

# Designing innovative solutions for the Water, Energy and Food Nexus

A comprehensive review of business  
models for the WEF Nexus



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# About

## Nexus Regional Dialogues Programme Phase II

Building on the results of Phase I, the Nexus Regional Dialogues Programme Phase II aims to institutionalise the WEF Nexus approach in national and regional governance structures and investment decisions and to engage the public and private investors for WEF Nexus projects.

*Vision:* Inclusive water, energy and food security on the path to a climate resilient and resource efficient future for all.

*Implementing organisation:* Regional Environmental Centre for Central Asia (CAREC); Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ); Global Water Partnership Southern Africa (GWP-SA)

*Collaborating partners:* National Partners in Central Asia; League of Arab States (LAS); Niger Basin Authority (NBA); Southern African Development Community (SADC)

*Implementation period:* July 2020 – June 2023

*Beneficiary countries:* Central Asia; Latin America and the Caribbean (LAC); Middle East and North Africa (MENA); Niger Basin; Southern Africa

*Funding by:* European Union (EU), German Federal Ministry for Economic Cooperation and Development (BMZ)

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The commissioning parties and cooperation partners all place their trust in GIZ, and we work with them to generate ideas for political, social and economic change, to develop these into concrete plans and to implement them. As a public-benefit federal enterprise in international cooperation with a focus on sustainability, we represent German and European values. Together with our partners in national governments worldwide and cooperation partners from the worlds of business, research and civil society, we work flexibly to deliver effective solutions that offer people better prospects and sustainably improve their living conditions.

## **RES4Africa Foundation**

Born in 2012, RES4Africa (Renewable Energy Solutions for Africa) is a Foundation that works in support of Africa's just energy transition in order to achieve the SDG7, ensuring access to affordable, reliable, sustainable and modern energy for all. It functions as a bridge between Europe and Africa: gathering a network of members from all over the clean energy sector from both continents and high-level international partnerships, we ensure constant dialogue between the most relevant energy stakeholders willing to mobilise investments in clean energy technologies.

We envision the sustainable transformation of Africa's electricity systems to ensure reliable and affordable electricity access for all, enabling the continent to achieve its full, resilient, inclusive and sustainable development.

We work towards creating favourable conditions for scaling up investments in clean energy technologies to accelerate Africa's just energy transition and transformation.

# Acknowledgements

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## Funding institutions



**Disclaimer:** This publication was produced with the financial support of the European Union and the German Federal Ministry for Economic Cooperation and Development through the NEXUS Regional Dialogues Programme Phase II. Its contents are the sole responsibility of Res4Africa and do not necessarily reflect the views of the EU or the Federal Ministry for Economic Cooperation and Development. The views expressed are solely those of the authors and do not necessarily reflect the views and position of the organizations they represent.

Published on March 2023, RES4Africa Foundation

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# Executive Summary

## *Setting the context*

African and Middle East countries still face **complex challenges** such as widespread poverty and unemployment, persistent food and water insecurity, lacking infrastructure and industrial capabilities, as well as economic and political instability. Expanding populations and economies will add stress on the current infrastructure and supply systems of countries, leading also to a **surge in demand for basic resources** such as water, food and energy in the coming years. It is estimated that by 2030 Africa's water consumption will grow by 283% compared to 2005 levels, food demand by 60% compared to 2015 levels, and electricity demand by 70% compared to 2016 levels. The nexus approach among the water, energy and food sectors aims at understanding the synergies within these domains, determining the trade-offs and maintaining the sustainability of the ecosystems.

The interlinkages captured by the **Water-Energy-Food (WEF) Nexus** offer a ground-breaking perspective to increase access to clean energy combined with water and food. As such, the WEF Nexus can reveal business models that look at how water, energy and food can be connected to **respond to essential development needs**, increasing economic productive capacities and driving socio-economic welfare.

**This report analyses WEF-based applications and business models in the Niger Basin region and the Middle East and North Africa (MENA) region** but, in order to understand their related benefits and challenges, it is necessary to assess the three sectors and their interactions separately. When looking at the general picture of the target areas, the challenge is to analyse a set of countries which highly differ, even within the same region. **MENA** consists of a heterogeneous group of countries **ranging from high-income oil-exporting nations of the Gulf to lower-middle-income countries**. Nonetheless, the whole region is one of the world's biggest food importers and two-thirds of the countries have less than 5% of land availability for agricultural use. In 2020, MENA's share of the world's acute food insecure population was 20%, incredibly high considering that only 6% of the global population live in the area.

In the other target area, **five of the nine Niger Basin countries are among the least world developed countries**; the economies within the area are predominantly based on agricultural and traditional activities which employ more than 80% of the local workforce. Considering that the area is experiencing a **fast population growth** (as the rest of Sub-Saharan Africa) and taking into account its **vulnerability** to climate change, it becomes pivotal to find game-changing **solutions for an integrated use of resources**.

Both areas highly rely on agricultural activities, in considerable part for **subsistence** purposes. Despite a long-term rooted tradition in farming activities, most of the businesses are run with traditional and often **inefficient use of resources**. Rain-fed subsistence agriculture supplies 78% of the total agricultural production of the Basin. This topic is particularly relevant as many of the countries of these two regions are suffering from **water stress**; as example, the MENA region has only 1.4% of the global freshwater availability. This longstanding condition will be **aggravated in the near future by the effects of climate change**, such as erratic rainfall, droughts and heat waves. Understanding the **energy sector** of the two regions is likewise relevant to investigate how the use of sustainable energy could foster the development of agricultural activities and support the diffusion of water-saving technologies. Obviously, the two regions have **a completely different energy profile**, with the MENA region showcasing almost full access to energy, in contrast with the Niger Basin countries, for which the electrification rate is still a challenge, with enormous difference between urban and rural areas. Demand for energy in the MENA region is steadily

growing especially because of an increase in population and large levels of industrialization. The governments of the Region have set an ambitious target to reach 75% energy to come from clean source by 2050. On the other hand, the average annual consumption per inhabitant in the Basin is 70 kWh, less than a tenth of the African average of 740 kWh. However, an increasing energy demand due to population growth, rapid urbanisation, and industrialisation is a concern also considering the challenges in energy exchanging across borders..

### *The water-energy-food nexus opportunity*

Despite a growing interest in the connections between the three sectors, several **challenges** and **barriers** still hamper the development of WEF nexus projects: i) the **silos mentality** of institutional and private organizations; ii) **inadequate financing schemes** for implementation and scale-up of nexus projects; iii) **lack of** viable and scalable **business models**; iv) **lack of adequate capacities** to regulate/supervise (institutions) and manage (companies) integrated projects.

This report explores integrated business models and innovative approaches in the MENA and Niger Basin starting from the existing projects developed by the relevant initiatives and companies in the WEF sector, with the objective to identify, analyse and present **the most promising WEF nexus solutions** and related business models. The outcome of this analysis is an overarching bulk of knowledge around the WEF state of the art both in terms of market segments, technology solutions and operating models to be further explored and supported for the implementation at scale and dissemination of the WEF projects and approaches.

Navigating through existing business models in two different regions is not an easy task, not only because of the differences between the regions and within the single countries, but also because of the variety of models that the interactions among water, energy and food sectors are able to generate. With the objective of identifying the most promising WEF-related business models in the two regions, a market analysis was carried out, giving a particular emphasis to **solar irrigation** systems, **agrivoltaic** technologies and **productive uses of energy**.

Building on these preliminary assumptions, a list of **42 solutions** with high potential of implementing the water-energy food nexus concept was identified. The list has then undergone an in-depth screening based on **8 criteria**: market size, scalability/replicability, WEF Nexus relevance, innovation, affordability, enabling environment, attractiveness for the agriculture & water sectors, attractiveness for the solar-PV sector.

The outcome of the screening was a **short-list of 15 business models**: 3 in the agrivoltaic sector, 5 in the solar irrigation sector and 7 in the productive use of energy in agribusiness. .

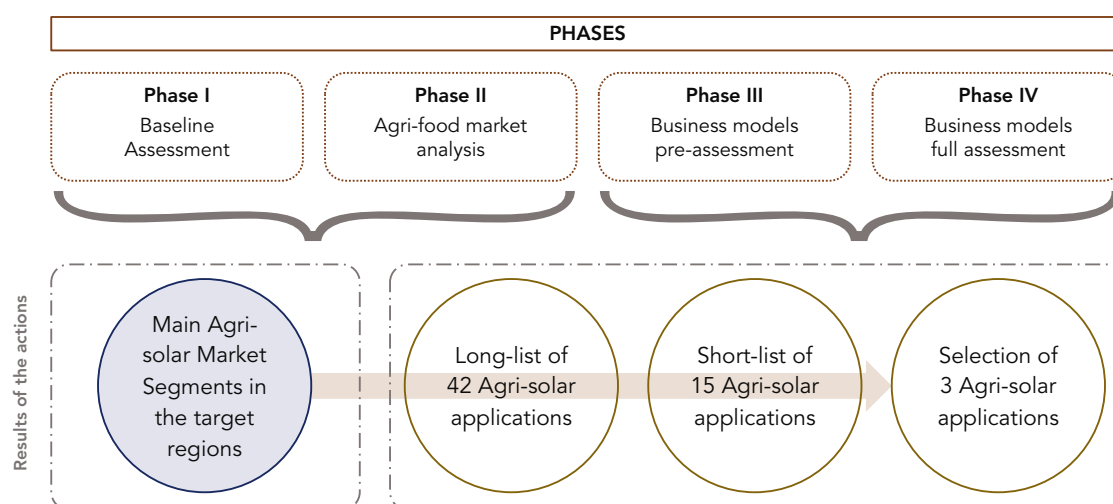
Agri-PV	PV shading for horticulture
	Herding of sheep within PV park
	PV shading for poultry
Solar Irrigation	Small-scale solar irrigation
	Medium-scale solar irrigation
	Water conservation, rainfall collection and storage
	Precision irrigation
Agri-PUE	Crop milling
	Drying (fruits, vegetables, coffee, tea, meat, fish, spices)
	Cold storage: small scale refrigeration (fridges, freezers)
	Cold storage: medium-large scale refrigeration (cold rooms)
	Cold storage: ice-making
	Animal feed production (pellets) and packaging
	Poultry incubation & heating



These 15 business models were further assessed: this process contributed to highlight key features, strengths and weaknesses of each model to restrict the selection to the **three among the most promising solutions**.

- PV shading for horticulture or agrivoltaic
- Precision irrigation
- Cold storage: medium-large scale refrigeration

In the table below the process of selection is highlighted.



### *PV shading for horticulture or agrivoltaic*

Businesses built around this model appear to be particularly interesting in overcoming some of the historical challenges faced by African and Middle Eastern farmers in land cultivation and post-harvesting processes. In both areas, activities related to agriculture contribute to employing 65-70% of the local workforce, while the PV sector is rapidly expanding and generates more than 50.000 jobs in Sub-Saharan Africa.

All the **Agri Photovoltaic (APV) applications can be considered among the most interesting examples of the WEF Nexus approach**: PV energy can power any type of water pumping, irrigation and cultivation systems, leading to an improvement of crop production as well as sustaining PV-powered post-harvest processing. With a focus on the water component, APV can lead to **reduced evapotranspiration** for crops due to panel shading effects and, consequently, to **decreasing water consumption** (-14 / -29% compared to conventional crop production). These elements are particularly interesting in water-stressed areas and where the abstraction of water needs a large amount of energy.

**The potential market for the application is high, both in MENA and in NB regions.** APV projects and PV shading for horticulture specifically record several case studies carried out by research groups and business actors who have implemented APV demonstrations around the world, and **at least 6 documented cases have already reached the market stage**. Thus, in terms of innovation, the technology is already proven in the targeted physical environment and has the characteristics to be scaled up and/or replicated.

The **APV affordability** is more and more demonstrated for application in developed countries, while it still needs further proves in developing countries, even if research projects and pilots have provided encouraging results.

At the policy level, both **MENA and NB regions have favourable regulatory frameworks able to support and encourage the diffusion of similar applications**. PV technology acceptance might be an obstacle, and partnerships with farms add emphasis on engaging local communities, even by means of community-based projects, with the aim to stimulate project acceptance, easing the whole development process and mitigating potential risks (mainly financial and social ones).

**APV solutions tend to be more attractive for the agricultural sector**, as agri-players can share land use with other parties such as energy players. In this way they can reduce the related costs (CAPEX and OPEX). It appears to be **less attractive for energy players**: on one hand APV projects can support them in building partnerships and land projects on the ground (with higher access to financing opportunities); on the other hand, the economic benefit of such a project could be limited. In this publication, 3 different applications of the same technology are compared to give an idea of the potential of a concrete implementation of PV Shading for horticulture:

- **Farm-owned PV plant**: an agri-player invests in a PV plant to be installed on cultivated land to improve efficiency and productivity. The agri-player is the owner of both land and assets..
- **IPP-owned PV plant**: an energy player invests in a PV plant, acting as an IPP, installed on land owned by an agri-player.
- **Agri-energy service company**: an energy player and an agri-player build a partnership to work as Agri-ESCO that delivers integrated agri-PV solutions.

### *Precision irrigation*

Precision irrigation is a useful approach to sustain agriculture activities, especially in countries affected by water scarcity and where farmers highly rely on rainfed agriculture. In the MENA region in particular, 11 out of 17 countries are considered water-scarce and at the same time **agriculture activities are responsible for the use of almost 85% of the region's water resources**.

Currently, large part of used technologies is inefficient. Most fields are only rainfed, leading to limited crop production, and are highly dependent on meteorological conditions. In this context, irrigation practices can i. **boost agricultural productivity**, gross margin and food security; ii. **increase water and energy efficiencies**; and iii. contribute **reducing farmers' vulnerability**.

The adoption of drip irrigation solutions could help **saving water resources between 30% and 55%**, in both regions with limited risks in terms of innovation and replicability, as a consistent number of businesses adopting this technology already exist. Considering a high attractiveness for agri-business players, precision irrigation might be less appealing for PV sector players, unless the business model foresees the involvement of medium-large sized enterprises or integration with mini-grid applications.

However it has to be considered that improving energy efficiency in irrigation technologies might lead to a rebound effect generating overconsumption of water. Case studies show that this trend can be observed where the intensification of agriculture production thanks to energy efficiency generated negative trade-offs on the water resources management.

Despite the fact that this sort of solution has a huge potential for development, it might be **limited to medium-sized companies**, as solar powered irrigation systems' cost could be an obstacle for most of farmers: indeed, in the Niger Basin Region half of agricultural activities consist of businesses that cultivate less than 2 hectares of land each, with **limited capital availability**. The integrations of solar power in precision irrigation technologies further increase the cost of investment.

The **enabling environment** in the two target regions is **quite different**, most of the countries in the MENA region have implemented policies and regulations to support the implementation of precision irrigation policies, also in terms of financing mechanisms. The Niger Basin's framework is very different, as neither policies nor financing mechanisms are in place.

The attractiveness for the agri-business sector is high because the application can help solve water scarcity and improve the productivity of agro-business. On the other hand, the attractiveness for the PV-business sector is low because energy consumption for such applications is limited. Considering the relevance of the application and the solar radiation rate of the regions, **precision irrigation should be encouraged**, and testing more promising business models should be prioritized for tangible and relevant impact in the regions (especially MENA).

In this publication, 3 different applications of the same technology are compared to give an idea of the potential of a concrete implementation of Precision Irrigation:

- **BM1 - Ownership to farmers:** a single private entity invests in precision irrigation systems for its exclusive usage. It is the sole owner of assets and lands.
- **BM2 - Ownership to agri-produce aggregators:** a single private entity invests in precision irrigation systems to serve farmers (individuals or association) with whom it has signed Agri-Produce Purchase Agreements..
- **BM3 - Ownership to technology provider / precision irrigation as a service:** a precision irrigation technology provider provides the Agri-player with a turnkey service for improved crop productivity..

### *Cold storage: medium-large scale refrigeration*

In the target regions there is a consistent market gap in the conservation of food and **about 40% of the production is lost before reaching the market** due to post-harvest spoilage and transportation. **Improving cold chains** could lead to an increasing shelf life that allows to reduce losses and, consequently, increase small farmers' ability to negotiate better prices, especially in poor-grid or off-grid settings. With growing urbanisation, **more and more people depend on well-functioning cold chains** for their daily supply. The fragmentation of the value chain, involving many stakeholders, constitutes a hindrance to the development and financing of necessary cold chain infrastructure and effective cold chain management.

**In MENA and NB regions, at least two private companies are actively present with business models proven at scale** dealing with fruit and vegetables, dairy products, fish and meat, and pharmaceuticals. In terms of scalability, the challenge is to reach a volume of production able to activate cold hubs in an enabling environment, bearing in mind that food cold chains may vary significantly, depending on the local context.

There are different cooling technologies and they are all proven technologies to address different types of usage/function: with the presence of private actors (developers/operators/technology providers) active in the target areas, **there are no relevant risks related to the innovation** of the technology.

With a focus on the **WEF nexus**, there is a very high energy-food synergy thanks to i. the high relevance of energy efficiency, ii. improved food security, and iii. improved nutrition and health. The water component may directly play a role in using natural refrigerant or ice-making and indirectly favour efficient irrigation (e.g., precision irrigation and solar-pumped irrigation systems for perishable fruit and vegetables).

In terms of **affordability**, pre-cooling and temperature-controlled storage are more affordable for farmers than refrigeration and freezing due to less power needs and related cost of cold storage services. The enabling environment does not hamper cold storage projects as this application is aligned with high-level policies and there are no relevant barriers in the regulatory frameworks.

**In the off-grid energy market, cold room operators are a key anchor load** and can strengthen off-grid projects viability. Cold storage powered by mini-grids or off-grid supply is protected from the impacts of an unstable grid system, and often better suited to the rural conditions in sub-Saharan Africa.

In this publication, 3 different applications of the same technology are compared to give an idea of the potential of a concrete implementation of Cold Storage:

- **BM1 – Cold chain logistic services:** a private company owns and operates integrated cold chain logistic services, connecting producers with the selling markets, exploiting renewable energy potential in large cold hubs.
- **BM2 – Pay-as-you-go cold storage services:** a private company owns and operates cold storage services by adopting a pay-as-you-go model by means of solar-powered walk-in cold rooms.
- **BM3 – Pay-as-you-go cold chain services:** a private company owns and operates integrated cold chain services, focused on cold storage and connection with the selling markets, by adopting a pay-as-you-go model through a solar-powered walk-in cold room and digital market linkage platform.

## Conclusions

The analysis on the business models related to the water-energy-food nexus has to be considered as a basis for further discussions; the subject of the report is indeed an evolving one, **new business models are explored every day** and the analysis doesn't have the objective to spot the best model among all the options, but rather to point out at the variety of available possibilities.

It becomes evident that the application of certain business models is more indicated in some regions than the others. Although addressing common issues and aiming at solving challenges in the three sectors, local conditions and enabling environment can make the difference between a success story and a failure of the same operational model. The analysis focuses on three very specific technologies: PV shading for horticulture (or agrivoltaic), precision irrigation and cold storage. These are the WEF applications that were considered to be the most promising for the Niger Basin region and the MENA region. The comparison among business models within the same technologies showed that **small changes in the setup of a business could generate consistent changes in the implementation phase**. Actors involved, ownership of assets, financing structure, geography of action, regulatory framework highly condition the possibility of success for a business. Widening the perspective on the comparison of businesses across different technologies, led to similar conclusions.

For different motivations, all three applications proposed could offer additional tools to **cope with climate change effects**, especially referring to rural communities. The agrivoltaic solutions could boost productivity while reducing soil consumption, the precision irrigation applications could improve the use of water resources while reducing the emissions related to power use, and finally cold storage could boost the efficiency of supply chains and contribute to the reduction of food insecurity. Access to finance for these technologies still remain a challenge, despite the enormous opportunity for local development that could be hindered by the lack of interest of financing institutions and or investors to invest in these applications. For this reason, the finance structure that defines the business models adopted is one of the key factors that could support or limit the diffusion or certain technologies. It indeed influences the attractiveness of applications and their possibility of being replicated and scaled up.

The current picture of the water-energy-food business models in the MENA region and in the Niger Basin region could look **completely different in the next few years**, depending on i) the ability of governments to embed the WEF Nexus in national regulations, ii) the ability of political and international institutions to create synergies among the three sectors, iii) the mobilization of resources dedicated to support WEF nexus related projects both at local and regional level, iv) the coordination of stakeholders to scale up current existing business models. Stakeholders of the value chain should come together to define overarching approaches that can support the development of such technologies. In the framework of the global challenge to contrast climate change's dire effects, the water-energy-food nexus approach is well-positioned to become a useful tool to support communities in raising their resilience, while optimising natural resources.

## Acronyms

APV	Agri Photovoltaic	MW	Megawatt
BMZ	German Federal Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung)	MWh	Megawatt/hour
		NBA	Niger Basin Authority
		NPV	Net Present Value
CAREC	Regional Environmental Centre for Central Asia	NRDP	Nexus Regional Dialogues Programme
EU	European Union	PUE	Productive use of energy
GDP	Gross Domestic Product	PPA	Power Purchase Agreement
GHG	Green House Gas	PV	Photovoltaic
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit	RES4Africa	Renewable Energy Solutions for Africa
GW	Gigawatt	ROI	Return of Investment
GWP-SA	Global Water Partnership Southern Africa	IRR	Internal Rate of Return
IPP	Independent Power Producer	SADC	Southern African Development Community
kW	Kilowatt	SDG7	Sustainable Development Goal 7
kWh	Kilowatt/hour	SPIS	Solar-Powered Irrigation Systems
LAS	League of Arab States	TW	Terawatt
MENA	Middle East and North Africa	TWh	Terawatt/hour
		WEF	Water-Energy-Food

# 01 / Introduction



This publication is developed by RES4Africa Foundation in collaboration with the Nexus Regional Dialogues Programme (NRDP) Phase II, funded by the EU and BMZ (German Federal Ministry for Economic Cooperation and Development) and implemented by GIZ. The NRDP has the objective to mainstream the Water-Energy-Food (WEF) Nexus approach through increased investor awareness, capacity building, concrete projects and expansion of knowledge management.

African and Middle East countries still face complex challenges such as widespread poverty and unemployment, persistent food and water insecurity, lacking infrastructures and industrial capabilities, as well as economic and political instability. Expanding populations and economies will add stress on the current infrastructure and supply systems of countries, also leading to a surge in demand over basic resources such as water, food and energy in the forthcoming years. It is estimated that by 2030 Africa's water consumption will increase by 283% compared to 2005 levels; food demand by 60% compared to 2015 levels, and electricity demand by 70% compared to 2016 levels<sup>1</sup>. The interlinkages captured by the WEF Nexus offer a ground-breaking perspective to increase access to clean energy combined with securing water and food. As such, the WEF Nexus can reveal business models that look at how water, energy and food can be connected to respond to essential development needs, increasing economic productive capacities and driving socio-economic welfare while reducing trade-offs and sustaining an efficient and sustainable use of limited natural resources.

Through the present analysis, RES4Africa aims at supporting the creation of an enabling environment for scaling up WEF nexus investments in the Middle East and North Africa (MENA) and Niger Basin (NB) regions. In fact, despite a growing interest in the connections between water, energy and food sectors, several challenges and barriers still hamper the development of WEF Nexus projects:

- 1) Silo mentality of institutional and private organizations.
- 2) Inadequate financing schemes for implementation and scale-up of nexus projects.
- 3) Limited capacities to regulate/supervise (institutions) and manage (companies) integrated projects.
- 4) Lack of viable and scalable business models.

With the objective of addressing the challenge 4, this report explores integrated business models and innovative approaches in the MENA and Niger Basin regions starting from the existing projects developed by relevant initiatives and companies in the WEF sector. The outcome of this research is an overarching knowledge around the WEF state of the art both in terms of market segments, technology solutions and operating models to be further explored and supported for the implementation at scale and dissemination of WEF approaches.

To identify promising WEF business models in MENA and Niger Basin regions, a comprehensive analysis of the agri-solar sector has been carried out focusing on solutions able to attract private sector investment and scale developers' initiatives: i. agrivoltaic technologies; ii. solar irrigation systems; and iii. productive uses of energy in agribusiness.

<sup>1</sup> UNEP & IRP, Options for decoupling economic growth from water use and water pollution, 2016



# 02 / **Methodology**





The methodology (see Figure 2-1) of the present work is structured in four main phases. A State of the Art (SoA) analysis to set the context of the target regions, MENA and Niger Basin (Phase I). Phase II includes an analysis of the agri-food sector and the related technologies; the outcome is the identification of specific

market segments and related agri-solar applications for the implementation of WEF Nexus projects (Phase III). Having identified the most promising applications, characterized by a higher potential for development, a detailed analysis of business models is carried out in Phase IV.

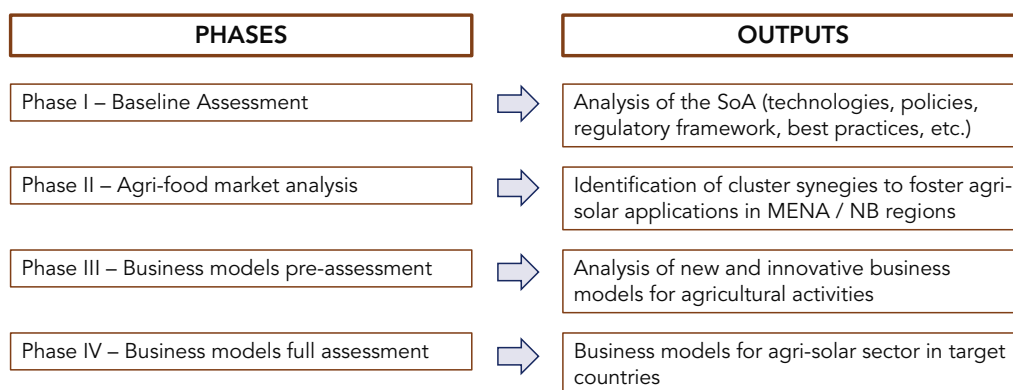


Figure 2-1 Main phases of the methodology

## 2.1 Phase I: Baseline assessment

Phase I analyses the current State of the Art of the agri-solar sector, in order to provide a preliminary assessment of the market for WEF Nexus solutions across the selected regions. Through desk research (e.g., official report, scientific

literature, etc.), analysis and consultation of key actors; phase I assesses the following elements: i. macroeconomic conditions; ii. agriculture and water resources; and iii. Energy status and natural resource potential.

## 2.2 Phase II: Agri-food market analysis

Phase II analyses the current State of the Art of the agri-food sector in order to identify opportunities and the most appropriate market segments for WEF Nexus solutions and business models in the MENA and NB regions. With the objective to assess sectors able to attract private sector investments, scale developers solutions and initiatives, three categories have been identified as a goal of the analyses:

- **Solar Irrigation:** production of energy from solar photovoltaic (PV) panels to power electric water pumps and irrigation systems.

- **Agrioltaic:** adjacent installation of PV systems and implementation of a sustainable agricultural activity.
- **Productive Use of Energy in Agribusiness (Agri-PUE):** deployment of PV in the vicinity of agricultural activities (crop production, transformation, and storage) to power agricultural machinery and related activities. It includes several business models that apply to a variety of beneficiaries: from small holder farmers to cooperatives and large companies.

Through desk research (e.g., official report, scientific literature, etc.), analysis and consultation of key actors, phase II analyses and identifies agriculture activities (largely diffused in the

target regions) able to create positive synergies with the above-mentioned categories, while significantly improving farm productivity and justifying investment costs.

## 2.3 Phase III: Business Model Pre-Assessment

The Business Model Pre-Assessment (Phase III) includes the identification and assessment of agri-solar business models which are able to promote WEF Nexus approaches in MENA and Niger regions. This phase is carried out in **three-steps**:

- 1) **Identification of a long-list of applications:** 42 potential agri-solar applications are identified in the target regions. The list is developed starting from both the baseline and agri-solar market assessment (Phase I and II).
- 2) **Screening of the long-list of applications:** a team of six experts (ANNEX I: Evaluation Matrix) carried out an independent evaluation of the 42 applications through an ad-hoc developed scoring system based on criteria reported in Table 2-2<sup>2</sup>, and disaggregated for MENA and NB regions.

Final scoring is given through a weighted scoring system which leverages on the experts' specific expertise:

- Double weight was assigned when criteria and/or application falls in the expert's fields of expertise. Knowledge of target regions as well as the education and professional background are considered.
- No weight is assigned when criteria and/or application falls out of such fields.

Out of the 672 scoring cells<sup>3</sup>, 420 cells (63%) record 6 scores, 216 cells (32%) record 5 scores, 22 cells (3%) record 4 scores, 12 cells (2%) record 3 scores. Relevant deviations from

the average values were discussed in team to validate the final scoring.

The result of the screening is a selection of 15 agri-solar applications, or short-list, that have undergone a more detailed analysis in the following step. In the selection process, no quantity of applications was pre-identified per each of the three sectors (Agri-PV, Solar Irrigation, Agri-PUE), so to prioritize applications with greater potential.

- 3) **Pre-Assessment:** 15 short-listed agri-solar applications were preliminarily assessed with the purpose to identify 3 agri-solar applications for the full assessment (Phase IV). The pre-assessment is performed by means of desk research focused on 8 key areas (Table 2-2), allowing a comparison between agri-solar applications (ANNEX II: Pre-Assessment Criteria Matrix including sub-areas).

The assessment disaggregates MENA and NB regions, while an additional focus for the business scale was added to better identify geographic differences and to make applications with a greater potential stand out. The pre-assessment method leverages on the experts' different expertise while adopting a participative approach:

- (i) the desk research of each application was assigned to a single expert according to his field of expertise
- (ii) the draft versions of main findings were integrated by other experts

<sup>2</sup> Note: In this short-list stage, a broader meaning was given to Criteria #3 "WEF Nexus" by including climate change mitigation effects.

<sup>3</sup> Note: 42 applications \* 8 criteria \* 2 regions (MENA and NB)

(iii) the scoring was discussed and assigned with the technical team

(iv) the results were discussed and validated by the RES4Africa and GIZ coordination teams.

1	<b>MARKET SIZE</b> Potential market size according to the farming systems
2	<b>SCALABILITY / REPLICABILITY</b> Scalability/replicability potential of existing business models related to this application.
3	<b>WEF NEXUS</b> Relevance of the application in promoting the WEF Nexus approach.
4	<b>INNOVATION</b> Level of innovation of the technology, its application and adopted business models.
5	<b>AFFORDABILITY</b> Estimate of application-related costs in relation to business model as a whole.
6	<b>ENABLING ENVIRONMENT</b> Synergy with government policies and international financing.
7	<b>ATTRACTIVENESS FOR THE AGRICULTURE SECTOR</b> Attractiveness of the application for the agriculture sector, taking into account the water-related aspects, and including private and public actors as well as government development agencies, commercial and development financing entities.
8	<b>ATTRACTIVENESS FOR THE SOLAR-PV SECTOR</b> Attractiveness of the application for the solar-PV sector, including private and public actors as well as government development agencies, commercial and development financing entities.

Table 2-2 Pre-Assessment Criteria Matrix

## 2.4 Phase IV: Business Model Full Assessment

The Business Model Full Assessment (Phase IV) is focused on the analysis of the 3 agri-solar applications selected in the Phase III, showing high potential of replicability in the targeted regions (for selection process, please refer to chapter 5).

Three alternative business models are presented for each selected agri-solar application. In order to develop business models based on lessons learnt and existing pilots, demonstrations and scale-up solutions, a desk review of existing models was carried out as well as a business stakeholder consultation. Each business model is presented with the following sections:

- Main reasons for supporting the agri-solar application under analysis.
- BM Canvas.<sup>4</sup>
- BM description (BM in a nutshell, overview, how it works, reference project in operation).
- BM scheme layout.
- Comparison between BM1, BM2 and BM3 per each selected agri-solar application.
- Business planning simulation to verify the economic sustainability.
- Key Enabling factors.
- Recommendations for the policy makers and developers.

<sup>4</sup> Osterwalder, Alexander; Pigneur, Yves; Clark, Tim., Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers. *Strategyzer series*, 2010.

# 03 / **Setting the context: MENA and Niger Basin regions**



The general objective of the preliminary baseline assessment for the agri-solar sectors in the MENA and the NB regions is to perform a high level analysis of the context, necessary to identify the potential impact that agri-solar applications could have on the target territories and onto local communities.

According to the preliminary results of the analysis, it emerges that both MENA and NB regions mostly rely on agriculture activities, largely for subsistence purpose, but the adopted practices are characterized by inefficiencies and vulnerabilities. In particular, MENA countries have a long-term tradition in farming activities. Nonetheless, major criticalities, as water scarcity, are becoming more and more relevant. Such issues are also affecting the NB region (with lower intensity) and it is partially a direct consequence of climate change effects, such as erratic rainfall. For this reason, for both regions, water saving technologies, are increasingly becoming relevant to improve yields, productivity, food security and resilience, particularly among subsistence farmers<sup>1</sup>.

The promotion of efficient practices in farming activities also enables access to a larger number of services for processing raw materials or improving the existing ones. Having a look to the macro-economic situations of MENA and NB markets, it is possible to understand which sectors could benefit the most: the MENA region is one of the biggest food importers in the world (cereals, grain, wheat) and, as a result, the secondary sector is quite advanced. On the other hand, Niger Basin countries rely on agriculture, which, together with the regional water availability (including both rain

and river water availability, despite variations in the different climatic areas) makes this area advanced in the primary sector.

Both areas (NB region in particular) will also have to cope with a growing population and urbanization. Such trends will affect the entire continent, but some countries (i.e., Nigeria, Cameroon) will report unique urban areas expansions.

The two regions are also characterized by different energy sectors. MENA countries rely on a more robust energy infrastructure, with high electrification rate and only few areas not covered by the national energy grid. Most of the countries take advantage of local fossil fuels deposits, thus abundant renewable resources are not exploited and related technologies not largely distributed. On the other hand, NB region has low electrification rates but, considering the local availability of water, hydroelectric generation is largely diffused (see Table 4-5 and Table 4-7 Total Energy Supply by sources in MENA and NB countries), even if a notable potential could be still exploited (see Table 4-8 "Estimates of technical potential for renewable energy in NB basin"). These elements are fundamental for identifying strategies to support farmers' activities and to promote sustainable energy services, as they could either favour or hamper deployment of agri-solar projects.

In order to identify challenges and opportunities in the target regions, the analysis takes into consideration (i) macro-economic conditions, (ii) agriculture and water resources and (iii) the energy status and natural resource potential. The main evidence is summarized in the next sections.

<sup>1</sup> IRENA and FAO, Renewable energy for agri-food systems – Towards the Sustainable Development Goals and the Paris agreement, 2021

### 3.1 Macroeconomic conditions

#### MENA region

The MENA region considered in this study includes the following countries: Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, Yemen.

It consists of a heterogeneous group of countries ranging from the high-income oil-exporting countries in the Gulf, to middle-income and lower-middle income countries. As one of the largest global net food importing region, it faces considerable uncertainties on both the supply side and the demand side. The same scenario is also evident in other sectors: the region is characterized by a relevant reliance on raw material exports for foreign exchange earnings as well as a dependence on foreign markets as a source of industrial produce. These dependencies have contributed to generate two of the main challenges of the region: economic growth volatility and high unemployment

levels, especially among the youth<sup>2</sup>. Economic diversification and the development of the non-resource sector are two strategies for ensuring a long-term economic stability.

Despite their heterogeneity, countries in the MENA region share several characteristics highlighted in Table 3-1. Growth in the region has underperformed, with GDP per capita growing at only 1.6% per year from 2001 to 2016, while middle income countries overall grew by 4.3% over the same period.

Taking into account that the region suffers from severe land constraints (less than 5% of land is arable in two-thirds of the countries of the region), and it is the most water-stressed in the world with two-thirds of countries using groundwater at rates exceeding renewable internal freshwater resources, the region has the lowest water prices in the world, spends massive resources on water subsidies (about 2% of GDP) and has total water productivity of only half the world average<sup>3 4</sup>.

	GDP per capita		Agricultural land	Arable land	Arable land	Annual freshwater withdrawals	Exports (2014)	Imports (2013)
	Current USD	Growth in % per year, 2000-16	% of total land area (2014)		(2014) billion m <sup>3</sup>		Share of mineral fuels, lubricants and chemical products (%)	Self-sufficiency ratio (%)
Qatar	86 853	0.6	6	1	0.06	0.44	87	3
United Arab Emirates	44 450	-2.1	5	0	0.15	4.00	38	-
Kuwait	42 996	0.1	9	1	0.0	0.9	94	-
Bahrain	24 983	-0.1	11	2	0.0040	0.3574	48	-
Saudi Arabia	24 575	1.2	81	2	2	24	90	33
Oman	20 458	-0.2	5	0	1.40	1.32	79	5
Lebanon	8 537	0.4	64	13	4.8	1.3	13	41
Iraq	6 703	2.7	21	12	35	66	95	54
Libya	5 603	-2.4	9	1	0.7	5.8	77	-

<sup>2</sup> G20-insights, Economic diversification in the MENA Region, 2020

<sup>3</sup> World Bank, 2018.

<sup>4</sup> Note: data considers a more extended region than the MENA region as defined in the introduction of section 4.

	GDP per capita		Agricultural land	Arable land	Arable land	Annual freshwater withdrawals	Exports (2014)	Imports (2013)
	Current USD	Growth in % per year, 2000-16	% of total land area (2014)		(2014) billion m <sup>3</sup>		Share of mineral fuels, lubricants and chemical products (%)	Self-sufficiency ratio (%)
Iran, Islamic Rep.	5 541	2.5	28	9	129	93	77	85
Algeria	5 466	2.0	17	3	11	8	98	64
Tunisia	4 270	2.3	65	19	4	3	14	75
Jordan	4 067	1.1	12	3	0.7	0.9	32	38
Egypt, Arab Rep.	3 328	2.2	4	3	2	78	31	72
Morocco	3 155	3.0	69	18	29	10	16	80
Palestinian Authority	2 961	0.6	50	11	0.81	0.42	6	16
Sudan	2 177	4.2	29	8	4	27	64	85
Syrian Arab Republic	2 058	2.1	76	25	7	17	24	-
Yemen, Rep.	1 647	-2.4	45	2	2	4	41	50
Mauritania	1 327	1.4	39	0.4	0.4	1.4	4	-

Table 3-1 MENA economic situation<sup>5</sup>

### NB region

The NB basin in West and Central Africa covers a total area of 2.13 million km<sup>2</sup> and its active basin is home to over 160 million people throughout nine countries: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger, and Nigeria. Five of the nine basin countries (Benin, Burkina Faso, Chad, Mali, Niger) are among the least developed countries in the world<sup>6</sup>, with large income disparities. On top of this, the NB region includes a group of countries characterized by similar environmental/geographical conditions.

Many of these countries are facing rapid population growth (an estimated annual average of +3.2%) and a strong urbanization process (currently 64% of the population is rural but by 2025, the urban population is expected to account for more than half of

the people) in a vulnerable environment. Agriculture is one of the most important sectors, it contributes to 25-35% of the basin's GDP, while livestock and fishery contribute 10-15% and 1-4%, respectively<sup>7</sup>. Therefore, the economy is highly dependent on agriculture, and considering unstable climate conditions and inefficient production methods, local economies, which employ 85% of the labor force, are fragile. With the exception of irrigated rice, agricultural production systems have not experienced any major improvement. The agricultural sector in this region is largely made up of small-scale farmers, using rudimentary material and registering very low yields. Rain-fed production accounts for the bulk of the basin's agricultural production, but it is prone to extreme weather events such as droughts and erratic rainfall.

<sup>5</sup> World Bank, 2018.

<sup>6</sup> UNCTAD, Least Developed countries list

<sup>7</sup> Namara E.R. et al., An Overview of the Development Challenges and Constraints of the Niger Basin and Possible Intervention Strategies, 2011



## 3.2 Agriculture and water resources

### MENA region

The MENA countries are challenged with increasing water deficit, while striving to achieve self-sustaining agriculture. The region only contains 1.4% of the world's freshwater resources, making it one of the world's most water-scarce regions. Food insecurity is a constantly growing challenge.

Even before COVID-19, World Bank estimated that over 55 million of its population (of a total of 456.7 million) was undernourished. In 2020, MENA's share of the world's acutely food insecure people was 20%, which was disproportionately high compared to its 6% share of the global population<sup>8</sup>. More than 50% of the food consumed in the MENA region is imported, making it the largest food importing region in the world. High rates of population growth combined with severely constrained water and land resources suggest that this dependence on imports will increase or remain at current levels for the foreseeable future.

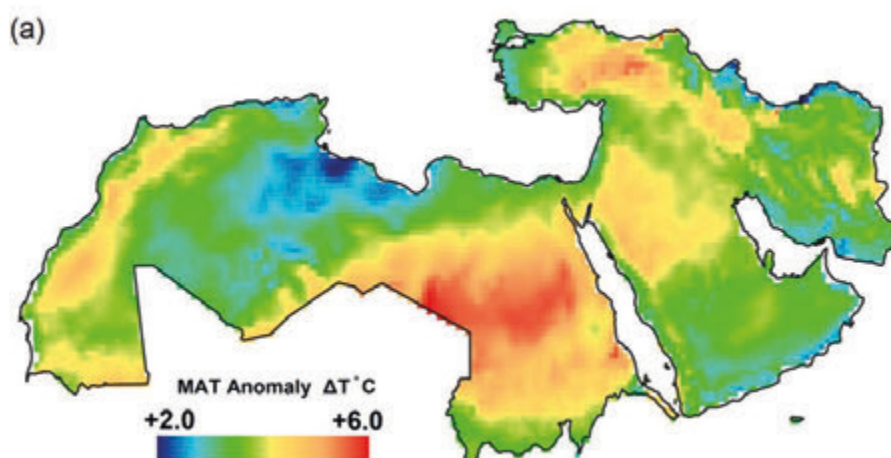
Generally, two factors determine the amount of water that is required: the growing periods and the water demands of particular crops. Improved agricultural practices can contribute

to increasing water-use efficiency, and consequently can save water to be relocated in other sectors or in additional agricultural activities. Optimizing the water usage in the agricultural sector is therefore crucial. A proper selection of crops should consider climatic conditions to enhance water-use efficiency.

With regard to **farming systems**, five major types are identified as predominant in the MENA region<sup>15</sup>:

- irrigated,
- highland mixed
- rain-fed mixed
- dryland mixed
- pastoral farming

Sparse and arid land, primarily used for nomadic pastoralism, covers 62% of the region; however, the majority of the agricultural population lives outside of this arid zone, falling within the highland mixed (30%), rainfed mixed (18%), irrigated (17%), and dryland mixed (14%) farming systems<sup>9</sup>. The main rainfed crops are wheat, barley, legumes, olives, grapes, fruit and vegetables.



<sup>8</sup> World Bank, Mena has a food security problem but there are ways to address it, 2021

<sup>9</sup> FAO, 2022



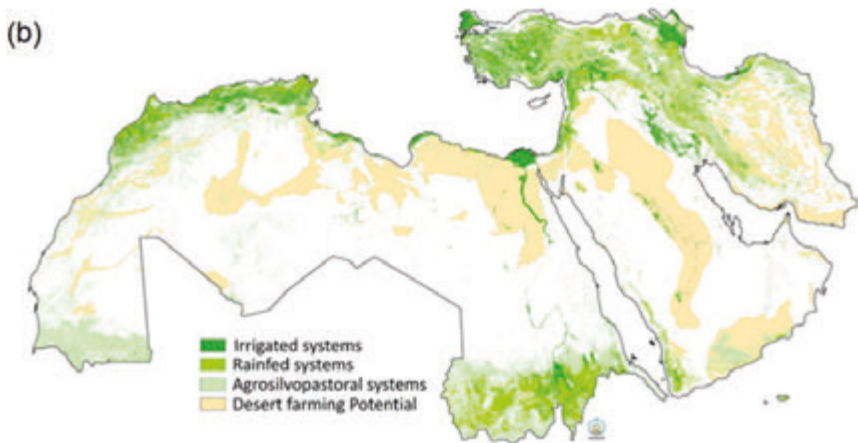


Figure 3-1 The climate vulnerability map of the MENA region (a) and irrigation management<sup>10</sup> (b)

The agriculture sector covers a significant part of the local commercial activities, even though it does not represent the core business for the area (it is often associated to subsistence agriculture).

The most active countries in the sector are the Al-Mashreq countries (Iraq, Syria, Lebanon, Jordan, Palestinian territories). More in general, the whole region is not characterized by an intensive use of the land, having one of the lowest performance rates for the land use. Actions addressed to the improvement of the

agriculture sector in the region could lead to major independency from export and to a significant economic growth.

As a large part of the regional agriculture is based on subsistence activities, the policies in MENA region mostly support grain production and consumption, with the result that 65% of cropland is planted with water-thirsty cereals, in particular wheat which accounts for a large share of calorie intake<sup>11</sup>. Wheat production is diffused in the whole region, with a very diversified performance rate (Figure 3-2).

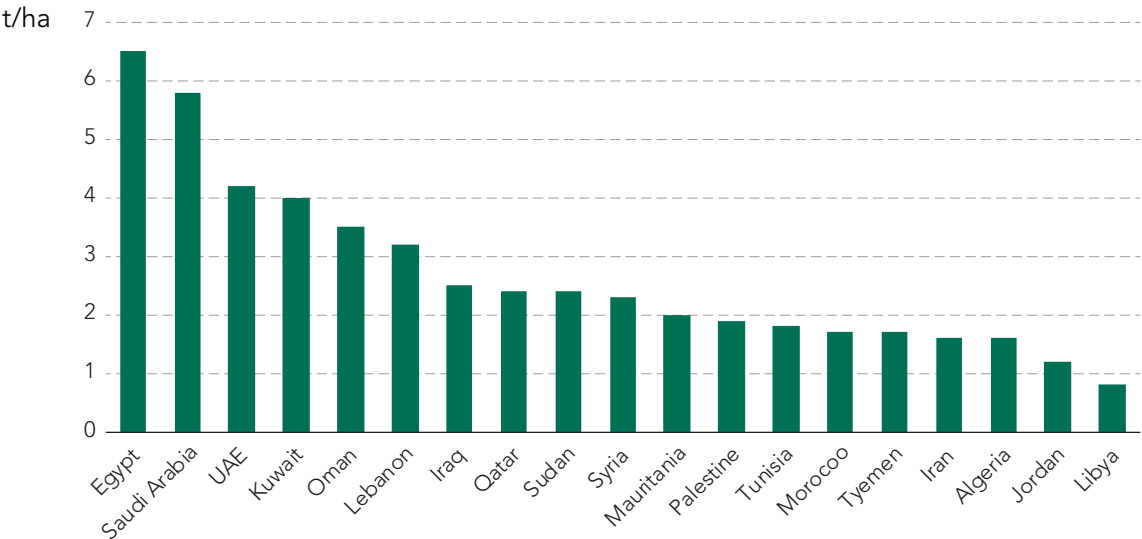


Figure 3-2 Average wheat yield in the MENA region, by country, 2010-16

<sup>10</sup> Govind et al., Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region, 20'21.

<sup>11</sup> OECD / FAO, Agricultural Outlook 2018 – 2027, 2018

Energy production in the region still strongly relies on fossil fuels, even though there is a high potential for renewable energies and 30 million people in the Arab region have no access to electricity yet. In addition, the countries are highly vulnerable to the impacts of climate change. Restructuring energy systems toward renewable energy sources contribute to water sustainability. Relevant benefits to the region would be brought by shifting toward less intensive power plant cooling technologies and investing in low water intensity

renewable technologies (in particular, solar photovoltaic)<sup>12</sup>.

#### NB region

L'Autorité du Bassin du Niger (ABN) or the Niger Basin Authority (NBA) is an intergovernmental organisation responsible for the joint management of the river and for sustainable development of the basin. NBA promotes coordinated development in different sectors: water, energy, agriculture, livestock, fisheries, forestry, and society<sup>13</sup> (Figure 3-3).



Figure 3-3 Niger Basin region

Agricultural activities in the basin can be classified into four groups: i) pastoral livestock, ii) agro-pastoralism, iii) fisheries and iv) irrigated farming. The spatial distribution of agricultural activities follows the agro-climatic zones and the annual rainfall variability.

About 50 million people practice agro-pastoralism, growing subsistence crops during the rainy season, and complement this with livestock

by-products, traditional food gathering and market gardening, typically for vegetables. Rain-fed subsistence agriculture supplies 78% of the total agricultural production in the basin. Nomadic pastoralists represent 2-3% of the rural population. They exploit the rangelands adapting to the limited amount of biomass by constantly displacing the herd which are usually composed of approximately 100

<sup>12</sup> Alberto Belda González, *The Water-Energy-Agriculture nexus in Jordan – A case study on As-Samra wastewater treatment plant in the Lower Jordan River Basin*, 2018.

<sup>13</sup> EU/GIZ, *Niger Basin Nexus profile*. 2018.

cattle, or several hundred sheep adapted to this mobility. These pastoral movements lead to regular conflicts between nomadic pastoralists and sedentary agro-pastoralists, mainly caused by disputes over access to resources such as fodder and water.

Rainfall distribution determines the type of crops cultivated in the basin:

- In the extreme north, rainfall is just sufficient for seasonal pasture.
- In the south there is millet and sorghum, then banana, plantain, cassava, yam and finally rice

as well as in irrigated areas in the Inner Delta in Mali, Niger and Nigeria<sup>14</sup>.

Currently, only 1% to 5% of the cultivated land within the basin is irrigated and projects are in progress to expand irrigated land. On one hand, the NBA traditionally favors large-scale irrigation development and on the other hand, some donors favor small-scale irrigation projects. Still, most of the irrigated surface rely on traditional techniques such as free flooding practiced in floodplains and recession flooding which takes advantage of the residual humidity of the soil and capillary action as the flood recedes<sup>15</sup>.

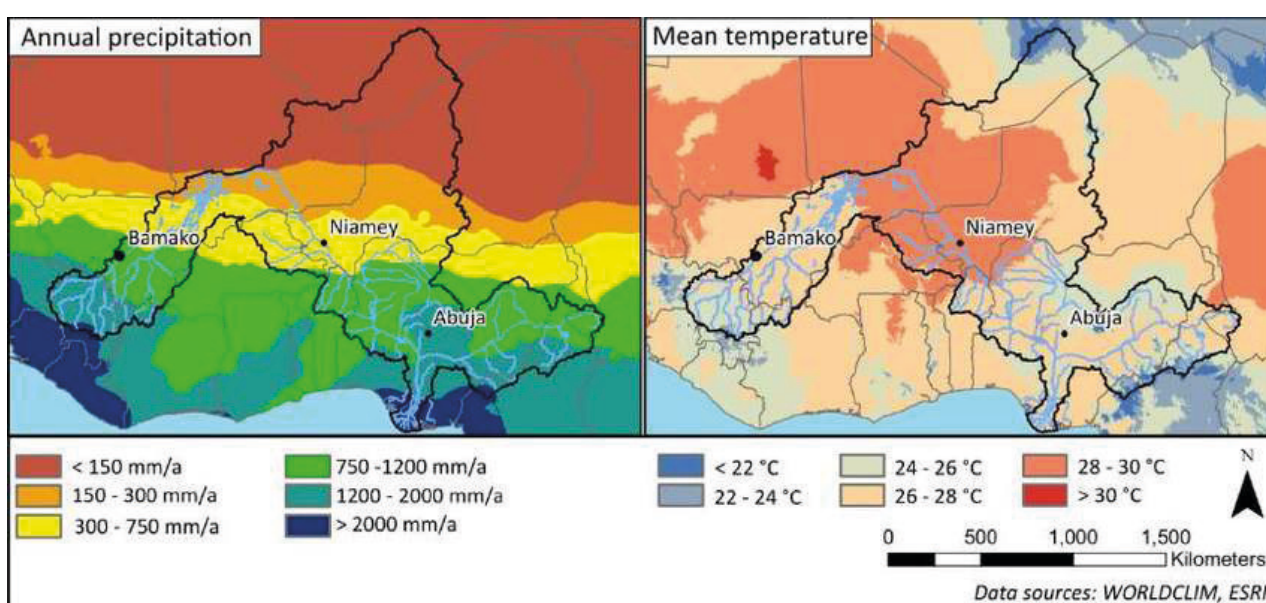


Figure 3-4 Average annual precipitation and mean temperature in the Niger Basin

The main challenges of the agriculture sector can be summarized as follows:

- Continued dependence on rain-fed agriculture.
- Unfavourable land tenure system.
- Inefficiencies in financial and marketing services.
- Decline in political commitment to agricultural and rural development, inadequate incentive framework and pervasive distortions in the macro-economy.
- Rapid shift of the population from rural to urban areas and the shift in consumption patterns from local to imported food items.
- Generalized aging of the plantations of coffee, cocoa, oil palm and coconut trees.
- Inadequate use and low mastery of modern farming techniques.

<sup>14</sup> EU/GIZ, Niger Basin Nexus profile. 2018.

<sup>15</sup> EU/GIZ, Niger Basin Nexus profile. 2018.

### 3.3 Energy status and natural resource potential

#### MENA region

The MENA region is characterized by a high level of electrification rate (Table 3-2): in 2019

it reached the 97.4 % of the local population, having at the lower limit Libya (68,5%) and Yemen (72,7%).

Country <sup>16</sup>	Access rate (2019, %)	Population (2020, million)	Rural Population (2020, %)	Energy Use per person (2020, kWh/year)
Algeria	99.5	43.8	26	14560.58
Bahrain	100	1.7	10	145193.3
Egypt	100	102	57	9899.44
Iran	100	84	24	39785.35
Iraq	100	40	29	14245.68
Israel	100	8.6	7	33624.58
Jordan	100	10.2	9	11483.72
Kuwait	100	4.2	0	98021.05
Lebanon	100	6.8	11	15613.75
Libya	68.5	6.8	19	25863.95
Morocco	99.6	37	36	6607.388
Oman	100	5.1	14	74513.6
Qatar	100	2.8	1	188811.8
Saudi Arabia	100	34.8	16	84261.77
Syria	89.3	17	45	-
Tunisia	100	11.8	30	10435.09
United Arab Emirates	100	9.8	13	117685.6
Yemen	72.7	29.8	62	1598.114

Table 3-2 Electrification rates in MENA region

Demand for energy in the MENA region is steadily growing because of an increase in population, large levels of industrialization, and other factors. Based on the World Bank's estimates<sup>17</sup>, primary energy demand in the region is forecasted to increase consistently at a rate of 1.9% per year until 2035. This increasing need for energy (around 1500 TWh of electricity consumption in 2015<sup>18</sup>) is coupled with dwindling reserves of hydrocarbons or fossil fuels within

the area, and also worldwide. As these finite resources diminish, countries aim at reducing as much as possible the quantity of any fuel import, since their exports generate larger revenues and energy imports are extremely expensive. There are approximately 28 GW of renewable energy capacity installed across the MENA region (of which 21 GW from hydropower), equivalent to only 7% of the region's total power generation capacity (Table 3-3).

<sup>16</sup> Ourworldindata.org

<sup>17</sup> World Bank, 2021

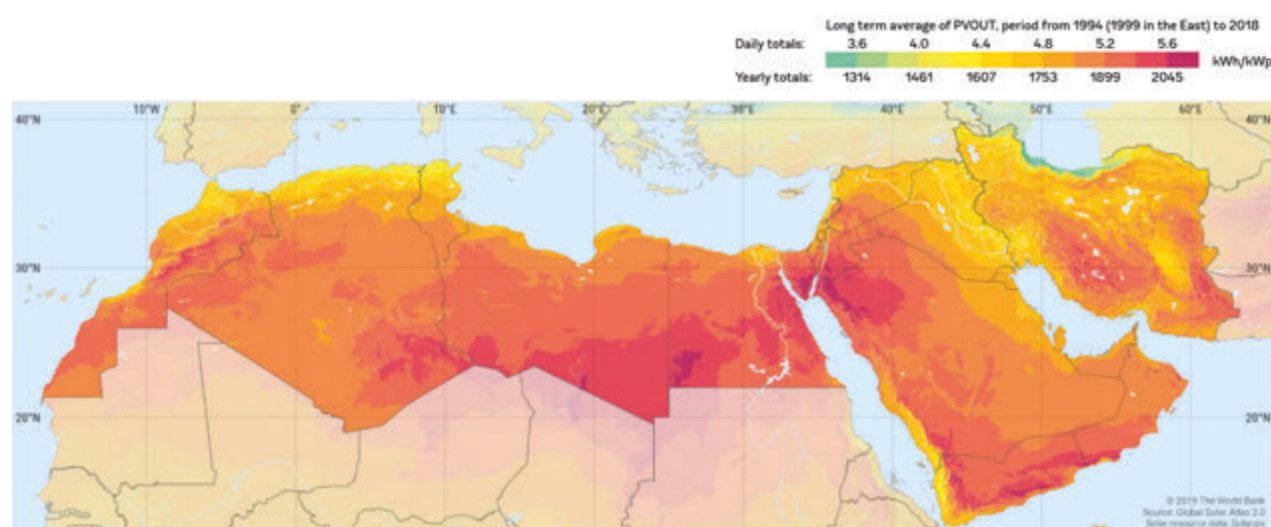
<sup>18</sup> IAI, The MENA Region in the global energy markets, 2018

Country <sup>19</sup>	Coal (%)	Natural gas (%)	Hydro (%)	Biofuels (%)	Oil (%)	Wind/ solar (%)	Nuclear (%)	Total Energy Supply (TJ)
Egypt	2.78%	54.74%	1.17%	3.50%	37.35%	0.46%	-	4,028,369
Algeria	0.49%	63.70%	0.02%	0.02%	35.68%	0.09%	-	2,637,742
Bahrain	-	87.42%	-	-	12.58%	-	-	644,999
Iran	0.36%	67.66%	0.50%	0.19%	30.58%	0.03%	0.68%	11,437,403
Iraq	-	27.71%	0.29%	0.09%	71.90%	0.01%	-	2,261,828
Israel	20.74%	38.39%	-	0.19%	37.27%	3.41%	-	928,671
Jordan	2.27%	37.26%	0.02%	1.06%	54.27%	5.12%	-	385,914
Kuwait	20.74%	38.39%	-	0.19%	37.27%	3.41%	-	895,980
Lebanon	1.82%	-	0.96%	1.91%	94.63%	0.68%	-	361,185
Libya	-	31.76%	-	2.75%	65.48%	-	-	914,061
Morocco	29.84%	3.92%	0.49%	5.88%	56.53%	3.35%	-	935,054
Oman	-	97.57%	-	-	2.43%	-	-	981,510
Qatar	-	92.40%	-	0.02%	7.58%	-	-	1,731,164
Saudi Arabia	-	37.37%	-	-	62.60%	0.02%	-	8,983,957
Syria	0.01%	30.76%	0.70%	0.08%	68.45%	-	-	389,343
Tunisia	-	49.09%	0.05%	9.80%	39.94%	1.12%	-	468,028
United Arab Emirates	2.88%	89.09%	-	0.07%	7.37%	0.59%	-	2,584,447
Yemen	2.03%	-	-	3.18%	93.77%	1.02%	-	170,616

Table 3-3 Total Energy Supply by sources in MENA countries (2019)

The region is blessed with abundant renewable energy resource (Figure 3-5) and characterized by increasing electricity demand of about 5% a year. Expanding renewables capacity is now one of the top priorities for governments in the

region, and governments have set ambitious clean energy targets in the 2022 Renewable Energy Conference in Dubai, aiming for 75% of MENA energy to come from clean sources by 2050.

Figure 3-5 MENA renewable energy potentials for power production<sup>20</sup>

<sup>19</sup> IEA, 2020

<sup>20</sup> S. Griffiths, A review and assessment of energy policy in the Middle East and North Africa region, 2017



### NB region

The NB region is characterized by a heterogeneous level of electrification rate (Table 3-4), having at the lower limit Chad (8.4%), Burkina Faso (18.3%) and Niger (18.7%).

The region is also characterized by a significant **urban-rural disparity in electricity coverage**. In rural areas, few households have individual electricity meters, and poor people usually use a group meter. In urban areas, the

supply of electricity is irregular and subject to frequent outages or cuts and the electricity services are not widespread. Among the basin countries, only Côte d'Ivoire has managed to have a widespread electricity coverage, ensured by six hydroelectric and three thermal power stations. The very low rate of access to modern energy services has a considerable influence on the **quality of life** of thousands of households.

Country <sup>21</sup>	Access rate (2019, %)	Population (2020, million)	Rural Population (2020, %)	Energy Use per person (2020, kWh/year)
Benin	40.3	12.1	52	2482.909
Burkina Faso	18.3	20.9	86	952.475
Cameroon	63.4	26.5	42	1818.164
Chad	8.4	16.4	76	461.715
Côte d'Ivoire	68.5	26.3	48	2417.203
Guinea	42.4	13.1	63	1211.762
Mali	48	20.2	56	1289.118
Niger	18.7	24.1	83	451.225
Nigeria	55.4	206	48	2481.222

Table 3-4 Electrification rates in NB region

The NB region largely relies on fossil fuels but it also has relevant **untapped renewable potential**, in particular in terms of hydropower (Table 3-5), estimated to be around 30,000 GWh of which only 20% is currently exploited<sup>22</sup>. The most important existing hydro plants are placed in Mali (Selingue 43,5 MW, Markala 10MW), Nigeria (Kainji 760 MW, Jebba 540 MW) and Cameroon (Lagdo 72 MW). Currently, firewood and charcoal are the main fuels used by households for cooking. In Niger, forests provide about 87% of the national energy requirements, and 97% of household energy consumption.

The annual primary energy consumption in the basin is only 3,4 MWh per capita (mostly coming from biomass), compared to the African and world averages of 8 MWh and 22 MWh, respectively<sup>23</sup>. Regarding electricity, the average annual consumption per inhabitant in the basin is 70 kWh, **less than a tenth of the African average** of 740 kWh. However, an increasing energy demand due to population growth, rapid urbanisation, and industrialisation is a concern also considering the challenges in energy exchanging across borders.

<sup>21</sup> Ourworldindata.org

<sup>22</sup> EU/GIZ, Niger Basin Nexus profile. 2018.

<sup>23</sup> World Bank, 2021

Country <sup>24</sup>	Coal (%)	Natural gas (%)	Hydro (%)	Biofuels (%)	Oil (%)	Wind/solar (%)	Total Energy Supply (TJ)
Benin	1.21%	0.91%	-	55.59%	42.28%	0.01%	216,960
Burkina Faso	1.00%	-	-	68.00%	30.00%	1.00%	192,739
Cameroon	-	5.94%	4.61%	71.09%	18.34%	0.02%	408,447
Chad	14.00%	-	-	86.00%	-	-	86,105
Ivory Coast	-	17.38%	2.77%	59.83%	20.01%	0.01%	448,362
Guinea	-	-	3.00%	66.00%	31.00%	-	171,563
Mali	-	-	4.00%	73.00%	23.00%	-	209,454
Niger	1.94%	0.96%	-	77.96%	19.08%	0.06%	138,597
Nigeria	0.02%	9.74%	0.37%	74.74%	15.13%	-	6,594,651

Table 3-5 Total Energy Supply by sources in NB basin (2019)

The region can rely on relevant renewable energy potential, from high solar radiations covering the whole region (from 4.4kWh to 6kWh/m<sup>2</sup> per day), to small hydro and wind resources, with the latter being limited to specific

areas. Biomass availability is a common feature of the region, even though the adoption of clean and secure combustion systems would be a major improvement.

Country <sup>25</sup>	Small Hydro <sup>26</sup> (MW)	Solar CSP (MW)	Solar PV (MW)	Biomass (MW)	Wind (MW)
Benin	187	-	3,532	761	322
Burkina Faso	38	-	82,556	1,075	9,881
Cameroon	970 <sup>27</sup>	-	40,000	-	400
Chad	-	-	-	-	-
Ivory Coast	41	213	28,919	3,260	2,548
Guinea	198	2,774	37,569	1,732	2,114
Mali	117	103,658	298,812	447	7,962
Niger	0	171,136	442,931	266	54,156
Nigeria	735	36,683	492,471	7,291	44,024

Table 3-6 Estimates of technical potential for renewable energy in NB basin

<sup>24</sup> IEA, 2020

<sup>25</sup> IRENA, Planning and prospects for renewable power: WEST AFRICA, 2018.

<sup>26</sup> Note: small hydro data are inputs for potential hydro-projects; this is the focus of IRENA's report. Large hydro projects fall into large infrastructures and are managed at Government level instead.

<sup>27</sup> LIU, D., LIU, H., WANG, X., and Kremere, E., eds, World Small Hydropower Development Report 2019.

# 04 / **Agri-solar technologies and market segments**





Any agri-solar project should be tailor-made to the local agronomical, environmental, and socioeconomic conditions and stakeholders involved. When such components are assessed together with the sustainability of the local agricultural practices, local ecosystem services and their integration within the local social and economic setting, it can be considered that a “Sustainable Agriculture Concept”<sup>1</sup> is in place. Agri-solar refers to the integration of solar PV projects within an agricultural activity. It includes

a variety of business models, co-designed between the solar and the agricultural sectors, such as agrivoltaic (or Agri-PV) systems, rooftop PV for agricultural buildings or powering agricultural machineries with solar power. Energy is needed in all steps along the agri-food chain, both directly (production, processing, and transport) and indirectly (manufacturing of fertilizers, agro-chemicals and machinery), although a significant amount of energy is lost through food losses.

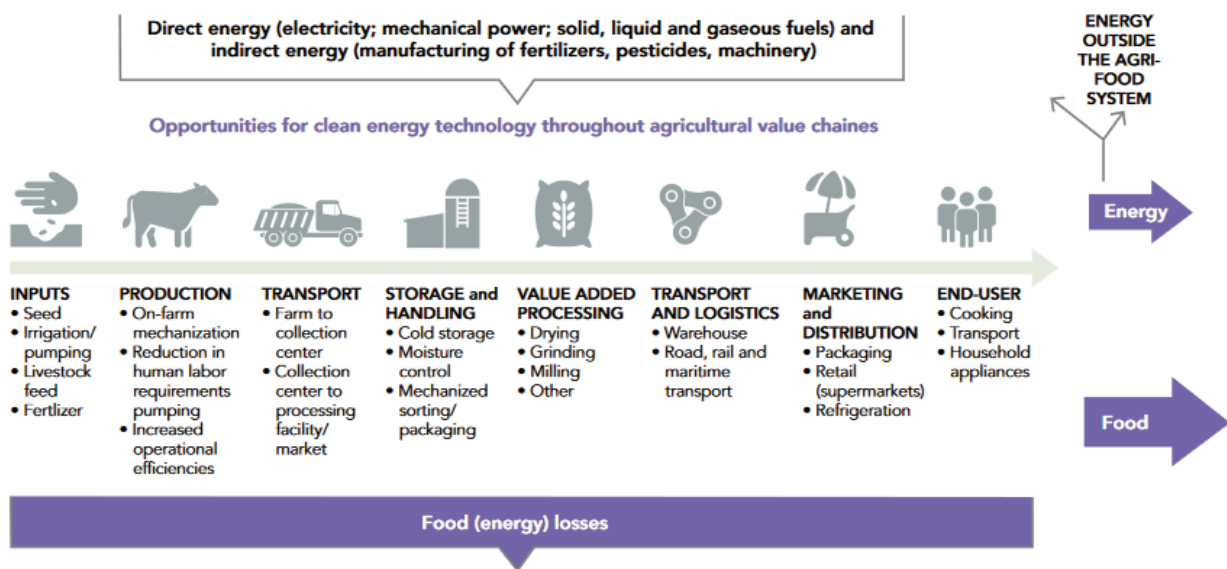


Figure 4-1 Energy to and from the food value chain<sup>2</sup>

Agri-solar projects can offer turnkey solutions to reduce greenhouse gas emissions in the agriculture sector; it can deploy additional solar capacity, promote more sustainable agricultural practices and it can drive rural development. In addition, the inclusion of agri-solar best practices in the African context may contribute to reducing the continent poverty condition. Increased agricultural productivity represents a primary driver for food security, improved nutrition, income generation, and development of peri-urban and rural areas. Greater agricultural

productivity and improved climate resilience can be realised through improvements in agricultural processes such as irrigation, empowered agro-processing, more and ameliorated post-harvest storage facilities, in addition to stronger distribution and retail chains. But all these improvements require energy as well as water. Thus, in this study the three sectors will be assessed not only individually but as an interdependent complex system too. As it will be more and more evident through the present analysis, existing synergies between the sectors should drive the actions of all stakeholders involved in a

<sup>1</sup> Solar Power Europe, Agri-solar Best Practice Guidelines version, 2022

<sup>2</sup> FAO/USDA, 2015

WEF nexus project to be able to extract the biggest value added with the lowest negative impacts. For the purpose of this study and considering that the agri-solar sector includes a variety of applications, and related business models, the present report aims at organizing applications into **three categories** (Agrivoltaic/Agri-PV systems; Solar Irrigation; Productive Use of Energy in Agribusiness/Agri-PUE) but it also takes into consideration that agri-solar solutions may fall into **hybrid categories**, such as:

- Agri-PV/Solar Irrigation cases where solar-PV plant covers cultivated lands and powers a water pumping system.
- Agri-PV/Agri-PUE case where solar-PV plant covers cultivated lands and powers processing machineries.
- Agri-PUE/Solar Irrigation case where solar-PV plant does not cover cultivated lands and powers both water -pumping systems and processing machineries.

## 4.1 Agri-PV

Agrivoltaic (Agri-PV) systems represent an integrated dual land-use approach which aims at optimising the combined use of a single area of land for simultaneous energy and crop production. In addition, the possibility of promoting the rainwater harvesting from the PV systems has made it serve a triple land-use purpose. This layout creates the opportunity of valorising available resources, differently from the more standard PV concept which assumes to place

panel installations next to the culture, leading to inefficient land exploitation with a limited interactions between water, energy, and food resources. The synergy between PV installation and an agricultural activity is made possible by specific structures (for supporting PV installation) to be placed above/laterally/among the crops. In this way, Agri-PV projects have the chance of optimising the quantity and quality of light that reaches crops and the PV cells.



Figure 4-2 Light transmission achieved using transparent panels application. SolarPower Europe, 2020

Agri-voltaics can lead to the identification of sustainable and cost-effective business models, starting from energy production for local uses at farm level (pumping water, small-scale machinery, etc.) as well as

for value-adding processes in agriculture (grinding, drying, packaging, allowing cold storage facilities, etc.). Additionally, the shading provided by the PV modules has the potential of increasing agricultural yield

through reducing evapotranspiration and physical protection of crops: according to recent studies, agrivoltaic systems could improve overall land use productivity by 60–70%. Such symbiosis can also help achieve higher crop yields or enable the use of different crops through i) the protection from heat or droughts; ii) more efficient electricity production by cooling PV panels; iii) better environment and biodiversity, resulting in positive economic

and social impacts<sup>3</sup>. On the contrary, many other crops could suffer lack of radiation, as it is reported in Figure 4-3. Some crops can fully benefit from lower irradiance rates, thus they perform better with shading (see the green box below) while others are not compatible with such procedures at all, thus are shade-intolerant crops (see red box below). Other crops are indifferent to shade when the overall crop yield is considered (see yellow box below).

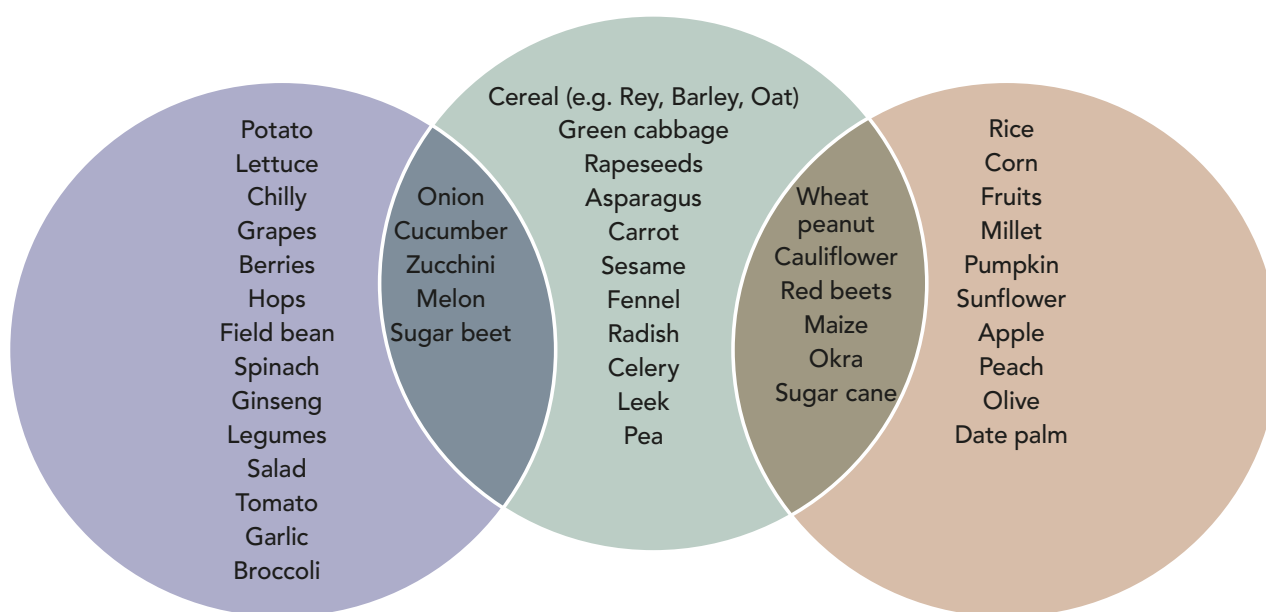


Figure 4-3 Example of crop synergies with Agri-PV concept<sup>4</sup>

Among the many existing classifications of the agrivoltaic installations, one possibility is to classify them in two broad categories: i) open agrivoltaic systems; and ii) closed agrivoltaic systems.

**Open agrivoltaic systems:** include interspaced PV systems which are standard fixed or single axis tracking ground mounted systems with extended spacing between module rows: the agricultural activity is realized in-between PV modules or in vertical. PV systems are usually

elevated (2–6 m) above ground level in order to ensure agricultural activity. The shading rates in this system range between 20 and 70% to ensure healthy crop growth. Orchards, vineyards, hay, and vegetables are among the suitable crops.

**Closed agrivoltaic systems:** PV greenhouses fall under the category of closed systems and the typical applications here are horticulture and aquaculture. The figure below shows a graphical representation of the above-mentioned agrivoltaic classification.

<sup>3</sup> European Union, JRC Low Carbon Energy Observation, 2020.

<sup>4</sup> Neupane Bhandari, S. et al. Economic Feasibility of Agrivoltaic Systems in Food-Energy Nexus Context: Modelling and a Case Study in Niger, 2021.

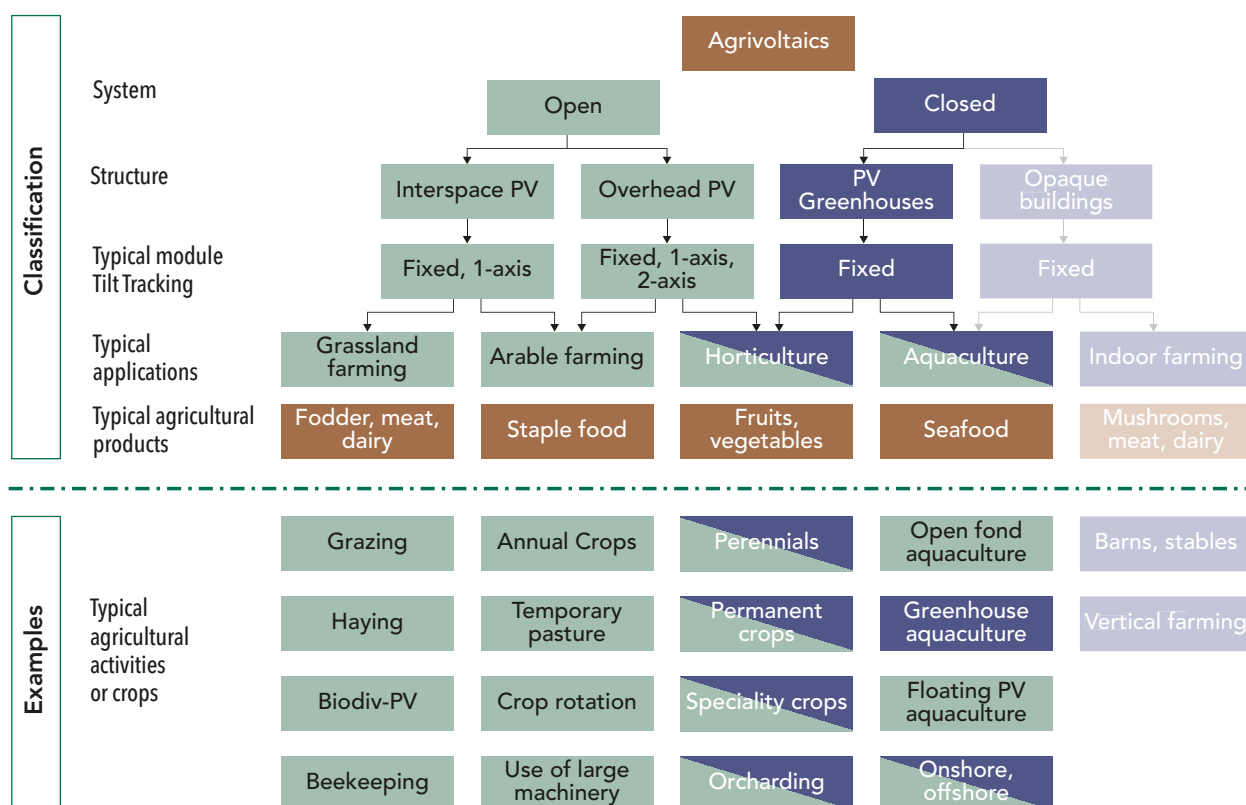


Figure 4-4 Classification of agrivoltaic systems and typical associated agricultural activity

Topic	Design related solution	Technology related solutions
Minimizing shadows on crops (biomass yield)	Optimal design: <ul style="list-style-type: none"> <li>- Distance between the arrays of modules (the stripes)</li> <li>- Distance of the modules from the ground</li> </ul>	Sun-tracking systems Semi-transparent PV modules (by spacing PV cells) Light-selective PV devices
Maximizing electric energy generation	Optimal planning: <ul style="list-style-type: none"> <li>- Avoiding shading losses from surrounding elements (structures, buildings, trees, inter-row shading of the PV modules should be minimized)</li> </ul> Optimal design: <ul style="list-style-type: none"> <li>- Azimuth facing equator and tilt close to latitude</li> </ul>	Highly efficient systems (e.g., sun-tracking systems) Highly efficiency modules or technologies (e.g., bifacial module technology)
Social acceptance (landscape dimension)	Optimal landscape design: <ul style="list-style-type: none"> <li>- Pattern of PV arrays aligned to the parcel</li> <li>- Natural fences and low height structures to minimize visual disturbance</li> <li>- Use of marginal areas</li> <li>- Removable systems</li> </ul> Optimal design: <ul style="list-style-type: none"> <li>- Different tilt, azimuth and height to reproduces the orography of the land</li> </ul> New business models: <ul style="list-style-type: none"> <li>- Higher economic efficiency per land unit (farmer perspective)</li> <li>- Benefits for local economy and employment (tourism, local recreation, etc.)</li> </ul>	New materials for structure

Table 4-1 Barriers and solutions to implementation of Agri-PV in open-field systems<sup>5</sup>

<sup>5</sup> Source: Toledo, C.; Scognamiglio, A., Agrivoltaic Systems Design and Assessment: A Critical Review, and a Descriptive Model towards a Sustainable Landscape Vision (Three-Dimensional Agrivoltaic Patterns), 2021.

Agrioltaic can assume multiple setups maintaining the initial purpose of co-production of food and energy on the same piece of land. Some examples of the main issues related to the use of co-located PV on cropland and the solutions commonly proposed to solve them are shown in Table 3-2. A further application of agri-solar is based on the exploitation of rural buildings surfaces in order to reduce land use. Agri-solar buildings can be used to:

- Provide storage, protection against ageing, theft and bad weather, hazard mitigation, avoiding loss of fodder from too much water, and reducing dependence on weather.
- Increase animal welfare, as buildings contribute to reduce livestock mortality rate.
- Provide shelter to aquaculture, thus protecting fish farming.
- Reduce the use of plastics and makeshift buildings.
- Improve supply chains and encourage local production by promoting workshops at the farm, direct sales, and short circuits.
- Better space management by avoiding transportations, journeys, and vehicle flows.
- Improving farm working conditions



Figure 4-5 Application on sheep breeding. SolarPower, 2020

Due to the inclusion of the agricultural sector, the complexity of an agrioltaic business model often exceeds that of a ground-mounted photovoltaic system. Various parties with different functions are involved in the implementation,

depending on the network of the project partners. At least four functions are usually differentiated<sup>6</sup> and two (#5, #6) can be added in innovative business models, as they could be managed by a non-agriculture stakeholder:

Functions in Development Phase	Functions in Operation Phase
#1. Providing the land	#2. Agricultural management of the land
#3. Providing the PV system	#4. Operating the PV system
#5. Providing the Irrigation System	#6. Operating the Irrigation System

<sup>6</sup> Fraunhofer Institute for Solar Energy Systems, Agrioltaics: opportunities for agriculture and the energy transition, 2020.



Functions in the Development Phase are mainly related to (i) the ownership and (ii) the financing structure, while functions in the Operation Phase are mainly related to (i) the operator and (ii) the operating conditions.

The identification of such functions in one or more actors is one of the key elements for identifying different business models. In the simplest business model, all four functions can be handled by one party – typically by a farm. This model is preferably applied to small farms because the investment cost is manageable, and ownership of the land belongs to the farm<sup>7</sup>.

The evolution of this business model is referred to an agrivoltaic installation where the land is owned by an external entity: here land leasing mechanism may intervene as it happens for more classical ground mounted PV installations (generally with a 20-year term). On the contrary, for larger installations, the ownership of the PV system is external, and a PV investor is often involved<sup>8</sup>. In other cases, neither ownership of the land or PV system nor the operation of the farm or PV system are in one hand. The chart below shows the main types of business model associated to Agri-PV applications.

Business model	Function			
	Providing land	Agricultural management	Providing the PV system	Operating the PV system
1. Base case	Farm			
2. External land ownership	Land owners	Farm		
3. External PV investment	Farm		PV investor	Farm
4. Cultivation and operation only	Land owners	Farm	PV investors	Farm
5. Cultivation only	Land owners	Farm	PV investors	PV operator

Figure 4-6 Different Agri-PV business models<sup>9</sup>

### Technologies

Several agrivoltaic pilot projects are being deployed in Africa, leveraging also on the experience of EU countries and partners. Integrating PV systems and agriculture activities is usually implemented through few highly replicable approaches, mostly referring to different type of installations:

1) **fixed panels**, placed onto a standard supporting structure tailored on the agricultural activities; these are mature technologies but not beneficial in every phase of crop growth (also in accordance with the height of the structure ),

and sometimes even counterproductive as they force crops to be shaded. This approach is also the most compatible with small size and less complex applications, such as solar irrigation.

2) **dynamic panels** include an intelligent and intermittent shading on crops, based on tracking structures (Figure 3-9) or light management techniques, with extensive monitoring processes. With this setup it is possible to significantly increase the installations performance, its energy production and better satisfy the shading requirements of crops. This approach requires a higher initial financial investment (monitoring

<sup>7</sup> Fraunhofer Institute for Solar Energy Systems, Agrivoltaics: opportunities for agriculture and the energy transition, 2020.

<sup>8</sup> Fraunhofer Institute for Solar Energy Systems, Agrivoltaics: opportunities for agriculture and the energy transition, 2020. ISE

<sup>9</sup> Fraunhofer Institute for Solar Energy Systems, Agrivoltaics: opportunities for agriculture and the energy transition, 2020.

system, tracking system) but it is particularly used in large scale installations and intensive cultivations.

3) **vertical bifacial PV** is the most recent agrivoltaic technology and it is based on a vertical fixed structure, having PV modules

on both the sides (East-West oriented). Such a solution is not widely used yet but it can boost the diffusion of PV technologies in the agricultural sector without having a large impact on crop shading or complex management mechanisms.

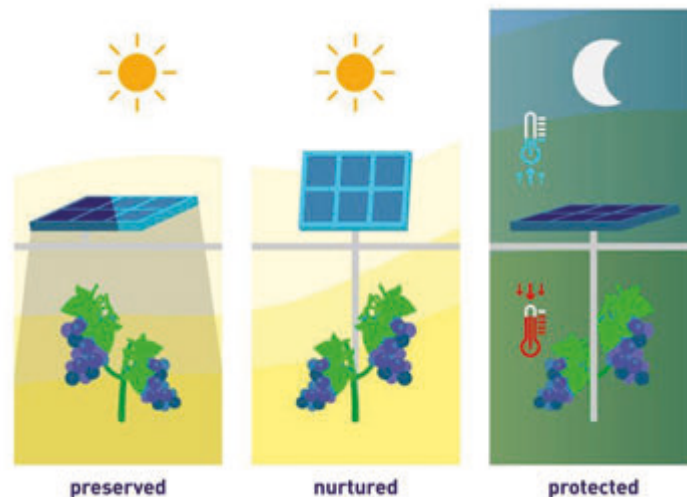


Figure 4-7 Potential use of tracking systems<sup>10</sup>

Being aligned with the above-mentioned classification (fixed, dynamic, or vertical PVs), it is possible to make some transversal remarks about the **mounting structure**.

The mounting structures must be adapted to the specific agricultural application and the related needs. In particular, the most important aspects to be considered are:

- the PV system installation's height: this aspect is relevant especially for the definition of crops' shading level.
- the frame structure behind the panels: this aspect is important to allow every kind of agricultural machine to properly operate nearby the PV panels.
- the sub ground anchoring of the mounting structure: classical concrete foundations are not acceptable considering the agricultural use of lands. Some alternatives are available,

for example piled foundations or other special anchoring systems.

- the spacing between multiple PV rows (in case of larger PV plant sizes): such an aspect is crucial for optimising the light availability between adjacent panels lines.
- the economic investment: complex and higher structures require additional initial capitals.

The application of Agri PV systems offers several opportunities, which differ depending on regional and climatic conditions. The benefit of Agri PV applications is particularly interesting in densely populated industrial countries, where the expansion of renewable energies is becoming increasingly important and where at the same time productive farmlands need to be preserved. In addition, rural areas, characterized by energy poverty and unsecure energy systems, are another target context for the diffusion of agrivoltaic.

<sup>10</sup> Sun'agri website

## 4.2 Solar irrigation

Solar irrigation is based on the exploitation of sun's energy to power irrigation systems that supplies water to crops. For the system to be efficient, crops should have the right amount of water at the right time: irrigation is the controlled application of water to respond to crop needs<sup>11</sup>.

In general terms, irrigation requires high energy amounts, with high related costs. But the decreased price of solar photovoltaic panels, extended the availability of solar irrigation technologies to small-scale farmers, providing rural off-grid farms with the opportunity to improve crop production and better deal with dry seasons. As of today, solar irrigation systems represent an opportunity to reduce costs and dependency from fossil fuels<sup>12</sup>, while contributing to increase productivity and limiting fossil energy input into the agricultural sector<sup>13</sup>.

Modernization of irrigation can be pursued by adopting diverse solutions. For example, the introduction of pressurized drip irrigation can increase water and energy efficiency<sup>14</sup>. However, to obtain and maintain a good productivity of crops over time, appropriate agronomic and water-saving practices should be adopted.

Furthermore, it is necessary to eliminate causes of technological or agronomic inefficiency by means of decision support systems (DSS), designed to facilitate use to the farmer.

On the contrary, improved water and energy efficiency can incentivize farmers to intensify their production, expanding irrigated areas and cultivating more water intensive crops ("rebound effect"). The control of excess water usage through drip irrigation also reduces return flows of water to aquifers and therefore water resources that would be available to other users. This could then result in pressure

on water resources at basin or national level that could remain high or even increase.

In conclusion, through an appropriate application (e.g. avoiding excess water usage) of modern solar irrigation practices and technologies relevant benefits can be achieved:

- Reduced GHG emissions for water pumping
- Energy independence in remote areas
- Access to water during dry-spells and dry season
- Improvement of income, food security and nutrition
- Promote aggregation of smallholders, especially in export crops such as horticulture

### Technologies

According to the size of the field to be irrigated, solar irrigation technologies can largely vary. The most diffused layout in the targeted regions is characterised by micro/small devices (PV panels and pumps in the range of 80-3000W), which are managed by farmers or groups of farmers.

The larger the irrigations systems are, the more they need supplementary technical requirements and complex infrastructures (i.e., piping, water intakes) increasing the cost of installation the installation cost. Overall, solar irrigation implies higher initial cost with lower running costs than diesel-based irrigation; however, fuel expenses could potentially set an incentive to keep the water abstraction lower (at an efficient rate) than in solar systems. This is, a rather rare scenario as solar systems do not usually have battery storage in irrigation application and the pumping water capacity is given by the power installed and

<sup>11</sup> Future Pump, What is solar irrigation, 2021

<sup>12</sup> H.Hoff et als., A Nexus Approach for the MENA Region—From Concept to Knowledge to Action, 2019

<sup>13</sup> H.Hoff et als., A Nexus Approach for the MENA Region—From Concept to Knowledge to Action, 2019

<sup>14</sup> H.Hoff et als., A Nexus Approach for the MENA Region—From Concept to Knowledge to Action, 2019:48.



the solar irradiation. It is also important to underline that for bigger plants, these systems can become a resource to deal with water

management issues at community level (especially during rainy season, when irrigation systems are not active).

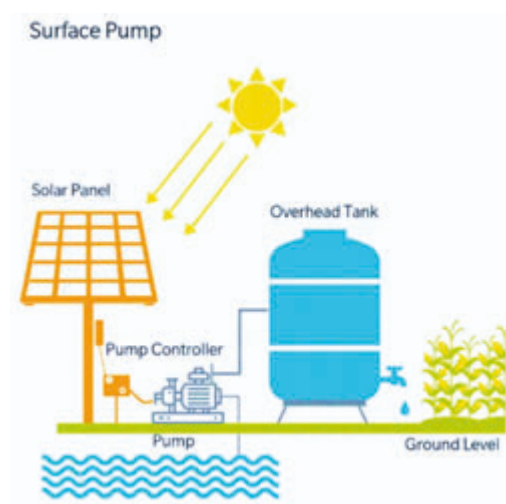


Figure 4-8 Conceptual scheme of Solar irrigation layout

With this technology, electricity is generated by solar photovoltaic (PV) panels in a solar-powered irrigation systems (SPIS) and it is used to operate pumps for the abstraction, lifting and/or distribution of irrigation water at different scales. Components of SPIS are<sup>15</sup>:

- solar generator
- mounting structure for PV panels, fixed or solar tracking system
- pump controller
- water pump
- storage tank
- distribution system

Solar irrigation systems are usually composed by PV panels (installed on a fixed mounting structure) and a submersible pump (near to a borehole). Largest part of the pumping devices already includes monitoring systems able to monitor the performances of the pump: this aspect enables the farmers to perform more precise groundwater management.

Solar pumps can support drip, sprinkler, pivot or flood irrigation methods when appropriately sized. Depending on the local conditions, a system can also include filtration or fertigation equipment<sup>16</sup>.



Figure 4-9 Example of drip irrigation

<sup>15</sup> FAO, Solar-Powered Irrigation Systems, 2017.

<sup>16</sup> FAO, Solar-Powered Irrigation Systems, 2017.

## 4.3 Productive Use of Energy in Agribusiness

Agri Productive Use of Energy (agri-PUE) applications entails a variety of synergies between renewable technologies (solar PV in particular) and any production process of the

agricultural sector. All PUE applications can be associated to different steps of the agricultural value chain: production, process, storage, and transport (Table 5-3).

Production	Processing	Storage/Transport
Sprayers	Mills	Freezers/Refrigerators
Irrigation pumps	Driers	Ice makers
Tractors	Butter makers	Siloes
Electric fences	Mazie thrashers	Milk chillers
Greenhouses	Cassava graters	Fish freezers
Animal feed mixers	Coffee pulpers	
Egg incubators	Oil presses	
Cow milers		
Fishing practices		

Table 4-2 Example of Agri PUE application

The productive use of clean energy can be defined as agricultural, commercial and industrial activities that generate income and are powered by clean energy sources. These activities increase productivity, enhance diversity, and create economic value. However, a successful implementation of agri-PUE projects requires the integration of specific supporting activities in the following business development's aspects:

- Business model design, to analyse how to manage products and market-entry.
- Access to finance, to raise capital, review grant applications, and prepare bids.
- Value chain analysis, to identify opportunities for off-grid solutions to boost productivity.
- Business planning, to set financial performance, sales forecast, and refine business models to streamline processes and operate efficiently.
- Market intelligence, to enter specific markets and scale-up to new ones.

- Product portfolio expansion and piloting of PUE products.

Agri-PUE is directly connected with a large variety of applications: starting from different types of milling (hammering, dehulling, deshelling, etc.) to cooling systems (pre-cooling to drop product temperatures from harvest levels at 25°C to storage levels at 4-10°C; temperature-controlled storage at 4-10°C; refrigeration at <4°C; and freezing at <0°C) as well as food dryers and water treatments.

### Technologies

A recent study sponsored by the World Bank has defined a new specific category of Agri-PUE applications: Productive Use Leveraging Solar Energy (PULSE)<sup>17</sup>. The market readiness of PULSE technology varies significantly depending on the use and associated energy consumption and system requirements, as shown in Figure 4-17.

<sup>17</sup> World Bank – IFC, The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa, 2019.

These applications are increasingly competitive with traditional alternatives. Nevertheless, a large market is yet to be found due to the

smallholder farmers lack of access to consumer financing who would most benefit from such appliances.

	<b>Irrigation pumps</b>	<b>Cooling &amp; refrigeration</b>	<b>Agro-processing</b>
	<b>&gt; 5 Ha</b>	<b>&gt;10,000 L</b>	<b>&gt; 10 MT/day</b>
Large	While technologies exists there are limited large scale applications in practice	Typically applied as walk-in cooling, technologies are available at an aggregated scale, but uptake remains low	The main examples that exist are mini-grid applications as like-for-like replacement of grid processing
	<b>2 – 5 Ha</b>	<b>2000 – 10000 L</b>	<b>2 – 10 MT/day</b>
Medium	The majority of supplier distributors are targeting this scale and uptake is reasonable depending on the geography	Fewer technologies in this category as providers are either looking at large aggregated systems or smaller individual systems	The main examples that exist are mini-grid applications as like-for-like replacement of grid processing
	<b>&lt; 2Ha</b>	<b>200 – 2000 L</b>	<b>1 – 2 MT/day</b>
Small	Technologies are well developed and available but affordability and market development are barriers	Productive uses typical adapt refrigeration intended for small retail enterprise use, uptake is low	Incumbent technologies exist but the system size is prohibitive for standalone applications
	<b>&lt;1 Ha</b>	<b>&lt;200 L</b>	<b>&lt; 1 MT/day</b>
Very Small	Recent product development has increased affordability, precedents are emerging in some markets and are starting to scale	Productive uses typical adapt refrigeration intended for household use and uptake is low	There are limited standalone technology choices and use cases are unproven

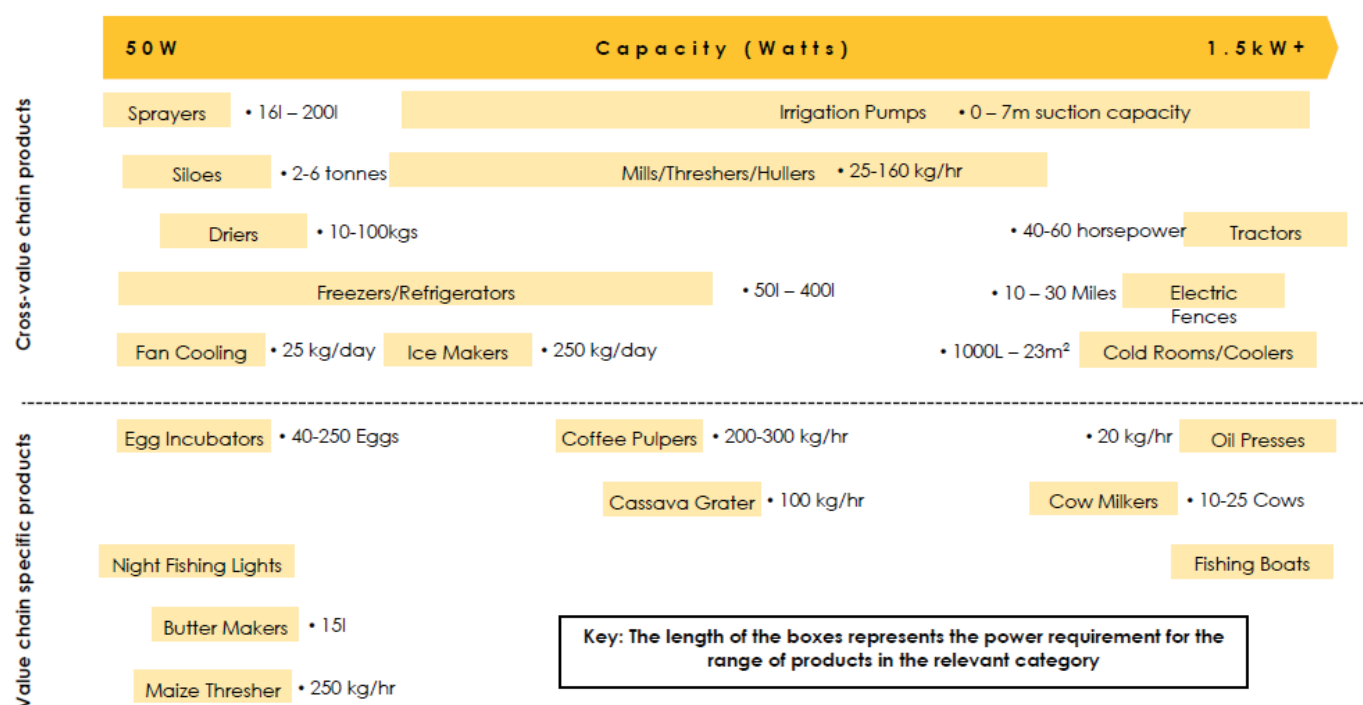
**Commercial readiness:** ■ High ■ Mid ■ Low

Figure 4-10 Commercial readiness of PULSE use cases by product size<sup>18</sup>

PULSE applications, imply different technologies. Each of these technologies includes a different power size device. An example is the agro-processing technology, whose commercial

readiness varies depending on the scale of the project. Same examples are reported in Figure 4-16.

<sup>18</sup> World Bank – IFC, The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa, 2019.

Figure 4-11 Spectrum of PULSE products by system capacity<sup>19</sup>

## 4.4 Market segments

Based on the analysis carried out in this and in the previous chapter, the main Agri-Solar market segments for the target regions are identified in Table 6-1. They represent the potential market

in which Agri-Solar applications fall and are grouped into the three categories: Agri-PV, Solar Irrigation and Agri-PUE.

Region	Agri-PV	Solar Irrigation	Agri-PUE
MENA region	Fruits (including tree crops), wheat, barley, legumes production		
	vegetable production*		
			fruits processing
			processed meat and dairy products
		unsecure irrigation due to upstream abstraction, salinity intrusion and coastal management issues	
	Livestock		
		severe land constraints** and water-stress	

<sup>19</sup> World Bank – IFC, The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa, 2019.

Region	Agri-PV	Solar Irrigation	Agri-PUE
NB region		Rice and sugar cane production	
	Fruits and maize crops production		
	vegetable production*		
			dairy products
			milling and stocks for cassava and cereals
	agro-pastoralism		livestock by-products

\*vegetable production would require cold storage

\*\*less than 5% of land is arable in two-thirds of the countries of the region

Table 4-3 Agri-Solar market segments

# 05 / **Screening and selection of agri-solar applications**



The aim of this chapter is to function as a summary for what has been treated extensively in the previous chapters and act as a bridge towards the following chapter, which represents the core of the study.

The first and second phases (chapter 3 and 4) have laid the basis for the identification

of the main market segments for the MENA and Niger Basin regions. The third and fourth phases (chapter 5 and 6), instead are the core of the analysis: they lay to the identification and assessment of the most promising applications and related business models in the targeted regions.

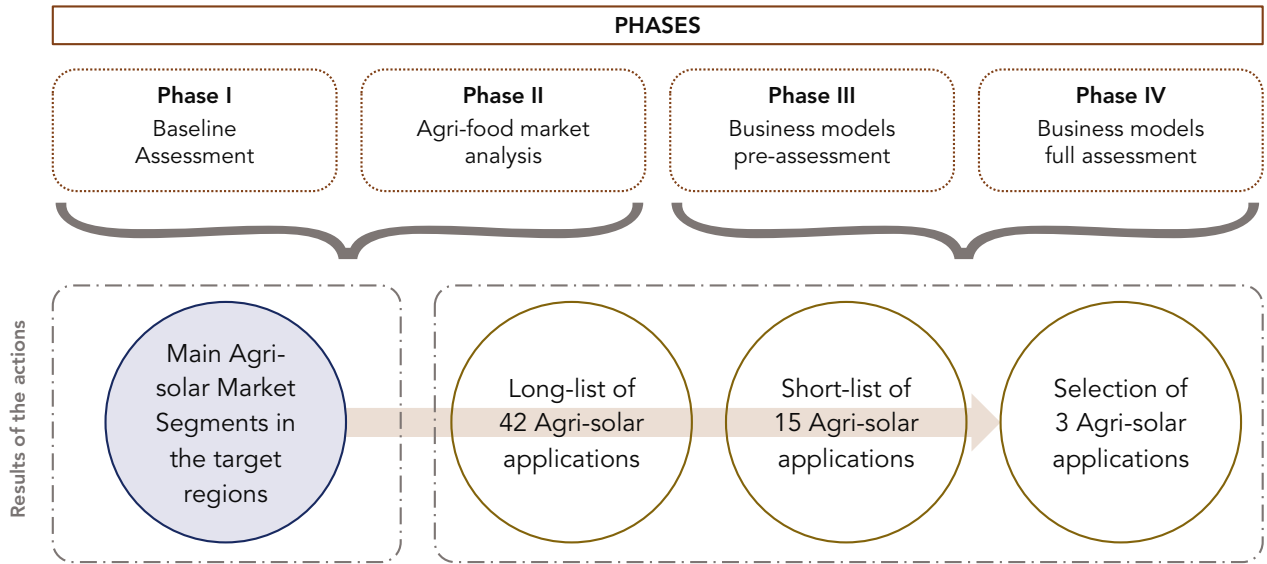


Figure 5-1 Phases of the analysis

As showed in the figure above, a wide list of 42 applications (Table 5-1), sufficient to cover most of the business opportunities applicable in the target regions within the WEF nexus concept, was firstly identified.

The list has then undergone an in-depth screening (see Annex - Evaluation Matrix) based on 8 criteria: market size, scalability/replicability, WEF Nexus relevance, innovation, affordability, enabling environment, attractiveness for the agriculture & water sectors, attractiveness

for the solar-PV sector. The outcome of the screening is a short-list of 15 applications: 3 in the agri-PV sector, 5 in the solar irrigation sector and 7 in the productive use of energy in agribusiness.

In order to select the top 3 applications for each region, a second and more detailed assessment has been performed. Assessment scoring (which sum up all the 8 criteria) are reported in the table below, both in disaggregated and aggregated figures for MENA and NB regions.



Long-list of Agri-solar applications	
Agri-PV	Photon sharing: PV shading for horticulture
	Photon sharing: greenhouses used for gardening and horticulture
	Photon sharing: adapted ground mounted systems to co-locate cash-crops production
	Deployment of solar on barn roofs
	Herding of sheep within PV park
	PV shading for poultry
	Precision farming <sup>1</sup> powered by solar-PV
	Electric agricultural machineries powered by solar-PV
	Phytosanitary treatments powered by solar-PV
	PV shelter to fodder and cash-crops storage: protection of animal feed
	PV shelter to livestock: protection of animal farming
	PV shelter to aquaculture: protection of fish farming
Solar Irrigation	Small-scale (land and power size) solar irrigation (pumping/distribution)
	Medium-scale (land and power size) solar irrigation (pumping/distribution)
	Dryland cropping systems
	Water conservation, rainfall collection and storage
	Drip irrigation and mobile drip irrigation
	Precision irrigation
	Crop spraying
	Conservation agriculture (minimum soil disturbance, crop diversification, and permanent soil cover)
Agri-PUE	Crop milling (grinding, hammering, de-shelling, threshing, de-hulling/de-husking and decorticating)
	Edible oil extraction
	Biofuel oil extraction
	Drying (fruits, vegetables, coffee, tea, meat, fish, spices)
	Smoking (fish, meat, cheese)
	Electric cooking (oven, hotplates)
	Improved warehousing – Cold storage: small scale refrigeration (fridges, freezers)
	Improved warehousing – Cold storage: medium-large scale refrigeration (cold rooms)
	Improved warehousing – Cold storage: ice-making
	Improved warehousing – by-products from post-harvest processing
	Milk pasteurisation and processing (yogurt, cheese, etc)
	Animal feed production (pellets) and packaging
	Water heating (e.g., textile dyeing, separating nut kernels)
	Water purification
	Crop cleaning/washing
	Fish processing (cleaning and packaging)
	Fish hatcheries & farming (water circulation and purification)
	Poultry incubation & heating
	Fruit juicing
	Brewery
	Sawmilling (carpentry)
	Electric fencing

Table 5-1 Short-listed applications

<sup>1</sup> Application only when/where needed, using precision equipment.

Short-list of Agri-solar applications			MENA	NB	MENA+NB	RANK
Agri-PV	#1	Photon sharing: PV shading for horticulture	54	51	105	2°
	#5	Herdling of sheep within PV park	50	48	98	4°
	#6	PV shading for poultry	55	53	108	1°
Solar Irrigation	#13	Small-scale solar irrigation (pumping/distribution)	38	44	82	13°
	#14	Medium-scale solar irrigation (pumping/distribution)	41	43	84	11°
	#16	Water conservation, rainfall collection and storage	36	47	83	12°
	#17	Precision irrigation (including drip irrigation)	48	39	87	10°
	#18					
Agri-PUE	#21	Crop milling	50	47	97	5°
	#24	Drying (fruits, vegetables, coffee, tea, meat, fish, spices)	47	45	92	6°
	#27	Improved warehousing - Cold storage: small scale refrigeration (fridges, freezers)	43	47	90	7°
	#28	Improved warehousing - Cold storage: medium-large scale refrigeration (cold rooms)	49	54	103	3°
	#29	Improved warehousing - Cold storage: ice-making	46	44	90	7°
	#32	Animal feed production (pellets) and packaging	45	45	90	7°
	#38	Poultry incubation & heating	41	41	82	13°

Table 5-2 Short-listed applications

Considering the assumption that each category (Agri-PV, Solar Irrigation, Agri-PUE) should be represented by one application, the selection of the most promising applications was based on the following main results:

- Top-3 (two tied) applications in MENA region are (ordered on code # basis):

#1	Photon sharing: PV shading for horticulture
#5	Herdling of sheep within PV park
#6	PV shading for poultry
#21	Crop milling

- Top-3 applications in NB region are (ordered on code # basis):

#1	Photon sharing: PV shading for horticulture
#6	PV shading for poultry
#28	Improved warehousing - Cold storage: medium-large scale refrigeration (cold rooms)

- No application in the Solar Irrigation category is among the top-3.
- In order to select at least one application in the solar irrigation category, the number **#17-18-Precision Irrigation** (including drip irrigation) has been included in the final

selection, being the best ranked in the aggregated scoring.

- **#28-Cold storage:** medium-large scale refrigeration is 1-ranked in NB and 5-ranked in MENA, with a minor difference with #21-Crop milling. Considering that crop milling is a well-known application, already analysed in several studies and widely experienced throughout Africa, **the priority is given to cold storage as a selected application in the Agri-PUE category.**
- In order to select the top-3 applications, and assuming to select at least one application per category, **#1- PV shading for horticulture was selected in the Agri-PV category** as it was preferred to #6- PV shading for poultry for (i) the relevance of the water component in horticulture and (ii) the indirect promotion of precision irrigation, that finds its primary adoption in the horticulture sector.
- **Top-3 applications are therefore selected** and listed here below:

#1	Photon sharing: PV shading for horticulture
#17-18	Precision Irrigation (including drip irrigation)
#28	Improved warehousing - Cold storage: medium-large scale refrigeration (cold rooms)

# 06 / **Assessment of agri-solar business models**



## 6.1 PV Shading for Horticulture

### *Why is it relevant?*

Agrivoltaic can lead to the identification of sustainable and cost-effective business models, both for productive use of energy and value-adding processes in agriculture. Thanks to agrivoltaics technologies the overall land use productivity could grow by 60-70% and could help overcome some of the longstanding challenges of the Sub-Saharan area and the MENA Region in cultivation and post-harvesting processing. PV shading for horticulture is gaining more and more attention in recent years, both in developed and developing countries, for its market potential, especially for agriculture players. Agrivoltaic technologies have huge potential for development in the target areas, especially thanks to a favourable regulation and to existing positive examples. There exist differences in terms of potential of implementation in MENA and the Niger Basin: in the first one a high electrification rate makes it more interesting for applications connected to the main grid, while in the second one it could be more interesting for off-grid solutions (provided the presence of electricity off-takers is ensured).

The adaptable nature of the agrivoltaic technologies could be exploited to support the development of agriculture in rural areas while contributing to boost access to electricity of the local communities. Nevertheless, the initial capital cost and needed investments could be prohibitive for most of agriculture players; it is therefore paramount to involve actors that are able to mobilize initial funding and/or de-risking instruments, adapted to agri-player's needs.

### *In this section*

In the following pages, a specific case for the agrivoltaic technology is explored: these sorts of technologies allow to optimise land use by combining crop and energy production on a single area.

Three possible business models' schemes are defined (see methodology at chapter 2 for details):

- **BM1 - Farm-owned PV plant:** an agri-player invests in a PV plant to be installed on cultivated land to improve efficiency and productivity. The agri-player is the owner of both land and assets.
- **BM2 - IPP-owned PV plant:** an energy player invests in a PV plant, acting as an IPP, installed on land owned by an agri-player.
- **BM3 - Agri-energy service company:** an energy player and an agri-player build a partnership to work as Agri-ESCo that delivers integrated agri-PV solutions.

The comparison among the 3 selected models shows how the synergies created among the three components of the nexus are more evident in the third model, mostly due to the players involved: the Agri-ESCo appears to be a promising concept. The models analysed appear to be economically more viable in presence of financing mechanisms (either grants or soft third-party financing), while the potential for replicability is medium for all of them. The third model especially, despite being the most interesting one, has more risks related to a higher level of innovation.

In the last part of this section input data for simulation are given for the model 3, for a business case set in Nigeria. The project includes a 200 ha crop cultivation plus a 5 MW PV-solar generation plant. In the simulation the theoretical project is financed with 70% of subsidised loan and 30% equity. Costs and revenues are estimated as well and take into consideration the local framework of operations in terms of taxes, market etc.

Below the summary of the comparison of the three business models.

	<b>BM1 Farm-owned PV plant</b>	<b>BM2 IPP-owned PV plant</b>	<b>BM3 Agri-Energy Service Company</b>
<b>WEF synergy</b>	strong synergy between the three components	strong synergy between the three components, even if BM2 tilts toward the Energy component more than BM1	strong and well-balanced synergy between the three components, supporting the Water component as BM1, the Energy component as BM2
<b>Agri-player type</b>	farmer associations or medium-large farmers	medium/large landowners (single or in associations)	medium/large farmers (single or in associations)
<b>Energy-player type</b>	EPC contractors	IPPs	Agri-ESCos
<b>Minimum project size</b>	small-scale: minimum PV size >100 kWp installed in a 0.15 ha cultivated land	medium-scale: minimum PV size >1 MWp installed in a 2 ha cultivated land	medium-scale: minimum PV size >1 MWp installed in a 2 ha cultivated land
<b>Post-harvest processing facilities</b>	low relevance for BM	medium relevance for BM	high relevance for BM
<b>Ownership</b>	energy-asset: Agri-player lands: Agri-player irrigation-asset: Agri-player processing facilities: not relevant	energy-asset: IPP lands: Agri-player irrigation-asset and processing facilities: ownership depends on a compensation mechanism	energy-asset: Agri-ESCo lands: Agri-player irrigation-asset: Agri-ESCo processing facilities: Agri-player
<b>Operations</b>	Agri-player with outsourced PV plant monitoring & control and extra ordinary maintenance	energy-asset: IPP irrigation-asset: Agri-player processing facilities: Agri-player	energy-asset: Agri-ESCo irrigation-asset: Agri-ESCo processing facilities: Agri-player
<b>Replicability</b>	medium: no need of stable and favourable relationships as prerequisite, but challenging access to finance	medium: less replicable than BM1 in terms of number of projects, requiring stable and favourable relationships, however it targets large size lands and counts on a pool of potential IPP with financial capability	medium: less replicable than BM1 in terms of number of projects, requiring stable and favourable relationships, however it targets large size lands and counts on a pool of potential IPP/Agri-ESCo with financial capability
<b>Viability</b>	viable with at least 50% grant financing and MFIs loans	viable without grant financing, but likely other third-party soft financing	viable without grant financing, but likely other third-party soft financing
<b>Innovation</b>	low: BM piloted and scaled-up in the target area by a pioneer company	medium: BM piloted out of the target area by a pioneer company	high: cutting-edge BM for Research and Innovation Actions
<b>Attractiveness for Agri-players</b>	attractive for Agri-players willing to diversify the agri-investments and empower efficient agri-tech systems	attractive for Agri-players willing to exploit partnerships for empowering efficient agri-tech methods with a low co-investment	attractive for Agri-players willing to have an expert service for improved crop production and/or carrying out energy-intensive agri-food processing nearby cultivation lands
<b>Attractiveness for Energy-players</b>	attractive for EPC contracts willing to explore new markets	attractive for Energy-player willing to exploit partnerships for access to a broader pool of financing opportunities	attractive for Energy-players with a predictable exit strategy and high replicability capacity

### 6.1.1 PV Shading for horticulture

PV shading for horticulture, which is a specific application of the broader “photon sharing” category (also known as agrivoltaic – APV - or agri-photovoltaic) represents the simultaneous use of areas of land for solar photovoltaic power generation and horticulture.

The coexistence of solar panels and crops implies a sharing of light between these two types of production, so the design of such a facility may imply trade-off between optimising crop yield, crop quality, and energy production. The use of such practice could bring an important contribution to overcome some of

the challenges African farmers are facing in land cultivation and post-harvest processing.

The **potential market for the application is high**, both in MENA and in NB regions. In 2020, MENA's share of the world's acutely food insecure population was 20%, which was disproportionately high compared to its 6% share of the population<sup>1</sup>. In the Niger Basin for over 70% of the population food security depends on unreliable rainfall and highly variable inter-and intra-annual river flows<sup>2</sup>.

The solar energy sector is expanding to tackle electrification challenges and already employs at least 50,000 people in MENA region and at least 40,000 people in the NB region<sup>3</sup>; this expansion requires innovative business strategies to enter nascent markets<sup>4</sup>. However, such a potential market must face the low financial capability of smallholder farmers and the lack of successful demonstrations of integrated WEF models. The **replication and scalability potential** are high as well, even if major limits are related to the full comprehension of benefit and constraints while some lessons learnt could be taken from experiences in the sector of water pumping and PV generation.

All the APV applications can be considered among the most interesting examples of the WEF Nexus approach: PV energy can power any type of water pumping, irrigation, and cultivation systems, leading to an improvement of crop production as well as sustaining PV-powered post-harvest processing. With a focus on the water component, APV can lead to a reduced evapotranspiration of crops due to panel shading effects and, consequently, to a decreasing water consumption (-14 / -29% compared to conventional crop production).

These elements are particularly interesting in water stressed areas (i.e., MENA region) and where the abstraction of water needs a large amount of energy.

APV projects, and PV shading for horticulture specifically, record several case studies carried out by research groups and business actors who have implemented APV demonstrations projects around the world and at least 6 documented cases have already reached the market stage<sup>5</sup>.

In terms of **Innovation**, the technology is already proven to be effective in the targeted physical environments (MENA and NB regions). The next step is to find a suitable business model to make these experimental systems pay off; private investors and local players should then step in, to make projects viable and replicable in the words of Brendon Bingwa<sup>6</sup>, APV project manager at Fraunhofer, who developed a H2020 project in Algeria.

With reference to the broader African market, the Government of Israel has launched a tender in 2022 to deploy around 100 MW of APV<sup>7</sup> and a successful business case has been developed by Agrinergie (Akuo Group) in La Reunion<sup>8</sup>.

APV demonstrations have shown that the land use efficiency is increasing when an APV system is installed (above 150% if compared to solely cultivation or PV installation)<sup>9</sup>. All types of crops are generally suited for planting under an APV; however, different effects on the yield can be expected due to shading effects. Highly shade tolerant crops such as leafy vegetables (lettuce), field forage (grass/clover mixture), various types of pomaceous and stone fruits, berries, soft fruits, and other special crops (such as wild garlic, asparagus, and hops) appear particularly

<sup>1</sup> World Bank, MENA has a food security problem but there are ways to address it, 2021.

<sup>2</sup> EU/GIZ, Niger Basin Nexus profile. 2018.

<sup>3</sup> IRENA, Renewable Energy Employment by Country database, 2020

<sup>4</sup> World Bank, Unlocking Africa's agricultural potential, 2013

<sup>5</sup> A. Weselek et al., Agrophotovoltaic systems: applications, challenges, and opportunities. A review, 2019

<sup>6</sup> AllAfrica.com, North Africa: Climate Change Puts Agrivoltaic Projects in Northern Africa in the Spotlight, 2022.

<sup>7</sup> Pv-magazine.com, Israel launches tender for 100 MW of agrivoltaics, 2022

<sup>8</sup> Akuoenergy.com.

<sup>9</sup> World Bank, Unlocking Africa's agricultural potential, 2013

suitable<sup>10</sup>. Among them, a research study specifically indicates tomato, salad, spinach, broccoli, legumes as lettuce<sup>11</sup> the most suitable cultivations for APV<sup>2</sup>.

The **APV affordability** is more and more demonstrated for application in developed countries, while it still needs further proves in developing countries, even if research projects and pilots have provided encouraging results.

**At policy level**, despite differences exist, both MENA and NB regions have favourable regulatory frameworks (solar supporting policies, efficiency policies in agriculture, policy integration, private sector inclusion, etc.) able to support and encourage the diffusion of similar applications, with Israel leading MENA countries with cutting-edge actions, followed by Islamic Republic of Iran, Tunisia, United Arab Emirates and Kuwait. When it comes to the NB region, policies in place are less efficient than the MENA ones, even if Nigeria is moving steps ahead in spreading PV with enabling regulatory framework for rural electrification and renewable energies involving the private sector with over 43,000 people employed in this sector (of which 34,000 people in the solar sector only out of 40,000 people recorded in the entire NB region<sup>12</sup>).

In conclusion, APV, and PV shading for horticulture specifically, has gained growing recognition as a promising means of integrating agriculture and solar-energy harvesting. Although this field has a great opportunity for further developments with a variety of potential applications and benefits for land productivity, data on crop growth and development are insufficient.

It is clear that **APV are very attractive for the agricultural sector** since an agri-player can share land use and reduce the related-costs (both for CAPEX and OPEX). For what concerns **APV attractiveness for energy players**, on one side, it has an increased complexity, in i) system design and ii) coordination with stakeholders, presenting a potential barrier to market acceptance instead of a sole solar-PV model. On the other hand, it helps PV developers to build partnerships and thus to actually deploy projects, representing an added value regardless of economic benefit (which may be limited) and access to a broader pool of financing opportunities. Lastly, PV technology acceptance might be an obstacle and partnerships with farm adds emphasis on the importance of engaging local communities, even by means of community-based projects.

<sup>10</sup> Fraunhofer Institute for Solar Energy Systems-ISE Agrivoltaics: Opportunities for Agriculture and The Energy Transition, 2020.

<sup>11</sup> S.Bahndari et al., Economic Feasibility of Agrivoltaic Systems in Food-Energy Nexus Context: Modelling and a Case Study in Niger, 2021

<sup>12</sup> IRENA. Renewable Energy Employment by Country database, 2020

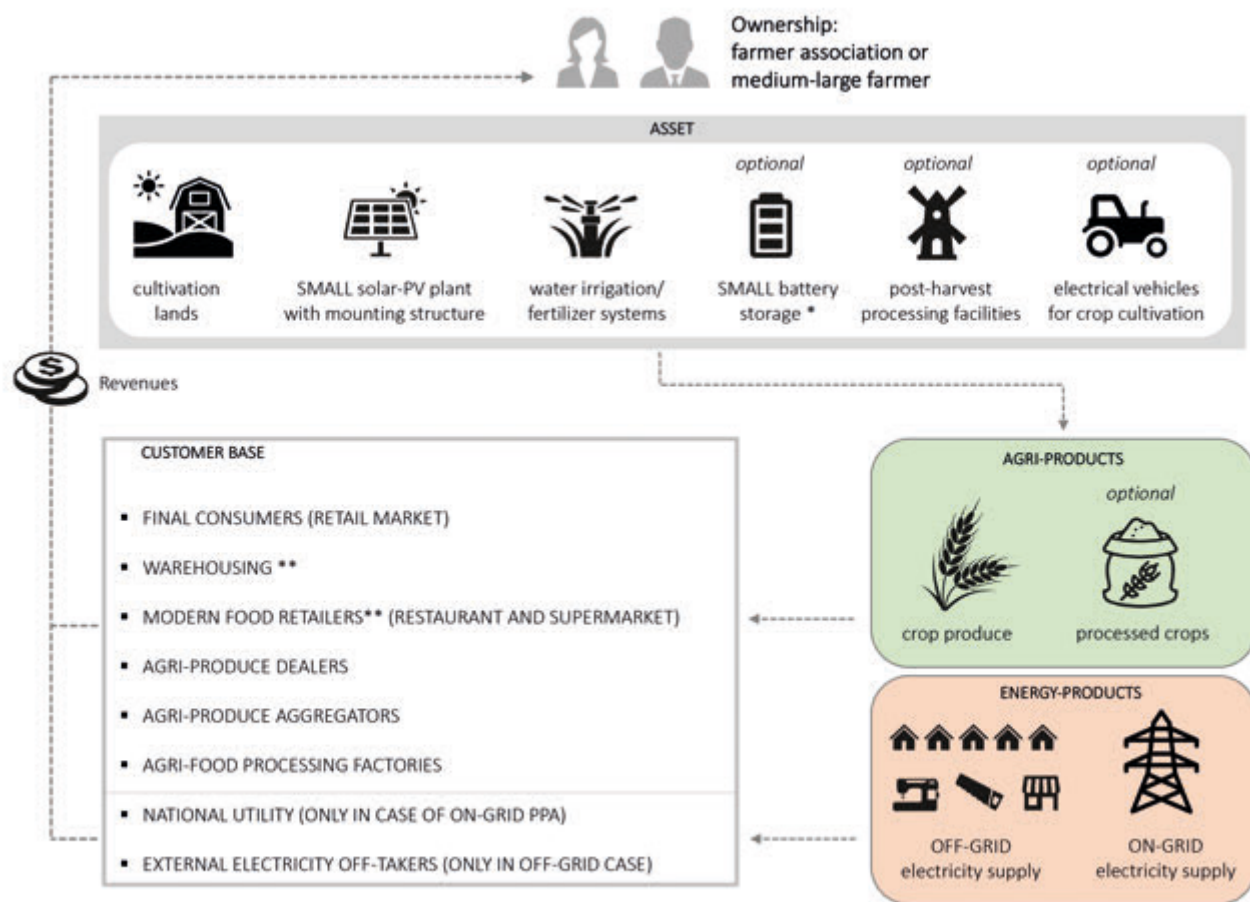


## Business Models description

### Business Model 1 – Farm-owned PV plant

#### In a nutshell

A player of the agriculture sector invests in the PV plant that is installed in its own cultivated lands to (i) power efficient irrigation systems and (ii) enter into the energy market (on-grid or off-grid). It is the sole owner of both land and technical assets (PV and agriculture-related assets) and it operates and maintains the technological asset thanks to the support of external technical assistance. The BM1 is suitable for farmer associations or medium-large farmers.



\* battery storage may be needed for load shifting in the off-grid setup in case a precision irrigation systems are adopted or there is a relevant off-taker component in the load profile.

\*\* only in case of large farms

#### Overview

Thanks to the PV plant ownership of the farm (or farmer associations), BM1 approach generates higher revenue streams than sole farming (sales of crop produce and sales of energy), in addition to the possibility of providing access to energy for farms in remote areas.

This BM is suitable for both on-grid and off-grid contexts:

- the on-grid concept is structured to satisfy the Agri-player energy needs and sell the extra energy production to the national utility.

- the off-grid concept is structured for local energy consumption, to satisfy the Agri-player energy needs and local external off-takers (processing facilities in the close proximity as well as nearby communities), with the outcome of deploying a sort of mini-grid project.

A battery storage may be needed for load shifting in the off-grid setup, in case precision irrigation systems are adopted or there is a relevant off-taker component in the load profile.

Since the PV-energy produced can be used to improve the quality of the local agriculture production, via the implementation of irrigation systems, it could generate economic and production benefits, as it would directly impact rural farmers. In case of farmer association (farmer are members/shareholders) the benefit is direct, while it is indirect in case of a medium-large farm. Thus, BM1 pursues to sustain the rural economy and may be able to move farmers' condition from subsistence to commercially active.

Such a model is very replicable and scalable, being available for different sizes of cultivated lands and a large variety of crops. However, the economic viability threshold is given by three parameters: (i) minimum land size required, (ii) maximum financing support (grant and/or debt) and (iii) PV-plant size. As reference values, BM1 can be viable with at least 50% grant financing support for small-scale projects (PV size >100 kWp installed in a 0.15 ha cultivated land) to medium-scale projects (PV size >1 MWp installed in a 2ha cultivated land). Viability is more easily reached in contexts where crops with high value per kilogram are cultivated, such as mango, avocado, banana, and french bean.

Thus, a suitable financing structure for BM1 could be composed of (i) grant financing (in form of work progress grant and technical assistance), (ii) microfinancing in case of farmer association, (iii) commercial loan in case of medium-large farmer and (iv) junior debt.

## How it works

BM1 has to be implemented by an Agri-player (farmer association or medium-large farmer) who wants to install a PV plant on its own cultivated fields.

Thus, **three assets** characterise BM1:

- 1) PV-power generation plant,
- 2) systems and equipment for land cultivation and
- 3) lands.

All the three assets are owned by the same entity, who is also committed to operate them in a kind of APV integrated business. Expert technical support for both agrotechnical and energy components is needed to assure the business sustainability.

The **business scope** is to diversify the revenue streams and enable cultivation practices (more or less innovative), that require energy. Revenues streams differ depending on whether the on-grid or the off-grid setup is present:

- in the on-grid setup, revenues come from the sale of agriculture products (pursued by operating water irrigation, fertiliser distribution, etc.) and the sale of energy to the national utility by means of a PPA
- in the off-grid setup, revenues come from sales of agricultural products and the sale of energy to local off-takers in a kind of mini-grid project. Thus, the BM1 value proposition identifies a cross-cutting customer base in both the agricultural sector and the energy sector.

However, the off-grid setup could be challenging in case of connection of a nearby community as the project is more complex in terms of business development (licence/permitting procedures,

techno-economic capabilities, etc.), and a positive cost-benefit balance should be verified. Such a mini-grid project should be supported by a profit or non-for-profit actor.

**Key partners** include

- (i) at least one financing entity able to support the capital costs by means of de-risking financing mechanisms;
- (ii) microfinance institutions, which could require a 10% to 40% savings deposit of the total loan amount. The inherent sustainability driver for a cost-sharing model is mitigating investment risk for individuals, also having some guarantee by the implementing partner. Joint partnership investments allow smallholder farmers to pool their collateral risks and negotiate for lower interest rate loans from financial institutions (e.g., commercial or rural banks);
- (iii) technology providers that may be divided into solar and storage (optional) technologies, irrigation kit providers;
- (iv) agronomic expert support in operation;
- (v) technical assistance, considering the lack of experience in the energy sector, for remote plant monitoring and control as well as for extraordinary maintenance.

### **Reference project in operation for the BM1**

In addition to scientific references<sup>1</sup>, BM1 refers to the APV-MaGa<sup>2</sup> project in terms of project governance, key actors involved (owners, operators, partners) and community-based approach.

**MaGa project** developers are installing **8 APV demonstrators in Mali and Gambia** in the period 2020-2023. Each installation will cover approximately 1 ha of cultivated areas having a PV plant ranging between 60 and 200 kWp. Each pilot aims to demonstrate the APV concept technically and economically by adopting a holistic approach: i) irrigated rice farm; ii) a pilot system with integrated rainwater harvesting; iii) a “transformation platform”; iv) a cold storage facility for food preservation.

MaGa projects boost the experiment to an **integrated triple land-use** system (solar-PV generation, cultivation, efficient exploitation of the water resource) to gain a deeper understanding of interactions between the Water-Energy-Food Nexus and prove its economic viability.

However, it is relevant to highlight differences with BM1. Unlike the proposed BM1, the MaGa projects foresees (i) the sale of water instead of water exploitation for the sole landowner's cultivation and (ii) several post-harvest processing activities, since the integration of a sustainable water management and a socio-economic embedment of the agrivoltaic concept represents the core of the MaGa R&D activities.

By adopting a more business-oriented approach, BM1 does not exclude post-harvest processing activities as they actually represent an added value and sustain the business (they can be optional); however, BM1 does not include such activities in its base case as they represent an additional layer of complexity, and not even to sustain the project viability, which can count on the sale of electricity to external off-takers, who could eventually operate such PUE.

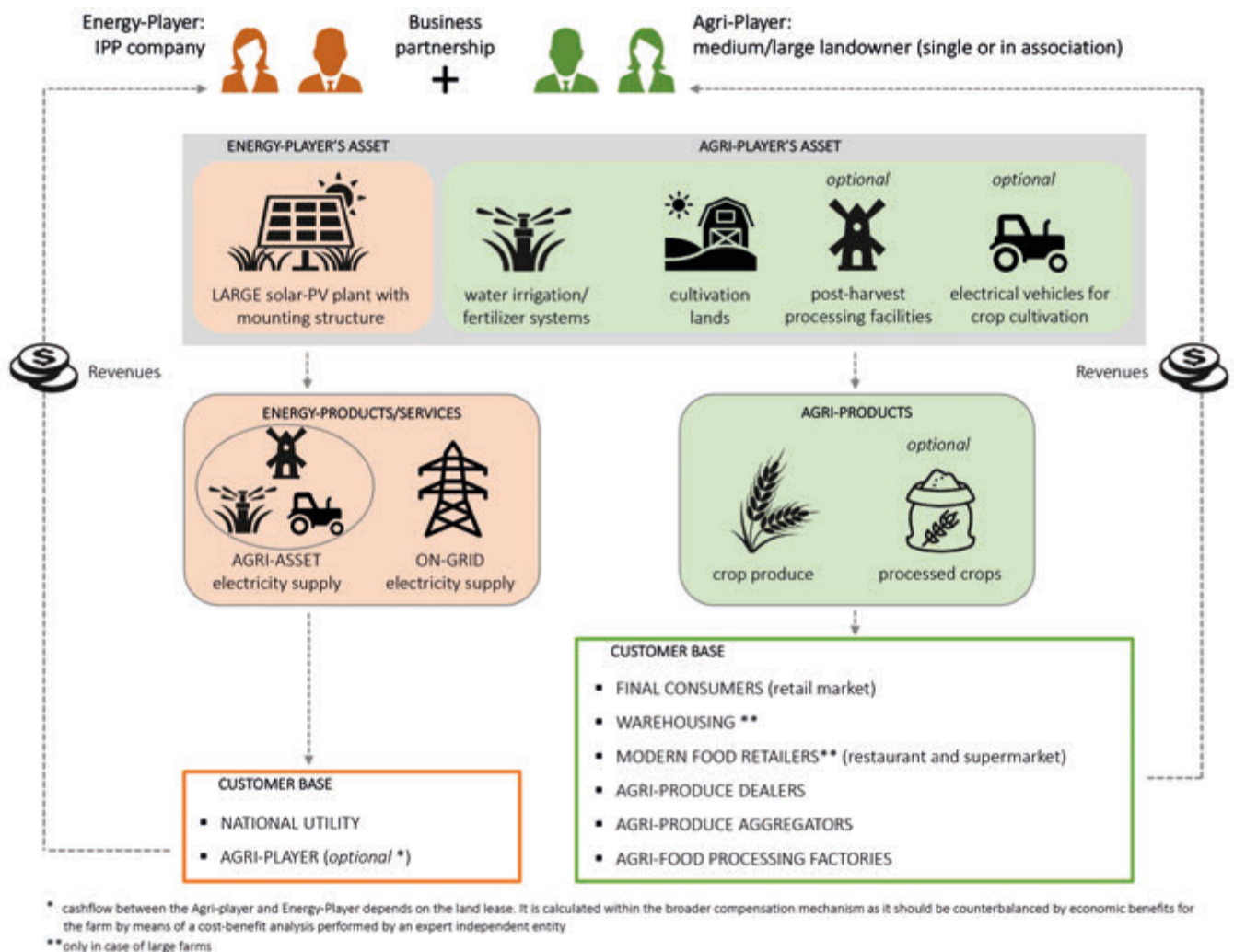
<sup>1</sup> S. Bhandari, *Economic Feasibility of Agrivoltaic Systems in Food-Energy Nexus Context: Modelling and a Case Study in Niger*, 2021

<sup>2</sup> Fraunhofer ISE, *APV-MaGa – Agrivoltaics for Mali and Gambia: sustainable electricity production by integrated food, energy and water systems*, 2023

## BM2 – IPP-owned PV plant

### BM2 in a nutshell

An Energy-player invests in the PV plant, that is installed in cultivated lands owned by an Agri-player. The energy player acts as an IPP who directs the main part of electricity generated to the national grid and provides a minor part to the Agri-player for agri-food activities. While the ownership of PV plant and lands is defined, the ownership of agri-food assets and the land lease fee depends on a compensation mechanism. The BM2 is suitable for medium-large IPP and medium/large landowners (single or in associations).



### Overview

The BM2 addresses the problem of exploitation of water and lands as well as the lack of reliable electricity supply for medium-large agri-food activities.

It embraces the WEF nexus approach with a strong synergy between the three components, even if BM2 tilts toward the Energy component more than BM1. However, the focuses are the same:

- (i) efficient use of the water resource;
- (ii) energy efficiency of agriculture production;

(iii) clean energy generation for improved agriculture production, thus pursuing food security (powering post-harvest processing is optional).

Both players mainly aim to efficiently exploit the land resource. Additionally, the Agri-player aims to take this opportunity to benefit from photon sharing with positive effects on agriculture production and water saving, thanks to the limited evapotranspiration.

With respect to BM1, BM2 minimises the Agri-player's investment but allows for the same effects on agri-food productivity, in exchange for hosting the PV plant installation on its land. On the other hand, Energy-player generally does not expect direct economic benefits but access to a broader pool of financing opportunities.

Since the PV plant is owned and operated by the energy player/ IPP, BM2's approach generates different revenue streams to feed the two different business actors. BM2 is suitable for on-grid contexts in order to activate PPA with the national utility. Potentially, electricity could be provided to nearby off-grid areas by implementing a kind of mini-grid project, even if this option constitutes a more complex business scenario.

More in general, such a model is less replicable and scalable than BM1 in terms of number of projects, as it requires stable and favourable relationships between the two key players. However, each project covers a large size of cultivated lands and can count on a pool of potential IPP with financial capability. In terms of viability, BM2 should only require commercial financing support to be activated. As reference values, BM2 can be viable without grant financing for medium-scale projects (PV size >1 MWp installed in a 2ha cultivated land). Viability is more easily reached in contexts where crops with high value per kilogram are cultivated.

Thus, a suitable financing structure for BM2 could be composed of (i) equity (ii) commercial loan (iii) junior debt and/or (iv) concessional senior debt (e.g., issued by development banks/funds).

### How it works

BM2 has to be implemented by an Energy-player (IPP or other energy investor) who wants to install a PV plant into a cultivated field owned by an Agri-player. Thus, three + 1 optional assets characterise BM2

- 1) PV-power generation plant;
- 2) systems and equipment for land cultivation;
- 3) lands, while
- 4) post-harvest processing facilities (optional).

Differently from BM1, the three assets are not owned by the same entity: while the ownership of PV plant and lands is defined (Energy-player and Agri-player, respectively), the ownership of agri-food assets (3 and 4) and the land lease fee depend on a compensation mechanism. In BM2, the Agri-player is responsible for O&M of agri-food assets, while it is expected that ordinary and extraordinary O&M procedures are managed by the IPP (internal or external O&M).

Regarding the land lease, it is calculated within the broader compensation mechanism as it should be counterbalanced by economic benefits for the farm (energy supply, improved production, resource/cost savings thanks to reliable energy and effects of shading on horticulture such as lower temperature, water savings) by means of a cost-benefit analysis performed by an expert



independent entity that should include aspects related to the Agri-player operation ex-ante and ex-post the energy plant operation.. In a standard IPP project, It is assumed that the Energy Player should charge a land lease fee. In a Agri-PV project instead, the Agri-player should directly benefit from such installation, which should correspond to an economic value. Thus, a land lease fee should be compared with the Agri-player's economic benefits, and eventually adjusted accordingly.

The **business scope** is to leverage on land sharing and photon sharing, enabling cultivation practices (more or less innovative) that require energy as well as access to a broader pool of impact finance. Agri-player's revenues come from sales of agri-food products (pursued by operating water irrigation, fertiliser distribution, post-harvest processing facilities), while Energy-player's revenues come from sales of energy through on-grid PPA.

The BM2 value proposition identifies a cross-cutting customer base in the agricultural sector (modern food retailers, food retail market, warehousing, Agri-Produce Aggregators), while the Agri-player and the national utility are the sole electricity off-takers but only the latter generates revenues (in case of on-grid PPA). Further off-takers could potentially be added in a kind of mini-grid project.

#### **Key partners** include

- (i) at least one financing entity able to support the capital costs by means of de-risking financing mechanisms;
- (ii) insurance company, depending on the country and PPA bankability;
- (iii) technology providers that may be divided into solar technologies, irrigation kit providers and other agri-food processing machineries;
- (iv) agronomic expert support in operations.

#### **Reference project in operation for the BM2**

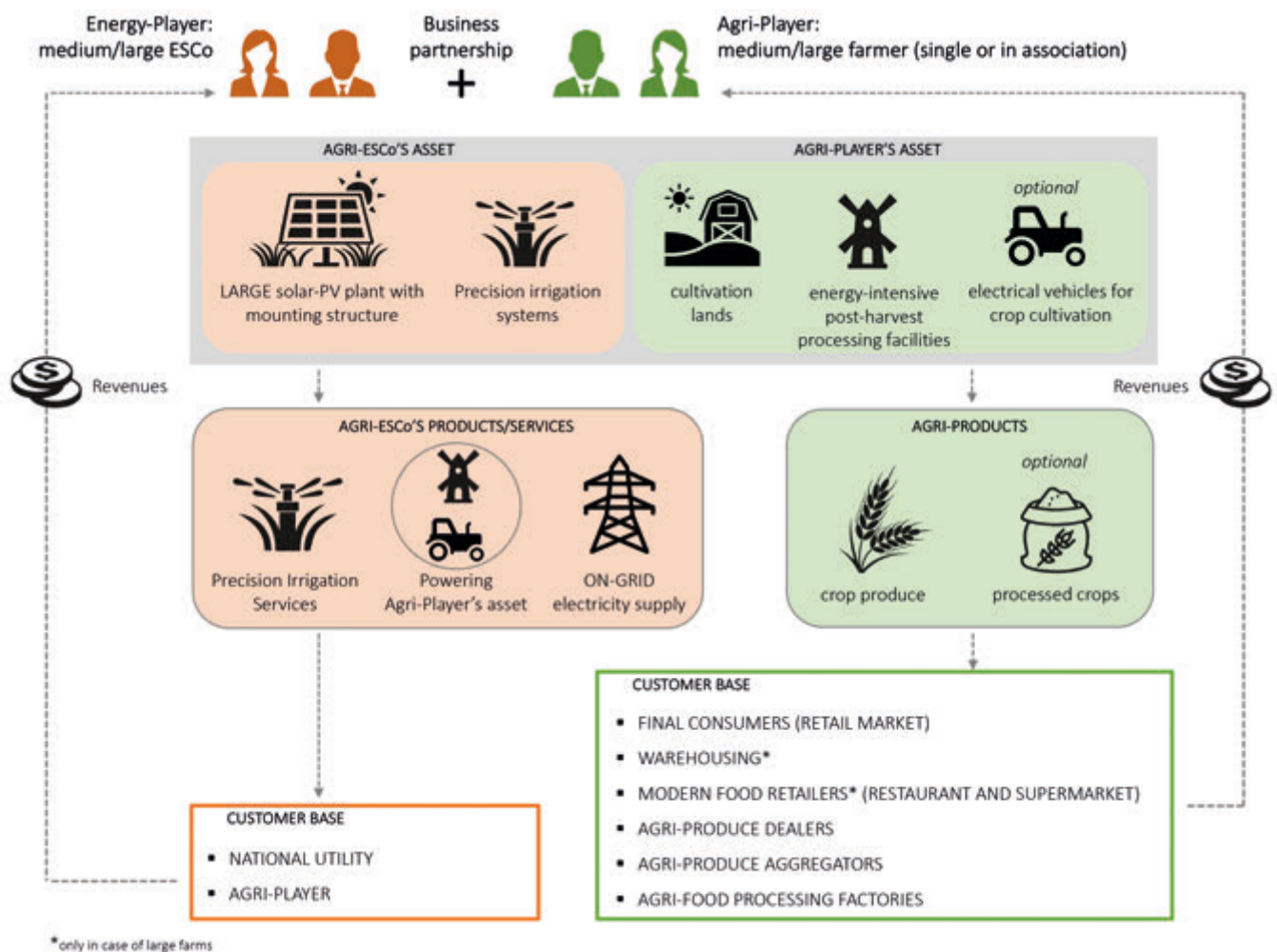
Akuo Energy installed 2.6 MW a La Reunion (Madagascar) on 5.7 ha which are cultivated by Agrinerie, a subsidiary of Akuo devoted to agriculture activities and community aggregation. The revenues, coming from the sale of energy, are used for sustaining farming activities, via the Agrinerie intervention. In addition, Akuo is promoting parallel projects in the region, with the installation of PV for aquaculture activities and greenhouses.

## BM3 – Agri-Energy Service Company

(cutting-edge BM for Research and Innovation)

### BM3 in a nutshell

An Energy-player invests in the PV plant, that is installed in cultivated lands owned by an Agri-player to act as an Agri-Energy Service Company (Agri-ESCo) who delivers an agri-PV solution (full package of energy and precision irrigation services) for efficient agri-food production and processing. The Agri-ESCo inputs the extra electricity generated to the national grid and manages Agri-PV assets for a given period by adopting a Build-Own-Transfer (BOT) model, even if other options could be explored. The BM3 is suitable for medium-large Agri-ESCos and farmers (single or in associations).



### Overview

The BM3 addresses the problem of exploitation of water and lands as well as the lack of reliable electricity supply for medium-large agri-food activities.

It embraces the WEF nexus approach with a strong and well-balanced synergy between the three components, supporting the Water component as BM1, the Energy component at the same scale of BM2, and boosting the Food component in terms of energy-intensive agri-food processing as driver, instead of optional as in BM2.



The focus is on:

- (i) efficient use of the water resource;
- (ii) energy efficiency of agriculture production;
- (iii) clean energy generation for improved agriculture production, thus pursuing food security (powering post-harvest processing).

Both players mainly aim to efficiently exploit the land resource, and the Agri-player, additionally, aims to take this opportunity to benefit from

- (i) photon sharing with positive effects on agriculture production and water saving, due the limited evapotranspiration;
- (ii) precision irrigation systems.

With respect to BM1 and BM2, BM3 minimises the Agri-player's investment, but allows for increased effects on agri-food productivity thanks to precision irrigation, in exchange for hosting the PV plant installation on its land and de-risking the Energy-player's investment.

In fact, in BM3, the Agri-ESCo expects greater economic benefits than an IPP and (in addition to access a broader pool of financing opportunities thanks to the Agri-PV attractiveness) can leverage on the Agri-player's financial capability and intensive-energy demand to reduce the off-taker risk in PPA with state-owned electricity utility.

There are different Agri-ESCo models. Even though other options could be explored depending on the nature of the players, their financial capabilities and country of intervention, BM3 is proposed with a Build-Own-Transfer (BOT) model, in which the Agri-PV asset (PV plant and precision irrigation system) is owned and operated by the Agri-ESCo for a given period and then transferred to the Agri-player. As BM2, BM3 approach generates different revenues streams to feed the two different business actors and is suitable for on-grid contexts to activate PPA with the national utility. Potentially, electricity could be provided to nearby off-grid areas by implementing a kind of mini-grid project.

More in general, such a model is less replicable and scalable than BM1 in terms of number of projects, requiring stable and favourable relationships between the two key players. However, as BM2, each project covers a large size of cultivated lands and can count on a pool of potential IPP/Agri-ESCo with financial capability. Still comparing with BM2, BM3 is more attractive (i) for Agri-players willing to have expert service for improved crop production and/or carrying out energy-intensive agri-food processing nearby cultivation lands, and (ii) for Energy-players with a predictable exit strategy with an asset ownership for limited period, and high replicability capacity.

In terms of viability, BM3 can be viable without grant financing, but likely other third-party soft financing, for medium-scale projects (PV size >1 MWp installed in a 2 ha cultivated land). Viability is more easily reached in contexts where crops with high value per kilogram are cultivated and where there is high ability/willingness to pay the Agri-player for such additional services (as the energy demand is easier to be justified).

Thus, a suitable financing structure for BM3 could be composed of (i) equity (ii) commercial loan (iii) junior debt and/or (iv) concessional senior debt (e.g., issued by development banks/funds).

## How it works

BM3 is implemented by an Energy-player acting as an Agri-ESCo (with or without a third-party financing) who wants to install an Agri-PV system (PV plant coupled with precision irrigation systems) into cultivated fields owned by an Agri-player. Thus, 4 assets characterise BM3

- 1) PV-power generation plant
- 2) precision irrigation systems
- 3) energy-intensive post-harvest processing facilities and
- 4) lands.

For a first given period (e.g., 5-7 years), the four assets are not owned and operated by the same entity: (1) and (2) are operated by the Agri-ESCo, (3) and (4) are operated by the Agri-player. Agri-ESCo can operate by means of internal or external O&M agreements.

The **business scope** is to leverage on land sharing and photon sharing, but the incentive for efficient energy-intensive cultivation practices and post-harvest processing is stronger than in BM2, as well as access to a broader pool of impact finance. The Agri-player's revenues come from sales of agri-food products (pursued by operating precision irrigation, post-harvest processing facilities) and Energy-player's revenues come from the Agri-Energy Services bill paid by Agri-player and from sales of energy through on-grid PPA.

As BM2, the BM value proposition identifies a cross-cutting customer base in the agricultural sector (modern food retailers, food retail market, warehousing, Agri-Produce Aggregators), while the Agri-player and the national utility are the sole electricity off-takers. Further off-takers could potentially be added in a kind of mind-grid project.

Key partners include

- (i) at least one financing entity able to support the capital costs by means of de-risking financing mechanisms;
- (ii) insurance company, depending on the country and PPA bankability;
- (iii) technology providers that may be divided into solar technologies, irrigation kit providers and other agri-food processing machineries;
- (iv) agronomic expert support in operation.

## Reference project in operation for the BM3

This business model is inspired by reference case studies for BM1 and BM2, which are hybridised and boosted leveraging on the author's expertise in order to design a *cutting-edge BM for Research and Innovation Actions*.

# Conclusions on PV shading for horticulture

## Business Models comparison

	<b>BM1 Farm-owned PV plant</b>	<b>BM2 IPP-owned PV plant</b>	<b>BM3 Agri-Energy Service Company</b>
<b>WEF synergy</b>	strong synergy between the three components	strong synergy between the three components, even if BM2 tilts toward the Energy component more than BM1	strong and well-balanced synergy between the three components, supporting the Water component as BM1, the Energy component as BM2
<b>Agri-player type</b>	farmer associations or medium-large farmers	medium/large landowners (single or in associations)	medium/large farmers (single or in associations)
<b>Energy-player type</b>	EPC contractors	IPPs	Agri-ESCOs
<b>Minimum project size</b>	small-scale: minimum PV size >100 kWp installed in a 0.15 ha cultivated land	Medium-scale: minimum PV size >1 MWp installed in a 2 ha cultivated land	medium-scale: minimum PV size >1 MWp installed in a 2 ha cultivated land
<b>Post-harvest processing facilities</b>	low relevance for BM	medium relevance for BM	high relevance for BM
<b>Ownership</b>	energy-asset: Agri-player lands: Agri-player irrigation-asset: Agri-player processing facilities: not relevant	energy-asset: IPP lands: Agri-player irrigation-asset and processing facilities: ownership depends on a compensation mechanism	energy-asset: Agri-ESCO lands: Agri-player irrigation-asset: Agri-ESCO processing facilities: Agri-player
<b>Operations</b>	Agri-player with outsourced PV plant monitoring & control and extra ordinary maintenance	energy-asset: IPP irrigation-asset: Agri-player processing facilities: Agri-player	energy-asset: Agri-ESCO irrigation-asset: Agri-ESCO processing facilities: Agri-player
<b>Replicability</b>	medium: no need of stable and favourable relationships as prerequisite, but challenging access to finance	medium: less replicable than BM1 in terms of number of projects, requiring stable and favourable relationships, however it targets large size lands and counts on a pool of potential IPP with financial capability	medium: less replicable than BM1 in terms of number of projects, requiring stable and favourable relationships, however it targets large size lands and counts on a pool of potential IPP/Agri-ESCO with financial capability
<b>Viability</b>	viable with at least 50% grant financing and MFIs loans	viable without grant financing, but likely other third-party soft financing	viable without grant financing, but likely other third-party soft financing
<b>Innovation</b>	low: BM piloted and scaled-up in the target area by a pioneer company	medium: BM piloted out of the target area by a pioneer company	high: cutting-edge BM for Research and Innovation Actions
<b>Attractiveness for Agri-players</b>	attractive for Agri-players willing to diversify the agri-investments and empower efficient agri-tech systems	attractive for Agri-players willing to exploit partnerships for empowering efficient agri-tech methods with a low co-investment	attractive for Agri-players willing to have an expert service for improved crop production and/or carrying out energy-intensive agri-food processing nearby cultivation lands
<b>Attractiveness for Energy-players</b>	attractive for EPC contracts willing to explore new markets	attractive for Energy-player willing to exploit partnerships for access to a broader pool of financing opportunities	attractive for Energy-players with a predictable exit strategy and high replicability capacity

## BM3 - business planning

The business planning in this section aims at creating a simulation to verify the economic sustainability of the **BM3 - Agri-Energy Service Company** since this is the most innovative BM that is proposed for the Agri-PV category. This simulation approach is necessary as for this business model there is no existing pilot, and it has been designed in the framework of this report.

CAPEX, OPEX, revenues, financial performance, payment structures are given based on a set of assumptions to define the simulation context of intervention. Thus, results are provided as reference values for the preliminary project design.

MAIN ASSUMPTIONS	
<b>Context of intervention</b>	Nigeria
<b>Inflation rate</b>	12,37%, as per the average value of the last 10 years (2011-2021) – World Bank data
<b>Project size</b>	200 ha crop cultivation + 5 MW PV-solar generation
<b>Equipment</b>	all-inclusive precision irrigation systems + PV generation plant, including: - 5 MW solar-PV - total energy production of 5,883 MWh/year - 1 water extraction pump of 16.7 kW - 4 water booster pumps of 2.5 kW - 1 water facility (borehole and water storage) - water distribution lines and treatment - monitoring & control equipment
<b>Soft costs</b>	Soft costs refer to all the development costs (human resources, transports, legal and authorization procedures, assessment, procurement, etc.) for the business activation, and are set at 5% of CAPEX
<b>Local taxes</b>	Withholding tax: 10% VAT: 7.5%
<b>Depreciation</b>	Calculated on a 20-year basis and applied to asset capital costs, excluding installation costs
<b>O&amp;M structure</b>	Field personnel salary and assistance Expert agronomic support Supervision/administration at headquarter level Operating costs (transport, office, etc.) Irrigation Equipment/Building ordinary maintenance: 0,02% of CAPEX/year, including all the asset Irrigation Equipment/Building extraordinary maintenance: 3% of CAPEX/5-years, including electronic and engines only PV plant ordinary maintenance: 0,01% of CAPEX/year PV extraordinary maintenance: 1% of CAPEX/5-years
<b>Financing structure</b>	0% grant subsidy 70% subsidised loan at 5% of interest rate (grace period 0, tenor 10) 30% equity
<b>Business tariffs</b>	Precision Irrigation Services yearly fee: 200.640.000 NGN (480,000 Euro) Yearly fee /ha: 1.003.200 NGN/ha (2,400 Euro/ha) The official feed in tariff (FIT) is 76,287.54 NGN (~182 Euro/MWh). However, to be more realistic and in line with continent trends, an initial tariff was set at 124 Euro/MWh for years 1-5 and further decreased to 77 Euro/MWh. FIT is fixed considering that the revaluation of tariffs and the exchange rate trend offset each other.

CAPEX					
Item	Unit	Quantity	Unit price	Total price (NGN)	Total price (EURO)
Building	piece	1	836,000	836,000	2,000
Power generation	MW	5	415,915,000	2,079,575,000	4,975,060
Water extraction pump	piece	1	4,180,000	4,180,000	10,000

Water booster pumps	piece	4	1,003,200	4,012,800	9,600
Water facility (borehole and water storage)	piece	1	12,540,000	12,540,000	30,000
Precision irrigation: distribution lines and treatment	ha	200	4,310,000	862,000,000	2,062,201
Precision irrigation: Monitoring & Control Equipment	forfait	1	20,900,000	20,900,000	50,000
Soft Cost (development cost)	forfait	5%		149,202,190	356,943
<b>Total</b>	<b>piece</b>			<b>3,133,245,990</b>	<b>7,495,804</b>

## Financial performance

<b>Financing structure</b> (177 USD/MWh)	0% grant subsidy 70% subsidized loan at 5% of interest rate (grace period 0, tenor 10) 30% equity
	NPV: 1,236,062,184 NGN IRR: 31,9% Payback Period: 4 years
<b>Financing structure</b> (1-5 years at 120 USD/MWh and then 75 USD/MWh)	0% grant subsidy 70% subsidized loan at 5% of interest rate (grace period 0, tenor 10) 30% equity
	NPV: 282,079,567 NGN IRR: 15,7% Payback Period: 7 years

## Key enabling factors

PV shading for horticulture	
a	The potential market for the PV shading for horticulture is huge as well as its replication and scalability potential.
b	Technology and business model readiness duly support the adoption of PV shading for horticulture since several case studies are recorded.
c	Both MENA and NB regions have favourable regulatory frameworks (solar support policies, efficiency policies in agriculture, policy integration, private sector inclusion, etc.) able to support and encourage the diffusion of PV shading applications.
d	Project financing can easily be finalised in countries with bankable PPA.

## Recommendations

PV shading for horticulture	
a	Policy makers and financiers should facilitate access to credit for farms as well as for technology suppliers and entrepreneurs prepared to invest in APV systems. Government should be committed to facilitate access to finance or directly provide incentives.
b	It is expected that the farm will involve at least one financing entity able to support the capital costs by means of financing mechanisms for de-risking investments. In this view, credit lines should adopt tailored solutions for the agriculture sector, such as a payment structure following the harvest seasonality (e.g., six-month instalments).
c	APV has a huge replicability potential in the target countries, also considering the diffusion of agriculture and the relevant solar potential. For instance, the MENA region has a higher electrification rate, therefore the sale of electricity to the main grid could be feasible. On the contrary, NB has lower electrification rate, so APV could be mostly adopted for self-consumption or in mini-grids – like setups (with specific off-grid tariffs and regulations).
d	Considering the minimal presence of APV plants in the African continent, all the future installations or pilot actions must be associated with dense awareness campaigns and training activities. This aspect is crucial for ensuring the full understanding of the technology.

e	APV systems must be intended also as a resource for boosting the energy access in the continent. The diffusion of this approach could become an added value for facing future climate challenges.
f	Off-grid solar generation and APV technologies can be used as a means for the development of rural communities and reach self-sufficiency. Also considering that average consumption levels in both households and enterprises remain quite modest in the continent, even small APV projects could provide significant community benefits.
g	The cost-benefit analysis that should be performed to assess economic benefits of an APV project can be the subject for a research/demonstration action to provide benchmarks to the business sector.
h	Capital expenditures are generally higher compared to a conventional ground-mounted photovoltaic system, mainly due to taller mounting structures. However, APV system cost can vary considerably from case to case, depending on factors such as the installed capacity, agricultural management, field location, chosen PV module technology, etc. Therefore, an intermediate stage of feasibility study is recommended (after the preliminary feasibility, which estimate rounded figures based on benchmarks and general data, and before the full feasibility, which define final figures based on comprehensive data set).
i	The off-grid case, where local needs are addressed through a 24/7 reliable supply for external off-takers, is a challenging scenario as a set of conditions are needed for its implementation: the presence of electricity off-takers (i.e., local communities, other farmers, other PUE) and a positive cost-benefit balance for the APV business. In this case, the intervention of a non-for-profit actor to empathise the project socio-economic impact would be crucial. Furthermore, the developer could be supported in access to blended finance or impact funds that are willing to support such kinds of activities.
j	Donor programmes should <b>monitor Agri-solar applications in operation</b> to: <ul style="list-style-type: none"> <li>- promote interlinks within the Agri-solar sector and with other PUE sectors to be tested in virtuous communities/areas;</li> <li>- evaluate financing mechanisms (insurance mechanisms to cover the off-taker risk and grants);</li> <li>- promote framework agreements between private entities and governments;</li> <li>- promote regional agreements;</li> </ul> In this monitoring activities, donors should involve (i) technology providers, as they are in contact with off-takers over a long period of time, (ii) academies, which would be particularly interested in observing results and (iii) owners/operators.
k	If a farmers' association is part of the business, the agreement between the parties should be carefully negotiated by pursuing a win-win solution, bearing in mind the risk of speculative approach at the expense of small-holder farmers and land workers. In case of funded projects, <b>expert shadowing or mediation in developing such agreements, might be strongly recommended</b>
l	In the pre-feasibility phase as well as in broader funding programmes, bankability of PPA should be verified, otherwise public entities should be driven toward an enabling regulatory framework.

## 6.2 Precision Irrigation

### *Why is it relevant?*

It is a controlled application of water in response to crop needs that makes the irrigation system efficient, also by exploiting solar energy. These technologies represent an opportunity to achieve independence from fossil fuels' energy input in the agriculture sector and to improve productivity during dry seasons, thanks to a more efficient use of the water resources. Overall, the initial cost for the installation solar irrigation systems is higher than diesel-powered systems, however running costs during the lifecycle of the plant are lower. It is crucial to underline that the availability of more energy to access water could lead to an overuse of water resources, generating a negative overall effect on resource management. This is one of the reasons why the WEF nexus component in these technologies has a pivotal role for the sustainability of precision irrigation applications.

The adoption of these applications in the target areas could lead to a reduction in water consumption between 30% and 55%. Considering that agriculture is one of the main drivers for the Niger Basin and the MENA regions' economies, the application of water-saving technologies would positively reflect on the ability of the target areas to cope with water scarcity and reduced arable lands. The presence of active projects in the two regions demonstrate that an enabling environment for the development of these technologies already exist, even if more could be done in terms of policy schemes to support these solutions. Capacity building of local expertise should be supported, as agromonic knowledge to adopt precision irrigation on the right crops is essential to guarantee that the technology is properly exploited.

### *In this section*

In the following pages, a specific case for the precision irrigation technology is explored: the applications in this field allow to optimise the use of water resources through technological

solutions and to reduce the use of fossil fuels as input of the agriculture sector.

Three possible business models' schemes are defined (see methodology at chapter 2 for details):

- **BM1 - Ownership to farmers:** a single private entity invests in precision irrigation systems for its exclusive usage. It is the sole owner of assets and lands.
- **BM2 - Ownership to agri-produce aggregators:** a single private entity invests in precision irrigation systems to serve farmers (individuals or association) with whom it has signed Agri-Produce Purchase Agreements.
- **BM3 - Ownership to technology provider / precision irrigation as a service:** a precision irrigation technology provider provides the Agri-player with a turnkey service for improved crop productivity.

The comparison of the three models shows a strong synergy especially in two of the three WEF nexus dimensions, namely water and food, therefore the attractiveness factor is reasonably more evident for agri-players. This technology and its declinations appear to be viable in small and medium scale, provided that different financing structures are put in place. For the small sized projects (referring particularly to the first business model), at least 50% grant financing should be taken into account, while for the other 2 BMs (more related to medium-scale) some sort of subsidised financed or third party soft financing should be foreseen. None of the mentioned models appears to be particularly risky in terms of innovation, only the third one presents a medium level of innovation.

In the last part of this section input data for simulation are given for the model 3, for a business case set in Nigeria. The business scenario entails a 200 ha crop cultivation equipped with an all-inclusive precision irrigation system. In the simulation the theoretical project is financed with 70% of subsidised loan and 30% equity.



Costs and revenues are estimated as well and take into consideration the local framework of operations in terms of taxes, market etc.

Below the summary of the comparison of the three business models.

	<b>BM1 Ownership to Farmers</b>	<b>BM2 Ownership to Agri-Produce Aggregator</b>	<b>BM3 Ownership to Technology Provider: precision irrigation as a Service</b>
<b>WEF synergy</b>	strong synergy between the Water and Food components	strong synergy between the Water and Food components	strong synergy between the Water and Food components
<b>Agri-player type</b>	farmer associations or medium-large farmers	medium-large processing factories or Agri-Produce Aggregators	medium-large farmers or Agri-Produce Aggregators
<b>Key Agreement</b>	No agreement is fundamental	Farmers Agri-player	Technology Provider Agri-player
<b>Minimum project size</b>	Small-scale: minimum land size of about 1 ha	medium-scale: minimum land size of about 200 ha	medium-scale: minimum land size of about 200 ha
<b>Ownership</b>	lands: farmers irrigation-asset: Agri-player	lands: farmers irrigation-asset: Agri-player	lands: farmers irrigation-asset: Technology Provider
<b>Operations</b>	different options: a) self-operations b) lease-to-own c) buy-as-you-use	different options: a) self-operations b) lease-to-own c) buy-as-you-use	all-inclusive and expert O&M management carried out by the Technology Provider
<b>Replicability</b>	medium: very replicable for different land sizes but water supply may be a barrier	medium: less replicable than BM1 in terms of number of projects, requiring stable and favourable relationships; however, it targets large land size and counts on higher financial capability to address the water need.	high: more replicable and scalable than BM1 and BM2, both in terms of number of projects and land size, not requiring stable and favourable relationships, and targeting medium/large land size
<b>Viability</b>	viable with at least 50% grant financing and MFIs loans for land size up to 200 ha	viable with subsidised financing in a pilot phase, and without it in a scale-up phase	viable without grant financing, but likely other third-party soft financing
<b>Innovation</b>	low: BM piloted and scaled-up in the target area	low/medium: BM piloted in the target area by more than one companies	medium: BM piloted out of the target area by a pioneer company
<b>Attractiveness for Agri-players</b>	attractive for Agri-players willing to optimise resources and generate higher economic and production benefits	attractive for Agri-players willing to strength the farmers' productivity and exploit a broader pool of financing opportunities	attractive for Agri-players looking for (i) securing ROI (expert operations from day one without learning curve), (ii) avoid risky operations of new technological asset and (iii) no depreciation costs

## 6.2.1 Precision Irrigation

Precision irrigation, including drip irrigation, is a set of solutions for promoting a modern concept of agriculture with huge potential market size. It can be considered as a transversal solution for farmers and/or companies who want to improve their productivity and/or commercial activities. However, precision irrigation coupled with solar energy comes at high costs; thus, the potential market is restrained to medium-large farmers.

Agriculture practices in the target regions are widely diffused and are expected to grow at a CAGR of 18.3% for 2020-2027 in MENA region. Currently, large part of used technologies is inefficient. Most fields are only rainfed, leading to limited crop production, and are highly dependent on meteorological conditions. In this context, irrigation practices can (i). boost agricultural productivity, gross margin, and

food security; (ii). increase water and energy efficiencies; and iii. contribute reducing farmers vulnerability. Adopting any drip/precision irrigation practice can reduce the amount of water that agriculture consumes by delivering water more precisely (water savings estimated to be between 30 and 55%) and increasing the overall production efficiency of 50-80% compared to rainfed agriculture<sup>3</sup>.

Target areas of this study are characterized by (i) high dependency on water for agricultural production with respect to the global average, (ii) water scarcity, particularly in the MENA region where 11 out of the 17 most water-stressed countries in the world are, and agriculture uses 85% of the region's water, (iii) very limited irrigated land, with only 5,8 % of the cultivated area equipped for irrigation (Algeria, Egypt, Morocco, Saudi Arabia, and Syria are the countries with the lowest rate).

Considering that small farming' activities are the majority, particularly in the NB region, where about half of all agricultural operations are less than 2 ha each in size, the scalability potential is limited to medium-large operators (farmer associations/farms). In MENA and NB regions, the literature presents a series of successful business models in this framework, mainly focusing on actual experiences.

The presence of many active projects (some using fossil fuels, some other renewables) shows the diffuse intention in the region to promote such practice. Providers of digital agriculture solutions, both agri-tech companies and mobile operators, successfully collaborate in this application to facilitate its adoption at scale. Even if the Middle East has a higher presence of actors, while northern Africa has a high but emerging demand, there are no relevant risks related to the innovation of the technology, whereas the risk of the "rebound effect" should be considered.

Regarding affordability, in Burkina Faso, Niger, Mali, and Senegal, a project<sup>3</sup> proved that the

solar-powered Californian and drip irrigation systems fared significantly better in improving water use efficiency and crop yields as opposed to all conventional irrigation methods. However, small-holder farmers preferred Californian irrigation over drip irrigation (a type of precision system) because of investment costs (600-1,000 \$/ha compared to 2000-\$/ha 5000), confirming that drip irrigation has low affordability for small-holder farmers.

The enabling environment differs in MENA and NB regions. In the MENA region, it does not hamper precision irrigation as a larger part of the countries in the African continent already have in place some water-related policies that all deal with irrigation techniques and financing mechanisms. Additionally, water tariffs and other costs (fuel and input subsidies) becoming very expensive with the energy crisis, have encouraged water use for low-value activities<sup>4</sup>. In the NB region, countries are not prioritising best practices in the sector, neither in policies nor in financing schemes, even if some part of the region still suffer water scarcity and low productivity agriculture activities<sup>5</sup>.

In conclusion, on the one hand, the attractiveness for the agri-business sector is high because the application can solve water scarcity and improve the productivity of agro-business. On the other hand, the attractiveness for the PV-business sector is low because energy consumption for such applications is limited. However, this application could also be interesting for Energy-players if integrated in a mini-grid business model since it can reduce electricity tariffs by 8-18%.

Finally, considering the relevance of the application and the solar radiation rate of the regions, precision irrigation should be encouraged, and testing more promising business models should be prioritize for tangible and relevant impact in the region (especially MENA), even if it is not particularly attractive for the PV sector.

<sup>3</sup> ICBA, Solar-powered small-scale irrigation can boost food security in sub-Saharan Africa – study, 2021.

<sup>4</sup> F.Molle et al., Irrigation Policies in the Mediterranean Trends and Challenges, 2019

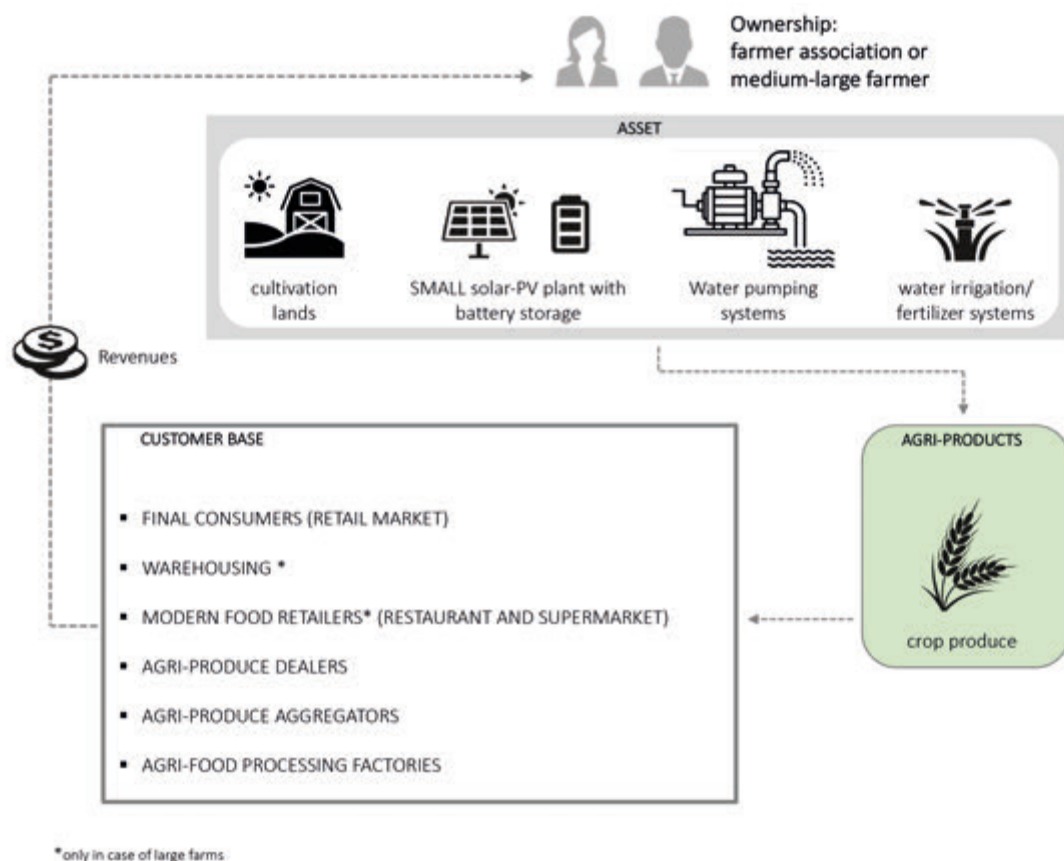
<sup>5</sup> E. Acheampong, Analysis of agricultural water productivity of irrigation schemes in the Niger River Basin, 2008

## Business Model description

### BM1 – Ownership to farmers

#### BM1 in a nutshell

A single private entity invests in precision irrigation systems for its exclusive usage. It is the sole owner of assets and lands. It operates and maintains technological assets through different options of operating modes. The BM is suitable for farmer associations or medium-large farmers.



#### Overview

Business model 1 addresses the problem of water scarcity and high dependency on water for agricultural production and efficient land use through RE-powered technologies.

It embraces the WEF nexus approach with a strong synergy between the Water and Food components, focusing on (i) energy efficiency of agriculture production and (ii) food security, respectively.

BM1 promotes a highly efficient PV-powered irrigation technology that optimizes resources (natural, labour, fertilizers) and generates higher economic and production benefits than other classical irrigation systems. Also, it can move farmers' conditions from subsistence to commercially active. Depending on the nature of BM actors, it can have a double effect: it could either directly impact rural farmers, which usually count on a family-base workforce, if the Agri-player is a farmer association, and thus farmers are members/shareholders sharing economic benefits; while it may

negatively impact land workers in case the Agri-player is a medium-large farm, as the human workload can be reduced and/or they may not access to economic benefits.

A set of services and assets are needed to ensure the proper operation of precision irrigation systems. The BM1's value position foresees an all-inclusive management carried out by the owner. Alternatively, depending on the owner's nature, O&M could be an outsourced specialized service. Such a choice would be reflected in an appropriate management and governance model and thus affect BM's sustainability.

More in general, such a model is very replicable and scalable, being available for different sizes of cultivated lands, if the crucial aspects of water supply and water quality is adequately addressed. However, the viability threshold is given by two parameters: (i) minimum land size required and (ii) maximum financing support (grant and/or debt). As a reference, value precision irrigation is viable without financing support over a land size of about 200 ha; otherwise, it would need up to 50% grant financing. Viability is more easily reached in contexts where crops with high value per kilogram are cultivated.

Thus, a suitable financing structure for BM1 could be composed of (i) grant financing (in the form of work progress grant and technical assistance), (ii) microfinancing in case of farmer association, (iii) commercial loan in case of medium-large farmer and (iv) junior debt.

### How it works

This BM is proposed for promoting a highly efficient irrigation technology.

In this way, different operating models with the Technology Provider can be adopted, for example: (a) standard products provision and installation, with a guarantee period (b) lease-to-own (regular payments for a given period, and after that, the operator owns the technology); and (c) buy-as-you-use (operator pays for use and maintenance service, and obtains ownership after paying a pre-set amount). Some of these mechanisms rely on information and communications technologies (ICT) linked to usage metres; a lack of access to the internet and other infrastructures may limit their feasibility.

Therefore, the ownership of the asset is (i) entirely up to small-holder farmers as shareholders of the farmer association (shares may follow a proportional mechanism or other preliminary agreements), or (ii) is up to a medium-large farm, and farmers are sole land workers. Thus, the farmers are fully committed to exploiting the precision irrigation systems, improving land productivity to save water, to reach the paying back period for case (i) or benefit of bonus or similar for case (ii).

The revenue streams of the application directly come from sales of agricultural products. Since adopting such a practice can reduce water consumption and improve the productivity of farming activity, precision irrigation allows for resource and cost savings (energy, water, fertilisers, field labour, etc.). The owner can sell excess water to neighbouring communities as an ancillary revenue stream.

Key partners include:

(i) financing entities, including microfinance institutions, which could require a 10% to 40% savings deposit of the total loan amount. The inherent sustainability driver for a cost-sharing model is mitigated investment risk for individuals, also having some guarantee by the implementing partner. Joint partnership investments allow smallholder farmers to pool their collateral risks and negotiate for lower interest rate loans from financial institutions (e.g., commercial or rural banks);

- (ii) technology providers that may be divided into solar technologies and irrigation kit providers.
- (iii) agronomic expert support in operation.

### **Reference project in operation for the BM1**

#### **Netafim**

Netafim is designing and installing family-based drip irrigation systems for parcels of 250 square metres and 2,500 square metres. Netafim provides the expertise, training, and support, and engages with local partners to secure the provision of drip irrigation systems, solar pumping systems, and microfinancing for farmers.

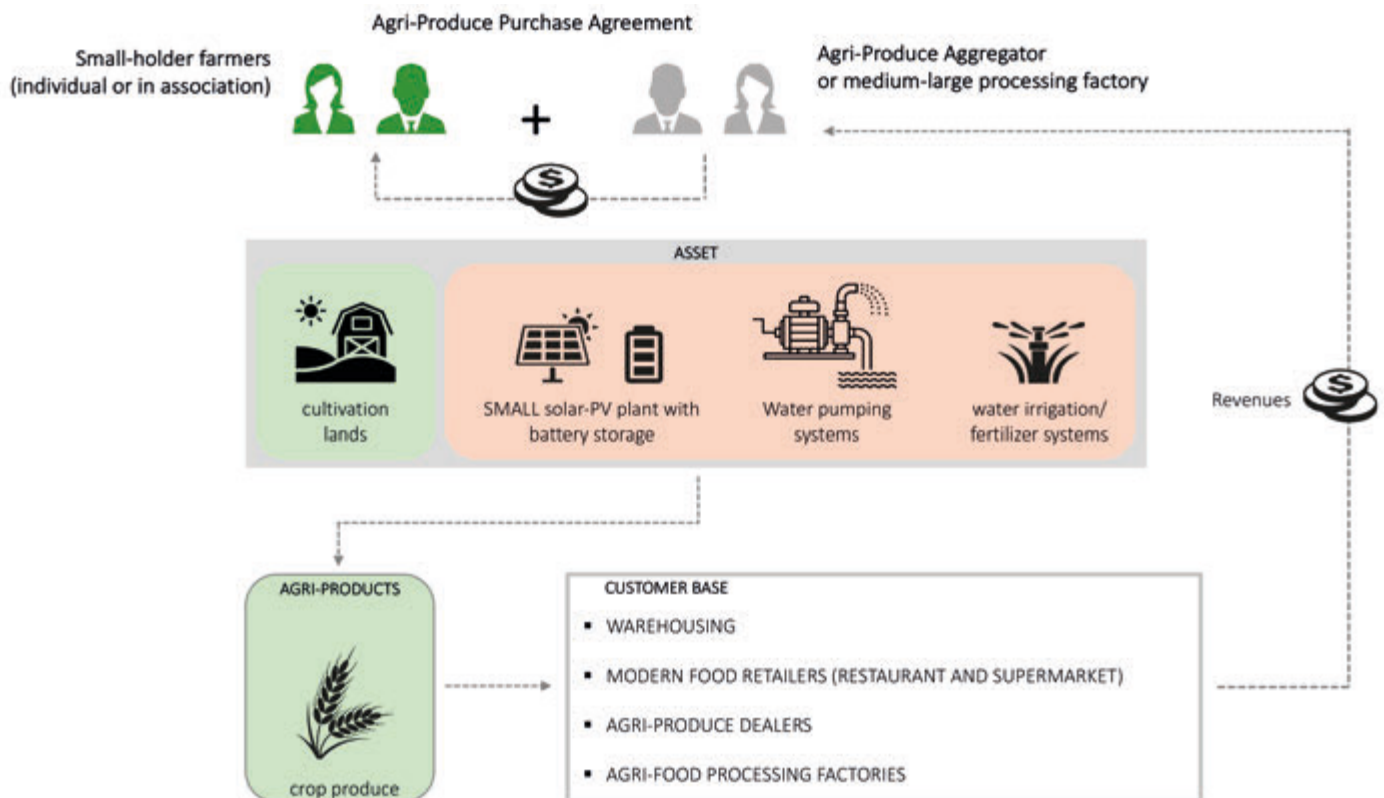
#### **WEBSOC project**

A business model is presented by an international development research and innovation project (Green Cohesive Agricultural Resource Management (WEBSOC)) which aims at implementing automated solar-powered drip irrigation systems for smallholder vegetable farmers in Ghana.

## BM2 – Ownership to Agri-Produce Aggregator

### BM2 in a nutshell

A single private entity invests in precision irrigation systems to serve farmers (individual or association) with whom it has signed Agri-Produce Purchase Agreements. It is the owner of the asset that is installed in the users' lands. So, it operates and maintains technological assets through different options of operating modes. The BM is suitable for medium-large processing factories and Agri-Produce Aggregators.



### Overview

Business Model 2 addresses the problem of water scarcity and high dependency on water for agricultural production as well as efficient land use through RE-powered technologies.

It embraces the WEF nexus approach with a strong synergy between the Water and Food components, with a particular focus on (i) energy efficiency of agriculture production and (ii) food security.

BM2 promotes a highly efficient PV-powered irrigation technology that optimizes resources (natural, labour, fertilisers) and generates higher economic and production benefits compared to other more classical irrigation systems, it may also be able to move farmers' conditions from subsistence to commercially active. However, it depends on the commercial agreement with the Agri-Produce Aggregator, which is a crucial aspect in this BM (it could foresee bonuses and fees for farmers). It boosts the crop production volume and mitigates climate change and seasonality effects on business activities using highly efficient irrigation technology. Furthermore, BM3 allows processing factories and Agri-Produce Aggregators to leverage socio-economic outcomes to explore a broader pool of financing opportunities, such as impact funds or blended finance.



A set of activities and assets are needed to ensure the proper operation of precision irrigation systems. The BM2s' value position foresees an all-inclusive O&M management carried out by the owner. Alternatively, O&M could be an outsourced specialised service depending on the owner's nature. Such a choice will be reflected in an appropriate management and governance model and thus affect the BM sustainability.

In general, such a model is less replicable and scalable than BM1 in terms of number of projects, because it requires stable and favourable relationships between the Agri-Produce Aggregator and farmers. However, each project covers a large size of cultivated lands and can better face the issue of water supply and water quality having higher financial capability.

Regarding economic viability, BM2 may only require subsidised financing (grant and/or debt) in a pilot phase, while it is viable without financing support in a scale-up phase. In general terms, viability is more easily reached in contexts where crops with high value per kilogram are cultivated.

Thus, a suitable financing structure for BM2 could be composed of:

- (i) equity;
- (ii) commercial loan;
- (iii) junior debt and/or
- (iv) concessional senior debt (e.g., issued by development banks/funds).

### How it works

This BM is proposed for promoting a highly efficient irrigation technology.

In this way, different operating models with the technology provider can be adopted, for example:

- a) standard products provision and installation, with guarantee period;
- b) lease-to-own (regular payments for a given period, and after that the operator owns the technology);
- c) buy-as-you-use (operator pays for use and maintenance service and obtain ownership after paying a set amount).

Some of these mechanisms rely on information and communications technologies (ICT) linked to usage metres; their feasibility may be limited by lack of access to internet and other infrastructure.

The ownership of the asset is entirely up to the Agri-Produce Aggregator, who signs a commercial agreement with farmers (Agri-Produce Purchase Agreements). The farmers are fully committed to exploiting the precision irrigation systems to improve land productivity and to save water, if economic conditions are duly provided for the agreement (e.g., bonuses or similar, but also fees for the precision irrigation systems) all-balanced agreement between the parties is important since proper daily usage is crucial to operate precision irrigation systems, which are quite sensitive and complex.

The revenue streams of the application directly come from sales of agriculture products (raw or processed, depending on the nature of the Agri-Produce Aggregator). Since adopting such a practice can reduce water consumption and improve the productivity of farming activity, precision irrigation allows for resource and cost savings (energy, water, fertilisers, field labour, etc.).

Key partners include:

- (i) financing entities;



- (ii) insurance companies;
- (iii) Technology Providers that may be divided into solar technologies and irrigation kit providers;
- (iv) agronomic expert support in operation.

**Reference project in operation for the BM2**

The scheme<sup>6</sup> has been tested by different companies, one of these is Integrated Tamales Fruit Company (ITFC) which provides, in Ghana, irrigation services to several hundreds of smallholders through pumps that have been connected to the drip irrigation schemes. ITFC is operating a mango farm and it is providing water services to additional 800 ha of land managed by 1,300 smallholder farmers. The ITFC provides inputs and technical assistance to the smallholders, who are charged in the form of an interest free loan. The ITFC also helps farmers in obtaining licences and certifications, a requirement for organic exportation.

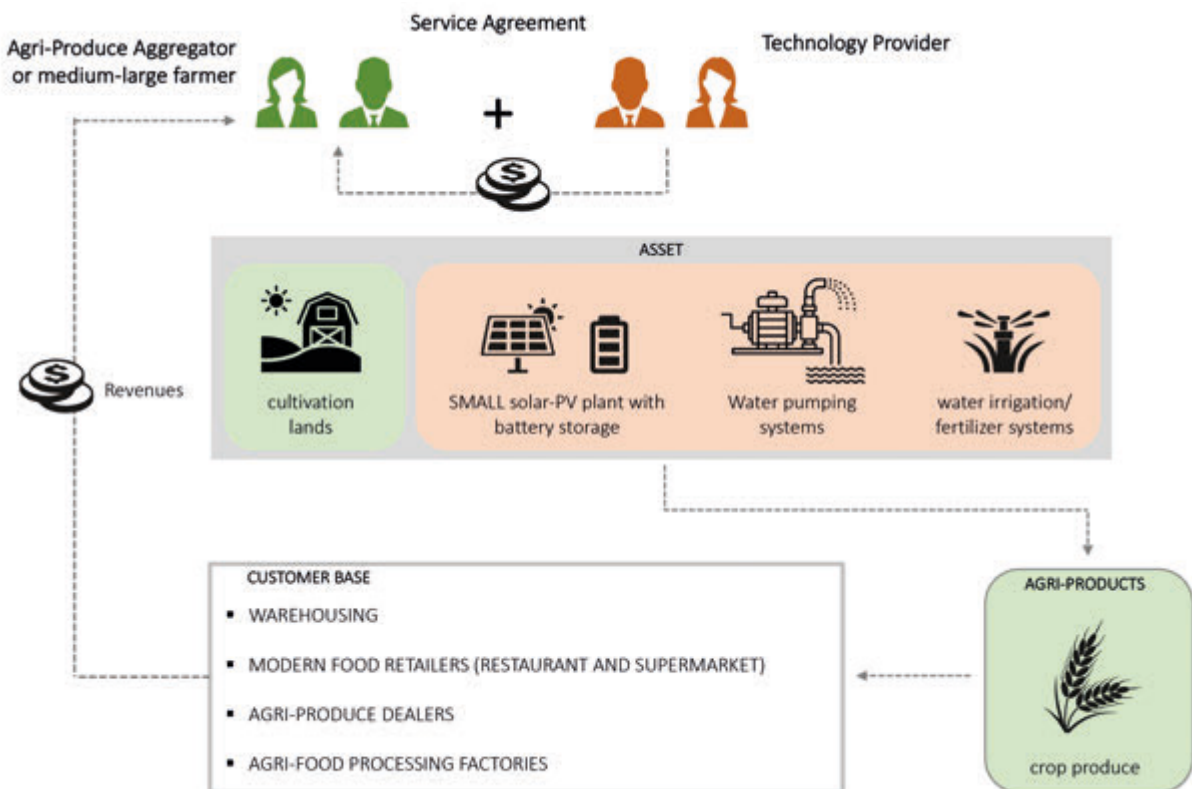
<sup>6</sup> World Bank, How to develop sustainable irrigation projects with private sector participation, 2016

## BM3 – Ownership to Technology Provider:

### Precision irrigation as a service

#### BM3 in a nutshell

A precision irrigation technology provider provides the Agri-player with a turnkey service for improved crop productivity. The Technology Provider remains both the owner and the operator of the precision irrigation systems in exchange for a monthly charge on a mid/long-term basis. The BM is suitable for medium-large farmers and Agri-Produce Aggregators.



#### Overview

Business model 3 addresses the problem of water scarcity and high dependency on water for agricultural production and efficient land use employing RE-powered technologies.

It embraces the WEF nexus approach with a strong synergy between Water and Food components, focusing on (i) energy efficiency of agriculture production and (ii) food security, respectively.

BM3 promotes a highly efficient PV-powered irrigation technology that allows to optimise resources (natural, labour, fertilisers) and generates higher economic and production benefits compared to other more classical irrigation systems. It may move farmers' conditions from subsistence to commercially active. However, BM3 may not directly impact smallholder farmers and land workers because it targets medium-large Agri-players to be sustainable, even if, as BM1 and BM2, it boosts the crop production volume and mitigates climate change and seasonality effects on business activities.

A set of activities and assets are needed to ensure the proper operation of precision irrigation systems. The BM3s' value position foresees an all-inclusive and expert O&M management carried

out by the Technology Provider to enable medium/large agri-food players to focus on their business. At the same time, the Technology Provider takes full responsibility for irrigating and fertigating crops, maximizing the potential of the installed technology.

In general, such a model is more replicable and scalable than BM1 and BM2, both in terms of the number of projects and land size, since there is no favourable relationship as a prerequisite, and it targets medium/large land sizes. Furthermore, BM3 is more attractive for Agri-players looking for (i) securing ROI, (ii) avoiding risky operations of new technological assets, and (iii) no depreciation costs.

In terms of viability, BM3 can be viable without grant financing, but other third-party soft financings could likely be needed, for medium-scale projects (PV size >1 MWp installed in a 2 ha cultivated land). Viability is more easily reached in contexts where crops with high value per kilogram are cultivated and where there is a high ability/willingness to pay off the Agri-player for precision irrigation services.

Thus, a suitable financing structure for BM3 could be composed of:

- (i) equity;
- (ii) commercial loan;
- (iii) junior debt;
- (iv) concessional senior debt (e.g. issued by development banks/funds).

### **How it works**

This BM is proposed to promote highly efficient irrigation technologies.

In this way, different operating models with the Technology Provider could be adopted as mentioned in BM1 and BM2; however, BM3 selects precision irrigation as a turnkey service: the Technology Provider designs, installs, operates, and maintains systems in exchange for a monthly charge on a mid/long-term basis (5-10 years).

The ownership of the asset is entirely up to the Technology Provider, who signs a service contract with the Agri-player (medium-large farms and Agri-Produce Aggregator) for improved crop productivity. Thus, the Technology Provider is fully committed to maximising the potential of the precision irrigation systems and implementing an efficient agronomic approach for improving land productivity and allowing for resource and cost saving (energy, water, fertilisers, field labour, etc.).

The revenue streams of the BM3 come directly from sales of agriculture products (raw or processed, depending on the nature of the Agri-player). Furthermore, there is an internal cash flow between key BM players, since the Agri-player pays a monthly fee to the Technology Provider for the precision irrigation service.

Key partners include:

- (i) financing entities
- (ii) insurance companies
- (iii) solar technologies providers.

### Reference project in operation for the BM3

The Irrigation as a service (IaaS) model is adopted by Netafim<sup>7</sup>, which is an international Technology Provider, leader in precision irrigation systems with experience in Africa.

IaaS is an innovative solution for major new agricultural investments. It enables the company to focus on the business while Netafim's agronomy experts manage the success of the crops production.

As in the proposed BM3:

- (i) Netafim takes full responsibility for irrigating and fertigating crops;
- (ii) Netafim designs, installs, operates and maintains irrigation systems;
- (iii) IaaS is charged monthly or on a long-term basis (5-10 years).

The IaaS' value proposition is based on the following:

- Turning irrigation from Capex to Opex: IaaS delivers the financial benefits of precision irrigation without the complexities of capital investment. The entire cost of irrigation is turned into a simple and predictable monthly operating cost.
- Securing the Return of Investment: leaving irrigation to the experts, the client knows its system will work from day one without the usual learning curve. It provides a faster return on agricultural investment.
- 24/7 client support: IaaS provides continuous irrigation operation and maintenance, with 24/7 irrigation and fertigation schedules managed by a Netafim irrigation manager.
- No depreciation: one of the significant benefits of IaaS is that there are no absorbing depreciation costs.
- Reduce hiring costs: with IaaS, the cost and time taken to find and hire own irrigation experts are avoided. This way, it lowers the client's risk and frees time.
- Cutting-edge digital farming and precision irrigation: Netafim has 250 registered patents and further 150 patents pending.

<sup>7</sup> [Netafim website](#)

## Conclusions on Precision Irrigation

### BM comparison

	<b>BM1</b> <b>Ownership to Farmers</b>	<b>BM2</b> <b>Ownership to Agri-Produce</b> <b>Aggregator</b>	<b>BM3</b> <b>Ownership to Technology Provider:</b> <b>precision irrigation as a Service</b>
<b>WEF synergy</b>	strong synergy between the Water and Food components	strong synergy between the Water and Food components	strong synergy between the Water and Food components
<b>Agri-player type</b>	farmer associations or medium-large farmers	medium-large processing factories or Agri-Produce Aggregators	medium-large farmers or Agri-Produce Aggregators
<b>Key Agreement</b>	No agreement is fundamental	Farmers Agri-player	Technology Provider Agri-player
<b>Minimum project size</b>	Small-scale: minimum land size of about 1 ha	medium-scale: minimum land size of about 200 ha	medium-scale: minimum land size of about 200 ha
<b>Ownership</b>	lands: farmers irrigation-asset: Agri-player	lands: farmers irrigation-asset: Agri-player	lands: farmers irrigation-asset: Technology Provider
<b>Operations</b>	different options: a) self-operations b) lease-to-own c) buy-as-you-use	different options: a) self-operations b) lease-to-own c) buy-as-you-use	all-inclusive and expert O&M management carried out by the Technology Provider
<b>Replicability</b>	medium: very replicable for different land sizes but water supply may be a barrier	medium: less replicable than BM1 in terms of number of projects, requiring stable and favourable relationships; however, it targets large land size and counts on higher financial capability to address the water need.	high: more replicable and scalable than BM1 and BM2, both in terms of number of projects and land size, not requiring stable and favourable relationships, and targeting medium/large land size
<b>Viability</b>	viable with at least 50% grant financing and MFIs loans for land size up to 200 ha	viable with subsidised financing in a pilot phase, and without it in a scale-up phase	viable without grant financing, but likely other third-party soft financing
<b>Innovation</b>	low: BM piloted and scaled-up in the target area	low/medium: BM piloted in the target area by more than one companies	medium: BM piloted out of the target area by a pioneer company
<b>Attractiveness for Agri-players</b>	attractive for Agri-players willing to optimise resources and generate higher economic and production benefits	attractive for Agri-players willing to strength the farmers' productivity and exploit a broader pool of financing opportunities.	attractive for Agri-players looking for (i) securing ROI (expert operations from day one without learning curve), (ii) avoid risky operations of new technological asset and (iii) no depreciation costs

### BM3 business planning

Business planning is simulated to verify the economic sustainability of the **BM3 - Ownership to Technology Provider: precision irrigation as a Service** since this is the most innovative BM that is proposed for the Solar Irrigation category. CAPEX, OPEX, revenues, financial

performance, payment structures are given based on a set of assumptions to define the simulation context of intervention. Thus, results are provided as reference values for the preliminary project design.

MAIN ASSUMPTIONS	
Context of intervention	Nigeria
Inflation rate	12,37%, as per the average value of the last 10 years (2011-2021) – World Bank data
Project size	200 ha crop cultivation
Equipment	all-inclusive precision irrigation systems, including: - 1 water extraction pump of 16.7 kW - 4 water booster pumps of 2.5 kW - 1 water facility (borehole and water storage) - water distribution lines and treatment - monitoring & control equipment
Soft costs	Soft costs refer to all the development costs (human resources, transports, legal and authorization procedures, assessment, procurement, etc.) for the business activation, and are set at 15% of CAPEX
Local taxes	Withholding tax: 10% VAT: 7.5%
Depreciation	Calculated on a 20-year basis and applied to asset capital costs, excluding installation costs
O&M structure	Field personnel salary and assistance Expert agronomic support Supervision/administration at headquarter level Operating costs (transport, office, etc.) Equipment/Building ordinary maintenance: 0,02% of CAPEX/year, including all the asset Equipment/Building extraordinary maintenance: 3% of CAPEX/5-years, including electronic and engines only
Financing structure	0% grant subsidy 70% subsidised loan at 5% of interest rate (grace period 0, tenor 10) 30% equity
Business tariffs	Precision Irrigation Services yearly fee: 16.720.000 NGN (40,000 Euro) Yearly fee /ha: 1.003.200 NGN/ha (2,400 Euro/ha)

CAPEX					
Item	Unit	Quantity	Unit price	Total price (NGN)	Total price (EURO)
Building	piece	1	836,000	836,000	2,000
Power generation	piece	1	15,486,900	15,486,900	37,050
Water extraction pump	piece	1	4,180,000	4,180,000	10,000
Water booster pumps	piece	4	1,003,200	4,012,800	9,600
Water facility (borehole and water storage)	piece	1	12,540,000	12,540,000	30,000
Precision irrigation: distribution lines and treatment	Ha	200	4,310,000	862,000,000	2,062,201
Precision irrigation: Monitoring & Control Equipment	forfait	1	20,900,000	20,900,000	50,000
Soft Cost (development cost)	forfait	15%		137,993,355	330,128
Total				1,057,949,055	2,530,979

## Financial Performance

Financing structure	0% grant subsidy 70% subsidised loan at 5% of interest rate (grace period 0, tenor 10) 30% equity
	NPV: 684,245,908 NGN IRR: 36,6% Payback Period: 4 years

## Key enabling environment factors

Precision Irrigation	
a	The potential market for the Precision Irrigation is huge, even if the scalability potential is limited to medium-large operators.
b	Presence of many active projects (some using fossil fuels, some other renewables) shows the diffuse intention to promote such a practice in the target regions. With specific reference to PV-powered precision irrigation, several research projects support its adoption and demonstrate successful business models that drive its market application.
c	MENA countries already have in place some water related policies that deal with irrigation techniques and financing mechanisms.

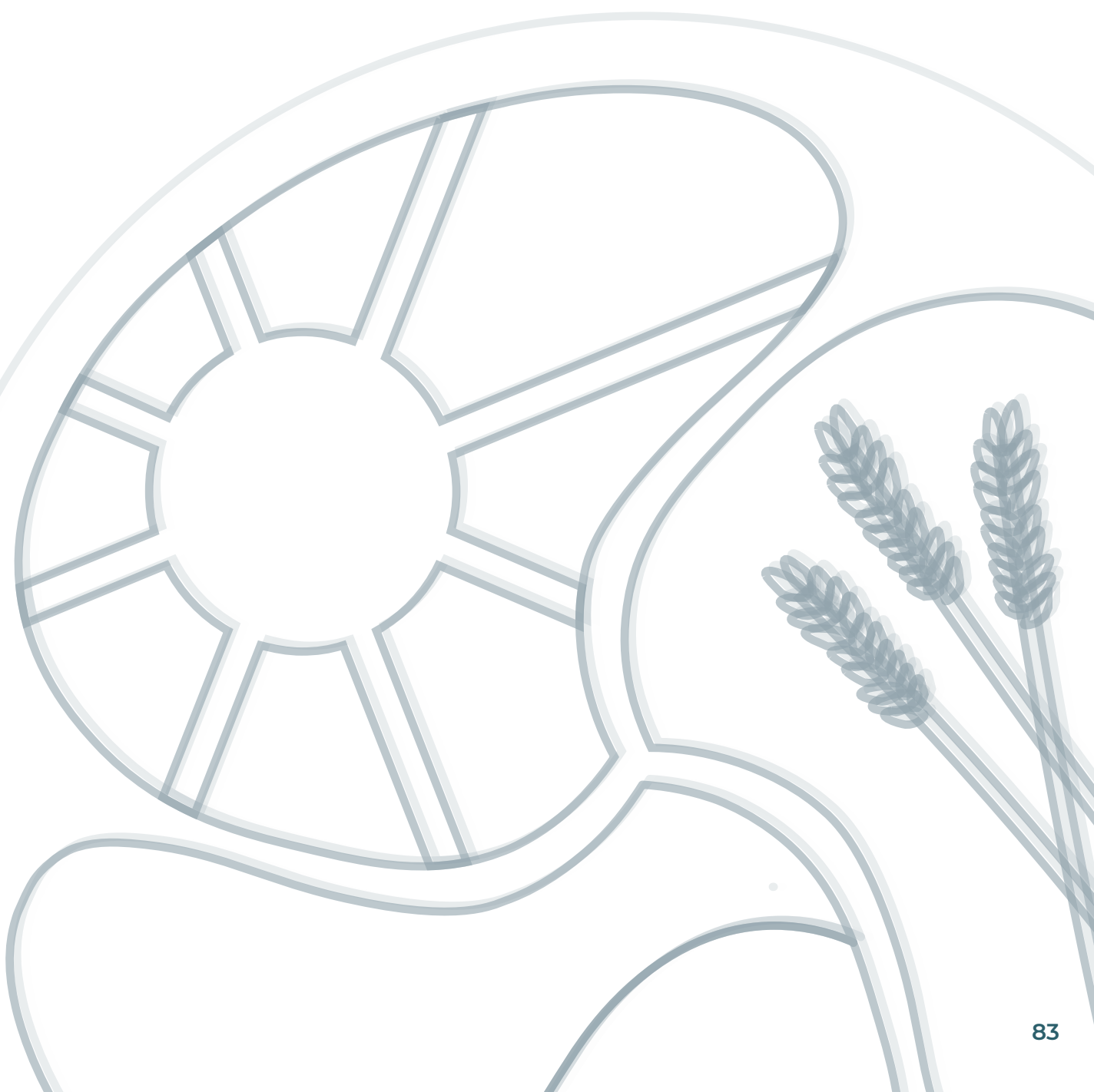
## Recommendations

Precision Irrigation	
a	There is an urgent need for enabling policies within the various irrigation schemes, particularly for precision irrigation. Countries are not prioritising best practices in the sector even if some parts of the region still suffer water scarcity and low productivity agriculture activities. <sup>8</sup>
b	Policymakers and financing entities should facilitate access to credit for farmers, technology suppliers, and entrepreneurs prepared to invest in irrigation service provision. Government should be committed to directly providing incentives for access to water and for spreading efficient irrigation technologies.
c	Financing entities should adopt <b>tailored credit lines for the agriculture sector</b> , such as a payment structure following the harvest seasonality (e.g., six-month instalments).
d	Donors could explore hybrid financing mechanisms (insurance mechanisms to take the off-taker risk and grants) to enable Technology Providers to apply favouring conditions in executing the construction of assets. In this case, the provider should be committed to activating the whole system (acting as an EPC contractor), applying a subsidised price to the farmer association, and managing payments by instalments. That would imply that the provider will be fully committed in optimizing the design, properly training beneficiaries, and providing technical assistance since it is directly linked to its financial exposure.
e	<b>Awareness creation</b> in the target areas is needed as precision irrigation can be largely diffused (especially in MENA), giving priorities to those countries where water scarcity is an issue, but there is a lack of knowledge among decision makers and operators.
f	The long-term sustainability and efficiency of the technology is ensured only if adequate expert technical support is provided: agronomic knowledge of the target crops is fundamental to optimise the precision irrigation technology performance. This way, experimental plants or pilots can help farmers better embrace and understand the technology. Expert support is particularly recommended in case the ownership belongs to a farmer association, which takes the financial risk (even if likely subsidised), distributed among all the members.
g	Partnerships with expert organisations in <b>capacity building programmes</b> are recommended to properly sustain key actors (owners, operators, farmers) to manage this technology and be informed on costs, weaknesses and O&M. In particular, farmers should be duly trained, since precision irrigation systems are sensitive and complex. Especially in BM1, it should be a mandatory activity, keeping in mind the long list of failed water projects and non-functional water facilities in sub-Saharan African countries. Additional effort should be foreseen in case of a newly established farmers association.
h	<b>Business models</b> play an important role as decision making tools to identify the conditions that will enable solar PV systems to sustainably enhance farmers' productivity and economic resilience. If combinations or variations of existing business models are considered, new positive experiences may rise.
i	Donor programmes should <b>monitor Agri-solar applications in operation</b> to: <ul style="list-style-type: none"> <li>- promote interlinks within the Agri-solar sector and with other PUE sectors to be tested in virtuous/vibrant communities/areas;</li> <li>- evaluate financing mechanisms (insurance mechanisms to take the off-taker risk and grants);</li> <li>- promote framework agreements between private entities and governments;</li> <li>- promote regional agreement.</li> </ul> In this monitoring activities, donors should involve: <ul style="list-style-type: none"> <li>(i) Technology Providers, as they are in contact with off-takers over a long period of time;</li> <li>(ii) academies, which would be particularly interested in observing results and</li> <li>(iii) owners/operators.</li> </ul>

<sup>8</sup> E. Acheampong, Analysis of agricultural water productivity of irrigation schemes in the Niger River Basin, 2008



j	Adopting precision irrigation systems may imply a challenging relationship between the asset owner/operator, landowners, and users, which may be different entities and be more or less subordinated. With such premises, commercial and service agreements between the parties should be carefully negotiated by pursuing a win-win solution, bearing in main the risk of a speculative approach at the expense of small-holder farmers and land workers. In the case of funded projects, expert shadowing or mediation is strongly recommended in developing such agreements.
k	<b>Farmers engagement in interacting with the Technology Provider</b> is recommended during the project deployment in order to favour a proper usage of the technology in operation and design tailored solutions.
l	The BM implementation could benefit from a <b>non-for-profit actor</b> (e.g., NGO, agency, local associations, foundation, research group). It could play a role of mediator, facilitator, and capacity building trainer along the whole implementation or (at least) in the start-up phase.
m	Exploring <b>insurance and guarantee solutions</b> , both with the Technology Providers and external insurance companies, to deploy and operate this technology is recommended.
n	The precision irrigation systems are quite sensitive and complex. They require a proper daily usage, and they may imply <b>saving or increasing field labour</b> , depending on the context and proper operations. On one hand, PV-powered precision irrigation systems optimise resources (natural, labour, fertilisers) and generate higher economic and production benefits compared to other more classical irrigation systems. On the other hand, it implies saving of human labour as well. Therefore, it directly and positively impacts rural farmers, (which usually count on a family-base workforce) if the Agri-player is a farmer association; thus, farmers are members/shareholders sharing economic benefits. Instead, it may negatively impact land workers if the Agri-player is a medium-large farm, as the human workload is reduced thanks/due to the efficient systems.



## 6.3 Cold Storage

### Why is it relevant?

Produce spoilage is one of the most critical issues causing food insecurity in the Niger Basin and MENA regions; in rural areas up to two thirds of the total production is often lost due to poor practices of conservation and storage. The situation might be further aggravated in the coming years, due to temperature rise and climate change effects on cultivations and productions. Moreover, rapid urbanization will contribute to the rising need of more reliable cold chains for daily food supply. Putting in place functional cold chains could boost farmers' income in a range from 40% to 100%. Cold storage can unlock benefits across the cold chain to mitigate losses from immediate post-harvest at the farm gate to transportation, logistics, and long-term storage.

Stimulating the implementation of cold storage technologies would have direct benefits on food security, nutrition and health and would positively contribute to agricultural activities' revenues. The model has already proven to be effective as a decent number of businesses already exist in both the target regions. It has to be noted that, in the plethora of possible applications linked to cold storage technologies, pre-cooling and temperature-controlled storage systems are more affordable than cold storage services, that are more electricity intensive.

The off-grid sector is also particularly interesting for cold storage applications, as it could support rural communities in strengthening their resilience and food security.

### In this section

In the following pages, a specific case for the precision irrigation technology is explored: the applications in this field allow to optimise the use of water resources through technological solutions and to reduce the use of fossil fuels as input of the agriculture sector.

Three possible business models' schemes are defined (see methodology at chapter 2 for details):

- **BM1 – Cold chain logistic services:** a private company owns and operates integrated cold chain logistic services, connecting producers with the selling markets, exploiting renewable energy potential in large cold hubs.
- **BM2 – Pay-as-you-go cold storage services:** a private company owns and operates cold storage services by adopting a pay-as-you-go model by means of solar-powered walk-in cold rooms.
- **BM3 – Pay-as-you-go cold chain services:** a private company owns and operates integrated cold chain services, focused on cold storage and connection with the selling markets, by adopting a pay-as-you-go model through a solar-powered walk-in cold room and digital market linkage platform.

The comparison among the three business models related to the cold storage technology show a strong synergy between the energy and food components of the WEF Nexus. These models are particularly relevant for their replicability potential especially in the cases of BM2 and BM 3 where the deployment of the technology can be done easily and with low initial capital. Low innovation risks contribute to make cold storage a very promising technology for the target areas.

In the last part of this section input data for simulation are given for the model 3, for a business case set in Nigeria's agricultural areas. It is based on the assumption of the existence of 10 facilities with the following technical specifications: all-inclusive 3 tons cold hub of 68 m<sup>3</sup> (about 20m<sup>2</sup>), including 10 kW vapour compressor refrigeration systems and 15 kWp solar-PV power generation with battery storage. The finance structure of this model is composed by 50% grant subsidy, 30% subsidised loan and 20% equity. Costs and revenues are estimated

as well and take into consideration the local framework of operations in terms of taxes, market etc.

Below the summary of the comparison of the three business models.

	<b>BM1 Cold Chain Logistic Services</b>	<b>BM2 Pay-As-You-Go Cold Storage Services</b>	<b>BM3 Pay-As-You-Go Cold Chain Services</b>
<b>WEF synergy</b>	strong synergy between the Energy and Food components	strong synergy between the Energy and Food components	strong synergy between the Energy and Food components
<b>Minimum project size</b>	3 cold hubs of 1000 tons/each	10 cold hubs of 3 tons/each	10 cold hubs of 3 tons/each
<b>Business Player type</b>	medium-large private actors (no community-based model)	small-medium private actors (community-based or hybrid private-community model could be tested)	small-medium private actors (no community-based model)
<b>Ownership</b>	The Player owns all the assets	The Player owns all the assets (Hybrid ownership in case of private-community model)	The Player owns all the assets
<b>Operations</b>	The Player directly manages the services as a whole, however can adopt different options for operating cold hubs: a) self-operations b) license to third parties	The Player directly manages the services as a whole, however can adopt different options for operating cold hubs: a) self-operations b) license to third parties (e.g., community-based entities)	The Player directly manages the services as a whole, however can adopt different options for operating cold hubs: a) self-operations b) license to third parties (e.g., community-based entities)
<b>Replicability</b>	medium: complex project development	high: huge demand, easy deployment, and low capital intensive	high: huge demand, easy deployment, and low capital intensive (even if higher than BM2)
<b>Viability</b>	viable without grant financing, but likely other third-party soft financing	viable with at least 50% grant financing	viable with at least 50% grant financing
<b>Innovation</b>	low: BM piloted and scaled-up in the target area	low: BM piloted and scaled-up in the target area	high: cutting-edge BM for Research and Innovation Actions
<b>Attractiveness for Business Players</b>	huge product volumes and large-size customers, which are likely multi-country operators	strong demand and high replicability potential	Strong demand and high replicability potential, with higher profits than in BM2
<b>Attractiveness for Agri- Players (customer base in these Business models)</b>	high-quality cold chain, outsourced supply chain management, expert support for quality control and certifications	extending shelf life of perishable food to sell at higher prices	extending shelf life of perishable food to sell at higher prices, and connection to a wider selling market than in BM2 thanks to the brokerage services

### 6.3.1 Cold Storage: medium-large scale refrigeration

In developing countries, considering that 40% of produce is lost before reaching the market due to post-harvest spoilage and transportation<sup>9</sup>, the **potential market size** is enormous. Increasing the shelf life allows to reduce losses and, consequently, increases the ability small

farmers to negotiate better prices, especially in poor-grid or off-grid settings. Smallholder farmers, who live in rural areas where up to two thirds of overall food losses occur<sup>10</sup> and functional cold chains are frequently absent,

<sup>9</sup> FAO, Key Facts on Food Loss and Waste You Should Know! SAVE FOOD: Global Initiative on Food Loss and Waste Reduction

<sup>10</sup> Lipinski et al., 2013.

could increase their monthly income in a range from 40%<sup>11</sup> to 100%.

Furthermore, the situation in developing countries is expected to be further aggravated over the coming years by a combination of factors. Rising temperatures driven by climate change are expected to cause an increase in refrigeration demand while continuing rapid population growth in developing countries will increase the demand for food. With growing urbanization, more and more people depend on well-functioning cold chains for their daily supply. Foodstuffs are mostly produced in rural areas or outside cities.<sup>12</sup>

The fragmentation of the value chain, involving many stakeholders, constitutes a hindrance to the development and financing of necessary cold chain infrastructure and effective cold chain management.<sup>13</sup> Thus, sustainable business models are not suitable for small businesses (e.g., single-served villages or districts), while medium/large businesses should be activated to face the problem.

In MENA and NB regions, at least two private companies are actively present with business models proven at scale (IFRIA and ColdHubs) dealing with fruit and vegetables, dairy products, fish and meat, and pharmaceuticals. In terms of **scalability**, the challenge is to reach a volume of production that can activate cold hubs in an enabling environment, bearing in mind that food cold chains may vary significantly, depending on the local context.

With a focus on the **WEF nexus**, there is a very high Energy-Food synergy thanks to (i) the high

relevance of energy efficiency, (ii) improved food security, and (iii) improved nutrition and health. Additionally, the Water component may play a direct role in using natural refrigerant or ice-making and indirectly favour efficient irrigation (e.g., precision irrigation and solar-pumped irrigation systems for perishable fruit and vegetables)

The Energy component refers to PV and biomass-based technologies, which can<sup>14</sup> provide solutions at lower financial and environmental costs than diesel or other traditional energy sources. They can pursue climate change mitigation effects, that are mainly related to: (i) cold storage units powered by renewable energy (each unit offsets 121 tons of carbon dioxide equivalent per year<sup>15</sup>); and (ii) refrigerants that are applied in transports and cold rooms.

The main difference between MENA and NB regions<sup>16</sup> primarily concerns energy costs and energy services availability. In particular, energy is crucial for ensuring a stable cold chain, and if within a specific area, energy resource is intermittent, it is not easy to guarantee the quality of service. In MENA, there are many regions where the national energy service is intermittent (i.e., Morocco and other countries in Maghreb), for this reason the integration with PV is crucial. The alternative is to rely on backup generators or to implement cold batteries<sup>17</sup>. In NB there is an extensive market for cold services, but cold chain service prices are a relevant constraint as they are higher than in MENA. This limits the massive diffusion of cold chain services<sup>18</sup>.

<sup>11</sup> AFN, SokoFresh offers cold storage & market linkage to minimize Africa's post-harvest losses, 2022

<sup>12</sup> GIZ, Promoting Food Security and Safety via Cold Chains, 2016.

<sup>13</sup> GIZ, Promoting Food Security and Safety via Cold Chains, 2016.

<sup>14</sup> Powering Agriculture, Navigating Policy and Regulation in the Clean Energy-Agriculture Nexus, 2020.

<sup>15</sup> AFN, SokoFresh offers cold storage & market linkage to minimize Africa's post-harvest losses, 2022

<sup>16</sup> Note: stakeholder consultation carried out in this study.

<sup>17</sup> Note: "Cold Battery" refers to using the negative temperature (sub-zero) chambers as a form of storage of coldness by lowering the temperature to deep sub-zero below actual needs and then letting this temperature rebound – one would do this for example using solar PV (or lower cost grid power in anticipation of a power cut or higher cost times). This is feasible if one has a high efficiency building with excellent insulation.

<sup>18</sup> Note: stakeholder consultation carried out in this study, 2022

There are different cooling technologies<sup>19</sup> (vapour compression cycle, evaporative cooling, ice-making), and they are all proven technologies to address different types of usage/function<sup>20</sup> (pre-cooling to drop product temperatures from harvest levels at 25°C to storage levels at 4-10°C; temperature-controlled storage at 4-10°C; refrigeration at <4°C; and freezing at <0°C). With the presence of private actors (developers/operators/Technology Providers) operating these applications and active in the target areas, there are no relevant risks related to the **innovation** of the technology.

In terms of **affordability**, pre-cooling and temperature-controlled storage are more affordable for farmers than refrigeration and freezing due to less power needs and related cost of cold storage services<sup>21</sup>. At least two African companies adopt business models tailored for small-holder farmers (ColdHubs in Nigeria and SokoFresh in Kenya). However, highly pronounced seasonal variation in production volumes affects the economic viability of bulk storage.

The **enabling environment** does not hamper cold storage projects as this application is

aligned with high-level policies and there are no relevant barriers in the regulatory frameworks. However, the large number of middlemen often involved in food value chains can significantly affect the viability of introducing and maintaining cold chains.

In conclusion, in terms of **attractiveness for the business sector**, cold storage can unlock benefits across the cold chain to mitigate losses from immediate post-harvest at the farm gate to transportation, logistics, and longer-term storage. But maintaining the integrity of a cold chain is therefore essential to harness its benefits.

In the off-grid energy market, cold room operators are a key anchor load and can strengthen off-grid projects viability<sup>22</sup>. Cold storage powered by mini-grids or off-grid supply is protected from the impacts of an unstable grid system, and often better suited to the rural conditions in sub-Saharan Africa. There is already a strong business case in areas with relatively high production levels<sup>23</sup>. Thus, it is a crucial application for both agri-food actors and energy actors, having also proved to be able to attract capital investment.

<sup>19</sup> GIZ, Promoting Food Security and Safety via Cold Chains, 2016.

<sup>20</sup> Sunchill, Preparation trip #1, 2014

<sup>21</sup> Note: stakeholder consultation carried out in this study, 2022

<sup>22</sup> CLIMATTERS, Pushing Off-Grid Renewables, 2022

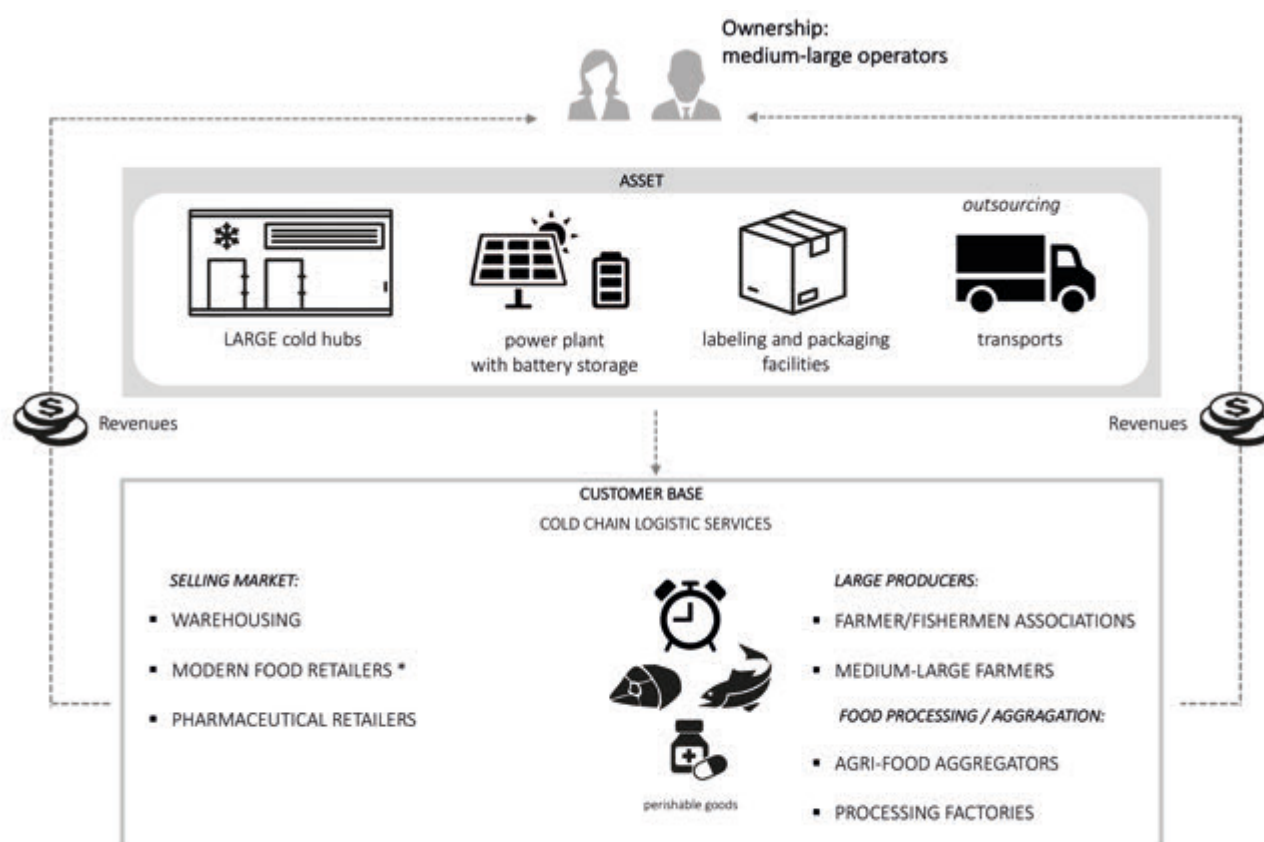
<sup>23</sup> Rockefeller Foundation, Impact agricultural productive use example, 2020.

# Business Model description

## BM1 – Cold Chain Logistic Services

### BM1 in a nutshell

A private company owns and operates integrated cold chain logistic services, connecting producers (medium-large farmers, farmer/fishermen associations, aggregators) with the selling markets. It may directly manage the cold chain logistics assets, or licence assets to third parties. The BM1 pursues full control of the cold chain and highly energy efficient renewable energy integration. BM1 is suitable for medium-large operators.



### Overview

Business model 1 addresses the problem of post-harvest spoilage and transportation in developing countries. It embraces the WEF nexus approach with a strong synergy between the Energy and Food components, with a particular focus on (i) energy efficiency of cold chain and (ii) food waste, respectively.

It is focused on a multi-service approach, with the objective to connect producers (medium-large farmers, farmer/fishermen associations, aggregators) with the selling markets. A set of services and infrastructure are needed to ensure a proper cold chain. The BM1s' value proposition is designed to manage a full package in an integrated manner along the perishable produce cold value chain. However, a single service can be activated on demand.



It is particularly suitable for contexts where there are various running agricultural activities of perishable products, with production volumes high enough to justify the installation of dedicated processing facilities (at least 1000 tons storage capacity). Dairy products could be included in processed products, while meat and fish are more challenging as they usually have a dedicated value chain. Coastal countries may have higher potential leveraging on a more vibrant import/export trade, and thus higher demand from international companies for such services focused on high-quality (or certified) cold chains.

Thus, a suitable financing structure for BM1 could be composed of (i) equity, (ii) commercial loan, (iii) junior debt and/or (iv) senior debt at favourable conditions (e.g., issued by development banks/funds).

### How it works

In the BM1, integrated cold chain logistic services are provided. They can be managed as a full package in an integrated manner, or a single service can be activated on demand.

With the scope to connect producers (medium-large farmers, farmer/fishermen associations, aggregators) with the selling markets, the business operations are structured along the following main streams:

- cold chain warehousing: bulk cold storage of perishable products by means of temperature-controlled, refrigerated or freezer storage rooms;
- value added services such as (but not limited to) labelling and packaging, that may require to be performed at different stages of the cold chain, depending on the specific products and needs;
- rental of production spaces (temperature-controlled rooms) to support and boost quality of food processing;
- documentation and administrative support (certifications, import/export docs, etc.) not only for integrated full package services but also as consultancy, leveraging on the expertise on quality control and certifications.

The BM value proposition covers a wide range of needs of the customer base with 24/7 product tracking and assistance and tailored solutions based on the specific context. The promoter of the project can act as a bridge between producers and selling markets; actors on both sides are potential customers: farmers associations, agri-food aggregators, processing factories on one side, warehousing, modern food retailers (restaurants and supermarkets), and pharmaceutical retailers on the other side.

The value proposition implies a wide range of activities and sub-activities requiring expert management and several infrastructures scarred in the country (cold hubs, labelling/packaging facilities, offices) to enable the revenue streams. Because of that, the owner should be a private actor with relevant financial capacity and expertise. It could directly operate cold chain logistics assets or license them to third parties. A franchising model can be considered.

Key partners include:

- (i) transport companies;
- (ii) import/export companies;
- (iii) large retailers/distributors.



## Reference project in operation for the BM1

### IFRIA BM<sup>24</sup>

Ifria traces its roots back to 2012 when the Management Team developed a cold storage warehouse, Friopuerto Tanger SA (FPT), at the Port of Tanger Med in Morocco. The FPT pilot project is North Africa's most modern Cold Hub offering multiple value-added services: import and export of perishable products to retailers, food processors, and food distribution companies in Morocco. Now IFRIA offers a comprehensive range of temperature-controlled services to agro-industries, modern grocery retail, pharmaceutical industries, hotels, and restaurants in North and West Africa.

In brief:

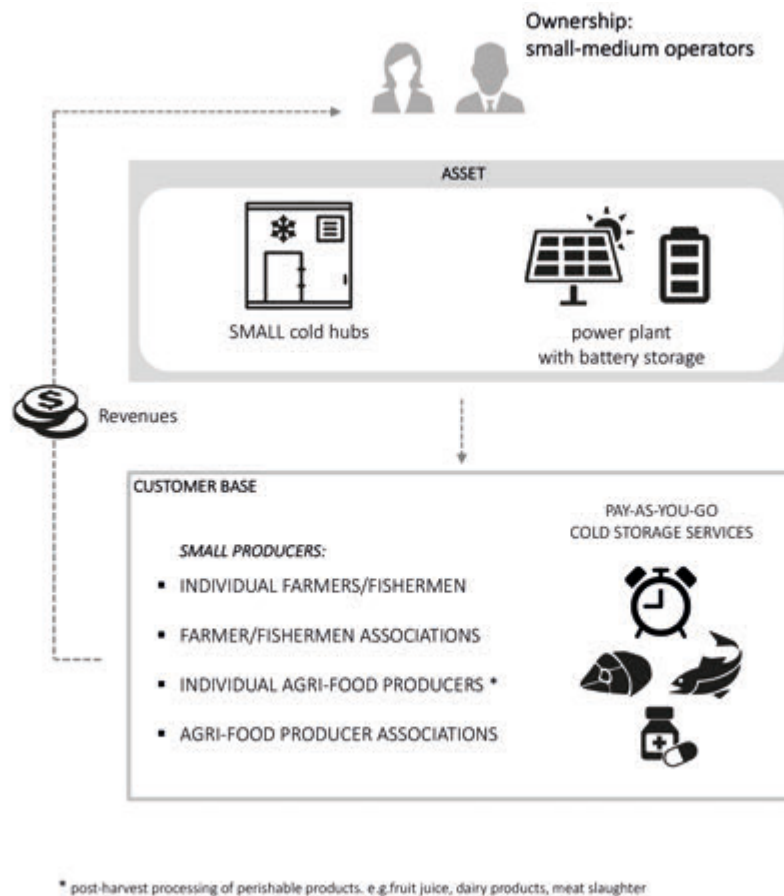
- BM piloted in Morocco and scaled-up in Senegal, Ivory Coast, Ghana and Tunisia so far, with the target of scaling-up in several MENA and NB countries;
- it acts as a 3PL (Third Party Logistics) by providing integrated cold logistic services, and does not purchase and resell products, connecting large aggregators with the selling markets.
- so far, it licences or directly operates Cold Chain logistics assets ranging from added value storage/logistic hubs to first mile Cold Chain. A franchise model will be likely explored in the future;
- One of the services that is largely provided to farmers' aggregations is temperature-controlled storage (and not refrigeration).
- IFRIA hasn't stable commercial partners.
- Major customers are warehousing (for example belonging to the import-export market), modern food retailers (restaurant and supermarket) and agri-food industry (mainly represented by farmers associations, in particular for export purposes).
- It establishes a backbone infrastructure of at least 10 Cold Hubs (in Airports, Maritime Ports, Agri-business zones or similar industrial zones)
- Highly energy efficient renewable energy integration

<sup>24</sup> Note: stakeholder consultation carried out in this study, 2022

## BM2 – Pay-as-You-Go Cold Storage Services

### BM2 in a nutshell

A private company owns and operates cold storage services by adopting a pay-as-you-go model tailored for small-holder farmers, fishermen and small food producers with the aim to extend shelf life of perishable food while increasing rural income, by means of solar-powered walk-in cold rooms. BM2 is suitable for small-medium operators.



### Overview

Business model 2 addresses the problem of post-harvest spoilage and low price point of small-holder farmers, fishermen and small food producers in the market trading.

As BM1, it embraces the WEF nexus approach with a strong synergy between the Energy and Food components, with a particular focus on (i) energy efficiency of cold chain and (ii) food waste, respectively.

It directly impacts on rural beneficiaries. Farmers frequently lose quality produce due to their inability to store it for longer than a day. As a result, they earn less, logistics costs are high, and vast quantities of food are wasted. If produce is managed well from harvest to aggregation, then farmers have enough time to find better buyers or negotiate for better prices or even access international markets for their produce<sup>25</sup>.

<sup>25</sup> AFN, SokoFresh offers cold storage & market linkage to minimize Africa's post-harvest losses, 2022

This BM is focused on flexible pay-as-you-go cold storage services, which is tailored for, but not limited to, rural markets to sustain the perishable products value chain and the related farmer/producer's income. Thus, it indirectly encourages the Productive Use of Energy for food processing by sustaining the retail of perishable produce in the local market.

As BM1, the BM2 is particularly suitable for contexts where there is a variety of running agricultural activities of perishable products, with production volumes high enough to justify the installation of dedicated processing facilities (with at least 3 tons storage capacity). Among processed products, dairy products could be included as well as meat and fish for local markets only (in regional/national markets, they usually have a dedicated value chain).

Thus, a suitable financing structure for BM2 could be composed of:

- (i) grant financing (in form of work progress grant and technical assistance);
- (ii) microfinancing;
- (iii) commercial loan, and (iv) junior debt.

### How it works

In the BM2, flexible pay-as-you-go services to store perishable products up to 21 days in cold hubs are provided.

With the scope to sustain an efficient and sustainable value chain of perishable produce with a focus on rural areas and small producers (individual or associations), the business operations are structured along the mainstream of:

- cold chain warehousing: cold storage of perishable products through temperature-controlled or refrigerated (no freezer) storage rooms.

The BM value proposition covers a broad customer base with 24/7 personal assistance and a daily fee for each stored crate (about 0.50 USD/day per crate<sup>26</sup>). Such a flexible payment solution is designed for individuals or associations of local producers such as (i) small-holder farmers, (ii) fishermen, and (iii) agri-food producers (post-harvest processing of perishable products. e.g., fruit juice, dairy products, meat slaughter).

The value proposition implies deploying and operating a wide range of cold hubs scattered in strategic locations (e.g., local markets) throughout the country. Because of that, the owner should be a private sector actor, and it could directly operate cold hubs or license them to third parties (e.g., community-based entities).

Key partners include:

- (i) micro finance institutions (to favour access to finance for customers);
- (ii) capacity building trainers for customers (profit or no-profit entities);
- (iii)-agri-food dealers/aggregators.

<sup>26</sup> Note: ColdHubs charges 0.50 USD to store a crate of a farmer's produce per day

## Reference project in operation for the BM2

### COLDHUBS BM<sup>27</sup>

ColdHubs manages a “plug and play” modular, solar-powered walk-in cold room, for 24/7 off-grid storage and preservation of perishable food. It adequately addresses the problem of post-harvest losses of fruits, vegetables, and other perishable food.

In brief:

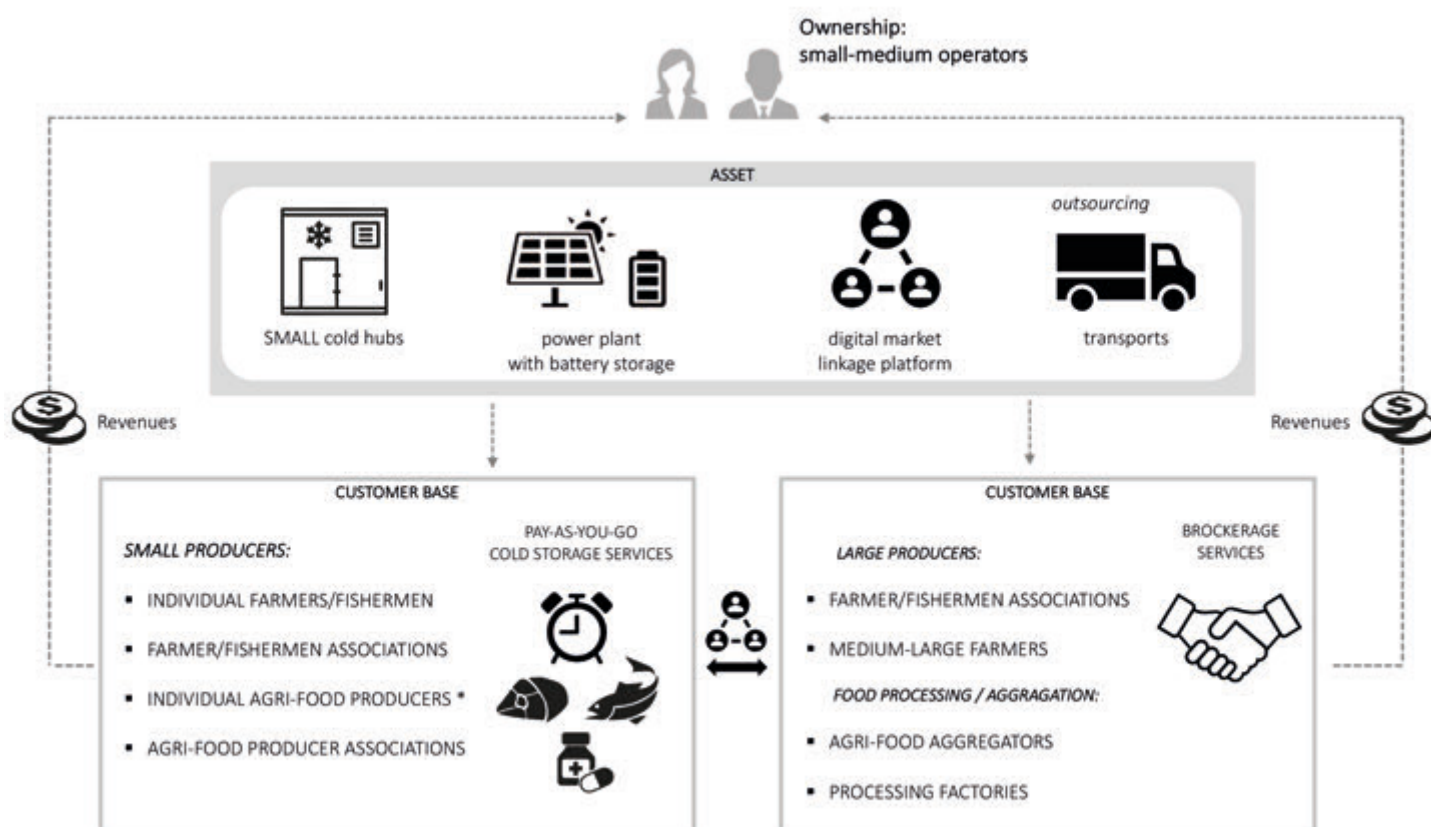
- BM piloted and scaled-up in Nigeria only;
- it uses a “plug and play” modular, solar-powered walk-in cold room,
- 24/7 off-grid storage and preservation of perishable food.
- ColdHubs are installed in major food production and consumption centres (in markets and farms)
- farmers place their produce in clean plastic crates, these plastic crates are stacked inside the cold room.
- this extends the freshness of perishable food from 2 days to about 21 days.
- energy efficiency is pursued: the solar powered walk-in cold room is made of 120mm insulating cold room panels to retain cold. Energy from solar panels mounted on the roof-top of the cold room are stored in high-capacity batteries, these batteries feed an inverter which in turn feeds the refrigerating unit.

<sup>27</sup> Cold Hubs website

## BM3 – Pay-as-You-Go Cold Chain Services

### BM3 in a nutshell

A private company owns and operates integrated cold chain services, focused on cold storage and connection with the selling markets, by adopting a pay-as-you-go model tailored for small-holder farmers, fishermen and small food producers. The BM3 aims to extend shelf life of perishable food and increase rural communities' income, through a solar-powered walk-in cold room and digital market linkage platform. This BM is suitable for small-medium operators.



\* post-harvest processing of perishable products. e.g fruit juice, dairy products, meat slaughter

### Overview

Business model 3 addresses the problem of post-harvest spoilage, low price point and transportation of food produced by small-holder farmers, fishermen and other small producers in the market trading.

As BM1, it embraces the WEF nexus approach with a strong synergy between the Energy and Food components, with a particular focus on (i) energy efficiency of cold chain and (ii) food waste, respectively.

It directly impacts rural beneficiaries but with higher outcomes than BM2, thanks to the additional connection service with the selling markets. Farmers frequently lose quality products due to their inability to store them for longer than a day. As a result, they earn less, logistics costs are high, and vast quantities of food are wasted. If produce is managed well from harvest to aggregation,

then farmers have enough time to find better buyers or negotiate for better prices, or even access international markets for their produce<sup>28</sup>.

The BM3 focuses on a multi-service approach based on flexible pay-as-you-go integrated cold chain services, which embrace (i) cold storage, (ii) connecting small/medium producers with the selling markets, and (iii) food transportation. It is tailored for, but not limited to, the rural market to sustain the perishable products value chain and the related farmer/producer income. Thus, it indirectly encourages the Productive Use of Energy for food processing by sustaining the retail of perishable produce in the local market. However, the supply chain management is not as comprehensive as in BM1 since it is limited to the first mile of the perishable produce cold value chain.

As BM1 and BM2, it is particularly suitable for contexts where there is a variety of running agricultural activities of perishable products, with production volumes high enough to justify the installation of dedicated processing facilities (at least 3 tons storage capacity). Among processed products, dairy products could be included as well as meat and fish for local markets only (in regional/national markets they usually have a dedicated value chain).

Thus, a suitable financing structure for BM3 could be composed of:

- (i) grant financing (in form of work progress grant and technical assistance);
- (ii) microfinancing;
- (iii) commercial loan;
- (iv) junior debt.

### How it works

In the BM3, a flexible pay-as-you-go integrated cold chain services to (i) store perishable products up to 21 days in cold hubs, (ii) favour trading while (iii) transports are provided.

With the scope to sustain an efficient and sustainable value chain of perishable produce, as well as to connect producers with the selling markets, BM3 targets two types of customer segments: customers on the production side (individual and associations of farmers/fishermen/agri-food producers - e.g. fruit juice, dairy products, meat slaughter), and customers on the selling market side (warehousing, modern food retailers - restaurant and supermarket-, agri-food aggregators and processing factories). Thus, the business operations are structured along the mainstreaming of:

- cold chain warehousing: cold storage of perishable products by means of temperature-controlled, or refrigerated (no freezer) storage rooms
- markup on purchase price through the digital market linkage platform.

The BM value proposition is based on 24/7 personal assistance for food producers and buyers. A daily fee is applied for each stored crate (about 0.50 USD/day per crate<sup>29</sup>) and a flexible markup is applied in a range of 5-15% depending on the type of products and the daily prices in local/regional markets, without purchase commitment on stored food.

<sup>28</sup> AFN, SokoFresh offers cold storage & market linkage to minimize Africa's post-harvest losses, 2022

<sup>29</sup> Note: ColdHubs charges 0.50 USD to store a crate of a farmer's produce per day

The value proposition implies deploying and operating a wide range of cold hubs scattered in strategic locations (e.g., local markets) throughout the country. Compared to BM2, BM3 implies a broader range of activities requiring expert management and a well-structured network in the selling market. Because of that, the owner should be a private actor, and it could directly operate cold hubs or license them to third parties. Despite BM2, a community-based or hybrid private-community model is not suitable for BM3, being a more complex model. In contrast, a community-based entity could only be involved as a third-party operator of cold hubs.

Key partners include:

- (i) micro finance institutions (to favour access to finance for customers);
- (ii) capacity building trainers for customers (profit or no-profit entities);
- (iii)-agri-food dealers/aggregators and (iv) transport companies.

### Reference project in operation for the BM3

This business model is inspired by reference cases studies for BM1 and BM2, as well as on an additional one that is reported below. BM1 and BM2 are hybridised and boosted leveraging on the author's expertise to design a *cutting-edge BM for Research and Innovation Actions*.

#### SOKOFRESH BM<sup>30</sup>

SokoFresh's key objective is to develop a scalable, replicable, and holistic approach toward eliminating post-harvest food loss in smallholder farmer value chains.

SokoFresh offers a farm-level cold-storage service and a digital market linkage platform to integrate small and medium-scale farmers into large-scale value chains. Their mobile cold storage solution and pay-as-you-store business model give farmers and aggregators a risk-free opportunity to safeguard the quality of their products and increase their revenue.

In brief:

BM piloted and scaled-up in Kenya only;

- Value proposition: "Ensuring nothing goes to waste."
- Three types of services: 1) storing products in cold rooms, 2) finding buyers through its market linkage platform, and 3) working with a processor to offtake any rejects,
- SokoFresh has managed to make sure that 100% of its farmer partners' produce is used – thereby decreasing food waste and increasing food security at the same time while boosting farmers' incomes.
- Second grade produce or rejects that no one wants to buy or eat are then moved to a third-party processing facility to ensure nothing goes to waste.
- It mainly caters to producers of selected products: (1) mangoes, (2) avocados, (3) bananas, and (4) french beans. While the issue of post-harvest loss cuts across most crops, SokoFresh has selected these specific varieties for different reasons: first, their value per kilogram is higher than for other crops and presents a variety of processing opportunities; second, cold storage enables the farmer to sell more products, and potentially at a higher price point – thereby securing an additional profit, which pays for the cost of the service.

<sup>30</sup> AFN, SokoFresh offers cold storage & market linkage to minimize Africa's post-harvest losses, 2022



# Conclusions on Cold Storage

## BM comparison

	<b>BM1</b> <b>Cold Chain Logistic Services</b>	<b>BM2</b> <b>Pay-As-You-Go Cold Storage Services</b>	<b>BM3</b> <b>Pay-As-You-Go Cold Chain Services</b>
<b>WEF synergy</b>	strong synergy between the Energy and Food components	strong synergy between the Energy and Food components	strong synergy between the Energy and Food components
<b>Minimum project size</b>	3 cold hubs of 1000 tons/each	10 cold hubs of 3 tons/each	10 cold hubs of 3 tons/each
<b>Business Player type</b>	medium-large private actors (No community-based model)	small-medium private actors (Community-based or hybrid private-community model could be tested)	small-medium private actors (No community-based model)
<b>Ownership</b>	The Player owns all the assets	The Player owns all the assets. (Hybrid ownership in case of private-community model)	The Player owns all the assets
<b>Operations</b>	The Player directly manages the services, however can adopt different options for operating cold hubs: a) self-operations b) license to third parties	The Player directly manages the services, however can adopt different options for operating cold hubs: a) self-operations b) license to third parties (e.g., community-based entities)	The Player directly manages the services, however can adopt different options for operating cold hubs: a) self-operations b) license to third parties (e.g., community-based entities)
<b>Replicability</b>	medium: complex project development	high: huge demand, easy deployment, and low capital intensive	high: huge demand, easy deployment, and low capital intensive (even if higher than BM2)
<b>Viability</b>	viable without grant financing, but likely other third-party soft financing	viable with at least 50% grant financing	viable with at least 50% grant financing
<b>Innovation</b>	low: BM piloted and scaled-up in the target area	low: BM piloted and scaled-up in the target area	high: cutting-edge BM for Research and Innovation Actions
<b>Attractiveness for Business Players</b>	huge product volumes and large-size customers, which are likely multi-country operators	strong demand and high replicability potential	Strong demand and high replicability potential, with higher profits than in BM2
<b>Attractiveness for Agri- Players (customer base in these Business models)</b>	high-quality cold chain, outsourced supply chain management, expert support for quality control and certifications	extending shelf life of perishable food to sell at higher prices	extending shelf life of perishable food to sell at higher prices, and connection to a wider selling market than in BM2 thanks to the brokerage services

## BM3 business planning

Business planning is simulated to verify the economic sustainability of the **BM3- Pay-As-You-Go Cold Chain Services** since this is the most innovative BM that is proposed for the Agri-PUE category. CAPEX, OPEX, revenues, financial performance, payment structures are given based on a set of assumptions to define the simulation context of intervention. Thus, results are provided as reference values for the preliminary project design.

MAIN ASSUMPTIONS	
<b>Context of intervention</b>	Nigeria, areas based on agricultural economy. (Conservative scenario with respect to a fishing-based economy)
<b>Inflation rate</b>	12,37%, as per the average value of the last 10 years (2011-2021) – World Bank data
<b>Equipment</b>	10 facilities with the following technical specifications: all-inclusive 3 tons cold hub of 68 m <sup>3</sup> (about 20m <sup>2</sup> ), including 10 kW vapour compressor refrigeration systems and 15 kWp solar-PV power generation with battery storage
<b>Soft costs</b>	Soft costs refer to all the development costs (human resources, transports, legal and authorization procedures, assessment, procurement, etc.) for the business activation, and are set at 15% of CAPEX
<b>Local taxes</b>	Withholding tax: 10% VAT: 7.5%
<b>Depreciation</b>	Calculated on a 20-year basis and applied to asset capital costs, excluding installation costs
<b>Average food market prices</b>	Fruit/vegetables: 120,000 NGN/ton Chicken meat: 1,254,000 NGN/ton
<b>Transport expenses</b>	Estimate of 3% of market price
<b>O&amp;M structure</b>	Personnel salary and assistance Operating costs (transport, office, etc.) Equipment/building ordinary maintenance: 0,05% of CAPEX/year ColdHubs ordinary maintenance: 0,08% of CAPEX/year ColdHubs extraordinary maintenance: 3% of CAPEX/5-years
<b>Financing structure</b>	50% grant subsidy 30% subsidised loan at 5% of interest rate (grace period 0, tenor 10) 20% equity
<b>Business tariffs</b>	Pay-as-you-go service at 100 NGN/day (about) 0.50 USD to store a crate of a farmer's produce Fruit/vegetables brokering fee at 7% (including transport services) Chicken meat brokering fee at 15% (including transport services)

CAPEX						
Item	Unit	Quantity	Unit price	Total price (NGN)	Total price (EURO)	
Field office	#facilities	10	627.000	6.270.000	15.000	
Dev. of the digital market linkage platform	#facilities	1	4.180.000	4.180.000	10.000	
Cold room (3 tons), all inclusive	#facilities	10	15.257.650	152.576.500	365.016	
Setting-up and Furniture	#facilities	10	418.000	4.180.000	10.000	
Training and job-shadowing of personnel	#facilities	10	2.090.000	20.900.000	50.000	
Marketing and awareness campaigns	#facilities	10	1.672.000	16.720.000	40.000	
Soft Cost (development cost)	forfait	15%		30.723.975	73.502	
<b>Total</b>				<b>235.550.475</b>	<b>563.518</b>	

FINANCIAL PERFORMANCE	
<b>Financing structure</b>	50% grant subsidy 30% subsidized loan at 5% of interest rate (grace period 0, tenor 10) 20% equity
<b>Performance indicators</b>	NPV: 17,737,662 NGN IRR: 15,6% Payback Period: 8 years

## Key enabling environment factors

Cold storage	
a	The potential market for the cold storage applications is huge and allows for different size and type of operators to enter the market, and leverage on the high scalability potential.
	The food security situation in developing countries is expected to be further aggravated over the coming years by a combination of factors and thus a growing demand for cold storage services is expected.
b	Technology and business model readiness duly support the adoption of cold storage, even if there are still few business cases in the target regions.
c	Cold storage applications are aligned with high-level policies and there are no relevant barriers in the regulatory frameworks.

## Recommendations

Cold Storage	
a	Polymakers and financing entities should facilitate access to credit for entrepreneurs prepared to invest in cold storage services. Specifically, bank credit should decrease the perceived risk of cold chain management with efficient facilities compared to traditional facilities. Government should be committed to directly providing incentives for such services, specifically for those using efficient facilities, as their diffusion is vital for food security.
b	Financing entities should adopt tailored credit lines for the agriculture sector, such as a payment structure following the harvest seasonality (e.g., six-month instalments). Particularly, producers' level of cause and effect understanding of the cold value chain is very low, leading to no use of produce: producers complain about food standards and export standards since their produce for exports is often rejected for lousy quality.
c	<b>Awareness creation</b> in the target areas is needed as the cold storage chain is not duly taken into consideration, while negative effects on perishable products are notable. There is a lack of knowledge among decision makers and operators.
d	Partnerships with expert organisations in <b>capacity building programmes</b> is recommended to properly sustain key actors (owners, operators, farmers) to manage the cold value chain. Farmers should be duly trained to fully understand market dynamics and be strengthened in negotiating price and timing with agri-products dealers by leveraging on added value given by the cold storage.
e	Donor programmes should <b>monitor Agri-solar applications in operation</b> to: - promote interlinks within the Agri-solar sector and with other PUE sectors to be tested in virtuous communities/areas; - evaluate financing mechanisms (insurance mechanisms to cover the off-taker risk and grants); - promote framework agreements between private entities and governments; - promote regional agreements; In these monitoring activities, donors should involve: (i) Technology Providers, as they are in contact with off-takers over a long period of time; (ii) academies, which would be particularly interested in observing results; (iii) owners/operators.
f	<b>Highly pronounced seasonal variation</b> in production volumes affects the economic viability of bulk storage. Where this is the case, a reduced ROI and longer payback periods are the consequence <sup>31</sup> . This aspect should be duly taken into account in selecting locations of cold hubs and properly design mitigation measures.
g	Average operating costs for bulk storage tend to be significantly higher in developing countries. Reasons for this discrepancy include the geographical dispersion of producers, small land holdings and a lack of uniformity in cropping. This is resulting in the need to establish multiple, small farm gate collection centres and often low-capacity utilisation. A lack of two-way cargo movement, especially for refrigerated transport, and the resulting <b>high transportation costs</b> further add to the high overall operating costs within cold chains <sup>32</sup> .
h	The large number of intermediaries often involved in food value chains in developing countries should be carefully managed and involved, as they can significantly affect the viability of introducing and maintaining cold chains. The resulting fragmentation of the value chain constitutes a hindrance to developing and financing necessary cold chain infrastructure and effective cold chain management.
i	Energy Efficiency in the Cold Storage application makes economic sense: this should be the key message for the private actors. Higher CAPEX is justifiable by energy savings and efficiency for long term payback. On one hand, an EE-focused approach requires a long-term vision as well as good capacity to access to capitals. On the other hand, it is vastly more profitable than the average cold storage by reducing energy expenses by 30-60% compared to traditional methods, as proved by a business case in Morocco <sup>33</sup> .

<sup>31</sup> GIZ, Promoting Food Security and Safety via Cold Chains, 2016.

<sup>32</sup> GIZ, Promoting Food Security and Safety via Cold Chains, 2016.

<sup>33</sup> Note: stakeholder consultation carried out in this study.

# 07 / **Conclusions and Recommendations**



This report presented an overview of applications and technologies based on the water, energy and food nexus and aims at disclosing their potential across the Middle East and North Africa Region and the Niger Basin Region.

The research is not meant to provide an exhaustive and whole-comprehensive list of applications in the water, energy and food sectors, but rather to **demonstrate the potential of certain technologies** to mainstream the overall WEF Nexus approach. To this end 42 applications were identified within 3 of the most promising areas of application for water, energy and food related projects: **agrivoltaic, solar irrigation, and productive use of energy**. The analysis led to the definition of one specific application for each one of the identified areas as the most relevant for the specific geographic scope of the research:

- i) PV Shading for horticulture in the agrivoltaic area;
- ii) Precision irrigation in the solar irrigation area;

### A path forward

The analysis of more than 40 applications in the water, energy and food sectors that present clear elements related to the nexus approach reveals that the potential for one or the other technology depends on **many factors and criteria** that were included in the process, but are nonetheless **subject to change depending on how the market will evolve** in the different geographies taken into consideration.

- The present analysis should be considered as a foundation for further discussions, and there is a wide range of available possibilities to explore.
- The success of implementing a business model is dependent on local conditions and the enabling environment, which can vary greatly between regions.
- The three specific technologies of **PV shading for horticulture, precision irrigation, and cold storage are promising solutions for the Niger Basin and MENA regions**, and

iii) Cold storage in the productive use of energy area.

For each application 3 possible business models have been analysed:

#### PV Shading for horticulture:

- Farm-owned PV plant:
- IPP-owned PV plant:
- Agri-energy service company

#### Precision irrigation:

- Ownership to farmers
- Ownership to agri-produce aggregators
- Ownership to technology provider / precision irrigation as a service

#### Cold Storage:

- Cold chain logistic services:
- Pay-as-you-go cold storage services
- Pay-as-you-go cold chain services

their success is highly dependent on the actors involved, ownership of assets, financing structure, geography of action, and regulatory framework.

- These technologies have the **potential to address the challenges posed by climate change**, such as boosting productivity, improving water resource use, reducing emissions, increasing efficiency, and contributing to the reduction of food insecurity.
- **Access to finance** for these technologies remains a challenge, and the finance structure defining the business models adopted is a key factor that could support or limit the diffusion of certain technologies. The future of the water-energy-food business models in the MENA region and in the Niger Basin, region is dependent on various factors such as embedding WEF Nexus in national regulations, creating synergies among the three sectors,

mobilizing resources, and coordinating stakeholders to scale up existing business models.

Given the relevance of the water, energy and food nexus in addressing some of the main challenges of our era linked with climate change and natural resources management and conservation, **a series of actions** would be highly beneficial for the deployment of WEF Nexus solutions at scale:

- **Develop integrated policies:** governments and other stakeholders should develop and implement integrated policies that address the interconnections between water, energy, and food systems. This could involve breaking down silos between different sectors, as well as coordinating efforts across different levels of government.
- **Increase funding** for WEF Nexus solutions: Given the importance of WEF Nexus solutions in addressing climate change and natural resource management, more funding should be directed towards the development and deployment of these solutions. This could involve public financing, private investment, or a combination of both.
- **Foster innovation:** innovation could be fostered by supporting research and development, as well as creating incentives for private sector innovation.
- **Build capacity:** building capacity among stakeholders is crucial for the successful deployment of WEF Nexus solutions. This could involve training programs for farmers, energy providers, and water managers, as well as capacity-building initiatives for policymakers and other decision-makers.
- **Promote collaboration:** collaboration between different stakeholders stimulates the creation of partnerships between different sectors, and it fosters collaboration between different levels of government, civil society, and the private sector.





# Annexes



# ANNEX I

## Evaluation Matrix Pre-Assessment Criteria Matrix

1	<b>MARKET SIZE</b> Potential market size according to the farming systems
1.1	Potential size of small-businesses to be activated.
1.2	Potential size of medium/large-businesses to be activated.
2	<b>SCALABILITY / REPLICABILITY</b> Scalability/replicability potential of existing business models related to this application.
2.1	What are the existing business models related to this application?
2.2	Is this application integrated in different (agri or not) sub-sectors?
2.3	What about the existing products value chain(s) this application should be integrated in? Are they robust and well-structured or not? Are they challenging and/or highly affected by external conditions?
3	<b>WEF NEXUS</b> Relevance of the application in promoting the WEF Nexus approach.
3.1	Water-Energy-Food synergy.
3.2	Level of (i) effective natural resource exploitation, (ii) climate change mitigations effects and (iii) potential impact on physical environment. Major differences between applications at different scales or on-grid/off-grid connected should be reported.
4	<b>INNOVATION</b> Level of innovation of the technology, its application and adopted business models.
4.1	Presence of projects (developed by profit and non-profit entities) in operation including this application. Specify if this application is part of the core business, or is ancillary and/or part of a business portfolio. Specify if they are research projects (and/or Technology readiness levels – TRL), demonstrations, innovation actions, pilots, or scale-up projects.
4.2	Presence of private actors (developers/operators/technology providers) operating this application and active in the target area.
5	<b>AFFORDABILITY</b> Estimate of application-related costs in relation to the business model (as a whole).
	<b>MENA</b>
5.1	Affordability of this application in existing small-business models.
5.2	Affordability of this application in existing medium/large-business models.
5.3	Would this application provide income all year round or is it seasonal? Are there effective measures adopted to mitigate the business seasonality?
6	<b>ENABLING ENVIRONMENT</b> Synergy with Government policies and international financing.
6.1	Role of the policy environment in promoting or holding back development of this application and related business models, stakeholders, and direct beneficiaries.
6.2	Availability of appropriate finance, funding programmes and/or strategy to support the development of this application at scale.
7	<b>ATTRACTIVENESS FOR THE AGRICULTURE &amp; WATER SECTOR</b> Attractiveness of the application for the agriculture and water sector, including private and public actors as well as government development agencies, commercial and development financing entities.
7.1	Expert advisory of the Consultants about the attractiveness of this application for the agriculture sector in terms of profitability, market positioning, level of risk, improved productivity, and quality etc.
8	<b>ATTRACTIVENESS FOR THE SOLAR-PV SECTOR</b> Attractiveness of the application for the Solar-PV sector, including private and public actors as well as government development agencies, commercial and development financing entities.
8.1	Expert advisory of the Consultants about the attractiveness of this application for the solar-PV sector in terms of profitability, market positioning, level of risk, energy demand etc.

## ANNEX II

### Business Model Canvas matrix – PV SHADING FOR HORTICULTURE

BM Blocks <sup>1</sup>	BM1 – Farm-owned PV plant <sup>2</sup>	BM2 – IPP-owned PV plant	BM3 – Agri-ESCo (cutting-edge BM for Research and Innovation)
<b>VALUE PROPOSITION</b> What value do you deliver to the customer?	<ul style="list-style-type: none"> <li>- Self-Production (off grid or on grid) of PV-energy for improving own agriculture production</li> <li>- Shading for horticulture</li> <li>- Dual use of land for agriculture and clean energy production</li> <li>- Reduced electricity costs</li> <li>- Solar PV for water savings and resources efficiency</li> </ul>	<ul style="list-style-type: none"> <li>- Production (on grid) of PV-energy for agri-food processes</li> <li>- Shading for horticulture</li> <li>- Dual use of land for agriculture and clean energy production</li> <li>- Reduced electricity costs</li> <li>- Solar PV for water savings and resources efficiency</li> </ul>	<ul style="list-style-type: none"> <li>- Agri-ESCo model for turnkey Agri-PV solutions</li> <li>- Self-Production (on grid) of PV-energy for energy-intensive agri-food processes</li> <li>- Highly efficient agri-food production</li> <li>- Shading for horticulture</li> <li>- Dual use of land for agriculture and clean energy production</li> <li>- Reduced electricity costs</li> <li>- Solar PV for water savings and resources efficiency</li> </ul>
<b>KEY ACTIVITIES</b> What are the main activities of your business?	<ul style="list-style-type: none"> <li>- Crop cultivation</li> <li>- Energy production</li> <li>- Water irrigation and fertilizer practices</li> <li>- Post-harvest processing (optional)</li> <li>- Sales of extra-electricity production to external off-takers (optional)</li> </ul>	<ul style="list-style-type: none"> <li>- Crop cultivation</li> <li>- Energy production</li> <li>- Water irrigation and fertilizer practices</li> <li>- Post-harvest processing (optional)</li> </ul>	<ul style="list-style-type: none"> <li>- Crop cultivation</li> <li>- Energy production</li> <li>- Precision irrigation systems (including but not limited to water irrigation and fertilizer practices)</li> <li>- Energy-intensive post-harvest processing</li> </ul>
<b>KEY RESOURCES</b> What are the resources used to operate the business?	<p><b>Asset:</b></p> <ul style="list-style-type: none"> <li>- solar-PV plant with mounting structure</li> <li>- water irrigation/fertilizer systems</li> <li>- post-harvest processing facilities (optional)</li> <li>- electrical (or not) vehicles for crop cultivation (optional)</li> <li>- cultivation lands</li> </ul> <p><b>Personnel:</b></p> <ul style="list-style-type: none"> <li>- ordinary maintenance workers</li> <li>- outsourced plant monitoring &amp; control + extra ordinary maintenance</li> <li>- land workers, sales agents, managers, administrative officers, external agronomic expert</li> </ul>	<p><b>Asset:</b></p> <ul style="list-style-type: none"> <li>- solar-PV plant with mounting structure</li> <li>- water irrigation/fertilizer systems</li> <li>- post-harvest processing facilities (optional)</li> <li>- electrical (or not) vehicles for crop cultivation (optional)</li> <li>- cultivation lands</li> </ul> <p><b>Personnel:</b></p> <ul style="list-style-type: none"> <li>- ordinary and extraordinary maintenance managed by IPP O&amp;M procedures (e.g., internal or external O&amp;M)</li> <li>- land workers, sales agents, managers, administrative officers, external agronomic expert</li> </ul>	<p><b>Asset:</b></p> <ul style="list-style-type: none"> <li>- solar-PV plant with mounting structure</li> <li>- energy-intensive post-harvest processing facilities</li> <li>- precision irrigation systems (including but not limited to water irrigation/fertilizer systems)</li> <li>- electrical (or not) vehicles for crop cultivation (optional)</li> <li>- cultivation lands</li> </ul> <p><b>Personnel:</b></p> <ul style="list-style-type: none"> <li>- ordinary and extraordinary maintenance managed by Agri-ESCo O&amp;M procedures (e.g., internal, or external O&amp;M)</li> <li>- land workers, sales agents, managers, administrative officers, external agronomic expert</li> </ul>
<b>KEY PARTNERS</b> Who are the important actors for this business?	<ul style="list-style-type: none"> <li>- Solar technologies providers</li> <li>- Agri-tech technologies providers (vehicles, irrigation systems, etc.)</li> <li>- Financing entities</li> <li>- Technical Assistance: agronomic expert</li> <li>- Technical Assistance: PV monitoring &amp; control + extra ordinary maintenance</li> </ul>	<ul style="list-style-type: none"> <li>- Solar technologies providers</li> <li>- Agri-tech technologies providers (vehicles, irrigation systems, etc.)</li> <li>- Financing entities</li> <li>- Insurance companies (depending on the country)</li> <li>- Technical Assistance: agronomic expert</li> <li>- O&amp;M provider (only in case of external O&amp;M)</li> </ul>	<ul style="list-style-type: none"> <li>- Solar technologies providers</li> <li>- Agri-tech technologies providers (vehicles, irrigation systems, processing equipment, etc.)</li> <li>- Financing entities</li> <li>- Insurance companies (depending on the country)</li> <li>- Technical Assistance: agronomic expert</li> <li>- O&amp;M provider (only in case of external O&amp;M)</li> </ul>

<sup>1</sup> Building blocks identified in the Business Model Canvas by Osterwalder, Alexander; Pigneur, Yves; Clark, Tim, Business Model Generation: A Handbook For Visionaries, Game Changers, and Challengers. Strategyzer series, 2010.

<sup>2</sup> S. Bhandari, Economic Feasibility of Agrivoltaic Systems in Food-Energy Nexus Context: Modelling and a Case Study in Niger, 2021.

<b>CUSTOMER SEGMENTS</b> What are the different types of customers you have?	<ul style="list-style-type: none"> <li>- Final consumers (retail market)</li> <li>- Warehousing– (only in case of large farms)</li> <li>- Modern food retailers (restaurant and supermarket) – (only in case of large farms)</li> <li>- Agri-produce dealers</li> <li>- Agri- Produce Aggregators</li> <li>- Agri-food processing factories</li> <li>- National utility (only in case of on-grid PPA)</li> <li>- External electricity off-takers (only in off-grid case)</li> </ul>	<ul style="list-style-type: none"> <li>- Final consumers (retail market)</li> <li>- Warehousing– (only in case of large farms)</li> <li>- Modern food retailers (restaurant and supermarket) – (only in case of large farms)</li> <li>- Agri-produce dealers</li> <li>- Agri- Produce Aggregators</li> <li>- Agri-food processing factories</li> <li>- National utility</li> </ul>	<ul style="list-style-type: none"> <li>- Final consumers (retail market)</li> <li>- Warehousing– (only in case of large farms)</li> <li>- Modern food retailers (restaurant and supermarket) – (only in case of large farms)</li> <li>- Agri-produce dealers</li> <li>- Agri- Produce Aggregators</li> <li>- Agri-food processing factories</li> <li>- National utility</li> </ul>
<b>CUSTOMER RELATIONSHIPS</b> What do you do to retain and satisfy your customers?	<ul style="list-style-type: none"> <li>- Personal assistance 24/7</li> <li>- Daily price negotiation of agri-food products</li> <li>- Loyalty bonus</li> <li>- Electricity supply for external off-takers (only in off-grid case)</li> <li>- No specific activities for PPA management</li> </ul>	<ul style="list-style-type: none"> <li>- Personal assistance 24/7</li> <li>- Daily price negotiation of agri-food products</li> <li>- Loyalty bonus</li> <li>- No specific activities for PPA management</li> </ul>	<ul style="list-style-type: none"> <li>- Personal assistance 24/7</li> <li>- Daily price negotiation of agri-food products</li> <li>- Loyalty bonus</li> <li>- No specific activities for PPA management</li> </ul>
<b>CHANNELS</b> What supply and sales channels do your services or products have?	<ul style="list-style-type: none"> <li>- Direct sales channels</li> </ul>	<ul style="list-style-type: none"> <li>- Direct sales channels</li> </ul>	<ul style="list-style-type: none"> <li>- Direct sales channels</li> </ul>
<b>COST STRUCTURE</b> What are the main costs associated with your business?	<i>Initial amount invested to start the business</i> (cost based on real cases, around 100 kW, 0.15 ha): <ul style="list-style-type: none"> <li>- CAPEX: 2250 €/kW</li> <li>- OPEX: 97 €/kW per year</li> </ul>	<i>Initial amount invested to start the business</i> (cost based on real cases, around 1MW PV, 2 ha land size <sup>3</sup> ): <ul style="list-style-type: none"> <li>- CAPEX: 1294 €/kWp<sup>4</sup></li> <li>- OPEX: 16 €/kWp per year</li> </ul>	<i>Initial amount invested to start the business</i> (5 MW PV, 200 ha land size): <ul style="list-style-type: none"> <li>- CAPEX: 7,495,804 €</li> <li>- OPEX: 53,848 €/year</li> </ul>
<b>REVENUES STREAMS</b> What are the main products or services that make the most money in this business?	<i>Revenues from customer segments:</i> <ul style="list-style-type: none"> <li>- Sale of crop products</li> <li>- Sale of electricity to the national utility (only in case of on-grid PPA)</li> <li>- Sale of electricity to external off-takers (only in off-grid case)</li> </ul> <i>Cashflow between Agri-player &amp; Energy-player:</i> <ul style="list-style-type: none"> <li>- Absent (Energy-player is a pure technology/service provider)</li> </ul>	<i>Revenues from customer segments:</i> <ul style="list-style-type: none"> <li>- Sale of crop products</li> <li>- Sale of electricity to the national utility</li> </ul> <i>Cashflow between Agri-player &amp; Energy-player:</i> <ul style="list-style-type: none"> <li>- Land lease fee is optional (see justification in the BM description)</li> </ul>	<i>Revenues from customer segments:</i> <ul style="list-style-type: none"> <li>- Sale of crop products</li> <li>- Sale of electricity to the national utility</li> </ul> <i>Cashflow between Agri-player &amp; Energy-player:</i> <ul style="list-style-type: none"> <li>- No land lease fee</li> <li>- Agri-Energy Services bill paid by Agri-player to Energy-player</li> </ul>

<sup>3</sup> S. Bolwig et al., Designing a sustainable business model for automated solar-PV drip irrigation for smallholders in Ghana, 2020.

<sup>4</sup> S. Schindele, Implementation of agrophotovoltaics: Techno-economic analysis of the price-performance ratio and its policy implications, 2020.

## Business Model Canvas matrix – PRECISION IRRIGATION

BM Blocks <sup>5</sup>	BM1 – Ownership to Farmers	BM2 – Ownership to Agri-Produce Aggregator	BM3 – Ownership to Technology Provider: precision irrigation as a Service
<b>VALUE PROPOSITION</b> What value do you deliver to the customer?	<ul style="list-style-type: none"> <li>- Adoption of highly efficient irrigation technology</li> <li>- Improved productivity</li> <li>- Improved farmers income</li> <li>- Efficient exploitation of natural resources (lands and water)</li> </ul>	<ul style="list-style-type: none"> <li>- Adoption of highly efficient irrigation technology</li> <li>- Improved productivity</li> <li>- Efficient exploitation of natural resources (lands and water)</li> </ul>	<ul style="list-style-type: none"> <li>- Adoption of highly efficient irrigation technology</li> <li>- Improved productivity</li> <li>- Efficient exploitation of natural resources (lands and water)</li> <li>- Turning irrigation from Capex to Opex</li> <li>- Turnkey expert irrigation service for the maximum exploitation of advanced agri-technologies</li> </ul>
<b>KEY ACTIVITIES</b> What are the main activities of your business?	<ul style="list-style-type: none"> <li>- Water pumping</li> <li>- Drip irrigation</li> <li>- Fertilizers application</li> <li>- Expert monitoring and control</li> </ul>	<ul style="list-style-type: none"> <li>- Water pumping</li> <li>- Drip irrigation</li> <li>- Fertilizers application</li> <li>- Expert monitoring and control</li> </ul>	<ul style="list-style-type: none"> <li>- Water pumping</li> <li>- Drip irrigation</li> <li>- Fertilizers application</li> <li>- Expert monitoring and control</li> </ul>
<b>KEY RESOURCES</b> What are the resources used to operate the business?	<p><b>Asset:</b></p> <ul style="list-style-type: none"> <li>- solar PV plant with battery storage</li> <li>- water pumping</li> <li>- drip irrigation/fertilizers distribution systems</li> <li>- cultivation lands</li> <li>- office spaces</li> </ul> <p><b>Personnel:</b></p> <ul style="list-style-type: none"> <li>- O&amp;M manager, maintenance workers</li> </ul>	<p><b>Asset:</b></p> <ul style="list-style-type: none"> <li>- solar PV plant with battery storage</li> <li>- water pumping</li> <li>- drip irrigation/fertilizers distribution systems</li> <li>- cultivation lands</li> <li>- office spaces</li> </ul> <p><b>Personnel:</b></p> <ul style="list-style-type: none"> <li>- O&amp;M manager, maintenance workers</li> </ul>	<p><b>Asset:</b></p> <ul style="list-style-type: none"> <li>- solar PV plant with battery storage</li> <li>- water pumping</li> <li>- drip irrigation/fertilizers distribution systems</li> <li>- cultivation lands</li> <li>- office spaces</li> </ul> <p><b>Personnel:</b></p> <ul style="list-style-type: none"> <li>- O&amp;M manager, maintenance workers, agronomic experts</li> </ul>
<b>KEY PARTNERS</b> Who are the important actors for this business?	<ul style="list-style-type: none"> <li>- Solar technologies suppliers</li> <li>- Irrigation/fertilizers kit suppliers</li> <li>- Financing entities, including MFIs</li> <li>- Agronomic expert</li> </ul>	<ul style="list-style-type: none"> <li>- Solar technologies suppliers</li> <li>- Irrigation/fertilizers kit suppliers</li> <li>- Financing entities</li> <li>- Insurance companies</li> <li>- Agronomic expert</li> </ul>	<ul style="list-style-type: none"> <li>- Solar technologies suppliers</li> <li>- Insurance companies</li> <li>- Financing entities</li> </ul>
<b>CUSTOMER SEGMENTS</b> What are the different types of customers you have?	<ul style="list-style-type: none"> <li>- Final consumers (retail market)</li> <li>- Warehousing– (only in case of large farms)</li> <li>- Modern food retailers (restaurant and supermarket) – (only in case of large farms)</li> <li>- Agri-produce dealers</li> <li>- Agri-Produce Aggregators</li> <li>- Agri-food processing factories</li> </ul>	<ul style="list-style-type: none"> <li>- Warehousing</li> <li>- Modern food retailers (restaurant and supermarket)</li> <li>- Agri-produce dealers</li> <li>- Agri-food processing factories</li> </ul>	<ul style="list-style-type: none"> <li>- Warehousing</li> <li>- Modern food retailers (restaurant and supermarket)</li> <li>- Agri-produce dealers</li> <li>- Agri-food processing factories</li> </ul>
<b>CUSTOMER RELATIONSHIPS</b> What do you do to retain and satisfy your customers?	<ul style="list-style-type: none"> <li>- Personal relation</li> <li>- Daily price negotiation of agri-food products</li> </ul>	<ul style="list-style-type: none"> <li>- Personal assistance 24/7</li> <li>- Daily price negotiation of agri-food products</li> <li>- Loyalty bonus</li> </ul>	<ul style="list-style-type: none"> <li>- Personal assistance 24/7</li> <li>- Daily price negotiation of agri-food products</li> <li>- Loyalty bonus</li> </ul>
<b>CHANNELS</b> What supply and sales channels do your services or products have?	<ul style="list-style-type: none"> <li>- Direct sales channels</li> </ul>	<ul style="list-style-type: none"> <li>- Direct sales channels</li> </ul>	<ul style="list-style-type: none"> <li>- Direct sales channels</li> </ul>

<sup>5</sup> Building blocks identified in the Business Model Canvas by Osterwalder, Alexander; Pigneur, Yves; Clark, Tim (2010). Business Model Generation: A Handbook For Visionaries, Game Changers, and Challengers. *Strategyzer series*. Hoboken, NJ: John Wiley & Sons. ISBN 9780470876411. OCLC 648031756.

<b>COST STRUCTURE</b> What are the main costs associated with your business?	<i>Initial amount invested to start the business</i> - (cost based on real cases, 500m <sup>2</sup> cultivated area <sup>6</sup> ): - CAPEX: 464 \$ (material) - Installation costs: 53 \$ - OPEX: 42 \$ per year	<i>Initial amount invested to start the business</i> - (cost based on real cases; 202 ha cultivated area <sup>7</sup> ): - CAPEX: 22.000 \$/ha - OPEX: 32.500 \$ (per 15 Years)	<i>Initial amount invested to start the business</i> - (200 ha cultivated area): - CAPEX: 2,530,979 € - OPEX: 40,812 €/year
<b>REVENUES STREAMS</b> What are the main products or services that make the most money in this business?	<i>Revenues from customer segments:</i> - Gross Income: 304 \$ - Net Farm income: 217 \$ - Gross margin: 265 \$ <i>Cashflow between Agri-player &amp; Tech-Provider:</i> - Absent (tech-provider is a pure technology/service provider)	<i>Revenues from customer segments:</i> - Data not available <i>Cashflow between Agri-player &amp; Tech-Provider:</i> - Absent (tech-provider is a pure technology/service provider)	<i>Revenues from customer segments:</i> - Data not available <i>Cashflow between Agri-player &amp; Tech-Provider:</i> - Monthly fee for the precision irrigation service

## Business Model Canvas matrix – COLD STORAGE

BM Blocks <sup>8</sup>	BM1 - Cold Chain Logistic Services	BM2 - Pay-As-You-Go Cold Storage Services	BM3 - Pay-As-You-Go Cold Chain Services (cutting-edge BM for Research and Innovation)
<b>VALUE PROPOSITION</b> What value do you deliver to the customer?	<ul style="list-style-type: none"> <li>- Integrated cold chain logistic services</li> <li>- Connecting producers (associations, aggregators) with the selling markets</li> <li>- High-quality produce by means of a full cold chain control</li> <li>- Highly energy efficient renewable energy integration</li> </ul>	<ul style="list-style-type: none"> <li>- Flexible pay-as-you-go cold storage services</li> <li>- Plug and play modular, solar-powered walk-in cold room</li> <li>- 24/7 off-grid storage and preservation of perishable foods</li> <li>- Extending shelf life of perishable food</li> <li>- Highly energy efficient renewable energy integration</li> </ul>	<ul style="list-style-type: none"> <li>- Integrated cold chain services</li> <li>- Connecting small/medium producers (farmers, farmer associations) with the selling markets</li> <li>- Flexible pay-as-you-go cold storage services</li> <li>- Plug and play modular, solar-powered walk-in cold room</li> <li>- 24/7 off-grid storage and preservation of perishable foods</li> <li>- Extending shelf life of perishable food</li> <li>- Highly energy efficient renewable energy integration</li> </ul>
<b>KEY ACTIVITIES</b> What are the main activities of your business?	<ul style="list-style-type: none"> <li>- Temperature-controlled storage</li> <li>- Refrigerated storage</li> <li>- Freezer storage</li> <li>- Labelling and packaging</li> <li>- Supply chain management</li> <li>- Expert support for quality control and certifications</li> </ul>	<ul style="list-style-type: none"> <li>- Temperature-controlled storage</li> <li>- Refrigerated storage</li> </ul>	<ul style="list-style-type: none"> <li>- Temperature-controlled storage</li> <li>- Refrigerated storage</li> <li>- Supply chain management</li> <li>- Brokerage through the digital market linkage platform</li> </ul>
<b>KEY RESOURCES</b> What are the resources used to operate the business?	<p><i>Asset:</i></p> <ul style="list-style-type: none"> <li>- infrastructure of at least 3 large cold hubs</li> <li>- labelling and packaging facilities</li> <li>- office spaces</li> <li>- transports in outsourcing</li> </ul> <p><i>Personnel:</i></p> <ul style="list-style-type: none"> <li>- executive managers, administrative officers, sales managers, logicians, maintenance workers</li> </ul>	<p><i>Asset:</i></p> <ul style="list-style-type: none"> <li>- infrastructure of at least 10 small cold hubs</li> <li>- transport: none (no key resource)</li> </ul> <p><i>Personnel:</i></p> <ul style="list-style-type: none"> <li>- executive managers, administrative officers, field managers, maintenance workers</li> </ul>	<p><i>Asset:</i></p> <ul style="list-style-type: none"> <li>- infrastructure of at least 10 small cold hubs</li> <li>- Transports in outsourcing</li> </ul> <p><i>Personnel:</i></p> <ul style="list-style-type: none"> <li>- executive managers, administrative officers, field managers, sales managers, field logicians, maintenance workers</li> </ul>

<sup>6</sup> S.Bolwig et al., Designing a sustainable business model for automated solar-PV drip irrigation for smallholders in Ghana, 2020.

<sup>7</sup> World Bank, Revised public irrigation PPP toolkit, 2016

<sup>8</sup> Building blocks identified in the Business Model Canvas by Osterwalder, Alexander; Pigneur, Yves; Clark, Tim, Business Model Generation: A Handbook For Visionaries, Game Changers, and Challengers. Strategyzer series, 2010..

<b>KEY PARTNERS</b> Who are the important actors for this business?	<ul style="list-style-type: none"> <li>- Transport companies</li> <li>- Import/export companies</li> <li>- Large retailers/distributors</li> </ul>	<ul style="list-style-type: none"> <li>- Micro finance institutions (to favour access to finance for customers)</li> <li>- Capacity building trainers for customers (profit or no-profit entities)</li> <li>- Agri-food dealers/aggregators</li> </ul>	<ul style="list-style-type: none"> <li>- Micro finance institutions (to favour access to finance for customers)</li> <li>- Capacity building trainers for customers (profit or no-profit entities)</li> <li>- Agri-food dealers/aggregators</li> <li>- Transport companies</li> </ul>
<b>CUSTOMER SEGMENTS</b> What are the different types of customers you have?	<ul style="list-style-type: none"> <li>- Warehousing</li> <li>- Modern food retailers (restaurant and supermarket)</li> <li>- Farmer associations</li> <li>- Agri-food aggregators</li> <li>- Processing factories</li> <li>- Pharmaceutical retailers</li> </ul>	<ul style="list-style-type: none"> <li>- Individual farmers/fishermen</li> <li>- Farmer/fishermen associations</li> <li>- Individual agri-food producers (post-harvest processing of perishable products. e.g.fruit juice, dairy products, meat slaughter)</li> <li>- Agri-food producer associations</li> </ul>	<p><i>Customers on the production side:</i></p> <ul style="list-style-type: none"> <li>- individual farmers/fishermen</li> <li>- farmer/fishermen associations</li> <li>- individual agri-food producers (post-harvest processing of perishable products. e.g.fruit juice, dairy products, meat slaughter)</li> <li>- agri-food producer associations</li> </ul> <p><i>Customers on the selling market side:</i></p> <ul style="list-style-type: none"> <li>- Warehousing</li> <li>- Modern food retailers (restaurant and supermarket)</li> <li>- Agri-food aggregators</li> <li>- Processing factories</li> </ul>
<b>CUSTOMER RELATIONSHIPS</b> What do you do to retain and satisfy your customers?	<ul style="list-style-type: none"> <li>- Customer care: 24/7 product tracking and assistance</li> <li>- Payment systems: tailored offer based on the specific context</li> </ul>	<ul style="list-style-type: none"> <li>- Personal assistance: 24/7 face-to-face assistance</li> <li>- Payment systems: daily flat fee for each stored crate</li> </ul>	<ul style="list-style-type: none"> <li>- Personal assistance: 24/7 face-to-face assistance for food storage</li> <li>- Personal assistance: 24/7 face-to-face assistance for food sales</li> <li>- Payment systems: daily flat fee for each stored crate</li> </ul>
<b>CHANNELS</b> What supply and sales channels do your services or products have?	<ul style="list-style-type: none"> <li>- Directly operate Cold Chain logistics assets</li> <li>- License Cold Chain logistics assets to third party</li> </ul>	<ul style="list-style-type: none"> <li>- Directly operate Cold Hubs</li> <li>- License Cold Hubs to third party</li> </ul>	<ul style="list-style-type: none"> <li>- Directly operate Cold Hubs</li> <li>- License Cold Hubs to third party</li> <li>- Digital market linkage platform</li> </ul>
<b>COST STRUCTURE</b> What are the main costs associated with your business?	<p><i>Initial amount invested to start the business</i></p> <p>CAPEX:</p> <ul style="list-style-type: none"> <li>- asset construction (cold hubs, labelling and packaging facilities)</li> <li>- training and job-shadowing of personnel</li> <li>- marketing and awareness campaigns</li> <li>- legal and authorization procedures</li> <li>- establishment of a reliable logistic network</li> </ul> <p>OPEX:</p> <ul style="list-style-type: none"> <li>- central executive management and administration</li> <li>- central sales department</li> <li>- logistic officers</li> <li>- asset maintenance</li> </ul>	<p><i>Initial amount invested to start the business</i></p> <p>CAPEX:</p> <ul style="list-style-type: none"> <li>- asset construction (cold hubs+office)</li> <li>- training and job-shadowing of personnel</li> <li>- marketing and awareness campaigns</li> <li>- legal and authorization procedures</li> </ul> <p>OPEX:</p> <ul style="list-style-type: none"> <li>- central executive management and administration</li> <li>- field management</li> <li>- asset maintenance</li> </ul>	<p><i>Initial amount invested to start the business</i></p> <p>CAPEX:</p> <ul style="list-style-type: none"> <li>- asset construction (cold hubs+office)</li> <li>- training and job-shadowing of personnel</li> <li>- marketing and awareness campaigns</li> <li>- legal and authorization procedures</li> <li>- development of the digital market linkage platform</li> </ul> <p>OPEX:</p> <ul style="list-style-type: none"> <li>- central executive management and administration</li> <li>- central sales department</li> <li>- field management and logistic</li> <li>- asset maintenance</li> </ul>
<b>REVENUES STREAMS</b> What are the main products or services that make the most money in this business?	<p><i>Revenues from customer segments:</i></p> <ul style="list-style-type: none"> <li>- cold chain warehousing (bulk cold storage)</li> <li>- value added services (labelling, packaging)</li> <li>- rental of production spaces (temperature-controlled rooms)</li> <li>- documentation and administrative support (certifications, import/export docs, etc.)</li> </ul>	<p><i>Revenues from customer segments:</i></p> <ul style="list-style-type: none"> <li>- pay-as-you-go cold chain warehousing (bulk cold storage or crate storage)</li> <li>-</li> </ul>	<p><i>Revenues from the production side:</i></p> <ul style="list-style-type: none"> <li>- pay-as-you-go cold chain warehousing (bulk cold storage or crate storage)</li> </ul> <p><i>Revenues from the selling market side:</i></p> <ul style="list-style-type: none"> <li>- markup in on purchase price through the digital market linkage platform</li> </ul>



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