Fungateria

Deliverable 7.1/v.1
Mapping emerging ethical, social and environmental issues for ELM technologies

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DELIVERABLE FACTSHEET

Project Acronym | Number		FUNGATERIA | 101071145	
Deliverable Title:	Mapping emerging ethical, social, and environmental issues for ELM technologies		
Deliverable Description:	This deliverable provides a summary of results for the work in Fungateria WP7, particularly task 7.1. It also includes details on the methods that have been developed to map ethical, social and environmental issue in WP7. This study is based for the most part on qualitative methods, although it includes an initial quantitative exploratory study. The study is informed and oriented by current policy approaches on science democratization and citizen sciences in Europe, and in particularly, the assumption that early public engagement with emerging technologies contribute to social robust technological governance and developments. The deliverable identifies consists of an introduction of to the challenges of upstream public enjoyment with emerging technologies, followed by an introduction to the methodology deployed in our study. We then present four categories under which we have distributed the affections, associations, and views of the citizens that participated in our study. These categories are: 1) A feeling for nature and naturalness; 2) Environments, multi-species and co-existence; 3) Response-ability, agency and control 4) Social need: Market, commodities and scales. The deliverable includes a last section in which we discuss results and suggest a way to move ahead.		
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1.	DET KONGELIGE DANSKE KUNSTAKADEMIS SKOLER FOR ARKITEKTUR, DESIGN OG KONSERVERING	KADK	DK
2.	VRIJE UNIVERSITEIT BRUSSEL	VUB	BE
3.	UNIVERSITEIT GENT	UGent	BE
4.	UNIVERSITEIT UTRECHT	UU	NL
5.	UNIVERSITETET I OSLO	UIO	NO
6.	UNIVERSITY OF THE WEST OF ENGLAND, BRISTOL	UWE	UK
7.	DIMOKRITIO PANEPISTIMIO THRAKIS	DUTH	GR

GLOSSARY & ABBREVIATIONS

ELMs – Engineered Living Materials

TA– Technology Assessment

RRI– Responsible Research and Innovation

STS – Science and Technology Studies

NI – Natural Intelligence

EXECUTIVE SUMMARY

Public participation for socially robust technological development has been a key component of European research and innovation policies for over two decades. Fungateria is funded by the European Innovation Council to develop a portfolio of Engineered Living Materials (ELMs). Fungateria WP7, is targeted to facilitate upstream public engagement with ELMs. Still at an emerging stage, ELMs offer great prospects to exploit and optimize exiting functionalities of living system such as sensing, self-repair and growth aiming to sustainable materials production. Drawing on previous TA and STS scholarship, we take that it is key to engage with the public "upstream", that is, before technological design attains closure, and it becomes difficult to steer. At the same time, it is challenging to take citizens' views and concerns into account at early design stages when concrete applications are still not in place and products have still not been commercialized. Regarding Fungateria task 7.1 this report will introduce the tension and challenges of upstream public engagement to then present how our research design addresses them.

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This deliverable presents an overview of our activities, including the move from mapping issues to a sensing-oriented methodology to capture feelings, associations, and concerns regarding ELMs. The results of our empirical work are presented in four categories: 1) A feeling for nature and naturalness; 2) Environments, multi-species, and co-existence; 3) Response-ability, agency, and control 4) Social need: Market, commodities, and scales. Although our participants were generally positive towards the Fungateria work on ELMs and the future development and impact of those materials, some skepticism was raised regarding the actual social need for such materials, the challenges of standardization and how Fungateria ELMs materials (and particularly the bacterial switch) are to be controlled overtime. Our participatory activities have been designed to avoid too much framing when introducing Fungateria ELMs and to let enough room for participants to freely express themselves. At the same time, we cared to provide enough technical detail for participants to understand the Fungateria portfolio. We anticipated several possible issues such as public reactions towards GMOs, which did not appear (the latter with respect to Fungateria deliverable 10.2 on biosafety and ethics)

In designing and developing our ELMs citizen sensing methodology (combining issue mapping and upstream engagement), we have succeeded in establishing a group of participants that we can invite to take part in the next task of WP7 (participatory modelling). We succeeded in recruiting participants from a variety of European countries. A shortcoming in our methodology is that despite our efforts to recruit participants from different social classes, most of the people that responded to our call were middle-class and educated. This is a challenge that we will continue working to overcome in our coming activities.

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1 Introduction

Taking an approach from the fields of Science and Technology Studies (STS) and Technology Assessment (TA), this deliverable considers Engineered living materials (ELMs) as emerging technologies. These are technologies that exist at an early stage of development, and with research often aiming at proofs of concept. ELMs present a great potential in so far as they are to exploit the functionalities of living systems, and concrete applications are still opened for design. The goal of Fungateria WP7-Futures is to develop a methodology that will enable citizens' early engagement in ELMs development. Upstream engagement is challenging as concrete applications may still need to be defined, and products do not exist in the market. Yet to be able to work in a participatory and future oriented fashion, science and technology are to be situated in concrete contexts of application [1]. In our work in WP7 we have suggested future Fungateria materials as applied to the built environments. We have used the vision of mycelium-bacterial living walls to inform our methods, while at the same time enabling enough room for citizens to image alternative applications that make most sense for them. For this purpose, in our work we focus not only on sensing materials and imagining possible functionalities and objects, but also we have invited citizens envision futures that are desirable and in which ELMs make sense and can contribute to those futures.

1.1 Public participation in technology development

Public participation has been a cornerstone of European research and innovation policies for the last two decades [2,3]. In the discourse of RRI, upstream engagement with citizens appears as a key to restore public trust in science and to ensure socially robust technological development. Aligning with such goals Fungateria's WP7 main objective is to develop a citizen science methodology that is integrated and runs in parallel with other research activities in the project. This methodology builds up in three steps: 1) Issue mapping; 2) Participatory modelling and; 3) Participatory prototyping. This deliverable regards the first of those steps by providing a summary of emerging ethical, social and environmental issues for ELMs that identified through our research activities.

ELMs research is still at an early stage, potential is large and there is still openness about the kind of applications and actual commercial products that this research will lead to. This makes public participation both important and challenging. While it is relevant to include citizens' view and values at a time when they can still actively shape technological design, lack of technical definition comes with inevitable uncertainty and difficulty to anticipate risk and undesirable effects [4]. This is a common condition of anticipatory governance: At an early stage of technological development, it might be difficult to take a clear position and to foresee the potentials and risks associated to a certain

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technology; On the other hand, when the technology has reached a certain closure/definition in the design process it might be too late for publics to be able to engage substantially with it, and to be able to shape that design. In the fields of ethics of technology and Technology Assessment (TA), this tension is known the Collingridge Dilemma: "early in the innovation process – when interventions and course corrections might still prove easy and cheap – the full consequences of the technology – and hence the need for change – might not be fully apparent (Collingridge, 1980). Furthermore, early interventions can unduly limit technological options before they are adequately explored" [4].

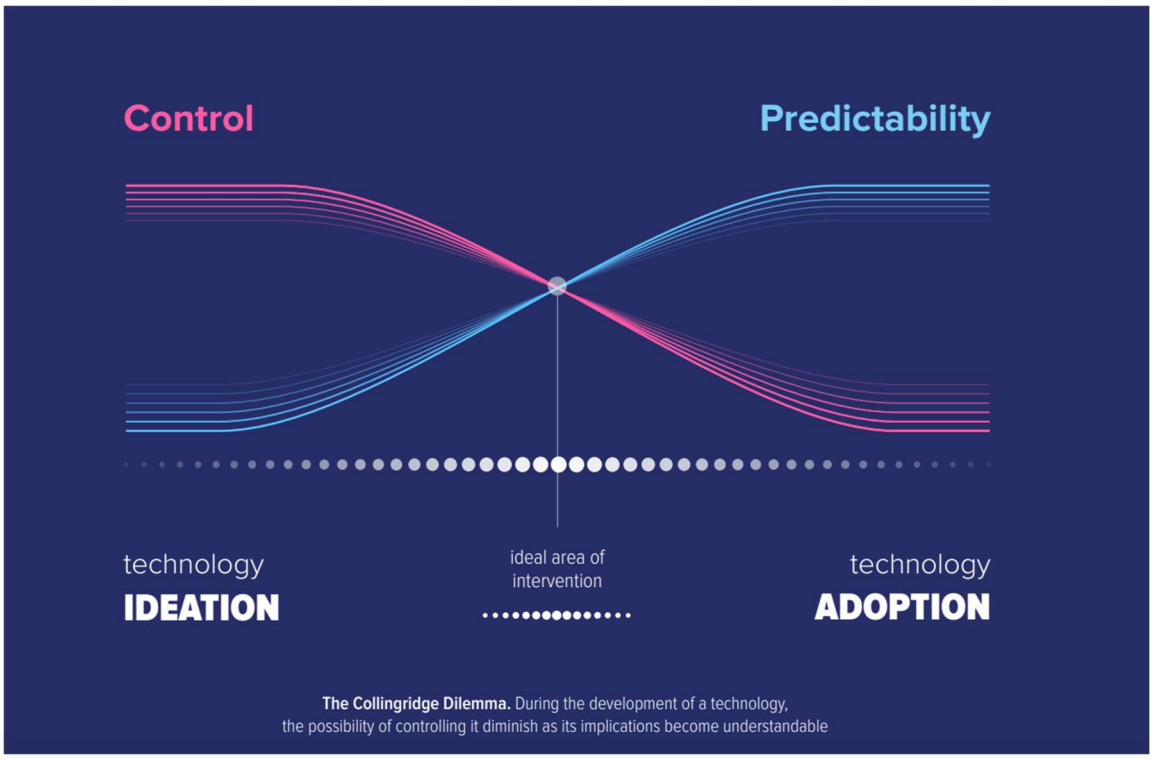

Figure 1. Source: Besti, F. and Samorè, F. (2018) Responsibility driven design for the future self-driving society | Autonomous systems and the complex challenges to designing a responsible, driverless future

Considering the Collindgride Dilemman, Fungateria WP7 aims at making an intervention at an ideal point in time (see figure 1). The first step has been to identify who relevant publics may be for the case of ELMs, and particularly for the kind of mycelium-based materials developed in Fungateria. We inquired: is there a public that is concerned or interested in ELMs? Are there any public reactions towards this emerging technology? To investigate these questions our work has built on conceptual perspectives from the fields of STS and TA. We work with the pragmatist hypothesis that publics are heterogeneous social configurations. But, what triggers a public into being? How do publics come to existence? A way to explain the formation of a public is by focusing on the circulation of text in the media. One could consider the public as media readers [7, 8]. A way to identify that public would then

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be by following published text. Another way of conceptualizing the formation of a public is by emphasizing affection and life experience [9]. Thus, a public would come into being when a heterogenous group of people articulate their experience with technological development as an issue of common concern [10]. We take these two approaches as complementing each other in our attempt at investigating who the public of ELMs may be. Our way of proceeding has been by trying to identify social, ethical and environmental issues as expressed by non-scientists by using social-media web scrapping in combination with qualitative methods (see data collection section).

Previous technological development in biotechnology has in some cases spark strong public reactions. That has been particularly the case for gene-editing technologies such as CRISPR. While GMOs have been the object of substantial public backlash in Europe, more recent technological developments such as developments in synthetic biology have not attracted much public attention [5]. Our initial research was set to identify traces of an emerging controversy relation to ELMs. We did not find that substantial controversial issues regarding this technology have been yet published in the media, which does not discard that this could still happen in the future. We went on to map non-controversial issues and just signs of interests on ELMs among publics. Our results indicate low-moderate interest. With this result, we turned to use a qualitative methodology that would enable us to work despite of that lack of active engagement, and in an anticipatory-future oriented fashion. In doing this, we have invited a public to sense and make sense of samples of materials developed in Fungateria. In our work we have combined a focus on materiality and sensing, with a focus on social desirability to open for dialogue about futures that we, as society, want to live in and the role that ELMs may perform in them.

1.2 Data collection and methodology

In our work to identify publics and to map issues we have initially drawn from digital methods for controversy analysis. Our first inquiry regarded whether ELMs are to some extent contested and if some emerging issues regarding, for instance health or the environment, have been articulated and put forward in the media. The first challenge has, therefore been to decide on a semantic strategy that would enable us to track ELMs digitally. In adopting a semantic approach, we faced the challenge of defining ELMs. The definition of ELMs is still quite loose and that has influenced our research strategy. In addition to tracing ELMs online using specific key words, we decided to focus on scientific communities and their science communication activities. We followed science communication activities by scientists involved in projects that were funded in the same call as Fungateria (EIC Pathfinder challenge). We concluded that ELMs are a concept that travels mainly

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within scientific networks, without attracting much public attention or reactions. A reason could be the way the ways in which ELMs is framed and presented broadly as “materials” rather than specific applications (for instance, in the case of GMOs the main reactions have been towards food related applications). Whereas the public interest on ELMs is not remarkable, we noticed in contrast an increasing public attention to living materials (non-engineered), both bacterial and fungal. This growing interest has been noticed in the academic literature and described in terms of a probiotic turn within sectors of the public [11, 12]. This already existing interest gave us a clue to design our further work. We moved to work with people who had already developed an interest in living materials through material experience through their hobbies or their work (for instance people involved in fermentations, mushroom-pickers or people working with biological materials in the construction business). We sent out invitations and carried out a first round of interviews. The interviewees were recruited based on their activities on social media such as Facebook, Instagram, etc. By entering keywords such as biomaterials, mycelium, microbial materials, etc. on the search field it displayed the public profiles engaged around these discussions. We conducted a total of 10 interviews and variety of insights came up during the conversation. While the participants shared a positive outlook mainly regarding the current environmental concerns with the need for alternate biomaterials, an issue that came up repeatedly was the knowledge gap between experts and lay-public.

After this first exploratory round of interviews, we designed a workshop called “Co-Living with Living Materials” to which we invited both people who had already been interested and had a relation to living materials, with people who could be counted as representing a less interested public. We invited both interested and uninterested publics to balance our research design. This workshop took place in the Botanical Gardens in Oslo in November 2023. To recruit participants, we sent invitations through various social media (Facebooks groups, LinkedIn, etc…). In addition, we printed out poster invitations and we posted them on bars, cafés, and other public spaces. In the invitations, we announced an economic incentive to make the workshop more attractive for the general public. Our success in recruiting non-interested publics has been limited. Most of the participants that responded to our invitation were university educated. Of a total of 30 persons signing for the workshop, we accepted 18 (a limit that is given by the design of the workshop, and the kind of group work that we wanted to carry out) of which 14 attended on the day of the workshop. The design of the exercise required that participants were distributed in three groups (with 5-6 persons in each group). The first group would be composed by people who already had developed a practical interest in biomaterials, in a second group participants would be as little familiar with these materials as

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possible (without an academic, professional of hobby-based relation), while the third group should be hybrid. Holding a European nationality, gender and age were also part of our selection criteria. To compensate for the lack of participants without university education and from a non-middle-class background, we organised a second workshop in which we invited people by approaching them personally. These were mainly people working at services (such as the cantina and others) on the UiO campus. It was during the recruitment process for the second workshop that we observed reluctance from the non-interested public to participate in discussions related to ELMs. We conveyed the message that this workshop required no prior knowledge about the topic, but it was still met with hesitation and therefore we proceeded with a smaller arrangement.

Particpant Code	Profession/ Interest	Nationality
P1	Work with innovation, testing biomaterials in construction	Norwegian
P2	Designer/ Entrepreneur working with mycelium materials	Dutch
P3	Cosplayer and fascinated with mushroom and mycelium	Norwegian
P4	Sourdough and fermentation practitioner	Norwegian
P5	Product designer interested in experimentation of new ecomaterials	Spanish
P6	General interest in biomaterials	Slovak
P7	General interest in design and new materials	Slovak
P8	General interest in biomaterials	Norwegian-Greek
P9	Professionally involved in renewable energy sector and generally Interested in knowing more about ELMs	Indian
P10	Fascinated about fungi and curious about the topic	German
P11	Interest in biomaterials, especially in building industry and regenerative way of living	Polish
P12	Fine arts student interested in the possibilities of living material	Czech
P13	Biology student interested in mycology	Greek
P14	Researcher working with fungi and interested in industrial use of fungi	Spanish

Table 1. Description of participants that attended the Co-Living workshop held in Oslo in November' 23.

2 Mapping emerging ethical, social and environmental issues for ELM technologies

This section summarizes general feelings, associations and concerns regarding ELMs that were expressed by the participants in our research activities. Participants in the Co-Living workshop

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expressed that ELMs sound as something very futuristic, very technical and difficult to engage with. Actual applications seem to be quite far away in the future, so it might not clear what their current relevance or interest is "I would not be engaging with it, if I was not here". Regarding this science-fiction character, another participant expressed fascination, particularly regarding the kind of functionalities that ELMs can perform (such as self-healing).

Advantage of living materials were pointed to, regarding sustainability, particularly in terms of CO2 emissions, and the current excess waste production and materials that are non-compostable. Current material scarcity is a problem that ELMs could serve to ameliorate in view of some participants in the workshop. However, scepticism was expressed in relation to the possibility of controlling these materials overtime. A young participant (student) expressed concern about "unknown consequences", he expressed it:

"Because it is a technology that has never been used before really. We build cities out of mushroom and after 50 years who knows what will happen. We think it is going to be one way, but in reality it is often a different way. So how do we deal with this uncertainty? This is kind of a high complexity solution, the whole process of manufacturing the mushroom requires extensive knowledge of biology, and the genetic process is even more complex and, and then the education process of the public so that people is attuned to it and know how to deal with it…It increases the complexity to deal with complex problems when things do not go well".

In this participant's view ELMs appears as a technology that both is itself too complex and that increases complexity. He suggested that more simple solutions/materials -some of them already existing- may be more relevant and appropriate. "Why to try to create these super complex solutions that needs so many years of research, and millions of Euros", he questioned why we need ELMs when we already have materials such as wood. In other worlds, he questioned the social need of ELMs, something that is also a key issue in TA approaches. To the question of which advantages may ELMs, and in particular, mycelium-based materials bring about in comparison to other materials another participant responded that the advantage of ELMs is that they "grow faster". Fast-growth rate and the fact that they are compostable were presented by this participant as the main advantage of these materials. This participant works in the research section of a construction and insurance company in Norway. She explains how in in a consumer society, people want to have new objects (and house interiors), so compostable materials such are these are something should be something desirable.

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In addition to these themes, we have mapped several more specific issues that we have organised under four categories: 1) A feeling for nature and naturalness; 2) Environments, multi-species and co-existence; 3) Response-ability, agency and control 4) Social need: Market, commodities and scales. We present these categories as main sections of this deliverable. The categories present a thematic summary of participants' expression on how Fungateria materials feel, could function, and the conditions under they could exist, including how they would be desirable or not. These are expressions that the participants formulated after they had the chance to interact with a sample of materials (to smell, see and touch them), and after the researchers had given a general introduction of the technical aspects of the Fungateria mycelium based envisioned materials.

2.1 A feeling for nature and naturalness

In our issue mapping research activities, we have been careful to allow for participant's to freely formulate their own feelings, associations, and concerns in relation to ELMs, while we have also cared to provide enough technical information to enable a focused and substantial conversation. Among other things, during the Co-Living workshop we introduced the participants to how Fungateria material are *engineered*. We introduced the participants to how the fungal-bacterial consortium is meant to function in Fungateria materials, how biological systems are seen as holding computational properties, the focus on modelling and on synthetic biology, particularly the bacterial-switch mechanism. Despite our emphasis on 'engineering', the participants expressed during the workshop how fungal based living materials such as the ones developed in Fungateria feel natural. This was remarked specially in relation to the material samples that we exhibited during the workshop and that participants were invited to sense. Interestingly, this sense of naturalness co-exists with the vision that in the future such living materials should behave as AI (or rather NI- Natural Intelligences).

Participants in Co-Living workshop pointed out that the samples of materials felt visually natural because they present different patterns, and they look unique. Lack of homogeneity made them feel alive. The materials were seen as versatile and organic, which was a positive feeling. At the same time, for some participants the fact that they could be alive made them uncomfortable, as they could be unpredictable, a material that cannot be controlled. Thus, being not regular in shape is something that appears both as making the materials feel alive in a positive way (organic) and being unstable and unpredictable. A participants expressed that she really liked that these materials feel so organic. Another participant mentioned that the fact that they are not dead felt scary "if you leave them in the bathroom and then you wonder, what would happen when I come back". Summing up, the samples of materials that we exhibited felt natural but that had ambiguous meaning: it can feel pleasant for some

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and disgusting or upsetting for others. The fact that natural-looking materials could have computational/sensing properties triggered the participants' curiosity. Participants imagined ELMs as AI/NIs (Artificial/Natural Intelligences), a point that we will come back to in a next section.

It was pointed out that the shape in which these materials is presented influences a lot how they appear visually, and the type of associations that can come to mind. Presenting them as leather-like skins would made them feel natural in a particularly familiar way. In some instances, these materials are imagined co-existing (or being supported by) other non-natural materials, and participants wondered how these relations would work, and how these materials would behave. For instance, if ELMs have to co-exist with electrical cables.

The texture of the samples materials that we made available for participants felt soft, and fragile. A participant wondered about how it could possibly be cleaned. In modern societies, lack of hygiene may be associated to something existing in a natural state while hygiene is associated to modernity and progress. As the main future applications that we consider for Fungateria materials are in the built environment, a participant mentioned that people would have to be warned if they were to enter a room where walls are made of mycelium for them not to feel disgusted because "the world in which we live today is very sterile". Yet lack of hygiene can also have more probiotic and positive connotations. A similar kind of ambiguity regards the sense of smell. As the main future applications that we considered for Fungateria materials regard the built environment, participants pointed to how the smell of fungi in a room can be both appealing and unappealing, or even repulsive and overwhelming. A group of participants discussed that fungi-like smell may get a positive or negative connotation depending on particular cultural and personal framings. They pointed out how fungi in a room can smell "like forest" or like you "forgot your cloths in the washing-machine" a few days ago.

The samples of materials that we exhibited during the workshop felt natural. Feeling closer to nature or connecting with it in new ways was generally seen as positive. However, a participant remarked that humans like nature when they can choose when to be close to it. For this participant the thought of being surrounded of mycelium materials (walls) permanently was suffocating. For her, the intimate space of the home is a place where one should have the option of not being surrounded by nature/ living things. Living materials have in her mind more sensible applications for objects that you can choose to have with you or to get away from at will, such as a purse or a bag, something you do not need to be surrounded with or exposed to permanently.

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2.2 Environments, multi-species and co-existence

The Co-Living workshop included group work on how the kind of conditions in which mycelium-based ELMs would be possible, including desired and undesired conditions of existence. Participants focused mainly on environmental and multispecies relations (without the researchers imposing that choice). The main interest was on how mycelium-bacteria based ELMs would adjust to certain environmental conditions, and how the mycelium-bacteria consortium would attract or co-exist with other species.

Participants pointed out that mycelium-based materials would probably not be suited to exist outdoors (in connection to the material feeling fragile). It could probably not resist too much humidity, wind, or heat and in that sense, it would be better suited for in-doors existence in most cases. The idea that these materials could only exist in interiors was quite extended. If it they were to exist outdoors it would have to be only for short periods of time, nothing permanent, otherwise they would need to be constantly self-repairing, one participant pointed out. However, those in-door environments would need to be controlled, participants imagined. Art galleries, museums, or interiors of cars where temperature can be regulated appeared as the best interiors for Fungateria kind of materials. Two groups expressed that they would not like to see these materials existing in bathrooms, and specially not in kitchens or restaurants, nor as kitchenware (any place where there is food around). Part of the participants said that they would not like to see these materials existing in kindergartens or places whether either children or animals could eat it (that would be scary, a participant mentioned), although it would always be better than plastic. Besides from concerns with food/eating, concerns about air quality and hygiene were also raised. A participant mentioned how he could imagine the human immune system reacting to these type of materials (particularly the immune system attacking the bacteria)

Participants wondered how these materials would behave or change under climate change conditions; If, for instance, the climate would become warmer, what would happen to them. A question that came about was how changes in climate would affect the durability of the material. One the other hand, these types of mycelium-based materials could be relevant to use in places under the occurrence of increasing wildfires due to their insulation and fire-proof properties. It was pointed out that mycelium-based materials such as these would be sensible to seasonal change and would not be viable in parts of the world such as Arctic or humid regions. A group pointed out that mycelium-based living materials would probably not be able to exist in polluted environments. In this sense, these materials were seen as being viable only in very stable social and environmental

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conditions, where the air is clean, and people have time for them. They were seen as “classy materials”, or materials for wealthy societies.

Regarding multispecies relations, participants expressed concerned about the type of “unwanted guests” that mycelium-bacteria based ELMs may attract. For instance, if existing in kitchens, they could attract moulds or other microorganisms. The material could be colonized by spores or by being eaten. As mentioned, participants expressed concern that children or animals (cats) might want to eat these materials. More, the capacity of mycelium to colonize surfaces appears as an exciting functionality, but also as a disturbing one (see next section). A participants called to pay attention to how “everything is connected”.

The idea that the Fungateria materials would be kept in a state of dormancy attracted attention within the participants. One of them wondered for how long a state of dormancy could be kept and the material would remain living. He noticed how every living being needs support (in energy terms) from other beings. And so he wondered for how long could so called living materials go on without a source of energy “Even if it is dormant at some point in time it will need some nutrient because it cannot live from just air”, periodically, they would need some maintenance and inspection. In the next section we provide further insights on the kind of questions that such state of dormancy might raise, particularly in relation to issues of agency, control, and response-ability.

2.3 Response-ability, agency and control

During the Co-Living workshop, the question of how Fungateria materials would be responsive, depending on the different types of relations and environments they would be existing in was raised. As mentioned, the idea that these materials would only be viable and desirable under controlled environments came up repeatedly. The main variables to be controlled would be temperature and humidity, participants expressed.

A group made the comparison of mycelium-based ELMs with Teflon and expressed that they imagined these materials being safe if they are not damaged and remain in a dormant state. Participants wondered what a dormant state was really about, and how might the bacterial switch mechanism in Fungateria materials be triggered. A group found it difficult to say anything about these materials without knowing exactly what triggers the bacterial switch. They expressed they would need to know what the trigger is in order to be able to say something about how this material could exist: “If water is the trigger, it could only live indoors”. Participants wondered whether the switch would always need

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a human agent (using, for instance, a spray) to be activated or if it could be triggered by non-humans (i.e. environmental factors or other bacteria or living organism). A participant remarked that she would not like to see this material in her kitchen or where there is food because there are lots of bacteria and she imagined that bacteria being able to trigger the Fungateria bacterial switch mechanism. Sensing materials with computational capabilities were imagined as Natural-Artificial intelligences that could be activated in case of fire, for example; Mycelium walls that grow by themselves to fight fires in the forest (so the trigger would be hit, in that case).

A group of participants pointed out that such materials should only exist in places where they can be seen all the time, so if something happens and the material goes out to dormancy, a human should be able to see it. In this sense, it was discarded that the material could be used in covered places, for instance, in between walls as insulation material. It is interesting how participants feel the need for a human to be in ultimately control, even they can simultaneously imagine material holding agency of its own.

The changing properties of these materials, the fact that is not permanently dormant, is seen as both exciting and disturbing. Participants imagined that the material could go out of control in certain situations and sets of relations. They'd like to see the materials existing in conditions in which it can always be controlled, so that it does not change much by itself. One of the groups indicated that a condition of possibility for the kind of ELMs envisioned in Fungateria is that users of these materials have knowledge on how they might behave. Thus, educating people in biology is seen as a way to make these materials viable and desirable. Or to put it differently, people that are educated in biology seem better prepared/equipped to take responsibility for this kind of mycelium-based ELMs materials. This adds to the idea that these materials are seen as 'classy', in the sense that they are possible in situations where people are educated, as well as, society is stable, there are no major conflicts, wars or emergencies and environmental conditions can be controlled (not in places where climate change has a major impact and there are floods, for instance). Besides, a group pointed that these materials would only be possible in conditions where current regulations for building materials are redefined and adjusted (particularly regarding hygiene).

We included a science-fiction based exercise at the end of the workshop, in which we asked participants to come up with a science fiction narrative for mycelium-based ELMs. It is interesting that when inviting participants to think in a less sensitive and more speculative fashion, ELMs appear as higher intelligences in post-apocalyptic scenarios in which they are attributed key roles such as

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redistributing nutrients among humans and hence contributing to human health. NIs then are imagined as mediating in human relations and satisfying human needs by producing (growing) "whatever" humans need. This post-scarcity scenario is imagined as one in which mycelium based NIs save humankind by transporting humans to more habitable environments (than an imagined exhausted Earth) or are even as such mycelium based NIs seen as able to debate on existential and ethical issues with humans.

2.4 Social need: Market commodities and scales

During the workshop and after the participants had been invited to sense (see, touch and smell) the Fungateria samples, they were asked to suggest possible and desirable functionalities and objects for those materials, including commercial objects. The samples of materials that we made available to the participants were characterized as: *absorbent, not rigid, flexible, vulnerable, fragile, having insulation properties (sound and fire-proof), fast-growing, light, non-lasting, disposable, soft, rubbery but not elastic, crispy when is dried, non-washable (difficult to clean and thus not hygienic)*. According to these attributes, a number of functionalities were imagined. In walls and the built environment more generally, mycelium-based ELMs were seen as most desirable for interiors and to function as insulation. They were not seen as resistant to water and so not appropriate for existing outdoors. Because of the smell some participants felt it would be overwhelming to have walls made of mycelium. For their absorbent and flouting properties, they were seen as suitable to make parts of boats, and sanitary products such as dippers. They should not be used, on the other hand, in hospitals or for first aid products such as bandages because it could mix with body bacteria. And not in kitchenware for the same reason (that it could mix with bacteria). The growing properties were seen as an advantage that could be exploited for instance in producing life-lasting shoes (a shoe that a person could use from childhood to adult age). Because the samples looked leather-like the participants suggested such materials could be used to replace leather, but in that case, it would need to be made more resistant and durable.

Generally, the best use for mycelium-based ELMs of this kind according to participants is on disposable products, such as headphones to be used in concerts and (here sound-proof properties were also mentioned). Because they are fast-growing and compostable, these materials were seen by one of the participants as being well suited for consumer societies where people like to change and have new things all the time. On several occasions the participants pointed out that mycelium-based materials appear as a good replacement for plastics. They would contribute to reducing pollution if used in soccer

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fields, or for car and bicycle tires. Because of their rubber-like properties, they were suggested as a good source for bioplastics.

Generally, participants would prefer to see mycelium-based ELMs used in objects that are non-permanent, are portable and disposable. Permanent and large objects such as walls or buildings may feel as not desirable for some participants. Scale was pointed out to be a changing factor. Participants expressed uncertainty about how using materials for building purposed at large scales (i.e. buildings) could affect the quality of the air in the building, or the smell could become too intense (depending on the scale, the smell of mushroom can go from pleasant to not pleasant or overwhelming). Additionally, participants also wondered about the effects of long-term exposure to mycelium-based ELMs such as the ones being developed in Fungateria, which they thought might depend on whether the material is used in an open or closed space. Scaling up the production of mycelium-based ELMs may appear also as challenging if taking into consideration, as participants pointed too, that these materials would have to adapt to many different locations. We see here a tension between the needs of standardisation that comes with scaling-up the production and use of ELMs as construction material, and the fact that people may actually value such materials precisely because they look unique and uneven and for that reason, they feel natural. The challenges of standardisation, an unavoidable requirement for products commercialization in industrial societies, appear to be difficult to deal with, and would possibly require a change on how commercialization chains are currently organised.

As we mentioned above, a participant questioned the actual need for mycelium-based ELMs to be used in the built environment and argue that already existing materials such as wood would make the job, the advantages of ELMs over natural materials not being clear. Another participant responded that the comparative advantage of mycelium-based living materials is that they can grow fast. So, materials could be grown in any location without needing to transport them, and this would serve to alleviate situations of resource scarcity. Wires were mentioned as a concrete example in this regard. Mycelium was envisioned as a surface where electricity can circulate and that could be used to replace Rare Earth Materials, to ameliorating dependency on importing such materials from certain countries and areas of the World. Mycelium-based ELMs are imagined as hardware, to complement visions of these materials behaving as Artificial-Natural Intelligences.

2.5 No-issues: Anticipated but not found

The feelings, associations, and concerns that section 2 of this document presents were expressed by citizens, with us, as researchers, being careful of not framing ELMs in a too positive or negative way

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as we introduced them to the participants. As researchers specialising in emerging technologies and public debate, we had anticipated a number of issues to come up during our interactions with publics, but they did not. We briefly mention them in what follows to finalize this section.

First, the Fungateria deliverable 10.2 on biosafety and ethics point to possible public reactions towards GMOs. However, this did not appear in our analysis of the digital media, nor in our exploratory interviews or the workshop(s). Publics seemed more concerned about issues related to user control of the switch mechanism and adjustment of ELMs to their new ecosystems than on risk of genetic modification for human health and for the environment per se. Second, we had anticipated that publics could be concerned about how to care for, and the maintenance of ELMs, particularly Fungateria materials. Yet, this was not formulated in those terms during our research activities (besides participants mentioning that they imagine those materials being viable in societies where people have time for them). Finally, regarding commercialization and standardization, we had anticipated that issues related to ownership, responsibility and liability could come up, in particular concerning the question of how to create a system of commercial insurance and warrantees for objects that are 'living' and that therefore could change overtime. Our participants expressed concerns regarding standardization, but that had to do rather with the capacity of Fungateria-like materials to adapt and remain functional in particular local environments.

3 Conclusion and research ahead

This deliverable has provided an overview of the type of ethical, social, and environmental issues that were articulated during our participatory activities in WP-7 so far. ELMs such as those developed in Fungateria, with applications to the built environment were in general not seen by our participants with scepticism. Nevertheless, some participants expressed scepticism regarding the actual social need for this kind of materials, and the challenges of standardization and adjustment to local environments. Questions about how these materials are to co-exist with other species were also raised. Fungateria-like materials were seen as viable mainly in controlled environments (interiors), and in stable, wealthy and educated societies, although they appeared also as an alternative to ameliorate situations of resource scarcity. The set of feelings, associations, and concerns that participants expressed during our research activities regarded technologies that are still in the making. Methodically, our goal has been to tackle the problems of upstream public engagement, by navigating the tension between undetermined present applications and wished-for futures, uncertain facts and speculative thinking. We have done that by creating a methodology that anchors itself in material samples and sensations, to trigger reflection and collective sense-making.

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We will present and discuss the results of our research so far with Fungateria partners in UGent, VUB and UU to inform the selection and design of functionalities for the Fungateria ELMs portfolio, including the design of the bacterial switch, and the controlled factors that are seen as most appropriate to activate fungal growth and self-healing capacities (i.e. light, humidity or other). Our results will also be used to prepare for the next task in the WP7 methodology, which is participatory modelling. We have through our research activities identified a number of elements that can inform and enrich the parametrization work carried out by KADK and UWE partners, including a set of conditions under which Fungateria mycelium based ELMs are imagined as being viable and desirable. This work is to be further developed through concrete participatory modelling activities. In our research activities so far, we have worked to establish a group of participants that will be taking part in that next step. However, our methodology has an important shortcoming in that the type of participants that the design has managed to attract for is the most part educated and middle class. Our aim is to continue working to overcome this methodological shortcoming for future WP-7 tasks, that is, participatory design and prototyping.

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