Enhancing Competitiveness, Resilience and Sustainability of Remote Farming, Forestry and Rural Areas through Holistic Assessment of Smart XG, Last-mile and Edge Solutions' Gains

D2.2: Social innovation analyses to ensure fair transition

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Funded by the European Union

Grant Agreement No.	101060294		
Project Acronym	XGain		
Project Title	Enhancing Competitiveness, Resilience and Sustainability of Remote Farming, Forestry and Rural Areas through Holistic Assessment of Smart XG, Last-mile and Edge Solutions' Gains		
Type of action	HORIZON Research and Innovation Actions		
Call Topic	HORIZON-CL6-2021-COMMUNITIES-01-03		
Project Start Date	September 1st, 2022	**Project End Date**	August 31st, 2025
Project URL	xgain-project.eu		
Work Package	WP2 | Interactive Definition of User-oriented Requirements		
WP Lead Beneficiary	Stichting Wageningen Research (WR)		
Deliverable type[1] | Dissemination level[2]	R | PU		
Contractual due date	30 December 2023	**Actual submission date**	20 December 2023
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Revision history (including peer reviewing & quality control)

Version	Issue Date	% Complete	Changes	Contributor(s)
V0.1	06/02/2023	10	Initial Deliverable Structure	Katrine Soma (WR); and WR team
V0.2	02/05/2023	60	First draft report	Katrine Soma (WR); and WR team
V0.2	12/05/2023		Quality control	Johannes Waldmüller (ZSI)
V0.2	12/05/2023		Quality control	Eirini Liotou (ICCS)
V0.2	25/10/2023		Peer review	Mark Ryan (WR)
V0.3	03/12/2023	95	Second draft report	Katrine Soma (WR); and WR team
V0.3	06/12/2023		Peer review	Mark Ryan (WR)
V0.3	08/12/2023		Peer review	Anargyros Roumeliotis (ICCS)
V0.3	11/12/2023		Peer & QA review	Panayiotis Klitou (eBOS)
V0.4	19/12/2023	100	Final report	Katrine Soma (WR); and WR team

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XGain Consortium			
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6	EIGEN VERMOGEN VAN HET INSTITUUT VOOR LANDBOUW - EN VISSERIJONDERZOEK	EVILVO	BE
7	FUNDACIO PRIVADA I2CAT, INTERNET I INNOVACIO DIGITAL A CATALUNYA	I2CAT	ES
8	INCITES CONSULTING SA	INC	LU
9	INTRACOM SA TELECOM SOLUTIONS	ICOM	EL
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12	STICHTING WAGENINGEN RESEARCH	WR	NL
13	UAB ART21	ART	LT
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Glossary of terms and abbreviations used

Abbreviation / Term	Description
ADOPT	Adoption and Diffusion Outcome Prediction Tool (https://www.csiro.au/en/research/technology-space/it/adopt)
AI	Artificial Intelligence
BRL	Balanced Readiness Level
CAP	Common Agricultural Policy
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Digital divide	Refers to gaps in access, use and impact of digital resources that affect individuals, populations, households, companies or regions
Digital sustainability	Refers to relevant to environmental, social, technological, economic and societal factors. Can account for multiple sustainable development goals (SDGs), including reduced inequalities (SDG10) and sustainable cities and communities (SDG11).
Digitalisation	Refers to social interactions including digital and media communications, referring to the broader use of digital and media communications including social interactions
Digitisation	Refers to a process to transform analogue data to 'digital' information
DoI	Digital Object Identifier
EcRL	Economic Readiness Level
EnRL	Environmental Readiness Level
ICTs	Information and Communication Technologies
Informational governance	Refers to two interrelated processes: new forms of governing through information, and transformative changes in governance institutions due to new information flows.
IoT	Internet of Things
MCA	Multicriteria Analyses
MRS	Multirobot System
PAL	Peak Adoption Level
SDG	Sustainable Development Goal
SoRL	Societal Readiness Level
SRL	Social Readiness Level
TPAL	Time to Peak Adoption Level
TRL	Technological Readiness Level
US	United States
VARI	Value Assessment of Relative Importance (weighting tool: vari.wecr.wur.nl)

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1 Executive Summary

Societies around the world are increasingly affected by the vast growth of information and new and rapid developments in technology, networks and social media. The Digital Age is characterized by enhanced opportunities for monitoring and control, for precision and efficiency, for maximising economic development and for minimising impacts on the environment by precision and reduction in travels, and hence reduced climate impacts. By means of Artificial Intelligence (AI) and robotics to the Internet of Things (IoT) and 5G, the latest technologies can offer invaluable support for farmers and agribusinesses. However, an urgent issue of concern from a social science perspective is the risk of digital divide. Inequalities in the access to, and use of, the digital technologies have long been a concern among researchers and policymakers to ensure fair transitions of technology innovations and social innovations, which are highly interrelated. With new technologies it becomes evident that society will be confronted with changes of human behaviour, must tackle new types of risks, as well as needs for changing regulations and governance systems. Therefore, the main aim of this deliverable is to: Explore how digital divide has implications for digital sustainability in the European context by analysing: Issues and actors involved in digital divide in a European context, as well as perceptions of; inclusion at regional level in technology development; adoption of high tech among stakeholders (farm) level, and relevance and readiness across use cases in the XGain project.

In XGain, a total of six use cases include; 1) Spain: Catalonia – drones operation in rural areas, 2) Greece: Central Macedonia – eHealth robots for elderly, 3) UK: Island of Scilly – precision agriculture and tourism, 4) Lithuania – precision agriculture and forestry, 5) Croatia: Dalmatia – remote oyster farming and water quality monitoring, and 6) Belgium: Flanders – livestock health and farm management. They are involved in this study to identify perceptions about digital divide (i.e., inclusion, adoption and readiness) with new technological innovations across different context areas and groups in different ways.

In this deliverable we apply a series of different methods, including: 1) a systematic literature review, 2) we apply a method called Value Assessments of Relative Importance (VARI) to analyse perceptions across contexts and people, particularly to analyse perceptions of digital divide and of relevance of readiness level categories, such as technological, economic, environmental, social and societal, and we conceptualise to come with new recommendations of taking the multiple readiness levels into policy considerations.

First, the literature review contributes to shedding light on the causes of digital divide that is still partly unexplored. The existing literature on digital divide is extensive and sometimes divergent, and in this systematic review we bring the different parts together We do that by identifying in the European scene literature (section 3.2), and reflecting on the dominant issues (section 3.3), as well as main actors affected by the digital divide (section 3.4). We identified the following main five categories on digital divide; 1) access to the digital, 2) education and digital literacy, 3) socio-economic and socio-cultural conditions, 4) communities and networks, and 5) e-government quality.

Second, applying a social innovation analysis on digital divide, we investigated the differences in perceptions about the main issues of concern across different areas represented by among XGain consortium partners. We asked the question: How to enhance inclusiveness and reduce digital divide? The differences include, among others, that technological user friendliness is seen particularly important to deal with digital divide in the UK and Belgium, but least important to Luxemburg and Estonia, and that investments in governance for inclusion is relevant across most cases, but highly so in Austria, and of only little relevance in the UK, Croatia and Austria,

among others. These differences in results are relevant to understand how policy measures may need to differ across Europe, to target on real context specific challenges for digital divide.

Third, conducting a social innovation analysis on the abilities of people to adopt and create opportunities by identifying perceptions at farm level of adopting high tech among stakeholders within use cases showed among others, that; for the case of Flanders, Belgium, there is substantial potential for the technology referred to as 'digital shepherd', and potential will increase if the environmental, economic and management benefits become larger than first anticipated, and for the case of Scilly Islands, UK, a so-called Multirobot System (MRS) holds significant promise for adoption. It is of high relevance in the XGain project to analyse adoption potentials because, on the one hand, it becomes clearer how many people will make use of the technology in the current situations, and on the other hand, if the identified bottlenecks get solved, the potential expansion of farmers included, as well shortened time period, can be estimated.

Fourth, we analyse readiness of adoption from an institutional setting perspective to first respond to the question: which readiness level is relevant to the specific six cases mentioned above? These analyses of relevance showed, among others, that social factors, such as health, inclusion and work, were seen as highly important in the cases of Greece, Belgium and Lithuania, the societal factors, such as poverty alleviation and sustainability, were perceived particularly important to the cases in Spain, Belgium and Lithuania, and the environmental factors were highest valued in Croatia, Scilly Island and Lithuania. Second, this analysis was followed by the question: what are the readiness levels, to illustrate that with multi-dimensions of digital sustainability, readiness levels should not only be limited to the technological, but also the economic, social, environmental and societal readiness levels are of relevance. A balanced readiness level takes all the technological, economic, environmental, social and societal readiness levels into account, and measures on a nine-point scale.

Digital sustainability can be seen in lines of technological, economic, environmental, social and societal sustainability. As for the policy analysis, based on the literature review, we conclude that there is a need for policies that combat digital inequalities, support for better skills in using and adopting Information and Communication Technologies (ICT), and provide infrastructure which reduces socio-economic imbalances, and recognises the many-layered challenges involved, where access to the digital is important but not sufficient. Concerns for both digital environmental footprint and social risks require a need for sustainable transition in technology development in the food and agricultural systems. The overall guideline should be based on the transitioning towards digital sustainability by transition pathways to the Sustainable Development Goals (SDGs).

This Deliverable 2.2. can be relevant to other activities in XGain, for instance, to the XGain Use Case Requirements and Specifications for Connectivity and Edge Technology Enablers (Task 2.3) and XGain Knowledge Facilitation Tool Architecture Design and Technical Specifications (Task 2.4). Moreover, in other work packages, the readiness level approach may be relevant to the Tasks 4.2: Socio-environmental Assessment of Last-mile and Edge Technological Solutions, Task 5.8: Social Acceptance, Performance Evaluation, Impact Analysis and Replication Guidelines, and Task 6.2: Standardisation and Interaction with Policy-makers, Associations and Other Related Projects.

2 Introduction

2.1 Motivation and main aim

Over the past few decades, humans' activities have been increasingly influenced by the development of new technologies. Since the Industrial Revolution, humans have been faced with major technological breakthroughs, but none of the previous ones had the same wide and rapid expansion and impact as the Information and communication technologies (ICTs) (Maiti & Awasthi, 2020). Today, ICTs are a fundamental part of the daily private, social and working life of a large part of society. ICTs are time-saving, empower individual capabilities, improve communications and data transmission, transparency in procedures making it difficult to deal with open data sources, create job opportunities, facilitate heavy work and so on (Castellacci & Tveito, 2018; Pianta, 2006). ICTs are used in many socio-economic aspects and support economic growth (Stanley et al., 2018). Moreover, technological innovation and digitisation can help to tackle climate change through enhanced opportunities to mitigate climate emissions, or adaptation through precision agriculture increasing opportunities to produce with water scarcity (George et al., 2021; Rolnick et al., 2023). But all this does not come without drawbacks, as the use of ICTs also generate inequalities. There are many and very diverse barriers to the access and usage of ICTs linked with, among others, the availability of infrastructure, cultural awareness and acceptance, affordability and skills (World Economic Forum, 2016). All these lead to or reinforce the so-called digital divide – referring to gaps in access, use and impact of digital resources that affect individuals, populations, households, companies or regions (Aissaoui, 2022; Vassilakopoulou & Hustad, 2021). Despite the long call for digital and technological inclusion, recent studies show that the digital divide has increased rather than decreased in recent years (Silva et al., 2022).

The concept of the digital divide is not new; it has been an issue of concern for policymakers and scholars since the 1990s (J. van Dijk, 2005). In 1995, the US National Telecommunications and Information Administration released a series of reports called "Falling Through the Net: Defining the Digital Divide", in which the issue of the digital divide in the US was raised, with the report that it is affecting civil rights and the economy (He et al., 2022). If initially the concern was on the physical availability of ICTs, to reach equal access to computers and the Internet connection, in recent years the focus is mainly on skills and competencies of individuals in use of technologies (A. J. van Deursen & van Dijk, 2014).

Inequalities in the access to, and use of, digital technologies have long been a concern among researchers and policymakers. Initially, research on the digital divide focused on the reproduction of social inequalities in terms of access to digital technologies, identifying the gap between individuals with and without access within and between countries (Cruz-Jesus et al., 2016; González-Betancor et al., 2021; Robinson et al., 2020). According to the literature, social inequality is a concern because of the risks of exclusion, unfairness, conflicts and even war (Pedersen, 2002; Alvarez, 2021; Kerras et al 2020).

The main aim of this deliverable is to: Explore how digital divide as a phenomenon has implications for digital sustainability in the European context by analysing:

- Relevant issues and actors involved in digital divide in a European context,
- Perceptions of inclusion at regional level in technology development among partners in the XGain project,
- Perceptions of adopting high tech among stakeholders at application (farm) level in the XGain project, and
- Perceptions of relevance and readiness across use cases in the XGain project.

2.2 Mapping XGain Outputs

This deliverable 2.2 is critically important to contribute to XGain's main ambitions, namely, to foster sustainable, balanced and inclusive development of rural, coastal and urban areas, by exploring the needs and opportunities of relevant stakeholders, such as municipalities, policymakers, farmers, to reduce digital divides between citizens, farms, sectors and regions.

Table 1: Adherence to XGain GA Deliverable & Tasks Descriptions

XGain GA Component Title	XGain GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D2.2. Social innovation analysis to ensure fair transition			
TASKS			
T2.2. Ensuring a Fair Social, Digital, Environmental and Economic Transition	T2.2 contributes to 'fair transitions' in several manners, by investigating the meaning of digital divide, by analysing social inclusion, adoption and readiness, and by linking this to digital sustainability	Ch3: Issues and actors involved in digital divide in a European context Ch4: Analyses of social inclusion, adoption and readiness Ch5: Policy implications Ch6: Concluding remarks	In this second and last version of D2.2 (Month 16), theories and strategies to deal with digital divide is presented, and results of analyses of social inclusion, adoption and readiness provided. This is further linked to the issues of digital sustainability and policy implications in a European context.

2.3 Deliverable Overview and Report Structure

With the main aim to explore how the digital divide as a phenomenon has implications for digital sustainability in the European context, this deliverable is built around first exploring the digital divide by means of a literature review (**Chapter 3**) to identify relevant issues and actors involved in digital divide in a European context. This is followed by a series of methodological approaches (i.e. mixed method approach) applied in analyses of social inclusion, adoption and readiness for making use of high tech among stakeholders in Europe (**Chapter 4**) to identify; 1) perceptions of inclusion in technology development among partners in the XGain project (at regional level), 2) perceptions of adopting high tech among stakeholders within use cases in the XGain project (at application/farm level), and 3) perceptions of relevance and readiness across use cases in the XGain project. This is followed by a discussion on digital sustainability and policy implications (**Chapter 5**), before a conclusion is provided (**Chapter 6**) .

3 Theoretical framework

The meaning of digital divide as a concept has developed over the years. In short, digital divide can be explained across three levels as follows: the first-order digital divides are based on differences in access to technological equipment, quality of equipment and internet access, while second-order divides are based on digital competencies and usage, or even motivation to engage in certain activities. Third-order digital divides refer to differences in the capacity to benefit from digital technology use, and may arise from first- and second-order divides (Corkin et al., 2022). These three categories are more precisely explained as described below.

First, the original use of the term 'digital divide' dates to the mid-1990s when several newspapers adopted it in the United States (US) and then gained international visibility by appearing in several United Nations (UN) reports (A. J. van Deursen & van Dijk, 2014). In this context, literature on digital divides was initially driven mainly by policy reports and focused on inequalities in ICT access, and it has evolved to encompass concerns beyond access. As the term digital divide gained popularity in policymaking contexts before the academic community devoted attention to it (Lythreatis et al., 2022), the early definitions referred to unequal access to computers and the Internet. The dominating and defining characteristic were then the dichotomy of 'haves and have-nots'. The digital divide referred then to the gap between those who have access to ICTs and those who do not have access to these technologies (Ramakrishnan et al., 2022; J. A. G. M. van Dijk, 2006; Xiao et al., 2015). Later this gap in access became known as the 'first level digital divide,' (Silva et al., 2022). The OECD defined in 2001 the digital divide as a gap between individuals, households, businesses and geographic areas at different socio-economic levels regarding access to ICTs and to their use of the Internet for a variety of activities (OECD, 2001).

Second, from the early 2000s onwards, scientific research extended the focus from the dichotomy of 'haves and have-nots' to accommodate a broader focus on the quality of internet connection, the knowledge and skills of the users, and patterns in use (J. van Dijk & Hacker, 2003). This was a shift labelled the 'second-level digital divide' (Hargittai, 2002). The attention also turned to the consequences and outcomes of ICT, to understand more thoroughly what the digital divide is about, the extent to which technology use enables individuals to participate and be part of society (Selwyn, 2004). By that the 'third-level digital divide' emerged as a shift from mere skills and use of ICT to the consequences of using the Internet. By that an acknowledgement took off with three primary levels of the digital divides: (i) access, (ii) use, and (iii) outcomes (Silva et al., 2022).

Third, the endeavour to understand the processes that generated the second divide led to an awareness coined as the third divide, which was related to individual digital skills that explain the gap between access and uses (Scheerder et al., 2017; A. J. A. M. van Deursen & van Dijk, 2015). However, to understand the digital divide better, the gap in digital skills suggested to researchers that there was a need to examine the sequential process that produces the gap. This sequence is starting from attitudes, motivations, and possibilities for physically accessing the internet and developing digital skills, and ultimately examining particular uses and possible outcomes of internet use (Lamberti et al., 2021).

We observe that the digital divide gradually is defined as part of a larger digital transformation, as a fundamental and ongoing socio-technological change process in which digitisation and inequities increase over time. **Digitisation is then the process of converting analogue information into digital form, while digitalisation refers to "the sociotechnical processes surrounding the use of (a large variety of) digital technologies that have an impact on social and institutional contexts"** (ibid.) (Martens & Zscheischler, 2022). These two definitions are important for clear understanding of this deliverable. Notably, in these definitions, attention is paid to how social inequality leads to a digital divide, the gap between groups who have access to information and communication

technology and groups who do not have access to them (van Dijk, 2006; Xiao et al., 2015). Moreover, the effect of not having access to the latest information technologies is of importance. This is important because there are links between the digital divide and broader societal outcomes, such as poor health (e.g., Dobransky & Hargittai, 2012; Hong & Cho, 2016); well-being (Ihm & Hsieh, 2015; Maiti & Awasthi, 2020); and reduced political knowledge (Pariso & Marino, 2020; Zhao et al., 2014). Although it is often conceptualised in terms of attitudes, access, skills and types of usage, the gap includes multiple disparities regarding skills on how to use the Internet and/or digital devices. Forms of digital inequalities multiply as we move from inequalities in access to disparities on the level of digital engagement, which differentiate between those who create digital content and those who only consume it (Vulpe & Crăciun, 2020).

The many forms of the digital divide are also seen by Helbig et al. (2009). They see a literature that can be organised in three different approaches: the technological access approach, the multi-dimensional digital divide approach, and the multi-perspective digital divide approach (Helbig et al., 2009). First, the technological access approach covers the dichotomy between those who have access to technology and those who do not, posits that overcoming the access barrier would close the digital gap since individuals would be able to harness ICT's benefits. Researchers who take this approach, Helbig et al., 2009 argue, seek to identify and analyse the socioeconomic characteristics of people who do or do not have access to computers and the Internet (Scheerder et al., 2017).

Second, the multi-dimensional digital divide approach of Helbig et al. (2009) inform that increased access to the Internet does not necessarily imply that digital divides will be closed across social groups, they may even be reinforced if capacity to use the information differ. Third, the multi-perspective digital divide approach, highlights that even individuals who have equal access "may not have the opportunity to access internet or to engage in a wide variety of uses." (Kennedy et al., 2003). Researchers propose this approach to understand particular barriers to access explained by gender, race, and culture (Helbig et al., 2009), taking a more realistic approach that recognises the relevance of "access, economic and social inequalities, cultural identity and subjectivity, gender, and class." (Hines et al., 2003). This approach looks at the intersection of technology, socioeconomic and individual characteristics (Helbig et al., 2009).

In this deliverable a systematic literature review is conducted to address the main issues and actors linked with digital divide in a European context, while perceptions of social inclusion, adoption and readiness are analysed by means of surveys. The theoretical overview of this deliverable is provided in Figure 1. The Figure provides the links between the main problem statement of digital divide, to reach a common goal of digital sustainability. For fair transitions of technology- and social innovations, social innovation analyses are needed to demonstrate; causes to digital divide to confirm exact inclusion level, ability for people to take part and create opportunities (adoption level), and institutional readiness level. Increased levels of inclusion, adoption and readiness levels can be reached by change in behaviour, risks, rules and governance, across individuals and institutions.

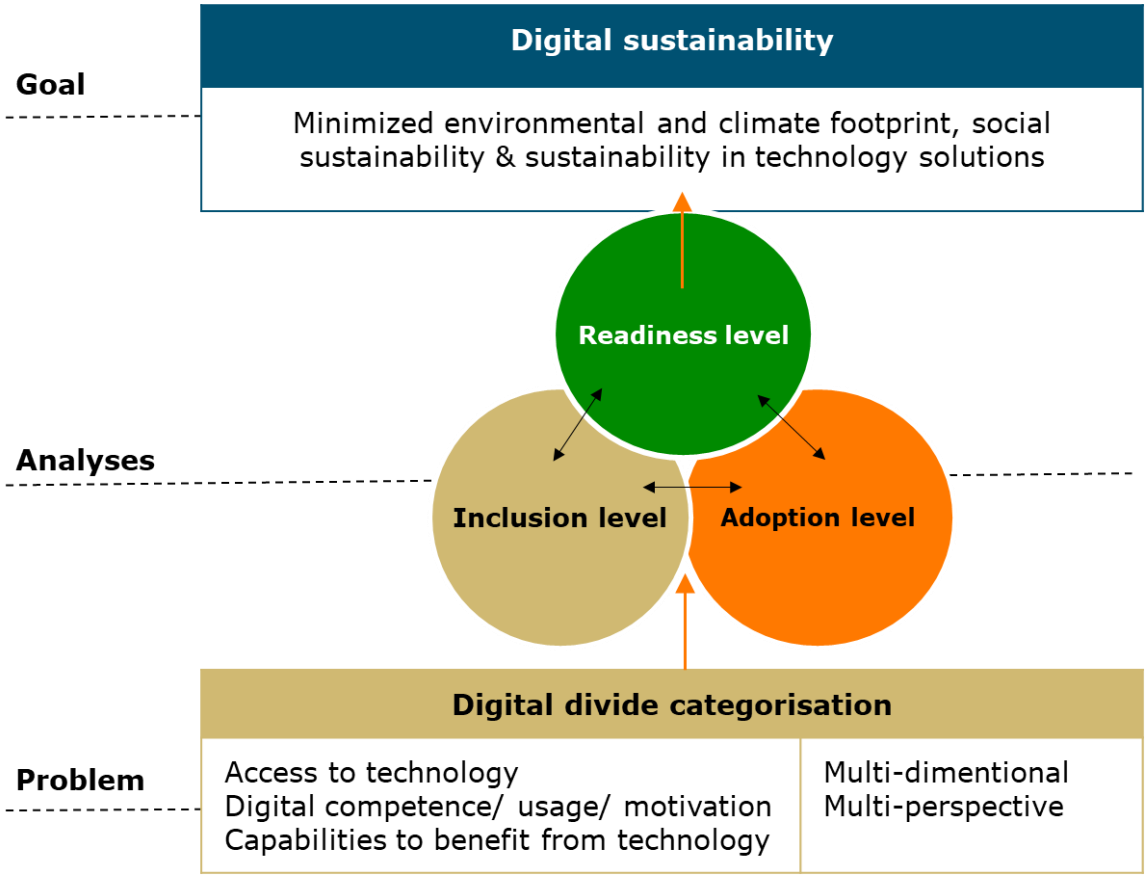

Figure 1: A framework of digital divide - problem, analyses and goal

The changes in societal interactions that are caused by the increase in digitisation are referred to as 'informational governance' (Soma et al, 2016a; Soma et al, 2016b). Inclusion, readiness and adoption of new technologies through processes of technological and social innovations can foster digital sustainability. The extent to which this is happening can be analysed by evaluating readiness levels, including the technological, economic, social, societal and environmental readiness levels.

XGain is dedicated to contributing to the identification of causes to digital divide following social inclusion, adoption and readiness analyses. Analyses will also explore potential ways to overcome the bottlenecks to enhance innovative and smarter solutions to increase access to services, opportunities and adequate innovation ecosystems. This deliverable will analyse digital divide by means of 1) a literature review; 2) social inclusion analyses (method: VARI); 3) farmers readiness level analyses (method: ADOPT); and 4) relevance and readiness analysis for applying technologies (method: VARI).

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4 Issues and actors involved in digital divide in a European context

4.1 Introduction

The digital divide is a global issue (Mubarak, 2015), however, the interest in this topic has been growing in recent years in Europe. The literature review carried out in this study shows that 35% of the post-pandemic articles mention COVID-19 either as a cause or as the background of the article. COVID-19 challenged several aspects of the European digital system, showing fallibility of our societies in terms of functioning, growing, interconnection and becoming fully digitalised. This literature highlights the social inequities that appeared in Europe during and after the pandemic. The aim of the literature review is to identify the most urgent issues and affected groups of actors of digital divide in Europe, to outline the need for future digital inclusiveness.

This chapter contributes, by means of a literature review, to shedding light on a topic of causes to digital divide that is still partly unexplored. We do that by identifying in the European context literature (section 3.2), and reflecting on the dominant issues (section 3.3), as well as main actors affected by the digital divide (section 3.4). Europe is highly digitised, although with Covid-19, several vulnerabilities in the field of ICT have led to enhancing inequalities. The digital divide has shown to affect economic growth but also sustainable development (Shirazi & Hajli, 2021). Increasing the insight into the digital divide is therefore a pivotal building block to meet the digital future of Europe, not in the least for rural areas.

4.2 A systematic literature review

In this study, the concept of the digital divide in Europe is addressed in terms of definitions, issues, actors and solutions proposed by scholars identified by the literature. A literature review was performed on the Scopus database with selected keywords (See Table 2). Although not claiming that these keywords cover all the existing literature on this subject, this review indeed intends to provide an outline of the digital divide covering the European context. The literature search was made in November 2022, including articles in the years 2015-2022. The choice of this period is based on the overview provided in Figure 2, showing the number of articles published on digital divide in Europe, which increased from a very low level in 2015.

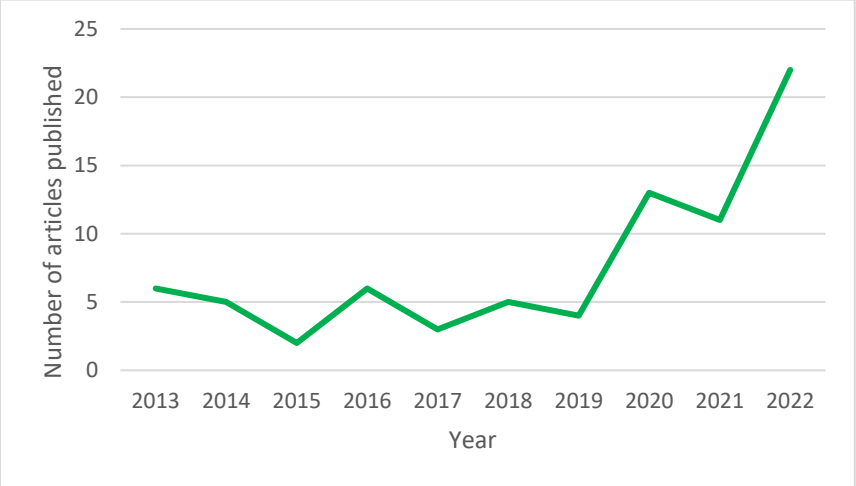

Figure 2: Articles per year on the digital divide in Europe *(Source: Scopus research November 2022)*

The first step of the literature review was to define Boolean searches, which consist of selections of combination of words and phrases, which are connected by applying the AND and OR operators (Table 2). The first Boolean search gave 6348 results. To make this study replicable in different spatial and terminal contexts, the exact combination of terms can be found in Table 2. The second Boolean search introduced several limitations in the interest of the study: year, keywords, language, and field of study, resulting in 77 articles (Figure 3).

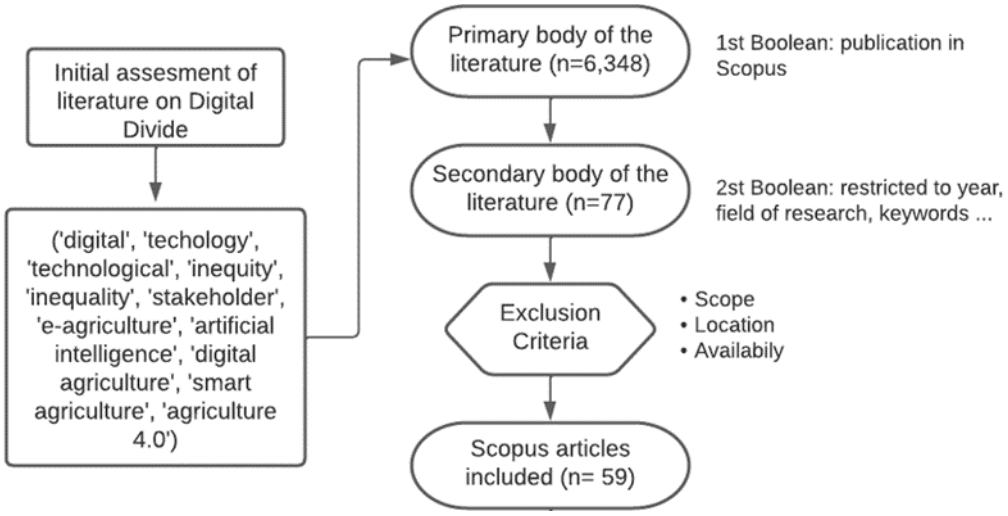

Figure 3: Data collection process of digital divide in Europe, November 2022

These articles were read and analysed by two reviewers. During the analysis, some exclusion criteria were determined:

- Online availability of the article;
- article location relevant with the European context;
- article subject relevant with the scope of the research

Based on these criteria, 18 articles were excluded from this study. Therefore, the present literature comprises a total of 59 articles. The total number of articles found was considered adequate for the issue outline. A qualitative analysis of the research results in the following highlights the main actors related to the contexts in which the digital divide occurs in the European context. The analysis was performed using Atlas ti software[3]. In the beginning, the main elements of the study were coded with the software: actors, issues and solutions. Then, interrelations between these elements were identified, and a qualitative analysis was performed in the next sections.

Table 2: Query entered on Scopus December 2022

Date	Search words	Research level	N. of articles
01/11/2022	TITLE-ABS-KEY (("DIGITAL") OR ("TECHNOLOGICAL") OR ("TECHNOLOGY")) AND (("DIVIDE") OR ("INEQUITY") OR ("INEQUALITY")) AND (("STAKEHOLDER") OR ("STAKEHOLDERS")) OR (("E-AGRICULTURE") OR ("ARTIFICIAL INTELLIGENCE") OR ("DIGITAL AGRICULTURE") OR ("SMART AGRICULTURE") OR ("AGRICULTURE 4.0")) AND ("EUROPE")	1st Boolean search	6,348

[3] https://atlasti.com/

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	TITLE-ABS-KEY (("DIGITAL") OR ("TECHNOLOGICAL") OR ("TECHNOLOGY")) AND (("DEVIDE") OR ("INEQUITY") OR ("INEQUALITY")) AND (("STAKEHOLDER") OR ("STAKEHOLDERS")) OR (("E-AGRICULTURE") OR ("ARTIFICIAL INTELLIGENCE") OR ("DIGITAL AGRICULTURE") OR ("SMART AGRICULTURE") OR ("AGRICULTURE 4.0")) AND ("EUROPE") AND (LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"ECON") OR LIMIT-TO (SUBJAREA,"AGRI") OR LIMIT-TO (SUBJAREA,"EART") OR LIMIT-TO (SUBJAREA,"MULT")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"ch") OR LIMIT-TO (DOCTYPE,"cp")) AND (LIMIT-TO (PUBYEAR,2022) OR LIMIT-TO (PUBYEAR,2021) OR LIMIT-TO (PUBYEAR,2020) OR LIMIT-TO (PUBYEAR,2019) OR LIMIT-TO (PUBYEAR,2018) OR LIMIT-TO (PUBYEAR,2017) OR LIMIT-TO (PUBYEAR,2016) OR LIMIT-TO (PUBYEAR,2015) OR LIMIT-TO (PUBYEAR,2014) OR LIMIT-TO (PUBYEAR,2013)) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (EXACTKEYWORD,"Digital Divide"))	2nd Boolean search	77
		Tot. in the literature	50

4.3 Dominant issues of the digital divide across Europe

From the literature, we identified key factors contributing to the digital divide, including demographic and socio-economic user characteristics that cause differences in their digital skills (Bagchi, 2005; Elena-Bucea et al., 2021; Rodríguez-Hevía et al., 2022). Then we defined five dominant categories of issues prominently present in the literature, varying from the more individual to the larger context of societal groups.

Without claiming to provide a complete overview of all factors that directly or indirectly contribute to the digital exclusion of certain actors, we have listed below five prominent factors that are recurrent in articles in the European context. This list is thus not meant to be exhaustive, but to give a representation of the complexity of the issue that needs to be addressed in regulations and policies.

- **Age**; is one of the most prominent drivers when it comes to ICTs adoption. Several articles have been produced in the EU on digitisation and inclusion of older people, coined as ‘the grey divide’ (Huxhold et al., 2020). This term identifies the difference between the 'digital natives', the younger people who are used to interfacing with ICTs on a daily basis, and the 'digital refugees', i.e. the people who were not born into this system and have to cope with it and often need external support (Lolich et al., 2022; Tirado-Morueta et al., 2021).
- **Gender**; the gender-related digital gap reflects the inequalities between men and women present in the social structure of a country (Correa, 2016). The main digital inequalities are most visible in developing countries, but these are also present in European States. Perifanou & Economides (2020) argued that “women should overcome stereotypes, cultural barriers, absence due to feminine issues (e.g., pregnancy, maternity and motherhood), male-dominated jobs, male aggressiveness, harassment, low self-esteem, and more.” This results in ICTs gender gap in profession, jobs, leadership and entrepreneurship (A. Perifanou & A. Economides, 2020) and exclusion from e-government participation (Macaya et al., 2021). For reasons of clarification, we define the concept of e-government as “the use and application of information technologies in public administration to streamline and integrate workflows and processes, to effectively manage data and

information, enhance public service delivery, as well as expand communication channels for engagement and empowerment of people." (United Nations, 2014).

- **Education;** is a significant variable in the acquisition of digital skills. There are two aspects of education to consider. One is the degree of education achieved by the individual, the higher it is, the more it facilitates learning to use ICTs. The other aspect concerns specific knowledge in the IT field (Cruz-Jesus et al., 2016). Today, this is the subject of several EU programs that recognise the essential role of this variable in narrowing the digital gap between generations and individuals. Since 2006, the European Union has recognised digital literacy as fundamental in education, employment and training (Choudhary & Bansal, 2022).
- **Income;** For the UN, the correlation between income and digital skills is very strong (United Nations, 2012; World Economic Forum, 2016). This aspect was crucial in the initial phase of technology diffusion, when the income of an individual or household allowed physical access to digital-enabling devices (hardware, software and internet connection). This is still the case especially in developing countries (Elena-Bucea et al., 2021). In the European context, this can represent a barrier to the opportunities and benefits of using ICTs.
- **Geography;** Geographic position is a factor with much influence on digital inclusiveness. There are some areas, defined as marginalised or rural, where it is complicated to ensure wide access to the Internet. This issue includes other variables, such as the absence of infrastructure, the cost of coverage in remote areas, severe climatic conditions, etc. All these variables contribute to the marginalisation of certain areas and/or communities. To overcome this problem, many scholars claim the need to collect data and have tailored solutions for specific regions (McMahon & Akçayır, 2022; Rodríguez-Hevía et al., 2022).

In addition to these globally relevant factors, the literature has highlighted others that derive from the European context. For instance, politics is a key factor in the implementation of digital inclusion policies and in establishment of the e-government model accessible to everyone (Reggi & Gil-Garcia, 2021). Related to this topic is the cultural context in which individuals operate. In a study on the digitisation of public administration in Southern Italy, ways in which managerial culture and trust in bureaucracy can trigger or retain ICTs usage is addressed (Pariso & Marino, 2020). Another deterrent to achieving e-inclusiveness is the western economic model criticised as capitalistic approach operating as a "source of invisibilities that support inequalities and ultimately injustices" (Stocchetti, 2018). Along this reasoning, making business-based choices can lead to injustices and discriminations that affect the most vulnerable actors (Rosales & Fernández-Ardèvol, 2020), including the elderly, disabled people (Macdonald & Clayton, 2013), marginalised communities (McMahon & Akçayır, 2022), and migrants (McAuliffe et al., 2021). Finally, language can be a key factor for exclusion of certain individuals in digitisation, as many documents and materials on the Web are in English and thus not accessible in native language (Bagchi, 2005; Elena-Bucea et al., 2021). Notably, a combination of several of these factors can have strong impacts on digital divide, resulting in higher isolation from ICTs knowledge and usage. The three categories of women, the elderly and the poorly educated was highlighted as the most affected groups of actors by the digital gap (Gounopoulos et al., 2020; Macaya et al., 2021).

In the literature reviewed, several issues were identified that trigger the digital divide in Europe. These issues have been collected in five categories.

- **Access to the digital category**; includes issues related to achieving inclusion and integration of services that are provided digitally. This phenomenon is increasingly present in our society and risks excluding some individuals or communities. Specifically, we refer to public services such as health care (Ollier-Malaterre & Andrade, 2016; Tirado-Morueta et al., 2021), financial services (Vasile et al., 2021) and public administration (Carlo & Sourbati, 2020; Ranchordás, 2022). These are fundamental services for society and cannot be

allowed to become the privilege of a few groups. This category also includes the need to have a fair data collection and distribution system to avoid imbalances in analyses and representation (McAuliffe et al., 2021; Sui et al., 2013).

- **Education and digital literacy category**; includes issues related to digitisation awareness and knowledge in ICT. Education as shown above is one of the key factors in achieving digital inclusion, hence several articles focus on this issue and propose solutions for overcoming this impasse in the future (Adhikari et al., 2016; Zarouali et al., 2021). This category also covers articles that, without proposing concrete solutions, simply highlight the problem to narrow the knowledge gap on the digital divide (Mubarak, 2015; Silva et al., 2022).
- **Socio-economic and socio-cultural conditions**; represent the category most discussed in the literature. This category includes the issues of social inclusion of all groups and communities and the opportunity to access digitisation as a means of improving quality of life (e.g., Groth, 2019; Lolich et al., 2022; Petrovčič et al., 2022; Pinto et al., 2022). It also addresses the need for protection of the most vulnerable actors, as elderly, immigrants, rural communities (Vulpe & Crăciun, 2020), and the identification of some structural inequalities, already identified as key factors of the digital divide, namely the gender gap (Macaya et al., 2021) and geographical disparities (Riddlesden & Singleton, 2014; Szeles, 2018).
- **Communities and networks**; this category deals with issues related to the need for efficient connectivity at an extended global level (Riddlesden & Singleton, 2014; Seo & Thorson, 2016). This leads to the formation of networks of complex services and actions possible through digitisation, including the use of social networks (Gelfgren et al., 2022; Ramakrishnan et al., 2022) and various forms of artificial intelligence (McAuliffe et al., 2021).
- **E-government quality category**; includes all problems arising from the use of technology at governmental level, electronic government (e-government) (Macaya et al., 2021; Pariso & Marino, 2020; Warf, 2018). It focuses on the difficulties that citizens, governments and policy makers face when interacting with e-government implementation. It is a very impactful tool for society development but does not come without drawbacks. In fact, it can cause several inequalities that need to be addressed to guarantee access to everyone.

In Table 3 we show the main categories of issues and key characteristics, with some illustrative references.

Table 3: Overview of the main categories of issues and key characteristics from the literature review

Issues	Key characteristics	References from the text
1. **Access to the digital**	Public services inclusion, equal data distribution, digital integration in the system.	Ollier-Malaterre & Andrade, 2016; Tirado-Morueta et al., 2021); Vasile et al., 2021; Carlo & Sourbati, 2020; Ranchordás, 2022; McAuliffe et al., 2021; Sui et al., 2013)
2. **Education and digital literacy**	Digital awareness, educational opportunities, narrowing the gap on digital divide knowledge	Adhikari et al., 2016; Zarouali et al., 2021; Mubarak, 2015; Silva et al., 2022
3. **Socio-economic and socio-cultural conditions**	Social inclusion (elderly; immigrants), vulnerable people protection, gender and geographical disparities.	Groth, 2019; Lolich et al., 2022; Petrovčič et al., 2022; Pinto et al., 2022; Vulpe & Crăciun, 2020;

		Macaya et al., 2021; Riddlesden & Singleton, 2014;
4. **Community (e-) networks**	Equitable connectivity, Artificial Intelligence, social network usage	Riddlesden & Singleton, 2014; Seo & Thorson, 2016; Gelfgren et al., 2022; Ramakrishnan et al., 2022
5. **(e-)Governance quality**	E-government implementation, performances, decrease inequalities of access and use	Macaya et al., 2021; Pariso & Marino, 2020; Warf, 2018; Demertzis et al., 2013

Source: this project

Another matter of interest is how frequently the issues have been studied in the literature. In Figure 4 we display the spread of the issues, based on the counting of the articles collected. We then see a clear dominance of studies addressing the socio-economic and socio-cultural conditions. There is also quite some focus on access to the digital and the governance quality. Relatively less attention is paid to education/ digital literacy and the focus on community networks receives the least attention.

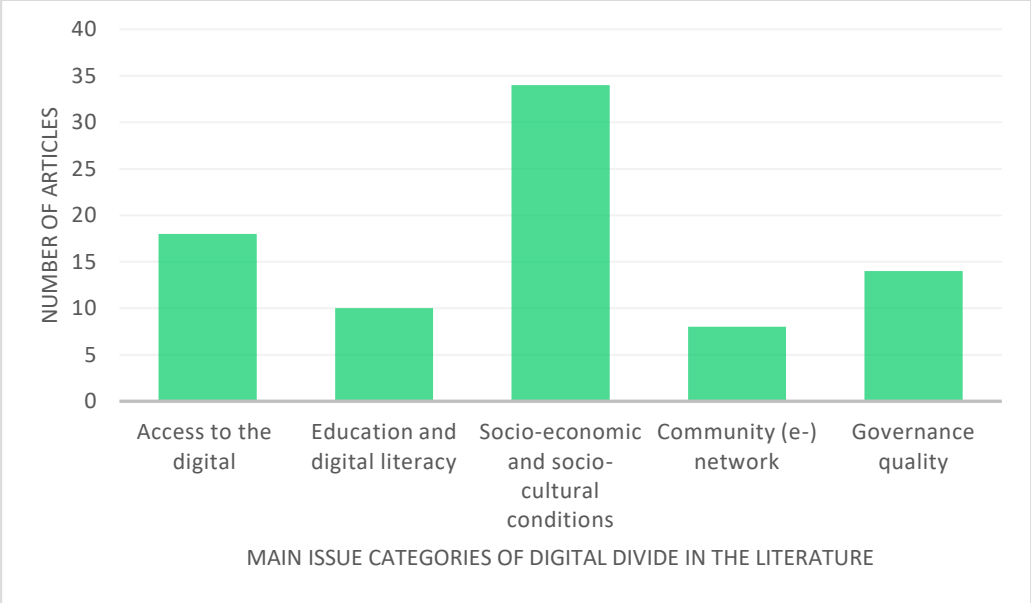

Figure 4: Frequency of issues in the five identified categories

4.4 Actors of the digital divide in Europe

From the literature, we have outlined an overview of the actors affected by the digital divide in Europe. The literature focuses particularly on citizens, sometimes considered as ICT users, others as citizens in the public system. Citizens is the target group of the technology-based services, and some articles determine who and why they might be excluded. Broad interest is also given to governmental activities and public administration focusing on understanding how they can be vehicles of inequalities. Although actors such as workers, students, people with disabilities and children appear in the literature review. We argue here that the focus should not be limited to single actors, but also look at interpersonal relations and interactions in networks, power relations and strategic behaviour (Hermans & Thissen, 2009).

It is interesting to note that the European literature is also particularly concerned about the elderly when addressing digital divide. Many articles deal with the digital divide of senior users as a problem, which can be explained by a relatively high share of elderly among the European population who are expected to apply new technologies and is thus affected by the requirements of digitisation. Another category of actors of great interest are marginalised or rural communities. They are often disconnected from many services for physical reasons such as the absence of infrastructure and for social reasons because customised decisions are not usually taken on the needs of these areas because they are often unattractive to the ICT business market. In the European context, there are several communities that live on the margins of the digitalised society, and to ensure inclusive technological development, they risk being ignored in policy decisions and development programs.

The actors typified as less digitised in the literature are often linked to the categories of issues defined in the previous section. Looking at the 17 articles addressing citizens, we see links towards every aspect of digital divide issues, although preponderances exist for the socio-economic and cultural category. They may in fact be the subject of various discriminations (Macaya et al., 2021) and exclusions (Szeles, 2018) from the social support system in the digital domain (Helsper & van Deursen, 2017; Riddlesden & Singleton, 2014). Here we see that governments might not be very inclusive. Some point to governments as being mainly involved in issues concerning the implementation and proper functioning of governance (Lněnička & Máchová, 2022; Myeong et al., 2014); while some articles about governments link them to issues of access to social equity services to be provided by the government (Pariso & Marino, 2020; Reggi & Gil-Garcia, 2021).

Elderly users are studied comprehensively in the field of the digital divide. In particular, this literature focuses on the social, economic and cultural difficulties they face with digitalisation (He et al., 2022; Lolich et al., 2022). In fact elderly persons often face various barriers like access to basic services (He et al., 2022; Lolich et al., 2022; Li et al., 2022). These can have a serious impact on their quality of life and health (Gallistl et al., 2020; Tirado-Morueta et al., 2021).

Marginalised communities face problems in all categories. There is a clear link with the social aspect that excludes this category of actors (Erdiaw-Kwasie & Alam, 2016; Groth, 2019). Equally relevant are connections with the area of digital access, at the physical, educational and data availability levels, and the creation of an efficient network between marginalised actors and the digital (McMahon & Akçayır, 2022).

For students and children, it is of relevance to address social and educational issues (Adhikari et al., 2016; Corkin et al., 2022; Reisdorf et al., 2019). This is because young people are being exposed to the use of technology at an earlier age, which can have some educational benefits, as well some challenges. The most burning issue is related with privacy, as well as internet security and safe sharing of material and data (Birkland, 2022; Carlo & Sourbati, 2020; Maineri et al., 2021).

Workers are affected in different categories, the literature highlights the difficulties of some categories of workers to reach certain digital welfare services (Ollier-Malaterre & Andrade, 2016). Business opportunities arising from Internet connection and access are highlighted (Philip et al., 2017; Szeles, 2018). The biggest challenges are the lack of digitisation in certain sectors such as agriculture (Bowen & Morris, 2019), customers (Philip et al., 2017) and data sharing (McAuliffe et al., 2021; Vasile et al., 2021).

Finally, our study identified a group of actors with disabled persons who encounters social and cultural problems in accessing digitalisation, as well as in forming an e-network in particular using existing social networks that tend to be discriminatory and not very inclusive (Gelfgren et al., 2022).

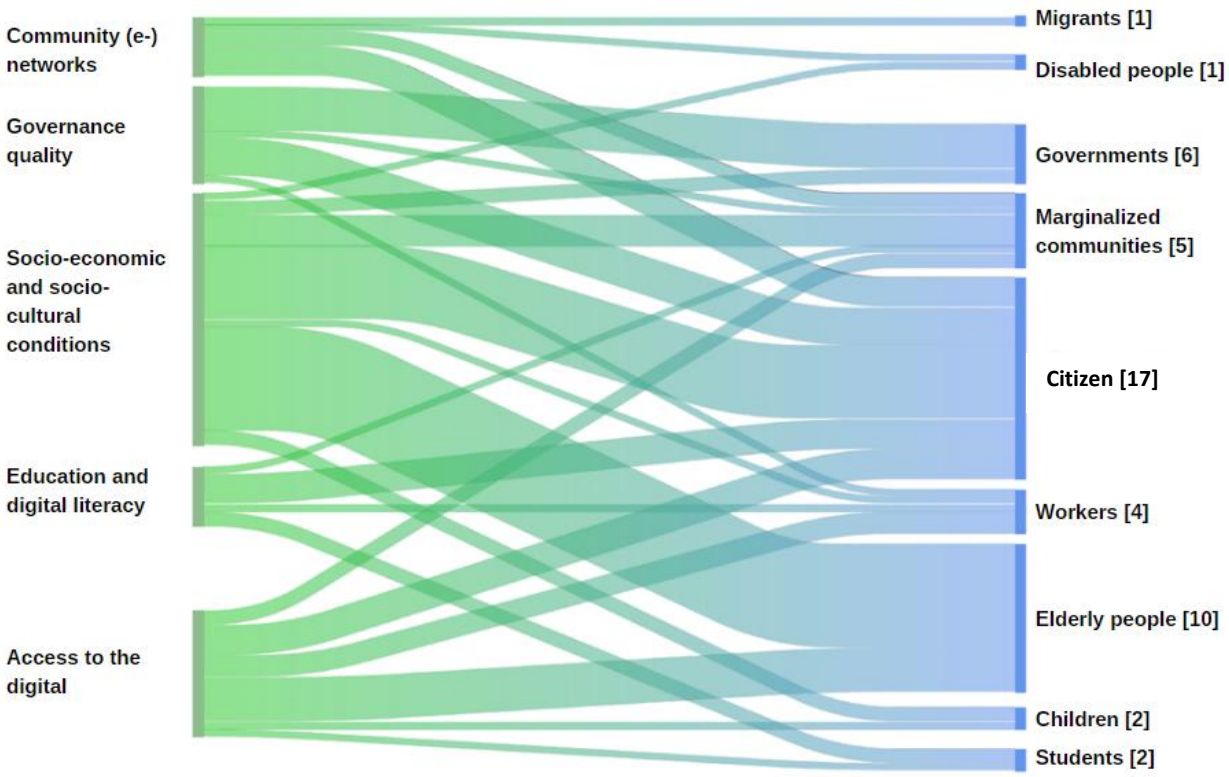

Figure 5: Overview on issues and actors of digital divide in literature review

The literature review shows that the main issues of interest often concern socio-economic and socio-cultural conditions as evidenced by the categories (Figure 5). Also, access to the digital, education, communities and governance are ICT related issues of concern. For instance, Perifanou & Economides (2020) argue that women even in digitised countries often are excluded from leadership positions due to their poorer digital literacy. The reasons can be found in cultural mechanisms excluding women from the field of ICT. Several articles have highlighted the need to tackle the gender gap also through the inclusion of women in the ICT area. Moreover, the interest in citizens at large and the elderly does not mean that sub-groups are not addressed, however, much of the literature takes a broad view to the actors involved.

4.5 Summing up

This systematic literature review highlights the main issues and the main actors addressed in the current literature about digital divide in Europe. The dominant issues that relate with digital divide in Europe, include; 1) age; sometimes referred to as the 'the grey divide' (Huxhold et al., 2020), or the 'digital refugees', i.e. the people who were not born into this system and have to cope with it and often need external support (Lolich et al., 2022; Tirado-Morueta et al., 2021). 2) Gender; reflecting on the inequalities between men and women present in the social structure of a country (Correa, 2016). 3) Education; addressing digital skills, referring to, on the one hand, the degree of education achieved by the individual, and the other hand, concerns specific knowledge in the IT field (Cruz-Jesus et al., 2016). 3) Income; which in the European context can represent a barrier to the opportunities and benefits of using ICTs. 4) Geography; referring to areas defined as marginalized or rural, where it is complicated to ensure wide access to the Internet. This issue includes other variables, such as the absence of infrastructure, the cost of coverage in remote areas, severe climatic conditions, etc.

The risk is that inequalities will be further emphasised where digitalisation is increasing, with the already digitalised increasing their empowerments, while he marginalised groups increasingly become excluded from digitisation. Solutions must be implemented holistically for the resolution of this deep-rooted and evolving problem (Cruz-Jesus et al., 2016; Elena-Bucea et al., 2021). We conclude here that, in order to solve the challenges of exclusion of particular groups from the ICT developments; e.g. closing the digital divide, the responsibility must be taken by many actors in society, among others governments, ICT industry, ICT training, labour organisations, schools and universities, libraries, public access centres, and user support groups (van Deursen & Helsper, 2015). Moreover, increased research efforts are needed to investigate peoples' perceptions and behaviour with digital divide, as well as institutional settings in transition across a variety of contexts within Europe.

The findings in this Chapter can be of specific relevance to the policy evaluations in WP6, particularly for Task 6.2: Standardisation and Interaction with Policy-makers, Associations and Other Related Projects.

5 The analyses of social inclusion, adoption and readiness

5.1 Introduction

In this Chapter, social innovation analyses are conducted on social inclusion, adoption and readiness of marginalised people and groups are presented, with the aims to identify 1) perceptions of inclusion in technology development among partners in the XGain project, 2) perceptions of adopting high tech among stakeholders within use cases in the XGain project, and 3) perceptions of relevance and readiness across use cases in the XGain project. These analyses take place at regional, farm and case levels, respectively.

Based on the literature review in Chapter 3, combined with expert consultations, a total of four investment categories have been defined for the handling of digital divide, namely the urgent needs for; education, technological user-friendliness, governance for inclusion and digital infrastructure. In XGain, a total of six use cases are involved in this study to identify perceptions about digital divide (i.e., inclusion, adoption and readiness) with new technological innovations across European areas and groups in different ways. In the Figures 6 and 7, the locations of use cases (orange circles) are put on maps showing the employment in high tech across Europe (Figure 6), and the usage of Internet of things (ICT) across Europe (Figure 7). The use cases include:

- Spain: Catalonia – drones operation in rural areas *(employment and usage high)*
- Greece: Central Macedonia – eHealth robots for elderly *(employment medium, usage unknown)*
- UK: Island of Scilly – precision agriculture and tourism *(employment low, usage unknown)*
- Lithuania – precision agriculture and forestry *(employment relatively high, usage low)*
- Croatia: Dalmatia – remote oyster farming and water quality monitoring *(employment and usage low)*
- Belgium: Flanders – livestock health and farm management *(employment relatively high, usage relatively low)*

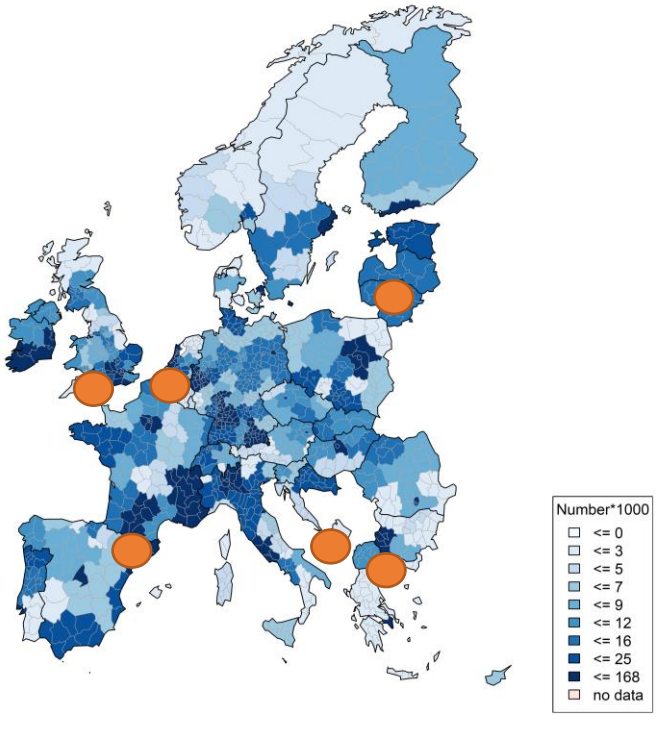

Figure 7: Employment in high technology sectors *(source: Eurostat)*

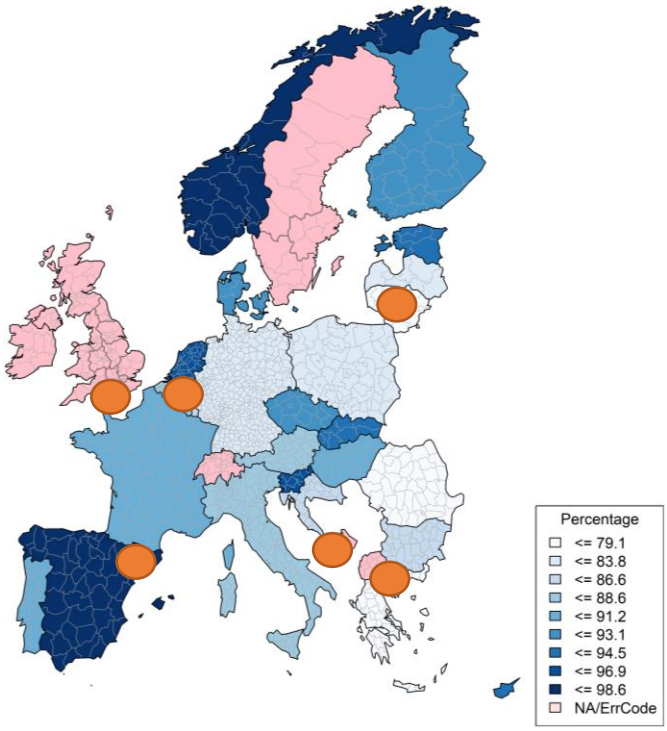

Figure 6: Usage of Internet of Things by ICT professionals *(Source: Eurostat)*

The figures illustrate that the Spanish use case is in an area with high employment in ICT and with high level of ICT usage. The use cases located in the areas with lowest employment and usage of ICT are Croatia and Greece, whereas Lithuania and Flanders show situations with relatively high employment and low usage of ICT. In the case of UK, the employment is low in the use case area, but has no information available on the usage of ICT.

Digital divide can be analysed from a regional level, a local level (e.g., farm level) and a case level, in both high tech areas such as Spain, Catalonia, and Belgium, Flanders, and low tech areas such as Croatia, Dalmatia, and UK, Scilly Islands. In the following, a regional level analysis of digital divide is conducted for the social inclusion analysis, farm level analyses are conducted to analyse the adoption level of new technologies locally, and case level analyses are conducted to analyse the readiness level.

5.2 Social inclusion analyses

5.2.1 Introduction

While high tech technologies are providing new opportunities for effectiveness and precision, reduced costs and improved business models, as well as reduced use of pesticides and water, the new opportunities also bring about some risks. For instance, the benefits may only please a few with enough investment capacities, i.e., farmers who already are having a lot of resources. Therefore, a large share of the population may suffer from exclusion, with low incomes and lacking opportunities for developments. XGain thus contributes with analyses of perceptions about digital divide. Such insight are beneficial to understand context specific relevance of the options identified. The aim of this section is to analyse perceptions of social inclusion in technology development among partners in the XGain project. While initially, the intention was to conduct this research including a larger sample of stakeholders in all use cases, the risk of stakeholder fatigue forced us to conduct this survey with partners within the consortium.

The analyses of perception are done by identifying priorities, i.e., weights, across relevant criteria to a main goal. In this social innovation analysis, the main research question was formulated to be: How to ensure inclusiveness and reduce digital divide?

A lot of different weighting methods exist designed for assigning priorities within multicriteria analyses (MCAs). One way is to just order the factors, i.e., 'direct assessment', without knowing how much more important the one factor is to the other. Other 'direct assessment' methods include so-called 'expected value method', 'random weights' and 'extreme weights', having in common that they set the rankings by quantifiable weights directly (Janssen, 2012). These methods suffer from a lack of accuracy because they must compare many factors at the time, and outcomes can differ when repeating the exercise. Another preferable option is 'pairwise comparison'. In this method only two factors are compared at the time, and the exact relative importance between all the factors are provided by shares (%) showing the extents to which importance difference between factors is relatively small or large. Pairwise comparison can thus handle distinct levels of specificity and is suited for weighting of multiple factors arranged in value-trees (Ramos et al., 2015; Saaty, 2004; Soma, 2010).

In this section we apply a social innovation analysis to confirm the exact inclusiveness, referred to as a Value-Analyses of Relative Important (VARI) [4] with pairwise comparison in this deliverable. Assigning weights is the same as to inform about what is relatively more important (Banani et al. 2016; Munda, 2004). If different people

[4] https://vari.wecr.wur.nl/

assign different sets of weights, the levels of importance of the factor, often referred to as objectives/criteria/sub-criteria, will vary for different people or groups. Their perceptions will differ.

The perceptions of interviewees are thus assigned by means of assigning the weightings, i.e., to understand which option is relatively more important to an individual or group. Before conducting the pairwise comparison, the factors to be compared must be carefully identified and arranged into a value-tree, see example in Figure 9. Based on such value-tree which will differ according to location and research question, a questionnaire survey based on pairwise comparison (Figure 8) has been conducted with the consortium partners of XGain. The questionnaire survey takes no more than 15 minutes and ask to compare the factors and sub-categories in the value-tree pairwise, in order to assign what is relatively more urgent in your opinion.

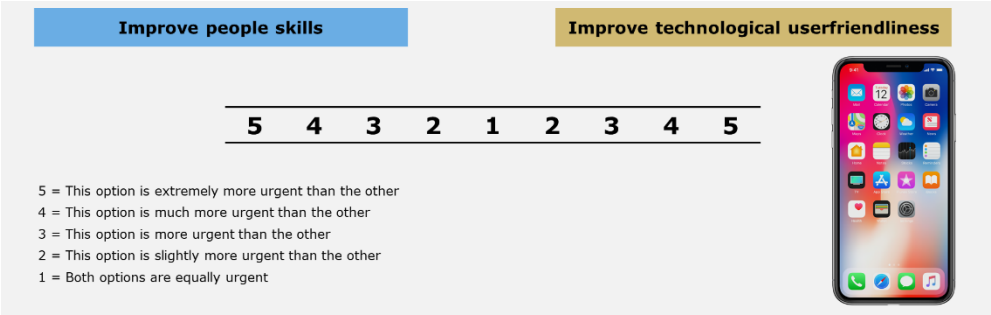

Figure 8: Example of questions asked in the survey based on pairwise comparison of two options at the time listed in the value-tree

5.2.2 Perceptions about factors of relevance to digital divide

A value-tree for digital divide

To answer the research question on "how to ensure inclusiveness and reduce digital divide?" the urgency factors must be identified and arranged into a value-tree, following the approach of Saaty (2004). A value-tree define the more general factors at the top and specify them into sub-factors which are more specific at lower levels in the value-tree. It is important to create a good value-tree because it defines the basis of the analyses. The factors in the value-tree creates the inputs of the analyses, and the better input the better output.

The value-tree is based on inputs during a one-day workshop with experts discussing the factors of relevance to digital divide, based on individual expertise. On 18 October 2023, a total of seven XGain experts discussed relevance of different issues to digital divide covering a range of scientific disciplines including; governance, social innovation, business models, Environmental Footprint Analyses, Social Life Cycle Analyses, economic impact assessments, etc. Some of the insights were derived during the literature review on digital divide.The main criteria were defined according to different main areas of investments which could result in reducing the digital gap. The highest-level factors refer to investments; here referred to as investments with finance, attention, time, research, organisation, infrastructure, public support, etc. Based on the literature review in Chapter 4, and the expert knowledge, the main criteria defined were: 1) Invest in education, 2) invest in technological user friendliness, 3) invest in governance for inclusion, 4) invest in digital infrastructure.

The factor "investment in education" was further specified into three levels, including 1) Improve people's technological skills, which was further specified to governmental officers, users of technologies and investors, 2) invest in digital information sharing, which was further specified into mediums with advertisement, social media

and face to face, and 3) research on digitisation, which was further specified to research on digital divide and social inclusion, research on digital business development and technologies, and research on sustainability impacts of digitalisation.

The factor “invest in technological user friendliness” included two sub-categories; 1) simplify language for digital technology use and 2) invest in user-friendly tools/websites/design.

The factor “invest in governance for inclusion”, following the literature review about digital divide especially related with the socio-economic conditions for the vulnerable groups, included a total of four sub-categories, including; 1) enhance socio-economic and cultural conditions, which was further specified into promotion of culture in tourism, agricultural, community businesses development, and enhancement of socio-economic conditions for vulnerable groups (e.g. elderly, migrants, women), 2) improve governance digital services, which was further specified into improved efficiency in digital services, transparency and anti-corruption measures in digital services, as well as trust in digital services, 3) improve public support, which was further specified into; improvements of regulatory quality, such as for basic employment conditions, privacy conditions and democratic development conditions; enhance financial means, such as more use of tax reduction to improve digitalisation and increase subsidies for digitalisation improvements, and 4) enhance public-private collaboration

The factor “invest in digital infrastructure” included a total of three sub-categories, referred to as; 1) invest in digital connectivity, such as LoRa, Wi-Fi, 4G, 5G, 2) invest in digital affordability, such as digital costs reduction and increased income among vulnerable groups (e.g., elderly, migrants, women), and 3) invest in digital availability, such as availability across areas (rural-urban) and availability to vulnerable groups (e.g. women, migrants, elderly).

While the value-tree looked more comprehensive after the workshop, after a series of trials, the value-tree was trimmed down to the size provided in Figure 9. The value-tree was plotted into a software referred to as; Value Analyses of Relative Importance (VARI), which is made for purposes of assigning weights with pairwise comparison following the approach of Saaty (2004).

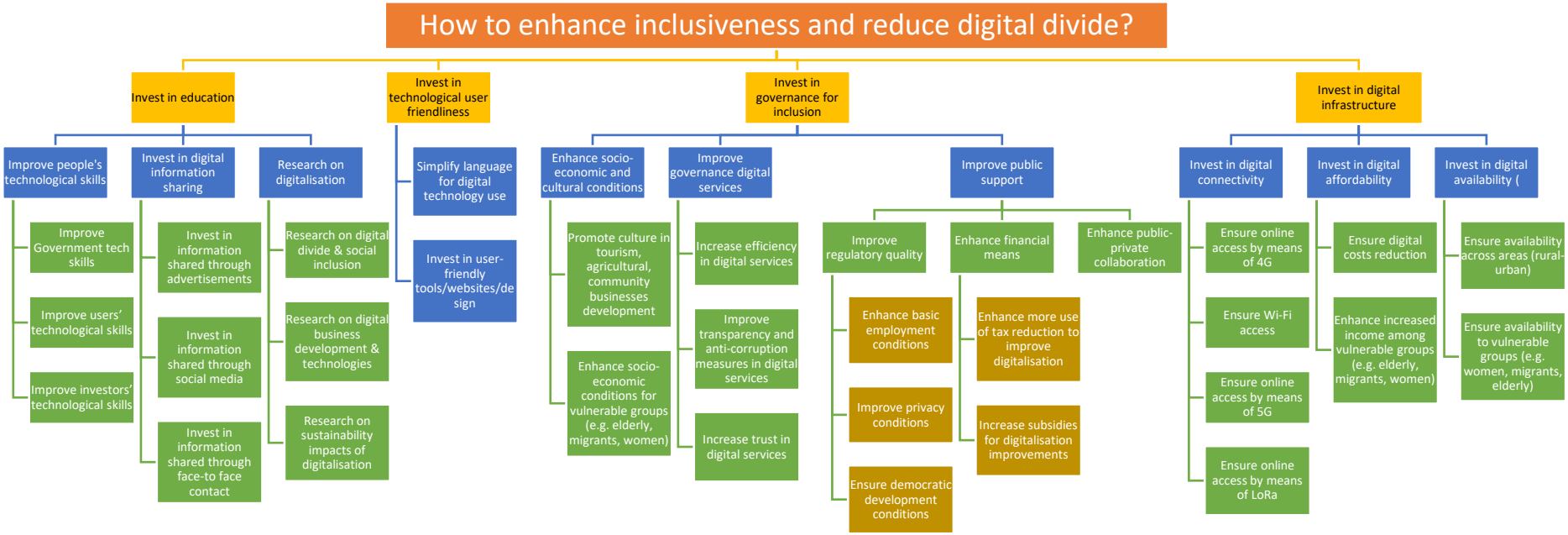

Figure 9: A value-tree of inclusion factors of digital divide (VARI)

Responses to the questionnaire

In Figure 10, a presentation of the demographics of the sample is provided showing that a) one third of the responses are female, b) the largest age groups responding are the between 26-35 and 36-45 years, with a share of about 40% each, c) the country representative of the survey is highly respondents from Greece (37%), followed by The Netherlands (15%), Cyprus (15%) and Spain (7.4%) with all other countries being represented by 3.7%, d) not only researchers (70.4%) have responded to the questionnaire, but also entrepreneurs (22.2%) and public officers (7.4%).

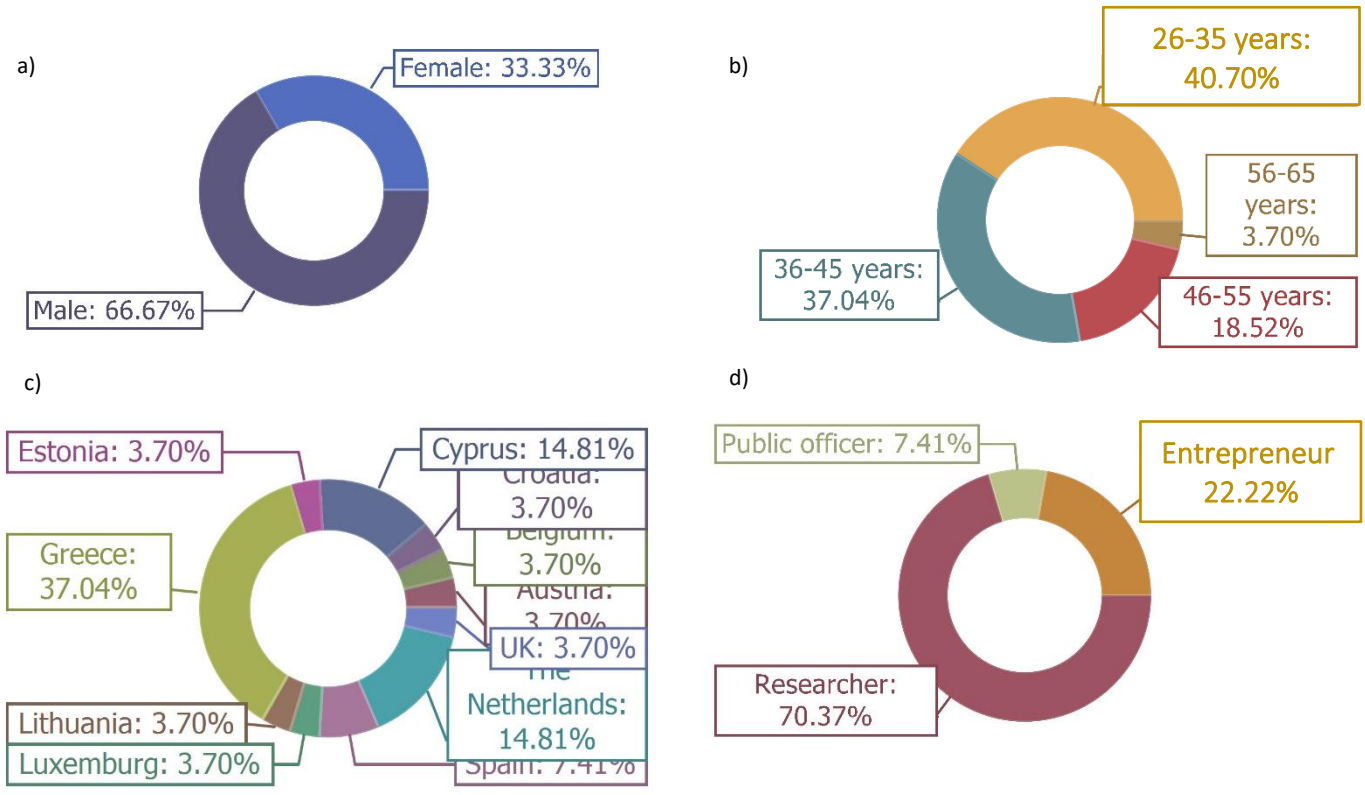

Figure 10: Characteristics of respondents filling in the questionnaire with respect to a) gender, b) age, c) area and d) occupation.

In Figure 11, the general overview of importance across the main factor categories defined to enhance inclusiveness and reduce digital divide across regional areas in Europe are provided, including investments technological user-friendliness, governance for inclusion, education and digital infrastructure. It appears technological user friendliness is seen particularly important in the UK and Belgium, but least important to Luxemburg and Estonia. Investments in governance for inclusion is relevant across most cases, but highly so in Austria, and of only little relevance in the UK, Croatia and Austria. Also, investments in education scores generally high, but extremely so in the UK, Luxemburg and Lithuania, and a bit less in Greece and the Netherlands. Investments in digital infrastructure is very much emphasised for Spain and Croatia, and the least emphasis is provided in Lithuania.

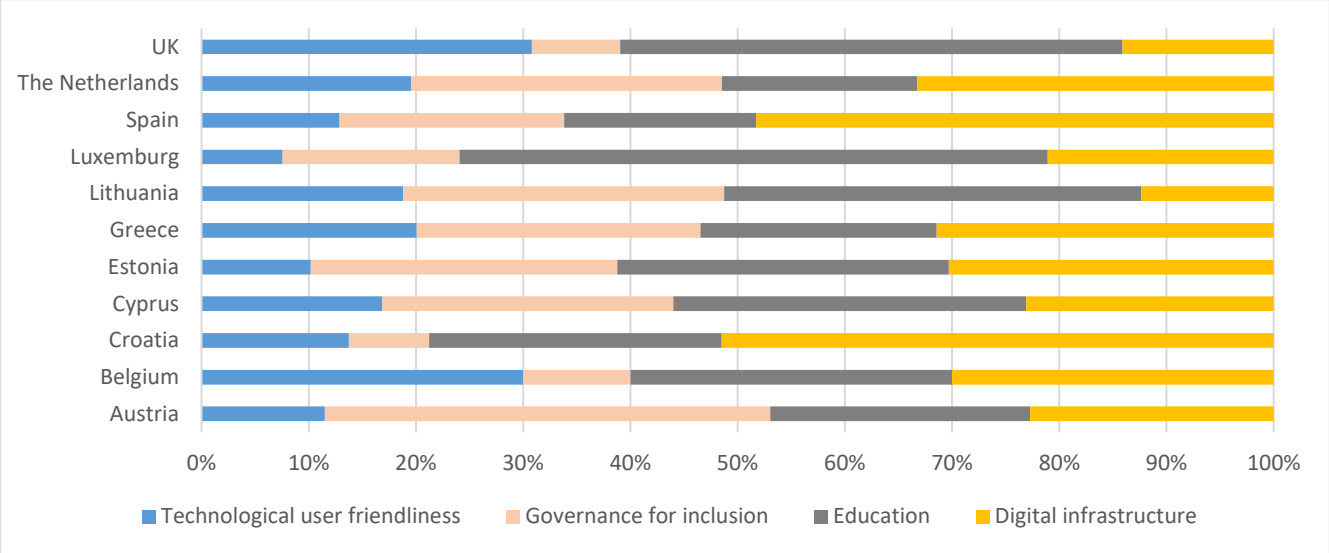

Figure 11: Importance of investments education, technological user-friendliness, governance for inclusion and digital infrastructure across areas in XGain to enhance inclusiveness and reduce digital divide

In Figure 12, the sub-categories of investing in technological user-friendliness are compared, for which the UK, the Netherlands, Spain, Cyprus, Croatia and Belgium are foremost concerned about the needs for improved tools, websites and designs, whereas Luxemburg, Lithuania, Greece, Estonia and Austria put more emphasis on the need to simplify the language.

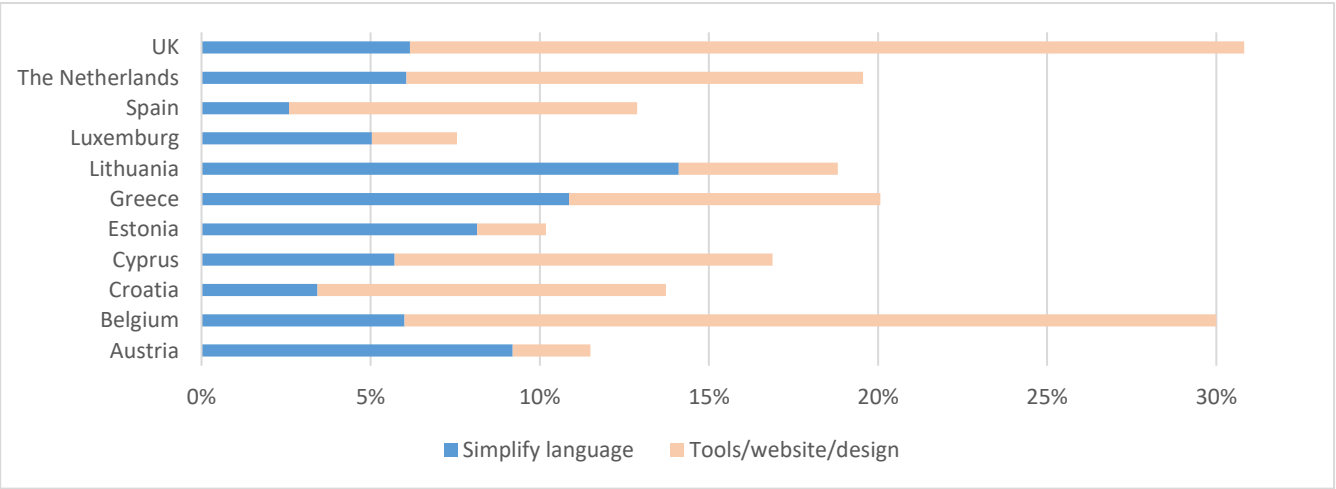

Figure 12: Importance of sub-factors of investing in technological user-friendliness, including simplifying language and improve tool/website design across areas in XGain to enhance inclusiveness and reduce digital divide

Looking at the sub-factors of investing in governance for inclusion, Austria who gave highest priority to this option, specified that the need for public support is the most urgent, followed by the improvements of digital services. Also, Spain, Luxemburg, Greece and Cyprus, put the highest scores to public support, whereas Estonia put highest emphasis on improving the digital services. The Netherlands and Lithuania support socio-economic and cultural conditions as the most relevant option.

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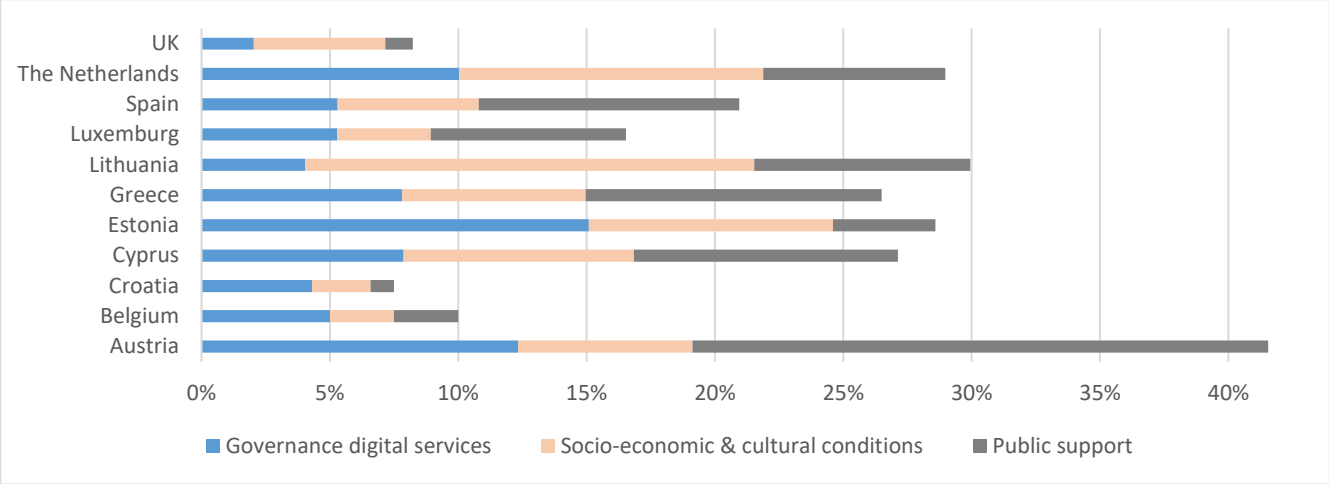

Figure 13: Importance of sub-factors of governance for inclusion, including digital services, socio-economic & cultural conditions and public support across areas in XGain to enhance inclusiveness and reduce digital divide

In the Figures 14-16, the sub-sub categories of governance for inclusion are addressed. First, the Figure 14 assesses the importance of sub-sub categories of investing in digital services to enhance inclusiveness and reduce digital divide, for which increase in efficiency in digital services is valued relatively low across all cases, and improve transparency and anti-corruption measures in digital services is highly valued as important in Estonia, as well as in the Netherlands and Austria, but very little in the UK. The option increase trust in digital services is highest favoured in Spain, Greece and Austria.

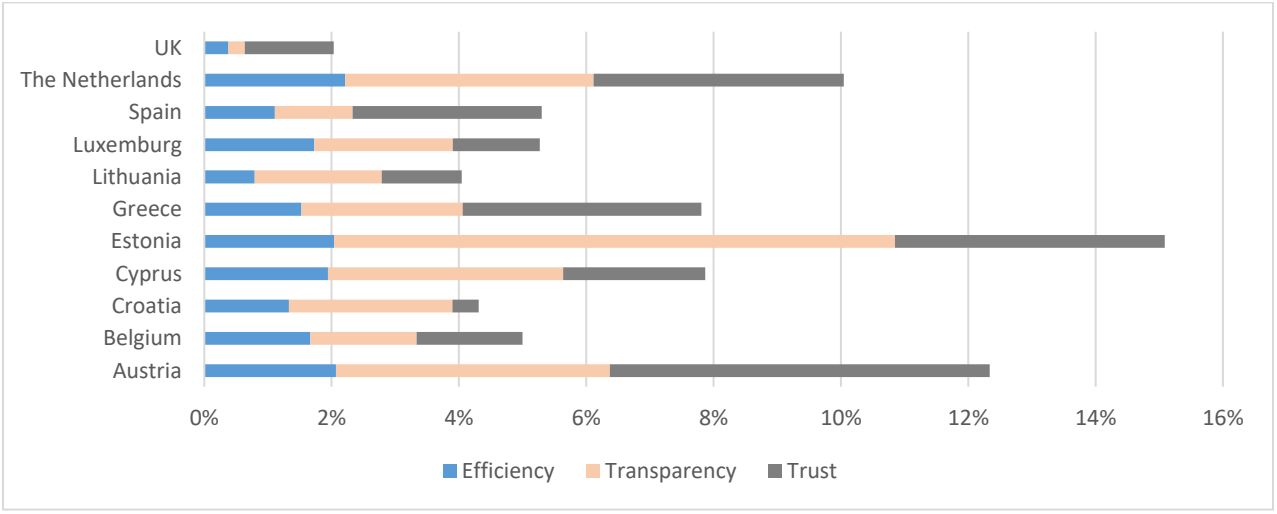

Figure 14: Importance of sub-sub factors of governance for inclusion -investing in digital services, including emphasising efficiency, transparency and trust across areas in XGain to enhance inclusiveness and reduce digital divide

Second, in Figure 15, the sub-sub categories of the option governance for inclusion - to enhance socio-economic and cultural conditions, promoting culture in tourism, agricultural, community businesses development is highly relevant to Spain, but also to the Netherlands and Lithuania, although these two countries emphasised the option to enhance socio-economic conditions for vulnerable groups (e.g., elderly, migrants, women) even more. Promoting culture is less relevant to Croatia, Belgium and Luxemburg, while enhancing socio-economic conditions is also not so relevant to these particular countries.

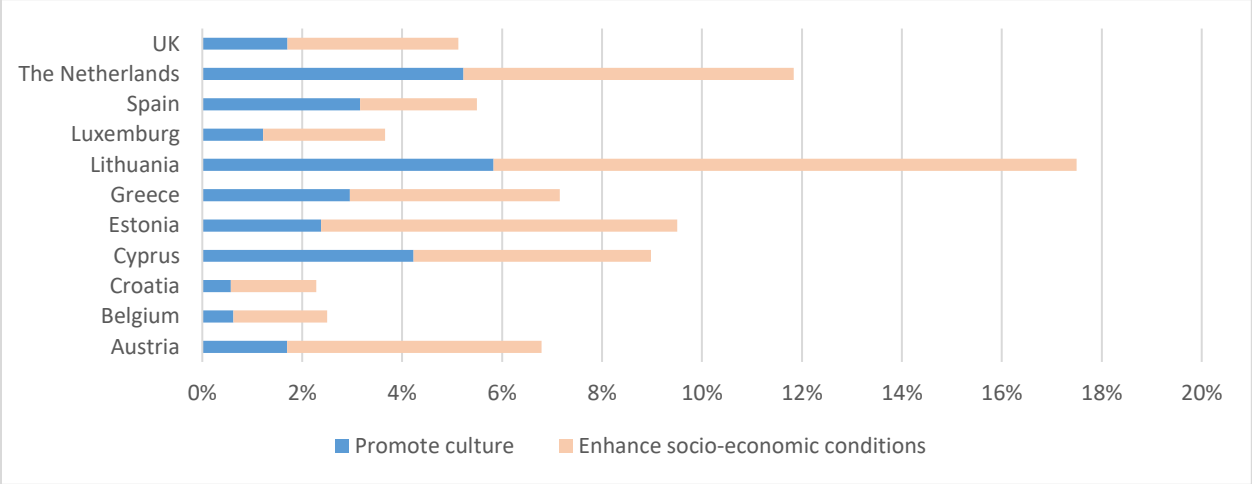

Figure 15: Importance of sub-sub-factors of governance for inclusion - investing in socio-economic & cultural conditions, including to promote culture and enhance socio-economic conditions across areas in XGain to enhance inclusiveness and reduce digital divide

Third, the sub-sub factors to governance for inclusion - improvement of public support is provided in Figure 16, got a very high importance level in Austria who favoured the option of enhancing public-private collaboration the most, followed by ensuring regulatory quality. The importance for improving regulatory quality was also judged relatively more important to Spain, Luxemburg, Cyprus, Belgium and Lithuania, and less important to the UK, Croatia, Estonia and Greece. The financial means were highly relevant to Greece in particular.

Note that the sub-sub-sub levels of improve regulatory quality and enhance financial means have not been reported on here because of the high detail levels, including the assessments of the relevance of enhancing basic employment conditions, improving privacy conditions and ensuring democratic development conditions specified for regulatory quality options, as well as enhancing more use of tax reduction to improve digitalisation and increasing subsidies for digitalisation improvements, specified as options for enhancing financial means.

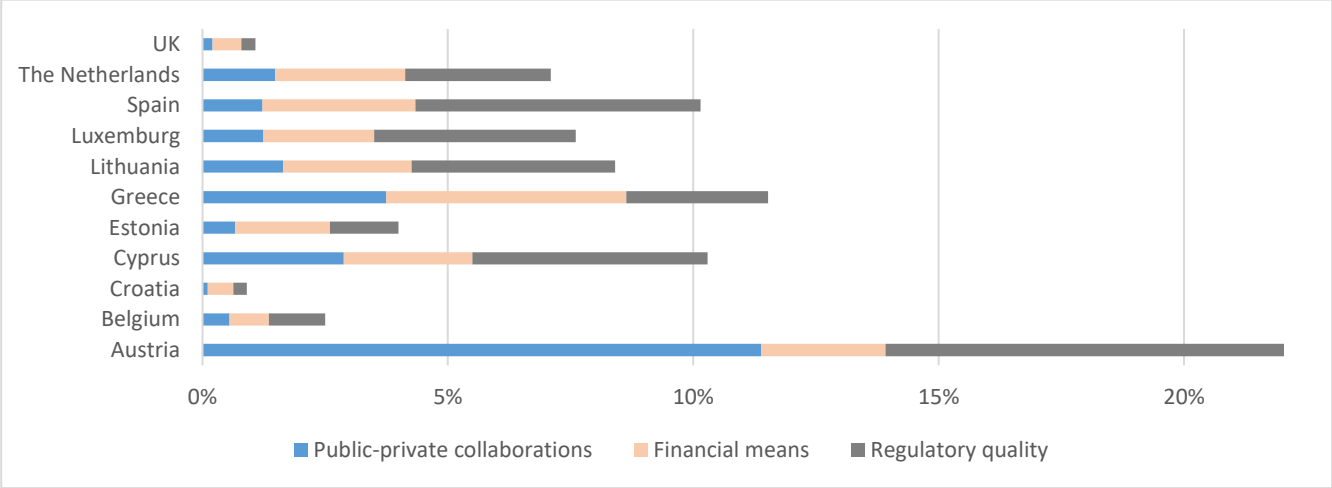

Figure 16: Importance of sub-sub factors of governance for inclusion - investing in public support, including emphasising public-private collaborations, financial means and regulatory quality across areas in XGain to enhance inclusiveness and reduce digital divide

In Figure 17, the sub-categories of invest in education is assessed across the areas. Improve people's technological skills is judged highly relevant to Luxemburg, Lithuania, Estonia, Cyprus, as well as in the

Netherlands, Croatia and Belgium, but less so in Spain and Austria. Whereas investments in digital information sharing is seen more relevant to the UK, as well as in Luxemburg and Lithuania, and less relevant to Spain and Croatia, research on digitalisation is seen relatively more important to Spain, Croatia and Austria, and less to Estonia and the Netherlands.

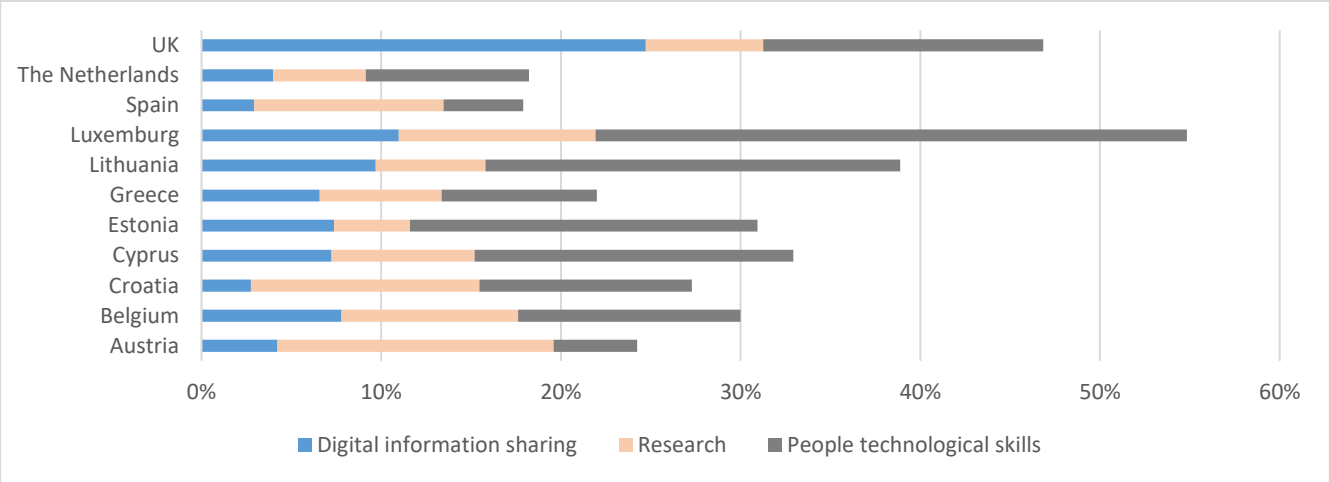

Figure 17: Importance of sub factors of investing in education, including emphasising digital information sharing, research and people technological skills areas in XGain to enhance inclusiveness and reduce digital divide

In the Figures 18, 19 and 20, the sub-sub categories of the investment in education option are assessed to understand their relevance. First, in Figure 18, the investments in digital information sharing, which was very mush priorities by the UK, show that they find it most important to invest in information shared through face-to face contact, followed by investments in information shared through social media. This order was similar in Belgium, however, most other countries put the social media option the highest. Investments in information shared through advertisements seems to be of no relevance to the Netherlands, Spain, Croatia and Austria, in particular.

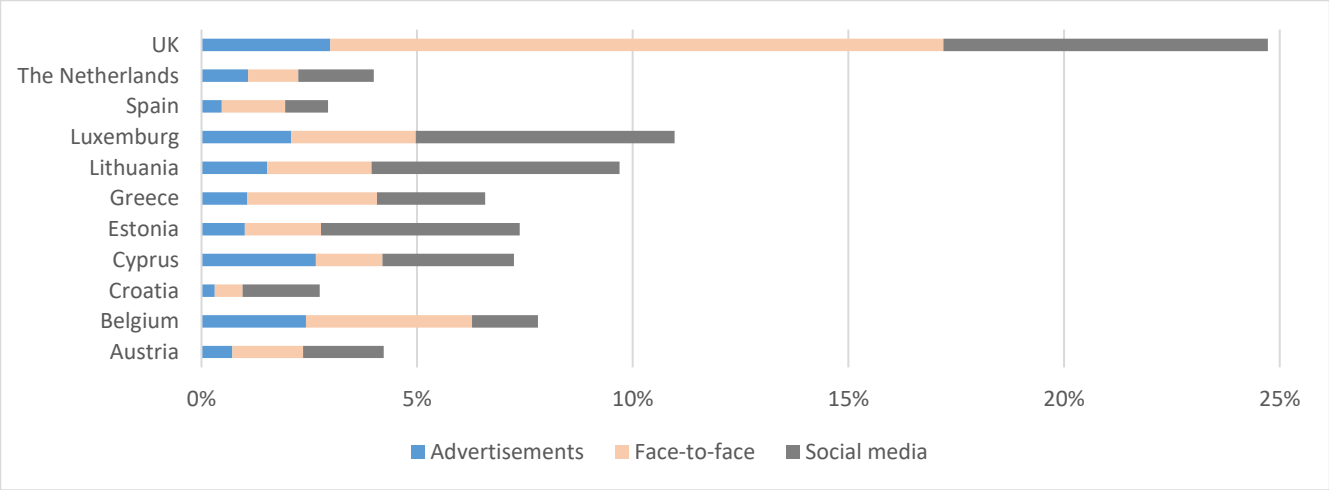

Figure 18: Importance of sub-sub factors of investing in digital information sharing, including emphasising advertisements, face-to-face and social media interactions across areas in XGain to enhance inclusiveness and reduce digital divide

Second, in Figure 19, the importance of the sub-sub categories of investment in education - research on digitalisation - are compared across the areas to judge on their importance to enhance inclusiveness and reduce

digital divide. Austria, who values this category the highest, specifies that research on sustainability impacts of digitalisation is of highest importance, followed by research on digital business development & technologies. This option is emphasised particularly for Spain, Greece and Belgium, and put low in the UK, the Netherlands and Lithuania. Croatia also values this category high, giving equally high importance to all the three options. Note that the third option to conduct research on digital divide & social inclusion is put relatively high in the Netherlands and Cyprus, and is also put high by Austria.

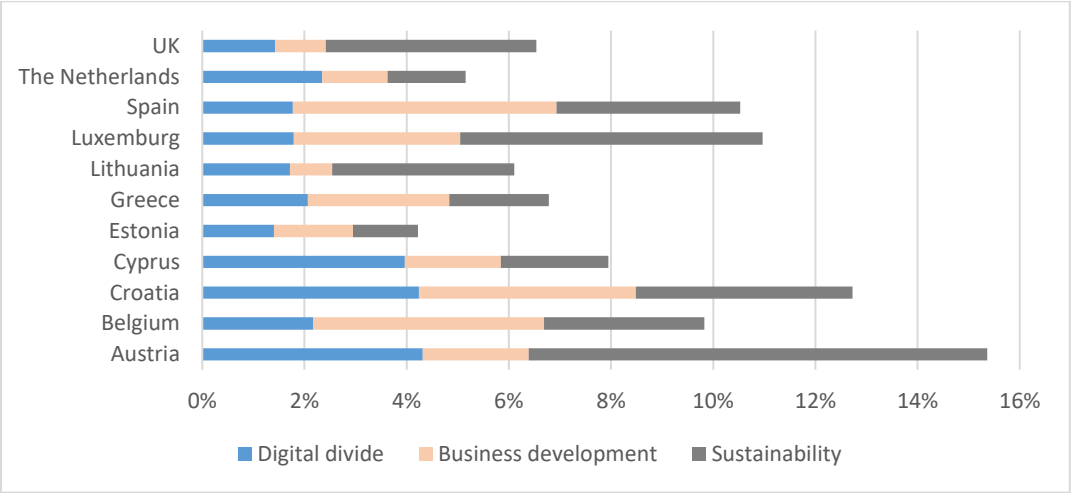

Figure 19: Importance of sub-sub factors of investing in research, including emphasising research on digital divide, business development and sustainability across areas in XGain to enhance inclusiveness and reduce digital divide

Third, in Figure 20, the sub-sub categories of governance for inclusion - improvements of people technological skills are presented, which was highly valued by Luxemburg, followed by Lithuania, Estonia and the UK. The option to improve users' technological skills was put particularly high in all these four countries, as well as in the other countries the Netherlands, Spain, Greece, Croatia and Austria. To improve Government tech skills was highly emphasised by Cyprus, and scored very low in Spain, Greece and Austria. The option to improve investors' technological skills was highly relevant to Lithuania, as well as Estonia and Luxemburg, and less relevant to the UK, Spain, Croatia and Austria.

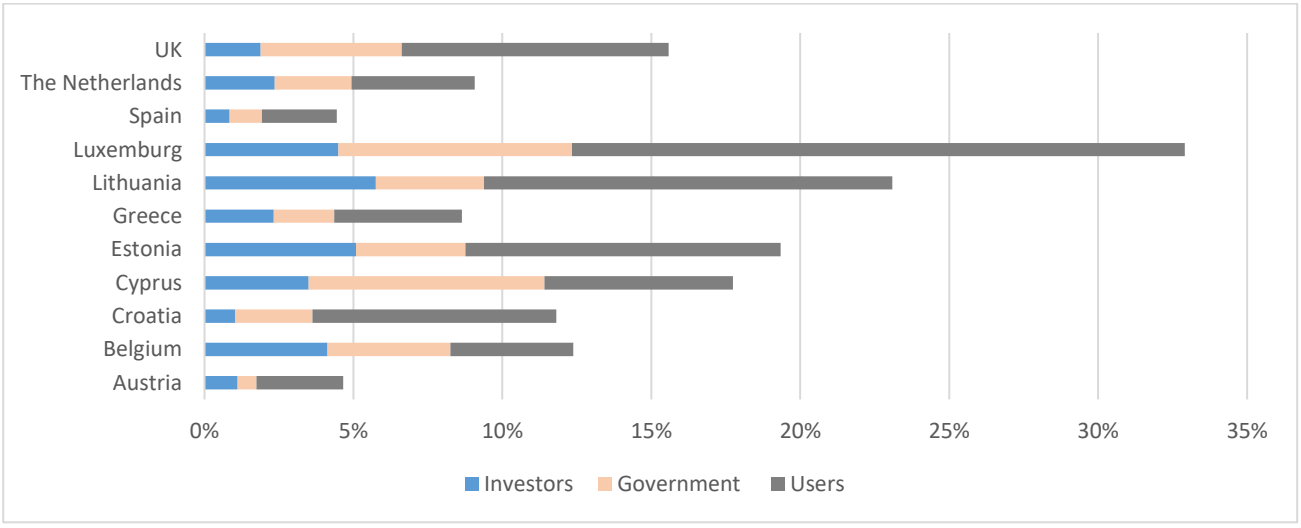

Figure 20: Importance of sub-sub factors of investing in people technological skills, including investors, government and users across areas in XGain to enhance inclusiveness and reduce digital divide

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The last figures belong to the main category of invest in digital infrastructure to enhance inclusiveness and reduce digital divide. Overall, the sub-categories are assessed in Figure 21, to which the extent they are relevant to the different areas, including investments in Invest in digital availability, which was emphasised the most by the UK, Spain, Greece, Estonia, Cyprus and Austria, and the least the Netherlands and Croatia. Digital affordability was highly priorities by the Dutch, and second highest by Croatia. Digital connectivity was foremost priorities by Spain and Croatia, followed by the Netherlands and Belgium. Below are the sub-sub-sub categories of each sub-sub category.

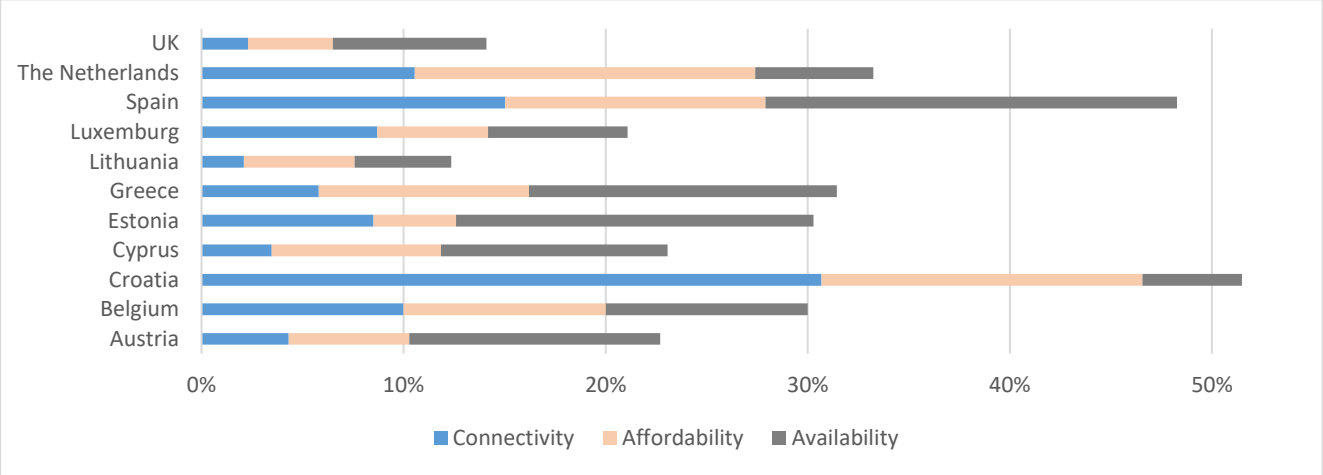

Figure 21: Importance of sub factors of investing in technology digital infrastructure, including emphasising connectivity, affordability and availability across areas in XGain to enhance inclusiveness and reduce digital divide

First, in Figure 22, the sub-sub categories of investing digital infrastructure – affordability are assessed across the areas, as means to enhance inclusiveness and reduce digital divide. It appears that the Dutch value this category particularly high, and put more emphasis on enhancing increased income among vulnerable groups (e.g. elderly, migrants, women), and less on ensuring digital costs reduction. This pattern is similar also in Spain, Croatia, and Belgium, whereas in Luxemburg and Austria, this option is ranked very low. The areas with highest priorities to the cost reduction option include Cyprus as well.

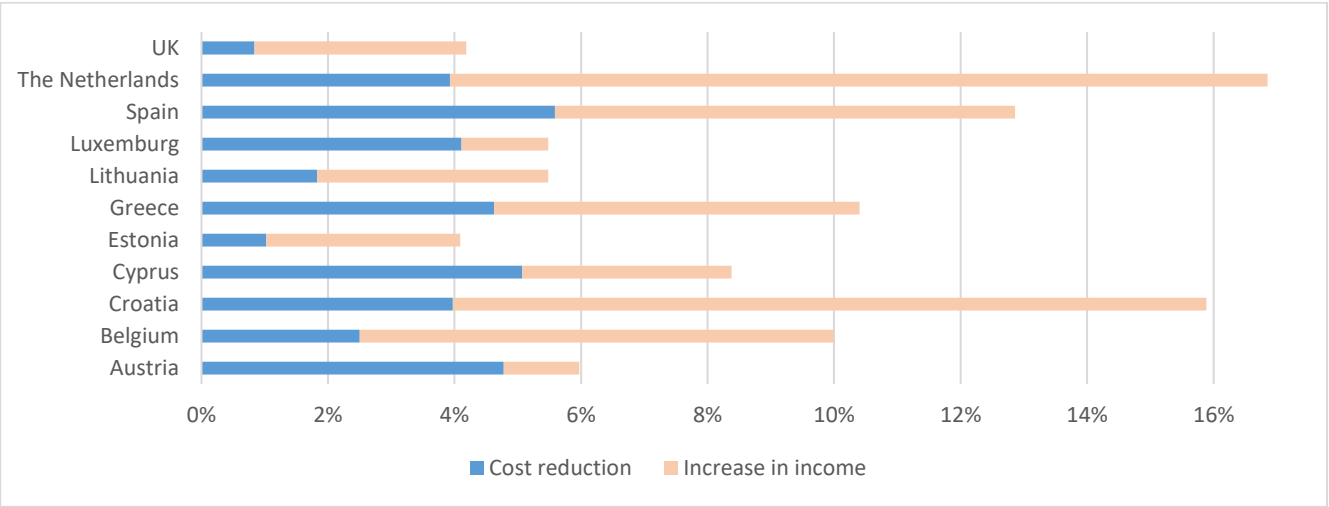

Figure 22: Importance of sub-sub factors of investing in affordability, including emphasising cost reduction and increase in income across areas in XGain to enhance inclusiveness and reduce digital divide

Second, in Figure 23, the sub-sub categories of investing digital infrastructure - digital availability - are assessed to judge on relevance to enhance inclusiveness and reduce digital divide in particular areas. It appears Spain emphasises this option the most, followed by Estonia, for which both areas put highest emphasis on ensuring availability to vulnerable groups (e.g., women, migrants, elderly), which is less relevant to the contexts in Luxemburg, Lithuania, Croatia and Austria, as well as the UK and the Netherlands. The option to ensure availability across areas (rural-urban), is highly relevant to all areas, but most to the UK, Luxemburg, Greece, and Austria, and less relevant to Belgium.

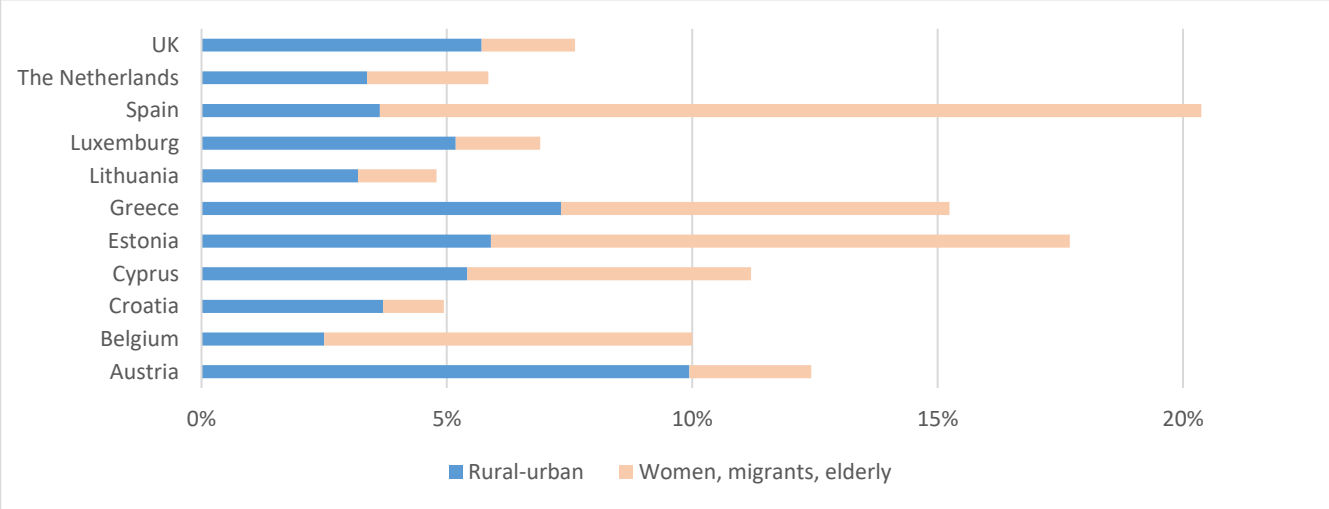

Figure 23: Importance of sub-sub factors of investing in digital availability, including emphasising rural-urban and vulnerable groups such as women, migrants and elderly across areas in XGain to enhance inclusiveness and reduce digital divide

Third, in Figure 24, the sub-sub categories of investing digital infrastructure - digital connectivity - are assessed to judge on relevance to enhance inclusiveness and reduce digital divide in particular areas. Connectivity as such scores high in Croatia in particular, who put the highest emphasis on ensuring online access by means of 5G, followed by Spain, the Netherlands and Luxemburg, while is of less importance in the UK and Lithuania. Belgium put equal emphasis on the 5G, 4G and Wi-Fi options, and less to ensuring online access by means of LoRa, which overall seems to be of less relevance across the cases, only with some importance in Croatia. Ensuring online access by means of 4G scores relatively high in the UK, and is second most important in Croatia. Ensuring Wi-Fi access seems to be less relevant to Cyprus and Austria.

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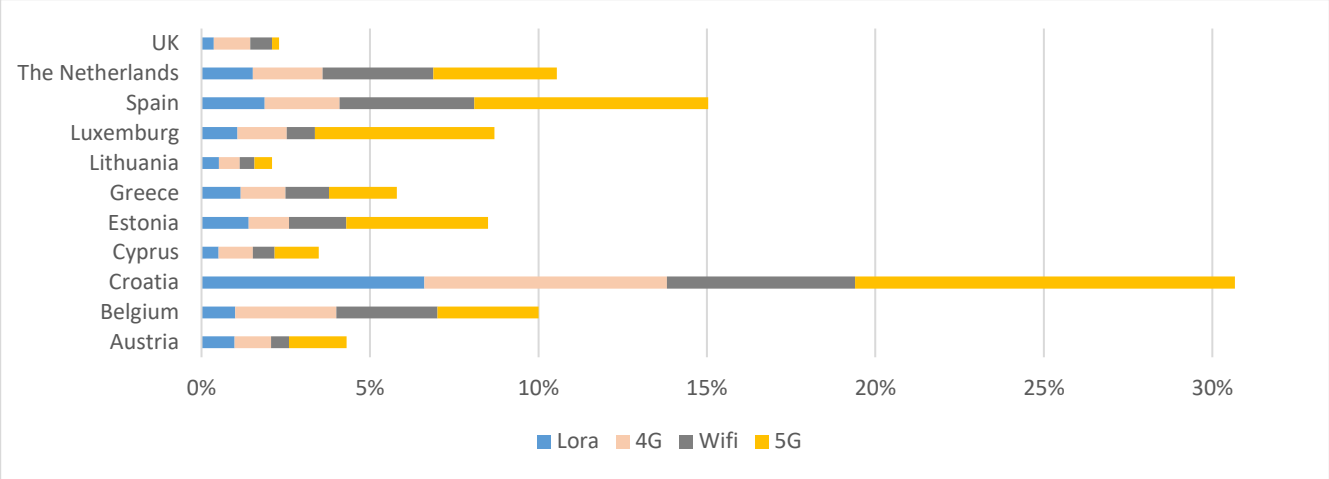

Figure 24: Importance of sub-sub factors of investing in digital connectivity, including emphasising LoRa, Wi-Fi, 4G and 5G across areas in XGain to enhance inclusiveness and reduce digital divide

5.2.3 Summing up

In this section, an exercise is carried out among the XGain partners to respond to the question: "how to ensure inclusiveness and reduce digital divide? Based on interactions and work carried out across the XGain deliverables as well as the literature, explanatory factors to the so-called VARI evaluations were identified and arranged into a value-tree, following the approach of Saaty (2004). These insights were communicated and discussed for their relevance for the value-tree during a one day workshop on 18 October 2023, as well as the literature review on digital divide. As a result some four main categories of criteria were defined according to different main areas of relevance to invest: 1) Invest in education, 2) invest in technological user friendliness, 3) invest in governance for inclusion, and 4) invest in digital infrastructure. These were further specified into more detailed levels. As shown in In Figure 11, the relative relevance of these general criteria on how to enhance inclusiveness and reduce digital divide across regional areas in Europe are provided, showing that technological user friendliness is seen particularly important in the UK and Belgium, but least important to Luxemburg and Estonia. Moreover, investments in governance for inclusion is relevant across most cases, but highly so in Austria, and of only little relevance in the UK, Croatia and Austria. Also, investments in education scores generally high, but extremely so in the UK, Luxemburg and Lithuania, and a bit less in Greece and the Netherlands. Investments in digital infrastructure is very much emphasised for Spain and Croatia, and the least emphasis is provided in Lithuania. Notably, these relevance scores are not obtained by a representative sample of respondents, but by a few people belonging to the XGain project knowing the context of their own use case. Because such knowledge can be biased, for instance, if some have high expertise in a specific field, the relative relevance will be higher than if the sample of respondents is larger. As such, this exercise is not meant to give direct advise on how to invest across the represented European contexts, but rather to show how urgencies can vary across different contexts and to give clues about a methodology that can be useful detect such variability. For policy making in Europe, there is no single manner of dealing with digital divide, but different investment strategies are needed in different countries.

The main criteria defined for digital divide can provide insights for Stakeholder Mapping and End-user Needs Analysis through Processes of Co-creation (Task 2.1), and is considered relevant to the XGain Use Case Requirements and Specifications for Connectivity and Edge Technology Enablers (Task 2.3) and the XGain Knowledge Facilitation Tool Architecture Design and Technical Specifications (Task 2.4). Moreover, in other work packages, this deliverable 2.2. has potentials to contribute to the impact assessments work in WP4, foremost the Socio-environmental Assessment of Last-mile and Edge Technological Solutions (Task 4.2), as well as for the case activities performed in WP5, in particular the Social Acceptance, Performance Evaluation, Impact Analysis

and Replication Guidelines (Task 5.8). For the policy evaluations in WP6, this exercise may be interesting for Task 6.2: Standardisation and Interaction with Policy-makers, Associations and Other Related Projects.

5.3 Stakeholder analyses of adoption of digital technologies

5.3.1 Introduction

Whereas the social innovation analyses in the previous section concentrated on confirming exact inclusiveness across different contexts, in this section the social innovation analyses concentrate on analysing the behaviour potential users of new technologies. The aim of this section is to identify perceptions of adopting high tech among stakeholders within use cases in the XGain project. In these analyses we operate at local level (farm level) and concentrate questions around very specific technologies offering services to the local farm. The adoption and diffusion of innovations are influenced by a wide range of factors, most prominently and influentially classified in the diffusion of innovations (DoI) theory by Rogers (2003). In particular, the following five main elements of diffusion are relevant:

- Characteristics of the innovation, including its relative advantage, compatibility, complexity, trialability and observability;
- Characteristics of the adopters, including orientation, motivation and abilities/skills;
- Communication channels, referring to the different means (from interpersonal to mass media) by which individuals get messages from each other;
- Time, needed to observe, learn and experiment with the innovation; and
- Social system, described as the interrelationships between adopters looking for solving a common problem to reach a collective goal.

There are numerous studies that assess the wide range of factors influencing the adoption and diffusion of agricultural innovations (see e.g., Feder & Umali, 1993; Knowler & Bradshaw, 2007; Pannell et al., 2006), which formed the basis for the Adoption and Diffusion Outcome Prediction Tool (ADOPT) that provides predictions of an innovation's level of adoption and rate of diffusion as well as estimates on the importance of factors influencing adoption and diffusion (Kuenhne et al., 2017). As such, ADOPT can be described as a social innovation analysis about the ability of people to take part in the high tech developments and create opportunities.

5.3.2 Survey on adopting digital technologies (ADOPT)

ADOPT is a web-based tool developed by the Commonwealth Scientific and Industrial Research Organisation (CISRO) along with other Australian laboratories and academic institutions (see Kuenhne et al., 2017). ADOPT is, amongst others, based on concepts explained by the DoI theory (Rogers, 2003), considering four categories (quadrants) of influences on adoption:

1. Relative advantage for the population (Quadrant Q1);
2. Learnability characteristics of the innovation (Quadrant Q2);
3. Population-specific influences on the ability to learn about the innovation (Quadrant Q3); and
4. Relative advantage of the innovation (Quadrant Q4)

The tool uses different interaction variables, including variables related to profit, risk and environmental outcomes, farmer networks, characteristics of the farm and the farmer, and the ease and convenience of the innovation (Kuenhne et al., 2017).

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ADOPT is composed of 22 variables divided over the abovementioned four main quadrants (Figure 25) (Kuenhne et al., 2017). The corresponding 22 questions are correlated, creating different intermediate variables with the objective to reach two central values in the prediction scenario: the Peak Adoption Level (PAL) and the Time to Peak Adoption Level (TPAL).

The PAL is dependent on the intermediate variable Relative advantage, which is based on 14 independent variables in the two relative-advantage quadrants Q1 (Relative advantage for the population) and Q4 (Relative advantage of the innovation). Relative advantage is dependent on the Profit advantage, Environmental advantage, Risk, Easy & convenience and Investment costs of the innovation in combination with characteristics of the farm and the farmer.

The TPAL is dependent on the intermediate variables Awareness, learning of relative advantage, relative upfront costs, and short-term constraints, which are based on 9 independent variables in, mainly, the two learning quadrants Q2 (Learnability characteristics of the innovation) and Q3 (Population-specific influences on the ability to learn about the innovation). Learning of relative advantage is dependent on (Farmer) networks & skills and Trialability of the innovation.

ADOPT has been validated using six specific agricultural innovations and populations with known complete or near-complete adoption outcomes (see Kuenhne et al., 2017). The model shows a good fit (predicted vs. actual) for PAL as well as TPAL.

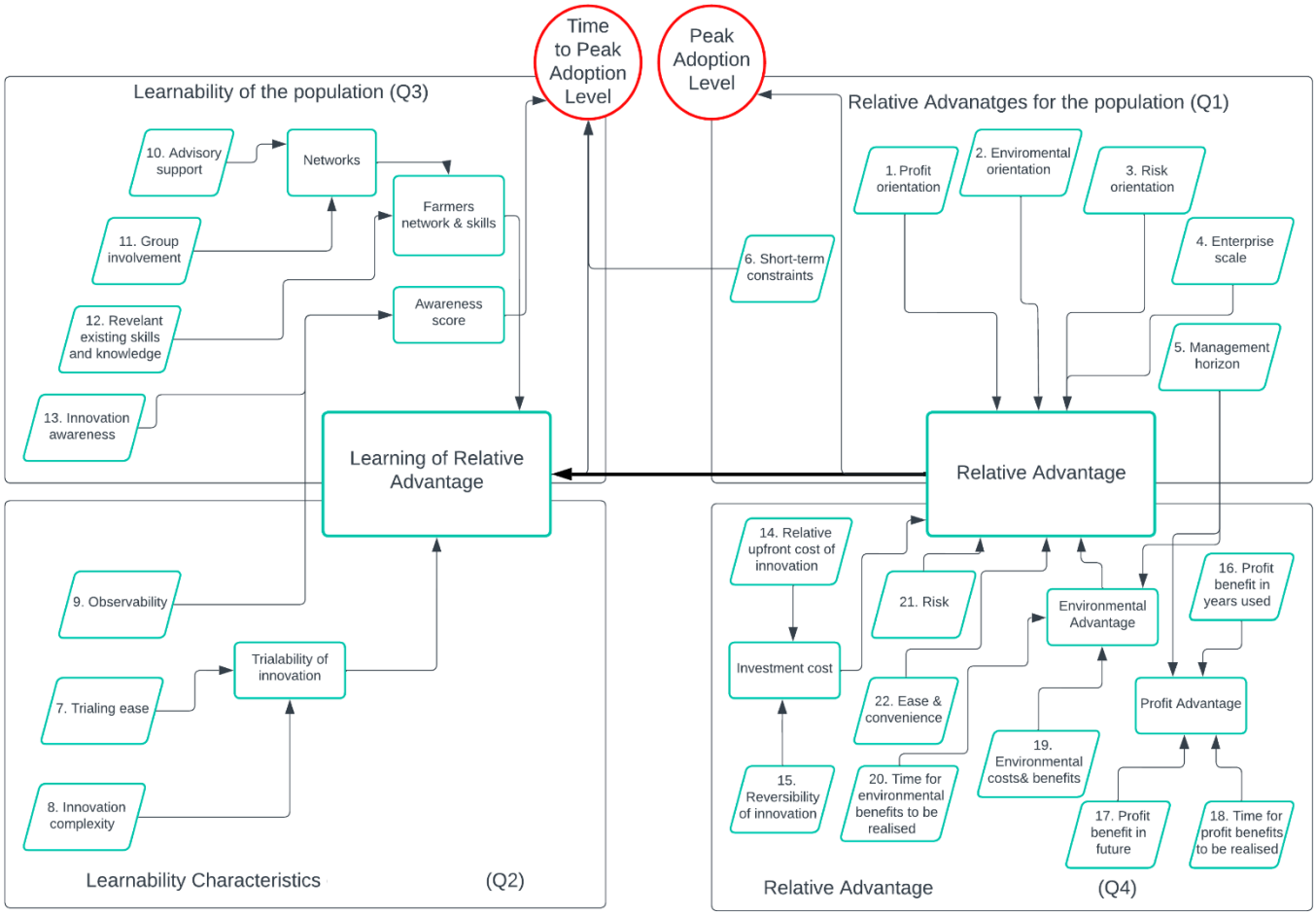

Figure 25: OPT quadrants, their relationships to the 22 questions, and their influences on Peak Adoption Level and Time to Peak Adoption (source: Kuehne et al., 2017; Lopez-Maciel et al., 2023)

The 22 questions comprising ADOPT are described in Table 4. ADOPT is intended to be used before or during the early stages of the adoption and diffusion process and is generally applied in a workshop setting with professionals working with farmers. Participants discuss each question and justify their responses, particularly for those questions where consensus is low. Questions that show low consensus are identified, and sensitivity analysis is performed to assess how different possible responses may affect adoption and diffusion outcomes. ADOPT has, however, also been adapted to an on-line survey format where potential adopters can fill-in their responses (see e.g., López-Maciel et al., 2023) – allowing for the spatially explicit assessment of adoption and diffusion patterns.

Table 4: ADOPT variables and questions (source: Kuenhne et al., 2017)

Quadrant	Variable	Question
Relative advantage for the population (Q1)	1. Profit orientation	What proportion of the target population has maximising profit as a strong motivation?
	2. Environmental orientation	What proportion of the target population has protecting the natural environment as a strong motivation?
	3. Risk orientation	What proportion of the target population has risk minimisation as a strong motivation?
	4. Enterprise scale	On what proportion of the target farms is there a major enterprise that could benefit from the innovation?
	5. Management horizon	What proportion of the target population has a long-term (greater than 10 years) management horizon for their farm?
	6. Short-term constraints	What proportion of the target population is under conditions of severe short-term financial constraints?
Learnability characteristics of the innovation (Q2)	7. Trialing ease	How easily can the innovation (or significant components of it) be trialed on a limited basis before a decision is made to adopt it on a larger scale?
	8. Innovation complexity	Does the complexity of the innovation allow the effects of its use to be easily evaluated when it is used?
	9. Observability	To what extent would the innovation be observable to farmers who are yet to adopt it when used in their area?
Population-specific influences on the ability to learn about the Innovation (Q3)	10. Advisory support	What proportion of the target population uses paid advisors capable of providing advice relevant to the innovation?
	11. Group involvement	What proportion of the target population participates in farmer-based groups that discuss this type of innovation?
	12. Relevant existing skills & knowledge	What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?
	13. Innovation awareness	What proportion of the target population would be aware of the use or trialing of the innovation in their area?
Relative advantage of the innovation (Q4)	14. Relative upfront cost of the innovation	What is the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?
	15. Reversibility of the innovation	To what extent is the adoption of the innovation able to be reversed?
	16. Profit benefit in years that it is used	To what extent is the use of the innovation likely to affect profitability of the farm business in the years that it is used?
	17. Profit benefit in future	To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm?
	18. Time for profit benefit to be realized	How long after the innovation is first adopted would it take for effects on future profitability to be realized?
	19. Environmental impact	To what extent would the use of the innovation have net environmental benefits or costs?

	20. Time for env. impacts to be realized	How long after the innovation is first adopted would it take for expected environmental benefits or costs to be realized?
	21. Risk	To what extent would the use of the innovation affect the net exposure of the farm business to risk?
	22. Ease and convenience	To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?

5.3.3 The applications of readiness to adopt digital technologies

The cases selected for the ADOPT analyses

For this deliverable, the social analyses of the behaviours of potential users of new technologies were conducted in two of the use cases. The one is taking place in Belgium, Flanders, to analyse adoption of a so-called Digital Shepard, which is a camera system that can monitor the herds in the field. The other use case is the Islands of Scilly, UK, for which farmers potentially could be interested in a s-called Multi Robot system including sensors for soil management, and a drone to enhance connectivity which is relatively unpredictable. The two cases were selected initially due to practicalities such as understandable language to the Dutch research team and time constrains. However, follow-up case study following this deliverable will be conducted, at least in Lithuania.

Digital Shepard in Flanders, Belgium

On 18 April 2023, an ADOPT workshop session was organised at the Flanders Research Institute for Agriculture, Fisheries and Food (ILVO) in Melle (Belgium), including participants (18) from the academic sector, ILVO, farmers' representatives from the Flander's Region and private sector companies as well as from Wageningen Research (WR), Zentrum Fur Soziale Innovation Gmbh (ZSI), Telefonica Investigacion Y Desarrollo Sa (TID) and the University of Aveiro (UAVR). The session was organised in two parts: the first part (75 minutes) introduced ADOPT (10 minutes) and discussed and responded to the ADOPT questions (65 minutes); the second part (45 minutes) presented and discussed the preliminary results based on the responses obtained in the first part.

The innovation considered in this ADOPT workshop is related to livestock farming in Flanders, Belgium. As shown in Figures 6 and 7, employment in the technology sector is relatively high, while usage of ICT is relatively low. Flanders is observed as a densely populated area, with communication infrastructure in place, however, there are differences in connectivity between different areas, providers and devices. Traditionally, Flanders is very active in the farming industry, but the available arable lands and pastures of each farmer are spread across multiple smaller fields in the same or neighbouring villages. Already, a digital divide can be observed between extensive and intensive livestock farming. The XGain scope aims to address this void by developing a 'digital shepherd' (i.e., the innovation), in two form of a camera system in the field that monitors the herd in pastures of relatively small size in densely populated and well-connected areas.

The 'digital shepherd' will support the farmers' daily operation (e.g., livestock monitoring), considering areas with both strong and poor network coverage. Real-time monitoring services will ensure animals (cows/sheep) are always observed, capturing relevant events for the farmer with a risk of health and welfare issues as well as generating targeted alerts. The digital shepherd will have a direct impact on productivity and welfare of the livestock, but also reduce stress for the farmer. Cameras at the border of fields will also be installed with automated zoom capabilities to monitor the behaviour of the animals at every moment, at a herd or individual

animal level (e.g., close monitoring of a potentially sick animal). Successful implementation of the 'digital shepherd' will improve livestock health and welfare, and result in a reduction of animal and farmers' stress.

Multi Robot system Islands of Scilly, United Kingdom

On 23-11-2023, an interview with the Scilly Organics farm representative in the islands of Scilly was performed on behalf of the local farming community. Much like the innovation discussed in the ADOPT workshop for livestock farming in Flanders, Belgium, the Multirobot System (MRS) for Scilly is tailored to address the unique challenges of this island environment. Comprising unmanned ground vehicles equipped with advanced sensors, the MRS traverses the agricultural landscapes, measuring parameters such as soil moisture, nutrient/pesticide content, humidity, and weather conditions across the farms. This data is seamlessly transmitted to a mobile app, serving as a hub that delivers pertinent information, expert advice, and timely warnings to farmers. By avoiding potential yield losses through its real-time monitoring capabilities and facilitating informed decision-making in response to dynamic weather and soil conditions, the MRS contributes not only to enhanced agricultural productivity but also positions itself as a key player in adapting to the effects of climate change on the Isles of Scilly.

5.3.4 The outcomes of stakeholder readiness levels to adopt

Digital Shepard in Flanders, Belgium

The workshop participants' answers (average) as well as standard deviation to the 22 ADOPT multiple choice questions are shown in Table 5. From the responses to quadrant Q1 (Relative advantage for the population) it can be observed that the majority of livestock farmers is considered to be profit/utility maximisers, about half is considered to be risk minimisers, have a long-term planning horizon and hold a major enterprise that could benefit from the innovation, while only a minority is considered to face severe short-term financial constraint or have protection of the environment as strong motivation. From the responses to quadrants Q2 (Learnability characteristics of the innovation) it can be observed that the innovation is moderately trialable, evaluable and observable. From the responses to quadrant Q3 (Population-specific influences on the ability to learn about the innovation) it can be observed that about half of the livestock farmers are considered to use relevant advisors, are involved in relevant farmer-based groups and would need new skills/knowledge; only a minority is considered to be aware of the use/trialing of the innovation. Finally, from quadrant Q4 (Relative advantage of the innovation) it can be observed that the innovation is considered to provide small recurrent and future profit and environmental benefits, management ease and convenience, and reduction in risk.

Table 5: ADOPT questions, answers and standard deviation (std. dev.)

	Question	Answer	Std. dev.
1.	What proportion of the target population has maximising profit as a strong motivation?	A majority have maximising profit/utility as a strong motivation (4/5)	0.6
2.	What proportion of the target population has protecting the natural environment as a strong motivation?	A minority have protection of the environment as strong motivation (2/5)	0.6
3.	What proportion of the target population has risk minimisation as a strong motivation?	About half have risk minimisation as a strong motivation (3/5)	0.6
4.	On what proportion of the target farms is there a major enterprise that could benefit from the 'digital shepherd'?	About half of the target population has a major enterprise that could benefit (3/5)	0.8
5.	What proportion of the target population has a long-term (greater than 10 years) management horizon for their farm?	About a half have a long-term planning horizon (3/5)	0.8

6.	What proportion of the target population is under conditions of severe short-term financial constraints?	A minority currently have a severe short-term financial constraint (4/5)	0.6
7.	How easily can the 'digital shepherd' (or significant components of it) be trialed on a limited basis before a decision is made to adopt it on a larger scale?	Moderately triable (3/5)	1.1
8.	Does the complexity of the 'digital shepherd' allow the effects of its use to be easily evaluated when it is used?	Moderately difficult to evaluate effects of use due to complexity (3/5)	0.8
9.	To what extent would the 'digital shepherd' be observable to farmers who are yet to adopt it when used in their area?	Moderately observable (3/5)	1.2
10.	What proportion of the target population uses paid advisors capable of providing advice relevant to the innovation?	About a half use a relevant advisor (3/5)	1.0
11.	What proportion of the target population participates in farmer-based groups that discuss this type of innovation?	About half are involved with a group that discusses Digital shepherds (3/5)	0.9
12.	What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?	About half will need new skills and knowledge (3/5)	0.8
13.	What proportion of the target population would be aware of the use or trialing of the innovation in their area?	A minority are aware that it has been used or trailed in their area (2/5)	1.2
14.	What is the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?	Moderate initial investment (3/5)	0.4
15.	To what extent is the adoption of the innovation able to be reversed?	Easily reversed (4/5)	1.0
16.	To what extent is the use of the innovation likely to affect profitability of the farm business in the years that it is used?	Small profit advantage in the years that it is used (5/8)	0.8
17.	To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm?	Small profit advantage in the future (5/8)	0.8
18.	How long after the innovation is first adopted would it take for effects on future profitability to be realized?	1 to 2 years (4/6)	0.7
19.	To what extent would the use of the innovation have net environmental benefits or costs?	Small environmental advantage (5/8)	1.5
20.	How long after the innovation is first adopted would it take for expected environmental benefits or costs to be realized?	Immediately (5/6)	1.1
21.	To what extent would the use of the innovation affect the net exposure of the farm business to risk?	Small reduction in risk (5/8)	1.0
22.	To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?	Small increase in ease and convenience (5/8)	1.5

Based on the standard deviation, it can be observed that there was some disagreement in relation to question 9 (To what extent would the 'digital shepherd' be observable to farmers who are yet to adopt it when used in their area?), 13 (What proportion of the target population would be aware of the use or trialing of the innovation in their area?), 19 (To what extent would the use of the innovation have net environmental benefits or costs?) and 22 (To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?). From the corresponding discussion, it became clear that the 'digital shepherd' is in the early stages of the adoption and diffusion process – with currently only very limited experimental trials (at ILVO grounds) and little concrete insights in the environmental, economic and management advantages, costs and benefits.

Based on the original information (see Table 7) entered in ADOPT, the tool gives as a result prediction adoption scenarios and sensitivity analysis graphs. Then, it is estimated that the PAL is 40% of the target population (Figure

26). The PAL ranges between 22% and 60% when performing a sensitivity analysis based on the most sensitive question – being Question 16 (To what extent is the use of the innovation likely to affect profitability of the farm business in the years that it is used?). The TPAL is 15 years from 2023 (when the workshop was held).

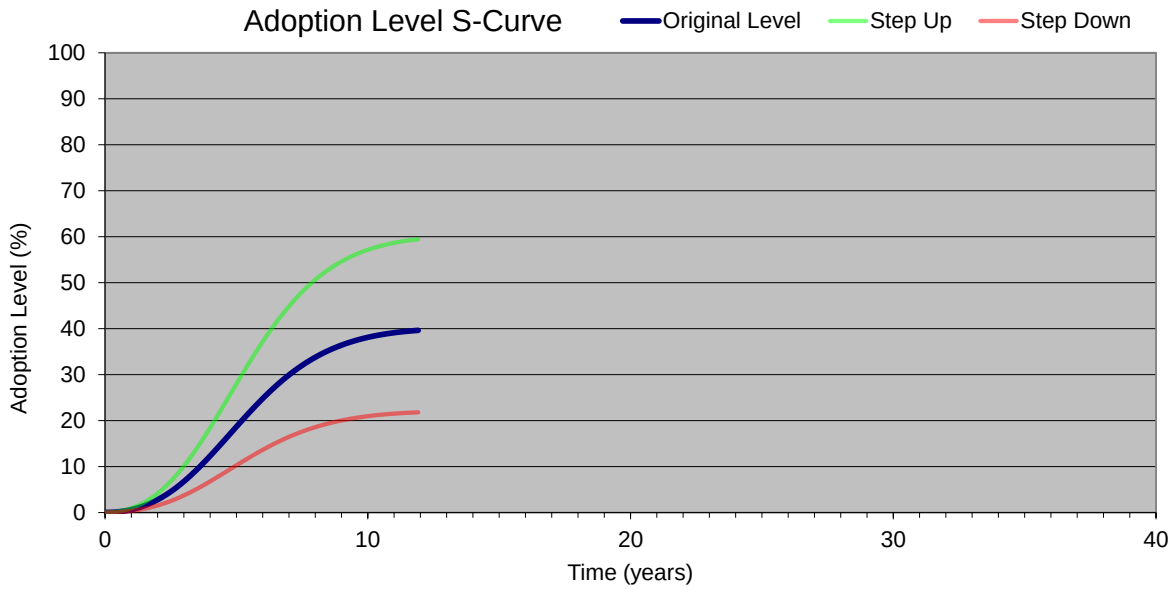

Figure 26: Adoption level curve from ADOPT for original (blue) and single step-up (green) and step-down (red) for the most sensitive question (16)

The sensitivity analysis on all questions shows that the PAL is mostly influenced by (Figure 27):

- Question 16: To what extent is the use of the innovation likely to affect profitability of the farm business in the years that it is used?
- Question 17: To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm?
- Question 4: On what proportion of the target farms is there a major enterprise that could benefit from the 'digital shepherd'?
- Question 19: To what extent would the use of the innovation have net environmental benefits or costs?
- Question 22: To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?
- Question 21: To what extent would the use of the innovation affect the net exposure of the farm business to risk?

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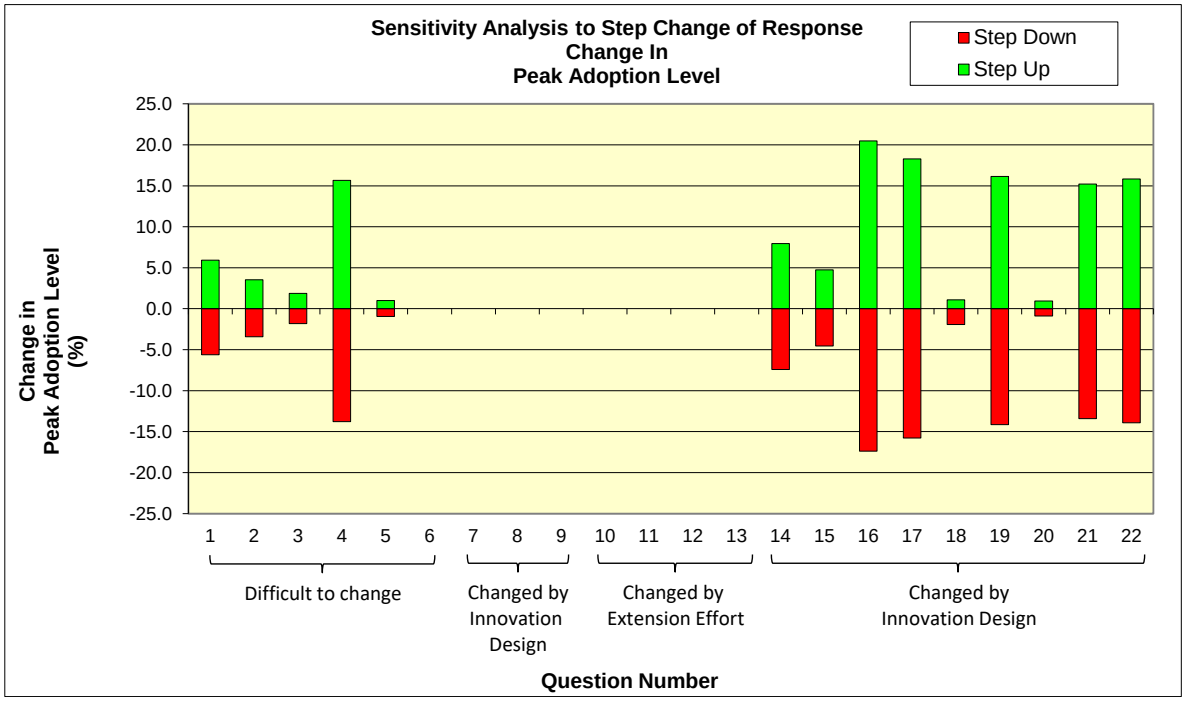

Figure 27: Sensitivity analysis for Peak Adoption Level of single step changes up and down for all questions

Hence, it can be concluded that recurrent and future profit and environmental benefits, management ease and convenience, potential size of innovation implementation on farm, and reduction in risk are critical aspects to be addressed by the innovation when wide adoption of the innovation is ambitioned. The sensitivity analysis on all questions shows that the TPAL is mostly influenced by (Figure 28):

- Question 7: How easily can the 'digital shepherd' (or significant components of it) be trialed on a limited basis before a decision is made to adopt it on a larger scale?
- Question 8: Does the complexity of the 'digital shepherd' allow the effects of its use to be easily evaluated when it is used?
- Question 12: What proportion of the target population will need to develop substantial new skills and knowledge to use the 'digital shepherd'?

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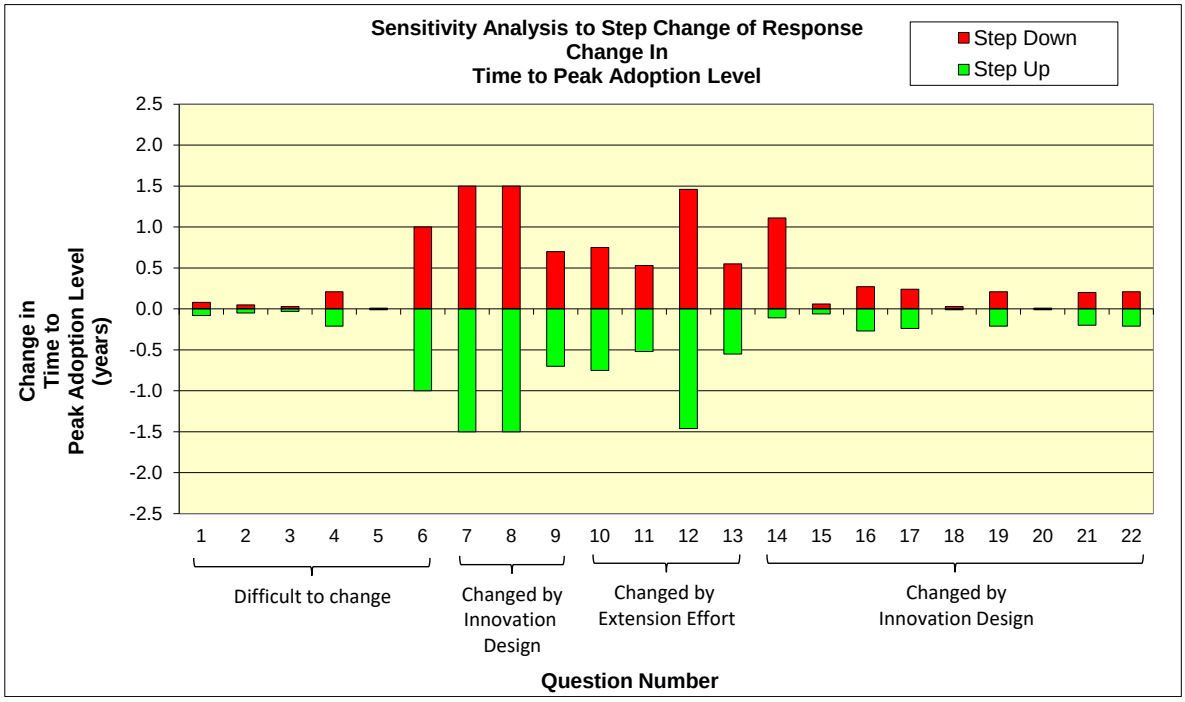

Figure 28: Sensitivity analysis for Time to Peak Adoption Level of single step changes up and down for all questions

Hence, trialability of the innovation, ability to assess its effects, and relevant skills and knowledge are crucial factors to be addressed when acceleration of the adoption process is ambitioned. Also note that the size of the upfront cost may slow down the diffusion process when it is larger than originally anticipated.

Multi Robot system Islands of Scilly, United Kingdom

The Multirobot System (MRS) for the islands of Scilly exhibits promising prospects based on a comprehensive analysis of the named parameters in ADOPT. The results indicate that approximately half of the target farms in the region are motivated by profit maximisation, aligning with the MRS's potential to provide a small profit advantage in both the short and long term. Moreover, the environmental orientation of the population is noteworthy, with almost all respondents expressing a strong motivation for environmental protection—an alignment with the MRS's characteristic of offering a moderate environmental advantage.

In terms of innovation learnability, the MRS stands out as easily trialable and observable, a key factor contributing to its predicted adoption levels. The innovation's complexity, although acknowledged, doesn't hinder its trialability, making it accessible for experimentation by the population. Most farmers in the region are involved in advisory groups, fostering an environment conducive to the adoption of the MRS, which offers advisory support.

The relative advantage of the innovation is evident in its potential to provide a small profit benefit not only during its usage but also in the future, aligning with the population's profit orientation. Additionally, the innovation boasts a small reduction in risk exposure and a slight increase in ease and convenience. (Figure 29)

The predicted peak level of adoption (PAL) for the MRS is estimated at 61%. The PAL ranges between 38% and 79% when performing a sensitivity analysis based on the most sensitive question – being Question 19 (To what extent would the use of the innovation have net environmental benefits or costs?). The MRS is projected to reach its PAL in 16 years from 2023 (When the interview was held).

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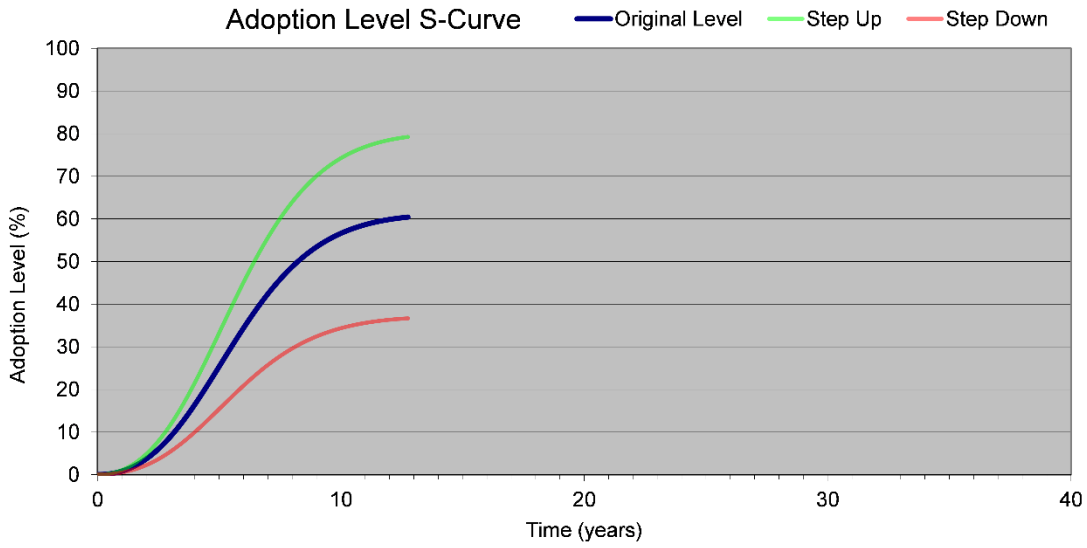

Figure 29: Adoption level curve from ADOPT for original (blue) and single step-up (green) and step-down (red) for the most sensitive question (19)

The sensitivity analysis on all questions shows that the PAL is mostly influenced by (Figure 30):

- Question 19: To what extent would the use of the innovation have net environmental benefits or costs?
- Question 4: On what proportion of the target farms is there a major enterprise that could benefit from the 'MRS'?
- Question 16: To what extent is the use of the 'MRS' likely to affect profitability of the farm business in the years that it is used?
- Question 22: To what extent would the use of the 'MRS' affect the ease and convenience of the management of the farm in the years that it is used?
- Question 21: To what extent would the use of the 'MRS' affect the net exposure of the farm business to risk?
- Question 17: To what extent is the use of the 'MRS' likely to have additional effects on the future profitability of the farm?

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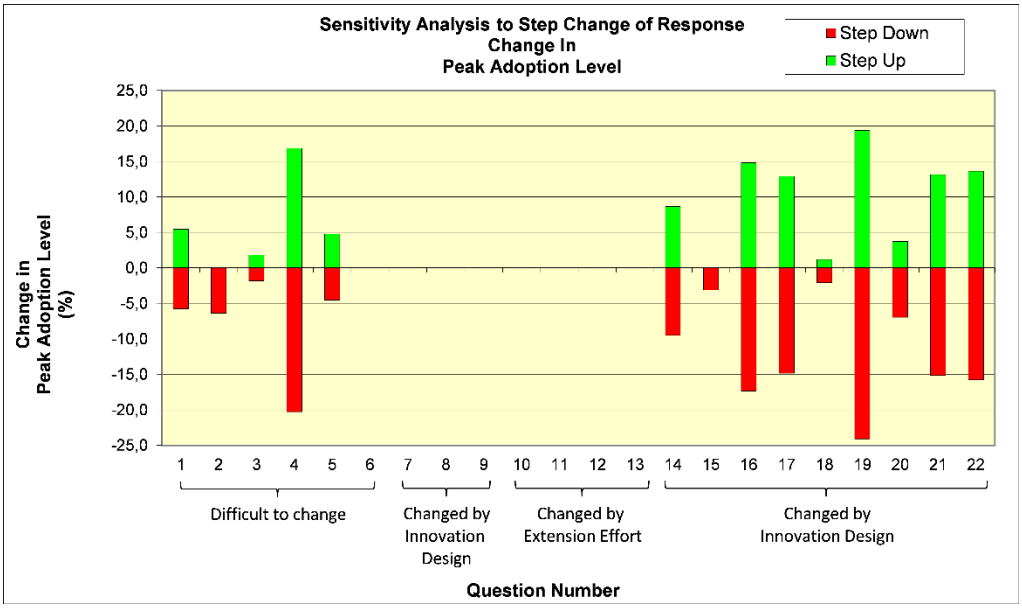

Figure 30: Sensitivity analysis for Peak Adoption Level of single step changes up and down for all questions

Consequently, ensuring net environmental benefits, understanding the proportion of target farms with major enterprises that could benefit, assessing the immediate impact on farm profitability, enhancing the ease of farm management, reducing risk exposure, and considering long-term effects on future profitability emerge as priorities for the MRS successful and widespread adoption.

The sensitivity analysis on all questions shows that the TPAL is mostly influenced by (Figure 31):

- Question 7: How easily can the 'MRS' (or significant components of it) be trailed on a limited basis before a decision is made to adopt it on a larger scale?
- Question 8: Does the complexity of the 'MRS' allow the effects of its use to be easily evaluated when it is used?
- Question 14: What is the size of the up-front cost of the investment relative to the potential annual benefit from using the 'MRS'?

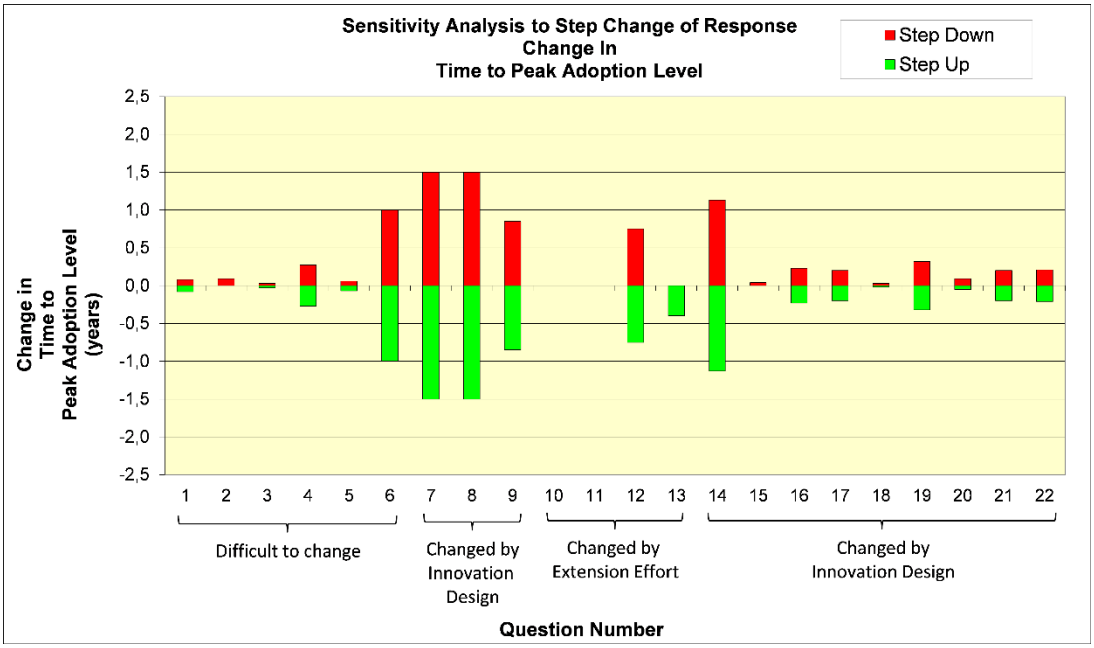

Figure 31: Sensitivity analysis for Time to Peak Adoption Level of single step changes up and down for all questions

In that sense, the TPAL is notably influenced by the trialability of the Multirobot System (MRS), the complexity of assessing its effects, and the size of the upfront cost relative to potential annual benefits. Streamlining trial processes, ensuring technology assessability, and managing cost-benefit ratios are crucial for expediting adoption timelines. It's essential to note that a larger-than-anticipated upfront cost may impede the diffusion process.

5.3.5 Summing up

The aim of this section is to identify perceptions of adopting high tech among stakeholders within use cases in the XGain project, following the theory developed by Rogers (2003) referred to as ADOPT. A total of 22 variables are analysed in two different use cases. One use case is conducted in Belgium, Flanders, to analyse a technology referred to as 'digital shepherd' (i.e. the innovation), which takes two forms of a camera system in the field that monitors the herd in pastures of relatively small size in densely populated and well-connected areas. It was found that there is substantial potential for the 'digital shepherd' to be adopted in Flanders – even more so when the environmental, economic and management benefits are larger than those originally anticipated (i.e., small benefits). The diffusion of the 'digital shepherd' is relatively quick, though it can be accelerated through the possibility of trialing and assessing effects as well as development of relevant skills and knowledge.

The other case is conducted in Scilly Island, UK, where the technology is referred to as Multirobot System (MRS), which holds significant promise for adoption in the Scilly Islands, particularly with the population's profit focus and strong environmental inclination. The MRS's features align with these priorities, demonstrating a potential small profit benefit, risk reduction, and increased ease. With a predicted Peak Adoption Level of 61%, addressing key factors such as environmental benefits, enterprise proportions, and farm profitability is important for successful and swift adoption. Simplifying trials, ensuring assessability, and managing cost-benefit ratios will be necessary for accelerating adoption timelines, although challenges may arise if upfront costs exceed expectations. Overall, the MRS is positioned for a good integration into Scilly's agricultural landscape.

The ADOPT analyses can be relevant to the XGain Use Case Requirements and Specifications for Connectivity and Edge Technology Enablers (Task 2.3) and XGain Knowledge Facilitation Tool Architecture Design and Technical Specifications (Task 2.4). Moreover, the ADOPT analyses can be useful to contribute to the Socio-environmental Assessment of Last-mile and Edge Technological Solutions (Task 4.2), the Social Acceptance, Performance

Evaluation, Impact Analysis and Replication Guidelines (Task 5.8), and the Standardisation and Interaction with Policy-makers, Associations and Other Related Projects (Task 6.2).

5.4 Balanced Readiness Levels: a tool for transition pathways

5.4.1 Introduction

Based on the analyses of the digital divide and adoption (sections 4.2 and 4.3), it becomes obvious that readiness level to contribute towards digital sustainability is not only about technological readiness (TRL), but also about economic, environmental, social and societal readiness levels. Social innovation analyses are needed that can inform about the adoption of the institutional setting. In this section we introduce an analysis of "Balanced readiness", which includes all these five dimensions. Notably, not all the five dimensions are relevant to different contexts and cases, and readiness must be seen together with what is relevant to a specific context. The aim of this section is to introduce analyses of readiness levels by first illustrating the need to analyse relevance of technological, economic, environmental, social and societal factors and thereafter to discuss how to introduce a framework for balanced readiness levels across cases. The relevance analysis of a technological, economic, environmental, social and societal readiness levels is conducted by means of a VARI analyses as explained in section 4.2 to analyse perceptions of relevance across use cases in the XGain project. For monitoring the progress of change, and to have a tool for discussion, we are then introducing the tool called Balanced Readiness Level (BRL). In the following we first present an assessment of relevance of different readiness factors, and then we discuss the readiness levels before we provide a provisional plot where we combine the relevance and readiness factors across the cases.

5.4.2 An assessment of context factors of relevance (VARI)

As explained above, in this section the readiness levels at case level in XGain are analysed by means of identifying the perceptions of relevance across use cases in the XGain project. The analyses take place at case level. Following the logics of VARI, introduced in section 4.2 for the regional analyses of digital divide, we now use the same approach to analyse balanced readiness across the use cases 1) design a value-tree, 2) pairwise comparison questionnaire conducted across use cases, and 3) estimates and presentation of what is more relevant to different contexts and actors across different contexts.

The value tree

The value-tree is designed by the context relevant factors at different levels of specifications; with the main goal on the top, followed by more general factors which are further specified into more specific factors at the bottom of the tree. The value-tree for the analyses of relevance across cases is provided in Figure 32. This was designed by the consortium partners and is a combination of inputs from different tasks across the XGain projects that has been merged. In particular, the main research question was agreed in an online XGain consortium meeting held on 27.10.2023 with consortium partners and use case leads. To answer the main research question formulated as "what is relevant to analyse readiness level to adopt new broadband connectivity levels?", a total of five main categories were identified as;

1) technological factors referring to LoRa, Wi-Fi, 4G and 5G;
2) Social factors, referring to improved health and safety, enhanced inclusion in terms of improved communication with tourists, increased service support to smallholders and overall increase in users of

technology, improved working opportunities, such as increased working opportunities and reduced working hours for individuals;

3) Societal factors, such as poverty alleviation, public commitment to sustainability, increased social acceptance of high tech, and enhanced ethical animal treatments; and
4) Environmental factors, such as reduced resource use (e.g. fertilizer, pesticides and irrigation water), reduced climate footprints and enhanced biodiversity, and
5) Economic factors, such as increased production (yield), reduced costs and increased profitability.

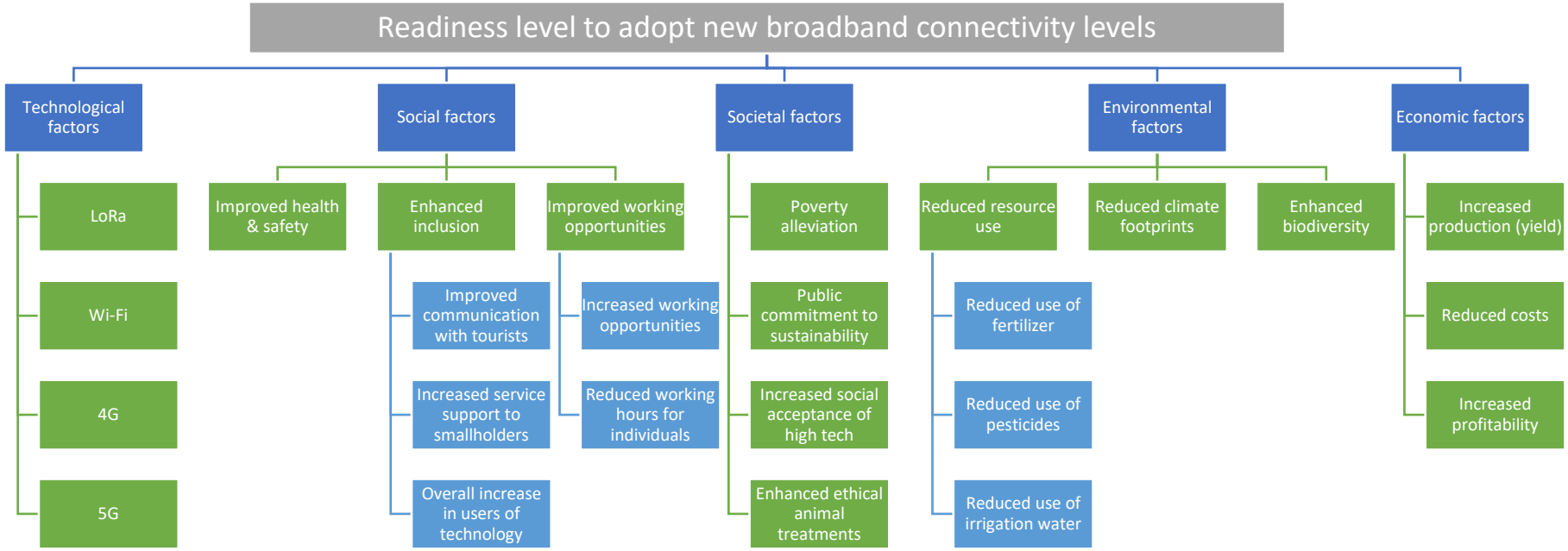

Figure 32: A value-tree for readiness level for adopting to new broadband connectivity levels in XGain

Responses to the questionnaire

The results in this section are based on XGain partners' who have some knowledge about the different contexts, and it must be clarified that the results are meant for illustration of a method. Still, the responses reflect on expertise within the XGain, and provides an overview of factors with relevance based on this. The Figures 33 a), b), c) give a brief overview of the gender, age and location of expertise of the people who filled in the questionnaire. Of the 10 respondents, 70% were male and 30% female, 10% filled it in for each of the cases of Croatia, Belgium, Greece, Lithuania and Isles of Scilly, 20% for Spain and also a group with no direct connection to the cases filled it in (30%), and the largest age category was 26-35 years (40%), and the smallest 56-65 years (10%).

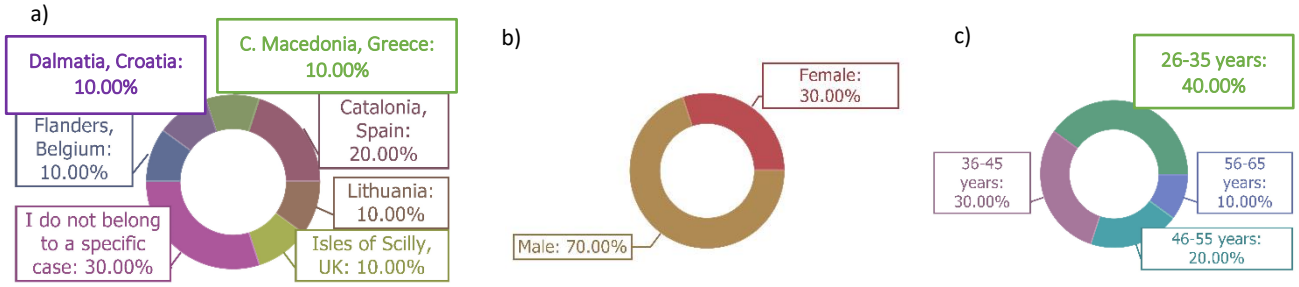

Figure 33: Characteristics of people filling in the questionnaire about relevance of readiness factors across the XGain cases (a) =location; b) =gender; c) =age)

Main level perceptions

In Figure 34, main level perceptions about what is most relevant of the main factor categories across the cases is presented. The economic factors got high scores in the cases of Greece and Scilly Island, whereas the technological factors were deemed relatively more important to the cases of Spain, Greece, Belgium and Scilly Island. Whereas the social factors, such as health, inclusion and work, were seen highly important in the cases of Greece, Belgium and Lithuania, the societal factors, such as poverty alleviation and sustainability, were perceived particularly important to the cases in Spain, Belgium and Lithuania. The environmental factors were highest valued in Croatia, Scilly Island and Lithuania. The researches in XGain with no case specific relation, put the technological and economic factors surprisingly low, with a relatively equal distribution of priorities across social, societal and environmental factors.

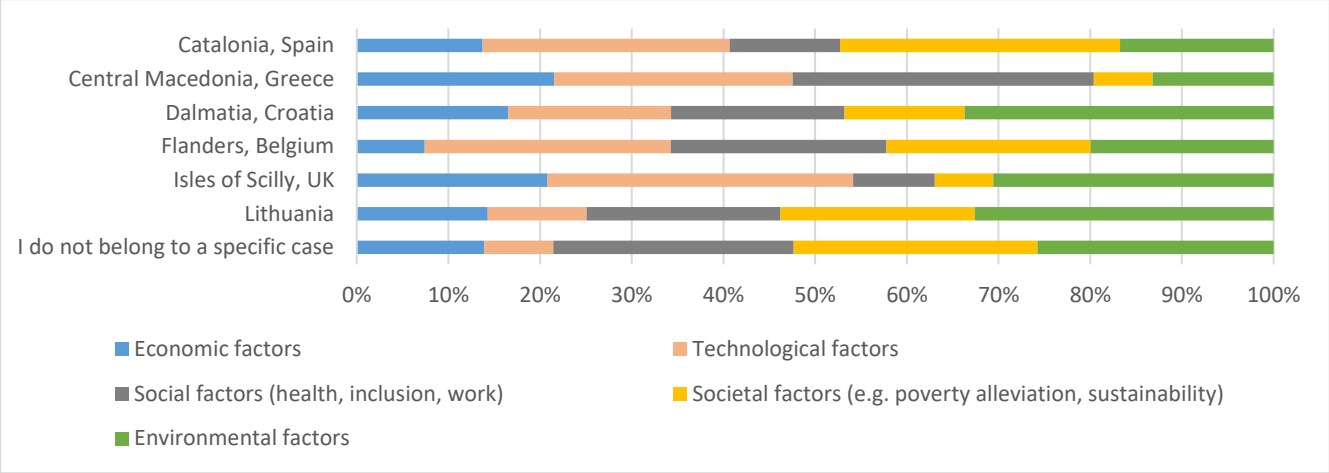

Figure 34: Relevance of economic, social technological, societal and environmental factors across use cases in XGain for readiness level to adopt new broadband connectivity levels

Sub-level perceptions

In the Figures 35 and 36, the perceptions about the sub-categories to the economic and technological factors are presented, respectively. As for the economic sub-factors, the reduce costs option is relatively more important to all cases, except the case in Belgium, where increased profitability is valued higher. Increase in profitability is also highly valued in Greece. The increase in production (yield) is mostly relevant to Spain and Croatia. For the technological sub-factors, it appears that for the cases in Croatia and Lithuania, there are no relative difference between the options, whereas in the cases in Spain, Belgium and the UK, the 5G seems to be highly relevant, and in Greece the Wi-Fi option scores relatively high, after the 4G which has the highest relevance to this case.

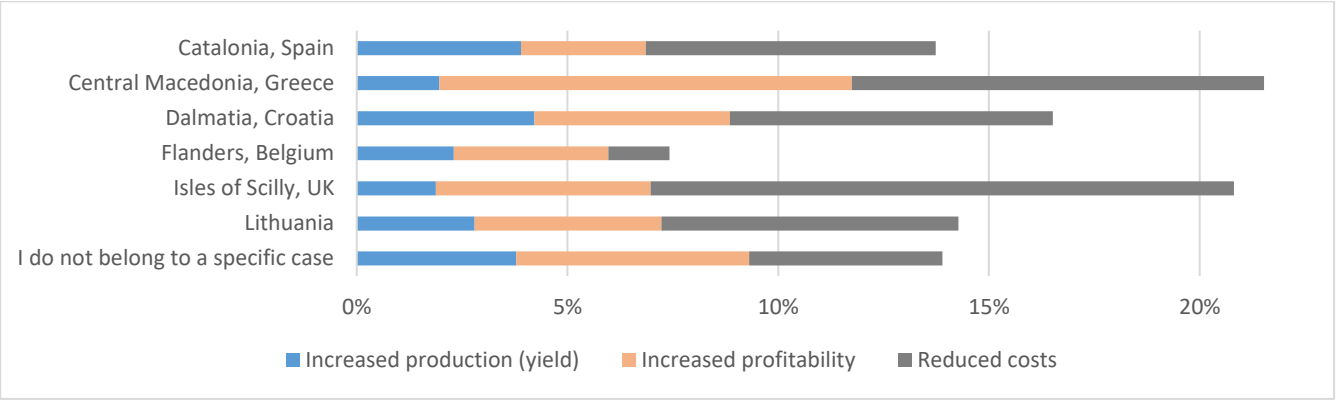

Figure 35: Relevance of economic sub-factors across use cases in XGain for readiness level to adopt new broadband connectivity levels

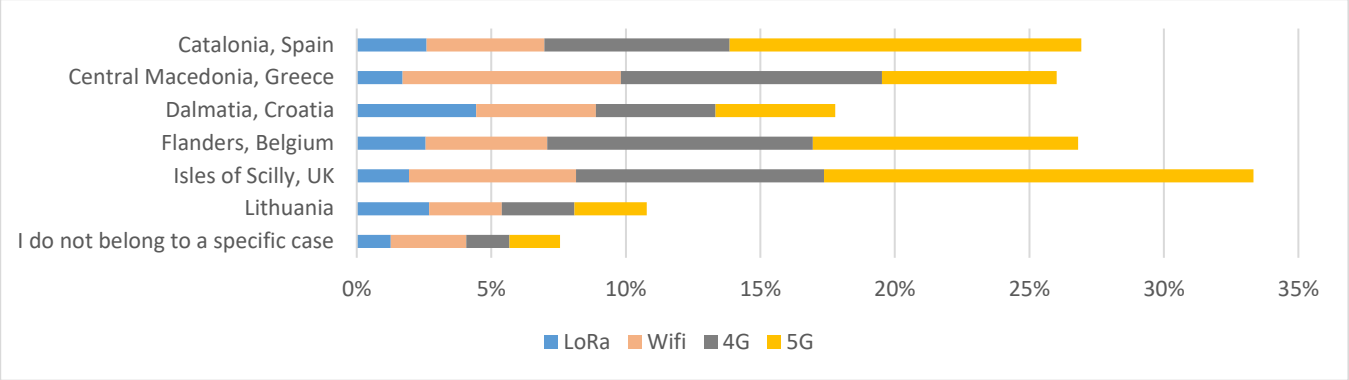

Figure 36: Relevance of technological sub-factors across use cases in XGain for readiness level to adopt new broadband connectivity levels

In the Figure 37, the perceptions about the relative relevance of sub-categories of societal factors are presented. It shows that in the two cases which gave higher priorities to the societal factors as such, namely in Spain and Belgium, emphasis was put the highest on the relevance of the sub-category poverty alleviation. Also in Lithuania this option was put high, although commitment to sustainability was put the highest in this case. Enhanced ethical animal treatment gained the highest relevance level in the case in Croatia, but was also highly relevant to the Belgium and Lithuanian cases. Increased social acceptance to high tech was relatively highly relevant to the Greece and UK cases, where in both cases the commitment to sustainability scored high.

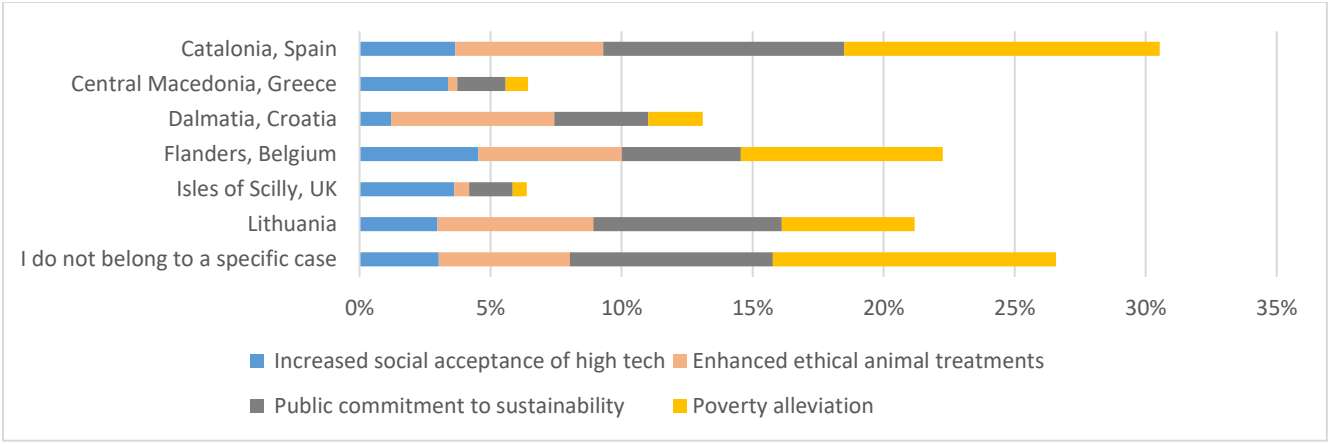

Figure 37: Relevance of societal sub-factors across use cases in XGain for readiness level to adopt new broadband connectivity levels

In the Figures 38, the perceptions about the sub-categories of the social factors are presented. The option improved health and safety scored the highest in most cases, including the cases in Greece, Croatia, Belgium and Lithuania, whereas in Spain working opportunities was assigned the highest. However, working opportunities got very low relevance in Croatia, UK and Lithuanian cases. Enhanced inclusion was mostly relevant to the cases in Greece, Belgium and Lithuania.

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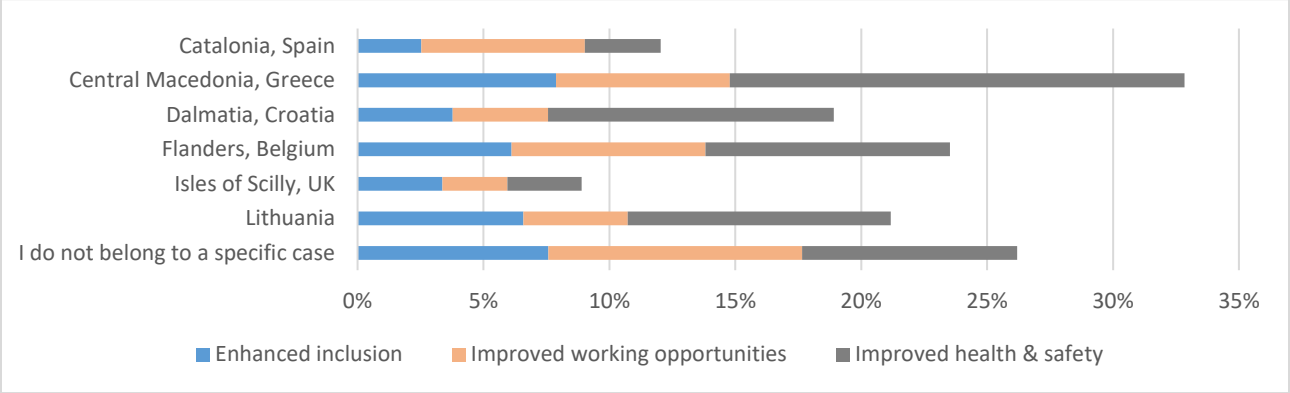

Figure 38: Relevance of social factors across use cases in XGain for readiness level to adopt new broadband connectivity levels

For the social factors, the value-tree happened to include two more sub-sub-levels, and for this category we present a total of three charts in the following. First, Figure 39 provides the overview of the sub-categories of enhanced inclusion. It appears that communication with tourists is not so relevant to the cases in Spain and Croatia, whereas in both these cases, as well as in Greece and the UK, the highest relevance went to overall increase in users of technology. Increase in service support to smallholders, seem to be less relevant to the cases in UK and in Spain.

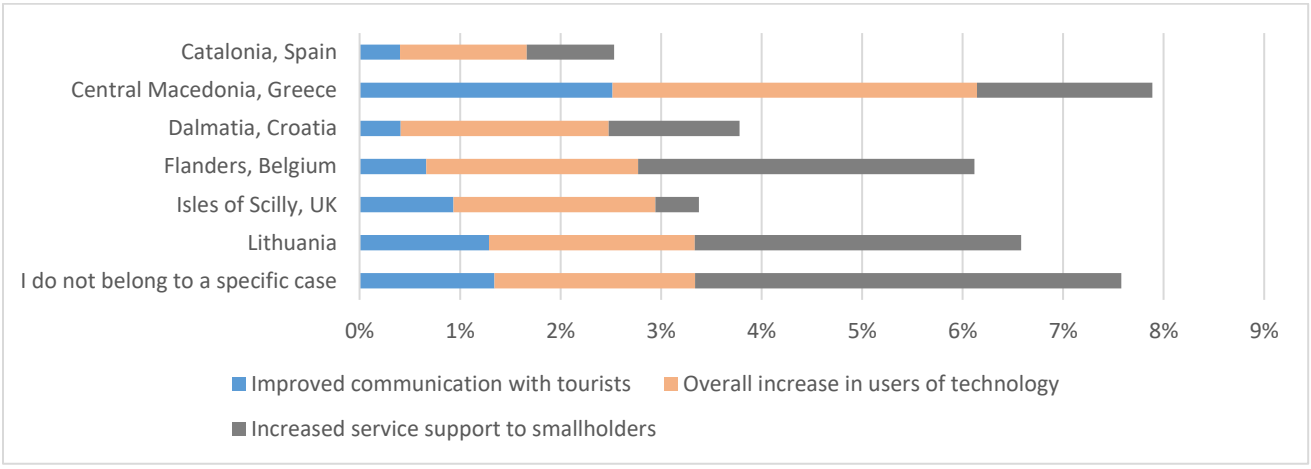

Figure 39: Relevance of social enhanced inclusiveness sub-factors across use cases in XGain for readiness level to adopt new broadband connectivity levels

Second, Figure 40 informs about the relevance of the sub-groups of improved working opportunities, indicating that reduced working hours and increased working opportunities are equally important to the cases in Greece and the UK, whereas in Spain, Croatia and Belgium, it is more relevant to increase working opportunities and in UK and the Lithuanian cases it is more important to reduce working hours.

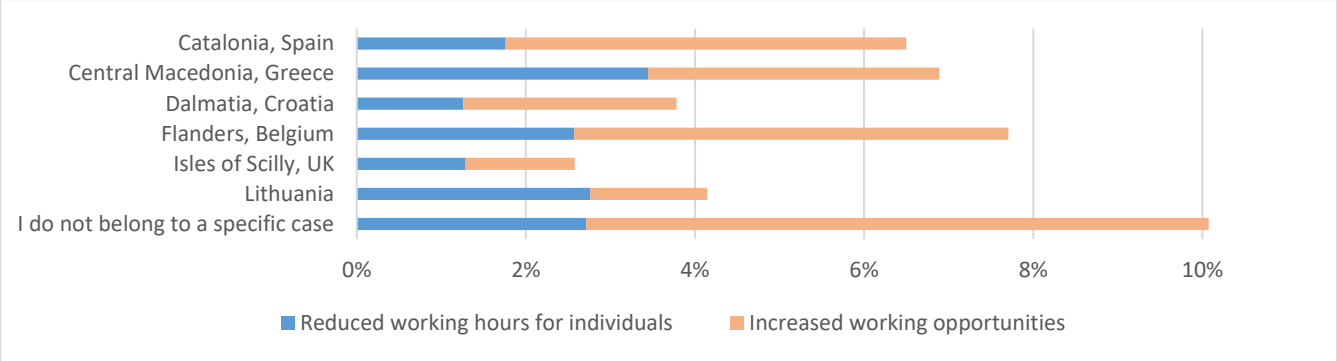

Figure 40: Relevance of social – improved working opportunities - sub-factors across use cases in XGain for readiness level to adopt new broadband connectivity levels

Also, for the environmental factors one of the options has a sub-category, allowing us to present two figures at different sub-levels to explain the relevance of the categories identified in the value-tree. First, in Figure 41 we see that the cases differ, for which reduction of climate footprints are particularly important to the cases in Spain, Greece and Croatia, although Croatia put even more emphasis on enhanced biodiversity, which is also the case for the Lithuanian use case. Reduced resource use seem to be less relevant in the cases in Spain and Greece, and very relevant to the UK case.

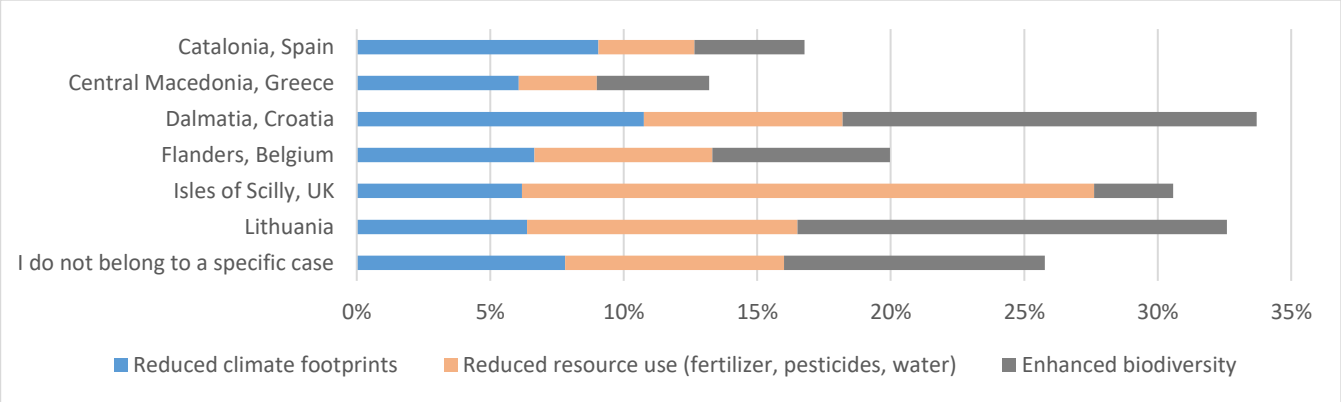

Figure 41: Relevance of environmental factors across use cases in XGain for readiness level to adopt new broadband connectivity levels

Second, in Figure 42, the relevance of the sub-categories in reduced resource use across the cases in the different countries is provided. The use of fertiliser is mostly relevant to the cases in Belgium, UK and Lithuania, although the option reduced use of irrigation water is relatively highly relevant to Spain, Croatia, UK and Lithuanian cases. The use of pesticides seems to overall be less relevant to the particular cases, although in Greece and Belgium, all three options are equally relevant.

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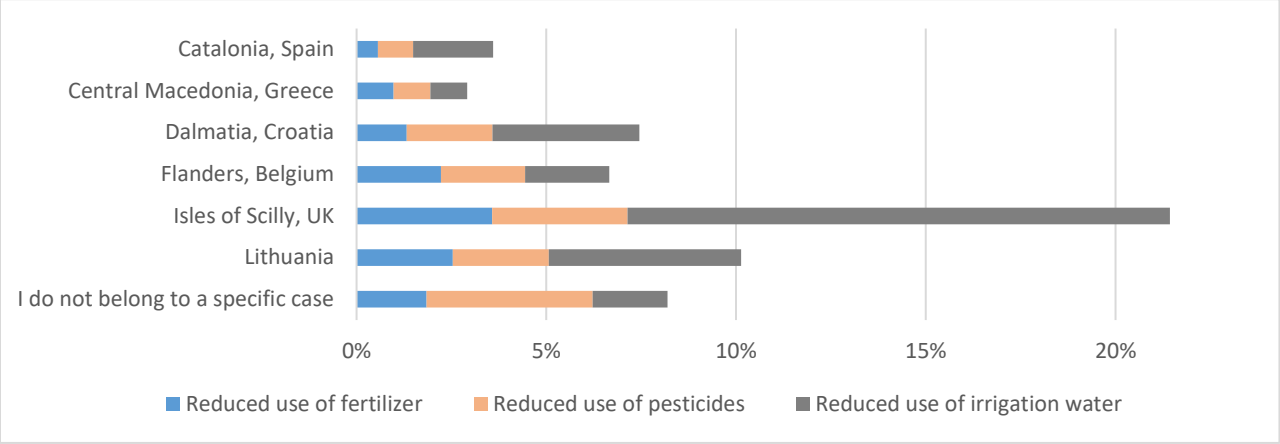

Figure 42: Relevance of environmental – reduced resource use - sub-factors across use cases in XGain for readiness level to adopt new broadband connectivity levels

5.4.3 Balanced readiness level

The Balanced readiness level (BRL) is inspired by the Technology readiness level (TRL). The TRL was originally developed by NASA in the 1970s for space exploration technologies[5]. It is a measurement system to measure the maturity level of a certain aspect. The TRL is scaled from 1 to 9, with 1 as the least mature level and 9 as the most mature level. Today TRLs are in common use by many products and organisations, for their own purposes. The European Union has also been adjusting the NASA readiness-level definitions, allowing for easier translation to multiple industry sectors. Here we use the concept of TRL and expand it to several dimensions. We distinguish between the five dimensions: technology, economic, environmental, social and societal readiness levels.

Equal to the TRLs, we follow this scale from 1 to 9, throughout the whole range of research, development and deployment progression phases, for the purpose of evaluating transition pathways, for which the TRL can play an important role.

First, as for the TRL, a technology project is then evaluated against the parameters for each **technology level** and is then assigned a TRL rating based on the project's progress.

When a technology is at TRL 1, scientific research is beginning, and those results are being translated into future research and development. TRL 2 occurs once the basic principles have been studied and practical applications can be applied to those initial findings. TRL 2 technology is very speculative, as there is little to no experimental proof of concept for the technology.

When active research and design begin, the technology is elevated to TRL 3. Generally, both analytical and laboratory studies are required at this level to see if a technology is viable and ready to proceed further through the development process. Often during TRL 3, a proof-of-concept model is constructed.

Once the proof-of-concept technology is ready, the technology advances to TRL 4. During TRL 4, multiple component pieces are tested with one another. TRL 5 is a continuation of TRL 4, however, a technology that is at 5 is identified as a breadboard technology (i.e., easy to replace) and must undergo more rigorous testing than technology that is only at TRL 4. Simulations should be run in environments that are as close to realistic as

[5] https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level

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possible. Once the testing of TRL 5 is complete, technology may advance to TRL 6. A TRL 6 technology has a fully functional prototype or representational model.

TRL 7 technology requires that the working model or prototype be demonstrated in a space environment. For TRL 8, technology has been tested and "flight qualified" and it's ready for implementation into an already existing technology or technology system. Once a technology has been "flight proven" during a successful mission, it can be called TRL 9.

Second, to gauge the "**Economic Readiness Level" (EcRL)** of these technologies, one can evaluate their progress and integration across nine distinct levels. While the digital era unfolds, the process of digitisation, enhanced connectivity, and the adoption of edge technologies significantly impact the economic landscape.

The first level marks the basic understanding of the economic implications and potential benefits of digitalisation, connectivity, and edge technologies. At this stage, stakeholders recognise the potential for cost reduction, increased efficiency, and job creation but have not yet developed practical applications or models.

At the second level, the development of economically viable concepts and applications begins. These may include cost-effective solutions or business models that harness the potential of digitalisation, connectivity, and edge technologies to drive economic growth. The following level 3 sees proof-of-concept demonstrations that showcase the economic benefits of these technologies, highlighting the potential for job creation and market opportunities. At level 4, validation of economically viable components and processes, assessing cost-effectiveness and return on investment (ROI). This is a crucial step in determining the feasibility of implementing these technologies on a larger scale.

Level 5 involves validation of economically viable components and processes in a relevant environment, such as successful pilot projects or market testing. This stage provides evidence of the potential for real-world application and success.

Then at Level 6, a demonstration of the system or technology occurs in a relevant environment, integrating economic considerations such as scalability and market penetration strategies. This stage demonstrates that technology can be successfully adopted and scaled up. The subsequent level 7 sees a system or technology prototype that demonstrates economic performance in an operational environment. The emphasis is on cost reduction, increased efficiency, competitive advantage and showcasing the technology's potential for widespread implementation.

A complete system with economically viable features is emerging at level 8, and qualified through tests and demonstrations. This stage includes market acceptance and user satisfaction, indicating that the technology is poised for successful integration into the economy.

Level 9 represents a proven and deployed system or technology with demonstrated economic benefits and viability in an operational environment. At this stage, digitalisation, connectivity, and edge technologies contribute to economic growth and development, solidifying their role as key drivers of the modern economy.

Overall, these nine levels of economic readiness provide a framework for evaluating the potential and impact of digitalisation, connectivity, and edge technologies on the global economy. As these technologies advance through the levels, they gain economic viability and ultimately contribute to economic growth and development.

Third, while the term **"Environmental Readiness Level"** (EnRL) is not as well-established as technological readiness, it can be inspired by the concept of TRL to create a framework for assessing the maturity and

preparedness of environmentally friendly conservation and protection efforts related to a specific technology, system, or innovation.

EnRL could be defined as a scale that measures the extent to which a system, technology, organisation, or community is prepared and capable of effectively addressing and managing environmental challenges, minimising negative environmental impacts, and promoting sustainable and environmentally friendly practices. This involves a comprehensive approach to assessing, planning, and implementing measures that safeguard the environment while ensuring that the system, technology, or organisation continues to meet its intended goals and objectives.

In the context of connectivity and edge technologies, EnRL can be used to evaluate the extent to which these technologies contribute to various aspects of environmental conservation, biodiversity preservation, and environmentally friendly practices, as well as considering Life Cycle Assessment (LCA) factors such as the manufacturing, use, and recycling phases. Within the manufacturing phase, EnRL could emphasize the adoption of circular economy principles, such as designing for disassembly, using renewable or recyclable materials, and reducing waste (Kristoffersen et al., 2020). This would help minimise the environmental footprint of the technology throughout its life cycle, from production to end-of-life management.

At the end of a product's life, EnRL could evaluate how well the technology supports the recovery, reuse, and recycling of materials, as well as the potential for upcycling or refurbishment (Potting et al., 2017). By incorporating these circular economy principles, EnRL would encourage the development of technologies that contribute to a more sustainable and environmentally friendly future.

By utilizing an Environmental Readiness Level (EnRL) scale, organisations and decision-makers can evaluate the environmental impact, friendliness, and sustainability of a technology, system, or innovation throughout its life cycle (Potting et al., 2017). This can help in making informed choices regarding its development, investment, and implementation while ensuring that environmentally friendly considerations are considered (Tukker & Jansen, 2006). These considerations include environmental monitoring (Ullo and Sinha, 2020), sustainable practices (Kates et al., 2005), public engagement in conservation efforts (McKinley et al., 2017), and circularity principles throughout the manufacturing, use, and recycling phases (Kristoffersen et al., 2020).

Fourth, the "**Social Readiness Level"** (SRL) is meant to clear out how mature the process of interaction is, within a project (Van der Valk & Selnes, 2023, forthcoming). The SRL covers the social process of a particular trajectory, throughout the various stages of development.

At level 1 a social process is observed. If a goal-oriented social process clearly is initiated then the process has shifted to level 2. For level 3, a project group or organisation is formalized, and collaboration has started. The further maturity of the development demands that the social process is supported by local government (level 4) and embedded in a larger community (level 5). At level 6 the social process has demonstrated to be active and in order to be defined as level 7, the social process has become an organisation or movement that deliver a well-known contribution. For arriving at maturity level 8, we must be able to see that the social process is working well with acknowledged qualifications. Finally, at level 9, it is an actual social process proven in practice.

The SRL assessment could then be used to stimulate discussions on how to move to a more mature level of development. To simply 'find out what works and do more of the same' does not match the complex diversity of the contexts at hand. Focus on for instance technological innovations is then vital but should not obscure the behavioural, organisational, and institutional changes that are present or needed. The usage of SRL could also

serve to stimulate critical reflection of bottlenecks and reveal new opportunities for a product, project or program (Van der Valk & Selnes, 2023, forthcoming).

Fifth, "**Societal Readiness Level" (SoRL)** is a concept being used for instance by the Innovation Fund Denmark[6] as a way of assessing the level of societal adaptation of, for instance, a particular social project, a technology, a product, a process, an intervention, or an innovation (whether social or technical) to be integrated into society. Bernstein et al (2021) explained that the TRL methods focus on "will it work?", while the societal readiness is about "will it acceptably address broader, long-term societal concerns?".

Level 1 id achieved if there is an identification of the generic societal need and associated readiness aspects. With a clearly known problem formulation, with proposed solutions and stakeholder identification, level 2 has been reached. Level 3 demands an initial testing with stakeholders. For level 4 it is necessary to have a pilot testing for problem validation with focus on societal impacts. Level 5 is more mature because it demands a solution validation by stakeholders in an actual societal setting or area. With an additional solution demonstration and feedback are gathered, then level 6 is achieved. Level 7 is when refinement and if needed, retesting with stakeholders, is conducted. At level 8 we will see a completed proposed solution in societal settings and plans. For the most mature level, level 9, there are society broad solutions proven at scale in the relevant environment; and widely accepted.

If the societal readiness is expected to be low, suggestions for a realistic transition towards societal adaptation should be developed. Naturally, a low level of societal acceptance and adaptation calls for major efforts to enhance the societal readiness level.

In general, major discrepancies between these dimensions would be worrying as there will be problems related to the actual functioning or implementation of a digital solution. There are good reasons to watch out for major differences. With a high technological and economic readiness but low environmental and societal readiness, for instance, one should re-think the situation at hand. Table 6 sums up the 5 dimensions of readiness.

[6] https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf

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Table 6: Balanced Readiness levels on Technological (TRL), Economic (EcRL), Environmental (EnRL), Social (SRL) and Societal (SoRL) Readiness Levels

Maturity level TRL	Technology Readiness Levels (TRL)	Economic Readiness Levels (EcRL)	Environmental Readiness Levels (EnRL)	Social Readiness Levels (SRL)	Societal Readiness Levels (SoRL)
Level 1	Basic principles observed	Understanding economic impacts of digitalisation.	Basic environmental understanding and circularity concepts.	A social process for is observed	Identification of the generic societal need and associated readiness aspects
Level 2	TRL2 Technology concept formulated	Developing cost-effective concepts and applications.	Developing sustainable concepts, e.g., remote sensors and IoT devices for environmental monitoring.	A goal-oriented social process is clearly initiated	Problem formulation, proposed solutions, and stakeholder identification
Level 3	Experimental proof of concept	Proof-of-concept for economic benefits and job creation.	Proof-of-concept demonstrating environmental benefits.	A project group or organisation is formalized, collaboration has started	Initial testing with stakeholders
Level 4	Technology validated in lab	Lab validation of cost-effective components and processes.	Validating sustainable components and processes, emphasizing energy efficiency and circular design.	The social process: supported by local government	Pilot testing for problem validation with focus on societal impacts
Level 5	Technology validated in relevant industry environment	Field validation through pilot projects or market testing.	Validating components and processes in relevant environments (e.g., smart cities) with a focus on resource efficiency.	The social process begins to be embedded in a larger community	Solution validation by stakeholders in an actual societal setting or area
Level 6	Technology demonstrated in relevant industry environment	Demonstrating economic considerations in a relevant environment.	Demonstrating integrated environmental considerations, public engagement, citizen science, and LCA strategies.	The social process has demonstrated to be active	Solution demonstration and feedback gathered

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Level 7	System prototype demonstration in operational environment	Prototype showcasing economic performance and scalability.	System or technology prototype showing environmental performance in an operational environment, emphasizing circularity.	The social process is, as an organisation or movement, a well-known contributor to circularity	Refinement and retesting with stakeholders
Level 8	System complete and qualified	Complete system with qualified features, market acceptance.	Complete system with sustainable features, qualified through tests, including LCA and closed-loop recycling.	The social process is working well with acknowledged qualifications	Completed proposed solutions in societal settings and plans
Level 9	Actual system proven in operational environment (competitive manufacturing)	Proven and deployed technology contributing to economic growth.	Proven and deployed system or technology with demonstrated environmental benefits, sustainability, and circularity.	The actual social process proven in practice	Society broad solutions proven at scale in the relevant Environment

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5.4.4 Relevance and readiness

The exercises above illustrate that readiness is a broad term that can be addressed at a more regional level by assessing digital divide and thus the main factors causing less readiness at a regional level (section 4.2), but also at farm/firm level by assessing the factors of hindrances for faster adoption and for broadening in future users of specific technologies in a specific case (section 4.3). In this section (4.4.) we analysed the relevant factors of readiness at case level to be able to analyse balanced readiness that includes technological factors, as well economic, environmental, social and societal factors. In the scatter diagram below, you can find an overview of cases in assessing the relevance and the readiness across cases.

In Figure 43, the relevance of the different readiness levels has been selected from Figure 34 for each case, and plotted against the scale of balanced readiness level going from 1 to 9 as explained in Table 6. Only two or three of the five readiness categories with the most relevance are included for each case. This is an illustration is not for direct use, because the sample sizes are too small to gather reliable values on the scale from 1 to 9.

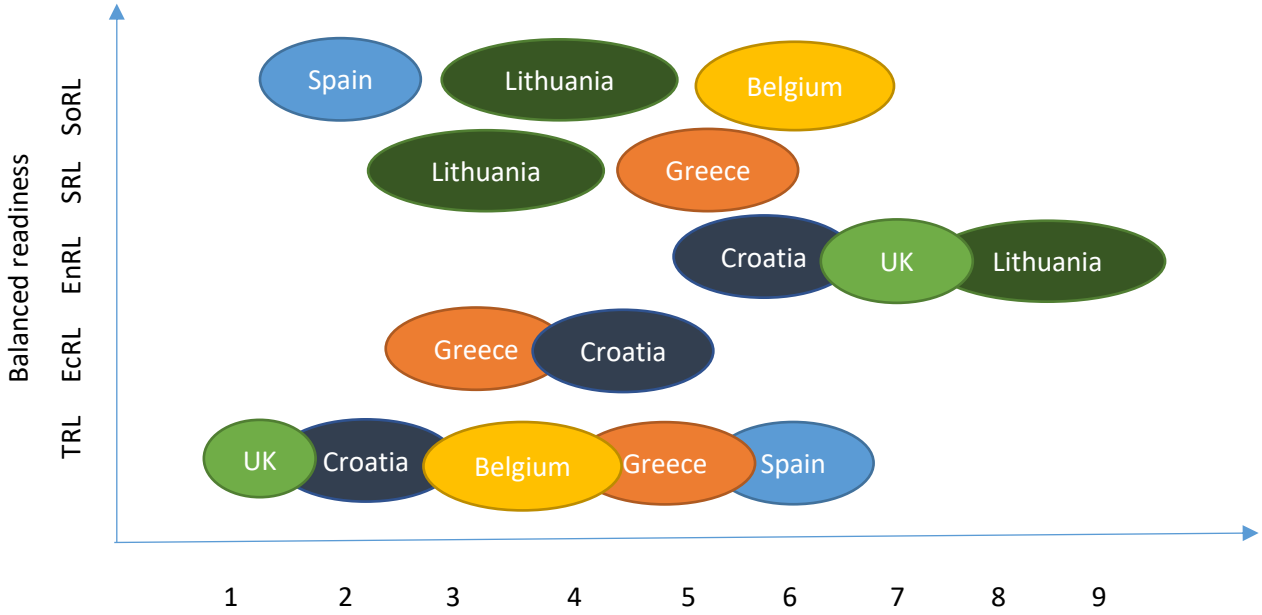

Figure 43: Selected relevance factors for different cases plotted against readiness levels of technological, economic, environmental, social and societal readiness levels, applying a scale (1-9) (illustrative, approximate values).

5.4.5 Summing up

This section responds to the shortcoming of addressing only technological readiness levels and often overlooking the economic, environmental, social and societal readiness to accelerate use of technologies across different contexts. Acknowledging that the different forms of readiness categories may not be relevant in all areas, it analyses what is more relevant across different contexts. Therefore, an exercise with explanatory factors were identified and arranged into a value-tree and evaluated by the VARI approach explained above, following the approach of Saaty (2004). A value-tree was designed by the XGain partners to respond to the question: "what is relevant to analyse readiness level to adopt new broadband connectivity levels?" The more general as well as the more specific criteria were agreed in an online XGain consortium meeting held on 27.10.2023 with consortium partners and use case leads. A total of five main categories were identified as; technological factors

(LoRa, Wi-Fi, 4G and 5G), social factors (improved health and safety, enhanced inclusion and improved working opportunities), societal factors (poverty alleviation, public commitment to sustainability, increased social acceptance of high tech, and enhanced ethical animal treatments), environmental factors (reduced resource use, reduced climate footprints and enhanced biodiversity), and economic factors (increased production (yield), reduced costs and increased profitability). The perceptions of relevance across context specific factors at the more general level (Figure 34), show that the economic factors got in particular high scores in the cases of Greece and Scilly Island, whereas the technological factors were deemed relatively more important to the cases of Spain, Greece, Belgium and Scilly Island. Whereas the social factors, such as health, inclusion and work, were seen highly important in the cases of Greece, Belgium and Lithuania, the societal factors, such as poverty alleviation and sustainability, were perceived particularly important to the cases in Spain, Belgium and Lithuania. The environmental factors were highest valued in Croatia, Scilly Island and Lithuania. The researches in XGain with no case specific relation, put the technological and economic factors surprisingly low, with a relatively equal distribution of priorities across social, societal and environmental factors. Note that these relevance scores are obtained by a few people belonging to the XGain project knowing the context of their own use case, and not by a representative sample of respondents. Following this exercise about relevance, the five different concepts of readiness are brought together in a so-called Balanced readiness level approach, where the impact scores on a scale from 1 to 9 are explained. An illustration combining the most relevant readiness levels in specific cases and the evaluation on the scale of 1-9 is used to plot the different cases accordingly (Figure 43).

The readiness level conceptualisation and analyses are expected to be relevant to the XGain Use Case Requirements and Specifications for Connectivity and Edge Technology Enablers (Task 2.3) and XGain Knowledge Facilitation Tool Architecture Design and Technical Specifications (Task 2.4). Moreover, in other work packages, the readiness level approach may be relevant to the tasks 4.2: Socio-environmental Assessment of Last-mile and Edge Technological Solutions, Task 5.8: Social Acceptance, Performance Evaluation, Impact Analysis and Replication Guidelines, and Task 6.2: Standardisation and Interaction with Policy-makers, Associations and Other Related Projects.

6 Digital sustainability and policy implications

6.1 Introduction

This deliverable is devoted to analysing the issue of digital divide of the digitalisation of the European agricultural sector, aiming at digital sustainability. With the current high tech development in the agricultural sector in Europe, needs and urgencies for change in the European policy frameworks is apparent, following the logics of the informational governance concept (Soma et al, 2016a; Soma et al, 2016b). This chapter is about the link between digital sustainability and policy. Digital sustainability is about taking account of a series of sustainable development goals (SDGs) of reduced inequalities (SDG10) and sustainable cities and communities (SDG11). Notably, these SDGs are highly related with other SDGs, including: gender equality (SDG5), decent work and economic growth (SDG8), as well as industry, innovation and infrastructure (SDG9), which also must be placed central to the issues addressed in this deliverable. Sustainability is thus multidimensional, including not just the environment but also economic and social aspects.

Digital sustainability with its multi-dimensional character has been addressed in multiple ways in this deliverable, across the different research activities carried out in this deliverable following a so-called mixed method approach. In the literature review in Chapter 3, main issues identified at a European level included; access to the digital, education and digital literacy, socio-economic and cultural conditions, community (e-) networks, and (e-) governance quality. This insights from the literature were brought forward in the analyses of digital divide at a regional level (section 4.2), asking about perceptions on how to enhance inclusiveness and reduce digital divide, and further combined with expert knowledge across different parts of the XGain project's activities, resulting in a value-tree exploring the relative importance of investing in education, technological user-friendliness, governance for inclusion and in digital infrastructure, specified with sub-factors. In section 4.3, in understanding adoption of new technologies at farm level, i.e., to analyse most probable adoption level of a specific technology in terms of number of people adopting and how much time will be needed to adopt, a total of 22 questions were formulated, covering issues of economic and societal advantages, as well as educational, technological and environmental sustainability. The readiness analyses at case level (section 4.4), asking what the readiness level is to adopt new broadband connectivity levels, not only technological factors were included, but also the social, economic, environmental, and societal factors.

For the link to policy, we note that digitalisation has become a major part of society at large. Digitalisation, i.e., the societal transformation of using high tech combined with media and digital communications (Brennen and Kreiss, 2016), has also been growing in recent years, with technologies increasingly being integrated into all aspects of human life, including business, education, and healthcare. Digital technologies such as cloud computing, artificial intelligence, the Internet of Things, and blockchain continue to evolve, offering new opportunities for businesses and individuals alike (Gill et al., 2019). This development has enabled more efficient and effective communication, information exchange, and data analysis (Ritter and Pedersen, 2020). While there are positive impacts that should not be overlooked, there are also concerns about the sustainability impacts of the digitalisation. In general, we can say that digital sustainability must reach many policy areas of concern.

6.2 Policy development relevant to digital sustainability

Within the EU, there are various policy developments relevant to digital sustainability, which represent both environmental, economic and social aspects of the development. The main parts are the Green Deal, the

Common Agriculture Policy (CAP) and the digital initiative called '2030 Digital Compass: the European way for the Digital Decade'.

The Green Deal

The European Green Deal is a package of policy initiatives aiming at stimulating a green transition with the goal to reach climate neutrality in EU by 2050. The Green Deal has been useful for placing digitalisation on the agenda. The European Commission (2019) states that one should promote and invest in the necessary digital transformation and tools as these are essential enablers of the changes, but also that careful attention will have to be paid to potential trade-offs between economic, environmental and social objectives. The Green Deal will make consistent use of all policy levers, including regulation and standardisation, investment and innovation, national reforms, dialogue with social partners and international cooperation. The European Pillar of Social Rights will guide action in ensuring that no one is left behind. (European Commission, 2019).

The Common Agriculture Policy (CAP)

For the more concrete policy measures, the EU's common agricultural policy (CAP) is of great importance. The CAP is a common policy for all EU countries. CAP is by the EU seen as a partnership agreement between agriculture and society, and between Europe and its farmers. It aims to support farmers and improve agricultural productivity, ensuring a stable supply of affordable food, safeguard EU farmers to make a reasonable living, help tackle climate change and the sustainable management of natural resources, maintain rural areas and landscapes across the EU, keep the rural economy alive by promoting jobs in farming, agri-food industries and associated sectors. It is managed and funded at European level from the resources of the EU's budget.

Modernisation through knowledge exchange, innovation and digitalisation is explicitly underpinning all CAP objectives. Modernisation in agriculture and rural areas is an explicit horizontal objective of the CAP (EU Factsheet "A Greener and fairer CAP", 2021).

Figure 44: The Common Agricultural Policy objective in European Union

The 2030 Digital Compass

With the 2030 Digital Compass, the EU (EU, 2022) has stepped up its ambition with its '2030 Digital Compass: the European way for the Digital Decade'. It is a vision for 2030 to empower citizens and businesses through a digital transformation called the 'Digital Decade'. This new policy initiative is a pathway to 'the digital transformation of the economy and society. Central to the ambition is the aim of encompassing digital sovereignty in an open manner, respect for fundamental rights, the rule of law and democracy, inclusion, accessibility, equality, sustainability, resilience, security, improving quality of life, the availability of services and respect for citizens' rights and aspirations. It should contribute to a dynamic, resource-efficient, and fair economy and society in the Union'. By that the EU policy emphasizes that 'digitalisation of the economy or society is a critical underpinning of economic and societal resilience'.

It seems clear that the topic of the digital divide is a key issue across EU policy developments, and that the EU aims to tackle it. Nevertheless, the digital divide is huge, persistent and it is causing major inequalities through the divides of access, usage, and skills, with serious consequences for society.

6.3 Policy integration

The digital divide is a challenge to policy makers. There is no silver bullet, as the subject involves many parts of policy. At the positive side, there are also plenty of opportunities. However, failing to understand and act on the multi-layered character of the digital divide will make it hard to arrive at the intertwined and integrated solutions needed to close the gaps and by that aid the development of a social, economic and sustainable future for European citizens. The argument is that identifying and linking the issues, risks and solutions needed to understand the digital divide in Europe is a foundation to solve the demanding problems involved through policy.

A crucial part of the problem is, on the one hand, the combination of the highly visible and great advantages of ICTs, and on the other hand, the much less visible but salient disadvantages. Today, we see ICTs as a fundamental part of the daily private, social and working life. ICTs are timesaving, empower individual capabilities, improve communications and data transmission, transparency in procedures, create job opportunities, facilitate heavy work and so on (Castellacci & Tveito, 2018; Pianta, 2006). ICTs contribute to socio-economic progress and support economic growth (Stanley et al., 2018). Moreover, technological innovation and digitisation can help to tackle climate change (George et al., 2021; Rolnick et al., 2023). The many advantages of ICTs are thus evident but so are the many drawbacks. ICTs generate inequalities and there are many and very diverse barriers to the access and usage of ICTs. The World Economic Forum recognises among others the availability of infrastructure, cultural awareness and acceptance, affordability and skills (World Economic Forum, 2016). All these lead to or reinforce digital divide – referring to gaps in access, use and impact of digital resources that affect individuals, households, companies or regions (Aissaoui, 2022; Vassilakopoulou & Hustad, 2021). Despite the long call for digital and technological inclusion (Nguyen, 2022), recent studies show that the digital divide has increased rather than decreased in recent years (Silva et al., 2022). In other words, the problem is getting bigger rather than smaller.

Based on the literature review in chapter 3, the following four policy areas have been recommended as critical to reduce the digital divide (Table 7); First, the need to develop educational programs is among the solutions most frequently mentioned by scholars. Education is seen as the tool to create a global digital literacy base and develop digital skills (Corkin et al., 2022; Hargittai & Hinnant, 2008). It is important that the needs of the whole

population are considered. In this way, it will be possible to include more marginalised actors such as the elderly and educate new generations free of these inequities (Choudhary & Bansal, 2022).

Second, another key element called for in the literature is the development of policies and regulations that facilitate inclusion (Maineri et al., 2021). To do so, future policies must consider the differences and characteristics of the actors and local (Reggi & Gil-Garcia, 2021; Rodríguez-Hevía et al., 2022) areas in which they are applied.

Third, for a successful policy outcome, a broad collection and diffusion of data and information is essential so that networks of positive experiences can be created and transferred (Myeong et al., 2014; Sui et al., 2013). It is also important to improve infrastructure. This requires more investment and funding, which can also take the form of subsidies to bridge the physical digital divide in some territories (Huxhold et al., 2020). Investments in broadband for example are crucial for the development of ICTs (Reggi & Gil-Garcia, 2021).

Fourth, it is important to mention the importance of having social support organised by a formal service. The support that may be provided internally within the family or friendship network should not be underestimated either, but systemic support can effectively address this issue (Lolich et al., 2022; Vulpe & Crăciun, 2020). Linked to this concept is the cultural change required to accept and integrate ICTs into daily activities, even where this step represents an individual and societal challenge (Pariso & Marino, 2020).

Overall, there is a need for crafting of policies that embrace the need to combat digital inequalities and to support underprivileged populations for better skills to benefit from ICT adoption and also providing infrastructure to reduce socio-economic imbalances. These insights are pivotal for policymakers, who also must have effective mechanisms for identifying and targeting all these issues and specific segments of society in need of policies to address digital divides appropriately (Silva et al., 2022). Policy makers must also recognise the many-layered challenges involved, where access to the digital is important but not sufficient. Access to the digital is essential but so are education and digital literacy, which in turn is linked to socio-economics and socio-cultural conditions, which can be supported by community (e-)networks and a profound governance to match the others. An integrated policy approach is thus needed to close the gaps and tackle the digital divide.

Table 7: Solutions to the digital divide according to the findings of the literature survey

Solutions	Characteristics
Enhancing the access to the digital	Better digital integration; digital services inclusion (health, financial, public); Smart(er) mobility implementation; use of the social media
Improving education and digital literacy	Building digital awareness; narrowing education gaps; facilitate learning for all ages, organise ways to reach all; be ambitious and 'leave nobody behind'.
Strengthening socio-economic conditions	Consumer opportunities; digital gender gap; identification and reduction of geographical inequalities; improve of life quality in general; protection of the most vulnerable actors; social inclusion
Building and fostering conditions for community networks	Arrange and facilitate joint communities, support thematic networks, such as e-privacy management; improve equitable connectivity; migrant mobility management

Improving (e-)governance	Developing ICT strategies; disaster management; E-gov implementation; reduce impact on labour market; improving government performance

6.4 Adoption towards digital sustainability

In the survey on how to adopt to digital technologies, i.e. a social innovation analysis about the ability of people to take part in the developments and create opportunities, we have seen that such adoption depends on the view to the relative advantages involved, and the ability to learn and to adopt to innovative change. The profit orientation is here of great importance, but also the orientation towards risks and the environment. Integration of environmental and social sustainability is highly needed.

Environmental sustainability

The increasing use of digital technologies has also led to significant environmental challenges, such as high energy consumption, high carbon footprint, e-waste, and other environmental impacts (Liu et al., 2019). Therefore, it is crucial to consider the environmental sustainability of digitisation and develop strategies to mitigate any negative effects. The rise of (the use of) digital devices leads to electronic waste. Discarded devices contain hazardous materials such as lead, mercury, and cadmium, which can pollute the environment, harm human health, and contribute to global warming. According to Forti et al. (2020), the world generated a record 53.6 million metric tons of e-waste in 2019, expected to double by 2050. To reduce the environmental impact of e-waste, sustainable practices must be implemented. This includes designing more durable devices, easier to repair and recycle and promoting the safe and responsible disposal of e-waste. Adopting these practices can reduce the amount of e-waste entering landfills and the amount of hazardous materials released into the environment. Moreover, promoting the circular economy, in which materials remain in use as long as possible through reuse, repair and recycling, can help reduce the environmental impact of e-waste while creating economic opportunities (WEF & PACE, 2019).

Considering the positive impacts of digitalisation, one of the most notable advantages is dematerialisation, which employs digital technologies to reduce the use of physical products and services. Dematerialisation can reduce resource consumption, waste production, and greenhouse gas emissions, leading to a more sustainable future. By using digital technologies to replace physical products and services, we can reduce the environmental impact of our operations while still meeting our needs and goals. Examples of dematerialisation include the transition to a paperless office, digital entertainment, virtual meetings, smart grids, and digital supply chains. For example, reducing the use of paper has significant benefits, including conserving trees and reducing energy consumption and greenhouse gas emissions associated with paper production and transportation. Paper manufacturing is also a significant contributor to environmental pollution, producing various pollutants such as sulfur, nitrogen, and greenhouse gases, contributing to air pollution and climate change (Tomberlin et al., 2020). (See example in Box 1)

We have seen in chapter 4 that adopting to the changes involves many types of change, ranging from how to view and balance profit and environmental concerns. Awareness of these matters, the sensitivity and also the ability to learn, are issues of pivotal interest. The matters at hand go beyond the reach of the Green Deal, the CAP and the 2023 Digital Compass, although these matters should be on the agenda of these polices as well.

Social sustainability

The UN Global Compact stated that social sustainability should be a critical part of any business because it affects the quality of business' relationships with stakeholders. Social sustainability is about identifying and managing business impacts, both positive and negative, on people. The quality of a company's relationships and engagement with its stakeholders is critical regarding the environmental dimension. Directly or indirectly, companies affect what happens to employees, workers in the value chain, customers and local communities, and it is important to manage impacts proactively. The first six of the UN Global Compact's principles focus on this social dimension of corporate sustainability, including the rights of specific groups: labour, women's empowerment and gender equality, children, indigenous peoples, people with disabilities, and people-centred approaches to business impacts on poverty. We see here a link to for instance economy, environment, education and health. The UN expect businesses to undertake due diligence to avoid harming human rights and to address any adverse impacts on human rights.[7]

BOX 1. ***Significant environmental negative impact of digitisation is the high energy consumption of digital devices, often powered by non-renewable sources such as coal and natural gas. For instance, data transmission networks consumed 260-340 TWh of electricity in 2021, accounting for 1.1-1.4% of global electricity use (Table 7). This figure is projected to increase to 13% by 2030 (IEA, 2022). In Ireland, for example, data center electricity consumption has tripled since 2015, accounting for 14% of the country's total electricity consumption in 2021. Similarly, data center energy use in Denmark is expected to triple by 2025, making up around 7% of the country's total electricity use (IEA, 2022). The energy consumption is part of the greater picture of the digital sustainability where the carbon footprint of digitalisation is the prime issue of environmental concern. Freitag et al. (2021), estimated that ICT contributes between 2.1% and 3.9% of global greenhouse gas emissions in 2020. The study highlights the need for more sustainable practices in the digital sector, such as using renewable energy sources and energy-efficient devices. By adopting such practices, it may be possible to mitigate the carbon footprint of digitalisation and reduce its impact on the environment.***

Global trends in digital energy indicators, 2015-2021	***2015***	***2021***	***Change***
Data center energy use (not crypto)	*200 TWh*	*220-320 TWh*	*+10-60%*
Crypto mining energy use	*4 TWh*	*100-140 TWh*	*+2 300-3 300%*
Data transmission network energy use	*220 TWh*	*260-340 TWh*	*+20-60%*

Source: IEA (2022)

The EU Sustainable Corporate Governance is currently an initiative developing to improve the EU regulatory framework on company law and corporate governance. It would in principle enable companies to focus on long-term sustainable value creation rather than short-term benefits; it aims to better align the interests of companies, their shareholders, managers, stakeholders and society. By that the social dimension would be strengthened and help companies to better manage sustainability-related matters in their own operations and value chains as regards social and human rights, climate change, environment, etc.[8] Social sustainability is a proactive way of managing and identifying business impacts on employees, workers in the value chain,

[7] https://unglobalcompact.org/what-is-gc/our-work/social

[8] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12548-Sustainable-corporate-governance_en

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customers, and local communities. Companies that raise the importance of social sustainability recognise the significance of their relationships with people, communities and society. [9]

The societal transition of both digitalisation with use of data through digitisation, as well as with communication and interaction through media, will need to be addressed in a comprehensive way. As ICTs are increasingly embedded in daily human activities and are becoming more and more sophisticated, it is crucial that policies make digitisation equitable by removing barriers in every context so that access to certain services and technological benefits does not become the privilege of an elite (Fang et al., 2018). The need to develop solutions suitable to rural areas is then crucial, as; in terms of land-size, Europe is for 80% rural, and is home to 30% of the population.[10] For ongoing change across all policy fields of the EU and its member states related with the digital realities, more thoroughness and integration will be highly needed. This includes the Green Deal, the CAP and the 2030 Digital Compass but it also goes at the heart of all economic and environmental policies.

[9] https://www.adecesg.com/resources/faq/what-is-social-sustainability/#:~:text=Social%20sustainability%20is%20a%20proactive,with%20people%2C%20communities%20and%20society.

[10] https://digital-strategy.ec.europa.eu/en/news/harnessing-innovation-unlock-potential-rural-and-remote-areas

7 Conclusions

The XGain project provides a comprehensive inventory of technological solutions for last-mile connectivity and edge computing. The intended beneficiaries are policymakers, municipalities, farmers, foresters, and their associations in rural areas, enabling business model development and decision-making in the selection of a technological ecosystem. The XGain project is based on a practitioner-oriented approach, including six use cases that assesses socio-economic and techno-environmental impacts. Digital sustainability is a key-concern for the analysis of use cases for a fair transition in social innovation, including digitalisation and digitisation.

In the analyses of fair transitions by means of social innovation analyses applied to; confirm urgency factors of inclusion, analyse ability for people to take part and create opportunities by adoption, and deepen insights about the readiness of institutional settings, the main aim of this deliverable is to explore digital divide in the European context. Core methods of analyses include; a literature review to define causes, perceptions of inclusion to analyse urgency in investing in factors leading to exclusion, perceptions of adopting high tech for people to take part and create opportunities, and perceptions of relevance and readiness for adoption of the institutional setting.

Note that the use cases in XGain cannot fully represent contexts of urgencies related to marginalisation with people suffering from lack of access, or exclusion, of individuals or groups of individuals from certain areas of benefits of society. Still, they are providing insights about these issues in different contexts across Europe, which assists us to reflect on context specific differences across Europe. This is critically important because of the heterogeneity in culture, development, policies, urban, rural and environmental contexts in Europe. In XGain, a total of six use cases include; 1) Spain: Catalonia – drones operation in rural areas, 2) Greece: Central Macedonia – eHealth robots for elderly, 3) UK: Islands of Scilly – precision agriculture and tourism, 4) Lithuania – precision agriculture and forestry, 5) Croatia: Dalmatia – remote oyster farming and water quality monitoring, and 6) Belgium: Flanders – livestock health and farm management. They are involved in this study to identify perceptions about digital divide (i.e., inclusion, adoption and readiness) with new technological innovations across marginalised areas and groups in different ways.

Looking at the results of this deliverable, they must be seen in the lights of introduction of new approaches into the field of digitalisation, to broaden the scope to for tackling urgent societal challenges in human behaviour, rules, regulations and governance, following rapid changes in the European settings in the transition towards digital sustainability. As such the results are of less relevance, because we cannot refer to representative samples within the different contexts. Instead we have consulted with consortium partners from specific areas and cases, and as such they also represent their own expertise in addition to the contexts, they are living in. It is complicated to involve large samples of stakeholders because of the problem of stakeholder fatigue, and in this case, we have solved this by concentrating on the richness of knowledge within the XGain consortium.

First, following the results of the literature review, the issues of urgencies represent five categories (Table 3); 1) access to the digital, which includes issues related to achieving inclusion and integration of services that are provided digitally, 2) education and digital literacy, which includes issues related to digitisation awareness and knowledge in ICT, 3) socio-economic and socio-cultural conditions, representing most discussions in the literature, including issues of social inclusion of all groups and communities and the opportunity to access digitisation as a means of improving quality of life (e.g., Groth, 2019; Lolich et al., 2022; Petrovčič et al., 2022; Pinto et al., 2022, 4) communities and networks, which deals with issues related to the need for efficient connectivity at an extended global level (Riddlesden & Singleton, 2014; Seo & Thorson, 2016), and 5) e-

government quality, which includes all problems arising from the use of technology at governmental level and electronic government (e-government) (Macaya et al., 2021; Pariso & Marino, 2020; Warf, 2018).

Second, in investigating the issue of digital divide across regions (among XGain consortium partners), we asked the question: How to enhance inclusiveness and reduce digital divide? This is a critically important question to understand context specific factors, and how different regions will respond differently. As shown in Figure 11, the main factor categories defined included investments technological user-friendliness, governance for inclusion, education and digital infrastructure. It was shown, for instance, that technological user friendliness is seen particularly important in the UK and Belgium, whereas investments in governance for inclusion is relevant across most cases, but highly so in Austria, and of only little relevance in the UK, Croatia and Austria. Also, investment in education scored generally high, but extremely so in the UK, Luxemburg and Lithuania, and a bit less in Greece and the Netherlands. Investments in digital infrastructure is very much emphasised for Spain and Croatia, and the least emphasis is provided in Lithuania.

Third, to identify perceptions of adopting high tech among stakeholders within use cases in the XGain project is important because; on the one hand, it gets clarified how many will make use of the technology within a specific time period in the current situations, and on the other hand, if the identified bottlenecks get solved, the potential expansion of farmers included, as well shortened time period, can be estimated. Findings included that, for the case of Flanders, Belgium, there is substantial potential for the technology referred to as 'digital shepherd', and potential will increase if the environmental, economic and management benefits become larger than first anticipated. The adoption of the 'digital shepherd' is relatively quick, and can be further accelerated through the possibility of trialing and assessing effects as well as development of relevant skills and knowledge. Also, in the case of Scilly Island, UK, a so-called Multirobot System (MRS) holds significant promise for adoption. With a predicted PAL of 61%, addressing key factors such as environmental benefits, enterprise proportions, and farm profitability is important for successful and swift adoption. Simplifying trials, ensuring assessability, and managing cost-benefit ratios will be necessary for accelerating adoption timelines, although challenges may arise if upfront costs exceed expectations. Overall, the MRS is positioned for a good integration into Scilly's agricultural landscape.

Fourth, following the multi-dimensions of digital sustainability in the adoption of institutional settings, readiness levels should not only be limited to the technological, but also the economic, social, environmental and societal readiness levels are of relevance. The question is not only "what are the readiness levels?", but also, which readiness level is of relevance to the specific case? The analyses of relevance showed, in Figure 34, that the economic factors got in particular high scores in the cases of Greece and Scilly Island, whereas the technological factors were deemed relatively more important to the cases of Spain, Greece, Belgium and Scilly Island. The social factors, such as health, inclusion and work, were seen highly important in the cases of Greece, Belgium and Lithuania, while the societal factors, such as poverty alleviation and sustainability, were perceived particularly important to the cases in Spain, Belgium and Lithuania. The environmental factors were highest valued in Croatia, Scilly Island and Lithuania. This is followed by an explanation of the Balanced readiness level, taking all the technological, economic, environmental, social and societal readiness levels into account, and measures on a nine-point scale (Table 6). In Figure 43, the relevance and readiness of different readiness levels per case are plotted. Notably, this is an illustration of a method, not a proof of results.

The next question is: How is the digital sustainability embedded in the EU policy? Within the EU, there are various policy developments which represent both environmental, economic and social aspects of the development, including; the Green Deal, the CAP and the digital initiative called '2030 Digital Compass: the European way for

the Digital Decade'. Based on the literature review we conclude that there is a need for policies that combat digital inequalities, support for better skills in using and adopting ICT adoption and provide infrastructure which reduce socio-economic imbalances. Moreover, policy makers should recognise the many-layered challenges involved, where access to the digital is important but not sufficient. Access to the digital is essential but so are education and digital literacy, which in turn is linked to socio-economics and socio-cultural conditions, which can be supported by community (e-)networks and a profound governance to match the others. An integrated policy approach is thus needed to close the gaps and tackle the digital divide (Table 7).

Concerns for both digital environmental footprint and social risks require a need for sustainable transition in technology development in the food and agricultural systems. In this deliverable a series of factors of relevance have been identified for specific questions and contexts, and for particular people responding to judge on urgencies. The overall guideline should be based on the transition towards digital sustainability by transition pathways to the SDGs. Digital sustainability can be seen in lines of technological, economic, environmental, social and societal sustainability.

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