Roles and potentials of urban and rural makerspaces in the digital and sustainability transition in post-Covid Europe

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ABSTRACT

This study investigates on the roles of both urban and rural European makerspaces in the dual dynamics of digital and sustainability transitions, and their potentials in a post-pandemic context. A well-designed questionnaire, provided in five European languages - English, German, French, Spanish and Italian - to the participants, unveiled the mechanisms behind makerspaces Covid-19 responses since the first wave of the pandemic in 2020. The general interest streams of the data gathering were both retrospect and prospect.

Indeed, makerspaces, as fabrication laboratories dedicated to social innovations, have responded quickly to the shortages of emergency goods since March 2020, by deploying 3D printers, among other maker fabrication technologies, to produce and provision vital medical equipment for hospitals and health workers to treat Covid-19 patients. The crisis marked a turning point of conventional production processes, with a resurgence of open source digital fabrication tools and rapid prototyping, through local supply chains, from the makerspace ecosystem turned into sustainable and collaborative production units. In order to understand how makerspaces can contribute to the digital and sustainability transition, their production processes and technology use were chosen as indicators of makerspaces' sustainability.

The aim of this research is to encompass whether makerspaces vital actions were due to force majeure related to the exceptional sanitary crisis, or if they could drive profound post-pandemic societal and sectoral transformations in Europe. The 124 valid responses collected in the survey enabled the extrapolation of various issues, in particular on exposing new types of multi-stakeholder collaborations between makerspaces and other formal institutions, in both rural and urban settings, regarding general dynamics of decentralization and digitalization of production processes. Thus, we notified a reconfiguration of patterns of value creation, not confined to urban typology and industrial settings. While some structures were temporary impacted to provide short-term solutions, other offer glimpses of feasible and long-term socio-economic models, such as distributed manufacturing and repair production, among others. Inclusive innovation initiatives among rural and urban makerspaces can tap grassroots capacity among the diversity of production processes experimented throughout the pandemic, to yield sustainable and socially useful outcomes in specific economic sectors. Yet, we are aware that the Covid-19 episode is not over, and ongoing maturation of niche-level activities are still developing towards concrete sustainability pathways.

Acknowledgements

My first sincere thanks and thoughts go to my surpervisor, Sabine Sedlacek, whose advice and feedbacks at all stages of this project have comforted me in my role as a researcher. My full gratitude to the pre-testers of my survey, and experts in the field of makerspaces: Marc Barto, Dr. Kit Braybrook, Lucia Corsini, Paulo Rosa, Valentina Imparato, Cindy Kohtala, Zoe Romano, for insightful comments to improve my survey design.

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Special thanks to my friends, Fabiana, Anita and Sophia, for having assisted me in the translation of the survey in Italian, German and Spanish, which undoubtedly enhanced the capture of a larger audience, leading to the collection of a greater amount of data.

To my parents and sister for daily support: 'Merci, je vous aime'

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CAS - Complex Adaptive Systems

CPBB – Commons-based peer production

DGML – Design Global Manufacture Local

DIY - Do It Yourself

DIT – Do It Together

DSI – Digital Social Innovation

EC – European Commission

JRC - Joint Research Centre Policy Lab

NUTS - Nomenclature of territorial units for statistics

P2P – Peer-to-Peer

RDM - Redistributed manufacturing

1. INTRODUCTION

The outstanding rally of makerspaces across Europe, to respond to the healthcare system crisis, has unveiled voluntary, individual and collective behavioural changes in the unfolding Covid-19 crisis. Self-organized networks of makers and digital solidarity chains emerged at multiple scales to respond to the emergency, in a context of disrupted global supply and logistics chains. This Covid Makers movement, as the new social energy amidst the pandemic, has been strongly deployed in many European countries, particularly in France, Italy, Spain and the UK. While traditional industries, international markets and some governments failed to cover on time the shortages of basic medical equipment, bottom-up organizational structures engaged proactively, spontaneously, autonomously and democratically in 'socially useful production'. From experimental fab labs and makerspaces, to homes transformed into miniature factories, citizens have been producing and distributing, on-demand and for free, critical items needed (ventilators, valves, face shields,…). Although this was not the first time that makers and makerspaces have played a major role in crisis response, the Covid-19 context exposed the particular adaptability of local and community economies to massive shocks. As a matter of fact, in such a resource-constrained situation requiring environmental and sustainability management, makerspaces could provision emergency goods during the crisis, due to their embeddedness in mutualism and solidarity. Moreover, makerspaces have deployed local manufacturing technologies such as 3D printers, which with other open source technologies, have been playing a central role in the minimization of Covid-19 impacts, and also covering more political dimensions, in particular the emphasis on the autonomy of individuals, the ethos of sharing, solidarity. Though global data reminds us the Covid-19 is not over, we have had time to ponder and tackle these emergent challenges, which have brought the talent and skills of makerspaces to a higher level.

As the author of this paper contributed in the implementation process of an African fablab with its atypical procedures and features, she took the opportunity of making a space in her academic research to honour makerspaces. The author meticulously chooses her thesis topic that will impact and sustain her personal and professional venture, by questioning on the consistence and precision of the subject. Exploring the culture and mentality of European makerspaces in this exceptional sanitary crisis, where their roles seem to adapt to global circumstances, whether they are effective in urban or rural areas, while considering sustainability and digital factors.

Hence the topic of this thesis paper: Roles and potentials of urban and rural makerspaces in the digital and sustainability transition in post-Covid Europe

1.1. Purpose statement

This study investigates the roles and potentials of both urban and rural makerspaces, which were so far reported separately due to the strong urban vs rural dichotomy and the dominance of the urban archetype. The present paper focuses on makerspaces' production processes and technologies, chosen as metrics of makerspaces' sustainability to measure their contribution in the digital and sustainability transitions, in a post-pandemic context. The study explores new modes of production and fabrication tools, deployed by these bottom-up organizational structures across Europe, since the beginning of the Covid-19 crisis. The aim of the research is to understand if makerspaces' vital actions were only a force of circumstance, confined to the particular Covid-19 context, or if they could drive profound transformations in Europe, by their manufacturing practices, and the replication of the supply chains deployed during the pandemic.

1.2. Research goals, research problems and hypothesis development

The Covid-19 pandemic has shown once again how grassroots economies and communities are more resilient to massive shocks, such as the disruption of global supply chains: makerspaces responded quickly to shortages of emergency goods, by producing and provisioning critical items effectively and efficiently since the beginning of the crisis. Makerspaces were not born during the pandemic: they are entrenched in the urban landscape and 'placemaking' since decades (Schoneboom, 2018). Covid-19 only rendered them more visible and highlighted their relevance and resilience, due to their embeddedness in mutualism, solidarity, inclusiveness, and often their 'unruliness' and informality (Leach et al., 2020; Corsini et al., 2021). "Should we look for a hero to save us from the Coronavirus?": this question was raised by Pazaitis et al. (2020), presenting makerspaces as 'covid-heroes'. Beyond the context of the pandemic, we should think of the future post-pandemic sectoral and societal changes that European makerspaces might trigger.

From these observations, we can wonder if those voluntary individual and collective solidarities are temporary and confined to the particular context of the Covid-19 emergency; or if they offer glimpses of alternative economies and sustainability pathways for the future. Pazaitis et al. (2020) refer to the 'commons' as an "alternative trajectory to social change", based on the convergence of localized manufacturing with the digitally shared knowledge commons. Also, from the perspective to enable more sustainable pathways for a post-covid economic recovery, many sectoral transformations need to happen. Manufacturing practices have been experimented in the healthcare sector, during the pandemic: makerspaces, i.e. fabrication laboratories dedicated to social innovations, produced medical equipment (face shields, ventilators) for hospitals and health workers. In this context, it would be interesting to investigate which other sectors, besides the health(care) sector were exposed and sensitive to disruption of global supply chains, as one of the consequences of the Covid-19 crisis on industries. In other words, how could these bottom-up Covid-19 responses, emerged by the *force of circumstance* be translated into longer-term structural and systemic transformations?

General research question and specific research question:

General Research question: How can urban and rural makerspaces drive the digital and sustainability transition in post-Covid Europe? Specific research question: How could makerspaces Covid-19 responses, emerged by the *force of circumstance,* be translated into longer-term structural and systemic transformations in Europe?

1.3. Introduction to the Literature Review

The literature review, theoretical framework and conceptual frameworks, often used interchangeably by researchers, serve similar functions within a report presenting empirical studies, according to Rocco & Plakhotnik (2009). Yet, there are distinctions between the last two frameworks. The presentation mode adopted in this paper was inspired from Creswell methodological insights of a literature review (2003): according to the author, an 'integrative literature review' on a new phenomenon leads to an 'initial holistic conceptualization' of it (Creswell, 2003, cited in Rocco & Plakhotnik, 2009). Therefore, in this paper, the theoretical and conceptual frameworks are presented in two separate parts (respectively section 2 and section 3), in order to offer a better reading flow, and respect a methodological rigor in organizing and conducting research on a new or existing topic (c.f. Figure 2). Figure 2 illustrates the structure of the literature review separated in different yet interconnected parts. Part I introduces the contextual and theoretical frameworks, presenting emerging literature and emerging field of studies. Then, *part II* presents the conceptual and analytical frameworks of the thesis, built upon the frameworks of part I, providing new understandings and reconceptualization of the concepts and bridging the topics that were presented separately in the first part.

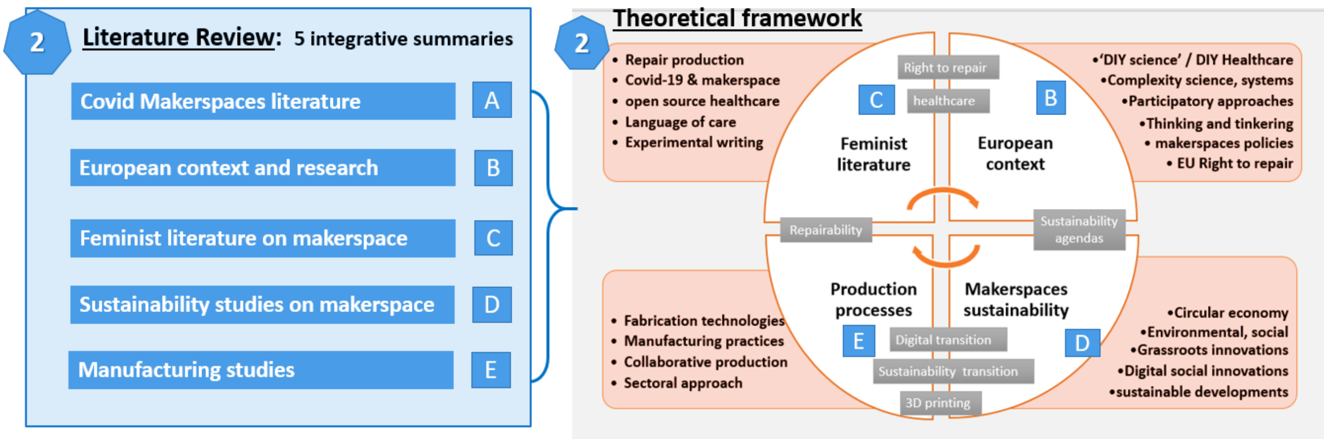
Literature review, part I: Contextual and theoretical framework

The first part of the literature review offers the initial holistic picture of the study to generate new perspectives and frameworks on the topic (Rocco & Plakhotnik, 2009, p.127): it establishes the relationship between the immediate phenomenon observed, current empirical research and the previous studies. Thus, part I synthesizes representative literatures on the topic under investigation, and references the major authors, through five 'integrative summaries' (annotated from A to E, in Figure 1 & 2), which casts a 'broad net' around the topic. The first two integrative summaries (A and B) set the contextual framework, with a temporal context (A): the Covid-19 crisis is seen as a landmark; and a geographical context (B) – Europe – as the scope of the study. Then, the integrative summaries from C to E are 'theoretical reviews', giving the main theories that will be further developed in the conceptual framework (*Literature review, part II*).

The immediate context is first delineated by the flourishing literature on makerspaces that emerged amid the Covid-19 crisis (A). Secondly, makerspaces are investigated into the European context (B). Third, the feminist literature and their experimental writing on makerspaces (C), before and amid the pandemic. Fourth, the sustainability studies on makerspaces from European experts and scholars (D). Finally, the emerging literature tackling makerspaces production processes (E).

Figure 1 shows how each integrative summary lays the foundation of the theoretical framework, i.e. the 'scaffolding' of the study, in Merriam's terms (2001, in Rocco & Plakhotnik, 2009). The five integrative summaries are both 'theoretical reviews' which incorporate theory relevant to the study, and 'methodological reviews' on potential literature gaps (Creswell, 2003, in Rocco & Plakhotnik, 2009, p.124). *Literature review part II* aims precisely at filling those literature gaps identified in part I.

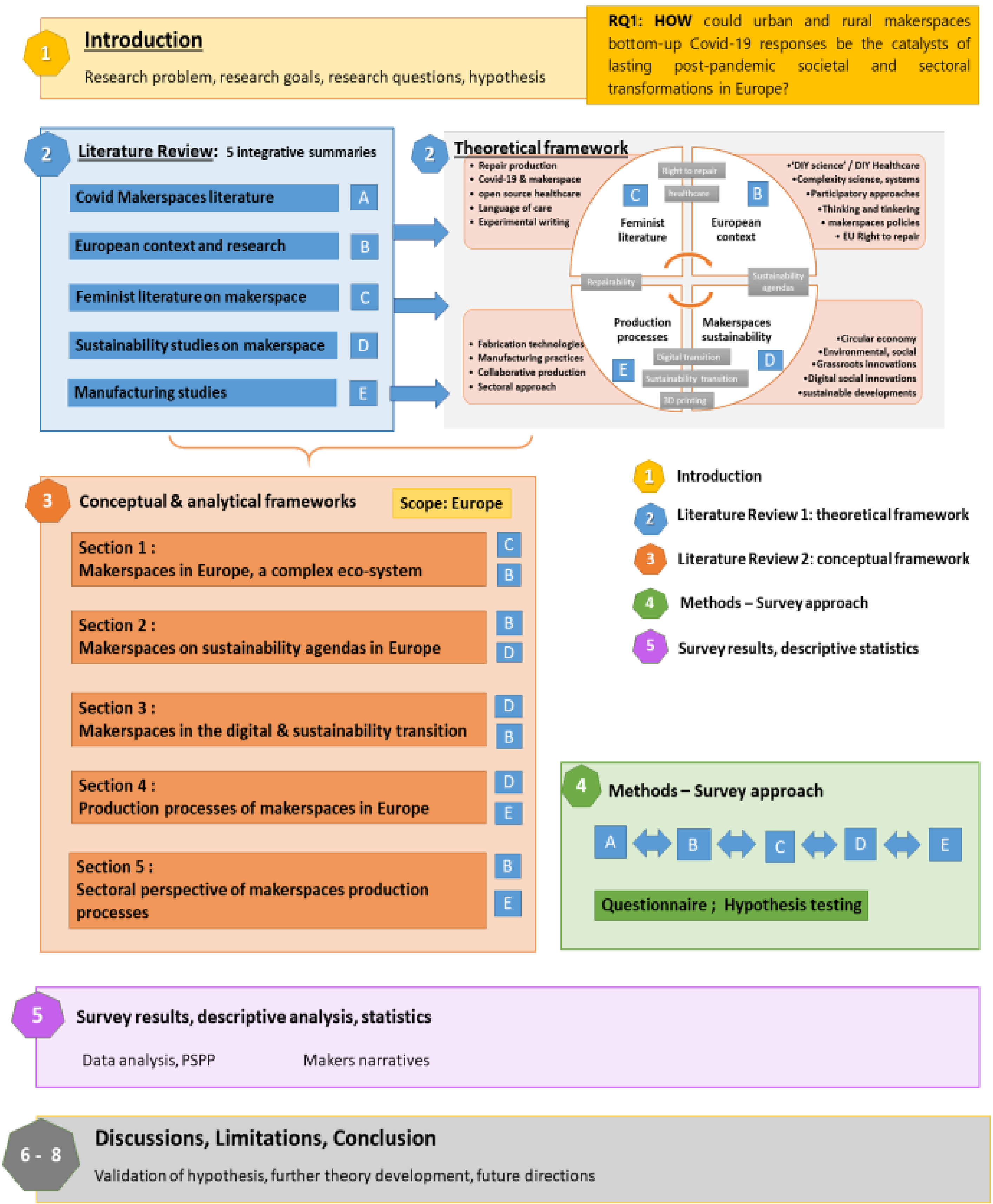
Figure 1 : Structure of the Literature Review, part I



<u>Literature review, part II</u>: Conceptual and analytical frameworks

The second part of the Literature review categorizes and describes the concepts relevant to the study and systematizes the relationships between the five integrative summaries of part I & part II of the literature review. Moreover, part II reports on unexplored areas, in the quest of an emergent theory, as it is often the case in qualitative research (according to Creswell, 2003, cited in Rocco & Plakhotnik, 2009). For this purpose, specific theoretical lenses are applied (sometimes for the first time) to the specific topic of makerspaces, which leads to the construction of an analytical framework for the thesis.

Figure 2: Overall structure of the thesis: interlinkages between sections



2. Literature review - part I : Contextual & theoretical frameworks

This first part of the Literature review presents the contextual framework of the research (2.1.), organized in five 'integrative summaries' (2.1. A, B , C , D and E), which gives an overview of the five broad themes of literature, with the respective main authors. Then, the theoretical framework section (2.2.) summarizes the literature gaps identified in 2.1, and bridges the literature streams. Figure 5, at the end of the section, summarizes the contextual framework and the connections between the integrative summaries and the theoretical framework, which together form the rationale of the present study, and the basis for the conceptual and analytical framework.

2.1. Contextual framework

A) A 'Covid makerspaces' literature: reporting on a rally amid the Covid-19 crisis

Makerspaces' terminology has stepped into the realm of everyday discourses, amid the pandemic, and the image of a 'rally' of European makerspaces is a powerful depiction of the social phenomenon: they 'mustered' their 'scattered forces' to renew an effort for a 'common purpose' ("rally" in *Merriam-Webster Dictionary*, 2020)., locally, nationally and at the European level, to renew an effort. Indeed, it is not the first time that makers and makerspaces have played a significant role in crisis responses (Corsini et al., 2021), yet it is the first time that they came together in such numbers, at all levels of governance (local, national, regional). Covid-19 triggered the concretisation of the 'alternative scenario' envisioned by Dickel et al. in 2016, which anticipated the involvement of "heterogeneous actor constellations and novel forms of self-organization such as the maker movement and the collaborative economy" (Dickel et al., 2016, p.9). Thus, a flourishing literature has been probing and perpetuating the actions of makerspaces across Europe, amid the pandemic context. For instance, French sociologists and scholars launched a new Research program on makerspaces innovation and self-organization processes, in the form of a sociological and digital investigation of makers : " « Make care »: face shields against Covid-19" (c.f. Chalet et al., 2020). Indeed, many researchers adapted their investigation modes and practices to the lockdown context (c.f. Chalet et al., 2020; Cozza et al., 2020). This investigation responds to the impressive (local, regional and national) media coverage of the "Covid Makers movement", i.e. the maker movement of fabrication of medical protection equipment, since March 2020, in order to contain and minimize the health impacts of the pandemic. Published on

November 24th 2020, the study aimed at understanding the mechanisms behind the emergence of bottom up initiatives in France, in times of urgency and crisis: makerspaces self-organization processes, their commons-based production, the common-pool resources involved, and their attitudes towards technology (conviviality). Those properties of makerspaces highlighted by Chalet et al., (2020) are further developed through specific theoretical lenses (c.f. 3.1), in order to understand holistically the phenomenon, **as pan-European.** They also observed that the public and non-for-profit sectors are important in areas where markets and governments fail. Covid makers initiatives within those digital fabrication workshops, mushroomed not only within France, but across Europe: besides a French Covid makerspace literature, Corsini et al. (2021) investigated on the Italian makerspaces Covid-19 responses, and in the UK (see Corsini & Moultrie, 2020). Hence the relevance of tackling the topic at the European or pan-European level. Thus, the coming of a European 'Covid makerspaces' literature has been nurtured throughout the pandemic, and notably by feminist authors (c.f. 2.1. C).

B) The European context: European research on makerspaces

Research on European maker movements and makerspaces appear since 2014, a period when the number of publications on the topic grew exponentially, and when makerspaces' terminologies ('Do It Yourself', 'tinkering') entered the realms of European academic explorations and EU participatory approaches(Rosa et al., 2018). The first report from the Joint Research Centre Policy Lab (hereafter: JRC Lab) was on the Do It Yourself movement, introducing a 'DIY Science': the fusion of a citizen science and the DIY makerspace culture (Nascimento et al., 2014; Calenbuhr, 2020). 'DIY' makers think by 'tinkering', i.e. a maker way of thinking (Nascimento et al., 2014, p.24). The JRC explored the potential of particular type of DIY spaces, for instance the fabrication laboratories, i.e. 'fab labs' (c.f. JRC, 2016), with a special attention given to 'quality assurance' practices (i.e. post-normal science approach) in the scientific development (Nascimento et al., 2014). The implementation of a makerspace inside the European Commission in JRC Ipsra (Italy) marked a milestone in the legitimization and coordination of makerspaces, both at the community and policy level. Thus, the JRC makerspace serves as an exploratory space of critical thinking and 'tinkering' new modes of policymaking (JRC, 2016). Yet each JRC technical reports is only a 'snapshot' of the movement regarding a specific year, and constant updates are required, given the versatility and evolutionary nature of makerspaces (c.f. section 3.1.). Conscious of the complexity of the phenomenon, the JRC Policy Lab created a public and online European makerspaces database (c.f. Sormani et al., 2020). Rosa et al. (2018) assumed that makerspaces, fablabs and hackerspaces are the physical representations of the (spatial spread of) maker movement, present in all major capital cities in Europe, with a predominance in Western Europe countries (France, Germany and Italy).

C) Makerspaces in the feminist literature: a new textured language

The feminist literature has brought a new 'texture' on the research of makerspaces across Europe, by 'tinkering' an 'experimental and collaborative writing' on makerspaces' repair work (see Cozza et al., 2020). Indeed, at the eve of the pandemic, Silvia Gherardi invited a cohort of European feminist authors to write with 'reflexivity' about the effects of Covid-19 on makerspaces, as a "breakdown in the texture" of daily social practices (Cozza et al., 2020, p.2). Feminist authors tinker with words, the same way makers tinker social goods and innovations. By embodying makers, they provide a theoretical framework of makerspaces repair practices, bridging the sociology of repair with 'ethnomethodology' (Cozza et al., 2020, p.2), to enrich the Covid makerspaces literature (c.f. 2.1.A). Their use of emotional language of 'care and response-ability' ('texture', 'breakdown', 'mending') form the "feminist ethos of care" (Cozza et al., 2020, p.3). Care, among other intrinsic values such as solidarity and autonomy, is the essence of the 'making' practice to maintain, repair and strengthen existing public infrastructures of social reproduction according to Rosa et al. (2018). Feminist authors addressed potential ways for 'repairing' production and the 'social fabric', after the breakdown, such as the building a 'care society' and 'politics of social care', essential to the health and wellbeing (Cozza et al., 2020, p.10). Feminist language of care contrasts with the weaponization of care with language of war and related metaphors (health personnel as 'heroes') (Cozza et al., 2020, p.2).

Before the advent of the pandemic, Graziano & Trogal (2019), in their latest issue on repair and care practices, provided an empirical evidence of contributions of makerspaces in urban areas across Europe. Entitled "Repair Matters", the issue explored the politics of repair in the context of organization studies, a well as the materiality of repair and a way to "think about complex systems and institutional practices" (Graziano & Trogal, 2019, p. 204). While makerspaces were considered at the fringes of economies, Cozza et al. (2020) repositions repair practices "at the centre of social order" (p.14), and depict makers as 'repair workers' to 'reconstruct' an emotional state after a breakdown, according to Cozza et al. (2020, p.11). European feminist authors called for a 'Right to useful production': the term 'useful' sets a 'public-service objective' to prioritize the common goods, like health services, rather than individual goods (Holman, 2020; Cozza et al., 2020). For makerspaces and other local factories, this right means that they convert their production purposes to meet "diverse social care needs" (Cozza et al., 2020, p.10). This right to useful production can find echoes in the recently enforced Right to Repair in EU laws, to reduce e-waste from modern manufacturing, and where the 3D printing industry might be crucial (Everett, 2021). This particular technology, 3D printing, and makerspaces' attitudes towards these digital fabrication tools will be further scrutinized in section 3.3.

D) Previous research and sustainability studies on makerspaces

Makerspaces have informally grown along with the maker movement during the last two decades, driven by two main waves of interest. In the first decade of the twenty-first century, Anderson (2010) and Gershenfeld (2012) tried to formalize their presence in the international economic and political landscapes: depicting makerspaces as ‘harbingers’ of an industrial or a digital revolution (Braybrooke & Smith, 2020; Rosa et al., 2018), and many authors have been analyzing how makerspaces could foster these multiple transitions in a sustainable way *(c.f. 3.4).* Then, at the beginning of the second decade, the Covid-19 context rendered this emergence and proliferation even more visible: makerspaces could scale up their production with digital fabrication tools.

In Autumn 2015, a workshop, organized by the STEPS Centre (Social, Technological and Environmental Pathways to Sustainability Centre), had gathered eighty researchers, practitioners, and experts across Europe, to shed light on the sustainability development potentials of makerspaces, during disasters and after disasters (Corsini et al., 2021). This workshop paved the way to a flourishing literature bridging makerspaces and sustainability issues: makerspaces as grassroots initiatives (Smith & Light, 2017), makerspaces and the peer production paradigm (Braybrook & Smith, 2020), makerspaces as places of “social innovations, democracy and sustainability” (c.f. Smith & Light, 2017), as pioneers in societal and repair matters (Graziano & Trogal, 2019), fab labs as ‘tools for sustainable development’ (Gadjanski, 2015). The bottom-up structures are providing doers and consumers with alternatives to mass production and business-as-usual, along with hybrid configurations that combine society’s demands for innovation with a strong focus on sustainability, both on the production side (design & distribution) and consumption side (Dickel et al., 2016; Voigt et al., 2017). Beyond their domestic and educational aspects, makerspaces took new political and global dynamics, as ‘real-life laboratories’ for sustainable innovations (Braybrooke & Smith, 2020), shaping the “future(s) of work”, beyond the exclusive narrative of digital transformation (Rosa et al., 2018). As ‘citizen labs’ and ‘spaces of dialogue’ fostering new forms of “collaborative problem solving”, they also contribute to sustainability, as they encourage active participation with a transformative and empowering role (Voigt et al., 2017; Smith & Light, 2017; Rosa et al., 2018; Tainter, 2006). Makerspaces grasp and nurture individual capabilities (Do It Yourself) and benefit for the entire community (Do It With Others - DIWO) (Graziano & Trogal, 2017; Rosa & Guimaraes, 2016; Dickel et al., 2016).

Another emerging field of research is ‘sustainability transitions’, introduced by Markard et al. (2020) at the 36th EGOS Colloquium on “Organizing for a Sustainable Future: Responsibility, Renewal and Resistance”, in Hamburg (July 2020). Sustainability transitions are defined as the profound transformations of an incumbent socio-technical systems , from unsustainable practices to more sustainable practices of consumption and production. Markard et al. (2020) raised policy framing, inter-organizational collaborations, multiple transitions, technology trajectories, under the label of ‘sustainability transitions’. However, the Covid-19 context triggered not only macro-econimic transformations, but also micro-economic impacts (c.f. Figure 40): bottom-up initiatives and grassroots innovations complete the scales of transformations in the broader sustainability transitions challenges. Thus, sustainability studies look at the commitment of societies and organizations to a transition. In this context, the makerspaces Covid-19 responses could be seen as organizational responses to micro challenges (e.g. healthcare systems crisis) as well as grand challenges at the macro level (e.g. disruption of global supply chains). The recent crisis revealed many of the potentials of makerspaces committed to more sustainable modes of production in particular sectors (c.f. *3.4.).*

E) Manufacturing studies and constellations

Pre-Covid literature on makerspaces modes of production. The Covid-19 crisis marked a turning point of conventional manufacturing practices, and the resurgence of (digital) fabrication responses (Corsini et al., 2021; Leach et al., 2020). Dickel et al. (2016) are the first authors to have blended the makerspaces constellations with the 'manufacturing constellations', by exploring the multiple applications of 3D printing within makerspaces. Dickel et al. (2016) distinguish two trajectories or patterns of value creation within makerspaces in the context of general dynamics of digitalization and decentralization (Dickel et al., 2016): on the one hand, a top-down approach mode of production by industrial manufactures and firms (1) and on the other hand, bottom-up modes by communities, among them makerspaces (2). The author identify also other hybrid arrangements of value creation production processes between (1) and (2). Indeed, the Covid-19 crisis has highlighted some reconfigurations of production and consumption patterns, as well as hybrid production modes.

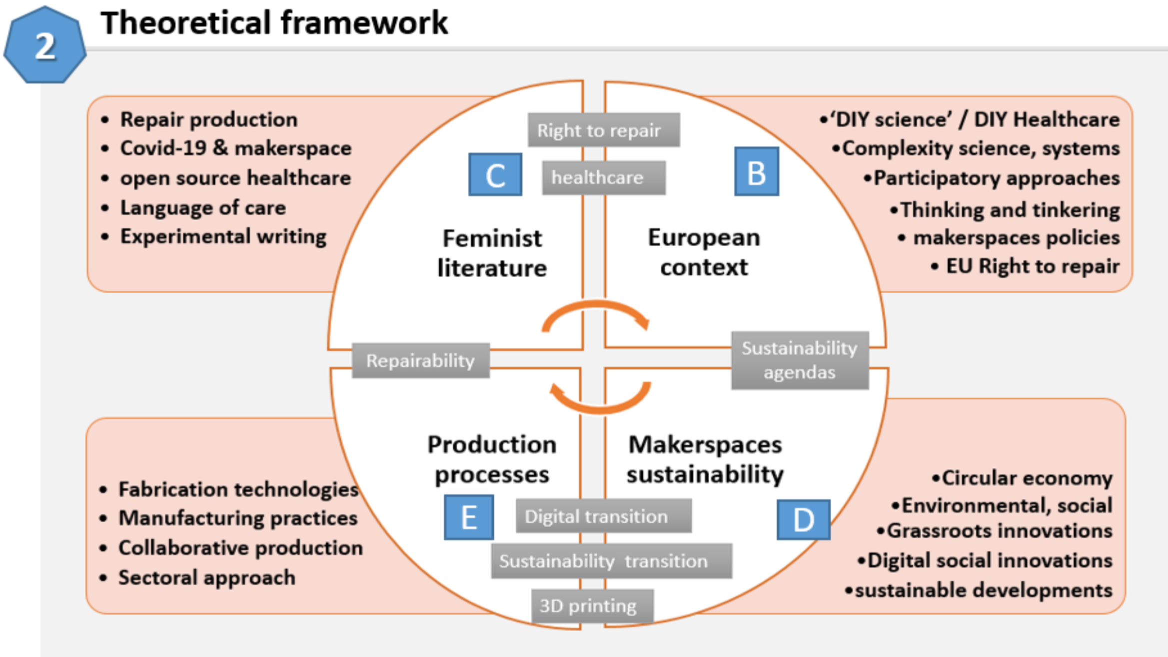
Post-Covid literature. Aligned with Dickel et al. (2016), Corsini et al. (2021) is one of the first post-Covid studies to connect the domain of frugal innovation (an innovative concept of production belonging to the manufacturing constellation) with the makerspace's constellation. By exploring the Italian digital fabrication responses to Covid-19, they show that European Covid makerspaces in general deployed digital fabrication tools to produce critical items that were running out in the healthcare sector, such as face masks, ventilators. The pandemic turned most European countries into resource-constrained environments (lack of both materials and time), thus driving the use of constraint-based innovations, for which makerspaces were particularly prepared for, compared to conventional manufacturers (Corsini et al., 2021). The use of digital fabrication tools in the context of resources constraints is called 'frugal innovation', aligning with the adage of 'doing more with less, for more people' (Corsini et al., 2021), bringing an environmental and sustainability management perspective to the combined makerspaces and manufacturing constellations. Most European makerspaces embraced frugality as a crisis response strategy, scrutinized in 3.4 and 5.

2.2. Theoretical framework

2.2.1. Theoretical diagram: Rationale of the study

Figure 3 shows the scaffolding of the present research, which aims at building bridges between sustainability studies, manufacturing, science & technology studies, organization studies, feminist literature and repair studies (C), all related to makerspaces. Thus, the theoretical framework (2.2) refines the pieces of literature collected in the contextual framework (2.1.) and narrows the focus of the topic to identifiable gaps in the literature. The conceptual framework (part II) aims at filling those gaps identified in each integrative summary (part I), and dig deeper into the four streams of literature (from A to D).

Figure 3: Theoretical framework diagram



2.2.2. Outline of the conceptual framework based on the theoretical framework

The literature review part II is organized as follow (depicted in Figure 4):

3.1 – Makerspaces in Europe, a complex eco-system: this section considers makerspaces as complex adaptive systems, and highlight two main emergent properties, resilience and self-organization under the realms of complexity science. It also presents how European policymaking embraces complexity science and DIY science. A first typology of the different sustainability pathways embraced by makerspaces is elaborated: those cultivating Sustainable Development, those cultivating circular economy, repair practices, nurturing a 'politics of repair', and other grassroots initiatives.

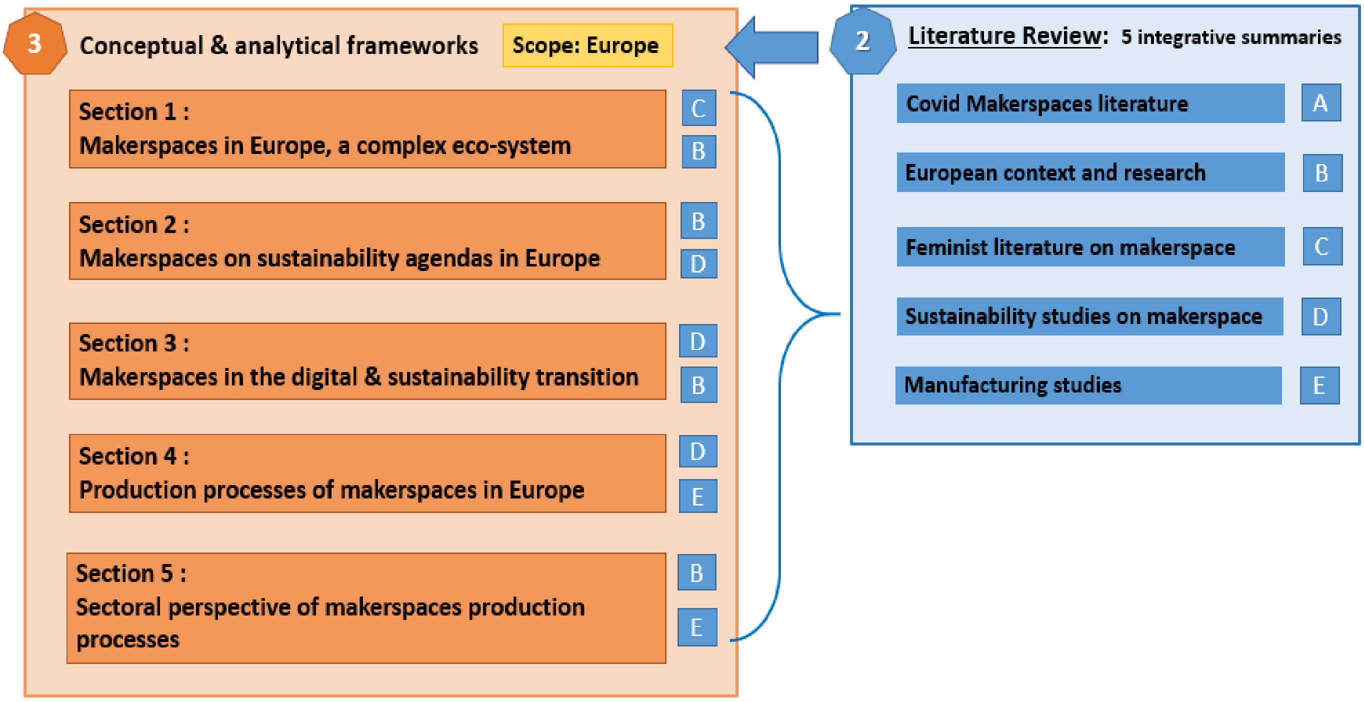
3.2 – Makerspaces on sustainability agendas in Europe: this section presents how makerspaces are 'cultivating' plural sustainable developments pathways and elaborates further the typology: corporatized makerspaces, circular makerspaces and grassroots makerspaces.

3.3 - Makerspaces in the digital and sustainability transition. This section presents makerspaces roles and potentials at the crossroads of two dynamics: the digital and sustainability transition. The section shows that, by offering open source digital fabrication and rapid prototyping for sustainable development projects, some makerspaces, as digital social innovations spaces, can lead both the digital and sustainability transition. A theoretical lenses of 'attitudes towards technology' helps analyse the different uses of technologies by makerspaces.

***3.4 – Production processes of makerspaces in Europe*.** This section blends makerspaces constellations with manufacturing constellations: production processes are selected as indicators of makerspace sustainability in Europe. This section integrates knowledge of the three previous sections, and dresses a typology of the different production processes, with their related EU programs.

3.5 - Sectoral approach of makerspaces. This section aims at reporting on both urban and rural makerspaces contributions, and offer two different socio-technical imaginaries, in the same study. Two sectors of activity have been selected where both urban and rural makerspaces manufacturing practices can be investigated: respectively the healthcare sector and the agriculture sector. On the one hand, the health(care) sector has been a field where urban makerspaces, before the pandemic, were already operational in Europe.

Figure 4: Conceptual & analytical frameworks



3. Literature review – part II :

Conceptual & analytical frameworks

The main subjects of the research are European makerspaces. In this paper, 'makerspaces' is being used as an umbrella term for the variety of organizational structures, dedicated to DIY making, repairing and 'hacking', most commonly labeled 'hack(er)spaces', 'FabLabs' (Fabrication Laboratories), DIY workshops or Labs. Whereas European studies mostly focused on fablabs (only a sub-category of makerspaces), the present study aims at exploring the roles and potentials of a larger spectrum of makerspaces. They are not pre-defined structure, but rather spaces of 'organized possibilities' (Braybrooke & Smith, 2020).

3.1. Makerspaces in Europe, a complex eco-system

In this section, makerspaces are scrutinized through specific theoretical lenses: systems thinking and complexity science, to analyze the makerspace eco-system holistically. As such an angle has not been adopted yet, the author of this paper put herself in the shoes of a maker to elaborate an 'experimental writing' of makerspaces through the systems thinking lenses. First, makerspaces are considered as complex adaptive systems, with two main emergent properties, resilience and self-organization, observed during the pandemic. The post-covid challenges of makerspaces are also discussed, such as the sustainability vs resilience dilemma. Second, complexity science and a DIY science are relevant approaches to help European policymakers communicate on makerspaces' complexity and cope with it, how the JRC makerspace is 'tinkering' makerspaces policies using the same experimental method as European feminist authors. Third, a complex spectrum of makerspaces in Europe shows a makerspaces unity in diversity, or a makerspaces diversity in unity.

A) Makerspaces: complex adaptive systems

In the realm of systems thinking, makerspaces are Complex Adaptive Systems (CAS), with three main 'emergent properties': self-organization, resilience and 'dynamic hierarchies' (Holling, 1986, Folke et al., 2004). The first wave of Covid-19 re-activated them.

a) Makerspaces' self-organization process since the COVID-19 pandemic

The system thinker Donella Meadows (2008, p.35): "Out of simple rules of self-organization can grow enormous, diversifying crystals of technology, physical structures, organizations, and cultures". This metaphor describes the self-organization process of makerspaces during the crisis: self-organized networks and digital solidarity chains emerged at multiple scales via collaborative platforms, to respond to the emergency of the healthcare sector (Ostrom, 1999, in Chalet et al., 2020; Cozza et al., 2020). Each makerspace involved has indeed its own culture, technology and structure: from experimental fablabs and makerspaces, SMEs, to homes transformed into 'miniature factories' (Bryson, 2014). According to the panarchy theory, complex adaptive systems emerge from localized networks of various 'bottom-up' regimes, i.e. the makerspaces, each driven by a set of spontaneous feedback loops (Meadows, 2008, p.34; Holling, 2001). Figure 5 shows the establishment of the makerspace ecosystem: from the self-organization of diverse structures and niches at the micro level, to groups at the meso level (Meadows, 2008). In times of lockdown and restricted movement, makerspaces had to rethink their collective, and a sharing, caring, collaborative and commons-based peer economy, where they could pool raw materials, resources and means of production to meet the ethical and technical requirements of production (Chalet et al, 2020; Corsini et al., 2021; Cozza et al., 2020).

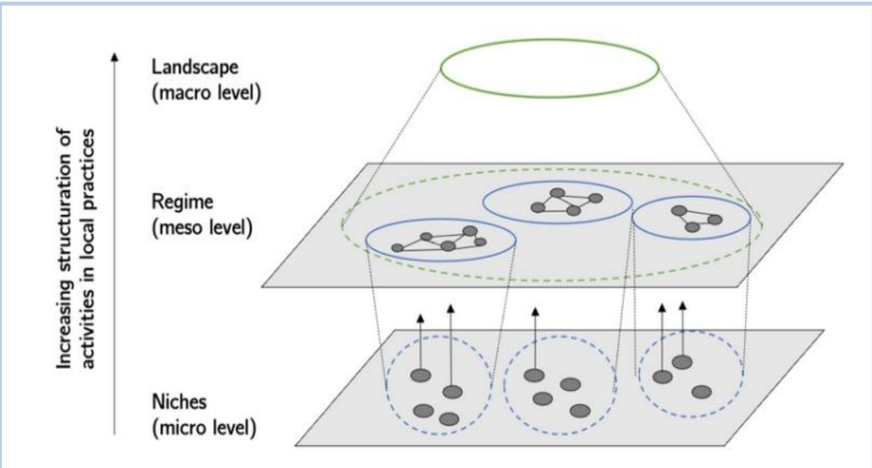


Figure 5:

Self-organization of complex adaptive systems

Source: Corsini & Moultrie (2021), p.232

b) Makerspaces' resilience since the Covid-19 pandemic

Since the advent of the pandemic, the term resilience has regained visibility and importance in the literature, associated with other concepts: for instance 'resilient manufacturing' (Andreoni & Hill, 2020), 'systemic resilience' (Leach et al., 2020), thinking about how economies can become resilient in the face of recurrent shocks such as pandemics, and the enhancement of "community disaster resilience" (Xu et al., 2020). Indeed, the concept of resilience is close to disaster research (Kerschner, 2012), and the pandemic context, considered as a disaster, has triggered an overuse of the term, as well as misunderstandings. Thus, it is necessary to reposition the term under the realm of complexity science, as an emergent property of complex adaptive systems, in order to understand how resilience can be associated with makerspaces structure and functionality.

Resilience is the capacity of a system to "absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks'' (Folke et al., 2010). Interestingly, this capacity of makerspaces did not appear during the 2020 pandemic: makerspaces nurtured their 'community resilience' throughout the years, and from their experience of earlier disasters or humanitarian issues (Corsini et al., 2021). Makerspaces' resilience is built on seven main levers: preparedness, engagement at the individual level and community level, sustained local leadership, partnership among organizations, culturally relevant education about risks, and self-sufficiency (c.f. *Roadmap for building community resilience in the context of health security*, by Chandra et al., 2010). This embeddedness in mutualism, solidarity and inclusiveness, explains why makerspaces, among other grassroots communities, can better (self-)organize in the face of shocks, while undergoing changes. Thus, rather than a sudden emergence, the 'reminiscence' of makerspaces resilience amid the Covid-19 crisis, has again played a major role in minimizing negative impacts (Leach et al., 2020; Corsini et al., 2021). Although there is no equation of resilience, there are empirical and general rules, stating that diversity and flexibility create resilience: *dynamic reorganization, built-in counter-mechanisms, tight feedback loops, 'decoupling', diversity, modularity, simplicity, 'swarming', 'clustering'* (Bardi, 2017, p.146). Thus, the diversity and flexibility of makerspaces involved amid the pandemic offered a 'response' tool for adaptive strategies (Kerschner, 2012). Moreover, the rally of makerspaces amid the crisis, at each level (micro, meso and macro) could be seen as the *swarming, clustering and dynamic reorganization* characteristics, as depicted in Figure 5. Finally, the radical 'decoupling' of manufacturing processes from industrial infrastructure (Dickel et al., 2016), as most of the critical items needed in hospital were 3D printed by makerspaces with alack of resources, simplicity and modularity, among autonomous individuals possessing the technical resources for production, which could be seen as the built-in counter-mechanisms.

c) Post-covid: Sustainability vs Resilience dilemma of makerspaces

Achieving sustainability is different from achieving resilience according to Tainter (2006): the author clearly distinguishes sustainability from resilience, by their scope of achievement. On the one hand, Tainter (2006) states that people sustain "positive or valued parts of their current way of life", which can only derive from what they know. In a broad sense, sustainability is in the realm of the known, whereas resilience is in the realm of the unknown and the 'surprise' (c.f. Holling, 1986). According to Tainter (2006, p.86), sustainability is the "capacity to continue a desired condition or process", whereas 'resiliency' is the "ability of a system to adjust its configuration and function under disturbance". Thus, sustainability and resilience can conflict, particularly in social systems: some institutions are said to increase their resilience, but in reality, there are normalizing and routinizing (static and conservative, under an institutional pressure for conformity), instead of adapting and transforming (Braybrook & Smith, 2020; Kerschner, 2012).

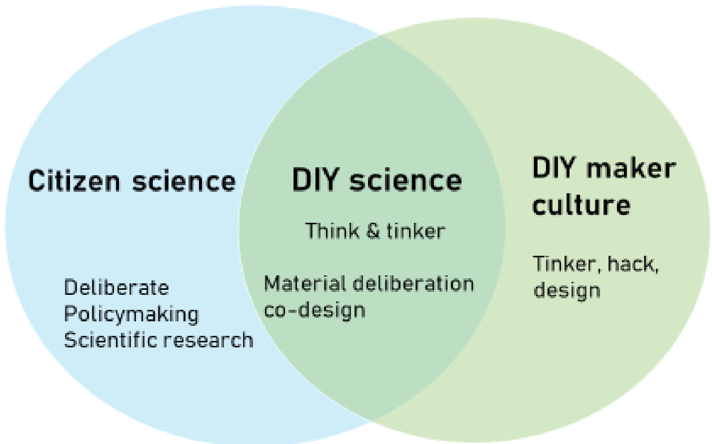
Echoing Tainter's theory (2006), the post-Covid feminist literature (c.f. Cozza et al., 2020) shows evidence of the Sustainability vs Resilience Dilemma amid the pandemic, under the metaphor of 'normalcy' vs 'impermanence'. Janet Johansson (in Cozza et al., 2020) observed that people during the pandemic were striving for sustainability rather than resilience: these attitudes revealed the obsession with 'normalcy' (i.e. sustainability) and regularity in general, and the refusal, even fear, of change in time of crisis (resilience) in particular. Tainter (2006) stated that "the goal of human groups is more often sustainability or continuity than resilience. Most of us prefer the comfort of an accustomed life [sustainability] to the adventure of dramatic change [resiliency]". Indeed, improving 'systemic resilience' seems to be one of the main post-covid challenges (Leach et al., 2020), and commonly regarded as the best solution towards more sustainable economic development, 'just' and 'green' transformations (Kerschner, 2012; Leach et al., 2020). Yet, resilience is usually understood in its engineering definition: either averting crises and disaster (static sense) or returning to the original state after a crisis or disaster (dynamic sense) (Kerschner, 2012). In both senses, there is a primary fear for changes, which is an actual 'pathological attitude' that can lead to the 'fatal error' of simply increasing the resilience of a system, whereas it is precisely a change of system that is intended. Johansson suggests to break that 'fixed vision' on sameness and normalcy, which neglected the fragility of the most vulnerable people (e.g. elderly and the chronically ill people) during the Covid-19 crisis, and instead be aware of system's resilience and vulnerability, i.e. exposure to risk and sensitivity. This mind shift would allow us to better see all possibilities to "enhance a system's owns restorative powers" (Meadows, 2008; Kerschner, 2012). According the feminist ethos of care, accepting 'change' (i.e. resilience) and vulnerability can counteract egocentrism, and allow care of the wellbeing of others, to be the motivation of the 'repair work' (Cozza et al., 2020), which refers directly to the potential and role of makerspaces. Makerspaces seem to drive this 'transition by design' (Kerschner, 2012), with a new benchmarking system of sustainability, resilience and adaptive capacities.

B) Complexity science in EU Policymaking on makerspaces

a) Complexity Science, DIY science and citizen science in EU policymaking

An effective EU policymaking on makerspaces requires new approaches (e.g. participatory, foresight) and new theoretical lenses (post-normal science, complexity science), to communicate the complexity of the phenomenon and the policies addressing these complexities, according to Calenburh (2020, p.5). Moreover, embracing post-normal science is even more relevant in the unfolding pandemic context, where facts are uncertain; stakes are high and decisions urgent (Funtowicz & Ravetz, 1994). The realm of Complexity Science is to shift the analysis from the parts of a system (reductionist approach) to the system as a whole (holistic approach): this new perspective is necessary for both scientists and policymakers to understand the complex dynamics resulting from the interaction between the parts of the system. Among the various complexity science methods to cope with complexity (c.f. Calenburh, 2020), EU policymakers are embracing participatory approaches in order to communicate on makerspaces' emergence over scales, and self-organization over time. For instance, the JRC Policy Lab, at the science-policy interface, brings together scientific and citizen knowledge to jointly account for the complexity of the makerspace eco-system: this practice is called 'DIY science' (introduced in 2.1.C.; Nascimento et al., 2014, in Rosa et al., 2018). DIY science, is the practice of thinking (designing and brainstroming) by tinkering (prototyping), as illustrated in Figure 6. Thus, the JRC incorporated the DIY paradigm inspired by makerspaces methods, to the **'citizen science'** i.e. a scientific practice of research, as depicted in Figure 6 (JRC Workshop Report, 2016). JRC makerspace is an example of a 'citizen lab' where grassroots innovation movements encounter mainstream EU institutions: 'citizen engagement' is a vital component of "Science for Policy 2.0" where learning and reflexivity, which are important aspects of complexity science (Guimarães Pereira & Völker, 2020; Calenbuhr, 2020, Sormani et al., 2020).

Figure 6: DIY science in EU policymaking



Source: own

b) The JRC Policy Lab: the 'tinkerer' of makerspaces policies

The JRC Lab set up its own makerspace in-house, labelled the "JRC Thinkers 'N' Tinkers Makerspace" (also called "TNT makerspace" or "JRC makerspace"), based in Ipsra (Italy). As a 'collaborative space and maker space' (Figure 7), the JRC makerspace shows the typical characteristics of European makerspaces, suitable within a European institution (Rosa & Guimarães Pereira, 2016). TNT makerspace is composed of five interconnected elements: a collaborative physical and digital environment (1) dedicated to open culture (2) and personal fabrication (3), a physical structure that federates 'communities of interest' (4) with an 'extended peer community' (5). This theoretical framework of post-normal science follows the work developed by the STS team (Short-Term business Statistics) in the Quality Assurance Hub (Rosa & Guimarães Pereira, 2016). The JRC Lab allows a better knowledge dissemination from in-house expertise to community knowledge, thanks to open content, data source and design blueprints, open hardware and software, that anyone can re-use (Rosa & Guimarães Pereira, 2016). TNT makerspace houses the essential digital fabrication technologies (3D printer, laser cutter, sign cutter, Milling Machine, Printed Circuit Board, to name a few) to allow the rapid prototyping of tangible objects with a high level of quality, customizability, risk-free and low-cost (Rosa & Guimarães Pereira, 2016). Thus, the JRC Makerspace fosters interdisciplinary and multidisciplinary approaches (cross-fertilzing science, arts, societal action, humanities, politics, and public policy), participatory approaches for dialogue through both traditional (deliberation) and non-traditional ('material deliberation', 'co-design') (Rosa & Guimarães Pereira, 2016). JRC Makerspace is a multi-faceted open space where thinkers meet tinkers, as the name suggests (Rosa & Guimarães Pereira, 2016). This dual function of thinking and tinkering makes it a 'material deliberation' space, operational and strategic, adaptive and modular: policy processes to deeply engage citizens (Rosa & Guimarães Pereira, 2016). On the one hand, JRC makerspace offers a work environment tailored for hands-on (hardware) prototyping and for housing the digital fabrication equipment, equipped as well for computer work, so that citizen can tinker with potential solutions for contemporary societal problems (Rosa & Guimarães Pereira, 2016). On the other hand, JRC makerspace allows a 'reflexive thinking' and a "learning by doing", to co-design and brainstorm through diverse activities, moderated by JRC DIY scientists (Figure 8). These activities are: prototyping workshops, citizen engagement sessions on specific policy matters relevant to the JRC (DIY science policy), training activities on "STEAM" (STEM skills + Arts), DIY festivals, hackathons and makers-in-residence programme at the EU Science Hub, with inter-makerspaces collaboration to comparatively look at different maker cultures (Rosa & Guimarães Pereira, 2016).

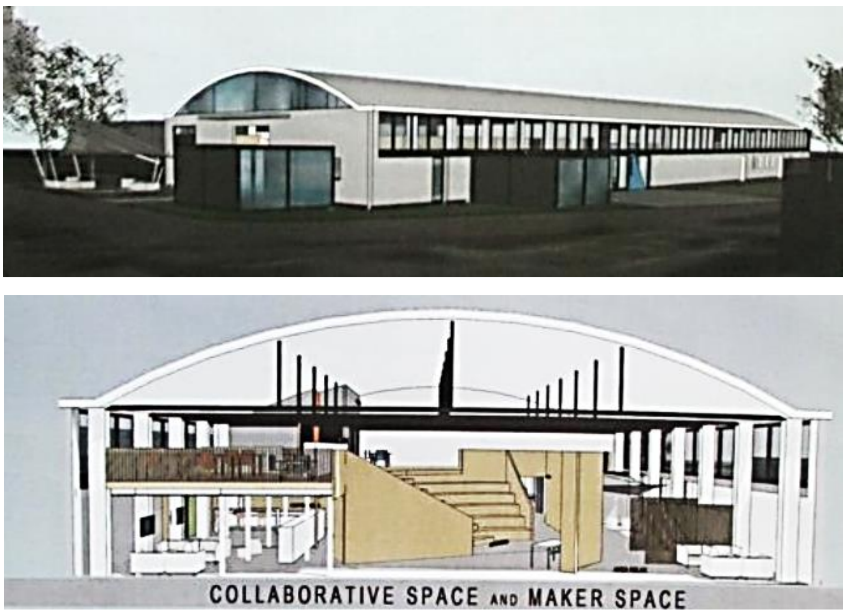


Figure 7:

JRC Makerspace, Ipsra Building, Italy

Thinkers 'N' Tinkers Makerspace

Source: Twitter #JRC_STS

c) Tinkering: a common practice of EU policymakers and feminist authors

The JRC policy approach converges with the feminist literature on makerspace. While feminist authors are tinkering with words to write on makerspaces practices, with a new language of care (c.f. 2.1.C), JRC policymakers are tinkering with "care-oriented forms of societal participation in techno-scientific innovation processes" related to makerspaces (Rosa & Guimarães Pereira, 2016). "Thinking through tinkering" is the leitmotiv of the JRC Makerspace, as illustrated in Figure 8: EU policymakers have been exploring makerspaces practices and potential, by 'tinkering' research programs (c.f. 2.1.B). Rosa & Guimarães Pereira (2016) defines tinkering as "a discovery process through inquire, exploration, prototyping, and iteration". Thus, in a policy process, tinkering could be seen as the 'fit-for-purpose' scientific approach for citizen engagement within makerspaces (Guimarães Pereira & Völker, 2020). JRC participatory approaches and governance styles, inspired by makerspaces, aim to bring citizens' knowledge, their expectations, values and imaginaries into policy, research, planning and monitoring (Guimarães Pereira & Völker, 2020; Rosa & Guimarães Pereira, 2016). For instance, at the JRC, 'co-design' and 'material deliberation', scenario workshops, collaborative ethnography and e-participation mirror the production processes and social practices of makerspaces (c.f. 3.4.). Material deliberation incorporates more open and interactive forms of engagement such as storytelling (discursive), 'materiality' (e.g. objects, places) and the affective component (Rosa & Guimarães Pereira, 2016). Materiality, i.e. 'the making of the material world', has been the focus of visual ethnographies of feminist critical theorists and practitioners, actively involved within specific repair initiatives (Graziano & Trogal, 2019; Schoneboom, 2018). Thus, both in European research and feminist writings on makerspaces, materials and tools become the means not only to enable creation but also make the thoughts visible (Rosa & Guimarães Pereira, 2016). Such complex practices of use and maintenance, and new labour practices need to be accounted and framed as a central strategy, where the roles and potentials of makerspaces can inspire employment policies (Rosa et al., 2018).

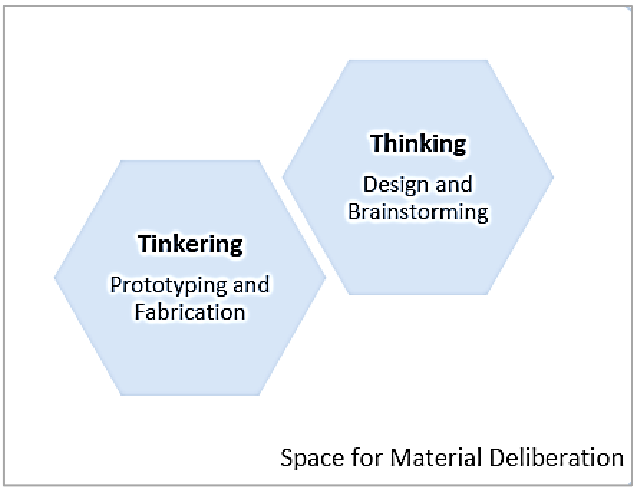


Figure 8: Thinking and tinkering dynamics

Source: Rosa & Guimarães Pereira (2016), p.6

C) Makerspaces in Europe: a unity in diversity or a diversity in unity?

a) Unity in diversity: common traits of makerspaces considered in EU policies

Makerspaces, under the realm of systems thinking and complexity science, are complex adaptive systems, sharing common emergent properties: self-organization, resilience, as well as: proximity, educational purposes, entrepreneurship, self-support, responsibility and ethics, model of civic engagement (Rosa et al., 2018). Discourses on makerspaces from the media, policy, academia, and collaborative economy cover many thematic narratives, among them: automation, globalisation, micro-factories, sharing economy, new skills, green economy (Rosa et al., 2018). Seeing the unity in diversity allows to formalize these narratives into four policy priorities: "education, training and youth", "Research and innovation", "employment and social affairs" and "consumers" in the digital transformation (Rosa et al., 2018). Thus, European Commission policies related to makerspaces are focusing on: innovation, growth and job creation in the territorial dimension, collaborative economy in the digital transformation, developing a vision for the future of work with the social model of the EU (Rosa et al., 2018). Yet, makerspaces are still emerging, continuously changing and bringing forward new types of organisations, manufacture and collaborative work (Voigt et al., 2017; Braybrooke & Smith, 2020), that is why policies insights need to be regularly updated and deliberated within the JRC Policy Lab.

b) Diversity in unity or unity vs diversity?

The use of the word 'makerspaces' as an umbrella term for the different forms of organizational structures, shows their diversity in unity. Among makerspaces, fab labs and hackerspaces, the most commonly cited, have distinct features. On the one hand, a distinctive feature of fab labs is their embeddedness in international networks (FabLab association) based on common terms of reference (such as identical hardware and software capabilities, FabLabs.io), and comply with the Fab Charter (Voigt et al., 2017). Most of fab labs are hosted by an institution (e.g. university, company, foundation, etc.). On the other hand, hackerspaces are more autonomous spaces, community-funded and community-managed, providing a technical infrastructure (hardware tools and manufacturing equipment) and learning environments where makers experiment new socio-technical imaginaries (Rosa et al., 2018). Beyond hackerspaces or Fab Lab structures, makerspaces have always been versatile and diverse places, with very innovative organizational model relying on emergent rules, either small-scale or large scale (Voigt et al., 2017): from informal neighbourhood centres (community-oriented) to "cradles for entrepreneurship" (business-oriented), and beyond ("ciphers for the broader sociotechnical aims and imaginations"), spaces of grassroots innovations for cultural change (i.e. studios for digital creativity and 'material culture') and "laboratories for smart urbanism" (Braybrooke & Smith, 2020). Thus, according to the adage of unity in diversity, unity does not imply uniformity, and despite the institutional pressure for uniformity (Braybrooke & Smith, 2020), makerspaces do not have homogeneous objectives and motivations.

c) A typology of makerspaces in Europe

From the literature, three main orientations of makerspaces have been identified: (1) makerspaces appropriated for profit, such as 'corporatised' FabLab serving ‘green’ capitalism (Schoneboom, 2018); (2) makerspaces serving circular practices: ‘circular (collaborative) makerspaces’ (Pavlopoulou, 2020) and (3) makerspaces offering radical socio-ecological alternatives (Phillips & Jeanes, 2018; Kerschner et al., 2018; Graziano & Trogal, 2019; Bauwens et al., 2019). In the first category (1), the 'corporatised' fab labs rationale is to promote ‘green’ capitalism, business-oriented (Schoneboom, 2018): indeed, in June 2014, Fab Foundation accepted a $10 million grant from Chevron Corporation supposed to help the foundation to provide access to digital fabrication around the world (Nascimento et al., 2014). Yet “big money does not necessarily imply bad intentions, but it might attract accusations of corporate Fab-washing”: according to Troxler (2014), the network has to develop a critical and constructive way of discussing the interactions between makerspaces and corporations, and between makerspaces and governments, both as a community and at the individual labs” (Troxler, 2014, in Nascimento et al., 2014). This capture of makerspaces by corporations in the U.S. raised controversies and ethical issues about makerspaces funding models, and European makerspaces are not secured from regulatory capture, “managerial control or capitalist hegemony” and from the influences of “homogenised, corporatised urban space” (Schoneboom, 2018). The second category introduces ‘circular makerspaces’ embracing the circular economy and circular collaborative production paradigms (c.f. 3.2.B). The third category refers to radical hackerspaces or ‘repair makerspaces’ committed to an ethos of care and the democratization of technology (O’Donnovan & Smith, 2020), ‘place-based organisation’ oriented to sustainable outcomes such as “vibrant sociality and urban revitalization” to counter “political amnesia and social atomisation that occurs in overly corporatised urban centres” (Schoneboom, 2018). Those three categories will be further scrutinized in 3.2 (c.f. Table 1).

3.2. Makerspaces on sustainability agendas in Europe

In Sustainability, Science and Technology Policy studies, makerspaces are illustrated as places that 'cultivate' sustainable developments. The formulation in the plural form indicates that makerspaces can indeed foster a multitude of socio-economic paradigms and 'systems-level transformations': from a global Sustainable Development, to Circular Economy, at the national level or local level. This section explores further the three-category typology dressed in the previous section (corporatised makerspaces, circular makerspaces and radical makerspaces) and presents the different sustainability pathways embraced by makerspaces. From sustainable makerspaces, to 'circular makerspaces', i.e. makerspaces cultivating circular economy practices, to 'grassroots makerspaces' and 'repair makerspaces'.

A) Makerspaces on the Sustainable Development agenda in Europe

Fab labs in particular are depicted as 'tools for sustainable development' (Gadjanski, 2015), given their internationality (global fablab network, Fab Foundation) and suitability with institutional and regulatory environment (Fab Charter): most fab labs are hosted by public institutions (universities and research centers might have the regulatory control), and technology transfers are regulated, digital fabrication *performed in a sustainable way* (Gadjanski, 2015). Activities organized within fab labs cover the 3D dimensions of sustainability: social sustainability with formal and informal education, environmental sustainability with health and environmental monitoring, and economic sustainability with economic and social development (Gadjanski, 2015). 3D printers as open source, technically feasible and economically viable, seem appropriate technologies for 'self-directed sustainable development', according to Pearce et al. (2010): they are easily made from readily available resources by local communities to meet their needs, which is in the realm of strong sustainability *(c.f. 3.3.C).* Fab labs have been recognized by the World bank as a very efficient way for: supporting STEM education and entrepreneurship, commercialization of research at higher education institutions, evolution of smart cities (or 'FabCity', DSI report, 2015), local industry development (Gadjanski, 2015). However, fab labs technologies might be captured by entrepreneurial actors and become rapidly business-oriented: union of fablabs and venture capitalist funds, accelerators, state-facilitated waste-management options (Gadjanski, 2015).

B) Makerspaces on the circular economy agenda: circular makerspaces

Prendeville et al. (2017) are the first authors to establish the synergies between makerspaces and the circular economy paradigm, by labelling them 'circular makerspaces', i.e. the makerspaces cultivating circular practices. Indeed, some makerspaces practices and circular economy (CE) converge, in the sense that both ecosystems are reforming the industrial and traditional systems, from the bottom up (Prendeville et al., 2017), in slowing resource loops through maintenance, repair, refurbishing, remanufacture, upcycling (Stahel 1984 cited by Prendeville et al., 2017). Makerspaces have the technological capacity to support circular economy practices and circular manufacturing *(c.f. 3.4. B).* 'Fab City' concept prototype of new urban circular economies by creating city-scale infrastructures fab lab districts that are networked with other cities for towards a "sustainable economic growth" (Pavouloupu, 2020). Yet, circular practices face limits in their impact if they want to lead the sustainability transition in Europe: negative rebound effects (continued over-consumption). Some makerspaces are more oriented towards 'resource sufficiency' rather than resource efficiency promoted by CE (Philipps and Jeane, 2018; Graziano & Trogal, 2019). An interesting investigation would be on the potential role of makerspaces in a future distributed manufacturing system based on CE principles (Prendeville et al., 2017). A concrete example is the makerspace 'Maakleerplek', aimed to become a circular collaboration Hub in Leuven (Belgium) and the establishment of a 'circular concept store' in Leuven, in October 2020 (on Internal Repair day) (Pop Machina, 2020a, 2020b). Both projects of circular makerspaces are in line with the "Leuven 2030" vision towards a climate neutral and circular city (Pop Machina, 2020b). Part of the makerspace network in Leuven, 'Maakleerplek' has launched a 'Building material platform' to register recuperated materials of the city, to be upcycled in their Loy tech Lab and Circular Production Lab (Pop Machina, 2020a, 2020b).

C) Makerspaces on the repair economy agenda: repair makerspaces

Repair makerspaces and 'place-based repair communities' shape "politics of repair" in many urban areas across Europe (see empirical case study in Germany, Graziano & Trogal, 2019). Makerspaces as "repair regimes" have the advantage to control the material culture, thus to have "usership", stewardship and ownership on it (Graziano & Trogal, 2017). The politicization of repair by makerspaces in Europe started in the early 1990s with the movement of hackerspaces and bicycle-repair workshops, considered as "subcultures" (Graziano & Trogal, 2017, p.56). The characteristics of the repair culture is the non-professional aspect, despite the fact that repair was a paid service: hobbyists, activists and tinkerers as volunteer workers, are building social interactions and togetherness. Political concerns among the repair movement converge but do not unify, given the lack of coordinated vision and strategies in a theoretical framework of repair (Graziano & Trogal, 2017). The most prominent collective repair initiatives in Europe from lobbying (The Repair Association) to an online community-based resource for DIY (iFixit). Besides these structured repair communities, 'public sites of repair' (Repair Café, Restart Parties) raise concerns about rights and labor, knowledge and skills, intellectual property, pedagogy and work (Graziano & Trogal, 2017). Repair makerspaces, and repair networks within makerspaces, indicate a form of citizen-led and local circular economy and local resource management (Graziano & Trogal, 2017).

D) Makerspaces sustainability goals: between grand visions and day-to-day challenges

Besides Circular economy and Sustainable Development trajectories, makerspaces offer a myriad of sustainability pathways tailored to their scale and practical requirements, in more autonomous ways and on a day-to-day basis (Braybrook & Smith, 2020). Thus, embracing such socio-economic paradigms does not mean conforming under institutional pressure, despite the increased institutionalization of makerspaces (Braybrook & Smith, 2020). On the other hand, the experimental approaches of makerspaces are inspiring and incentivizing some institutions, at the European and national levels, to reform their own practices. At the European level, the JRC Policy Lab in Ipsra Italy is “thinking through tinkering” new forms of citizen engagement and created its own makerspace (as discussed in 2.1.B and 3.1.B, Figure 7 & 8). At the national level, in Spain for instance, the *Citizen Innovation Laboratories* in Madrid, also depicted as a social innovations laboratory for “commons”, convenes citizens in the co-production of new institutional forms (Braybrook & Smith, 2020). Other socio-economic paradigms are currently considered in institutional agendas. Their fabrication tools (digital or traditional), as well as their manufacturing practices and technologies show the potential of makerspaces in radical sustainable innovations, especially in a ‘distributed production’ system or redistributed manufacturing (RDM) (Prendeville et al., 2017; c.f. 3.4.B). Thus makerspaces are seen as trailblazers in prototyping systems through local supply chains, to harness more sustainable and local fabrication (Smith & Light, 2017).

On the other hand, new niches for sustainable innovation in society are developing with ‘grassroots digital fabrication’ through peer production, oriented towards ‘resource sufficiency’, ecological design and repair culture (Philipps & Jeane, 2018; Graziano & Trogal, 2019). Yet considering them as ‘green niches’, limit the scaling up of grassroots innovations (Smith & Seyfang, 2007). However, localized initiatives do not necessarily need to follow the imperative of ‘scale up’ (Graziano & Trogal, 2019). However, the problem could rather lie in the conventional ideas about scaling up and rolling-out innovations within science and technology institutions (STI). According to Johan Shot (2003, 2021), STI ‘modernist technology politics’ of market- and state-agendas hinder the democratization and diffusion of innovation capabilities from grassroots communities. “Deep Transition analysis” on radical institutional changes (Smith & Shot, 2021) to frame grassroots innovation grounded on complex systems and social practices theories, are often neglected by modernists discourses (Labanca et al., 2020). Complexity science precisely allows to consider grassroots makerspace innovations as essential elements of the national socio-economic system (holistic view), and not as fringes that happen outside of the mainstream (reductionist view) (Calenbuhr, 2020). Even if policies might not be effective, makerspaces did not wait for the government to set rules on how to contain the pandemic. Their spontaneous, autonomous and quick responses reveal the subversiveness of makerspaces in the context of government and market failures. Subversiveness refers to their informality in terms of institutionalization and governance, due to the lack of visibility in the economic landscape, and a recognition by the government.

Table 1: Typology of makerspaces

TYPOLOGY	Sustainability pathways	Examples	references
Circular makerspaces	**Circular economy**	Maakleerplek (Netherlands)	Pop-Machina; New European Bauhaus
Repair makerspaces	**Circular practices**	Maker Space (Newcastle upon Tyne, UK)	Graziano & Trogal, 2017, 2019
Grassroots makerspaces	**Radical sustainable pathways**	UK	Smith & Light, 2017
Other makerspaces	**Sustainable Developement**	Fab labs	Gadjanski, 2015

3.3. Makerspaces in the digital and sustainability transition in Europe

Some makerspaces are at the crossroads of two dynamics, that seem contradictory: the digital and sustainability transition. This section tackles these dual dynamics, by presenting makerspaces as digital social innovations spaces. Focusing on both sustainability and innovation potentials is a dual analysis strategy. Then, identify different uses of technologies by makerspaces, and focuses on a specific digital maker fabrication technology. Expanding on the knowledge on sustainable developments potentials of makerspaces, the aim of the study is also to investigate how European makerspaces can drive multiple transitions. By offering open source digital fabrication and rapid prototyping for sustainable development projects, some makerspaces can lead both the digital and sustainability transition.

A) Makerspaces as digital social innovations spaces in Europe

Makerspaces as cradles of digital social innovations can tackle both digital and sustainability transition (Bria et al., 2019; Smith, 2017). According to Smith & Light (2017), socio-economic indicators can also measure makerspace sustainability, as sustainability is confined to environmental indicators (Corsini & Moultrie, 2021). For instance, metrics for the social sustainability of makerspaces measure 'making community' as the wider role of makerspaces in public life (Smith & Light, 2017). In this paper, makerspace sustainability will be measured through the different manufacturing practices and technologies employed within those spaces, in order to understand how they can contribute to the digital and sustainability transition in Europe. The Digital Social Innovation Report from the European Commission (DSI Report- EC, 2015) considers makerspaces as a network of 'digital social innovators', "using digital technologies to co-create knowledge and solutions for a wide range of social needs and at a scale and speed that was unimaginable before the rise of the Internet" (DSI report, 2015, p.9). The appropriate framing of DSI policies could have a direct and high social impact on the makerspaces ecosystem in Europe (DSI report, 2015, pages 88-91). The framing of makerspaces technology has been raised by Smith (2014) as a 'social shaping of technology' for "more socially useful purposes" (Smith, 2014), and 'frugal technologies', which are the main types of technology observed within makerspaces involved in the Covid-19 containment efforts (Corsini et al., 2021).

Different uses of the technology define the space: from 'high-tech' makerspaces using state-of-the-art equipment, to 'frugal makerspaces' using frugal innovations and technology (Corsini et al., 2021), as well as low-tech labs. For instance, fab labs are usually depicted as open high-tech workshops, as an alternative to conventional and industrial technologies (Gadjanski, 2015). Fab managers strongly believe that "the most sustainable way to bring the deepest results of the digital revolution developing communities is to enable them to participate in creating their own technological tools for finding solutions to their own problems" (Gadjanski, 2015). Given the risks of technological rebounds effects on production and consumption of 'easy-to-make, easy-to throw-away gadgets', production and waste within the 'high-risk' makerspaces must be regulated. EU policymakers new "hands-on" approaches towards technology and science, i.e. complexity science and DIY science, offer a critical alternative to the modernist, techno-enthusiast discourses, technology-driven solutions (Sormani et al., 2020; Calenbuhr, 2020).

C) 3D printing: the symbol of makerspaces modes of production and technology

3D printing is the most cited mode of production of makerspaces, and the one used widely during the pandemic and appeared as a 'disruptive technology' (Corsini et al., 2021). At the crossroad of the three main production paradigms exposed in this paper - circular collaborative production (1), social manufacturing (2) and commons-based peer production (3) - 3D printers are thus the common features of most makerspaces types. However, there are multiple applications of 3D printing, associated with different 'futures of manufacturing' (Dickel et al., 2016; Table 2): 'frugal technology' (Corsini et al., 2021), sometimes as an 'additive manufacturing' technology, or as a technology for 'repairing' in the feminist literature (Cangiano & Romano, 2019: 445).

On the one hand, **circular makerspaces** consider 3D printers as an 'additive manufacturing' technology, for 'circular collaborative production' (Pavlopoulou, 2020, Pop-Machina) and 'social manufacturing' (iProduce; c.f. *3.4.B*). 3D printing in circular makerspaces can contribute to many phases of the CE system: in maintenance (print broken parts, replacements), reuse/remanufacturing (upgrading parts), and the recycling of products and goods (plastic waste as secondary raw material for 3D printers) (Pavlopoulou, 2020). The framework also accounts for legal issues such as intellectual property rights, patenting, certification from 3D printed products ('circularity labeling') (Pavlopoulou, 2020).

On the other hand, within commons-based makerspaces for peer production, 3D printing is also the epitome of 'local manufacturing technologies' (Kostakis et al., 2018; Bauwens et al., 2019; Braybrook & Smith, 2020; c.f. *3.4.B*). Finally, within repair makerspaces, 3D printing is seen as a technology for 'repairing', i.e. to repurpose and fight obscolescence, "through the assembly and combination of new printed parts, without infringing copyright laws": open source technologies such as 3D printers can print up to eighty percent of their own components (Cangiano & Romano, 2019, p.32). Thus, some production tools are embedded in an innovative 'repair culture', with the advantages of open licenses and ownership of products (Cangiano & Romano, 2019, p.34). Those 'reparing' aspect of technologies is very often underestimated, and considered as 'pirate', given the hegemony of technology-centered and market-centered discourse on innovation and manufacturing (Cangiano & Romano, 2019, p.32). This is where the feminist literature can shift the narrative and position makerspaces in the Right to Repair revolution in Europe. However, there are still come implementation and legal issues concerning 3D printed products (certification requirements, warranty liability, intellectual property rights) (c.f. Survey Q14; Appendix 1). Thus 3D printing technology has political power, in the sense that it is accessible to a maximum of people and it enables technology transfer to protect innovation for the benefit of makers and prosumers, but also for public and large companies or SMEs (Pavlopoulou, 2020).

Table 2: Typology of makerspaces and their respective production processes and attitudes towards technology

	Production processes	Attitudes	References
Circular makerspaces	Circular collaborative production, circular manufacturing	Additive technology	Pavloloulou, 2020; Pop-Machina; iProduce
Repair makerspaces	Repair production	Frugal technology Technology for repair	Feminist literature : Cangiano & Romano, 2019; Graziano & Trogal, 2017, 2019
Convivial/ grassroots makerspaces	Commons-based peer production	Local manufacturing technology	Commons Manifesto ; Kostakis et al., 2018; Bauwens et al., 2019

3.4. Production processes of makerspaces in Europe

In this section, production processes are defined as indicators of makerspace sustainability. This section expands knowledge of the two previous section. Thus, analyzing the production processes can help identify the roles and potentials of urban and rural makerspaces in the digital and sustainability transition in post- covid Europe.

A) Why are makerspaces' production processes relevant?

The Covid-19 crisis marked a turning point of conventional manufacturing practices, and the emergence of new production processes from makerspaces ecosystems: more human-centered alternatives for commons-based technology, in stark contrast with 'Industry 4.0' paradigm (Smith, 2014). Makerspaces' fabrication responses are a resurgence of strong maker cultures across Europe: a network of sustainable and collaborative production units, "prototyping shops for local manufacturers" or "open community workshops for peer production" (Braybrooke & Smith, 2020; Chalet et al., 2020). New expressions and terminology in the literature attest to this turning point of production practices and purposes. For instance, 'resilient manufacturing' (Andreoni & Hill, 2020), 'repair production' (Cozza et al., 2020), or a resurgence of manufacturing paradigms such as the 'socially useful production' (Smith, 2014 in Cozza et al., 2020).

The mastery of manufacturing practices and technologies can fulfill the "3D sustainability impacts" (social, economic, environmental) while also covering more cultural and political dimensions, in particular the emphasis on the autonomy of makers (Chalet et al., 2020). That is why the investigation on manufacturing practices is relevant today, as catalysts of new socio-economic paradigms that can be implemented in the post-pandemic era in Europe. Amidst the pandemic, the majority of European makerspaces deployed 3D printers, vital digital fabrication tools for the healthcare sector (Chalet et al., 2020). In some cities, the phenomenon of digital fabrication maker response crystallized into a sharing, caring, collaborative and 'commons-based peer economy' (Kostakis et al., 2016). Yet, makerspaces production processes are more 'versatile', and represent each different sociotechnical practices (Braybrooke & Smith, 2020). EU policy agendas are considering policy frameworks to support 'collaborative production processes' employed by makerspaces in pilot countries (Panori et al., 2020).

Production vs manufacturing: the importance of language when writing about makerspaces practices. From the feminist literature on makerspaces (*c.f. 2.1.C*), we have seen the pertinence of the collaborative writing style and language. Despite being used interchangeably, 'production' and 'manufacturing' are two different economic and social approaches towards sustainability (weak vs strong sustainability). First, manufacturing is mostly associated with industrialism (in

Cozza et al., 2020; Graziano & Trogal, 2017), whereas ‘production’ describes rather strong sustainable production processes, such as ‘socially useful production’, ‘commons-based peer production’, ‘collaborative production’ (O’Donnovan & Smith, 2020). Thus, ‘urban manufacturing’, ‘social manufacturing’, ‘circular manufacturing’, ‘additive manufacturing’ have a more industrial connotation, while some ‘manufacturing’ paradigms tend towards stronger sustainable modes of production, such as the ‘circular collaborative production’ (Pavlopoulou, 2020). Second, the result of production, such as knowledge, cannot always be commodified: we do not ‘manufacture’ knowledge, we rather produce knowledge (Cozza et al., 2020; Pazaitis et al., 2020). Thus the term production best refers to the ethos of sharing, commoning and mutuality. Braybrooke & Smith (2020) differentiate ‘manufacturing practices’ (e.g. co-design) from ‘modes of production’ (e.g. 3D printing).

B) Typology of makerspaces’ production processes in Europe

This section presents specific manufacturing practices being considered in EU policy agendas: social manufacturing, circular collaborative production, socially useful production, commons-based peer production, in Table 3. These production processes have been selected according to their advanced implementation process by EU programs. Some processes haven been considered before the advent of the Covid-19 global crisis, some re-emerged, and some had to adapt to the circumstances.

a) Social Manufacturing

Social Manufacturing is a new manufacturing paradigm, supported and funded by the EU: iPRODUCE (January 2020-December 2022) is elaborating a “Social Manufacturing Framework for Streamlined Multi-stakeholder Open Innovation Missions in Consumer Goods Sectors” (iPRODUCE D2.3, 2020). Through the iPRODUCE program, EU institutions want to connect makerspaces to more conventional manufacturing systems and scale-up through product development and commercialization, incubate novel prototypes and entrepreneurship (Smith & Light, 2017). The goal is to avoid asymmetric power relations between the three stakeholders involved in the process - makers, manufacturers and consumers - by engaging the trio in the co-creation challenges for the manufacturing of new consumer products (Froes, 2021). Social manufacturing builds on ‘prosumerism’, i.e. allows users to build personalized products and customized services (Jiang et al., 2015). Social manufacturing was proposed a ‘third industry revolution’ similarly to the ‘maker movement’ which was depicted as the new ‘industrial revolution’ (Anderson, 2012), hence the convergence of the two, towards “a sustainable social mode of mass individualization” (Jiang et al., 2015). The iPRODUCE platform is deployed in “Collaborative Manufacturing Demonstration Facilities” (cMDFs) in six EU pilot countries since January 2020: in Denmark, France, Germany, Greece, Italy and Spain. These clusters are composed of Fablabs, makerspaces, as well as SMEs, associations, manufacturers. Three months after the launching of the program, these countries became important resources for local manufacturing facilities, given the disruption of international supply chains since the first lockdown (Froes, 2021). For instance, the Greek social manufacturing community engaged in the production of face shields through additive manufacturing and 3D printing technologies, during the pandemic: multistakeholder collaborations between conventional entities (e.g. HealthTech startup) and makers widened the societal benefits and enhanced the diffusion of innovation. Yet, according to Smith & Light (2017, p.171), there are lots of compromises in promoting sustainability between bottom-up organizations and conventional firms, and in contrast, the collaboration between makers and social movements might prove more fruitful.

b) *Circular collaborative production*

This new ‘production’ paradigm refers to the ‘circular makerspaces’ introduced in the Literature review (c.f. 3.2.B). A recent European framework of the ‘Circular Collaborative Production’ (c.f. Pavlopoulou, 2020) introduces a governance of ‘collaborative makerspaces’ and their modes of production (3D printing). Pavlopoulou (2020) refers to the B2B collaboration where the output of B1 (waste, by-product or underutilised resources such as materials, energy, water, capacity, expertise, assets) is the raw material input for B2: a sustainable and mutually beneficial transactions for the reuse of waste and by-products, sourcing, materials, key sustainability aspects of circular production, the localization of manufacturing in ‘circular cities’, to minimize the importation of raw materials and reliance on global supply chains. Similar to iPRODUCE, Pop-Machina supports the upscaling and commercialization of makerspaces’ circular products via ‘collaborative marketplace’ for makers, under the form of social collaboration platform and open knowledge tool (Pavlopoulou, 2020). Yet these programs emphasize on urban makerspaces with ‘urban upcycling ecosystems’, ‘urban metabolism’, ‘urban growth’ (Pavlopoulou, 2020, p.32; p.97; Tsui et al., 2021). Thus, in the context of Pop-Machina, urban circular makerspaces support a collaborative economy facilitated by digitalisation, decentralisation, blockchain technologies (Pavlopoulou, 2020). These open innovations and online platforms for ‘inter-organisational learning’ seem at the crossroad of digital and sustainability transition, in compliance with European and national regulations on digital collaboration (Pavlopoulou, 2020). Despite being coined ‘production’ or ‘collaborative’, and promoting ‘grassroots communities’, the industrial orientation of the ‘circular collaborative production’ can be pointed out, as well as the techno-enthusiast attitudes towards technology (AI, blockchain, machine-learning technologies, hence the name ‘Machina’), collaboration with ‘technologists’, ’tokenisation’ (Pavlopoulou, 2020, p.45). The author acknowledges the negative externalities of such ‘cutting-edge technologies’ (e-waste footprints, energy consumption) (Pavlopoulou, 2020, p.30).

c) *Socially useful production*

Socially useful production refers to the 'repurposing' of innovation skills and technological capabilities to address social needs, products or services which maintain or "promote health, welfare", and supports the development of workers' skills and knowledge to control the technology (Smith, 2014, p.9). The notion of socially useful production dates back to the 1970s economic crisis in Britain: workers at 'Lucas Aerospace' developed their own alternative corporate plan for 'socially useful work' in order to secure their manufacturing jobs threatened by international competition, industrial restructuring and technological changes (Smith, 2014 in Pansera & Fressoli, 2020). Workers have been self-organising slowly (over a year) and repurposed the production process from arms-related products to items for medical uses (e.g. kidney dialysis machines), as well as ecological products, designed to be affordable and accessible for heating and powering local homes and communities (Smith, 2014 in Pansera & Fressoli, 2020). Their socially useful production process was ecological, social, democratic and pedagogical altogether. Yet the weakening of unionism in the UK, during the Thatcher period, prevented the replication and scaling up of socially useful production processes (Pansera & Fressoli, 2020; Graziano & Trogal, 2020 in Cozza et al., 2020).

This resurgence of 'socially useful production' in the US amid the Covid-19 crisis (March 2020), when workers at General Electric protested against the company's large-scale job loss plan (nearly 2600 jobs, or 10 percent of GE workforce) under the same motto: "Guns or ventilators?", is the most similar case to the Lucas Plan in 1976 (Holman, 2020; Cozza et al., 2020; Pansera & Fressoli, 2020). The GE workers' union demanded (physically and online) the conversion of the domestic aviation division (manufacturing of aircraft engines) into a 'Healthcare Division' to produce ventilators for Covid-19 patients (Pansera & Fressoli, 2020). We can draw some paralells in the European context, between the Lucas Aerospace in 1976 and makerspaces' fabrication responses at the service of health(care) systems, in many countries in Europe (c.f. 5.3.1). Indeed, while traditional industries failed to cover the shortages of basic medical equipment (Leach et al., 2020), resulting from the disruption of global supply and logistics chains, makerspaces self-organized proactively, spontaneously, autonomously and democratically in 'socially useful production' (Smith, 2014 in Cozza et al., 2020; Pansera & Fressoli, 2020). From experimental fab labs and makerspaces dedicated to digital social innovations, to homes transformed into 'miniature factories' (Bryson, 2014), basic medical equipment (PPE) were produced and distributed on-demand, for free, to satisfy the essential health needs of the population amid the pandemic (Cozza et al., 2020). Also, European Socialists and Social Economist Movement vindicated 'the right to socially useful work' and a 'New Lucas Plan' in the UK (Socialist Project, 2020) as a 'public-service objective' to prioritise the common good (e.g. health services and diverse social care needs) rather than individual goods (Holman, 2020; Cozza et al, 2020).

d) Commons-based peer production (CBPP)

Commons-based peer production (CBPP) refers to the democratisation of technology via collaborative platforms, where innovation processes becomes increasingly distributed, hierarchies flatter, decisions more consensual and peers more interconnected in networked social structures (Aryan et al., 2018, p.3). This specific kind of peer production is based on open resource pools of information, domain knowledge, software, hardware and infrastructure. Their most important resource, however, is the multitude of participants: makers, users, producers, platform operators, involve in a 'collaborative value creation' with 'digital commons', i.e. "non-rival goods" are used simultaneously by all the actors, and each of them increase the value of output produced. Examples of digital commons are low-cost 3D printed prosthetic arms, and agricultural tools and machines (Kerschner et al., 2018, p.233; Pazaitis et al., 2020; Pantazis & Meyer, 2019). CBPP grows in synergy with the emergence of 'networked makerspaces' and inter-institutional collaborations, which cultivate conviviality and autonomy (Kerschner et al., 2018). Commons-based peer production is being promoted at the EU level, under the framework "COSMOLOCALISM for equitable and sustainable living" (Giotitas et al., 2020). and 'design global and manufacture local' (DGML) model, which promotes modular designs and distributed modes of production with small-scale fabrication technologies (both precision tools like 3D printers and laser cutters and traditional low tech equipment) (Kerschner et al., 2018). This type of configuration can be complementary to the concept of circular economies as it makes smaller, regional cycles or production/repair/recycling possible, sustainable and resource efficient technologies for a short, flexible and agile production towards sustainable practices and a responsible decision-making about production (Srai et al. 2016 in Pendreville et al., 2017). Thus, distributed production is characterised by local production, a decentralisation of both consumption and production, which are the two sides of the 'sustainability equation' (Pendreville et al., 2017). There are evidences in the literature that Commons-Based Peer Production and the democratisation of knowledge and technology is particularly relevant and operational in the field of agriculture and rural makerspaces (Pantazis & Meyer, 2019) (c.f. 3.5.C).

e) New production processes, new terminology

On the one hand, we saw a resurgence of redistributed manufacturing (RDM), during the pandemic, where makerspaces engage in rapid protoyping with local supply chains (Corbin & Stewart, 2018). In particular, Hennelly et al. (2019) identified makerspaces as "potential scalable forms of redistributed manufacturing", and "catalyst of local regeneration in urban areas", while acknowledging their limited role in local production systems. Hennelly et al., 2019 introduced a new category of makerspaces applying Redistributed Manufactring practices: the 'RDM-makerspaces' (Hennelly et al., 2019, p.540). RDM was defined as *" … the ability to personalise product manufacturing at multiple scales and locations, be it at the point of consumption, sale, or within production sites that exploit local resources [..] enabled by digitalisation and new production* *technologies*" with the particularity to involve 'prosumers', i.e. users actively shaping the product (Srai et al., 2016 cited in Hennelly et al., 2019, p.541). More recently, in October 2020, amid the pandemic, French makers called for the implementation of a distributed manufacturing paradigm in a Manifesto (c.f. Appendix 20).

On the other hand, "resilient manufacturing" describes a manufacturing thinking that emerged during the pandemic. The term was coined by Antonio Andreoni and Dan Hill, two Design researchers from the UCL Institute for Innovation and Public Purpose (c.f. Italian Magazine Domus November, 2020) to focus on the manufacturing and availability of masks and ventilators for the healthcare sector, particularly exposed by the pandemic. New needs requiring a "strategic design" that would allow the emergence of broader perspectives in medical innovation (Andreoni & Hill, 2020). In order to build "resilient health care systems", the manufacturing practice must be resilient itself: key lesson learned from the pandemic (Sosa Lerin, 2020). Both institutions (governments, hospitals, universities) and industries (medical device manufacturers) put great efforts to produce ventilators to fill the shortages in hospitals: for example, the hospital of Bologna doubled its ventilator stock by adding a circuit in one device to serve two patients rather than one (Sosa Lerin, 2020). This 'double ventilator' device was conceived by a UniBo Professor and prototyped by the Italian manufacturer Intersurgical SpA, yet maximizing the available devices in the case of medical equipment shortage has some limitations: one ventilator for two patients should be considered only as a "last resort solution", as it raises quality and ethical dilemmas (Tonetti et al., 2020).

Moreover, ventilators challenges and contests launched by governments (e.g. 'Ventilator Consortium' in the UK), recurring yet very short events throughout the Covid-19 pandemic, do not constitute a sustainable solution to overcome future crises (Sosa Lerin, 2020; Andreoni & Hill, 2020). Despite the great efforts put into place by institutions and industries to provide more ventilators for hospitals, a high supply-demand mismatch of ventilators remained. Indeed, increasing the stock of only one resource does not increase the resilience of the healthcare system as a whole. Also, the simplistic focus on science, technology and engineering, diverted us from the root cause of the shortage: the absence of ventilators, in the first place (Andreoni & Hill, 2020). Thus, governments' call for ventilator production was a palliative solution, as it had only addressed the symptoms of the crisis, reduced to a pure engineering problem, i.e. the shortage of ventilators which needed to be produced quickly (discussed in 3.4. B) e)). Despite the great efforts put into place by institutions and industries to provide more ventilators for hospitals, there is still a high supply–demand mismatch of ventilators (Sosa Lerin, 2020). According to Andreoni & Hill (2020), the main lesson learnt from the crisis is that shoratges are not an engineering problem, and it can be addressed by different forms of design (Sosa Lerin, 2020).

Table 3: Typology of production processes of makerspaces in Europe

Production process	EU program/policy, national program	Attitudes towards technology	Authors, references
Social manufacturing	iProduce	Conventional tech	iProduce
Circular collaborative production/manufacturing	Pop-Machina	Additive, repair, reuse; Prosumer	Panori et al. (2020)
Commons-based peer production (CBPP)	COSMOLOCALISM'design global and manufacture local' (DGML) model	Convivial, frugal, Prosumer	Giotitas et al., 2020; Kostakis et al. (2015); Kerschner et al. (2018)
Socially useful production	Lucas Plan (EU, UK)	convivial	Smith (2014)

3.5. Sectoral perspective of makerspaces production practices

A) Purpose of the sectoral approach: two sectors for two types of makerspaces

The sectoral approach of manufacturing practices aims at tackling both urban and rural makerspaces in an equitable way. So far, most of the studies on makerspaces emphasize the urban archetype of makerspaces and fab labs, due to their ubiquity in large cities, and the priority of urban economic development plans ('smart cities', 'fab cities') and 'urban manufacturing' practices in the context of circular economy implementation. Yet, rural makerspaces have also a non-negligible role to play in specific sectoral dynamics. The VULCA program funded by the EU attests precisely to the interest in rural makerspaces in Europe (c.f. Figure 10). The agriculture sector is where the latter have proved their most innovative technological approaches. On the other hand, the health(care) sector has been a field where urban makerspaces, before the pandemic, were already operational in Europe as reported by feminist literature on digital health innovations (c.f. Bria et al., 2019), as well as the JRC Technical report on the emerging concept of 'Do-It-Yourself' Healthcare (c.f. Vesnic-Alujevic et al., 2018), which reveals the digital roles and potentials of makerspaces in the healthcare sector.

B) The roles and potential of urban makerspaces in the health sector

a) The role of makerspaces before the Covid-19 health crisis

Covid-19 has triggered many crises, one of them being the health(care) systems crisis, where makerspaces ecosystems have been the most subversive: their effective contribution could be seen as a "Rebellion with care", according to feminist authors (Bria et al., 2019). Indeed, where industrial capitalism failed to cover the shortages of basic medical equipment, resulting from the disruption of global supply and logistics chains (Pansera & Fressoli, 2020), grassroots creator-innovators engaged in a 'socially useful production' of health and medical public goods provisioned for free (Smith, 2014 in Cozza et al., 2020). Makerspaces were engaged in the healthcare sector before the advent of the pandemic in 2020, by deploying open technologies for 'commoning of healthcare' (Bria et al., 2019). The feminist literature explored the digital transition in the healthcare sector in the "The Digital Social Innovation Manifesto" introducing the medical innovations of makerspaces (DSI, 2015). The DIY manufacturing of specific healthcare goods, with convivial and DIY tools, contribute to a 'Do-It-Yourself' Healthcare, coined by Vesnic-Alujevic et al. (2018), decision-makers of the JRC Policy Lab. Considering DYI healthcare technologies as digital social innovations is shifting the current 'efficiency' and productivity narrative of care and healthcare, towards the social narrative on DIY technologies (Vesnic-Alujevic et al., 2018). EU policies are accounting for the potentials of "Patient-driven healthcare model" , according to Vesnic-Alujevic et al. (2018). For instance, low-cost and adaptable 'Too Wheels' (200 euros), a DIY alternative to sports wheelchairs (2,000 euros), yet comparable to the industrial version, in terms of performance (Bria et al., 2019). Open source platforms allow makers and local producers to share their blueprints: anyone can access them, download the models online and replicate them with their own digital fabrication tools at hand. Thus, open source platforms pave the way to a new distributed governance and new disitributed manufacturing systems, with great potentials in the healthcare sector.

b) "Visual Guide for Makers" for open source medical device in the EU"

Back in June 2019, the "Visual Guide for Makers" within the DSI4EU project, introduced the regulations to design, commercialize and distribute an open source medical device in the EU" (c.f. Appendix 9). Bria et al., 2019 elaborated four main steps (categorize, certify, identify classes of risk, market provision with a conformity assessment) and scenarios. Makers should first understand what they are releasing, the nature of the solution (hardware device, or digital fabrication) and then categorize it (Step 1). Depending on the category, the device would need to be certified as medical devices: as a "DIY healthcare device" if the solution is a functioning DIY prototype, openly accessible by other makers, free access to the documentation, design files to potentially produce and use it for themselves, to test, improve or study it. In that case, makers should document the solution clearly and inform about rooms of stability improvements (Scenario A, Bria et al., 2019, p. 116). If the maker solution is customizable, can be personalized, produced and replicated in Fab labs or makerspaces to support real people's needs (Scenario B). In that case, makers should inform about the safety and document the results of testing sessions (successful or not, for example the prototype test at the local hospitals in Italy), and make other makerspaces aware of possible risks when using the solution (Bria et al., 2019). If the solution is a hack of an existing object or medical device, the makers should make people aware of the 'hackability' of its device, as the hacked version of a medical device is not suitable for all (Scenario C). If the maker self-produced for at least one person on a day-to-day basis, he is responsible for the design, and should reflect on the risks for the people (Scenario D, in Appendix 9). Any maker innovation falling into the scenario A to D does not require a certification. Yet a certification aligned with EU regulation compliance for the design and development process, allows the production of the device to be scaled-up and even mass-produced, and distributed by a third party (e.g. NGO, "tech for good" company, or social enterprise) (Bria et al., 2019, p.116). For the certification procedure (Step 2, Scenario E), makers should identify the exact category of its medical device in terms of medical purposes (prevention; diagnosis; monitoring; prediction; treatment; compensation for; providing info with analysis (c.f. Appendix 9). Step 3 is about the identification of the Classes of risks of the medical device (low, moderate, medium, high riskout of 22 rules, c.f. Appendix 9). Medical devices are rated by their potential risk of use, and most maker projects are low risk (Bria et al., 2019). Step 4 determines the conformity assessment procedure (depending on the Class of Risk) before placing products on the market (Bria et al., 2019, p.117). Without certification or prescription, makers might be sued over intellectual property infringement and other legal issues related to the manufacture and distribution of protective equipmen (see Section 5.4.3.).

B) The roles and potential of rural makerspaces in the agriculture sector

Some authors covered the rural makerspace scene in different European communities (Pantazis & Meyer, 2019) through the prism of Cosmo-localism (Giotitsas et al., 2020; Giotitsas, 2019; Bauwens et al., 2019; Pazaitis et al., 2017). For instance, Pantazis & Meyer (2019) in their Working Papers entitled "Tools from below: making agricultural machines convivial", show evidences of the contribution of Greek and French rural makerspaces to the agricultural sector. L'Atelier Paysan run by French rural makers, and Melitakes run by "Tzoumakers" (i.e. the Greek rural makers) embody the rural potential of makerspaces to transform the agricultural sector (Giotitsas et al., 2020; Giotitsas, 2019; Bauwens et al., 2019; Pazaitis et al., 2017, 2020; Pantazis & Meyer, 2019). These two rural makerspaces are unique in Europe, and highly depend on national, regional and local political and economic conditions as well as cultural factors in the cases presented need to be accounted for. Each unique set of conditions in combination with the special characteristics of the initiatives allow their emergence in the first place, so the replicability in other European rural areas is limited (Giotitsas et al., 2020).

a) L'Atelier Paysan: French rural makerspace

L'Atelier Paysan is a French cooperative of small-scale organic farmers and engineers who co-designed and locally manufactured agricultural machines and technologies customised to their needs (Pazaitis et al., 2020). The cooperative shares its designs as a 'digital commons' under the DG-ML model (Pazaitis et al., 2020). L'Atelier Paysan has been experimenting a "socio-economic model for collaborative and open innovation", as a resilient economic and shareholder model towards a technological sovereignty of French farmers and makers (L'Atelier Paysan, 2021). The various sources of finance dedicated to agriculture, from territorial funding (local, national, regional and the EU) to donations and cowdfunding, allow the rural makerspace to run the training and skill development (Giotitsas et al., 2020, L'Atelier Paysan). The makerspace is also mobile with fully equipped trucks to reach other farms in their vicinity, to share with farmers the conception and prototyping of tools and machinery, and can appropriate them (L'Atelier Paysan, 2021). Especially, state funding enables the organisation to involve a multistakeholer team of community workers, engineers, for assistance in the workshops, quality assessment, R&D and documentation (L'Atelier Paysan, 2021). The economic business model of the rural makerspace is unique, context-specific and dedicated to small-scale organic agriculture and socially driven goals (Giotitsas et al., 2020, (L'Atelier Paysan, 2021).

c) Attitudes of rural makerspaces towards technology.

Rural makerspaces are depicted as real "alternative trajectory to social change", particularly in the agriculture sector, where the convergence of localized manufacturing with the digitally shared knowledge commons, empower small-scale European farmers and rural communities (Pazaitis et al., 2020). Rural makerspaces nurture a culture of 'technological sovereignty' amid small-scale organic farmers, and co-develop appropriate machinery to support their work (Giotitsas 2019; Pazaitis et al., 2020; *L'Atelier Paysan website*). Technological sovereignty in the sense that farmers build their own agricultural tools instead of depending on commercial equipments and industrial manufacturing (Pantazis & Meyer, 2019). Compared to its urban counterparts, rural makerspaces adopt the Matrix of Conviviality and Autonomy (Vetter, 2017), in their use of *technically feasible, socially desirable, ecologically appropriate tools* (Kerschner et al., 2018). The deployment of *open source agriculture grassroots technologies* among rural makerspaces shows the democratisation of knowledge and technology in the agriculture sector (Giotitsas, 2019; Pantazis & Meyer, 2019). Some examples of agriculture grassroots technology: legume-harvesting machine and the construction of a pole-hammering tool (Pantazis & Meyer, 2019). Among the different production production processes within makerspaces, explored in the previous section, the main modes of production of rural makerspaces is the Commons-Based Peer Production (CBPP) (Pantazis & Meyer, 2019): CBPP in the agricultural context refers to the interaction between 'digital commons', distributed physical manufacturing and farmers.

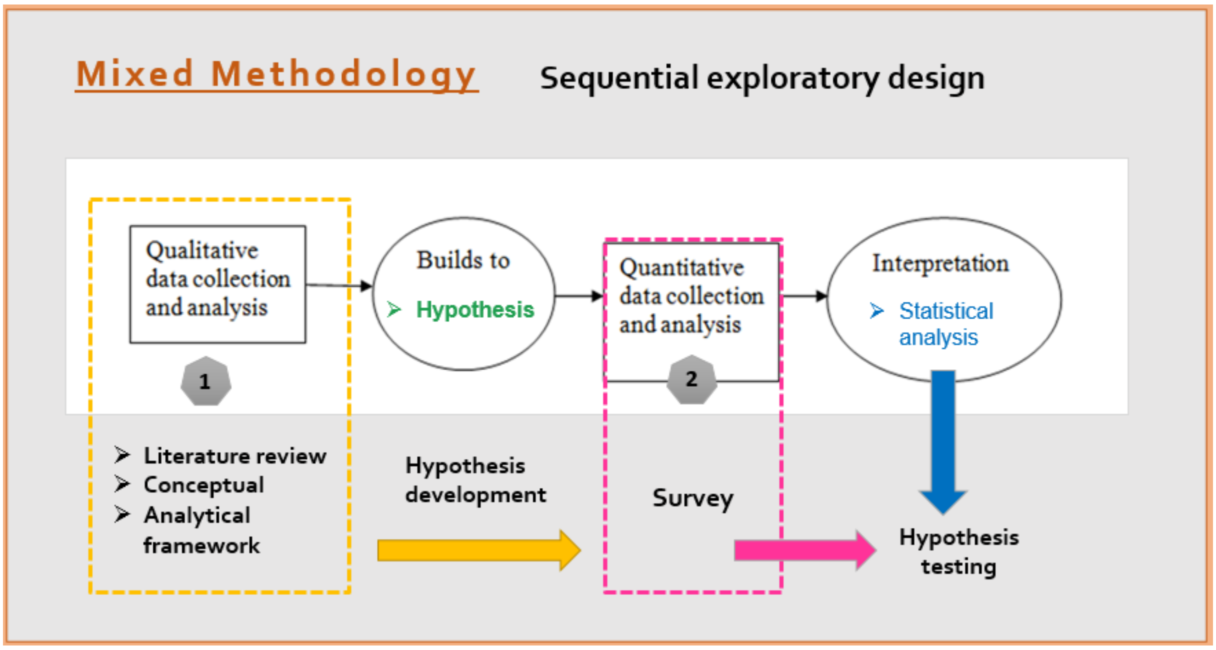
The survey investigates how these two particular sectors were impacted during the Covid-19 crisis, among other sectors, how they were exposed and sensitive to disruption of global supply chains, as one of the consequences of the Covid-19 crisis on industries. Are makerspaces still niche in these sectors, or do they have the potential to further develop towards longer-term structural and systemic transformations?

4 - METHODOLOGY

4.1 Sequential exploratory approach

The exploratory sequential design was chosen as the mixed methods approach (c.f. Creswell & Plano Clark, 2011, cited in Subedi, 2016). The first phase consists of gathering the qualitative data from literatures and resources, to build the theoretical framework. In a second phase, the quantitative data were collected, along with empirical data from real-life observations, which constitute a rich database for in-depth analysis (Indeed, the qualitative part of the present paper explores the socio-technical phenomenon of makerspaces in Europe. Thus, the conceptual and analytical framework built from the qualitative part is the basis for the Survey design. As shown in Figure 9, the first sequence of the mixed methods approach is the explanatory phase composed of the literature review, including the theoretical and analytical framework, which are the backbone of the survey design. The quantitative data collected from the survey (phase 2), would support the qualitative data of the explanatory part (phase 1). Then, the survey combines the findings and tests the hypothesis.

Figure 9: Outline of the methodology



*Source : **Exploratory** Sequential Design, adapted from Subedi (2016)*

4.2 Writing approaches on makerspaces

The writing style of the present paper was inspired from innovative social methodology applied by European researchers, policymakers, as well as feminist authors, when reporting on makerspaces actions and challenges (c.f 3.1. C). On the one hand, the participatory action research has been a prominent approach to tackle makerspaces challenges, as observed in the European research on makerspaces, and recently by David Cuartielles (2020). Moreover, in reporting on rural makerspaces ecosystems and technologies, Panzaitis & Meyer (2019) consider themselves as "embedded and engaged researchers who closely collaborate with the actors in the field practicing participatory action research", instead of researchers that analyse open source tools from a distance (Panzaitis & Meyer, 2019). This participatory research approach echoes the experimental writing of feminists (Cozza et al., 2020; Graziano & Trogal, 2019). Indeed, the approach of the JRC policy converge with the feminist literature on makerspace (c.f. 3.1.C). While feminist authors are 'tinkering' with words to write on makerspaces practices, with a new language of care (Cozza et al. 2020; Graziano and Trogal, 2019), JRC policy-makers are tinkering with "care-oriented forms of societal participation in techno-scientific innovation processes", to implement appropriate and convivial policies related to makerspaces (Rosa & Guimarães Pereira, 2016). Thus, like JRC policymakers and feminists authors, "thinking through tinkering" has also been the leitmotiv of the author of this paper. For instance, in the literature review part II, the author of this paper put herself in the shoes of a maker and elaborated an 'experimental writing' of makerspaces through the systems thinking lenses. As such, an angle has not been adopted yet, it was insightful for the author to scrutinize makerspaces eco-systems through specific theoretical lenses (systems thinking and complexity science) and experiment a theory development on those topics.

4.3. Selection of the research instrument: the questionnaire

Similar methods were used by European research programs such as iPRODUCE and Pop-Machina (c.f. 3.4.B). Both conducted large-scale European survey to inform the National and EU Strategic plans to take effective policy measures for the promotion of collaborative production projects throughout Europe. Yet with different purposes. Pop-Machina, as part of a "Market research" focus on the social acceptance factors that might affect implementation and sustainability of the makerspaces' collaborative production projects (the complex multi-actor involvement, makerspaces position on global value chains) (Panori et al., 2020). The large-scale survey included all EU countries, so that they could detect potential differences in perceptions between countries, stakeholder groups, and types of regions or have a general EU citizens' perceptions.

As the general interest streams of the data gathering in the present research are are both a pandemic responses and prospects, the survey approach was also chosen, in order to understand how makerspaces have been involved from the first wave of the Covid-19 crisis (since March 2020) until now. The main advantage of the survey approach is that it can be completed at respondents' convenience, within the planned schedule (Bhattacherjee, 2012; Grimm, 2010). The data collection method is the web-based questionnaire (*Google Forms*).

During the 'fieldwork' period of data collection (Grimm, 2010), between March and May 2021, the researcher of this paper sent personalized e-mails containing the link of the online survey. Additionally, the author engaged in an active social media research, in order to get a visibility within makers social networks, mostly Twitter and Facebook. In total, more than 1,500 e-mails were sent, for an outcome of 124 valid responses to be analysed at the end, corresponding to a response rate of 12%. This very low response rate can be explained by the huge amount of invalid e-mail addresses. From the feedbacks received from makers, other reasons were the drop out due to the length of the survey, as well as some recall biases, as the survey is completed almost one year after the targeted sample time (March 2020). Meanwhile, respondents' motivations or behaviours might have evolved, due to the conjuncture of other global concerns or a return to a business as usual.

The survey design and pre-test phase were very interactive parts of the research, during which the author engaged proactively and directly with makers, PhD students, researchers, JRC policymakers, and experts in the field of the present investigation. Their responsiveness and advice were valuable to improve the survey design and come up with the final questionnaire structure (4.4).

4.4. Sampling procedures

The section presents the target population, the sampling frame, the sampling technique and estimation of the sample size of the questionnaire.

The target population is the 'Coronavirus Makers' or 'Covid makers', i.e. the makers who were actively involved in the production of critical medical equipment for hospitals, since the pandemic started, in five pilot European countries: France, Italy, Spain, the United Kingdom and Germany. Among the various eligible actors considered as Covid makers' (engineers, tinkerers, social entrepreneurs or local manufacturers), the managers of makerspaces were particularly targeted.

The sampling frame of the research is based on analytical dashboards, maps and collaborative platforms developed by makerspaces, providing quantitative and qualitative data on my sampling units. On the one hand, *MakerSpacesRadar*, helped me select the four 'pilot' countries: the analytical dashboard (developed by MAKE-IT, EU funded projects) shows a distribution of makerspaces in Europe and within each country. Data were gathered from Fablabs.io, Hackerspaces.org and DIYbio.org with the help of the Makerlabs Python module, a library for accessing online data about Makerspaces, Fab Labs, Hackerspaces. On the other hand, the sampling framework would include only managers from the *Makery Maps database* and Maps providing contact details of makerspaces in each country. Makery Maps of Labs is a dynamic and open source cartography, based on data from the Fabfoundation (which indexes fablabs charted by MIT – Massachusetts Institute of Technology), hackerspaces.org, diybio.org. Additionally, VULCA Research programme is referencing rural makerspaces across Europe, as shown in Figure 10. Their road map is a precious sampling frame for the present study.

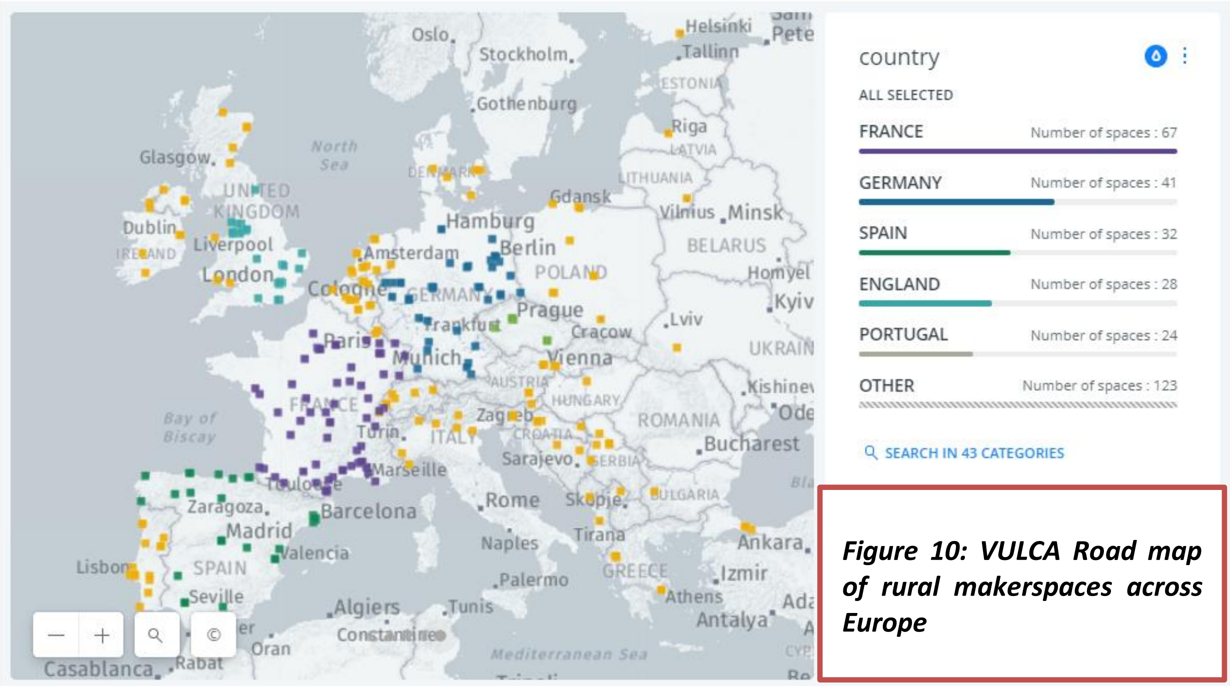


Figure 10: VULCA Road map of rural makerspaces across Europe

Moreover, Sormani et al., 2020 (European Commission) developed the "EU Makerspaces dataset" since 2016. This project is part of the operationalization of a Citizen Science Platform, gathering datasets on citizen engagement activities across the EU and users add their organization, project, and/or makerspace (Sormani et al., 2020). To date, they were more than 800 EU-based Makerspaces chartered on the dataset. The "CE Navigator of EU Makerspaces" aims to offer an interactive map to find makerspaces across the EU, and filter per typology (hackerspace, fab lab), per country and per areas of interest (art, sciences, education) (Sormani et al., 2020). The sampling frame was completed with digital and open-source collaborative platforms developed by makerspaces, in the form of observatories of Covid makers:

- France developed the "Covid-Initatives" platform (covid-initiatives.org) to reference makerspaces (equipped with 3D printers and those producing face-shields, among other medical equipment) in lists and tables with full details (address contacts, name, and status) of each structures, and with a map to localize them.
- Spanish makers created also a similar map referencing Spanish Covid makers: Coronavirus Makers – Comunidad de voluntarios Makers.

- Nesta UK Makerspaces Mapping Research Dataset contains all of the publicly releasable information on the 97 makerspaces we identified in our research (Sleigh, Stewart & Stokes, 2015).
- The collaborative platform "Make in Italy" with a Covid-19 Open data of Italian makerspaces: "Makers for COVID-19 emergency"[1]
- The German makerspaces collaborative platform "Makers vs virus"[2]:
- Greece "Menoumemazi"[3] platforms connecting makers and health experts

4.5. Questionnaire structure

The survey is structured in thematic sections corresponding to main factors and specific research questions. This survey aims to explore tools and techniques employed within the makerspaces, as well as, community strategies during the Covid-19 pandemic. Also uncover the socio-technical and socioeconomic impact of the initiatives in the longer-run. The survey comprises 30 questions, and is divided into six sections (see Appendix 1):

Section 1: "Your Makerspace". This section aims at dressing the identity of the makerspace by collecting socio-demographic data, such as name, urban/rural typology, public/private, financial resources, and the different types of capital (financial capital, human capital, capital created by people).

Section 2: "Your makerspace since the Covid-19 crisis". This section of the survey explores the role of makerspaces during the pandemic: how they responded, the type of goods they produced, the issue they faced, the strengths and weaknesses. The data collected in this section help to elaborate the SWOT analysis of makerspaces.

Section 3: "Production processes". This section incorporates the concepts introduced in 3.4. and 3.5. of the analytical framework, about respectively the production processes and the sectoral approach. Section 3 gives also an idea of the most relevant EU programmes.

Section 4: "Attitudes of your space towards technology". This section explores makers attitudes towards technology. 'Attitudes towards technology' in different makerspaces, so that we can see the links between the Technology use and the Sustainability purpose it serves.

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[1] Italian platform: Make in Italy | Associazione ; as well as Officine Mediterranee – il Fablab diffuso made in sud

[2] German platform: Maker vs Virus - STARTSEITE (mvv-ulm.org)

[3]Greek platform: Ανοιχτό Δίκτυο Makers - Μένουμε Μαζί - Κόμβος ενημέρωσης και δράσης (menoumemazi.org)

Section 5: " Your maker profile" collects socio-economic data such as employment/ occupational status; educational background, STEM skills.

Section 6: "Express yourself ". How they would have talked about the topic. The narratives were classified and categorised per themes, coded according to the occurrence of key words, included in the bigger Theme category.

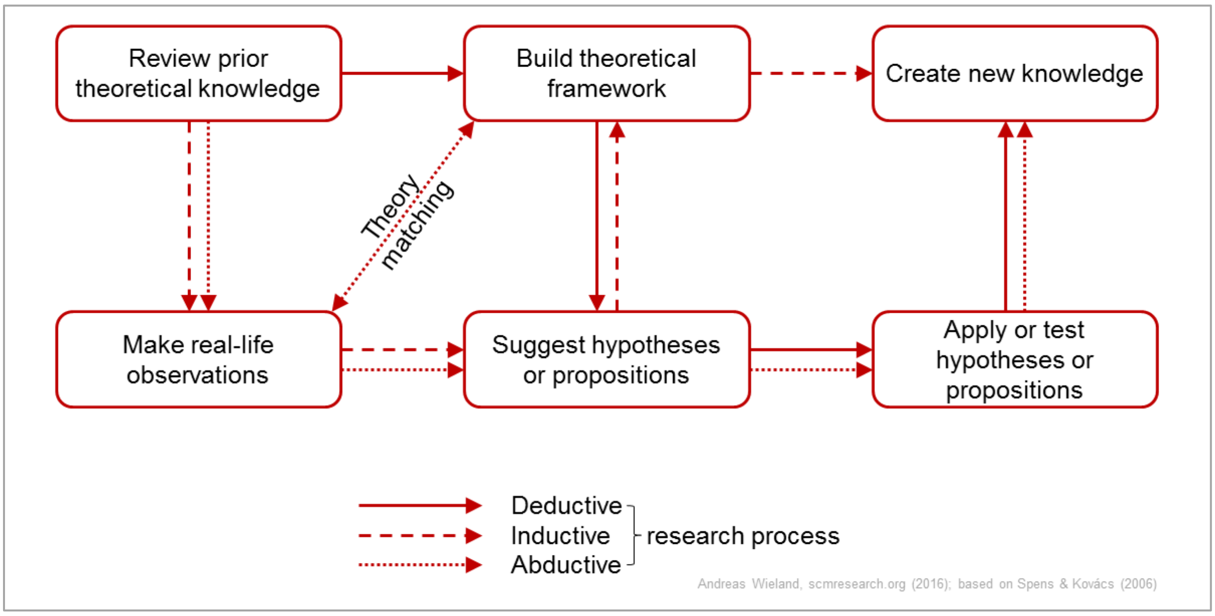
The survey was provided in five European languages (French, English, Spanish, German and Italian), the answers were translated and quoted accordingly, while respecting the anonymity participants.

4.6. Data analysis

The Data collected via the Google form, were then reported manually on Excel sheets, using a specific colour coding scheme to create matrices. PSPP allowed running descriptive statistics tables, with mean values, standard deviation, frequencies, correlations (Pearson and Chi-square). The data files were split into two main groups: rural and urban

The analysis of the survey results was abductive, navigating constantly between theory and empirical data. This approach was selected as it is well suited to deal with complex phenomenon, as illustrated in Figure 11.

Figure 11: Abductive approach



Source: Spens &Kovács (2006)

5. Results of the survey

The survey was designed in a way to bridge all the concepts exposed in the Literature review and the conceptual framework, following the scaffolding of the paper structure. Thus, this section presents the results of the survey, in the following order:

5.1. Socio-demographics - European makerspaces

5.1.1. European participants

5.1.2. Urban-rural typology

5.2. Economic sustainability of makerspaces

5.2.1. At the European level

5.2.2. Strong v.s. weak economic sustainability

5.2.3. Example of strong economic sustainability: Spanish makerspaces

5.3. Makerspaces Covid-19 responses

5.3.1. Pan-european response

5.3.2. Rural makerspaces responses to Covid-19

5.3.3. Makerspaces expertise in critical medical items

5.3.4. Example of makerspace expertise in the heatlh sector

5.4. SWOT Analysis of European makerspaces

5.4.1. Impact analysis & weaknesses: the main issues faced during the pandemic

5.4.2. Prospective analysis & opportunities: Five Capitals Model for makerspaces

5.4.3. Focus on certification and other legal issues and supply chain

5.4.4. Strengths and weaknesses of makerspaces at the European level

5.4.5. Strengths and weaknesses of rural makerspaces

5.5. Production processes of European makerspaces

5.5.1. Production processes of makerspaces overall

5.5.2. Production processes of rural makerspaces

5.6. Sectoral perspective of makerspaces production

5.6.1. General sectoral perspective in Europe

5.6.2. During the crisis: a repurposing of makerspaces activities

5.6.3. Sectoral aspirations: where makerspaces envisage to operate after the crisis

5.7. Attitudes towards technology

5.8. Insights from makers: narratives

5.8.1. Tables of narrative: negative and positive feelings

5.8.2. Summary of narratives

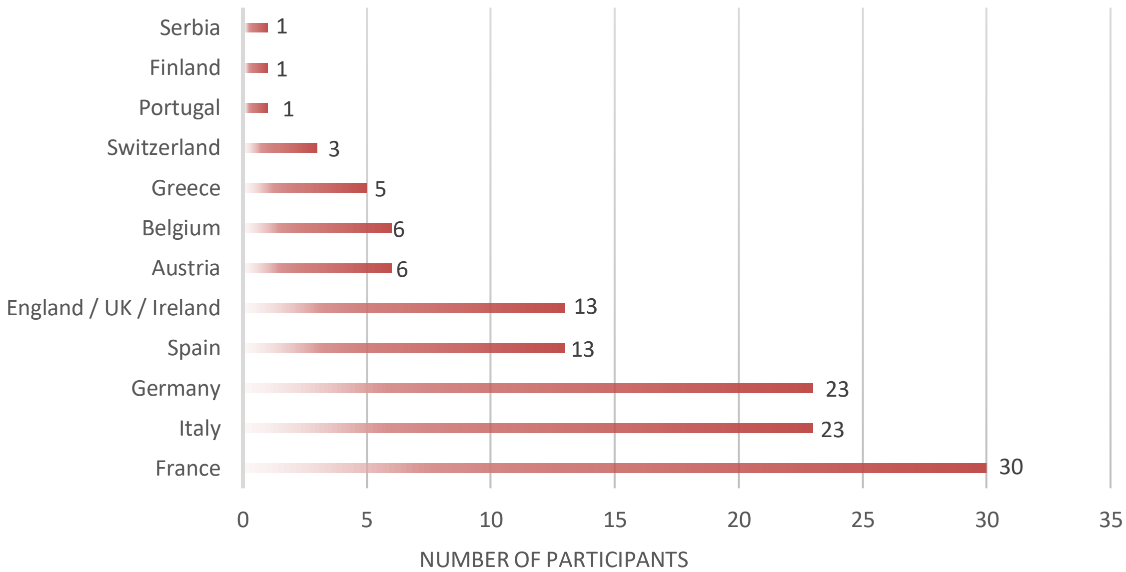
5.8.3. Validation of hypothesis

5.1. Socio-demographics - European makerspaces

5.1.1. European participants

The survey collected in total **124 makerspaces from 13 European countries**: France, Italy, Germany, UK/Ireland, Spain, Austria, Belgium, Greece, Switzerland, Portugal, Finland and Serbia.

FIGURE 12: SURVEY PARTICIPANTS PER COUNTRY



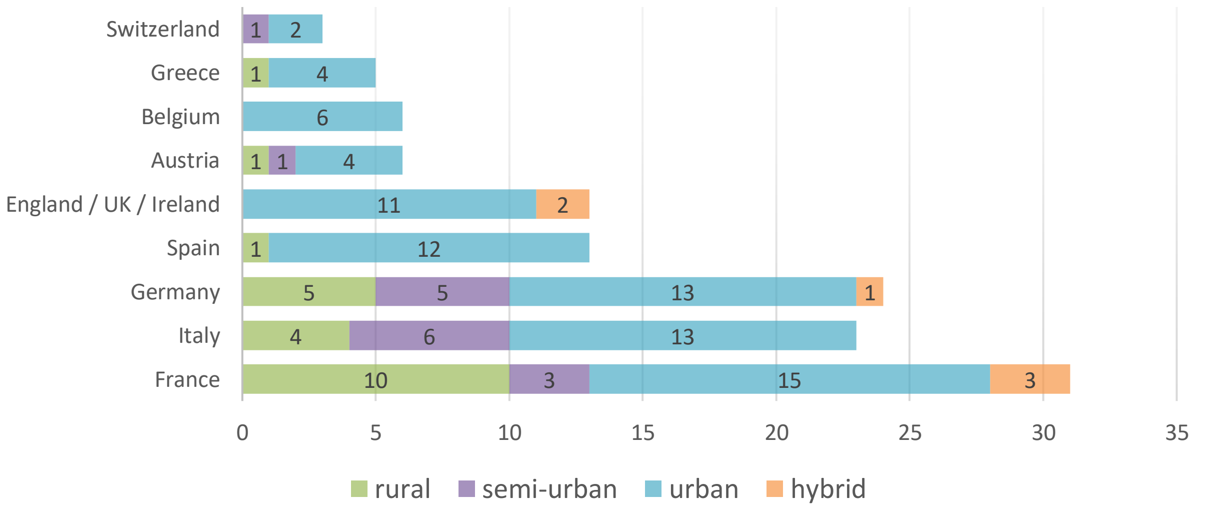
France, Italy, Germany, UK and Spain were initially the four pilot countries of the survey approach. Then, other countries were willing to participate, thus enriching the investigation and broadening the scope, as spatially represented in Figure 12. Already in 2016, the higher number of makerspaces were in France, Germany and Italy accounting for more than half of the makerspaces identified ('Overview of the Maker Movement in the European Union' by Rosa et al., 2017 cited in Vuorikari et al., 2019). When the term 'European makerspaces' is used, it indicates that the entire sample (N=124) was used for the analysis of the response, with the 13 countries listed in Figure 12. Otherwise, it is precised if only the pilot countries were selected (N>13): France, Italy, Germany, UK/Ireland, and Spain, as depicted in Figure 13.

Their mean age is 6.51 and 6.7% of them (N=120) were born during the Covid-10 crisis (1 year and younger; c.f Appendix 2 for the European level, and Appendix 3 for each country)

In this report and in Appendices, results for each survey questions are reported in different ways: at the European and at country level; and most of the time split into urban / rural.

Figure 13: Spatial sample distribution of urban and rural makerspaces in Europe

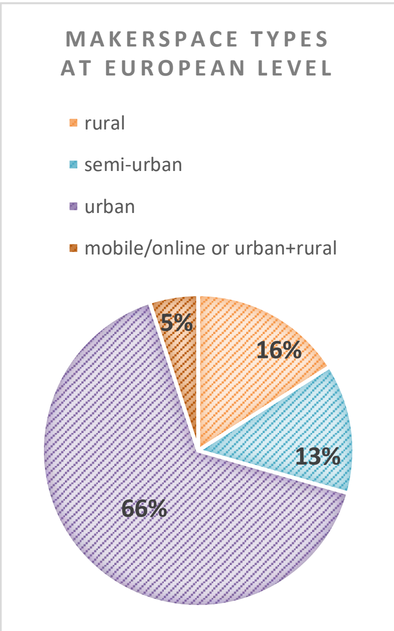
FIGURE 14: MAKERSPACE TYPOLOGY AT COUNTRY LEVEL



5.1.2. European makerspaces: the urban-rural typology

One of the goal of the present study was to cover both rural and urban makerspaces in the same research, in order to transcend the urban vs rural dichotomy and the dominance of the urban archetype (discussed in 3.5). Q4 of the survey helps to dress a typology of makerspaces in the main European countries selected for the investigation. Participants could select the typology: urban, rural or semi-urban (defined as: between rural and urban, not entirely characteristic of urban areas). The Nomenclature of territorial units for statistics (NUTS) Framework, established by EUR-Lex and European statistics (EUROSTAT), provides a classification of areas according to their degree of urbanisation: 'urban areas' (with sub-categories: cities; towns and suburbs) and 'rural areas'. Rural areas are "all areas outside urban clusters". 'Urban clusters' are clusters of contiguous grid cells of 1 km² with a density of at least 300 inhabitants per km² and a minimum population of 5 000 (Source: EUROSTAT).

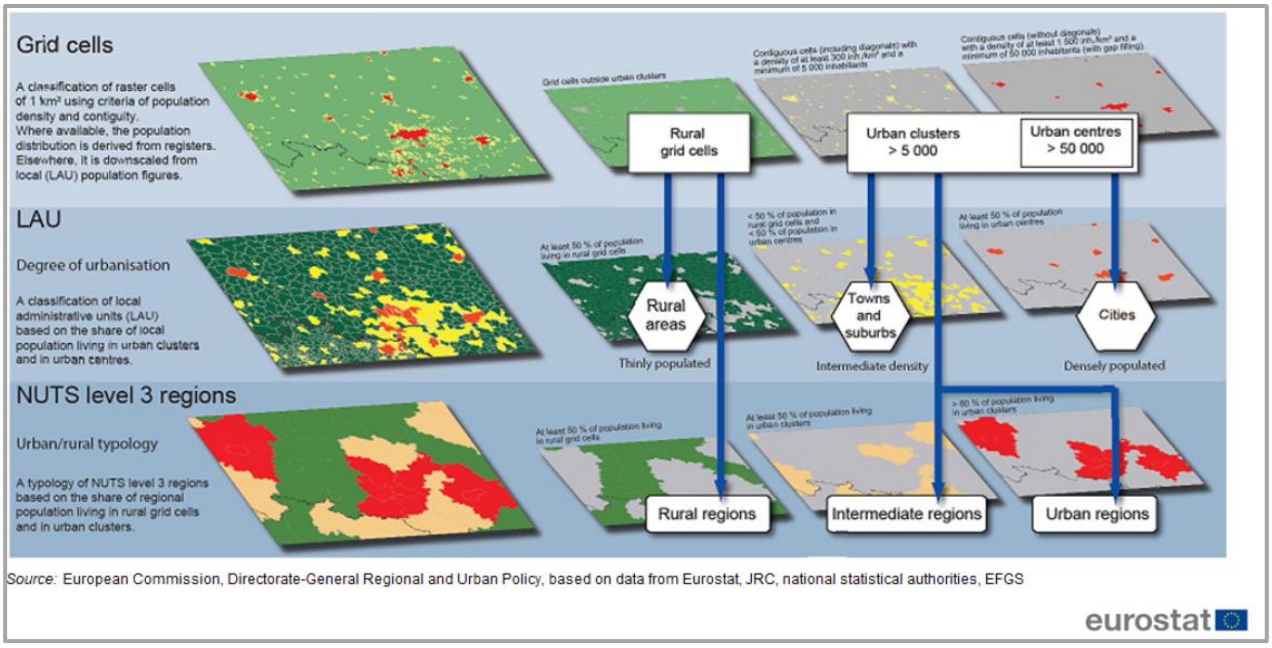
Figure 15:



In the present investigation, the urban archetype is dominant at the European level (66%, as illustrated in Figure 15). Yet, there is a good representativeness of rural and semi-urban makerspaces, together covering 30% of the participants. It is important to highlight the representativeness of the latter, because the crisis has revealed the existence of multiple networks of volunteers, tinkerers and makers, scattered across the countries, including their rural areas and communities. At national levels, rural, semi-urban or hybrid makerspaces are well represented, especially in France, Germany, Italy and Austria, as depicted in Figure 13 & 14 and in Appendix 2 &3.

Besides the rural and urban types, other settings were mentioned by the participants, such as hybrid (both rural and urban) or online settings, Some makerspaces (5%) specified an another category: "online" or hybrid mode. This new category of 'mobile makerspaces' (or mobile fab labs) emerged during the Covid-19 pandemic (among the 5% at the European level), present in Germany and Ireland. Indeed, due to the lockdown restrictions, the physical spaces were forced to shutdown, especially in urban areas. Nevertheless, makerspaces were still operational on the online space, via multiple digital supports. Their mobility allow them to operate both in urban and rural settings, e.g. in several locations in rural areas or 'priority neighbourhoods' ('quartiers prioritaires', in France). Specific locations of makerspaces, such as 'technopole', i.e. science park, were mentioned (twice in the survey), usually located in peri-urban or suburban areas. Technolopole are labelled EU BIC (Business & Innovation Centers).

Figure 16: Schematic overview defining urban-rural typologies, NUTS -3



Source: European Commission, Directorate-General Regional and Urban Policy, based on data from Eurostat, JRC, national statistical authorities, EFGS *[EUROSTAT](), [Territorial typologies manual - urban-rural typology - Statistics Explained (europa.eu)]()*

The urban-rural typology is one of the territorial typologies of the NUTS Framework which collects, develops and harmonises European regional statistics, and for socio-economic analyses of the regions, and the economic territory of the EU and the UK. The three main units are: NUTS 1: covering the major socio-economic regions; NUTS 2: covering the basic regions for the application of regional policies; NUTS 3: small regions for specific diagnoses (EUROSTAT). Precisely, the urban-rural typology at the regional level (NUTS 3) classifies regions in three types, illustrated in Figure 16. NUTS 3 is the main territorial typology used for the present investigation, according to the socio-demographic data collected.

5.2. Economic sustainability of European makerspaces

The economic sustainability of makerspaces depends on their financial resources, adressed in Q9 of the survey. Participants were asked the revenue streams of their structure, among EU funding, government funding, self-financing, membership subscription, commercial activities. These propositions were clustered into two main categories: internal and external sources, depicted in Table 4 & Figure 17. However, makerspaces' financial resources are complex, various, and difficult to sum up in few categories. Some participants specified other territorial funding including different budgets at different administrative layers, sometimes overlapping: municipal subvention, local funding (city funding, agglomeration, department funding, funding from local authorities), regional funding ; and other (minor) sources of finance, yet worth mentioning, such as sponsorship, either public or private, (*mecenat* in French) or foundations (Stiftung in German), university grants, and subventions from project applications ('bandi' in Italian).

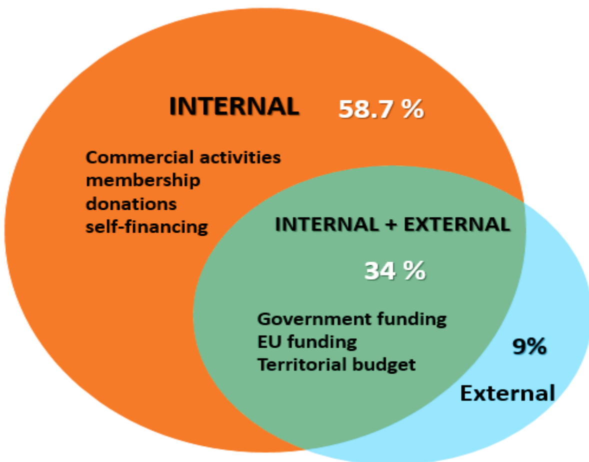
5.2.1. Economic sustainability of makerspaces at the European level

Makerspaces have diverse sources of revenues to sustain their activities, either internal financial resources or external financial resources. Overall, the vast majority of makerspaces (58.7%) strongly rely exclusively on their internal resources, comprising: subscription fees from members (membership), donations, self-financing, and the revenues from their commercial activities, as reported in Table 4 and illustrated in Figure 17. On the other hand, 9% of makerspaces rely exclusively on external resources such as EU funding, government funding and other territorial funding (city, province, region). Then, 34% of makerspaces need both internal and external funding to sustain their space. Rural makerspaces rely more on external funds than urban makerspaces, in particular government and EU funding (see details in Appendix 6).

Table 4

Resources category	Financial resources : details	Share European level
internal	Commercial activities, membership, donations, self-financing	58.7%
external	EU funding Government funding Territorial budget*	9%
	internal + external	34%

Figure 17



The main financial resource of European makerspaces are internal and come from membership subscription (mentioned by 58% of makerspaces, N=124) and their commercial activities (mentioned by 33%, makerspaces income come from the DIY products they conceive and sell on the market). These resources are not exclusive: most makerspaces rely on the combination of multiple resources, as illustrated in Table 5. Some of the strongest financial resource combinations are: commercial activities & self-financing (in Italy), commercial activities & membership fees (UK/Ireland and France), membership & donation (in Germany and Austria).

Table 5 : Combination of multiple financial sources within makerspaces, per country

Financial resources	**Internal external**	**Italy**	**UK /Ireland**	**Spain**	**France**	**Germany**	**B/S**	**Austria**
EU funding	external	17%	8%	0	13%	14%	38%	0
government funding		13%	23%	31%	20%	14%	25%	17%
Territorial funding		13%	0	15%	27%	5%	0	0
crowdfunding		4%	0	0	7%	14%	0	17%
Commercial activities	internal	48%	46%	54%	**57%**	18%	13%	33%
membership		35%	69%	38%	73%	55%	**88%**	83%
donations		26%	8%	31%	20%	59%	38%	50%
self-finance		48%	0	15%	33%	27%	25%	33%
sponsor, call for applications		17%	0	0	13%	14%	25%	0

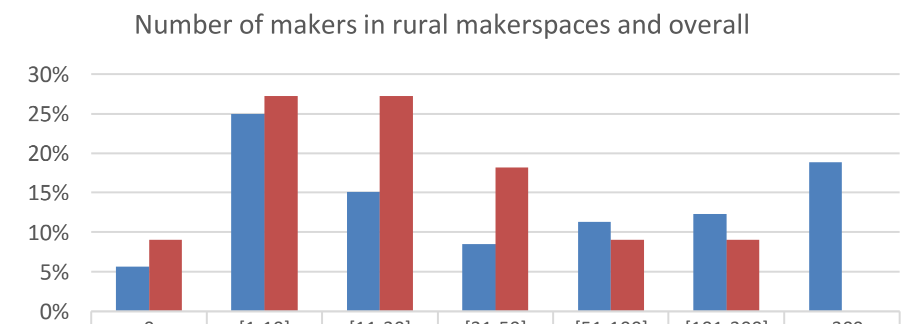
We can observe a commercial orientation of makerspaces in Europe, highlighted in red in Table 5: commercial activities are very strong financial resources for the Italian, Spanish, French makerspaces, as well as makerspaces from the UK and Ireland. According to Hennelly et al. (2019), there is evidence that 'commercial makerspace' are on the rise: they include 'TechShop', or 'hackerspace' (categories of makerspaces mentioned by participants in the survey, Q7), where prototype manufacturing and small-scale production takes place.

At the same time, most of the makerspaces, which took part in the survey (especially from the United Kingdom and Ireland), are education-oriented and non-for-profit. Indeed, in the United Kingdom, the majority of makerspaces have a predominant educational role (according to a NESTA report mentioned by Hennelly et al., 2019; with a sample of 157 UK makerspaces). Therefore for non-commercial makerspaces, membership subscription represent a strong source of finance: as reported in Table 5, membership subscription is the strongest internal financial resource for British/Irish (69%), French (73%), Austrian (83%). In general, members subscribe monthly for an amount of up to 40 euros.

5.2.2. Strong economic sustainability vs weak economic sustainability

Makerspaces having at least three different sources of finance can be considered strongly economically sustainable. 13% of European makerspaces mentioned having at least 3 funding resources (up to 5 different resources) (c.f. Appendix 6, Matrix). On the other hand, 35% of makerspaces mentioned only a single source of finance. Depending on the nature of this single source, it might indicate a weak or a strong economic sustainability of makerspace. For instance, 50% of North European makerspaces (UK/Ireland/England) rely exclusively on membership subscription (c.f. Table 5), with more 300 members contributing to the finances of the makerspaces. The very high number of members makes it a very strong financial resource for British and Irish makerspaces and can ensure their strong economic sustainability, despite their dependency to a singular source of finance. Indeed, a membership can be up to 40 euros per month. The majority of rural makerspaces (64 %) count less than 30 members. None of the rural makerspaces counts more than 300 members, whereas 19% of urban makerspaces count more than 300 members, as depicted in Figure 18 (se details in Appendix 5, Q6).

However, makerspaces relying exclusively on membership subscriptions or self-financing (9.8%) as financial resources were hit the most by the pandemic, as the spaces were closed and members could not use the equipment and space they have paid for: "*our self-financing via the public reception and our management of the associative café was badly affected, the reception of new residents was also a constraint"; "It is hard to keep members paying for a space they cannot use. Online is nice but not that same"* (UK participant) (c.f. Table 15, "Lockdown-shutdown" row). Therefore, makerspaces relying exclusively on self-financing are economically unsustainable. Thus, commercial and non-commercial makerspaces tried to contribute to the Covid-19 efforts, with the respective resources they had at hand. Non-commercial makerspaces as education-oriented and non-profit spaces were particularly involved for community services, despite the rise of however social isolation due to successive and ongoing lockdowns: "*Since we are more of a hacker than a makerspace and also not commercial, the biggest loss is the social interaction and knowledge sharing"; "The community becomes hard to grasp if you can't at least meet locally from time to time"; "Community meetings are missed" ; "The community makerspace I am involved in has remained shut for most of the past year so there has been no activity there*" (c.f. Table 16).



	0	[1-10]	[11-30]	[31-50]	[51-100]	[101-300]	>300
overall	6%	25%	15%	8%	11%	12%	19%
rural	9%	27%	27%	18%	9%	9%	0%

Figure 18

5.3. European makerspaces Covid-19 responses

5.3.1. A pan-European response to Covid-19: "Plan C from makerspace"

The rally of European makerspaces during the pandemic has been called the "Plan C from makerspaces" as depicted in Figure 19, which symbolically echoes the "Lucas Plan", elaborated in section *3.3*. "Plan C" is a concept coined by David Cuartielles (2020), the co-founder of Arduino who developed the "ABC governance model". Plan A refers to the action of government, Plan B refers to the market reaction, and Plan C refers to the manoeuvers of civil society. During the Covid-19 crisis, Plan A and Plan B failed, thus a citizen supply chain organized to respond to the crisis. Indeed, while government (Plan A) and markets (Plan B) failed to cover the shortages of basic medical equipment, resulting from the disruption of global supply and logistics chains, makerspaces (Plan C) engaged proactively, spontaneously, autonomously and democratically in 'socially useful production': the produce and distribution on-demand (and for free) the basic medical equipment needed (ventilators, valves, face shields, etc. c.f. section 2.1).

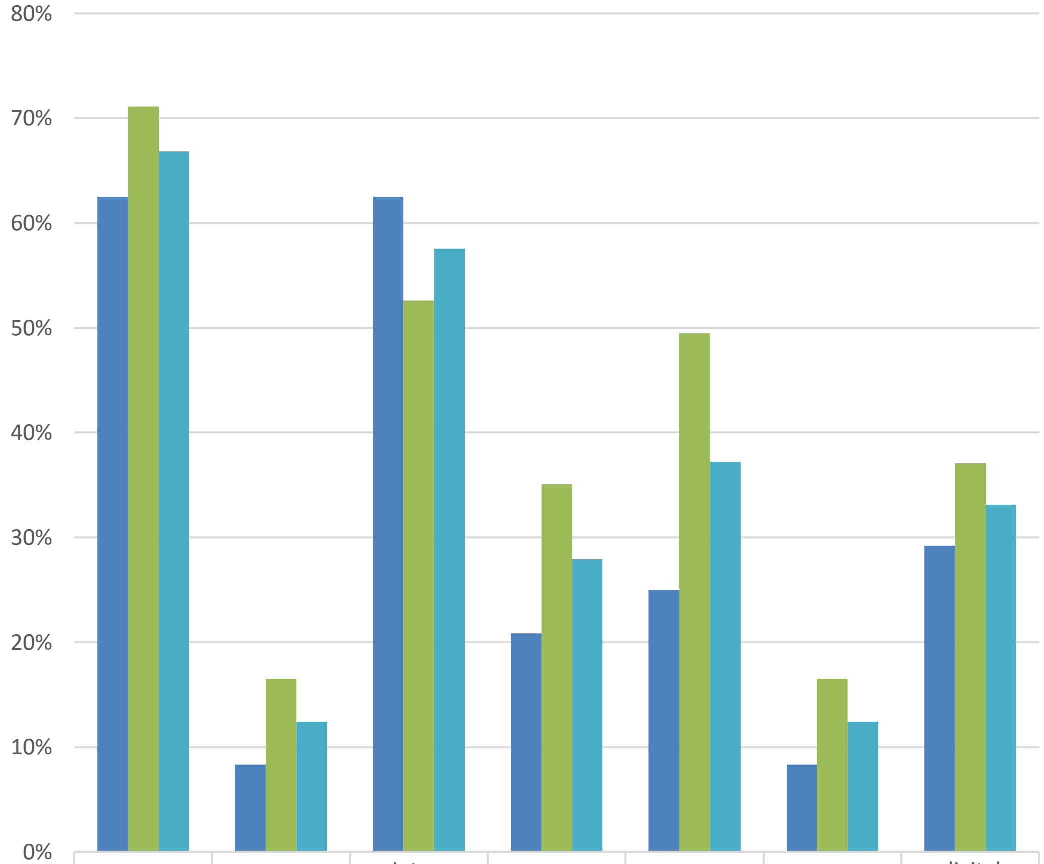
Figure 19: "Plan C from Maker space"

Source: Make Magazine, 2020

The following section gives an overview of the 'Makerspace Plan' in Europe. Appendix 3 provides additional data on rural and urban makerspaces Covid-19 responses at national and European level. Makerspaces during the Covid-19 crisis had to rethink the collective action in times of lockdown and restricted movement, as well as new ways to pool raw materials, resources and means of production to meet the ethical and technical requirements of fabrication.

In Q10, participants were asked how their makerspaces reacted to the Covid-19 crisis. The eight propositions of responses types are indicated in Figure 16, for both rural (N=20) and urban (N=75) makerspaces response (see Appendix 7).

Figure 20: Rural & urban makerspaces responses



	individual	government	inter-makerspaces	experts	hospitals	university	digital platforms
rural	63%	8%	63%	21%	25%	8%	29%
urban	71%	16%	53%	35%	49%	17%	37%
Average	67%	12%	58%	28%	37%	12%	33%

The seven responses types presented above were classified in three main types of mid-crisis responses from European makerspaces (classification inspired from Mishall, 2020) :

(1) A nationally coordinated response (top-down) for instance the government call for Covid-relevant projects
(2) A direct response (either bottom-up or top-down), referring to the individual initiatives, either as free riders, or in collaboration with other grassroots communities to proactively fight against the pandemic.
(3) A community response (bottom-up), with different types of collaborations : inter-makerspaces (makerspaces/makerspaces), makerspaces/experts, makerspaces/hospitals, makerspaces/universities,… as well as the digital responses, via solidarity and open source platforms to facilitate the aforementioned multistakeholder collaborations

(1) A nationally coordinated response - "Plan A": Figure 20 shows that only 12% of makerspaces on average responded to government's calls for Covid-related projects. On the one hand, this very low proportion reveals a government failure to support makerspaces' efforts during the sanitary crisis. On the other hand, it is a perfect illustration that both rural and urban adopted a bottom-up approach - response types (2) & (3) - without waiting for a government support (1), which mostly targeted industrial manufacturers. Hence the low participation of even commercially oriented makerspaces. Ventilators challenges and contests launched by governments, recurring yet very short events throughout the Covid-19 pandemic, do not constitute a sustainable solution to overcome future crises (as discussed in 3.4. B) e): Resilient manufacturing). Indeed, increasing the stock of only one resource does not increase the resilience of the healthcare system as a whole. Also, the simplistic focus on science, technology and engineering, diverted us from the root cause of the shortage: the absence of ventilators, in the first place (Andreoni & Hill, 2020). Thus, governments' call for ventilator production was a palliative solution, as it had only addressed the symptoms of the crisis, reduced to a pure engineering problem, i.e. the shortage of ventilators which needed to be produced quickly (discussed).

(2) Individual & direct responses: 67% of European makerspaces on average mentioned an individual initiative response to the Covid-19 crisis (c.f. Figure 20). This high proportion reveals the autonomy of makerspaces ecosystems in responding to crises, both in rural and urban settings. Among the direct responses, only 19% on average were free riders, i.e. purely individual responses without other collaborations (13.4% urban makerspace and 25% rural makerspaces, c.f. Appendix 7). Most makerspaces Covid-19 responses at the European level have been community responses, such as inter-makerspaces collaborations, especially in rural areas (63%, whereas 53% of urban makerspaces mentioned it, c.f. Appendix 7). The main **multistakeholder approaches**:

- <u>Inter-makerspaces collaborations</u>: 58% of makerspaces on average mentioned a collaboration with other makerspaces. Spain is the country where inter-makerspaces collaborations have been the strongest (c.f. Appendix 7, Table 3), and they sustained these strong partnerships until today (see section 6, REDIM case study). However, few participants pointed out precisely a lack of collaboration between makerspaces, in a period where it should have been much stronger, given the government inertia and the economic vacuum: hence the need for Diplomacy for makerspaces (elaborated in 5.7.3.).
- <u>A collaboration with local hospitals</u> is mentioned by 37% of European makerspaces on average, mostly in urban areas (49%) due to the concentration of health institutions. For instance, *Makespace* (a Cambridge-based makerspace) has engaged with the medical and technical teams at Addenbrooke Hospital (University Hospital NHS) to produce visors, clips and masks: 2,000 mask kits as well as 10,000 reusable face masks distributed freely and locally (see Makespace, 2020).
- <u>A collaboration with experts</u>, either doctors or engineers, is mentioned by 28% of participants. For instance, to produce air purifiers, and medical prototypes. Among the

collaboration with experts (35%), 29% are doctors, crucial in the co-creation of appropriate and certified medical equipment (c.f. Appendix 9).

- A collaboration with universities is mentioned by 12% of makerspaces, on average, reported in Figure 20. It concerns specifically the makerspaces affiliated with educational institutions (10% with universities, c.f. Appendix 4) which took part in the Covid-19 efforts by producing PPE. Other types of collaboration were mentioned, such as a collaboration with companies to produce relief goods (4% of makerspaces are affiliated with SMEs or social enterprise, c.f. Appendix 4).

(3) These initiatives in the physical structures were facilitated by digital solidarity platforms to organize the Covid-19 responses (see section 4.4.), especially in the context of lockdown, movement restrictions and State of Emergency across European countries. On average, 33% of European makerspaces were active on different digital platforms (as reported in Figure 20). These digital commons solved the main structural and management, and fostered multistakeholder and multisectoral initiatives: between makerspaces and experts, doctors, government officials, engineers and health officials. and could connect makerspaces social enterprises, and local firms willing to make a voluntary contribution. Indeed, as an open source platform, it merged all the scattered digital supports into cohesive entities. The digital platforms allowed to share *'digital commons'* of knowledge: such as design blueprints of faceshields, illustrated in Figure 21 that can be produced at scale and made available for the clinical staff at the forefront. For instance, Spanish makers for instance developed spontaneously, in record times, the CoronavirusMakers platform, with the motto "open source to live": sharing 3D models and blueprints for PPE creation, and achieved technological prowess with open hardware and reusable UCI mask (FFP3) and DIY emergency material (Source: CoronavirusMakers.org), with all the information in open, without patent problems: under Creative Commons License, it allows quick response to any emergency.

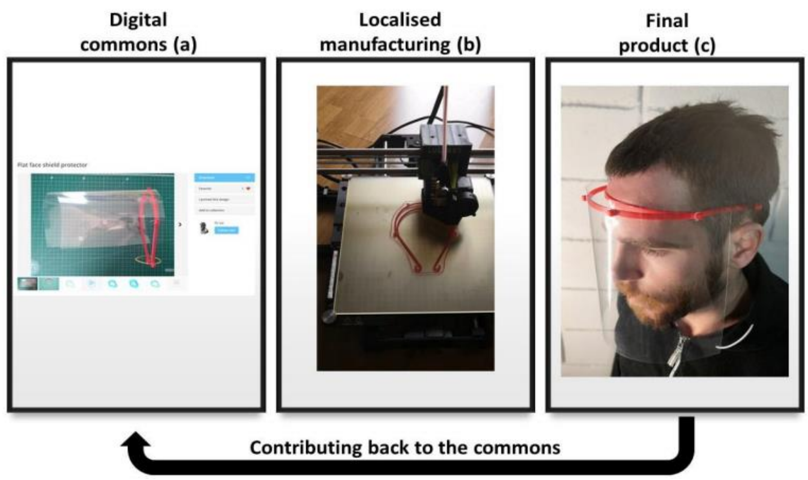


Figure 21: Digital commons and localised manufacturing

Source: Pazaitis et al., 2020, page 618

5.3.2. Rural makerspaces responses to Covid-19

Most of **rural makerspaces' response** types has been multistakeholder collaborations (37.5%), i.e. simultaneous collaboration with experts, and other makerspaces: inter-makerspaces collaborations have been particularly strong in rural areas. On the other hand, 25% of them have responded individually, without any collaborations (25%), except with a government support (8.3%) as illustrated in Figure 22.

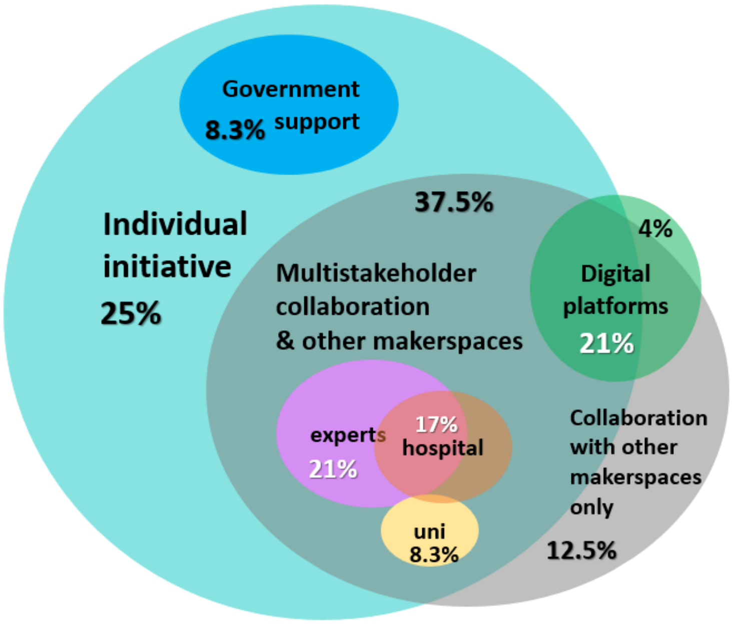


Figure 22:
Rural makerspace response

Source: own

5.3.3. Makerspaces expertise in critical medical items

Since the beginning of the pandemic in Europe, we could observe an early excitement around PPE designs among rural and urban makerspaces across Europe (see Figure 123, 24 & 25, and Appendix 8). The majority of makerspaces have been repurposing their activities towards the local production of personal protective equipment (PPE) and other emergency medical goods, in order to better cope with the shortages and international supply chain issues that arose since the first lockdown. As shown in Figures 22, 23 & 24, the most produced items by makerspaces were PPEs. On average, 81% of European makerspaces have produced PPE, i.e. face masks, face shields (c.f. Appendix 8). Besides PPEs, ventilators, and valves which were running out in local hospitals. Spain and Italy were leading the production of respectively ventilators and valves. Makerspaces have been filling the gaps left by government and market failures. The main difference of supply chain between the two types of makerspaces lies in the production of non-medical items. Rural makerspaces which did not produce medical items per se, have been producing 21% of non-medical goods only, including common goods (33%), and developed open source platform or software (12.5%) to enhance the makerspace networks. In contrast, urban makerspaces produced only 4% of non-medical items only. Yet, 39% produced both medical and non-medical items. This difference in production reveals the needs in each respective area.

Figure 23: rural makerspaces production

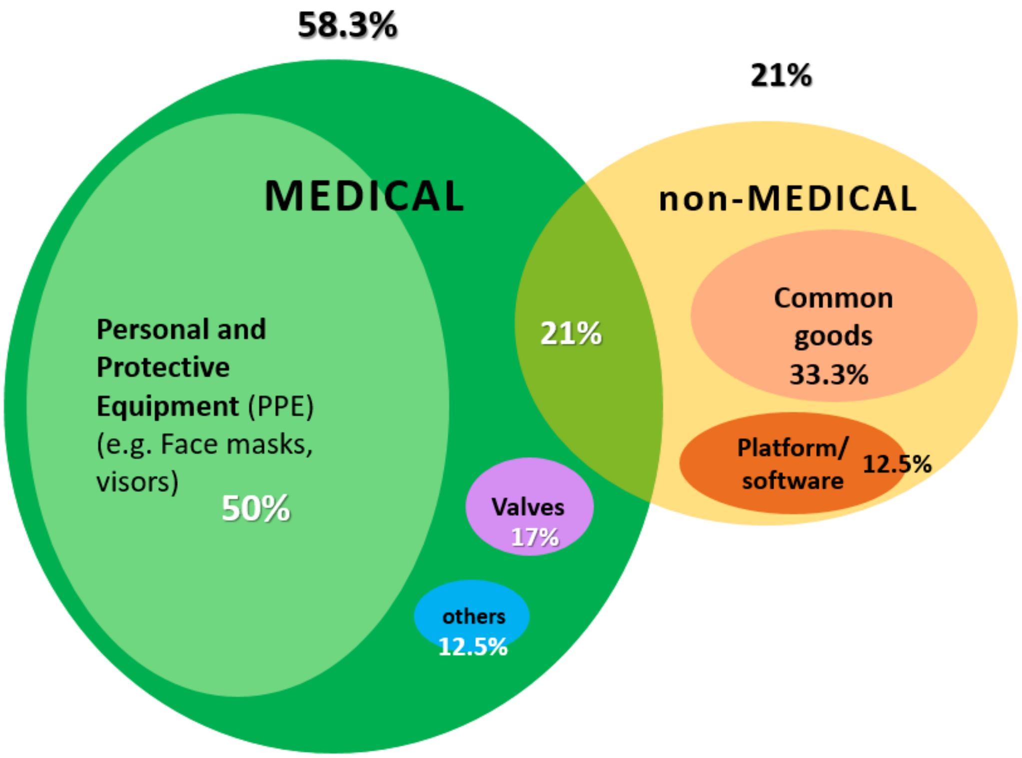
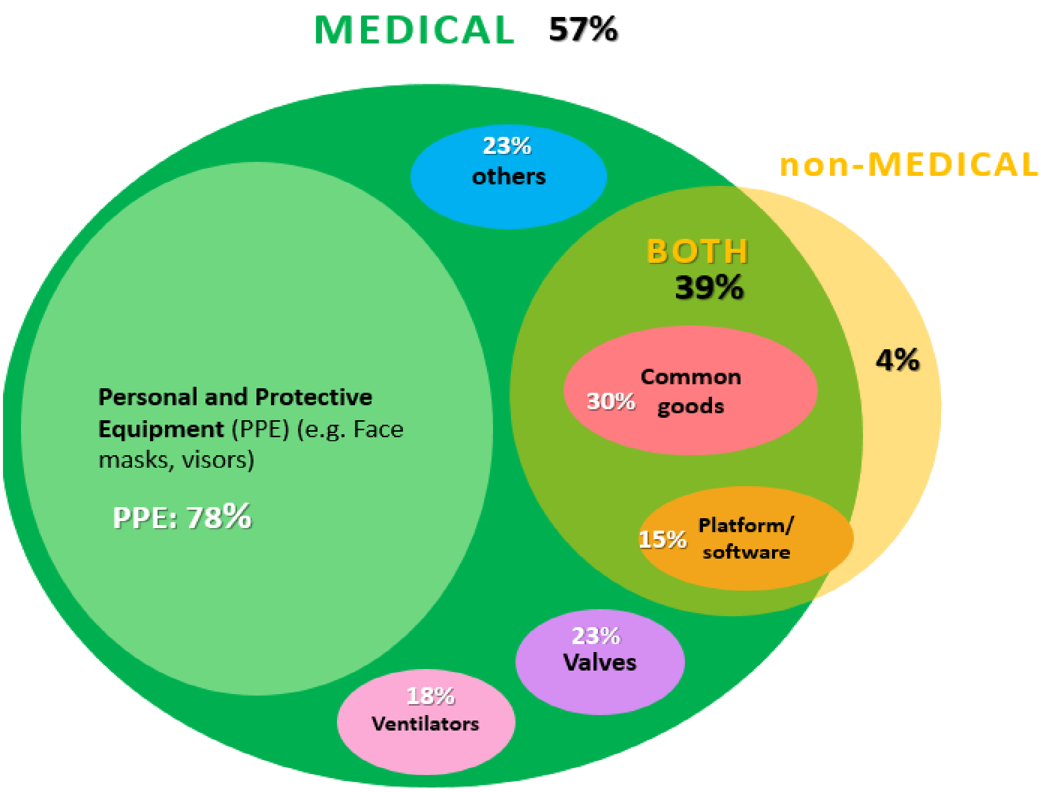


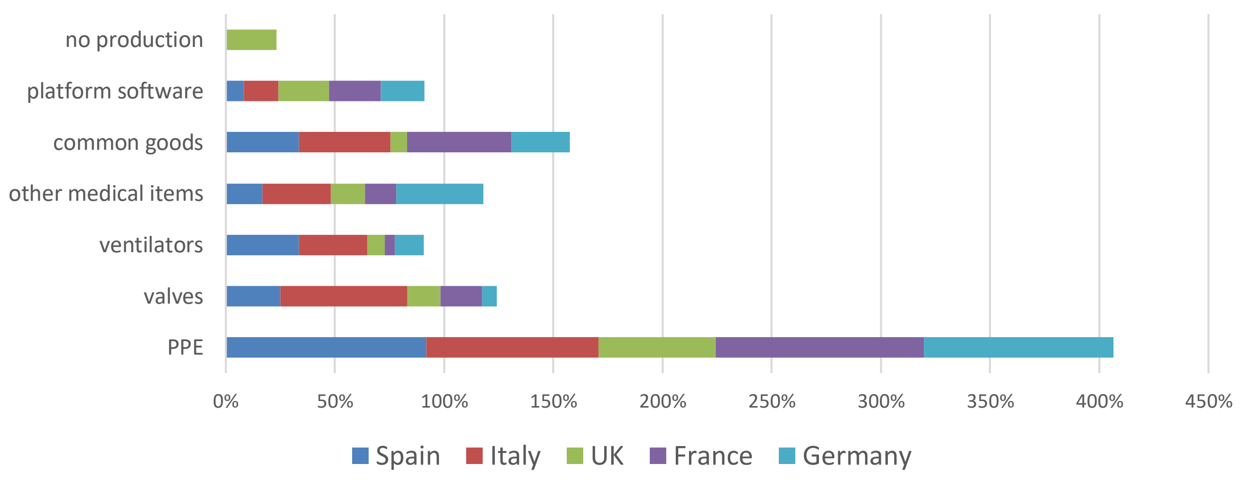
Figure 24: urban makerspaces production



5.3.4. Example of makerspaces expertise in Italy

Valves have been the main emergency medical items produced by Italian makerspaces (58% , while the average in Europe is 21%) during the first wave of the pandemic (Figure 25; Appendix 8). This survey result corroborates the fact that Italy is leading the production of valves in Europe, thanks to the very strong collaboration between Italian makerspaces with experts (doctors, engineers) and local hospitals to produce DIY valves for Covid-19 patients.

Figure 25: Items produced per country: mass production of PPE



Italian makerspaces followed the 'open-health process': (1) Makerspaces networks, self-organization; (2) Rapid repurposing; (3) Beta-test of the prototype; (4) Approval (5) Scale-up phase. It started when the Milanese Fab lab (FabLab Milano) contacted and involved (1) the Brescia-based 3D printing start-up *Isinnova*, well positioned to prototype the valves needed (Corsini et al., 2020). First, the two Italian engineers at Isinnova could rapidly repurpose (2) their 3D printers and 'reverse engineer' (i.e. produce a copy of) the valve in less than six hours (Cozza et al., 2020). Then, the prototype of the valve was tested (3) with success (4) at the Chiari Hospital (Corsini et al., 2020). Isinnova could not produce the quantity needed alone, and federated other local 3D printing makerspaces, to scale up (5) the production of valves (100 in less than 24 hours) to meet the needs of the local hospital. In that same dynamics of self-organization, Italian makerspaces further developed a multi-stakeholder and 'alternative design' approach to anticipate shortages of other critical items in hospitals, in the unfolding pandemic (Corsini et al., 2020). Stronger collaborations with public local institutions (hospitals, polyclinics, universities), medical experts (doctors, clinical engineers), and conventional manufacturers (Decathlon) (Corsini et al., 2020). Isinnova collaborated with a retired doctor (1), to co-design an alternative Continuous Positive Airway Pressure (CPAP), from a retrofitted 'full-face scuba diving mask' (2), as illustrated in Figure 26. Isinnova did not design the mask itself, which is industrially manufactured by Decathlon, but rather created the key piece that turned the scuba mask into a functioning CPAP for Covid-19 patients: the “Charlotte valve” is the makerspace added value (c.f. Figure 26). Once Decathlon sent them the mask design files, it took Isinnova less than ten hours to prototype and print ‘Charlotte valves’, successfully tested at the local hospital (4) (Corsini et al., 2020). Concerning the legal approvals (5), DIY healthcare technologies do not meet the EU standards of medical life-critical device, and are forbidden in hospitals (Bria et al., 2019). However, the retrofitted CPAP mask was welcomed by practitioners (5) only because of the emergency situation and lack of alternatives (Corsini et al., 2020; Sher, 2020), unless patient “subject to the acceptance of use of an uncertified biomedical device” sign a declaration form (Sher, 2020). Without a certification (5), Isinnova immediately patented the “Charlotte valve”, in order to prevent regulatory capture or any speculation on its price (Sher, 2020). By distributing over 1000 functioning masks for free to more than 50 hospitals in Italy, Isinnova could meet the demand for CPAP devices on time, before it ran out (Corsini et al., 2020) became the norm despite strict considerations, especially in the healthcare sector.

Figure 26: Charlotte valve, DIY innovations from Italian makerspaces

Source: Corsini et al. (2021)

5.4. SWOT analysis of makerspaces

5.4.1. Impact analysis & weaknesses: the main issues faced during the pandemic

The main issues faced by both rural and urban makerspaces are in terms of finance and resources (including human resources), illustrated in Figure 27. In terms of capital, the main makerspaces capitals impacted by the crisis were the financial capital (41%), the natural capital (35%) and the human capital (30%), among other issues shown in Table 7. Thus, a large share of makerspaces overall in the five pilot countries, mentioned issues related to resource constraints, proving that the Covid-19 pandemic turned most European countries into resource-constrained environments (lack of both materials and time), as observed by Corsini et al. (2021) and discussed in section 2.3. The magnitudes of the impacts are felt stronger in rural settings than in the urban one, as highlighted in Figure 22. Most of the issues faced by rural makerspaces are a lack of human resources (mentioned by 42%), a lack of Financial Capital (mentioned by 46%) and resources constraints (38%) (see details in Appendix 10).

FIGURE 27: URBAN AND RURAL MAKERSPACES ISSUES

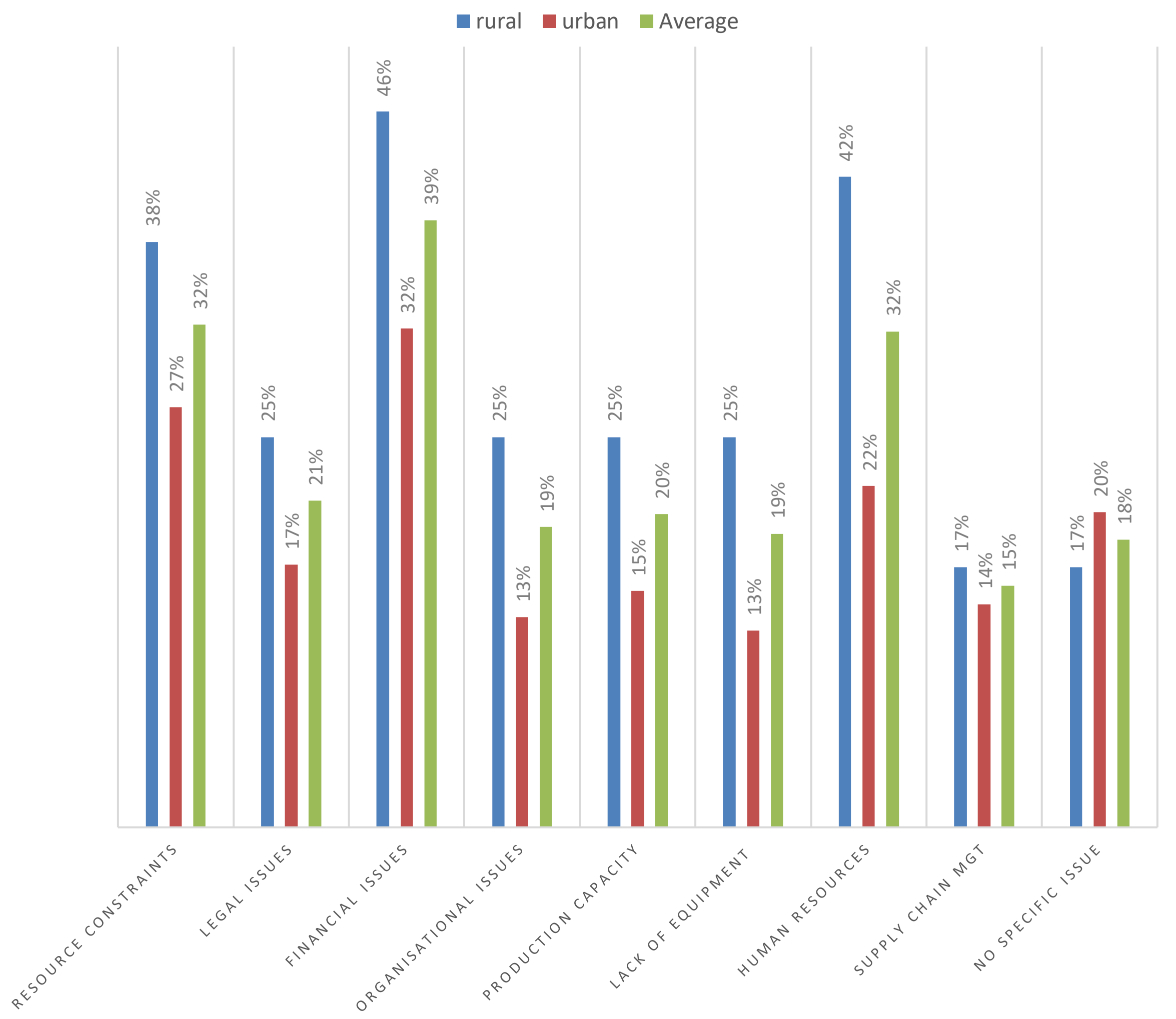


Table 6 shows that makerspaces, at national levels, were impacted at different magnitudes, and if one capital was affected, the other capitals of makerspaces were also impacted. For instance, Spanish makerspaces were hit the hardest in terms of Financial Capital, Natural Capital and Human Capital. Yet Spanish makerspaces did not face any legal issues, whereas makerspaces France, Italy and the UK/Ireland/England have encountered severe legal issues, especially related to certifications and intellectual property of DIY medical items. Italian makerspaces experienced the highest negative impacts on their external Social Capital (legal issues), their Manufacturing Capital (internal production capacity) and their Human Capital (lack of human resources). Thus, in Italy we can think of a correlation between the production capacity (Manufacturing Capital) and the human resources (Human Capital), both mentioned by 26% of Italian makerspaces: the less the number of makers, the less production. However, this correlation does not hold in Spain where makerspaces lacked the most of human resources (33%), however the production capacity was not affected (8%).

Most of the issues faced by UK makerspaces are of legal nature. A majority of makerspaces in the UK/Ireland did not face particular issues: their Manufacturing Capital (production capacity, supply chain and equipment) was the least affected. Manufacturing Capital is the type of Capital that was the least affected overall, except in Italy and France (the production capacity and supply chain). However common features are apparent (rows highlighted in red in the Table 6): financial issues were encountered almost unanimously. Makerspaces in Spain, France and Germany were impacted similarly in terms of Natural Capital (resources constraints issues) and Financial Capital (financial issues), thus we can think of **correlations** between Financial Capital and Natural Capital.

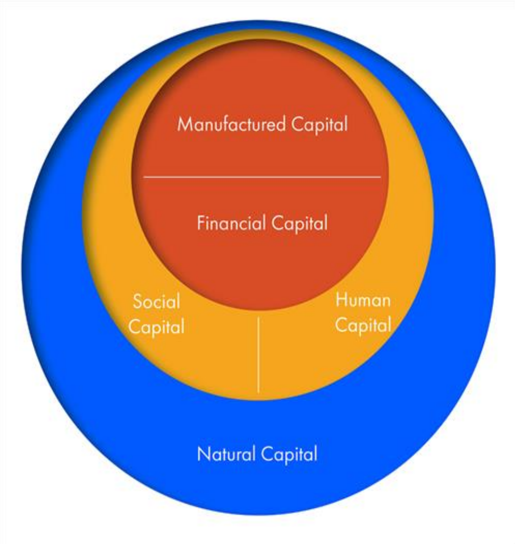
Table 6: Issues faced by urban makerspaces in each country

	overall urban	Italy	UK /Ireland	Spain	France	Germany	**Average**
resource constraints	27%	17%	18%	42%	35%	29%	**28%**
legal issues	17%	35%	27%	0%	27%	19%	**22%**
financial issues	32%	30%	18%	50%	31%	29%	**32%**
organisational issues	13%	13%	18%	8%	12%	14%	**13%**
production capacity	15%	26%	0%	8%	23%	14%	**14%**
lack of equipment	13%	22%	0%	8%	15%	14%	**12%**
human resources	22%	26%	18%	33%	19%	24%	**24%**
supply chain Mgt	14%	17%	0%	8%	23%	10%	**12%**
No specific issue	20%	17%	45%	8%	15%	29%	**23%**

5.4.2. Prospective analysis & opportunities: Five Capitals Model for makerspaces

In a more prospective approach, and under the realm of *The Five Capitals Model* (economic framework for sustainability and system change for sustainability), we can decipher if makerspaces can achieve sustainable outcomes, and be economically sustainable in the future. The 8 types of issues were clustered into the 5 categories of Capitals, as shown in the Table 7. The data reported concern all participants, both in urban and rural structures.

Figure 28: Five Capital Model



Source: [The Five Capitals - a framework for sustainability | Forum for the Future]

Table 7: Makerspaces capitals impacted by the crisis

Types of capital	Issues	Fre-quence	Share of mentions
Financial capital	Financial problems	48	**41 %**
Natural capital	Resource constraints	41	**35 %**
Human capital	Lack of human resources	35	**30 %**
Social capital	Legal issues	24	21 %
Manufactured capital	Production capacity	23	20 %
Social capital	Organisational issues	21	18 %
Manufactured capital	Supply chain management	20	17 %
Manufactured capital	Lack of equipment	18	15 %
Manufactured Capital	Lack of space	3	3 %

Makerspaces, like any organisation, need these five capitals in order to be operational and sustainable. If one capital is impacted, it affects the other, as illustrated in Figure 28. The following definitions for each capital was taken from Forum for the Future.

1) Financial capital: reflects the productive power (revenue) of the other types of capital

> 41% of makerspaces faced financial problems, a lack of financial capital, especially makerspaces with a single source of funding. Lockdowns caused the shutdown of many makerspaces, especially hackspaces, thus a pause in all commercial activities as well as community workshops.

2) Manufactured capital: material goods, technologies (from simple tools and machines to IT and engineering) and infrastructure (transport networks, communications) owned, leased or controlled by an organisation that contribute to production or service provision, but do not become part of its output (*Source: Forum For the Future*).

> Table 7 shows that 20% of European makerspaces faced production capacity limits, and supply chain mismanagement (17%), a lack of equipment, tools and machines (15%), lack of affordable space or the usual constraints of rents“ (3% faced a problem of relocation and leasing contract).

3) Human capital: incorporates health (joy, passion, empathy and spirituality), as well as "knowledge, skills, intellectual outputs, motivation and capacity for relationships of the individual" (as defined by *Forum for the Future*).

4) Natural capital: defined as "environmental or ecological capital, natural resources and processes needed by organisations to produce their products and deliver their services" (*Source: Forum For the Future*).

The Covid-19 pandemic turned most European countries into resource-constrained environments (lack of both materials and time), as 35% of European makerspaces mentioned issues related to resource constraints. Moreover, 20% of European makerspaces faced production capacity limits (Table 7).

5) Social capital: Internal Social Capital: defined as "shared values, trust, and communications and shared cultural norms, which enable people to work cohesively and so enable the organisation to operate effectively" (*Source: Forum For the Future*). Any benefit "the economic outputs of an organisation by human relationships and co-operation": e.g. networks, communication channels, communities, voluntary organisations, to name a few (*Source: Forum For the Future*). **External Social Capital**: wider socio-political structures, include government, legal entities, trade unions among others (*Source: Forum For the Future*).

Organisational issues are part of the internal Social Capital of makerspaces, and legal issues as external Social Capital. 18% of makerspaces mentioned organizational issues (management, leadership): a long and slow decision-making process. Indeed, makerspaces that are dependant or hosted by institutions (e.g. universities, social enterprise) might have felt the vertical hierarchy: "*as the space is hosted by the municipality of Thessaloniki, restrictions apply and the procurement process is slow*". Another reason might be the "interpersonal problems" within the makerspace, social relationships and interactions.

5.4.3. Focus on the external Social Capital: certification and other legal issues

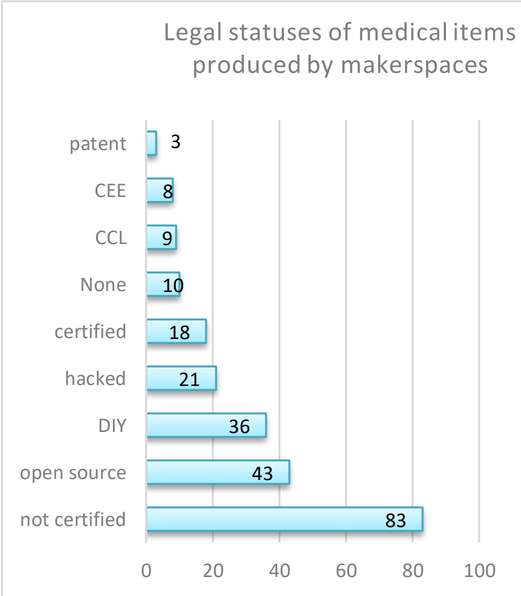
Q13 of the survey investigates further makerspaces' external Social Capital in the healthcare sector, introduced in 3.5: the legal compliance to consider for makerspaces open source innovations in the healthcare sector in Europe. We found that the majority of the medical items produced by makerspaces during the pandemic were **not certified (70%),** as shown in Table 8 and Figure 29: the different legal statuses clustered into the categories of open source medical device in the EU, from the "Visual Guide for Makers" (introduced in 3.5.B.; Appendix 9): 30.5% of makerspaces medical production are under the category of "DIY healthcare device", i.e. functioning DIY prototype, openly accessible and customizable by other makers, free access to the documentation, design files (e.g. the "Charlotte valve", in 5.3.3.): the maker solution is replicated in Fab labs or makerspaces to support real people's needs. 18 % of makerspaces medical production are 'hacked', designed from an existing object or medical device, reported in Table 8.

In that case, makers should make people aware of the 'hackability' of the device, as the hacked version of a medical device is not suitable for all (Bria et al., 2019, p.116). Two main labels were mentioned by the participants: the Creative Commons Licence (7.6%) and the CE certification (7%). Only 2.5% of medical devices (especially valves) produced by makerspaces during the pandemic were patented, e.g. the "Charlotte valve", in order to prevent regulatory capture or any speculation on its price (Sher, 2020). Certification requirements depend on the items among the PPEs. For instance, Face shields are not certified, whereas ventilators and valves are open source (36.4%).

Table 8: Legal status & quality standard

Legal status & quality standard	Scenario of the "Visual Guide for makers"	Share
not certified	Step 1 : identification of certifiability	**70%**
open source	A - "DIY healthcare device" B – "Replicability"	**36.4%**
DIY – co-design	A - "DIY healthcare device"	**30.5%**
hacked	C - "Hackability"	18%
certified	Step 2 : certification process	15%
None		8.5%
CCL – Creative Common Licence	Scenario E – "Certification"	7.6%
CEE	Scenario E – "Certification"	7%
patent	Charlotte valves	2.5%

Figure 29



Non-certification can represent an obstacle in the scalability of makerspace production in the sector of health, as observed with the results of Q12. Table 6 highlights that 39% of Italian makerspaces experienced the highest negative impacts on their external Social Capital (legal issues), as they produced the highest quantity of valves, and faced multiple certification issues due to the DIY nature of the critical medical item produced (Appendix 8 & 9). Indeed, producing DIY medical goods requires ex ante official certification from health authorities (takes about 8 to 12 months in Italy) (Corsini et al., 2020; Bria et al., 2019). Otherwise, they are forbidden in hospitals. However, the retrofitted CPAP mask was exceptionally welcomed by practitioners, due to the emergency situation and lack of alternatives, and under the condition that patient "subject to the acceptance of use of an uncertified biomedical device" sign a declaration form (Sher, 2020; Corsini et al., 2020). Similarly, 28% of French makerspaces faced legal issues (see Table 6). In a context of emergency, solidarity and mutual aid, legal risks such as certifications of medical items, liability or standardization processes, were considered secondary by makers and caregivers: there were only non-mandatory "notes to users" signs attached to the visors (Makery

France, 2020). The French fablab network from the beginning, called the APHP (public authority of university-hospitals of Paris) to elaborate an approval procedure for DIY medical devices: they commissioned a fleet of 3D printers at a hospital, and a website (Covid3d.org) where medical devices could be approved by AHPH without patents, and disseminated with secure 3D manufacturing and distribution specifications. The digital platform aimed also to connect caregivers with engineers, manufacturers and makers. On April 10, 2020, the National Agency for the Safety of Medicines (ANSM) published a "framing sheet", relaxing the rules on 3D printing medical device, during the time of the crisis, thus broadening the spectrum of production activities (Makery, 2020). Apart from the few makers working closely with hospitals on complex projects (ventilators) and exempted from certification, the validation process was not effective and discriminatory, therefore some makerspaces experimented self-certification (Makery, 2020). The inefficient validation tool in addition to the legal vacuum around the manufacture of medical devices in makerspaces reveal the government inertia at the highest level (Makery, 2020; Appendix 20). Despite the lack of certification on their products, a majority of makerspaces were not prevented to act and persevere, as expressed by a survey participant (c.f. section 5.8). Under normal circumstances, obtaining a CE Marking certificate in Europe for a medical device or PPE involves a conformity assessment either from a ‘Notified Body’ or a self-declaration for low-risk products and low categorized products, as stipulated under European Directives (Emergo by UL, April, 2020). Yet, given the shortages of medical devices & equipment needed to treat Covid-19 patients, these products were needed at a faster rate than for the long ‘standardization’ process’ to obtain a CE Marking certification. Thus, derogations from *EU Conformity Assessment* procedures allowed by the EU Commission during emergency public health situations, EU member states individually have the ability to temporarily permit access to ‘European healthcare markets’, for ‘not-yet-certified’ devices and PPE products (Emergo by UL, April, 2020).

5.4.4. Strengths and weaknesses of makerspaces at the European level

Survey participants were asked to think about the strengths and weaknesses of their makerspaces. Q15 is a Likert scale question with four scales: from 0- weak; 1-to be improved; 2-still strong; 3-very strong. They could express themselves on 10 characteristics:

1) purpose and values promoted by their space (Social Capital: human relationships, partnerships and co-operation: e.g. networks, communities, social norms, values and trust) ; 2) their community & network (Human capital - knowledge, skills, intellectual outputs, motivation and capacity for relationships of the individual); 3) knowledge and expertise acquired (Human Capital); 4) supply chain management (Manufactured Capital) ; 5) Autonomy, i.e. the ability to freely decide on the future, and have control over technology; 6) Adaptability, i.e. accepting changes, being flexible to transform and repurpose their processes; 7) Resilience, i.e. the resistance to disruptions and crises; 8) Techn(olog)ical Efficiency, i.e. the internal production capability; 9) Resource efficiency, i.e. the optimal use of limited resources in a sustainable manner while minimising

impacts on the environment; 10) Sufficiency, i.e. the voluntary reduction of resource use, moderation of consumer demand (the charachteristics from 5) to 10) were discussed in 3.1.A).

Table 9 gives an overview of makerspaces' strengths and weaknesses, of the whole sample. Overall, their strengths of are their Human Capital and Social Capital, respectively their purposes & values (91.5%) and knowledge & expertise (96%), as well as their adaptability, autonomy and resilience (83%). On the other hand, their weaknesses highlighted in red in Table 9, are the supply chain management and the insufficient community spirit.

Table 9: Overview of European makerspaces strengths and weaknesses

Category (theory)	Characteristics (in the survey)	Strong (very)	Weak (very)
Social Capital	**1) Purpose & values**	**91.5%** (59.3%)	8.5%
	2) Community & network	76%	**24%**
Human Capital	**3) Knowledge & expertise**	**96%**	14,2%
Manufactured Capital	4) Supply chain management	47%	**53%** (24.5%)
Panarchy theory **Systems & Resilience Thinking**	5) Autonomy	**83%**	17%
	6) Adaptability	**86%**	14%
	7) Resilience	82.6%	17.4%
Adaptive Resource Management: **Efficiencies**	8) Technological efficiency	75 % (25%)	26%
	9) Resource efficiency	76%	24%
	10) Sufficiency	77%	23%

5.4.5. Focus on a weakness: makerspaces supply chain

Supply chain management is the biggest concern weakness of makerspaces across Europe since the Covid-19 pandemic, highlighted in red, in Table 6. Many makerspaces did not produce the medical equipment by themselves: for instance, they conceived one element, which was then shipped to another supplier to be finalised. Some questions arise: Do makerspaces still have their supply chain in place, can it be reproduced? Thus, envisioning and reflecting upon a better supply chain management of makerspaces should bring elements of responses to the research question of this paper: HOW could makerspaces 'bottom-up' Covid-19 responses be the catalysts of lasting post-pandemic societal and sectoral transformations in Europe? HOW the new modes of sustainable production deployed by makerspaces for the health sector, be applied in other sectors in Europe to enable a deep sustainability transition?

A recent investigation conducted by Hennelly et al. (2019) analysed the potential scalability of urban makerspaces modes of production and the strategic role that 'RDM makerspaces' could play in the establishment of local production activity, especially the Redistributed Manufacturing model (as introduced in 3.4). Hennelly et al. consider RDM makerspaces as 'local community-based makerspaces' with a 'flexible supply chain': *"RDM makerspaces are an exemplar model of short run 'flexible capacity' in which no long run fixed logistic structures need to be created"* (Hennelly et al., 2019, p.542). However, the flexibility of the supply chain is project-based and temporary, meaning that it lasts only the time of the crisis: design and supplier relations are organized on a "temporary project by project basis as the flexible supply chain dissolves once demand has been satisfied" (Hennelly et al., 2019, p.542). Consequently, the temporary nature of the flexibility might be the main cause of the weakness of the supply chain. For instance, 33% of Italian makerspaces mentioned a lack of supply chain management, along with a lack of network (20%), 41% of French makerspaces are concerned with their supply chain. Also, 76% of German makerspaces mentioned a weak supply chain, even extremely weak (19% of them), along with very weak internal production capabilities (mentioned by 55%) and a lack of sufficiency (mentioned by 46%) (see in Appendix 12).

5.4.6. Strengths and weaknesses of rural makerspaces

Hennelly et al. (2019) focus on the potentials of urban makerspaces and on a specific type of manufacturing practice, whereas this paper aims at covering the potentials of makerspaces in rural areas on the one hand, and different modes of production (circular, socially useful, resilient) on the other hand. Thus, the present investigation fills the research gap, and bring new elements of responses (c.f. Matrices in Appendix 12), in complement to Hennelly et al. results.

European rural makerspaces show very strong Social Capital, such as the purposes & values, as well as the level of knowledge of their members, as shown in Table 10; Human Capital (community, networks). 58% of them stressed a problem of supply chain, in most cases accompanied by a lack of sufficiency, technological efficiency and resource efficiency, and affects the autonomy, adaptability and resilience of makerspaces (highlighted in red in Table 10; c.f. Appendix 12, Matrix). 33% of makerspaces in rural area have a weak technical efficiency, i.e. internal production capacity due to a very weak supply chain. The strengths and weaknesses of urban and rural makerspaces have also been analysed in depth at national levels, illustrated by matrices for Italian, French, German, Spanish makerspaces, in Appendix 12.

Table 10: Urban & rural makerspaces strengths and weaknesses

	Magnitude	rural	urban	Average
purpose	strong	100%	90%	95%
	weak		10%	5%
community	strong	79%	75%	77%
	weak	21%	25%	23%
knowledge	strong	92%	97%	94%
	weak	8%	3%	6%
supply chain	strong	42%	43%	42%
	weak	**58%**	48%	53%
autonomy	strong	79%	75%	77%
	weak	13%	14%	13%
adaptability	strong	83%	86%	84%
	weak	17%	12%	15%
resilience	strong	88%	80%	84%
	weak	13%	16%	14%
Technological efficiency	strong	63%	73%	68%
	weak	33%	22%	27%
Resource efficiency	strong	75%	72%	74%
	weak	21%	24%	22%
sufficiency	strong	75%	71%	73%
	weak	21%	22%	21%

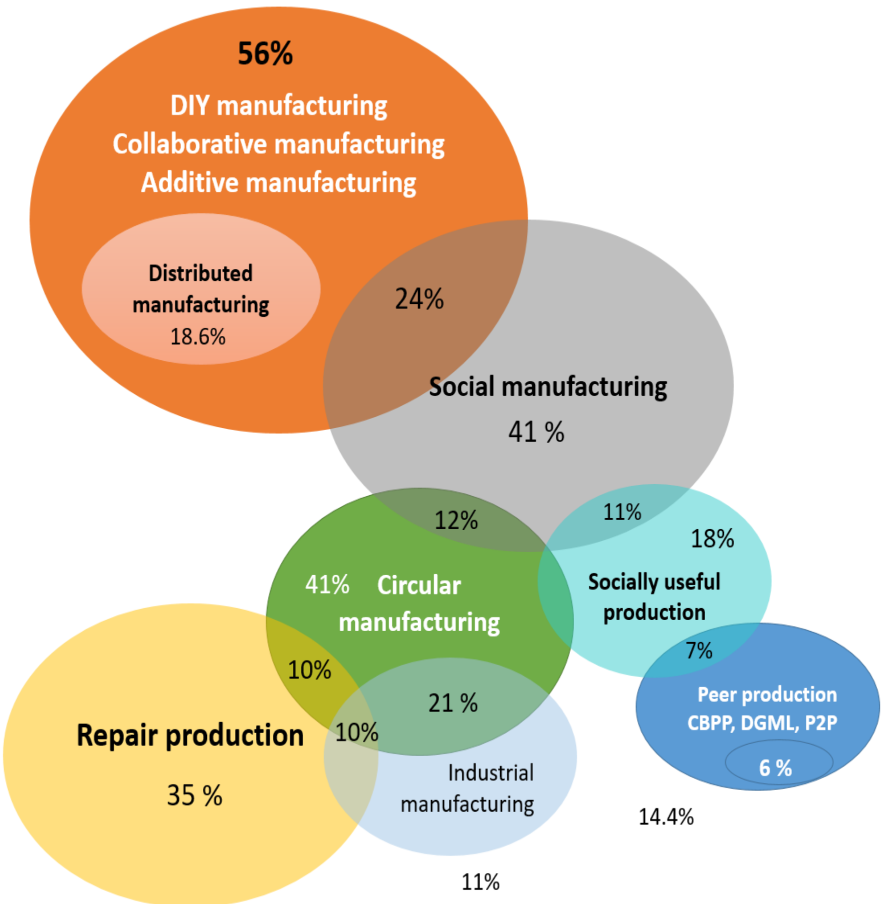
5.5. Production processes of European makerspaces

5.5.1. Production processes at the European level

Production processes were defined as indicators of makerspace sustainability as well as drivers of digital and sustainability transition in Europe (c.f. 3.4). Q19 of the survey (Appendix) aimed at identifying the production processes of makerspaces in Europe, and which terminology is mostly used to describe makerspaces activities. All of the concepts listed in Table 11 and Figure 30 were introduced and elaborated in 3.4. and a typology was dressed (c.f. Table 2 & 3). The production processes were further classified into four main categories, as production paradigms converge, depending on the technologies available in the spaces and the socio-economic orientation (c.f. Appendix 15). By investigating the diversity of modes of production and sociotechnical practices being experimented within makerspaces since the pandemic, we identify potential economic models or socio-economic paradigms, illustrated in Figure 30: the collaborative manufacturing paradigm, including DIY manufacturing, distributed manufacturing and additive manufacturing (orange cluster) social manufacturing, repair production and circular manufacturing.

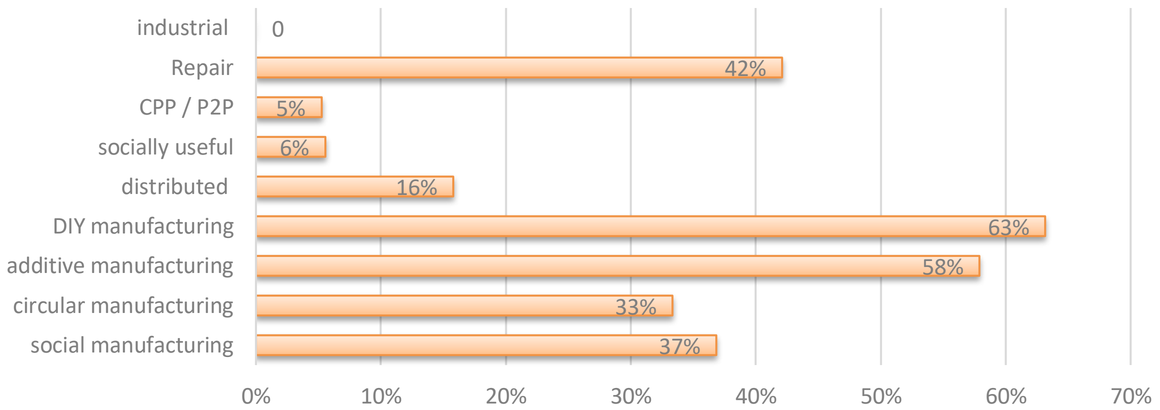
Table 11 & Figure 30: cluster of production processes observed among European makerspaces

Production process (survey)	Rural %	Overall %
DIY manufacturing	**63 %**	56 %
Additive manufacturing	**58 %**	52.5%
Social manufacturing	37 %	**41 %**
Repair production	**42 %**	35 %
Circular manufacturing	33 %	25 %
Distributed manufacturing	16 %	**19%**
Socially useful production	5 %	18 %
P2P	5 %	**14.4 %**
Industrial Manufacturing	0	**11 %**
Commons-based Peer production	5 %	**7.6 %**
DGLM	5 %	**6 %**



The most common terminology used to describe makerspaces production processes are 'DIY manufacturing', mentioned by 56% of the participants and 'Additive manufacturing' (52.5%). The two concepts might be used interchangeably, as the majority of makers mentioned both simultaneously. Social Manufacturing - trio makers/manufacturers/consumers in the co-creation challenges for the manufacturing of new consumer products - is also a dominant production process: overall, 41% of makers mentioned it as part of their processes without necessarily being part of the EU-funded program iPRODUCE, aiming at enforcing Social manufacturing in the EU (only 8% of makers are familiar with it; c.f. Appendix 16). Then, Repair production is mentioned by 35% of European makers (mostly German, c.f. Appendix, matrix). Figure 30 shows that repair is particularly strong among rural makerspaces (42% in Figure 31), hence the necessary consideration of rural makerspaces in repair economy agenda, as discussed in 3.2.C.

Figure 31: Rural makerspaces production processes



4) Circular manufacturing is mentioned by 25% of makerspaces overall (c.f. Table 11). Repair is generally considered intrinsically linked with circularity: circular makerspaces reuse their waste and by-products by repairing them, sourcing, materials, optimising the value of the residues of their processes (c.f. 3.2.B.). Yet only 10% mentioned both repair production and circular manufacturing as their production processes. Thus, the correlation between a repair production and circular manufacturing is weaker (10% < 21%) than the correlation between circular manufacturing and industrial manufacturing (as illustrated in Figure 30). This correlation confirms the industrial orientation and urbanity of the circular mode of production, i.e. 'circular urban manufacturing' referring to the urban manufacturing that contributes to a circular economy, by leveraging the availability of affordable, digital, and distributed production technology (elaborated in section 3.4.). On the other hand, within rural makerspace, circular manufacturing would be rather understood as a 'circular collaborative production', minimizing the importation of raw materials and reliance on global supply chains (Figure 31). The most notable difference between rural and urban makerspaces is that there is no industrial manufacturing in rural makerspaces (c.f. Table 11). This observation demonstrates that value-creation is not confined to urban

makerspaces and industrial settings. We expected to see more rural makerspaces engaged in CPBB, P2P or DGML (Design Global Manufacture Local), as we discussed the predominance of those modes of production in rural areas: for instance Commons-Based Peer Production in the field of agriculture in rural makerspaces (c.f. 3.4.). Thus, CBPP, P2P and DGLM models (green cluster in Table 11) are still in a niche development phase.

5) The term 'Distributed manufacturing' was mentioned by 18.6% of the participants. This low share could reveal the limited yet promising role of makerspaces in local production systems, as acknowledged by Hennelly et al. in 2019. 'Distributed manufacturing' is being recently used in the design field, as well as in environmental and social sustainability studies (Corsini & Moutlrie, 2021) Moreover, in October 2020, a collective of French makers signed the 'Manifesto for a Distributed manufacturing' calling makers to organize an industrial renewal towards an economic recovery and an 'ecological transition' (c.f. Appendix 20). The structuration of this manufacturing paradigm throughout France would be the key to a resilient, job-creating and environmentally friendly production system" (FabriCommuns, 2020, in Appendix 20).

6) Peer-to-peer production (14.4%), Commons-based peer production (7.6%) and DG-ML model (6%) were the least mentioned modes of production by both rural and urban makerspaces (c.f. Table 11 and Figure 30). Those three production modes were clustered under the category of peer production (in green in Table 11). Commons-based peer production was the focus of CoWerk Research program (2014-2018)[4], focusing on German makerspaces applying CBPP (CoWerk stands for *"Commons-based Peer Production in Offenen Werkstätten"*): the "Verbund offener Werkstätten" is the bottom-up coordinated infrastructure, mentioned by some German participants in the survey. CoWerk contributed to the conceptualization of peer-to-peer distributed innovations in collaborative platforms within the German makerspaces (Aryan et al., 2018) and the wider European institutional context (Aryan et al., 2020). They mentioned that the results reflect the goals of the entire CBPP landscape in Germany and not just those that engage with digital fabrication (Aryan et al., 2020).

7) Socially useful production. Overall, 18% of makerspaces mentioned "socially useful production" as their modes of production. Indeed, during the pandemic, many initiatives similar to a 'Makerspace Plan' have been observed (mentioned in 3.2). For instance, the Spanish makerspace Espacio Open was hosted in a small cookie factory and repurposed it to create PPE, thus a socially useful production. They would extend their blueprints and supply chains out to other makerspaces to help speed up and increase production, in a commons-based peer production. This lead to other ad-hoc makerspaces being created (OSMS, 2020). The Italian 'networked' makerspaces ecosystem also engaged in a socially useful production: by co-designing convivial and appropriate medical devices, they could meet diverse social / health care needs. Considering health as a common good,

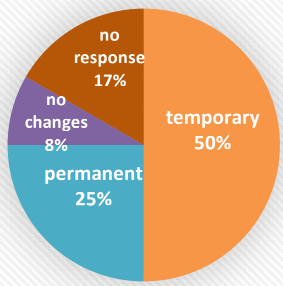
[4] CoWerk project: https://www.cowerk.org/das-projekt-cowerk.html

instead of a mere individual good, is the core of a socially useful production (Cozza et al., 2020; Bria e al., 2019; Corsini et al., 2021). Similarly in the UK, some factories, converted their production purposes to meet diverse social care needs: hand sanitizer surprisingly produced by gin distilleries, face masks produced donated by drinks manufacturers produced, protective visors and gowns produced by car manufacturers (Williamson, 2020 cited in Cozza et al., 2020). Williamson (2020) created a repertoire of every UK-based manufacturers, which adeptly pivoted from their typical output to produce PPE and ventilators for NHS workers: masks, shield, gowns, gloves, hand sanitiser. This re-conversion of production represents an important terrain where different political trajectories are present (Cozza et al., 2020).

8) Even though the DG-ML production model was the least cited by the participants in the survey (only 6% overall), it is worth considering the concept, especially to understand how makerspaces did manage to implement their solutions without a certification. For instance, Isinnova immediately patented the “Charlotte valve” (Figure 27), in order to prevent regulatory capture or any speculation on its price (Sher, 2020). While Isinnova distributed over 1000 functioning masks for free to more than 50 hospitals in Italy, 50,000 of that same retrofitted mask with the Charlotte valve have been manufactured in Brazil, and millions by makerspaces all over the world (Corsini et al., 2020). The medical device prototyped and manufactured locally, pioneered by a local Italian start-up, could be manufactured and designed globally: this is the principle of the DG-ML model (Kostakis et al., 2018). Since the Charlotte valve patent became open source, free to download (over 2.5 million times by makers worldwide): any makerspace with 3D printers could replicate in complete autonomy, and adapt the design with other types of mask available on local markets (Corsini et al., 2020). The DG-ML model of the DIY mask was the following: healthcare facilities purchased the Decathlon mask and then local 3D printing makerspaces could produce the tailored valve (Sher, 2020). In a crisis context, the “Charlotte valve” is thus a paradigmatic example of a frugal maker innovation, and the success of its implementation is due to its disruptivess, its anticipatory conception and the simplicity of its design: Isinnova could meet the demand for CPAP devices on time, before it ran out (Corsini et al., 2020), and became the norm, despite strict standardization processes, especially in the healthcare sector (Sher, 2020). Thus, we can deduce that the DG-ML model is intrinsically linked with certification requirements, and can help makerspaces tackle important legal issues.

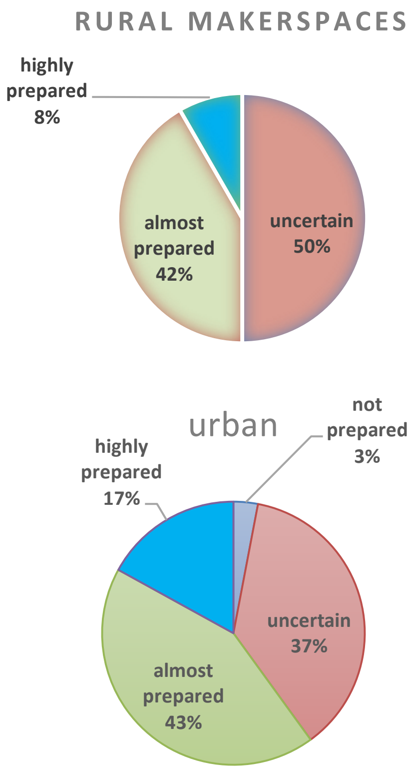
5.5.2. Impacts and preparedness

Figure 32: Changes of production among rural makerspaces



Q14 reveals how Covid-19 affected the structures. More rural makerspaces have been impacted in a permanent way (25%) than urban makerspaces (19%), as shown in Figure 32. This can be explained by the fact that most of rural makerspaces were born during the pandemic, thus their initial purpose is to contribute to the Covid-19 efforts. 50% of them were temporally affected in their production processes, while 8% were not impacted (status quo). Overall, the majority of makerspaces (57%) mentioned that their production processes changed temporarily during the Covid-19 crisis, meaning that they might bounce back to their initial production practices, due to the dissolution of the 'flexible supply chain' once demand has been satisfied (Hennelly et al., 2019). 20% of makerspaces overall mentioned a permanent change of production process, mostly in France (43.5% of them; c.f Appendix 11). The results between urban and rural makerspaces are not significantly different in terms of impacts felt and preparedness (c.f. Appendix 14). Yet makerspaces have been differently impacted on a national level, there is a significant correlation between the degree of changes and the country where the structure is located (c.f. Appendix 14).

Figure 33: Preparedness of rural and urban makerspaces



In terms of preparedness, the majority of both rural and urban makerspaces feel prepared for the future and to face new disruptions (Figure 33), e.g. supply chain, shortages of essential goods: 60% feel prepared including 43.7% almost prepared and 16% highly prepared overall (N=120, see Appendix 14).

Uncertainties. Rural makerspaces express more uncertainties (50%) than urban makerspaces (37%). More urban makerspaces feel highly prepared (17%) than rural makerspaces (8%) due to the uncertainties of the latter (Figure 33). It is important to acknowledge uncertainties, i.e. the fact that probabilities of potential outcomes are not known (Leach et al., 2021, p.7). Thus, coping with uncertainty requires a fundamental 'rethinking' from makerspaces (Leach et al., 2021). Precisely, the attitudes towards uncertainty is the main difference between structures aiming at achieving short-term goals versus long-term goals. Indeed, sustainability is in the realm of the known, whereas resilience is in the realm of the unknown, surprise and uncertainties, as discussed in section 3.1.A.c) .

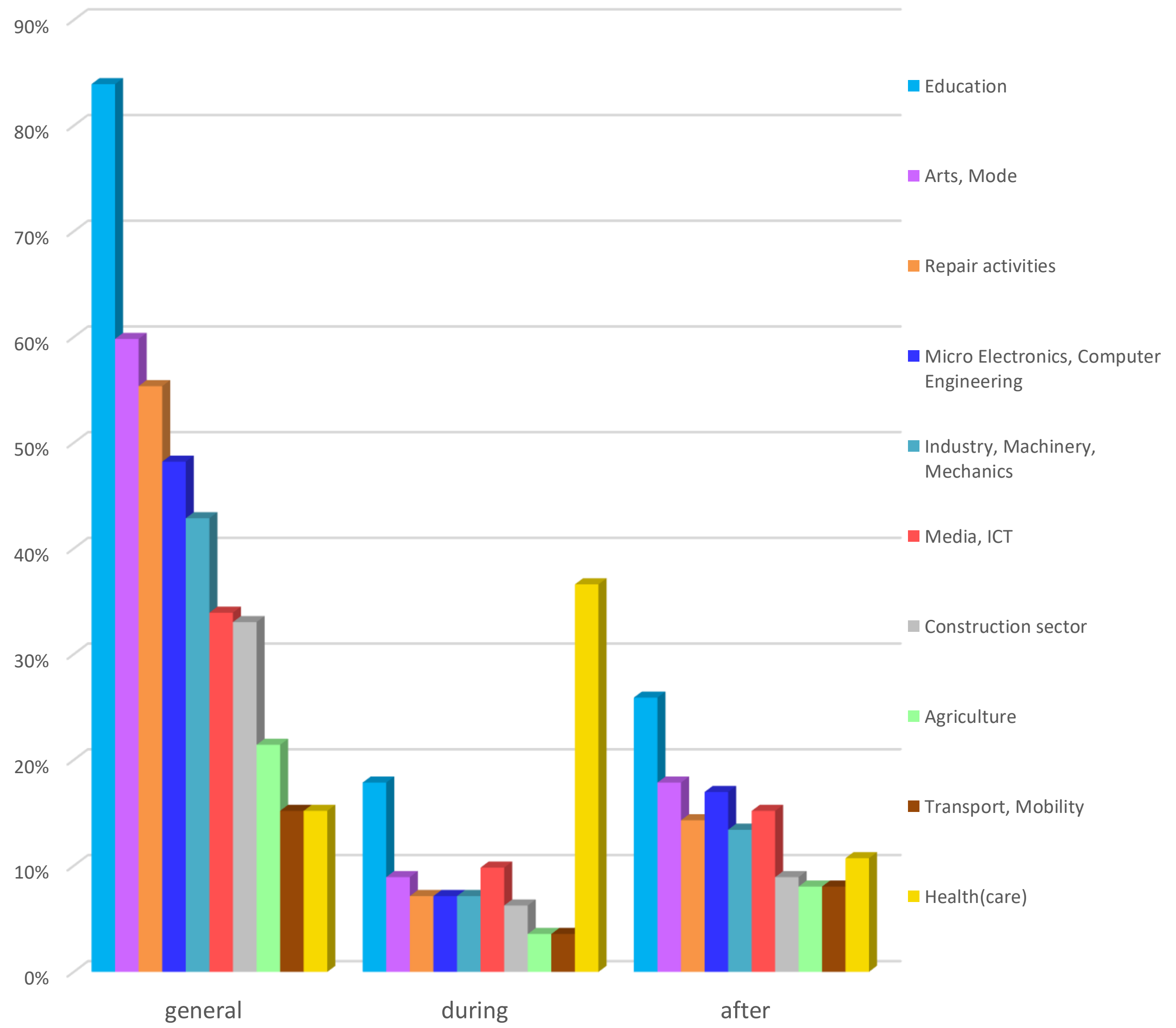
The survey results of Q14 and Q17 raise the Dilemma of makerspaces: Sustainability vs Resilience, discussed in 3.1.A.c. The higher share of temporal changes (50%) than permanent changes (25%) indicates that makerspaces might be more inclined to achieve sustainability rather than resilience. On the one hand, the majority of makerspaces impacted only temporally might feel that they increased their resilience, but in reality, there are normalizing and routinizing (static and conservative, under an institutional pressure for conformity). The reason is that resilience is usually understood in its engineering definition: either averting crises and disaster (static sense) or bouncing back to the original state after a shock (dynamic sense) (c.f. section 3.3.). In both senses (static and dynamic), it reveals the fear for changes, whereas it is precisely a change of an existing system that is intended.

On the other hand, makerspaces impacted permanently during the pandemic were able to adjust, adapt and transform their configuration and function under the disturbance. This category of makerspaces, those impacted permanently sine the Covid-19 crisis (22% overall, and 25% of rural makerspaces) have great adaptive resource management potentials, that promotes adaptability (accept changes) and 'transformability' (adapt the strategies and re-organize profoundly) (Folke et al., 2010). It is necessary to be aware of system's resilience and vulnerability (i.e. exposure to risk and sensitivity) in order to see all the possibilities to enhance a system's owns restorative powers, and engage in a repair work.

5.6. Sectoral perspective of European makerspaces

Q18 of the survey aimed at exploring makerspaces' sectors of activities in Europe, before the pandemic, during and after. The results reported in Figure 34, show a significant repurposing of makerspaces activities in the health(care) sector where the bulk of energy and attention were needed during the pandemic, illustrated in the histogram below. Beside the healthcare sector, other sectors were exposed and sensitive to the crisis, among makerspaces. We observe a pause of activities across sectors, even a drastic decrease, during the Covid-19 crisis. Sectors priorities might not significantly change after the crisis, except a boost in the sectors that were revealed particularly useful during the pandemic among the makerspaces ecosystems (education, arts & culture, media & ICT, healthcare). Yet the priorities might still change, as the crisis is not over yet.

Figure 34: Makerspaces' sectors of activities in Europe: in general, and during & after the crisis



The survey results of Q18 show that, in general, most makerspaces operate in the **education sector, art & culture sectors, and in repair activities** (the three sectors cited by more than 50% of makerspaces, see the exact shares in the tables below) but they are not exclusive. Makerspaces across Europe are transdisciplinary and operate in multiple sectors simultaneously, covering a wide range of skills, expertise and interests. As discussed in the conceptual framework, makerspaces are places of 'organized possibilities': 'innovators of education', cradles for entrepreneurship, studios for digital creativity and explorations of 'material culture', catalysts of social change, prototyping workshops for local manufacturers, 'twenty-first century libraries', laboratories for smart urbanism (Braybrook & Smith, 2020).

Table 12: Sectors of activities within makerspaces, overall, in general, during and after the crisis

Sectors in which makerspaces operate in general	%
Education	84%
Craftsmanship (Arts, Mode, wearables)	59,8%
Repair activities	55,4%
Micro Electronics, Computer Engineering	48,2%
Industry, Machinery, Mechanics	43%
Media, ICT	34%
Construction sector	33%
Agriculture	21,4%
Transport, Mobility	15,2%
Health(care)	15,2%

Sectors during the crisis	%
Health(care)	36,6%
Education	17,9%
Media, ICT	9,8%
Craftsmanship (Arts, Mode)	8,9%
Repair activities	7,1%
Micro Electronics, Computer Engineering	7,1%
Industry, Machinery, Mechanics	7,1%
Construction sector	6%
Agriculture	3,6%
Transport, Mobility	3,6%

Sectors in the future	%
Education	**25,9%**
Arts, Mode	17,9%
Micro Electronics, Computer Engineering	17,0%
Media, ICT	15,2%
Repair activities	14,3%
Industry, Machinery, Mechanics	13,4%
Health(care)	10,7%
Construction sector	9%
Agriculture	8,0%
Transport, Mobility	8,0%

First a general sectoral perspective to observe in which sectors makerspaces operated **before** the pandemic (6.1), then the sectoral activities **during** the pandemic, which is still the period at the time of writing the present paper (6.2), and finally the sectors where makerspaces envisage to operate in the future, in a **post-pandemic** context (6.3).

5.6.1. General sectoral perspective of makerspaces in Europe

In general, most makerspaces operate in the Education sector (84%) followed by art & culture sectors (60%), and repair activities (55%), as illustrated in Figure 34 and detailed in Table 12.

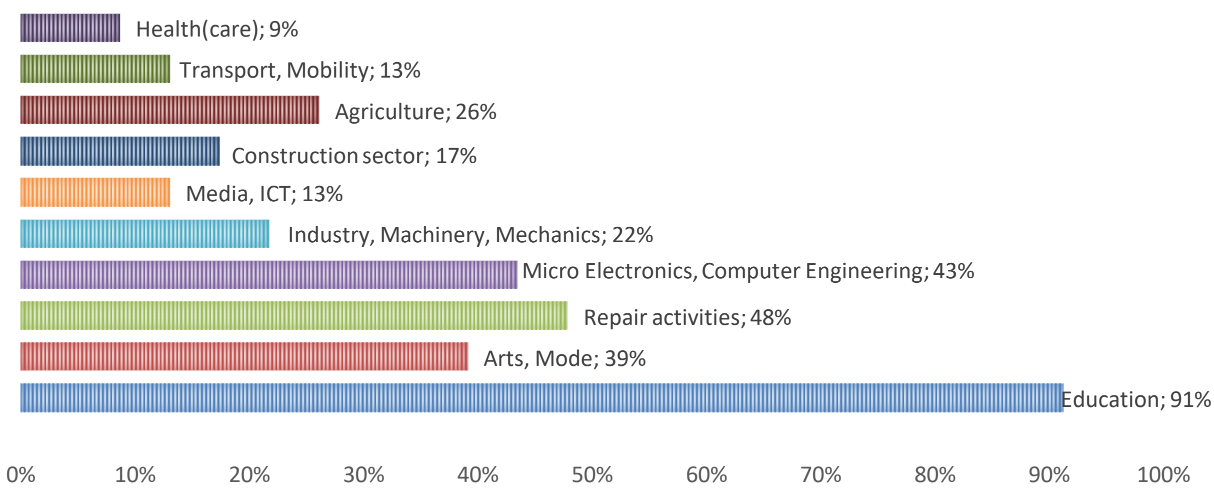
Education. From the survey results, we observe that a majority of makerspaces in Europe (84%) are ‘learning spaces’ with educational environments where people can learn digital fabrication skills. From the survey results, 10.2% of makerspaces participants are embedded in educational environments (universities, engineering schools, technopole) as well as librairies (c.f. Appendix 4).

Culture & Arts, Repair. Mentioned by a large majority of makerspaces, the Culture & Arts sector includes the Fashion industry (textiles), woodworking, and *Repair activities* (55%). Repair makerspaces have many potentials with the new repair policies enforced at the EU level, as introduced in 3.2.C.

Concerning the healthcare and agriculture sectors, elaborated in 3.5., the survey responses reveal that makerspaces operating in these two fields were niches before the advent of the pandemic. Yet they are emerging fields, which need to be considered for new sectoral focus. The crisis has unveiled enormous potentials of makerspaces in the health(care) sector, where French (31%) and Italian (22%) makerspaces in particular are already operational (c.f. Appendix 14).

Agriculture: 21.4% of makerspaces overall mentioned their operations in the agricultural sector, particularly French (34.5%) (c.f. Appendix 14). As illustrated in Figure 31, 26% of **rural makerspaces** are operating in the agriculture sector, a non-negligible share (in the 5th position of sectoral priority, out of 10). An Austrian participant suggested that rural makerspaces might be “the next generation farming” (c.f. Table 15). The quasi totality of rural makerspaces are involved in the education sector (91%) and a vast majority in repair activities (48%).

FIGURE 35: RURAL MAKERSPACES: SECTORS OF ACTIVITY IN GENERAL



5.6.2. During the crisis: a repurposing of makerspaces activities

The sectoral focus of makerspaces during the pandemic was in Healthcare (37%) and Education (18%) (c.f. Appendix 14). These survey results bring an additional evidence of their outstanding involvement in the healthcare sector during the pandemic (discussed in 3.5): they produced medical emergency items for health workers and Covid-19 patients. While the healthcare sector was not a priority sector for makerspace in Europe before the Covid-19 crisis (15%, the lowest share), it became a top priority sector of makerspace activities during the pandemic (37%, the yellow peak shown in Figure 34). Thus, it can be deduced that makerspaces across Europe embraced 'frugality' as a health crisis response strategy: they deployed digital fabrication tools to produce emergency medical items.

As an example, the JRC makerspace hosted by the European Comission (described in 3.1.B) was also actively engaged in this health crisis response strategy. JRC members among them the President of the JRC Ispra staff committee) organised in a '3D visor group' of 'Covid-19 fighters': JRC makerspace financed, produced and donated over 250 protective facial 3D-printed visors to local Italian healthcare services, hospitals and municipalities. Inspired by initiatives from private citizens using a 3D-printer to create protective gear for medical staff in Lombardy, they mobilised their own personal 3D-printers at the JRC makerspace to produce the visors and donate them to local municipalities (EU Science Hub, 2020). Then, they extended their actions to other hospitals and institutions in the area who needed such equipment, and to the JRC's own medical service in Ipsra (EU Science Hub, 2020).

Thus, makerspaces have been repurposing their activities at the service of the health(care) sector since the beginning of the pandemic. Among those, which contributed in the health sector, 73.5% have engaged in a socially useful production of health and medical public goods. Yet, the share of the involvement in the health sector seems underrated, compared to the percentage of makerspaces having produced PPEs (83%). Although makerspaces unanimously produced PPEs, the healthcare sector was not necessarily their focus, and continued nevertheless their other sectoral activities. For instance, German makerspaces have been operating in a diversity of sectors, and did not focus on one particular sector during the pandemic. This discrepancy might be also explained by the temporary nature of the phenomenon: makerspaces repurposed their activities, just the time of the crisis. This transdisciplinarity proves that, some makerspaces remain multidisciplinary even in times of crisis and pursue their previous activities that provide them a financial sustainability.

Education is also a strong focus of makerspaces during the ongoing crisis (18%) along with Media & ICT (10%). This can be interpreted with the shift of most makerspaces activities into digital mode, due to the lockdown restrictions. The third sectoral focus in Craftsmanship mentioned by 9% of makerspaces. Indeed, crafts and design were needed in conceiving PPEs, DIY items during the pandemic.

5.6.3. Sectoral aspirations: where makerspaces envisage operating after the crisis

Participants could indicate in which sectors their makerspace would operate in the future. Despite the rapid repurposing of makerspaces' activities in the health sector during the crisis (Rank 1 with 37%), the shift seems only temporary, as the sector does not represent a priority after the crisis (Rank 7 with 11%). Nevertheless, among the 10% of makerspaces pursuing in the health sector, some participants are confident about their potentials: "The Covid-19 has revolutionized the entire [health] industry by accelerating its growth and defining new working scenarios, an example can be the distributed production, or the mass customization, it has given birth to new opportunities in all sectors, one of all, the medical sector with new materials, new machines, new software, etc." (c.f. 5.8. Table 13). An another participant mentioned some potentials of distributed manufacturing, i.e. bringing small-scale manufacturing units to many locations, in building a "sustainable vaccine industry" with "the design and prototyping of vaccines […] with final manufacture in small-scale facilities offers the possibility to bring manufacturing close to the point of care" (see Kitney et al., 2020), thus in direct contradiction with the centralised mass production paradigm.

Unlike the Healthcare sector, Education remains a top priority (Rank 1 with 26%) in a post-pandemic context, depicted in Figure 34. Table 12 highlights that Education (in green) has always been at the core of makerspaces activities across Europe, despite the large-scale events. Indeed, makerspaces are considered as places for STEAM education (Science, Technology, Engineering, Arts, and Mathematics) and training. The JRC Policy Lab (see Vuorikari et al., 2019) elaborated a scenario of makerspaces in the Education sector in 2034, shown in Figure 36, and makerspaces located within educational institutions (schools, universities, libraries, museums, engineering schools) has become an important factor in fulfilling that scenario. Particularly the potential of 'library makerspaces', i.e. makerspaces in libraries: incorporating digital fabrication and "maker" technologies into libraries, museums, and other cultural spaces (Susanne Bjørner in Pope, 2014). Arts & culture is the second promising sector, where 18% of makerspaces envision pursuing their activities.

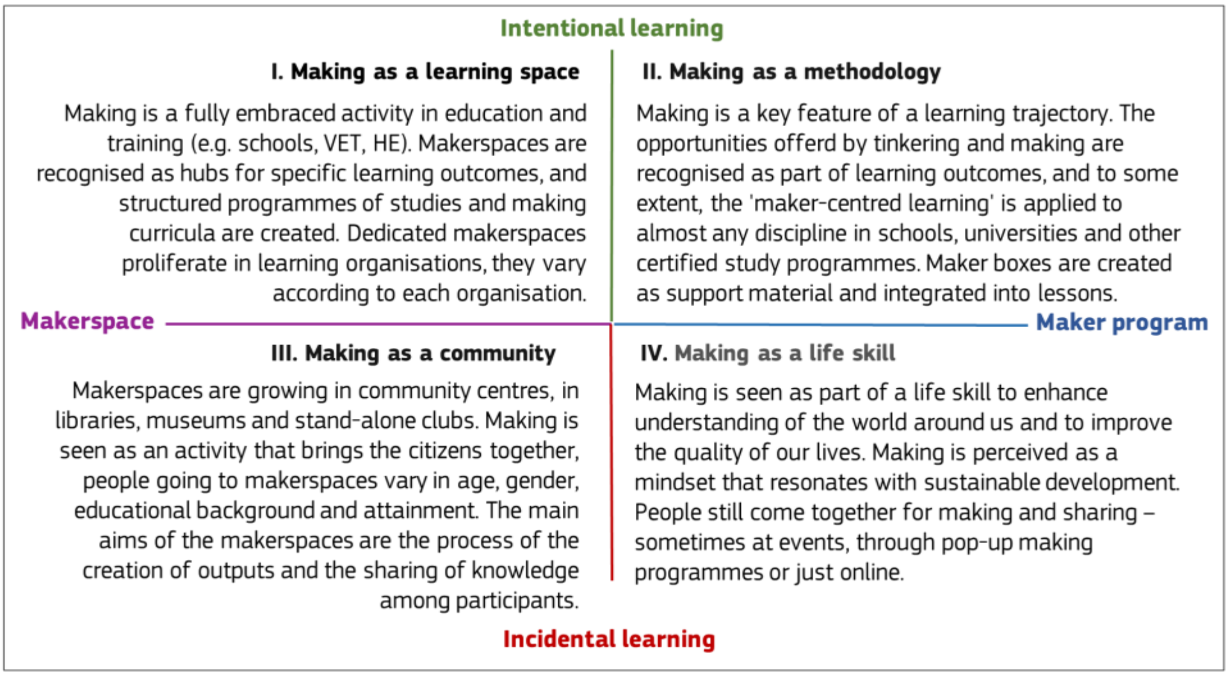
Libraries also repurposed their activities in makerspaces (in France, in the UK and Spain) to respond to the sanitary emergency, as narrated by a survey participant:

"Within a municipal public library in rural areas, its participation in the fight against COVID-19, positioned it locally and nationally as a vital social infrastructure, also suitable for states of emergency. It is a space that allows democratic access to all types of public to technological tools that forms citizens throughout their lives; it is the third space in the library of the XXI century, necessary in a society immersed in the digital transition. Libraries have a place in the national plans of recovery and digital skills.". This particular category of library makerspaces are accounted in public diplomacy and cultural diplomacy agendas (Pope, 2014), and feature in Digital Strategy agenda (UK) recognizing their value and impact (UK Government, 2019).

Thus, the survey results for Q18 confirm that both rural and urban makerspaces are drivers of change, as learning spaces for anticipatory thinking in the post-Covid-19 era.

This present Research paper provides an another evidence that makerspaces need to be considered as catalysts of societal and technological developments powered by citizens who want to make a difference (Vuorikari et al., 2019). Makerspaces, when integrated into curriculum or syllabus, are likely to serve as a ‘stepping stone back’ to more formal learning activities and outcomes, and can provide pathways for employment, for example, through validation of non-formal and informal learning (Vuorikari et al., 2019). Hence, the need of makerspaces policies related to the Education sector to fulfill the scenario 2034 for ‘competence-based education’ and for addressing *European Key Competences for Lifelong Learning* (Vuorikari et al., 2019, p.7).

Figure 36: Future scenarios for makerspaces in Europe in 2034

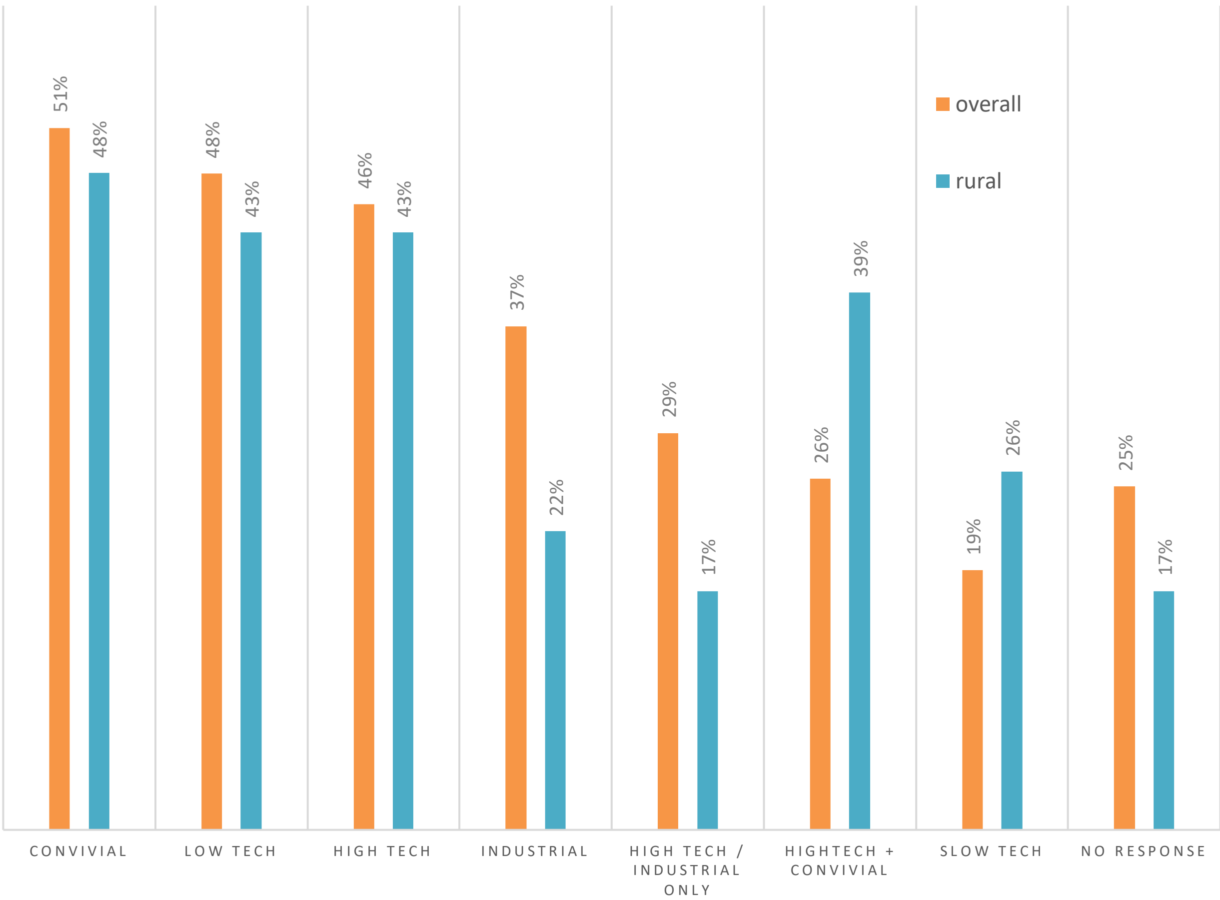


Source: Vuorikai et al., 2019, p.7, p.26 (JRC Report, European Commission)

5.7. Attitudes towards Technology

In this paper, manufacturing practices and technologies are chosen as indicators of makerspace's sustainability, in order to understand how they can contribute to the digital and sustainability transition in Europe. Figure 37 shows that the majority of the participants (51%) consider their manufacturing technologies as convivial tools (including, frugal tech/ jugaad /DIY) easy to repair and modify. In general, the spectrum of makerspaces' technologies ranges from traditional crafts ("low tech") to the use of 3D printers ("high tech"). Makers mentioned at an almost equal share high tech (46%) and low tech (48%). Low tech is defined as useful, accessible and sustainable technology. Yet, this dichotomy high vs low tech is becoming blurry, as 23% of makers have both high tech and low tech types of technology in their makerspaces, and 26% mentioned both high tech and convivial technology, especially rural makerspaces (39%). Some makers specified "wild tech", a transgressive category of technology, beyond the high vs low tech category (Grimaud, 2017). These are new technological possibilities in the context of decentralized and community-based production and digital value creation. The use of slow tech is higher in rural settings (26%) than in urban settings.

FIGURE 37: TYPE OF TECHNOLOGY IN MAKERSPACES, OVERALL AND IN RURAL AREAS



Q21 refers directly to section 3.3. and aims at deciphering multiple applications of 3D printing reveal different attitudes towards it, and different 'futures of manufacturing'. Indeed, the technological focus within makerspaces has been mostly on 3D printing, as it embodies the "material and symbolic convergence of technical and social considerations for a decentralized system of innovation" (Dickel et al., 2016).

Table 13 : Q21

Share	**3D printing as …..**
75%	**Additive manufacturing technology**
53%	**Local Manufacturing technology**
41%	**Technology for repair**
28%	OSAT – Open source and appropriate technology
25%	Technology for Sustainable development
12%	Frugal technology
5%	Prototyping technology

Table 13 shows that a large majority of makerspaces overall perceive 3D printing as an additive manufacturing technology (75%) and as a local manufacturing technology (53%). 41% of makers see it as a technology for 'repairing'. Only 25% of makers find the technology suitable for sustainable development (c.f.Table 13)

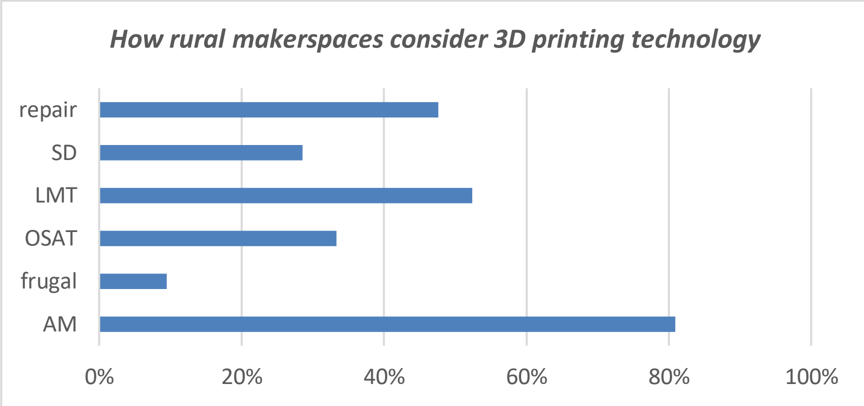
Considering 3D printing as a local manufacturing technology or frugal technology show that there are potentials for peer production (decentralized and collaborative), repair production and DIY fabrication intertwine, with projects exchanged online, globally accessible (e.g. the Charlotte valve designed by Italian makers).

Interestingly, considering 3D printing as a repair technology (48% of rural makerspaces, c.f. Table 14) can reposition repair practices of makerspaces as a remedy after the crisis. Beyond the technological work, makers can engage in a 'repair work' that would benefit themselves and society after after a breakdown, as discussed in 2.1.C. (feminist literature). These different attitudes indicates that makerspaces might be well positioned in the Right to Repair revolution in Europe and not only in an 'industrial revolution'. Despite the great accessibility of open source and low cost 3D printers to allow 'repair-friendly' and alternative design, there are still implementation issues, as discussed in 3.3.C.

Despite the 'hype' of 3D printers within makerspaces during the crisis, this equipment is just one out of many makerspaces technologies. A German maker suggested the promotion and dissemination of other fabrication technologies, typical and operational in most of the structures surveyed, such as 'milling': "*Many techniques are fun but mostly not efficient to use. e.g. 3D printing is really only suitable for valuable parts due to the slow production processes" ; "there is clearly also a lack of (open) platforms to improve and distribute design plans and objects. In software development there is e.g. the git (hub/lab) software and platforms for collaborative work. This is missing for other techniques Possible would be of course also legal requirements that partial components of products must be entered into such platforms, so that these can be repaired more easily*" (c.f. Table 15).

Table 14: How rural makerspaces consider 3D printing technology

AM	**81%**
frugal	10%
OSAT	33,3%
LMT	52,4%
SD	28,6%
repair	47,6%

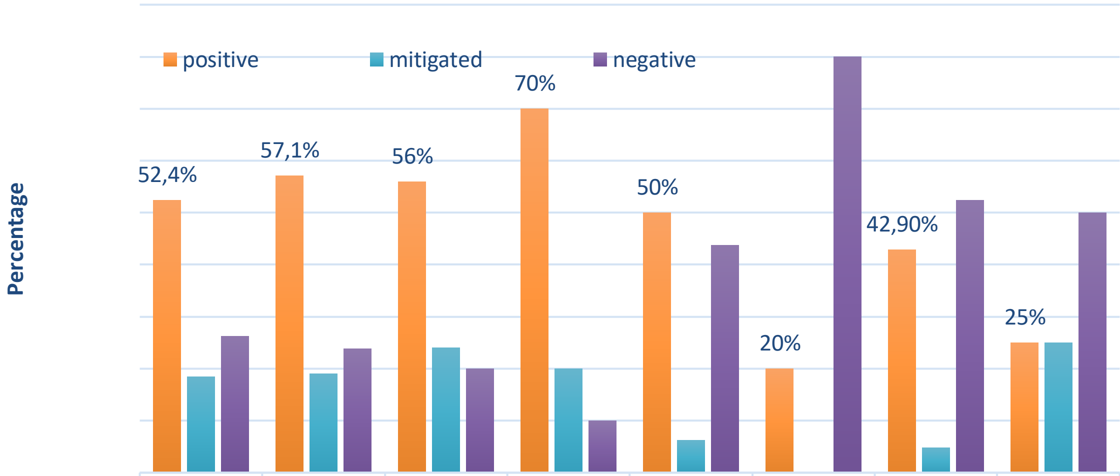


The advent of commercial makerspaces demonstrates that complex interdependencies hybrid constellations of top-down and bottom-up forms of coordination, between a profit-oriented business approaches and a commons-based community effort; decentralization offers some potential opportunities in terms of environmental sustainability of the technology, but these should not be overestimated. What matters is “the manner in which technological opportunities become socio-economically embedded that could contribute to a change of course toward more sustainable development” (Dickel et al., 2016, pp. 23-24). This is a matter of not only individual innovations, but also modifications of infrastructure and the associated behavioural changes.

5.8. Insights and perspectives from makers

In this section, we analyse the perspectives gathered through the open-ended question at the very end of the questionnaire: out of 130 participants, 103 engaged in the comments section and expressed themselves, from one word, to a paragraph. In general, two opposing trends have been both reported by the participants of the survey: on the one, hand the emergence of makerspaces, and on the other hand the resistance and inertia of the incumbent regime (government, health authorities). The responses are clearly divided into three different feelings and perceptions (positive, mitigated and negative) regarding the roles and potentials of makerspaces since the Covid-19 crisis as illustrated in Figure 38.

Figure 38: Makers insights per country



	Overall	Italy	France	Spain	Germany	Austria	UK/Ireland	Greece
positive	52,4%	57,1%	56%	70%	50%	20%	42,90%	25%
mitigated	18,4%	19,0%	24%	20%	6,3%		4,80%	25%
negative	26,2%	23,8%	20%	10%	43,8%	80%	52,40%	50%

Overall, the majority of European makers (52.4%) have positive and optimistic perceptions of their roles during and after the crisis, especially in Italy, France and Spain. Overall, 18.4% expressed a nuanced perspective by highlighting the dual impact (positive and negative) and uncertainties regarding their future role or potential. Negative and pessimistic insights prevail in Germany, Austria, the UK / Ireland, and Greece, as illustrated in Figure 38..

5.8.1. Table of makers narratives

The narratives are snapshots of makers insights and retrospection. The fieldwork was conducted from March to May 2021. Many makers kept a daily diary, on their website or other digital platforms (Youtube channels, Facebook accounts), to tell their stories, document thoroughly their actions and perceptions, since the beginning of the pandemic (March 2020). For instance, Italian makers developed a storytelling and documentation series on their actions and perceptions, with weekly thematic videos (e.g. "*Communication and the importance of documenting"; "Charlotte and Dave valves*"). For Italian makers themselves, it was an experiment of their own communication in widespread documentation, through which they were raising fund as an additional support for health workers involved in the Covid-19 emergency and for promoting the manufacture of the devices (Officine Mediterranee, 2020). Also, French makers, designed a platform specifically to collect and share "solidarity narratives" during the first wave of pandemic in France. Part of the Covid Initiatives, this platform serves as an 'observatory' of multiple situations and practices, which emerged in order to respond to the Covid-19 crisis. Interviewees were citizens and makers who acted to serve social urgent needs during the crisis:

> *« Since the start of the crisis, many citizens have mobilized and organized collectively through various exchange platforms to respond urgently to the needs generated by the health crisis. Everywhere, mutual aid and self-organization demonstrate their ability to provide credible solutions in the spirit of the commons, whether it is to ensure educational continuity, to guarantee the food supply of people in difficulty, to help single people or to prototype medical equipment in an attempt to respond to emergencies. Initiatives flourish; each of them locally generates new networks and brings out new forms of solidarity, which link a wide variety of human collectives and materials. These situations and these new forms of collective organization are experienced in a heterogeneous way and many questions arise. This site aims to collect and share stories about these citizen mobilizations to better show the practices, emerging networks, motivations and feelings of contributing citizens, as well as the issues raised in this emergency situation. » (Translated in English from: https://recits-solidaire.dodoc.fr/)*

All of these records, testimonies, digital diaries and narratives helped reducing 'recall biases', as the survey is conducted one year after the beginning of the pandemic in Europe and are precious resources and qualitative data to decipher makers feelings. Some makers shed light on important aspect that were not reported or analysed yet in Research papers on the topic.

In the positive insights, the main themes are: Responsiveness, flexibility, adaptability, resilience, the power of networks and community, the territorial embeddedness of makerspaces, the potential scalability, the role of makerspace in the healthcare and education sectors, and the production processes. The min terminology proposed by makers *"flexibility", "responsiveness", "collaboration*" and "resilience" (c.f. Appendix 27) refers to the key concepts of CAS and emergent properties, discussed in 2.1.

In the negative insights, the main themes are the shutdown of spaces due to the lockdown, social isolation, employment issues, bureaucracy, government inertia, government failures, resource constraints, and the public opinion on makerspaces. As the survey was provided in five European languages (French, English, Spanish, German and Italian), the answers were translated and quoted accordingly: in order to keep the anonymity of the participants, the narratives are quoted by their country (e.g. : German participant). The narratives were classified and categorised per themes, **coded** according to the occurrence of key words (Tables 15 & 16).

Table 15 : Makers narratives - positive insights

Themes	Narratives, quotes (comments section of the survey)
Rapidity & responsiveness Key words: "quickly", "responsiveness"	▪ Makerspaces react "much earlier than the business community. From this point of view, makerspaces are a way to address social issues **very quickly"** ▪ "rapid "reaction force" (schnelle "Eingreiftruppe") ▪ "It was amazing **how quickly** the various makers worked together. There is a huge potential here that we should tackle." (Participant 2) ▪ "Positive impact where we've been able to react **quickly** and contribute" ▪ "**speed of response** from makerspaces to the real and present danger of viral transmission in the form of both manufacturing" (UK) ▪ We [makers] have collectively decided to carry out public service actions (...) to **give a quick and efficient answer to the sanitary need of the moment**" (French maker)
Flexibility Adaptability Resilience	▪ fablabs as "places of resilience with health-level capacity" (French maker). "Adapt or die" (French participant). ▪ "The flexibility and rapid response capabilities were an asset in the race against time as the virus spread and hospitals became overwhelmed" (French maker). ▪ "Fablabs can contribute by their capacity to adapt, to collaborate on opensource solutions, to ensure a technological monitoring in order to help in the conception phase" (French maker). ▪ **"the SSE economy** has a bright future ahead of it for the sake of **resilience**" (French participant)
Power of networks & community	▪ "We act as a hub for an incredible **network** that was created very quickly thanks to the web! We started with 3D printer owners to supply Charlotte and Dave valves from the Isinnova project**. In just a few days, companies of all sizes and types (even multinationals) joined in:** designing, experimenting, laser cutting, printing, supplying materials, professionalism, time, knowledge, work **and** incredible machinery. **The network that started in Piedmont soon expanded. Requests came from hospitals** in Sardinia, where we have already made several shipments, to local ones: Novi, Tortona,... " We **coordinate with our contacts, we look for new ones constantly according to the requests, so many are joining the network and we put together the supply and demand**" (Italian participant). ▪ "societal awareness of the power of community (...) the power of connected like-minded people with a focus on community over commerce" (Irish Participant) ▪ We have a science centre with ~150 employees behind us and can thus throw manpower at problems in an emergency (Germany) ▪ Through our non-profit status, we are a place that is decidedly non-commercial and offers people resources independent of their own. We have an ethical foundation through the CCC Hackerehtics and the CCC and a network of spaces that think and act similarly (German maker)

Other strengths	▪ "Motivation, teamwork and willingness to innovate" ▪ External collaboration and interpersonal skills (Italian maker) ▪ "Internal exchange, flexibility, diversity of competences and interests, diversity of opportunities" (German maker)
Territorial embeddedness	▪ The Covid-19 crisis "made Makerspaces visible and empowered to <u>accompany territories in their digital transformation</u>" (Participant 1) ▪ "This experience [the pandemic context and lockdowns] has helped to move the lines and **the SSE economy** has a bright future ahead of it for the sake of **resilience**" (French participant) ▪ "Recognition of the power of makerspaces and their place in the future **economic fabric**" (French participant) ▪ "COVID has revealed the potential of practices **on the territories** while weakening the economic models of places. Nevertheless, the perspectives give reason to FabLabs and makerspace models, especially on **territorial logics like the FabCity, in response to the depletion of resources and the globalization of productive tools, to respond locally to needs**" (French participant) ▪ "We have become an identified innovative hub in the territory" (French maker)
Scalability **Rural areas**	▪ "Our established practices of managing tasks and dividing up work in a **collaborative, online way helped us to respond quickly and scale up our response.** Our standard operating methods and culture acted as a practice drill for how we would respond in a crisis" (UK Participant) ▪ "How to go from a community of makers that produces prototypes, to a community that produces products **(local, as a startup or open source, sustainable)** is a real question" (French maker). ▪ Within a municipal public library in rural areas, its participation in the fight against COVID-19, positioned it locally and nationally as a vital social infrastructure, also suitable for states of emergency." (Spanish maker) ▪ "Networks like Vulca or the association of open workshops can unleash massive manpower in a short time through makerspaces, but still the need for an organizational structure (like the website maker-vs-virus) remains to use the maximum potential and to convince "non-specialist institutions" like DRK/hospitals etc of the offer of help." (Austrian maker) ▪ We live in a land of very high potential, where you can live very well, in good health, assisted by technology, and make the 'revolution' by restarting from the recovery of artisan jobs and innovating them to make them competitive in the market. Young people are leaving in despair in search of fortune, while fortune is right in front of their eyes. Southworking is here (Italian maker) ▪ "Networks like Vulca or the association of open workshops can unleash massive manpower in a short time through makerspaces, but still the need for an organizational structure (like the website maker-vs-virus) remains to use the maximum potential and to convince "non-specialist institutions" like DRK/hospitals etc of the offer of help." (Austrian maker)

Health sector	▪ fablabs as "places of resilience with **health-level capacity**" (French maker). ▪ "The Covid-19 has **revolutionized the entire industry** [health industry] by accelerating its growth and defining new working scenarios, an example can be the **distributed production, or the mass customization**, it has given birth, and grow **new opportunities in all sectors, one of all, the medical sector with new materials, new machines, new software, etc."** (Italian participant). ▪ "We have been able to contribute to access our Fab Lab specifically to support the local response, initially with PPE and ventilator parts. After that we were again able to access to support businesses to continue our research and development contacts with them" (UK Participant)
Education sector **Pedagogy**	▪ "Covid has forced us to innovate in ways that we did not think possible. Even though we miss in person education and look forward to its return, we have found **a meaningful blended learning model that gives us the ability to reach our audience in new ways i.e. instead of taking the place of a teacher, we work with them so that they can deliver maker activities** with their class groups with us on the sidelines instead of at the front." (Irish maker) ▪ Some schools with appropriate equipment have also manufactured PPE equipment. We have tried to encourage, spread knowledge and skills to other Makerspaces to keep them relevant and active" (UK participant) ▪ "Public present on site, strong pedagogical support in the design of projects, awareness of the "maker" spirit from 10 years old" (French maker) ▪ "Currently, I see Makerspaces at most in a position to advance education and support projects in the start-up phase" (German maker)
Production processes Key words: distributed manufacturing/production; DIY production	▪ **<u>Distributed manufacturing</u>**: "I don't believe in the proposed model of distributed manufacturing but I would like it to work a little." (French maker) ▪ ▪ "The Covid-19 has revolutionized the entire industry by accelerating its growth and defining new working scenarios, an example can be the distributed production, or the mass customization, it has given birth, and grow new opportunities in all sectors, one of all, the medical sector with new materials, new machines, new software, etc." (Italian participant). ▪ **<u>DIY production and industrial production</u>** : "production methods between diy and small scale industrial"; "DIY for individuals, but also large industrial productions for the companies of our network". ▪ "Additive manufacturing is the only lean manufacturing method that can stop, reinvent and restart without getting lost. The impact of Covid-19 has made it clear how unsustainable it is to continue towards uncontrolled mass production, makerspaces on the other hand have been able to make up for this lack precisely by using production methods between DIY and small scale industrial" (German maker) ▪ "Many techniques are fun but mostly not efficient to use. E.g. 3D printing is really only suitable for valuable parts due to the slow production processes. Technically, I would put more focus on the promotion and dissemination of e.g. **milling** etc..." (German participant) ▪ "But there is clearly also a lack of (open) platforms to improve and distribute design plans and objects. In software development there is e.g. the git (hub/lab) software

	and platforms for collaborative work. This is missing for other techniques Possible would be of course also legal requirements that partial components of products must be entered into such platforms, so that these can be repaired more easily. **So much Potential**!“ (German maker)
Open source	▪ “Fablabs can contribute by their capacity to adapt, to collaborate on **opensource solutions, to ensure a technological monitoring** in order to help in the conception phase” (French maker). ▪ “The solutions proposed by the maker world and fablabs have been a great proof of the interest of **opensource, local production and collective intelligence, locally and globally**”.

Table 16 : Makers narratives - negative insights

LOCKDOWN **SHUTDOWN** **Social isolation**	▪ “The proximity restrictions have hindered the operations of makerspaces significantly, especially in the cases where tangible products or methods are the goal. (…) makers are easily tired of online meetups, as they do not fully comply with their personal goals of actual making” (Greece) ▪ **“It has closed our space. It is hard to keep members paying for a space they can not use**. Online is nice but not that same” (UK participant) ▪ “We have been at a standstill for a year with training activities”; “Same as the impact suffered by any commercial or noncommercial activity, with the difference that for third sector entities there are no refunds”. ▪ “Difficult, since social aspect of coming together in a hackerspace is omitted: Since we are more of a hacker than a makerspace and also not commercial, **the biggest loss is the social interaction and knowledge sharing**” (UK maker) ▪ “The community becomes hard to grasp if you can't at least meet locally from time to time”; “Community meetings are missed” (Austrian maker) ▪ “The community makerspace I am involved in has remained shut for most of the past year so there has been **no activity** there - which is understandable”. ▪ “Covid-19 is continuing to have an impact. My projections say that the lockdowns will re-start and continue till at least the next 9-18 months” (UK participant) ▪ “we miss in person education and look forward to its return” (Irish maker) ▪ “There is too little cooperation between makerspaces even locally” (French maker); “lack of physical aggregation with consequent difficulty in expanding the group and elaborating new ideas” (Italian maker). **Despite the lockdown and shutdown of spaces, makers did their best to help**

	▪ "Our space was closed and we could not meet during the covid, but the members of "La Caja" did everything we could to help" (Spanish maker) ▪ "The space was closed, but our members worked on all kinds of things" (Makers from London).
Employment	▪ "Fablabs have been caught up in liberalism in the attempt to replace institutions. Because of the maker vs. covid movement, the public is more than ever lost on what fablabs can do for them and is **waiting for volunteers (and eventually employees) to become multi-hatched startuppers paid unfairly for the good cause.** This movement has done a lot of damage to the world of third places [including makerspaces]" ▪ "**voluntary work can only achieve a limited amount**. From a certain level of quality, it is **necessary that people are paid and get promoted** (German maker) ▪ "Covid caught us as a makerspace at an inopportune time. We moved and wanted to **actively recruit new members to cover the higher running costs. That was not possible now"** (Austrian maker). ▪ "Many small, non-profit makerspaces have already had to close due to financial problems or override Covid measures to avoid this (also not good)" (Austrian maker)
Bureaucracy, Government inertia, Government failures	▪ "Meanwhile the dependence on municipal authorities has hindered greatly the speed of operations" (Greek maker) ▪ "Things can be done, but the authorities need to make the action more fluid" (French maker) ▪ "Positive impact where we've been able to react quickly and contribute - **negative where we've lacked government support and had to react constantly to changing rules - which is hugely energy draining"** (UK) ▪ "the ultimate chapter in **the government's denigration of our actions and even rejection of the idea of citizen autonomy, self-organization** and "homemade", **the recent ban on homemade masks** was hard to swallow..." (French maker). ▪ We [makers] have collectively decided to carry out public service actions **because neither the companies nor the public authorities have been able to give a quick and efficient answer to the sanitary need of the moment".** ▪ "We haven't changed the world in that time, we only "plugged holes" [gaps left by government and markets]. I don't believe in the proposed model of distributed manufacturing but I would like it to work a little." (French maker) ▪ "Bankruptcies, misfortunes and breakdowns (Pleiten, Pech und Pannen)", and bureaucracy (German maker)
Resource constraints	"The bigger challenges during our COVID response were around securing materials for our visor production (because supply chains were disrupted and there was great demand for materials), and balancing collaborating

	with other groups with taking decisions and moving forwards independently so we could make progress." (UK maker)
temporary	▪ "Makerspaces served as a buffer and allowed companies to react" (French maker) ▪ "Makerspaces supplied EPIS until the industry took over. Our help was temporary and very important. It could not be sustained over time" (Spanish maker) ▪ "The business model must be strengthened, it exists, and we need ONE, and a unique network that gives: - FORMAT: PRECISE, guidelines (point by point) on people to have, skills to have or build, audience to engage, and only lastly tools to build or buy; - OBJECTIVES: build projects, machinery and skills FOR -> training? training to artisans? school training? Digitization of businesses? A budget is established, one part is put in by the state, the other by the territory or the institution with funds, self-financing or sponsorships, and at the end: IMPACT REPORT. "What went wrong? What can be done better?" (dixit an Italian maker)
Public opinion, mis-understandings	▪ Fablabs have been caught up in liberalism in the attempt to replace institutions. Because of the maker vs. covid movement, **the public is more than ever lost on what fablabs can do for them** (...). This movement has done a lot of damage to the world of third places [including makerspaces]" (French maker). ▪ "However, it seems to me that **the public perception of makerspaces is** still "invisible" ; "we have been forgotten. Like many other clubs and groups, for example, in terms of requirements and rules" (German makers). ▪ "Our focus is on social aspects, not on production. We are also not a company" (German maker) ▪ "We dare to hope that the Covid-19 crisis was able to show people that FabLabs are valuable tools when it comes to meeting an urgent need, thanks to the prototyping and small production machines at its disposal" (French maker) ▪ "Perhaps we could add questions about the disappearance of the post-covid customer profile, or other questions that help to identify more specifically the problem that we may be suffering post-confinement maker spaces to make it easier to identify the type of support we can receive or at least how the public sector can avoid actions that damage the private spaces that are weak after covid" (dixit a Spanish maker). ▪ "I hope that the work done in makerspaces during this period will help to clear some preconceptions that there are, and especially to understand the potential for development that there are in makerspaces" (Italian maker).

5.8.2. Summary of the narratives

The general interest streams of the data gathering in the survey were both retrospect and prospects. This section summarizes the narratives about pandemic responses. Then, section 6 selects the narratives about the prospects, and from them, elaborates the answers to the research question.

A maker summed up in three words the dilemma that makerspaces were facing during the Covid-19 pandemic: “Adapt or die”. An another participant highlighted the dual impact of episode : “Positive impact where we've been able to react quickly and contribute - negative where we've lacked government support and had to react constantly to changing rules - which is hugely energy draining”. Half of makers felt that the Covid-19 crisis unveiled the “ultra-necessity” and the value of their makerspaces, especially in emergency situations, in the healthcare sector, at many territorial scales (c.f. Table 15). On the other hand, some makers clarified the overall positive impact by expressing their biggest concerns, moral and financial difficulties during the pandemic; without neglecting hackspaces, for whom repeated standstill resulted in social isolation (c.f. Table 16, first row). Human Capital (social interaction and knowledge sharing) has been indeed a huge loss for non-commercial makerspaces (hackerspaces) during the pandemic. While some makers saw the crisis as a new momentum for their recognition, others consider their position as a stop gap to alleviate few government’s failure in the crisis management, which for them constitutes a “denigration” of their existence in the sphere of general interests: the ban on homemade mask certification requirements is the most appealing manifestation of government blockade on makerspaces legitimacy. Thus, despite optimistic claims of collaborative effort, the resentment that competition was stronger than solidarity, as the case between makerspaces and industrial manufacturers, where the formers regret being perceived as ‘gaps plugger’, a “factory” or a “store”. These misunderstandings have raised the need to consider a fair wage due to voluntary Covid-19 efforts and initiatives to avoid exploitation of their members (c.f. “Employment” in Table 15).

Makerspaces deserve an equal status alike a government authority with complementarity responsibilities at the same title like commercially orientated makerspaces could secure socially oriented makerspaces. In that respect they would stop being generalized as commercial production spaces to honour their initial engagement of collaborative workshops (“the power of connected like-minded people, passionate about technologies/innovations, with a focus on community over commerce”, c.f. Table 15). Many survey’s participants warned about the misconceptions of makerspaces but still hope that public opinion has shifted (c.f. Table 16), for instance, by admitting that makerspace have a permanent social impact, not only in times of crises: “what makerspaces did during covid is what they usually do in normal times. They usually provide people with special needs an environment to build, co-design, share solutions not available commercially. Makerspaces have a big social impact all year long and it should be recognised broadly”.

6. Answers to the research question & recommendations

The narratives provide a better understanding of the makerspaces ecosystem, from within, and bring elements of answers to the research question of the present investigation: How could urban and rural makerspaces 'bottom-up' Covid-19 responses, emerged by the force of circumstance, be the catalysts of lasting post-pandemic societal and sectoral transformations in Europe?

Thus, from the narratives validating the hypothesis, we can answer the research question and provide recommendations. We can argue that urban and rural makerspaces 'bottom-up' Covid-19 responses could be the catalysts of lasting post-pandemic societal and sectoral transformations in Europe:

- **By reinforcing inter-makerspaces cooperations and other relevant multistakeholder collaborations, for instance under a European diplomacy for makerspaces.**

Some makers highlighted conflicts and tensions, such as a lack of cooperation in the vicinity of their unit, from the very beginning and at the micro level (c.f. Table 16). The government inertia and the economic vacuum from the first lockdown needed to be compensated by more community spirit. Therefore, there is an evident need for the art of Diplomacy to overcome "interpersonal problems" within the makerspace, as well as external interactions like dealing with government or business administration to facilitate the performance of makerspaces.

So far, makerspaces were associated with "public diplomacy", as introduced by Pope (2014): "makerspaces are another exciting new avenue of digitization to explore for diplomatic potential. It offers new opportunities and gives us a chance to question what constitutes cultural diplomacy", "how digital technologies affect public diplomacy efforts". JRC policymakers, EU DYI scientists and feminists, with a crafted participatory approach toolkit, complexity science and post-normal science, to tinker makerspaces policies (elaborated in 3.1.B), could initiate a European diplomacy of makerspaces. A 'makerspaces diplomacy' at the European level would give the structures a legitimacy beyond their subversive character and encourage more EU community management. Moreover, a European diplomacy of makerspaces could be a promising field of research: cross-fertilizing science & technology studies, with sustainability (transition) studies, organisational and systems studies, feminist literature, as attempted through this paper.

- **By enhancing a governance of digital collaborative platforms in order to allow makerspaces to operate on multiple fronts - the digital and physical spaces - as well as tackling both day-to-day challenges and grand challenges, to drive the digital and sustainability transition.**

Digital platforms had a strong political action during the crisis, in the sense that they were accessible for everybody. The open source platform solved the main structural and management problems faced by the organisations, as they could merge all the scattered digital supports into a cohesive (digital) entities with distributed governance. Digital Social Innovation (DSI) policies would be the key of a governance to allow the sustainability of makerspaces initiatives in digital agendas. EU policymakers can further co-design and implement DSI policies together with makerspaces policies, especially identify the link and synergy between makerspaces technologies (open data, open hardware, open networks, and open knowledge) and DSI areas: (1) open access; (2) awareness networks; (3) collaborative economy; (4) new ways of making; (5) open democracy; and (6) acceleration and incubation.

- **By a proper structuration of their production processes, such as distributed manufacturing, with financial sustainability framework**

Overall, makers strive for the structuration of the makerspaces ecosystem and how to sustain it with a robust framework, with defined objectives in the long-term, and financial support, government funding or other territorial funding. Makerspaces can enhance their capacity in specific sectors ("places of resilience with health-level capacity") or the scalability of their production processes, from prototypes to actual products (c.f. Table 15).

From the survey results, collaborative manufacturing paradigms (including DIY fabrication, distributed manufacturing) and additive manufacturing have been identified as potential socio-economic paradigms and sustainable modes of production. Additive manufacturing, even as an industrial process could be considered sustainable at a small scale, compared to the unsustainability of the incumbent regime production processes (mass production). A participant stated: "Additive manufacturing is the only lean manufacturing method that can stop, reinvent and restart without getting lost. The impact of Covid-19 has made it clear how unsustainable it is to continue towards uncontrolled mass production, makerspaces on the other hand have been able to make up for this lack precisely by using production methods between DIY and small scale industrial" (c.f. Table 15). Similar to additive manufacturing, the Redistributed manufacturing model has a flexible supply chain, innovative with high level of customization (c.f. 3.4.B). Previous studies have identified local community-based makerspaces as catalysts of local regeneration in urban areas, and this present research highlights also the potential of rural makerspaces in promoting sustainable modes of production, such as a repair production, as well additive manufacturing, not confined in urban settings.

The call for the structuration of a distributed manufacturing paradigm in France is a landmark in the makerspaces landscape and could initiate other initiatives across Europe, towards their recognition as essential structures in the socio-economic fabric. Distribited manufacturing is indeed presented as the "key to a resilient, job-creating and environmentally friendly production system" (see Appendix 30), and could be supported by the reinforced "Resilient Budget" of the

Next Generation EU (2021-2024), which aims at stimulating a post-pandemic socio-economic recovery (EC, 2020; c.f. Appendix 30). Makerspaces can attract other sustainable funding schemes currently "embracing complexity", to support transformative changes (see Ashoka Austria, 2020), aligning with The Five Capitals Model, i.e. the economic framework for sustainability and system change for sustainability (5.4.2.).

- **By strengthening their territorial embeddedness in order to be better integrated into the economic fabric (e.g. social and solidary economy), and prepare their scalability, to tackle both day-to-day challenges and grand challenges, both part of the digital and sustainability transition**

Minimizing the impact of the Covid-19 crisis on human health became an additional day-to-day challenge of makerspaces. Yet, makerspaces' roles in grand challenges such as the circular economy, repair economy and sustainable development goals are also considered in institutional agendas. To tackle grand challenges, makerspaces offer a myriad of sustainability pathways tailored to their scale and practical requirements. Their fabrication tools (digital or traditional), as well as their manufacturing practices and technologies, show the potential of makerspaces in sustainable innovations, especially in a 'distributed production' system through local supply chains. Makerspaces' territorial embeddedness is a key towards a "strongly sustainable functional economy", as coined by Roman et al. (2020). FabLabs and makerspace models are crossing territorial logics like the 'FabCity', in response to the depletion of resources and the globalization of productive tools, to respond locally to needs. Being actively involved in EU programs can strengthen their territorial embeddedness and scalability: for instance, VULCA connecting rural makerspaces across Europe; the New European Bauhaus Initiative, environmental (related to the circular economy), economic and cultural project to help shape the post-pandemic future; Pop-Machina, iProduce, Reflow, all sponsored by the EC supporting circular makerspaces initiatives (Panori et al., 2020).

- **By increasing their 'absorptive capacity', turning their flexibility and adaptability of their supply chain into sustainable assets for high social impacts, under the realm of adaptive resource management.**

The adaptability, 'serendipity' and frugality of makerspaces during the pandemic and their pooling of social capital, have unlocked 'alternative design' possibilities and productive capacities at the service of health secruity (Corsini et al., 2020). The diversity and flexibility of makerspaces was their 'response tool' for adaptive strategies. Yet, some well-intended maker initiatives have struggled to reach implementation, as theier supply chain dissolved once the demand had been met. Lange & Bürkner (2018) defined 'flexible value creation' as the value generated on rather unforeseen occasions, such as the Covid-19 crisis, during which digital technologies are deployed among self-determined networks. The short-run and context-specific flexibility of value creation and supply chain of makerspaces thus explain the limited scalability and sustainability of their production processes: a flexible value creation is part of a "context-dependent routines of trial & error, latency and flexible processes effect changes in field-specific configuration of value creation" (Lange & Bürkner, 2018, p.96). That is why, the challenge for makerspaces is to turn the short-run flexible capacity into a long-run 'absorptive capacity', which is the ability to draw from external knowledge bases and to learn interactively (Hennelly et al., 2019). This shift could be achieved by embracing adaptive resource management, an integrative and multidisciplinary approach that promotes adaptability and transformability (Kerschner, 2012; Folke et al., 2010). To achieve adaptive resource management, 'adaptive leaders' need to be designated with 'adaptive leadership' skills, autonomous, resilient, self-organized, experimental and in perpetual transition - , makerspaces have the potentials to drive a 'transition by design', or 'design for social sustainability (see Corsini & Moultrie, 2021). They detain all the levers and built-in counter-mechanisms necessary to drive the transition, and need to upgrade them: preparedness, engagement at the community level, sustained local leadership, partnership among organizations, individual-level and community level, culturally relevant education about risks and self-sufficiency (c.f. 3.1. A. b).

- **By coordinating their 'citizen productive reserves' at different levels: at micro level, at meso level, at national level, and European level. In other words, structuring the civil society response and citizen supply chain.**

The notion of makerspaces' "citizen productive reserve" mentioned by a participant (survey Q30) when envisioning the structuration of the distributed manufacturing: he suggested the coordination of a *"citizen productive reserve"* the same way as other human reserves such as the *"military, or material reserves in case of crisis, or civil security material which could be the object of preventive investments to absorb production crises*" (see Table 15). On the one hand, this 'makerspaces reserve' would be the core of a "resilient manufacturing" (defined in 3.4.E.), a new production thinking and practice which aims at maximizing the availability of medical tools and supplies for the healthcare sector, particularly exposed by the pandemic, towards a "resilient health care systems". In this perspective, makerspaces goals would align with sustainable development goals, in particular with UN SDG 9: "build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation" (Source: UN statistics).

On the other hand, the makerspace reserve could be an additional reserve to the existing "rescEU pool", i.e. a new European pool of resources established in March 2019 when the rescEU policy, resulting from the latest reform of the European Union's Civil Protection Mechanism entered into force, as the third pillar of the Resilient Budget (EC, 2020). According to Ursula von der Leyen, "Europe must be able to react more quickly and flexibly when a serious cross-border emergency strikes, affecting several Member States at the same time" (EC, 2020). The reinforced rescEU wants to guarantee that the EU is well equipped to support Member States and citizens when national capacities are overwhelmed, to strengthen health security whilst preparing for future health crises. Horizon Europe provides increased funding for health-related research, resilience, and the green and digital transformation: between 2014-2020, the Mechanism was activated more than 100 times for disasters, ⅔ of the activations being Covid-19 related (EC, 2020). Thus, an integration of makerspace productive reserve into the existing rescEU reserve would enhance the structuration of the citizen supply chain and a better governance at the national and EU levels.

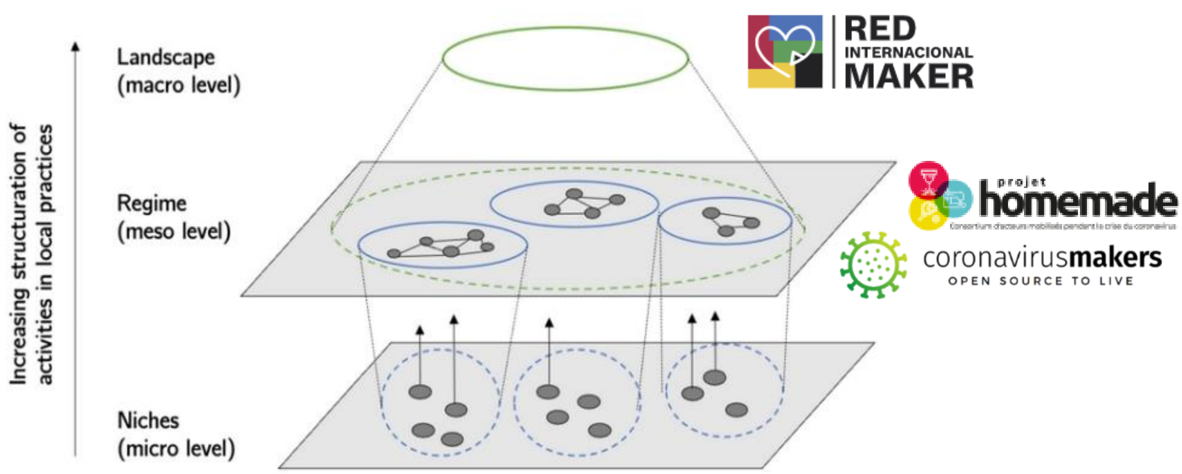
Concrete cases. Two landmark initiatives, reported by makers in the survey, are currently applying most of the recommandations listed above (section 6.), and have demonstrated so far a successful implementation of long-term makerspaces plan, following the two-phase dynamic from the short-term and direct response to the crisis (1) turned into a long-term orientation (2):

> *"We have been able to contribute to access our Fab Lab specifically to support the local response, initially with PPE and ventilator parts (1). After that we were again able to access to support businesses to continue our research and development contacts with them (2)" (Participant 1) ; "Makerspaces have provided PPE equipment during the pandemic. Some schools with appropriate equipment have also manufactured PPE equipment (1). We have tried to encourage, spread knowledge and skills to other makerspaces to keep them relevant and active (2)" (Participant 2).*

Figure 39 illustrates the two phases of development and the double effect of the Covid-19 episode 2020 on makerspaces ecosystems: first lockdown (from March 2020) allowed to go towards the creation of a strong local network at the micro level, and the second lockdown (from November 2020) it put in action this network and actions or projects were created following this starting point. These notable cases of both urban and rural makerspaces prove that short-term crisis response from bottom-up makerspaces during the pandemic, have the transformative power to engage in a long-term prosperity sectoral changes:

1. ***REDIM in Spain: urban makerspaces at the service of open health care, at a national and international level***
2. ***Home Made in France: a consortium of rural makerspaces at a regional level***

Figure 39: Structuration of makerspaces niches during the 2020 episode



Source: Adapted from Corsini & Moultrie (2021), page 232

1) RED Internacional Maker (REDIM), Spain

REDIM international makers organization, is the result of a horizontal and vertical structuration process. The organisation emerged during the Covid-19 pandemic, but did not stay confined to the forces of circumstances. Spanish makerspaces started their operations with donations, initially for the transport of their PPE production to hospitals. Thanks to their self-organization into the Coronavirusmakers group: the largest network of Covid-19 volunteers and makers in Spain with more than 20,000 members and 74 companies involved: 3D printing companies, health institutes, tech companies and universities; police and military organizations (OSMS, 2020). They became more visible and could attract sustainable & multistakeholder funding (Ashoka, Austria, 2020). They became economically sustainable and reinforced their infrastructure and supply chain to mass produce medical equipment (1.5 million supplies) (OSMS, 2020). Spanish makerspaces show the emergent properties of complex adaptive systems (c.f. 3.1.): through open source platform, Spanish makers joined forces to self-organize actively in a decentralized manner at a micro level, with regional representatives to connect with healthcare centres across Spain at the meso level (the subsidiarity principle). The organisation encapsulates a national committee with regional representatives across Spain (seventeen communities, and two autonomous cities), an overall R&D coordination team, internal/external communication groups, an economic committee handling donations and how those would be distributed to sub-projects applying for funding (OSMS, 2020; c.f. 5.2.3.). The national organisation facilitates communication between health care services and makers regarding the supplies needed (OSMS, 2020). Roberto Garcia-Patron, a prominent actor in the "Manufacturing 4.0" paradigm, is the coordinator of REDIM (OSMS, 2020).

This successful governance model and organisational structuration via digital platforms, connecting makers from Latin America, Spain, France and Ireland, has great potential to drive a digital transition in the healthcare sector. This example validates the hypothesis of the research:

the bottom-up Covid makers responses during the pandemic, have the transformative power to engage sectoral changes, and drive a digital transitional in a post-covid era.

2) HomeMade : structuration of 'makerspace sectors' in France

HomeMade is a consortium of makers mobilised around the manufacture of PPEs, integration structures and research laboratories, with the financial support of the Nouvelle-Aquitaine Region. HomeMade is working on the regional structuration of a '**makerspace sector'** through three main axes: (1) Financing material and human needs; (2) Perpetuating the large-scale mobilisation, initiated or revealed during the crisis, of communities of French makers to respond to future local health emergency needs, by federating them in a consortium of 2000 volunteers and professionals from the region; (3) Analysing the transformative potential of the makers' dynamic at regional level (Figure 11), especially **cross-sectoral initiatives,** combining the competences from the Health(care), Education and Social work sectors.

The French network of Fablabs estimates the number of protections made at around 2 million. The supply of raw materials and the coordination of orders and distribution was managed in a decentralised manner, with networks of local actors and the sharing of resources. In Nouvelle-Aquitaine, initiatives multiplied with nearly 1,500 volunteers and makers people to manufacture nearly 220,000 visors and 273,000 masks from March to June 2020. In compensation to government's inertia and lack of support, HomeMade allocated €271,000 to operators to cover part of the material and human costs incurred on makerspaces pandemic responses (HomeMade, 2021). Then, Home Made finances the cooperation between fablabs and **medico-social structures**: health establishments, groups of liberal professionals, companies, associations linked to disability, for the production of PPEs (HomeMade, 2021). Eligible initiatives concern the improvement of the daily life of patients/residents as well as employees, through the creation of tools/objects, but also the maintenance, adaptation or repair of existing equipment or the creation of specific aids in collaboration with ergonomists. This may therefore involve the design and implementation of technical solutions, but also the transfer of know-how, training, and the sharing of material resources for the benefit of the public in the establishments concerned or the employees of these structures. Henceforth, HomeMade aims at the implementation of new activities with a sustainable collaborative economic approach, by bringing together actors from fab labs, makerspaces, or other actors from the SSE (HomeMade, 2021). Somehow, we can talk about an aspect of 'makerspace's diplomacy' where the concept is to encourage commitment and development of power to act in the territories by supporting cooperation in a "proximity logic": seizing the local initiatives born during the Covid crisis, relying on new alliances between different types of makerspaces (third places, prototyping places) towards inclusive and quality employment perspectives (HomeMade, 2021).

These two recent initiatives in promising makerspaces sectors are thus validating the hypothesis of the present paper and illustrate how urban and rural makerspaces 'bottom-up' Covid-19 responses are engaging post-pandemic societal and economic transformations in Europe. These are just two examples, among other ongoing maturation of niche-level activities, which are nurturing the expertise, knowledge, and network and sustaining the supply chain assembly they have developed since the crisis (Figure 40).

Figure 40: ongoing maturation of makerspaces, from niches to emergent regime

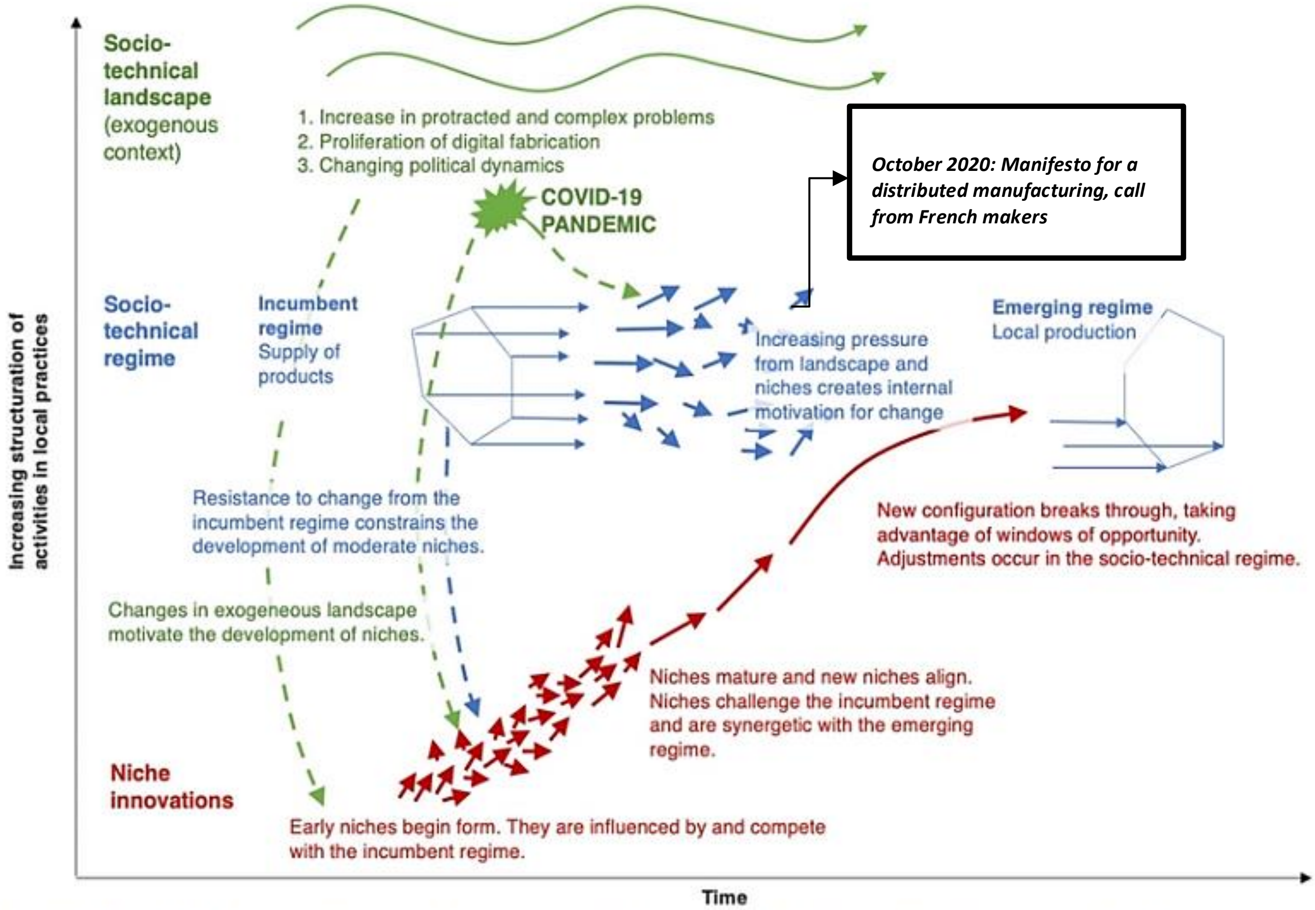


Figure 2 – Multi-Level Perspective model showing speculative transition pathways to sustainable development.

Source: Adapted from Corsini & Moultrie (2021), page 232

7. Limitations

As the results of the present study aim to impact policymakers on implementing scalability amid urban and rural makerspaces ecosystems, in pilot countries across Europe, the author relies on the sincerity of the feedback. Otherwise, responses distort the project.

Though the percentage of responses is satisfactory, more makerspaces could be targeted: a larger sample of rural makerspaces would have allowed a better statistical analysis and comparison tests between urban and rural typologies. Indeed, from 124 responses out of the 1500 questionnaires sent, 81 represented urban makerspaces and, 21 were rural makerspaces (c.f. Figure 41). Balanced representativeness of typology is important, especially when the challenges are to overcome the territorial disparities and think of a holistic strategy on a sustainable and 'equitable' rural and urban development in the EU, to unlock the potential of both communities, and foster their sustainable development (c.f. ESCC, 2021).

Similarly, higher participation of makerspaces from specific countries would have allowed better national comparisons. As the scope of the research was Europe, the 13 European countries that took part in the survey were considered in the analysis. Thus, some great disparities between the countries having above 13 participants, and those having less than 6 participants (Austria, Belgium, Greece, Switzerland, Finland, Serbia). Maybe, only the most responsive countries with a close proportion should have been considered for the analysis: France (n=30), Germany (n=23), and Italy (n=23).

Then, the indicator chosen to assess makerspace sustainability could be completed with other metrics such as environmental sustainability or social sustainability indicators, to cover more aspects of sustainable development in this present research.

Finally, a professional personalized e-mail address, with the full name instead of an anonymous number, would have given a better legitimacy to the author, when sending the links to the participants via e-mails. On many occasions, the sender felt this issue was a severe limitation while conducting a survey.

Figure 41: Sample urban / rural

Typology

Étiquette de valeur	Valeur	Fréquence
urban	1	81
semi urban	2	16
rural	3	21
hybrid	4	6
	.	1
	Total	125

8. Conclusion

8.1. Summary

In this paper, we have considered the possible impacts of the Covid-19 ongoing crisis on makerspaces, and the window of opportunity for a digital and sustainability transition. The pandemic has been a new catalyst to speed up landscape trends, galvanize grassroots and socially useful initiatives, and localized and distributed manufacturing paradigms. The results of the survey show that most makerspaces Covid-19 responses, in pilot European countries, were community-based and bottom-up coordination, along with new multistakeholder collaborations, in the context of general dynamics of decentralization and digitalization. Makerspaces' transformative potential was amplified by the spontaneous emergence of new makerspaces niches during the emergency context, in rural and urban areas, in addition to the existing niche-level activities still in maturation. The results show that value creation is not confined to urban makerspaces and industrial settings, with reconfigurations in non-industrial and rural settings. Rural innovation processes integrate additive manufacturing technologies and local manufacturing technologies, as well as technology for repairing. This attitude towards technology unveils potential futures of manufacturing, aligning with the Right to Repair revolution in Europe. Moreover, production processes as an indicator of sustainability, reveals that rural makerspaces can contribute to the digital and sustainability transition: repair production and circular collaborative production, both minimizing the importation of raw materials and reliance on global supply chains. This inclusive innovation process combines high-tech and slow tech, traditional and emerging (peer-to-peer) models, to yield sustainable production processes and solutions.

Both urban and rural makerspaces repurposed their production into DIY manufacturing of specific healthcare goods during the pandemic in 2020, by deploying a specialised supply chain with open technologies. Framing makerspaces as digital social innovation spaces is shifting the current efficiency and productivity narrative of healthcare, towards the social narrative on DIY technologies, and how makerspaces contribute to the social shaping of technology in the healthcare sector, among other sectors of activity. Open design combined with digital fabrication and rapid prototyping has empowered makers and designers to release customizable, patient-driven healthcare solutions, considered in EU policies and in EU health markets. By offering open source digital fabrication for sustainable development projects, makerspaces as DSI spaces can lead both the digital and sustainability transition. Makerspaces initiatives and actions were happening on two fronts: on physical spaces, as well as digital spaces, in the context of lockdown and movement restrictions. However, the digitalisation of makerspaces with inclusive and solidary collaborative platforms, allowed positive spill-over effects of knowledge, expertise and innovations, pooling of resources and means of production, between rural and urban, to meet the ethical and technical requirements of production.

Therefore, beyond the dichotomies urban/rural, commercial/non-commercial, profit/non-profit, makerspaces are complex adaptive systems with diverse resources, and represent a kaleidoscope: from commercial makerspace, where prototype manufacturing and small-scale production takes place, to education-oriented non-for-profit makerspaces. The Covid-19 episode was an another example of makerspaces subversiveness and autonomy in crisis response, in the context of government and market failures, lack of support in Covid-19 efforts. Both urban and rural makerspaces across Europe embraced 'frugality' as a health crisis response strategy, by deploying digital fabrication tools to produce emergency medical items, under the context of resource-constrained environment (lack of human resources, natural capital and financial capital), bringing an environmental and social sustainability management perspective.

Given the resistance from the incumbent regime creating inertia and legal vacuum around the open source innovations in the healthcare sector in Europe, the makerspace regime needs further structuration of production modes and supply chain at local, national and regional levels, a better governance of multistakeholder collaboration and a strong political representation networks, in order to gather sufficient momentum to effectively challenge the current regime.

8.2. Implication for relevant stakeholder and contribution to knowledge

The paper contributed to the evaluation of both urban and rural makerspaces actions and impacts, to make the case for spreading, scaling and attracting sustainable funding opportunities. In addition, this impact and prospective analysis might help policymakers understand the extent to which the policies they are putting in place can affect makerspaces ecosystems in pilot countries in Europe. Indeed niche development is a long-term agenda, and makerspaces must be supported over a significant period of time in order to provide credible alternatives during windows of opportunity. Some EU research and funding programs are targeting specific niches and contribute to their development.

This present research paper provides another evidence that makerspaces need to be considered as catalysts of societal and technological developments powered by materially engaged citizens who are willing to 'make' a difference. Education has always been a strong sectoral focus of makerspaces, and places for STEAM education and training: both rural and urban makerspaces are drivers of change, as learning spaces for anticipatory thinking in the post Covid-19 era. Hence, the need of makerspaces policies related to the Education sector to fulfill the scenario anticipated for 2034 for 'competence-based education' and for addressing European Key Competences for Lifelong Learning.

8.3. Future research

In addition to the roles and potentials of urban and rural makerspaces, future research should consider the potential of semi-urban makerspaces, one of the categories mentioned in the survey besides the urban/rural typology. Considering rural, urban and hybrid categories of makerspaces altogether seems relevant, in the light of the recent holistic strategy on sustainable rural & urban development in the EU, by the European Economic and Social Committee (EESC, 2021), aiming to unlock the potential of rural & urban communities and foster their sustainable development.

As the present research has shed light on the territorial embeddedness of rural and urban makerspaces in pilot European countries , it can contribute to the ongoing discussions between experts, stakeholders and European Commission representatives on rural/urban/peri-urban areas, about how to overcome the challenges of balanced territorial development and which opportunities are emerging in economic and social cohesion, in regions' resilience, and in the contribution of countless services from various local ecosystems. Additional research could also provide a more detailed makerspaces production processes and technologies, and their impacts on social and environmental sustainability. A promising field of research could be the subversiveness of makerspaces, their institutionalization at the EU level, and the potential of a European diplomacy of makerspaces to pave the way for a governance of structures and technologies.

'Thinking through tinkering' has been the leitmotiv of the author of this paper, to elaborate an 'experimental writing' on makerspaces, the same way makerspaces themselves experimented new ways of producing, collaborating and sharing, during the ongoing crisis. Thus, the present research is an additional resource to the emerging post-covid literature on makerspaces paradigms, and can be seen as a prototype to be thought and tinkered by other 'makers researchers' and EU policymakers.

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APPENDIX 1: SURVEY

Makerspaces since the Covid-19 crisis in Europe

Dear maker, 10 minutes of your attention would help in sustaining the actions of European makerspaces!

You are part of it !

Through this survey, I wish to explore the challenges of European makerspaces, which have been deploying specific models to overcome the crisis. Hence the following issues constitute the key questions of my research:

- Chould European makerspaces be catalysts of post-pandemic societal & sectoral operations?

- How could we develop new socio-economic models from the production processes & supply chains put in place by makerspaces, to face the ongoing sanitary crisis, in anticipation of future potential disruptions?

Omara RÉ

MSc. in Sustainability Management, Economics and Policy at MODUL University Vienna (Austria). Title of the Master Thesis: Roles and potentials of urban and rural makerspaces in the digital and sustainability transition in post-Covid Europe.

Informed consent

Most of the information collected is about your makerspace, and only few personal information (educational level, occupational status, age, gender) for socio-demographic purposes. By participating in the survey, you voluntarily consent to the collection and use of your information by myself. All data is anonymised, and your privacy is guaranteed. The collected data will be saved in my database and used ONLY for the purpose of my Master Thesis, until the end of the research period (March 2021 - June 2021). The lawfulness of the processing of personal data, based on consent, is determined pursuant to Article 6 of the EU's General Data Protection Regulation (GDPR).

If you have any questions concerning my data collection practices, contact me at omaevare@gmail.com (Omara RE)

SECTION 1 : YOUR MAKERSPACE

General and specific information about your organisation

1. What is the name of the space? ____

2. How old is the space? (you can also indicate the year of inauguration) _______________

3. Where is it located? (city / town / village) ____

4. Is the space closer to urban style or rural type?

☐ urban ☐ rural ☐ semi-urban

*semi-urban: zwischen ländlich und urban, nicht gänzlich charakteristisch für urbane Gebiete

5. Is the space open to public or private?

____

6. How many makers in the structure?

- In general: _____
- Manager / full-time makers : _____
- Members: ____

7. How would you define the space?

☐ makerspaces (general) ☐ FabLab ☐ Hackspace / HackLab

☐ DIY space / community workshop ☐ DIYbio

☐ repair workshop ☐ co-working space

☐ (Health)care Lab ☐ Media Lab / Art Lab

☐ social enterprise ☐ start-up

☐ cooperative ☐ third place

☐ other : ____________

Q8. Is the space independent or hosted by an institution?

☐ Independant

☐ Hospital ☐ University ☐ Library

☐ SME ☐ corporation ☐ Incubator

☐ Third place / co-working space ☐ Repair Café

☐ other : _____________

9. What are the financial resources of your organisation? *You can tick many boxes.*

☐ commercial activities

☐ membership subscription ☐ donations ☐ crowdfunding

☐ EU funding ☐ government funding

☐ other : ______________

SECTION 2: YOUR MAKERSPACE SINCE THE COVID-19 PANDEMIC

Q10. How did your makerspace respond to the COVID-19 situation? *You can tick many boxes.*

☐ application to governments' programmes for Covid relevant innovations

☐ individual initiative

☐ collaboration with other makerspaces

☐ collaboration with experts (e.g. engineers,...)

☐ collaboration with local hospitals

☐ collaboration with universities

☐ via digital platforms

☐ other : _____________________

11. What type of goods / services has the space been producing during the pandemic? *You can tick many boxes*

☐ Personal and Protective Equipment (PPE) (e.g. Face masks, visors)

☐ ventilators ☐ valves

☐ other critical medical items

☐ non-medical goods ☐ common goods

☐ Platform or Software ☐ Hardware devices

☐ other services: ____________________

☐ other goods, precise the type of goods : ____________

12. Are the products being certified? (the legal and quality standards of the device produced)

☐ not certified

☐ certified ☐ patented

☐ Open source ☐ Creative Commons License

☐ CE-marked (EU/EEA)

☐ Co-designed /DIY ☐ "Hacked" (copy of an existing device)

☐ other legal/ quality standards : ______________________

13. Is your space facing any issue? *You can tick many boxes. In 'other', you can specify the type of issue.*

☐ No specific issues

☐ Legal issues (certification, intellectual property, norms)

☐ Resource constraints ☐ Production capacities

☐ Organisational issues (leadership, management,...)

☐ Lack of tools / equipment ☐ Lack of human resources

☐ Financial resources ☐ Supply chain management

☐ other issues : ________________

14. Did the production processes of your space change since the COVID-19 crisis ?

☐ Yes, permanently ☐ Yes, temporarily ☐ Status quo ☐ No will to change

15. What are the internal strengths of the space, in your opinion ?

Tick of colour the boxes for each category from 1 to 10

	weak	To be improved	Still strong	Very strong
1. **Purposes, values**				
2. **Community / network**				
3. **Knowledge, expertise**				
4. **Supply chain**				
5. **Autonomy** (freely decide on the future, have control on technology)				
6. **Adaptability** (accept changes, be flexible to transform and repurpose)				
7. **Resilience** (resistance to disruptions and crises)				
8. **Techn(olog)ical Efficiency** (internal production capability)				
9. **Resource Efficiency** (optimal use of limited resources in a sustainable manner while minimising impacts on the environment)				
10. **Sufficiency** (voluntary reduction of resource use, moderation of consumer demand)				

16. Do you think of other strengths or potentials?

____
____

17. Given the strengths or weaknesses, would you say that your space is prepared to face new disruptions? (e.g. disruption of supply chain, shortages of essential goods, etc.)

Not prepared	uncertain	almost prepared	highly prepared
☐	☐	☐	☐

Section 3: Production processes of your makerspace

18. In which sectors does your makerspace operate? (In the column "After COVID", please specify the sector in which your space might or would likely operate in the future)

	In general	During Covid	After Covid
Medicine / health(care)			
Transport / Mobility			
Agriculture			
Construction			
Repair			
Education			
Machinery or Mechanics			
(Micro/nano) Electronics / Computer Engineering			
Accessories, Wearables			
Arts, Handcraft, Woodworking			
Fashion (clothing, textiles, fabrics)			
Medien / Communication / ICT			
Food or packaging			
Other sectors: __________________			

19. Which production process better reflect your space now ?

☐ Social Manufacturing (trio Manufacturers, Makers and Consumers)

☐ Circular Manufacturing

☐ Additive manufacturing (AM)

☐ DIY / collaborative manufacturing

☐ Distributed manufacturing

☐ Socially useful production

☐ Peer-to-Peer-Production (P2P)

☐ Commons-based peer production (CBPP)

☐ Design Global Manufacture Local (DG-ML)

☐ Repair production

☐ Industrial manufacturing

☐ other production processes : ______________________________

20. Which EU makerspace programs are you familiar with, and in which one is your space involved in

EU-Program	Familiar with	Active member
Pop-Machina (‚circular makerspaces‘, collaborative circular production) (pop-machina.eu)		
REFLOW (circular economy) https://reflowproject.eu/about/		
iPRODUCE (Soziale Manufacturing): About | iPRODUCE (iproduce-project.eu)		
COSMOCALISM (DGML- Design Global Manufacture Local): https://www.cosmolocalism.eu/pilots/		
OPENNEXT (Open-Source-Hardware): https://opennext.eu/resources/		
MAKE-IT (collaborative Platform for makers): https://make-it.io/		
MakersXchange (creative hubs): makersxchange – MAX (Makers' eXchange) project		
EU Right to Repair (EcoDesign policy): Home - Right to Repair Europe		
Digital Social Innovation (DSI) programme https://www.dsimanifesto.eu/manifesto/		
VULCA (Mobility, rural makers) HOME - Vulca		

If you are familiar with or involved in other European, national or local program / funding schemes, please mention them

____

Section 4: Attitudes of your space towards Technology

21. How do you consider the main type of technology proper to your organisation?

☐ Industrial technology

☐ High tech (state-of-the-art, not modular)

☐ Convivial tech (Frugal tech / jugaad /DIY) easy to repair and modify

☐ Low tech (useful, accessible and sustainable technology)

☐ Slow tech / No tech (non-motorized tools or handmade)

☐ other : ______________________________________

How do your space consider 3D printing technology?

☐ additive manufacturing technology

☐ frugal technology

☐ local manufacturing technology

☐ open source appropriate technology (OSAT)

☐ technology for repairing

☐ technology for sustainable development

☐ other aspect of the technology : ______________________

22. The main operational equipment selected by your makerspace (Type your answer)

Ex: Digital fabrication tools: computer-numerical controlled machining (CNC) machines, milling machine, Printed Circuit Board (PCB), laser /sign cutters, sewing machines, micro-electronics, 3D Printers; Hardware / Software, ICT, ARDUINO, ...

23. What are the communication and digital tools inherent to the space?

☐ Social Media platforms (Facebook, Twitter, Instagram, ...)

☐ Physical networks (Maker Fair, Festival, Events)

☐ Forum ☐ Shopping platform ☐ Open source platform

☐ Website ☐ Radio / Podcast ☐ other : ______________________________________

24. If your makerspace was referenced or active on digital platforms during COVID-19, you can provide the name below

____

Section 5: your maker profile

25. What is your status in the space? *You can tick many boxes*

☐ Founder ☐ Owner ☐ Manager ☐ Project Manager

☐ Member ☐ Full-time employee ☐ Part-time employee

☐ Volunteer ☐ other : _________________

26. Educational background and skills

☐ Apprenticeship ☐ Bachelor ☐ Master ☐ PhD

☐ STEM skills (Science, Technology, Mathematics, Engineering) ☐ STEAM (STEM + Arts)

☐ other competences: ______________________

27. Which new vocabulary / tools would illustrate for you the makerspaces actions during the Covid-19 crisis?

If you think of words, terminology, metaphors or expressions ('tinkering', 'mending', 'care', 'repurpose', 'commoning'), or if you think of specific literature, authors, technology, symbolic device/ tools, ...

____
____

28. Gender: how do you identify yourself? (for socio-demographic purposes)

☐ Male ☐ Female ☐ other: _____

29. How old are you? (for socio-demographic purposes)

Section 6: Questions, issues, additional comments?

If you would like to discuss further on the two key questions of my research:

- HOW could European makerspaces be catalysts of post-pandemic societal & sectoral operations?

- HOW could we develop new socio-economic models from the production processes & supply chains put in place by makerspaces, to face the ongoing sanitary crisis, in anticipation of future potential disruptions?

Or any additional comment you may have.

Express yourself: if you feel so, please deliver few words on whatever angle you would have talked about the impacts of COVID-19 amid the world of makerspaces

____

____

Maker, you made it!

Thank you for taking part in this survey. Please send the questionnaire to me at the following e-mail address: omaevare@gmail.com (Omara RE).

Your input is very valuable in understanding the potential transformative power of makerspaces in Europe.

If you would like to read the results of my research project, please contact me again at omaevare@gmail.com (Omara RE).

APPENDIX 2 : MAKERSPACES TYPOLOGY & AGE

Table of frequencies [PSPP] : Age of makerspaces, for the whole sample (N=120

```
FREQUENCIES
    /VARIABLES= Age Typology
    /FORMAT=AVALUE TABLE.
```

Age

Étiquette de valeur	*Valeur*	*Fréquence*	*%*	*Pourcentage valide*	*Pourcentage cumulé*
	,5	1	,80	,83	,83
	1,0	7	5,60	5,83	6,67
	1,5	1	,80	,83	7,50
	2,0	10	8,00	8,33	15,83
	2,5	2	1,60	1,67	17,50
	3,0	14	11,20	11,67	29,17
	4,0	9	7,20	7,50	36,67
	5,0	15	12,00	12,50	49,17
	6,0	13	10,40	10,83	60,00
	7,0	10	8,00	8,33	68,33
	8,0	12	9,60	10,00	78,33
	9,0	7	5,60	5,83	84,17
	10,0	7	5,60	5,83	90,00
	11,0	3	2,40	2,50	92,50
	12,0	2	1,60	1,67	94,17
	13,0	1	,80	,83	95,00
	15,0	2	1,60	1,67	96,67
	16,0	1	,80	,83	97,50
	17,0	1	,80	,83	98,33
	23,0	1	,80	,83	99,17
	61,0	1	,80	,83	100,00
	.	5	4,00	Manquant(e)	
	Total	125	100,0	100,0	

50% of makerspaces are under 6 years old

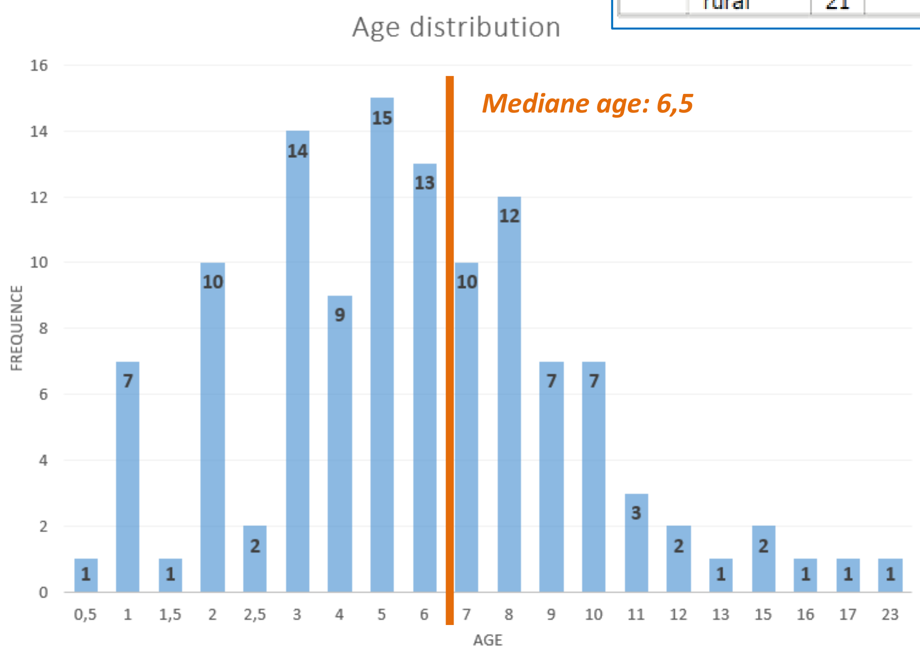
Age

N	*Valide*	120
	Manquant(e)	5
Moyenne		6,51
Écart-type		6,27
Minimum		,50
Maximum		61,00

```
T-TEST /VARIABLES= Age
    /GROUPS=Typology(1,3)   /MISSING=ANAL
    /CRITERIA=CI(0.95).
```

Statistiques de groupe

	Typology	*N*	*Moyenne*	*Écart-type*
Age	urban	78	6,77	3,54
	rural	21	4,21	2,45



APPENDIX 3: TYPOLOGY & AGE PER COUNTRY

Survey results for Q2 and Q4 : makerspaces typology & age per country

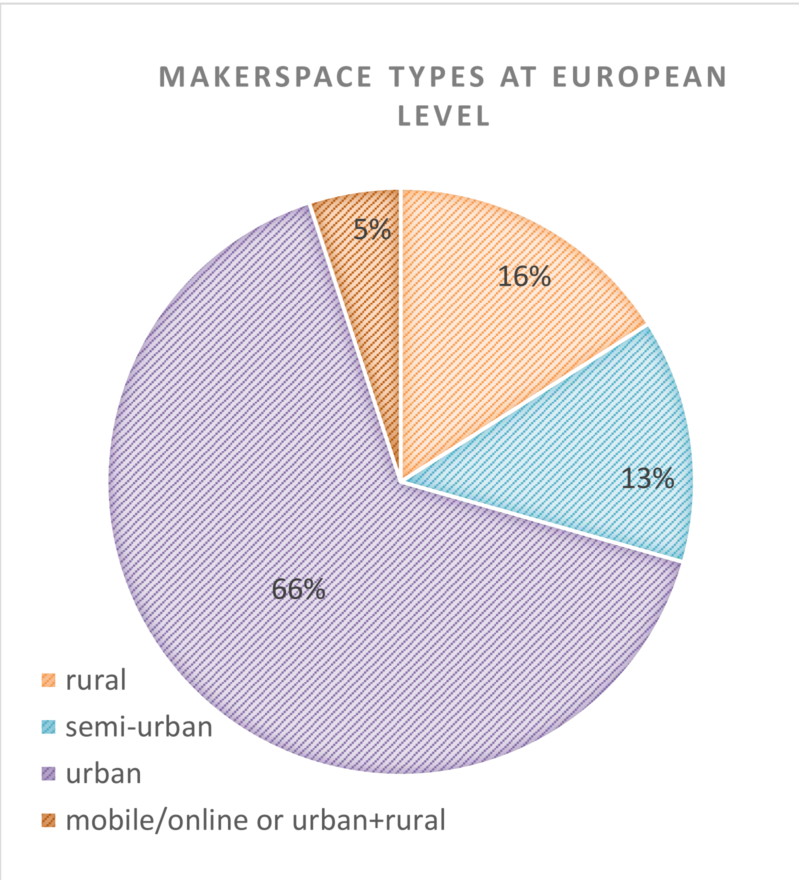
Frequencies table: Q4 – Typology

Typology

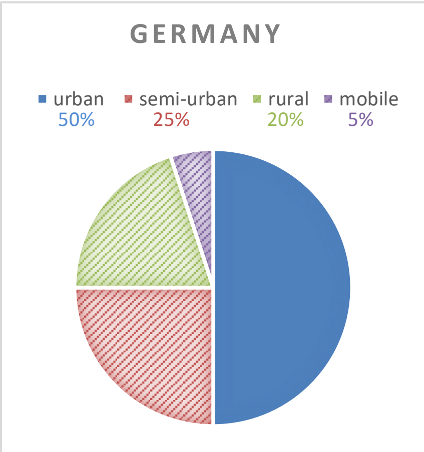
Étiquette de valeur	*Valeur*	*Fréquence*	*%*	*Pourcentage valide*	*Pourcentage cumulé*
urban	1	81	64,80	65,32	65,32
semi urban	2	16	12,80	12,90	78,23
rural	3	21	16,80	16,94	95,16
hybrid	4	6	4,80	4,84	100,00
	.	1	,80	Manquant(e)	
	Total	125	100,0	100,0	

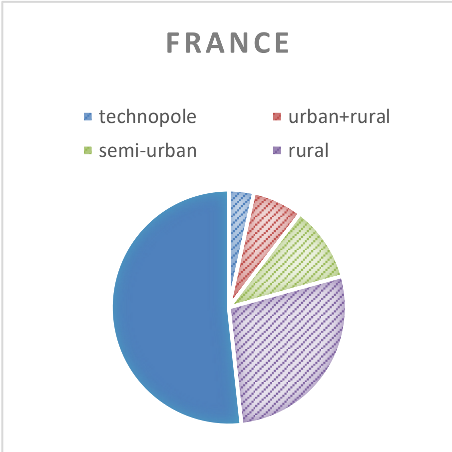
Typology

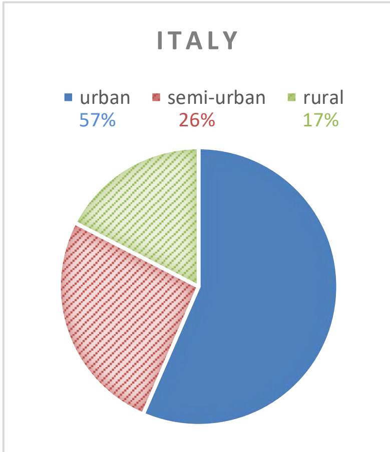
N	*Valide*	124
	Manquant(e)	1
Moyenne		1,61
Écart-type		,93
Minimum		1,00
Maximum		4,00

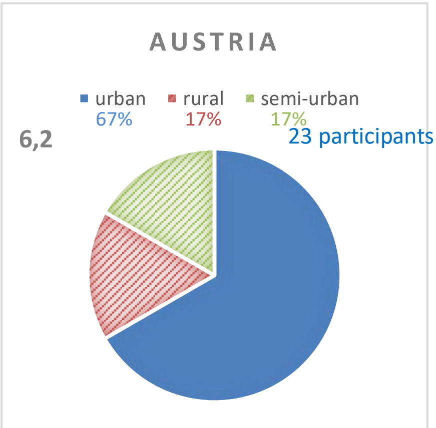


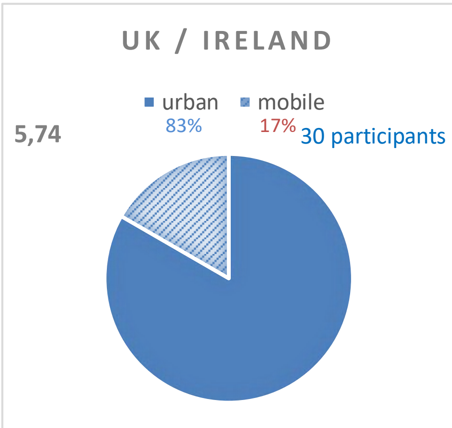
Rural, urban or semi-urban and other types (mobiles, or hybrid rural/urban) depending on their host (technopole). Also the number of makerspaces for each country (bottom right) and the average age of the makerspaces (bottom left)

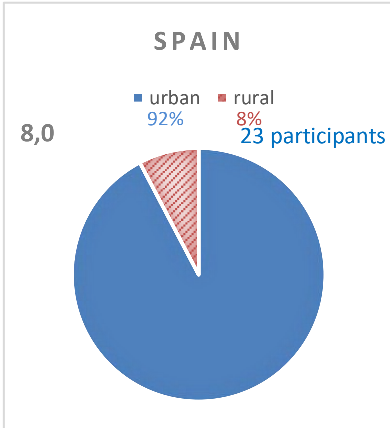


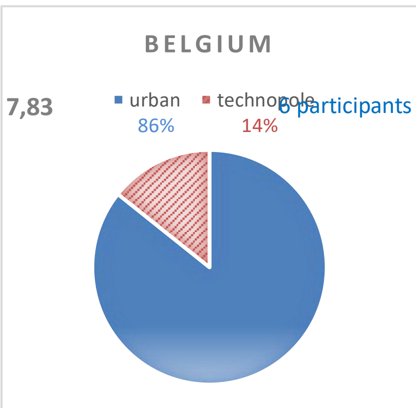


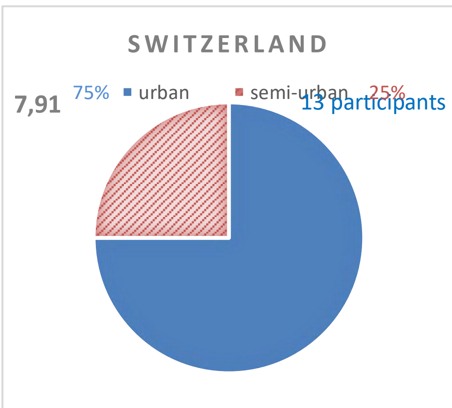


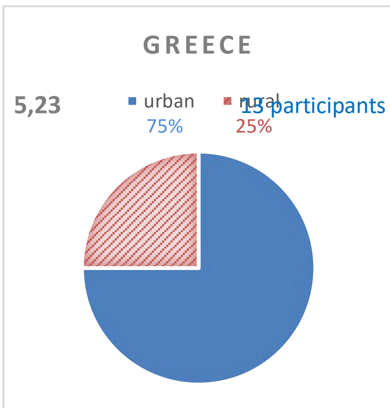












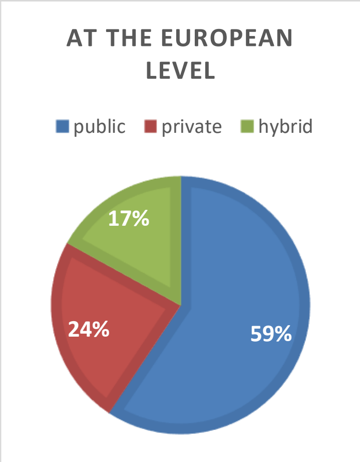
7,83 7 participants

2,75 4 participants

3,0 5 participants

APPENDIX 4 : INDEPENDENT OR DEPENDENT, PUBLIC OR PRIVATE

Q5. Is the space open to public or private? Q8. Is the space independent or hosted by an institution?



Makerspaces are proliferating both in public and private spaces. Overall, 59 % of makerspaces are public, 24 % are private. 17% are hybrid (either fully private nor fully public). Most of the hybrid makerspaces would be considered private in the sense that they welcome members only. Under the category "hybrid": some makerspaces are initially private spaces or private association, i.e. open to **members only** who are allowed to use the facilities. Yet they open for the public occasionally, e.g. for workshops. Some makerspaces are initially public, but welcome members only. Most of the makerspaces or fablabs hosted in universities are open to students only. A specific configuration of makerspace mentioned by an Italian maker: *"It is an asset confiscated from the mafia and owned by the municipality of Palermo*". Thus all of these different configurations have been included in the category "hybrid" in the graph.

Q8. Independent or hosted	*share*
Independent	**61%**
other institution	11%
university	10%
association	6%
Incubator /coworking space	5%
Socent /SME	4%
third place	4%
library	2%
hospital	1%

Overall, the vast majority of makerspaces (61%) are independent, i.e. have their own physical space (30% of them being public and 25% private), **and 39% are being hosted by entities (clustered in blue).** Among them, 10% are located within educational institution (mostly universities, also schools), therefore pulic makerspaces, although they are only open to students. 4% are affiliated with enterprises (social enterprises, SME), 4% in third places, i.e. multi-tasking community spaces; 2% are located within libraries, but also as membership organisations by third parties (e.g. private sector and NGOs). 11% of makerspace mentioned being hosted by other types of organisation (Research Insitute, Laboratories). All of these kinds of alternative space accessibility mentioned by the participants can engage more local people in using the available tool and hardware in the community to develop and prototype new ideas.

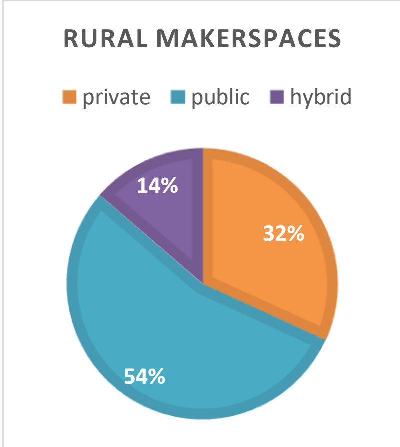
There is no correlation between the independent status of the space and the private or public status. The Pearson correlation is not significant (p-value= 0.111 > 0.05) so there is a negative correlation between indepenedent and public/private.

Corrélations

		Independent	*PublicPrivate*
Independent	*Corrélation de Pearson*	1,00	-,14
	Sig. (bi-variée)		,117
	N	123	122
PublicPrivate	*Corrélation de Pearson*	-,14	1,00
	Sig. (bi-variée)	,117	
	N	122	123

Table: Rural makerspaces configurations (Q5 & Q8)

Country	Q8	Q5
Greece	Independent	public
Italy	socent	private
Italy	Independent	private
Italy	Independent	private
Italy	Independent	private
Ireland	SME	Hybrid
Spain	library	public
France	other	public
France	third place	public
France	other	public
France	Independent	public
France	Independent	public
France	Independent	private
France	Independent	public
France	Independent	public
France	other	public
France	other	public
Germany	independent	public
Germany	third place	public
Germany	Independent	private
Germany	Independent	private
Germany	other	Hybrid
Österreich	Independent	Hybrid



Overal, half of rural makerspaces are public. 26% are independent and public and 26% independent and private. All Italian rural makerspaces are private entities, the majority are independent makerspaces, or hosted by a social enterprise.

status	share
independent	57%
other institution	22%
third place	9%
socent / SME	9%
library	4%

Tables 2: Classification of makerspaces according to their typology, age of creation and stauses either public/private and independent/dependent

Variable	Valeur	Étiquette
Typology	1	urban

Cas valides = 81; cas avec valeur(s) manquante(s) = 4.

Variable	*N*	*Moyenne*	*Écart-type*
Age	78	6,77	3,54
Independent	81	1,33	,47
PublicPrivate	80	1,60	,82

Variable	Valeur	Étiquette
Typology	2	semi urban

Cas valides = 16; cas avec valeur(s) manquante(s) = 1.

Variable	*N*	*Moyenne*	*Écart-type*
Age	16	8,41	15,04
Independent	15	1,33	,49
PublicPrivate	16	1,81	,83

Variable	Valeur	Étiquette
Typology	3	rural

Cas valides = 21; cas avec valeur(s) manquante(s) = 0.

Variable	*N*	*Moyenne*	*Écart-type*
Age	21	4,21	2,45
Independent	21	1,43	,51
PublicPrivate	21	1,62	,74

Variable	Valeur	Étiquette
Typology	4	hybrid

Cas valides = 6; cas avec valeur(s) manquante(s) = 1.

Variable	*N*	*Moyenne*	*Écart-type*
Age	5	6,00	2,55
Independent	6	1,67	,52
PublicPrivate	6	1,50	,84

APPENDIX 5: ECONOMIC SUSTAINABILITY, FINANCIAL RESOURCES

Appendix 3 covers Q6 and Q9 of the survey. Q6 refers to the number of makers in the structure and Q9 asked about the financial resources. Q6 and Q9 are linked.

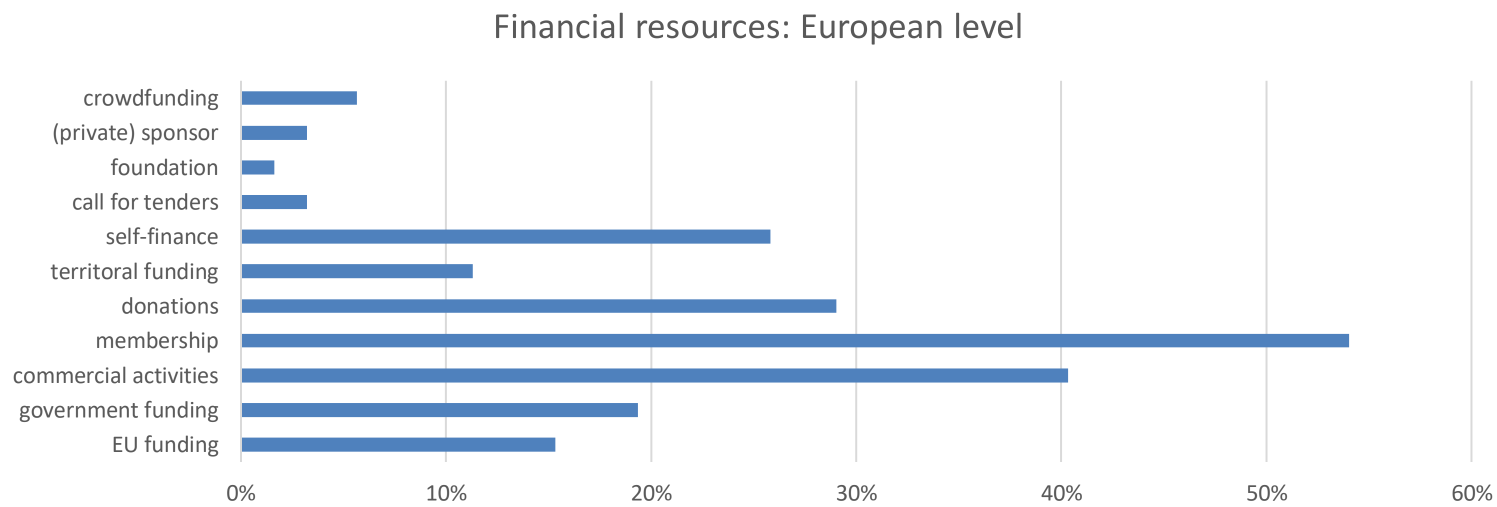
Q9. What are the financial resources of your organisation?

☐ commercial activities ☐ membership subscription ☐ crowdfunding

☐ EU funding ☐ government funding ☐ donations

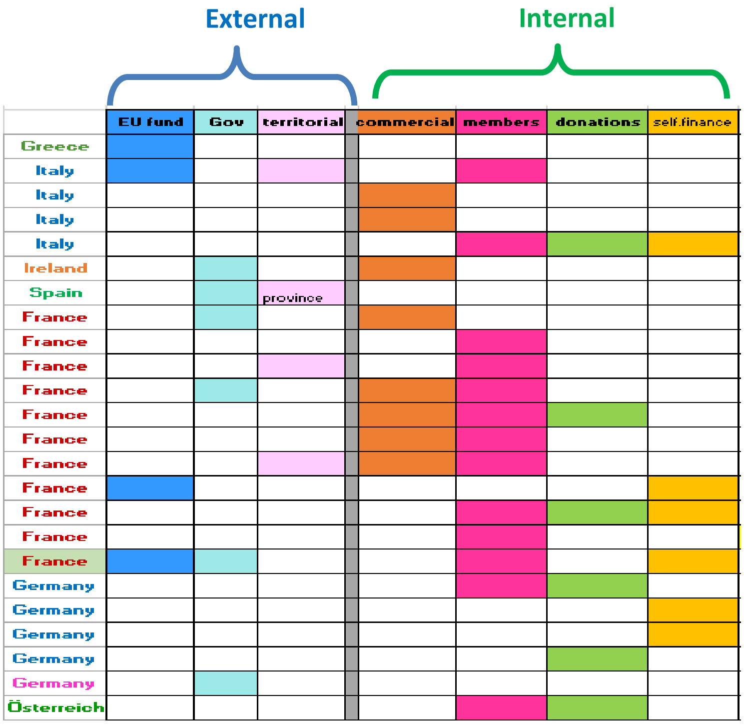
☐ other sources mentioned: (private) sponsorship, call for tenders, public funding, project-based funding, university grants, foundation, specific territorial funding, local funding from province, municipality

Survey results:

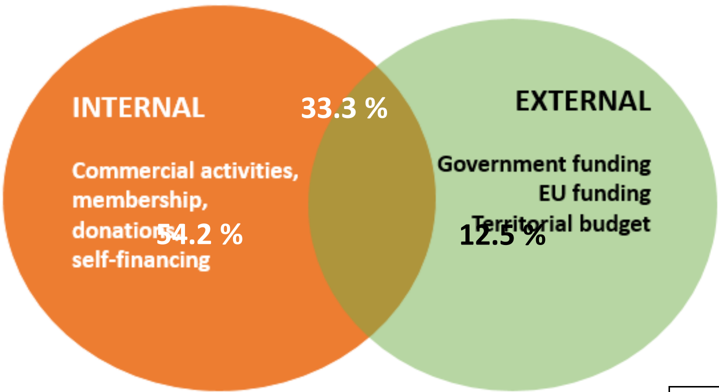


	EU funding	government funding	commercial activities	membership	donations	territoral funding	self-finance	call for tenders	foundation	(private) sponsor	crowdfunding
Series1	15%	19%	40,3%	54,0%	29%	11,3%	25,8%	3,2%	1,6%	3,2%	5,6%

Financial resources of rural makerspaces (n = 24)



membership	54,2%
commercial activities	33,3%
government funding	25,0%
donations	25,0%
self-finance	25,0%
EU funding	16,7%
territoral funding	16,7%

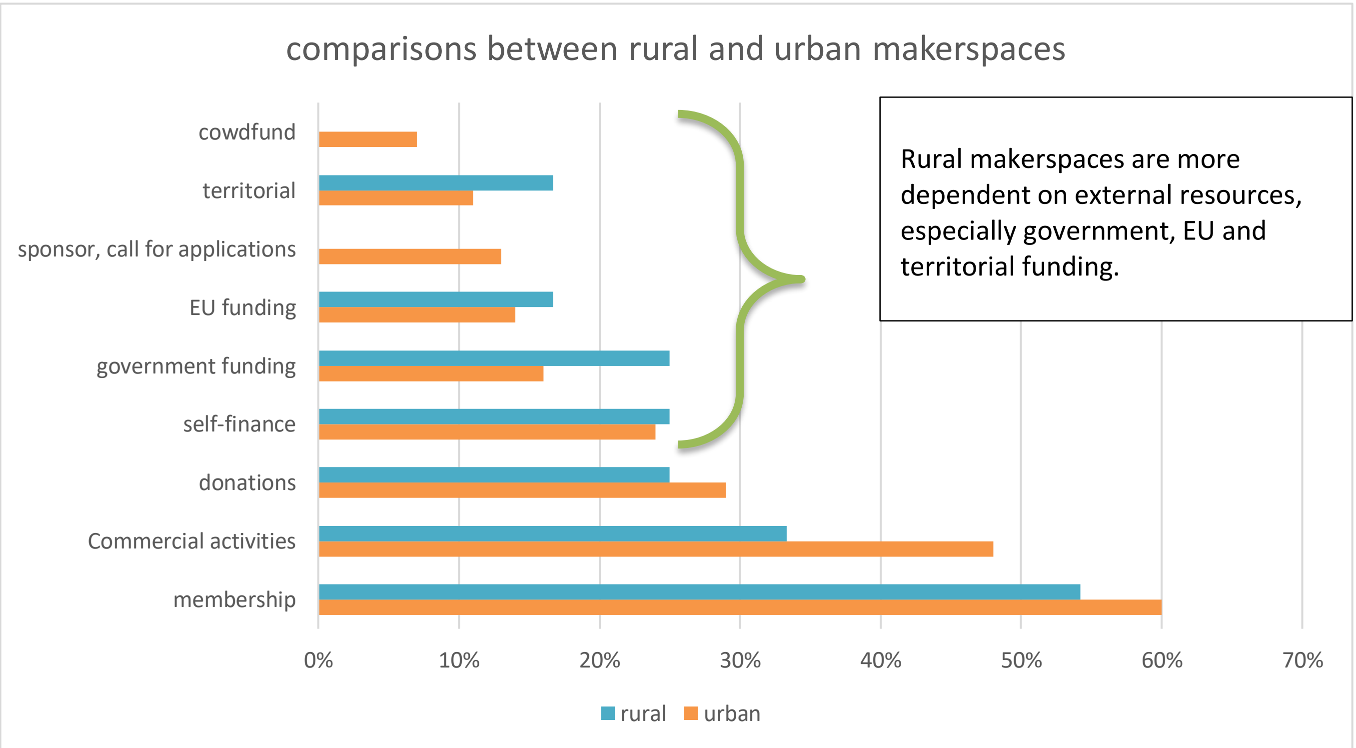


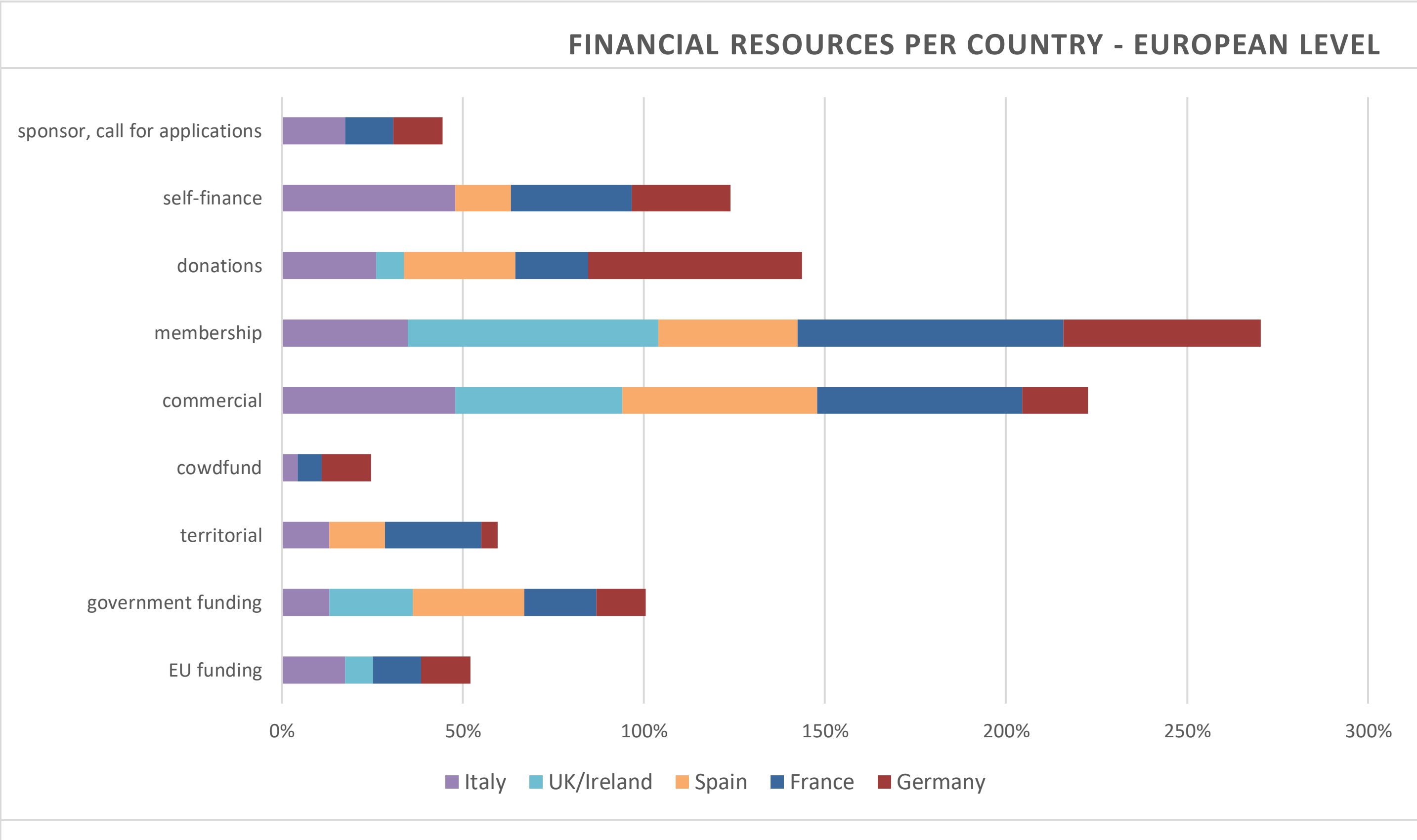
Resources category	rural	urban
internal only	54.2%	59%
external only	12.5%	11%
internal + external	33.3%	30%

Comparison between urban and rural makerspaces

Financial sources	**Internal /external**	**urban**	**rural**
membership	internal	60%	54,2%
Commercial activities	internal	**48%**	33,3%
donations	internal	29%	25,0%
self-finance	internal	24%	**25,0%**
government funding	external	16%	**25,0%**
EU funding	extenal	14%	**16,7%**
sponsor, call for applications	external	13%	0
Territorial fund	external	11%	**16,7%**
cowdfund	external	7%	0

Unlike urban makerspaces, rural makerspaces do not count on crowdfunding, or sponsorship.

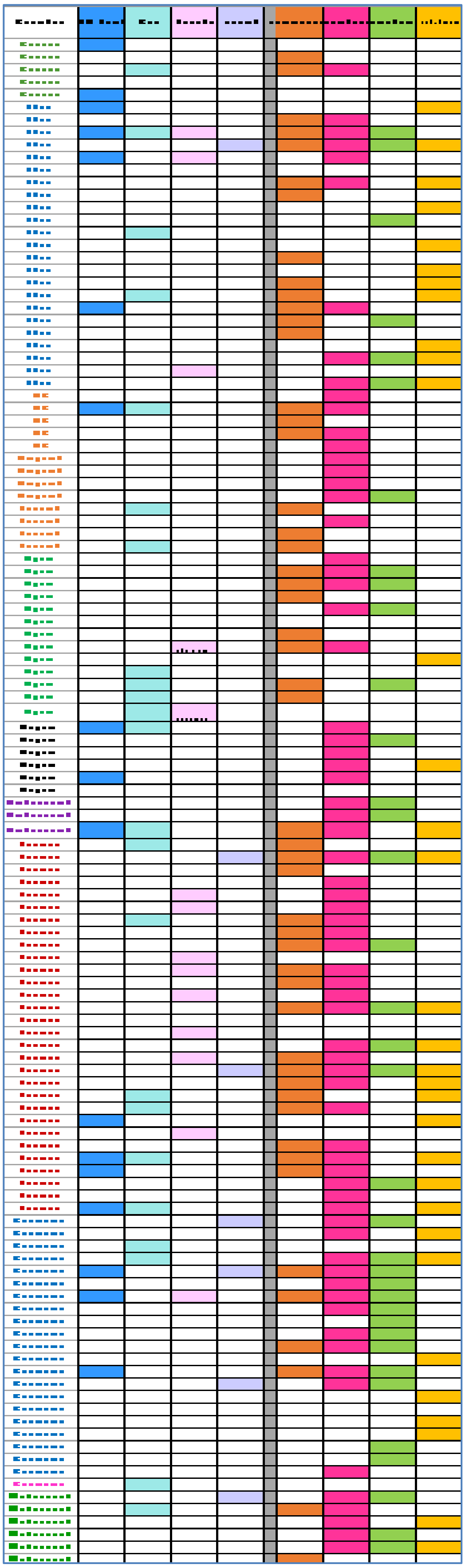




Commercially-oriented and non-for-profit oriented makerspaces

Financial resources	Internal external	Italy	UK/Ireland	Spain	France	Germany	B/S	Austria
EU funding	external	17%	8%	0	13%	14%	38%	0
government funding		13%	23%	31%	20%	14%	25%	17%
territorial		13%	0	15%	27%	5%	0	0
cowdfund		4%	0	0	7%	14%	0	17%
Commercial activities	internal	48%	46%	54%	57%	18%	13%	33%
membership		35%	69%	38%	73%	55%	88%	83%
donations		26%	8%	31%	20%	59%	38%	50%
self-finance		48%	0	15%	33%	27%	25%	33%
sponsor, call for applications		17%	0	0	13%	14%	25%	0

MATRIX of financial resources at the European level



The Matrix helps to better visualize the multiple sources of finance for each makerspaces of each country. The data were entered on an Excel sheet and classified per category, each color coded. Legend (From left to right): EU funding, government funding, territorial funding, crowdfunding, commercial activities, membership subscription, donations, self-finance.

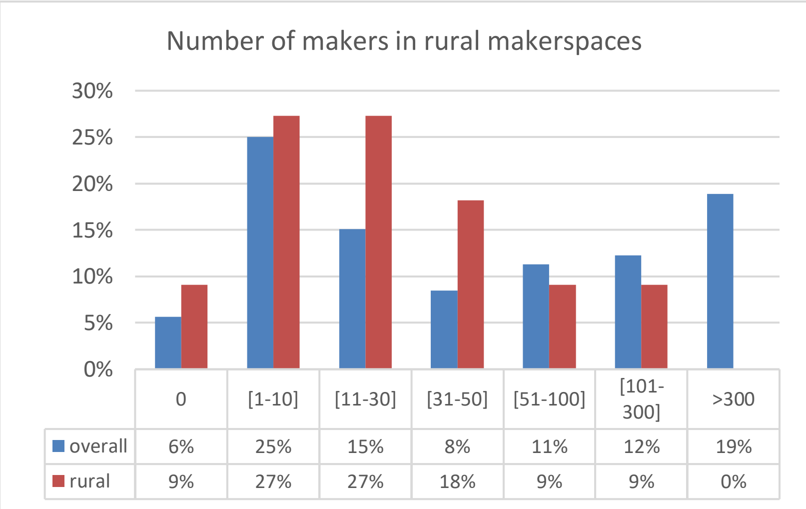
At the European level: 15.4% of makerspaces have mentioned EU-funding, mostly makerspaces identified as fablabs (13% of makerspaces described as fablabs are EU-funded). 18,3% mentioned government funding: 31% of them are Spanish. 4,2% overall are exclusively funded by the government. 10.6% makerspaces mentioned other territorial fundings including different budgets at different administrative layers. French makerspaces rely particularly on those territorial fundings: 27.6% of French makerspaces mentioned budget from the 'Conseil departemental' (municipal subvention/budget) overlapping with other local fundings (city funding, agglomeration, department, collectivities), and regional funding. These diverse sources of finances among French makerspaces can be explained by the French administrative structure divided in many territorial entities: the State, the Region, the Department (complement to the Region, 'departement'), the Inter-communality: the districts ('arrondissements'), the 'cantons', the urban communalities ('communautes urbaines'), the communalities of agglomerations; the communal level: the communalities of communes, and finally the communes.

19.5% mentioned self-financing, mostly association or cooperative. 9.8% of makerspaces are exclusively self-financed. 43,5% of Italian makerspaces have mentioned self-financing as one of their financial resources, and 26% of Italian makerspaces have weak financial resources (self-financing exclusively, or self-financing with other unstable resources such as donations or membership). The other 9,7% have mentioned self-financing among other more stable resources such as government funding and income from makerspaces commercial activities. Makerspaces relying exclusively on membership subscriptions as financial resources were hit the most by the pandemic, as the spaces were closed and members couldn't use the equipments and space they have paid for. 4,88% of makerspaces identifying as association or third place diversify their financial resources, with crowdfunding campaigns, for project-based fundings. Income from workshops (2).

Donations : 29,2% of European makerspaces. For 30% of Spanish makerspaces, 66% of Swiss makerspaces, 20,6% of French makerspaces, 65% of German makerspaces (15% of German makerspaces are exclusively financed through donations).

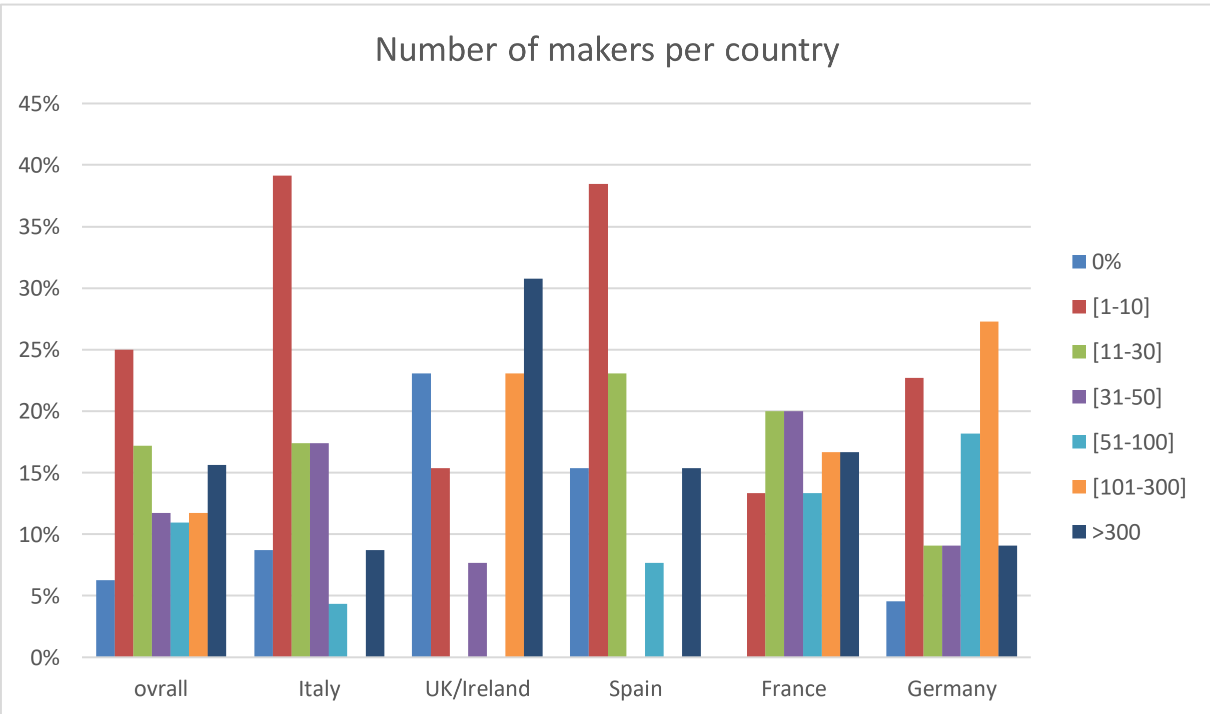
APPENDIX 6: NUMBER OF MAKERS

Q6. How many makers in the structure?



The majority of rural makerspaces (63.6%) count less than 30 members. None of the rural makerspaces count more than 300 members, whereas 19% of urban makerspaces count more than 300 members.

19% of makerspaces have more than 300 members affiliated to their organisations, most of them fablabs, makerspace, DIY space / community workshop, coworking space, third place. 43.3% of European makerspaces have less than 30 members, and 26.7% have less than 10 members. **Those makerspaces must thus diversify their sources of revenue**.



APPENDIX 7: MAKERSPACE RESPONSE SINCE THE COVID-19 PANDEMIC

Q10. How did your makerspace respond to the COVID-19 situation?

Table 1: Descriptive statistics (mean and standard deviation) of makerspaces Covid responses, according to their typology (rural, urban, semi-urban

Variable Valeur Étiquette
typo 1 urban

Cas valides = 75; cas avec valeur(s) manquante(s) = 0.

Variable	*N*	*Moyenne*	*Écart-type*
individual	75	,72	,45
gov	75	,17	,38
makerspaces	75	,53	,50
experts	75	,33	,47
hospotal	75	,55	,50
uni	75	,13	,34
digital	75	,33	,47

Variable Valeur Étiquette
typo 2 semi urban

Cas valides = 16; cas avec valeur(s) manquante(s) = 0.

Variable	*N*	*Moyenne*	*Écart-type*
individual	16	,75	,45
gov	16	,13	,34
makerspaces	16	,50	,52
experts	16	,50	,52
hospotal	16	,44	,51
uni	16	,19	,40
digital	16	,44	,51

Variable Valeur Étiquette
typo 3 rural

Cas valides = 20; cas avec valeur(s) manquante(s) = 0.

Variable	*N*	*Moyenne*	*Écart-type*
individual	20	,65	,49
gov	20	,05	,22
makerspaces	20	,70	,47
experts	20	,20	,41
hospotal	20	,25	,44
uni	20	,00	,00
digital	20	,25	,44

Variable Valeur Étiquette
typo 4 specific

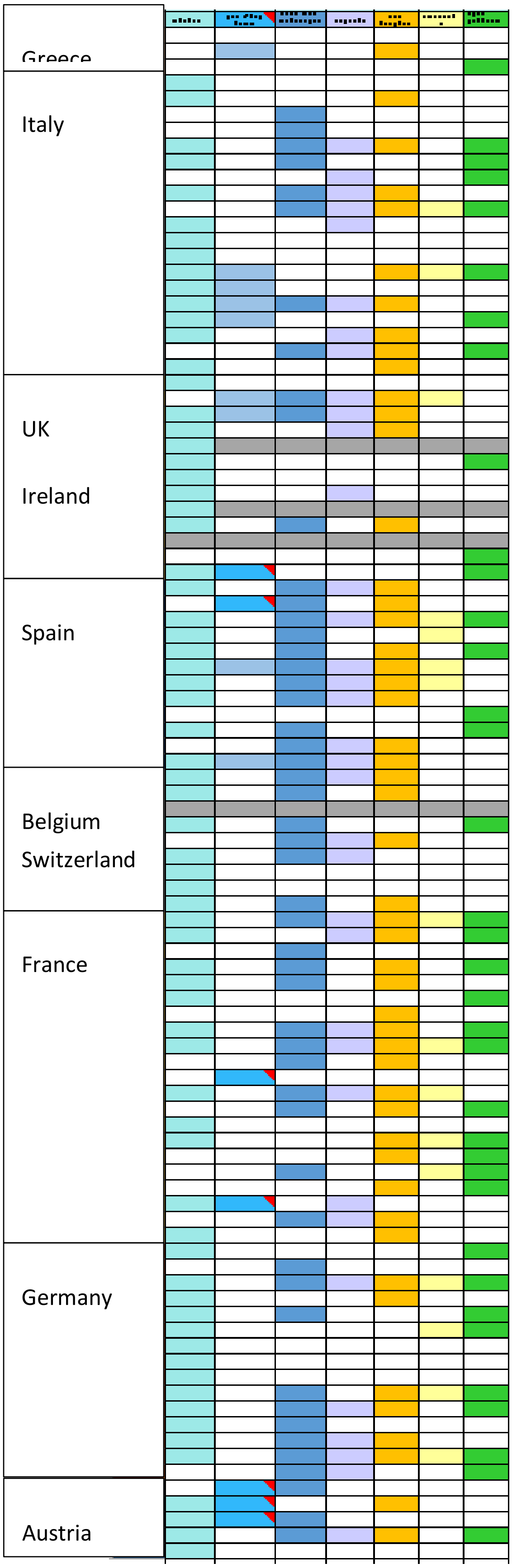
Table 2: Correlation between the type of response and the typology

```
CORRELATION
    /VARIABLES = typo individual gov makersp
    /PRINT = TWOTAIL SIG.
```

Corrélations

		typo
typo	*Corrélation de Pearson*	1,00
	Sig. (bi-variée)	
	N	118
individual	*Corrélation de Pearson*	-,12
	Sig. (bi-variée)	,178
	N	118
gov	*Corrélation de Pearson*	-,10
	Sig. (bi-variée)	,268
	N	118
makerspaces	*Corrélation de Pearson*	,05
	Sig. (bi-variée)	,622
	N	118
experts	*Corrélation de Pearson*	-,06
	Sig. (bi-variée)	,486
	N	118
hospotal	*Corrélation de Pearson*	-,23
	Sig. (bi-variée)	,013
	N	118
uni	*Corrélation de Pearson*	-,02
	Sig. (bi-variée)	,822
	N	118
digital	*Corrélation de Pearson*	,04
	Sig. (bi-variée)	,654
	N	118

Urban makerspaces response types

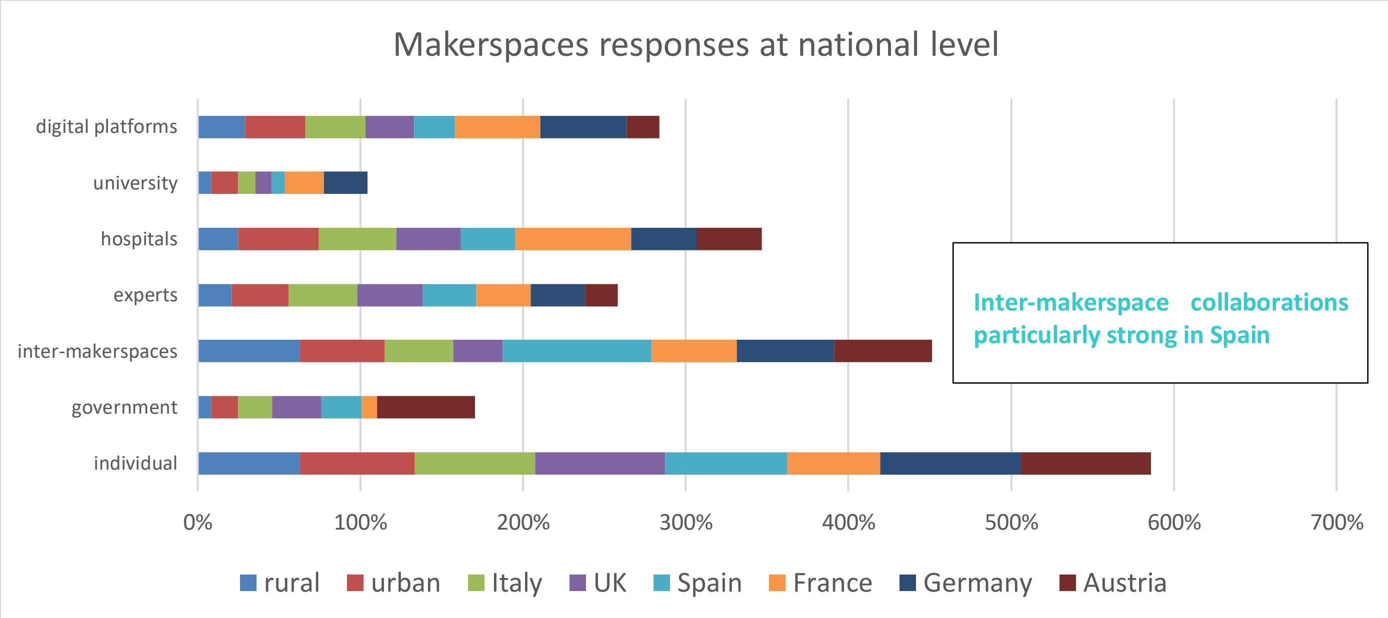


Overall, collaborative responses have been quite strong (52.6% mentioned a collaboration with other makerspaces). On the other and, 13.4% have responded on their own, without any collaboration. Half of urban makerspaces have strongly collaborated with **hospitals** during the pandemic, as they quickly ran out of emergency medical items to treat the increasing numbers of patients. Among the collaboration with experts (35%), 29% are doctors, crucial in the co-creation of appropriate and certified medical equipments.

Urban makerspaces have been also very active on the digital space (37%). 5.2% of makerspaces did contribute to the Covid-19 effort digitally only, they didn't produce tangible items, but rather developed the digital platforms and software necessary to connect makerspaces.

individual	71,1%
collaboration with other makerspaces	52,6%
local hospital	**49,5%**
digital platforms	37,1%
Collaboration with experts	35%
doctors: hospitals + experts	29%
university	16,5%
government	16,5%
individual only	13.4%
no response	5%
Digital only	5.2%

A collaboration with experts, either doctors or engineers, is mentioned by 33,3% of participants. 25,6% of makerspaces have been collaborating with doctors (the combination "makerspaces + experts + local hospitals"). For instance, to produce air purifiers, and medical prototypes. Then, 11,1 % of makerspaces collaborated with both universities and hospitals. 8,5 % of makerspaces collaborated with experts, local hospitals and universities ("experts + hospital + university").



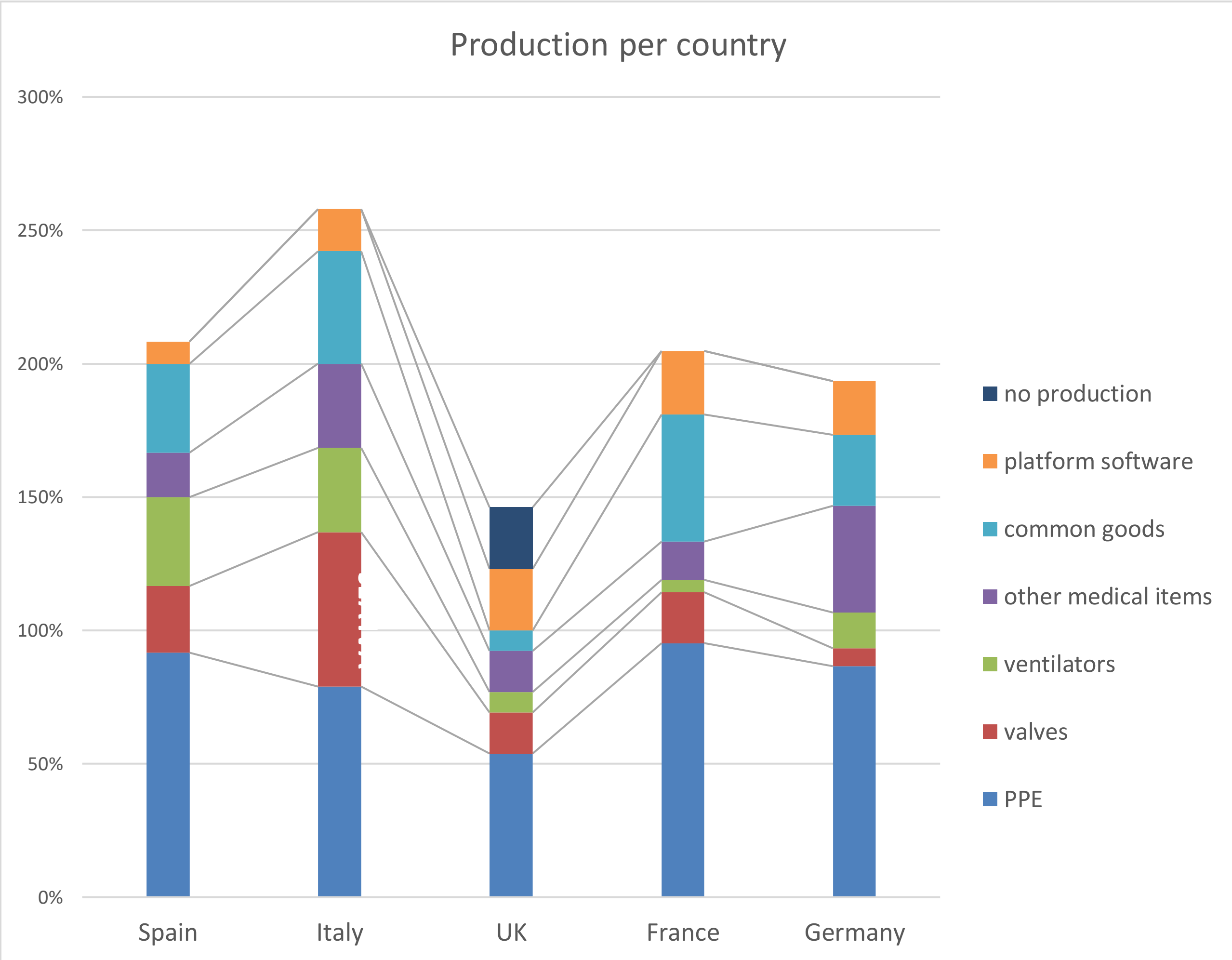
Despite the development of digital platforms for Spain to connect Spanish makerspaces in the efforts, only 25% of Spanish makerspaces mentioned a digital activity, thus we can interpret that most of the makerspaces' actions were happening in the physical spaces, despite lockdown restrictions. The most active digitally were German, Italian and French makerspaces. Urban makerspaces have been also very active on the digital space (37%).

Table: makerspaces responses at national level

	rural	urban	Italy	UK	**Spain**	**France**	**Germany**	Austria
individual	63%	71%	74%	80%	75%	57%	87%	80%
government	8%	16%	21%	30%	25%	10%	0%	60%
inter-makerspaces	63%	53%	42%	30%	92%	52%	60%	60%
experts	21%	35%	42%	40%	33%	33%	33%	20%
hospitals	25%	49%	47%	40%	33%	71%	40%	40%
university	8%	17%	11%	10%	8%	24%	27%	0%
digital platforms	29%	37%	37%	30%	25%	52%	53%	20%

APPENDIX 8: MAKERSPACE PRODUCTION SINCE THE COVID-19 PANDEMIC

Q11. What type of goods / services has the space been producing during the pandemic?



Items	Spain	Italy	UK	France	Germany	Austria	Belgium/S	Average
PPE	92%	79%	54%	95%	87%	80%	78%	**81%**
valves	25%	**58%**	15%	19%	7%	0%	22%	**21%**
ventilators	33%	32%	8%	5%	13%	0%	22%	**16%**
other medical items	17%	32%	15%	14%	40%	20%	22%	**23%**
common goods	33%	42%	8%	48%	27%	20%	0%	**25%**
platform software	8%	16%	23%	24%	20%	0%	0%	**13%**
no production	0%	0%	23%	0%	0%	20%	22%	**9%**

APPENDIX 9: CERTIFICATION

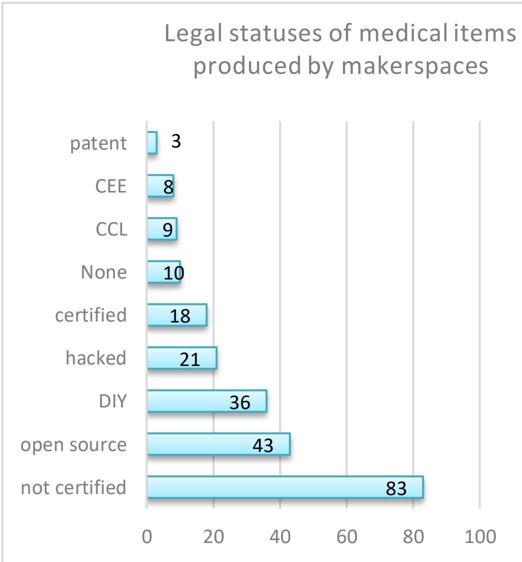
Q12. Are the products being certified? (the legal and quality standards of the device produced)

☐ not certified ☐ certified ☐ patented ☐ Open source ☐ Creative Commons License
☐ CE-marked (EU/EEA) ☐ Co-designed /DIY ☐ "Hacked" (copy of an existing device)

☐ other legal/ quality standards : ______________________

Legal statuses of medical items produced by makerspaces, in Europe

Legal status & quality standard	Scenario of the "Visual Guide for makers"	Share
not certified	Step 1 : identification of certificability	**70,3%**
open source	A - "DIY healthcare device" B – "Replicability"	**36,4%**
DIY – co-design	A - "DIY healthcare device"	**30,5%**
hacked	C - "Hackability"	17,8%
certified	Step 2 : certification process	15,3%
None		8,5%
CCL – Creative Common Licence	Scenario E – "Certification"	7,6%
CEE	Scenario E – "Certification"	6,8%
patent		2,5%



During the pandemic, most of the makerspacesinnovations belonged to the Scenario A, B and C: for instance, the respiratoryvalve was 'hacked' by Isinnova's engineers in order to produce the exactmedical item needed for the ventilators (Scenario C),. Then Isinnova createdtheir own functioning DIY prototype - the "Charlotte valve" - (Scenario A) which was openly accessible andreplicated in many makerspaces locally and globally (Scenario B –"Replicability"). Moreover, the DIY CPAP mask was 'non-invasive' (Sher, 2020)which refers the lowest Class of Risks of maker medical device. Isinnovaengineers collaborated with a doctor and the 3D printed solution was supportedby the local hospital of Brescia (Corsini et al., 2020). A custom medicaldevice is a device that is prescribed by a doctor to a patient. Withoutcertification or prescription, makers might be sued over intellectual propertyinfringement and other legal issues related to the manufacture and distributionof protective equipment. For instance, AFNOR (French Certification Authority)closed the French COVID-makers platform (covid3D.fr), less than two weeks afterthe announcement of containment (March 14-17) (Makery, 2020).

OPEN SOURCE MEDICAL DEVICES

A VISUAL GUIDE FOR MAKERS

An introduction to the regulations to design, commercialize and distribute an open source medical device in EU

STEP ONE — UNDERSTAND WHAT YOU ARE RELEASING

Are you developing a hardware device or a digital fabricated solution to solve a challenge in the field of health and care? Not all the solutions need to be certified as medical devices. Identify which scenario your solution belongs to.

SCENARIO A

Your solution is a functioning DIY prototype. People can access the documentation to potentially produce and use it for them-selves, to test, improve or study it.

SCENARIO B

Your solution can be personalized and produced in a fablab or a makerspace to support real people's needs.

SCENARIO C

Your solution is a hack of an existing object or medical device.

SCENARIO D

You are self-producing a solution for one person, or a few people, who will get it directly from you to use it in their daily life.

SCENARIO E

Your solution can be potentially mass produced or manufactured in small scale,and distributed by a third party, like a non profit organization, a tech for good company or by your future social enterprise.

YOU PROJECT NEEDS THE CERTIFICATION !

WHAT SHOULD YOU DO?

- A: Document the solution clearly and do not forget to add some information regarding what it should be improved to make it more stable. SEE EXAMPLES ON CAREABLES.ORG
- B: Do not forget to add information about the safety and the results of testing sessions into the documentation. Make people aware about possible risks when using the solution.
- C: Make people aware that the hacked version of a medical device is not suitable for all. SEE INITIATIVE HACKABILITY.IT
- D: You are responsible for your designs. Reflect on how to avoid risks for the people.
- E: Be sure that the requirements for the EU regulation compliance are considered in the design and development process of your solution. GO TO STEP TWO

STEP TWO — UNDERSTAND THE MEDICAL PURPOSE

To start the certification procedure you should identify what category your medical device belongs to. Look at the following medical purposes to work out what type of medical device you are working with.

TYPE	PREVENTION	DIAGNOSIS	MONITORING	PREDICTION	TREATMENT	COMPENSATION FOR	PROVIDING INFO WITH ANALYSIS
DEFINITION	The act of stopping something from happening.	A judgment about what a particular illness or problem is, made after examination.	To watch and check a situation carefully for a period of time in order to discover something.	A statement about what it will or might happen in the future.	Medical care given to a patient for an illness or injury.	To make something bad less severe, such as pain or problems.	In vitro analysis of specimens derived from the human body
EXAMPLE	Device for breast self-examination	Low cost echo-stethoscope	Intelligent monitoring device for Parkinson›s	Low cost sensors for early disease detection	Pad for growing bacteria and cure vaginal infections	DIY stoma bag	Open source machine (PCR) to make copies of DNA segments

STEP THREE — IDENTIFY THE CLASS OF RISK

Medical devices are rated by their potential risk of use. The EU has 22 rules which will allow you to classify your project in the official Classes of Risks. Most maker projects are low risk. Explore the rules to work out what Class of Risk your project fits into.

RULES	CLASSES OF RISK
NON INVASIVE (Rule 1-4)	CLASS I Low risk
INVASIVE (Rule 5)	CLASS IIA Moderate Risk
ACTIVE (Rule 9-13)	CLASS IIB Medium to High Risk
SPECIAL (Rule 14-22)	CLASS III High risk

EXAMPLE

YOUR PROJECT IS A SPORT WHEELCHAIR

It is not invasive because it does not touch orifices or emit radiations.

It is not invasive because it touches only intact skin.

It is not active because it is not electrified.

YOU PROJECT BELONGS TO CLASS I

Use the free Decision tree on UBORA platform to identify the Risk Class of your Medical Device: https://platform.ubora-biomedical.org

STEP FOUR — DETERMINE THE ASSESSMENT PROCEDURE

Medical device manufacturers have to follow conformity assessment procedures before placing products on the market. The type of conformity assessment procedure depends on the Class of Risk your project fits into.

ANY RISK FOUND?
If your device belongs to Class of Risk II or III, a Notifying Body must inspect and control your device.

If your device is low-risk and classified in CLASS I you can start a self-assessment procedure and check the compliance with the general safety requirements and harmonised standards.

Read all 23 Requirements on Annex I at this lin bit.ly/EURegulationsMedicalDevices

LET'S DO AN EXERCISE TO ASSESS THE GENERAL SAFETY AND QUALITY OF YOUR DEVICE

RISK MANAGEMENT

Are you aware of all risks that your device can cause? Can you anticipate them? Can you find a solution to them?

DESIGN AND MANUFACTURE

What materials are you using? Are they potentially harmful? What are the physical properties of your device? Is it stable enough?

INFORMATION

Does your device need instructions to be used? Is all information stated clearly?

WHAT IF — YOU DEVELOPED A CUSTOM MEDICAL DEVICE

A custom medical device is a device that is prescribed by a doctor to a patient. If you made a custom orthosis with a 3D printer that fits one person's need, this does not mean that your orthosis is a custom medical device according to the EU regulations.

"Custom-made device' means any device specifically made in accordance with a written prescription of any person authorised by national law by virtue of this person's professional qualifications which gives, under his responsibility, specific design characteristics, and is intended for the sole use of a particular patient exclusively to meet their individual conditions and needs." MDR 2017/745 Article 2 (3)

ARE YOU HACKING?
A hacked version of an existing device is not a custom device.
See Scenario 3 In STEP ONE

EXAMPLES

A doctor uses your lab and equipment to commission a custom insole. You are making a custom medical device Class I, but you do not need a certification.

Open Bionics prosthetics hand

You made a custom 3D printed hand that is attached to a support. You need to certify only the universal support.

Universal Socket Prosthetic

A doctor uses your lab and equipment to commission a custom insole. You are making a custom medical device Class I, but you do not need a certification.

Gyrobot Limited 3D printed insole

WHAT IF YOU DEVELOPED A SOFTWARE

Software with a medical purpose can also be considered a medical device and belong to different Classes of Risks. Discover your options.

Your software connects to a medical device

Your software allows the user to read and visualise data from a glucose sensor through the sensor's official APIs.

YOU DON'T NEED THE CERTIFICATION

Glimp is an app to remotely share glycemia data from certified sensors and does not need a certification.

Your software is standalone and works as a medical device

Your software suggests a therapy according to the level of insulin. It means that the software is suggesting a cure and it is then a medical software.

YOU NEED THE CERTIFICATION !

See the regulations for classifying the standalone software mdr 2017/745, Chapter I, Article 2 (4)

CREDITS AND RESOURCES

This guide is based on the webinar Open Source Medical Device held by Carmelo De Maria and Licia di Pietro on 6th February 2019 within the series Digital Social Innovation webinars by WeMake - DSIScale/DSI4EU.

The resources are issued from project UBORA - Euro-African Open Biomedical Engineering e-Platform for Innovation Through Education. Infovis and graphics created by Serena Cangiano, Maddalena Fragnito and Zoe Romano.
Most icons are by The Noun Project. Header grid is a derivative of Open Grid by Open Structures. We love open source.

www.wemake.cc

www.digitalsocial.eu

ubora-biomedical.org

LIST OF PROJECTS AND REFERENCES

- Careables Open Source Hardware in health care *www.careables.com*
- Hackability Methodological hackathon to co-design supports *www.hackability.it*
- Palpreast Wearable Device for Breast Self- Examination *https://bit.ly/2QCNqGN*
- Echopen open source and low-cost echo- stethoscope *www.echopen.org*
- OneRing Intelligent Monitoring Device for Parkinson›s *https://bit.ly/2XkgXYC*
- E-Health: Low Cost Sensors for Early Disease Detection *https://bit.ly/2ELP7wX*
- Insoles Generate Insoles for 3D Printing *www.gensole.com*
- Glimp App to sharing glycemia data *https://bit.ly/2EJUrkG*
- E-Health: Low Cost Sensors for Early Disease Detection *https://bit.ly/2ELP7wX*
- Future Flora Kit to treat and prevent vaginal infections *www.gitomasello.com/Future-Flora*
- Stomanoir Cap for stoma bags *https://bit.ly/2EL7fap*
- Open PCR Open-source PCR Thermocycler *www.openpcr.org*
- Openbionics Open-source Robotic & Bionic Hands *www.openbionics.org*
- Toowheels Open-source sport wheelchair *www.toowheels.org/*
- Universal Socket Prosthetics *www.thingiverse.com/thing:2718065*
- DSI Webinars - Learning Journey Playlist *https://bit.ly/2wr5WZF*

"Open Medical Devices - A visual guide for makers" is included in e-book "Rebelling with care" available at this link
http://wemake.cc/digitalsocial/cure-ribelli/

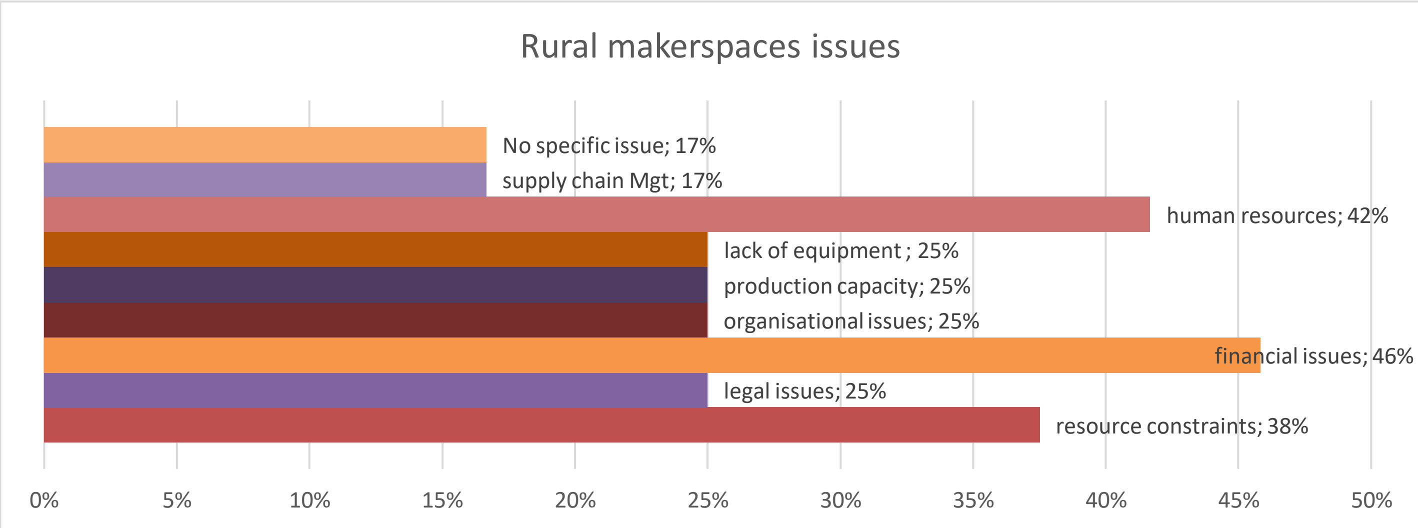
DIGITAL SOCIAL INNOVATION

DSISCALE, operating under the DSI4EU brand, is funded by the European Commission Directorate General for Communications Networks, Content & Technology, Net Futures, Administration and Finance, under Grant Agreement No. 780473.

APPENDIX 10: MAKERSPACE ISSUES

Q13. Is your space facing any issue?

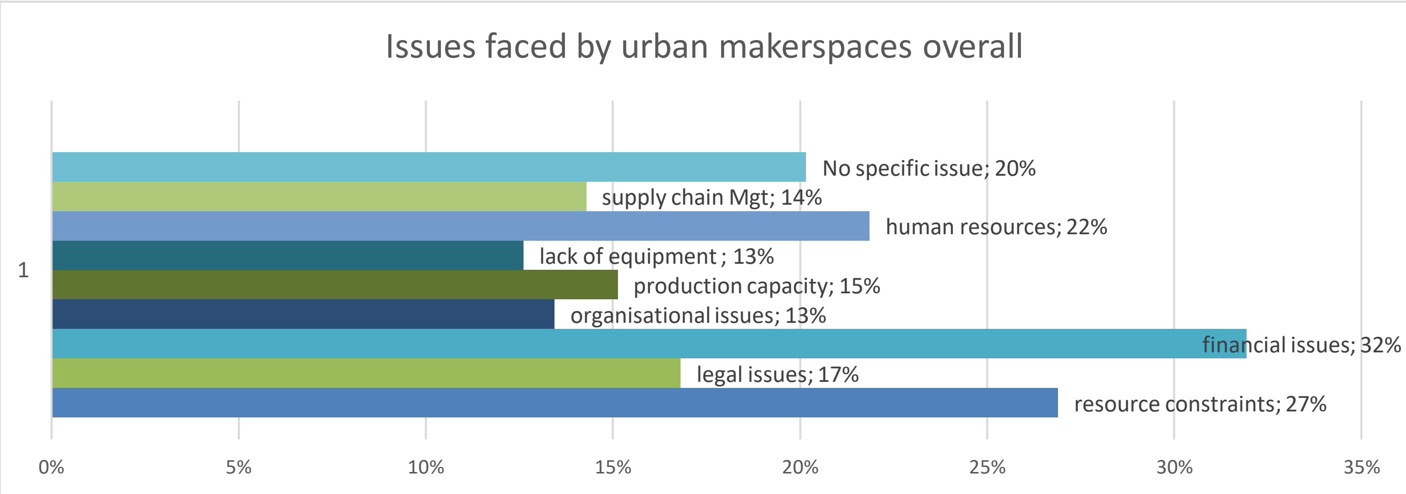
Most of the issues faced by rural makerspaces are a lack of human resources / Human Capital (mentioned by 42%), a lack of Financial capital (mentioned by 46%) and resources constraints (38%)

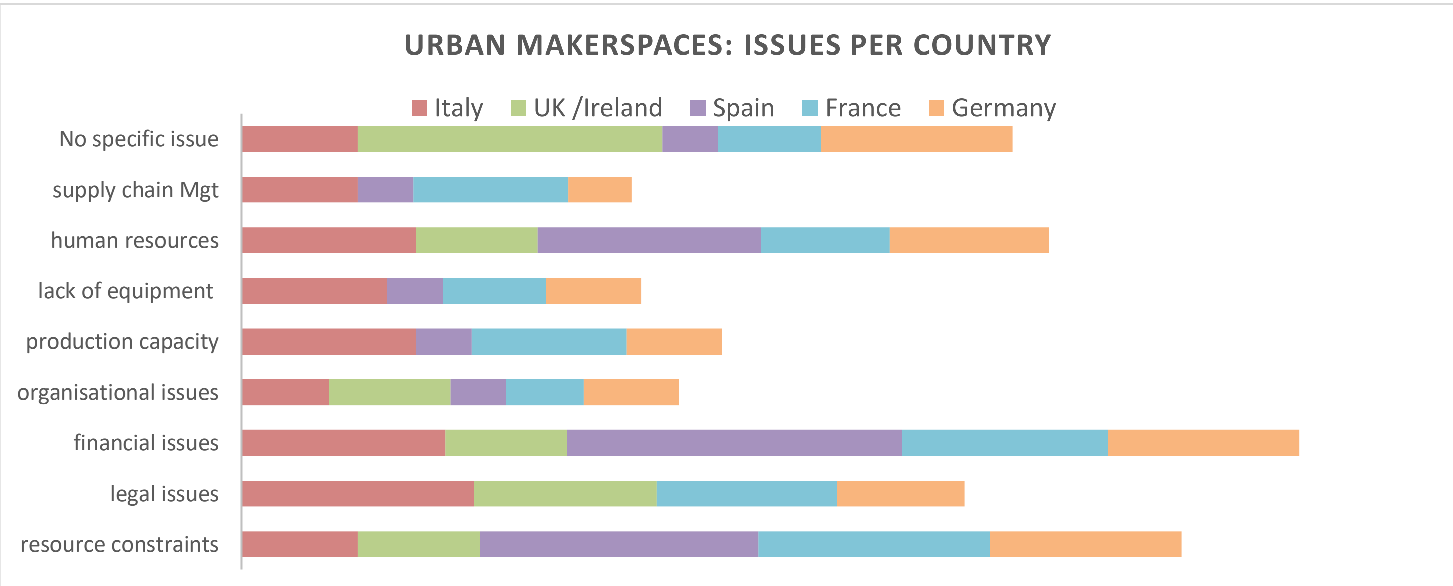


Matrix of rural makerspaces (n=24)

	resource constraints	legal issues	financial	organisation	production capacity	lack eq	lack human	supply chain	None
Greece							X		
Italy				X	X		X	X	
Italy			X						
Italy					X	X			
Italy	X	X		X			X		
Ireland			X					X	
Spain	X				X		X		
France									X
France									X
France				X					
France	X		X	X	X		X		
France	X	X	X	X	X	X	X	X	
France	X		X				X		
France		X			X	X			
France						X		X	
France							X		
France	X		X						
France		X	X				X		
Germany	X	X	X						
Germany									X
Germany									X
Germany	X		X			X			
Germany		X	X	X			X		
Österreich	X		X			X			

The matrix shows the issues faced by rural makerspaces. This representation mode gives a better overview of the simultaneity of problems, and possible correlations between different issues, depending on their occurence. For instance the correlations between legal issues and financial issues (17%) that would be worth digging deeper into.





	Italy	UK /Ireland	Spain	France	Germany	Austria	**Average**
resource constraints	17%	18%	42%	35%	29%	0%	**23%**
legal issues	35%	27%	0%	27%	19%	0%	**18%**
financial issues	30%	18%	50%	31%	29%	33%	**32%**
organisational issues	13%	18%	8%	12%	14%	0%	**11%**
production capacity	26%	0%	8%	23%	14%	0%	**12%**
lack of equipment	22%	0%	8%	15%	14%	0%	**10%**
human resources	26%	18%	33%	19%	24%	17%	**23%**
supply chain Mgt	17%	0%	8%	23%	10%	0%	**10%**
No specific issue	17%	45%	8%	15%	29%	50%	**28%**

APPENDIX 11: IMPACTS OF COVID-19 ON MAKERSPACES

14. Did the production processes of your space change since the COVID-19 crisis ?

☐ Yes, permanently ☐ Yes, temporarily ☐ Status quo ☐ No will to change

Table 1: Frequency table for the whole sample (N = 120)

```
FREQUENCIES
      /VARIABLES= Changes Preparedness
      /FORMAT=AVALUE TABLE.
```

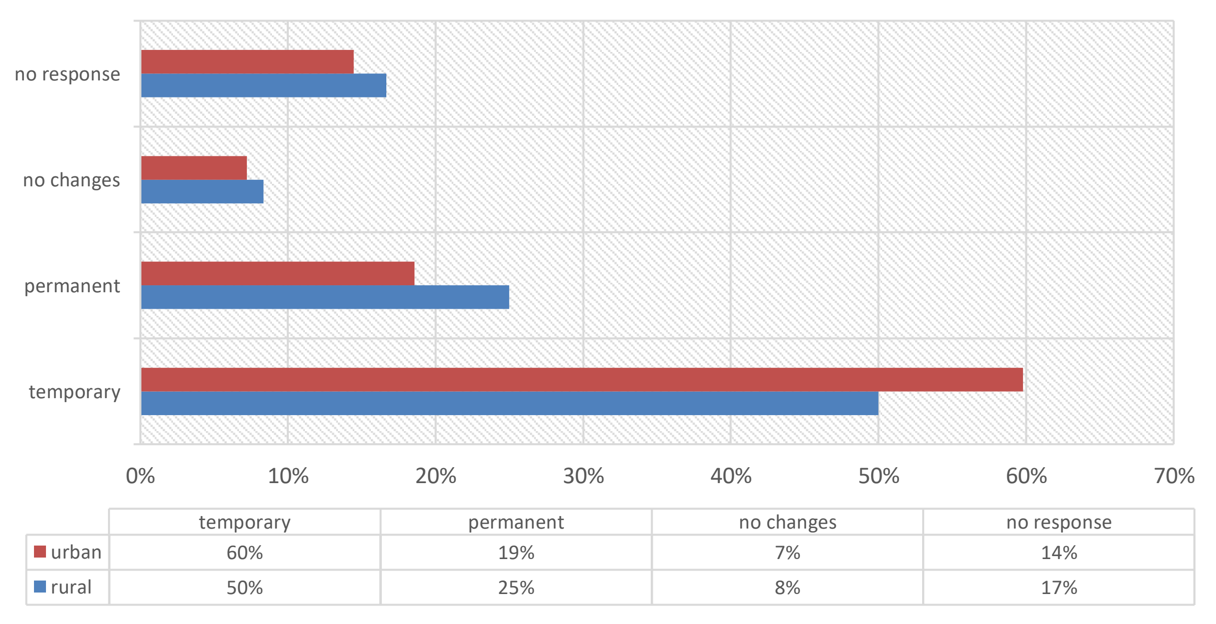
Changes

Étiquette de valeur	*Valeur*	*Fréquence*	*%*	*Pourcentage valide*	*Pourcentage cumulé*
temporal	1,00	68	54,40	56,67	56,67
permanent	2,00	24	19,20	20,00	76,67
status quo	3,00	19	15,20	15,83	92,50
no changes	4,00	9	7,20	7,50	100,00
	.	5	4,00	Manquant(e)	
	Total	125	100,0	100,0	

Changes

N	*Valide*	120
	Manquant(e)	5
Moyenne		1,74
Écart-type		,98
Minimum		1,00
Maximum		4,00

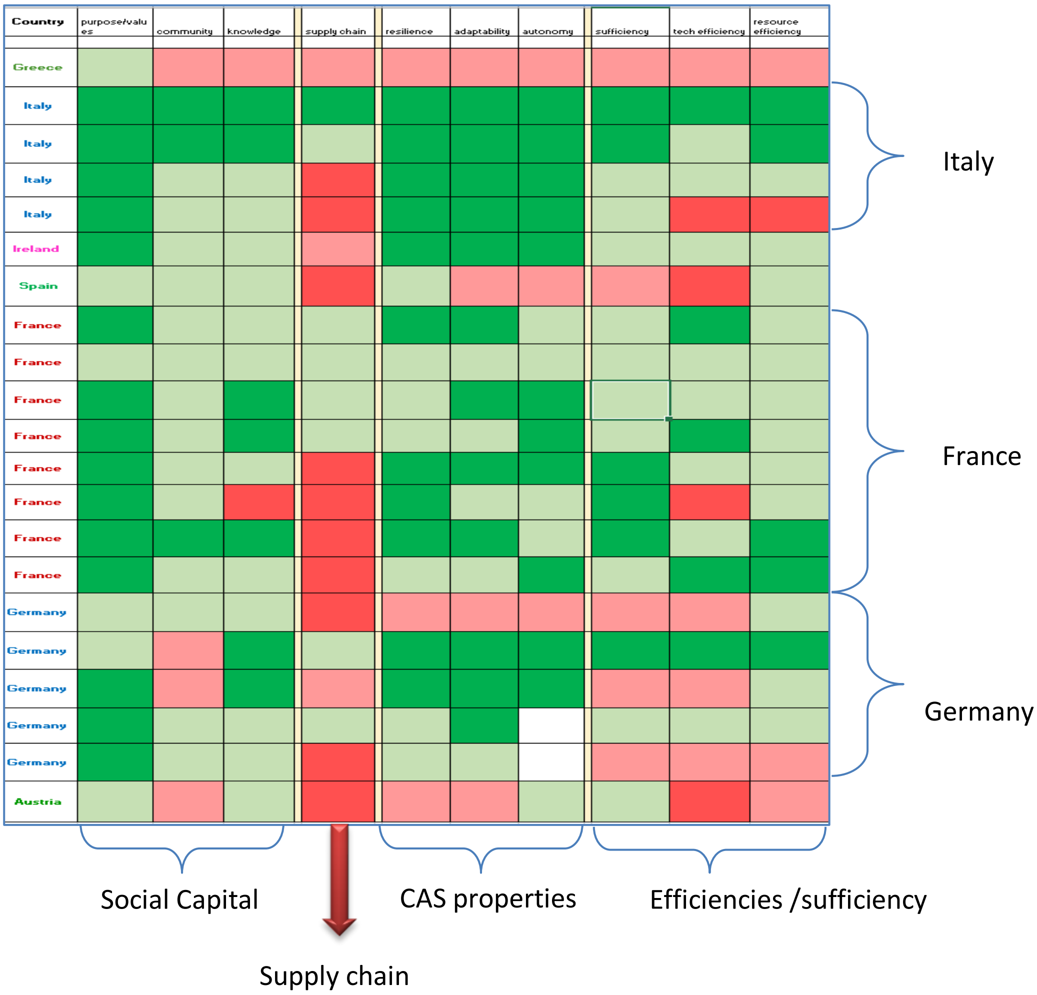
Figure 1: Changes among rural and urban makerspaces



APPENDIX 12: SWOT ANALYSIS

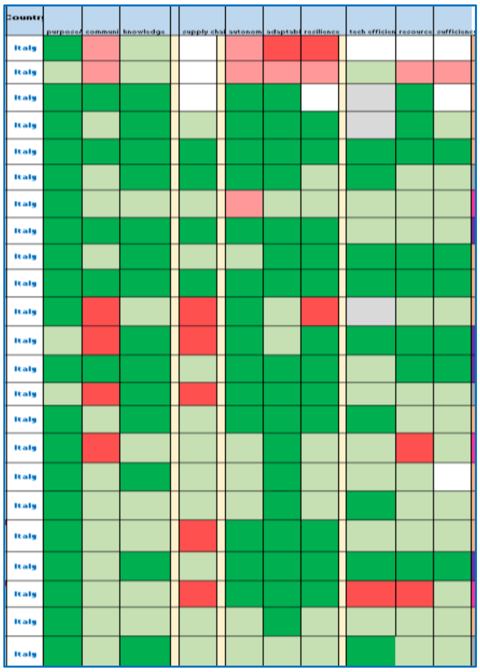
15. What are the internal strengths of the space, in your opinion ?

Matrix for European rural makerspaces



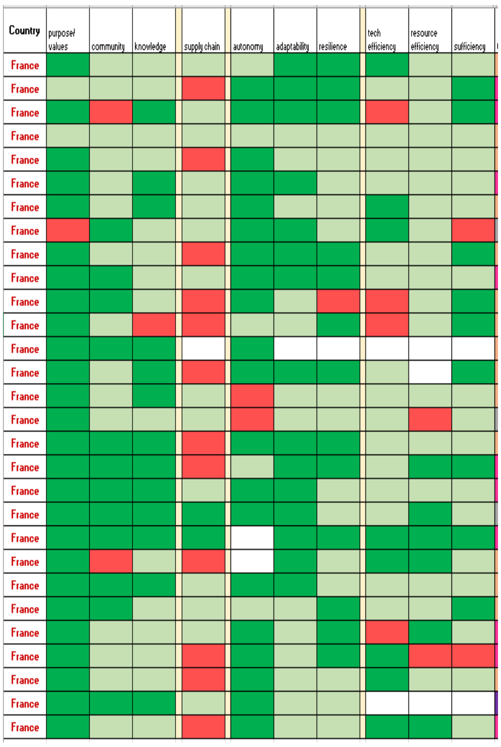
European rural makerspaces show very strong Social Capital (purposes, values and knowledge) and Human Capital (community and networks). Yet, Greek and 50% of German makerspaces mentioned that the community spirit could be improved in their area. 62% of European rural makerspaces stressed a problem of supply chain. And in most cases, the problem is accompanied by a lack of sufficiency, technlological efficiency and resource efficiency, and affects the autonomy, adaptability and resilience of makerspaces. 38% of makerspaces in rural area have a weak technical efficiency, i.e. internal production capacity due to a very weak supply chain .29% of rural makerspaces have been impacted permanently by the crisis, 47.6% temporally affected in their production processes and 24% were not impacted mostly status quo). 43% of rural makerspaces feel almost prepared to face new disruptions, and 9.5% highly prepared. 48% expressed uncertainties for the future. There are many potential for innovation in rural areas, but the capacities are still untapped, according to an Austrian rural makerspace.

Matrix SWOT of Italian Makerspaces :



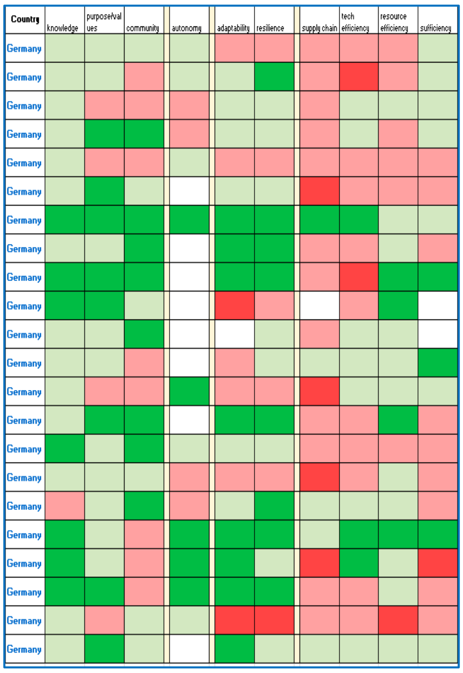
Overall, Italian makerspaces show very strong potentials in all categories (predominance of green pixels in the Matrix): very strong Social Capital, Human Capital, a great Adaptive Resource Management, efficiencies in technology and use of resources, and highly sufficient. External collaboration (Social Capital) and interpersonal skills (Human Capital), as well as strong purpose & values, with a strong knowledge base, R&D, dissemination of expertise (100% for both category) allowed a *"fast and flexible problem solving"* during the pandemic, according to Italian participants in the survey. Community and network (Social Capital): "*Flexibility in offering products/services, and a 'network' of companies*, museums and schools with which makerspaces collaborated. The multistakeholder collaboration: *"ability and willingness to collaborate and co-design*" with external actors (e.g. doctors, therapists, etc.)". "independence, solidarity, social involvement and help for schools". Yet some weaknesses have been observed in the Social Capital and the supply chain (Manufactured Capital): 26,1% of Italian makerspaces mentioned extremely weak community spirit or a lack of networked actions (red boxes in the Matrix). In terms of supply chain, 33,3% mentioned having a lack of management, along with a lack of network (20%).

Matrix SWOT of French Makerpaces :



Overall, French makerspaces show very strong Social Capital (purposes & values, community & network), Human Capital (knowledge, skills, intellectual outputs, motivation and capacity for relationships of the individual), great Adaptive Resource Management in terms of resilience, adaptability and autonomy. Concerning the Human Capital, the importance of the transmission of knowledge and the creation of a 'knowledge pool' among peers has been highlighted by French makers. Other French makers mentioned the "solidarity and pedagogy": despite the lockdown, makers and the public could meet on site, makerspaces were "widely open and free", and enjoy the "strong pedagogical support in the design of projects", and instill a maker spirit from 10 years old (translated from French). Most fablabs mentioned "Networking and territorial impact (FabCity)”. Most of the weaknesses are in the Manufactured Capital, i.e. the supply chain: 41,4% of French makerspaces mentioned it. Then, the technological efficiency and resource efficiency among French makerspaces are quite strong, but could be improved (more hell green boxes than dark green boxes in the Matrix); 13,8% of French makerspaces mentioned an extremely weak technological efficiency, i.e. internal capacity production assisted by the technology (red boxes in the Matrix).

Matrix SWOT of German Makerpaces :

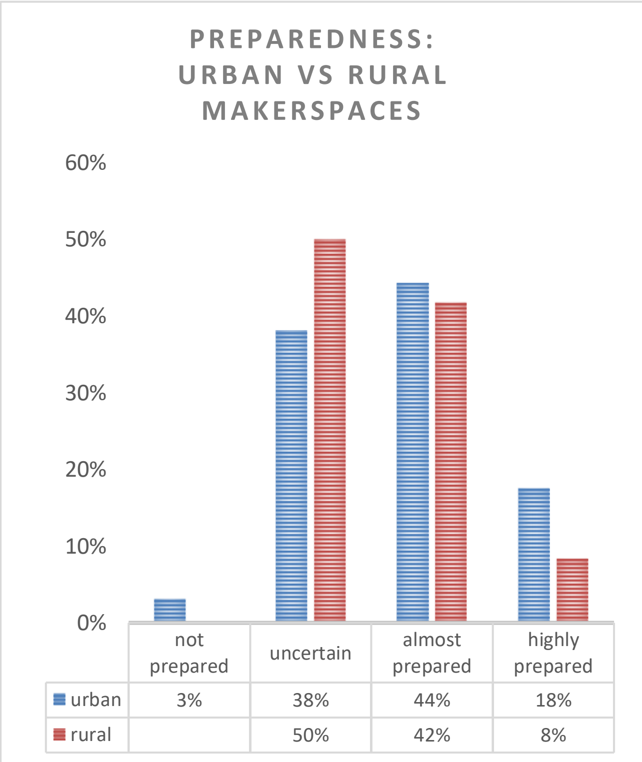


Overall, German makerspaces show a more nuanced picture, and more heterogeneity of capabilities than French and Italian makerspaces. Similar to the latter, German makerspaces show a strong Human Capital in terms of knowledge and expertise (95.5% and among them, 31.8% seing it as a very strong advantage) and strong purposes and values (Social Capital). Yet some weaknesses have been observed in the Social Capital regarding the community and networks of makersapces (36,4% of German makerspaces recognized that the community could be improved). Again, the supply chain (Manufactured Capital) of German makerspaces represent also a weakness: 76,2% mentioned having a weak supply chain (among them 19% supply chain as a strong weakness), thus only 23,8% of strong supply chain management. The weaknesses of the supply chain go along with very weak internal production capabilities (55% mentioned a weak technical efficiency of their space) and a lack of sufficiency (mentioned by 45.5%). Overall, German makerspaces were having a rather good adaptive management during the crisis, with 63.6% of German makerspaces mentioning simulteanously a strong adaptability and resilience, both essential emergent properties in a crisis context (c.f. Section 1, Complexity science), and 27.3% of German makerspaces felt a lack of both.

APPENDIX 13: PREPAREDNESS

Q17. Given the strengths or weaknesses, would you say that your space is prepared to face new disruptions? (e.g. disruption of supply chain, shortages of essential goods, etc.)

Not prepared	uncertain	almost prepared	highly prepared
☐	☐	☐	☐



Preparedness * Typology [nombre, total %].

Preparedness	*Typology* urban	semi urban	rural	hybrid	Total
highly prepared	12,00 10,17%	4,00 3,39%	2,00 1,69%	,00 ,00%	18,00 15,25%
almost prepared	33,00 27,97%	7,00 5,93%	9,00 7,63%	3,00 2,54%	52,00 44,07%
uncertain	29,00 24,58%	4,00 3,39%	10,00 8,47%	2,00 1,69%	45,00 38,14%
not prepared	3,00 2,54%	,00 ,00%	,00 ,00%	,00 ,00%	3,00 2,54%
Total	77,00 65,25%	15,00 12,71%	21,00 17,80%	5,00 4,24%	118,00 100,00%

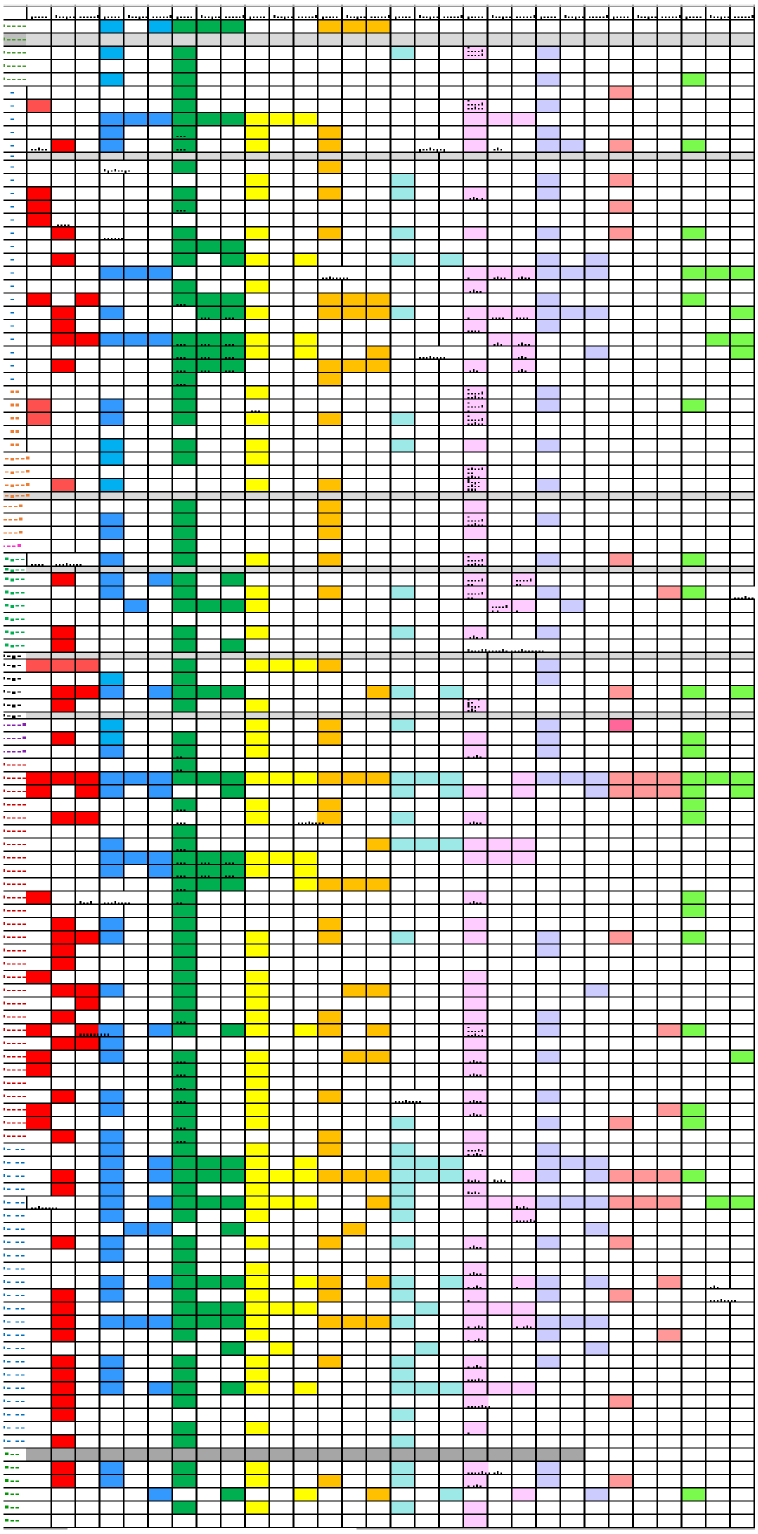
Tests de Khi-Deux.

Statistique	*Valeur*	*df*	*Sig. asymptotique (bi-variée)*
Khi-Deux de Pearson	5,46	9	,792
Rapport de vraisemblance	7,02	9	,635
Association linéaire-par-linéaire	,06	1	,804
Nombre d'observations valides	118		

The impacts of Covid-19 on production processes within makerspaces did not affect the preparedness of makerspaces in the future, as the correlation between changes and preparedness is not significant (Chi square is not significant). If a makerspace was permanently impacted by the crisis, it does not necessarily mean that it will be highly prepared to face new disruption in the future. It questions the vulnerability, exposure, sensitivity and resilience of makerspace after a shock.

APPENDIX 14: MAKERSPACES SECTORS

Q18. In which sectors does your makerspace operate?



Overview at the European level:

Mosaic of sectors in which makerspaces operate before, during and after the pandemic.

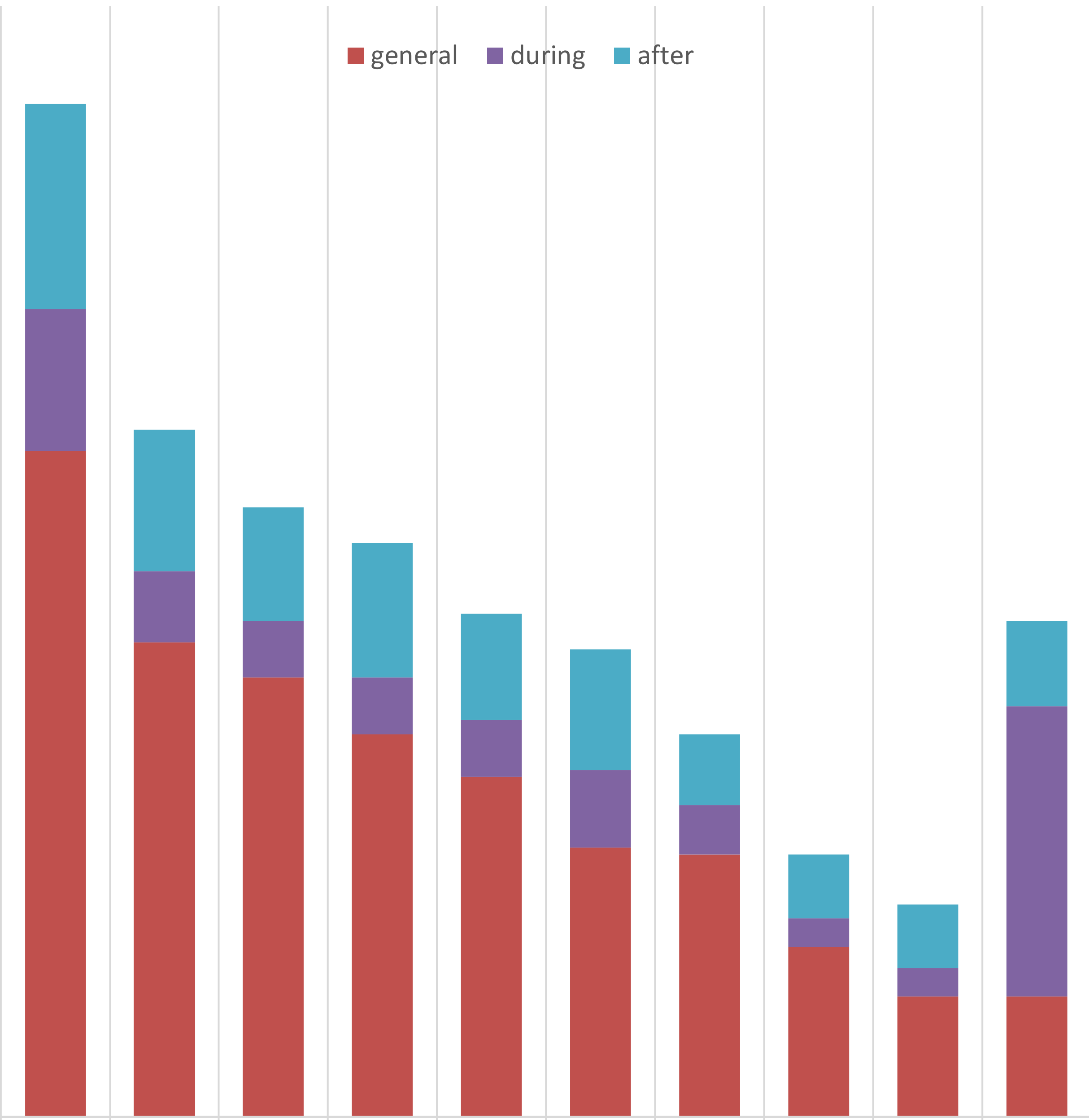
This mode of presentation better shows the transdisciplinarity of makerspaces and the diversity of sectors they operate.

Each row rcorresponds to a makerspace and each colomun refers to the temporal scale: in general, during and after the crisis.

Each colours respresents a sector:

The most predominant and regular color is dark green representing the education sector

SECTORS IN WHICH MAKERSPACES OPERATE IN EUROPE



	Education	Arts, Mode	Repair activities	Micro Electronics, Computer Engineering	Industry, Machinery, Mechanics	Media, ICT	Construction sector	Agriculture	Transport, Mobility	Health(care)
after	25,9%	17,9%	14,3%	17,0%	13,4%	15,2%	9%	8,0%	8,0%	10,7%
during	17,9%	8,9%	7,1%	7,1%	7,1%	9,8%	6%	3,6%	3,6%	36,6%
general	84%	59,8%	55,4%	48,2%	43%	34%	33%	21,4%	15,2%	15,2%

APPENDIX 15: PRODUCTION PROCESSES

Q19. Which production process better reflect your space now ?

```
DESCRIPTIVES
  /VARIABLES= SM Circular AM DIY Distribute SUP P2P CBPP DGML Repair IM
  /STATISTICS=MEAN STDDEV.
```

Cas valides = 114; cas avec valeur(s) manquante(s) = 1.

Variable	*N*	*Moyenne*	*Écart-type*
SM	113	,52	,61
Circular	113	,36	,60
AM	113	,62	,60
DIY	113	,65	,59
Distribute	113	,30	,58
SUP	113	,30	,58
P2P	113	,25	,56
CBPP	113	,19	,53
DGML	113	,19	,53
Repair	113	,42	,58
IM	113	,19	,49

Variable	Valeur	Étiquette
Typo	1	urban

Cas valides = 72; cas avec valeur(s) manquante(s) = 0.

Variable	*N*	*Moyenne*	*Écart-type*
SM	72	,47	,56
Circular	72	,25	,50
AM	72	,51	,56
DIY	72	,64	,54
Distribute	72	,22	,48
SUP	72	,25	,50
P2P	72	,18	,45
CBPP	72	,13	,41
DGML	72	,13	,41
Repair	72	,29	,46
IM	72	,10	,30

Variable	Valeur	Étiquette
Typo	2	semi urban

Cas valides = 16; cas avec valeur(s) manquante(s) = 0.

Variable	*N*	*Moyenne*	*Écart-type*
SM	16	,69	,70
Circular	16	,56	,73
AM	16	,81	,66
DIY	16	,56	,73
Distribute	16	,44	,73
SUP	16	,56	,73
P2P	16	,44	,73
CBPP	16	,31	,70
DGML	16	,31	,70
Repair	16	,63	,72
IM	16	,50	,73

Variable	Valeur	Étiquette
Typo	3	rural

Cas valides = 21; cas avec valeur(s) manquante(s) = 0.

Variable	*N*	*Moyenne*	*Écart-type*
SM	21	,57	,75
Circular	21	,57	,75
AM	21	,90	,62
DIY	21	,86	,65
Distribute	21	,48	,75
SUP	21	,33	,73
P2P	21	,33	,73
CBPP	21	,33	,73
DGML	21	,33	,73
Repair	21	,76	,70
IM	21	,29	,72

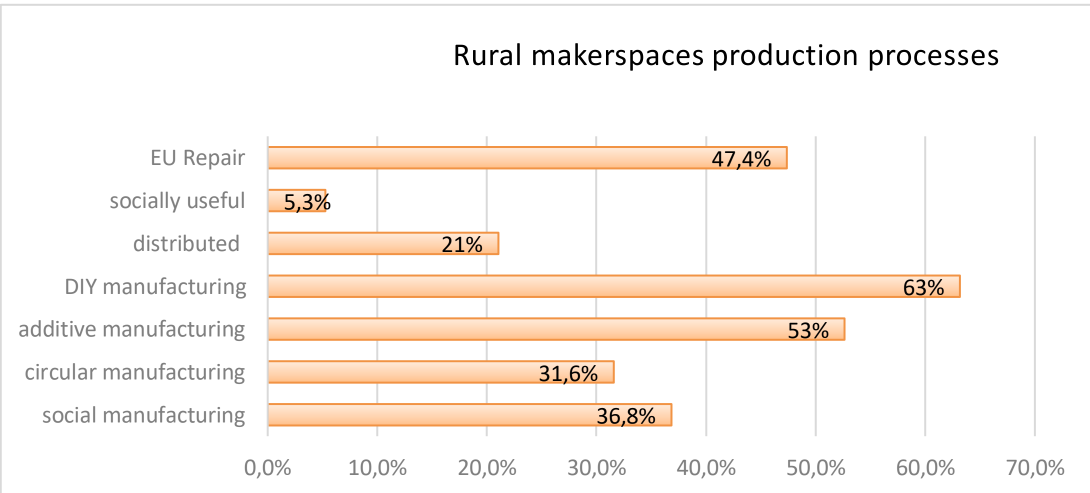
Variable	Valeur	Étiquette
Typo	4	specific

Rural makerspaces production process

We observe a clear pattern of rural makerspace, despite the small sample at hand (19 responses). Among the 22 makerspaces which participated, 3 non-responses. The sample is not representative of rural makerspaces in Europe, but can give some directions.

Country	Social Manufacturing	Circular manufacturing	Additive manufacturing	DIY Manufacturing	Distributed manufacturing	Socially useful	P2P	CBPP	DGML	Repair
Greece		REFLOW		VULCA	Distributed Design				COSMO	
Italy										
Italy										
Italy										
Italy										
Ireland										EU repair
Spain										
France										
France										
France				VULCA						
France				VULCA						
France										
France	POP MACHINA	REFLOW								
France				VULCA						
France				VULCA						
France				VULCA						
Germany										EU REPAIR
Germany										
Germany										
Germany										
Germany										
Austria										

social manufacturing	**36,8%**
circular manufacturing	31,6%
additive manufacturing	53%
DIY manufacturing	63%
distributed	21%
socially useful	5,3%
EU Repair	47,4%



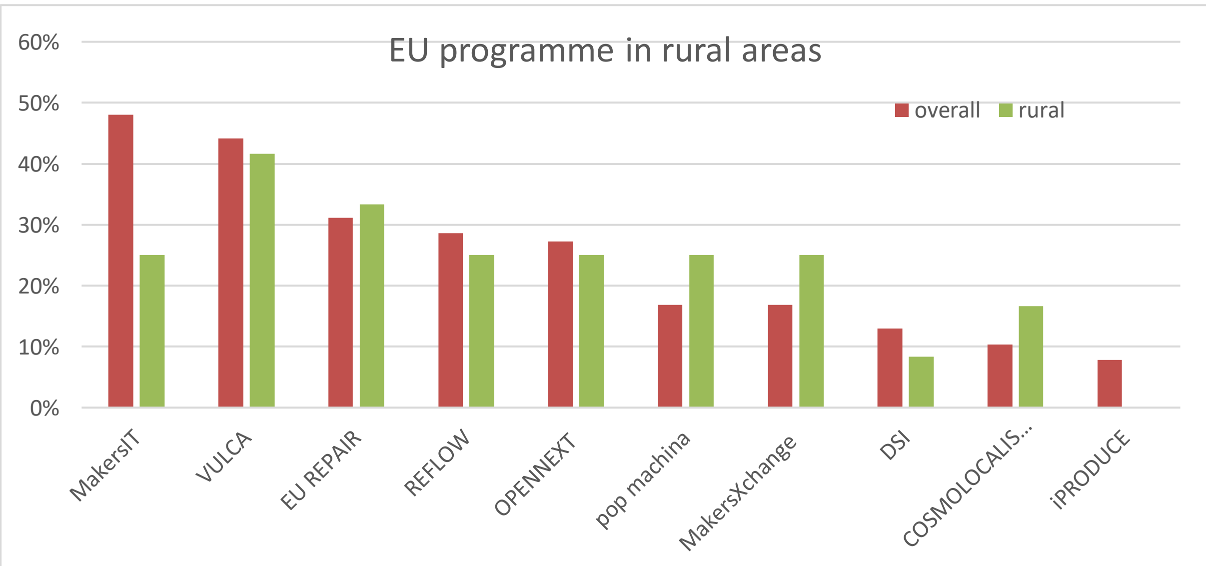
APPENDIX 16: EU PROGRAMMES

20. Which EU makerspace programs are you familiar with, and in which one is your space involved in ?

Makerspaces familiar with EU programmes overall

EU program	familiar with	active
MakersIT	48%	
VULCA	44%	12
EU REPAIR	31%	5
REFLOW	29%	5
OPENNEXT	27%	
pop machina	17%	3
MakersXchange	17%	
DSI	13%	
COSMOLOCALISM	10%	1
iPRODUCE	8%	

Only half of responses from rural makerspaces (n=12 instead of n=24)



APPENDIX 17: MAKERS PROFILE

Status (Q25), education & skills (Q26), gender (Q28) and age (Q29)

Table: Descriptive statistics of education and skills

/STATISTICS=MEAN STDDEV VARIANCE.

Diploma

Étiquette de valeur	*Valeur*	*Fréquence*	*%*	*Pourcentage valide*	*Pourcentage cumulé*
bachelor	1	29	23,20	23,58	23,58
master	2	42	33,60	34,15	57,72
Phd	3	11	8,80	8,94	66,67
other diploma	4	19	15,20	15,45	82,11
apprenticeship	5	8	6,40	6,50	88,62
no specific education / self taught	6	14	11,20	11,38	100,00
	.	2	1,60	Manquant(e)	
	Total	125	100,0	100,0	

Diploma

N	*Valide*	123
	Manquant(e)	2
Moyenne		2,81
Écart-type		1,65
Variance		2,71

STEAM

Étiquette de valeur	*Valeur*	*Fréquence*	*%*	*Pourcentage valide*	*Pourcentage cumulé*
mentioned	1	40	32,00	32,52	32,52
not mentioned	2	83	66,40	67,48	100,00
	.	2	1,60	Manquant(e)	
	Total	125	100,0	100,0	

STEAM

N	*Valide*	123
	Manquant(e)	2
Moyenne		1,67
Écart-type		,47
Variance		,22

Founder

Étiquette de valeur	*Valeur*	*Fréquence*	*%*	*Pourcentage valide*	*Pourcentage cumulé*
no	0	44	35,20	35,77	35,77
yes	1	79	63,20	64,23	100,00
	.	2	1,60	Manquant(e)	
	Total	125	100,0	100,0	

Founder

N	*Valide*	123
	Manquant(e)	2
Moyenne		,64
Écart-type		,48
Variance		,23

Gender

Étiquette de valeur	*Valeur*	*Fréquence*	*%*	*Pourcentage valide*	*Pourcentage cumulé*
male	1	104	83,20	85,95	85,95
female	2	17	13,60	14,05	100,00
	.	4	3,20	Manquant(e)	
	Total	125	100,0	100,0	

Gender of makers, Eropean level

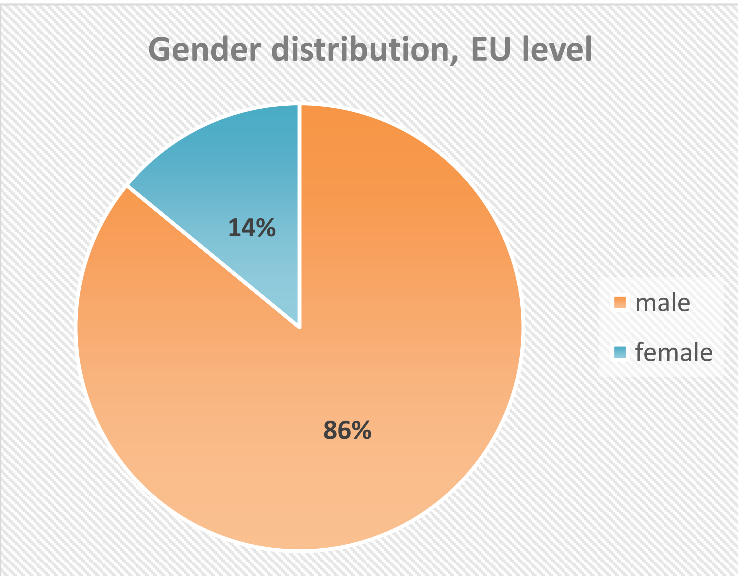
Frenquency table: gender for N=125

Gender

Étiquette de valeur	*Valeur*	*Fréquence*	*%*	*Pourcentage valide*	*Pourcentage cumulé*
male	1	104	83,20	85,95	85,95
female	2	17	13,60	14,05	100,00
	.	4	3,20	Manquant(e)	
	Total	125	100,0	100,0	

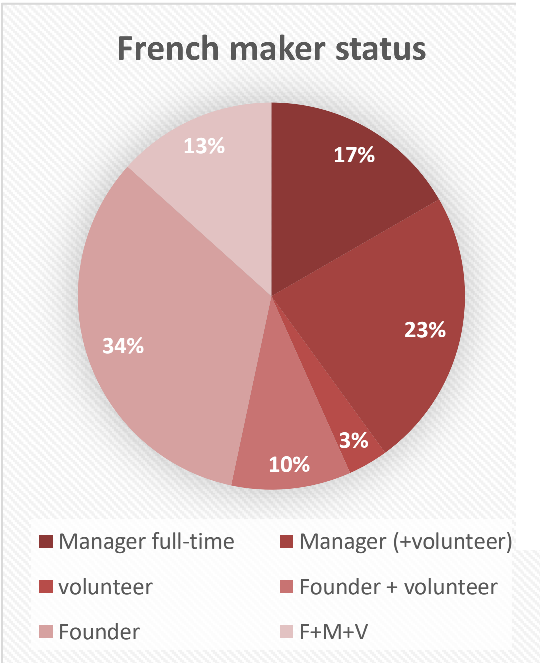
Gender

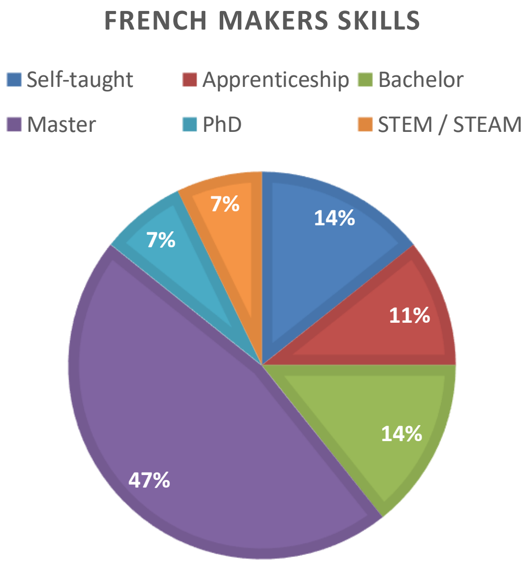
N	*Valide*	121
	Manquant(e)	4
Moyenne		1,14
Écart-type		,35
Variance		,12



French makers

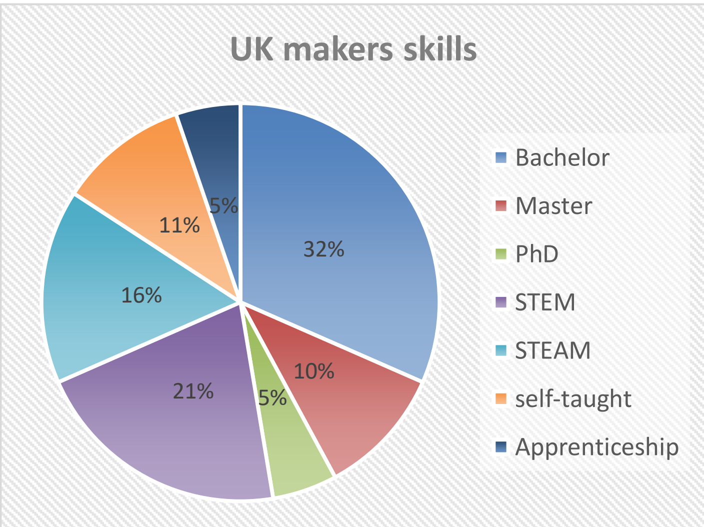
Among the French makers participants, 15% women and 85% men (c.f. Graph). The majority of French makers (61,5%) are between 25-45 years old. The majority of makers are pluridisciplinary and **endorse multiple roles** within the makerspaces (54% of them), for instance being both a Manager (Communication or Project Manager) and a volunteer (23% of Manager + volunteer) or Founder and volunteer (31%), as illustrated in the Graph French makers status). The majority of French makers have a Master Degree (46%), then a Bachelor Degree. Some makers mentioned specific educational background, such as FACLAB, CISCO certification. Specific skills, the STEM skills, and Design skills (Master in Product Design) which refers to the STEAM skills (STEM + Arts). Some are self-taught makers (11%).

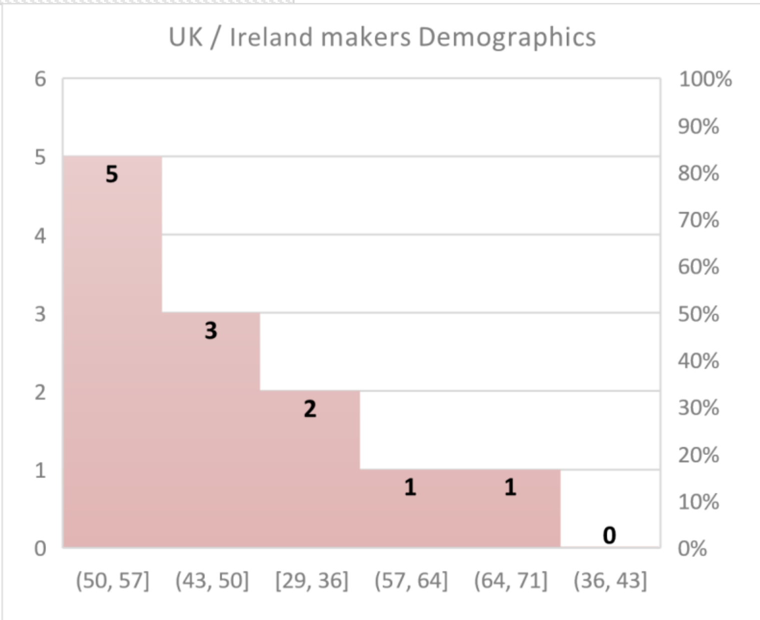




UK makers

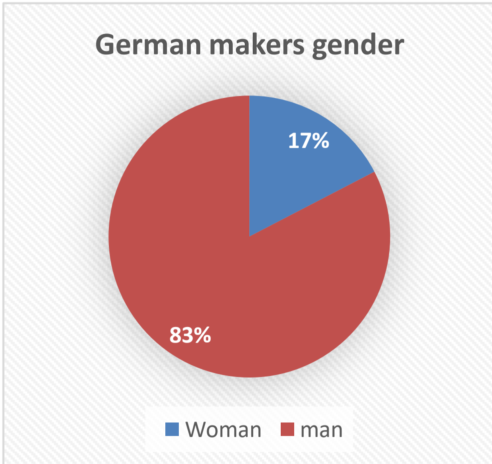
All UK and Irish makers participants are men (c.f. Graph). The majority of them (82%) are between 47-68 years old. The majority of makers are pluridisciplinary and **endorse multiple roles** within the makerspaces (% of them), for instance being both a Manager (Communication or Project Manager) and a volunteer (% of Manager + volunteer) or Founder and volunteer (31%), as illustrated in the Graph French makers status). The majority of French makers have a Master Degree (46%), then a Bachelor Degree. Most makers holding a Bachelor Degree accompanied by STEAm or STEAM skills (27% of makers). STEM skills and STEAM skills (39%). Some are self-taught makers (11%). **Not representative of the skills of all members in the makerspace** : “LHS has people from 6-year-olds learning beginner's wood-working skills up to post-Doc's working on their research”. There are only members in our space. There are Trustee's that act as the directors of the Ltd Company that we use as the legal shell that allows us to rent the buildings that we have had/are using currently/will use in future.”





***German makers*.**

Among the 23 <u>German makers participants</u>, 17% women and 83% men. The large majority of German makers (75%) are between 25-38 years old: **a new generation of very young German makers, who founded German makerspaces** (41.6% of the 25-38 years old) with an average age of 30.5. The majority of makers are pluridisciplinary and **endorse multiple roles** within the makerspaces (54% of them), for instance being Manager, volunteer and Founder (63.6%), as illustrated in the Graph. They have a Master Degree (19%), then a Bachelor Degree (19%). 31% of them have STEM skills. In Other educational, some specific education to Germany: “Fachabitur”, Diplom FH, “fachhochschuleriefe”. No specific educational background (6%).



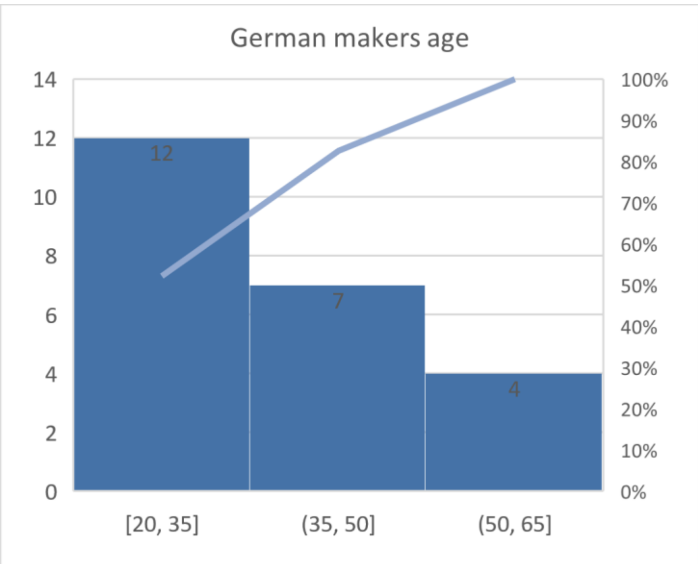
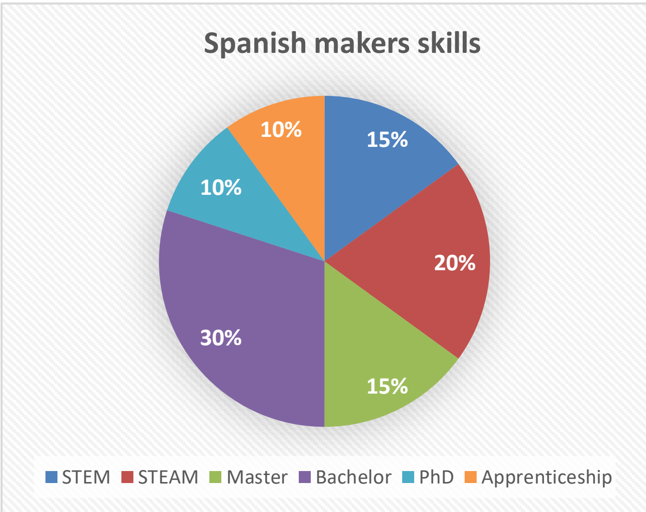


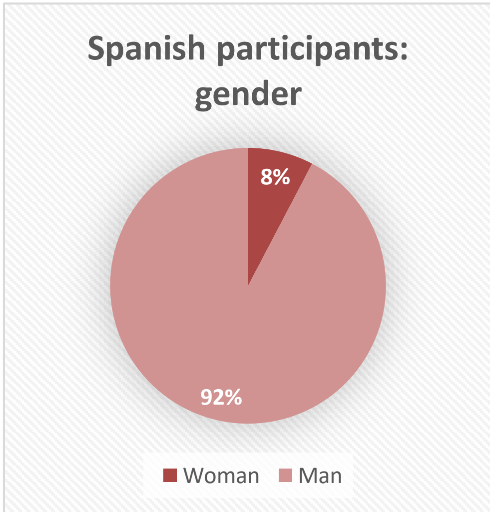
Table : German makers profile

STATUS	**DIPLOMA**	**AGE**	**GENDER**
Member	Fachabitur	37	Woman
Founder, member. Volunteer	fachhochschuleriefe	25	Man
Founder, Member, Administration, Volunteer	Diplom FH, STEM	42	Man
Founder, volunteer	Master. STEM	42	MAn
Founder, Manager, Project, Member, volunteer	Bachelor	35	Man
Founder, Manager, Project, Member, volunteer	Bachelor	31	Woman
Member, Founder, Manager, volunnteer	Master	36	Man
member, not regular	micht	30	Man
member	STEM, Staatlich geprüfter Techniker	26	Man
Founder, Manager	STEM, Bachelor	25	Man
member, volunteer	Bachelor	34	Woman
Manager, volunteer	Master, STEM	53	Man
member, volunteer	Bachelor	34	Woman
Founder, Member, part-time employee	stattl. gepr. Techniker Maschinenbau Fertigungstechnik	64	Man
Full-time emplyee	STEM, Fachinformatiker für Anwendungsentwicklung	28	Man
Founder, owner, Manager, Project Manager, member	Secondary school, IT specialist in application development	20	Man
Founder, owner, Manager	PhD + STEM	63	Man
Founder, owner, Project Manager	Master	50	Man
Member	Master + STEM	32	Man
Founder, Member, Volunteer	Bachelor	49	Man
Founder, owner, Manager, Project Manager	STEM	51	Man
Founder, fulltime	Master	47	Man
part-time employee/ volunteer	STEM / Bachelor	26	Man

Spanish makers.

Spain is the country in Europe when we observe a very young generation of founders of Spanish makerspaces especially men between 24-30 years old (36% of Spanish makers), although they do not represent the majority of Spanish makers: 64% are between 44-54 years old. Half of the Spanish makers participants holds conventional Degree (53%), either a Bachelor (23%), a Master (28%) or a PhD (12%). Their degree is most of the time accompanied by the typical makers skills, i.e. the STEM & STEAM skills, respectively 17% and 18% of them. Indeed most of the Spanish makers (54%) mentioned having both theoretical and practical knowledge, i.e. the combination of either Master/Bachelor/PhD with a STEM/STEAM skill set: Master + STEM/STEAM skills, or PhD + STEM skills, or a Bachelor + STEM / Bachelor + STEAM skills, or Apprenticeship + STEAM skills.





Austrian makers. Among the 5 Austrian makers participants, they are all men and founders of makerspaces, with an **average age of 47**. They have a Master Degree (19%), then a Bachelor Degree (19%). 31% of them have STEM skills.

Belgium makers. Among the 6 makers participants from Belgium, they are all men and Managers of makerspaces, with an **average age of 32.3**. They have a Master Degree (67%), a Bachelor Degree (16%), with some specifities: one having STEM skills together with his Bachelor Degree, an another maker having an Engineer Diploma working full-time at the makerspace, an another having a CAPS (professional formation), an another being self-taught.

Greek makers. Among the 4 Greek makers participants, 1 woman and 3 men. They are between 30-45 years old, **thus a generation of young Greek makers** with an average age of 36.5**,** mostly Managers and Project managers (3 out of 4) and 1 Founder (30 years old). They have Master Degree (40%), Bachelor Degree (20%). 20% of them have STEM skills.

APPENDIX 18: VOCABULARY

Q27 (open-ended question) : Which new vocabulary / tools would illustrate for you the makerspaces actions during the Covid-19 crisis?

If you think of words, terminology, metaphors or expressions ('tinkering', 'mending', 'care', 'repurpose', 'commoning'), or if you think of specific literature, authors, technology, symbolic device/ tools, ...

The written text and words were coded and translated into a word coulding chart (c.f. Figure below), with a software which classifies proportionally the words according to their frequence

Other specific responses in the survey:

- "stoici" (in Italian means: who endures pain and adversity with courage),
- "Corolab" a new terminology describing labs, i.e. makerspaces, dedicated to the conception of Coronavirus-related items or products

Figure: Word clouding chart of makerspaces terminology mentioned in Q27

APPENDIX 19

Manifesto for a Distributed manufacturing in France

October 2020

<< Distributed manufacturing: the key to a resilient, job-creating and environmentally friendly production system

Distributed manufacturing is a decentralized mode of production made possible by the deployment of the Internet. It is based on the pooling of skills and means of production on a human scale, with the aim of designing, manufacturing and distributing products. The singular dynamics of this network is based on the great variety of its actors, ranging from citizens equipped with 3d printers, to specialized territorial actors (fablabs, hackerspaces, third places of innovation) through VSEs and SMEs.

By destabilizing the whole of our productive apparatus, the health crisis of Covid-19 has highlighted its intrinsic fragility. Caregivers have lacked essential equipment, and supply disruptions have occurred abruptly.
Such upheavals of the classical productive system produce long-lasting economic and social damages, like those we see today. These effects will accumulate with each health or ecological crisis, and are likely to multiply in the short term. It is therefore more than necessary today to innovate in our modes of production.
It is in this context that, throughout France (and around the world), craftsmen, citizen-manufacturers, caretakers, engineers, entrepreneurs and « makers » have spontaneously organized themselves to meet the basic material needs of people on the front line. From hand-stitched masks to state-of-the-art medical equipment and new decentralized platforms and mutual aid networks, everyone was able to participate in the collective effort according to their talents and means. Far from being new, these territorial, collaborative and distributed modes of production are now taking full advantage of the potential of digital tools.
By compensating for the damage to our usual production system, they have demonstrated their effectiveness in responding rapidly to new needs and making our societies more united and resilient. We defend the idea that we need to learn from and implement these agile approaches, in order to diversify and improve our productive system at the cost of little investment and in the near future. Such an evolution is possible thanks to the intrinsic and unique qualities of these modes of production.
First of all, their **efficiency**: during containment, groups of manufacturers, caregivers and designers have spontaneously formed and self-organized around platforms and forums. While

the international mask industry was saturated, it was these new players who took over. The model proposed by the Grenoble University Hospital Center has toured all over France. Volunteers, VSEs, SMEs, and certain manufacturers have entered the distributed manufacturing dynamic based on simple, accessible and easily replicable methods. If these collaborative design and production methods are so effective, it is because they are rooted in the history of free software, which dates back to the 1990s, and have never ceased to be experimented with and improved in places with a « maker » philosophy, such as hackerspaces, fablabs and other third places.

Their agility and quality: Thanks to the collective intelligence, the materials are designed extremely quickly. The plans put online are accessible to all, tested, validated and improved by the entire international community of engineers, researchers, caregivers and enthusiasts. Objects are manufactured almost instantaneously thanks to simple and accessible machines, such as 3D printers, allowing to produce reliable and inexpensive equipment in record time. Networks of « makers » have thus helped save lives by alleviating the lack of spare parts in state-of-the-art medical equipment (respirators, syringe pumps, etc.).

The social and ecological impact of distributed manufacturing: thousands of citizens participated in the collective effort, spontaneously, and with the recognition and help of all. These modes of production meet the aspirations of our societies: a more local production whose ecological footprint is taken into account, a more circular, inclusive and virtuous economy.

To accompany the transformation of our post-crisis production system, and to lay the foundations for a more resilient society, we need to develop and support these practices.

Internet platforms are deployed and able to demonstrate economically viable distributed manufacturing, remunerating the contributions of each individual, and facilitating collective intelligence by using open source licenses in particular. They would allow everyone to benefit from each other's skills and creativity.

Our country is rich in know-how and innovative dynamics that are just waiting to be contributed and developed. Today, it is possible to deploy a production system based on a network of micro means of production that create jobs that cannot be relocated, strengthening social ties, favoring short circuits and simplifying logistics flows.

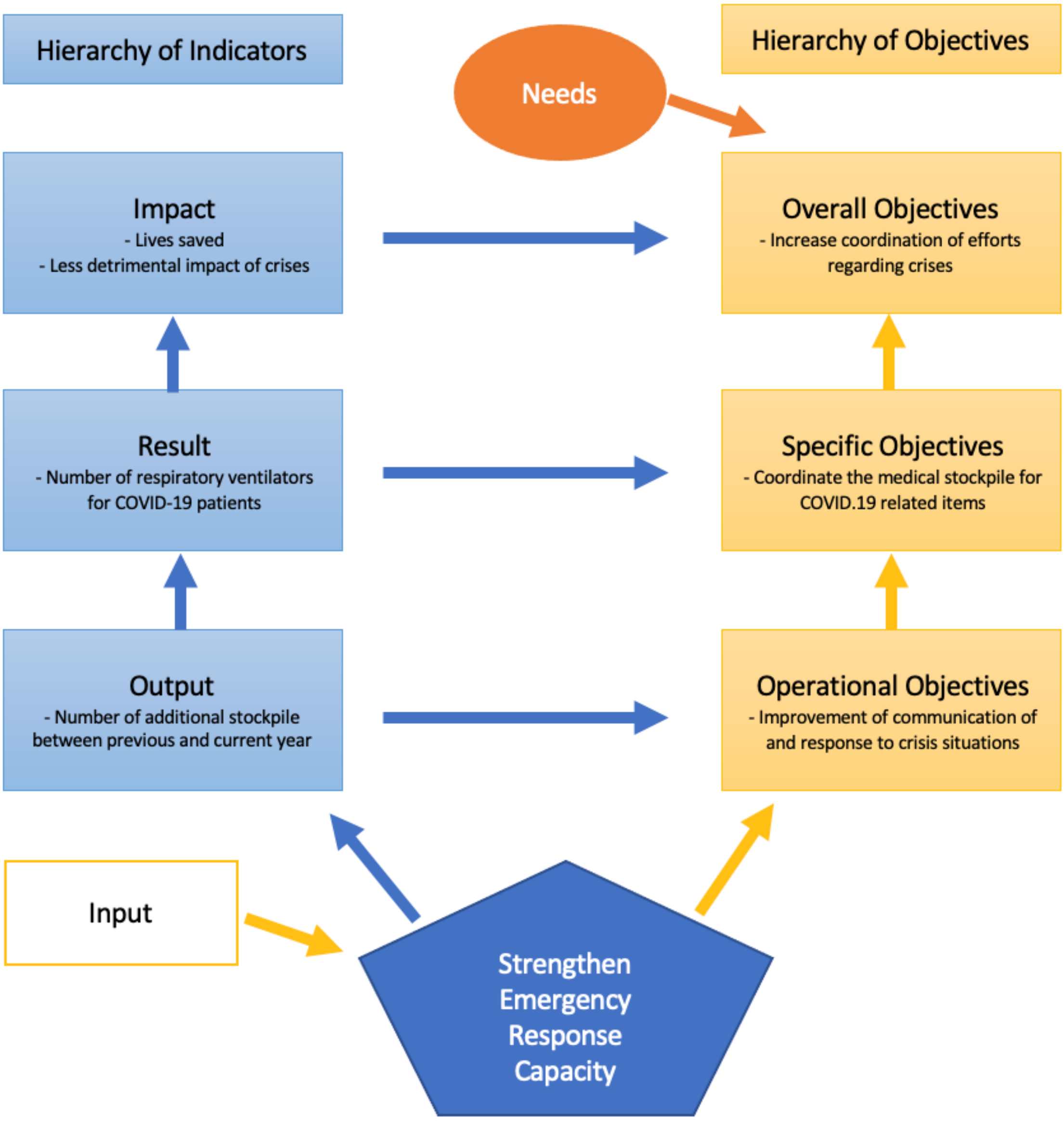
Let's dare to organize an industrial renewal participating in the economic revival and ecological transition. Everything is already in front of our eyes, it is up to us to act. An ambitious public policy is needed to give real scope to these flourishing, innovative, ethical and inclusive initiatives. >>

Source: 200 signataires pour la fabrication distribuée | FabriCommuns
[French & English version]

APPENDIX 20

RescEU policy

Figure 2: Intervention Logic of the rescEU policy



Source: own

Figure 1: rescEU Medical Stockpile for COVID-19 related items in 2021