or will exist in a near future based on activities undertaken in WP5.

Simultaneously to the use of a detailed protocol for the field assessment of floral resources, a simplified “ready-to-use” protocol will also be developed to be used widely by beekeepers/beekeeper associations for a simple assessment of flower resources surrounding their apiaries. The design of this self-explanatory protocol will be aligned with WP1 and will be tested in pilot and field studies after validation within WP3.

The information on the temporal and spatial dynamics of flower resources created by the flower resources model will also be used to create landscape suitability maps for honey bees across Europe. These maps will translate the floral resources available for honey bees in different landscapes across Europe into “suitable landscapes” for honey bees. These can be further converted into landscape fitness for honey bees and in potential honey production maps. These maps could be used by local or national authorities when defining strategic areas for honey production or enhancement of pollination service.

WP4: Socio-Economic Drivers; Lead partner: 1; major involved: 2, 9

WP4 will assess the socio-economics of healthy and sustainable beekeeping, perform socio-economic analyses using qualitative and quantitative research methods, and identify viable and sustainable business models for European beekeeping while taking the national, regional, environmental, agricultural and policy context into account. To achieve these objectives, WP4 will collect data from multiple stakeholders and the wide diversity of beekeepers across the EU, who will also be actively involved – through participatory workshops in collaboration with WP8 – in the process of co-learning and the co-development of solutions and business models for sustainability.

First, following a management strategy and strategic planning approach, a SWOT/SOR-analysis and social-ecological inventory (SEI) of EU beekeeping will be performed. The SWOT within B-GOOD will be preceded by the application of the PrOACT protocol (Problem, Objectives, Alterantieves, Consequences, and Trade-offs) and extended with a SOR to fully exploit its potential, including a comprehensive mapping of the complexity of the business environment and identification of the key attention points for strategy development and business models for a healthy and sustainable European beekeeping sector. Stakeholders will be interviewed, giving specific attention to the identification of actors and networks (SEI) and the perceived strengths, weaknesses, opportunities and threats (SWOT) of beekeeping in the EU. Starting from the SWOT results, the procedure of a Strategic Orientation Round (SOR) will ask stakeholders to score the identified SWOT-components, leading to the identification of key attention points for strategy and business development.

Second, following a behavioural economics and micro-economic production efficiency approach, a comprehensive assessment of beekeepers' attitudes, behaviours and economic performance will be provided. By surveying beekeepers in selected EU countries, we will map their personal characteristics including attitudes, beliefs, perceptions, opinions and interests in relation to their business environment, the key characteristics and economic performance of their beekeeping practices, and the management characteristics such as their business objectives and plans, management styles and activities. Production efficiency will be assessed through data envelopment (DEA) and stochastic frontier analysis (SFA). Economic efficiency will be linked with colony health status data and ecological-environmental data through the specification and estimation of environmentally adjusted production efficiency (EAPE) models. Beekeepers will be segmented and the resulting beekeeper segments will be profiled to allow for targeted communication and advice. The factors that associate with management decisions and efficiency, which are hypothesized to consist of personal beekeeper characteristics (e.g. age, experience), beekeeping characteristics (e.g. number of hives), management (e.g. objectives, plans, activities) and environmental characteristics (e.g. landscape pattern, farming practices, floral diversity) will be assessed through regression analysis.

Third, following the business models for sustainability theorem and compliant with the multi-actor approach, B-GOOD will identify current business models and their characteristics, as well as set forth and validate potential and viable business models for healthy and sustainable EU beekeeping in the future. Insights from the stakeholder interviews and beekeeper surveys will be integrated to identify context-specific business models and plans for healthy and sustainable European beekeeping and provide recommendations and guidelines for communication and policy development. These business models will identify values and objectives (why?), products and services (what?) and markets (to whom?) in line with the key attention points for strategy development identified in the strengths, weaknesses, opportunities and threats (SWOT)-analysis. The resulting business plans will include amongst others a marketing plan and cost-benefit analysis, while taking into account possible constraints and boundaries such as environmental and ecological landscape conditions, or the presence or absence of public interventions. The feasibility and acceptability of the proposed business plans will be tested with beekeepers through participatory workshops.

WP5: Data Analysis and Decision Making; Lead partner: 8; major involved: 5, 17, 15

WP5 will provide data and analysis necessary to establish the relationship between environmental, biological and management drivers and bee health status. This will be achieved using top-down analysis using observed patterns in data to generate relationships, as well as a bottom-up approach in the form of mechanistic modelling with the same ultimate aim. These approaches are complimentary and thus provide a balanced approach to reducing uncertainty in the analysis and eventual relationships used by WP6 and WP8. Top-down methodologies will be in the form of statistical approaches and machine learning. Here, past and newly acquired data in B-GOOD will be used to identify correlative relationships in complex data, and between real world descriptive data and aspects of the HSI. In this task we postulate that a relationship exists, allowing us to relate a specific combination of parameters measured inside and outside the honeybee hive (the 'input'), to the colony instantaneous health status (the 'output'). Our goals are

1. to train computers to clarify this relationship, using a number of distinct well-established methods,
2. to assess the reliability of these methods on data that were not used in the training stage, and
3. to conclude on the degree of relevance of the input parameters.

In instances where outside-hive input data correlate well with inside-hive data, the approach may also provide

1. short term prediction of weather and
2. feedback to the agricultural sector (e.g. use of pesticides) both obtained from inside-hive data.

In concert with this machine-based approach, WP5 uses state of the art mechanistic modelling, leveraging the ALMaSS framework and the EFSA ApisRAM model for a honey bee colony, to develop scenarios and analyse the impact of management strategies of bees in their local context. The ALMaSS framework has been developed over 20 years to provide tools to evaluate human impact on wildlife and is used extensively for pesticide risk assessment. ALMaSS integrates multiple actors (including farming and governance) and multiple drivers to produce systems level predictions from detailed mechanistic representation of processes. It is agent-based and landscape-scale framework, but works at a highly detailed resolution. The model can replicate landscapes, including farm simulation at farm unit and individual field level, and works by simulating human actors and wildlife as agents. ApisRAM is the honey bee simulation model being developed for EFSA by partner 8. The ApisRAM model differs from all other existing bee models in that it represents the behavioural and energetic (including temperature) relationships between the bees and their environment in a highly detailed individual-based way. For example, using numerical analysis methods to implement a dynamic, spatially explicit thermal model. Nodal analysis, a method used by electrical engineers to solve these problems, is directly applicable, and ApisRAM makes use of the highly optimised SPICE computer code to perform calculations. ApisRAM uses an ALMaSS framework and utilises the bee forage resources modelled at a 1m2 resolution by WP3. Pollen and nectar are modelled as dynamic and limited resources changing daily and altered by the foraging of the bees. Bee foraging and communication is highly realistic and interactions between bees, forage and e.g. pesticides are a natural feature of the mechanistic approach, creating emergent dynamics in response to local conditions. ApisRAM also includes the beekeeper and biological agents (diseases and predators) as dynamic and configurable entities in the simulation.

The results of a wide range of scenarios and analyses based on landscape context from across the EU (WP3) will be analysed and a synthesis of these results will be fed forward to WP6 and WP8 for incorporation in the learning and innovation system. This will comprise a combination of relationships from the machine learning and meta-models of the ApisRAM simulations. Meta-modeling is an efficient way of alleviating the high computational cost and complexity for iterative function evaluation in design optimization. In B-GOOD we will use this approach to approximate the results of ApisRAM simulations to a simpler mathematical construct more easily used in web-based user-interfaces, allowing the results of complex simulation to be communicated to end-users without the need to actually run the simulation.

WP6: Operationalization and Application; Lead partner 13; major involved: 4

The B-GOOD **EU-wide bee health and management data platform** consists of three components: the digital bee data logbook, a database for (semi-) automated data acquisition and the web portal. The objective of WP6 is to operationalise the Health Status Index in the digital data logbook, to optimise the incoming (semi-)automatic data streams, to ensure reliable storage of data from different sources and formats, to share data and information online and finally integrate the decision support and to ensure sustained use of the tools and services developed in B-GOOD.

We will use user-driven product design. In collaboration with WP4 and WP8’s MAA, stakeholders will be involved in initial research right up to the end where they will be asked for their input and feedback. The development process will be iterative to ensure that the end result will be complete yet easy to use.

Data forms the foundation of this work package. A database architecture will be designed to ensure all data types needed, can be accommodated for. We provide a coordinated collaboration with existing EU-wide data platforms, e.g. those of MUST-B and the EU Bee Partnership, to prevent overlap and instead promote mutual enrichment and maximum complementarity, as well as contribute to the develop a bee data standard. Manually entered data will be stored in a normalised database built for that purpose, benefitting from easily extendable data classification. Automatically acquired data will be stored in a database designed for fast storage, retrieval and calculation of time-series data. The data and information gathered in the programme will be shared online – and anonymised where needed – via an EU-wide bee health data web portal. The portal development will make use of an established data portal template.

In this work package we wil technically facilitate the data streams and decision methodologies required and developed in WP1 and WP5 in close collaboration with these work packages. A modular and flexible approach will be chosen to be able to quickly and easily add new (automatic) data sources, protocols or decision-making methodologies for beekeepers to be efficient and effective in keeping colonies healthy. Details about data sources, data, procedures, standards and policies will be covered in B-GOOD's Data Management Plan (WP9).

The foundation for the collection of both manual, semi- and automatic beekeeping related data is the existing online platform, BEEP, of the Stichting Beep (partner 13; https://beep.nl) launched in July 2017 with over 1,000 users (August 2018). Originally developed as a digital logbook for beekeepers, its novelty comes from integrating manually entered data with (semi-)automatic data from sensors. It makes use of and shares the software under an open source license. Furthermore, it already contains a starting point for the standardised and extendable bee data classification. All of these key features combined make the BEEP digital beekeeping platform unique and the preferred tool of choice for B-GOOD as compared to alternative tools. We will continuously upgrade this IT-application in order to streamline the dataflow from B-GOOD, make the HSI fully operational and enable sustainable use of the developed tools, data and protocols after the B-GOOD programme ends.

Customisation of digital logbooks in the B-GOOD health and management data platform in combination with a bee data classification will ensure consistent and structured data acquisition. The data will be useful for both stakeholdes and the end-users (beekeepers), socio-economic analysis and scientific analysis. Bee health decision making will be incorporated in the data platform, practically giving beekeepers effective decision-making tools on their personal computer or tablets, and in their hands via the smartphone interface.

WP7: Communication and Exploitation; Lead partner: 12; major involved: 1, 4, 13

The aims of the activities of WP7 are (i) to maximise the external visibility and impact of the project to relevant actors, stakeholders, beekeepers and their associations, and policy makers and (ii) to ensure a smooth exchange of information between the partners of B-GOOD, the members of the Steering Committee (WP-leaders and selected stakeholders), the Advisory Board (selected stakeholders subdivided into three groups: practitioners, administrators and scientists), other ongoing EU projects (EU Bee Partnership, MUST-B, SMARTBEES, and POSHBEE), a diverse group of dedicated stakeholders (COLOSS) and the public at large. A targeted communication and dissemination strategy will be developed during the project that includes publications in scientific journals and beekeeping magazines, newsletters, abstracts in EIP-AGRI format, recommendations and policy briefs, social media coverage, the B-GOOD multi-lingual project website, with guaranteed permanent character, as a knowledge and learing resource and linked to existing initiatives and organizations, regional stakeholder meetings, thematic workshops, annual international conferences and training sessions. Each of the partner institutes involved in B-GOOD is closely connected with national and regional actor networks, stakeholder groups, and beekeeper associations. B-GOOD's communication will capitalise on these connections to ensure the widespread dissemination of its findings, and the adoption and application of its innovations in practice.

WP8: Multi-Actor Co-Management; Lead partner: 8; major involved: most others

WP8 will provide the framework and mechanisms to realise an inclusive, iterative and lasting multi-actor approach (MAA) for the B-GOOD project. The active participation of multiple actors and the use of networks is crucial for the co-creation of new knowledge, its wide scale transfer/dissemination and the co-design of new ground-breaking and adaptable beekeeping tools and strategies, to maximize the benefits for beekeepers, agriculture and society. This will be achieved by fully engaging multiple actors in the project, in conjunction with other work packages, facilitating collaboration and establishing a dynamic shared learning platform that enables innovation and adaption (e.g. flexible bee management tools and strategies for different contexts). Our multi-actor approach follows the guiding principles of the well-establish adaptive co-management framework. It will involve

1. engagement of a wide array of actors, in order to determine objectives, alternative actions to achieve these objectives and identify uncertainties amongst different actor groups;
2. gather and share knowledge to guide research and development strategies (e.g. beekeeping tools and business models;
3. sharing and evaluation of results and outcomes, to generate joint learning and enable adaptation of research as well as beekeeping developments;
4. establish a durable learning system and strengthen multi-actor partnerships/ networks.

To clearly define the social-ecological system and boundaries of the B-GOOD project an initially scoping study will be undertaken using actor network theory and a socio-ecological inventory (SEI) in collaboration with WP4. These methodologies focus on connecting people, artefacts, institutions and organizations and will provide data and improve our understanding of the various beekeeping systems (both professional and amateur) in the EU and their dynamics. By analysing and evaluating these systems and networks, missing links can be identified and rectified by building the capacity to enhance collaboration and learning. This will be facilitated in WP8 by engaging multiple actors in a series of national participatory workshops to be held in 5 EU countries. These workshops will provide opportunities to integrate scientific, expert and practical knowledge, as well as the interests of a wide range of relevant actors. Using the PrOACT protocol, a rigorous and formal method used in decision analysis, will enable participants to collectively frame the problems they face and generate individual and collective objectives, both management and research. This approach is intended to compliment the SWOT analysis in Task 4.1, helping participants think about and determine the consequences, trade-offs, risks and uncertainties of their envisaged objectives and possible beekeeping strategies/actions (alternatives) to achieve these. These workshops will also provide the means to strengthen existing partnerships and/or multi-actor networks that support beekeeping in the EU. Selected participants from these workshops (from a wide array of actor groups and from different countries) will be asked to act as representatives in the Multi-actor Forum. This forum will provide a conduit for vertical and horizontal flows of information, as well as a forum for collaborative reflection on learning and the outcomes management actions (knowledge development), enabling the adjustment actions (research or management) to aid further learning. The envisaged outcome of WP8 is the establishment of a co-knowledge and development cycle that is iterative and replicable, to create a lasting LIS that promotes social-ecological resilient and sustainable beekeeping in the EU.

WP9: Coordination and Management; Lead partner 1; major involved: all others

WP9 will comprehensively address all coordination and managerial aspects of B-GOOD. The activities cover the monitoring of scientific progress, as well as of communication and dissemination activities; risk analysis; decision-making as well as administrative, legal, financial, and data management issues. WP9 will also be responsible for the planning and organisation of consortium meetings, installation of the B-GOOD advisory boards; preparation and updating of the B-GOOD Data Management Plan; preparation of analyses proposal and publication plans; maintenance of the Grant Agreement and Consortium Agreement. The internal monitoring will be based on regular communication with appropriate consortium bodies. Team communication tools (Mattermost) will ensure effective within-project communication. All WPs will have Key Performance Indicators and clear milestones and deliverables to ensure that objectives are fully met.

Gender issues

The principle of equality between men and women. All B-GOOD participants support the principle of equality between men and women as a common value of the European Union. As enshrined in the Treaty on European Union (Treaty of Maastricht), Art. 2 and 3(3), equality between women and men is established as a specific task of the Community and is a horizontal objective affecting all Community tasks. We acknowledge and fully underscore that research must be carried out to contribute to an enhanced understanding of gender aspects and must address the needs of both men and women equally. Also, the participation of women must be encouraged both as scientists/technologists and within the evaluation, consultation and implementation process. Members of the B-GOOD consortium are fully aware and agree with the principles given in relevant EU position documents about gender aspects. These include: Treaty of Amsterdam signed in 1997, Women and science: Mobilizing women to enrich European Research, and the Framework Strategy on Gender Equality aimed at achieving equality including policies and specific actions for women.

Equal opportunities. The B-GOOD consortium strongly encourages the participation of women in research as scientists as well as within management, monitoring, consultation and implementation processes. In promoting equality between men and women in scientific research, B-GOOD will apply the concepts of 'Equal Opportunities' while keeping in mind the need to ensure scientific excellence. This will not only be ensured by encouraging women to participate at all decision levels in the B-GOOD project but also during recruitment of research, technical and administrative staff. Decisions on employment of new staff will be made on the basis of merit, regardless of gender, race, religion, marital status, family circumstances, age, sexual preferences or social class. All EU regulations on awarding maternity/paternity leaves during the course of the project will be fully respected. To lend credence to our efforts to increase equal opportunities, all participating beneficiaries have an active institutional equal opportunities policy and an excellent track record in this area. The exact participation of women in B-GOOD will be determined after the start of the project, when the recruitment process of additional staff is finished. Anyhow, all recruitment will follow the Code of Conduct as detailed in the European Charter for Researchers. Recruitment will be based on the Equal Opportunity principles, specifically to encourage applicants from both genders and minority groups and to avoid discrimination on the basis of age, disability, gender, race, religious observance or sexual orientation.

The gender dimension in the project execution. Beekeeping has often been considered as a male-dominated enterprise. However, more recently women are increasingly participating in training sessions, taking up beekeeping activities and leadership roles in beekeeping associations and networks. B-GOOD will further stimulate female involvement in beekeeping through balanced communication and dissemination activities. Both genders will be represented in the socio-economic study samples, in line with their distribution in the study population. Eventual gender effects, e.g. in terms of attitudes, beliefs, perceptions, interests, opinions, values or management styles in relation to beekeeping, will be analysed in the socio-economic studies of WP4. This will allow formulation of targeted advice and recommendations in case any significant gender effects are discovered, contributing to the fostering of equal involvement of men and women in future beekeeping in the EU.

1.4. Ambition

B-GOOD has identified 5 gaps (Section 1.3.1: Overall concept), and will provide key progress towards bridging each of these through combining existing and new technology and products originating from the project's activities. Below we give an overview of the state-of-the-art and the expected advances (Ambition) in each gap.

Gap 1: Health Status Index

State-of-the-art:

The key factor within a holistic approach towards healthy honeybee colonies in the EU is a better understanding of honeybee colony health and its relationship with the socio-economics of EU beekeeping and the human-ecosystem equilibrium. The three components of healthy colonies, viable socio-economic circumstances, and optimal human-ecosystem equilibria are essential preconditions for sustainable beekeeping. For decades, beekeepers have been troubled by bee health related problems (e.g. parasites, pathogens, reduction of resources) that cause high colony losses. These high losses do not only concern the beekeeping sector (Potts et al. 2010, Jacques et al. 2017, EPILOBEE), but are also of great societal and economic concern, as they are experienced as a sign of the vulnerability of the environment, including the service of crop pollination (Goulson et al. 2015).

However, due to the continuing crisis status of these high honeybee colony losses, the main focus lays at dead colonies and colonies at risk. Preventing loss and underpinning of the causes and the mechanisms is essential to avert this crisis. However, though losses have indeed been high, from a beekeepers perspective the majority of the colonies live. In addition to reducing losses, EU beekeepers are in dire need of information on all of their colonies. What is the health status of their colonies? How can they monitor this without disturbing the colonies to prevent health reduction due to monitoring activities? How to interpret the collected data? To act or not to act, when and how?

‘Health’ is a very complex and anthropogenic concept. The medical conception of health is “absence of disease” with the main elements biological function and statistical normality, where diseases are internal states that depress a functional ability below species-typical levels (Boorse 1977). However, health and illness can also be defined and conceptualized in a specific frame of reference (e.g. sociological or economic). The concept ‘health status’ is linked to social stratification, ethnicity, and situational factors (Twaddle 1974). To date, Huber et al. 2016 describe human health as a dynamic concept with 556 health indicators, categorised into six dimensions and 32 underlying aspects. In evolutionary biology, ‘health’ may be more related to survival and fitness of organisms, where fitness represents the quantitative reproductive success of a genotype, or a phenotype in a given environment. But fitness is also a very complex concept, especially in honeybee colonies, from the perspective of the evolution of eusociality (Nowak et al. 2010), where many individuals do not reproduce within the colony. Honeybee health, whether simply based on the absence or presence of disease, being the driver for survival or reproduction, or indicating the amount of ‘well-being’, it will be influenced by the environment in which the colonies are located and by the beekeeper who may choose to (not) intervene. This complexity at any point in time and space, does not surprisingly often lead to a lack of single causes for these colony losses, and the subsequent conclusion that ‘many contributing stressors may act in concert’ (Goulson et al. 2015).

To date, honey bee colony health, the underlying implications of interacting stressors and consequent effects of colony performance (including survival and reproduction), are generally studied by monitoring studies (Genersch et al. 2010, Francis et al. 2013, Meixner et al. 2014, van der Zee et al. 2015, Tsvetkov et al. 2017, Biesmeijer 2017, COLOSS, EPILOBEE), or by experimental colony exposure (Alaux et al. 2011, Pettis et al. 2012, Mariani et al. 2012, Blanken et al. 2015; van Dooremalen et al. 2018). However, though large in their set up, these studies still only show a result of one particular experiment, region, or country. General trends within highly standardized set ups may change when repeated at other locations or with a different type of honeybee. Moreover, most studies are difficult to compare or data sets are difficult to combine, e.g. for datamining, determining general trends, or finding general solutions for stress related losses, due to differences in set up or the use of a variety of protocols.

Ambition:

The Health Status Index (HSI) research activities within B-GOOD will expand previous insights providing innovation and advances in the following four domains compared to the state-of-the-art. First, the Health Status Index (HSI), inspired by EFSA's Healthy-B toolbox, within B-GOOD will build upon the integration at colony level of the colony attributes, colony outputs, external drivers (human-ecosystem equilibrium), operating within the context of genetic background of the colony and the preferred business model of the beekeepers. We propose to designate the superorganism level (colony) as the unit for health and distinguish between current and future health, including some preconditions.

- Current health: No clinical symptoms of disease (by visual inspection, supported with laboratory analyses). In addition, when food resources are available there should be brood in all stadia (BIAS) and (weather permitting) foraging activity present. When food resources are not present or forging activity is hampered, sufficient amount of storage of resources should be present to survive until this down period is lifted.
- Future health: the ability to survive (winter or other long periods of low resource availability) and reproduce (or willingness to reproduce) during the growing season.

Second, B-GOOD will make the Health Status Index (HSI) fully operational by building the primary infrastructure to facilitate the coordinated and harmonised flow of data from various sources and by testing and validating each component thoroughly. By linking all components at the colony level, and making each colony a complete monitoring unit, B-GOOD ensures a new holistic way of harmonised data collection with an almost limitless sample size potential in time and space. Eventually this will enable standardized measuring and reporting of bee health status in time and across numerous geographical locations. This monitoring approach will enable B-GOOD to discriminate between all components and gain a holistic insight in the complexity of the underlying mechanisms of bee health (building upon knowledge from e.g. COLOSS and EPILOBEE, while aligning with MUST-B).

Third, the infrastructure build by B-GOOD will facilitate the collection of harmonised data, essential to interpret the current health status, translate it to a prediction for the future health status and give computational-assisted guidance to beekeepers to support the maintenance or improvement of their colonies' health status. These components are essential to work towards sustainable beekeeping.

Fourth, the same infrastructure for monitoring bee health will in the project be used as a tool to disseminate knowledge from researchers to beekeepers and other stakeholders. By involving beekeepers in a citizen-science approach they will learn by doing about bee health, the environment in which they keep their bees and become aware of their socio-economic role, performance and optimal business model.

B-GOOD will develop a B-Health matrix composed of harmonized protocols and monitoring technologies, to facilitate large scale (pan European) harmonisation of data collection. This matrix will not only serve the project, but also the time beyond. Within our infrastructure of pilots and field studies we will develop, test and validate novel technologies for health monitoring, one of which is completely in line with the EU Bee Partnership recommendations: an autonomous hive monitoring system for non-invasive real-time data collection from multiple hives. This modular hardware platform will be extended with equipment for vibration monitoring by accelerometry, the basics of which have been laid out in the FP7 SWARMONITOR project. Although our work is inspired by EFSA's Healthy-B toolbox, which consists of sets of abiotic or biotic components, we introduce a fourth set related to the bee gene pool. This is consistent with recent scientific work indicating that locally adapted bees have greater vitality and that selection for resilient bees is possible. Moreover, B-GOOD further explores the pioneering work of partners 1 and 6 on genetic profiling of *Varroa*-tolerance.

Gap 2: Socio-economics of beekeeping

State-of-the-art:

The crucial role of human socio-economic behaviour in relation to health problems and colony loss in beekeeping has become fully recognised recently. Owen (2017) argued that human socio-economic activity has been a key driver in the global distribution of honeybees and the associated spread of pathogens impacting bee health, pointing at necessary adaptations in management decisions. Several studies confirmed that environmental conditions together with beekeeping management determine *Varroa destructor* infestions in honeybee colonies (Pohorecka et al. 2014; Giacobino et al. 2017), but also indicated that the interplay between different sets of determinants is complex. Insights provided by Jacques et al. (2017) and the EPILOBEE consortium stressed the role of beekeeper background, knowledge, experience, and management practices in honeybee colony survival. Several socio-economic studies have focused on the role of beekeeping in the context of rural development and from a development economics perspective, e.g. Affognon et al. (2015) and Shiferaw and Gebremedhin (2016). Other studies dealt with how the socio-economic profile of beekeepers influences honey production (Glavan 2014), assessed economic performance – though only in single EU countries or regions (e.g. Makri et al. 2015) – or studied the trend of urban beekeeping and it impact (Colla and MacIvor 2017). Within the EU, beekeepers fall largely into two broad categories: professionals deriving their main income from honeybees, and hobbyists with a small home apiary. The latter have been shown to perform significantly worse with respect to colony survival (Owen 2017; Jacques et al. 2017), which is associated with their smaller scale, lack of experience and knowledge, amongst other potential factors that require further study. Furthermore, objectives, values and drivers of these two groups differ substantially. As a result, their perception of bee health – as an indicator of wellbeing – may differ. Moreover, a single professional business model and policy and advice system may not benefit all beekeepers. Understanding the diversity across the EU and the respective socio-economic goals, value propositions and drivers of all types of beekeepers is essential for deriving tailored advice and recommendations for beekeeping management, policy and communication.

Ambition:

The socio-economic research activities within B-GOOD will expand previous insights providing innovation and advances in the following five domains compared to the state-of-the-art. First, the analyses will simultaneously cover multiple EU countries and regions representing the North-South and East-West axes of the EU. The research herewith provides a unique opportunity to identify, assess and deal with cross-national and cross-cultural diversity in socio-economic drivers, stakeholder and beekeeper attitudes and management decisions, and to understand differences in management decision-making, economic performance, efficiency and their determinants. Second, B-GOOD will integrate information on bee health status and external drivers relating to the ecological-environmental context in its socio-economic analyses. The research will herewith provide the first integrative insights into the role of colony health and the ecological-environmental characteristics together with personal, attitudinal, behavioural and managerial determinants of economic efficiency. Third, B-GOOD will identify and profile cross-national segments of European beekeepers based on attitudinal and managerial characteristics, as target groups for tailored and targeted advice aiming at fostering healthy and sustainable beekeeping. Fourth, the socio-economic research will focus on the role of multiple actors and networks, including but not exclusively beekeepers. These activities will be fully embedded in a multi-actor approach through the adoption of the adaptive co-management perspective (WP8). Fifth, the socio-economic research activities are designed in a way that they will result in the identification of viable business models for sustainability for a future healthy and sustainable beekeeping sector in the EU.

In each of its defined tasks, specific methodological advances as compared to the state-of-the-art will be realised. The classical SWOT within B-GOOD will

1. be accompanied by a social-ecological inventory (SEI) to identify networks and actors in EU beekeeping,
2. include the application of the PrOACT protocol to get participants to focus on fundamental objectives and envisaged value creation and create imaginative alternatives to achieve these, and
3. be extended with a SOR to fully exploit its potential.

This activity will provide a comprehensive mapping of the complexity of the business environment, an identification of the key attention points for strategy development and business models for a healthy and sustainable European beekeeping sector. As a strategic foresight and planning tool, SWOT has advantages related to its user-friendliness, its straightforward format, and its adaptability to a variety of situations, people, events, and contexts. A point of criticism is that SWOT is merely a descriptive and synthesis instrument lacking the establishment of a hierarchy between and prioritization of components. In response to such criticism, B-GOOD will extend the SWOT with a Strategic Orientation Round (SOR), i.e. a quantitative strategic method (Van Wezemael et al. 2013) involving a scoring of components following a predetermined pattern, and leading to the identification of key attention points for strategy development. While the SWOT analysis provides the situation analysis, the SOR analysis bridges from situation analysis to strategy.

Using large-scale quantitative and pan-European survey data, B-GOOD will map beekeepers' personal and colony attributes; their views, attitudes, interests, and management decisions; how they deal with their complex business environment; assess their economic performance and identify its key determinants while accounting for bee health status and ecological-environmental characteristics. The collected data will be used to segment beekeepers through cluster analysis. The segments will be profiled through descriptive statistical analyses. Associations between management styles, decisions and personal characteristics of beekeepers will be validated through multivariate analyses. The surveys will also collected economic data from beekeeping practices as the basis for assessing production efficiency and its determinants. Production frontiers, which define a benchmark relationship between inputs and outputs (honey and pollination services), will be determined and efficiencies of beekeeping businesses are measured relative to these estimated frontiers (Coelli et al. 2005) using Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) (Shiferaw and Gebremedhin 2016) as efficiency measurement techniques. Such analyses provide insight in the Technical Efficiency (TE) of beekeeping. The modelling will reveal the determinants of economic performance depending on the country, region, beekeeper and beekeeping characteristics, i.e. covering a diversity of personal and behavioural factors. Thus far, none of such studies integrated colony health and ecological-environmental conditions in the models. This will be realised in B-GOOD through the specification and estimation of Environmentally Adjusted Production Efficiency (EAPE)-models (Lauwers 2009), in particular those that integrate multiple outcomes that measure sustainability in terms of value co-creation. The analyses will herewith provide a first systematic and consistent cross-national production efficiency analysis based on harmonized socio-economic data collection, and an efficiency analysis integrating also health and environmental characteristics in the EU beekeeping sector.

Within B-GOOD, the business model concept will be defined and approached following the business model for sustainability theorem as proposed recently by Schaltegger et al. (2016). Business models for sustainability are defined as describing, analyzing, managing, and communicating

1. a company's sustainable value proposition to its customers and all other stakeholders,
2. how it creates and delivers this value, and
3. how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries.

This approach extends the conventional view of a business model designed around economic value creation for customers with an ability and willingness to pay, to sustainable value co-creation for customers and a broad range of other stakeholders, stakeholder networks and society at large, including economic value, social and environmental benefits and the balancing among them (Evans et al. 2017). While this business model is still a market-oriented approach, it is explicitly embedded in stakeholder and actor networks and embodies the co-development of integrative and competitive solutions by either radically reducing negative and/or co-creating positive external effects for the natural environment and society (Schaltegger et al. 2016, p.3). Business models for sustainability are particularly relevant for beekeeping in the EU considering, first, its diversity of outputs including both private (bee and bee hive products) and public goods (pollination, education) or combinations thereof. As a typical product-service system, beekeeping has the potential to envisage diverse value propositions that can provide both economic (e.g. profit, long-term viability, financial resilience), social (e.g. well-being, community development, training and education services) and ecological value (e.g. biodiversity, biology conservation, pollution prevention) (Evans et al. 2017). Second, the business model for sustainability theorem is fully compliant with the multi-actor approach adhered to in B-GOOD through deliberate interaction, partnering, networking and co-learning from multiple stakeholders and focusing on co-creating value to a diversity of stakeholders and the natural environment. Third, this theorem allows to cover the diversity in EU beekeeping management and business models, ranging from fully professional to hobbyist, from small to large scale, from rural to urban environments, and from businesses with predominantly economic to integrated social and ecological objectives.

Gap 3: Sustainable beekeeping

State-of-the-art:

The key factor within a holistic approach towards sustainable beekeeping in the EU is a better understanding of the triptych of honeybee colony health, flanked by the socio-economics of EU beekeepers and the human-ecosystem equilibrium, and to implement and translate this understanding into effective beekeeping data processing, management decision-making and policy. Hence, sustainable beekeeping involves the ecological balance between healthy bees and the environment while safeguarding economic viability and the development of management strategies to maintain bee health, including a correct identification and treatment of problems, and correct beekeeping practices.

Honeybees as pollinators have high ecological value for their environment, but they also rely on this environment for their survival and reproduction. Kuchling et al. (2018) showed that honeybee colonies in agricultural areas had a higher probability to die compared to other land use areas, though this varied between years. Habitat loss, fragmentation and agrochemicals – factors often related to agricultural land use – were found to negatively affect bee survival (Potts et al. 2010), most likely due to reduced food resources or lack of foraging success. Less pollen reduces growth and protein build-up in young bees (van Dooremalen et al. 2013), or the immune-competence of colonies (Alaux et al. 2010). Less resin reduces the use of propolis and thus the social immunity (Simone-Finstrom and Spivak 2010). It should be stressed that beekeepers have a role in this as well: intensive stocking rates of colonies will decrease bee health during critical environmental resource bottlenecks, thus negatively impacting on sustainability. The eusocial structure of the colony makes honeybees extremely adaptable to changing environments, by storing food to overcome periods of low food availability. Wild honeybee colonies can choose to abscond their nest when deteriorating foraging environment occurs (Schneider and McNally 1992); managed colonies cannot. Managed honey bee colonies will be stopped from absconding by the beekeeper, making it the responsibility of the beekeepers to provide the colony with a sufficient amount of foraging resources by placing them in an appropriate environment. To be able to make a well-founded choice for an optimal operation area for their colonies ensuring sustainability, beekeepers need information on potential bee resources. Information that is to date not easily accessible for beekeepers or policy makers. Such information requires substantial knowledge of flowering plants and a substantial amount of time to manually map the foraging resources within an operation area. Standardized spatio-temporal information on floral patterns and landscape features most relevant for bees is still not readily available in Europe. Widely accessible insight in the diversity of floral resources across the EU at a detailed level is essential for deriving tailored advice and recommendations for beekeeping management and sustainability of the beekeeping sector. Integrating this approach of ecological balance with efficient data transfer and advice on bee health is a key to maximise and safeguard the sustainability of beekeeping.

Ambition:

The landscape data and floral indicators derived in B-GOOD will provide innovation and advances compared to the state-of-the-art and will lead to understanding the value and potential of European landscapes for beekeeping on local to regional scales. Temporal and spatial dynamic landscape maps of pollen and nectar resources across the EU will be produced and validated, after defining a typology of landscape elements important for bees across the EU and prediction of the quantity and quality of resources (nectar and pollen) available for honey bees in the landscape elements over time. Within B-GOOD the flower resource model will cover different countries representative of the major edaphoclimatic regions across the EU where an EFSA ApisRAM scenario is existing or will exist in the near future thanks to other on-going projects, to which B-GOOD is linked (H2020 EcoStack, H2020 PoshBee and EFSA MUST-B). Moreover, the wide spatial use of the flower resource model will also allow building landscape suitability, landscape fitness, or honey production maps for honey bees across Europe by converting them from the floral resources map. For sustainable beekeeping, however, it is essential that these maps become integrated into an EU-wide database platform and that the decision making guidance is based on bee health, socio-economics of beekeepers, as well as the human-ecosystem equilibrium. Through realising the latter, B-GOOD will contribute to the safeguarding of sustainability of beekeeping in the EU.

Gap 4: EU-wide database platform

State-of-the-art:

Data standardisation and access is of major importance to realise sustainable beekeeping. Especially in the case of threats to bee colonies, recent and even real-time information is essential to be able to take appropriate decisions and react swiftly. Data storage and sharing can be complex. In the context of bee data, EU-wide (and international) standards for storage of such data are absent. Also, bee health related data is essential to store, share and link to bee data in order to be able to draw conclusions. The questions which are asked inform the type of data linkages that are needed, for example when researching the forage conditions when the summer weather is substantially warmer than on average. One needs to link bee health data to weather and forage data to be able to draw conclusions on the correlations. This requires a well though-through data storage and accessibility set-up In extension, a platform is needed which integrates information available at the EU level, including information on farming, environment and socio-economics, to provide all the relevant data for guiding decision making at local, regional and international scales.

Ambition:

We will develop an EU-wide bee health data and management platform in close cooperation with the EU Bee Partnership to support sound decision-making at all levels, having positive impact on bee health. Data will collected from various sources from the past and present and will be accessible for scientists (inside and outside the consortium), beekeepers and other stakeholders. We will utilise and further expand the classification (data standard) of the open source IT-application for digital beekeeping, BEEP, to streamline the incoming flow of data related to beekeeping management, the bee hive and its environment (stressors, landscapes, agricultural practices and weather) from various sources. We provide a coordinated collaboration with existing EU-wide data platforms, e.g. those of MUST-B, Bee Health Workbench and the EU Bee Partnership, to prevent overlap and instead promote mutual enrichment as well as contribute to the develop a bee data standard. Such a standard is of great importance to ensure data quality and being able to compare data. Regarding standards we will collaborate amongst others with the new Apimondia Working Group on the Standardization of data on bees and beekeeping, coordinated by the president of the European Professional Beekeepers Association.

Reliable, high quality data storage and its easy retrieval is a core requirement to our project. In order to accommodate the richness is types of data as well as meta data, three specialised types of databases will be used. This is further detailed under WP6: Operationalisation and Application. The data will be stored and shared in compliance with the General Data Protection Regulation 2016/679 of the EU law on data protection and privacy. Access to the project data will be provided through a state-of-the-art web portal focused on sharing, retrieval, and analysis of data. It will be upgraded to give overview of the best practices and key aspects of bee colony health measurements and decision-making. This includes visualisation of high priority health indicators and factors on maps and charts and other data visualisations. We will hereby build on the experience gained in the creation of the Bee Health Workbench. Accessibility also means easy readability by machines. Machine-readable means that incoming data from for example sensors, can be automatically read from the database and processing in specialised data processing software. Like-wise, data from other databases with bee data will be shared on the web portal, either as links or technically integrated.

The setup and management of the data platform and web portal will be done professionally for use during the program with the aim of continued use for many years after the end of the B-GOOD research program, managed by the EU Bee Partnership (focussing on the data standards and the data itself) and operationalised by BEEP in terms of technical tools and services.

Gap 5: Guidance in decision making

State-of-the-art:

Decision analysis is an evolving research field in applied natural resource management (Conroy and Peterson 2013). Its emphasis is on the systematic decomposition of complex decision problems and the use of broad sets of tools, as well as the integration of multiple knowledge sources (data/information) to foster more effective decision-making. However, in many decision-making contexts there has been a reliance on the analysis of data and informational aspects with little or no emphasis on the 'value' positions that affect decisions in local contexts. However, there is increasing realization of the importance of adopting rigorous methods such that information, as well as views and judgements of relevant stakeholders and experts, are used in systematic and iterative ways at each stage of decision-making (Mukherjee et al. 2018). What drives decisions is the value that decision-makers place on outcomes, rather than simply the means to achieve these (Keeney 1992). This structuring of decisions requires breaking them down into two distinct characteristics for consideration,

1. evidence based components (quantitative aspects) and
2. values-based components (qualitative and subjective aspects).

This in-turn necessitates clearly establishing who 'decision-makers' are and who are likely to be impacted by the outcomes of decisions made across various scales (geographical and temporal).

In agricultural research for development, it has been recognized that stakeholder groups can provide insights about the biophysical, technological and institutional dimensions of problems, and what innovations are technically feasible, economically viable and social-culturally and politically acceptable (Schut et al. 2016). Institutions charged with fostering innovation are often locked into old approaches and methods of intervention, with a linear view of knowledge transfer as a top-down process from research to advice and practice (Moschitz et al. 2015). However, there has been a gradual shift from narrow technology-oriented approaches to more holistic systems approaches, that focus on understanding how interactions between different value chains, stakeholders, and organizations across different levels influence agricultural innovation processes (Klerkx et al. 2012). Innovation in agricultural systems is often impeded by horizontal and vertical fragmentation of collaborative networks, since creating and fostering effective learning and innovation processes among stakeholders and scientists is difficult when coming from different backgrounds, often with varying technological, social, economic and cultural values (Hermans et al. 2015). Nevertheless, stakeholder groups are more likely to support specific solutions when they have been part of decision-making processes (Neef and Neubert 2011).

Currently these approaches are not used to support apiculture; however, beekeepers operate within a dynamic socio-ecological environment, influenced and having to respond to many, variable factors that influence the health of their bee colonies. Beekeepers increasingly have to face complex and challenging circumstances, with emerging stressors and risks not only for bee colonies but also for the sustainability of their livelihoods. They often have to make hard decisions with limited information, despite a plethora of scientific data and sometimes ambiguous or conflicting guidance that may or may not be relevant to their *local contexts*. There is clearly a need for user-friendly decision support mechanisms and tools to help beekeepers identify issues, analyze relevant data, considering possible options and to make judgements and trade-offs, leading to well-informed decisions that achieve valued outcomes.

Ambition:

B-GOOD via its MAA approach, data generation and analysis will develop for a LIS with web portals for communication to and from stakeholders. The science underlying this system, merges several theoretical approaches and concepts related to knowledge development and decision-making in an innovative and iterative approach that integrates the soft elements of decision-making (e.g. objectives, uncertainties, risk tolerance) and technical aspects (e.g. scientific and environmental data, modeling and decision support-tools). Actor network theory and socio-ecological inventories will be used to determine the interconnectedness between stakeholders and scientists, their respective roles as decision-makers, as well as their links with physical entities related to beekeeping. Nevertheless, the processes leading from data to decisions are complex and we will expand upon the 4-step concept called the Data-Information-Knowledge-Wisdom pyramid, adding a last component, Decisions (DIKWD). The model shows that data, when given context, becomes information that, in turn, when given meaning, becomes knowledge. Knowledge, given insight, becomes wisdom which, when combined with purpose, results in better decisions and strategic plans. To compliment this, a structured decision-making (SDM) framework will be used to facilitate transparent, logical and consistent decision-making amongst targeted stakeholder groups. This framework draws upon elements of decision theory, risk assessment and psychology to improve the effectiveness of decision-making at various levels (scientific to local). With rigorous protocols (e.g. PRoACT) SDM helps decision-makers identify impediments to decisions and innovative solutions, as well as establishing what additional expertise, tools or other resources are required to solve them. These latter steps will also include value driven socio-economic insights, principles and directions of development that will enable the tailoring of decisions which are inextricably linked to the type of business run by a particular beekeeper or beekeeper community. The B-GOOD MAA approach will also include linkage to policy via direct access to the EFSA MUST-B working group and will support and further develop the simulation tools used for honey bee risk assessment and consideration of multiple stressors. The resulting LIS, based on B-GOOD data collection, modelling and analysis will include the necessary detail to disentangle issues of local context both in the DIKWD information flow and in terms of incorporation of context in value-driven goals.

2. Impact

2.1. Expected impacts

2.1.1. How B-GOOD will contribute to the expected impacts

The SFS-07-2018 *Making European beekeeping healthy and sustainable* call states five expected impacts, and we demonstrate how B-GOOD meets and exceeds these below. As such B-GOOD contributes to the understanding of bee colony health and the identification of important socio-economic characteristics of sustainable beekeeping.

<u>Expected Impact 1:</u> **Developing an EU platform on science and practice in relation to honeybees, their environment and agricultural and beekeeping practices**;

Impact. B-GOOD will build an EU-wide bee health and management data platform that brings together facts and experience on diverse aspects of bees, beekeeping practices, the environment, including the landscape, agricultural practices, weather and climate. This will foster collaboration, pro-active dealing with challenges and a bridge between science and practice. We provide a coordinated collaboration with existing EU-wide initiatives, e.g. MUST-B and the EU Bee Partnership, to prevent overlap and instead promote mutual enrichment. Data, information and knowledge exchange including standards and protocols will be at the heart of this platform and will benefit honeybee colonies and their health, the beekeeping sector, the agricultural sector, the environment and society at large. This will allow rapid, meaningful alarms to be triggered in instances of local incidents that have the potential of causing large-scale detrimental consequences such as epidemic diseases. The propagation of problems will be better understood, picked up earlier, and easier to tackle at their start. Local incidents of illegal or accidental polluting or poisoning caused by humans will be picked up with speed and efficiency; this will reduce their likelihood as perpetrators will soon become aware of this new strength in beekeeping. This will also allow better understanding of instances where beekeeping particularly promotes agriculture and the environment, and it will provide opportunities e.g. for feedback to beekeepers engaged with pollination. Such feedback will improve their business and that of farmers and the EU agriculture sector who benefit from pollination services. (Table 6)

<u>Expected Impact 2:</u> **Providing a pilot toolbox to improve monitoring of honeybee colonies and assessment of the multiple stressors that affect colony health**;

Impact. B-GOOD will fine-tune a toolbox for determining the health status of a colony, containing components that derive from EFSA’s Healthy-B study with an H-HH score and completed with additional innovative and promising tools. All components will be tested and validated thoroughly in different settings across the EU and considered ready for measuring the impact of multiple stressors and mitigation actions on bee health. This will empower beekeepers with unprecedented means to allow them to record and quantify outside-colony events and actions that directly affect their profession. This will empower governments with new means to effectively help the beekeeping sector, as they will be better informed on what really affects colony health and welfare.

The professional activity of beekeeping will be made more efficient, and the hobbyist activity more smoothly manageable. In particular, there will be numerous instances of colonies, deemed to be healthy or in recovery by the application of the toolbox, which will therefore not require intervention other than for honey collection or moving for pollination purposes. The lack of need for colony inspection will release time, efforts and funds to the beekeeper. Health inspections are usually critical just before transhumance takes place. Increased reliability in the health assessment and in the choice of the location for moving colonies will substantially increase the success of large scale transhumance processes. Young workers interested in the profession of beekeeping will be more likely to become committed to the profession. They will be given simple, generic, and smartphone assisted classification methods to assess a colony's status and will be given reliable training to start a successful career in beekeeping. The likelihood of unexpected catastrophic losses of bees, very depressing and harmful to the professional, hobbyist and society, will be substantially reduced. (Table 7)

Table 6.
Impact indicators.

Stake holders*	Expected impact	Impact indicators
ALL	Sharing of data, information and knowledge and collaboration among the parties involved	Number of a) participating parties; b) contributions
SCIE	EU-wide bee health and management data platform used for studies, publications and grant applications	Number of a) articles in peer-reviewed journals; b) talks, (infographic) posters, conference proceedings, national and international conferences; c) follow-up projects; d) popular articles founded on science in local beekeeping and veterinary journals in the language of the Member State
RISK	EU-wide sharing of studies and latest insights on (emerging) risks	Number of risk assessments; risk alerts
IND	Pollination is sustained, contributing to food security	Where feasible, mapping of effective pollination in relation to number of honeybees and their health
POL	The platform contributes to policy decisions	Number of a) policy briefs; b) interactions with policy makers; c) policy decisions

Stake holders*	Expected impact	Impact indicators
BEE	Non-invasive beekeeping practices, quicker response to deteriorating health of colonies, better decision making	a) Bee health indicators show that bee colonies in the programme are healthier compared to the start situation; b) from the beekeeping digital record we see that less inspections are needed than regularly; c) from the beekeeping records we see that beekeepers follow the decision advice presented to them through the developed tools and can link that to the(improved) health of the colonies
	Viable businesses models are successfully implemented	Number of business models shared and used (survey)
*ALL = all stakeholders; SCIE = scientists; RISK = risk assessors; IND = industry; POL = policy makers; BEE = beekeepers; LAND = land owners		

Table 7.
Impact indicators.

Stake Holders*	Expected impact	Impact indicators
SCIE	Toolbox used for studies, publications and grant applications	Number of a) articles in peer-reviewed journals; b) talks, posters, conference proceedings, national and international conferences; c) follow-up projects
RISK	Toolbox used for monitoring	Number of a) monitoring schemes taking advantage of the toolbox; b) popular articles, case study reports, guidelines (e.g. disease control, diagnosis) and articles in local beekeeping and veterinary journals
IND	Toolbox used for developing bee-safe products	Number of developed bee-safe products
BEE	Toolbox used for decision making in practical beekeeping	Number of a) popular articles; b) good beekeeping practice guidelines; c) reduced winter losses
*SCIE = scientists; RISK = risk assessors; IND = industry; POL = policy makers; BEE = beekeepers; LAND = land owners		

Expected Impact 3: Contributing to a better understanding of the management decisions made by beekeepers;

Impact. B-GOOD will provide an in-depthe assessment of management decisions made by beekeepers, their diversity, determinants, link with bee health, ecological-environment conditions, and economic efficiency. Segments of beekeepers will be identified and profiled based on managerial and attitudinal characteristcs, herewith providing unique and distinct target groups for tailored advice, recommendations and communication with maximum potential effectiveness and impact. B-GOOD will determine which decisions should be made at various levels, including the individual beekeeper, the beekeeper community, responsible authorities and, if applicable, any other stakeholder. Beekeepers will soon realise that B-GOOD recommendations are beneficial to 'the bee', with no other hidden agenda, and will become naturally atracted to follow them. For the same reason, soon other actors will see the benefit to their profession or activity, substantially decreasing the likelihood of societal conflicts or tensions. (Table 8)

Table 8.

Impact indicators.

Stake Holders*	Expected impact	Impact indicators
SCIE	Studies on efficacy of decisions by beekeepers; identification and profiling of pan-EU beekeeper segments	Number of a) articles in peer-reviewed journals; b) talks, posters, conference proceedings, national and international conferences; c) follow-up projects
BEE	Beekeeping management advice and recommendations; usage of B-GOOD recommendations for decision making; improved management decision-making by EU beekeepers	Number of a) popular articles; b) guidelines for good beekeeping practice; improved economic performance of EU beekeepers
LAND	Supplying B-GOOD with information on resources in return for additional pollination	a) Optimized distribution of colonies over high resource quality areas in space and time; b) pollination network, linking supply and demand across the EU
POL	Identified segments of beekeepers as target groups for advice, recommendations and communication	Number of a) policy decisions and b) actions targeting specific segments of beekeepers

*SCIE = scientists; RISK = risk assessors; IND = industry; POL = policy makers; BEE = beekeepers; LAND = land owners

Expected Impact 4: Providing potential and viable business models for EU beekeeping, with and without public interventions;

Impact. B-GOOD will gain a better understanding of the socio-economics of beekeeping. It will map current business models and link these bee health, ecological-environment conditions, and economic efficiency. B-GOOD will identify, describe and assess the feasibility and likelihood of acceptance of viable future business models for sustainability of EU beekeeping. It will herewith provide comprehensive blueprints of successful business models for European beekeeping that will identify objectives (why?), products and services (what?) and markets (to whom?). (Table 9)

Table 9.
Impact indicators.

Stake holders*	Expected impact	Impact indicators
IND	Objectives, products and services as well as markets identified and communicated	Number of a) articles in peer-reviewed journals; b) talks, posters, conference proceedings, national and international conferences; c) follow-up projects
POL	Objectives, products and services as well as markets identified and communicated; Identified segments of beekeepers as target groups for interventions	Number of a) policy recommendations based on B-GOOD results; b) of interventions targeting specific segments of beekeepers
BEE	Objectives, products and services as well as markets identified and communicated	Number of a) popular articles; b) guidelines for good beekeeping management, and c) marketing of beekeeping products and services

*SCIE = scientists; RISK = risk assessors; IND = industry; POL = policy makers; BEE = beekeepers; LAND = land owners

Expected Impact 5: Giving support to scientists, risk assessors and policy makers in assessing and managing multiple stressors that affect the sustainability of the EU's apiculture.

Impact. B-GOOD will show directions forward in bees and beekeeping to risk assessors and policy makers by targeting pertinent questions about the risk of emerging pests and predators, and of the mobility of the beekeeping sector. (Table 10)

2.1.2. How B-GOOD will contribute to additional sustainable impacts

Additional sustainable impact 1: The EU bee health and management platform will allow improved monitoring of the effects of climate change, as year to year changes will be better quantitated and predicted. It will be possible to warn beekeepers of shifts that are likely to take place on the best locations to keep bees at a specific season of the year. Pollination services, honey production and bee welfare will be kept optimal by shifting the timings of the beekeepers' routines to the benefit of the honeybee. This will attract the investment opportunities from outside Europe because other countries will see the benefits from the same technologies, the U.S.A. in particular. Young beekeepers will have more direct evidence of the broader beneficial impact of their profession and will be more likely to be drawn and committed to the activity of beekeeping.

Additional sustainable impact 2: The risk assessment of emerging pests and predators, the use of pesticide and that of specific beekeeping practices will be improved by the work done in B-GOOD, and will most probably be extended to other countries, including developing countries. In the latter, often a holistic approach is lacking. They could benefit of the extrapolation of the risks assessed in EU.

Table 10.

Impact indicators.

Stake holders*	Expected impact	Impact indicators
SCI	B-GOOD will conduct and stimulate cutting edge research on bee health	Number of a) articles in peer-reviewed journals; b) talks, posters, conference proceedings, national and international conferences; c) follow-up projects; d) popular articles, case study reports, guidelines (e.g. disease control, diagnosis) and articles in local beekeeping and veterinary journals in the language of the B-GOOD member country
RISK	Will use tool box and data platform to conduct risk assessments	List of reports mentioning usage
POL	Policy decision are based on B-GOOD results	List of policy decisions; number of a) interventions targeting specific segments of beekeepers; b) actions targeting specific segments of beekeepers

*SCIE = scientists; RISK = risk assessors; IND = industry; POL = policy makers; BEE = beekeepers; LAND = land owners

Additional sustainable impact 3: Through providing EU beekeepers with healthy honeybee colonies and improved management practices, B-GOOD's insights will foster the competitiveness and profitability, as well as the high quality reputation of the EU beekeeping sector as part of EU agriculture. This will create additional sustainable impact in terms of the quality of EU beekeeping products and services, in conformity with consumers' and customers' expectations and in line with the key principles of EU Food Quality Policy. Through fostering knowledge transfer and promoting innovation in the EU beekeeping sector; enhancing the sector's viability and competitiveness as an agricultural activity strongly (though not exclusively) embedded in rural areas; and through restoring, preserving and enhancing ecosystems related to agriculture and forestry, B-GOOD will contribute to the objectives of EU's Rural Development Policy. The improved beekeeping practices that will result from B-GOOD's activities will benefit rural areas in terms of potential poverty reduction and economic development.

Additional sustainable impact 4: B-GOOD contributes to the wider societal, economic and environmental cumulative changes envisaged by Horizon 2020. Beneficial health and well-being impacts are expected through the provision of healthy and high quality beekeeping products. B-GOOD's research program is strongly embedded in the societal challenge relating to food security, sustainable agriculture, climate action and environment. Through public dissemination and education activities target the public at large, B-GOOD will contribute to the inclusive, innovative and reflective EU society.

2.1.3. Barriers, obstacles, and any framework conditions that may determine whether and to what extent the expected impacts will be achieved

- Cost of adoption: B-GOOD will only be successful in the long run if the stakeholders truly adopt and sustain
- the change.
- Lack of knowledge/understanding: even if stakeholders are adequately informed, with efficient B-GOOD
- dissemination and communication, a certain proportion will still refuse to adopt recommended changes.
- Poor beekeeping practice exposed: B-GOOD may end up revealing specific beekeeping practices that are not
- the most favourable ones, or not considered or proven or acknowledged as 'best practice'. Some beekeepers will refuse recommended practices or changes.
- Unproven effectiveness: A key component of stakeholder management is the recognition and reward of contributors and the celebration of successes.
- Lack of government support: B-GOOD will be in close contact with EFSA and directly with the EU to foster information exchange and to ensure that B-GOOD will be up to date and timely in its delivery when respective EU decisions will be due.
- Policy makers: Beekeeping friendly policy making, recognizing the impact of apiculture for food security and maintenance of EU biodiversity.
- Agricultural sector: Farmers in Europe acknowledge the importance of pollination and are willing to contribute to the well-being of bees.
- Specific responsibilities exposed: B-GOOD may end up revealing enclaves within the EU territory where beekeeping is totally safe and sustainable, and others where it is not, which may result in revealing the responsibility of specific stakeholders in those.

2.2. Measures to maximise impact

2.2.1 Dissemination and exploitation of results

Governance – All dissemination, communication and exploitation activities of B-GOOD will be based on a targeted strategy that will be outlined in two strategic documents: the **B-GOOD Communication and Dissemination Strategy** and the **B-GOOD Exploitation Plan**. Both documents will be produced as described under WP7, Task 7.2 and correspond to the deliverables D7.2 and D7.3. Under WP9 Task 9.3 the **B-GOOD Data Management Plan** (DMP) will be drafted at the host institute under the supervision of the project coordinator (UGENT) in consultation with the other project partners. The initial DMP will be submitted as deliverable D9.2 by Month 6 after the start of the project. Moreover, the Management Structure of B-GOOD (see Section 3.2.1) provides for specific 'Support of the Coordinator' of Dissemination, Exploitation and Data Management, elected from the WP leaders and the other consortium members, and supported by administrative staff with specific competence from their host institutes (e.g. Data Stewards as recently established at UGent). They will be part of the Coordination Team, which is the supervisory body for the execution of the project. As such, dissemination, communication, exploitation and data management are embedded in dedicated WPs, with corresponding tasks and deliverables, and supervision is guaranteed by the members of the Coordination Team. However, responsibility remains with the Coordinator.

In order to draft the demarcations of **the B-GOOD Communication and Dissemination Strategy** we have defined **9 basic principles** to which it will adhere:

1. Open access of B-GOOD data and results to the greatest extent possible while considering Intellectual Property Rights (IPR);
2. Multi-targeted dissemination of results based on identifying all relevant target groups using target-specific intelligible language;
3. Multiple use of the project results for various dissemination and outreach purposes;
4. Multiple modes of dissemination based on traditional (scientific papers, flyers, posters, factsheets, policy briefs, press-releases, newsletters) and innovative methods (online broadcasting, podcasts, blogs, open-access journals, data publishing);
5. Extensive use of social networks (Twitter, Facebook, LinkedIn, Mendeley, Google+) and Web 2.0 technologies (RSS feeds, semantic tagging);
6. Translation of the scientific results, such as best practices, recommendations, factsheets, policy briefs and report cards, into comprehensive and more understandable forms for lay audiences, and whenever needed into national languages;
7. Regular coordinated press releases and news feeds and announcements posted through the world's leading (Eurekalert.org; AlphaGalileo) and EU-based (Science for Environment Newsletter, Biodiversity Information System for Europe (BISE), European Topic Centre Biological Diversity (ETC Biological Diversity), etc.) distributors of science news;
8. Widest possible integration of B-GOOD results into existing European and national portals, international networks (COLOSS), professional organisations, national and international symposia and NGOs;
9. Feedback from stakeholders used to improve the usability of results integrated into the COLOSS BEEBOOK Information Hub (http://www.coloss.org/beebook/).

Expected impact of the B-GOOD Communication and Dissemination Strategy – In Section 2.1.1 we explained how B-GOOD will contribute to the expected impact of the project:

- Developing an EU platform on science and practice in relation to honeybees, their environment and agricultural
- and beekeeping practices;
- Providing a pilot toolbox to improve monitoring of honeybee colonies and assessment of the multiple stressors
- that affect colony health;
- Contributing to a better understanding of the socio-economics of and management decisions made by

- beekeepers;
- Providing potential and viable business models for sustainability for EU beekeeping, with and without public
- interventions;
- Giving support to scientists, risk assessors and policy makers in assessing and managing multiple stressors that
- affect the sustainability of the EU's apiculture.

The **B-GOOD Communication and Dissemination Strategy** will help to achieve the expected impact of the project by:

1. Channelling / targeting awareness, knowledge, and know-how of beekeepers, multiple actors and the public at large;
2. Lowering the threshold to really turn the new insights and possibilities into action;
3. Creating a greater involvement of beekeepers, multiple actors and the public at large.

Exploitation and sustainability – Sustainability of B-GOOD results will be ensured by:

1. Maintaining the website for at least 5 years after expiration of the funding phase of the project;
2. B-GOOD members carrying on in various follow-up and complementary and already ongoing projects and initiatives (e.g. EU Bee Partnership, COLOSS), thereby ensuring that our results will have an impact after the end of the project;
3. The BEEBOOK Information Hub at the COLOSS website (http://www.coloss.org/beebook/) will be further developed to integrate and present the final results and recommendations from the project in a well-organised web platform. The latest edition of the BEEBOOK (Volume 4: Standard methods for *Apis mellifera* beekeeping practice) will include the main outcomes of B-GOOD. By taking full advantage of Web 2.0, B-GOOD results will evolve via user comments and feedback, and initiate a dynamic and adaptable standard for future apiculture.
4. B-GOOD will adhere strictly to the principles of free and open exchange of data and knowledge, in accordance with the latest EU directives, such as the Directive of the Council of Europe recognising “the strategic importance for Europe’s scientific development of open access to scientific information”. The FP7 pilot initiative towards open access covers 20% of seven key areas, including Environment. On 17th July 2012, the European Commission outlined measures to improve access to scientific information produced in Europe in a http://ec.europa.eu/research/science-society/document_library/pdf_06/era-communication-towards-better-access-to-scientific-information_en.pdf and a Recommendation to the Member States. The need for the widest possible access to publicly funded research results, while maintaining a solid and sustainable scientific dissemination system, has been a key consideration in defining the concrete measures of the Commission's initiative. B-GOOD will therefore strongly pursue publication of the project results under the Creative Commons Attribution License 3.0 (CC-BY) and publication of databases under the Open Data Commons Attribution License (ODC-By). To secure long-term

digital preservation or our results, B-GOOD will link to global initiatives in data archiving, such as the Dryad Digital Repository, and others. Our project will in particular benefit from the existing novel workflow and experience in open access data publishing of PENSOFT (e.g., open access journals BioRisk, Nature Conservation and the Biodiversity Data Journal) in the form of “data papers”.

Follow-up – Continuation of the B-GOOD EU-wide bee health and management data platform (see Task 6.3) will be stipulated in the B-GOOD Data Management Plan. B-GOOD envisages a strong involvement of the EU Bee Partnership and B-GOOD partner BEEP herein. Without anticipating the contents of this plan, we will present below a possible track with regard to the involvement of both partners. We first provide some background information of both entities.

EU Bee Partnership. According to reference (EFSA 2018): “As part of the European Parliament’s Week of Bees and Pollination 2017, there was a general agreement that an EU Bee Partnership Discussion Group (DG) should be established, with the vision of “a Platform run by stakeholders for the benefit of society to ensure that bees in the EU can thrive and prosper”. Subsequently, an EU Bee Partnership was identified as one of the targeted platforms established by EFSA, under the Stakeholder Engagement Approach. This document describes the terms of reference developed by and for this EU Bee Partnership DG. The objective of the EU Bee Partnership is to improve data collection, management, sharing and communications to achieve a holistic approach to the assessment of bee health in Europe and beyond.”

Putative role of the EU Bee Partnership in the follow-up. Expected key roles of the EU Bee Partnership are:

1. Contributing to a harmonised data collection, using approved and shared standards where possible;
2. Enabling data sharing and utilization;
3. Responding to emerging risks.

BEEP. The ‘Stichting Beep’ or Beep Foundation is B-GOOD partner 13. We refer to the participant description under section 4.1, but in short: BEEP is a Small and Medium-sized Enterprise registered in The Netherlands as a foundation. Its mission is to modernise beekeeping practice and it consists of beekeeping and data/IT professionals. As described in WP6, BEEP already provided a platform for data collection (the BEEP bee app) including a powerful standardised bee data classification and an open source, extendable and affordable sensor system.

Putative role of BEEP in the follow-up. BEEP will be the operational partner. This entails several key roles and responsibilities:

1. Managing, enhancing and supporting the software (apps, websites, portals);
2. Production and user service of the hardware inclucing sensor measurement devices;

3. Involvement in the management of the EU-wide bee health and management dataplatform;
4. Research and development benefiting the EU beekeeping community.

These roles and responsibilities by a single partner/foundation ensure the continuity of BEEP.

Knowledge management – The consortium members are all experienced in undertaking collaborative research and are well aware of the necessity to define a common strategy towards the management of the knowledge generated, in agreement with the commitments agreed on and described in the Grant Agreement, and in respect of each partner's policy and objectives. All rules and regulations for management of intellectual property (specifically joint inventions), dissemination and exploitation will be defined in the Consortium Agreement (CA) that will be signed by all partners before the project's start. Similar to the B-GOOD management structure and procedures, the DESCA CA model for H2020 will be followed. The B-GOOD CA, based on this model, will be negotiated with all participants and will be signed before the project start. It will then define in detail the procedures for the management of these issues at the implementation stage and beyond. B-GOOD partners agree in principle with the following provisions of the CA:

1. Background will be identified in an annex to the CA. Access rights to background needed for the implementation of the work of a particular partner under the project shall be granted free of charge; access rights to background needed for subsequent use of the results shall be granted based on fair and reasonable conditions. However, in the latter case specific background may be excluded in the CA.
2. Access to knowledge created during B-GOOD will be available royalty-free to other partners for the execution of this project. Access knowledge created during this project needed for subsequent use of the results shall be granted based on fair and reasonable conditions. For parties entering the project later, any foreground created before their entry will be regarded as background. Preferential or market conditions apply for use.
3. Specific Intellectual Property Rights issues that might arise in the course of the project that are not ruled by the provisions of the Grant Agreement and the CA or for which mediation between partners is needed, will be studied by the Exploitation and Dissemination Support of the Coordinator and recommendations made to the General assembly (GA) for discussion and agreement.

IP is likely to be in the form of software and databases, but may also include remote sensing devices and diagnostic tools. Consequently, a comprehensive view will be taken of IP protection including but not limited to patents. Other potential protection methods will be considered including copyright (e.g. for software), non-disclosure (e.g. for technical know-how), design right and registered trademarks (to protect the name and or description of new products or services developed) as and when appropriate.

The Dissemination and Exploitation Support of the Coordinator have the responsibility to oversee the project, provide guidance to the researchers and to propose to the GA a possible use of the generated knowledge. The appropriate dissemination or exploitation channels are pursued with the approval of all partners. B-GOOD partners are obliged to notify other partners before any dissemination activity. Objection is possible if they consider that their legitimate interests in relation to their foreground or background could be affected.

The Exploitation Support of the Coordinator will initially liaise with each tech transfer office and business development sections of each entity to identify the primary contact personnel. Following this, the individual procedures of each entity for management of intellectual property will be obtained, along with invention declaration forms and integrated into a common ‘project procedure’. This document and procedure will not be considered valid until it has been approved by each entity.

2.2.2 Communication activities

To ensure the broadest possible impact and highest level of dissemination, all B-GOOD partners will be actively engaged in the dissemination process by:

- Providing content to the dissemination team;
- Using their own personal and/or institutional networks and websites to promote the project;
- Using relevant conferences to present the project results and distribute dissemination materials;
- Publishing research and data papers in reputable international scientific journals, in line with their academic and institutional policies.

Global media and science news distributors (e.g. http://www.eurekalert.org, AlphaGalileo) will be used for additional promulgation of project results to reach the broad public and mass-media audiences. Special emphasis will be placed on posting B-GOOD results onto existing international networks and organisations, based on completed and on-going EU projects (e.g. EU Bee Partnership, MUST-B, POSHBEE, etc.), associations and large international fora (APIMONDIA, EurBee, IBRA, OIE, etc.) and research networks (e.g. COLOSS). This approach will enable B-GOOD to reach professional as well as other interested end users, including beekeepers and veterinary associations and industry.

Special efforts will be spent on active promotion and feedback through novel Web 2.0 tools, such as social network profiles of B-GOOD (Twitter, Facebook, LinkedIn, Google+), content sharing platforms (YouTube, etc.) and research blogging. Social networks will be used for three main purposes:

1. Broadcasting of project news, announcements, and podcasts;
2. Receiving feedback, comments and organising discussion fora;
3. Increasing the user base of the project results.

Blogs and news will be posted regularly (minimum 1-2 per month) by the project partners and invited external parties. This will help the project to engage with the youth of society, who are likely to have to deal with future challenges. The new generation of researchers and decision-makers will further be reached through contributing to summer schools and other training initiatives.

Where appropriate the findings of the project will be elaborated as research papers and submitted for publication in peer-reviewed academic journals. A Special Issue team will be set up to plan the topics and processes for publishing a Special Issue in relevant open-access science journals. Print-friendly PDFs of the B-GOOD results will be generated every twelve months and distributed to the email alert subscribers and other relevant mailing lists. Multimedia clip(s) and/or documentaries will be produced and used to promote key products or findings of B-GOOD. In particular, the B-GOOD communication will substantially benefit from the global COLOSS network (>1,000 members from >90 countries, www.coloss.org) and the userbase of its BEEBOOK Information Hub (http://www.coloss.org/beebook/). The main outcomes of B-GOOD will be integrated into a novel edition of the BEEBOOK (Volume 4: Standard methods for *Apis mellifera* beekeeping practice) and used for dissemination and feedback to/from a wider scientific and practitioner audience as well as a means for involving the community of beekeepers and other interested parties, including politicians, conservationists and land managers. With funding guaranteed by the *Ricola Foundation - Nature and Culture* until 2024, the future COLOSS is secure, and it will act as a major platform for dissemination of B-GOOD results, approaches and best practices especially after the end of the project funding.

Table 11.

Overview of the B-GOOD communication activities.

Tool	**Target group**	**Contribution to impact**	**Impact indicators**
Core activities			
Project website	Researchers, graduate and post-graduate students; policy and decision-makers, administrators and other project-relevant stakeholders; beekeepers and veterinarians; broad public interested in environment, nature conservation, and beekeeping	Inform and engage interested parties through the provision of general information about the project and its main outcomes	Number of visits, number of requests and downloads
a) Public online library	All interested stakeholders, academics	Open access to papers, reports and deliverables	Number of downloads, number of additional requests and/or comments

Tool	Target group	Contribution to impact	Impact indicators
b) Email alert	Stakeholders and generally interested public	Automated dissemination of news, announcements, and podcasts	Numbers of subscribed users and emails
c) Internal Communication Platform	Project participants, associated partners and advisory board members	Inform and discuss specific topics of common interest within the consortium	Number of users and emails
d) COLOSS BEEBOOK Information Hub	Beekeepers, policy and decision-makers and other project-relevant stakeholders, scientists, graduate and post-graduate students	Knowledge transfer and integration of project results into a linked data platform	Number of visits; number of feedbacks and comments
Supporting materials and publications			
Scientific publications, B-GOOD Special Issue on beekeeping guidance	Academics, post-graduate and graduate students	Presentation of research findings and evaluation of its scientific quality through feedback from the scientific community	List of publications, number of downloads, number of citations
Presentations at scientific national, international, and general conferences	Academics, post-graduate and graduate students; industry; professional associations	Presentation of research findings and evaluation of its scientific quality through feedback from the user community	List of international or national conferences where the project results are presented, number of conference participants attending sessions with B-GOOD presentations
Wider outreach activities			
Outreach materials:	Project stakeholders, academics and students	Promotion of the project	Number of downloads of electronic copies
a) Posters			
b) Flyers, leaflets	Project stakeholders, academics and students, generally interested public	Increase awareness about the topics dealt with by the project	
c) Policy factsheets and policy briefs	Policy and decision-makers, administrators, professional associations	Knowledge transfer from the project to policy-makers for key issues; engagement of scientists in the policy-making process	

Tool	Target group	Contribution to impact	Impact indicators
B-GOOD Blog, Newsletter (including print-friendly PDF) and Podcasts	Project stakeholders, academics and students, professional associations, industry, generally interested public	Provision of information about on-going events, project outcomes and related activities	
e) Concise final B-GOOD brochure, translated into languages of the member countries	Decision and policy makers and other project stakeholders, academics, industry, professional associations, general public; stakeholders at national/regional level	Provision of a concise summary of the project outcomes to stimulate decision-making, policy implementation, as well as awareness among the different target groups	
Coordinated press releases	Journalists, mass media, project stakeholders, general public	Announcement significant project results	Number of press releases issued; number of downloads/visits of particular press releases
Social network profiles • Facebook • Twitter • Google+ • LinkedIn • YouTube • Slideshare			Number of posts; number of re-tweets (Twitter); number of followers and "likes"
Mass media Publications Interviews Broadcasts	General public	Raising public awareness on key project results and necessity of policy decisions / adaptation and mitigation measures	List of publications and broadcasts
Multimedia clip	General public	Communication of project key messages	Number of visits and comments on YouTube, Vimeo; number of downloads from the website

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