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Presented by

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Assessing the use of Digitalization and Artificial Intelligent in the measurement of progress and the implementation of SDG 6 alongwith synergy and tradeoffs with 2, 7 in Africa.

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PAN-AFRICAN UNIVERSITY INSTITUTE OF WATER AND ENERGY SCIENCES (including CLIMATE CHANGE)

Assessing the use of Digitalization and Artificial Intelligent in the measurement of progress and the implementation of SDG 6 alongwith synergy and tradeoffs with 2, 7 in Africa.

A thesis submitted to the Pan African University Institute of Water and Energy Sciences (including Climate Change) in partial fulfilment of the requirements for the degree of Master of Science in Water (Policy option).

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DEDICATION

I dedicate this work to my parents; my Father COMLAN SESSI Kohovi, my Mother KOUNOU Claudine and my Sisters Linda and Corine.

STATEMENT OF THE AUTHOR

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ABBREVIATIONS AND ACRONYMS

AI	Artificial Intelligent/Intelligence
AOSTI	African Observatory for Science, Technology and Innovation
AU	African Union
D&AI	Digitalization and Artificial Intelligent
DSM	Digitalization – Sustainability Matrix
GDP	*Gross domestic product*
ICT	Information and communication technologies
IOT	Internet of Things
M2M	Machine to Machine communications
MC	Multi-Criteria Analysis
SDG's	Sustainable Development Goals
ST	Science, Technology and Innovation
UN	United Nations
W-E-F	Water-Energy-Food

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ABSTRACT

The United Nations has formulated integrated global goals for transformation with targets and indicators. These goals are aligned with those of Agenda 2063 which is presented as a strategic framework for structural transformations and sustainable development with the support of digitalization and artificial intelligence as tools with great potential to accelerate the achievement of integrated objectives. However, there is little clear on how digitalization and artificial intelligence can enable the goals for positive and sustainable transformation. This work aim to explores the degree that the digitalization and Artificial Intelligent has been used to measure progress and in the implementation on the SDG 6 with alongsynergy and trade-offs with 2, 7 in Africa. The Study is based on series of case studies. With the pairwise comparison to establish the lists of interconnected indicators that belong to the decision support tool based on multi-criteria analysis (MCA) and established the similitude between Agenda2063 targets. Sustainable Digitalization Matrix (DSM) has enabled the different practices and challenges of digitization and artificial intelligence for the progress and implementation of SDG 6 with synergy and trade-offs with 2, 7 in Africa. In order to establish the different pathways for the promotion of digitalization and artificial intelligence to achieve progress in the implementation of SDG 6 with synergy and compromises with 2, 7 in Africa.

The method used made it possible to establish 12 main indicators interconnect, the links that exist with the targets of Agenda 2063 and raise the potential of digitalization and artificial intelligence for progress. Therefore there is a large gap between knowledge and practices on the mutual relations between digitalization and artificial intelligent (D&AI) and SDGs research-based Nexus-based approach for promoting D&AI in order to benefit from the power of D&AI while minimizing these possible risks. Overall D&AI is a potential enabler end pathways for SDG progress and also represents a perspective for the effective use of D&AI for the SDG's for making progress thought implementation of SDG 6 with synergies and trade-offs with 2, 7 in Africa, with a complexity of indicators and their transdisciplinary interactions of digital technologies that implies relevant, irrelevant and sometimes neutral impacts.

Keys words: Digitalization, Artificial intelligence, SDGs, SDG's indicators, W-E-F Nexus

Chapter 1: INTRODUCTION0000

This chapter present the information necessary to understand the objective of the thesis. It presents the situation of the use of Digitalization an Artificial Intelligent (D&AI) in Africa through the case study, states the heart of the problem and defines the main objectives as well as the scope of the research and its importance.

1.1 Background

The pressures of globalization with world finite resources leads in search of stability of the economy and environment, through the integration and acknowledgement of economic, environmental, and social concerns throughout the decision making process for sustainability. The United Nations (UN) describes sustainability as a movement for safeguarding a better and more sustainable well-being for all, including future generations. Through the SDG's, all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. The SDGs are a collection of 17 goals, with 169 associated targets and 247 indicators. With a view to create a dynamic between the developmental objectives, African Union (AU) establish interlinkage between Agenda 2063 objectives to UN goals while describing priority targets. In the same purpose, AU develops digital transformation strategies (2020-2030) to achieve these objectives which enter into the dynamics of development through the interconnection which exist between Agenda 2063 and 2030. The Transformations are not a new grouping of the 17 SDGs and their 169 targets. They are based on the systemic and integrative changes that are essential to reverse the trends for sustainable change. It is capture much of the global, regional, and local dynamics and thus encompass major drivers of future changes: Human capacity and demography; Consumption and production; Decarbonisation and energy; food, biosphere and water; Smart cities; and digital revolution. The digital revolution, specifically virtual and augmented reality (VR and AR), additive manufacturing (AM), artificial intelligence (AI) , deep learning, robotics, big data, internet of things (IoT), and automated decision systems, has been at the heart of debates and introduced in several countries (Nakicenovic et al., 2019). The transformations involve integrated solutions, approaches and different stakeholders for goals achievement. It built on fundamental pillars and based on the existing policies and regulations which are existing frameworks and focus on industrialization. The document is based on the conceptual framework to shorten to practice and takes into account D&AI as technologies.

In addition to digital transformation, through different strategic documents AU states member shows the willing to use technologies to achieve the goals and more the perspectives for Digitalization. Digitalization is transforming the world in almost every aspect of life during the last few decades (Friedrich-Ebert-Stiftung Rwanda, 2019). As regards innovation and technology policies for achievement of the objectives of agenda 2063, African observatory for Science, Technology and Innovation (AOSTI) is the body indicated the purpose of stimulate and promote the use of Science, Technology and Innovation (STI) to support evidence-based decision making for sustainable development in Africa. The strategy specifies different categories: the cross cutting themes, the critical sectors to drive digital transformation and foundation pillars. Governments have a responsibility to create an enabling environment with policies and regulations that promote digital transformation. In terms of technologies, Artificial Intelligence (AI), the Internet of Things (IOT), Machine to Machine communications (M2M) and 5G is fundamental.

Moreover the New Africa-Europe Digital Economy through Partnership Accelerating of the Achievement of the Sustainable Development Goals (SDG's) report, generally based on digital infrastructures for transformation. The strategic documents recognizes the importance, the necessity of digital transformation and how it will prevail in Africa, proposes strategies and makes recommendations. The digital revolution is design to support the achievement of SDG's and help to measure the progress. The SDG's seek to operationalize and integrate sustainability into all current and future development processes in order to meet societal, environmental and economic needs. On this basis, the SDGs aim to combine sustainable environmental development, economic and social inclusion (Sachs, 2012). This combination reveals the relationship that exists between the different objectives. The relationships represent the interconnections and integrated nature that are the foundation for achieving the SDGs with the making of meaningful progress (Biggs et al., 2015).

1.2 Problem Statement

African countries are thinking and are ready for a comprehensive digital transformation strategy to guide a common, coordinated response to reap the benefits of the fourth industrial revolutionThe African States in different strategies support the digital revolution to achieve their objectives. The digital revolution take care of digitalization and artificial intelligent which comes like tools and accelerate sustainability. The Digital Revolution, through artificial intelligence includes virtual and augmented reality (virtual reality and AR), Additive Manufacturing (AM), AI, deep learning, robotics, big data, IOT and automated decision-making systems, has entered the public discourse in many countries.

Digitalization is affecting all aspects of daily life, decent work, employment, business, community development and the whole economic development. Particularly for SDG 6 which focuses on sustainable access to clean water and sanitation, pledges to ensure the availability and sustainable management of water and sanitation for all people. In terms of Digitalization and Artificial Intelligent the SDG 6 involve management systems, smart water solutions for sanitation and hygiene.

The 2030 Agenda recognizes sustainability as a dynamic system, with interdependencies and interlinkages which promote synergies and compromises which are managed by stakeholders (Fortier, 2015). Energy is used throughout food supply chain, from the manufacture and application of agricultural inputs, such as fertilizers and irrigation services, to processing and distribution (Ina, 2017).

Thus, SDG's 7 and 2 are interconnected with SDG 6. SDG 7 aims to ensure access to reliable, sustainable, and modern energy services for all at an affordable cost and SDG 2, through Zero Hunger, aims to end Hunger, ensure food security, improve nutrition, and promote sustainable agriculture.

In the quest for sustainability, resilience technologies are measures that are relevant and can be used for adaptation and resilience. In practice, this implies integrated solutions and different stakeholders for achieving the SDG's.

However, the role of digital infrastructure, technology and innovation in achieving SDG 6 and its integration with the closely related SDG's 2 and 7 has not been specifically addressed in a context where digitalization and artificial intelligence are revolutionizing, with integrated approaches that also promote sustainable development. Although emerging technologies such as block chain, artificial intelligence, Internet of things, 3D printing are recognized in the digital transformation strategy document, it remains to be proven whether they are used in Water Energy and Food Nexus in Africa .

Moreover currently only few studies have so far investigated the nexus between D&AI and the SDGs thus limiting the possibility for open debates and a coherent dialogue between key stakeholders in Africa. The strategies still at perspective level. It is crucial to map the impact of D&AI on SDG 6 with alongsynergies and trade-offs with SDG 2, 7 in Africa, since there is a great distortion and an absence of information in the field. The present task, therefore will help policy makers to acknowledge how the use of digitalization and AI can create positive effects in the implementation of SDG 6 along with synergy and trade-offs with 2 and 7 in Africa.

1.3 Significance of the Study

The application of D&AI associated with the SDG's promotes efforts in favour of sustainable development by bringing new opportunities (Osburg and Lohrmann 2017).

Due to the complex nature underlying the SDG's, there is a lack of information regarding efforts to explore the significance of applying D&AI to achieving the SDG's, particularly in W-E-F nexus context. There is therefore a limit to the possibility of open debates and coherent dialogue between key actors. So far, only a few studies have investigated the link between D&AI and the SDGs (e.g. Global Enabling Sustainability Initiative 2019, Kostoska and Kocarev 2019, Vinuesa et al., 2020, Gupta et al., 2020), there are therefore gaps in terms of points of view to identify interactions and affirm the possible results. Thus, it is essential to establish synergies and trade-offs between the SDGs or their indicators must be evaluated to establish the links and potential progress between the SDG's and D&AI. To better understand and provide evidence-based evidence, which is not yet well recognized and poorly reflected in debates, more research is needed to provide methodologies. Although still evolving, research on a conscious use of D&AI is beginning to take shape. Further work is needed especially in Africa to continue to explore the conscious and sustainable applications of D&AI technologies for transformation. In our case the SDG 6 alongwith synergies and trade-offs with SDG 2 and SDG 7 has been privileged.

Therefore, the findings of this study will help policy makers in Africa to acknowledge the importance of digitalization and Artificial Intelligent for W-E-F Nexus and to include that point in their policy and government strategies. Also promote the use of D&AI in the implementation and measurement of progress in SDG's

1.4 Research question and Objectives

1.4.1 Research questions

The research question (RQ1) is subdivided into the following sub research question:

RQ1: What are the link between SDG 2, 6 and 7 through the indicators?

RQ2: Which integrations exist between the SDG 2, 6 and 7 at indicators level and 2063 agenda?

RQ3: What are the possible Practices and challenges of D&AI to support the achievement of SDG 6 along with synergy and tradeoffs with 2, 7

RQ4: What is the necessary approach for the acceleration between digital cooperation, D&AI for progress and the implementation of SDG 6 along with synergy and trade-offs with 2, 7 in Africa ?

1.4.2 Objectives

General Objective

Explores the degree that the digitalization and Artificial Intelligent has been used to measure progress and in the implementation on the SDG 6 with along synergy and trade-offs with 2, 7 in Africa.

Specific objectives (SO)

In the frame of this study, four specific objectives have been identified, which are:

- **SO1:** Identify interconnected indicators of SDG's 2, 6 and 7 for mapping the conceptual nexus between them
- **SO2:** Measuring the affinity between identified indicators and Agenda 2063
- **SO3:** Determine practices and possible challenges of using D&AI to support the achievement of SDG 6 along with synergy and tradeoffs with 2, 7
- **SO4:** Evaluate the approach needed with D&AI to foster synergy and promptly address potential trade-offs for achieving SDG 6 along with synergy and tradeoffs with 2, 7

Chapter 2: LITERATURE REVIEW

General Concepts

This chapter presents a brief review of the literature (concepts and theories). It begins by clarifying the main concepts and showing the obvious link between Digitalization, Artificial Intelligence and the relevant SDG's. The chapter goes on to present the link between Goals 2, 6 and 7 while emphasizing the synergies, trade-offs and introducing the interactions with Agenda 2063 in order to specify the African context. It ends with the different evidences of the use of D&AI of SDG 6 alongwith synergy and trade-offs with 2, 7 in Africa.

2.1 Digitalization

Digitalization is defined as the increase in the use of digital technology by organizations, industries, countries (Gorenšek, 2018). On the other hand digitalization is the growing application of Information and Communication Technologies (ICT) across the economy encompassing a range of digital technologies, concepts and trends like the IoT AI and the Fourth Industrial Revolution (IAE, 2017)**.** IoT is a network of physical objects connected through the internet and through embedded sensors, software and other technologies that enable the exchange and collection of data (Mondejar et al., 2021)**.**

The same concept involves other aspect in another study, where the author defines digitalization as the increased digitization, connectivity and networking of digital technologies to improve communication, services and commerce between people, organizations and objects (Linkovet al., 2018). His study present digitalization as an emerging opportunity and also as a challenge for the United Nation in achieving the Sustainable development goals. As an opportunity it takes into account the objectives of the AU which are linked to UN SDG's. Also from the same study, digitalization promotes the development of artificial intelligence.

For Katz and Koutroumpis (2013), digitalization refers to the social transformation triggered by the mass adoption of digital technologies that generate, process, and transfer information.

Digitalization cover the use of digital ICT, including the interconnectivity and networking of these technologies (van der Velden, 2018). This definition of digitalization is different from digitization which is the replacement of a physical by a digital object while digitalization goes beyond it and represents a fundamental transformation that goes beyond a simple use of digital data for a specific action. Digitization has fostered the adoption of technologies with the integration of information and data through information systems (Imgrund et al., 2018). Moreover, it shows by Imgrund et al., (2018) that digitization has been the main point for the use of IT. Digitization is therefore the first step in the process of digital transformation as shown in the following figure (figure1).

On the other hand, digitalization, also known as digital transformation, is a combination of two procedures; digitization and digitalization with the aim of improving existing products and services with advanced capabilities (Yoo et al., 2012).

Figure 1 : A Framework for Understanding Digitalization (Udovita, 2020)

According to Mittal, 2018 digitalization offers access to knowledge, reduced costs, and greater interdisciplinary.

Further, large-scale digitalization is changing business and technology environments (Skog, 2019). In addition, digitalization provides access to an integrated network of untapped big data with potential benefits for society and the environment (Mondejar et al., 2021). In the context of the SDGs, digital technologies are defined as ICT's that are enablers of sustainable development (van der Velden, 2018). In other words, digitalization technologies are potential tools that could propel sustainable development with several opportunities that are classified under several dimensions as shown in the following table (table 1). Of the previous definitions, in this study digitalization is the use of digital technology for the transformation of a specific sector for sustainability.

Table 1 : Digital transformation Dimension (Zaoui et al., 2019)

Dimension	Description
Structural dimension	Involves changing the organizational structure, processes and skills needed to exploit new technologies
Legal dimension	Rules governing the digital question (data protection, transaction regulation)

Political dimension	General framework governing a population integrating the digital move
Participative dimension	Consists of the collaboration / interaction of any stakeholder, including the user
Innovation dimension	Includes innovation in technology design, technology processes and ICT Management
Financial dimension	Consists of investment / return on investment
Environmental dimension	Includes macro-environmental factors influencing ICT integration (Regulatory Framework, Resources)
Security dimension	Includes; IT security (hardware, application and network), data and human security and environmental security
Quality dimension	Consists of the quality of the product and service resulting from Digital Transformation
Technical dimension	Includes technical infrastructure, development and technical implementation
Technological dimension	Includes Hardware, Software and Network Components
Organizational dimension	Consists of ICT adoption, ICT deployment, Dissemination, Implementation, Infusion, Integration.
Operational dimension	Definition of all actions / activities after digital transformation
Regulatory dimension	Consists of the legal and political framework

2.2 Artificial Intelligent

The term artificial intelligence is defined as: "The study of intelligent problem-solving behaviour and the creation of intelligent computer systems. AI therefore describes the work processes of machines that would require intelligence if they were performed by humans" (Wisskirchen et al., 2017).

According to Emerj Artificial Intelligence Research, AI is an entity, capable of receiving inputs from the environment, interpreting and learning from these contributions, in order to exhibit flexible behaviours and actions that help the entity achieve a particular goal or objective over a period of time (Pedemonte, 2020). Apart from the impressive growth opportunities that AI presents it also involve implications and concerns. Artificial intelligence is a constellation of many different technologies working together to enable machines to sense, comprehend, act, and learn with human-like levels of intelligence therefore a set of abstraction that is considered to be a reality for the achievement or attainment of a goal.

Artificial intelligence works for the growth of several sectors. It should affect global productivity; equality and inclusion; environmental outcomes in the short and long term (Vinuesa et al., 2020).Since 2010 artificial intelligence has known a real explosion both academically and industrially, with the development of big data, data science and deep learning (Basdevant, 2017).

A recent definition indicates that AI can be a set of computerized systems that require intelligence as the ability to learn, solve problems and achieve goals under uncertain and variable conditions (Harris, 2021). There is a common subset of terms used in the AI which are ML techniques such as deep learning, neural networks and GANs; and training methods such as supervised, unsupervised and reinforcement learning.

AI has great potential to contribute immensely to solving existing problems and people's well-being in the near future (Fuso-nerini et al., 2021). Artificial intelligence is therefore the way in which machines can perform tasks autonomously.

Digital technologies there have 8 main ones emerging and they are presented below.

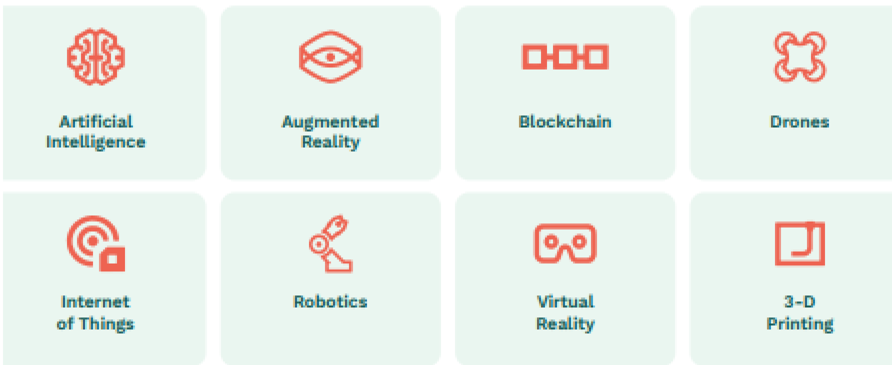

Figure 2 : The Eight Emerging Technologies (Butcher et al., 2021)

2.3 SDG 6 Synergies and trade-offs with SDG 2, SDG 7

2.3.1 Synergies and Trade-offs

Synergy refers to the interaction between two or more actions, which leads to an impact greater or less than the sum of the individual effects. Synergy can be positive or negative, when it is negative it is a trade-off. Trade-offs can be understood as negative effects, when the achievement of one objective is implemented in such a way that it imposes negative impacts or constraints on the achievement of another objective (Mainali et al., 2018).

In this study, synergies are understood as the positive effects of achieving SDG 6 that would, in turn, enable the achievement of other goals, development mutually that can facilitate the implementation and progress of SDG 2 and 7. While the trade-off is when the achievement of one objective is implemented in such a way that it imposes negative impacts or constraints on the achievement of another objective.

The 2030 Agenda is holistic, involving the goals of Agenda 2063 with deep and complex interactions between the SDGs, the goals of Agenda 2063 and their targets. Understanding the interactions is therefore crucial for effective implementation of the SDG agenda.

The objectives are integrated; they must be addressed on the basis of the potential trade-offs and synergies that exist between them for positive impacts and progress. Indicators for each of the SDGs are defined for each target and allow for the measurement of progress towards the goals, three of the SDGs specifically refer to food (SDG 2), water (SDG 6) and energy (SDG 7) through increased renewable energy, agricultural productivity and water accessibility. These three objectives are intrinsically linked, and their integration is based on resource management, infrastructure development and policies. The interconnection between these different sectors implies potential synergies but also risks of trade-offs (Fader, Cranmer, Lawford, & Engel-Cox, 2018).

Synergy and trade-off analyses are concepts used in international development that help foster a critical understanding of development issues, interactions between policies, and promote coherence and coordination in the implementation of the 2030 Agenda at the level of countries that are stakeholders in the Agenda. Synergies and trade-offs are discussed and analysed under different variables. Depending on the interconnections, the study of synergies and trade-offs has become an increasingly important research topic (Moyer & Bohl, 2018). It focuses on the interaction between the local, sub-national, national and international levels.

Synergies are the positive effects of achieving one goal which in turn has the potential to achieve other goals. Conversely, negative correlations indicate likely trade-offs (Hegre, Petrova, & von Uexkull, 2020). Synergy therefore allows for mutual development through infrastructure and policies that can facilitate the implementation of the SDGs (Fader et al., 2018).

Sustainable management of water resources and improvement of water quality and access will facilitate the achievement of the goals of SDG 2 and 7. At the same time there is a strong negative dependence of the achievement of SDG 2 on water and energy resources.

2.4 W-E-F Concept

The links and interconnection between W-E-F have been established through the Nexus concept, which has been a priority in scientific studies in recent years. As a concept, the W-E-F link still been to translate from theory to practice. W-E-F nexus provides a coherent, holistic, and integrated implementation of the SDG’s (Olawuyi, 2020).

The Nexus approach was first launched at the Bonn 2011 Nexus conference in response to climate change and social changes including population growth, globalization, economic growth and urbanization (Endo et al, 2017). For some authors, the nexus emerge as a response for the challenges that the world is facing in terms of security of water, energy and food. The nexus focuses on the interdependence of W-E-F by understanding the challenges and finding opportunities. It recognizes the interconnectedness of W-E-F across space and time (Salam et al., 2017).

Some authors argue that the concept of "W-E-F Nexus" has emerged to interpret the linkage of water, energy and food resources and to suggest an integrated management plan. There is a trade-off relationship among input resources such as energy, water and cost, for increasing food productivity (Purren et al, 2019). Moreover, Food and Agriculture Organization of the United Nations (FAO) describes the link as a new approach to support food security, sustainable agriculture and as a means of understand and manage the complex interactions between water, energy and food (Mohtar & Lawford, 2016). This link serves to create a balance between the different SDG's and the interests of the parties (stakeholders) using W-E-F resources.

Specifically a study from 2018, shows that water is essential for improving agricultural productivity and food production. The use of groundwater pumps to irrigate cropland requires increased water demand but also the availability of electricity. A projection made according to these different in comparison to the current use shows that the demand for freshwater will increase by 30%, energy by 50% and food by 40% until 2030 (Andrews-Speed et al., 2019).

In detail, the agricultural sector needs energy along the entire value chain from harvesting to distribution of products (United Nations, 2011). In addition, access to energy plays an indispensable role in the supply of drinking water in many remote locations (Mainali et al., 2018). The W-E-F nexus is therefore the study of the links between these three resource sectors, as well as synergies, conflicts and trade-offs that arise from the way they are managed through food for water, water for food, energy for water and water for energy, food for energy and energy for food.

2.5 Trends in the use of AI and digitalization for the SDGs

2.5.1 Integrating Artificial Intelligence and Digitalization

There are a significant number of publications that integrate AI and other digital technologies to achieve the SDG. AI systems need the support of other digital technologies that cooperate symbiotically with AI in many real-world application scenarios related to achieving the SDGs.

Sustainability is a broad concept based on all aspects of the world. It has an abundant literature that has environmental, economic and social sustainability as its fundamental pillar.

Application of D&AI for sustainable development is being viewed as a major movement shaping the economy, environment, and society. D&AI, particularly under the framework of SDG including the AU objectives with priorities domains is less explored yet promising, since it fosters coherent efforts towards sustainable development by providing new value generating opportunities (Fuso-nerini et al., 2021).

The SDG's take into account a number of frameworks to assess the impact of AI and digitalization on different sectors and identify the possible synergies to be the different sectors provide an excellent framework to assess the impact of AI and digitization on different industries as well as to the identification of possible synergies between them. AI can enable the accomplishment of 134 targets across all the goals, but it may also inhibit 59 targets (Vinuesa et al., 2020).The same studies have found that in general 79% of SDG's targets can be positively affected by AI, while 35% can be negatively affected by the development of AI.

Particularly in the exploit literature, there are examples of possible positive effect that have been possible through the use of artificial intelligence. The use of satellite data made possible to monitor poverty (Jean et al., 2016). There are also positive aspects regarding the link between SDGs 8 and 9 where artificial intelligence can help generate new jobs while increasing productivity. Specifically through smart grid applications and through the development of more robust tools to predict and manage pollution in cities SDG's 7 and 13 have experienced positive effects in the context of more efficient use of energy (Torres, Clainche, & Vinuesa, 2020).

Based on the case studies, Goralki et al., 2020 were able to establish that D&AI can accelerate the achievement and make progress towards the implementation of the SDG's. They made their claims based on several case studies. These case studies show that D&AI tend to improve the efficiency of industrial processes, conserve non-renewable resources, contribute to the dissemination of specialized knowledge, reduce the gap between resources and technology, and Foster the creation of alliances between governments, the private sector and society to maximize global sustainability.

The SDG's call for action by all and in all these areas, AI has a big role to play. AI as an enabling technology to promote the achievement of the SDGs has gained significant consensus within the UN (poor, rich and middle-income). Several UN member states, academic institutions, industries, etc., recognize that D&AI should be deployed in the best possible way to support the achievement of the SDG's and benefit the public. It is has been integrated into the SDGs in various forms, through experimentation and then into sustainable management and leadership programs (Goralski and Tan., 2020), AI has a wide range of applications that can accelerate the pursuit of sustainable development, which will involve multiple actors from different countries, cultures and sectors. Artificial intelligence is the ally that development needs to more effectively design, execute, advise and plan for the future of our planet and its sustainability. Technology like AI will help us build more efficiently, use resources sustainably, and reduce and manage the waste we produce more effectively, among other things. Specifically, according to a study published in Nature, AI could help achieve 79% of the SDG's (SDG's), however it may also inhibit 59 targets (figure 1) (Vinuesa et al., 2020). In side of enabling, this technology could become a key tool to facilitate a circular economy and build smart cities that use their resources efficiently. D&AI are therefore a technologies for sustainability in resource management.

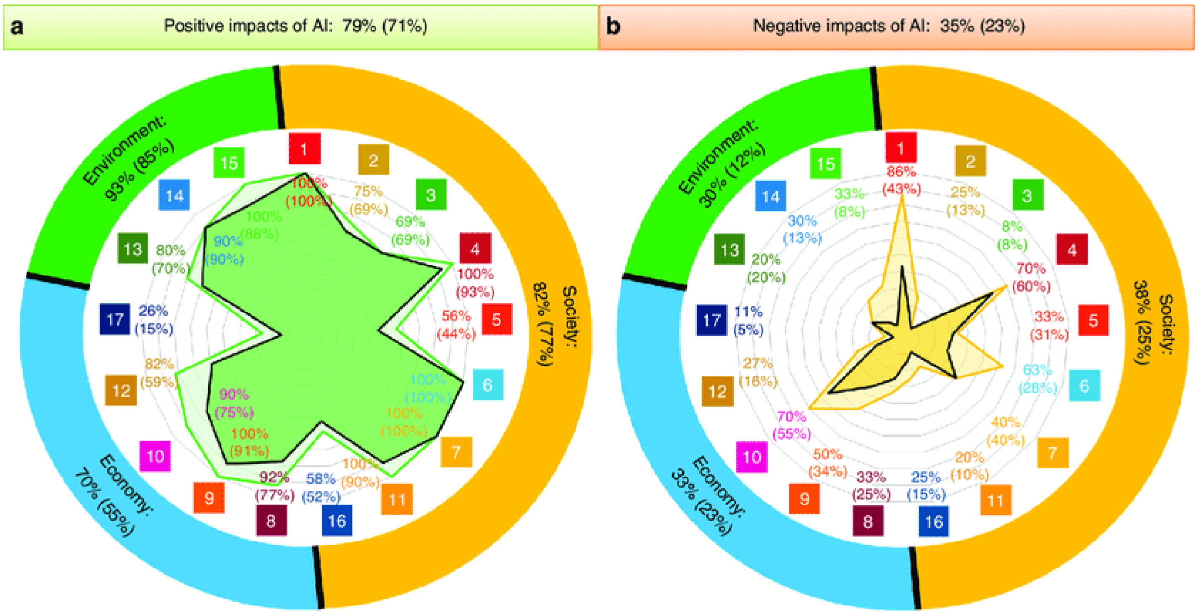

Figure 3 : Summary-of-positive-and-negative-impact-of-AI-on-the-various-SDGs (Vinuesa et al., 2020)

2.6 Roles of D&AI for SDG's

D&AI have emerged in a context where sustainable development is a priority for the entire international community. D&AI can support the achievement of the SDGs and have capacity for change (United Nations, 2021).

According to Thomas Osburg, digitalization is indeed changing the world of work and the ways in which we work together. The author claims that, digitalization has opened the door to; new forms of work organization; for low- and high-skilled tasks and problem-solving and interpersonal skills and new opportunities. Digitalization can generate unique opportunities that can strategically address the UN's sustainable development challenges and enable the development of countries that are pursuing the same development challenges (Mondejar et al., 2021). This perspective describes the opportunities that digitalization can offer to build a sustainable society and environment. The integration of new technologies in the specific sectors of water, energy and food is driving tool for change.

2.6.1 D&AI for Water

Climate change, population growth and increasing urbanization are major challenges of our era in the management of water resources. To meet these complex challenges, new systems are being developed that are increasingly integrated to enable informed decisions in an increasingly changing, complex and uncertain world. The water industry therefore relies on technology to meet the requirements in a dynamic environment (ICDL, 2019).

The introduction of digital technologies in the water sector has the potential to make management more significant. This potential offers solutions to a number of challenges and environmental externalities in the sector. In general, water digitalization through ICT tools plays an important role in improving water use efficiency in the agricultural sector, water supply and reducing vulnerabilities and has positive impacts on water and sanitation services as following figure.

Figure 4 : Summary of Digitalization Role sin Water Sector

According to The Digital Revolution and Sustainable Development: Opportunities and Challenges (2019) report, there is potential for video imaging and pattern recognition to be applied in real-time water quality monitoring and asset detection. Digital technologies are tools already used to distinguish between green, blue and grey water, and to understand the sources and types of water (Nakicenovic et al., 2019). Digitalization and information technologies are already playing, and in the future will play, a key role in enabling real-time information and early warning to reduce the impacts of water-related hazards in order to strengthen resilience and adaptation to climate change (Giordano et al., 2017). Digital technologies are therefore booming in risk analysis and disaster recovery. On the other hand, technologies are used for efficient irrigation systems that allow farmers to save water through remote management and optimize the amount and timing of water application, while minimizing energy consumption for pressure irrigation in rural and urban areas (Germer et al., 2011).

Moreover, it has been established that technologies are a promising field of mediation between water demands for energy production and agricultural productions. In order to avoid overconsumption, and to prove efficiency measures the specific use of block chain could address the problem of drought (Nakicenovic et al., 2019). These different technologies will be able to strengthen the participation of local communities in water management.

Although digitalization presents many opportunities and prospects, it is demonstrated that the challenges are still enormous as water management systems have not historically been designed on the basis of data science and intelligence techniques.

2.6.2 D&AI for Energy

Digitalization is an emerging trend that is reshaping the energy landscape and enabling progress toward continuous improvements in energy efficiency (Verma et al., 2020).

Digitalization has the potential to transform the energy system and facilitate integration between systems. It has the potential to enable integrated, dynamic, open, data-driven and optimized planning to provide universal access to energy at the lowest possible cost and time.

Specifically from The Digital Revolution and Sustainable Development: Opportunies and Challenges report (Nakicenovic et al., 2019) shows that digitalization offers a number of independent opportunities in four forms:

- an intelligent response to demand and increased system flexibility;
- greater integration of variable renewable energies;
- smart charging of electric vehicles for greater grid flexibility and

- better coordination of distributed energy resources. Digitalization therefore intervenes to predict, measure, monitor and improve.

With digitalization, traditional utility problems have relatively inexpensive fo next-generation solutions.

2.6.3 D&AI for Food

Feeding a growing population without harming the environment is one of the major challenges of the sustainable development agenda. Agricultural and food systems need to become more sustainable and efficient. Technologies are emerging as drivers for sustainable agriculture and food systems (Nakicenovic et al., 2019) and they has redefined agriculture over the years and technological advances have affected the agricultural industry in many ways. These technologies are ways for agriculturists and agribusinesses to increase production and reduce waste. The contribution of digital in agriculture is called "precision agriculture". It aims to accurately measure the needs of crops or livestock to be able to apply "the optimal quantities. Thanks the computer science development, accompanied by GPS and machine control interfaces.

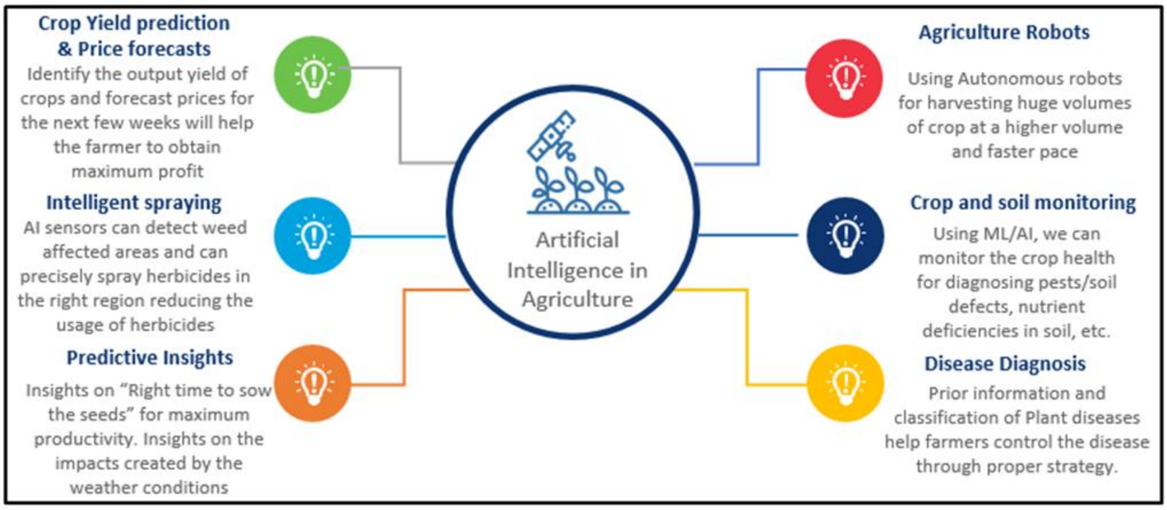

Figure 5 : Summary of Digitalization role in Agriculture sector (Nakicenovic et al., 2019)

However, the use of technologies for sustainable agriculture does not take into account all aspects. Scientists have therefore called these limitations "technological lock-in" (Reboud & Bohan, 2019).

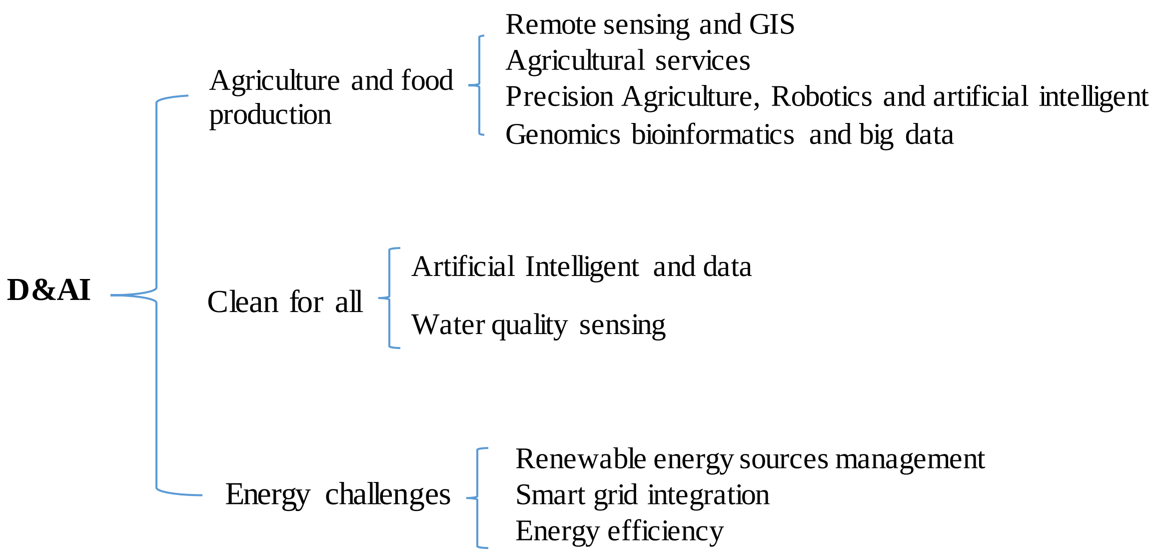

Figure 6 : Summary of the digitalization aspects related to each SDG's

Digital technology and AI has big potential to deliver the achievement of the SDGs to improve the need to accelerate the achieving the goals. This potential is not without negative aspects, which can be minimized through standard governance strategies.

2.6.4 D&AI in Africa

To achieve socio-economic development the Au founded the SMART Africa initiative in 2013 based on ICT. The objectives of this initiative were to harmonize policies and frameworks, generate greater demand for goods and expand markets, attract large-scale investment, create new industries and jobs in education, health, tourism, agriculture and trade (Friedrich-Ebert-Stiftung Rwanda, 2019). This first initiative has laid the groundwork for a clear view of the potential actions to be taken for the integration of digitalization in development as drivers.

The position of artificial intelligence and digitalization in Africa has highlighted the need for policy makers, innovators, researchers through academic institutions and even civil society to intensify their engagement in the field. Through policy strategies, AU member states have prioritized specific areas for digital transformation.

The strategy (Science, Technology and Innovation Strategy for Africa 2024) is firmly anchored on six priority areas that contribute to the achievement of the AU Vision. Eradication of Hunger and Achievement of Food Security; Disease Prevention and Control; Communication (physical and intellectual mobility); Protection of our space; Living Together, let's build society; and wealth creation are priority areas.

Through its mission which is to accelerate the transition towards a system based on innovation and knowledge Economy. Which is carried out by:

- improve ICT readiness in Africa in terms of infrastructure, professional and technical skills, and entrepreneurial capacity;
- the implementation of specific policies and programs in science, technology and innovation that address needs of society in a holistic and sustainable way.

However, Science, Technology and Innovation Strategy for Africa 2024 does not offer specificities. The strategy still at perspective level and does not make specific case of integrated management technologies according to the priority axes, but digital infrastructure is mentioned as tools.

The digital transformation strategy for AFRICA (2020-2030) which is recent document supports the 2020-2024 strategy. It built on fundamental pillars and based on the existing policies and regulations which are existing frameworks. It focus on industrialization. The document is based on the conceptual framework to shorten to practice. And takes into account Digitalization and artificial intelligence as technologies. Many countries have already outlined their digital agenda in their national development plans (Olumide, 2021). There are a very small number of countries that have not established digital strategies and policies. Some have specific documents that describe their program, others have strategy or policy documents that take into account digital strategies. These different strategic digital plans aim to increase the country's growth through digital technologies and encourage the adoption of artificial intelligence. So far in Africa, Egypt is the only country that has a national strategy on artificial intelligence.

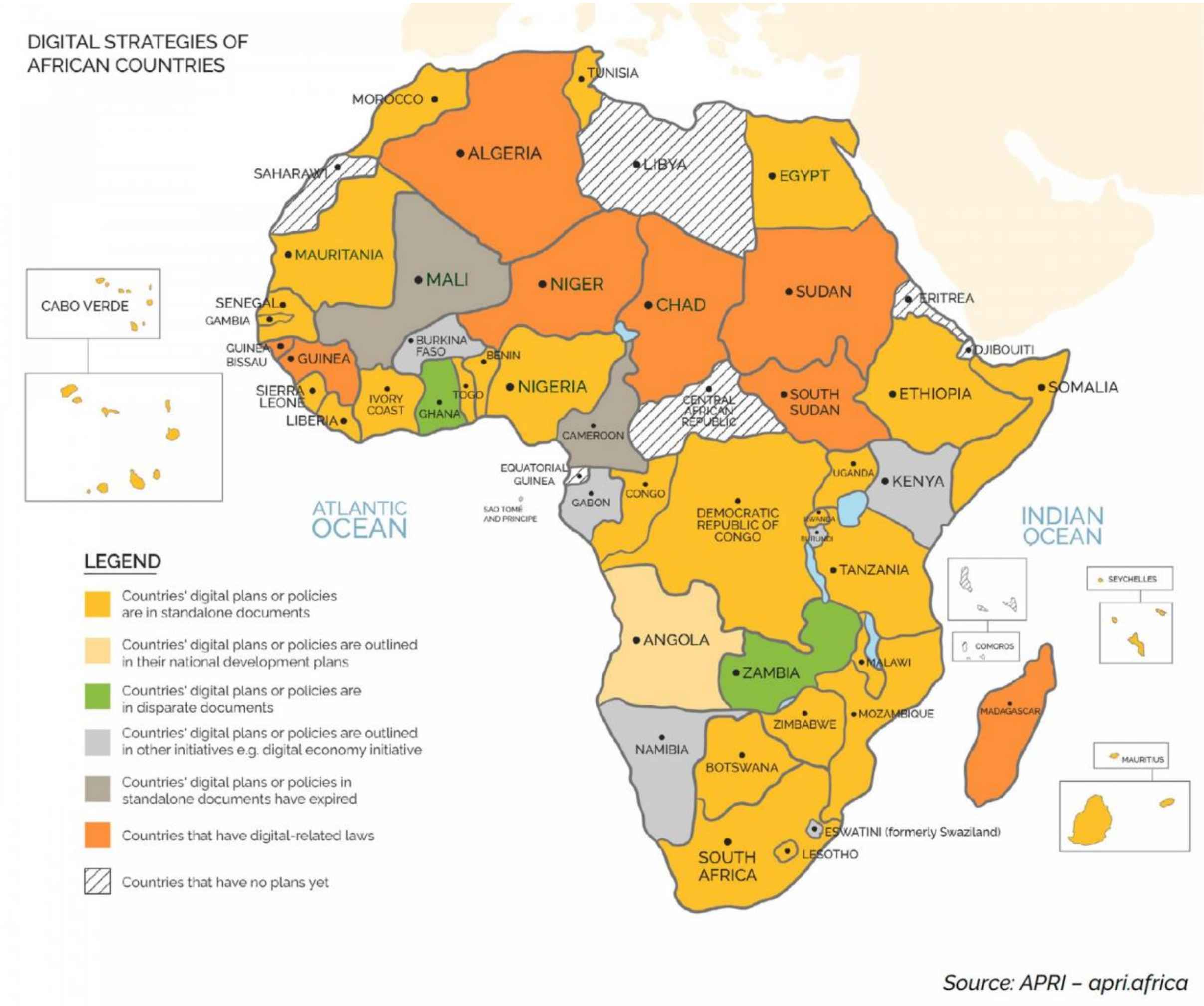

Figure 7 : Digital Strategies of African Countries (Olumide, 2021).

The Digital Transformation Strategy for Africa 2020-2030 has enabled member states to put the digital agenda at the heart of national policies and plans to address future development challenges. Most African countries therefore have digital strategies which are in some cases stand-alone strategies, in other cases the strategies are found in legal texts and in other cases in national development plans. These different digital strategies have several external and internal stakeholders for implementation with the European Union being the largest donor and has a large place for the development of the African regulatory framework for digital transformation, with China as the infrastructure provider.

The most important infrastructures are shown in the following figure.

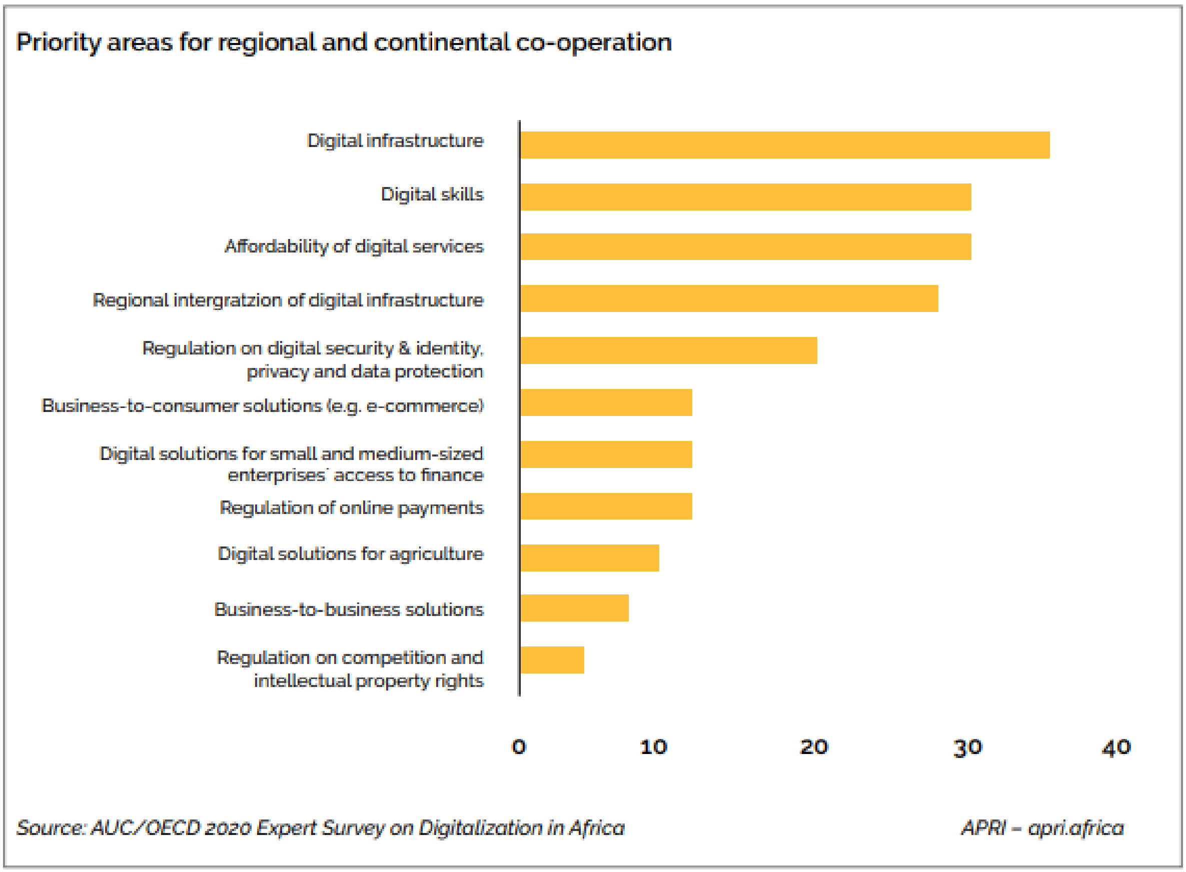

Figure 8 : Priority areas for regional and continental co-operation (Abimbola et al., 2021)

There is therefore a wide variation in the nature and scope of policy instruments used by African countries for governance through AI as following table.

Table 2 : Types of initiatives taken by a country for the governance of AI (Unesco, 2021).

Country Name	Strategies	Policies	Legislation	Ethical Guidelines	Centres of excellence on AI, start-up and incubation centres
Benin			✓		
Cabo Verde					✓
Cameroon	✓	✓	✓		
Congo	✓	✓	✓	✓	
Côte d'Ivoire					✓
Egypt	✓	✓	✓		✓
Equatorial Guinea		✓	✓		✓
Eswatini	✓	✓			✓
Gambia	✓				✓
Ghana	✓	✓			✓
Madagascar	✓				✓
Rwanda		✓			✓
Sao Tome and Principe	✓	✓		✓	
Senegal	✓	✓			✓
Sierra Leone	✓	✓			✓
Uganda	✓	✓			
Zambia	✓	✓			
Zimbabwe	✓	✓	✓	✓	✓

With policies and strategic documents most African countries recognized that digital transformation is an opportunity to stimulate economic and industrial growth that can reduce poverty and improve the living conditions of the people. It contributes to the full realization of the African Union's Agenda 2063, which is perfectly aligned with the objectives of Agenda 2023.

According to "The future is intelligent: Harnessing the potential of artificial intelligence in Africa" report, there are ten keys enabling technologies that are driving digital transformation, of which AI has many opportunities that will positively affect already struggling industries in Africa (Ndung'u & Signe, 2019). Specifically, AI for Africa is about specific areas as shown in the following figure

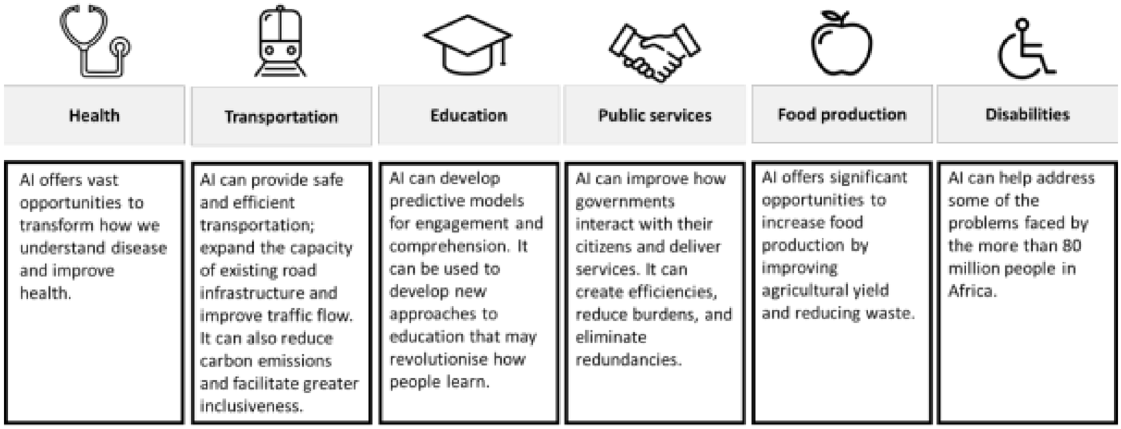

Figure 9 : Summary of the different potential areas that AI can drive (University of Pretoria, 2018)

AI solutions have shown success on a large scale in some African countries. Kenya, Nigeria, Ghana Ethiopia and South Africa. The solutions are based in healthcare, agriculture and financial services (Gadzala, 2018).

2.6.5 Digitalization and Artificial Intelligence Policy in Africa

It is clearly recognized that digital technologies will increase productivity and innovation and help countries across sub-Saharan Africa to achieve the SDG's - helping to improve outcomes from health care to agriculture to education.

However the policies and regulations on digital technology are very little developed, with respect to policies on Artificial Intelligence, currently, of the 46 states in Sub-Saharan Africa, only Kenya has an AI task force working on a national strategy (AI4D 2019). This shows the limitations in terms of strategy and regulation in the field in Africa.

Apart from the guidelines in the strategies of the different documents of the AU which urge the member countries to define their own policy, many of the reports define policy potentials that are still in the prospect stage, specifically these are:

- Working to develop a national strategy on AI and new technologies, developed through broad multisector consultation, such as through AI policy and related discussion forums.
- Develop public sector expertise in AI, with relevant ministries leading this effort.
- Establish and define codes of conduct for responsible use of data and algorithms by the public sector.
- Support AI to improve the delivery of public services and public goods, especially those targeted at marginalized groups.
- Ensure the creation of systems of transparency, responsibility, accountability, accountability and redress for decisions made on the basis of AI (Butcher et al., 2021).

2.7 D&AI for Food and Agriculture systems, Water and Energy

Digital technologies have characteristics that offer the possibility of creating new models of production and consumption.

2.7.1 Kenya Background

According to case study country, Kenya is a regional leader in innovation where the digital ecosystem is booming with its digital transformation strategy document "the Digital Economy Blueprint". The document is based on five pillars. The digital government pillar aims to use digital technologies to improve the relationship between the citizen-government relationships through public service. The digital business pillar is based on the consolidation of a strong increase in e-commerce activities with digital financial services and for growth and a reduction in operating costs of doing business. The pillar of entrepreneurship focused on innovation is based on funding for innovative research. The fifth and final pillar; digital skills and values is based on the acquisition of digital skills of citizens.

This document aims to foster a dynamic digital economy to help the country overcome development challenges.

The strategic level, the Kenyan government has developed a vast program of support that aims to prepare the various stakeholders to digital with different technologies priority (Figure) and introduced programs to address the digital revolution as a pillar of its development in its vision 2030 (Weiss, 2016). It is therefore one of the pioneers in digital advances in Africa (Nakicenovic et al., 2019). Kenya was the first African country to make available open data on education, energy, health, population, poverty, and water and sanitation, which were very difficult to access (University of Pretoria, 2018). It also come up with Digital Agriculture Profile recently with 113 institutions offer digital solutions for agriculture.

Through the master plan document DIGITAL ECONOMY BLUEPRINT based on the national priorities as articulated by Kenya Vision 2030 and the Big Four Agenda, Kenyan government aims to: Improved services to citizens, increased revenue and productivity to ensure that big data technologies improve agricultural, energy and water services in a more intelligent way.

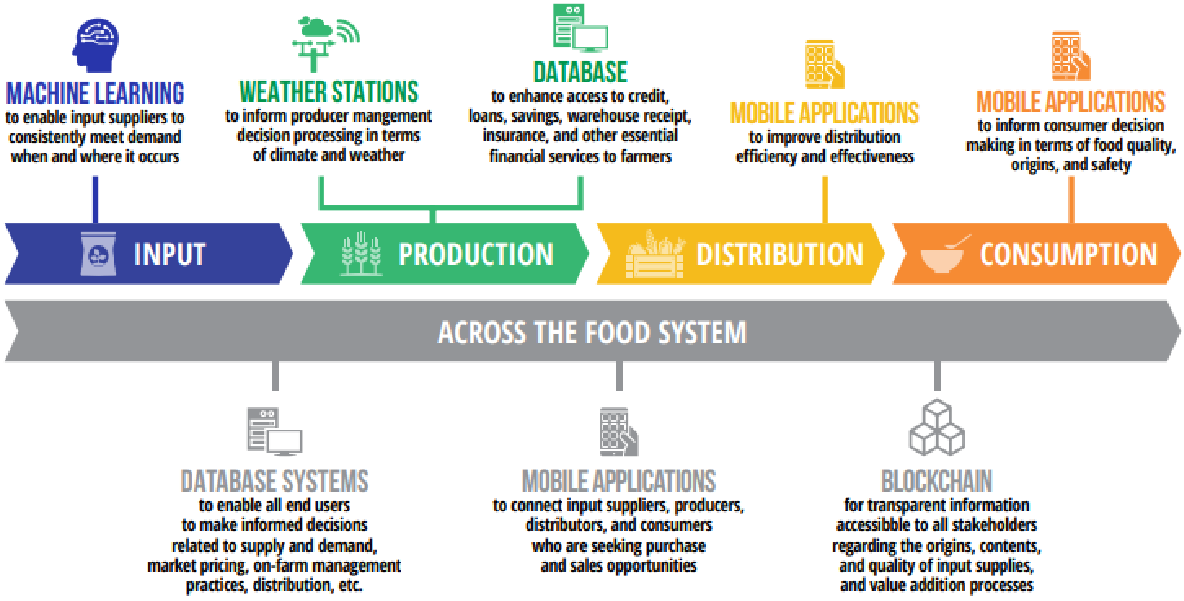

Figure 10 : Summary of the different priority agriculture tech solutions in Kenya (FAO and World BANK, 2021)

Digital agriculture is the integration of new technologies and advances to enable different stakeholders to improve their products and processes for efficiency. Digital infrastructure used different technologies for different applications as showing the following table.

Table 3 : Digital infrastructure and technologies applications in Agriculture and food systems

Technologies	Description	Applications
Mobile	Infrastructure, hardware, and software system that enables a portable device, usually a mobile phone, to send and receive messages, make and receive calls, and (in some cases) access the Internet. Smartphones have touchscreens, while feature phones do not	Information, knowledge sharing, and advisories on weather, extension, early warnings, pricing, market supply and demand, Financial services such as credit, loan, payment, and vouchers, Digital receipts, records, contracts, Market linkages e.g. input access, real-time communications between stakeholder hubs, equipment rentals, product monitoring and tracing
Broadband Internet	Internet infrastructure that is always on, and that delivers a minimum of 5 megabits per second (mbps) to homes and businesses for high speed access to voice, data, video and applications for development	Extension and information services, Digital records, Market linkages
Big data, data analytics, data	High-speed collection and processing of large quantities of interconnected	Weather forecasting, Crop forecasting, Supply and demand prediction, Precision agriculture,

management	(structured or unstructured) datasets from multiple sources and their presentation in a single interface to a user	Product traceability, quality control, Financial services, Data and information sharing, Digital records, Early warning systems
Artificial intelligence / machine learning	Computer systems able to perform tasks that normally require human intelligence, such as speech recognition, decision-making, and translation	Precision farming, Market information, Financial services e.g. determining credit scores, Extension services, Data and information sharing, Digital recordkeeping, Early warning systems
Internet of Things	Assembly of sensors, networks, and analytics communicating on the same platform and/or using the same protocols	Extension, Farm and soil evaluation, Smart greenhouses, Financial services, Data and information sharing, Digital recordkeeping, Early warning systems, Irrigation systems
Blockchain	An open, distributed ledger to record transactions between two parties efficiently and in a verifiable and permanent way	Product and supply monitoring and tracing, Quality control, Digital contracts and recordkeeping, Financial services e.g. credit, loans, advances on receivables, insurance
Drones	Small remote-controlled aircrafts with no human pilot on-board	Farm health evaluations, Tailored extension services
Weather stations	Permanently installed devices that detect weather metrics, e.g. precipitation, temperature, wind speed, humidity, and pressure	Weather forecasting, Early warning systems
Geographic Information Systems	Systems designed to capture, store, manipulate, analyse, manage, and present spatial or geographic data	Extension and advisories, Early warning systems, Financial products, Information sharing, Precision agriculture, Farm monitoring and evaluation

Digital technologies have unique characteristics that allow for energy transitions, leaving traditional systems for more sustainability (Nwaiwu, 2020.). In particular, several technologies such as smart grids, digital platforms and block chains have already shown their practical ability in the energy sector. In Kenya, digitalization is promoting access to clean and reliable energy by acting on electrification, planning and regulation. It is increasingly encouraging the involvement of various investors. The technologies with high impact and potential for digital applications in the energy sector that are attracting the attention of various stakeholders are summarized as follows (Models, 2019)

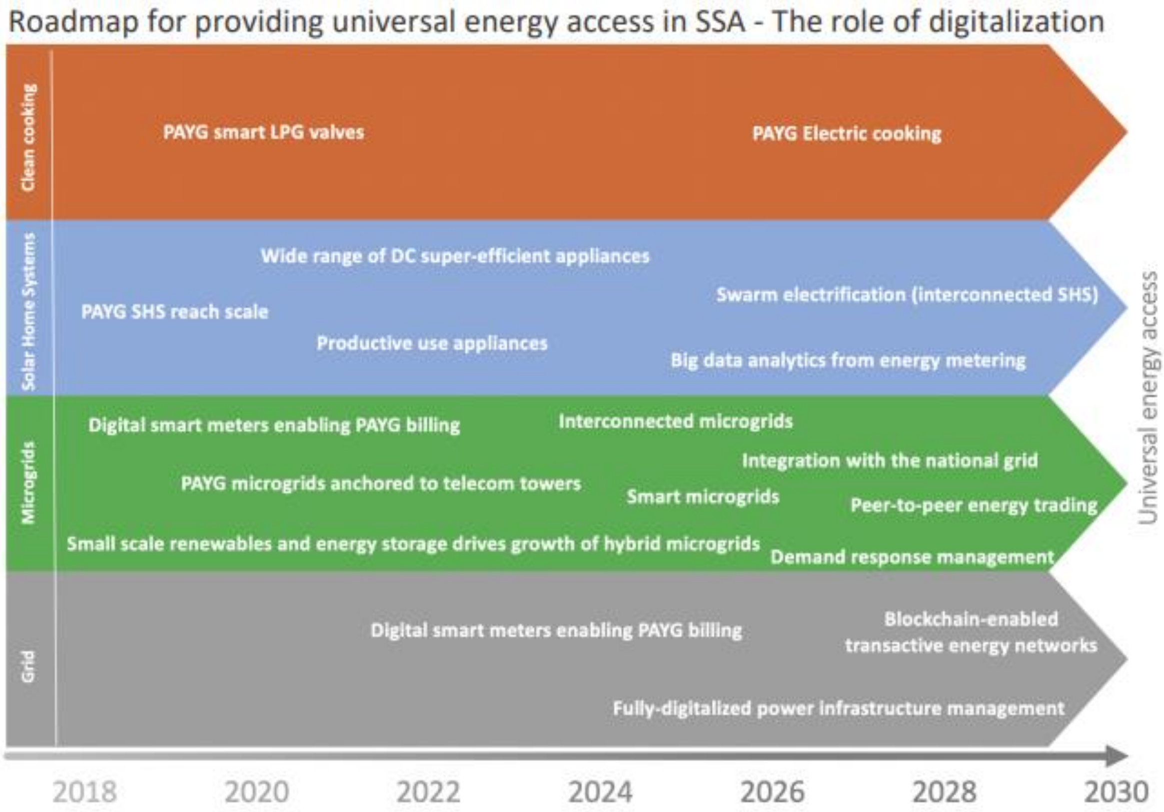

Figure 11: Roadmap for providing universal energy access in SSA (Models, 2019)

Digital technologies are improving the efficiency of water access in Kenya. The introduction of the use of digital technology to improve efficiency, reliability and access. Sensors have been installed on motorized wells to monitor pump run time and functionality as indicators of water use and mechanical efficiency. It also integrated drought resilience impact platform (DRIP), remote sensing data from the Famine Early Warning System (FEWS) network to plan targeted actions to prevent drought emergencies and mitigate famine in the region. The digital transformation in the sector enhances the reliability of water supply to communities and enables integrated management.

2.7.2 Benin Background

Innovation in Benin's technological environment is growing and involves many stakeholders of institutions especially in the environment, agriculture and health sectors. The policy context has facilitated the engagement of regulators, universities, government agencies in the development of ICT-based solutions and has opened up the voice of all stakeholders, start-ups, incubators, innovators, civil society and donor initiatives.

Many recent strategies propose perspectives for digital transformation. In the agricultural sector, the national strategy for e-agriculture aims to build a digitally transformed agricultural sector by 2025, adapted to climate change and that will ensure food and nutrition security but also economic and social development for all (MENC, 2020).

According to Global Information Society Watch report (2020), initially, technology made it easier to move from ploughing with a hoe to precision farming using drones or big data.

2.7.3 Algeria Background

Algeria the government is focusing on digitalization and the start-up industry. However in Algeria, partial implementation of new regulations adopted, existing laws and lack of accountability responsibility and clear vision hinder the development of the ecosystem. Algeria is therefore at the stage of preparation for the diffusion of its digital transformation strategy. With its ecosystem based on four key aspects:

- Users of digital services, which represent consumers;
- Producers who provide digital services
- Government interventions and laws governing digitalization which represent regulation and the physical networks which are the infrastructure. There is a big gap in the documentation according to the SDGs that this study is considering.

According to the latest global report on the digital economy (Network Readiness Index (NRI 2020)) considering future technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) to the role of digital transformation in the pursuit of the SDG's (SDGs) Algeria is ranked 107th in terms of Technology, People, Governance, and Impact (Dutta & Lanvin, 2020a). The greatest room for improvement is in governance and technology as following figure.

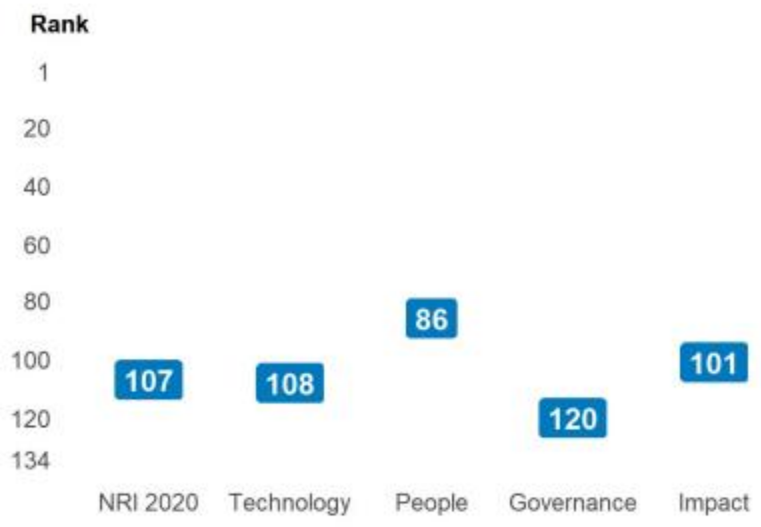

Figure 12: Algeria global ranking, overall and by pillar (Dutta & Lanvin, 2020b)

The technological capacities of the country are presented in the following table with the non-availability of some technologies.

Table 4 : The network readiness index (technology case) Source: (Dutta & Lanvin, 2020b)

Indicator	Rank	Scores
Technology Pillar	108	25.66
1st sub pillars: Access	93	43.71
1.1.3 Internet access	54	75.31
2nd sub pillar: Content	111	12.79
1.2.1 Github Commits	113	0.33
1.2.4 Mobile development	123	25.02
3rd sub pillar: Future technologies	96	20.48
1.3.1 Adoption of emerging technologies	65	47.15
1.3.3 ICT PCT patent applications	78	0.24
1.3.4 Computer software spending	122	0.63
1.3.5 Robot density	NA	NA

2.8 Gaps of the existing literature and added value of the present research

2.8.1 Huge gap between different SDG and D&AI

The use of the participatory research approach: Digitalization–Sustainability Matrix (DSM) on the use of D&AI for SDGs and their respective indicators has been conducted so far on SDGs 4 (Education) and 13 (Climate Action) and their respective indicators (Gupta et al., 2020). There is a lack of knowledge about the potential interrelationship between D&AI and the 17 SDGs. The present research is the first using the participatory research approach: DSM on the use of D&AI for SDG's 2, 6 and 7 and their respective indicator.

Chapter 3: METHODOLOGY

This Chapter provides the methods used to obtain the results required by the main objective of the study. Therefore, this Chapter begins by providing the approaches, the methodologies employed to generate the results to realise the formulated specific objectives. The Chapter ends by providing information on the case study and the data used.

3.1 Overall methodological approach

The study used a descriptive case study strategy to obtain qualitative evidence from multiple sources and gain theoretical propositions.

Preliminary requirement consists in detailed literature review using rapid review. Rapid review is a type of knowledge synthesis in which components of the systematic review process are simplified or omitted to produce information in a short period of time with systematic review procedures. This method employs systematic and repeatable technics to locate select and critically appraise a maximum relevant research. Internet sites and reference lists were consulted to identify articles, papers, books and reports, to collect and analyse data.

A rapid literature review method was employed to clarify and understand the different concepts as well as relative research on D&AI of SDG 6 along with synergy and tradeoffs with 2 and 7 in Africa and the link between sustainability goals, to provide the existing theory and to suggest guidelines for future research. Secondary data was used to establish the different interconnections between SDGs 2, 6 and 7 considering the indicators and targets with some expert view. Also secondary data was the basis for clarifying the interconnection and complementarity of Agenda 2030 and 2063 through the indicators of SDGs 2, 6 and 7 interconnected. Then, to understand and establish the interconnections between SDGs 2, 6; 7 and to see the similitudes pairwise comparison was used. Mind map support the pairwise comparison to show how SDG 6 through indicators is leading 2 and 7.

Through interview with different stakeholders the possible practices, challenges of D&AI to support the achievement of SDG's interconnected have been established. Also a participatory research approach through the Digitalization-Sustainability Matrix (DSM) help to present the necessary approaches for progress and the implementation of SDG 6 along with synergy and trade-offs with 2, 7 in Africa. Basically, qualitative method was used based on primary data related to the case study.

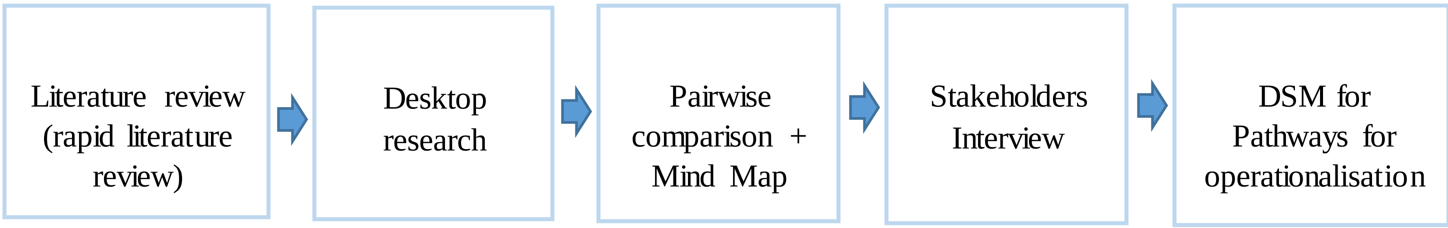

Figure 13 : Simplified schematic overview of the methodological approach

3.2 Methods for data collection: desktop research, interview, DSM

Four main methods were used in order to gather the specific data required for the study: the desktop research, the pairwise comparison, the interview and the DSM tool.

The desktop research based on extensive desktop research, consisted on gathering secondary data for the mapping of interconnecting indicators to show the link between SDG 2, 6 and 7 through the indicators (Agenda 2030) in terms of specific objectives 1. Pairwise comparison and mind map as tool was used to support the interconnection between indicators. A Pairwise Comparison belong to decision support tool base on multi-criteria analysis (MCA), it is a decision support tool developed to solve complex multi-criteria problems that include qualitative and / or quantitative aspects in a decision-making process (Mendoza et al., 2000). Pairwise Comparison is mostly used in scientific studies, it is a method of comparing items in pairs. Its purpose in this study is to organize the indicators in order to establish the relationships that exist between them. Each Indicator under a criterion, then, is compared with every other indicator under the criterion to assess its relative importance (Mendoza et al., 2000). The most important indicators of the study were established for each development objectives through the fundamental scale of values for pairwise comparison (Hussain et al., 2015) (Appendix 1, Table 16)

MCA procedure

- top-down approach (AHP) (Guarini et al., 2018)
- rating (attribution of score)
- classification (Regular and Ordinal)
- Analytical prioritization process: it allows the organization of important components of a problem in a hierarchical form, much like a family tree.
- pairwise comparison (Ordinal value measurement)

➢ **The top down approach AHP consist on:**

- define an objective;

- data collection;
- use of a scale from 1 to 9;
- create a decision matrix
- choose the corresponding AMC for the analysis
- calculation of relative weights
- calculation of the consistency index (CI)
- interpretation of results

With a frequency analysis in the Excel spreadsheet, the most cited indicators were identified. In order to prioritize these indicators, the participants assigned scores from 1 to 9, with 1 "Of equal importance" and 9 "Much more important" corresponding to the previously defined criteria that are the possible interaction between the indicators. The importance of each indicator is estimated through a pairwise comparison with the Analytic Hierarchy Process Survey package in the R software. Then the consistency index is calculated to measure the consistency of the experts' judgments.

It should be noted that after the preliminary results of the analysis, a correction of the participant's judgment was carried out following the Harker method with 10 iterations in order to satisfy the fundamental condition of coherence, which stipulates that the coherence index of each judgment must be less than 10% (Harker, 1987). In order to identify the main criteria that guided the selection of priority indicators, a Factorial Component Analysis (FCA) was conducted, preceded by a Chi-square test.

Mind map is a tool for made to outline the similarities and differences between different concepts were any idea can be connected to any other. It is aim to find creative associations between ideas. Mapping of the similitude between the 2063 and 2030 agendas, allowed to establish the different integrations between the W-E-F indicators and the 2063 agenda.

Then in order to meet the objectives 3 and 4, conducting an interview was the first main method used to gather the practical primary data necessary for the validation of the study. The task consisted in defining very well, first, the purpose of the interview, then identify the profile of a suitable interviewee specific stakeholders, designing a questionnaire and finally conduct the interview and analyse the result through content analysis and calculate frequencies in excel spreadsheet. The interview was conducted online with internal stakeholders (Appendix 1: Table 17)

Stakeholders have been identified according to whether they are the organizations that provide data regarding the implementation of the SDG's in the case studies.

The non-probability snowball approach to identifying respondents based on whether they are stakeholders. A stratified sampling procedure was applied to identify a certain respondent.

In each stratum, stakeholders were selected using a non-probabilistic snowball approach to identifying respondents, which consists of asking individuals in the initial sample to identify other stakeholders who are asked to identify them in turn. The second was a fixed size taking into account time, available resources, constituted from a sampling rate.

The DSM as a tool help in the systematic discussion and the transdisciplinary knowledge generated on several aspects. The DSM is a tool that serves as a means for collaborative methods, such as participatory action research (PAR), for the knowledge production process to use, to fill this gap and bring together.

It provides broader perspectives on the potentials and limitations of D&AI for SDG 2, 6 and 7 interconnected indicators.

The DSM with ordinal values helps in the systematic investigation of the potential gaps and opportunities that D&AI provides to monitor/support (directly or indirectly) the technological and social dimensions for each undertaken SDG indicator.

The DSM helps to identify the specific relevance of D&AI vis-à-vis the SDG indicators to identify the inadequacies and existing for a sustainable development (Gupta et al., 2020).

Table 5 : Overview methods on the specific objectives

Specific Objectives	Methods applied	Outcomes
SO1: Identify indicators of W-E-F SDGs for mapping the conceptual nexus between them	Pairwise comparison based on multi-criteria analysis (MCA) and mind map	- Interconnection between SDG's 2,6, 7 -Main interconnection indicators -Indicators interconnected
SO2: Measuring the affinity between identified indicators in SDGs and AU Agenda 2063	Mechanism of comparison based on content analysis	- Different forms of similitude - Connection at targets level in Agenda 2063
SO3: Determine the practices and possible challenges of using D&AI to support the achievement of SDGs 6 alongwith the synergies and trade-offs with 2 and 7.	Interview based on Participatory analysis tools (DSM)	Practices and Challenges in terms of digitalization for sustainable

SO4: Evaluate the approach needed with D&AI to foster synergies and promptly address potential trade-offs for achieving SDGs 6, considering synergies and trade-offs with 2 and 7	Interview protocol based on Participatory analysis tools (DSM)	Pathways for operationalisation

3.3 Rational for the case study

With the adoption of the new strategies, African countries have put the digital transformation at the centre. Some countries through the strategies are already ready to embrace the new technology in East Africa Kenya is one of those countries where the development of applications is high, and the government wanted to support the growth of the industry through digital technologies. In addition, Kenya was the first African country to launch an open data portal to make information on education, energy, health, population, poverty, water and sanitation accessible. Kenya is one of the best positive examples in terms of digitization and artificial intelligence. The proliferation of new technologies in Kenya is evident in the agricultural sector. Kenya has emerged as an African leader of Digitalization (Banga & Velde, 2018). In addition Kenya relies on technology for improving water service (Study, 2021).

On the Algerian side, New Government has put an emphasis on digitalization and startups with (Arabia & Initiative, 2020). In terms of digital technologies there is just an attempt to set up a National Strategic Plan for Artificial Intelligence 2020-2030. There are not many initiatives in the field of AI in Algeria (Mejri, 2020). It is therefore necessary through a mapping to see if even in the absence of strategies if the different technologies are used in a context where technologies are drivers of development.

At the same time, Benin's digital sector is dynamic, with an environment that includes a wide variety of start-ups. Benin's ICT sector strategy aims to make Benin West Africa's digital services hub for accelerated growth and social inclusion 2021. Although AI seems new and unclear to some people. Digital policy does not formally include AI as a sub-sector, and the concept is still not well known (Finlay 2019).

3.4 Case Study Background

The study considers three countries, Kenya, Algeria and Benin, which are located in Eastern, Northern and Western Africa respectively.

Kenya, officially the Republic of Kenya is a country with the capital Nairobi. Kenya has an area of 580,367 square kilometres. It is bordered by South Soudan in the northwest, Ethiopia to the north, Somalia to the east, Uganda to the west, Tanzania to the south and the Indian

Ocean to the southeast. Kenya's population was estimated at 53,771,300 in 2020. Despite the significant political, structural and economic reforms that have led to sustained economic growth and social development, Kenya still faces the challenges of poverty, inequality, climate change, low private sector investments and the economy's vulnerability to internal and external shocks. Kenya's GDP amounts at 98,842,939.65 US dollars in 2020.

With its economic growth of 5.7% in 2019, Kenya is one of the fastest growing economies in Sub-Saharan Africa (World Bank, 2020). As of 2020, Kenya is the third largest economy in Sub-Saharan Africa after Nigeria and South Africa.

Algeria, officially the People's Democratic Republic of Algeria, is a country in the Maghreb region of North Africa. It is the largest country in Africa by total area, and by extension is bordered to the northeast by Tunisia, to the east by Libya, to the southeast by Niger, to the southwest by Mali, Mauritania and the Western Sahara, to the west by Morocco and to the north by the Mediterranean Sea. Algeria covers an area of 2,381,741 square kilometers (919,595 square miles), making it the tenth largest nation in the world and the largest nation in Africa by area. With a population of 43,851,043, Algeria is the ninth most populous country in Africa. Algeria's GDP in 2020 is US$43,851,043. As of 2020, it has the fourth-largest economy on the continent, based largely on energy exports, with sixteenth-largest oil reserves and the ninth-largest reserves of natural gas. With an economic growth rate of 20.399, the country is facing many climate change issues that have a significant impact on the country.

Because a large part of the country is in already hot and arid geographies, including part of the Sahara, already strong heat and water resource access are principals challenges expected to get worse.

The Republic of Benin is bordered by Togo to the west, Nigeria to the east, Burkina Faso to the northwest and Niger to the northeast. Benin covers an area of 114,763 square kilometers and its population in 2020 was estimated at approximately 12123198. Benin is a tropical nation, heavily dependent on agriculture. A significant portion of employment and income is derived from subsistence agriculture. The country has an estimated GDP of 15,651,545.21.

Chapter 4: RESULTS AND DISCUSSION

4.1 Mapping of interconnected indicators of SDG's 2, 6 and 7 and different interactions

The SDG's are known to guide the world towards achieving common actions for sustainable development. Thus, a number of goals are developed and used to implement the different strategies of the SDG's, indicators are defined to measure the levels of complex and multidimensional sustainable development across the strategies for the achievement of the goals and finally the targets specify the SDG's.

Globally the Sustainable development goals have a lot of interconnection. The indicators, gives a clear view on the interactions and interconnections of the SDGs at the concrete level with clear political implications.

4.1.1 Interaction for considering SDG's at indicator level

Indicators for SDGs 2 (Eradicate hunger, achieve food security and improved nutrition and promote sustainable agriculture), 6 (Ensure availability and sustainable management of water and sanitation for all) and 7 (Ensure access to affordable, reliable, sustainable and modern energy for all) were considered. The results were used to select 12 indicators (Table 6) based on their high scores. Based on the existing literature, one indicator was selected even though its score was lower than another.

In order to put the proposed method into practice, the indicators presented in Table 6 in will be considered. The indicators refer to table are interrelated and linked to the 2030 Agenda objectives on water, energy and food according to the method used. This study just establishes potential interconnections that exist between the indicators and does not propose a new qualitative method to map the linkages.

Table 6 : Iinterconnected indicators

SDG number	SDG Term	Indicators number	Indicators
2	Food/ Agriculture	2.1.1	Prevalence of undernourishment
		2.3.1	Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size
		2.4.1	Proportion of agricultural area under productive and sustainable agriculture
6	Water	6.1.1	Proportion of population using safely managed drinking water services
		6.2.1	Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water
		6.3.1	Proportion of wastewater safely treated
		6.4.1	Change in water-use efficiency over time
		6.4.2	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
		6.6.1	Change in the extent of water-related ecosystems over time
7	Energy	7.1.1	Proportion of population with access to electricity
		7.2.1	Renewable energy share in the total final energy consumption
		7.3.1	Energy intensity measured in terms of primary energy and GDP

4.2 Different type of interlinkage at indicators level

Currently literature specifies the types of linkages that exist between the different SDG's at target level. On this basis, the direct and indirect supportive linkages, directs and indirect conflicting linkages were defined between the SDG's indicators using a simple correspondence.

4.2.1 Directs and indirect supportive linkage

In terms of direct supportive link, some indicators of the same objective may have direct supportive links, namely indicator 2.3.1 (Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size) is directly supportive to indicator 2.4.1(Proportion of agricultural area under productive and sustainable agriculture) which is directly supportive indicator 2.1.1 (Prevalence of undernourishment by ending hunger and ensure access by all people).

Apart from the direct supporting relationship within indicators of the same objective, the results show that there are indicators of different objectives that directly support each other. In particular, 2.1.1, 2.3.1, and 2.4.1 have direct supporting links to indicator 7.2.1 (Renewable energy share in the total final energy consumption), which in turn supports directly 2.1.1 and 7.1.1 (Proportion of population with access to electricity). In addition, there are several supportive indirect links as following. Firstly, indirect links between indicator 2.3.1 and indicator 2.1.1 are supported by indicators 2.4.1 and 7.2.1. Therefore, Indicator 2.3.1 indirectly supports Indicator 2.1.1 via Indicator 2.4.1. Similarly, indicator 2.3 indirectly supports indicator 2.1 via indicator 7.2.1.

Secondly, within SDG 6, through indicator 6.2.1(Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water) and 6.4.1(Change in water-use efficiency over time) and 6.4.2 (Level of water stress: freshwater withdrawal as a proportion of available freshwater resources). Indicators 6.1.1 (Proportion of population using safely managed drinking water services) and 6.2.1 through 7.2.1 there is an indirect supporting link. There is an indirect supporting link between indicator 6.1.1 and 7.2.1 through indicators 6.2.1 and 6.4.1.

4.2.2 Direct and indirect conflicting linkage

Conflicting links can occur between different indicators because of their interconnectedness. Between indicators 2.3.1 and 6.1.1; 6.1.1 and indicator 7.2.1, there is a direct conflictual relationship because intensive agriculture requires in some cases intensive access to water resources that could represent a barrier to access to drinking water. At the same time, indicators 6.1.1 and 7.2.1 have direct conflicting relationship; the increased use of non-conventional water supply options through desalination processes to cover the growing demand for fresh water could limit the deployment of renewable energy due to high energy consumption. So on the other hand there is an indirect conflicting link between target 2.3 and target 7.2.

These different types of linkages show that the approach of integrating SDGs may be more positive than negative. Although there are many types of links, the different analyses support the idea that there is a predominance of positive interactions over negative interaction. Also in the report A GUIDE TO SDG INTERACTIONS: FROM SCIENCE TO IMPLEMENTATION, the evaluation specifically identified 316 interactions between targets, of which 238 are positive, 66 are negative, and 12 are neutral (International Council for Science 2017).

These different aspects could serve as gas pedals (synergy aspects) on the one hand and controls (trade-offs) on the other hand to achieve the SDGs on the basis of the interdependencies that exist between them.

The various interconnections obtained by correspondence were established mainly thanks to the results of Karnib (Karnib, 2017b) which based on a qualitative study to map direct and indirect linkage across the SDG's 2, 6 and 7 which fall in Water, Energy and Food Nexus perspectives. This study concluded that there are linkages between targets 2.1, 2.3, 2.4, 6.1, 6.2, 6.3, 6.4, 6.6, 7.1, 7.2, and 7.3 of SDGs 2, 6, and 7 respectively. These are clearly established through direct and indirect positive linkages, direct and indirect conflicting linkages, and even the absence of linkages that allow for trade-offs and synergies through the SDG integration approach. Earlier, the same author based his analysis of the linkages between the SDGs on a bottom-up process that relied on a quantitative nexus theory method to assess the direct and indirect quantitative interactions between the SDG variables. This approach allowed him to show the direct and indirect links between the SDGs, but could not specify in terms of indicators. The method was limited to providing information on the synergies and trade-offs of the SDGs in general as well as the consequences that could affect the achievement of the SDGs according to the integration approaches (Karnib, 2017a).

Moreover, the UN Interaction Report (International Council for Science 2017) clearly shows that there are different interactions between the SDGs, in the report SDG 2 and 7 are part of the privileged SDG's. The different interactions are classified into two categories: positive and negative interactions and defined as the keys of realizing the full potential of the SDGs at all levels (Figure14 and 15). Through a framework of scores previously defined the report shows the different types of interaction that exist.

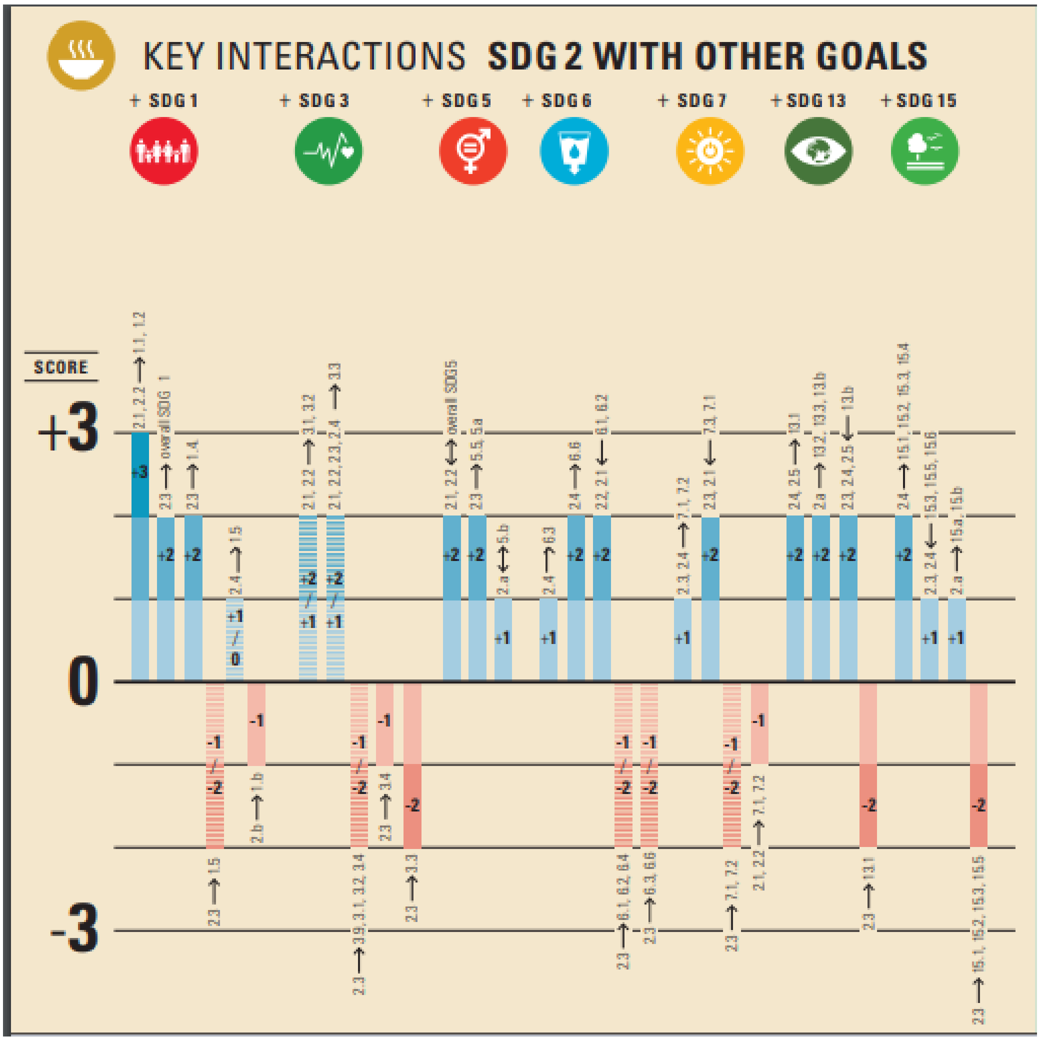

Figure 14 : Key interactions of SDG 2 with other (International Council for Science 2017)

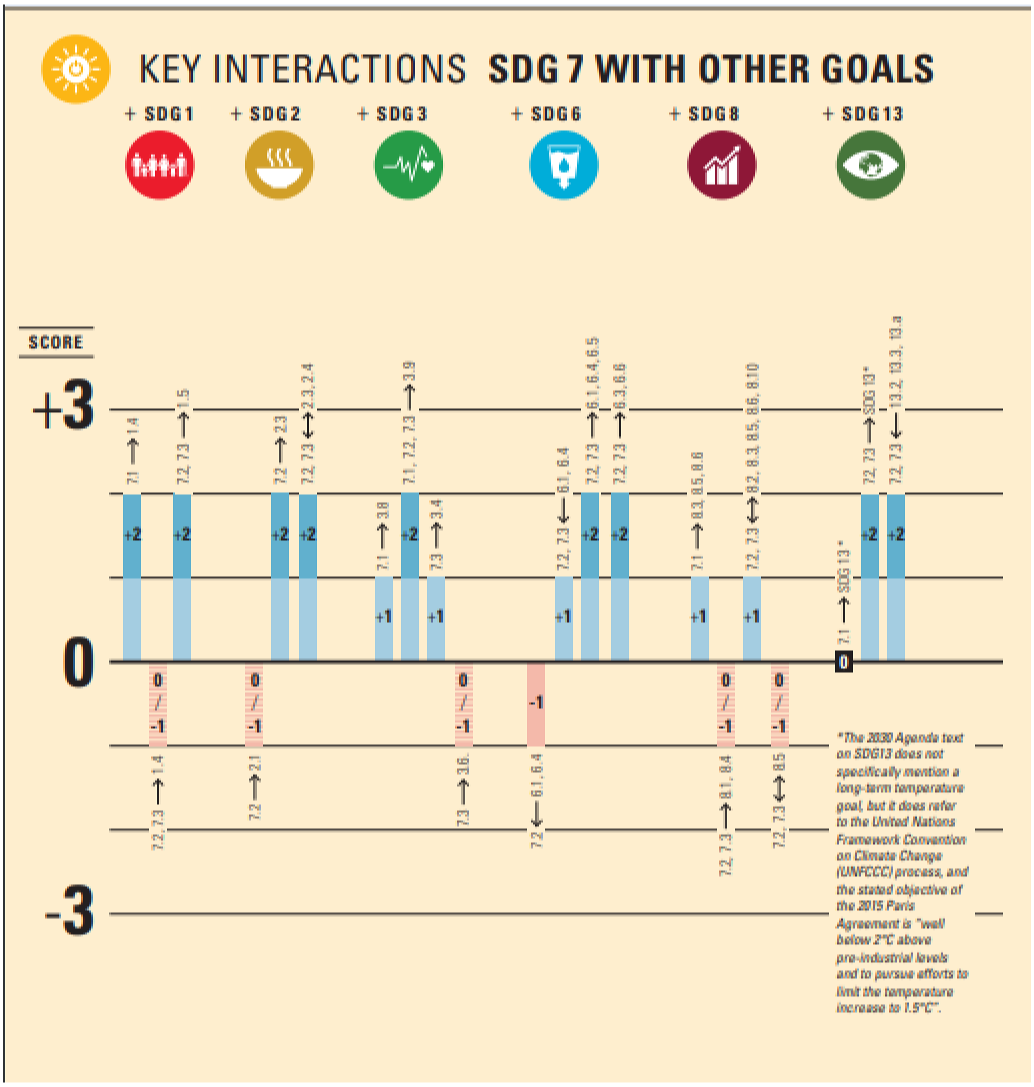

Figure 15 : Key interactions of SDG 7 with other (International Council for Science 2017)

Through the various scores the results that can be read on the figures, show types of interactions similar to those found through the correspondence between the interconnected targets found in the literature to the indicators of our results. One key interaction is energy for agricultural production, which facilitates groundwater pumping and mechanization of agricultural equipment to increase food crop yields, a positive energy supply action (International Council for Science 2017). Also increasing water variability adds uncertainty to agricultural production (International Council for Science 2017).

4.2.3 Interlinkages between the indicator of SDG, 2 and 7

The results show that SDG 6 accounts for 50% of the total number of interconnected indicators. This result allows to assert that SDG 6 could lead SDGs 2 and 7 when based on the indicators.

On the basis of the interconnections established between SDG 6 and the others, the matching approach was used to establish a mind map between the indicators of SDG 6, 2 and 7

4.2.3.1 Map of the interlinkages between SDG 6 and other 2, 7

The mind map describes the synergies, trade-off and potentially reinforcing relationships that exist between the indicators, considering the integration approach between SDG 6 and 2 and 7 as following figure.

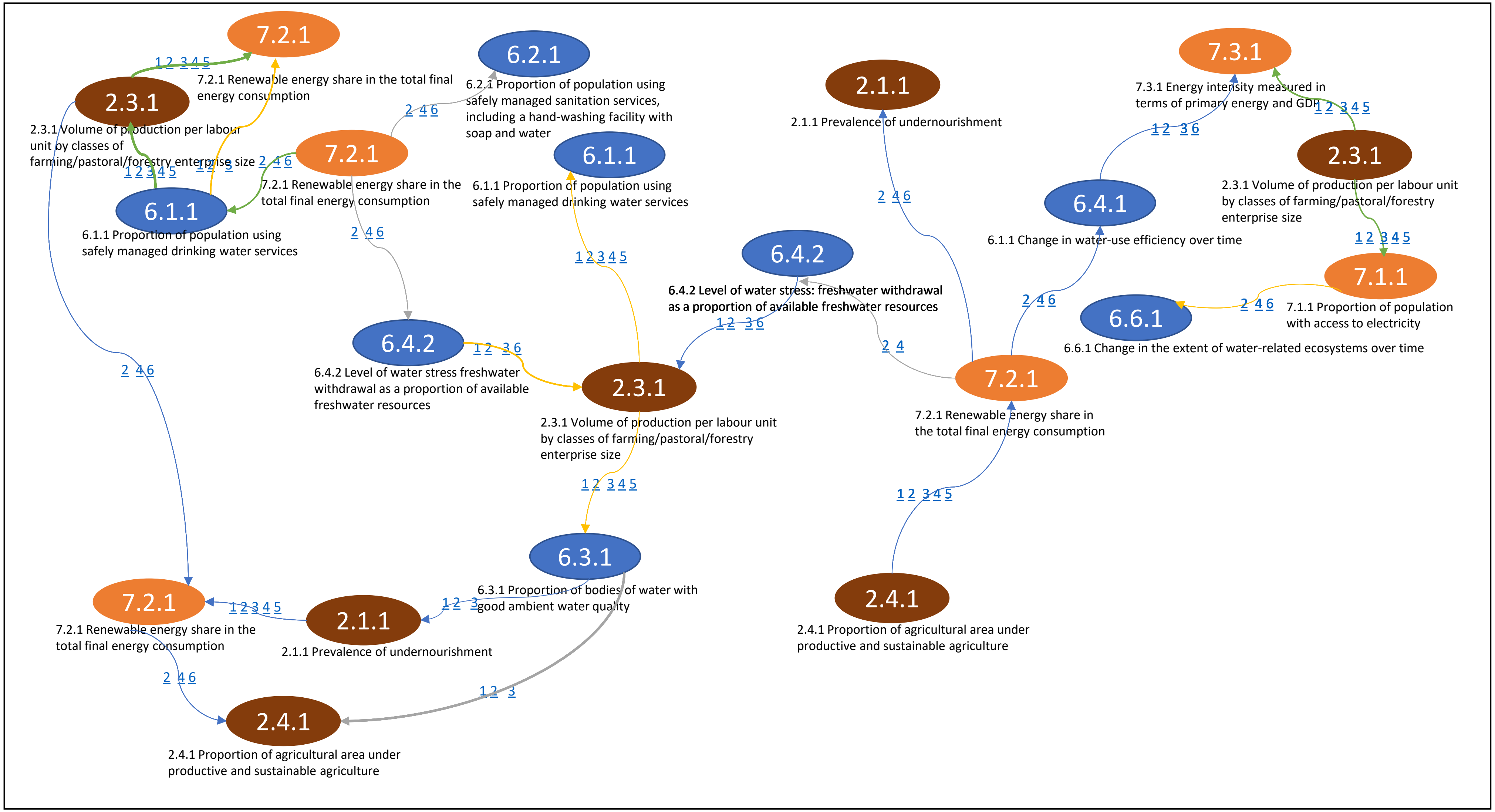

Figure 16 : SDG6 interconnected with 2 and 7 mind map

Efficiency water , Safe and affordable water access Safe sanitation and Water quality and water-related ecosystems support directly or indirectly, End hunger, Agriculture productivity and Sustainable agriculture, with regard to indicators; Access to energy, Renewable energy and Energy efficiency.

The links between the SDG's at indicators level related to access to water and the provision of clean water (6.1.1, 6.2.1, 6.3.1, 6.4.1, 6.4.2) as well as the appropriate management of water (wastewater) to the indicators of SDG 2 show how often the indicators of SDG 6 have an important influence through the multiple relationships that it can have with SDG 2. Also SDG 6 through its indicators is distinguished by its interconnection with SDG 7 through mainly, indicators 7.1.1 and 7.2.1 where water can be used in energy production and moreover used in agriculture to increase agricultural production (2.3.1, 2.4.1) to cover food needs. This result allows to conclude that SDG 6, through its indicators listed above, has an influence on energy access in general, particularly renewable energy and sustainable agriculture in terms of volume of production and produced proportions.

The Food-Energy-Water link, through the indicators, gives then a clear view on the interactions and interconnections of the SDGs at the concrete level with clear implications. From an operational point of view, the indicators aiming to structure the components of the nexus, focus on the proportion of availability, the accessibility, efficiency and sustainability of resources.

Based on the targets, the map of the interlinkages between SDG 6 and the other SDGs concludes the same results while specifying that the use of wastewater for energy generation and food production in peri-urban areas (UNESCAP, 2018).

This analysis of the results is supported by the SDG interactions: from science to implementation (International Council for Science 2017) report's conclusions, which indicate that the protection and restoration of water-related ecosystems, including aquifers, influence conventional agricultural production systems. In another sense, in the same report, access to safe drinking water and adequate and equitable sanitation is affected by increased agricultural productivity.

In addition, access to safe and affordable drinking water for all is essential to prevent undernourishment. Also the findings of the same report state that the world's energy systems require a large amount of water. However, on the other hand, the production of renewable electricity, specifically solar photovoltaic and wind power, has a lower impact on water resources (Davies et al., 2013).

The SDG indicators have many links that can be mapped. These links are presented as opportunities for full realization and also links of rivalry. The aspects of opportunity in the Water-Energy and Food integration approach through indicators could represent potential solutions to trade-offs, key dimensions of effective integrated management, particularly governance and technology are essential.

4.3 Affinity between the indicators identified in the SDGs in the African Union's 2063

Through a mapping exercise, interactions of SDGs 2, 6, and 7 were established on the target scale. The interaction consider the degree of similarity between the two Agendas by indicating whether they linked and depend, if targets or indicators have the same focus.

This exercise resulted in a list of 10 Agenda 2063 targets based on the SDG indicators considered in this study as following table.

Table 7 : List of target interconnected in Agenda 2063 based on SDG's consider

Number of targets	Targets
4 (1.1.2.4.1)	Reduce 2013 levels of proportion of the population who suffer from hunger by at least 80%
9 (1.5.1.9.1)	End Hunger in Africa
2 (1.5.1.2.1)	Double agricultural total factor productivity
1 (1.7.1.1.1	At least 30% of agricultural land is placed under sustainable land management practice
3 (1.1.4.3.1)	Reduce 2013 level of proportion of the population without access to safe drinking water by 95%
4 (1.1.4.4.1)	Reduce 2013 level of proportion of the population with poor sanitation facilities by 95% (Change the phrasing of the target).
4 (1.7.2.4.1)	At least 10% of waste water is recycled for agricultural and industrial use
2 (1.7.2.2.1)	Increase 2013 levels of water productivity from rain-fed agriculture and irrigation by 60%
3 (1.7.2.3.1)	At least 10% of rain water is harvested for productive use
4 (1.7.3.4.1)	Reduce proportion of fossil fuel in total energy production by at least 20%

The 2030 and 2063 Agendas converge on sustainable development. The SDG's call for a substantial increase, while Agenda 2063 specifically defines this increase, in access to energy and water and investment in agriculture.

Agenda 2063 is much more specific about the goals to be achieved. Water safety is an example. Agenda 2063 is therefore in a contextual dynamic with the SDGs and their targets themselves being aligned with the priorities of Africa as a whole.

Agenda 2063 could represent a strategic framework that builds on the African context with more precision in defining indicators and also its targets. The two agendas have different monitoring and reporting mechanisms, so harmonizing them should be the first task to measure progress (UN 2017). The two agendas are not identical but are linked at of targets and indicators level. This interaction highlights the potential for synergies and trade-offs within and between the two agendas.

4.4 Policy implication for interactions

The indicators considered have multiple linkages that may be reinforcing or constraining.

These linkages provide challenges and potential opportunities for implementation. Through implementation, policies play a critical role with appropriate and coordinated strategies and institutions that can enable value-added and development in complex situations.

In the context of interactions designing policies to avoid competition is an option.

4.4.1 Water + Food interaction policy implication at indicators level

Table 8 : Water + Food policy implication

Indicators interconnected	Policy implication
6..3.1; 6.6.1 ⟶ 2.3.1; 2.4.1, 2.4.2 **6.1.1; 6.2.1 ⟶ 2.1.1**	Restoration of water related ecosystems trough sustainable agricultural technologies promotion
6.1.1; 6.2.1; 6.4.1; 6.4.2 ⟶ 2.3.1	Promote sustainable agricultural technologies and research/ technology activities, such as breeding of drought tolerant crops, or use of advanced irrigation technologies to reduce water use in agriculture; develop guidelines for sustainable agricultural water use
6.3.1 ; 6.6.1 ⟶ 2.3	Strengthen institutional capacity, and coordination between coordination among public services to design water resources policies and regulatory practices to address water scarcity

4.4.2 Water + Energy interaction policy implication at indicators level

Table 9 : Water + Energy policy implication

Indicators interconnected	Policy implication
6.6.1; 6.4.1; 6.4.2⟶ 7.2.1	Ensure that non-conventional water supply options do not generate excessive loads
6.1.1; 6.4.1;6.4.2⟶ 7.2.1; 7.3.1	Better integrate water and energy to realize the benefits
6.1.1; 6.4.1; 6.4.2⟶ 7.2.1; 7.3.1	Ensure that water resource management and energy policies plans for renewable energy options
6.3.1 ; 6.6.1⟶ 7.2.1 ; 7.3.1	Align energy and water management policies so that negative effects on ecosystems are minimized.

4.4.3 Energy + Food interaction policy implication at indicators level

Table 10 : Energy + Food policy implication

Indicators interconnected	Policy implication
7.3.1;7.1.1 ⟶ 2.1.1; 2.3.1	Defining policies for energy production from agricultural waste
7.2.1;7.3.1⟷ 2.3.1; 2.4.1; 2.4.2	Establish mechanisms to manage energy and water in agriculture
7.2.1⟶ 2.3.1	Policies to promote agricultural waste to energy projects
7.1.1 ; 7.2.1⟶ 2.1.1 ; 2.3.1	Promote the local production of renewable energy that can have an impact on agricultural land (in terms of area and volume)

There are many links between the SDG indicators that can be mapped. These linkages come in the form of opportunities for full achievement, but also rivalry linkages. The opportunity aspects of approaching Water, Energy and Food integration through indicators could represent potential solutions to inhibit rivalries.

Eradicating hunger, achieving sustainable food security, providing access to clean and sanitation water, and affordable and clean energy are fundamental requirements for maintaining and accelerating development. This requires the mobilization of adequate resources, particularly innovation and technology development to mitigate the trade-offs, policies, supportive investments, innovation and technology development are needed to mitigate the trade-offs.

In practice, the integrated approach of the W-E-F at indicators level has allowed the identification of potential trade-offs, and has allowed the identification of interconnected indicators that positively benefit multiple SDGs to better link the SDGs for implementation.

4.5 DIGITALIZATION AND ARTIFICIAL INTELLIGENT FOR SDG'S

4.5.1 Practices and possible challenges of using digitalization and artificial intelligence to support the achievement of SDGs 6 alongwith the synergies and tradeoffs with 2 and 7

From outcomes, the different technologies are used in diversified sectors and brings new ways of doing things and new experiences in Benin, Algeria and Kenya. Technologies such as Geographic Information System (GIS), remote sensing, resource information system (GHRIS), robotics, Big Data, Supervisory Control and Data Acquisition, mobile internet and drones are the most mentioned.

Many technologies are mentioned but at the state of perspective in particular in the field of sustainable agriculture for food systems. The block chain for agriculture, ICT for small scale irrigation for efficiency and monitoring of water use in agriculture, flying sensors to reduce water consumption in agriculture and Early Warning Systems integrating indigenous and scientific drought forecasts.

In addition, the IoT is listed as a technology with great potential in areas such as energy, water, agriculture, and transportation, but it is a technology with little potential to improve productivity and process efficiency. So most of technologies in digitalization are used and those of the artificial intelligence are much more in perspective.

Of our results, water production systems, distribution systems and in the control of water treatment systems for drinking water and purified water that will later be used in agriculture. Also these different technologies are used in the control of the sewage network.

The monitoring tools are used to control the production and distribution of water, which will help to make the access to water equitable as the distribution is made on the basis of demand with accurate data bases. This form of management helps conserve water resources by minimizing losses and positively impacting the sustainability of the resource.

Thanks to the different alarm systems, to the movement detectors in the lifting stations, there are alerts to possible risks. This function allows to anticipate possible damages and to implement solutions to these damages. The alert systems are made possible by automation and telecommunication which take into account the mobile internet. There is also the development of reasoning models with user interactivity that are widely used in real-time prediction in all water production, distribution operations and waste water management. A simple example is where these models can help control flows. Data-driven performance analyses of wastewater treatment plants (WWTPs) (Newhart et al., 2019), reported that there are data-driven technologies used in WWTPs for the purpose of fault detection, variable prediction, and automation.

The reasoning models are also used to inform on the amount of energy needed. This feature could have a positive impact on energy efficiency. These different tools are used to ensure water production in terms of quality and quantity and also prevent system failures.

In sum, the different tools evaluated in water management intervene in the supervision, control, distribution, production and allows to plan the management. The different technologies can be considered as tools for decision making in water management planning.

The existing literature provides more precision and a clear categorization of water technology. (Newhart et al., 2019)Digital technologies are present in WWTPs, drinking water treatment plants (DWTPs) and desalination plants, with complex systems using instrumentation, control and automation techniques (Asadi et al., 2017).

Currently GIS-remote sensing applications are central to agriculture for sustainable food systems. According to our results GIS is a main technology used in agriculture and in the form of precision agriculture, and in drone technology. One example of drones is its ability to collect real-time data from the earth's surface to assess and estimate crop productivity. Drones can be used by farmers to make instant, actionable decisions in real time. The agricultural industry has been transformed by geospatial technology (GIS) that allows crop monitoring and positively impacts food production (Bill et al., 2012). For correlation between different parameters (agricultural practices and yields), for the creation of digital elevation models, for the design of irrigation plans, and for crop monitoring, drones are the appropriate technology. At perspective level the integration of intelligent GIS-based technology promises better agricultural systems with increased resilience plus mitigation to climate change (Mondejar et al., 2021).

ICT are central elements of agriculture and represent one of the main functions for sustainable agriculture. The effective use of mobile application software by actors in the agricultural sector contributes to increased production and has positive impacts on agricultural systems particularly in climate change context. Specifically, the use of mobile applications by different actors, (professionals of agriculture), science and technology allows access to information related to o climate-smart agricultural practices (Mondejar et al., 2021).

In the energy sector, digital technologies are involved in renewable energy, smart grid integration and energy efficiency. Digital technology represents the basis for the energy transition a policy that is taking root in Africa to renewable energy, with emerging technologies. In particular, the GSM connectivity, software platforms and mobile technology platform combines an integrated global system for mobile communications, also using smart meters and mobile payment methods. GIS is helping to detect remotely potential geographic spaces to implant solar panels.

The various technologies listed above are making their way into the implementation and are accelerating progress of SDGs 2, 6 and 7. They are tools to support decision making with high efficiency and effectiveness while reducing production costs.

5.2 DSM for Sustainable assessment

The interconnected indicators for SDGs 2, 6 and 7 were used as a basis for developing the anatomy of digitalization (Appendix 2) and also as a case study. One anatomy of digitalization in terms of indicators according to SDG 2, 6 and 7 goals interconnected and the second at Agenda 2063 targets interconnected related to SDG 2, 6 and 7 goals as following figures.

These two types of matrix have been filled in by different stakeholders in the different countries that have constituted the case studies and allowed to know the different applications of D&AI using DSM as following results. Participants preferred to use the indicator-based anatomy of the SDG's to the target-based anatomy of Agenda 2063.

Even though the indicators are less precise in terms of measurement. This choice reflects the fact that they do not have statistics. The results are therefore in the generality and based on SDG's indicators anatomy to make the analysis.

The results on using DSM for the 12 indicators of the interlinked SDG's, 2 (zero hunger), 6 (clean water and sanitation) and 7 (clean and affordable energy) established the different levels of relevance of the use of technologies in Africa, especially the case studies show that the stakeholders constituted per sector on D&AI for sustainability. Through frequency calculations, the results show the level of relevance of the different technologies on the indicators considered. The countries that made up the study have all the technologies with Kenya which is in practice and dynamic followed by Algeria and Benin where the different technologies exist but less dynamic.

First, this result based on the perception of the participant (stakeholders) allows us to affirm that the use of D&AI has an impact on the achievement of the SDGs thanks to the relevance of certain technologies on the interconnected indicators. There are several technologies where the level of performance could not be defined. This could be due to the fact that the participants lacked information about these technologies.

The level of relevance was positive in some cases and in others negative, there were also cases where there was no relevance.

The mobile internet followed by Cloud computing/Edge computing, AI/Machine learning/Deep learning, big data, Internet of Things/Digital twin technologies and Block Chain are not negatively relevant for any of the indicators (Appendix 3). They are either positively relevant, not relevant or there is no answer on the indicators. With Block Chain having received less response it can be said that this technology is less known by different stakeholders who participated.

All the results allow to enumerate the potential technologies which can make progress in the implementation of SDGs 2, 6 and 7 in general and specifically on the basis of the interactions which exist between them. The use of DSM also made it possible to see that there is a synergy between D&AI and sustainability. Based on the response of the participants who are practitioners, the technologies taken into account in the DSM (list of different technologies in appendix 1) have a great potential for the implementation of the Agenda 2030 and in particular the achievement of the agenda based on the interactions that exists between the different objectives. Also thanks to the outcomes we can list the different technologies that need special attention, technologies that are absent and not known in the implementation and achievement of SDGs 2, 6 and 7 at the level of indicators that could have potential positive.

The use of the DSM also made it possible to know that in practice, there is a lack of a real interaction between the different SDGs taken into consideration for this study.

Literature presents a large number of technologies that support the SDGs. These different technologies present themselves as potential enabler in the implementation of the SDGs in some cases their adoption is becoming indispensable. D&AI provides unique and dynamic value-added services. The various opportunities that D&AI bring also come with challenges that sometimes give uncertainty (*UNGIS* 2020) . In a context where there are opposing effects (challenge and opportunity), control measures are needed to slow down or inhibit the challenges that could be disruptive through special attentions to control potential gap. Key actors are needed in the implementation of the SDGs using D&AI for sustainable transformation with participatory approaches. The matrix has particularly provided relevant ideas from a technological point of view.

Overall, the results of our study provide practical reflections on the application of DSM as a tool for integrating the PAR approach to transdisciplinary research and producing qualitative, integrative, and open-ended research results for more concrete consideration of the meaningful use of D&AI for indicator-level SDGs.

Mapping the relevance of D&AI of SDGs 2, 6 and 7 at the indicator level based on the use and prospects of D&AI in the implementation of the SDGs.

Realize some of the interdependencies between digital technologies and provide information on the relevance of the different categories of technology to the implementation of the SDGs considered at the indicator level.

The use of the DSM for the cross-cutting SDGs at the indicator level has allowed for the observation that at the operational level, there is a lack of synergy between the relevant SDG's. The DSM could therefore be used to focus on the short comings of the integrated approaches of SDGs 2, 6 and 7.

The DSM used as a participatory tool in an integrated approach to implementing the SDG's could better help from a multi-sectoral perspective to define the real and precise prospects for using D&AI in the implementation of the SDG4s for progress.

Nevertheless, the use of the DSM in the Nexus framework has some limitations, as different stakeholders have used the DSM on the basis of different knowledge and contexts, and also with technology that has a lot of similarity. Iterations are needed to make the DSM-based participatory approach more useful and widely used.

Equitable access to Water, Energy and Agriculture services with access to sustainable Food Systems enjoy and will rely on D&AI to guide sustainable transformations. D&AI are therefore presented as tools for optimizing sustainable development making progress through implementation.

5.3 Challenges of D&AI to support the achievement of SDGs 6 alongwith synergies and trade-offs with 2 and 7

The methodology used to collect the data showed that there are many challenges for D&AI to support the implementation of the identified SDGs. These different challenges are found at several levels.

5.3.1 W-E-F Nexus Challenges

The Nexus concept presents limits which become challenges for the implementation. As following the main challenges are:

- complexity of the nexus approach which integrates several aspects;
- lack of integration of the SDG's at stakeholders level
- implementation based on sectoral approach
- difficulty in moving from sectoral approaches to integrated scale (W-E-F nexus)inability to adapt approaches to serve the implementation of the s SDG's based on the W-E-F nexus
- W-E-F nexus is far from being considered as a whole
- the different stakeholders are likely not to take action in other areas in view of not appearing as amateurs (person who lacks qualification)
- lack of appropriation, the reinvention of modes of cooperation to promote collective action.
- lack of practical evidence that could serve as a motivation for the various stakeholders
- lack of agreement and clarity on the Nexus W-E-F, all that brings together constitute the lack of knowledge in the field. There are still some precisions to be made depending on the context. This brings back the policy-related challenges that are defined in some cases but with inadequate ownership by different stakeholders.

The concept is not yet felt in the applications it is still much more in the idea state according to a case study this factors also limits the potential technology which are likely to add possible effects. Some currently review fund that W-E-F Nexus concept is still at abstract representation (Smajgl et al., 2016). Also the concept much more narrative than practical (Middleton, Allouche, Gyawali, & Allen, 2015). The W-E-F link must still be well established in order to remove these limits which are the challenges. Further, the W-E-F Nexus approach did not define its limits beforehand (Galaitsi et al., 2018) and lack of data to illustrate the practicability (Shannak et al., 2018).

5.3.2 D&AI challenges to support the achievement of SDGs

Although there is a diversity of D&AI practices within the SDGs considered, it is noted that these different practices also present challenges.

In terms of the existing challenges concerning the main technologies used; Mobile internet is cited as one of the first technologies with positive relevance, however its availability represents its limitations according to participants. Limitations are justified by the fact that the internet is limited in Africa in general as showing by following figure.

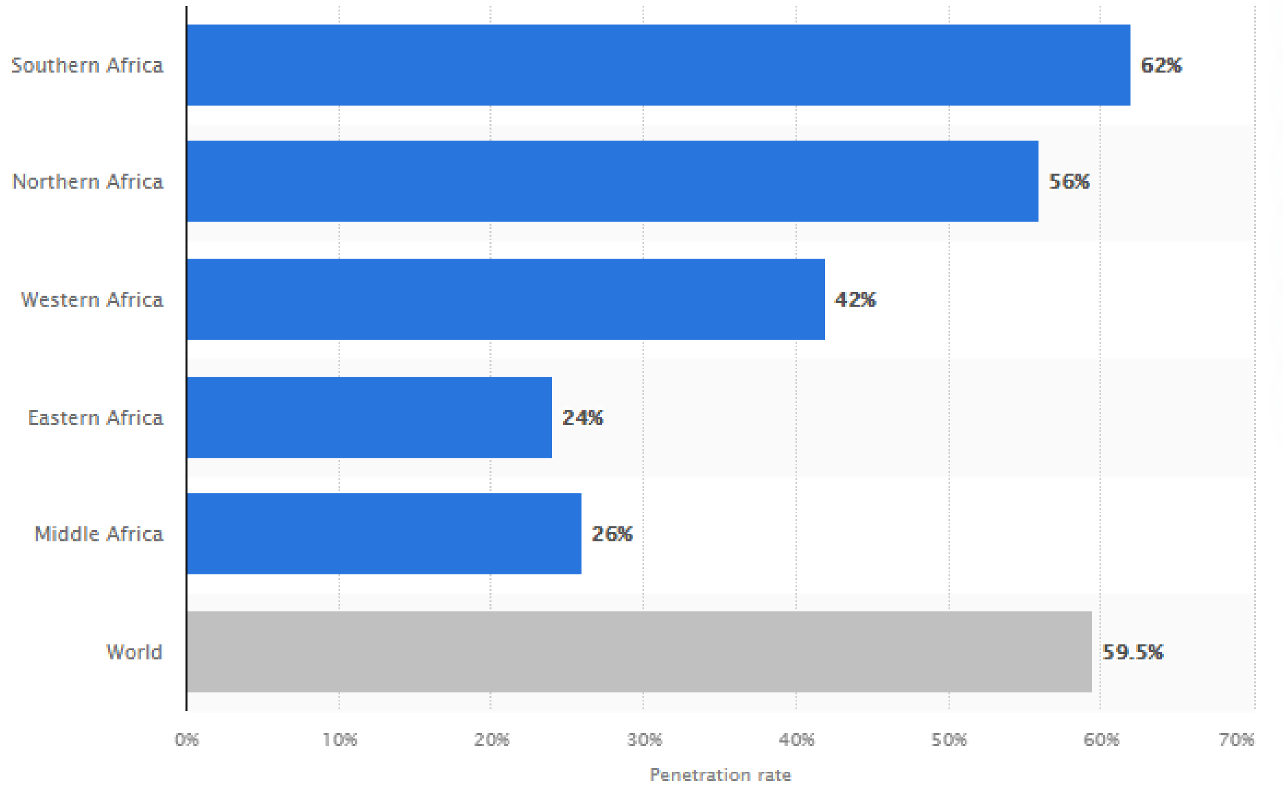

Figure 17 : Internet penetration rate in Africa as of January 2021, by region (Statista 2021)

In addition, there are other aspects as following:

- lack of knowledge about the different types of technology

- lack of updates in technologies

- lack of dynamic infrastructures

- lack of policies to introduce the relevant tools

- lack of integrated training on new technologies at national level

- D&AI is not well known, especially AI, which is still poorly interpreted and represents a major challenge for its use.

- limited understanding in the potential of AI on the implementation of the SDGS the lack of robust research methods to assess the long-term impact of AI in the case studied for our study.

This enters a lack of a solid basis for formulating contextual policies

- lack of balance between technologies, policy and needs for using
- AI is more at the perspective stage

In terms of policy D&AI are at starting the policy dialogue.

5.4 Pathway for operationalisation of SDG using D&AI

The above results show how D&AI is leading the way to sustainable development and how D&AI may be relevant to some of the SDG's indicators under consideration. To operationalize these potential opportunities, special attention should be paid to W-E-F Nexus and to all digital technologies aspect that can generate the positive impact for making progress. The paths are at two levels, firstly the need is to:

- Initiate updates to enable stakeholders to take ownership of the relevance of the W-E-F Nexus based on a participatory and inclusive approach. This method will ensure that all water, energy and food stakeholders are aware of the linkages and the different policy, governance and implementation implications of making the W-E-F Nexus relevant and practical.
- Provide evidence on results from practical applications through an efficient framework with relevant information available on the W-E-F Nexus
- Design a W-E-F Nexus frameworks (framework which must be adapted to all contexts) that take into account country contexts at different scale so that they can be adapted to any environment

A W-E-F Nexus framework that could be easily integrated into planning, strategy, development governance decisions and policies. Contextualization will require a top-down approach (from a global concept to national level) which must be based on the inclusion of stakeholders for better dissemination of information.

There is also a need to integrate theoretical aspects with contextual implementation approaches to solve policy problems.

Strengthen policy initiatives to define clear policies accompanied by effective implementation mechanisms

The pathways to increase the awareness of the various stakeholders of the current and future use of digital technologies and facilitate the migration to innovative approaches

- broad collaboration and leadership among governments, the private sector and civil society to develop specific and inclusive policies
- conduct prospective studies to enumerate the potential of D&AI for implementation based on the nexus approach at country level
- identify the indicators that are reached with the same results in order to know where to reverse and focus the different technologies
- define precise policies and regulations taking into account the context based on the integrated approach
- increased investment in infrastructure with the development of stakeholder capacity and skills the above results show how D&AI sets the course for sustainable

development. to operationalize these potential opportunities, special attention should be paid to all the externality that D&AI can generate.

- increase prospective studies to enumerate the potential of D&AI for implementation based on the nexus approach
- update of the different notions of technology for a better understanding in order to effectively exploit their potential combinations
- involving different stakeholders for strategic actions
- monitoring national policies for implementation
- promoting research and development for D&AI
- investing in the necessary infrastructure and skills to support it
- base future prospecting of research on the potential of D&AI
- countries may draw on successful examples with realistic contextualization by using on successful policy and practice elsewhere
- concerning technologies which have no relevance or those which are negative, it is necessary to develop policies and strategies in order to control their use
- there is therefore a need to strengthen policy initiatives to define clear policies accompanied by effective implementation mechanisms policy frameworks as well as the human and institutional.

Chapter 5: CONCLUSION AND RECOMMENDATION

The aims of this study was to explore the degree of use of digitalization and artificial intelligence in measuring progress and in the implementation of SDG 6 alongsynergy and trade-offs with SDG's 2 and 7 in Africa with specific case studies and to promote the use of D&AI in the implementation and measurement of progress of the SDG's.

The interaction analysis based on expert opinion supported by case studies available in the literature has highlighted the different interactions that exist between the SDGs considered on the basis of the Nexus approach. It informs on the different interactions between the SDG's at the indicator level and the direct and indirect consequences that affect the achievement of the SDG's for sustainable development.

Examining Agenda 2030 versus Agenda 2063 which are two unique agendas with distinct points that converge towards sustainable transformation identified how the indicators and target are linked. This projection is useful in understanding the linkages and allows one to say that the progress of the 2030 Agenda impacts the continental outlook framework and raise the similarities of the two frameworks based on the indicators and targets.

After analysing the practice of using D&AI on the linked the use of D&AI is based on a more holistic approach to the water sector. This observation allows the assertion that use of D&AI for the implementation and achievement of progress on SDG 6 alongwith the synergies and trade-offs with SDG 2 and SDG 7 is much more based on integrated water resources management which is an approach based on the different sectors using water. While the W-E-F which is between the different sectors of water, energy and food is at the conceptual stage and less in practice. In practice, the WEF approach calls for potential trade-offs as well as the establishment of a water management system.

D&AI is one of the key strategies in pursuing and achieving the SDGs at the operational level, with considerable perspective. Its use on the SDG's is known as a tool to drive towards sustainable development and guide change with the potential to solve problems. The mobile internet is one of the key technologies and a gas pedal for the implementation of the relevant SDGs at the indicator level that facilitates services. Block chain, Big Data, Internet of Things, Cloud Computing, AI, 3D improve efficiency and offer alternatives. These technologies enable the collection of information, the storage of databases, the location of networks and the creation of maps and offer precise solutions. They are therefore decision support tools for planning and indicators to optimize implementation.

However, although the use of D&AI supports the progress of the SDGs, it would not apply to all interconnected indicators, its use implies negative impacts and sometimes it has no effect on the achievement of the goals. This aspect highlights the limitations of D&AI in the context of achieving the SDG's.

The use of D&AI needs to be supported upstream by knowledge, regulation and enforcement in order to slow down the negative effects that constitute its limitations.

The assessment of the use of D&AI on the inter-connected DSM-based SDG's as a participatory tool for investigation helps to identify the gap that exists between the W-E-F Nexus and the digital transformation by identifying the relevance, irrelevance and neutrality between the relevant indicators and D&AI. This information can therefore serve as a basis for formulating engagement policies, using D&AI on the SDG's based on their potentials at the integration scale, and also promote D&AI in the implementation of the interconnected SDG's. Different stakeholders could find particular and practical interest in the involvement of D&AI that supports the achievement of SDG 6 with long synergy and trade-offs with 2, 7 in Africa.

5.1 Recommendation from the research findings

This research can serve as a guideline for policy makers in all African countries to adopt digital technologies based on the W-E-F Nexus approach.

In the first instance it will be necessary to move from the holistic approach to the Nexus which is more precise and impacts several sectors at once. With evidence of leaving the conceptual aspect of the W-E-F Nexus to the practical aspect that takes into account the digital technologies in the implementation.

Valuing the use of digital technologies to improve the efficiency of operational systems based on the sharing of knowledge on the potentiality of D&AI and Build strong realistic strategies on which practices can develop.

Based on national policies, prioritize D&AI as indicators for optimizing W-E-F achievement in Africa and specific case study. Develop clear strategies in the policies that should serve as the goal for the use of D&AI W-E-F in Africa and particularly in Benin and Algeria which do not have the policies for D&AI. In the case of Kenya, which has well-developed strategies, foster the foundations that are primarily the infrastructure needed for wider use to optimize how D&AI supports the SDG's.

5.2 Future prospection of research

The present research has focused mainly on the importance of digitalization and Artificial Also promote the use of D&AI in the implementation and measurement of progress in SSDGs.

However, the field of implementation of digital technology in SDG is very broad and involves many aspects. Therefore, further study on those other aspects would be necessary to complete this research. It includes:

- Design a frameworks which will make the W-E-F Nexus more understandable, its importance with data and adaptable to all scales in Africa
- Evaluate the best D&AI technologies that will enable the SDGs to be achieved in real time the use of specific digital technology in the measurement of progress and the implementation of W-E-F Nexus in Africa
- Study the technical aspect of the implementation of the SDGs based on the W-E-F Nexus using the D&AI in Africa
- Assess policy framework for the promotion of D&AI in Africa based on SDG's

Appendix 1

Table 11 : fundamental scale of values for pairwise comparison

Intensity of importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Wewak or flight	
3	Moderato importance	Experience and judgement slightly favour one activity over another
4	Moderato plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

List and definitions of different technologies

Mobile internet technologies/apps: Mobile technologies are those who go where the user goes. They are based on portable two-way communication devices, computing devices, and the networking technology that connects them. These days, mobile technologies are internet-enabled devices like smartphones, tablets, and watches. These latest innovations include two-way pagers, notebook computers, mobile telephones, GPS navigation devices, etc. The communication networks enable mobile devices to share voice, data, and applications (mobile apps).

Blockchain: Blockchain is a data structure technology that allows people and organizations to reach agreement on and permanently transparently record transactions and information without a central authority. It has been recognized as an essential tool for building a fair, inclusive, secure, and democratic digital economy. This has significant implications for how we think about many of our economic, social, and political institutions.

Internet of Things/digital twin technologies: The Internet of Things (IoT) is a network of billions of interconnected devices or systems ('things') that can be remotely controlled over the Internet. These devices collect and exchange data that can be analysed and aggregated to monitor, maintain, and improve processes to deliver products and services to consumers. Furthermore, digital twin technologies are the digital replicas of products or systems that are maintained as a virtual equivalent throughout the physical product's lifespan. Digital twin technologies utilize the IoT for creating the digital twin.

Big data: Big data refers to large amounts of data produced very quickly by a high number of diverse sources. Data can either be created by people or generated by machines, such as sensors gathering climate information, satellite imagery, digital pictures, and videos, purchase transaction records, GPS signals, etc. It covers many sectors, from healthcare to transport and energy.

Cloud computing/edge computing: Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. In edge computing, the massive data generated by different types of IoT devices can be processed at the network edge instead of transmitting them to the centralized cloud infrastructure, owing to bandwidth and energy consumption concerns.

Artificial intelligence/machine learning/deep learning: Artificial intelligence is the use of science and engineering (software or hardware) to create intelligent machines that can make and/or act on decisions that usually require organic intelligence. As Max Tegmark said, "Intelligence that is not biological".

Machine learning: Machine learning is the process of training a machine by developing algorithms to find patterns in massive amounts of data. Moreover, here, data encompass many things—numbers, words, images, and clicks. If it can be digitally stored, it can be fed into a machine-learning algorithm. Deep learning is a subset of machine learning where algorithms are created and function similarly to machine learning, but there are many levels of these algorithms, each providing a different interpretation of the data it conveys. This network of algorithms is called an artificial neural network. In simple words, it resembles the neural connections that exist in the human brain.

Virtual/augmented reality: Virtual reality (VR) implies a complete immersion experience that shuts out the physical world. Using VR devices such as HTC Vive, Oculus Rift, or Google Cardboard, Sustainability 2020, 12, 9283 19 of 27 users can be transported into a number of real-world and imagined environments, such as the middle of a squawking penguin colony or even on the back of a dragon. Augmented reality (AR) is the visualization technology that adds digital elements to a live view, often by using the camera on a smartphone. Examples of augmented reality experiences include Snapchat lenses and the game Pokemon Go.

Adaptive manufacturing or 3D printing: Adaptive manufacturing or 3D printing is a process of making three-dimensional solid objects from a digital file. The creation of a 3D-printed object is achieved using additive processes. An object is created by laying down successive layers of material in an additive process until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object.

Table 12 : List of stakeholders

County	Type Stakeholders
Kenya	Ministry of Water and Irrigation Ministry of Energy Ministry of Agriculture livestock fisheries and Co-operatives
Benin	Directorate General for Coordination and Monitoring of the SDGs
Algeria	National Agency for Integrated Water Resources Management SEOR

```
Z  0.12500000 3.5711381 9.0000000
AA 0.11111111 0.3333333 0.5000000
BB 0.12500000 7.0000000 8.0000000
CC 1.00000000 8.0000000 8.0000000
DD 0.12500000 1.0000000 2.0000000
EE 0.12500000 0.5000000 1.0000000

>
> ahp.cr(focusedited, atts)
[1] 0.3155894 0.3252061 0.3224396 0.3213683 0.3044756 0.3021266
> focusmean2 <- ahp.aggpref(focusedited, atts, method = "arithmetic")
> focusmean2
          A           B           C           D           E           F
0.034651867 0.015159083 0.004071451 0.002947288 0.027383726 0.007775625
          G           H           I           J           K           L
0.045196287 0.017329216 0.011201144 0.011525973 0.012418977 0.009666079
          M           N           O           P           Q           R
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          S           T           U           V           W           X
0.060622230 0.073520720 0.014276382 0.011463927 0.078139424 0.019623036
          Y           Z          AA          BB          CC          DD
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         EE
0.017499608
>
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Table 13 : Result of interconnected indicator scores

Appendix 2: **Anatomy of digitalization**

Table 14 : Anatomy of digitalization for Agenda 2030 indicators interconnected (SDG's 2, 6 and7)

Anatomy of digitalization for Agenda 2030 Indicators interconnected (Water-Energy-Food)

digitainable

Negatively relevant ✗
Not relevant ○
Positively relevant ✓

Agenda 2030 Indicators		Data Driven			Analytics Driven			Design Driven	
		Mobile internet technologies/ App	Block chain	Internet of Things Digital twin technologies	Big data	Cloud computing Edge computing	AI Machine learning Deep learning	Virtual/ augmented reality	Adaptive manufacturing 3D printing
2.1.1	Prevalence of undernourishment								
2.3.1	Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size								
2.4	Proportion of agricultural area under productive and sustainable agriculture				✓ s				
6.1.1	Proportion of population using safely managed drinking water services								
6.2.1	Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water								
6.3.1	Proportion of wastewater safely treated								

Table 15 : Anatomy of digitalization for Agenda 2030 indicators interconnected (SDG's 2, 6 and7)

Anatomy of digitalization for Agenda 2030 indicators interconnected (Water-Energy-Food)

digitainable

Negatively relevant

Not relevant

Positively relevant

		Data Driven			Analytics Driven			Design Driven	
Agenda 2030 Indicators		Mobile internet technologies/ App	Block chain	Internet of Things Digital twin technologies	Big data	Cloud computing Edge computing	AI Machine learning Deep learning	Virtual/ augmented reality	Adaptive manufacturing 3D printing
6.4.1	Change in water-use efficiency over time								
6.4.2	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources								
6.6.1	Change in the extent of water-related ecosystems over time								
7.1.1	Proportion of population with access to electricity								
7.2.1	Renewable energy share in the total final energy consumption								
7.3.1	Energy intensity measured in terms of primary energy and GDP								

Table 16 : Anatomy of digitalization for Agenda 2063 targets interconnected (SDG's 2, 6 and 7)

Anatomy of digitalization for Agenda 2063 Targets interconnected (Water-Energy-Food

digitainable

Negatively relevant ✗

Not relevant ●

Positively relevant ✓

Indicators/Targets 2063			Data Driven			Analytics Driven			Design Driven	
			Mobile internet technologies/ App	Block chain	Internet of Things Digital twin technologies	Big data	Cloud computing Edge computing	AI Machine learning Deep learning	Virtual/ augmented reality	Adaptive manufacturing 3D printing
1.1.2.4.1	4	Reduce 2013 levels of proportion of the population who suffer from hunger by at least 80%								
1.5.1.9.1	9	End Hunger in Africa								
1.5.1.2.1	2	Double agricultural total factor productivity								
1.7.1.1.1	1	At least 30% of agricultural land is placed under sustainable land management practice								
1.1.4.3.1	3	Reduce 2013 level of proportion of the population without access to safe drinking water by 95%.								
1.1.4.4.1	4	Reduce 2013 level of proportion of the population with poor sanitation facilities by 95% (Change the phrasing of the target).								

Table 17 : Anatomy of digitalization for Agenda 2063 targets interconnected (SDG's 2, 6 and 7)

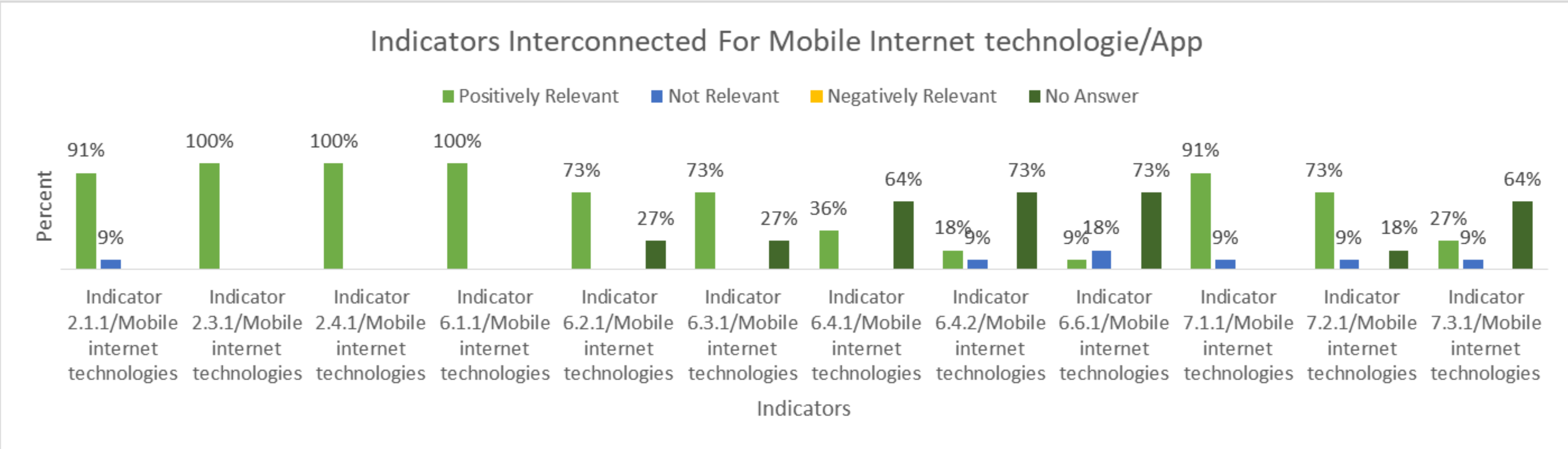
Anatomy of digitalization for Agenda 2063 Targets interconnected (Water-Energy-Food)

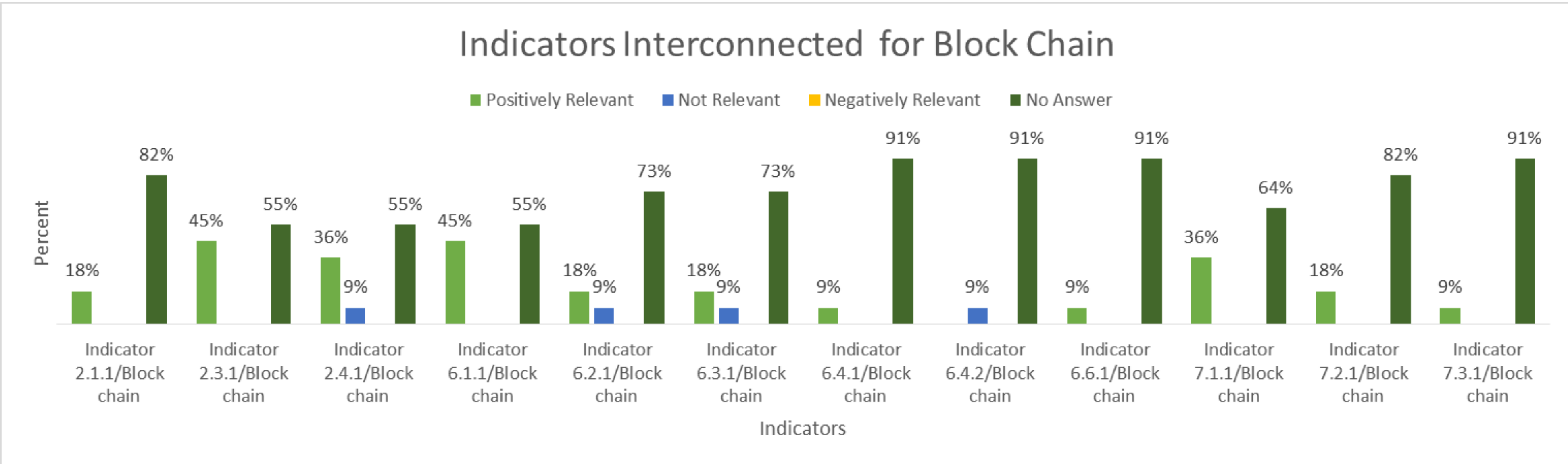
digitainable

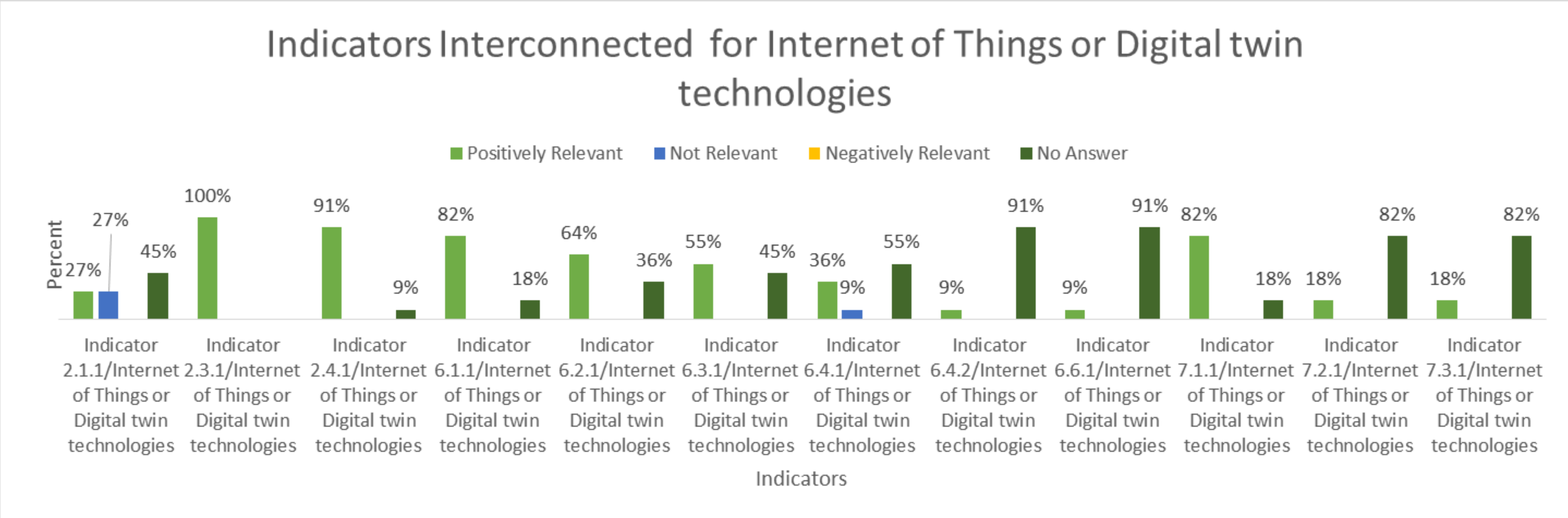
Negatively relevant (✗) · *Not relevant* (○) · *Positively relevant* (✓)

Goals/Targets			Data Driven			Analytics Driven			Design Driven	
			Mobile internet technologies/ App	Block chain	Internet of Things Digital twin technologies	Big data	Cloud computing Edge computing	AI Machine learning Deep learning	Virtual/ augmented reality	Adaptive manufacturing 3D printing
1.7.2.4.1	4	At least 10% of waste water is recycled for agricultural and industrial use								
1.7.2.2.1	2	Increase 2013 levels of water productivity from rain-fed agriculture and irrigation by 60%								
1.7.2.3.1	3	At least 10% of rain water is harvested for productive use								
1.7.3.4.1	4	Reduce proportion of fossil fuel in total energy production by at least 20%								

Appendix 3: Interconnected SDG's for technologies







Indicators Interconnected for Internet of Things or Digital twin technologies
Positively Relevant
Not Relevant
Negatively Relevant
No Answer
Percent
27%
27%
45%
100%
91%
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82%
18%
64%
36%
55%
45%
36%
9%
55%
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91%
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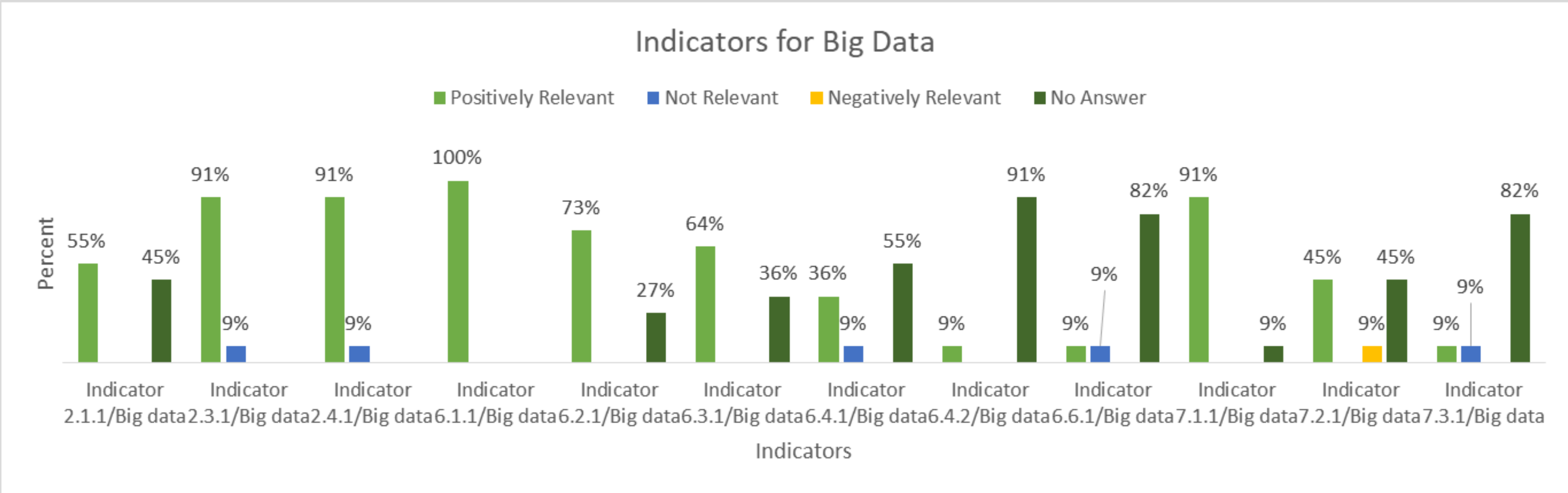
82%
Indicator 2.1.1/Internet of Things or Digital twin technologies
Indicator 2.3.1/Internet of Things or Digital twin technologies
Indicator 2.4.1/Internet of Things or Digital twin technologies
Indicator 6.1.1/Internet of Things or Digital twin technologies
Indicator 6.2.1/Internet of Things or Digital twin technologies
Indicator 6.3.1/Internet of Things or Digital twin technologies
Indicator 6.4.1/Internet of Things or Digital twin technologies
Indicator 6.4.2/Internet of Things or Digital twin technologies
Indicator 6.6.1/Internet of Things or Digital twin technologies
Indicator 7.1.1/Internet of Things or Digital twin technologies
Indicator 7.2.1/Internet of Things or Digital twin technologies
Indicator 7.3.1/Internet of Things or Digital twin technologies
Indicators



Indicators for Big Data
Positively Relevant
Not Relevant
Negatively Relevant
No Answer
Percent
55%
45%
91%
9%
91%
9%
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73%
27%
64%
36%
36%
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45%
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45%
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Indicator 2.1.1/Big data
Indicator 2.3.1/Big data
Indicator 2.4.1/Big data
Indicator 6.1.1/Big data
Indicator 6.2.1/Big data
Indicator 6.3.1/Big data
Indicator 6.4.1/Big data
Indicator 6.4.2/Big data
Indicator 6.6.1/Big data
Indicator 7.1.1/Big data
Indicator 7.2.1/Big data
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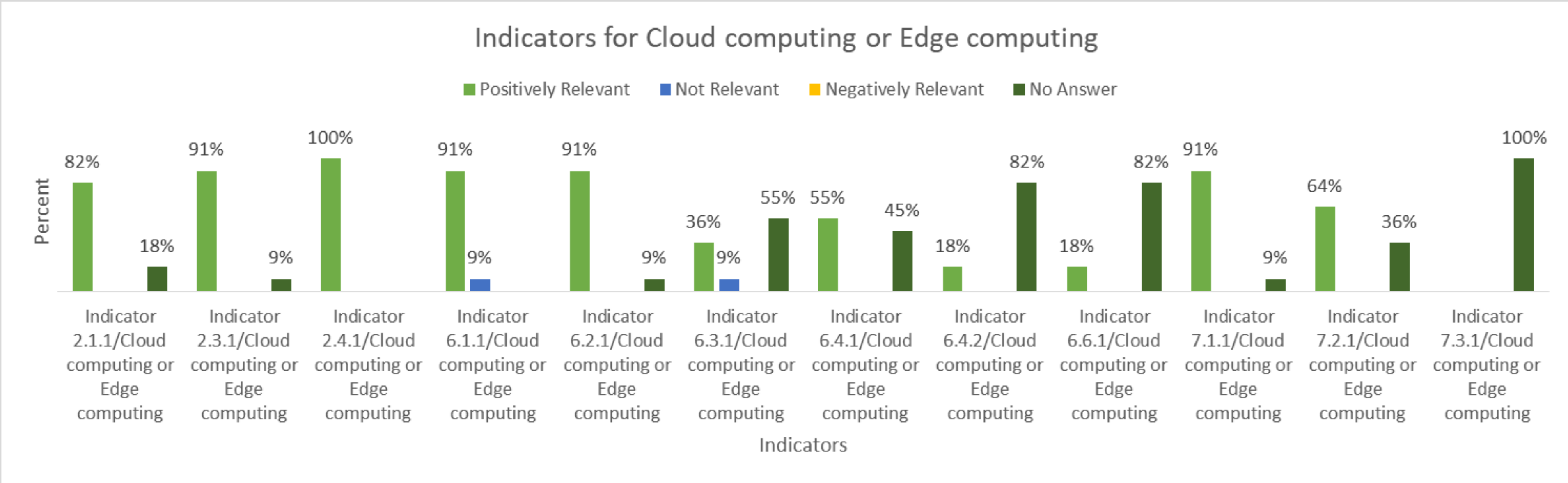
Indicators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Positively Relevant
Not Relevant
Negatively Relevant
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36%
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Indicator 2.1.1/Cloud computing or Edge computing
Indicator 2.3.1/Cloud computing or Edge computing
Indicator 2.4.1/Cloud computing or Edge computing
Indicator 6.1.1/Cloud computing or Edge computing
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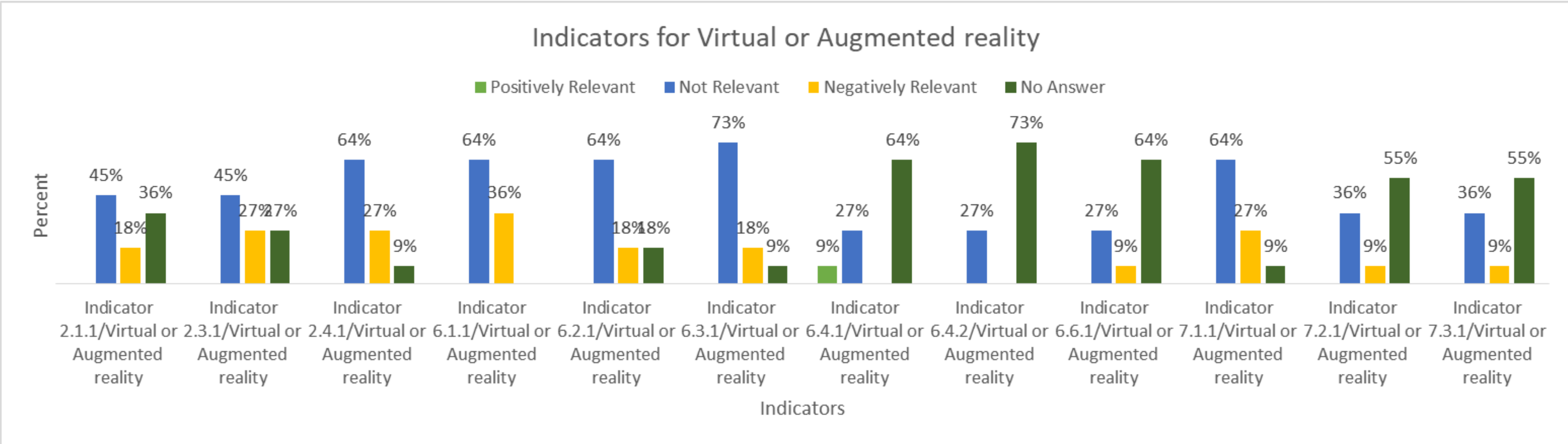
Indicators


Indicators for Virtual or Augmented reality
Positively Relevant
Not Relevant
Negatively Relevant
No Answer
Percent
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36%
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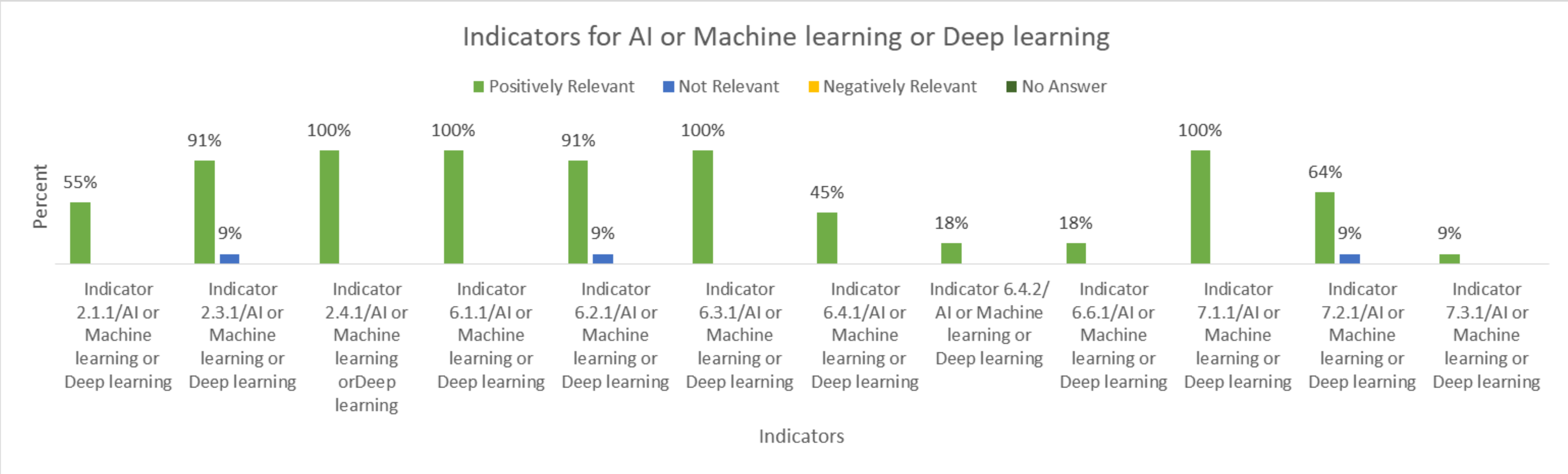
Indicator 2.1.1/Virtual or Augmented reality
Indicator 2.3.1/Virtual or Augmented reality
Indicator 2.4.1/Virtual or Augmented reality
Indicator 6.1.1/Virtual or Augmented reality
Indicator 6.2.1/Virtual or Augmented reality
Indicator 6.3.1/Virtual or Augmented reality
Indicator 6.4.1/Virtual or Augmented reality
Indicator 6.4.2/Virtual or Augmented reality
Indicator 6.6.1/Virtual or Augmented reality
Indicator 7.1.1/Virtual or Augmented reality
Indicator 7.2.1/Virtual or Augmented reality
Indicator 7.3.1/Virtual or Augmented reality
Indicators


Indicators for AI or Machine learning or Deep learning
Positively Relevant
Not Relevant
Negatively Relevant
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Percent
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91%
9%
100%
100%
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9%
100%
45%
18%
18%
100%
64%
9%
9%
Indicator 2.1.1/AI or Machine learning or Deep learning
Indicator 2.3.1/AI or Machine learning or Deep learning
Indicator 2.4.1/AI or Machine learning orDeep learning
Indicator 6.1.1/AI or Machine learning or Deep learning
Indicator 6.2.1/AI or Machine learning or Deep learning
Indicator 6.3.1/AI or Machine learning or Deep learning
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Indicator 6.4.2/ AI or Machine learning or Deep learning
Indicator 6.6.1/AI or Machine learning or Deep learning
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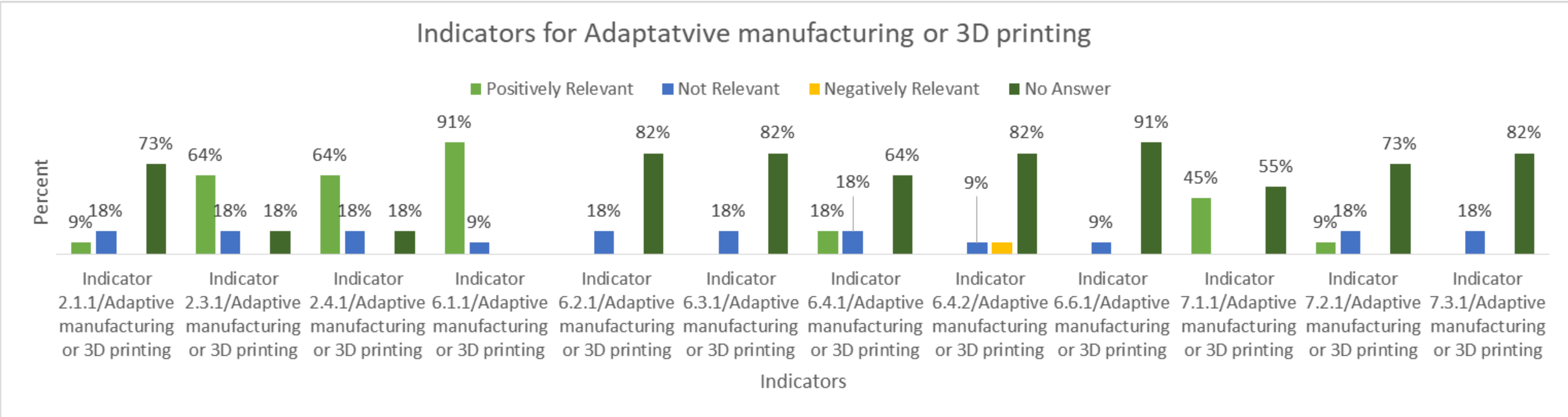
Indicator 7.2.1/AI or Machine learning or Deep learning
Indicator 7.3.1/AI or Machine learning or Deep learning
Indicators


Indicators for Adaptatvive manufacturing or 3D printing
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Negatively Relevant
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Percent
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Indicator 2.1.1/Adaptive manufacturing or 3D printing
Indicator 2.3.1/Adaptive manufacturing or 3D printing
Indicator 2.4.1/Adaptive manufacturing or 3D printing
Indicator 6.1.1/Adaptive manufacturing or 3D printing
Indicator 6.2.1/Adaptive manufacturing or 3D printing
Indicator 6.3.1/Adaptive manufacturing or 3D printing
Indicator 6.4.1/Adaptive manufacturing or 3D printing
Indicator 6.4.2/Adaptive manufacturing or 3D printing
Indicator 6.6.1/Adaptive manufacturing or 3D printing
Indicator 7.1.1/Adaptive manufacturing or 3D printing
Indicator 7.2.1/Adaptive manufacturing or 3D printing
Indicator 7.3.1/Adaptive manufacturing or 3D printing
Indicators

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