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Market analysis and SRA of the climate services

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Summary

Deliverable 6.5 of the FOCUS Africa project presents a comprehensive market analysis and evaluation of climate services' scalability and replicability within the Southern African Development Community (SADC). This report addresses the critical need for tailored climate services to mitigate the impacts of climate variability on four key sectors: agriculture and food security, water, energy, and infrastructure. Key Findings: 1. Market Potential: The SADC region demonstrates significant demand for climate services due to pressing challenges in agriculture, food, water security, energy management, and infrastructure development, all of which are exacerbated by climate variability. 2. Sectoral Analysis: ? Agriculture: Limited access to financing and modern technologies hinders productivity. ? Energy: Outdated infrastructure and climate change impacts pose significant challenges. ? Infrastructure: Climate-resilient development is crucial for sustainable growth. 3. Scalability and Replicability: ? Success Factors: Localized climate data, stakeholder engagement, and accessible financing mechanisms are crucial for wider adoption. ? Expansion Potential: Climate services show promise for adaptation across other African regions, with emphasis on local context customization. 4. Climate Services Impact: Accurate predictions and data provision can substantially improve decision-making processes across all targeted sectors. This report underscores the strong potential of climate services in driving sustainable development across the SADC region. By addressing sector-specific challenges and leveraging key success factors such as localized climate data, stakeholder engagement, and accessible financing, the FOCUS Africa project is well-positioned to catalyze the adoption of these services.

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Market analysis and Scalability and Replicability Analysis of the climate services

Deliverable D6.5

Lead Beneficiary: Amigo
August 2024

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www.focus-africaproject.eu

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About FOCUS-Africa

FOCUS-Africa – Full-value chain Optimised Climate User-centric Services for Southern Africa – is developing sustainable tailored climate services in the Southern African Development Community (SADC) region for four sectors: agriculture and food security, water, energy and infrastructure.

It will pilot eight case studies in six countries involving a wide range of end-uses to illustrate how the application of new climate forecasts, projections, resources from Copernicus, GFCS and other relevant products can maximise socio-economic benefits in the Southern Africa region and potentially in the whole of Africa.

Led by WMO, it gathers 14 partners across Africa and Europe jointly committed to addressing the recurring sustainability and exploitation challenge of climate services in Africa over a period of 48 months.

For more information visit: www.focus-africaproject.eu

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Executive Summary

Deliverable 6.5 of the FOCUS Africa project presents a comprehensive market analysis and evaluation of climate services' scalability and replicability within the Southern African Development Community (SADC). This report addresses the critical need for tailored climate services to mitigate the impacts of climate variability on four key sectors: agriculture and food security, water, energy, and infrastructure.

Key Findings:

1. Market Potential: The SADC region demonstrates significant demand for climate services due to pressing challenges in agriculture, food, water security, energy management, and infrastructure development, all of which are exacerbated by climate variability.
2. Sectoral Analysis:
   - Agriculture: Limited access to financing and modern technologies hinders productivity.
   - Energy: Outdated infrastructure and climate change impacts pose significant challenges.
   - Infrastructure: Climate-resilient development is crucial for sustainable growth.
3. Scalability and Replicability:
   - Success Factors: Localized climate data, stakeholder engagement, and accessible financing mechanisms are crucial for wider adoption.
   - Expansion Potential: Climate services show promise for adaptation across other African regions, with emphasis on local context customization.
4. Climate Services Impact: Accurate predictions and data provision can substantially improve decision-making processes across all targeted sectors.

This report underscores the strong potential of climate services in driving sustainable development across the SADC region. By addressing sector-specific challenges and leveraging key success factors such as localized climate data, stakeholder engagement, and accessible financing, the FOCUS Africa project is well-positioned to catalyze the adoption of these services.

Keywords

Climate Services, Sustainable Development, Market analysis, Scalability and Replicability, Climate Resilience

Introduction

The objective of this report is to provide a clear overview of the opportunities and weaknesses within the climate services market in the Southern African Development Community (SADC) through a careful analysis of the economic context of each country of interest. This report is the Deliverable 6.5, which is the result of Task 6.4, and it plays a critical role in the broader FOCUS Africa project. Specifically, Task 6.4 is dedicated to analyzing potential markets for the developed climate services and defining their scalability and replicability across different environments. By doing so, this report not only serves as a standalone analysis but also contributes directly to the FOCUS Africa project's overarching aim of enhancing climate resilience in Africa. This report facilitates the potential transfer and application of climate services beyond the initial case studies. This work is essential for informing stakeholders and policymakers in regions identified as having high potential for successful climate service implementation, thus advancing the FOCUS Africa project's mission of fostering sustainable development and climate adaptation across the continent.

Section 2 introduce a brief overview of the economy of each sector in the region, examining the main issues of the SADC market sectors, such as food and water security, energy supply, and infrastructure design. Moreover, it analyses the climate services market and how it contributes to mitigate those problems.

Section 3 explores solutions to the problems outlined in the previous section. Here, an in-depth analysis of the climate services market in the SADC is conducted, addressing both the actors operating within it and the methods and tools that enable them to engage with the market.

Finally, section 4 contains a scalability and replicability analysis. Here, key features observed in various climate services are analysed to learn which elements are essential among all SADC countries. It is also discussed what are the main aspects needed to create an easily scalable product and the economic possibilities and funds required to sustain the scalability and the replicability of the project.

Moreover, the activities discussed in this report directly contribute to the UN Sustainable Development Goals (SDGs), 2, 6, 7, and 9. This report aligns with SDG 2 (Zero Hunger) by promoting sustainable agricultural practices and improving food security through enhanced climate services. SDG 6 (Clean Water and Sanitation) is supported by the focus on water security, where climate services play a crucial role in managing water resources and ensuring access to clean water. The emphasis on energy supply in the SADC region ties into SDG 7 (Affordable and Clean Energy) by identifying opportunities for climate services to enhance energy planning and support the transition to sustainable energy systems. Finally, the attention to infrastructure in the context of climate services aligns with SDG 9 (Industry, Innovation, and Infrastructure), fostering resilient infrastructure and promoting inclusive and sustainable industrialization. The report's scalability and replicability analysis further highlights the potential for these climate services to be expanded across the region, amplifying their impact on these critical SDGs.

1 Identification of potential markets for Climate Service development

In many economies, it is often the demand itself that generates supply, and this is especially true in cases where there are competing needs where essential goods are lacking, such as food, water, or electricity. This dynamic is particularly evident in the SADC, this region indeed has a pressing need for services that can help overcome significant growth-limiting challenges, namely food security, water security, energy management, and infrastructure management. In this chapter, we describe these themes in detail and explain their significant implications for Africa. This analysis forms the basis for understanding how climate services can help the continent address these challenges.

These issues are indeed particularly linked to climate variability, which is where climate services come into play as a solution. Accurate climate predictions can assist farmers in safeguarding their crops against extreme events, optimising planting, and harvesting times and enhancing overall agricultural resilience. Predicting climate patterns can also aid in managing water basins and their maintenance and it is crucial in energy management, especially for renewable energy which is often directly dependent on climate conditions. Moreover, anticipating extreme weather events is essential in guiding the construction of infrastructure, enabling for strategic planning that accounts for the risks posed by these events.

1.1 Agriculture and Food Security

According to the World Bank, **food security is achieved when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life[1].**

Africa is predominantly an agricultural continent, where agriculture serves not only as the primary source of income and employment for its citizens but also as the main provider of food. Safeguarding agriculture is, therefore, synonymous with ensuring the ability of African citizens to nourish themselves adequately.

As reported by the Africa Centre for Strategic Studies in October 2023[2] 149 million Africans are experiencing severe food insecurity The condition of food insecurity is expected to worsen due to climate change, a significant contributor to the food crisis. In several countries, the issue of food insecurity is linked to crop losses caused by extreme weather events or inaccurate predictions of rainfall and drought. Food security is also threatened by the variability and unpredictability of climatic events, such as delayed onset of the rainy season or sudden droughts.

The International Monetary Fund reports[3] that a one-degree Celsius increase in Africa's temperature leads to a 3% decrease in agricultural productivity, and in sub-Saharan Africa, a crop yield reduction of up to 17% is projected by 2050. These factors, coupled with a significant increase in the African population, will exacerbate the food security situation in sub-Saharan Africa.

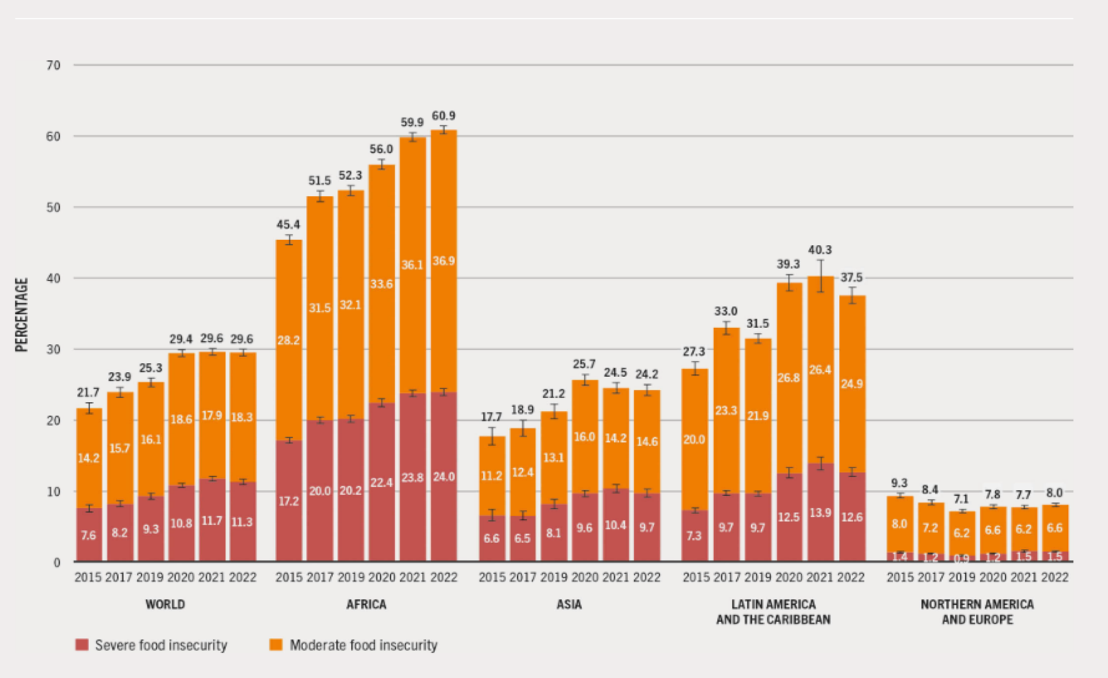
Figure 1 shows the percentage of the world population experiencing severe and moderate food insecurity between 2015 and 2022.

As evident, Africa is the continent lagging behind in terms of food security. In 2022, more than 60% of the African population was food insecure, with 24.0% experiencing severe food insecurity. Furthermore, from 2015 to the present, Africa is the only continent where this problem has consistently worsened.

In the coming years, climate services will be crucial to counteract the worsening conditions and improve food security in Africa. In this context, climate services become essential as they enable agriculture to become more resilient.

Precise climate predictions provide valuable insights into the characteristics of rainy seasons, including their duration, onset, and cessation. With this knowledge, farmers can optimize their planting and harvesting schedules, leading to several benefits, such as: **Timely cultivation**: Knowing when the rains will start allows farmers to prepare their fields and sow crops at the most opportune moment. **Crop selection**: Understanding the length of the rainy season helps in choosing appropriate crop varieties that align with the expected water availability. **Harvest optimization**: Knowing when the rains are likely to end allows farmers to plan for timely harvesting, reducing post-harvest losses. **Increased yield:** By aligning agricultural practices with climate patterns, farmers can significantly improve both the quantity and quality of their harvest.

[1] World Bank. https://www.worldbank.org/en/topic/agriculture/brief/food-security-update/what-is-food-security
[2] Unresolved Conflicts Continue to Drive Africa's Food Crisis (16 October 2023), African Center for Strategic Studies
[3] Climate Change and Chronic Food Insecurity in Sub-Saharan Africa (2022), Diogo Miguel Salgado Baptista et al. , International Monetary Fund



NOTE: Differences in totals are due to rounding of figures to the nearest decimal point.
SOURCE: FAO. 2023. FAOSTAT: Suite of Food Security Indicators. In: *FAO*. [Cited 12 July 2023].

Figure 1: Percentage of severe and moderate food insecurity population in the world, between 2015 and 2022.[4]

1.2 Water Security

Water security involves various risks associated with water resources, such as poor water quality due to pollution, insufficient water quantity resulting from ineffective management of water basins and inadequate water treatment.

Hydropower, as a critical element of water security, holds a significant position in energy generation within the SADC region. While hydropower relies on the availability and management of water resources, it minimally competes with the agricultural sector for these resources. This partial competition exists because both sectors depend on water, yet the conflict is minimal due to effective resource management and prioritization strategies. Therefore, the use of water for hydropower does not substantially detract from its availability for agricultural purposes, allowing both sectors to coexist and thrive in the SADC region. Efficient hydropower systems require well-managed water basins that can provide consistent and controlled water flow. As such, hydropower not only contributes to energy security but also demands water management to maintain its viability and efficiency. For Example, in Malawi, the use of rivers and lakes, particularly Lake Malawi, for energy production plays a vital role in balancing water resources across agriculture, civilian needs, and energy generation. As Lake Malawi and precipitation are the most important water sources in the country, their careful management ensures that water usage for energy production minimally impacts agricultural and civilian demands. This strategic approach promotes sustainable development in all sectors, highlighting the importance of hydropower in maintaining equilibrium in water resource allocation.

Water security is a multifaceted issue that extends beyond health concerns and impacts other aspects outlined in this document. For instance, water is vital for agricultural irrigation and, consequently, food security. to the Organization for Economic Co-operation and Development (OECD),

[4] The State of Food Security and Nutrition in the world 2023, Chapter 2: Food Security and Nutrition Around the World, Food and Agriculture Organization (FAO)

by 2030, there could be up to 700 million displaced individuals due to water management issues. Currently, 40% of Africans lack access to a reliable water supply.[5]

Water security is becoming an increasingly prominent issue in development plans for Africa. In September 2023, the African Union declared water security as one of the most urgent priorities[6] and announced an additional investment of $30 billion per year to expedite actions outlined in the United Nations Water Action Agenda[7]. The management of water resources is also closely tied to the prediction of extreme weather events such as droughts and floods, making it highly vulnerable to climate variability. In this context, climate services are crucial in planning and managing water resources by forecasting periods of heavy rainfall and dry spells, enabling to handle water reserves and high-risk periods associated with imminent extreme events more effectively.

1.3 Energy

Access to a reliable energy source is a complex challenge in many African countries. **Often, energy production is insufficient to meet the growing demand in the African continent. While energy production is increasing slowly, the African population is growing more rapidly than in other continents, exacerbating the energy needs over time.**

A significant obstacle lies in the distribution of energy to citizens. While this may be a relatively minor concern in urban centres, situations of energy isolation frequently occur in peripheral regions.

Currently, most of the energy in Africa is produced with fossil fuels and several African countries are forced to import them from abroad, which makes energy production very expensive. Approximately 600 million Africans lack consistent access to energy sources, as highlighted by the Africa Energy Outlook of the International Energy Agency[8].

Figure 2, derived from a study by the International Renewable Energy Agency titled "Renewable Energy Market Analysis”[9], shows the percentage of the population in Sub-Saharan Africa without access to electricity and clean cooking, in 2010 and in 2019.

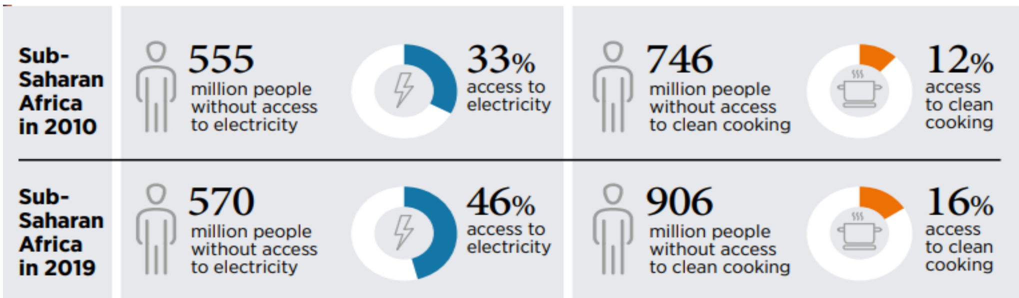


Figure 2: Percentages of people without access to electricity and clean cooking in 2010 and in 2019, in Sub-Saharan Africa[10].

Figure 2 illustrates the limited progress in recent years in terms of electricity access for citizens in sub-Saharan Africa. Given the exponential growth in demand anticipated in the coming years, this improvement is expected to slow down, unless there is a substantial enhancement of the energy production system.

[5] The Roundtable of African Mayors for Water Security, Organization for Economic Co-operation, and Development (OECD)

[6] PRESS RELEASES, Concrete actions towards water security in Africa brought forward as the continent prepares its Water Investment Action Plan (2023)

[7] A Rising Tide of support for women in water diplomacy (2023), Water Action Agenda, United Nations (UN)

[8] IEA (2022), Africa Energy Outlook 2022, IEA, Paris https://www.iea.org/reports/africa-energy-outlook-2022, Licence: CC BY 4.0

[9] International Renewable Energy Agency (2022), Renewable Energy Market Analysis

[10] International Renewable Energy Agency (2022), Renewable Energy Market Analysis

Given the challenges in producing a sufficient amount of energy, renewable energy sources in Africa are assuming an increasingly crucial role and will soon become essential to meet the continent's energy needs. Currently, many African countries are already leveraging hydroelectric, solar, and wind energy extensively and efficiently, albeit on a limited scale. The market trend indicates a strengthening of these energy sources in the near future.

However, renewable energies are strongly influenced by the climate and its variability. Therefore, the implementation of specific climate services for predicting the production of energy from renewable sources would enable Africa to more accurately forecast energy generation during specific time periods and thus improve the overall design and management of the energy system.

1.4 Infrastructure

One of the sectors where Africa significantly lags behind the rest of the world is infrastructure. Currently, **in the sub-Saharan region, only 47% of roads are paved, and less than 50% of the rural population has access to the few paved roads available**[11]. The same situation applies to other modes of transportation, characterised by sparse and often abandoned railways and limited, ageing ports.

The lack of infrastructure or its underdevelopment is a cross-cutting issue, hindering the effective transportation of goods, energy, and water. According to the African Infrastructure Consortium, this costs Africa 40% of its annual productivity and 3% of its growth rate[12]. On a positive note, there has been growth in infrastructure related to telecommunications, with the support of the African Development Bank, making Africa the world's second-largest telecommunications market with the highest growth rate.[13]

Many infrastructures also face a significant resilience problem, meaning their ability to withstand frequent extreme events in Africa is compromised. In modern infrastructure design, especially for large structures exposed to extreme events like bridges and highways, risk assessment, including climate variability risk, is crucial. Building infrastructure resistant to extreme weather events where they are more likely is crucial. However, climate predictions are also essential during the construction periods of these infrastructures. Indeed, the construction timelines for large projects, such as highways, are quite long, and climate variability needs to be considered as a factor.

Among the problems described in this document, infrastructure is perhaps the most complex and challenging to address, primarily due to the substantial investments required that far exceed Africa's financial capabilities. Therefore, assistance from external state and supranational entities is crucial to support the demographic and economic growth of the continent.

[11] Modernizing Infrastructure Vital to Fulfilling Africa's Promise (2023), Jerry Haar, Wilson Center

[12] Solving Africa's infrastructure paradox (2020), McKinsey & Company

[13] Modernizing Infrastructure Vital to Fulfilling Africa's Promise (2023), Jerry Haar, Wilson Center

2 Market research

In this section, we explore several market research studies to gain a deeper understanding of the previously discussed issues and to introduce the opportunities available for climate services in Africa. Water security is not addressed as a standalone topic in this chapter, as it is inherently integrated into the discussions of agriculture, energy, and infrastructure. Each of these sectors heavily relies on water resources, and their respective analyses naturally encompass water security considerations.

2.1 Agriculture and food security

Africa is a continent of immense agricultural potential on a global scale. With a staggering 60% of the world's uncultivated arable land, its economy is already deeply rooted in agriculture. Within Sub-Saharan Africa, agriculture contributes a substantial 14% to the Gross Domestic Product (GDP) and employs the majority of the population. Despite these promising indicators, the region faces significant challenges, notably an overwhelming demand that surpasses the local supply, leading to reliance on food imports. This highlights the market inefficiencies within the region, a paradox considering its considerable size and potential.

The African continent, besides being extremely large, is also highly biodiverse, ranging from tropical and humid zones to dry and desert areas. This variability results in a wide variety of crops that can thrive on the continent.

Table 1 illustrates the gross agricultural production in Africa and their growth until 2029.

Table 1: Gross agricultural production in Africa and their growth until 2029[14].

	2007-09 average (000 tonnes)	2017-19 average (000 tonnes; base)	2029 projection (kt)	Growth from base to 2029 (%)	2010-19 average growth (%)	2020-29 proj. average growth (%)
Cereals	109,695	141,025	169,397	20.12	2.42	1.66
Roots & tubers	56,740	86,825	112,016	29.01	3.67	2.28
Pulses	12,350	17,788	19,758	11.08	2.83	0.93
Meat	9080	11,715	14,675	25.27	2.36	2.21
Oilseeds	8044	11,149	13,288	19.18	2.26	1.58
Sugar	6445	7632	10,174	33.31	1.56	2.53
Fish	5626	7695	8291	7.75	2.84	1.07
Vegetable oil	4657	6855	8106	18.24	2.82	1.37

From Table 1, it is evident that cereals have consistently been the most popular crop on the continent, followed by tubers, which have experienced a substantial growth between 2020 and 2029. The production of meat and sugar has also seen significant growth in recent times, driven by the increasing demand, fuelled by demographic growth.

Despite the continuous growth in agricultural production, Africa has never produced enough to meet its food needs. The trade balance of the continent consistently favours imports, leading to a

[14] Oxford Business Group, Agriculture in Africa 2021

significant increase in food costs. This situation makes it challenging for some families to afford a proper diet.

Table 2 clearly illustrates this point. Imports are much more significant than exports, and they also have a higher growth rate, which is consistently increasing.

Table 2: Average value and average growth in percentage of import and exports between 2007 and 2009; 2017 and 2019 and projection to 2029[15].

	2007-09 average ($ bn)	2017-19 average ($ bn; base)	2029 projection ($ bn)	growth from base to 2029 (%)	2010-19 average growth (%)	2020-29 proj. average growth (%)
Exports	7.3	9.7	9.4	-3.1	1.8	-0.6
Imports	19.8	27.5	40.1	45.8	2.6	3.5

The inflation of prices for African food, which is one of the most critical elements in discussions about food security, is caused by a series of interconnected factors that influence each other in a vicious circle. Indeed, the inability of African agriculture to meet the demand for agricultural goods not only prevents people from being adequately fed but also affects livestock. Consequently, Africa is forced to import food both for its citizens and for livestock. Livestock, in turn, needs to grow due to the continent's population growth and the increasing demand for meat. At this point, given the market's inability to meet the supply, governments are compelled to import what is necessary, driving up costs.

To address this situation, strategies must be developed to enhance local agriculture, improve productivity, and reduce dependence on imports. Additionally, targeted investments in agricultural research, infrastructure, and agricultural policies can help break the negative cycle and promote long-term food sustainability.

One of the most significant reasons for Africa's challenges in agricultural production and meeting the demand for agricultural products is the prevalence of small-sized agricultural enterprises. These entities face substantial difficulties in growth primarily due to the challenges they encounter in accessing financing. Currently, the majority of funding for African agriculture comes from the public administration or micro-investors. However, certain sectors, such as venture capital, are showing promising growth and becoming increasingly popular on the continent.

Despite these challenges, Africa is experiencing continuous growth and currently receives $80 billion in agricultural financing annually. The World Bank, in a report published in 2013[16], predicted that by 2030, the African agricultural market would reach a staggering one trillion dollars. This prediction is also confirmed in the 2023 report Africa Agricultural Policy Leadership Dialogue[17]. This highlights the potential for expansion and development in the agricultural sector, especially if more diverse and accessible financing options become available to small-scale agricultural businesses in Africa.

Another factor contributing to the challenges of African agricultural production is the climate variability. According to the Oxford Business Group, a significant portion of African crops heavily relies on rainfall, with only 6% of fields being artificially irrigated[15]. This makes the crops particularly vulnerable to climatic events such as floods and droughts. The frequency of extreme climate events

[15] Oxford Business Group, Agriculture in Africa 2021

[16] Growing Africa: Unlocking the Potential of Agribusiness. World Bank report, 2013

[17] Africa Agricultural Policy Leadership Dialogue. World Bank report, 2023

has increased from once every 12.5 years between 1982 and 2006 from once every 2.5 years between 2007 to 2016, reducing agricultural production by at least 2.5%[18].

The worsening climate conditions also pose a risk of desertification in areas currently suitable for cultivation but may not be so in the future. The Food and Agriculture Organization (FAO) reports that Africa is already the second driest continent, with 50% composed of deserts and 40% of the soil at risk of desertification. Desertification further threatens biodiversity, risking the extinction of plant and animal species which are crucial for the continent and its inhabitants. Addressing the impact of climate change on agriculture is essential not only for food security but also for preserving the ecological balance and sustaining the livelihoods of African communities.

In response to this issue, African institutions appear to have mobilised extensively, despite being the only financiers of plans to increase the climate resilience of African agriculture. Globally, we observe that the majority of public investments in financing for climate change-related issues, especially for small enterprises, are directed towards Africa, as illustrated in Figure 3. This demonstrates a significant commitment at both regional and international levels to address the challenges posed by climate change in the African agricultural sector.

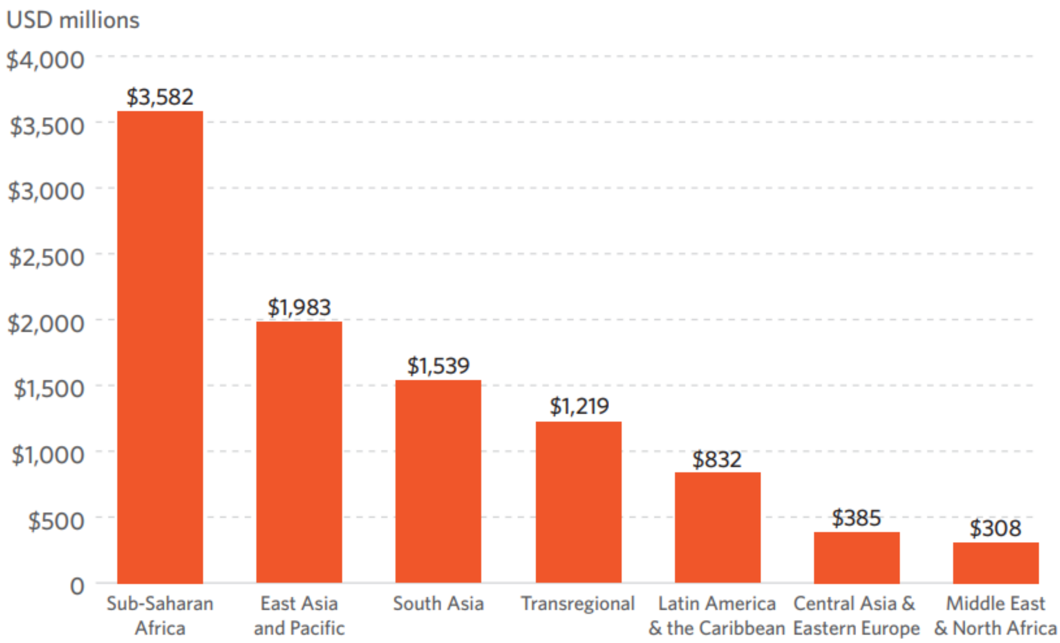


Figure 3: Distribution of climate finance by region of destination [19]

Figure 3 reveals that investments in climate-related initiatives for small-scale agricultural enterprises are predominantly absorbed by Sub-Saharan Africa, with nearly $3.6 million invested between 2017 and 2018, compared to almost $2 million in East Asia and the Pacific. This difference is attributed to the fact that in Sub-Saharan Africa, 60% of the population belongs to the category of small-scale agricultural entrepreneurs. The focus on this region reflects the recognition of the urgent need to address climate change challenges in the agricultural sector, particularly among small enterprises, where the majority of the population is engaged.

However, a significant issue in the field of investments is the demographic discrimination in the allocation of funds. Indeed, it is predominantly adult males who find themselves in debt. This is not

[18] McKinsey Global Institute (2020) How will African farmers adjust to changing patterns of precipitation?

[19] Daniela Chiriac, Baysa Naran and Angela Falconer, November 12, 2020 *Examining the Climate Finance Gap for Small-Scale Agriculture*, Climate Policy Initiative https://www.climatepolicyinitiative.org/wp-content/uploads/2020/11/Examining-the-Climate-Finance-Gap-in-Small-Scale-Agriculture.pdf

only because they are the main owners of small agricultural businesses but also due to a significant discriminatory factor. Banks are hesitant to provide funding to women or young individuals, slowing down the entrepreneurial growth of the African agricultural economy. The FAO estimates that if women had the same access to financial tools as men, agricultural output would increase by 4%, contributing to market growth and addressing humanitarian issues such as food security.

Another issue is the slow technological advancement in the agricultural industry. Old smallholder farmers, who own small African agricultural businesses and receive more trust and funding from banks, tend to be extremely conservative, remaining attached to outdated practices and resisting the adoption of new technologies. At the same time, the slow technological progress in the sector is also a result of the lack of young individuals in the field, facing difficulties in entrepreneurship due to a lack of funds. Technological advancement would not only make the sector more efficient but would also help it capture broader markets.

Currently, African agricultural production mainly yields raw materials without any processing. Industrialising the sector could enable agricultural entrepreneurs to sell semi-finished or finished products, building larger profit margins, and expanding the industry, thereby creating job opportunities for more people. Bain & Company reports that even simple processing can lead to a significant price (and margin) increase for some typical African agricultural products[20]. This is evident in the case of coffee, which sees a 900% price increase when sold already roasted, and peanuts, which, when sold already roasted and salted, see a 600% price increase.

This technological lag significantly delays the value chain of African agricultural products, causing a substantial loss of margin for African producers, especially when dealing with products that perish quickly if not processed promptly. In African agricultural products, the dominant factors influencing the final product price are the stages at which the product is processed before wholesale distribution. This is well illustrated in Figure 4 from Bain & Company, depicting all the stages of the value chain and the extent to which these stages influence the final product price, expressed as a percentage of the total price.

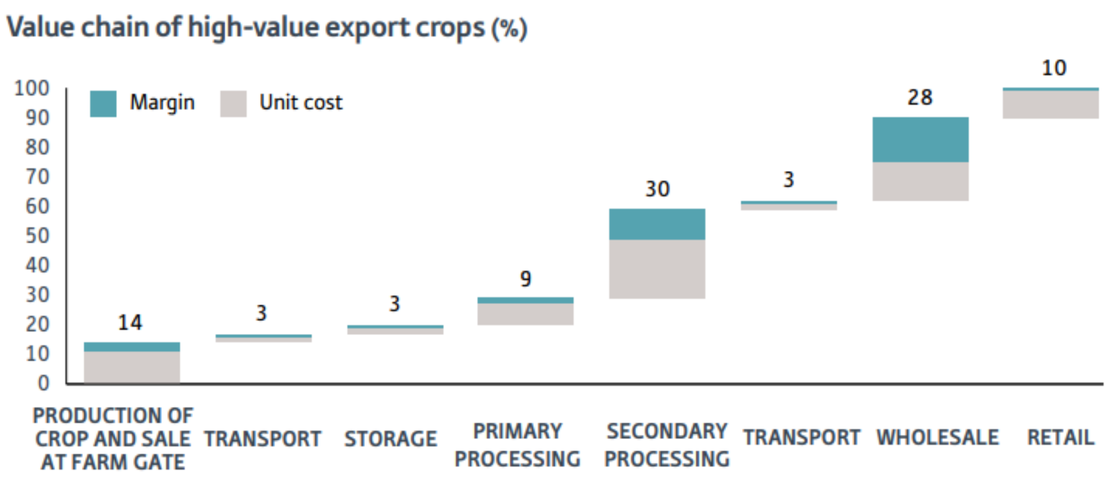


Figure 4: Value chain of high-value exports crops in percentage.

This highlights the critical importance of efficient processing and technology adoption throughout the value chain to maximise the value retained by African producers. Addressing the technological gap in these processes is crucial not only for improving the economic prospects of African agricultural producers but also for reducing waste and ensuring the timely delivery of high-quality products to the market.

[20] Bain & Company (2020) A New Paradigm of African Agricultural development

Africa is in urgent need of climate finance for mitigation and adaptation, estimated at between $750 billion and $1.3 trillion per year by 2025.

Additionally, the continent's forests play a crucial role in carbon sequestration, potentially generating revenue through carbon trading.

Upfront private investment potential to adapt to droughts and floods could amount to up to 4.0 percent of Africa's GDP, close to $100 billion a year through 20403.

Africa faces a pressing need for substantial climate finance to address both mitigation and adaptation challenges. **Estimates indicate that by 2025, the continent will require between $750 billion and $1.3 trillion annually** to effectively combat climate change and its impacts. [21] This financial requirement underscores the urgent necessity for the development and implementation of comprehensive climate services. These services are crucial in supporting sustainable agricultural practices, enhancing climate resilience, and ensuring effective management of financial resources aimed at combating climate change impacts in the region.

The continent's extensive forests play a pivotal role in carbon sequestration, presenting a lucrative opportunity through carbon trading schemes. The development of climate services is essential for accurately monitoring and managing these forests, **thereby maximizing their potential for generating revenue from carbon credits.[22].** By leveraging advanced climate services, African countries can secure financial resources to invest further in climate-smart agriculture and enhance their overall climate adaptation strategies. This dual benefit not only contributes to global carbon reduction efforts but also bolsters the economic resilience of rural communities dependent on agriculture.

Moreover, there is considerable potential for private investment in climate adaptation measures, particularly to counteract the adverse effects of droughts and floods. It is projected that upfront private investment in these areas **could reach up to 4.0 percent of Africa's GDP, amounting to nearly $100 billion annually through 2040**[23]. Estimating conservatively, **the market potential for agriculture climate services could exceed 500 million euros annually.** The development of innovative climate services is critical to attracting and effectively utilizing these investments. These services can drive the development and implementation of adaptive strategies for agriculture, improving productivity, ensuring food security, and reducing vulnerability to climate risks. The economic benefits of such investments are vast, promising enhanced agricultural yields, sustainable economic growth, and greater resilience against climate challenges.The scientific and technological advancement will be of paramount importance for African agriculture in the coming years. Despite the solid foundation of the agricultural market, its efficiency is significantly limited. A substantial part of this lack of efficiency can be attributed to technological backwardness, which not only prevents agriculture from embracing tools such as climate services and modern agricultural processing but also hampers the rapid development of techniques useful for cultivation and efficiency improvement in the diverse geographical regions of Africa.

Technology, indeed, would enable scientific research in this field to conceive the best strategies for cultivating the most useful and effective plants on the continent. The availability of advanced technological tools could enhance precision in agricultural practices, optimizing resource use and reducing wastage. Furthermore, the application of innovative technologies could facilitate access to crucial information, such as accurate weather forecasts and soil condition data, thus contributing to smarter crop management.

The synergy between scientific and technological progress, coupled with improved agricultural practices, could pave the way for a revolution in African agriculture, not only ensuring food security but also promoting environmental sustainability and economic prosperity in agricultural communities.

[21] https://www.africa.com/the-africa-climate-summit-carbon-credits-legislation-and-african-unity-in-the-face-of-climate-change/
[22] https://www.weforum.org/agenda/2024/02/green-finance-can-unlock-africas-vast-potential-and-aid-the-global-fight-against-climate-change/
[23] https://www.afdb.org/sites/default/files/aeo_2023-chap2-en.pdf?te=1&nl=climate-forward&emc=edit_clim_20230617

Technological advancement in African agriculture is also hampered by inadequate communication regarding novel techniques. Outdated methodologies persist not solely due to a resistance to change, but also because several modern cultivation techniques are not well-known. On the other hand, the access to soil amendments like fertilizers is particularly difficult due to generally high prices and price volatility, partly due to conflicts and shortages in the production of fertilizers.[24]

The adoption of innovative technologies and methodologies in African agriculture is mainly pioneered by start-ups, that are rapidly emerging from the few but highly productive tech hubs across the continent. Numerous young companies, for instance, are developing dedicated land mapping techniques for precision farming to increase the efficiency of crop production or focus on simplifying the African agriculture value chain less, promoting a more direct connection between supply and demand. To foster the adoption of innovative techniques and enhance food security in the continent, it is crucial to improve the communication about the value of such techniques in the African context and encourage the sharing of best practices among farmers. Additionally, supporting, and incentivizing innovation in African start-ups can significantly enhance agricultural practices and promote sustainable development in the continent's agricultural sector.

One relevant aspect for the SADC agriculture activities is the use of seeds: the cycle of seed utilisation often increases the vulnerability of smallholder farmers. As a rule, the seed for the next planting season is obtained from the last harvest. Although this practise makes economic sense, it harbours considerable risks, especially when harvests are poor. In such years, the pressure to use the seed as an immediate food source, rather than reserving it for future sowing, can lead to a critical shortage when the next sowing is due. As a result, farmers are forced to buy seed on the market, where prices are often prohibitive for smallholders due to scarce supply and high demand.

The CS3 study on climate resilient seed varieties shows how these seeds have been developed to withstand the fluctuating climatic conditions that increasingly characterise the SADC agricultural landscape. Resistant seeds could lead to better yields in unfavourable weather conditions such as droughts or floods, which would stabilise the availability of seeds for the following planting seasons and reduce dependence on the market.

The work on climate resilient seeds carried out under CS3 is one of the forms of climate services developed under Focus Africa. This has created a strategic adaptation tool that could significantly change the agricultural landscape in Mozambique and other SADC countries. It offers the potential not only to protect food production against climatic uncertainties, but also to ensure the economic stability of smallholder farmers. By mitigating the risk of seed loss due to poor harvests and reducing the need to buy expensive market seed, these varieties could provide a buffer that allows farmers to maintain agricultural productivity and economic stability. Integrating climate resilient seeds into the agricultural practises of Mozambican smallholder farmers could contribute significantly to improving food security and economic stability across the region. Exploring market opportunities for these seeds is therefore not only a viable economic endeavour, but also a critical adaptation strategy in the face of global climate change.

Technological underdevelopment, high vulnerability to extreme weather events, and an underdeveloped agricultural market limit the agricultural potential of Africa. Despite its vast size and workforce employed, the productivity of the African agricultural sector remains low and is currently unable to meet local demand. Nonetheless, the African agricultural sector has an immense potential for growth and innovation, with capacity to attract international investments that could contribute not only to the continent's prosperity but also to the development of mutually beneficial economic ties with neighboring continents.

[24] World Bank Blogs, (2022). A transformed fertilizer market is needed in response to the food crisis in Africa, https://blogs.worldbank.org/voices/transformed-fertilizer-market-needed-response-food-crisis-africa

2.2 Energy

In recent years, the African energy sector has been gradually shifting from fossil fuels towards more sustainable renewable energy sources, following the global trend towards energy transition. At present, the market of fossil fuels is characterised by frequent merger and acquisition activities, leading to a more concentrated market. At the same time, large players of the fossil fuel market in the continent are increasingly divesting from oil and gas operations to invest in renewable energy sources.

However, the response of each country to the shift towards renewable energy is influenced by its degree of economic reliance on oil and gas revenues. For instance, some nations such as Nigeria and Angola could face significant challenges due to their heavy dependence on oil and gas production. On the other hand, countries which are less dependent on fossil fuels now have an opportunity to accelerate investments in renewable energy and carbon-offset initiatives, as in the case of Senegal and Côte d'Ivoire.[25]

Leveraging on the vast resource potential in wind, solar, hydro, and geothermal energy of the African continent, renewable energies have the potential to drive a significant improvement in GDP, employment, and human welfare across Africa, overcoming energy poverty and supporting economic transformation.

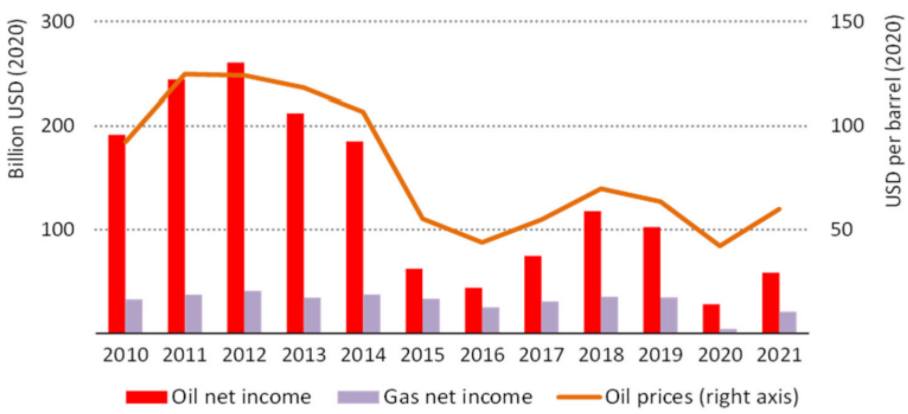


Figure 5: net income of fossil fuel producers and oil prices from 2010 to 2021 in USD[26]

Figure 5 shows the net income generated by oil and gas in African countries: it is evident that, in the last few years, the fossil fuel market in the continent is considerably less profitable and has been experiencing a phase of decline.

Figure 6 shows data on access to electricity and clean cooking facilities (i.e. energy-efficient, modern stoves with clean fuels) in Sub-Saharan Africa. Although progress has been made between 2010 and 2019, the energy market continues to face challenges in meeting demand. On the one hand, population growth has increased energy consumption, while on the other, outdated infrastructure is hampering efficient energy distribution. Together, these factors result in a lower number of people having access to energy, despite improvements in percentages.

Furthermore, **Africa is experiencing robust demographic growth, and currently, the majority of energy is consumed by households,** due to the low density of businesses. The overall to rise in the coming years, with estimates suggesting a 75% increase in energy demand by 2030[21].

[25] McKinsey, (2022). The future of African oil and gas: Positioning for the energy transition. https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-future-of-african-oil-and-gas-positioning-for-the-energy-transition#/

[26] IEA (2022), Africa Energy Outlook 2022, World Energy Outlook Special Report

This prospective steep increase in energy demand, could further accelerate investments in the African energy market, leveraging its potential in renewable energy generation. In addition to this, **South Africa is one of the world's largest exporters of minerals that are essential for the production of renewable energy technologies**, potentially placing it in a key role in the renewable energy production landscape.

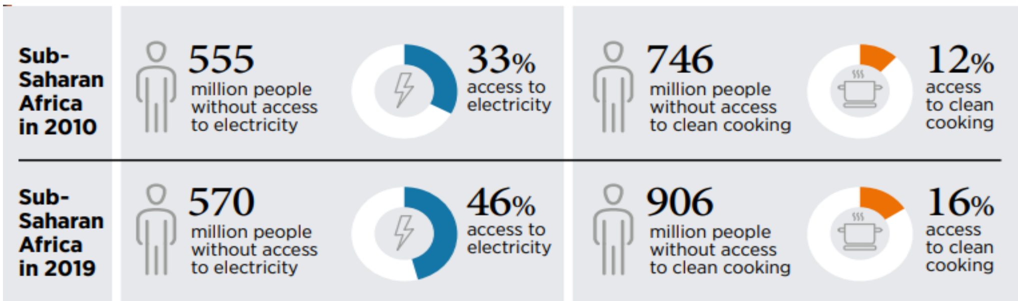


Figure 6: Access to electricity and to clean cooking (i.e. stoves powered by clean-burning fuels) in Sub-Saharan Africa, as total count, and percentage in 2010 and in 2019.[27]

Africa has an enormous potential in terms of renewable energies, especially in hydroelectric, solar, and wind energy. This suggests that future investments in this sector could increase significantly in the near future.

Interestingly, it seems that the African renewable energy sector is growing at least as rapidly as the rest of the world.

At present, hydropower plays a crucial role in Africa and has been utilised for a long time. The combined output of African hydropower plants is approximately 131 GW, which is only about 5% of the total potential hydroelectric capacity, estimated around 1750 GW.[28] Moreover, Africa boasts one of the highest annual solar irradiance levels globally, reaching 2119 kWh per square meter. The installation of solar capacity is growing at an annual rate of about 50% a pace comparable to that of the rest of the world (Figure 7), despite the market being less developed than in other continents.

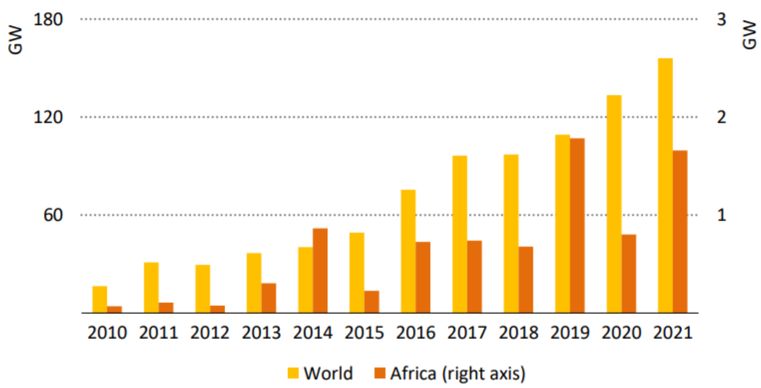


Figure 7: Yearly GWs of solar energy capacity installed globally and in Africa from 2010 to 2021[29]

[27] International Renewable Energy Agency (2022), Renewable Energy Market Analysis

[28] IRENA and AfDB (2022), Renewable Energy Market Analysis: Africa and Its Regions, International Renewable Energy Agency and African Development Bank, Abu Dhabi, and Abidjan.

[29] IEA (2022), Africa Energy Outlook 2022, World Energy Outlook Special Report

Wind energy production has also a high potential in Africa, as the current capacity still only taps into 0.2% of the continents' total technical potential capacity, which stands at more than 33000 GW[30].

Despite Africa's potential energy production capacity, investments in renewables over the past 20 years have been relatively low compared to the global trends. Of the $2.8 trillion invested globally, only 2% has reached Africa, with the majority concentrated in South Africa; and despite significant production capabilities, Africa still falls short of meeting its energy demand, as discussed earlier. South Africa alone has attracted over $22 billion in investments in this sector. From 2000 to 2019, the entire African continent attracted $109 billion in the energy sector, with $64 billion specifically in renewables. These investments are expected to increase significantly in the coming years, with a growing emphasis on renewables.

In Africa, most investments in renewable energy come from the public sector, as the region faces challenges in attracting private capital due to limited guarantees. While public funds are the primary source of investment, in the private sector energy producers take the lead.

	2000-2009	2010-2020	Cumulative 2000-20
Global	587 USD billion	2 254 USD billion	2 841 USD billion
Africa	4.8 USD billion (0.8% of global investment)	55 USD billion (2.4% of global investment)	60 USD billion (2% of global investment)
North Africa	1.9 USD billion	17.5 USD billion	
West Africa	0.5 USD billion	3.9 USD billion	
East Africa	2.0 USD billion	9.7 USD billion	
Central Africa	0	1.3 USD billion	
Southern Africa	0.3 USD billion	22.4 USD billion	

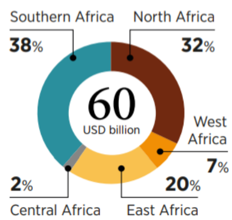


Figure 8 Global and African investments in renewable energy in the 2000-2009 and in the 2010-2020 decades[31]

On average, 65% of energy investments in Africa have been allocated to renewable sources, as evident from Figure 8. Economically more developed areas tend to invest more in renewables compared to less developed regions. Investments in fossil fuels have also seen an increase, with China contributing 51% of these investments mostly by private actors, and the rest coming from the International Bank for Reconstruction and Development and the Islamic Development Bank.

	Overall energy	Renewable energy	Renewable energy share (percentage)
Africa	54* USD billion	35.1 USD billion	65%
North Africa	13.3 USD billion	8.9 USD billion	67%
West Africa	10.0 USD billion	1.5 USD billion	15%
East Africa	3.9 USD billion	3.2 USD billion	82%
Central Africa	1.9 USD billion	0.2 USD billion	11%
Southern Africa	24.9 USD billion	21.3 USD billion	86%

Figure 9: Overall and the renewable focus investment in Africa divided by region in USD.[32]

[30] Global Wind Energy Council, (2023). Status of Wind in Africa. https://gwec.net/the-status-of-wind-in-africa-report/

[31] International Renewable Energy Agency (2022), Renewable Energy Market Analysis

[32] International Renewable Energy Agency (2022), Renewable Energy Market Analysis

The expected growth of the renewable energy market in Africa will also boost all complementary services and goods, such as climate services. Renewable energies are often highly dependent on climate factors, and accurate knowledge and forecasting of these factors are necessary to optimize the use of these energy sources.

Currently, in Europe, where the energy market is well-developed, mature, and has reached a balance between supply and demand, the total consumption is about 40,000 petajoules (PJ). In Africa, with a population soon to be double that of Europe, the current total energy demand is only 23,000 PJ.

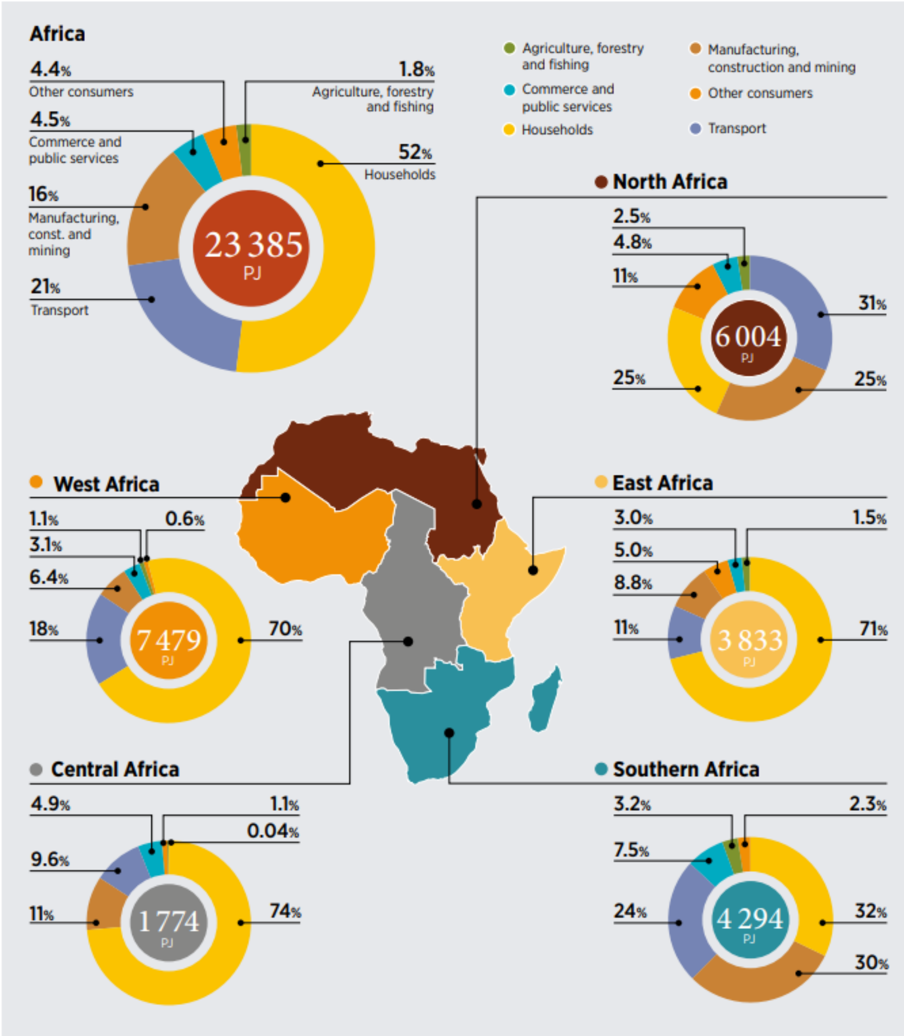


Figure 10: Energy consumption in Africa, overall and divided by region and by consumers in PJ[33]

The energy consumption in Africa and its distribution among different consumers is illustrated in Figure 10. It is important to highlight that, in regions with higher economic development, household consumption has a lower share and consumption by businesses increases.

The market for climate services for energy in Europe is estimated to be worth 600 million euros. As for the African market for climate services for energy, there are no in-depth studies available, likely due to the relative youth of this specific branch of the market in Africa. However, based on the data

[33] International Renewable Energy Agency (2022), Renewable Energy Market Analysis

we have for Europe[34], we can estimate that, **given the energy consumption in Africa, the market for climate services for energy has a potential value of at least 350 million euros**. This number is steadily growing and has enormous growth potential due to various factors, such as the current imbalance between energy demand and supply on the continent.

One crucial factor to consider is the prevalent energy poverty in many African regions. A significant portion of the population lacks access to reliable and affordable energy, which not only limits economic development but also exacerbates social inequalities. Climate services have the potential to address these issues by optimizing energy production and distribution, particularly from renewable sources, which can help reduce energy poverty.

Additionally, Africa's vast renewable energy resources, particularly in solar and wind, present the potential for some countries to eventually become net exporters of energy. As the continent invests in renewable energy infrastructure and as climate services help optimize these resources, African countries could not only meet their domestic energy needs but also supply surplus energy to neighboring regions or even international markets. This potential shift from energy poverty to energy abundance underscores the importance of developing a robust market for climate services that can support this transition, further boosting the market's growth prospects.

Countries in the SADC region have shown a strong commitment to integrating climate services into the energy sector, which is critical given the region's vulnerability to climate variability and its impact on energy resources. According to available data, an impressive 87% of SADC members actively provide climate services to the energy sector[35], focussing primarily on data services and climate monitoring. These services are essential for energy management and enable member countries to make informed decisions on energy production and distribution based on current climate conditions. This high adoption rate emphasises the recognition of the importance of climate data for maintaining energy stability and planning in the face of environmental change.

Despite this widespread implementation of basic climate services, there is a notable gap in the provision of more advanced climate projections and customised products. Only half of SADC members offer these specialised services to the energy sector. Customised climate services, which include detailed forecasts and model-based projections specifically for energy production and consumption, are critical for long-term strategic planning and risk management in the energy sector. These services enable utilities to anticipate potential disruptions and adapt their operations to mitigate the negative effects of future climatic conditions. The lack of these tailored solutions could hinder the region's ability to take full advantage of climate-resilient energy planning and optimisation.

Despite the fact that the African energy market has not yet reached full maturity and is characterized by a mismatch between supply and demand, Africa is experiencing a period of substantial demographic growth, which will not only increase the demand for energy and investments in the sector but will also boost the demand for employment.

At present, global market trends, including the abandonment of fossil fuels and the enhancement of renewable sources, are driving significant change. On the front of renewable energy, Africa holds vast potential, leveraging its favourable geography and natural resources necessary for the production of renewable energy. Given the current energy consumption in Africa, the market for climate services for energy could amount to more than 350 million euros.

2.3 Infrastructure

Infrastructures play a crucial role in providing essential services, facilitating the movement of people and goods, and supporting the economic and social development of a region.

[34] State of the energy union report 2023 (2023), European Commission

[35] The 2022 State of Climates Services Report (State of Climates Services Energy, 2022)

In 2017, the World Bank estimated that globally, the infrastructure deficit is about $15 trillion across 50 nations, and those in sub-Saharan Africa appear to be the least developed.

In 2015, Wentworth & Makokera reported that the majority of African states invest between 6% and 12% of their annual GDP in infrastructure. Despite these investments, Africa struggles to keep pace with the rest of the world, reflecting the low economic capacity of African national entities[36].

The lack of infrastructure is an extremely pervasive issue, as it often gives rise to other problems, such as the lack of energy or drinking water, a typical issue in rural areas that are often poorly connected to electrical grids, sewage systems, and water supply networks. Furthermore, the lack of transportation infrastructure, such as roads, railways, and ports, hinders the movement of people and the transportation of goods. The cost of transporting goods makes it challenging for sellers to maintain competitive prices and causes a substantial rise in prices for those who purchase, often preventing many African families from affording the essential food they need.

Table 3 shows an overview of the condition of the most important infrastructures in the African continent in terms of quantity of infrastructures, categorized by type, region, and income, at two distinct points over the past 30 years.

Table 3: Infrastructures, categorized by type, region, and income, between 90s and 00s[37]

		Region					Income		
		SSA	SA	MENA	LAC	EAP	LIC	LMC	UMC
Telecommunications									
Telecommunication Density	1990	3	7	38	55	17	3	5	55
Fixed and mobile telephones per 1,000 people (median)	2014	736	807	1,323	1,240	1,444	687	794	1605
Internet Density	2005	1.3	2.1	11.2	12	11.8	1.1	1.3	7.5
Number of users per 100 people (median)	2015	16.7	22	48.5	51.6	45	11.4	20.8	50.1
Fixed broadband	2005	0.0	0.1	0.4	0.8	1.4	0.0	0.0	0.3
Number of subscriptions per 100 people (median)	2015	0.2	1.2	4.3	8.1	9.1	0.2	0.1	5.3
Power									
Electricity generating capacity	1990	0.03	0.07	0.25	0.3	0.15	0.02	0.06	0.33
Megawatts per 1,000 people (median)	2012	0.04	0.15	0.4	0.43	0.84	0.03	0.06	0.72
Transport									
Road Density	1990	0.11	0.31	0.11	0.13	0.16	0.09	0.12	0.27
km of road per sq km of land area (median)	2011	0.09	0.48	0.14	0.19	0.47	0.09	0.08	1.04
Railroad Density	1990	0.004	0.021	0.005	0.003	0.006	0.005	0.002	0.010
km of road per sq km of land area (median)	2014	0.002	0.016	0.006	0.007	0.007	0.003	0.002	0.010

Sources: International Telecommunications Union's World Telecommunication/ICT indicators; World Bank, World Development indicators. International Energy Agency; World Energy Outlook; International Road Federation, World Road statistics
Note: EAP= East Asia and Pacific; LAC= Latin America and the Caribbean; MENA= Middle East and North Africa; SA= South Asia; SSA= Sub-Saharan Africa; LIC=low-income countries; LMC= lower-middle income countries; UMC= upper-middle income countries.

[36] Wentworth, L., & Makokera, C. (2015) Private sector participation in infrastructure for development, South African Journal of International Affairs, 22:3, 325-341, DOI: 10.1080/10220461.2015.1081568

[37] World Bank Group, (2018). Infrastructure Development in Sub-Saharan Africa. https://openknowledge.worldbank.org/entities/publication/e9b72ad5-9163-50b1-b0ac-4aa852b1ee0b

The growth of telecommunication infrastructure from 1990 to 2014 is surprisingly not matched by the growth of internet users. In Sub-Saharan Africa, the total number of internet users has indeed increased, but the number of users per 100 inhabitants remains relatively low.

The low internet penetration poses challenges for effective communication among African citizens and hinders international communication, particularly in the commercial sphere. This situation can have economic implications, as the continent may face difficulties in fully participating in global trade and establishing robust commercial relationships with more advanced economies.

Energy is one of the sectors that suffers the most from the lack of infrastructure, despite the incredible hydroelectric potential on the continent. Two-thirds of the global population without access to electricity live in Africa, with the majority of them residing in sub-Saharan Africa. The data shows that low-income and low-middle-income countries have experienced minimal growth in energy capacity from 1990 to 2012.

The underdevelopment of energy infrastructure in Sub-Saharan Africa is a well-known challenge, and the almost negligible growth in the period is a cause for concern, especially considering the continent's severe mismatch between energy demand and supply.

However, it's worth noting that significant progress has been made from 2012 onwards, particularly in the field of hydroelectric energy, which has seen substantial growth in recent years, also thanks to several international investments in the African electric market.

The trajectory of progress in the energy sector is promising, but addressing the energy deficit in Sub-Saharan Africa remains a complex challenge that necessitates sustained efforts and investments to meet the growing demands of the population, which have been estimated at approximately $500 billion[38].

Regarding transportation, the data indicates that, from 1990 to 2014, the transportation sector in Africa experienced a significant deterioration, both in terms of road and rail transport. Specifically, the situation seems to be more severe in the Sub-Saharan Africa region.

Low-income and medium-low-income countries, on average, have either maintained similar levels or even worsened conditions in road and rail transport during the period under consideration. This highlights a systemic challenge in improving transportation infrastructure, with particular relevance to Sub-Saharan Africa. The need for investment in transportation infrastructure has been estimated at about $340 billion.

Table 4 on the other hand, shows that the only significant improvement between 1990 and 2014 is in the field of telecommunications. Power losses have worsened in sub-Saharan Africa, increasing from 15.5% to 16.7%, and generally, in low-income countries, the situation in this regard has deteriorated. There is no significant improvement either in the quality of transportation, nor in terms of roads, where it has even worsened in sub-Saharan Africa, nor in the railway sector.

Table 3 and Table 4 not only reveal that the African continent lags behind in terms of infrastructure, but also highlights how little it has grown compared to other developing continents between 1990 and 2015. The most critical point seems to be that of roads, which not only fail to increase and improve, but the few existing ones deteriorate, making the movement of people and goods even more complex, lengthy, and costly. However, it is important to note that significant investments have been made in the last 10 years, especially from China. Nevertheless, the continent still requires substantial financial resources, much more than what African public institutions can currently afford. Therefore, Africa will continue to depend on external investments in the path towards urbanization.

A portion of these investments will need to be dedicated to adapting infrastructure to climate changes and increasingly frequent extreme events, including climate services, which have become

[38] McKinsey (2015). Brighter Africa: The growth potential of the sub-Saharan electricity sector. https://www.icafrica.org/fileadmin/documents/Knowledge/Energy/McKensey-Brighter_Africa_The_growth_potential_of_the_sub-Saharan_electricity_sector.pdf

essential tools for constructing durable and secure infrastructure. The growth of the climate services market for infrastructure will be directly linked to the expansion of the infrastructure market itself.

In the SADC region, the integration of climate services into the infrastructure sector is developing visibly, even if the picture is mixed. Available data indicates that a large majority, 81%, of SADC members provide climate services to the infrastructure sector, with a focus on basic data services. These services are essential in the initial stages of infrastructure planning and development as they help to ensure that structures are designed with current climatic conditions in mind. Such integration is crucial to improve the resilience of infrastructure to the immediate effects of climate variability.

Table 4: Quality of infrastructures, categorized by type, region, and income, between 90s and 00s[39]

Table 3. Infrastructure quality trends

		Region					Income		
		SSA	SA	MENA	LAC	EAP	LIC	LMC	UMC
Telecommunications									
Internet Traffic	2000	97	117	127	171	113	102	74	70
Bits per second per internet user (median)	2015	4,370	8,816	27,524	43,394	35,764	4,107	3,424	33,896
Power									
Power losses	1990	15.5	19.4	10.2	15.4	10.1	15.5	22.5	9.0
% of output (median)	2014	16.7	17.7	13.8	13.6	6.8	16.9	11.8	8.9
Transport									
Paved roads	1990	17	45	54	18	58	17.0	16.5	17.0
Share of paved roads (%)	2010	16	53	79	24	71	18.0	10	*
WEF - Road quality	2006	2.41	2.98	4.18	3.06	4.52	2.42	2.22	4.53
Score (0, worst - 7, best)	2015	3.34	3.95	3.97	3.57	4.53	3.31	3.23	4.78
WEF - Railroad quality	2009	1.93	3.24	3.24	1.53	3.57	1.87	1.97	3.54
Score (0, worst - 7, best)	2015	2.23	3.88	2.99	1.89	4.31	2.14	2.66	3.05

Sources: International Telecommunications Union's World Telecommunication/ICT indicators; World Bank, World Development indicators. World Economic Forum, Global competitiveness report; International Road Federation, World Road statistics
Note: EAP= East Asia and Pacific; LAC= Latin America and the Caribbean; MENA= Middle East and North Africa; SA= South Asia; SSA= Sub-Saharan Africa; LIC=low-income countries; LMC= lower-middle income countries; UMC= upper-middle income countries.

Despite the widespread provision of basic data services, there are significant gaps in broader climate services in the SADC region, which are critical to the long-term sustainability and efficiency of infrastructure projects. More than half of SADC members report that they do not provide advanced climate services such as climate monitoring, analysis and diagnostics, as well as climate forecasting, projections and customised products. These services are critical to ongoing infrastructure management and adaptation strategies and allow stakeholders to anticipate and respond to future climate impacts. The lack of these services could lead to infrastructure vulnerability, resulting in higher maintenance costs, shorter infrastructure lifetimes and a higher risk of failure during unfavourable climate events.

To address these critical gaps, there is an urgent need to improve the scope and depth of climate services in the infrastructure sector across the SADC region. The development of comprehensive climate services that include detailed monitoring, forecast modelling and tailored diagnostics can enable infrastructure planners and operators to make more informed decisions that take into account long-term climate scenarios. Strengthening these services not only increases the resilience of infrastructure to future climate conditions, but also supports the Sustainable Development Goals by ensuring that infrastructure investments are both climate-aware and economically viable. This

[39] Infrastructure Development in Sub-Saharan Africa, World Bank Group

strategic enhancement of climate services could promote more robust infrastructure development, which is critical to the region's economic stability and growth.

The Sub-Saharan Africa (SSA) region has significant potential to enhance its infrastructure development through increased Private Participation in Infrastructure (PPI) commitments. On average, SSA could raise PPI commitments **by an additional 0.8 percentage points of GDP, with certain countries like Gabon, Liberia, Madagascar, Mauritania, and Rwanda potentially increasing this figure to more than 1.5 percentage points of GDP**[40]. This potential increase highlights the critical need for comprehensive climate services that support infrastructure projects, ensuring their resilience and sustainability amidst changing climate conditions.

Climate services for infrastructure play a pivotal role in identifying vulnerabilities, planning adaptive strategies, and optimizing the design and maintenance of infrastructure projects. In 2021 and 2022, 53 cities across 22 African countries disclosed a total of 181 climate projects through CDP-ICLEI Track[41], demonstrating a growing recognition of the importance of integrating climate considerations into urban infrastructure planning. These projects reflect the diverse needs and opportunities for infrastructure climate services, ranging from flood risk management and resilient transportation networks to sustainable water supply systems and energy-efficient buildings.

Given the current infrastructure development needs and the increasing focus on climate resilience in Africa, the market for climate services for infrastructure holds substantial potential. Leveraging the rising private investment in infrastructure and the growing number of climate projects, it is estimated that the market for infrastructure climate services in Africa could amount to more than 400 million euros annually. This estimation underscores the critical economic opportunity presented by climate services, which can attract investment, enhance the longevity and reliability of infrastructure assets, and contribute to sustainable development across the continent.

Africa not only has the opportunity to reach the levels of urbanization and infrastructure density already achieved by developed continents but also to do so using more modern methodologies. Furthermore, it can construct infrastructure not only to withstand events related to climate variability but also to counteract the worsening of climate change. This involves optimizing the construction of infrastructure in consideration of this variable, an approach that, especially in the older areas of the United States and Europe, has not been fully implemented.

2.4 Climate service Actors

2.4.1 Introduction

According to the World Meteorological Organization (WMO), the climate service value chain includes observing networks, service production, capacity development, and user interface mechanisms. However, when focusing on the commercial or economic value chain of climate services, we have to define how different players act within the climate service production.

In this context, the production of climate services involves several key actors and processes. Final users, such as farmers and energy managers, rely on accurate climate information to make informed decisions. International funds can provide financial support to governments, enabling them to initiate and develop climate service projects. Public projects and capacity-building initiatives, often supported by these funds, play a crucial role in enhancing the infrastructure and knowledge base needed for effective climate services. Additionally, private actors contribute by partnering with governments to develop and implement these services.

Each of these actors are essential in creating a robust climate service ecosystem that supports sustainable development and resilience to climate change.

[40] https://www.ifc.org/content/dam/ifc/doc/2023/working-paper-infrastructure-in-africa.pdf
[41] https://www.cdp.net/en/research/global-reports/africa-infrastructure-projects-in-need-of-funding-2021-2022

Considering the production of climate services in Africa, governments and their National Meteorological Services play a crucial role, through participation in projects, the development of skills, and collaboration with private companies. By doing so, they can enhance their capacities to deliver key climate services, tackling the challenges posed by climate variability across the continent.

Private companies, such as established climate services providers, can collaborate with National Meteorological Services entities for the development and provision of climate services to address specific problems.

The role of National Meteorological Services is to act as actual providers of climate services or intermediaries through which services can reach the population, overcoming economic or logistical obstacles. Their interest is to ensure the development of the state by providing essential services for the well-being of the population.

National and international fund can be used for innovating and improving existing Climate Services. These funds enable governments to have the economic resources needed to collaborate with other entities or develop the skills required to develop such new services. The funds support various projects related to the development of the economy of an African state, recognizing that economic growth and the formation of a solid market are crucial for the prospects of the area. The existence of these funds is justified by the fact that the long-term return on investment, in terms of market growth and social well-being, is very high and will ensure a fertile ground for various investments in the future.

The combination of these forces, including governments, holders of expertise in the field, and funds, leads to the climate services that are tailored for tackling the climate challenges that Africa is facing.

2.4.2 Actors of the value chain

At the heart of the climate services value chain in Africa lie the governments with their National Meteorological Services. To ensure access to innovative climate services for economically disadvantaged communities, governments can exploit strategies such as partnering with international institutions, collaborating with private companies, and implementing capacity-building initiatives.

Governments are capable of acquiring and subsequently offering these services to those in need, thereby addressing issues such as food security, water security, lack of resilient infrastructure, and poor energy management.

To implement and ensure the provision of climate services, governments can adopt various strategic approaches

1. **Collaborating with regional and international institutions**, that possess the resources to provide the necessary funds or infrastructure to improve existing climate services. The National Meteorological service's role in such collaborations often involves supplying the requisite data to service providers and facilitating infrastructure development, or permissions for service creation. Moreover, they have a strong interest in establishing strategic collaborations with both public and private entities to develop innovative products.
2. **Capacity building, co-production and co-creation with the final users and the sector's representatives.** This step is crucial for the development of internal skills and resources for the independent production and management of climate services. This approach can yield long-term benefits, fostering greater sustainability and operational autonomy. While capacity building may be complex and time-consuming, it establishes a robust foundation for addressing intricate issues within communities.
3. **Collaboration with private companies** is another relevant process to improve climate services. Numerous companies offer climate services in Africa, as detailed in this chapter. However, direct beneficiaries of climate services, such as farmers, may struggle to afford them.

Therefore, governments can support farmers by partnering with private companies, negotiating economic agreements to enable those in need to benefit from the services.

Irrespective of the chosen strategy, it's crucial to emphasize the importance of funding for successful development of innovative climate services. Funds play a vital role in assisting governments in this aspect, **providing the necessary liquidity for the creation and the update of innovative climate services.**

A fund serves as a collective investment vehicle, pooling money from various sources, including institutional investors, companies, or nations, to finance a specific purpose.

Funds can be both public and private, national or international, thematic, or broadly oriented, offering financial support for specific projects or diverse situations. Funds typically provide three types of financial products: **grants**, a financial contribution provided by governments, foundations, and corporations, often designed for research, community development, education or initiatives aligning with the grantor's objectives; **loans**, money borrowed with the agreement of repayment, often without interest and guaranteed by a third party; and **equity**, representing ownership of a company exchanged for liquidity required to complete a project. Funds not only assist governments economically in providing climate services but also serve as valuable partners in project development, facilitating collaboration among different project components and playing a role in project management. Bringing all these pieces together forms a cohesive chain, as illustrated in the diagram below.

2.4.2.1 Public actors

Public actors encompass institutions, both domestic and international, that collaborate with other entities to provide and deliver climate services. An example of such actors is the National Meteorological and hydrological services.

National Meteorological authorities, government agencies or organizations, are entrusted with monitoring and forecasting weather and climate conditions within specific countries or regions. They hold a pivotal role in providing accurate weather and climate information. The primary thrust of African national meteorological authorities is to generate weather forecasts for early warnings purposes. Furthermore, they are dedicated to providing comprehensive weather and climate data tailored to various socio-economic sectors, including agriculture, water resources and infrastructures. Moreover, public institutions are engaged in research and development initiatives aimed at enhancing the quality of weather and climate data for the benefit of the general public.

Additionally, government and public institutions are responsible for establishing and maintaining networks of meteorological stations.

In this frameworks, international institutions, NGO, private companies and other mixed partnership with a broader role, aid countries in adapting to climate variability and fostering resilience. Importantly, they serve as crucial nodes for connectivity. They often serve as convergence points of significant international projects, facilitating collaboration among nations facing similar challenges. Beyond offering technical support, these institutions provide coordination and a solid base for fostering collaborations.

Understanding the entities delivering climate services is instrumental in identifying potential collaborations opportunities, establishing relationships with African institutions, and discerning effective outreach strategies for service utilization.

A diverse array of public institutions is delineated in Table 5 below.

Table 5 Public Institutions

Country	Name
Tanzania	Tanzania Meteorological Authority (TMA)
Mozambique	The Mozambique National Institute of Meteorology (INAM)
Malawi	DCCMS (under the Ministry of Natural Resources and Climate change)
Mauritius	The Mauritius Meteorological Services (MMS)
South Africa	South African Weather Service (SAWS)
South Africa	Agricultural Research Council
South Africa	Council for Scientific and Industrial Research
South Africa	South African Earth Observation Network (SAEON)

- The **Tanzania Meteorological Authority**, focuses on providing quality, reliable and effective weather, and climate services to contribute to the safety, socio-economic well-being, and national development agenda. Some of its functions include implementing national climate-related policies, coordinating meteorological activities, providing weather and climate services for safety of life, property, and various users, collaborating with other institutions and authorities involved in meteorology and related fields for training, studies, research, environment, and climate variability and change.
- Additionally, TMA archives all meteorological data collected from meteorological stations nationwide, using it to address climate variability-related issues in the country, and generating forecasts for aviation, agriculture, and extreme events alerts.
- The TMA is also one of Focus Africa's participants, playing a crucial role as a service provider in case study 4, 5 and 6, focusing on food security, energy, and infrastructure in Tanzania.
- The **Mozambique National Institute of Meteorology,** a public institution under the Ministry for Transportation and Communications (MTC), aims to provide meteorological information necessary to ensure the sustainable development of the national economy and mitigating negative climate-related impacts on human well-being and the natural environment, fulfilling national and international responsibilities in data sharing.
- The institute provides some essential services such as weather and meteorological forecasts for: public, navy, aeronautics, and other related services; seasonal climate forecast; production and dissemination of the monthly meteorological bulletins.
- In Malawi, the **Department of Climate Change and Meteorological services,** strives to provide high quality climate services to meet national, regional, and international obligations by disseminating accurate and up-to-date data and information for socio-economic development. Objectives include monitoring, analysing, and predicting weather and climate; providing weather and climate data for various sectors such as aviation, agriculture, water resources; and conducting research and development to improve the quality of weather and climate data for the public. The department serves a wide range of sectors including environment, transportation, water resources, construction industry, energy, and disaster preparedness. Moreover, it provides a crucial role in the support of the National Early Warning Systems and Food Security; crop weather insurance; crop protection and management; irrigation and climate risk management.

- The **Mauritius Meteorological services** (MMS), operating under the Ministry of Local Government and Disaster Risk Management, offers a wide range of weather, climate, and extreme event-related services. Regarding climate services, MMS provides information and data they stored over the last 50 years; climate services for water management including forecasts tailored for agriculture, and monthly afro-climate bulletins.
- The **South African Weather Service,** part of the Department of Forestry, Fisheries, and the Environment, aims to. provide meteorological solutions for improved quality of life for all in South Africa. It offers various climate information and services, including historical data dating back to 1836, recent climate information, annual climate reports, extreme weather indices, regional weather reports, and a drought monitoring desk. The service also provides online weather products such as WeatherSmart and HydroNET, and real-time lightning information.
- The **Agricultural Research Council's** mission is to be a premier science institution conducting research, developing human capital, and fostering innovation to support and develop the agricultural sector. It provides weather and climate observation data, publishing the Umlindi/Watchman newsletter, and offers agrometeorology and geoinformatics services.
- The **Council for Scientific and Industrial Research** is a scientific and technology research organization in South Africa. Its mission is to research, develop, localize, and diffuse technologies to accelerate socio economic prosperity in South Africa. It provides seasonal climate forecasts; the GreenBook for climate change adaptation planning, wide area monitoring and information systems, and an advanced fire information system.
- The **South African Environmental Observation Network**, established in 2002, is an environmental research platform, operating in the field of data modelling and management, research, decision support and education. It hosts the South African Risk and Vulnerability Atlas, an open access platform uniting data to solve complex and interconnected problems.

After reviewing the service providers, understanding the allocation of resources to these projects is crucial.

These sources primarily come from public (and sometimes private) funds, essential for building climate resilience, particularly in SADC countries where general poverty and very low GDPs make them vulnerable to climate change.

In Table 6 we present list of the most relevant funds and the associated institution which provides these funds.

Table 6 List of some relevant funds

Fund name
Adaptation Fund
CDSF (ClimDev (Climate for Development in Africa) Special Fund) from the African Development Bank
Climate Investment Funds
European Bank for Reconstruction and Development
Global Environment Facility
Green Climate Fund
National/regional development funds
Special Climate Change Fund (SCCF)
World Bank

- The **Adaptation Fund, established in 2007,** is an international fund dedicated to financing projects and programs aimed at assisting developing countries in adapting to climate change-related challenges. Since 2010, it has founded 160 projects and programmes with over 1 billion dollars. It has the potential to fund projects in agriculture, water access preservation, and infrastructure. Additionally, it can collaborate with CIS programmes through funding adaptive measures and risk prevention.
- The **African development bank** has multiple funds targeting climate and relate activities. It interacts with CIS programmes either through direct funding or project establishment. Its mission is to foster sustainable economic development and social progress in its regional member countries, thereby contributing to poverty reduction. Its goals include ensuring water and sanitation access to all, providing affordable and sustainable energy, building resilient infrastructure, promoting inclusive industrialization, ending hunger, achieving food security, and promoting sustainable agriculture. One of this funds is The **ClimDev Special Fund,** established by the African Development Bank in 2009, invests in enhancing Africa's capacity to generate, share and utilize high-quality climate and weather information. Through this fund the bank is investing 36 million euros to modernize Africa's climate and weather observation networks, thereby providing timely and reliable weather and climate forecasts. Similarly, the fund interacts with CIS programmes through direct funding or certified project allocation. This fund is not anymore active, but similar funding schemes are available at the African development bank.
- The **Climate Investment Funds, operational since 2008, support** low and middle-income countries in adapting to and mitigating climate change. It has supported more than 370 projects in 72 countries, by collaborating with governments, the private sector, and local communities. By Providing funds to reduce investor risk, pilot new technologies, scale up solutions, and mobilize private sector capital, it's playing a crucial role. Currently co-financing, on average, with a rate of 1:8.3. It offers various types of funds, including the **Clean Technology Fund** and the **Strategic Climate Fund, each with its unique focus and financial instruments.**
- The **European Bank for Reconstruction and Development (EBRD)** focuses on agribusiness, infrastructure, and transport, offering various financial products like loans, equity investments, and guarantees. Projects founded by EBRD must demonstrate profitability, significant equity contributions from sponsors, benefits to the local economy, and adherence to environmental standards. A dedicated team of specialists oversees project finance, regional expertise, and environmental compliance.
- The **Global Environment Facility** (GEF) addresses biodiversity loss, climate change, pollution, and land and ocean health. Over three decades, it has provided more than 23 billion dollars, mobilizing 129 billion in co-financing for more than 5000 regional projects. It interacts with CIS through application for "impact programs" focusing on food systems, land use and restoration, sustainable cities, and forest management, with a requirement for national management.
- **National and regional development funds support** economic, social, and territorial cohesion, interacting with CIS through institutional management or direct fundings.
- The **Special Climate Change Fund, established** in 2001, assists countries under the United Nation Framework Convention for Climate Change (UNFCCC) in adapting to climate change impacts by fostering innovation, mainstreaming adaptation, and creating enabling conditions. Its cumulative pledge at the end of 2020 was approximately 375 million USD, allocated to fund CIS through certified project allocation.
- The **World Bank** provides a very wide range of financial products and technical assistance in various development areas. Financing options include **Investment project** financing

governments for creating physical and social infrastructure to reduce poverty and promote sustainable development; **Development Policy Financing, Program-for-Result.**

These funds play a crucial role in providing climate information and climate services to countries, ensuring food security, proper water and energy management, and resilient infrastructure. Understanding these funds and their mechanisms is essential for national institutions and communities facing financial challenges. Effective collaboration with public and private fund providers is key for governments to achieve their goals.

2.4.2.2 Private actors

In the climate services market, private actors encompass all private companies dedicated to providing such services or supplying crucial tools in support of them. These companies may be based in Africa or abroad, and their collaboration with governments often plays a pivotal role.

Not all companies involved in these collaborations are directly engaged in the provision of climate services. Sometimes, collaboration between companies and governments arises from shared interests. For instance, insurance companies collaborate with governments to help citizens protect themselves from risks related to climate variability. Similarly, the consulting sector commits to working with governments to assist African businesses in managing and reducing risks.

Many of these companies based in Africa emerge thanks to incentives provided by the states themselves, often through innovation hubs. These centres act as true hubs for networking and idea development, serving as catalysts for transforming new ideas into vital businesses for the development of the region. For instance, in Burkina Faso, a private company that offers agrometeorological data started to share climate updates via SMS as part of the BRACED program[42]. Whether this indicates a broader shift in the climate services field is still uncertain, as the emergence of such players varies from country to country. In Ethiopia, for example, government policies have not encouraged significant involvement from the private sector in the climate services sector[43].

A useful clustering method for private climate service providers could be the one find in the Market Research for Climate Services Observatory, which categorizes private service providers into three categories:

- Weather and climate information providers: providing forecasts and other commercial services.
- Software providers: those who develop specific software solutions for analyses.
- Infrastructure providers: companies that provide the infrastructure necessary to develop climate services. The production of infrastructure is largely state controlled in the majority of the SADC states; hence, the last category is almost entirely populated by public institutions.

In the landscape of private actors, some of them are summarized below.

Ignitia
Ignitia is a deep-tech company specialized in the development of models tailored for tropical climates. With comprehensive coverage across emerging markets, Ignitia assists farmers in making crucial agribusiness decisions, including crop selection, and soil preparation. In the long term, Ignitia provides a range of forecasts, including rainfall quantity and air temperature. By offering tailored climate data, Ignitia empowers African farmers to effectively

[42] Visman E, Audia C et al (2017) Developing decision-relevant climate information and supporting its appropriate application. Learning Paper #6, for the Christian Aid-led BRACED consortia. King's College London, London

[43] Harvey, B., Jones, L., Cochrane, L. et al. The evolving landscape of climate services in sub-Saharan Africa: What roles have NGOs played?. Climatic Change 157, 81–98 (2019). https://doi.org/10.1007/s10584-019-02410-z

manage their agricultural operations and overcome business challenges.

Link: https://ignitia.se/en/

Location: Sweden and Ghana

Weather impact
The company specializes in agriculture and its susceptibility to climate variability. It conducts climate analyses across different scales, projecting climate risks up to 50 years into the future. Operating across numerous African countries, it delivers location-specific weather forecasts via SMS. These forecasts include details on rainfall amounts, probabilities, and air temperature up to four days in advance. heir Weather4Farmers app facilitates digitalization for African farmers, providing essential access to weather and climate forecast. **Link:** https://www.weatherimpact.com/ **Location:** Netherlands

Amigo S.r.l.
Amigo specializes in developing customized solutions for insurance, agriculture, energy, and infrastructure sectors, enabling clients to assess, manage and forecast their climate-related risks effectively. Amigo's diverse range of products caters to various sectors and scenarios. In agriculture, Amigo offers NUA, which evaluates exposure to climate-related events. Additionally, it provides solutions such as SnowPower for forecasting hydropower generation and ARIA, for wind forecasting. **Link:** https: //amigoclimate.com/ **Location:** Italy

Insight Climate Service
ICS utilizes climate data to forecast the impact of climate on its clients' business and performance. They offer a range of forecasts, including seasonal predictions of water availability to enhance resource management. Their services also encompass the analysis of historical events and seasonal predictions to optimize future crop planning, as well as projections to enhance renewable energy production. **Link:** https://www.inclimateservice.com/ **Location:** Italy

Predictia
Predictia offers data management and modelling solutions for scientific challenges, particularly those related to climate and health. They specialize in providing seasonal predictions, which are valuable for projecting output levels in the renewable energy sector, expected crop yields for agriculture and many other applications. Additionally, they offer regional climate change projections to support adaptation and mitigation measures. Their flagship product, Climadjust, is a web service that enables users to apply bias adjustment techniques to climate projections. **Link:** https://predictia.es/en/home **Location:** Spain

Meteosim
Meteosim is a global leader in meteorological and environmental services, operating in over 45 countries. Specializing in advanced numerical modeling, Meteosim provides tailored solutions for sectors sensitive to weather and climate conditions. Meteosim provides Climate Change Adaptation strategies for agriculture, water management, energy, and infrastructure; Risk Management solutions that identify atmospheric hazards and anticipate environmental risks; Air Quality Management services to assess pollution episodes and improve air quality; and Environmental Monitoring systems that integrate sensor networks to provide early warnings for environmental alerts. Link: Meteosim Website **Location:** Spain

Amigo, ICS, and Predictia offer seasonal forecasts-based products, which fill the gap between short-term weather forecasts, typically extending up to two weeks, and long-term climate predictions, which cover a period starting from one year onwards.

Seasonal forecasts share similarities to climate forecasts and aim to provide estimates of essential parameters. They are designed to capture and describe broader climate patterns and anomalies such as the likelihood of above-normal rainfall or temperature.

Sust
Sust is a company providing climate risk data, analytics, and APIs, particularly focused on AI use. Their products consist in provisioning of interactive dashboards that a) provide instant climate risk insights b) transform complex data into actionable business intelligence c) provide economic impact of climate change d) zoom in to understand risks of specific assets, infrastructure, and networks, globally. **link:** https://www.sustglobal.com/ **Location:** USA

Jupiter
Jupiter has the aim to turn climate science into actionable data, helping businesses looking to strengthen their climate resilience by mitigating and adapting to climate risk. In the list of Jupiter's customers there are many companies within the Global 2000, the US Department of Defense and various public sector authorities around the world. Their main product is ClimateScore Global, a portfolio and asset-level physical risk analysis, that delivers decision-ready climate risk analytics providing data in a flexible way and clarifying the economic impact of the risk found. **Link:** https://www.jupiterintel.com/ **Location:** USA

Climate Scale
CS provide climate data, analysis, reporting and guidance to quantify climate physical risks for wind farms, solar plants, and other renewable energies technologies. They have different product lines. Report provides a high-level summary of climate risks at project portfolio level; Series provide

access to high resolution downscaled daily time series for multiple climate variables, spanning from 2000 to 2099; Maps provides high resolution maps of projected changes for multiple sector specific climate variables, horizon, and emission scenarios **Link:** https://www.climatescale.com/ **Location:** Belgium

Climate X
Climate X helps the organizations to build resilience to the impact of climate change by quantifying, at an asset level, the probability and severity of weather events decades before they happen. Their main product is Spectra, a location-specific and transition risk rating as well as climate-adjusted VaR forecasts between now and 2100 under RCP/SSP pathways to map existing and future risks. **Link:** https://www.climate-x.com/ **Location:** United Kingdom

Sust, **Jupiter**, **Climate Scale** and **Climate X** develop **climate scenarios-based products** that take into account potential future conditions and events. These products reflect predictions about the future of the climate, incorporating factors such as natural variability and emissions patterns.

Hypermeteo
Hypermeteo is a start-up specializing in collecting and processing weather data from global observation datasets. It consolidates this information into an independent database offering weather data for various applications, The company provide several data types, including historical datasets, near-real time observations, nowcasting forecasts and climate scenarios **Link:** https://www.hypermeteo.com/ **Location:** Italy

Visual Crossing
Visual Crossing is a provider of weather data and enterprise analysis tools. They provide a wide variety of products: weather data, weather forecasts, climate summaries, historical data in particular they are specialized in providing weather measures such as solar radiation, degree days, and weather alerts. **Link:** https://www.visualcrossing.com/ **Location:** USA

MeteoMatics
MeteoMatics provides weather information to improve operational processes and manage extreme weather situations better. The weather API is their main product, which provides standard parameters; sun radiation parameters; satellite parameters; radar parameters; climate change parameters; weather warnings; power forecast parameters and others. **Link:** https://www.meteomatics.com/

Location: Switzerland

Hypermeteo, **Visual Crossing** and **MeteoMatics** provide **weather forecasts**, predicting the condition of the atmosphere for a given location and time in a short temporal range. Weather forecasts are made by collecting quantitative data about the current state of the atmosphere, land, and ocean projected to show how the atmosphere will change at a given place.

Radarmeteo
Radarmeteo develop and supply ISO 9001- certified platforms, applications, data and solutions for weather and climate monitoring and operational support. Radarmeteo provides a very wide range of products, here some examples: Meteotrigger, a service that provides meteorological data report or statement for ex post analysis of events on each are of the national territory; Hydrometeorological Alert, a service focused on forecasting heavy rains for customers who need to know the occurrence of strong storms of heavy rainfall in advance. **Link:** https://www.radarmeteo.com/ **Location:** Italy

EOS data analytics
EOS is a global provider of satellite analytics solutions in agriculture and forestry with the mission to harness the power of satellite technologies to provide businesses. EOS products integrate satellite imagery and proprietary AI-powered algorithms to drive business decisions-making and endorse sustainable practices. Some examples of their products are: EOSDA Crop Monitoring, an agriculture platform for cost-effective and sustainable crop monitoring and farm management; the LandViewer, a catalog of satellite imagery and tool for processing satellite data. **Link:** https://eos.com/ **Location:** USA

Radarmeteo and **EOS** provide mainly meteorological observations, recording state of the atmosphere measuring quantities such as temperature, rainfall, pressure, wind, and humidity, fundamental for further elaborations done in forecasting processes.

2.4.2.3 Insurance sector

In the public-private partnership context, the insurance sector plays a crucial role. **States and insurance companies often collaborate, not only in Africa, to reduce risks for citizens and businesses**. Many insurance companies have, in recent years, focused on providing climate risk assessments. This paragraph lists and explores some of them.

SwissRe is one of the world's leading providers of reinsurance, insurance, and other risk transfer services, and it has been analysing climate change since 1979.

SwissRe focuses on three primary areas of climate change risk:

Natural catastrophes and protection gap: natural disasters are, most of the time, not covered by insurance, so SwissRe protects communities and businesses against financial fallout from natural catastrophes.

Transition to a net-zero economy and renewable energy: they offer innovative solutions by minimizing the risks associated with renewable energy and infrastructure projects.

Public-private partnerships enhance partnership between public and private sectors to resolve major challenges, often too big to overcome alone.

SwissRe provides risk mitigation tools for almost all the region worldwide, concerning flood risk, tropical cyclone risk, earthquake rapid response.

The company's main product for the risk mitigation in reinsurance market, is **CatNet**, a global, web-based natural hazard analysis and mapping tool, which enables clients to assess and visualize their natural hazard exposure for any location in the world.

The French group **AXA,** one of the biggest insurance companies in the world, in 2016 entered the African specialty insurance market in partnership with Lloyd's specialty insurance group. Targeting a rapidly expanding market, with a dedicated venture, the "AXA Africa Specialty Risks", dedicated to cover specialty insurance lines in Africa, covering business such as political risks, energy, and infrastructure.

In 2018, the AXA group founded **AXA Climate**, an AXA group entity committed to addressing climate and environmental adaptation challenges, serving this mission through 4 business lines:

1. **Insurance**, covering climate related disasters with a fast financial recovery with specific products for agriculture.
2. **Finance**, unlocking investments for projects that accelerate and scale environmental transition.
3. **Training**, enabling companies to upskill through learning experiences helping companies to succeed in the sustainable transition.
4. **Consulting**, suggesting adaptation measures.

The main solution AXA Climate provides is AXA Altitude, a decision-making support tool, which provides quantitative and qualitative risk summaries or risk forecast for aiding business decisions.

AXA Climate publishes articles covering various topics, like parametric insurance and business but also science topics like agriculture, adaptation, climate change, natural disasters, and nature in general.

Allianz have developed a number of adaptation-related products:

1. Insurance: they placed 1 billion USD to mitigate the risk of severe, regional floods.
2. Micro–insurance: they provide tailor made packages specifically for people who live near coasts and work in fishing, agriculture, and plantations in are developing many projects aiding customers affected by the damage of a climate disaster.
3. Eco Trends Fund: Funds done to invest in renewable energy, environmental protection, and water enhancement projects, with a 20% of the fund invested in emerging economies.

The African insurance market is steadily increasing with an actual size of 87 billion US dollars, with life insurance leading the market.

Climate related insurance is not that popular on African insurance companies' catalogue, these indeed, as we learned above, are mostly provided by international insurance companies.

Other big insurance companies with interest in climate related risk but not already committed like AXA or Allianz are the American Prudential Finance, or the Italian Generali.

2.4.2.4 Consultancy sector

Similar to insurance agencies, consulting firms also frequently collaborate with governments, both in terms of risk assessment and assistance in capacity building. Consulting firms can provide methods and knowledge to governments, as well as managerial advice, helping them achieve a certain level of autonomy.

Ernst & Young, with the climate and decarbonization services help businesses respond to the physical and transition risks associated with climate change, as well as advise on how to operate in new markets and regulatory environments related to carbon and renewable energy. EY can help companies in identifying potential climate risk and opportunities, develop and implement climate strategy and communicate performance with stakeholders. Main activities are related to carbon foot printing, climate risk and opportunities assessments and climate change scenario analysis and stress testing.

Deloitte has a solution called “Sustainability & Climate change” that provides strategy and governance advisory, ESG reporting, Climate Change and Decarbonization tools, circular economy consultancy, sustainable finance insights and human relations related services. Deloitte already invested 1 billion USD in sustainability and climate research, assets, and expertise, and is working with scholars, policymakers, and business leaders on result-driven research.

The **BostonConsultingGroup** provides many services to accelerate companies' climate and sustainability journey, from sustainability strategy to climate innovation, food system and security services.

With its climate risk, adaptation and resilience solution, BCG works with both national and local governments to assess their exposure to climate risk, support their climate adaptation and resilience strategies, develop their solution responses, and mobilize funding. For the public sector BCS assess existing local and national adaptation plans, support decision makers with advanced analytics and help partnering with relevant private sector actors to deliver adaptation plans. While for the private sector BCS maps climate risks and hazards, identifies climate vulnerabilities for assets, quantifies operational and financial impact of the risks, defines strategies, and helps partnering with the public sector.

BostonConsultingGroup helps the food system companies too, with sustainable agriculture, food loss and waste, food supply chain and food packaging.

PricewaterhouseCooper helps organizations plan, source, deliver, finance, and measure the wider impact of products and services. PwC teams help companies to manage emerging sustainability risks and opportunities, build trust by understanding, managing, and communicating about social and environmental impacts, create value by making better-informed decisions.

Sometimes consultancy companies and insurance companies collaborate to provide climate related services. For example, **KPMG** collaborates with the insurance company **Zurich** to offer advisory services to address physical and transition risks, respectively, associated with climate change. This enables companies to better manage their exposure to climate risk and identify opportunities for sustainable growth. The service offers a dual approach: an analytical segment featuring risk and opportunities heatmaps and scenarios, followed by a strategy and implementation phase, which details risk integration and assessment, all supported by advanced reporting tools.

Consultancy companies are omnipresent actors in the market, often connected with a wide range of sectors and nodes. They are a good networking pivot, helping companies with relations with other sectors and other companies.

Their contribution to the climate variability adaptation of big companies and governments is noticeable, while their services are often very generic, due to the lack of specific solutions for the most part of climate variability related problems, except for decarbonization, where we already see many solutions provided by almost the whole consultancy market.

2.4.2.5 Innovation hubs

Innovation hubs are spaces where individuals with ideas come together and discuss how to bring their projects to life. They are crucial for networking and the birth of new businesses. They also serve as a field where virtuous ideas can capture the attention of governments, which assist in turning them into reality. Often, **governments can find important future partners here, collaborating to foster local development and internalize what was previously outsourced**.

In Africa are present innovation hubs strictly related to climate topics and to climate services providers start-up, like the **Climate Action Innovation Hub**, launched by the African Union Commission. This hub vision is to provide a continental framework for collective action and enhanced cooperation in addressing climate change issues that improves livelihoods and well-being, promotes adaptation capacity, and achieves low-emission, sustainable economic growth. Another hub is the **Climate Innovation Centre South Africa (CICSA),** which provides business development support to start-ups in the SADC region in three sectors: energy, water, and waste management.

This study also finds value in exploring hubs beyond mainstream topics, focusing on entities like the African Innovation Hub. This hub addresses Africa's major challenges by offering seed funding and facilitating networking opportunities for companies. Similarly, the Innovative Hub for Research in Africa is relevant for its comprehensive approach to surveys, studies, research, and training throughout the continent, delivering high-quality data to inform decision-making processes. These hubs exemplify the diverse mechanisms through which innovation and research contribute to regional development and problem-solving.

UVU Africa empowers young entrepreneurs to transform their technology-driven ideas into reality. Through specialized training and sector-specific incubators, such as UVU Bio founded in 2019, it offers a collaborative platform for science, business, and investment to converge, aiming to develop technology with a positive impact.

Another key player, BongoHive, supports start-ups with a comprehensive array of programs, guiding them from conceptualization to securing investments. Additionally, BongoHive organizes targeted workshops and seminars, supports community developer groups across diverse subjects, and hosts numerous industry networking events.

2.5 Conclusions

As outlined in chapter 2, the value chain for climate services in Africa relies on the support of governments and local organizations. The development of these services is complex as they involve many factors. They often start with international efforts to improve agriculture, manage water resources and strengthen infrastructure in Africa. Climate services can also be included in insurance products or used as important tools for risk assessment and informed decision-making based on climate data. In addition, these services can also be developed within Africa, especially in innovation centers. These hubs are crucial as they promote technological advancement and entrepreneurial ventures and play an important role in developing local solutions and start-ups that focus on climate-related challenges.

At present, government institutions play a more prominent role in developing climate services for Africa. However, there seems to be an emerging trend towards greater participation by the private sector in this area, mirroring developments already seen in Europe and America. This shift is driven by the expansion of the continent's internal market and the growing interest of significant international private entities in the region.

Funding projects related to the provision of climate services in Africa have the potential for substantial returns, both socially and economically. The development of a new market would multiply investment opportunities, generating exponential returns. From a broader perspective, adding a new regional market to the global market for climate services would increase competitiveness, benefiting end consumers with advantageous prices and overall sector quality improvement.

Addressing some of the major obstacles to African growth through the utilization of climate services is crucial, as is the awareness of their importance in the near future. Africa is and will be one of the continents most affected by climate variability, making it one of the major consumers of such services.

3 Scalability and replicability analysis

The analysis of key factors for the success of a climate service plays a fundamental role in formulating effective strategies aimed at making it scalable and replicable.

Scalability refers to the product's ability to maintain high levels of effectiveness and efficiency even during growth phases. On the other hand, **replicability** concerns the possibility of reproducing the methodologies with which the product was originally created, allowing for its implementation in different contexts multiple times.

Having defined a strategy for scaling up and replicating the services developed for the Southern African Development Community (SADC), partial predictions can be made about the development of these services in the near future. These predictions are based on the growth rate of the region and the speed at which key milestones in the provision of climate services are achieved.

3.1 Key factor of success in the regional climate service market

In order to ensure the success of a climate service within the region and facilitate strategy implementation, it is crucial to identify key success factors. These factors are fundamental characteristics that play a vital role in supporting various operational areas of the service, such as food security, water security, energy management, and infrastructure resilience

The key factors for each operational area of the service are broken down into the four main areas we have discussed in this report: agriculture, food security, water, energy and infrastructure. The discussion will look at the key factors to consider in supporting food security, water security, energy management and infrastructure resilience. The key needs of Africa as observed in the case studies are presented schematically below.

Agriculture and Food Security:

- **Accurate climate predictions**: A successful climate service must provide specific climate forecasts to enable farmers to plant crops optimally.
- **Extreme events alert**: The prediction of extreme events and an accurate estimation of exposure to them are crucial for educating farmers about risk.
- **Adaptability of crops**: Tools supporting the transition to crops more adaptable to climate change are crucial for food security.

Water:

- **Meteorological predictions for water resources**: Accurate prediction of precipitation and water availability is essential for sustainable water resource management.
- **Monitoring of water bodies**: Tools for constant monitoring of rivers, lakes, and aquifers contribute to preventing water stress situations.

Energy:

- **Energy production prediction**: Climate predictions are directly linked to production forecasts in most renewable energy sources; therefore, accurate prediction is essential.
- **Energy demand planning**: Tools that help forecast and plan energy demand contribute to ensuring a stable and efficient supply.
- **Enhance and support energy infrastructure building:** Provide information on where to place plants and how to maintain them.

Infrastructure:

- **Climate risk assessment**: Tools that assess and mitigate climate risks on infrastructure, such as floods and storms, are essential.
- **Resilient design**: Adopting resilient climate design practices contributes to ensuring the stability and durability of infrastructure.

- **Early warning systems**: An effective early warning system for extreme climate events enables preparation and timely response.
- **Climate forecasts**: Climate forecasts, along with short-term weather predictions, are highly valuable during the construction of a very large infrastructure project.

After this schematic introduction to the main challenges associated with each topic, let us elaborate on the type of service that is best suited to solve these problems and how it should be implemented, highlighting the key success factors.

3.1.1 Agriculture and Food Security

Among the most important problems associated with agriculture in Africa are the vulnerability of plantations to extreme climatic events and the challenges farmers face in deciding how much to grow and when to harvest in the face of a changing climate. **Critical to the success of a climate service is making the most destructive climate events for African plantations predictable and effectively forecasting the optimal time periods for planting and harvesting the continent's most common crops.**

As reported in an article by McKinsey & Company on sub-Saharan Africa[44], 60% of the population consists of farmers, and agriculture contributes directly to 23% of the GDP. However, the African agricultural sector faces significant challenges in terms of efficiency.

The disparity between the substantial workforce employed in agriculture and the market value is apparent. This discrepancy is largely attributed to various factors, with a significant emphasis on the influence of climatic variables. Currently, agricultural production is heavily impacted by unpredictable climatic events such as droughts, floods, and temperature fluctuations. These factors, challenging to predict accurately, directly affect productivity and crop yields.

The dependence and vulnerability of African agriculture to such climatic variables make the sector susceptible to unforeseen fluctuations and ongoing challenges. The lack of accurate predictions makes it challenging for farmers to adopt long-term strategies, compromising the economic stability of the agricultural sector.

The accurate prediction of climatic variables stands as the foremost challenge that a climate service must tackle to attain success in the region. A more dependable forecasting system would pave the way for a host of benefits, with one of the most notable being the cultivation of a more consistent agricultural output. This consistency is not merely a plus for individual farmers but holds the potential to catalyse overall market expansion, fostering increased efficiency within the agricultural sector.

Agricultural stability, in turn, translates to enhanced economic security for those engaged in farming activities. By mitigating the impact of unpredictable weather patterns, farmers can plan their operations more effectively, manage resources efficiently, and make informed decisions regarding crops and cultivation practices.

Furthermore, a more reliable and stable agricultural production system plays an important role in addressing the pressing issue of food uncertainty. As markets grow and become more efficient, the surplus agricultural output can be channelled to meet rising food demands, ultimately contributing to food security in the region. The ripple effect extends beyond economic benefits, encompassing social and environmental dimensions by ensuring a more robust and sustainable food supply chain.

Another crucial factor where the application of climate services can be decisive is in the management of water resources for agriculture. In Africa, planting and harvesting periods are closely tied to the onset and cessation of the rainy season. Moreover, having accurate knowledge of the amount of water available for agriculture becomes critically important during periods of drought, where compensating for the lack of natural irrigation is essential.

[44] McKinsey Global Institute (2020) How will African farmers adjust to changing patterns of precipitation?

The planning of agricultural activities, including planting and harvesting times, is strongly influenced by climatic variability, particularly the duration and intensity of precipitation. This not only contributes to ensuring the success of crops but is also crucial for addressing drought situations, allowing for timely interventions and supplementary irrigation measures to mitigate adverse effects on crops.

The resolution of the food security challenge, linked to agricultural issues, is a concern for both African governments and international entities. Given this pressing need, financial support for climate services aimed at encouraging a more resilient agriculture sector in Africa becomes even more relevant. **Figure 11** illustrates the service value chain for a climate service, highlighting the interconnection between the actors that are needed for a successful implementation.

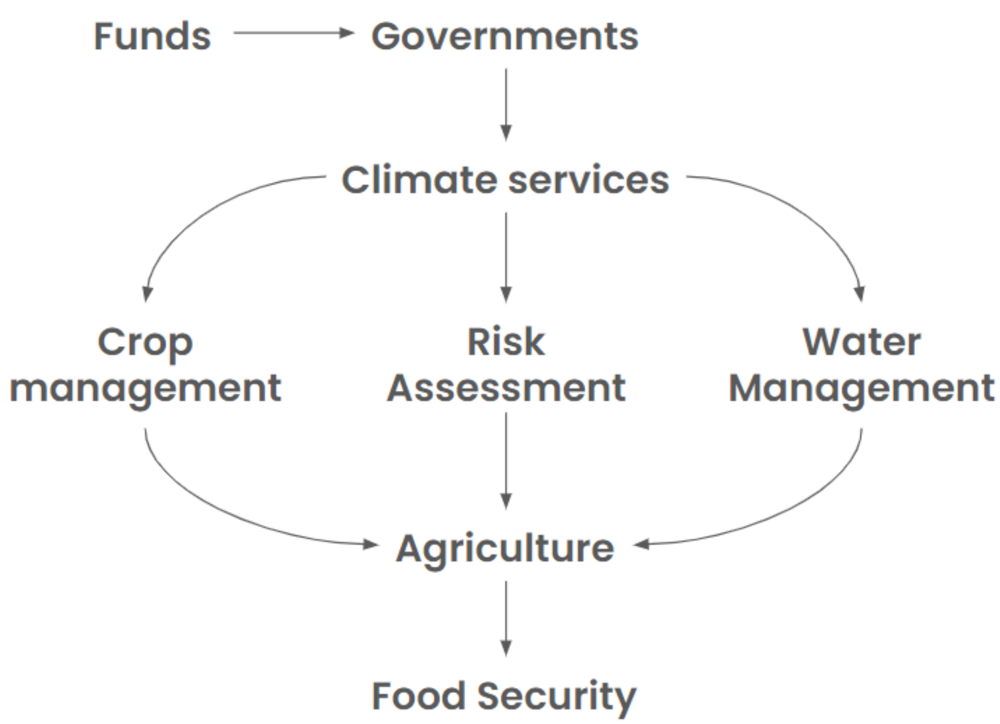


Figure 11: Value chain of the agriculture climate service.

3.1.2 Energy

The factors that can characterise the success of a climate service for energy in Africa are related to solving the problem of excess demand over supply. The solution to this problem usually involves the entry of new players into the market or a significant growth of existing ones.

The energy market in Africa is currently in a significant phase of maturation and transition to renewable energy sources, following a similar path to the rest of the world. In Africa, this process can take place more easily as the continent has extremely high production potential and the energy market is not as tied to fossil fuels as is the case in more economically developed continents.

The most important energy- related issues in Africa concern the availability of energy. Demand is constantly increasing, while supply is growing more slowly. Renewable energy is already playing an important role in Africa's energy supply and is expected to expand further in the coming years.

Given the importance of renewable energy and the challenge of balancing energy demand and supply in Africa, providing a service that is able to accurately predict the energy generated by wind or solar plants is crucial. Another key element for success could be the ability to link consumption forecasts with production forecasts and thus anticipate increases in consumption during particularly hot or cold periods, for example.

The connection between consumption and production forecasts is important to address one of the main challenges in the African energy sector, namely the alignment of demand and supply.

Such a service could be of great interest to all companies already active in the African energy market and seeking to scale up their assets in order to achieve a balance between supply and demand. It would also attract new entrants to the market. For a newcomer, assessing the optimal location for construction and forecasting energy production based on the chosen location could be crucial for analysing the costs and benefits of an investment.

Given the projected robust growth of the market and its relatively young age, such a service can shine in feasibility and profitability analyses for future investments. Currently, investments in renewable energy in Africa amount to $60 million, but are expected to increase significantly in the coming years. Reducing risk and accurately predicting certain factors in advance would undoubtedly facilitate investment in this sector.

Figure 12 illustrates the value chain of this service. Funding for this service can either come from the customers themselves, e.g. large energy producers and sellers who want to invest in a product that is important for their growth, or from funds and public institutions focussed on African economic development. This would encourage the emergence of services that are beneficial for the introduction of new companies to the market. In both cases, the product would then be made available to companies that are already present in the market or are looking to enter the market and use it to evaluate their upcoming investments.

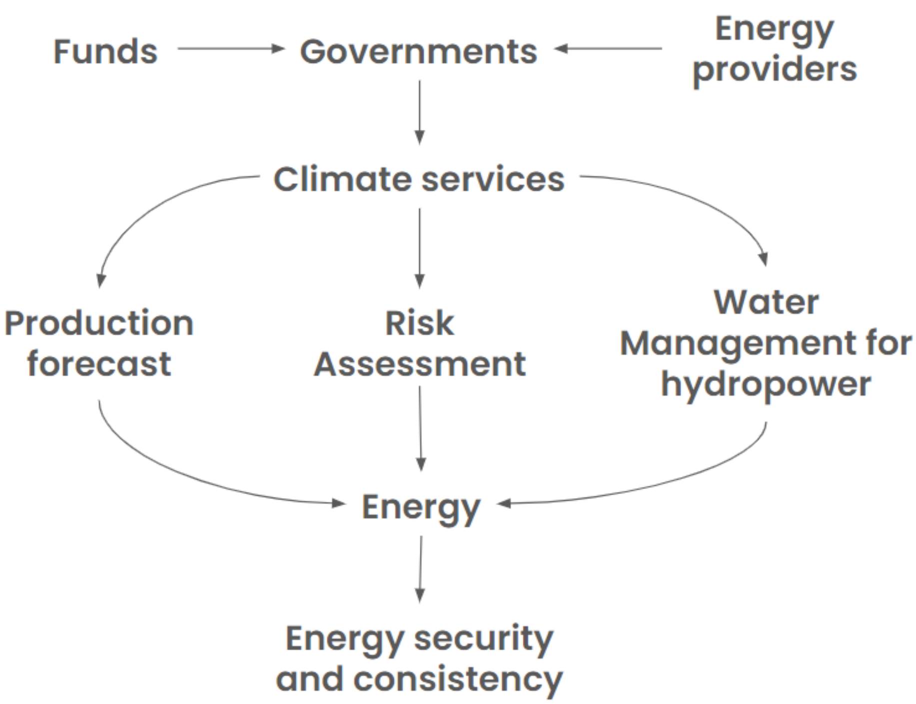


Figure 12: Value Chain of the energy climate service.

The energy sector in Africa is closely linked to the management of water resources, with hydropower playing a central role. South Africa in particular is a major player, accounting for a quarter of the continent's total hydropower production. While hydropower offers significant potential to meet

Africa's energy needs, its successful utilisation requires effective and careful management of water resources — a factor that is directly influenced by climate variability.

The ability to predict fluctuations in water volume in the catchment areas designated for hydropower generation is of paramount importance. This foresight is crucial for accurately predicting the reliability and actual energy yield of hydropower plants. In this context, a service that can predict the increase in water volume during the rainy season and the decrease during the dry season is crucial. Such a service not only helps to optimise energy production, but also plays an important role in overcoming the challenges faced by energy market operators. These challenges often revolve around the difficulty of meeting the ever-changing demand for energy, a task made even more complex by the uncertainties created by climate variability.

The interplay between energy and water management emphasises the overall importance of climate-resilient strategies in Africa's quest for sustainable and reliable energy sources. By considering the impact of climate variability on water resources, particularly in the context of hydropower, the continent can improve its energy security and contribute to a more sustainable and resilient energy infrastructure.

A service capable of providing production forecasts would also prove useful in situations where there is a need or obligation to communicate the estimated production of a power plant on a specific date, as is the case in Europe, for example. In this scenario, plant owners are obliged for technical reasons to provide accurate forecasts of their production.

In this context, we would have a service structured for existing and operating plants that can predict the variability of energy production based on meteorological variables. In this case too, financing could be provided by public organisations to promote the continent's economic growth or directly by the energy producers already located in the region, who would then be the end users of the service.

3.1.3 Infrastructure

Climate variability poses a threat to African infrastructure, both to existing infrastructure that is not able to withstand extreme weather events and to future realisations whose design process is intended to enable climate-proof investments. This challenge can be effectively addressed through the implementation of climate services.

As described in paragraph 3.3, less than 50% of the roads in Africa are paved, and the percentage of the population that has access to these roads is even lower. For the rural population, the lack of access to communication infrastructure means isolation, lack of energy, water and internet access, as well as significant economic disadvantages due to inflation caused by transport costs. In addition, the current infrastructure on the continent is outdated and therefore very vulnerable to climate fluctuations and extreme weather events. Floods, which occur particularly frequently in Africa, cause considerable damage to infrastructure and render it temporarily unusable or permanently impaired.

Given the significant impact of climate variability on infrastructure, the implementation of climate services capable of characterising future climate conditions that could threaten these structures is crucial and represents a key success factor. The construction of infrastructure is a lengthy process and therefore requires a service that can provide robust climate predictions over a period of decades and beyond. This is crucial both during the construction phase for cost planning and anticipating potential disruption due to unfavourable weather conditions, as well as for planning the resilience of the infrastructure, including knowledge of extreme climatic events to which the structure will be exposed. Floods often prove to be the most influential climatic event for infrastructure. Therefore, characterising their frequency and intensity is crucial for the African infrastructure market.

Businesses and governments would be the buyers and funders of the services needed to carry out risk assessments when planning new projects and to predict the level of resilience to extreme climatic events, which would feed directly into the design of structures. These services would also enable the prediction of extraordinary maintenance and inspections before or immediately after a particularly relevant climate event. The value chain of such a service should therefore be as follows:

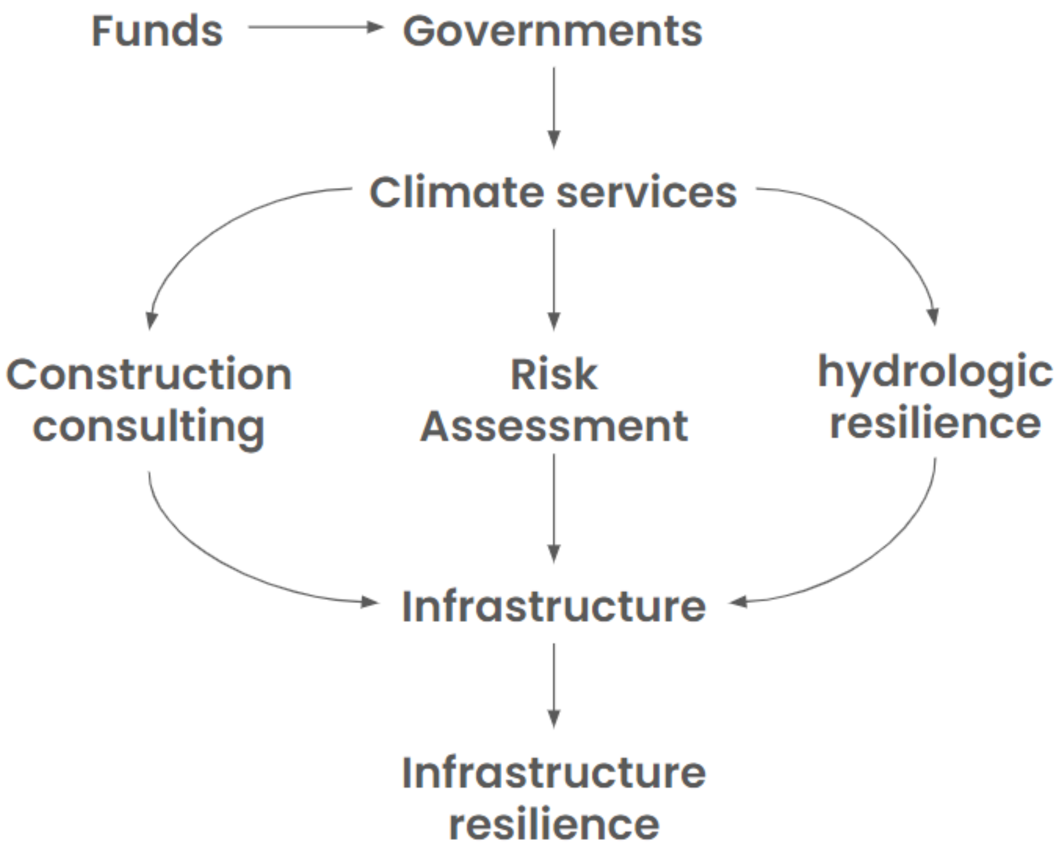


Figure 13: Value Chain of the Infrastructure Climate Service

Starting with interested donors, including companies in the construction sector and governments, these organisations would purchase or obtain the service to incorporate the data into the planning and monitoring of the structures built.

As Africa's infrastructure becomes more resilient, the continent can better prepare for expected population growth and make currently isolated areas more accessible and urbanised. This would promote more equitable urbanisation and population distribution and avoid over- concentration, which often leads to a reduction in quality of life.

3.2 Scalability and replicability analysis

The key success factors discussed in section 3.1 are not only crucial for the proper functioning of a strategy, but also as levers for the effective scaling and replication of services that enable controlled growth and expansion into different contexts.

Thanks to the groundwork done in Focus Africa in the Case Studies, certain aspects of this analysis have already been streamlined. We have an initial understanding of replicability through the examination of various case studies that explore different geographical and demand-driven contexts. In addition, the factors for scalability and replicability, the essential tools for implementing these processes, have already been analysed.

In the following sections, we will discuss these aspects in detail and categorise them according to specific needs.

3.2.1 Agriculture and Food Security

A climate service focused on food security must demonstrate both scalability and replicability. Scalability means that the service can be applied across a larger geographic region beyond the initial pilot projects. Replicability ensures that the service can be used effectively in different geographical contexts with different agricultural activities and climatic conditions. This flexibility is essential to maximize the reach and impact of agricultural climate services and support food security efforts in a region or even globally. By developing climate services that are scalable and replicable, we can deliver customized, actionable insights to a wide range of stakeholders, from smallholder farmers to large agribusinesses.

Scalability usually requires high-resolution spatial forecasts and a customised system for interaction with end users that can inform the farmer about local temperature changes or precipitation levels in a specific area of his cropland. Of particular importance when discussing scalability is the factor of customer growth. Given the increasing demand for food in the region, significant growth in food sources and therefore food production is foreseeable. Therefore, it is necessary to have a product ready for situations that may not yet exist in the market but are anticipated, such as larger acreages than currently exist or projections for geographically uncultivated areas. This approach aims to minimise the time to market during the expansion of the agricultural market.

Replicability, on the other hand, poses additional challenges. While the strategy and climate service can easily be transferred to customers nearby, sub-Saharan Africa is large and diverse, both in terms of climate and agricultural practices. Different crops have different needs and farmers need knowledge of different variables, particularly in relation to planting and harvesting times. When discussing replicability, it is therefore important to consider that the information required by the customer may vary depending on the type of crop.

Some plants have very different needs from others, such as tobacco and cocoa, which are very popular on the continent. The former require dry and well-drained soils, warm temperatures, and sunlight to grow, while the latter require volcanic soils, tropical climates and little to no sunlight to grow. Consequently, the product must be tailored to the specific needs of the individual farmer.

Furthermore, the main consumers of catastrophic event prediction tools are usually states or supranational institutions. These entities require the ability to predict the probability of extreme events such as flooding for large areas. A climate service focussed on predicting the probability of extreme events would probably have few but significant customers, all of which are quite similar. Therefore, scalability and replicability strategies are less relevant in this context.

Case studies 1-2-3-4 of the Focus Africa project are the ones that focus most on the issue of food security and its solutions. Therefore, these climate products need to be scaled up and replicated in this context.

The first product described in Case Study 1 (see 5.1) is a climate service designed to assist banks in credit risk assessment by predicting the impact of climate change on plantations in the future. This enables the bank to take this risk into account in its valuations.

Such a product is manageable in terms of **scalability and replicability**. In terms of scalability, the ability to respond effectively to a rapid increase in the number of interested parties and the areas in which the service needs to be active is not a particular problem. This is because the data required for credit risk assessment is often similar for different banks and financial institutions, which makes scalability much easier.

As far as **replicability** is concerned, i.e. the ability of a product to adapt to use in a different context, this service could be replicated in different countries with different banking systems. The difficulty in this case could be regulatory compliance. Different jurisdictions may impose different regulatory obligations on financial institutions, leading to potentially different risk assessment processes and requirements.

In both cases, the core of the climate service remains the same, making it easier to adapt to the growing clientele and apply in different contexts.

As for the other case studies, the proposed climate products are very similar in all three cases. In fact, all three focus on predicting key variables to help farmers ensure continuous and secure production, such as the start and end of the rainy season and any periods of prolonged drought.

As already mentioned, a product of this type has already been partially replicated at Focus Africa. This is possible because different case studies in different geographical contexts address the issue of food security with a similar climate service.

In terms of the **scalability** of such a climate service, it is critical that the product can sense all the small differences that can affect the variables that impact a client farmer's production.

In fact, some geographical differences, albeit small, could cause the results to be slightly different for each customer. This factor could significantly increase the cost and the necessary workforce. Therefore, to ensure the scalability of the product, the challenge of accommodating these subtle variations and differences across different geographical locations must be overcome in order to maintain the effectiveness of the service for each individual farmer.

3.2.2 Energy

The strategies of replicability and scalability in the energy sector, especially in the field of renewable energies, represent a major challenge for a provider of climate services. Scaling and replicating a service that predicts energy production based on climate variables is complex and costly. This is because many of the variables that influence the end result of a forecast are tied to the producer. Therefore, there are different variables for each producer that need to be taken into account.

One of the key aspects that propel the success of a climate service lies in its scalability and replicability — the ability to broaden its reach and duplicate its effectiveness across diverse contexts. To achieve this for renewable energy climate services, particularly in wind and solar energy sectors, we must approach the scaling and replicating processes with innovative strategies.

When you consider **scaling up** a climate service to estimate energy production, the degree of complexity varies depending on the scenario. Scaling becomes easier when the growth involves similar customers or existing customers increasing their production capacity. In such cases, the service can adapt to the changing needs of familiar stakeholders, simplifying the expansion process.

And even if the expansion involves a significant increase in geographic coverage, particularly in relation to wind and solar energy installations that occupy large areas, the challenges can be overcome through strategic planning and the use of advanced technologies. While it is true that climatic conditions can vary within a larger geographic area, introducing additional variables for production estimation, modern forecasting techniques and data analysis tools can mitigate these challenges.

By utilising high-resolution climate forecasts and integrating them into the service framework, we can improve the accuracy of production estimates without exponentially increasing costs for both the supplier and the customer. This approach not only optimises the efficiency of the service, but also improves its value proposition in the market.

When discussing the **replicability of climate services** in the renewable energy sector, the focus shifts from complexity to adaptability. It is indeed possible to replicate a successful product for multiple customers with different technical requirements. By focussing on a modular design

Replicability in the water sector, especially in the hydropower sector, is both simple and economically advantageous on a large scale. Water and the benefits it provides are fundamental to many sectors, and the climate services associated with it are replicable across the continent, including those associated with hydro-derived energy.

One solution that could address both the challenges of scalability and replicability in the energy sector is to reduce the product focused on production forecasting only the necessary climate predictions for the energy producer. This approach would simplify scalability and replicability and make it more cost-efficient, but leave the product at a more general level.

The disadvantages of such a solution become apparent when the provision of such a service is entrusted to the private market rather than the public sector. In a competitive scenario, a generic product is more likely to be abandoned in favour of a competing product than a customised solution.

A climate service capable of predicting energy production may be more complex and costly, but could offer a competitive advantage in the near future as the market expands and becomes more competitive. Of the markets discussed, climate services for the energy sector is the one that is most likely to be privatised quickly and grow just as fast. This is due to several factors, including the fact that energy production is already in the hands of large private companies worldwide that already use climate services provided by private companies on other continents, and furthermore, these two markets are growing in interdependence and are characterised by strong technological leverage.

Typically, markets where technological and scientific advances are of great importance grow much faster than those where these variables are less important. An example of this was the market for mobile phones in the early years of the 21st century, where every small technological advance that could ensure an improvement in even a single function represented a competitive advantage.

Vertical integration in our context involves integrating the process of forecasting energy production based on climate forecasts, which was previously external, either upstream or downstream. This integration can pose significant barriers to market deter potential market players. The technological adaptation required to develop a product that can accurately predict both the climate conditions and their impact on production may demand substantial short-term investments. Not all companies may be willing to commit to such high initial costs.

Case studies 6 and 7 (Deliverable D5.1) deal with climate services for the energy sector that have already been implemented in Focus Africa. The first service developed for Tanzania is a service that is primarily intended for state-controlled companies that operate hydropower plants. The service aims to improve current hydropower generation and assess the potential of other renewable energy sources such as solar and wind power.

As reported, climate services for support of renewables' assets operations to:

- Develop site- and area-specific seasonal predictions of rainfall, including onset, cessation, and duration of rainfall for hydropower.
- Develop a statistical model for hydropower production for the TANESCO plants for which local data are available.
- Incorporate seasonal forecast data into the hydropower statistical model to predict the generation of reservoir-fed and run-of-river hydropower stations up to a few months ahead.
- Incorporate climate projections data into the hydropower statistical model to estimate impacts on reservoir-fed and run-of-river hydropower stations.

Concerning the scouting of future opportunities for renewable energy climate service would enable:

- Identification and analyse historical datasets to produce reliable climatology maps and long-term statistics.
- Analysis of most recent future climate projections and evaluate the potential impact on renewable energy production.

The scaling and replication of such a service becomes quite complicated the more specific it becomes. Scalability is less important in this particular case as countries are often direct energy producers or owners of energy production facilities. It is unlikely that the number of users and thus the countries themselves will increase. If this were to be the case, it would primarily be a replicability issue, as the service would have to be replicated in a different geographical context, namely in a different country.

In terms of replicability, the methods used to assess the potential of renewable energy in an area can be easily replicated by modifying historical data and climate maps that are consulted. What is complicated in this context, however, is the co-operation between different interest groups, which is associated with considerable costs. On the other hand, anything to do with optimising the use of hydropower is difficult and expensive. This component of the climate service is particularly linked to the specific characteristics of the area and the energy producer.

While climate predictions relating to the start and end of the rainy season are reproducible, at least in the models used for forecasting, this is not the case for the statistical models used to translate climate predictions into energy predictions. In all cases, these models need to be adapted to the equipment of the energy producing company and the characteristics of the watersheds.

Replicability here could be facilitated by the interest of nations willing to invest significant amounts of money from international funds so that such services can improve the conditions for hydroelectric power generation in African countries.

The replicability of such a service may find a place in neighbouring sectors such as solar and wind energy, which often require similar forecasts, thus allowing existing climate services to be adapted to their needs.

3.2.3 Infrastructure

Climate services that impact the infrastructure sector predominantly focus on predicting extreme weather events. This type of climate service is strategically simple to scale and replicate, allowing for the efficient servicing of multiple clients with a single service. This, in turn, generates economies of scale, streamlining management processes and optimizing resource utilization.

The scalability of climate services for infrastructure development in Africa is a major concern, particularly when it comes to scaling up services for multiple large-scale projects. While individual governments may not be able to tackle numerous infrastructure projects simultaneously due to financial and time constraints, strategic collaborations between nations and partnerships with private companies offer a viable solution. Such co-operative approaches can make it possible to advance a portfolio of infrastructure projects in parallel, increasing efficiency and progress.

Climate services tailored to infrastructure must therefore be designed to be scalable and provide comprehensive support for a range of projects that may span different regions and climate zones. These services must provide high-resolution data and insights that are critical to the planning and construction phases of infrastructure development. This will ensure that each project— - whether it is a single nation's project or part of a collaborative multi-project initiative — is supported by accurate and actionable climate information.

With this in mind, scalability means more than just the ability to handle a larger number of projects. It also includes the ability to integrate different climate risk assessments and adapt to different project requirements. This can lead to a more resilient infrastructure that is designed to withstand the specific climatic conditions of each location.

As climate patterns continue to evolve, the scalability of climate services becomes essential for the ongoing assessment and adaptation of existing and future infrastructure. This proactive approach not only protects investments, but also ensures that the infrastructure can cope with the changing environment and ensures the long-term sustainability and security of these critical assets.

Similarly, when it comes to making **infrastructure services replicable**, the ability to predict extreme weather events that affect large areas means a single forecast can benefit multiple countries and stakeholders at the same time. The main challenge to full replicability stems from the varied exposure to different climate events based on where specific infrastructure projects are located. This means that services predicting extreme weather events may be partially replicable depending on these geographic differences.

The scalability and replicability of climate services to predict climate variability for risk assessment during the design and construction of a building is very similar to what was mentioned in the previous section. Also in this case, it is a service developed for specific customer needs, so scalability and replicability depend on how similar the customers' requirements are. In this case, however, the challenge is less significant as such structures are rarely built and climate data is required for risk assessment.

As for Case Study 5, which focuses on a climate service for infrastructure, there have been some interruptions at the moment and the details can be explored further on Deliverable D5.1. In any case, the service has been developed to investigate climate-related risks that may impact infrastructure so that African infrastructure can be built with climate-related risks in mind.

Scaling up and replicating climate services for infrastructure in Africa is a complex problem, not only because of the high costs or the need for collaboration between different experts, but also because of the complex nature of climate risks and their impact on different types of infrastructure. Each project, whether residential buildings or energy infrastructure, is unique and is influenced by a variety of factors that require a customised approach.

The complexity of this task stems from the need to develop services that can assess extreme climate indices for large areas while being accurate enough to fulfil the specific requirements of individual projects. For example, while a flood risk assessment might be applicable to a large region, the specific impact of this risk on a particular bridge or power plant needs to be tailored to the unique characteristics and constraints of the site.

The process of scaling such services involves not only expanding their reach, but also refining their scope. It requires a sophisticated understanding of local climate patterns and the ability to predict how these patterns might change over time. This can then inform the planning and construction of resilient infrastructure.

Replicability in this context refers to the ability to apply the same underlying risk assessment methods to different projects, with the flexibility to take into account local specificities. This is where collaboration between engineers, building scientists and climate experts becomes crucial. Their collective expertise enables the development of risk assessments that can be adapted to the different needs of each individual infrastructure project. This ensures that each project benefits from findings that are both globally sound and locally applicable.

On a positive note, the infrastructure market is already used to providing significant amounts of money for construction projects, often funded by public organisations. This could facilitate the spread of similar services and increase their potential for scalability and replicability.

3.2.4 Water

Water is a cross-cutting variable that affects all the areas described in the previous sections. It has a major influence on agriculture, which depends on the rainy season and is threatened by floods and droughts. It influences energy production, as hydropower is one of the most popular and important sources of energy in Africa. In addition, water affects infrastructure construction, as rainfall measurements are of great interest to infrastructure builders and flooding poses a significant threat to roads and telecommunications infrastructure.

As water is a cross-cutting issue, the scalability and replicability of a climate service are crucial for water management. Such a service must be scalable and replicable across multiple sectors and consequently across different markets.

In terms of scalability, the rapid and significant customer growth, driven in particular by the energy and agriculture markets, poses a major challenge. Providing climate services for water management requires offering different services that can meet the needs of different sectors. For example, while farmers are interested in the beginning and end of the rainy season, hydropower stakeholders may only be interested in the water collected in reservoirs. For a climate service to be easily scalable, it should be able to fulfil both requirements and effectively predict the start and end of the rainy season as well as the amount of precipitation that will fill the reservoirs during this period. To achieve this, it may be necessary to develop "modular" services that allow customers to receive only the information they need, so that the service provider does not have to create numerous products for different customer groups.

This practise not only reduces costs, but also increases the recognisability of the supplying company through its unique product used in different sectors, eliminating the need to promote a different product for each market and sector.

As far as replicability is concerned, it should be relatively simple. Differences in the onset of the rainy season or the amount of rainfall between different geographical areas are factors that need to be taken into account, but the tools to measure them remain the same. As explained in section 2, differences in power generation technologies can occur between different hydropower producing customers. However, this challenge only exists if the energy production resulting from a significant filling of the water reservoirs is also to be measured.

Extending the reach of a climate service involves significant costs and continuous efforts by industry experts. The key enablers for scalability, as mentioned earlier, are financial donors, including public, governmental and international sources.

When examining the technical aspects of scalability of climate services, the challenge of expanding coverage becomes apparent. While this endeavour is technically feasible, it proves to be particularly costly and requires the ongoing expertise of professionals in the field. The key driver for scalability lies with those who fund these services. This is particularly emphasised in Section X, where the crucial role of public, governmental and international funding is highlighted.

Replicability is greatly facilitated by the groundwork done in the previous outputs of this project, as different climate services have been implemented in different contexts. However, the scientific outputs of these services, particularly in forecasting extreme climate events, are inherently different and cross-contextual. The challenge lies in transforming this data into actionable information.

The scientific output of a climate service is generally valuable, but its conversion into information varies considerably depending on the end user. For example, a farmer and a dam manager use the same data in different ways and require different and possibly time-critical final information. Although replicability through case studies has been partially successful, the final hurdle is transforming the data into information, a complex and costly aspect. Similar to scalability, the feasibility of replicability is highly dependent on the investment of states and public organisations.

In case study 8, the climate service for water management in the Mauritius Islands is a service that can provide rainfall forecasts by analysing historical data. This product, which is similar to the one already used in agriculture, is extremely versatile and can therefore be easily scaled up and replicated. As it is based on historical data, it can be customised to the specific needs of the customer by modifying it.

A similar product can be used in different contexts and therefore scalability is extremely important. As customers can grow exponentially and rapidly, the ability to scale becomes an important factor. The speed at which historical data can be analysed to create forecasts and the associated costs as the number of customers increases are therefore crucial.

On the other hand, replicability is a simple matter. To ensure effective replicability, each interested customer only needs to provide the historical data required for forecasting.

To summarise, the landscape of scalability and replicability of climate services highlights the difficult balance between technical advances and financial support. While scaling up requires significant investment and expertise, financial contributions, especially from public, governmental and international sources, play a crucial role. The groundwork laid in previous work has facilitated reproducibility, but the real challenge is to turn the scientific results into actionable information. The universal scientific value meets the diversity of end users, which emphasises the need for customised information. Overcoming this final hurdle will require sustained investment from states and public organisations that will shape the future feasibility of scalable and replicable climate services.

Conclusion

This deliverable provides a comprehensive analysis of the climate services market in the Southern African Development Community (SADC). It examines the critical challenges faced by the SADC region and investigates how climate services can deliver solutions. The report emphasizes the significant need for climate services to safeguard these critical sectors of the economy.

Key takeaways from the market analysis of this report include:

- The pressing necessity for robust climate services to address the adverse impacts of climate change, particularly in the agricultural sector where erratic weather patterns jeopardize food security.
- The importance of effective water management in preventing floods and ensuring adequate water supply, which is vital for both the population's well-being and the ecosystem's health.
- The pivotal role of climate services in predicting and optimizing energy production, especially as Africa moves towards renewable energy sources like solar and wind power.
- The urgent need for climate-resilient infrastructure to withstand extreme weather events, thus protecting investments and ensuring the longevity of development projects.

The report underscores the significant market potential for climate services in Africa, with the agricultural sector alone being worth around one trillion dollars and growing. However, current inefficiencies call for improved climate services and technology to enhance productivity sustainably.

In highlighting the essential role of governments as key players in the development and delivery of climate services, the report points out the critical support provided by external funding from international organizations and the private sector. It also notes the diverse range of public institutions involved in this effort, as well as the insurance sector's contribution to financial protection against climate risks.

Consultancy firms and innovation hubs are recognized for their strategic guidance and support in fostering climate solutions. These entities play a crucial role in building capacity and promoting the development of climate services tailored to Africa's unique needs.

This report has highlighted that scalable climate services must not only perform well as they grow but also maintain their effectiveness and efficiency. Replicability is equally important, ensuring these services can be duplicated and applied in diverse African settings, from the arid Sahel to the lush tropics of the Congo Basin.

- For agriculture, scalable climate services are essential in providing farmers with accurate weather forecasts tailored to their specific locales and crops. This precision supports better planning for planting and harvesting, directly enhancing food security and the agricultural economy. As climate patterns shift, the ability of these services to replicate across the continent's varied agricultural zones will be key to maintaining productivity and sustainability.
- In the energy sector, the challenge lies in tailoring climate services to the unique needs of different energy producers while also ensuring these services can be scaled up to

accommodate the growing shift towards renewable energy sources. Modular services that can be adapted for use in wind, solar, and hydroelectric power generation offer a pathway toward managing the continent's diverse energy portfolio.

- Infrastructure, which is essential for Africa's growth, requires climate services that can be consistently replicated to inform the design and construction of robust structures capable of withstanding extreme weather. The scalability of these services ensures that as development projects expand, they remain informed by the most current and comprehensive climate data.
- Water management is another critical area where scalable and replicable climate services can make a significant impact. With the threat of both drought and flooding prevalent across Africa, services that can predict water availability and risks are indispensable. These services must be versatile, providing valuable information for agriculture, urban planning, and disaster preparedness.

This report strongly advocates for the targeted development and implementation of climate services in the SADC region. These services are essential for mitigating the negative impacts of climate change, enhancing key economic sectors, and meeting a clearly defined and growing market demand. Investments in climate services are not only vital for the immediate protection against climatic threats but also serve as a long-term enabler of sustainable development and economic growth in Africa.

Moreover, investing in scalable and replicable climate services is not just a technical necessity but a strategic imperative to bolster resilience across Africa's economies. These services stand as a testament to innovation, providing a foundation for sustainable development in the face of climate variability and change. Their expansion and adaptation will be central to improving the lives of millions on the continent, showcasing a compelling opportunity for investment in Africa's resilient future.