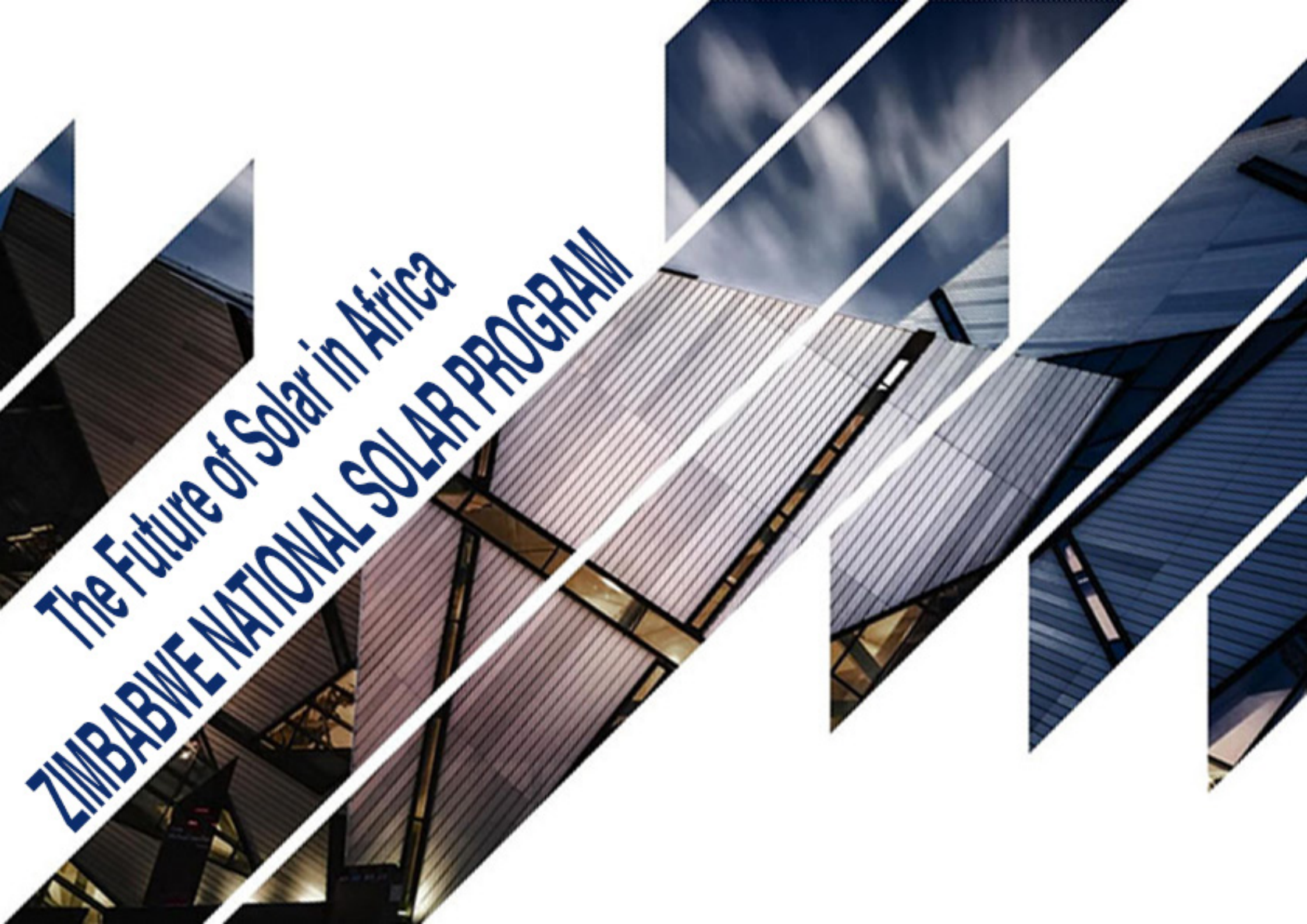




The Future of Solar in Africa
ZIMBABWE NATIONAL SOLAR PROGRAM

Introduction

According to the International Energy Agency Renewables forecast 2022-2027, renewables are seen growing by almost 2,400 GW, equal to the entire installed power capacity of China today. Renewables are the only electricity generation source whose share is expected to grow, with declining shares for coal, natural gas, nuclear and oil generation. Electricity from wind and Solar PV more than doubles in the next five years, providing almost 20% of global power generation by 2027.

Cumulative Solar PV capacity almost triples in this period, growing by almost 1,500 GW over the period, exceeding natural gas by 2026 and coal by 2027. Annual Solar PV capacity additions increase every year for the next five years. Despite current higher investment costs due to elevated commodity prices, utility-scale Solar PV is the least costly option for new electricity generation in a significant majority of countries worldwide.

THE ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP) concept was developed with the view of Zimbabwe becoming the leader in the development of Solar Power within Sub Saharan Africa. To achieve that status is not just about fundraising and delivering Solar Farms, like the **CHEMAGORA SOLAR FARM** project, which was the catalyst for the entire ZNSP concept, it requires a fully integrated infrastructure, covering every aspect, from **EDUCATION**, both at college and at university level leading to **QUALIFICATIONS**, as well as **TRAINING COURSES**, to ensure a constant pool of qualified personnel, **RESEARCH & DEVELOPMENT**, development of **AGRIVOLTAIC** and **FLOATOVOLTAIC** projects and of course the most important of all **MANUFACTURING**.



Introduction

Zimbabwe could establish a robust domestic Solar manufacturing supply chain and become a competitive leader in a global solar industry. This could lead to tremendous benefits for the climate as well as for local workers, employers, and the economy.

To achieve the goal of 100% clean electricity by 2030, solar energy would need to grow from 2% of electricity supply today to 40%, dramatically increasing demand for solar modules and components. This rapid expansion of solar energy has the potential to yield broad benefits in the form of economic activity, improved public health, and workforce development.

Key Findings

- * Developing Zimbabwe PV manufacturing could mitigate global supply chain challenges and lead to tremendous benefits for the climate as well as for local workers, employers, and the economy.
- * The Solar supply chain is global and reliant on products from China or companies with close ties to China, a country with documented human rights violations and an unpredictable trade relationship with African countries.
- * Significant growth in Zimbabwean manufacturing across the supply chain is possible with incentives that offset the higher cost of manufacturing in the Republic.
- * Existing polysilicon production facilities just do not exist in the region and expansion in the ingot and wafer sectors outside of China would create demand for potential producers to run at high capacity almost immediately.
- * Zimbabwe could begin production of thin-film or nano-paste modules, which do not rely on obtaining materials from Chinese companies.

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THE FUTURE OF SOLAR IN AFRICA

The future of Solar in Africa

With 25% of the continent of Africa dominated by desert, and large areas benefiting from as much as 5.48 kWh per m² per day of direct sunlight, the potential for Solar development on the African Continent is huge.

Home to almost 60% of Africa's population, the Eastern and Southern Africa region is geographically, culturally, and economically diverse and comprises 26 countries stretching from the Red Sea in the North to the Cape of Good Hope in the South.

The region had an estimated gross domestic product (GDP) of \$1,917,904 million with South Africa as the region's largest economy followed by Angola, Kenya, and Ethiopia.

The Eastern and Southern Africa region boasts some of the world's richest natural resources. The Democratic Republic of Congo (DRC) produces much of the world's mined cobalt, and Angola leads the region in the production of crude oil. For many East African countries, agricultural products are the main export commodities: Ethiopia and Uganda lead the region in coffee exports while Kenya is the largest tea exporter.

For countries in Southern Africa, precious metals and minerals are the biggest exports, including gold and diamonds from South Africa and platinum from Zimbabwe.

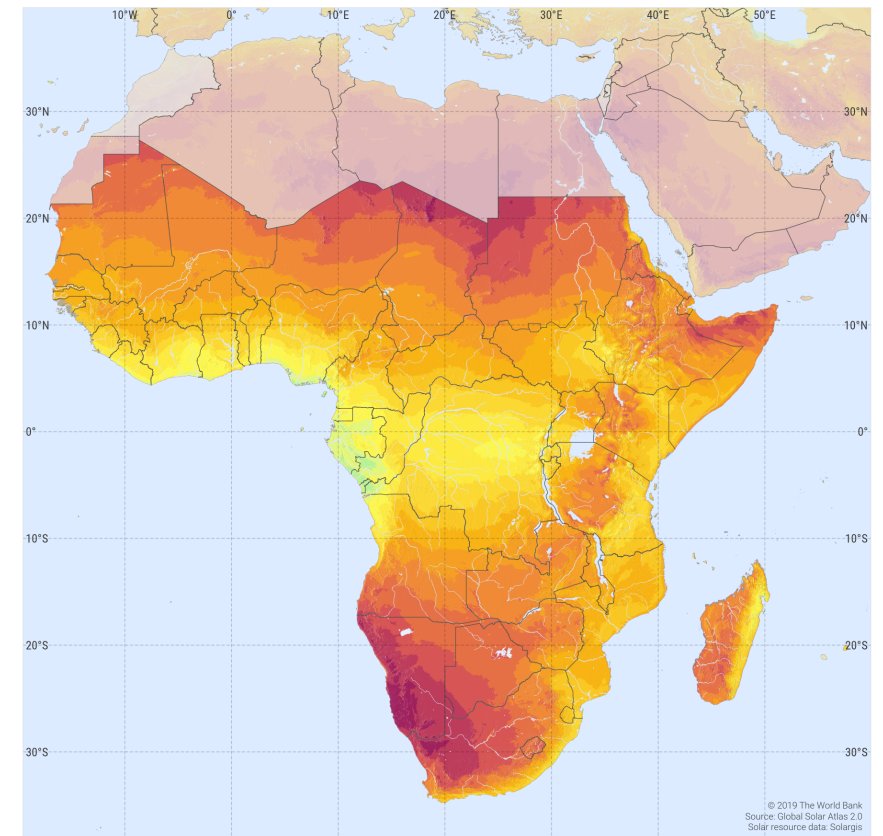
While much of Africa's population lives in rural areas, Eastern and Southern African cities continue to grow. In South Africa, nearly half of the population lives in urban areas such as Johannesburg, the country's largest city.

SOLAR RESOURCE MAP

PHOTOVOLTAIC POWER POTENTIAL SUB-SAHARAN AFRICA



ESMAP SOLARGIS



Long term average of PVOUT, period 1994-2018	
Daily totals:	3.2 3.6 4.0 4.4 4.8 5.2 5.6 kWh/kWp
Yearly totals:	1168 1314 1461 1607 1753 1899 2045

This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit <http://globalsolaratlas.info>.

The future of Solar in Africa

Africa has the world's fastest growing population: almost one-in-two people added to the global population over the next decade will be African. Combined with increasing economic activity and household incomes, this will drive up demand for energy services.

Households remain the largest final energy consumers in Africa by 2030. The number of air conditioners, fans and refrigerators more than doubles.

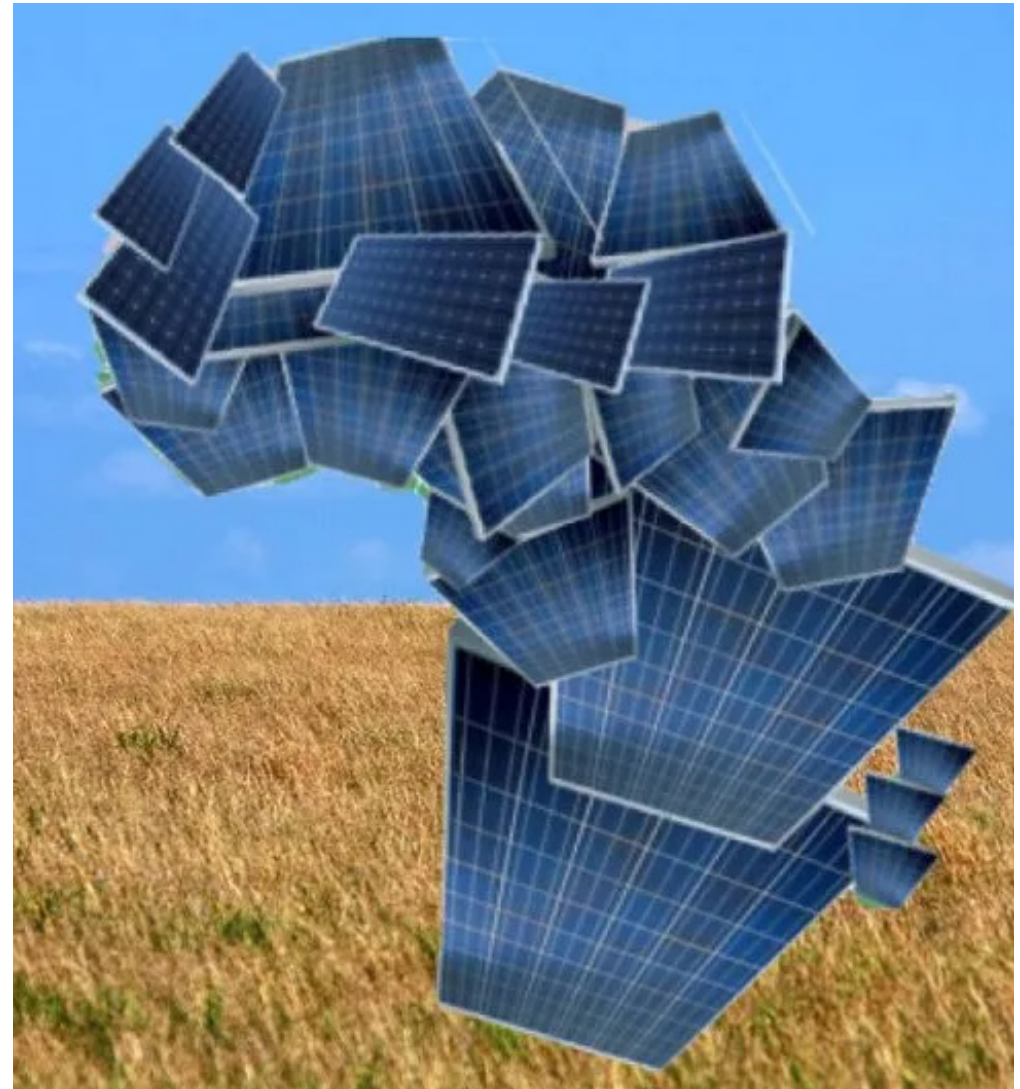
Africa's electricity demand increases by 75% in 2030. Renewables, mainly Solar PV, account for the majority of new capacity additions due to ever-declining costs driven by rapid global uptake. By 2030, Solar and Wind together provide 27% of power generation, eight-times more than today.

Among Africa's energy challenges, in the power sector, is improving reliability and integrating fourteen-times more Solar PV and Wind capacity by 2030.

Reaching universal access to electricity by 2030 requires a tripling of the current rate of progress. Today, more than three-quarters of all the people in the world that lack access to electricity and more than a third that lack access to clean cooking fuels and/or technologies are in Africa.

Most of the 600 million without electricity and the 970 million that relied on harmful fuels for cooking in 2021 were sub-Saharan Africans.

Renewables are expected to meet more than 80% of electricity capacity additions this decade, which highlights the need for renewable energy manufacturing, as well as research and development in this crucial field within the Continent.





THE FUTURE OF SOLAR IN AFRICA

**RENEWABLE ENERGY IN AFRICA IN
THE ERA OF CLIMATE CHANGE**

The future of Solar in Africa - Renewable energy in Africa in the era of climate change

Africa's contribution to greenhouse gas emissions historically has been negligible, and currently comprises less than 2 percent of the world's total.

At the same time, African countries collectively are expected to commit to reduce the continent's contribution to greenhouse gas emissions by 32 percent by 2030, through a strategy to be presented to the United Nations Framework Convention on Climate Change before COP26 in November 2021.

Unlike its contribution to emissions, the impacts of climate change on Africa have been disproportionately severe, and it is feared that the continent will carry a large share of the burden of climate change - especially if the world fails to limit further increases in average temperatures.

Factors driving demand for renewable energy sources

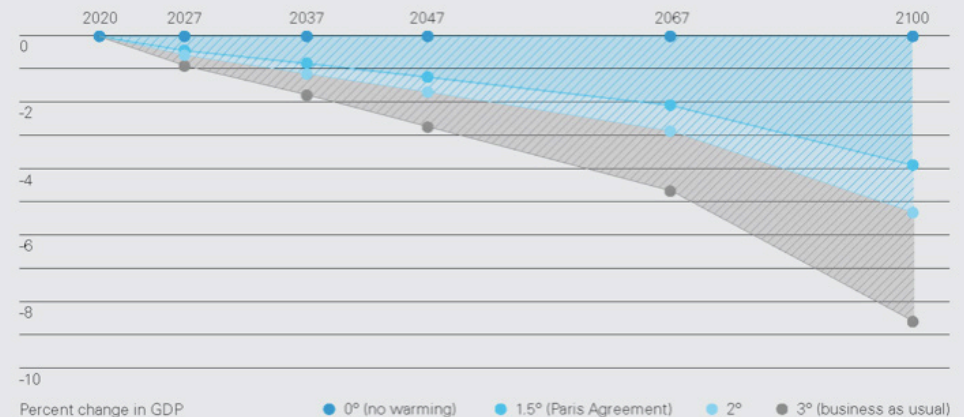
According to the Brookings Institute, climate change's impacts in Africa will likely include lowered crop yields, reduced agricultural and labor productivity, and damage to human health. An increase of three degrees Celsius (the assumption if there are no major changes in the world's social, economic and technological trends) is forecast to decrease Africa's gross domestic product (GDP) by as much as 8.6 percent per year after 2100. Limiting the increase to the 1.5 degrees Celsius specified in the Paris Agreement will do significantly less harm, decreasing GDP by only 3.8 percent per year after 2100.

Yet, Africa's energy demands are projected to triple by 2030.

“

Historically, Africa's contribution to greenhouse gas emissions has been negligible

Figure 1: The impact of climate change on sub-Saharan Africa's GDP



Source: Tom Kompas, Van Ha Pham and Tuong Nhu Che, "The Effects of Climate Change on GDP by Country and the Global Economic Gains from Complying With the Paris Climate Accord," *Earth's Future* 6, no. 8 (2018): 1153-73.

The future of Solar in Africa - Renewable energy in Africa in the era of climate change

Lack of access to electricity is only one of the challenges that Africa faces, but it is one of the most significant obstacles to socio-economic development. And transitioning from energy generated through fossil fuels to energy generated through renewable resources contains its own challenges.

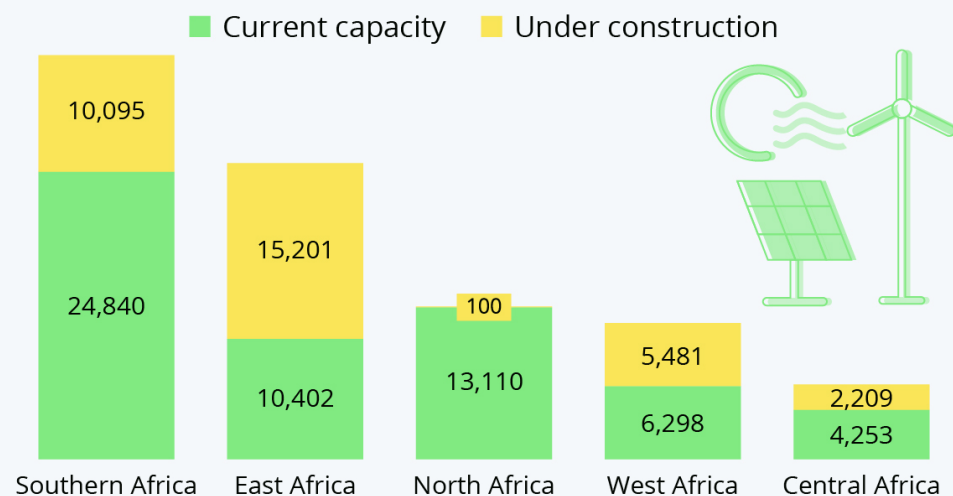
The private sector is currently the driving force behind much of the renewable energy projects in Africa. However, regulatory regimes and “ease of doing business” can make these investments difficult at times. State-owned enterprises (SOEs) lag behind the private sector, and will likely continue unless more African governments reform their SOEs and their energy sectors more generally. For instance, competitive procurement for electricity supplies could offer opportunities in renewable energy to African institutions and markets and drive down the cost of power. As an example, South Africa’s Renewable Energy Independent Power Producer Procurement (REIPPP) program and the World Bank and International Finance Corporation’s Scaling Solar Program have driven the price of solar-generated energy to as little as US\$0.05 per kilowatt-hour.

Africa currently accounts for more than one-sixth of the world’s population, but it generates only 4 percent of the world’s electricity.

Furthermore, South Africa and the countries north of the Sahara account for three-quarters of the continent’s energy consumption. Close to 600 million Africans have no access to electricity and 780 million Africans rely on traditional solid biomass (mainly fuelwood and agricultural waste) for cooking. Nearly 80 percent of those lacking access to power across sub-Saharan Africa live in rural areas.

Renewable Energy in Africa

Current/under construction capacity of African renewable energy projects in 2021, by region (in MW)



Renewables as a share of all African energy generation (2020)

9%

Source: PricewaterhouseCoopers



statista

The future of Solar in Africa - Renewable energy in Africa in the era of climate change

Options for renewable energy in Africa

With its strong supply of wind, sunshine, hydropower and even geothermal resources, Africa offers great potential for renewable energy deployment and investment.

Enhancing access to power generally across the continent is a core objective of both the African Union's Agenda 2063 and the national development plans of nearly all African nations.

Renewable energy technology has a crucial role to play in achieving these objectives.

Africa enjoys considerable opportunities to deploy renewable energy.

A study by the University of California, Berkeley, mapping out the location and energy potential of renewable energy sources in Eastern and Southern Africa shows that, although the energy generation resources are vast, they are not evenly distributed.

Some of Africa's most oil gas-rich nations are leading the way in the move to renewable energy in order to diversify their economies from overdependence on and reduce demand for oil.

“
Africa's adoption of
renewable energy
projects is
accelerating

Figure 2: Cumulative investment needs for African power generation, 2015 to 2030

Region	Investment US\$ billion (2015 –2030)			
	All generation	Large hydo	Other renewables	T&D
North Africa	342	2	218	186
West Africa	89	36	31	52
Central Africa	32	13	17	14
East Africa	72	36	21	49
Southern Africa	145	18	94	74
Total	681	106	381	375

Source: International Renewable Energy Agency (IRENA) (2015), Africa 2030: Roadmap for a Renewable Energy Future. IRENA, Abu Dhabi. www.irena.org/remap

The future of Solar in Africa - Renewable energy in Africa in the era of climate change

Investing in African renewable energy projects

Aligning with the 2030 vision to energize and “light up” Africa and the African Union’s Agenda 2063, more renewable energy sources are being actively explored.

Funders are proving less inclined to finance coal-fired power stations, driven by their own corporate governance concerns and the proven economic viability of renewable resources. Consequently, Africa’s adoption of renewable energy projects is accelerating.

The World Bank has estimated that US\$43 billion per year of investment is required for infrastructure in the power sector, while the African Development Bank estimates a need for US\$230 to US\$310 billion until 2025, with an additional US\$190 to US\$215 billion required for 2026 to 2030.

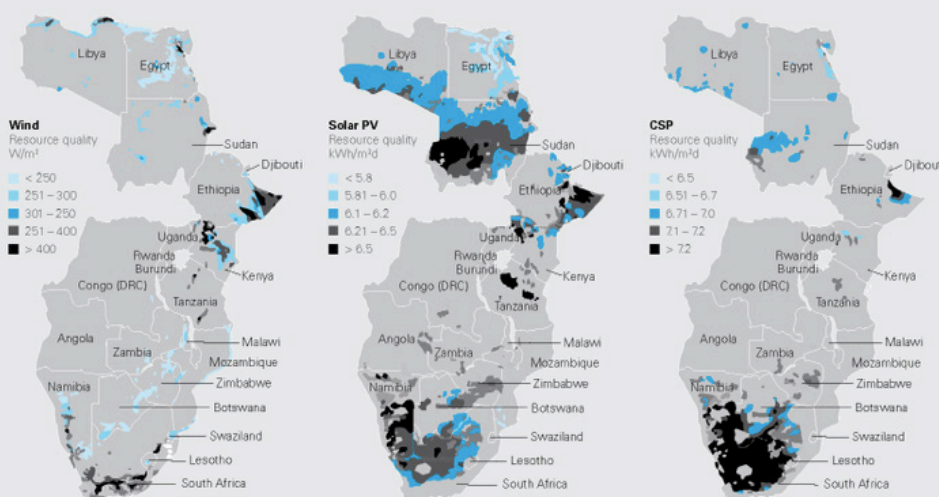
Energy is at the core of the African Development Bank’s economic transformation agenda, and the Bank committed more than US\$12 billion worth of investments to the sector between 2016 and 2020. The World Bank’s implementation of the Africa Climate Business Plan includes a plan to apply US\$16 billion toward renewable energy projects in Africa.

Over the past decade, the World Bank has financed close to US\$2.3 billion of investments in infrastructure and reforms to support the West Africa Power Pool. As recently as June 2021, it provided US\$465 million to expand energy access and renewable energy integration in West Africa.

US\$1 trillion

needed over the next 20 years to meet Africa's power demand.

Figure 3: The location and energy potential of African renewable energy resources in selected African countries (terawatt hours)



Source: UC Berkeley

The future of Solar in Africa - Renewable energy in Africa in the era of climate change

Investing in African renewable energy projects cont...

The Green Climate Fund (GCF), the world's largest climate finance fund dedicated to supporting developing countries to mitigate and adapt to climate change, is extremely active in Africa. As of July 2021, it had committed US\$3.29 billion to 70 approved projects in Africa, 52 of which are already being implemented. This constituted 37.2 percent of GCF's global portfolio.

Nevertheless, more investment is required.

Significant potential exists for investors to invest in renewable energy technologies in Angola. Angola's 2025 goal is to provide modern electricity to approximately 60 percent of its population, and the country has approximately US\$18 billion of renewable energy investments underway as part of that strategy.

The new Angolan government is taking steps to enhance the country's attractiveness for foreign direct investment, including reforming its legislative framework to attract funding from the International Monetary Fund and other multilateral investment organizations.

According to the African Development Bank Group's estimate, Angola has substantial opportunity to develop solar power and wind power, as well as huge hydropower potential: 18.2 GWs, of which currently only 20 percent is being utilized.

“
With an abundance of
solar, wind and
geothermal resources,
Africa enjoys
considerable
advantages and
opportunities for
renewable energy.”

The future of Solar in Africa - Renewable energy in Africa in the era of climate change

Investing in African renewable energy projects cont...

Morocco is another example of an African country taking active steps to enhance investment in renewable energy projects.

Morocco is liberalizing its renewables sector, including by increasing the minimum threshold for hydropower plants from 12 MWs to 30 MWs and by establishing the Moroccan Agency for Solar Energy to carry out programs for solar energy generation for up to 2,000 MWs. The country has also begun projects to amend its renewable energy law.

More relevant at this particular time, investor confidence is recovering in Zimbabwe under President Mnangagwa's administration.

Opportunities exist in many industry sectors for both developers and financiers, particularly in renewable energy, such as the Zimbabwe National Solar Program (ZNSP).

With African states recognizing their renewable energy generation capacity and taking action to implement the necessary reforms to make foreign investment possible, opportunities for investment in Africa will continue to expand.

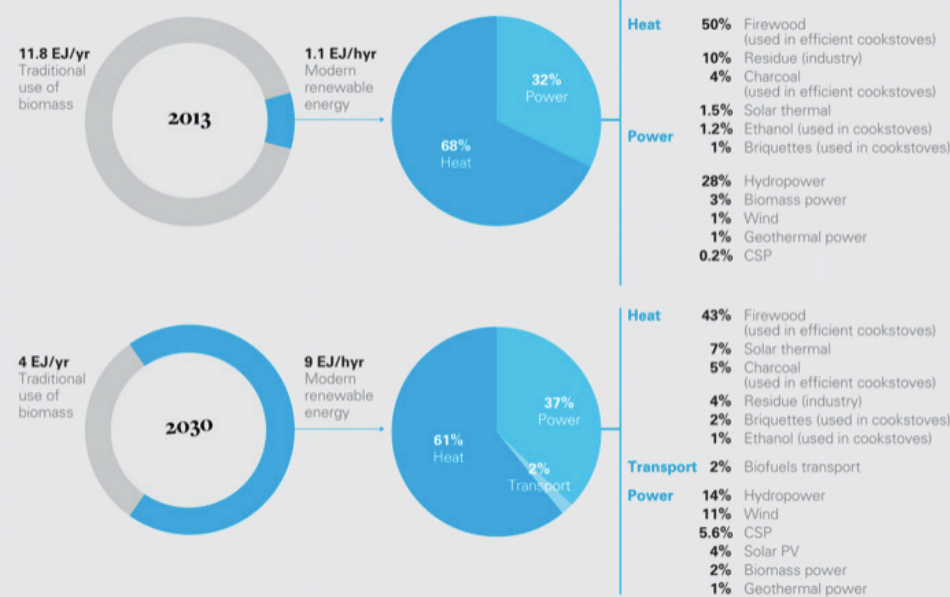
Progressive regulatory reforms, especially establishing independent power producer programs, would accelerate that momentum. Attractive investment returns coupled with steadily decreasing risk profiles suggest that Africa will continue to attract investment into its renewable energy sector in the coming years.

< 1%

Africa's share of global renewable energy investment.

Source: miningreview.com

Figure 4: Africa's use of renewables is expected to significantly displace biomass as an energy source by 2030, compared to 2013



Source: International Renewable Energy Agency (IRENA) (2015), Africa 2030: Roadmap for a Renewable Energy Future. IRENA, Abu Dhabi. www.irena.org/remap



THE FUTURE OF SOLAR IN AFRICA

AFRICA RENEWABLE ENERGY MANUFACTURING OPPORTUNITY AND ADVANCEMENT

The following report, by Sustainable Energy for All, supported by Bloomberg Philanthropies, ClimateWorks Foundation, African Climate Foundation and Chinese Renewable Energy Industries Association, has assessed the potential of renewable energy in Africa and creates a roadmap for African countries to localise manufacturing has been included, even though does not include Zimbabwe as provides crucially important insights into requirements for creating a solar manufacturing culture

The future of Solar in Africa - Africa renewable energy manufacturing opportunities

Africa's demand for power is projected to surge over the coming decades, more than two times by 2030 and eight times by 2050. This growth will be driven primarily by industrialisation as African countries push to electrify and grow their economies while decarbonizing in line with the global energy transition.

Renewables provide a potential solution to meet much of this demand growth:

Africa has almost unlimited potential for solar capacity (10 TW) and abundant hydro (350 GW), wind (110 GW), and geothermal energy sources (15 GW).

Building renewable energy capacity would bring two significant benefits:

First, it would reduce the amount of energy sourced from fossil fuels, lowering future carbon emissions; second, it would help build local manufacturing capabilities to create employment, grow economies, and develop export partnerships with other countries.

Investment in energy-transition technologies creates three times as many jobs as fossil fuels per investment dollar, and up to 14 million energy transition jobs could be created in Africa by 2030.



The future of Solar in Africa - Africa renewable energy manufacturing opportunities

Renewables are expected to play a central role in Africa's power sector development, with capacity expected to grow to 180 GW by 2030 and 1.2 TW by 2050.

This growth in renewables presents a significant opportunity for the continent to accelerate its overall economic growth, develop new local value chains, reduce the trade deficit, and create between 8 million and 14 million good-quality jobs.

The Sustainable Energy For All's 'Africa Renewable Energy Report' identified ten opportunities across eight countries with a high readiness for successfully localising renewables manufacturing.

The report analysis considered key success factors, including demand, manufacturing scale, political stability, policies and regulations, international trade relations, infrastructure, and the ability to export.

The ten stated opportunities - four in solar photovoltaics (PV) and battery materials refining, three in only solar PV assembly, and three in only battery materials refining.

The report identified ten countries ranked favorably in the analysis: Morocco, South Africa, Egypt, Ghana, Algeria, Tunisia, Nigeria, Namibia, Kenya and Tanzania, although Zimbabwe is not one of those stated, we believe that Zimbabwe could and should be the leading force on the continent.



The future of Solar in Africa - Africa renewable energy manufacturing opportunities

While Africa already has many tools and mechanisms to encourage renewables manufacturing, several gaps and barriers are working against further growth.

Several strengths—including policies (e.g., fiscal incentives, local content requirements), technical assistance, transaction facilitation, and financing, could spur further investment.

However, production factors, supply chain concerns, regulations and lack of incentives, and local market potential are holding back market investment.



The future of Solar in Africa - Africa renewable energy manufacturing opportunities

Growing power demand across Africa is driven by industrialization and urbanization, with renewables expected to become the primary power source on the continent due to economic and environmental drivers.

The shift toward renewable energy is driven by several factors. First, renewable energy is becoming more affordable—the cost of unsubsidized solar PV levelised cost of electricity (LCOE) has decreased by about 90% from \$400/MWh in 2011 to \$41/MWh in 2022.

Second, rising demand for environment-friendly energy sources has been driven by calls for reducing CO2 emissions and the depletion of fossil fuels.

Third, demand has been driven by the need for energy access: around half the population of sub-Saharan Africa has no access to electricity.

This gap in access drives the market for distributed solar generation installations, expanding access.

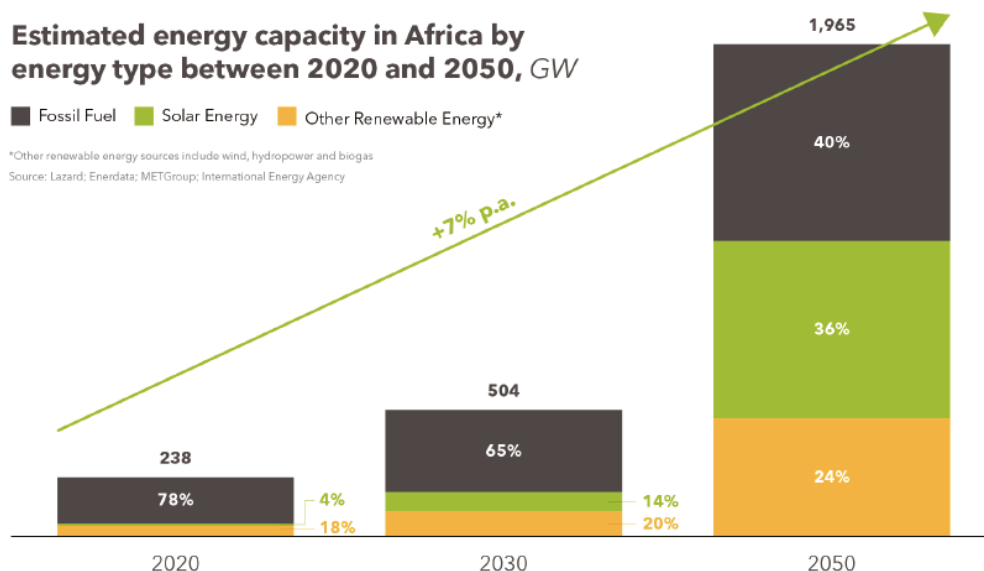


Exhibit 1
Renewables are expected to become the primary power source on the continent.

The future of Solar in Africa - Africa renewable energy manufacturing opportunities

Economic benefits of African renewables manufacturing

Renewable energy could be crucial to Africa's economic development by stimulating economic growth and job creation while improving trade balance and socioeconomic outcomes.

1) Economic growth: On average, Africa could experience a ~6.4% increase in GDP between 2021 and 2050 that is directly attributable to the energy transition. Economic growth is expected to be driven by public investment and expenditure; private investment in energy transition technologies; and net trade differences. Key sectors likely to benefit from this transition include electricity supply-or underserved and low-income areas-public and personal services, basic manufacturing, and business services.

2) Job creation: Investment in energy transition technologies creates three times as many jobs as fossil fuels per \$1Million invested. Through 2030, between 8 million and 14 million energy transition jobs could be created in Africa, potentially driven by government spending on public services and investment in transition technologies. Beyond 2030, job creation is estimated to be driven by induced and indirect efforts through increased spending by low-income households. Transitions to clean cooking and electric vehicles will further drive job creation as demand-and its associate supply needs-will drive additional labour opportunities.

3) Trade balance: Renewable energy generation could improve Africa's trade balance by lowering spending on fossil fuel imports, which has resulted in negative trade balances for many African countries. Africa is uniquely positioned as a net exporter of crude oil but a net importer of petroleum products, with sub-Saharan Africa's fuel imports equivalent to around 2% of GDP¹⁰. Homegrown energy sources would offer protection from external shocks and sharp price movements, such as the oil price surge in the first half of 2022. Furthermore, if African countries can build manufacturing capabilities, they could also export the renewable energy components to other countries, creating further positive trade flows.

4) Socio-economic outcomes: Renewable energy could play a significant role in closing Africa's energy-access gap and meeting United Nations Sustainable Development Goal 7 (SDG 7) to ensure universal access to energy. Currently, around 60 million people in Africa have electricity access through off-grid solutions, with fifteen countries having electrification plans incorporating distributed renewables. Energy access would promote agricultural productivity, modern health services and education, and industrial development.

The future of Solar in Africa - Africa renewable energy manufacturing opportunities

China's role in Africa's energy transition

China leads the manufacture of renewable energy products. It produces the vast majority of the solar PV supply chain and battery cells; it also globally leads in material processing (e.g., lithium, nickel, cobalt) for critical elements of EV battery production (Exhibit 2).

In addition to being the world's principal manufacturer of renewable energy components, China has also emerged as Africa's largest economic partner, with no other country ranking in the top five for trade, foreign direct investment (FDI) stock, FDI growth, infrastructure financing, and aid. China's leadership extends to renewables development, and solar PV in particular; it garnered 55% share in the supply market for PV modules and 19% in engineering, procurement, and construction (EPC)

Due to its strength in renewables and existing trade ties, China's prominent competitive players and companies are the highest potential partners in scaling up manufacturing in Africa.

However, the most advanced photovoltaics development is not Chinese, in fact it is Europe that leads the development of new photovoltaic innovations, followed by North America, as such it is advisable in our view European and American technology, as well as manufacturing partnering, should also be considered.

Geographic distribution of renewable products supply chain, %

Source: International Energy Agency

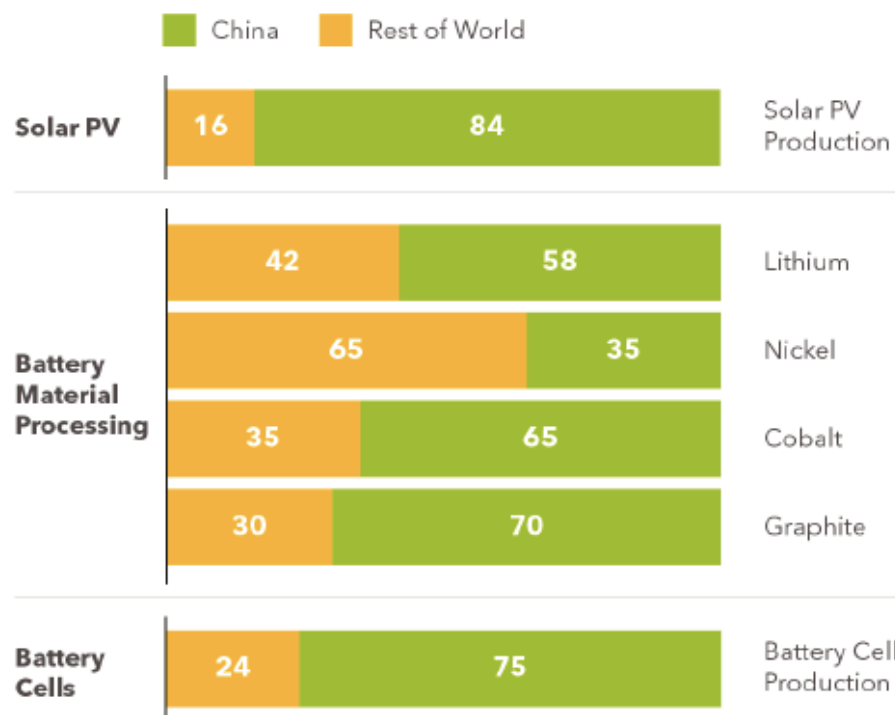


Exhibit 2

China leads the manufacture of renewable energy products globally.

The future of Solar in Africa - Africa renewable energy manufacturing opportunities

Trends affecting China's interest in manufacturing renewable energy products in Africa

Further Chinese investment in the African market for renewable energy products presents an opportunity for mutually beneficial growth for both China and Africa. Several tailwinds and headwinds can aid—or hinder—the potential for China to manufacture renewable energy products in Africa.

There are four significant tailwinds:

- 1) Increasing usage of renewable energy:** Demand for renewable energy is increasing. This demand growth is happening both at utility scale—driven by the acceleration of large-scale investments in renewable technologies—and at the micro scale—driven by improved economics for distributed renewable energy. This trend is further amplified by an increasing aspiration by countries to reduce dependency on grid infrastructure to solve energy-access challenges.
- 2) Africa's push for industrialization and localized manufacturing:** Calls are increasing to localize processes along the manufacturing value chain as recent events such as the COVID-19 pandemic have exposed the overreliance of African countries on global supply chains. The African Development Bank has launched Industrialize Africa to support industrialization and manufacturing efforts. The organization approved \$300Mn in financing for these efforts.
- 3) Africa is resource rich in several raw materials critical for renewable energy products:** The continent has high availability of raw materials with large reserves of inputs such as cobalt, manganese, and lithium. These resources provide an attractive option for companies looking to install renewables manufacturing facilities closer to resource supply chains.
- 4) Evolving geopolitical dynamics:** A favorable relationship is developing between Africa and China. Trade between Africa and China was valued at around \$192Bn in 2019 and China is Africa's leading individual trade partner, with about 14% of total trade.

However, there are also several headwinds. **First, insufficient enabling policies in Africa discourages investment.** China's competitive advantage in producing renewables components includes supportive governmental policies and the ready availability of labour and raw materials. At the same time, many African countries are hamstrung by a lack of action-oriented government policies; manufacturers cite a lack of governmental support that would otherwise encourage innovative and high-value manufacturing investment.

cont...

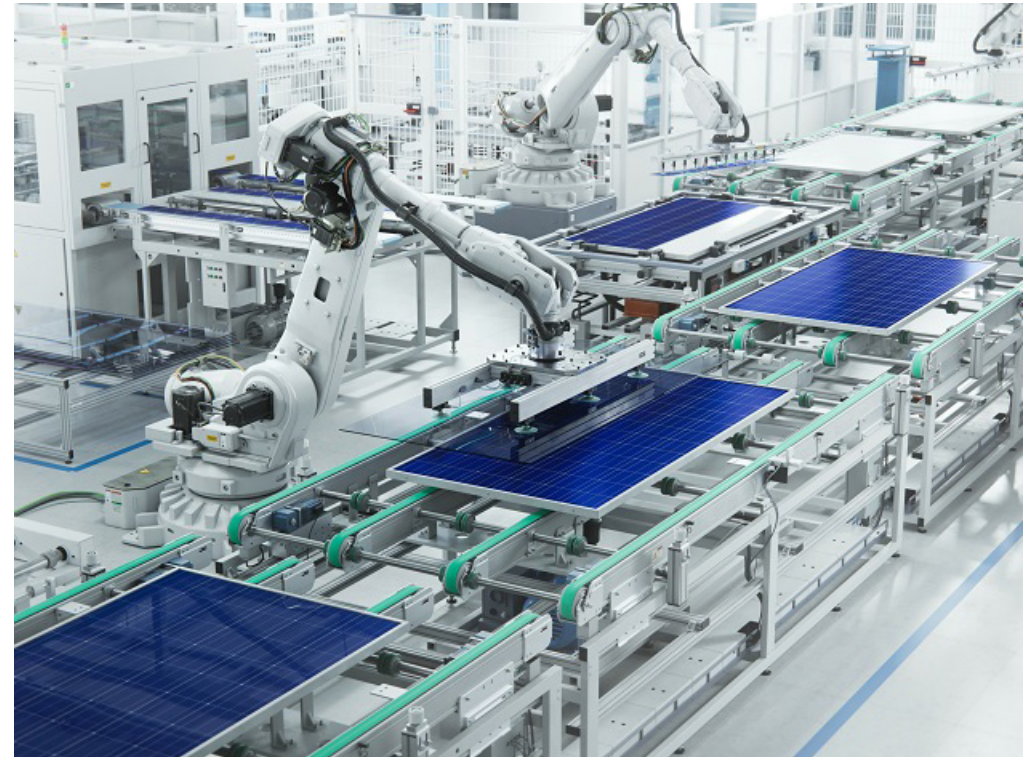
The future of Solar in Africa - Africa renewable energy manufacturing opportunities

Trends affecting China's interest in manufacturing renewable energy products in Africa cont...

Second, Africa has a complex business environment, including high initial costs for setting up renewable energy production plants. Furthermore, renewable energy systems and products attract taxes and tariffs across many African countries, resulting in higher costs.

Third, there is a lack of legal frameworks and policies that promote renewable energy development and the substitution of fossil fuels. Many African countries still subsidise fossil fuels in various ways, providing fossil fuel providers with economic advantages that are not available to renewable energy providers and manufacturers.

Finally, some countries have insufficient power and limited grid development, which may hinder the scale-up of renewable energy solutions. For example, solar energy PV production requires significant energy inputs, which may not be readily available in parts of the continent.



The future of Solar in Africa - Africa renewable energy manufacturing opportunities

The Africa Renewable Energy Report assessed 14 African countries on their feasibility of manufacturing renewable energy products.

This assessment spanned several categories that are critical for success in the sector:

Renewables demand: to guarantee seamless access to market and offtake of installed capacity

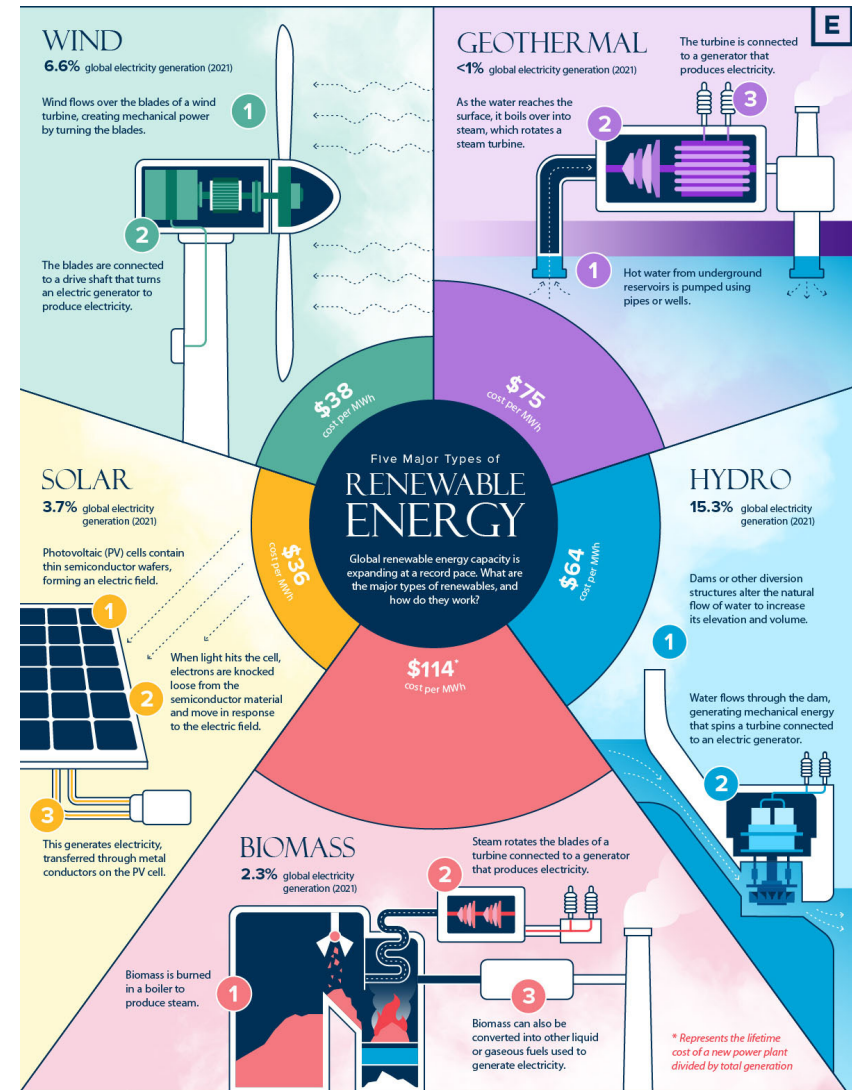
Manufacturing maturity: to determine the level of readiness to scale renewables manufacturing in each country

Political stability: enabling policies and regulations to determine the suitability of the business climate

Trade relations with China: enabling infrastructure to determine that necessary production factors are in place to manufacture energy-intensive products and transport them adequately

Ability to export: to determine the country's ability to act as a distribution hub for renewable products within the continent.

Ten countries were identified with medium or high feasibility and are listed on the following pages.



The future of Solar in Africa - Africa renewable energy manufacturing opportunities

- 1 Morocco (7/7).** Morocco has the fourth-highest projected solar energy demand in 2030. The North African country's manufacturing GDP is fifth on our shortlist. Its policies and infrastructure are suited to renewable energy manufacturing and exporting, with its infrastructure scoring second best in our shortlist overall. It also has significant ties to China, with \$6.9Bn in imports in 2021.
- 2 South Africa (6.5/7).** South Africa ranks first on our shortlist in three categories: projected solar energy demand in 2030, imports from China, and merchandise exports (excluding oil and gas). It is third on our list for manufacturing GDP, at \$5Bn in 2021. The country has enabling policies in place for renewable energy and manufacturing.
- 3 Egypt (6/7).** Egypt ranks first on our list for manufacturing GDP, third for its imports from China, and fifth in projected solar energy demand in 2030. It has specific laws for renewable energy and manufacturing and is one of the largest exporters in Africa (excluding oil and gas). Its policies and infrastructure also support manufacturing and exporting.
- 4 Ghana (5.5/7).** Ghana has a manufacturing GDP of more than \$7Bn and merchandise exports (excluding oil and gas) of \$11.7Bn. It has specific policies for renewable energy and manufacturing. However, trade with China and infrastructure are on the middle-to-lower end of our shortlist.



The future of Solar in Africa - Africa renewable energy manufacturing opportunities

- 5 | Algeria (4.5/7).** Algeria has the second-highest projected solar energy demand. It ranks fourth in both manufacturing GDP and imports from China. It provides policies for renewable energy and manufacturing, but its infrastructure is perceived as average. Its exports, excluding oil and gas, are the second lowest on the shortlist.
- 6 | Tunisia (4.5/7).** Tunisia provides specific policies for renewable energy and manufacturing. Tunisian manufacturing, although relatively complex, generated \$6Bn in 2021. Trade, infrastructure, and exports score toward the middle of our shortlist, while projected solar demand in 2030 is one of the lowest on the shortlist.
- 7 | Nigeria (4/7).** Nigeria ranks second on our shortlist in manufacturing GDP, projected solar capacity in 2030, and imports from China. It provides a legislative framework for renewable energy and manufacturing, but it scores the lowest on our shortlist in terms of infrastructure, and third lowest for exports, excluding oil and gas.
- 8 | Namibia (4/7).** Namibia is a politically stable country with strong local projected demand for RE by 2030. It has very high-quality infrastructure, being the highest overall scorer on our shortlist, but has a relatively under-developed manufacturing sector. It had minimal trade with China in 2021.



The future of Solar in Africa - Africa renewable energy manufacturing opportunities

- 9** | **Kenya (3.5/7).** Kenya provides a specific legislative framework for RE and manufacturing in general. The country is on its way to 100% RE in its electricity mix and has a developing manufacturing sector. However, political instability and a small scale of merchandise exports might challenge its potential to scale.



- 10** | **Tanzania (3/7).** Tanzania is the seventh-highest importer from China on our shortlist. It has policies for renewable energy and manufacturing; manufacturing represented \$5Bn of GDP in 2021. Its infrastructure is perceived as average, while its projected solar demand and ability to export are among the lowest on our shortlist.



* It should be noted that the report does not include **Zimbabwe**, however in our view the report highlights all aspects required for developing Solar manufacturing on the African Continent.

* It has been noted that in early July 2023 a Chinese mining company formally opened a \$300 million lithium processing plant in Zimbabwe. The newspaper report stated that Zimbabwe has one of the world's largest reserves of the metal as demand surges globally

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The Africa Renewable Energy Report identified 10 solar photovoltaic (PV) and battery opportunities across the continent—four in solar PV and battery materials refining, three in solar PV assembly, and three in battery materials refining.

Solar PV module manufacturing

The Solar PV module manufacturing value chain comprises four main steps: the production of wafers from polysilicon and chemicals, wafer production, cell manufacturing, and module assembly (Exhibit 3).

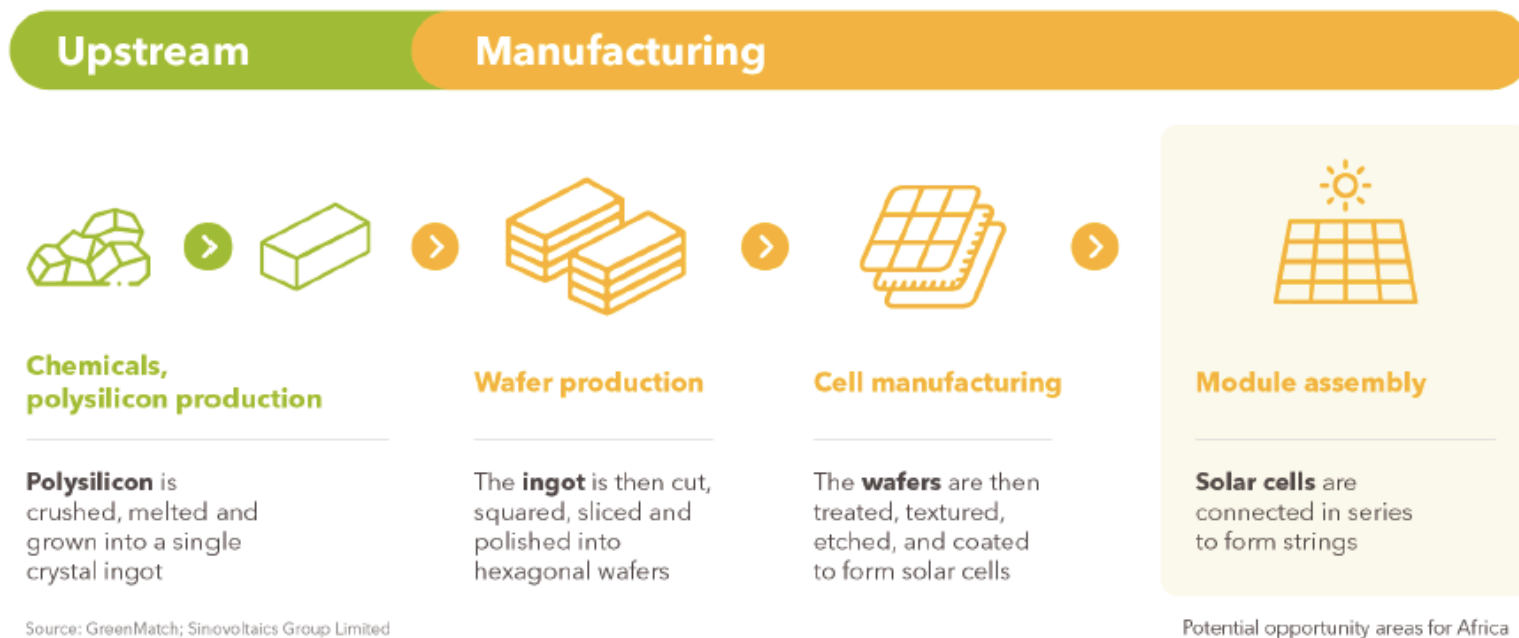


Exhibit 3
The Solar PV module manufacturing value chain has four main steps.

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Solar PV module manufacturing

African solar PV manufacturing could start by prioritising the cell manufacturing and module assembly steps. This is due to less technological and chemical complexity, input-import and product-export opportunities, labor availability, and existing solar panel assembly. Polysilicon and wafer production could be considered when other manufacturing steps scale up, as production of these components is complex and requires high energy availability.

The feasibility, market potential, and competitiveness of solar PV in Africa were assessed across seven metrics:

- (1) availability of raw materials,
- (2) human resources capability,
- (3) infrastructure readiness,
- (4) capital intensity per industrial unit,
- (5) enabling policies and regulations,
- (6) demand dynamics,
- (7) production competitiveness.

After assessing the sample countries across these metrics, the report researchers identified that Solar PV manufacturing is immediately feasible in the following five African countries...

- 1) **Egypt:** Egypt's highest feasibility score is driven by high manufacturing value added (MVA), VA infrastructure availability, and labor capabilities; Egypt also has the highest competitiveness score due to existing adjacent industries.
- 2) **Tunisia:** Much like Egypt, Tunisia's feasibility score is primarily driven by high MVA, availability of manufacturing labor, and competitiveness driven by existing adjacent industries.
- 3) **South Africa:** South Africa's feasibility is driven by high MVA, infrastructure availability, high competitiveness based on adjacent industries, and low importation costs.
- 4) **Morocco:** Morocco's feasibility is driven by high MVA, infrastructure availability, labor competitiveness, and competitiveness based on the presence of adjacent industries. However, Morocco faces slightly higher input importation costs from China.
- 5) **Algeria:** Algeria's overall fifth-place ranking is driven by high estimated additional installed solar power capacity and infrastructure availability.

Nigeria, Namibia, Kenya, Ghana, Côte d'Ivoire and Rwanda would be the next six countries prioritized from a feasibility point of view. Building local solar PV manufacturing is possible in each of these markets as well but will require incremental effort to overcome some of the deterrents to investment. Given political commitment to accelerate local manufacturing in some of these markets, particularly Nigeria and Kenya,

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Estimated module assembly costs in all shortlisted countries are, however, currently higher than average costs in China (Exhibit 4).

Cost-competitiveness of PV module assembly

Production cost*, \$cent/W

*All cost based on stable energy markets (does not include current Poly-Si prices)

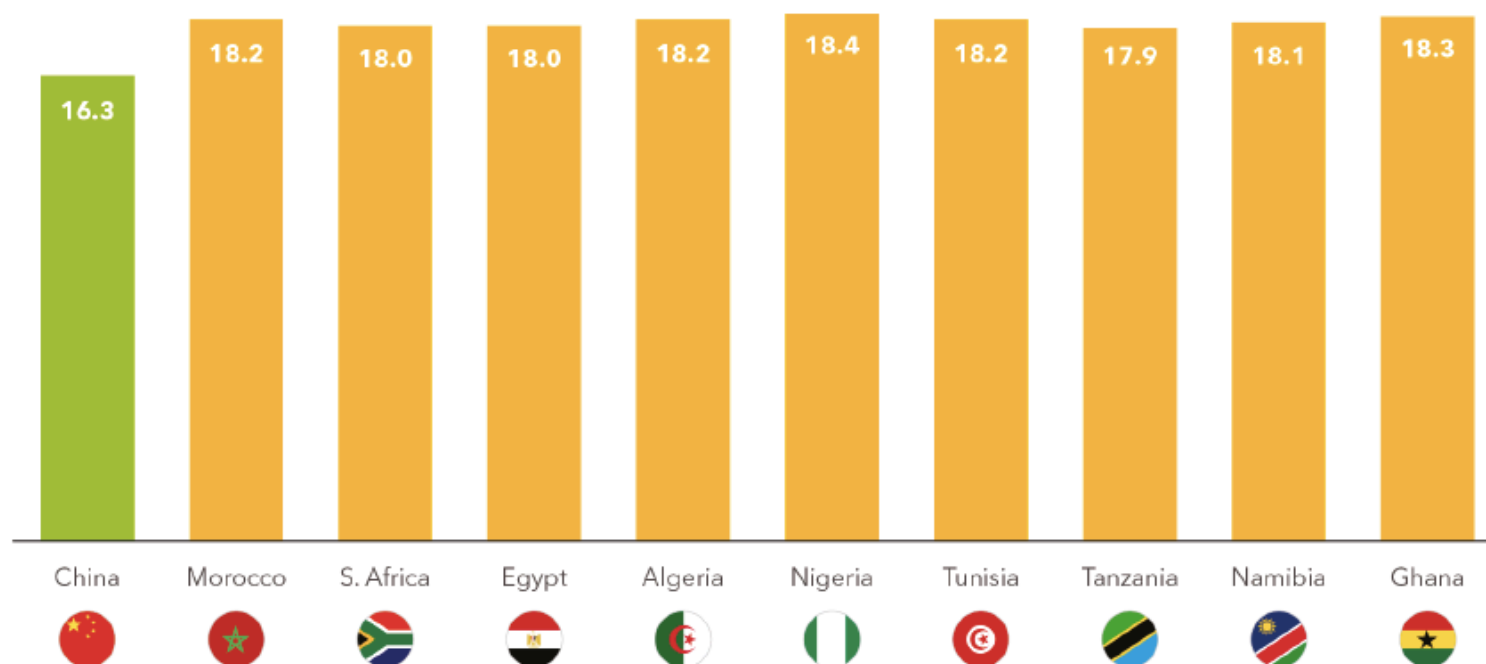


Exhibit 4
African solar PV
manufacturing can
be cost competitive
with China.

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Battery manufacturing

The battery manufacturing value chain has six main steps: mining, refining, cell components, cell manufacturing, packaging and integration, and recycling (Exhibit 5).

Assessing the specifics of shortlisted countries and the critical success factors for each step shows that the two most feasible industries in Africa are

(1) refining*

(2) packaging and integration.

Refining includes the refining and processing of materials into usable production. Critical success factors include being close to the source of raw materials, complex technology, process competence to perform safe and cost-effective refining, and ample energy supplies.

Packaging and integration involve assembling cells into modules, modules into packs, and connecting hardware and software into complete packages. Critical success factors include cost-efficient assembly competence; integration of battery management systems and hardware into packs; and minimizing the complexity and cost of a battery pack.

However, research indicates there is currently insufficient local demand for building one giga-factory in Africa. This opportunity can be considered once the market has matured.

BESS production value chain



Exhibit 5

The battery manufacturing production value chain consists of six steps.

* It has been noted that in early July 2023 a Chinese mining company formally opened a \$300 million lithium processing plant in Zimbabwe. The newspaper report stated that Zimbabwe has one of the world's largest reserves of the metal as demand surges globally

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The assessment used ten indicators to assess the feasibility, market potential, and competitiveness of mineral refining in Africa:

- (1) availability of raw materials,
- (2) labor productivity,
- (3) skill availability,
- (4) infrastructure readiness,
- (5) available power,
- (6) maturity of complex manufacturing,
- (7) enabling policies and regulations,
- (8) ability to export,
- (9) demand dynamics,
- (10) production competitiveness.

The assessment shows that battery manufacturing can begin with mineral refining in five shortlisted countries:

- 1) **Ghana:** Ghana actively mines lithium and scores highly on feasibility, which means it could refine both local and imported lithium.
- 2) **Morocco:** Morocco actively mines cobalt reserves and is already engaged in primary and secondary refining. The country could expand its refining capacity by importing more raw materials.
- 3) **Namibia:** Namibia actively mines lithium and scores highly on feasibility, which means it could refine both local and imported lithium.
- 4) **South Africa:** South Africa has the largest manganese reserves in the world and scores highly on feasibility, indicating a high likelihood of success for refining manganese. South Africa emerges as the only country with a credible battery-energy-storage-system (BESS) packaging opportunity, given that its projected demand is the highest on the continent. However, the near- and intermediate-term opportunity remains limited given the scale of demand in the next 5-10 years.
- 5) **Tanzania:** Tanzania has large nickel reserves with a high nickel ratio has has a high potential to start mining in the coming years. Therefore, Tanzania offers the top nickel-refining opportunity in Africa.

Please Note: With regard to Zimbabwe feasibility, It has been noted that in early July 2023 a Chinese mining company formally opened a \$300 million lithium processing plant in Zimbabwe. The newspaper report stated that Zimbabwe has one of the world's largest reserves of the metal as demand surges globally

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An analysis of battery-material refining shows that African countries can be cost-competitive with China for various minerals (Exhibit 6).

Cost-competitiveness of refining

Delivered cost* to EU, \$/ton

*Delivered cost = Production cost + shipping cost to EU; For lithium carbonate, only production cost is included

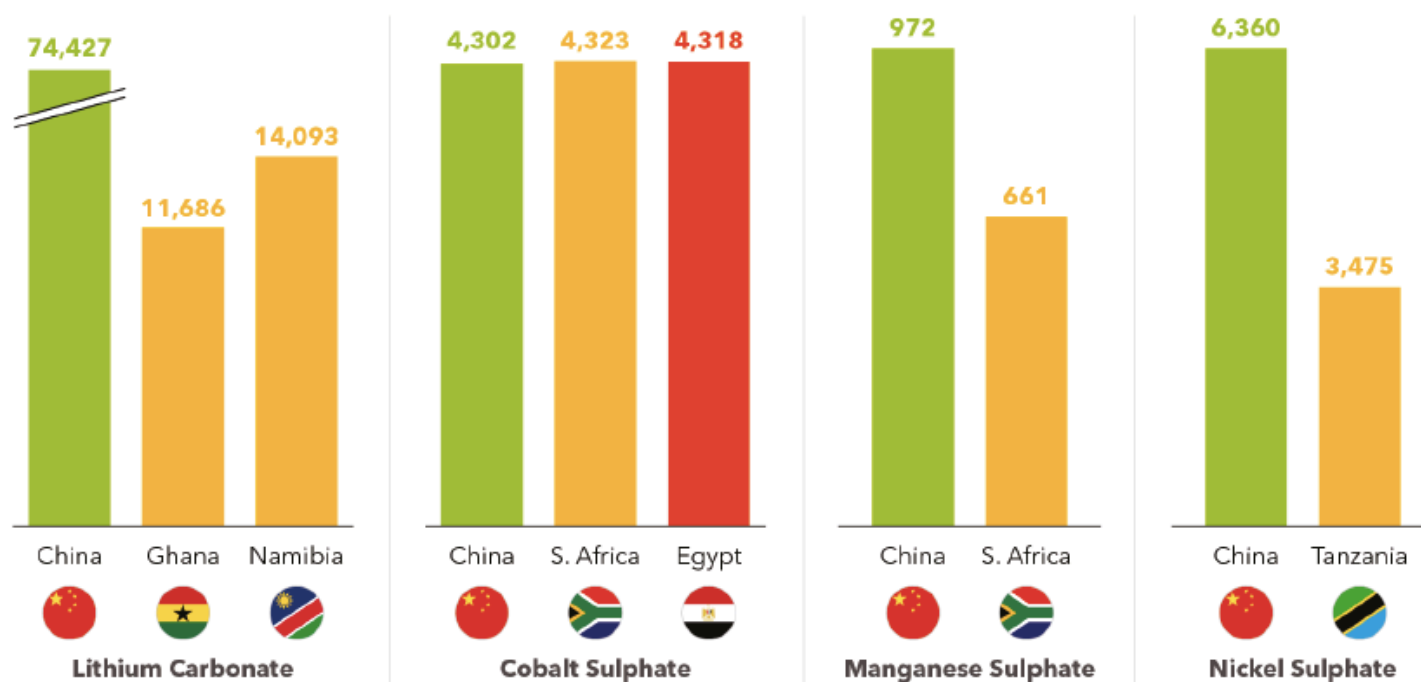


Exhibit 6
African battery material refining can be cost-competitive with Chinese refining.

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China pursues active foreign direct investment (FDI) across Africa and has prevalent bilateral agreements in place based on South-South cooperation and the “Belt and Road Initiative.” The top recipients of China FDI in Africa are estimated to be Kenya, South Africa, Nigeria, Senegal, and Tanzania.

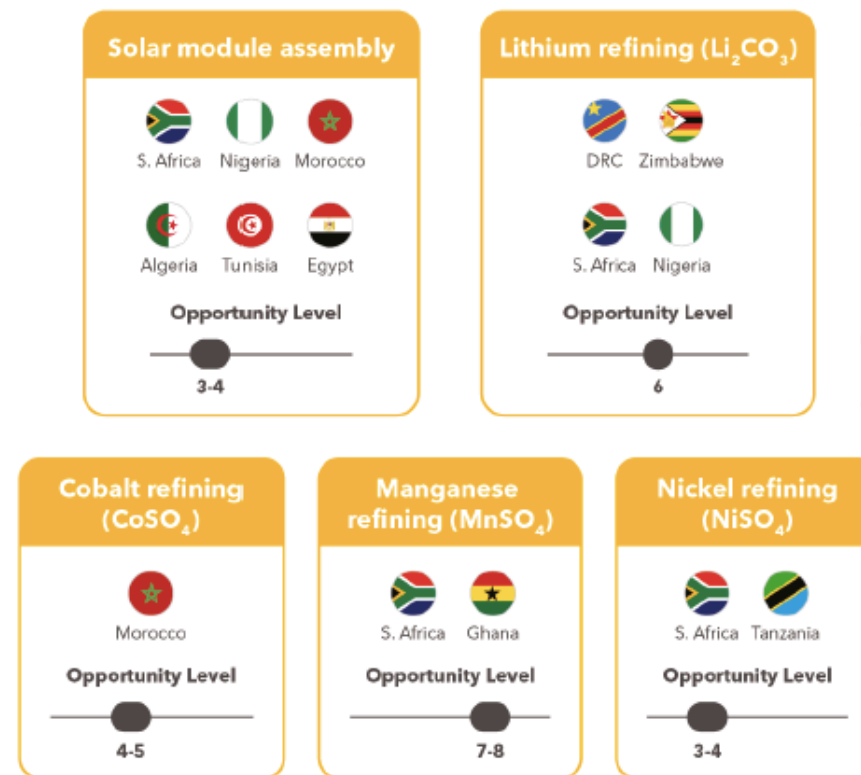
In manufacturing industries, Chinese companies have built factories in several sectors, including automotive, cement, and appliances. However, at the time of this report, the only three projects in the renewables space are facilities in South Africa operated separately by Jinko, Seraphim and Talesun—all for solar module assembly.

In solar PV, Chinese companies lead PV module supplies in Africa (55%) and are active in engineering, procurement, and construction (EPC) in solar products (19%) but only represent 5% of owners/operators.

The report looked at 15 Chinese solar PV manufacturers and 15 battery manufacturers based on multiple criteria, including footprint in Africa, overseas capacity, exposure to the US and Europe, and recommendations from Chinese industry. The report writers conducted interviews with these manufacturers to:

- (1) identify opportunities for solar module assembly and battery material refining
- (2) determine the main “pull” factors and perceived drawbacks of such investments Their assessment of the opportunities is shown in Exhibit 7.

Where are the opportunities situated on the continent?



Source: Expert interviews, team analysis

Exhibit 7

Industry players ranked the opportunity level of renewables manufacturing on the continent.

The future of Solar in Africa - Africa renewable energy manufacturing opportunities

Catalysts for investing in Africa's solar PV manufacturing

Chinese solar PV manufacturers suggested several factors should provide a catalyst for investment in PV manufacturing in Africa.

1) Increased local market potential: A large, growing, and profitable solar market is a prerequisite for Chinese manufacturers to build factories in Africa, as it is the safest way to ensure revenue, given the export uncertainties. Chinese players would like to see Africa's solar demand boosted by national plans for solar capacity, continuous solar feed-in-tariff schemes, and regular solar tenders. Investments could also be attracted by secured offtake, either by prioritising procurement or assigning development rights to solar stations.

2) Enhanced production factors: Cost competitiveness of solar PV products can only be achieved if there are strong local production factors, including labor force, utility, and infrastructure. To attract Chinese manufacturers' investment, Africa should consider incentives for local manufacturing, labor force improvements, infrastructure support, a secured supply of low-cost green electricity, and preferential financing packages.

3) Strengthened local supply chains: Local capacity of solar PV assembly materials is largely missing in Africa, including solar PV glass, which is costly to ship. Chinese manufacturers would like to see local supply chains strengthened by reducing import barriers (e.g., low tariffs or tax waivers for material imports) and cultivating adjacent industries (e.g., building local capacity and creating industrial zones to gather value chain partners).

4) Improved enabling environment: Also crucial is a stable macro/micro environment with low sovereign risks, few public security issues, and good bilateral relations. Chinese manufacturers would like enhanced security levels for factory sites and societies.



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Catalysts for investing in Africa's battery refining industry

Input provided regarding battery refining revealed many similarities with solar PV manufacturing needs, albeit with a stronger focus on securing raw materials

1) Secured raw material through access to mines: Close proximity to mines and the associated reduction in potential shipping costs—is the top motivation for Chinese manufacturers to build refineries overseas. Given that Africa has rich mineral resources, it could be highly attractive to Chinese manufacturers. This advantage, though, could be further enhanced by accelerating the administrative process for mining and refining and by supporting partnerships between refiners and miners.

2) Enhanced production factors: Similar to solar PV, strong production factors are needed, including a specific emphasis on stable power and water supplies to ensure continuous operation. Chinese manufacturers would appreciate utility support on captive power plant investment and administrative processes for surface-water abstraction certificates. Improved labor force and tax benefits would also be attractive factors.

3) Strengthened local supply chains: Investments in adjacent industries and lower import barriers are required to strengthen Africa's supply chain for battery refineries. For example, sulfuric acid is required in most refinery processes, and it is challenging for logistics and warehousing to manage. Further restricting manufacturing interest is the lack of production capacity for sulfuric acid and other key input materials.

4) Improved enabling environment: It will be crucial to offer Chinese players a stable macro/microenvironment with low sovereign risks, free flow of foreign capital, and good bilateral relations. Chinese manufacturers also voiced support for lower currency control in the host countries used for mining operations.



Prospect Lithium Zimbabwe's processing plant in Goromonzi about 80 miles southeast of the capital Harara which was officially commissioned in July 2023

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Existing tools and mechanisms to encourage renewables manufacturing

Africa already has several enablers to attract potential investments in renewables manufacturing. They fall into three main categories: fiscal incentives, local content requirements (LCR), and capability building.

1) Fiscal incentives: Fiscal incentives have been a driver of market growth for renewable energy product manufacturing. They include VAT and import duty exemptions, reduced corporate income tax, accelerated depreciation on equipment, and tax holidays for investors.

2) Local content requirements (LCRs): Local authorities have encouraged manufacturers to derive a certain percentage of the final value of renewable energy products from domestic firms. These policies were enacted to develop local industries using tender requirements, targets, and commitments.

3) Capability building: In some cases, the local workforce is trained with technical expertise for renewable energy product manufacturing. This capability growth was achieved through joint ventures with international renewable energy companies, through academic institutions, and investment in R&D within the renewable energy space.

Tools and incentives have driven some success across the continent

Fiscal incentives have helped the growth of solar PV module manufacturing companies in South Africa, Egypt, and Tunisia. They have also facilitated the emergence of an assembly sector for solar energy products in sub-Saharan African countries, including Nigeria, Ghana, and Kenya.

LCR has aided the inclusion of local supply chains in developing renewable energy products and components.

For example, 50% of the CSP solar field in the Kuraymat project in Egypt was manufactured locally.

Capability building has been driven by the development of training programs and the emergence of renewable energy-focused learning centers and research institutions (e.g., the Regional Center for Renewable Energy and Energy Efficiency in Egypt, Research Institute for Solar Energy and Renewable Energies (IRESEN) in Morocco and National Agency for Energy Management in Tunisia).

Moreover, the strengthening of local engineering, procurement and construction companies through technological transfer is enabled by joint ventures with international companies.

Other potential tools, such as transaction facilitation and funding of renewable energy manufacturing, have already been deployed in Africa. To date, though, these efforts have generated little noticeable impact in capability building.

While several enabling factors are in place, there are also numerous gaps and barriers to the success of renewable energy manufacturing in Africa.

Stakeholder conversations consistently revealed opportunities were diminished by four aspects:

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Elements that would discourage investment in renewable manufacturing

1) Absence of necessary production factors: Inadequate technical capabilities—such as a dearth of local expertise in high-value manufacturing, and a low number of renewable-energy-related educational programs contribute to the perception that Africa lacks the necessary labor pool for production operations; “labor productivity is low for assembly, let alone (for) more complex products,” one stakeholder commented. Africa is also seen as having constrained infrastructure and utility support. For example, the high cost of electricity is further compounded by unreliable supply in some cases, and less developed transport infrastructure in others (e.g., roads and ports), which may adversely impact opportunities for intra-Africa trade of renewable energy products. “Power/water is generally in short supply,” and this lack of “bottom-line criteria” limits investment.

2) Weak local supply chains: Import barriers, including high tariffs and taxes on equipment and components, cause a competitive disadvantage, while many African countries lack adjacent industries such as glass, aluminum, and sulfuric acid. “Africa has (an) absence of local supply chain for not only core materials (e.g., PV cells), but also (for) the auxiliary materials (e.g., glass, back sheet, EVA).” This weakness requires additional time and investment for manufacturers to secure the necessary supply chain to enable production.

3) Constrained regulatory development and incentive structures: There are limited existing regulations to encourage manufacturing localization, and many countries lack a comprehensive regulatory framework for designing and implementing renewable energy manufacturing programs.

Additionally, there is an absence of incentives to attract renewable energy manufacturers and encourage local value creation. “We will consider building solar factory if governments approach us with attractive incentive packages, but that’s missing in Africa,” said one stakeholder. Other stakeholders mentioned a lack of “clear planning” and the stability and consistency of policies that impact investment.

4) Absence of incentives to boost local demand: Most African countries lack adequate incentives to promote local and regional demand for renewable energy products. For example, many countries lack clear solar plans and feed-in-tariff programs to encourage solar panel manufacturing at scale. This lack of local demand was seen as “a critical factor hindering development” by stakeholders, who cited the need for local demand to drive further investments throughout the value chain—including further development in the supply chain.



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Other countries have used successful tactics to facilitate the manufacturing of renewable energy products

Countries outside Africa have facilitated renewable energy product manufacturing by implementing favorable regulations, offering capital benefits, and investing in R&D.

1) Regulatory environment: The successful growth of a country's renewable energy product manufacturing sector can be enabled by comprehensive strategy development and policy implementation to strengthen supply chains, spur local demand, and exploit export opportunities. Malaysia, for example, created a 10% sales tax exemption on locally manufactured solar PV modules. China offered a reduced corporate income tax to clean energy manufacturers. Beneficial regulatory actions include:

- **Fiscal incentives (e.g., lower corporate income tax, VAT, and import duty exemptions for inputs)**
- **Import tariffs imposed on imported components**
- **Ban on dumping of materials from other markets**
- **Execution of local content requirements**

2) Capital benefits: Manufacturers of renewable energy products are further incentivized by capital benefits. For example, Indonesia established a Sustainable Energy Fund (SEF) grant to encourage rooftop solar systems, incentivizing local demand and attracting investors; Maharashtra, India, allocated government land to solar panel manufacturers.

Capital incentives can include:

- **Access to low-cost capital**
- **Provision of guarantees for long-term assets and equipment**
- **Availability of land (at affordable prices) to set up manufacturing plants**
- **Accelerated depreciation on equipment**

3) R&D: Long-term sustainability and competitiveness of the renewable energy manufacturing sector can be facilitated through innovation and technology development. In Germany, for example, the government funded R&D on lower-cost solar PV under the Photovoltaics Innovation Alliance. R&D has been facilitated in various countries by:

- **Running competitive innovation programs**
- **Direct funding to manufacturing companies**
- **Financial support to research and academic institutions**

Learnings from these global examples are being incorporated into the approach that philanthropies and other stakeholders can adopt in scaling renewable energy manufacturing in Africa.

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Potential interventions and proposed pathway forward

Stakeholders, especially philanthropies, could deploy these levers to scale renewable energy manufacturing in Africa.

Capability building: Help organisations strengthen their capabilities through technical assistance, training, and tools

Knowledge: Discover, develop, interpret, and share knowledge throughout the sector

Advocacy: Support decision-making institutions in crafting and implementing policies that provide conducive business climates

Convening: Establish forums for ideas and exchange

Pilot: Support small-scale experiments or pilots for innovation and first-of-their-kind projects

To bridge gaps in Africa renewable energy manufacturing through a combination of these levers, this report proposes four potential overarching program types, each with a different approach to driving growth.

1) Policy: Enable the set-up of a best-in-class business environment. Inform, train, and support African government officials to accelerate and bolster their policymaking for “Africa for Africa” renewable energy manufacturing.

Four levers could be used: capability building (e.g., develop policy awareness programs and policy master classes); knowledge (e.g., research on country-specific policy pathway and policymaking toolkits); advocacy (e.g., sponsor advocacy organizations to articulate the Africa renewable energy manufacturing policy needs); and convening (e.g., support policy forums and high-level dialogues).

2) People: Build Africa’s future renewable energy manufacturing workforce.

Sponsor the training, employment, and career development of renewable energy engineers and technicians in Africa, focusing on solar PV, battery refinery, and key adjacent industries. Three levers would be used: capability building (e.g., develop renewable energy technician schools, online education programs for renewable energy manufacturing, and renewable energy scholarship programs); knowledge (e.g., workforce best practices, online library for renewable energy manufacturing technology); and convening (e.g., career centers, labor information exchange platforms).

3) Anchor: Attract mature renewable energy manufacturers at scale in Africa.

Provide mature renewable energy manufacturers with better access to consulting and financing services and cultivate a robust renewable energy manufacturing ecosystem in Africa. Four levers would be used: knowledge (e.g., business model support, legal and tax consulting services, national playbooks for renewable energy factory financing); advocacy (e.g., tailored advocacy and policy negotiations for renewable energy factory projects); pilot (e.g., grant support for scaled renewable energy factories); and convening (e.g., a global alliance for Africa renewable energy manufacturing).

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4) Accelerator: Incubate Africa's renewable energy manufacturing projects.

Provide end-to-end grant support for renewable energy and adjacent manufacturing projects in Africa, from planning and financing to operations and sales of end products. Four levers would be used: knowledge (e.g., business model support, market intelligence reports); capability building (e.g., renewable energy manufacturing boot camps, renewable energy factory twinning visit programs); convening (e.g., innovative financing hubs); and pilot (e.g., grant support for pilot renewable energy/adjacent factories, power solutions).

Four overarching programs are proposed to bridge the gaps

Policy: Enable the setup of a best-in-class business environment	People: Build Africa's future RE manufacturing workforce	Anchor: Attract mature RE manufacturers at scale to Africa	Accelerator: Incubate Africa RE manufacturing projects
Inform, train, and support African government officials to accelerate and bolster their policy making for "Africa for Africa" RE manufacturing	Sponsor the training, employment, and career development of RE engineers and technicians in Africa	Provide mature RE manufacturers with better access to consulting and financing services, and cultivate a robust RE manufacturing ecosystem	Provide end-to-end grant support for RE and adjacent manufacturing projects in Africa, from planning, financing to operations and sales

Capability building	RE manufacturing policy awareness RE policy master class RE leadership development	RE technician school RE manufacturing online education RE scholars RE worker exchange	N.A.	RE manufacturing boot camp RE factory twinning program
Knowledge	RE manufacturing online platform – policy module Country-specific policy pathway Policymaking toolkits	RE manufacturing online platform – tech module Workforce best practices	Business model support Legal and tax consulting services Financing playbook	Business model support Market intelligence reports RE manufacturing online platform – project and product info module
Advocacy	RE manufacturing policy advocacy	N.A.	RE factory incentive package negotiation	N.A.
Convening	RE manufacturing policy forum High-level dialogue on Africa RE manufacturing	Career center Labor info exchange High-level dialogue on RE workforce	Global alliance of Africa RE manufacturing	Innovative financing hub
Pilot	N.A.	N.A.	Grant for scaled RE capacity investment	Grant for pilot RE/adjacent factories Grant for power solutions

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With adequate investments in these four programs, there is a potential to achieve 10 scaled renewable energy factories; ten pilot renewable energy/adjacent factories; 3,000 trained renewable energy technicians; and 500 qualified future leaders, all supported by a best-in-class business environment (Exhibit 9).

Impact to be achieved through 4 programs ...



Exhibit 9

Significant impact in renewables energy manufacturing in Africa could be achieved through four programs.

... with best-in-class business environment

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Africa can seize the opportunity to build a leading, world-class renewables industry

Africa has many of the right ingredients to build a globally-competitive renewable energy ecosystem—it has the demand, the natural resources, the trade partnerships, and many supporting tools and incentives.

With the right approach, several African countries could emerge by 2030 as significant players in the sector, benefitting the entire continent.

By identifying the most feasible entry-points in the renewable energy value chain, the best locations to create opportunities, and the right partners, Africa can start to attract investment and expertise to build a competitive edge.

The strong growth outlook for African economies, coupled with the drive for a global transition to cleaner energy, make this the right time to start building Africa's renewable energy future.

Investment attractiveness and readiness methodology

The Africa Renewable Energy Report assessed 14 African countries on their feasibility of manufacturing RE products, across seven categories: renewables demand, manufacturing scale, political stability, enabling policies and restrictions, trade relations with China, enabling infrastructure, and ability to export (Exhibit 10).

Exhibit 10

Countries were evaluated across seven dimensions and ranked high, medium or low on feasibility.

	HIGH	MEDIUM	LOW
RE demand assuming stringent climate policies	Projected solar energy capacity in 2030 $\geq$ 2 GW	Projected solar energy capacity in 2030 $<$ 2 GW and $\geq$ 1 GW	Projected solar energy capacity in 2030 $<$ 1 GW
Manufacturing scale	Manufacturing GDP $\geq$ USD 10Bn	Manufacturing GDP $<$ USD 10Bn and $\geq$ USD 5Bn	Manufacturing GDP $<$ USD 5Bn
Political stability	Aggregate of 4 select components of World Bank Governance Indicators $\geq$ 150	Aggregate of 4 select components of World Bank Governance Indicators $<$ 150 and $\geq$ 125	Aggregate of 4 select components of World Bank Governance Indicators $<$ 125
Enabling policies and regulations	Aggregate select RISE indicators $\geq$ 200 and/or specific policies to incentivize manufacturing	Aggregate select RISE indicators $<$ 200 and $\geq$ 100 and/or specific policies to incentivize manufacturing	Aggregate select RISE indicators $<$ 100
Trade relations with China	Total imports from China $\geq$ USD 5Bn	Total imports from China $<$ USD 5Bn and $\geq$ USD 500Mn	Total imports from China $<$ USD 500Mn
Enabling infrastructure	Aggregate score on quality of electricity/ports/roads on the WEF executive survey $\geq$ 14	Aggregate score on quality of electricity/ports/roads on the WEF executive survey $<$ 14 and $\geq$ 7	Aggregate score on quality of electricity/ports/roads on the WEF executive survey $<$ 7
Ability to export	Merchandise exports globally (excluding O&G) $\geq$ USD 10Bn	Merchandise exports globally (excluding O&G) $<$ USD 10Bn and $\geq$ USD 5Bn	Merchandise exports globally (excluding O&G) $<$ USD 5Bn

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Renewable energy demand: Review of the current electricity mix in the country and projections for future mix. This analysis assumed ambitious climate policies, such as alignment to the Science-Based Target initiative (SBTi) of keeping a global temperature increase below 2 degrees Celsius. A high ranking indicated a projected solar capacity in 2030 equal two or beyond 2GW, while a low ranking indicated less than 1GW of solar capacity.

Manufacturing scale: Manufacturing value added (MVA) is calculated as a contribution to GDP by manufacturing. MVA includes a share of low tech and medium/high tech and included a qualitative review of complex and adjacent industries and country ambitions. High scores in the category indicated a generated value exceeding \$10Bn, while a low score indicated a value below \$5Bn in generated value.

Political stability: Scores were determined by using Worldwide Governance Indicators defined by the World Bank. High scores were considered to have an aggregate value greater than or equal to 150 from four select components. Low scores were given for values less than 125.

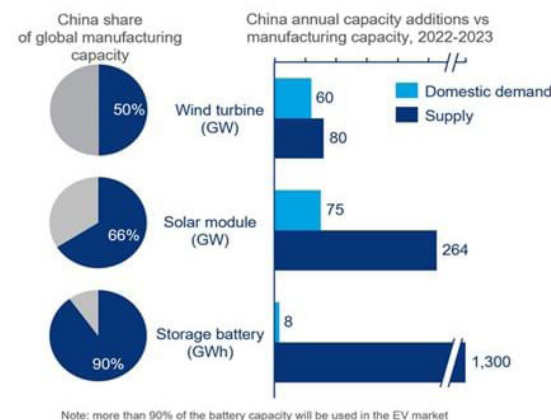
Enabling policies and regulations: This category ranks the ease of doing business with a country and includes a review of policies for stimulating renewable energy demand, manufacturing, and overall policy/regulatory effectiveness. Scores were compiled as an aggregate of select RISE indicators and/or the presence of specific policies that incentivize renewable energy manufacturing. High scores required a 200 threshold, while low scores were given to totals less than 100 or countries that did not have specific incentives for renewable energy manufacturing.

Trade relations with China: Figures are directly linked to total imports from China, with high scores requiring at least \$6Bn in exports while low scores were given to export totals below \$500Mn.

Enabling infrastructure: This category scores the overall quality of electricity supply, ports and roads, and other manufacturing enablers. High scores met or exceeded a 14 on the World Economic Forum's executive survey of electricity/ports/roads; low scores fell below 7.

Ability to export: This category reviews existing and relevant trade agreements and export volumes, both to other countries in Africa and globally. High scores totalled merchanded exports, excluding oil and gas, of at least \$10Bn; low scores fell below \$5Bn.

China's renewables and battery manufacturing dominance



The future of Solar in Africa - Africa renewable energy manufacturing opportunities

Exhibit 11

Fourteen countries were evaluated across seven dimensions to assess feasibility of manufacturing renewables energy products in each country.

	HIGH Performance	MEDIUM Performance	LOW Performance					
	RE demand	Manufacturing maturity	Political stability	Policies and regulations	Trade relations with China	Enabling infrastructure	Ability to export	Overall assessment (out of 7)
1. Morocco								7
2. South Africa								6.5
3. Egypt								6
4. Ghana								5.5
5. Algeria ¹								4.5
6. Tunisia ¹								4.5
7. Nigeria ¹								4
8. Namibia ¹								4
9. Kenya ¹								3.5
10. Côte d'Ivoire ¹								3.5
11. Rwanda ¹								3.5
12. Tanzania ¹								3
13. Senegal ¹								3
14. Botswana								2.5

¹ Countries with equal overall scores are ranked in decreasing order of GDP

Exhibit 12

The feasibility, market potential and competitiveness of solar PV manufacturing was assessed across 7 metrics and ranked high, medium or low.

Feasibility and competitiveness assessment framework

		HIGH	MEDIUM	LOW
FEASIBILITY	Availability of raw materials ² Weight = 10%	Availability of quartz sand to produce silicon	Partial availability of quartz sand silicon	Absence of quartz sand
	Human resource capability Weight = 30%	Labour productivity of $\geq \$15$; $\geq 10\%$ of workforce in manufacturing	Labour productivity of $< \$15$ and $\geq \$10$; $< 10\%$ and $\geq 5\%$ of workforce in manufacturing	Labour productivity of $< \$10$; $< 5\%$ of workforce in manufacturing
	Infrastructure readiness Weight = 30%	Score on quality of electricity/ports/ roads on the WEF executive survey ≥ 4.5	Total score on quality of electricity/ports/ roads on the WEF executive survey < 4.5 and ≥ 3	Total score on quality of electricity/ports/ roads on the WEF executive survey < 3
	Capital intensity per industrial unit Weight = 20%	Capital investment of USD 50Mn required based on project	Capital investment of between USD 50Mn and 150Mn required based on project	Capital investment of $> USD 150Mn$ required based on project
	Enabling policies and regulations Weight = 10%	Score on select RISE indicators ≥ 75	Total select RISE indicators < 75 and ≥ 50	Total select RISE indicators < 50
COMPETITIVENESS	Demand dynamics Weight = 50%	Annual additional installed solar power capacity (MW) ≥ 400 MW	Annual additional installed solar power capacity (MW) < 400 and ≥ 50 MW	Annual additional installed solar power capacity (MW) < 50 MW
	Production competitiveness Weight = 50%	$\leq 20\%$ estimated increase in the cost of production when compared to China	$\geq 20\%$ to $\leq 40\%$ estimated increase in the cost of production when compared to China	$> 40\%$ estimated increase in the cost of production when compared to China

² Polysilicon used in production of Solar PV cells is produced using metallurgical grade silicone, which is produced by reacting high grade pure silicon, wood and charcoal then used in the production of polysilicon

The future of Solar in Africa - Africa renewable energy manufacturing opportunities

Exhibit 13

The feasibility, market potential and competitiveness of refining individual battery metals was assessed across 10 metrics and ranked high, medium or low.

Feasibility and competitiveness assessment framework

		HIGH	MEDIUM	LOW
FEASIBILITY	Availability of raw materials Weight = 20%	Local accessible reserves	N.A.	No reserves
	Labour productivity Weight = 20%	Labour productivity of $\geq \$15$	Labour productivity of $< \$15$ and $\geq \$10$	Labour productivity of $< \$10$
	Skill availability Weight = 20%	$\geq 10\%$ of workforce in manufacturing	$< 10\%$ and $\geq 5\%$ of workforce in manufacturing	$< 5\%$ of workforce in manufacturing
	Infrastructure readiness Weight = 15%	Score on quality of electricity/ports/ roads on the WEF executive survey ≥ 4.5	Total score on quality of electricity/ports/ roads on the WEF executive survey < 4.5 and ≥ 3	Total score on quality of electricity/ports/ roads on the WEF executive survey < 3
	Available power Weight = 5%	$\geq 40,000$ MW capacity	$< 40,000$ and $\geq 10,000$ MW capacity	$< 10,000$ MW capacity
	Maturity of complex manufacturing Weight = 5%	Manufacturing GDP $\geq 20\%$	Manufacturing GDP $< 20\%$ and $\geq 10\%$	Manufacturing GDP $< 10\%$
	Enabling policies and regulations Weight = 5%	Score on select RISE indicators ≥ 75	Total select RISE indicators < 75 and ≥ 50	Total select RISE indicators < 50
	Ability to export Weight = 10%	Merchandise exports $\geq \text{USD } 10\text{Bn}$	Merchandise exports $< \text{USD } 10\text{Bn}$ and $\geq \text{USD } 5\text{Bn}$	Merchandise exports $< \text{USD } 5\text{Bn}$
COMPETITIVENESS	Demand dynamics (BESS Focus) Weight = 50%	Solar + Wind capacity in GW ≥ 10	Solar + Wind capacity in GW < 10 and ≥ 5	Solar + Wind capacity in GW < 5
	Production competitiveness Weight = 50%	$\leq 20\%$ estimated increase in production cost compared to China	$\geq 20\%$ to $\leq 40\%$ estimated increase in production cost compared to China	$> 40\%$ estimated increase in production cost compared to China



THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE

The future of Solar in Africa - Zimbabwe

Zimbabwe, officially the Republic of Zimbabwe, is a landlocked country in Southern Africa, between the Zambezi and Limpopo Rivers, bordered by South Africa to the south, Botswana to the south-west, Zambia to the north, and Mozambique to the east. The capital and largest city is Harare, and the second largest is Bulawayo.

A country of roughly 15 million people, Zimbabwe's largest and dominant ethnic group are the Shona, who make up 82% of the population, followed by the Northern Ndebele and other smaller minorities. Zimbabwe has 16 official languages, with English, Shona, and Ndebele the most common.

Beginning in the 9th century, during its late Iron Age, the Bantu people (who would become the ethnic Shona) built the city-state of Great Zimbabwe; the city-state became one of the major African trade centres by the 11th century.

By the mid 15th century, the city-state had been abandoned. From there, the Kingdom of Zimbabwe was established, followed by the Rozvi and Mutapa empires.

The British South Africa Company of Cecil Rhodes demarcated the Rhodesia region in 1890 when they conquered Mashonaland and later in 1893 Matabeleland after a fierce resistance by Matabele people known as the First Matabele War.

Company rule ended in 1923 with the establishment of Southern Rhodesia as a self-governing British colony. In 1965, the white minority government unilaterally declared independence as Rhodesia.



The future of Solar in Africa - Zimbabwe

The state endured international isolation and a 15-year guerrilla war with black nationalist forces; this culminated in a peace agreement that established de jure sovereignty as Zimbabwe in April 1980.

Zimbabwe then joined the Commonwealth of Nations, from which it was suspended in 2002 for breaches of international law by its government under Robert Mugabe and from which it withdrew in December 2003.

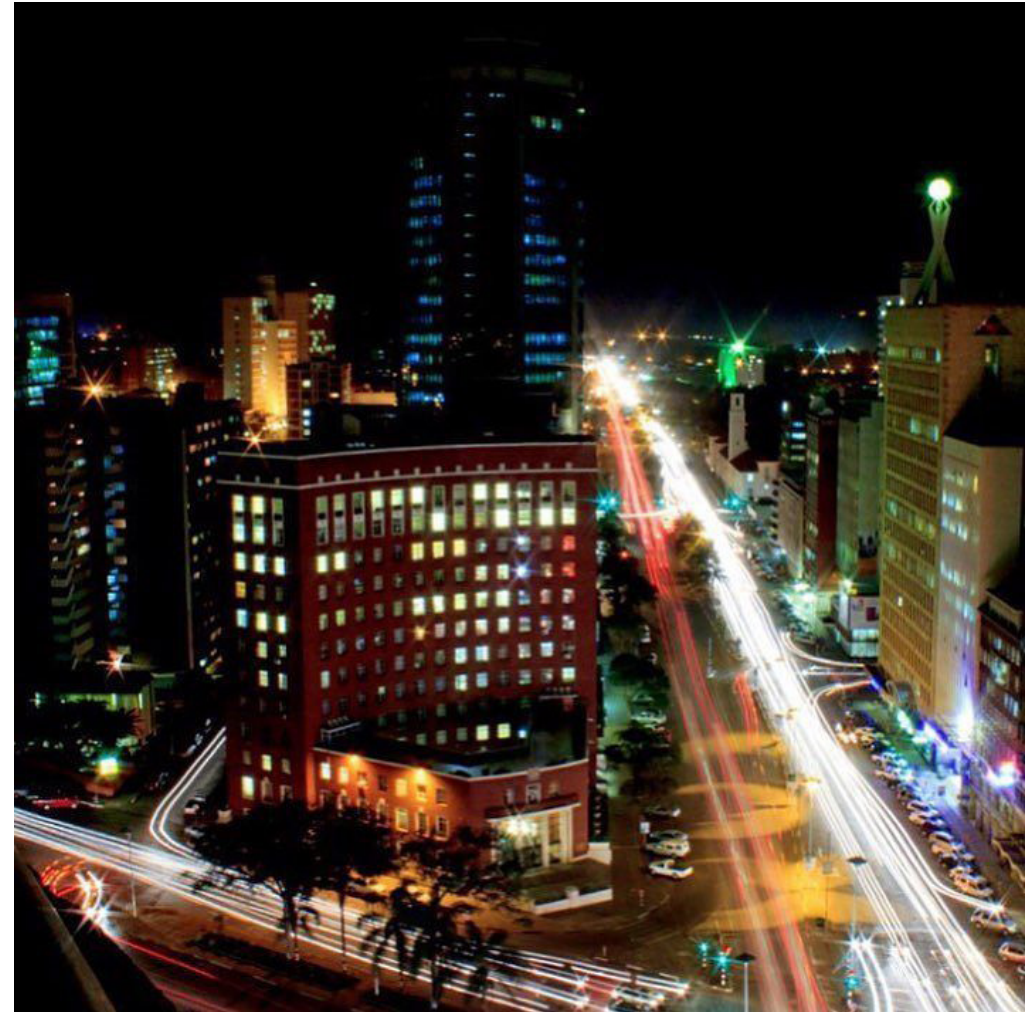
Mugabe became Prime Minister of Zimbabwe in 1980, when his ZANU–PF party won the general election following the end of white minority rule; he was the President of Zimbabwe from 1987 until his resignation in 2017.

Under Mugabe's authoritarian regime, the state security apparatus dominated the country and was responsible for widespread human rights violations.

From 2000 to 2009 the economy experienced decline and hyperinflation before rebounding after the use of currencies other than the Zimbabwean dollar was permitted, although growth has since faltered.

In 2017, in the wake of over a year of protests against his government as well as Zimbabwe's rapidly declining economy, a coup d'état resulted in Mugabe's resignation. Emmerson Mnangagwa has since served as Zimbabwe's president.

Zimbabwe is a member of the United Nations, the Southern African Development Community, the African Union, and the Common Market for Eastern and Southern Africa.



The future of Solar in Africa - Zimbabwe

Geography

Zimbabwe is a landlocked country in southern Africa, lying between latitudes 15° and 23°S, and longitudes 25° and 34°E.

It is bordered by South Africa to the south, Botswana to the west and southwest, Zambia to the northwest, and Mozambique to the east and northeast.

Its northwest corner is roughly 150 meters from Namibia, nearly forming a four-nation quadripoint.

Most of the country is elevated, consisting of a central plateau (high veld) stretching from the southwest northwards with altitudes between 1,000 and 1,600 m.

The country's extreme east is mountainous, this area being known as the Eastern Highlands, with Mount Nyangani as the highest point at 2,592 m.

The highlands are known for their natural environment, with tourist destinations such as Nyanga, Troutbeck, Chimanimani, Vumba and Chirinda Forest at Mount Selinda.

About 20% of the country consists of low-lying areas, (the low veld) under 900m.

Victoria Falls, one of the world's largest and most spectacular waterfalls, is located in the country's extreme northwest and is part of the Zambezi river.



The future of Solar in Africa - Zimbabwe

Geology

Over geological time Zimbabwe has experienced two major post-Gondwana erosion cycles (known as African and post-African), and a very subordinate Plio-Pleistocene cycle.

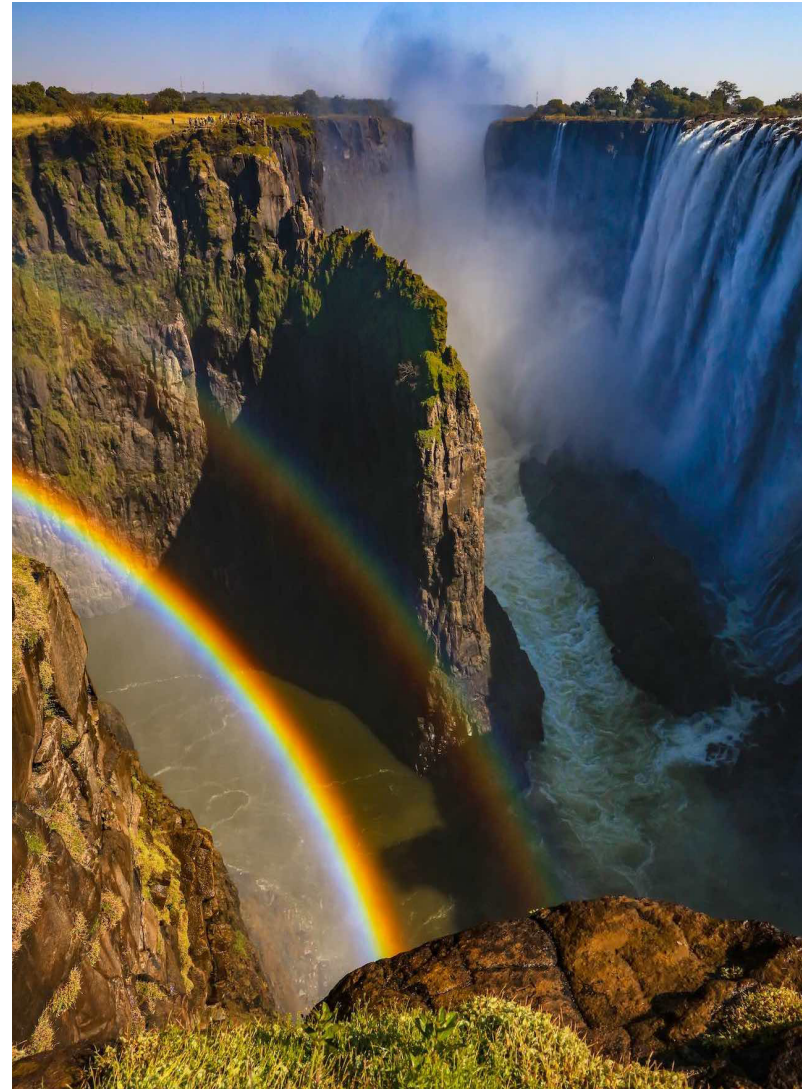
Climate

Zimbabwe has a subtropical climate with many local variations. The southern areas are known for their heat and aridity, while parts of the central plateau receive frost in winter.

The Zambezi valley is known for its extreme heat, and the Eastern Highlands usually experience cool temperatures and the highest rainfall in the country.

The country's rainy season generally runs from late October to March, and the hot climate is moderated by increasing altitude.

Zimbabwe is faced with recurring droughts. In 2019, at least 55 elephants died because of drought. Severe storms are rare.



The future of Solar in Africa - Zimbabwe

Biodiversity

Zimbabwe contains seven terrestrial ecoregions: Kalahari acacia–baikiaea woodlands, Southern Africa bushveld, Southern miombo woodlands, Zambezian Baikiaea woodlands, Zambezian and mopane woodlands, Zambezian halophytics, and Eastern Zimbabwe montane forest-grassland mosaic in the Eastern Highlands.

The country is mostly savanna, although the moist and mountainous Eastern Highlands support areas of tropical evergreen and hardwood forests.

Trees found in the Eastern Highlands include teak, mahogany, enormous specimens of strangler fig, forest Newtonia, big leaf, white stinkwood, chirinda stinkwood, knobthorn and many others.

In the low-lying parts of the country fever trees, mopane, combretum and baobabs abound. Much of the country is covered by miombo woodland, dominated by brachystegia species and others.

Among the numerous flowers and shrubs are hibiscus, flame lily, snake lily, spider lily, leonotis, cassia, tree wisteria and dombeya.

There are around 350 species of mammals that can be found in Zimbabwe.

There are also many snakes and lizards, over 500 bird species, and 131 fish species.



The future of Solar in Africa - Zimbabwe

Environmental issues

Large parts of Zimbabwe were once covered by forests with abundant wildlife.

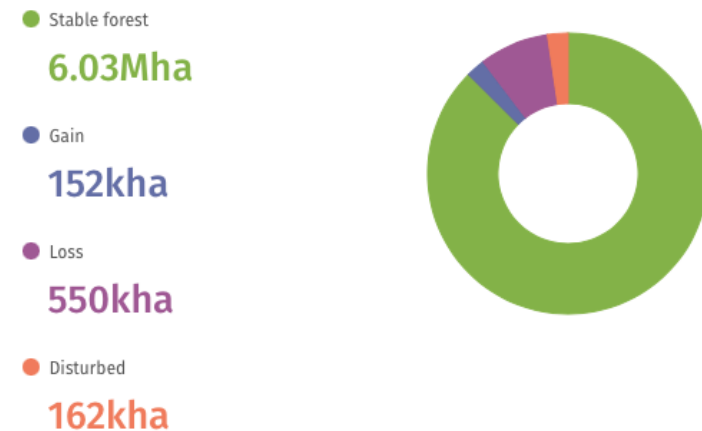
Deforestation and poaching has reduced the amount of wildlife.

Woodland degradation and deforestation caused by population growth, urban expansion and use for fuel are major concerns and have led to erosion which diminishes the amount of fertile soil.

Local farmers have been criticised by environmentalists for burning off vegetation to heat their tobacco barns.

The country had a 2019 Forest Landscape Integrity Index mean score of 6.31/10, ranking it 81st globally out of 172 countries

From 2000 to 2020, **Zimbabwe** experienced a net change of **-398kha (-5.9%)** in tree cover.



⚠ The loss total is different from annual tree cover loss, as this data was created using a different method and forest definition. For gross or annual loss information, please see the tree cover loss widget.

The future of Solar in Africa - Zimbabwe

Capital: Harare

Ethnic Groups:

African 99.4% (predominantly Shona; Ndebele is the second largest ethnic group), other 0.4%, unspecified 0.2%

Languages:

Shona (official), Ndebele (official), English (official; traditionally used for official business), 13 minority languages (official; includes Chewa, Chibarwe, Kalanga, Koisan, Nambya, Ndau, Shangani, sign language, Sotho, Tonga, Tswana, Venda, and Xhosa)

Religions:

Protestant 74.8% (includes Apostolic 37.5%, Pentecostal 21.8%, other 15.5%), Roman Catholic 7.3%, other Christian 5.3%, traditional 1.5%, Muslim 0.5%, other 0.1%, none 10.5%

Population:

Total: 15.4 million

Median age: 20.5 years

Population growth rate: 1.95%

Urban: 32.5%

Rural: 67.5%



The future of Solar in Africa - Zimbabwe

Fertility:

Birth rate: 32.77 births/1,000 population

Total fertility rate: 3.88 children born/woman

Sex ratio of population: 0.97 male(s)/female

Mortality:

Death rate: 8.51 deaths/1,000 population

Life expectancy at birth: 63.79 years

Maternal mortality rate: 458 deaths/100,000 live births

Infant mortality rate: 287.67 deaths/1,000 live births

Migration:

Net migration rate: -4.74 migrants/1,000 population

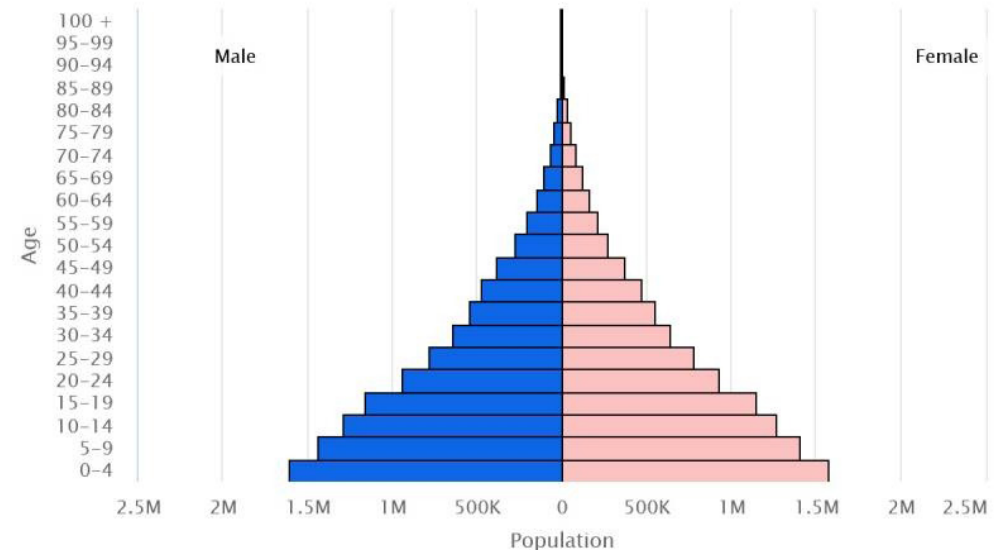
Health:

Current health expenditure: 3.4%

Physician density: 0.2 physicians/1,000 population

Adult obesity: 15.5%

Alcohol consumption per capita: 3.11 litres of pure alcohol



This is the population pyramid for Zimbabwe.

A population pyramid illustrates the age and sex structure of a country's population and may provide insights about political and social stability, as well as economic development. The population is distributed along the horizontal axis, with males shown on the left and females on the right.

The male and female populations are broken down into 5-year age groups represented as horizontal bars along the vertical axis, with the youngest age groups at the bottom and the oldest at the top. The shape of the population pyramid gradually evolves over time based on fertility, mortality, and international migration trends.

The future of Solar in Africa - Zimbabwe

Education:

Education expenditures: 3.9% of GDP Literacy: 86.5%

Population Distribution:

aside from major urban agglomerations in Harare and Bulawayo, population distribution is fairly even, with slightly greater overall numbers in the eastern half

Demographic Profile

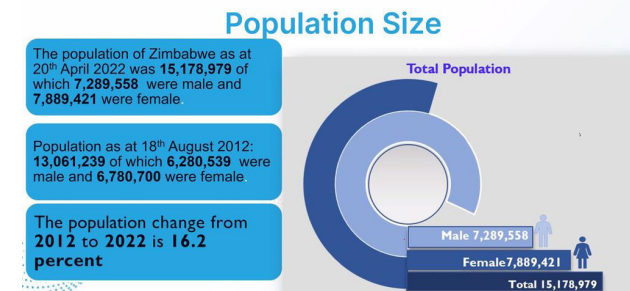
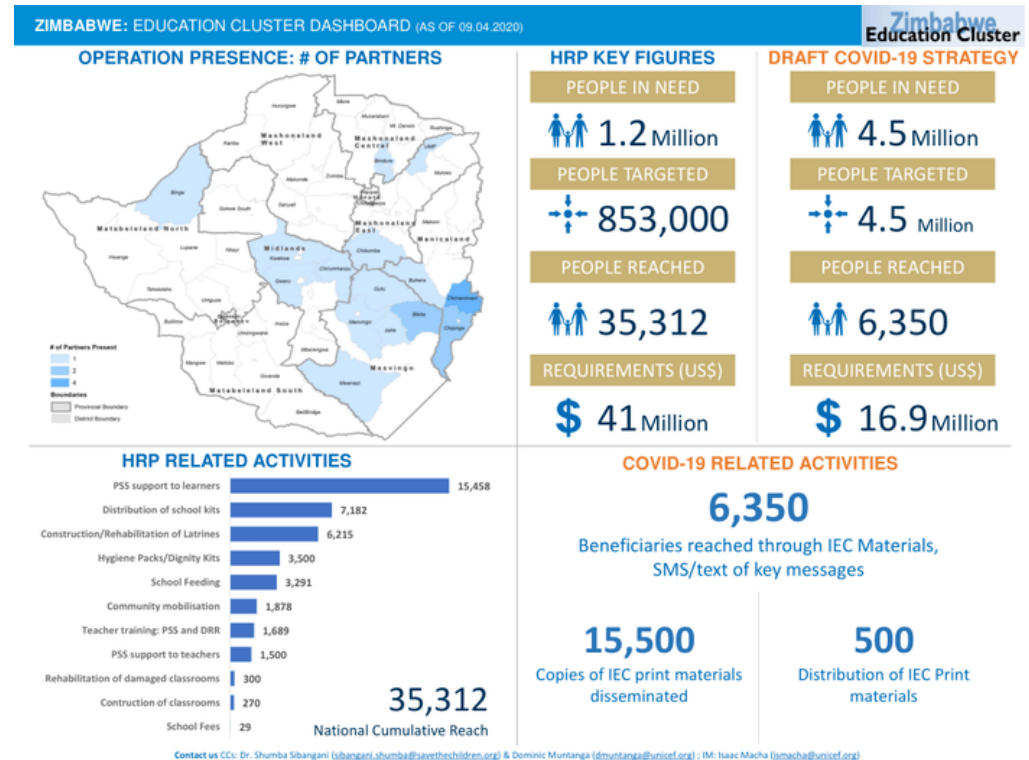
Age Structure:

Zimbabwe's progress in reproductive, maternal, and child health has stagnated in recent years.

According to a 2010 Demographic and Health Survey, contraceptive use, the number of births attended by skilled practitioners, and child mortality have either stalled or somewhat deteriorated since the mid-2000s.

Zimbabwe's total fertility rate has remained fairly stable at about 4 children per woman for the last two decades, although an uptick in the urban birth rate in recent years has caused a slight rise in the country's overall fertility rate.

Zimbabwe's HIV prevalence rate dropped from approximately 29% to 15% since 1997 but remains among the world's highest and continues to suppress the country's life expectancy rate.



The future of Solar in Africa - Zimbabwe

Historically, the vast majority of Zimbabwe's migration has been internal – a rural-urban flow.

In terms of international migration, over the last 40 years Zimbabwe has gradually shifted from being a destination country to one of emigration and, to a lesser degree, one of transit (for East African illegal migrants traveling to South Africa).

As a British colony, Zimbabwe attracted significant numbers of permanent immigrants from the UK and other European countries, as well as temporary economic migrants from Malawi, Mozambique, and Zambia.

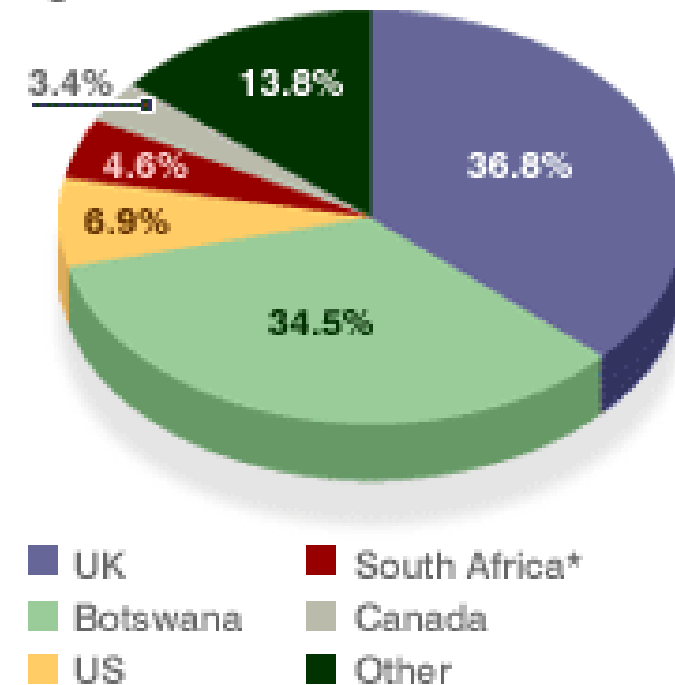
Although Zimbabweans have migrated to South Africa since the beginning of the 20th century to work as miners, the first major exodus from the country occurred in the years before and after independence in 1980.

In the 1990s and 2000s, economic mismanagement and hyperinflation sparked a second, more diverse wave of emigration.

This massive outmigration – primarily to other southern African countries, the UK, and the US – has created a variety of challenges, including brain drain, illegal migration, and human smuggling and trafficking.

MIGRANT DESTINATIONS

Percentage-by-country of the estimated 535,600 Zimbabweans who have legally migrated since 1990



* Zimbabwe Central Bank estimates at least 1.2 million people illegally migrated to South Africa during this period

SOURCE: SIRD/COM



THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

ZIMBABWE MINERALS & MINING

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Minerals & Mining

Zimbabwe's mining sector is highly diversified, with close to 40 different minerals, according to the Chamber of Mines of Zimbabwe. The predominant minerals include platinum group metals (PGM), chrome, gold, coal, and diamonds.

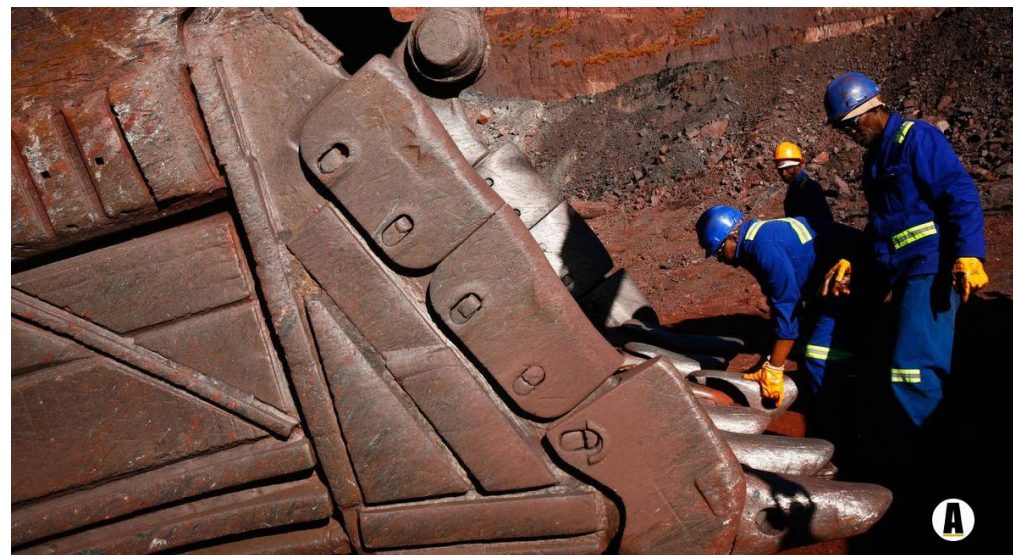
The country boasts the second-largest platinum deposit and high-grade chromium ores in the world, with approximately 2.8 billion tons of PGM and 10 billion tons of chromium ore.

The sector accounts for about 12 percent of the country's gross domestic product (GDP), and the minister of mines claims the sector has the potential to generate US\$12 billion annually by 2023 if the government addresses challenges such as persistent power shortages, foreign currency shortages, and policy uncertainties.

The government's expectations the sector would drive economic growth were dampened by COVID-19 in 2020, but there have been some initial signs of recovery in 2021 driven by improved international commodity prices.

The government intends to amend the Mines and Minerals Act to make it more progressive and investor-friendly to attract more investment.

Companies are required to export all minerals through the state-owned Minerals Marketing Corporation of Zimbabwe (MMCZ), except gold which must be sold to the Reserve Bank of Zimbabwe's (RBZ) subsidiary Fidelity Printers and Refiners (FPR).



Zimbabwe's top minerals include gold, platinum group metals (PGM), chrome, coal, diamonds, and lithium.

Compared to largely depressed mining activities in 2020 due to COVID-19 induced lockdowns, demand increased in 2021 for a wide range of commodities. Supply chain disruptions in South Africa and Russia helped increase global PGM prices in 2021.

Zimbabwe's Chamber of Mines 2021 state of mining report projected significant growth in the diamond, coal, and chrome subsectors, with PGM continuing to lead the sector.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Minerals & Mining cont...

According to the RBZ, legal exports of gold, Zimbabwe's top mineral export, increased from US\$1.2 billion in 2020 to US\$1.7 billion in 2021.

The RBZ attributed the 42 percent increase in 2021 to improved gold output and firm prices as economies recovered from COVID-19 lockdowns. Challenges including suspected smuggling, fuel shortages, and antiquated technology persisted.

FPR announced in mid-2021 that it will combat these underlying issues by allowing large-scale gold mining companies to export a portion of their bullion directly. FPR expects this measure to increase production by allowing companies to secure funding in the form of gold loans.

FPR also hopes that direct payments will help prevent the illegal export of gold, estimated at US\$1.2 billion per year by small-scale miners who extract most of the country's gold.

A 2022 Center for Natural Resource Governance report on illicit financial flows in the artisanal mining sector estimated as much as US\$1.9 billion is lost annually due to leakages.

The RBZ retracted its August 2021 announcement it would divide FPR into two separate companies and sell a majority stake in the new gold refinery business to ten mining companies in May 2022, noting FPR was now off the market. FPR remains the country's sole buyer and exporter of gold.



The consolidation of diamond mining companies into the Zimbabwe Consolidated Diamond Company in Marange and the transition to conglomerates should lead to increased investment and purchases of new mining equipment.

The consolidation led to some international firms exiting the diamond sector, though some were later invited and returned.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Minerals & Mining cont...

According to the African Mining Market, Zimbabwe's lithium deposits are the largest in Africa, and the country will become one of the world's largest lithium exporters due to growing world demand for rechargeable batteries.

The government claims the country will meet 20 percent of the world's total demand for lithium when it fully exploits its known lithium resources, and four major lithium projects are currently under development.

Lithium Processing Plant

Early in July 2023 Zhejiang Huayou Cobalt commissioned a lithium concentrator in Zimbabwe as it seeks to consolidate its position as one of the world's top battery materials producers.

Huayou acquired the Arcadia hard rock deposit, 40 kilometres outside Harare, from Australia-listed Prospect Resources (PSC.AX) for \$422 million in April 2022.

The Chinese company invested a further \$300 million to build a plant to produce 450,000 metric tons of lithium concentrates annually.

The Zimbabwe government wants lithium miners operating in the country to go beyond producing lithium concentrates and process battery-grade lithium.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Minerals & Mining - Minerals in alphabetical order

1. Agate	Nyamandhlovu, Chikomba (Charter) Lupane	19. Copper	Makonde, Kadoma, Mutare, Chirumanzu, Chegutu, Kwekwe, Shurugwi, Beitbridge, Gokwe, Bindura, Chipinge, Bikita, Insiza,
2. Aluminum	Mutare, Nyanga, Mwenezi		Makonde, Harare, Bulawayo, Shamva, Chiredzi, Nkayi, Mudzi, Chegutu, Bindura, Kwekwe, Hurungwe, Bubi, Makonde, Bikita, Gwanda, Masvingo.
3. Amazonite	Nyamandhlovu, Rushinga	20. Cordierite	Hurungwe, Beitbridge, Chimanimani, Rushinga, Makuti
4. Amethyst	Nyamandhlovu, Hurungwe, Hwange, Makonde, Lupane	21. Corundum	Beitbridge, Chiredzi, Shurugwi, Marondera, Mberengwa, Mazowe, Rushinga, Insiza, Goromonzi, Wedza, Makoni
5. Antimony	Kwekwe, Bubi, Mberengwa, Kadoma, Shurugwi		Gweru, Bubi, Beitbridge, Binga, Mwenezi, Mutate.
6. Arsenic	Bubi, Shurugwi, Mutare, Gwanda		Hurungwe
7. Asbestos	Masvingo, Gwanda, Matobo, Mberengwa, Insiza, Makonde, Umzingwane		Mutate, Beitbridge, Makonde, Mudzi, Masvingo, Rushinga.
8. Aventurine	Masvingo, Beitbridge	22. Diamond	Gutu, Masvingo, Insiza, Mberengwa, Hurungwe.
9. Barites	Kwekwe, Mwenezi	23. Diatomite	Harare, Bikita, Umzingwane, Goromonzi
10. Beryl	Hurungwe, Kariba, Goromonzi, Harare, Mudzi, Rushinga, Mutoko, Bindura, Marondera, Gutu, Buhera, Bikita, Chegutu, Hwange, Mberengwa, Gweru	24. Dolomite	Hwange, Chiredzi, Kwekwe, Lupane, Nkayi, Kadoma, Kwekwe
11. Bismuth	Gwanda, Insiza, Goromonzi, Hwange	25. Emerald	Mwenezi, Beitbridge
12. Cesium	Mudzi, Bikita, Goromonzi	26. Feldspar	Hwange, Guruve, Binga
13. Calcite	Hwange, Bindura, Chiredzi, Mwenezi	27. Fireclay	Beitbridge, Hurungwe, Mudzi, Guruve, Rushinga, Marondera
14. Chromium	Mberengwa, Guruve, Makonde, Gweru, Kwekwe, Shurugwi, Chegutu, Kadoma, Gwanda, Insiza, Masvingo, Chirumanzu	28. Flint clay	Hwange, Hurungwe, Kariba, Makonde
15. Citrine	Marondera, Harare, Goromonzi	29. Fluorite	Beitbridge
16. Clay	Harare, Bulawayo, Gwanda, Gweru	30. Garnet	All Districts
17. Coal	Over 11 Billion tones of in - situ reserves. Gokwe, Chiredzi, Beitbridge, Mwenezi, Hwange, Lupane, Binga, Kariba, Hurungwe, Bikita	31. Graphite	
18. Cobalt	Kwekwe, Insiza, Shamva, Bubi, Bindura	32. Gypsum	
		33. Gold	

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

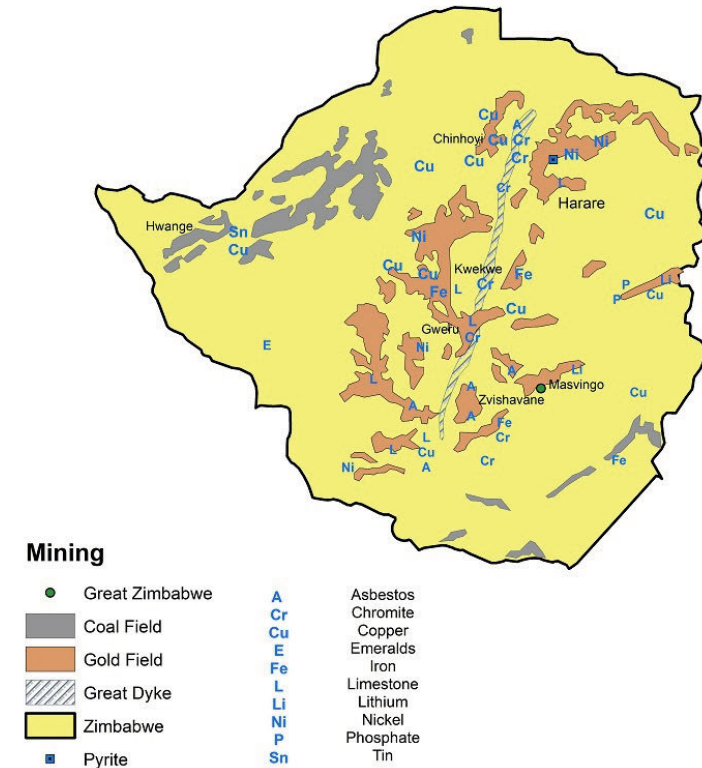
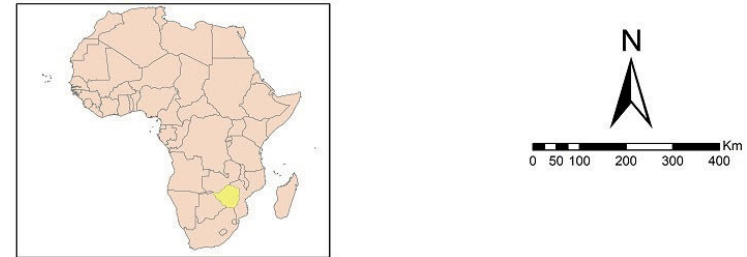
Minerals & Mining cont...

34. Iron	Kwekwe, Mberengwa, Harare, Kwekwe, Buhera, Gweru, Charter, Chiredzi, Masvingo, Mazowe, Kadoma.	51. Platinum 2	Kwekwe, Makonde, Shurugwi, Chegutu, Centenary
35. Jade	Masvingo	52. Pyrite	Shurugwi, Gwanda, Mazowe, Kadoma, Bulilimangwe, Shamva, Hwange.
36. Kaolin	Kwekwe, Mutatre, Bubi, Hwange, Kadoma, Mazowe, Harare, Umzingwane, Nkayi, Chegutu	53. Salt	Mwenezi
37. Kainite	Hurungwe, Nyanga, Mudzi, Rushinga	54. Sapphire	Mudzi
38. Lead	Mberengwa, Kwekwe, Gokwe, Mutare, Wedza, Hwange	55. Selenium	Makonde
39. Limestone	Mberengwa, Gwanda, Bindura, Shamva, Mazowe, Kadoma, Umzingwane, Gweru, Chegutu, Chimanimani, Mudzi, Harare, Hurungwe	56. Silica	Gweru, Kwekwe, Makonde, Chegutu, Gokwe, Harare, Goromonzi
40. Lithium	Goromonzi, Mudzi, Buhera, Bikita, Chegutu, Hwange, Harare, Insiza, Rushinga, Mutoko, Mutare, Hwange	57. Sillimanite	Hurungwe
41. Magnetite	Gwanda, Nyanga, Kadoma, Mwenezi, Insiza, Buhera, Mberengwa, Beitbridge, Gweru	58. Silver	Makoni, Makonde, Kwekwe
42. Manganese	Kwekwe, Gweru, Makonde, Mberengwa.	59. Talc	Bubi, Guruve, Insiza, Nyanga, Mutare, Mt Darwin, Mberengwa, Goromonzi, Mutoko, Wedza, Kwekwe, Makoni
43. Mercury	Bubi, Kadoma	60. Tantalum	Hurungwe, Guruve, Kariba, Mudzi, Mutoko, Shamva, Bindura, Harare, Goromonzi, Murehwa, Mt Darwin, Rushinga, Mazowe, Marondera, Gutu, Masvingo, Buhera, Bikita, Mutare, Hwange, Chivhu, Mberengwa, Chimanimani, Makoni, Insiza
44. Mica	Hurungwe, Rushinga, Kariba, Hwange	61. Tin	Hurungwe, Mudzi, Shamva, Bindura, Goromonzi, Harare, Rushinga, Mt Darwin, Nyanga, Gutu, Bikita, Hwange, Masvingo, Mutare
45. Molybdenum	Kwekwe, Insiza, Shurugwi, Makonde, Chipinge, Gweru, Mutare	62. Topaz	Hurungwe, Gweru, Mutare
46. Mtorolite	Guruve, Mutare	63. Tungsten	Hurungwe, Kariba, Shamva, Mazowe, Rushinga, Bindura, Guruve, Mt Darwin, Harare, Mudzi, Goromonzi, Bulawayo, Insiza, Matobo, Gwanda, Umzingwane, Bubi, Buhera, Mberengwa, Kadoma, Bikita, Shurugwi, Mutare, Chipinge, Chegutu, Kwekwe,
47. Nickel	Bubi, Makonde, Kwekwe, Insiza, Guruve, Shamva, Shurugwi, Matobo, Chegutu, Bindura, Gweru.		
48. Ochre	Gweru, Kwekwe		
49. Palladium	Kwekwe, Makonde, Shurugwi, Chegutu		
50. Phosphate	Buhera		

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Minerals & Mining cont...

63. Tungstan cont..	Chiredzi, Wedza, Gweru, Hwange, Masvingo, Makoni
64. Uranium	Hwange, Hurungwe, Mutare, Guruve, Hwange, Binga
65. Vanadium	Mt Darwin, Guruve, Bulawayo
66. Vermiculite	Buhera, Mudzi
67. Zinc	Kwekwe, Gokwe, Nyanga





THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

ZIMBABWE POWER GENERATION

The future of Solar in Africa - Zimbabwe

Zimbabwe Power

Zimbabwe has an installed electricity generation capacity of about 2,300 MW, however the actual capacity is only around 1400 MW against a peak demand of about 1700MW, and winter peak maximum demand of about 2200MW thus, creating a shortfall of about 1000 MW during peak periods

The Zimbabwe Power Company's (ZPC) thermal plants are very old and keep breaking down.

There are three small coal power plants in Harare, Munyati, and Bulawayo that have installed capacities of at least 80 MW but most of the time, the output at each plant is 0 MW.

Then there is 920 MW at Hwange where breakdowns are also common. The plant rarely reaches 500 MW, usually hovering around 300 MW.

However it should be noted ZPC is also recently added two new 300 MW units at Hwange, at a cost of \$1.4Billion.

The country's other major plant is the 1,050 MW hydropower plant in Kariba.

This plant is usually very reliable, however, due to the low rainfalls in the region, ZPC has had to curtail generation to about 300 MW. This is the second time in 3 years low water levels are affecting generation at the plant and implement a load shedding program. The last time was in 2019, as such, climate change induced droughts are a major concern now.



The future of Solar in Africa - Zimbabwe

Energy - Electricity:

electrification - total population: 53% (2019)

electrification - urban areas: 89% (2019)

electrification - rural areas: 36% (2019)

installed generating capacity: 2.473 million kW (2020 est.)

consumption: 10,928,240,000 kWh (2019 est.)

exports: 504 million kWh (2019 est.)

imports: 1.612 billion kWh (2019 est.)

transmission/distribution losses: 1.491 billion kWh (2019 est.)

Electricity generation sources:

fossil fuels: 32.9% of total installed capacity (2020 est.)

nuclear: 0% of total installed capacity (2020 est.)

solar: 0.1% of total installed capacity (2020 est.)

wind: 0% of total installed capacity (2020 est.)

hydroelectricity: 65.3% of total installed capacity (2020 est.)

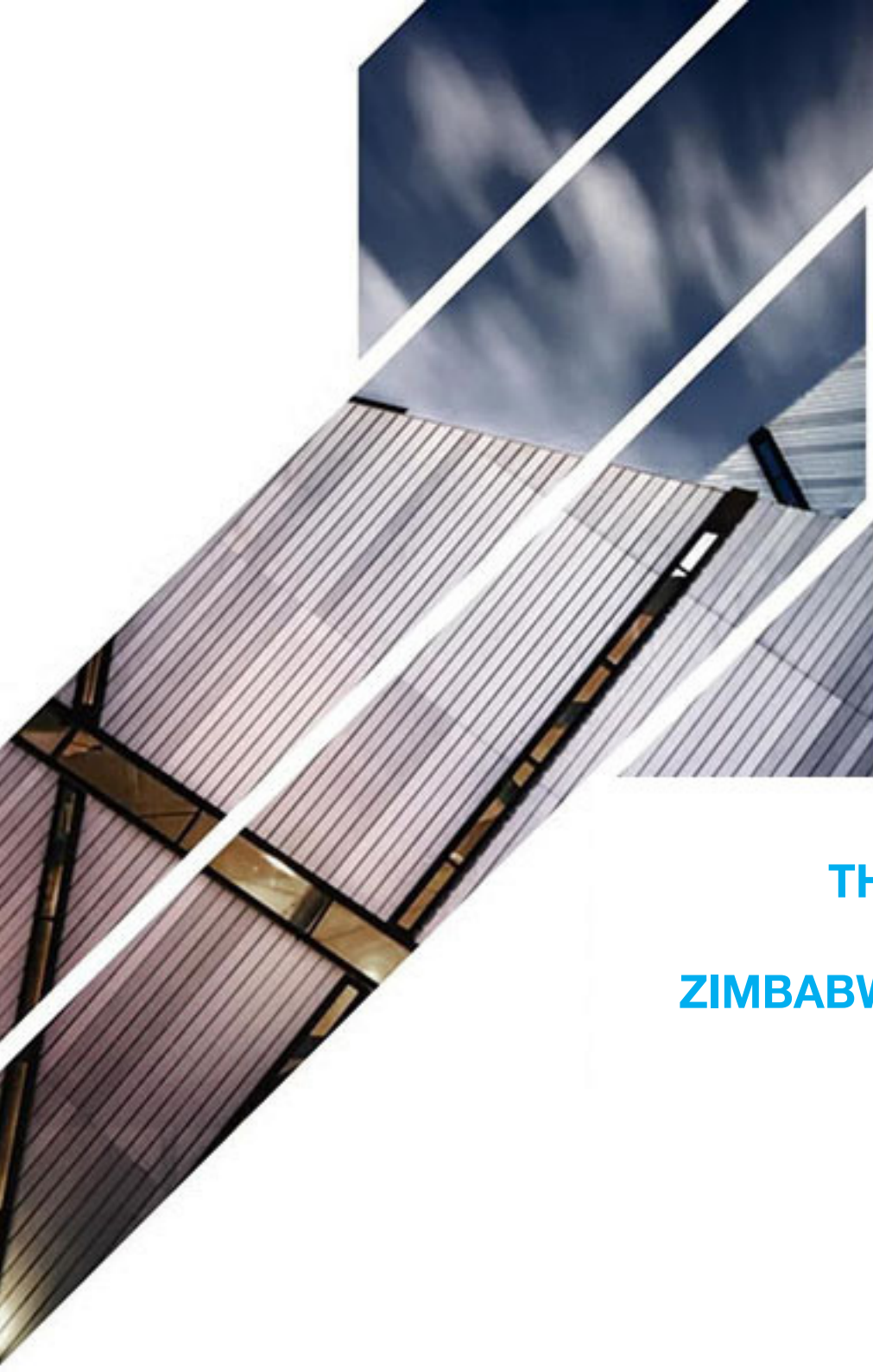
tide and wave: 0% of total installed capacity (2020 est.)

geothermal: 0% of total installed capacity (2020 est.)

biomass and waste: 1.7% of total installed capacity (2020 est.)

Zimbabwe's electricity infrastructure





THE FUTURE OF SOLAR IN AFRICA
ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

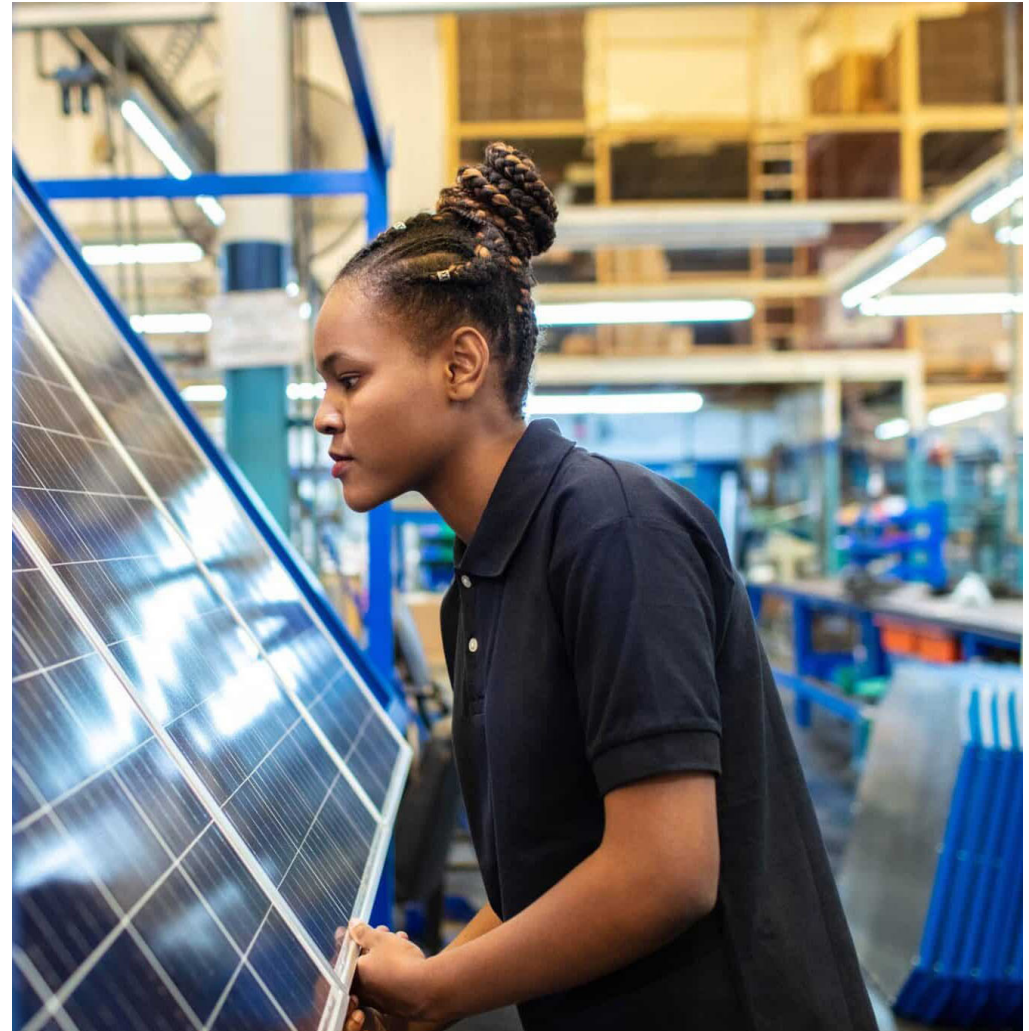
The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Zimbabwe National Solar Program Overview

The Zimbabwe National Solar Program (ZNSP) is a multi-disciplined project designed to not only develop a national program of Solar Power Generation developments, that meet the requirements of the Zimbabwean Government's Implementation Agreement (GIA) for solar IPP projects, but also to attract overseas investment by establishing relationships with established Solar PV and Lithium Battery manufacturers to partner and develop Manufacturing and/or Assembly plants in Zimbabwe.

Employment would not just be within the manufacturing and/or assembly of Solar PVs and Lithium power storage, but also within the sphere of research and development, design and construction, as well as maintenance of delivered Solar Power projects in Sub Sharan Africa.

To ensure a future pool of qualified Zimbabwean specialists in the field the ZNSP project encompasses Education, such as College courses on Renewable Energy as well as University Degree Courses.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Solar Farm Development

The catalyst of the proposed Zimbabwe National Solar Program (ZNSP) is the \$540Million **Chemagora Solar Farm in Zhombe**.

The developers, Chemagora Solar Farm Consortium, a wholly indigenous owned Zimbabwean company, is a joint venture between;

- * The Ministry of Lands, Agriculture, Fisheries, Water and Rural Development
- * African Renaissance Sustainable Development(ARSD) a nonprofit partnership incorporating Telliguss Energy, a private agricultural engineering consultant,
- * The Rio Tinto Agricultural College in Zhombe communal area of Midlands Province.

The 500MWp Solar Plant is planned to be installed at Rio Tinto in Zhombe, along Kwekwe Gokwe Highway, Midlands Province (Zimbabwe).



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Development Stages

PHASE	DETAILS	IMPLEMENTATION PERIOD	ESTIMATED CAPEX COST (USD)	ESTIMATED OPEX COST (USD)
1	5Mwp proof of concept	7months	5,400,000.00	2,700,000.00
2	195MWp	18months	210,600,000.00	2,106,000.00
3	3000MWP	32 months	324,000,000.00	3,240,000.00
totals	500MWp	57 months	540, 000,000.00	8,046,000.00

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Technical Aspects

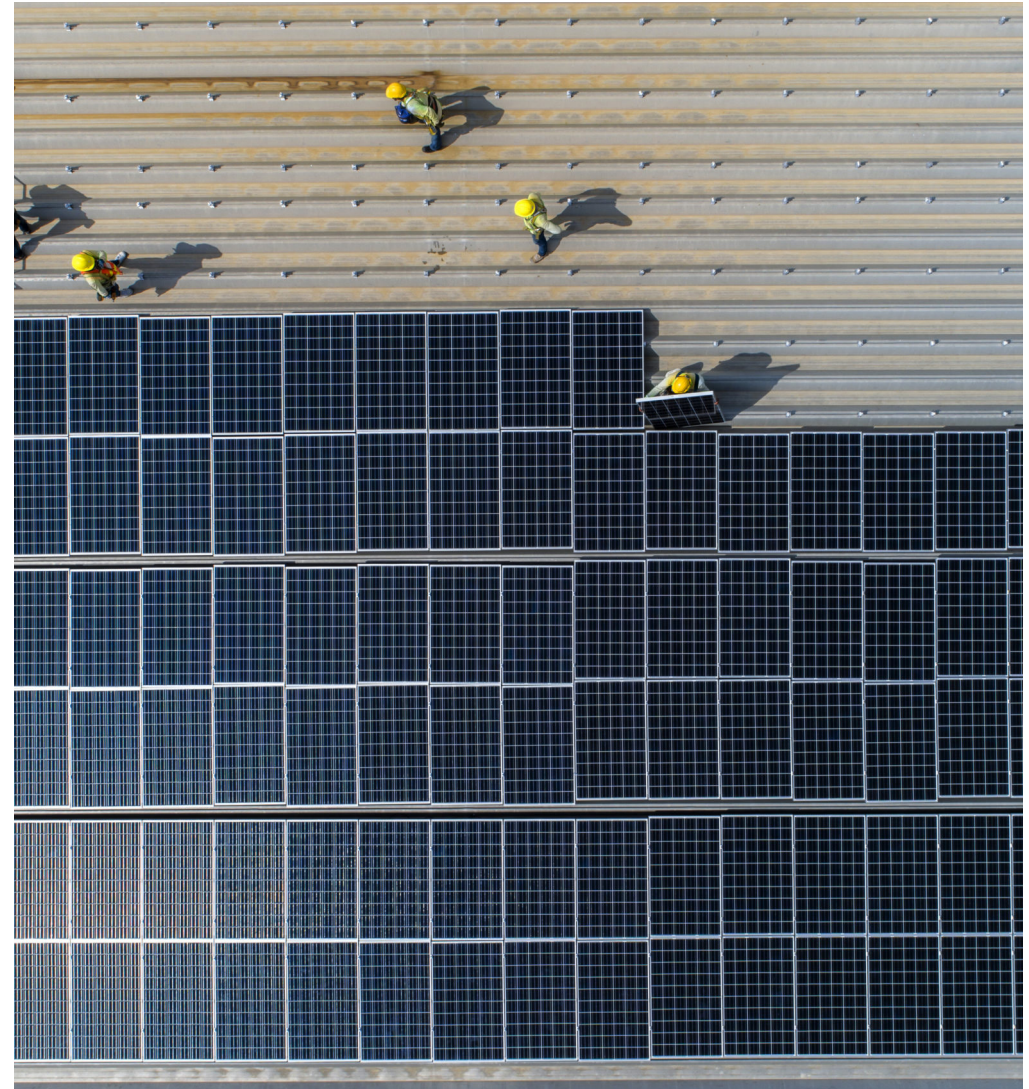
The proposed project will be a grid tied; ground mounted 500MWPV Solar plant. Solar panels, Inverters and other system components will be sourced from reputable international manufacturers.

A SCADA system will enhance both internal and external communication while in-built protective devices will reduce associated technical risks.

Engineering, Procurement, Construction and Operation and Maintenance (O&M) will be through local and international partners.

The project will create up to 2000 direct construction jobs during the approximately 36 months construction period.

Fifty additional jobs will be created to operate and maintain the Solar plant during its expected 25-year life-span, providing long term employment opportunities and associated benefits for local businesses and services.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Quantified Generation Elements

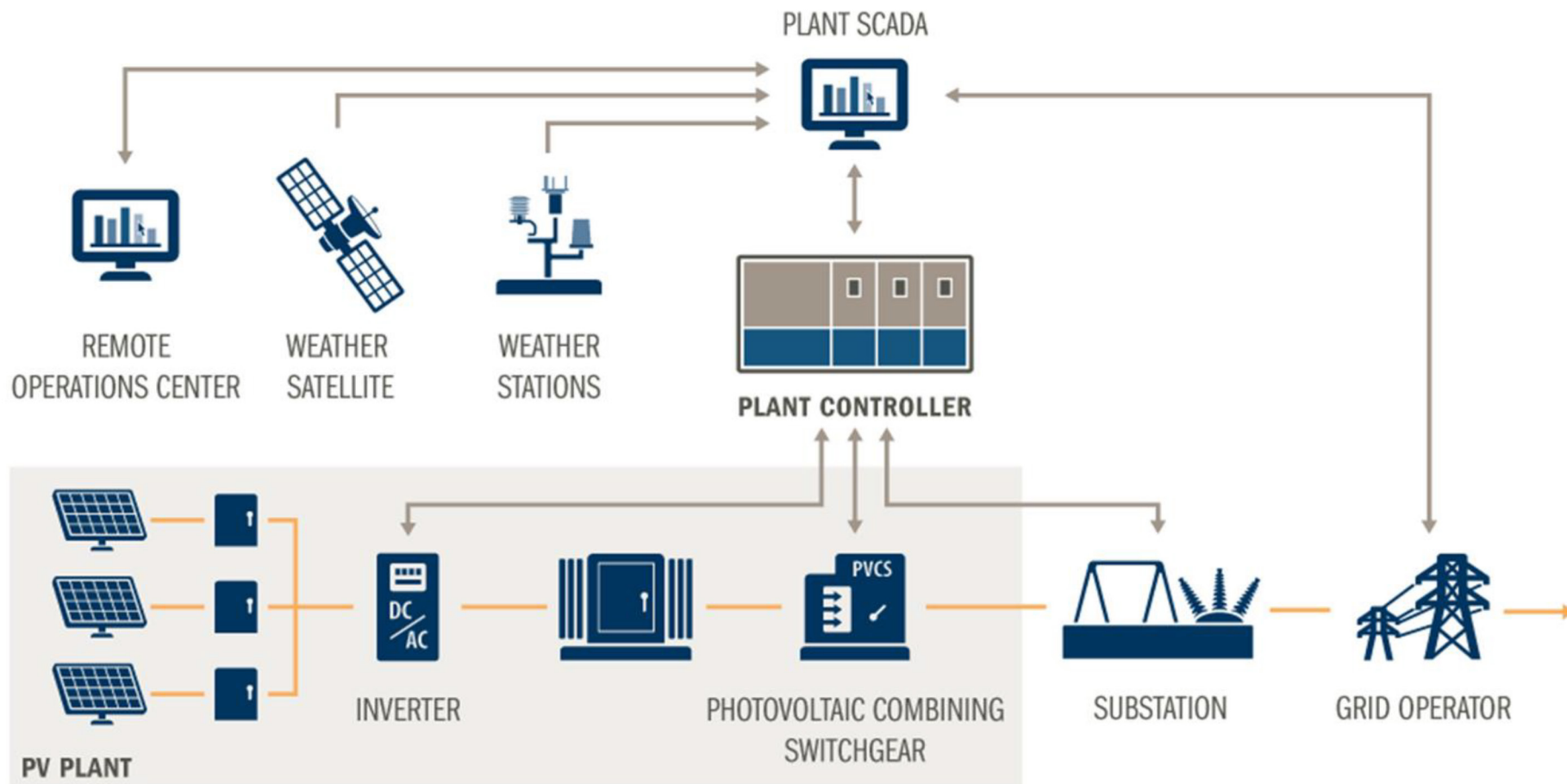
Overall Layout:

- * 909,090 panels (monocrystalline, bifacial 550Wp each)
- * 20 X 2 0MWp Transformer stations / blocks
- * 200 X 2.5MWp central invertors
- * 500MWp capacity
- * Mounting structures shall be ground mounted with 8,117 single axis trackers.
- * 3 X 250 MVA OLTC auto transformers for the delivery station
- * Outdoor delivery station switchgear station
- * SCADA ,monitoring and control system



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Key Elements of a Solar Power Generation Plant



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Sunshine Hours per Day

Sunshine & Daylight Hours in Harare, Zimbabwe

The data indicates sunshine hours in Harare range between 5:50 for every day in February & December & 9:24 to each day in August

The longest day of the year is 13:04 long and the shortest day is 10:55 long.

The longest day is 2:08 longer than the shortest day.

There is an average of 2871 hours of sunlight per year (of a possible 4383) with an average of 7:51 of sunlight per day.

It is sunny 65.5% of daylight hours.

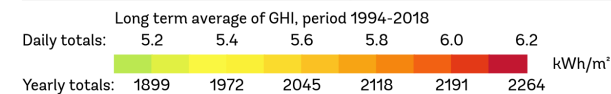
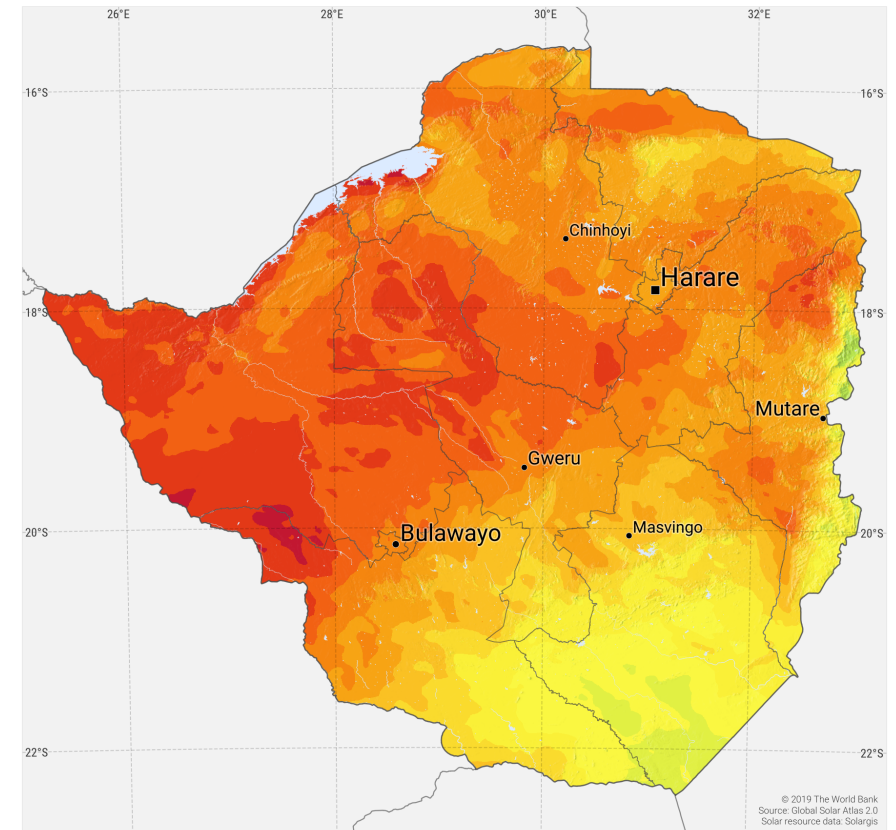
The remaining 34.5% of daylight hours are likely cloudy or with shade, haze or low sun intensity.

At midday the sun is on average 69.7° above the horizon at Harare.

SOLAR RESOURCE MAP

GLOBAL HORIZONTAL IRRADIATION

ZIMBABWE



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The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Sunshine Hours per Day cont...

Sunrise and sunset in the most important cities of Zimbabwe

The cities are ordered by their geographic position from east to west, so in an approximate direction of the sun's course. Since the orbit around the sun is elliptical, sunrise or sunset never happen on a whole longitude at the same time. All data given for July 9th., localtime in Zimbabwe

City	Sunrise	Sunset	Hours of daylight
Mutare	06:21 am	05:27 pm	11:05 h
Marondera	06:25 am	05:32 pm	11:08 h
Bindura	06:24 am	05:35 pm	11:11 h
Chitungwiza	06:26 am	05:35 pm	11:09 h
Harare	06:26 am	05:35 pm	11:09 h
Masvingo	06:31 am	05:32 pm	11:01 h
Norton	06:27 am	05:36 pm	11:09 h
Chinhoyi	06:28 am	05:39 pm	11:11 h
Chegutu	06:30 am	05:38 pm	11:08 h
Zvishavane	06:34 am	05:34 pm	11:00 h
Kadoma	06:31 am	05:39 pm	11:07 h
Gweru	06:34 am	05:37 pm	11:03 h
Kwekwe	06:33 am	05:38 pm	11:05 h
Bulawayo	06:40 am	05:41 pm	11:01 h
Victoria Falls	06:47 am	05:56 pm	11:09 h

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Sunshine Hours per Day cont...

Sunrise and sunset by month (Harare)

Month	Sunrise	Sunset	Hours of daylight
January	05:31 am	06:38 pm	13:07 h
February	05:48 am	06:31 pm	12:43 h
March	05:57 am	06:12 pm	12:15 h
April	06:03 am	05:47 pm	11:44 h
May	06:12 am	05:31 pm	11:19 h
June	06:23 am	05:29 pm	11:06 h
July	06:25 am	05:37 pm	11:12 h
August	06:14 am	05:46 pm	11:33 h
September	05:50 am	05:51 pm	12:01 h
October	05:25 am	05:57 pm	12:31 h
November	05:10 am	06:09 pm	12:59 h
December	05:13 am	06:27 pm	13:14 h

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Sunshine Hours per Day cont...

	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Annual</u>
 Average Sunlight Hours/ Day	08:48	09:23	09:24	09:05	06:54	05:50	06:17	06:24	06:54	08:12	08:36	08:24	07:51
 Average Daylight Hours & Minutes/ Day	11:09	11:31	12:01	12:32	12:58	13:10	13:03	12:42	12:13	11:42	11:16	11:03	12:00
 Sunny & (Cloudy) Daylight Hours (%)	80 (20)	82 (18)	79 (21)	73 (27)	54 (46)	45 (55)	49 (51)	51 (49)	57 (43)	71 (29)	77 (23)	77 (23)	66 (34)
 Sun altitude at solar noon on the 21st day (°).	51.6	60	71.4	81.9	86.1	84.5	86.7	81.9	71.7	60.2	51.9	48.7	69.7

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

CHEMAGORA PV: Plant Generation Potential

month	Midlands Monthly Average Global radiation(MJ/m ²)	KWh/m ²	No of days	Monthly Energy Generation(GWh)
Jan	23.3	6.47	31	100.30
Feb	22.2	6.17	28	86.38
March	21.5	5.97	31	92.50
April	19.6	5.44	30	81.6
May	17.5	4.86	31	75.33
June	16	4.44	30	66.60
July	17	4.72	31	73.16
Aug	19.9	5.53	31	82.95
Sept	22.8	6.33	30	94.95
Oct	23.6	6.56	31	101.68
Nov	23.2	6.44	30	96.60
Dec	21.9	6.08	31	94.05

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Condensed Financials

- * **Generation capacity:** 500 MW
 - * **Payback/Positive cash flow year:**
Initial investment: USD540 million
 - * **Technology choice:** monocrystalline solar panels
 - * **Lifespan:** 20-25 years
 - * **Gross Income/year:** USDmillion TBA
 - * **Expenditure/year:** USDmillion TBA
 - * **Margins/year:** USD million for debt, taxation etc, TBA
 - * **Investment model:** Both equity finance and long term loans being pursued
 - * Secrecy and Non disclosure agreements and Memorandum of Agreement/Service contract
- Options:**
- * National sources:
 - * International financing being sort
 - * Engaged promoters: [3 considered]

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Compliance Issues

- ✓ **Change of Land use:** Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement Granted Authority for change of land use from agric to industrial for 1000 hectares
- ✓ **Grid Impact Assessment (GIA):** ZETDC yet to conduct the Grid Impact Assessment and approve it.
- ✓ **Zimbabwe Energy Regulatory Authority (ZERA) Generation License:** ZERA yet to awarded to chemagora Generation License for a 500Mega Watt Solar Farm
- ✓ **An Environmental Impact Assessment (EIA)** is yet to be conducted for the project. PPA to be submitted to the Environmental Management Agency (EMA)
- ✓ **PPA** yet to be negotiated and concluded/signed with ZETDC.

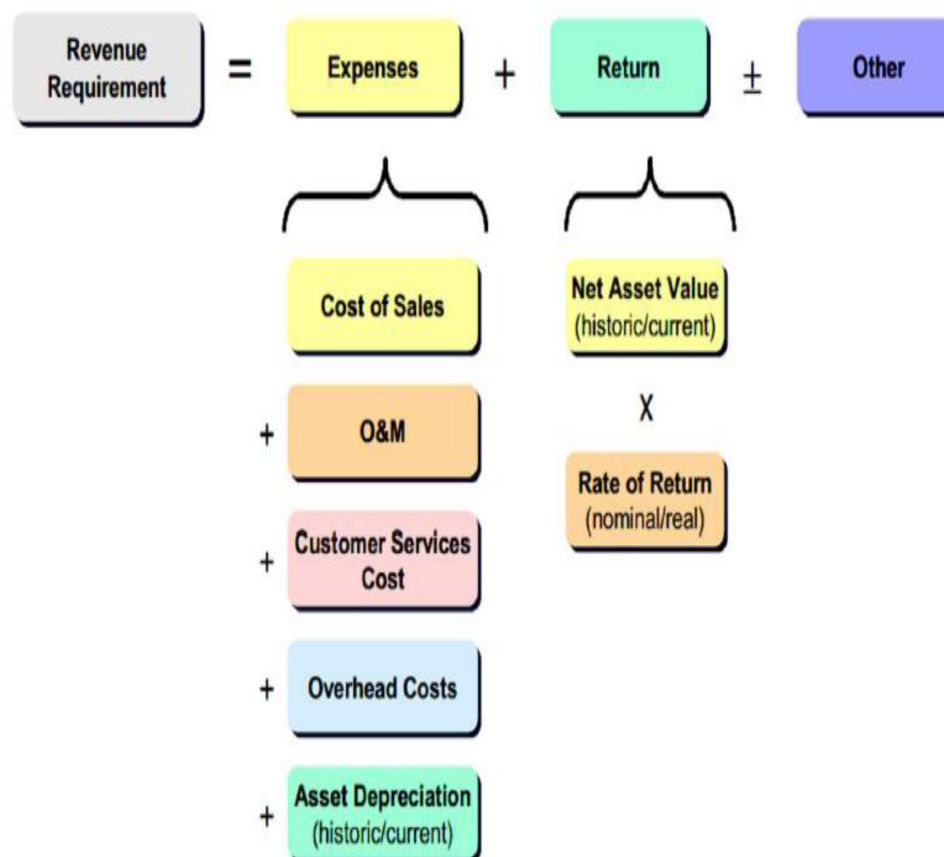
The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Compliance Issues cont...

✓ ZETDC Transmission Connection Agreement (TCA):
pending

✓ ZERA/ZETDC Tariff Award:
pending
(US\$0.---
cents/KWH)

✓ ZETDC Power Purchase Agreement (PPA): pending



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Original Roll-out Plan

	<u>Activity</u>	<u>Original Time-line</u>	<u>Comments</u>
1.	Issuance of Solar Generation Licence	March 2023	In progress
2.	Conclusion of PPA negotiations with ZETDC	may 2023	In progress
3.	Issuance of EIA Certificate	[2 months after PPA]	EIA yet to be conducted. Awaits submission to EMA with PPA
4.	Reaching financial closure	31 june 2022	Actively seeking for Financing arrangement
5.	Commencement of construction	9 months after reaching financial closure	
6.	Completion of Construction	36 months after commencement of construction	
7.	Commissioning	6 months after completion of construction	
8.	Commercial Operation Date	10 day after commissioning	

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Significance of Project (Prescribed Asset Status)

- ☐ Supplies an environmentally clean form of energy
- ☐ Produces energy using a locally available resource (solar) to meet high power needs for the country.
- ☐ Eases out national grid outages.
- ☐ Mitigates importation pressures (power deficits will be alleviated as industry, agriculture and mining get revived)
- ☐ Job creation (directly and indirectly)
- ☐ Lessons learnt will be shared by new players for better power productivity.
- ☐ As partners optimise processes, they stand to create intellectual property

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

In addition to the Chemagora Solar Farm project there are many other projects that can be incorporated into the Zimbabwe National Solar Program (ZNSP).

Currently Independent Power Providers contribute less than 2% to Zimbabwe's electricity generation mix.

Here is where the other big problem is in Zimbabwe's electricity sector. Despite having over 100 projects from IPPs with licenses to generate electricity from solar PV and wind etc., very few of them have taken off.

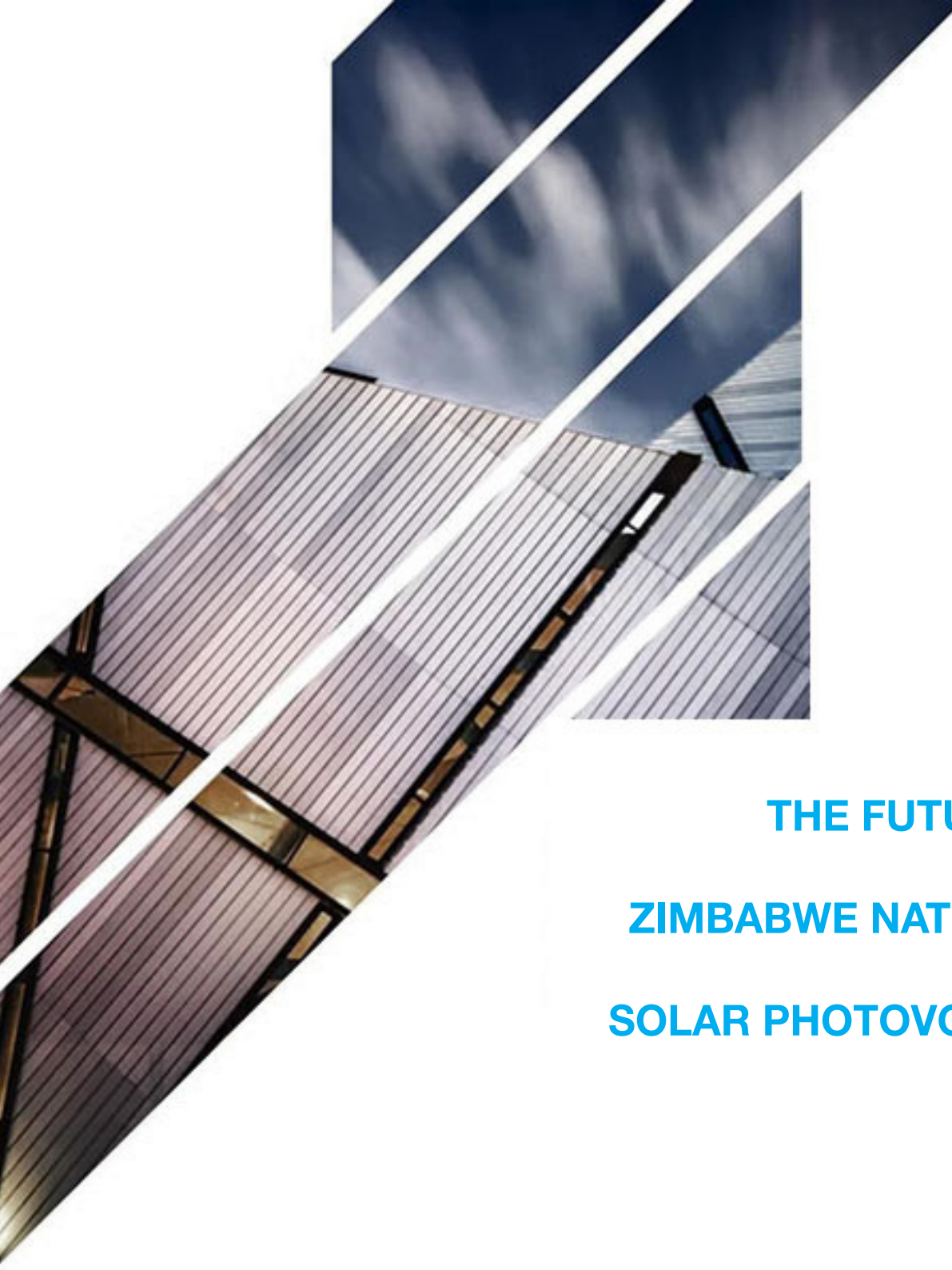
Developers have been struggling to reach financial closure due to the chaotic currency environment in Zimbabwe over the last decades.

The Zimbabwean Government clearly desires to catalyze growth in the solar PV sector under the standardized Government Implementation Agreement (GIA) for all solar IPP projects.

Zimbabwe's minister of finance recently announced some new measures to help the sector. The Finance minister said "A key ingredient to the successful implementation of the solar IPPs projects is a bankable GIA with an economic tariff. The GIA has three major components which are; Project Development Support Agreement; Power Purchase Agreement; and The Reserve Bank Undertaking for Foreign Currency Convertibility and Transfer."

Here is a summary of the solar IPP projects recommended for government support. The solar IPP projects listed will generate about 1000 MW for an estimated cost of US\$1Billion:

No.	IPP	CAPACITY MW	LOCATION
1	Lueven Investments	10	Millgrove Farm, Marondera
2	TD Energy	40.8	Hunyani Park, Norton
3	The Solar Group	50	Chertsey Farm, Gweru
4	Sinogy Power	75	Chapfuche Farm, Beitbridge, Matabeleland South Province.
5	MoPower	50	Orient Farm of Somabhula in Gweru, Midlands Province
6	Africa Oracle	25	Antelope Estate, Chivhu
7	Murombedzi Solar	10.5	Murombedzi Industrial Park, Zvimba
8	New Glovers Solar	10	Glovers Farm, Munyati, Kwekwe
9	DeGreen Rhino	50	Rufaro Farm, Marondera
10	Solarwise Energy	20	Nuanetsi Ranch, Chiredzi District, Masvingo Province
11	Triangle Solar System	45	Nuanetsi Range A, Chiredzi District, Masvingo Province
12	Gombe Power Solutions	50	Twyford Estate, Selous, Mashonaland West Province
13	TD Energy – Ecosoft	36	Lot 3 of Stuhm Farm, Goromonzi District, Mash East Province
14	Hapnust Investments	5	Kamureza in Hurungwe District, Mashonaland West Province
15	Custodian Energy	50	Puri Farm, Alaska, Mashonaland West Province
16	Zororo Energy	50	Randhurst Grange Estate, Bromley in Mashonaland E. Province
17	Camelzone Enterprises	50	Sans Souci Farm, Mashava, Masvingo Province
18	AF Power	50	Upper Nondwene Estate in Bulawayo District.
19	Acacia Energy	50	Chipangayi Growth Centre, Chipinge Dist, Manicaland Province
20	Equinox Energy	10	Makaha 30, Mudzi Mutoko, Mashonaland East Province
21	Parvalue	50	Westgate Suburb, Donnington West, Bulawayo
22	Matshela Energy	100	Timber Farm, Gwanda, Matabeleland South Province
23	Pito Investments	25	Mvuma, Chirumanzu
24	CoreZim Mining	20.6	Sessombi 11 Farm, Kwekwe, Midlands
25	EPCA South	5	Gweru Aerodrome, Gweru, Midlands Province
26	Yellow Africa	50	Division of 3 Broad Acres, Matabeleland North Province
27	Indo Africa	10	Rourka Farm, Mutorashanga. Mazowe District
TOTAL CAPACITY		997.9	



THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

SOLAR PHOTOVOLTAIC MANUFACTURING BASICS

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Photovoltaic (PV) technologies – more commonly known as solar panels – generate power using devices that absorb energy from sunlight and convert it into electrical energy through semiconducting materials. These devices, known as solar cells, are then connected to form larger power-generating units known as modules or panels.

Solar manufacturing encompasses the production of products and materials across the solar value chain. While some concentrating solar-thermal manufacturing exists, most solar manufacturing in the United States is related to photovoltaic (PV) systems. Those systems are comprised of PV modules, racking and wiring, power electronics, and system monitoring devices, all of which are manufactured.

PV Module Manufacturing

SILICON PV

Most commercially available PV modules rely on crystalline silicon as the absorber material. These modules have several manufacturing steps that typically occur separately from each other.

Polysilicon Production – Polysilicon is a high-purity, fine-grained crystalline silicon product, typically in the shape of rods or beads depending on the method of production. Polysilicon is commonly manufactured using methods that rely on highly reactive gases, synthesized primarily using metallurgical-grade silicon (obtained from quartz sand), hydrogen, and chlorine.

PV Module Manufacturing cont...

In one process, called the Siemens process, the silicon-hydrogen-chlorine compound gas passes over a heated silicon filament, breaking the molecular bonds and depositing the silicon atom on the filament, which ultimately grows into a large U-shaped polysilicon rod. The hydrogen and chlorine atoms are reused in a closed cycle. To keep the filament from contaminating the high-purity poly, the filament itself is also made of pure silicon. In another method, small silicon beads sit at the bottom of an inverted cone-shaped vessel where a compound gas of silicon and hydrogen is pumped in, causing the small beads to float near the surface. Heating the vessel causes the silicon-hydrogen bonds to break, which results in the silicon atoms depositing onto the small beads until they are too heavy to float and drop to the bottom of the vessel where they are harvested, ready for use.

Ingot and Wafer Production – To turn polysilicon into wafers, polysilicon is placed into a container that is heated until the polysilicon forms a liquid mass. In one process, called the Czochralski process, a large cylindrical ingot of monocrystalline silicon is grown by touching a small crystalline seed to the surface of the liquid and slowly pulling it upward. In another process, called directional solidification, the liquid mass is slowly cooled until it solidifies from the bottom up, forming a large-grained multicrystalline-silicon ingot. Silicon ingots are then sliced into very thin wafers using diamond-coated wire saws. The silicon sawdust that is created is called kerf. Though less common, kerfless wafer production can be accomplished by pulling cooled layers off a molten bath of silicon, or by using gaseous silicon compounds to deposit a thin layer of silicon atoms onto a crystalline template in the shape of a wafer.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

PV Module Manufacturing cont...

Cell Fabrication – Silicon wafers are then fabricated into photovoltaic cells. The first step is chemical texturing of the wafer surface, which removes saw damage and increases how much light gets into the wafer when it is exposed to sunlight. The subsequent processes vary significantly depending on device architecture. Most cell types require the wafer to be exposed to a gas containing an electrically active dopant, and coating the surfaces of the wafer with layers that improve the performance of the cell. Screen printing of silver metallization for electrical contacts is also very common among cell types.

Module Assembly – At a module assembly facility, copper ribbons plated with solder connect the silver busbars on the front surface of one cell to the rear surface of an adjacent cell in a process known as tabbing and stringing. The interconnected set of cells is arranged face-down on a sheet of glass covered with a sheet of polymer encapsulant. A second sheet of encapsulant is placed on top of the face-down cells, followed by a tough polymer backsheet or another piece of glass. The whole stack of materials is laminated in an oven to make the module waterproof, then fitted with an aluminum frame, edge sealant, and a junction box in which the ribbons are connected to diodes that prevent any backward flow of electricity. Electrical cables from the junction box convey the current produced by the module to an adjacent module or to the system's power electronics.

Thin Film PV - Thin film PV can refer to a number of different absorber materials, the most common of which is cadmium telluride (CdTe).

PV Module Manufacturing cont...

Thin film PV modules are typically processed as a single unit from beginning to end, where all steps occur in one facility. The manufacturing typically starts with float glass coated with a transparent conductive layer, onto which the photovoltaic absorber material is deposited in a process called close-spaced sublimation. Laser scribing is used to pattern cell strips and to form an interconnect pathway between adjacent cells. Copper ribbons are applied, an encapsulant sheet and second sheet of glass are placed on top, and the stack is laminated to make it waterproof. Finally, a junction box is attached to the rear of the module. There, the module's electrical cables are attached to the copper ribbons, which pass into the junction box through holes in the rear glass.

In addition to the established types of PV, we have identified a new nanotechnology process.

Photo Energy - The Photo Energy (PE) panel technology represents several advantages over the photovoltaic competition.

The coatings are printed by nano-pastes developed in a specific way, in particular the coatings allowing the production of energy and its storage which fit perfectly into the category of renewable energy solutions.

Organic photovoltaic (OPV) solar cells can be used for covering greenhouses, windows and even cladding and they can be utilized in heating and cooling systems. - please see Nanotec Next Generation Solar section

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

PV Module Manufacturing cont...

Racking Systems - The support structures that are built to support PV modules on a roof or in a field are commonly referred to as racking systems. The manufacture of PV racking systems varies significantly depending on where the installation will occur. Ground-mounted racking is made from steel, which is typically coated or galvanized to protect from corrosion and requires concrete foundations. Large ground-mounted systems typically use a one-axis tracking mechanism, which helps solar panels follow the sun as it moves from east to west. Tracking requires mechanical parts like motors and bearings. Stationary racking (referred to as “fixed tilt”) can be used as well. Roof-mounted racking depends on the type of roof. For flat roofs, like those on large commercial or industrial buildings, fixed-tilt steel racking is used. It is commonly attached to heavy blocks that sit on the roof. For pitched residential roofs, racking is designed to attach securely to the rafters and hold the modules a few inches above the roof. This allows airflow to cool the rear of the modules, improving their performance.

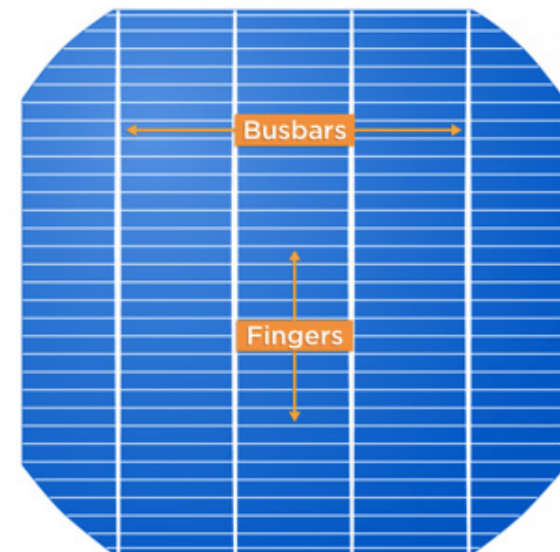
Power Electronics - Power electronics for PV modules, including power optimizers and inverters, are assembled on electronic circuit boards. This hardware converts direct current (DC) electricity, which is what a solar panel generates, to alternating current (AC) electricity, which the electrical grid uses.

Assembly starts with a circuit board template. A solder-paste is printed where small components, like transistors and diodes, are placed using robotics.

PV Module Manufacturing cont...

Sometimes, larger components such as capacitors and transformers are placed by hand on the board. Once all components are in place, the board passes across a solder bath in a furnace to connect the components. The entire board is coated with lacquer and sealed into a waterproof housing with ports for external connections

Front Contact of a Silicon Solar Cell



energy.gov/solar-office

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

PV Module Manufacturing cont...

PV Modules

37% of utility-scale system cost



Electrical & Structural BOS

21% of utility-scale system cost



Inverter

4.5% of utility-scale system cost



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

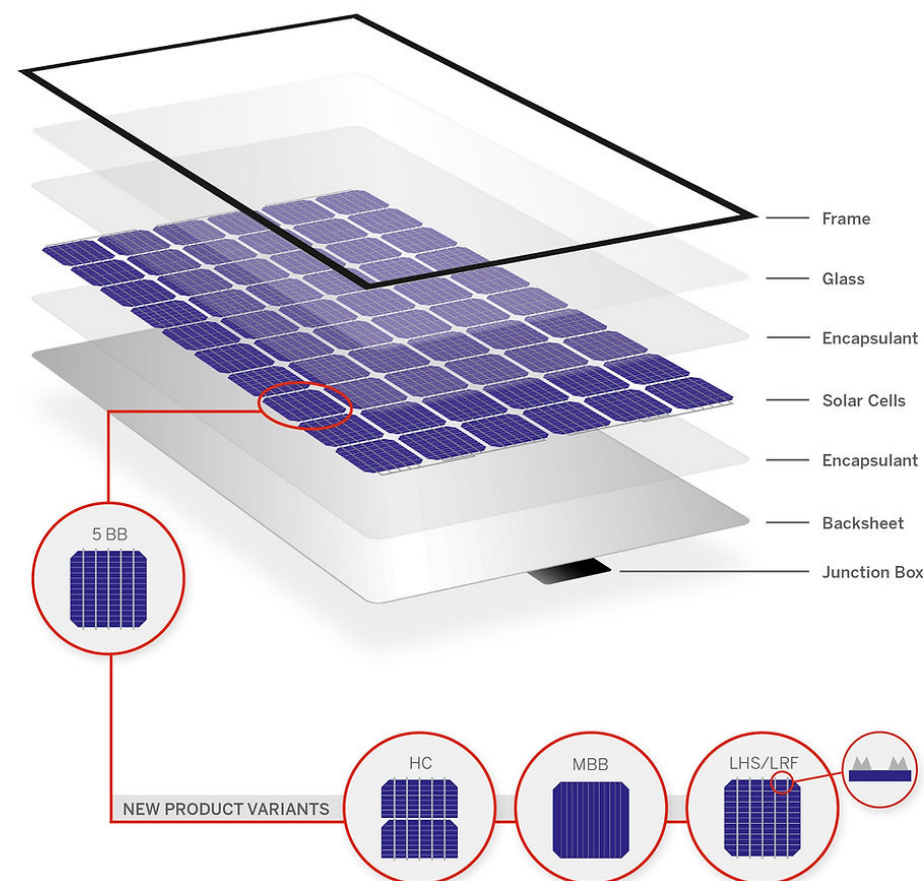
PV Module Manufacturing cont...

Solar Photovoltaic Cell Basics - When light shines on a photovoltaic (PV) cell – also called a solar cell – that light may be reflected, absorbed, or pass right through the cell. The PV cell is composed of semiconductor material; the “semi” means that it can conduct electricity better than an insulator but not as well as a good conductor like a metal. There are several different semiconductor materials used in PV cells.

When the semiconductor is exposed to light, it absorbs the light's energy and transfers it to negatively charged particles in the material called electrons. This extra energy allows the electrons to flow through the material as an electrical current. This current is extracted through conductive metal contacts – the grid-like lines on a solar cells – and can then be used to power your home and the rest of the electric grid.

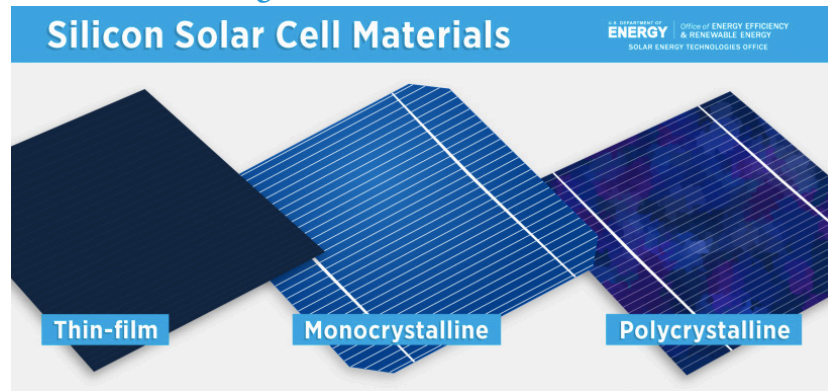
The efficiency of a PV cell is simply the amount of electrical power coming out of the cell compared to the energy from the light shining on it, which indicates how effective the cell is at converting energy from one form to the other. The amount of electricity produced from PV cells depends on the characteristics (such as intensity and wavelengths) of the light available and multiple performance attributes of the cell.

An important property of PV semiconductors is the bandgap, which indicates what wavelengths of light the material can absorb and convert to electrical energy. If the semiconductor's bandgap matches the wavelengths of light shining on the PV cell, then that cell can efficiently make use of all the available energy.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

PV Module Manufacturing cont...



SILICON - Silicon is, by far, the most common semiconductor material used in solar cells, representing approximately 95% of the modules sold today. It is also the second most abundant material on Earth (after oxygen) and the most common semiconductor used in computer chips. Crystalline silicon cells are made of silicon atoms connected to one another to form a crystal lattice. This lattice provides an organized structure that makes conversion of light into electricity more efficient.

Solar cells made out of silicon currently provide a combination of high efficiency, low cost, and long lifetime. Modules are expected to last for 25 years or more, still producing more than 80% of their original power after this time.

THIN-FILM PHOTOVOLTAICS - A thin-film solar cell is made by depositing one or more thin layers of PV material on a supporting material such as glass, plastic, or metal.

PV Module Manufacturing cont...

There are two main types of thin-film PV semiconductors on the market today: cadmium telluride (CdTe) and copper indium gallium diselenide (CIGS). Both materials can be deposited directly onto either the front or back of the module surface.

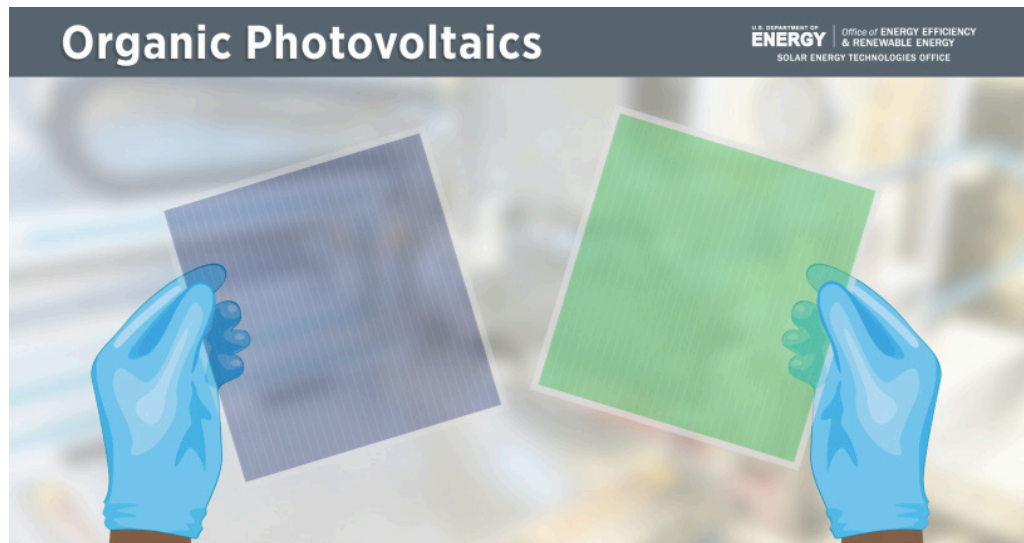
CdTe is the second-most common PV material after silicon, and CdTe cells can be made using low-cost manufacturing processes. While this makes them a cost-effective alternative, their efficiencies still aren't quite as high as silicon. CIGS cells have optimal properties for a PV material and high efficiencies in the lab, but the complexity involved in combining four elements makes the transition from lab to manufacturing more challenging. Both CdTe and CIGS require more protection than silicon to enable long-lasting operation outdoors.

PEROVSKITE PHOTOVOLTAICS - Perovskite solar cells are a type of thin-film cell and are named after their characteristic crystal structure. Perovskite cells are built with layers of materials that are printed, coated, or vacuum-deposited onto an underlying support layer, known as the substrate. They are typically easy to assemble and can reach efficiencies similar to crystalline silicon. In the lab, perovskite solar cell efficiencies have improved faster than any other PV material, from 3% in 2009 to over 25% in 2020. To be commercially viable, perovskite PV cells have to become stable enough to survive 20 years outdoors, so researchers are working on making them more durable and developing large-scale, low-cost manufacturing techniques.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

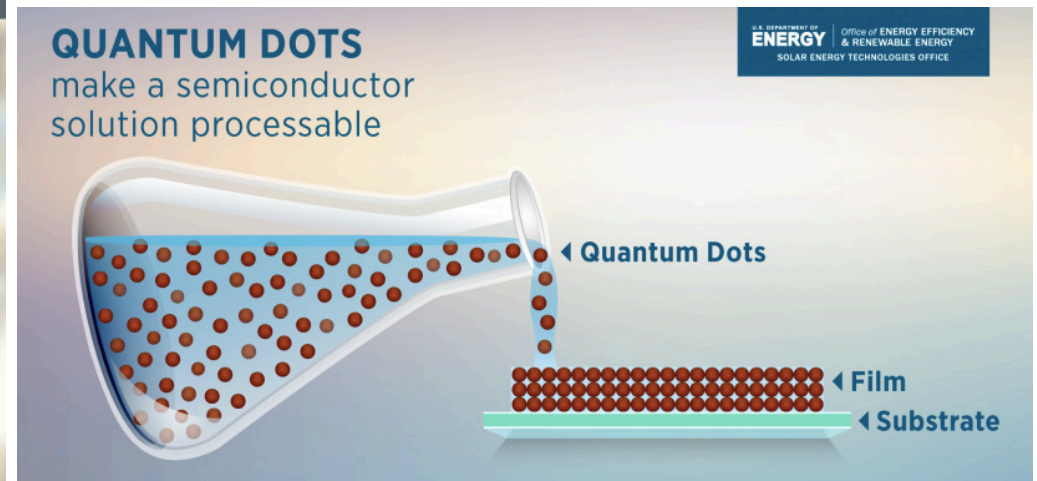
PV Module Manufacturing cont...

Organic PV, or OPV, cells are composed of carbon-rich (organic) compounds and can be tailored to enhance a specific function of the PV cell, such as bandgap, transparency, or color. OPV cells are currently only about half as efficient as crystalline silicon cells and have shorter operating lifetimes, but could be less expensive to manufacture in high volumes. They can also be applied to a variety of supporting materials, such as flexible plastic, making OPV able to serve a wide variety of uses



PV Module Manufacturing cont...

QUANTUM DOTS - Quantum dot solar cells conduct electricity through tiny particles of different semiconductor materials just a few nanometers wide, called quantum dots. Quantum dots provide a new way to process semiconductor materials, but it is difficult to create an electrical connection between them, so they're currently not very efficient. However, they are easy to make into solar cells. They can be deposited onto a substrate using a spin-coat method, a spray, or roll-to-roll printers like the ones used to print newspapers. Quantum dots come in various sizes and their bandgap is customizable, enabling them to collect light that's difficult to capture and to be paired with other semiconductors, like perovskites, to optimize the performance of a multijunction solar cell



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PV Module Manufacturing cont...

MULTIJUNCTION PHOTOVOLTAICS - Another strategy to improve PV cell efficiency is layering multiple semiconductors to make multijunction solar cells. These cells are essentially stacks of different semiconductor materials, as opposed to single-junction cells, which have only one semiconductor. Each layer has a different bandgap, so they each absorb a different part of the solar spectrum, making greater use of sunlight than single-junction cells. Multijunction solar cells can reach record efficiency levels because the light that doesn't get absorbed by the first semiconductor layer is captured by a layer beneath it.

While all solar cells with more than one bandgap are multijunction solar cells, a solar cell with exactly two bandgaps is called a tandem solar cell. Multijunction solar cells that combine semiconductors from columns III and V in the periodic table are called multijunction III-V solar cells.

Multijunction solar cells have demonstrated efficiencies higher than 45%, but they're costly and difficult to manufacture, so they're reserved for space exploration. The military is using III-V solar cells in drones, and researchers are exploring other uses for them where high efficiency is key.

CONCENTRATION PHOTOVOLTAICS - Concentration PV, also known as CPV, focuses sunlight onto a solar cell by using a mirror or lens. By focusing sunlight onto a small area, less PV material is required. PV materials become more efficient as the light becomes more concentrated, so the highest overall efficiencies are obtained with CPV cells and modules.

PV Module Manufacturing cont...

However, more expensive materials, manufacturing techniques, and ability to track the movement of the sun are required, so demonstrating the necessary cost advantage over today's high-volume silicon modules has become challenging.

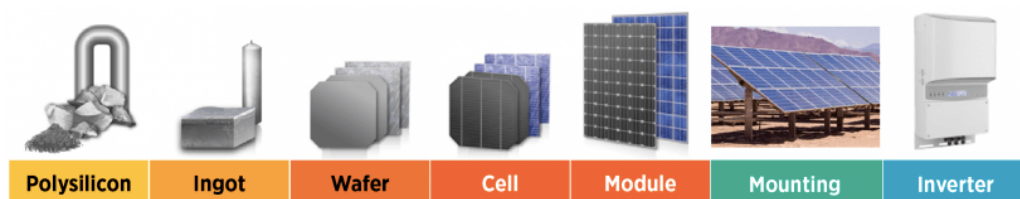
In addition to the established types of PV, we have identified a new nanotechnology process.

PHOTO ENERGY - The Photo Energy (PE) panel technology represents several advantages over the photovoltaic competition.

The coatings are printed by nano-pastes developed in a specific way, in particular the coatings allowing the production of energy and its storage which fit perfectly into the category of renewable energy solutions.

Organic photovoltaic (OPV) solar cells can be used for covering greenhouses, windows and even cladding and they can be utilized in heating and cooling systems. - please see Nanotec Next Generation Solar section

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Solar Photovoltaics Supply Chain

The Solar Photovoltaics Supply Chain Review explores the global solar photovoltaics supply chain and opportunities for developing manufacturing capacity. The assessment concludes that, with significant financial support and incentives from government as well as strategic actions focused on workforce, manufacturing, human rights, and trade, Zimbabwe could establish a robust domestic solar manufacturing supply chain and become a competitive leader in a global solar industry. This could lead to tremendous benefits for the climate as well as for local workers, employers, and the economy.

To achieve the goal of 100% clean electricity by 2030, solar energy would need to grow from 2% of electricity supply today to 40%, dramatically increasing demand for solar modules and components. This rapid expansion of solar energy has the potential to yield broad benefits in the form of economic activity, improved public health, and workforce development.

The supply chain for solar PV has two branches: crystalline silicon (c-Si) PV, which made up 84% of the U.S. market in 2020, and cadmium telluride (CdTe) thin film PV, which made up the remaining 16%.

The supply chain for c-Si PV starts with the refining of high-purity polysilicon. Polysilicon is melted to grow monocrystalline silicon ingots, which are sliced into thin silicon wafers. Silicon wafers are processed to make solar cells, which are connected, sandwiched between glass and plastic sheets, and framed with aluminum to make PV modules. Then, they are mounted on racking or tracking structures and connected to the grid using a power electronics device called an inverter.

The supply chain for CdTe PV starts with refining cadmium and tellurium to high-purity powders, which are then deposited directly onto a glass sheet. Another piece of glass and plastic sealant are applied to finish the module, which then can be mounted and connected to the grid in an identical fashion to c-Si modules.

The primary inputs to the global solar supply chain include: metallurgical -grade silicon (MGS), glass, resins to make plastic sheets (encapsulant and backsheets), and aluminum. MGS is produced from high-grade quartz. Quartz is a compound of silicon and oxygen, the two most abundant elements in the earth's crust.



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SOLAR PV MANUFACTURING COSTING ANALYSIS

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Estimated Costings for Development of 1 GW Integrated Solar Module Manufacturing Plant

According to industry standards, the capital cost for setting up 1 GW of backward integrated solar panel manufacturing capacity, right from the manufacturing-grade silica, is approximately \$390,000,000,.00

The cost breakdown across segments shows that cell and balance of module (BOM) components account for the major share of module costs, of which cell contributes 60%. Raw material cost accounts for 80% of the total cell manufacturing cost, within which the major contributor is the wafer, accounting for 56% of the overall cost. Polysilicon accounts for 32% of wafer manufacturing costs, which, along with other materials, account for 60% of the cost share.

Table: Capital expenditure for 1 GW manufacturing capacity

Segment	Capital Expenditure (US\$ Million)
M.G. Silica	39
Poly Silicon	165
Wafer	78
Cell	78
Module	30
Total	390

Table: Module manufacturing costs

Cost Component	Percentage Share
Cell	60%
Balance of Module (BOM)	32%
Other Material	2%
Energy	1%
Labour	1%
Other Costs	4%

Table: Ingot/Wafer manufacturing costs

Cost Component	Percentage Share
Polysilicon	32%
Other Materials	28%
Other Expenses	23%
Energy	13%
Depreciation	2%
Labour	2%

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Estimated Costings for Development of 1 GW Integrated Solar Module Manufacturing Plant

Table summarizing the cost of setting up a polysilicon manufacturing plant:

Cost Component	Percentage of Overall Cost
Raw Material	38%
Other Material	28%
Energy and Depreciation	10% each
Labor, Maintenance, and Other Expenses	14%

The cost of domestically manufactured polysilicon is estimated to be around \$10/kg. A polysilicon plant of 10,000 TPA capacity can produce around 2.4 GW of PV modules per annum.

The Trichlorosilane (TCS) Siemens CVD3 technology is typically used to manufacture polysilicon.

Raw material is the biggest cost contributor at 38%, followed by other material at 28%.

Energy and depreciation are also significant cost components, each accounting for 10% of the overall cost.

Labor, maintenance, and other expenses make up the remaining 14%.





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SOLAR GRID PLANNING AND OPERATION

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Grid Planning and Operation?

When it comes to systems integration, “planning” refers to near- and long-term power system designs under various generation and load scenarios; “operation” refers to real-time sensing, communication, and control that ensure system reliability.

Many organizations work together to maintain the grid’s performance through planning and operation.

Private, cooperative, and public utility companies, federal and state agencies, independent system operators, and others work to ensure safe, reliable electricity is delivered to consumers.

The technologies necessary to achieve safe, secure, reliable, and affordable power delivery fall into four categories: balancing, protection, situational awareness, and utility management tools.

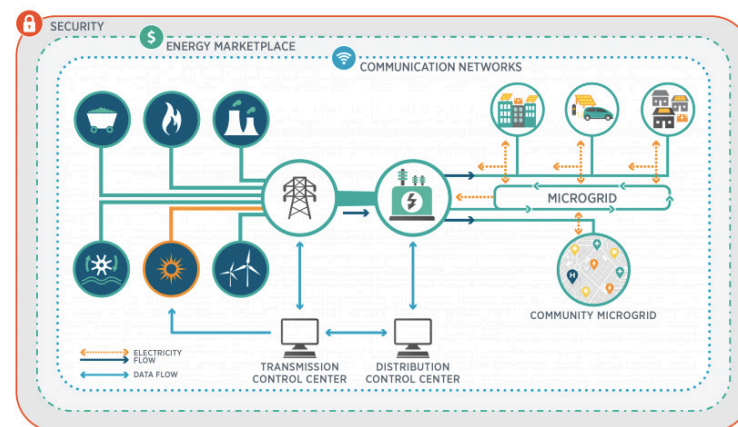
Balancing

Balancing is the task of ensuring electricity generation matches consumption. The electrical grid is not like a grocery store, where products are stocked on the shelf then sold.

Electrical power is generated and then almost instantly consumed by devices in homes and businesses. Therefore, utilities must carefully balance generation, minute to minute, with power that is being used, also known as load.

Consumers change the load when they turn their devices on and off. Generators ramp up and down, and may go offline owing to an equipment fault. With renewables like solar, weather conditions and the daily passage of the sun across the sky introduce additional variability in generation. If there is too much or too little generation to serve the current load, over- or under-generation occurs.

A temporary drop in generation might need to be compensated by ramping up other generators, by reducing load, or by tapping stored energy. Solar can help balance the grid by keeping some generating capacity in reserve. Solar plants can then respond to increasing demand by releasing the power they were holding back. Because a solar plant doesn’t have a lot of mechanical inertia like traditional fossil-fueled turbines, it can respond much more quickly to changes. Solar can therefore provide grid operators with a fast, almost instantaneously available resource to help balance the grid, potentially distributed across millions of homes in an area.



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Protection

Protection refers to the use of devices such as relays, breakers, and fuses that protect people and equipment from unsafe electricity. For instance, if a power line is down, creating a condition known as a line-to-ground fault, large amounts of current will flow into the ground.

This is dangerous for people near the power line, but it's also dangerous to electrical equipment that is not designed to carry as much current as the line will carry when it's lying on the ground.

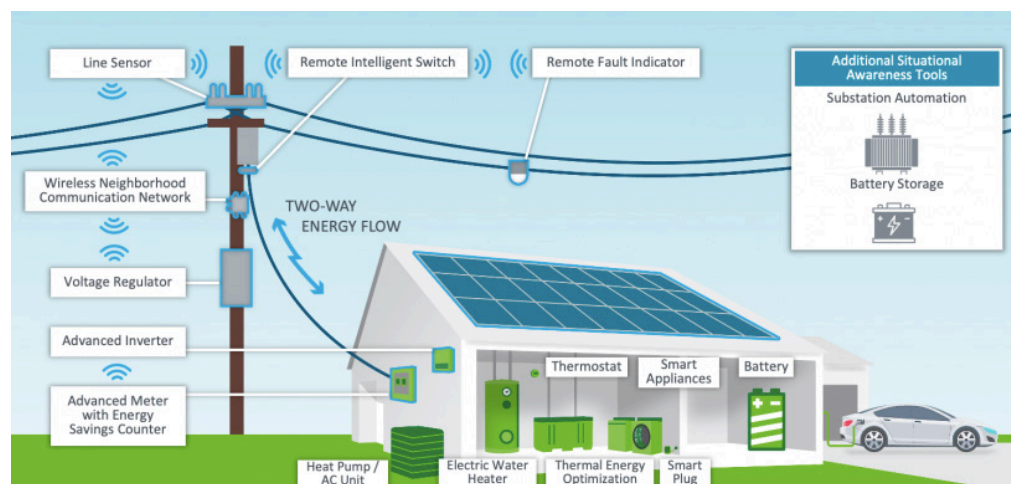
Therefore, automated systems must be installed to disconnect the line quickly when necessary. Effective protection will allow the system to isolate and clear the fault while the rest of the grid remains operational during a disruption.

Distributed energy resources (DER), such as household solar panels, present new challenges to grid protection measures, simply because they provide new sources of generation that need to be monitored and safely disconnected during faults.

On the other hand, DER represent a new fleet of smart, connected devices that can serve as gateways for monitoring and control, giving grid operators a new window onto the condition of the grid for identifying problems faster than ever.

In addition, because DER produce power where it will be used, communities are better equipped to deal locally with the consequences of failures in the power system.

Situational Awareness



All these issues highlight the need for improved sensing, communications, and control in electrical grids with large amounts of solar generation, especially distributed rooftop solar. Situational awareness refers to the utilities' awareness of the current load, the current generation, and where that generation and consumption is occurring.

As the electricity system modernizes, the instrumentation and technology required to observe and control it has become more complex.

Advanced power electronics and other smart devices in your home can give utilities information so they can better manage loads.

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Line sensors and other devices on utility poles can provide information on a neighborhood level. Power lines can be equipped with fault indicators, and digital substations can also present important information.

Situational awareness is always important, but it becomes especially important when there is a disaster or an accident that requires a fast, smart response.

Historically, utilities have not had fine-grained insight into the distributed grid. For instance, grid operators are unlikely to have access to real-time information about how much electricity individual households are using, nor are they aware of downed power lines unless a customer reports it.

In a disaster, understanding where a problem is occurring is the first step to solving it.

Utility Management Tools

To realise the benefits of DER for grid operation, utilities need a way to interface with these generators. That means they need a software platform that allows DER to be seen, managed, and controlled effectively and efficiently while maintaining privacy and security. That's where a distributed energy resource management system (DERMS) comes in.

A DERMS allows a grid operator to securely monitor and control distributed resources and make better decisions about what resources to tap in different situations.

DERMS is an active area of software engineering and research. A good DERMS should be able to deal with demand-response resources (loads the utility can control to reduce demand, like water heaters or smart thermostats), distributed generation (such as solar), electric vehicles, and energy storage (like batteries). It should also be aware of grid conditions so that decisions can be made based on real-time power flow.

Building a software platform that allows operators and DER aggregators to conduct this orchestra of energy resources is difficult, but it can lead to more efficient, cleaner, and more cost-effective grid operation.



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SOLAR SYSTEMS INTEGRATION

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Solar systems integration involves developing technologies and tools that allow solar energy onto the electricity grid, while maintaining grid reliability, security, and efficiency.

THE ELECTRICAL GRID

For most of the past 100 years, electrical grids involved large-scale, centralized energy generation located far from consumers. Modern electrical grids are much more complex. In addition to large utility-scale plants, modern grids also involve variable energy sources like solar and wind, energy storage systems, power electronic devices like inverters, and small-scale energy generation systems like rooftop installations and microgrids. These smaller-scale and dispersed energy sources are generally known as distributed energy resources (DER).

The electrical grid is separated into transmission and distribution systems. The transmission grid is the network of high-voltage power lines that carry electricity from centralized generation sources like large power plants. These high voltages allow power to be transported long distances without excessive loss. The distribution grid refers to low-voltage lines that eventually reach homes and businesses. Substations and transformers convert power between high and low voltage. Traditionally, electricity only needed to flow one way through these systems: from the central generation source to the consumer. However, systems like rooftop solar now require the grid to handle two-way electricity flow, as these systems can inject the excess power that they generate back into the grid.

POWER ELECTRONICS

Increased solar and DER on the electrical grid means integrating more power

electronic devices, which convert energy from one form to another.

This could include converting between high and low voltage, regulating the amount of power flow, or converting between direct current (DC) and alternating current (AC) electricity, depending on where the electricity is going and how it will be used. By 2030, as much as 80% of electricity could flow through power electronic devices. One type of power electronic device that is particularly important for solar energy integration is the inverter. Inverters convert DC electricity, which is what a solar panel generates, to AC electricity, which the electrical grid uses.

SOLAR PLUS STORAGE

Since solar energy can only be generated when the sun is shining, the ability to store solar energy for later use is important. It helps to keep the balance between electricity generation and demand. This means that developing batteries or thermal storage is key to adding more solar.

GRID RESILIENCE AND RELIABILITY

The electrical grid must be able to reliably provide power, so it's important for utilities and other power system operators to have real-time information about how much electricity solar systems are producing. Increasing amounts of solar and DER on the grid lead to both opportunities and challenges for grid reliability. Complex modern grids with a mix of traditional generation and DER can make responding to abnormal situations like storms or blackouts more difficult. However, power electronics have the potential to collect real-time information on the grid and help to control grid operations. In fact, special "grid-forming" inverters could use solar energy to restart the grid in the event of a blackout.

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Solar Integration: Distributed Energy Resources and Microgrids

Simply put, we need a reliable and secure energy grid. Two ways to ensure continuous electricity regardless of the weather or an unforeseen event are by using distributed energy resources (DER) and microgrids. DER produce and supply electricity on a small scale and are spread out over a wide area. Rooftop solar panels, backup batteries, and emergency diesel generators are examples of DER. While traditional generators are connected to the high-voltage transmission grid, DER are connected to the lower-voltage distribution grid, like residences and businesses are.

Microgrids are localized electric grids that can disconnect from the main grid to operate autonomously. Because they can operate while the main grid is down, microgrids can strengthen grid resilience, help mitigate grid disturbances, and function as a grid resource for faster system response and recovery.

DISTRIBUTED ENERGY RESOURCES

Solar DER can be built at different scales—even one small solar panel can provide energy. In fact, about one-third of solar energy in the United States is produced by small-scale solar, such as rooftop installations. Household solar installations are called behind-the-meter solar; the meter measures how much electricity a consumer buys from a utility. Since distributed solar is “behind” the meter, customers do not pay the utility for the solar power generated.

The cost of owning DER varies from province to province and among utility companies. One way the electric bill is determined is through net metering, where utilities calculate the total power generated by the customer’s solar system

and subtract it from the total power the customer consumes. Customers are credited for the amount of power they supply to the grid.

DER could fundamentally change the way the electric grid works. With DER, power is generated right where it is used and can be connected with other DER to optimize its use. Households and other electricity consumers are also part-time producers, selling excess generation to the grid and to each other. Energy storage, such as batteries, can also be distributed, helping to ensure power when solar or other DER don’t generate power. Electric cars can even store excess energy in the batteries of idle cars. DER can also include controllable loads, like water heaters or air-conditioning units that the utility can use to shift power consumption away from peak hours. While the grid was designed to generate power at large facilities and move it through the transmission grid to the distribution grid for consumption, DER enable local generation and consumption of electricity.

ISLANDS AND MICROGRIDS

Distribution grids are vulnerable to outages that can affect large regions and millions of people and businesses, particularly as a consequence of extreme, destructive weather events. When parts of the grid are equipped with DER, they can continue serving other loads on the same distribution network, meeting local needs with local generation. This is called islanding. Electrical systems that can disconnect from the larger grid, engaging in intentional islanding, are often called microgrids.

Microgrids vary in size from a single-customer microgrid to a full-substation microgrid, which may include hundreds of individual generators and

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consumers of power. Small, off-the-grid electrical systems are not a recent invention. Ships, military bases, remote outposts, and communities around the world have long relied on local generation and electricity management to meet their energy needs. DER make microgrids a more widespread option, because the means of energy production are now more easily obtained and sited in neighborhoods. Community-scale microgrids may provide resiliency and backup during and after disasters like hurricanes.

Technology is advancing to manage the risks caused by islanding with better control software and to provide grid services. Without the larger grid to help stabilize the power supply, an islanded grid could damage connected equipment or injure workers who think it is disconnected from power. For this reason, many solar energy systems are programmed to detect islanding and disconnect from the grid if it occurs. Beyond microgrids, some researchers are studying nanogrids—smart electricity systems on the scale of a single building.

BLACK START

Another way DER and microgrids can contribute to grid stability is by aiding “black start” processes, which turn power on after it has gone down. During a widespread electrical failure, electrical generators can be put offline. To come back online, many electrical generators require an external battery to start. To achieve this, utilities create black start plans, in which small generators start larger ones to steadily bring generation online. Throughout this process, service restoration must be well-timed, to ensure that generation and load are matched continuously. DER could become a valuable black start resource by allowing communities with microgrids to begin start-up processes on their own and provide the capacity required to start up larger generators.

Solar Integration: Inverters and Grid Services

INVERTERS

An inverter is one of the most important pieces of equipment in a solar energy system. It's a device that converts direct current (DC) electricity, which is what a solar panel generates, to alternating current (AC) electricity, which the electrical grid uses. In DC, electricity is maintained at constant voltage in one direction. In AC, electricity flows in both directions in the circuit as the voltage changes from positive to negative. Inverters are just one example of a class of devices called power electronics that regulate the flow of electrical power.

Fundamentally, an inverter accomplishes the DC-to-AC conversion by switching the direction of a DC input back and forth very rapidly. As a result, a DC input becomes an AC output. In addition, filters and other electronics can be used to produce a voltage that varies as a clean, repeating sine wave that can be injected into the power grid. The sine wave is a shape or pattern the voltage makes over time, and it's the pattern of power that the grid can use without damaging electrical equipment, which is built to operate at certain frequencies and voltages.

The first inverters were created in the 19th century and were mechanical. A spinning motor, for example, would be used to continually change whether the DC source was connected forward or backward. Today we make electrical switches out of transistors, solid-state devices with no moving parts. Transistors are made of semiconductor materials like silicon or gallium arsenide. They control the flow of electricity in response to outside electrical signals.

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If you have a household solar system, your inverter probably performs several functions. In addition to converting your solar energy into AC power, it can monitor the system and provide a portal for communication with computer networks. Solar-plus-battery storage systems rely on advanced inverters to operate without any support from the grid in case of outages, if they are designed to do so.

TOWARD AN INVERTER-BASED GRID

Historically, electrical power has been predominantly generated by burning a fuel and creating steam, which then spins a turbine generator, which creates electricity. The motion of these generators produces AC power as the device rotates, which also sets the frequency, or the number of times the sine wave repeats. Power frequency is an important indicator for monitoring the health of the electrical grid. For instance, if there is too much load—too many devices consuming energy—then energy is removed from the grid faster than it can be supplied. As a result, the turbines will slow down and the AC frequency will decrease. Because the turbines are massive spinning objects, they resist changes in the frequency just as all objects resist changes in their motion, a property known as inertia.

As more solar systems are added to the grid, more inverters are being connected to the grid than ever before. Inverter-based generation can produce energy at any frequency and does not have the same inertial properties as steam-based generation, because there is no turbine involved. As a result, transitioning to an electrical grid with more inverters requires building smarter inverters that can respond to changes in frequency and other disruptions that occur during grid operations, and help stabilize the grid against those disruptions

GRID SERVICES AND INVERTERS

Grid operators manage electricity supply and demand on the electric system by providing a range of grid services. Grid services are activities grid operators perform to maintain system-wide balance and manage electricity transmission better.

When the grid stops behaving as expected, like when there are deviations in voltage or frequency, smart inverters can respond in various ways. In general, the standard for small inverters, such as those attached to a household solar system, is to remain on during or “ride through” small disruptions in voltage or frequency, and if the disruption lasts for a long time or is larger than normal, they will disconnect themselves from the grid and shut down.

Frequency response is especially important because a drop in frequency is associated with generation being knocked offline unexpectedly. In response to a change in frequency, inverters are configured to change their power output to restore the standard frequency. Inverter-based resources might also respond to signals from an operator to change their power output as other supply and demand on the electrical system fluctuates, a grid service known as automatic generation control. In order to provide grid services, inverters need to have sources of power that they can control. This could be either generation, such as a solar panel that is currently producing electricity, or storage, like a battery system that can be used to provide power that was previously stored.

Another grid service that some advanced inverters can supply is grid-forming. Grid-forming inverters can start up a grid if it goes down—a process known as black start.

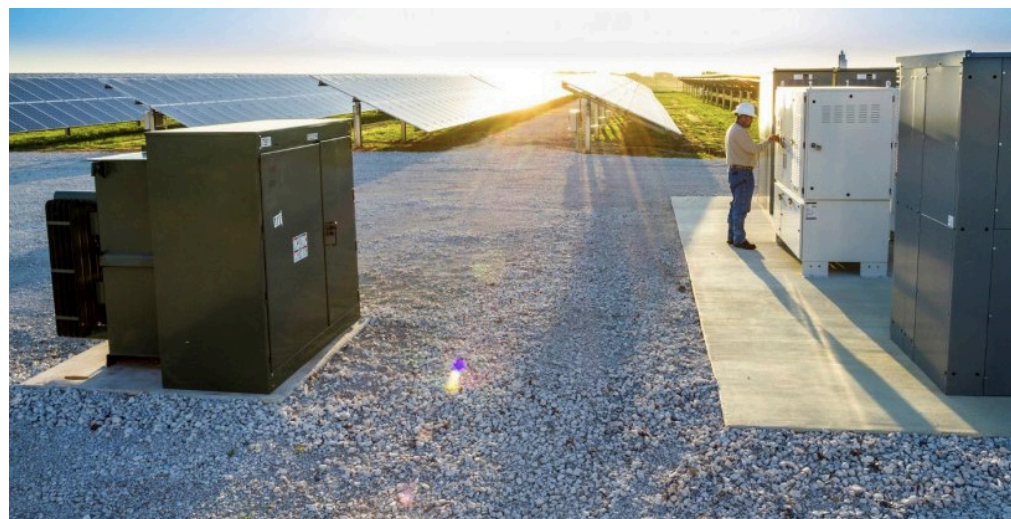
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Traditional “grid-following” inverters require an outside signal from the electrical grid to determine when the switching will occur in order to produce a sine wave that can be injected into the power grid. In these systems, the power from the grid provides a signal that the inverter tries to match. More advanced grid-forming inverters can generate the signal themselves. For instance, a network of small solar panels might designate one of its inverters to operate in grid-forming mode while the rest follow its lead, like dance partners, forming a stable grid without any turbine-based generation.

Reactive power is one of the most important grid services inverters can provide. On the grid, voltage—the force that pushes electric charge—is always switching back and forth, and so is the current—the movement of the electric charge. Electrical power is maximized when voltage and current are synchronized. However, there may be times when the voltage and current have delays between their two alternating patterns like when a motor is running. If they are out of sync, some of the power flowing through the circuit cannot be absorbed by connected devices, resulting in a loss of efficiency. More total power will be needed to create the same amount of “real” power—the power the loads can absorb. To counteract this, utilities supply reactive power, which brings the voltage and current back in sync and makes the electricity easier to consume. This reactive power is not used itself, but rather makes other power useful. Modern inverters can both provide and absorb reactive power to help grids balance this important resource. In addition, because reactive power is difficult to transport long distances, distributed energy resources like rooftop solar are especially useful sources of reactive power.

TYPES OF INVERTERS

There are several types of inverters that might be installed as part of a solar system. In a large-scale utility plant or mid-scale community solar project, every solar panel might be attached to a single central inverter. String inverters connect a set of panels—a string—to one inverter. That inverter converts the power produced by the entire string to AC. Although cost-effective, this setup results in reduced power production on the string if any individual panel experiences issues, such as shading. Microinverters are smaller inverters placed on every panel. With a microinverter, shading or damage to one panel will not affect the power that can be drawn from the others, but microinverters can be more expensive. Both types of inverters might be assisted by a system that controls how the solar system interacts with attached battery storage. Solar can charge the battery directly over DC or after a conversion to AC.



A worker checks an inverter at the 2MW CoServ Solar Station in Krugerville, Texas. Photo by Ken Oltmann/CoServ.

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Solar Integration: Solar Energy and Storage

Sometimes two is better than one. Coupling solar energy and storage technologies is one such case. The reason: Solar energy is not always produced at the time energy is needed most. Peak power usage often occurs on summer afternoons and evenings, when solar energy generation is falling. Temperatures can be hottest during these times, and people who work daytime hours get home and begin using electricity to cool their homes, cook, and run appliances.

Storage helps solar contribute to the electricity supply even when the sun isn't shining. It can also help smooth out variations in how solar energy flows on the grid. These variations are attributable to changes in the amount of sunlight that shines onto photovoltaic (PV) panels or concentrating solar-thermal power (CSP) systems. Solar energy production can be affected by season, time of day, clouds, dust, haze, or obstructions like shadows, rain, snow, and dirt. Sometimes energy storage is co-located with, or placed next to, a solar energy system, and sometimes the storage system stands alone, but in either configuration, it can help more effectively integrate solar into the energy landscape.

ENERGY STORAGE

“Storage” refers to technologies that can capture electricity, store it as another form of energy (chemical, thermal, mechanical), and then release it for use when it is needed. Lithium-ion batteries are one such technology. Although using energy storage is never 100% efficient—some energy is always lost in converting energy and retrieving it—storage allows the flexible use of energy at different times from when it was generated.

So, storage can increase system efficiency and resilience, and it can improve power quality by matching supply and demand.

Storage facilities differ in both energy capacity, which is the total amount of energy that can be stored (usually in kilowatt-hours or megawatt-hours), and power capacity, which is the amount of energy that can be released at a given time (usually in kilowatts or megawatts). Different energy and power capacities of storage can be used to manage different tasks. Short-term storage that lasts just a few minutes will ensure a solar plant operates smoothly during output fluctuations due to passing clouds, while longer-term storage can help provide supply over days or weeks when solar energy production is low or during a major weather event, for example.



 The AES Lawai Solar Project in Kauai, Hawaii has a 100 megawatt-hour battery energy storage system paired with a solar photovoltaic system.
National Renewable Energy Laboratory

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Advantages of Combining Storage and Solar

1) Balancing electricity loads – Without storage, electricity must be generated and consumed at the same time, which may mean that grid operators take some generation offline, or “curtail” it, to avoid over-generation and grid reliability issues.

Conversely, there may be other times, after sunset or on cloudy days, when there is little solar production but plenty of demand for power.

Enter storage, which can be filled or charged when generation is high and power consumption is low, then dispensed when the load or demand is high. When some of the electricity produced by the sun is put into storage, that electricity can be used whenever grid operators need it, including after the sun has set. In this way, storage acts as an insurance policy for sunshine.

2) “Firming” solar generation – Short-term storage can ensure that quick changes in generation don’t greatly affect the output of a solar power plant. For example, a small battery can be used to ride through a brief generation disruption from a passing cloud, helping the grid maintain a “firm” electrical supply that is reliable and consistent.

3) Providing resilience – Solar and storage can provide backup power during an electrical disruption. They can keep critical facilities operating to ensure continuous essential services, like communications. Solar and storage can also be used for microgrids and smaller-scale applications, like mobile or portable power units.

Types of Energy Storage

The most common type of energy storage in the power grid is pumped hydro-power. But the storage technologies most frequently coupled with solar power plants are electrochemical storage (batteries) with PV plants and thermal storage (fluids) with CSP plants.

Other types of storage, such as compressed air storage and flywheels, may have different characteristics, such as very fast discharge or very large capacity, that make them attractive to grid operators. More information on other types of storage is below.

Pumped-Storage Hydropower - Pumped-storage hydropower is an energy storage technology based on water. Electrical energy is used to pump water uphill into a reservoir when energy demand is low. Later, the water can be allowed to flow back downhill and turn a turbine to generate electricity when demand is high. Pumped hydro is a well-tested and mature storage technology that has been used in the United States since 1929. However, it requires suitable landscapes and reservoirs, which may be natural lakes or man-made by constructing dams, requiring lengthy regulatory permits, long implementation times, and large initial capital. Other than energy arbitrage, pumped hydro’s value of services to integrate variable renewables are not fully realized, which can make the financial payback period long. These are some of the reasons pumped hydro has not been built recently, even though interest is evident from requests to the Federal Energy Regulatory Commission for preliminary permits and licenses.

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Electrochemical Storage - Many of us are familiar with electrochemical batteries, like those found in laptops and mobile phones. When electricity is fed into a battery, it causes a chemical reaction, and energy is stored. When a battery is discharged, that chemical reaction is reversed, which creates voltage between two electrical contacts, causing current to flow out of the battery. The most common chemistry for battery cells is lithium-ion, but other common options include lead-acid, sodium, and nickel-based batteries.

Thermal Energy Storage - Thermal energy storage is a family of technologies in which a fluid, such as water or molten salt, or other material is used to store heat. This thermal storage material is then stored in an insulated tank until the energy is needed. The energy may be used directly for heating and cooling, or it can be used to generate electricity. In thermal energy storage systems intended for electricity, the heat is used to boil water. The resulting steam drives a turbine and produces electrical power using the same equipment that is used in conventional electricity generating stations.

Thermal energy storage is useful in CSP plants, which focus sunlight onto a receiver to heat a working fluid. Supercritical carbon dioxide is being explored as a working fluid that could take advantage of higher temperatures and reduce the size of generating plants.

Flywheel Storage - A flywheel is a heavy wheel attached to a rotating shaft. Expending energy can make the wheel turn faster. This energy can be extracted by attaching the wheel to an electrical generator, which uses electromagnetism to slow the wheel down and produce electricity. Although flywheels can quickly provide power, they can't store a lot of energy.

Compressed Air Storage - Compressed air storage systems consist of large vessels, like tanks, or natural formations, like caves. A compressor system pumps the vessels full of pressurized air. Then the air can be released and used to drive a turbine that produces electricity. Existing compressed air energy storage systems often use the released air as part of a natural gas power cycle to produce electricity.

Solar Fuels - Solar power can be used to create new fuels that can be combusted (burned) or consumed to provide energy, effectively storing the solar energy in the chemical bonds. Among the possible fuels researchers are examining are hydrogen, produced by separating it from the oxygen in water, and methane, produced by combining hydrogen and carbon dioxide. Methane is the main component of natural gas, which is commonly used to produce electricity or heat homes.

Virtual Storage - Energy can also be stored by changing how we use the devices we already have. For example, by heating or cooling a building before an anticipated peak of electrical demand, the building can “store” that thermal energy so it doesn't need to consume electricity later in the day. The building itself is acting as a thermos by storing cool or warm air. A similar process can be applied to water heaters to spread demand out over the day.

Ultimately, residential and commercial solar customers, and utilities and large-scale solar operators alike, can benefit from solar-plus-storage systems. As research continues and the costs of solar energy and storage come down, solar and storage solutions will become more accessible to all Americans.

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Solar-Plus-Storage

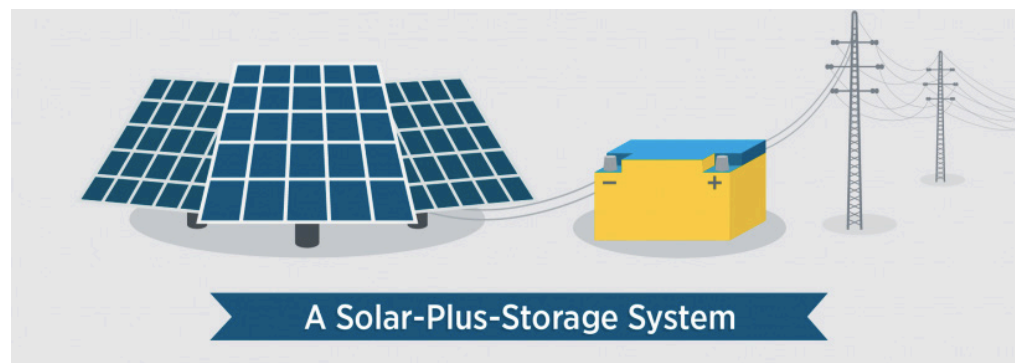
Solar panels have one job: They collect sunlight and transform it into electricity. But they can make that energy only when the sun is shining. That's why the ability to store solar energy for later use is important: It helps to keep the balance between electricity generation and demand. Lithium-ion batteries are one way to store this energy—the same batteries that power your phone.

Lithium

There are many ways to store energy: pumped hydroelectric storage, which stores water and later uses it to generate power; batteries that contain zinc or nickel; and molten-salt thermal storage, which generates heat, to name a few. Some of these systems can store large amounts of energy.

Lithium is a lightweight metal that an electric current can easily pass through. Lithium ions make a battery rechargeable because their chemical reactions are reversible, allowing them to absorb power and discharge it later. Lithium-ion batteries can store a lot of energy, and they hold a charge for longer than other kinds of batteries. The cost of lithium-ion batteries is dropping because more people are buying electric vehicles that depend on them.

While lithium-ion battery systems may have smaller storage capacity in comparison to other storage systems, they are growing in popularity because they can be installed nearly anywhere, have a small footprint, and are inexpensive and readily available—increasing their application by utilities.



Solar-Plus-Storage

Many solar-energy system owners are looking at ways to connect their system to a battery so they can use that energy at night or in the event of a power outage. Simply put, a solar-plus-storage system is a battery system that is charged by a connected solar system, such as a photovoltaic (PV) one.

In an effort to track this trend, researchers at the National Renewable Energy Laboratory (NREL) created a first-of-its-kind benchmark of U.S. utility-scale solar-plus-storage systems. To determine the cost of a solar-plus-storage system for this study, the researchers used a 100 megawatt (MW) PV system combined with a 60 MW lithium-ion battery that had 4 hours of storage (240 megawatt-hours). A 100 MW PV system is large, or utility-scale, and would be mounted on the ground instead of on a rooftop.

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Utility-scale lithium-ion Energy Storage

From 2008 to 2017, the United States was the world leader in lithium-ion storage use, with about 1,000 MWh of storage, and 92% of it, or about 844 MWh, is deployed by utilities, according to the benchmark report.

The average duration of utility-scale lithium-ion battery storage systems is 1.7 hours, but it can reach 4 hours. Batteries account for the biggest share of a storage system's cost right now—a storage system contains an inverter and wiring in addition to the battery—and utilities will need big battery packs if they're going to provide backup power for all of their customers.

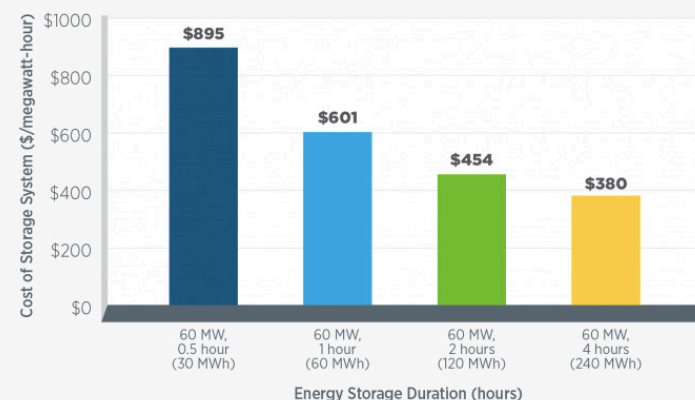
According to NREL, there's only one utility-scale PV system in the United States connected to storage, and it's a 13 MW PV plant with 52 MWh of storage in Kauai, Hawaii.

There are more systems that have storage co-located with a solar array, but those batteries can be charged by other sources of power on the grid.

According to GTM Research's "U.S. Energy Storage Monitor 2017 Year in Review," more than 5,500 energy storage systems are installed in the U.S., in the residential and commercial sectors with over 95% connected to PV in the residential sector at the end of 2017, which amounts to about 4,700 systems.

By the end of 2018, GTM estimates that solar-plus-storage will have accounted for about 4% of distributed PV and could reach 27% by 2023

Storage System Cost Breakdown by Time



A standalone 60 MW storage system will decrease in cost per megawatt-hour (MWh) as duration increases. Meaning, the longer your storage lasts, the lower the cost per MWh. That's because the cost of inverters and other hardware account for more of the system's costs over a shorter period.

The system costs range from \$380 per kWh for those that can provide electricity for 4 hours to \$895 per kWh for 30-minute systems.

Putting a PV system and a storage system in the same place, known as co-location, enables the two systems to share some hardware components, which can lower costs. Co-location can also reduce costs related to site preparation, land acquisition, labor for installation, permitting, interconnection, and developer overhead and profit.

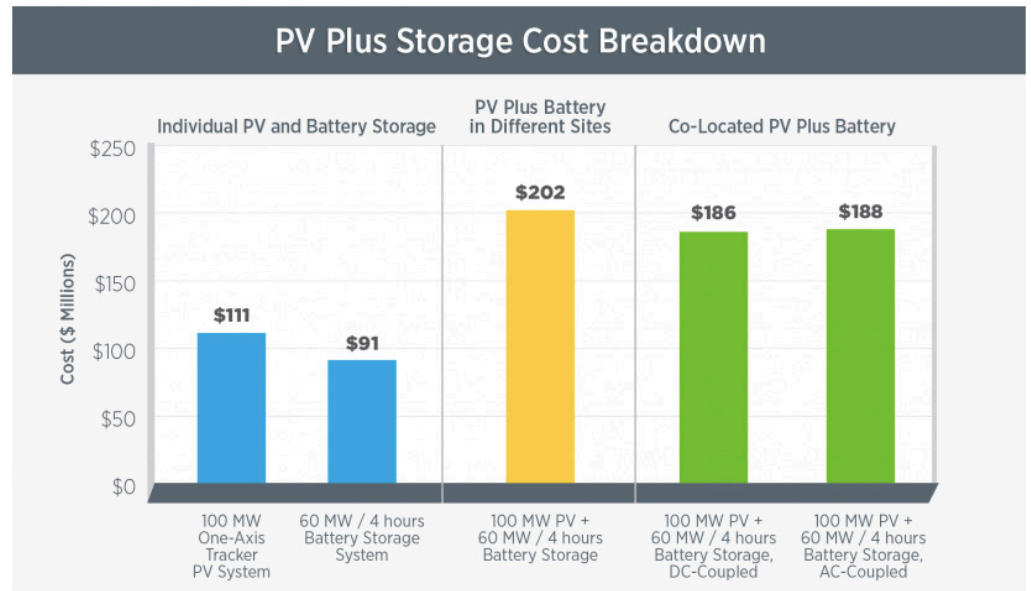
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PV-Plus-Storage

When PV and battery storage are co-located, they can be connected by either a DC-coupled or an AC-coupled configuration. DC, or direct current, is what batteries use to store energy and how PV panels generate electricity. AC, or alternating current, is what the grid and appliances use. A DC-coupled system needs a bidirectional inverter to connect battery storage directly to the PV array, while an AC-coupled system needs a bidirectional inverter and a PV inverter. Various factors figure into the choice of system, and it's up to the owner to decide which would work best.

When choosing between DC and AC, the technical factors that affect the system's performance must be considered, as well as costs. The cost of the co-located, DC-coupled system is 8% lower than the cost of the system with PV and storage sited separately, and the cost of the co-located, AC-coupled system is 7% lower. NREL's new cost model can be used to assess the costs of utility-scale solar-plus-storage systems and help guide future research and development to reduce costs.

As solar energy becomes cheaper and more widely used, the market potential for energy-storage devices grows. The challenge is making storage affordable too, with cheaper batteries while improving management and integration techniques. The goal, of course, is to make sure the Zimbabwean electric grid can deploy enough energy to accommodate everyone during peak times at an affordable cost, ensuring the reliability of the grid.





THE FUTURE OF SOLAR IN AFRICA

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SILICON CARBIDE IN SOLAR ENERGY

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Silicon Carbide in Solar Energy

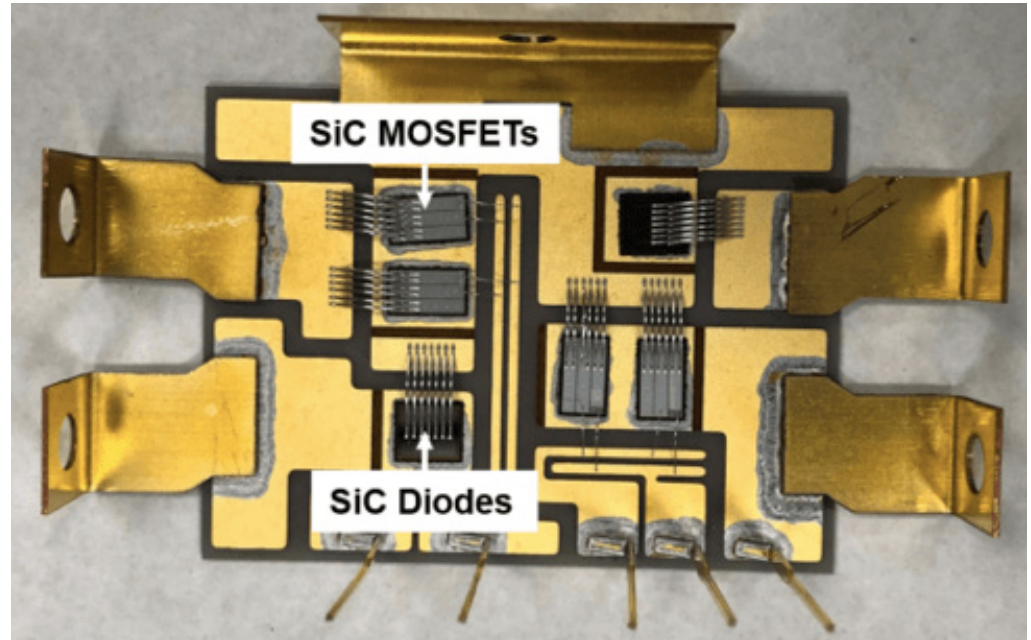
Semiconductor silicon carbide (SiC). SiC is used in power electronics devices, like inverters, which deliver energy from photovoltaic (PV) arrays to the electric grid, and other applications, like heat exchangers in concentrating solar power (CSP) plants and electric vehicles.

When PV modules generate electricity, energy first flows through a power electronics device that contains a semiconductor.

Until around 2011, silicon was the preferred semiconductor used to make these devices, but research has shown that SiC can be smaller, faster, tougher, more efficient, and more cost-effective.

SiC withstands higher temperatures and voltages than silicon, making it a more reliable and versatile inverter component. Inverters convert direct current electricity generated by solar panels from to grid-compatible alternating current.

During the conversion process, some energy is lost as heat. State-of-the-art silicon inverters operate at 98% efficiency, whereas SiC inverters can operate at about 99% over wide-ranging power levels and can produce optimal quality frequency. While the 1% increase in efficiency might seem small, it represents a 50% reduction in energy loss. With 60 gigawatts of solar installed in the United States, a 1% increase in efficiency would amount to 600 megawatts of additional solar power each year and cost savings over the device's lifetime.



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Benefits of Silicon Carbide

SiC has an edge over silicon because it enables the following:

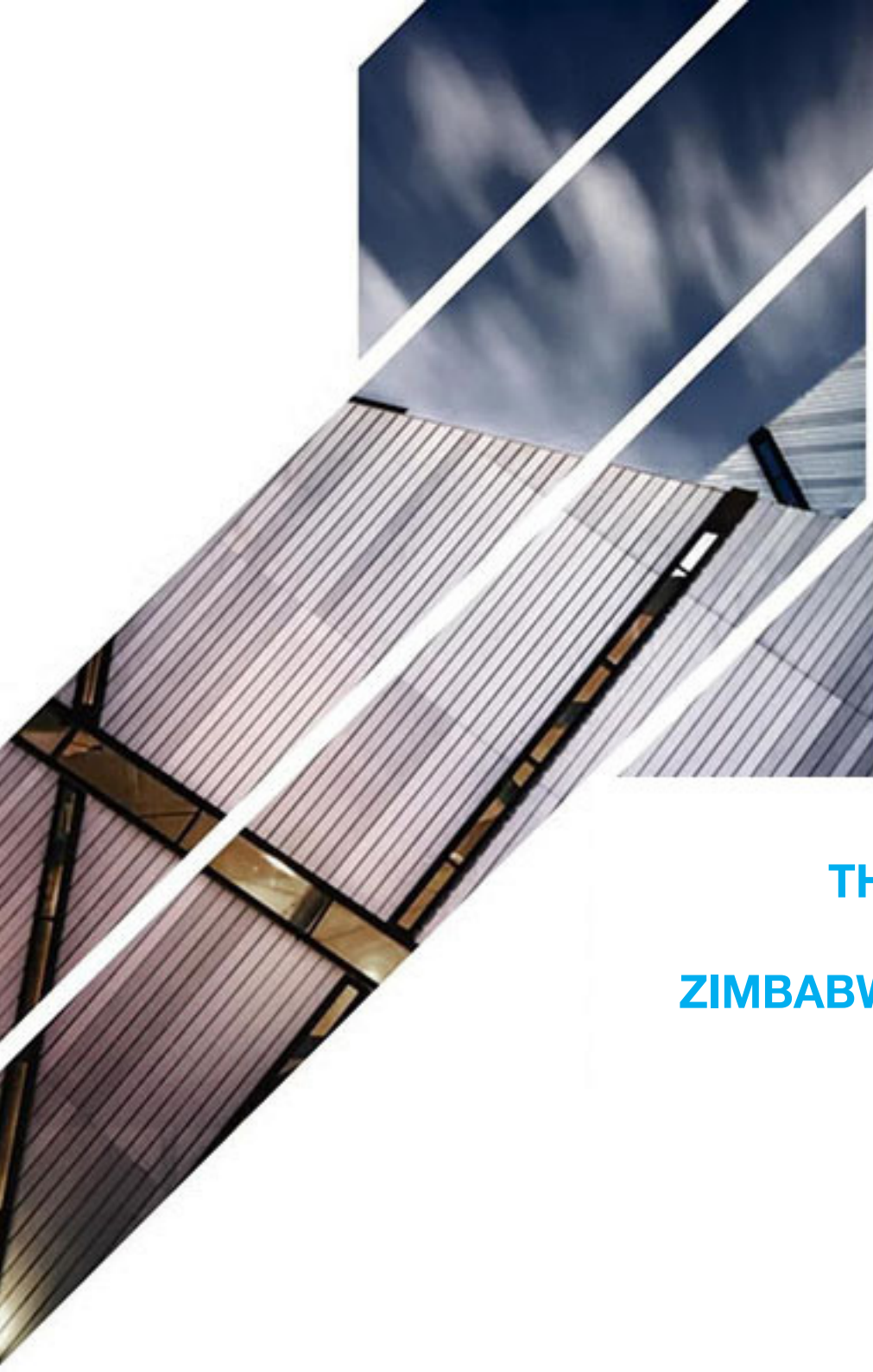
- * Higher temperatures: SiC-based power electronics devices can theoretically endure temperatures of up to 300° Celsius, while silicon devices are generally limited to 150°C.
- * Higher voltage: Compared with silicon devices, SiC devices can tolerate nearly 10 times the voltage, take on more current, and move more heat away from the energy system.
- * Faster switching: A power electronics device needs a switch that turns on to convert low voltage to higher voltage. SiC can switch on and off quickly, and although some energy is lost during switching, faster switching limits that loss and improves device efficiency.
- * Less-costly equipment: SiC translates to lower system costs because it allows for smaller, more affordable equipment. For example, the heat sink, which protects the rest of the components by taking on excess heat, can be smaller because with less energy loss, less heat is produced.

The Wide-Bandgap Advantage

One attribute is responsible for these benefits: SiC's wide bandgap.

The bandgap is a measure of energy that signifies the distance between two states—an electron's starting point in the valence band, which is the nonconduction state, and the level it has to move to in order for electricity to flow.

The wide bandgap allows for high voltage, which means SiC can better tolerate voltage spikes, and because devices can be thinner, they perform faster.



THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

SOLAR CYBER SECURITY

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Solar Cybersecurity

Solar energy technologies can be vulnerable to cyberattack through inverters and control devices that are designed to help manage the electric power grid. Operating-technology (OT) devices like solar photovoltaic inverters, when connected to the Internet, are at higher risk relative to stand-alone OT devices. They must be able to prevent, detect, and respond to unauthorized access or attack. While some cyberattacks manipulate information-technology (IT) systems, cyberattacks on electric-grid devices can cause physical impacts like loss of power and fires.

The electric grid is becoming increasingly digitized and connected, so maintaining cybersecurity is a top priority, for example the U.S. Department of Energy (DOE) state that there are daily attempts to attack the grid, but the majority are not successful. In March 2019, however, hackers breached a utility's web-portal firewall, causing operators to lose visibility of parts of the grid intermittently for 10 hours.

What is a Cyber Attack?

You may envision lone hackers furiously entering commands in dark rooms, illegally breaching and controlling sensitive systems, but many cyberattacks are more ordinary. For example, phishing scams use emails that appear to come from reputable sources and trick people into giving important information to a malicious actor. This type of manipulative, fraudulent practice is called social engineering. Failure to recognize such deceptions is the entry point into many systems.

Outdated software is another risk: A novice hacker could take advantage of a system's known vulnerabilities by running code downloaded from the Internet to attack it. Advanced hackers might discover problems so new that they're called "zero-day attacks," meaning security professionals have had no time to prepare for them.

A cyberattack on a cyber-physical system is different from one on an enterprise IT system because of the physical consequences. Cyber-physical systems are engineered systems that are built from, and depend upon, the seamless integration of computation and physical components.

How Could Hackers Attack Solar Power Systems?

Historically, cyber risk for solar was relatively minor, given how few systems were deployed and because most solar inverters did not communicate for monitoring or control.

However, as more solar is installed and inverters become more advanced, this risk grows. Inverters are the interface between solar panels and the grid. If the inverter's software isn't updated and secure, its data could be intercepted and manipulated. An attacker could also embed code in an inverter that could spread malware into the larger power system.

A cyberattack that introduces instabilities or false information into the power system can cause physical as well as financial damage. For example, a security breach could make an unauthorized change in power delivery.

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Unauthorized changes to inverter controls or communications like these are called cyber-physical security breaches, because the result is a change in the voltage or the electric current that the inverter injects into homes or the grid.

Microgrids are also a potential target for cyberattacks. Microgrids are local power systems that can operate independently of the larger grid in case of a power outage. Protecting them from cyberattack becomes part of an overall resilience strategy to maintain critical electrical infrastructure in emergencies.

Managing Vulnerabilities

The introduction of widespread digitization and interconnectivity across the modern grid presents a great challenge for grid operators. As more solar and other distributed energy resources (DER) are added to the grid, so are more tools that provide utilities with real-time solar power generation and other information. These tools must be secured, or the grid will become more vulnerable to cyberattack.

Security software can help utilities maintain control of their DER and prevent attackers from injecting false information into the system. Most attempted attacks on the grid are mitigated by intrusion-detection software that alerts grid operators to abnormal behavior.

Utilities and solar system owners and operators can use a dynamic survival strategy based on defense-in-depth measures, which are basically diverse layers of security that cover everything from individual components to entire systems.

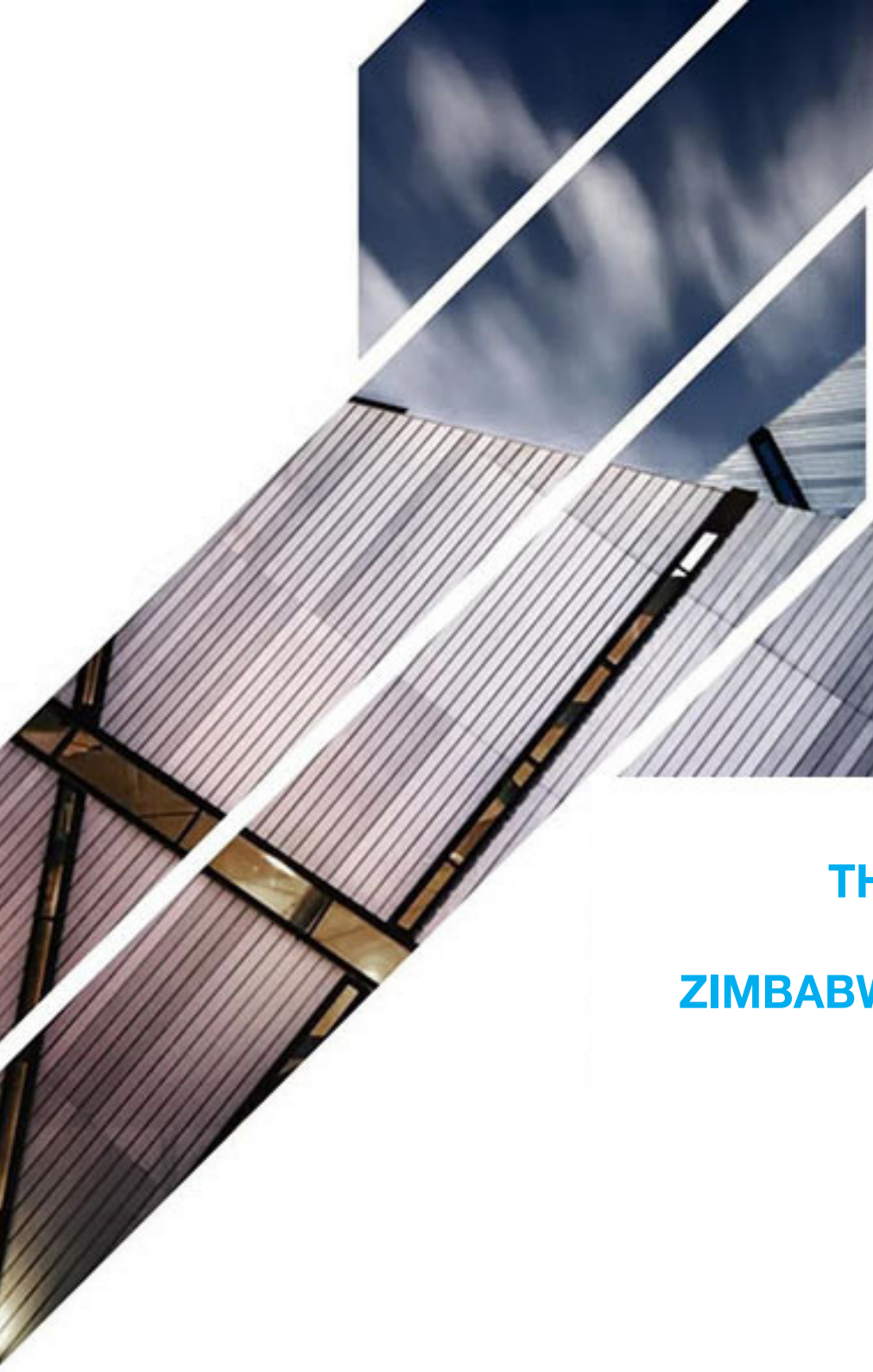
For example, installing anti-virus software in DER systems, such as solar inverters and battery controllers, is one layer of protection. Installing virus protection and detection on the firewalls and servers that integrate DER into the broader system of grid operation is another layer. This strategy for DER is complex, considering the number of owners, operators, and systems involved, but it's crucial to reduce the chance of cyberattack.

Cyber Attack Example:

In December 2015, a cyber security attack in Ukraine left 225,000 people without power. A similar attack was carried out a year later that caused an outage of 200 MW.² This, in combination with the increasing presence of distributed denial of service (DDoS) attacks, malware, ransomware, data theft, and other internet-based attacks, indicate the scale of the challenges power grid operators face as attackers increase their level of sophistication.

The emergence of cyber security threats to industrial control systems (ICS) over the last decade poses real risks to a nation's energy delivery systems.

The best method for long-term resilience from these risks is to understand the latest emerging threats and harden the power system infrastructure, deploy intrusion detection tools, and establish and install novel response mechanisms through cyber security research and development (R&D) programs, industry outreach and engagement, and codes and standards development.



THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

SOLAR AND RESILIENCE

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Electric Power Resilience

A resilient power system, as defined by the National Academy of Sciences, must be capable of lessening the likelihood of long-duration electrical outages occurring over large service areas, limiting the scope and impact of outages when they do occur, and rapidly restoring power after an outage.

Here is an example of a resilient power system scenario: A flood forces a local utility substation to shut down, interrupting electric service. Within seconds, residential photovoltaic (PV) solar panel systems with battery storage automatically detect the loss of grid power and switch to an “islanded” mode to keep the power on.

At the same time, a backup battery system at a local fire station enables the utility company to keep its communication equipment on so it can coordinate rescue operations. When the utility company is able to restore service, these backup resources will seamlessly reconnect to the grid, ready to be used during the next incident.

A completely resilient electric grid will help communities keep the power on during man-made or natural disruptions.

How Does Solar Improve Resilience?

Solar energy technologies can play an important role in strengthening energy system’s resilience. Two key attributes make solar a unique asset for resilience

The first is that solar generation can be distributed, as opposed to centralised. This means individual buildings can host their own solar systems to meet some or all of their power needs. Communities can combine solar with storage and other technologies to create a microgrid that will provide power to critical infrastructure when it is needed.

Most electric power is generated in large, centralized power plants—which then send the electricity to homes and businesses through power lines. This power can be disrupted if the transmission or distribution system gets damaged.

Distributed generation in combination with local energy storage allows power to be generated locally, near the customers, and could be used even if the centralized system experiences interference or disruption.

The second attribute that makes solar energy a key contributor to resilience is that sunlight-generated electricity can be stored and discharged without the need for fuel deliveries, unlike conventional diesel generators, which are the most common source of emergency backup power. In a long outage, solar and its associated energy storage can continue delivering power, even at night, to homes and businesses.

In addition to providing energy savings, solar energy systems have the potential to make homes, commercial buildings, and entire communities more resilient. By identifying the critical infrastructure in a community—like hospitals, fire stations, and shelters—and equipping those buildings with solar and energy storage systems, the community can respond better to, and recover faster from, electrical service loss.

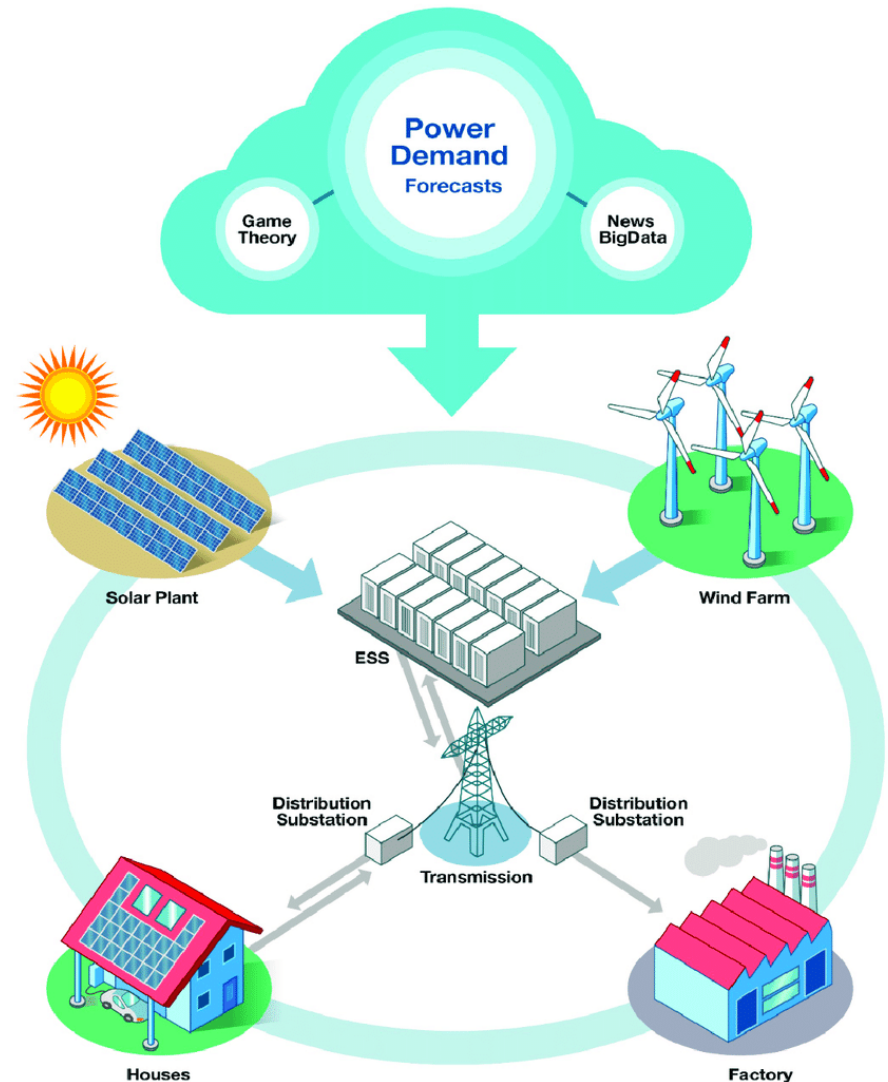
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Resilient systems like these have been built and demonstrated in regions prone to outages, fuel-supply constraints, and natural disasters. For example, the American DOE's SunSmart program helped equip more than 100 schools with backup solar and storage systems. In response to power system vulnerabilities revealed by Superstorm Sandy, the New York Governor's Office of Storm Recovery announced a project in 2019 to place solar panels and energy storage systems in flood-prone areas.

Technically, residential solar panels alone are not enough to make homes resilient. This is because solar systems generally depend on the electrical grid to produce power—and, for safety reasons, they're designed to switch off if the grid power cuts out. For solar panels to produce power on their own, they need two things: a properly configured inverter and a storage system. The solar inverter generates alternating-current power from the solar panel's direct-current output, while the storage system, like a battery, can keep power steady amid changes in output and building loads.

Communities can become more resilient with advanced solar technologies, pairing solar with storage can help make solar energy available during outages.

With new grid-forming inverters, a solar-plus-storage system may be able restart the grid after disruptions if the system is large enough. Microgrids could also provide resiliency benefits. Microgrids are a smaller version of the electrical grid that can help a large building, campus, or neighborhood balance its electrical supply and demand when the larger grid is down. By combining solar with these new technologies, we can build a robust energy system that responds to whatever threats and disruptions might lie ahead.





THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

SOLAR PANEL TYPES & MAJOR SOLAR PV PLAYERS

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Types of Solar panel

The most common types of solar panels are monocrystalline solar panels, polycrystalline solar panels and thin-film solar panels:

Monocrystalline silicon panels are made from a single crystal. They are the most efficient solar panels, but they're also the most expensive.

Polycrystalline silicon solar cells are made from multiple silicon crystals melded together. They're not quite as high-efficiency as monocrystalline panels, but they are a more budget-friendly rooftop solar option.

Thin-film solar cells are made from amorphous silicon, which makes them the most flexible solar panels but also the least efficient.

However, there are two European designed systems that are so cutting edge, they could well be the future of the Solar industry.

One is a **vertical Photovoltaic module system**, which Agamine mainly use on their range of Moroccan designed and manufactured Solar street lighting and other pole based street furniture, such as traffic signals - see image.

The second is the Nanotec **Photo-Energy panels** produced by utilising functional, printable pastes based on nanoparticles with specific physical, electrochemical, and photomechanical properties that allow the generation of electrical energy from sunlight to store this energy, which then converts the energy into light and heat.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Top Ten Solar Panel Manufacturers

Whilst the majority of the major Solar PV manufacturers are Chinese or based in Asia, there are a few majors based in other countries, such as USA, Canada, India and Israel.

Hanwha Q Cells – Market Cap: \$817.76M

Hanwha Q Cells is a South Korean company that manufactures solar cells and modules. Currently, the company is enjoying the number one market share position in the United States residential and commercial markets. It supplies quality products for global, residential, commercial, and utility-scale projects. As one of the world's largest PV manufacturers, Hanwha Q Cells can offer competitive prices for its products. It uses cutting-edge technologies to produce high-quality solar panels that require less space to generate enough electricity for residential use. Its products rank among the most efficient solar panels on the market today.

SMA Solar Technology – Market Cap: \$1.70B

SMA is one of the largest manufacturers of solar inverters. Its headquarters are in Germany, and they have offices worldwide, but they've established a strong presence in Europe, Asia, and North America. The company offers other products, including energy storage solutions and grid management systems. It has been around since the 1970s, consistently innovating new technologies to improve its products. It is committed to providing high-quality products at competitive prices.

SMA inverters convert the direct current (DC) from solar panels into alternating current (AC), which is then fed into the electrical grid. It has been a pioneer in this technology, and its products rank among the most reliable on the market today.

JinkoSolar Holding Co. Ltd – Market Cap: \$2.85B

JinkoSolar is one of the largest solar panel companies in the world, with factories in China and Europe. It offers a wide range of solar products, including panels, mounting systems, and inverters. The company has snowballed over the last decade, expanding its production capacity to meet the growing demand for solar power solutions. It employs IHS Technology, an advancement that ranked it among the top three PV module manufacturers worldwide in 2015. JinkoSolar offers more efficient, durable, and affordable products than comparable panels on the market. It has gained a competitive edge in the solar industry by focusing on innovation and quality.

Canadian Solar Inc. (CSIQ) – Market Cap: \$2.86B

Canadian Solar Inc. (CSIQ) is a leading global solar PV module manufacturer with a strong focus on R&D and innovation. It provides high-quality products at competitive prices. Its core competencies lie in manufacturing, engineering, and project development. Though recognized as a leader in solar PV technology, Canadian Solar is ever-expanding its product line and improving its manufacturing process's efficiency. It designed one of the first thin-film modules to be commercially available and strives to provide customers with the best possible products.

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Top Ten Solar Panel Manufacturers cont..

SMA Solar Technology has been in business since 2001 and has its headquarters in Ontario, Canada. It has over 14,000 employees worldwide and offices in the United States, Europe, and Asia.

SunPower – Market Cap: \$3.97B

This is a U.S.-based solar power company founded in 1985 and has since grown into one of the largest solar panel makers worldwide, with facilities across the United States, Europe, and Asia. It offers reliable solutions for those interested in installing solar panels on their residential or commercial properties. It has been at the forefront of solar technology since its inception. Hence, it's a one-stop shop for your project modules, design, installation, and maintenance services. It is among the first solar panel manufacturers to develop and deploy high-efficiency solar cells.

Sharp Solar – Market Cap: \$4.56B

What started as a small company has grown exponentially over the past several decades. Sharp Solar is now a global leader in solar panel manufacturing, with offices in over 100 countries and more than 8,000 employees. It has its headquarters in Japan and has been in business for over 40 years. Committed to the environment, Sharp Solar is one of the world's most innovative solar panel companies. It uses its technology and expertise to help reduce carbon footprint worldwide. It has developed some of the most efficient solar panels today. Its solar panels are suitable for homes, businesses, farms, and schools.

First Solar – Market Cap: \$13.47B

First Solar is a global solar energy services provider headquartered in Tempe, Arizona. The company sought to bring the benefits of solar energy to homeowners and businesses by making it affordable and accessible. First Solar started by developing its technology for high-efficiency solar panels, aiming to produce more electricity from each panel than its competitors could. This has seen it become one of the world's most efficient solar companies and one of the largest solar panel manufacturers worldwide. First Solar is a vertically integrated manufacturer renowned for designing, producing, and installing PV systems for commercial, industrial, and utility customers. Its solar panels use thin film technology, which allows them to be more flexible than traditional crystalline silicon panels while also being more efficient.

Trina Solar – Market Cap: \$19.94B

Trina Solar is a leading global solar panel manufacturer with over 25 years of experience in the industry. It is headquartered in China, with manufacturing facilities worldwide, including in Europe and the United States. Trina Solar has an annual capacity of over 100 GW. Its products have a strong reputation for quality. This company focuses much on developing innovative technology and maximizing efficiency. It also prioritizes producing environmentally friendly products. That explains its commitment to using recyclable materials and manufacturing processes with low environmental impact.

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Top Ten Solar Panel Manufacturers cont..

Kyocera Solar – Market Cap: \$20.71B

Kyocera Solar is a subsidiary of Kyocera Corporation, a Japanese company that has been in business since 1920. Kyocera Solar has grown to be one of the world's largest solar panel manufacturers. It has a significant presence in Japan and plans to expand into European, Asian, and North American countries. Its solar panels are for both residential and commercial applications. The company also produces energy storage solutions and solar-powered household appliances. It uses its business model to sell its technology to other industry players.

LONGi Solar – Market Cap: \$57.92B

LONGi Solar Technology is one of the most valuable brands in the solar industry. It manufactures PV modules and silicon wafers. This company offers high-quality solar panels and professional advice under the same roof without breaking the bank. It is always on the cutting edge of the most advanced solar technologies, including N-type TOPCON, P-type HJT, P-type TOPCON, and N-type HJT. Though it serves the global market, LONGi Solar has established its operations in China, Malaysia, Yunnan, and Kuching.





THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

NANOTEC NEXT GENERATION SOLAR

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Nanotec Next Generation Solar

Today's solar cells are simply not enough efficient and are too expensive to manufacture for large-scale electricity generation. However, advancements in nanotechnology have opened the door to the production of cheaper and slightly more efficient solar cells.

Conventional solar cells have two main drawbacks: efficiencies and their expensive manufacturing cost.

The first drawback, inefficiency, is almost unavoidable with silicon cells. This is because the incoming photons, or light, must have the right energy, called the band gap energy, to knock out an electron. If the photon has less energy than the band gap energy, then it will pass through.

If it has more energy than the band gap, then that extra energy will be wasted as heat. These two effects alone account for the loss of around 70 percent of the radiation energy incident on the cell.

Nanotechnology might be able to increase the efficiency of solar cells, but the most promising application of nanotechnology is the reduced manufacturing cost.

PVs based on CdTe, CuInGaSe (CIGS), CuInSe (CIS), and organic materials are being developed with the aim of reducing the price per watt even if that means sacrificing conversion efficiency and reliability. Utilising nanotechnology in inexpensive solar cell would help to preserve the environment.



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Nanotec Next Generation Solar cont...

The coatings are printed by nano-pastes developed in a specific way, in particular the coatings allowing the production of energy and its storage which fit perfectly into the category of renewable energy solutions.

Organic photovoltaic (OPV) solar cells can be used for covering greenhouses and they can be utilized in heating and cooling systems.

Price Competitiveness

The second drawback of the conventional solar panels is the manufacturing price, we have analysed here the selling price of the different types of silicon-based panels, the review is as follows :

Polysilicon prices have soared to the highest in nearly a decade. From the PV Insights, Solar Panels are getting more expensive. In 2021, The solar module prices have risen 18% since the start of the year after falling by 90% over the previous decade. The reversal, fueled by a quadrupling in the cost of the key raw material polysilicon, threatens to delay projects and slow uptake of solar power just as several major governments are finally throwing their weight behind it in an effort to slow climate change.

By the Energy research group BloombergNEF. “This causes Developers and Governments to have to stop expecting solar to get much cheaper quickly.” Largescale projects in the U.S. could also get postponed, which might force state-owned power giants in China to push projects into next year.

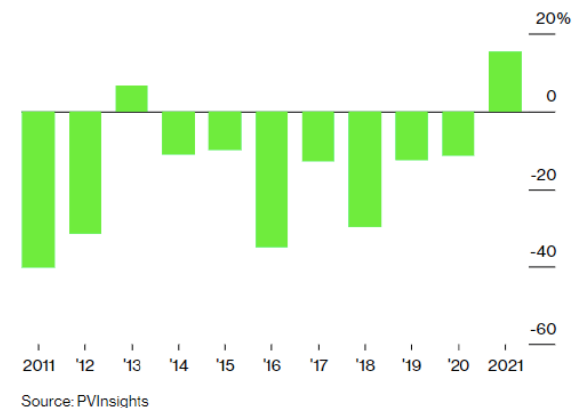
Price Competitiveness cont..

Largescale projects in the U.S. could also get postponed, which might force state-owned power giants in China to push projects into next year.

Polysilicon prices are expected to remain strong through the end of 2022, according to Roth Capital Partners analysts.

In contrast, the Nanocoating can be produced in any RAL color and are not based on any rare or toxic material, they are based on non-polluting products widely available in nature and inexpensive. At the end, the Nanotec Panels fully comply with the most severe European environmental standards: They are CO2 emission friendly power generation solution.

The PE Panels are expected to cost about 100Euros whereas the PV Panel is about 350Euros.



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Nanotec Next Generation Solar cont...

Weather Resistant

In addition, PE Panels have unique distinctive elements compared to the competition from conventional solar panels:

- * Performance resistance over a wide temperature range.
- * Energy production as soon as light is available, natural, or artificial, then production of a greater quantity of energy by the nanocoating.
- * Low maintenance.



Nanotec Next Generation Solar cont...

Thin Film Solar Cells

EXCEPTIONAL THIN SOLAR CELLS THICKNESS

Nano-structured layers in thin film solar cells offer three important advantages.

First, due to multiple reflections, the effective optical path for absorption is much larger than the actual film thickness. Second, light generated electrons and holes need to travel over a much shorter path and thus recombination losses are greatly reduced. As a result, the absorber layer thickness in nano-structured solar cells can be as thin as 150 nm instead of several micrometers in the traditional thin film solar cells. Third, the energy band gap of various layers can be made to the desired design value by varying the size of nano particles. This allows for more design flexibility in the absorber of solar cells.

COST EFFECTIVE

Thin film is a more cost-effective solution and uses a cheap support onto which the active component is applied as a thin coating. As a result, much less material is required (as low as 1% compared with wafers) and costs are decreased. Most such cells utilize amorphous silicon, which, as its name suggests, does not have a crystalline structure and consequently has a much lower efficiency (8%), however it is much cheaper to manufacture .

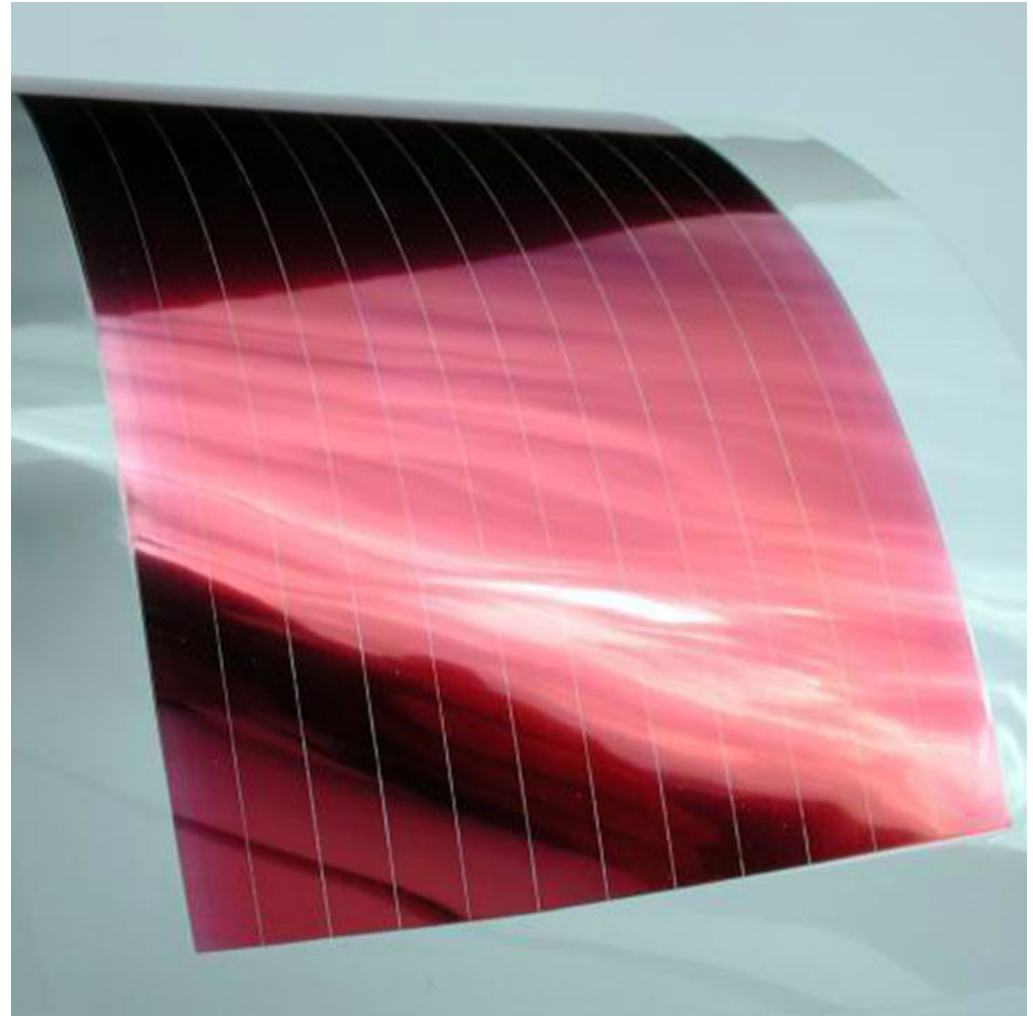
The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Nanotec Next Generation Solar cont...

Competitive Insight Summary

The Photo Energy (PE) panel technology represents several advantages over the photovoltaic competition:

- * A light weight, which will generate a lower cost of transport and logistics.
- * Easy and less restrictive installation.
- * Requires less technicality for installation.
- * Better weather resistance.
- * A real competitive cost.
- * Better performance due to resistance to high temperatures.
- * A possibility of installation on several types of surfaces (optimization of the land).
- * A possibility of deploying a dual product.
- * Energy production as soon as light is available, natural, or artificial, then production of a greater quantity of energy by the nanocoating.
- * Low maintenance.



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Nanotec Competitive Insight cont...

Characteristics	PV panel	Electroluminescent panel
Power	375 - 400 W	340 - 400 W
Number of cells	60 - 144	0 (<i>Nano-coating</i>)
Guarantee	15 - 30 years	30 years
Linear production guarantee *	80 - 92 % after 25 years	94 % after 30 years
Yield range	12 % - 21,7 %	15,8%
Performance sensitivity to temperature	-40% loss and more from a temperature equal to or higher than 40-45 ° C	No sensitivity between -40°C and +140°C
Spectral sensitivity	peak in solar radiation	Solar radiation + Daylight + Artificial light
Maintenance	Standard	Cleaning of external surface

(*) *Under normal temperature conditions*

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Nanotec Next Generation Solar cont...

Paste Technology

Diverse design possibilities of the PV-functional and tox-free printed, both rigid and flexible carrier material regarding size, form and colour result not least also due to the low-light capability in best application possibilities as facade or roof modules, but also in many other areas, such as e-mobility, or direct device power supply (cell phone, laptop, music devices, camping equipment, etc.).



The company's headquarters has been built with a combined façade module as a coloured photovoltaic façade module and energy storage unit

Nanotec Next Generation Solar cont...

Printing Machine Technology

The production line consists of a minimum of 4 modules, each equipped with a robot for the application of the materials to be printed, a 10-axis CNC special screen-printing machine and a high-performance dryer, which allows to dry the printing pastes within seconds with a flash of light. With this development, the cycle time has been reduced to less than 15 seconds, allowing a high output in a fully automated and integrated production process.

Individual technical components that make accurate and high-quality printing possible are currently in the patenting phase. These are among others:

- Laser doctor blade measurement
- Screen expansion compensation
- 10-axis CNC screen printing machine
- Special vacuum printing table
- High frequency squeegee

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Nanotec Next Generation Solar - Technology Advantages

The PE panel technology represents several advantages over the photovoltaic competition, cited below:

A light weight, which will generate a lower cost of transport and logistics

Easy and less restrictive installation

Requires less technicality for installation

Better weather resistance

A real competitive cost

Better performance due to resistance to high temperatures

A possibility of installation on several types of surfaces (optimization of the land)

A possibility of deploying a dual product

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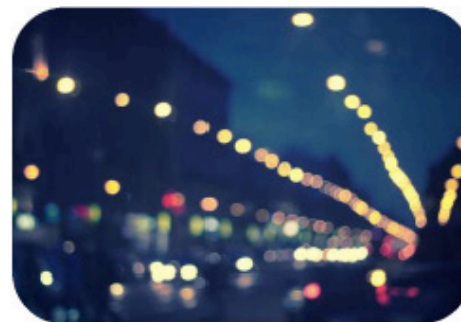
Nanotec Next Generation Solar - Application Examples



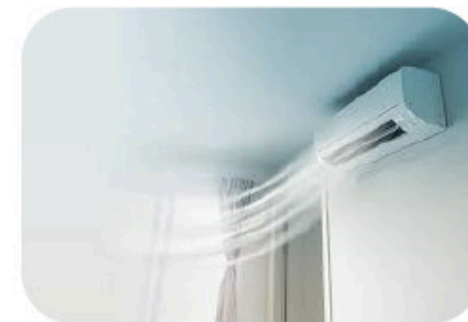
Photovoltaics



Storage technology



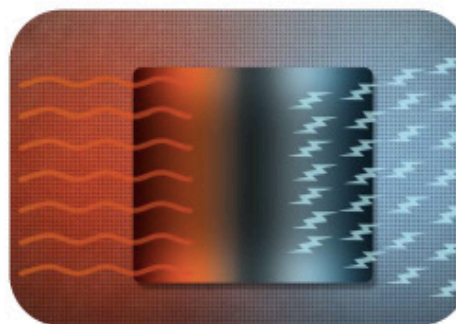
Lighting



Air conditioning



Smart-Glass



Heat-to-Energy



Façade module



THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

AGAMINE SOLAR STREET LIGHTS

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Agamine are an Agadir, Morocco based manufacturer of Solar Street Lighting systems.

They produce a range of Street lighting, with Classic and Modern designs combined with state-of-the-art components to ensure outstanding performance, reliability and a long service life.

Features:

- * High-performance street light for various lighting situations
- * Fully autonomous and energy self-sufficient
- * Smart, reliable and affordable
- * Strong construction and closed design
- * Easy to install and minimum maintenance

Options:

HYBRID STREET LIGHTING - a combination of batteries and grid connectivity where the batteries serve as back-up.

SOLAR POWERED CAMERA - all types of IP cameras for wide area surveillance can be integrated - either invisible mounted in the lamp head or be visibly attached.

SMART MONITORING - remote configuration and lighting control from anywhere via a modern web application.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Agamine Solar Street Lights include a unique self-cleaning cylindrical vertical photovoltaic module, rather than the normal solar panel.

VERTICAL PHOTOVOLTAIC MODULE

A vertical, cylindrical photovoltaic module with high-performance monocrystalline cells: it can pick up direct and indirect sunlight and is unsusceptible to dust and sand (“self-cleaning”).

SMART CONTROL AND REMOTE MONITORING

The custom-developed controller allows for maximum autonomous operation and is designed for smart city remote monitoring.

SURVEILLANCE CAMERA & EXTENSIBLE FEATURES

Easy implementation of additional functions e.g. surveillance camera, WiFi hotspot, USB charging point, motion sensors, or various other sensors.

EXCELLENT ILLUMINATION

The custom lenses are designed to focus the light, deliver excellent illumination and have a long lifetime.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

STRONG CONSTRUCTION

Agamine outdoor street lighting systems are strong, durable and resistant to environmental impacts and vandalism.

RELIABLE & RESISTANT

Their energy self-sufficient lighting systems are strong, durable and resistant to environmental impacts and vandalism.

SECURITY DOOR

Pole door only accessible with security key

INTEGRATED BATTERIES

Batteries integrated into the pole with passive cooling

WATER AND IMPACT PROOF

High protection grade for all parts (IP66/IK09)

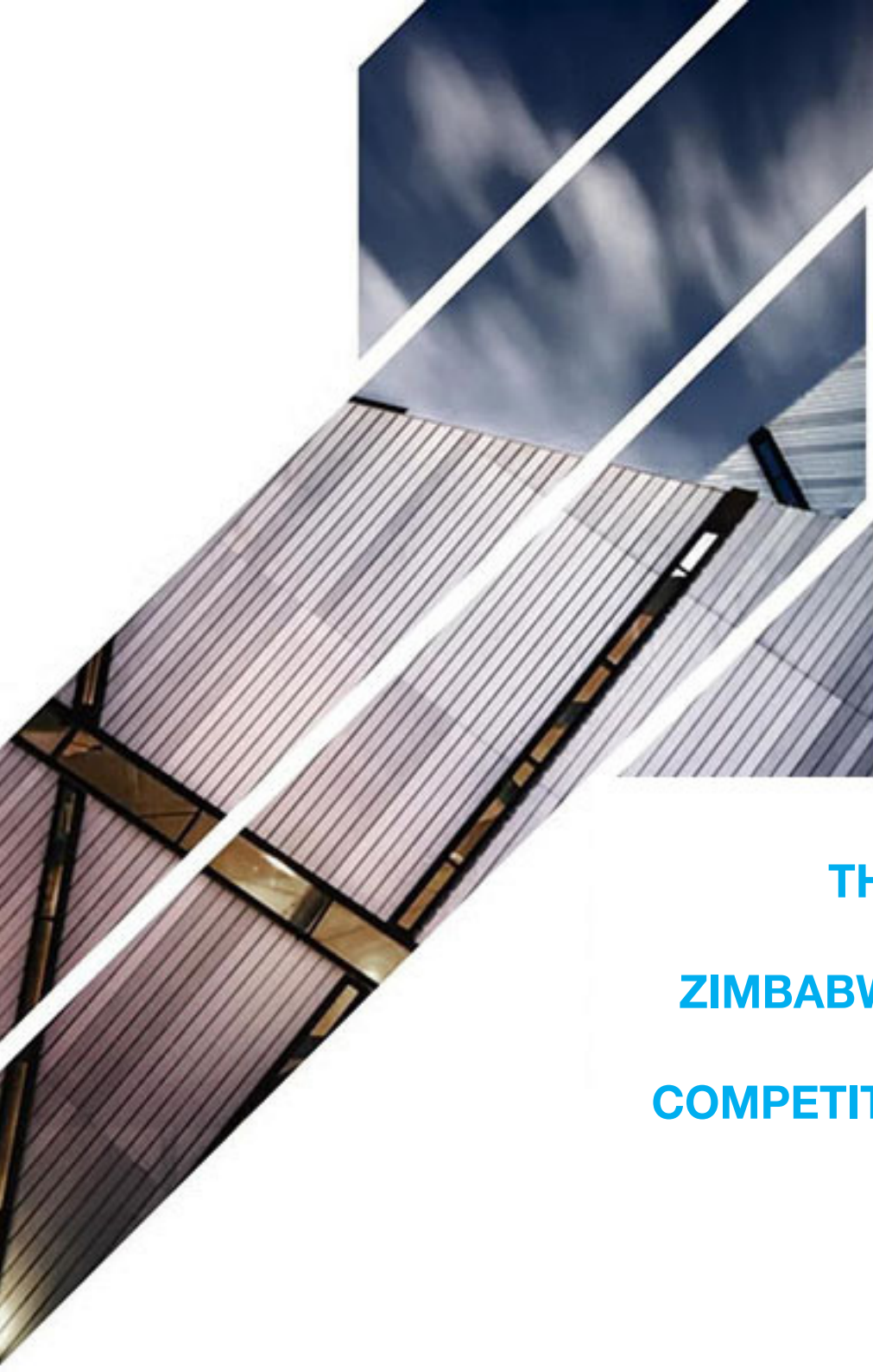
WIND RESISTANCE

Resistant to high wind load (40m+/s)

ROBUST POLE

Steel pole hot-dip galvanized and powder coated with high-graded finishing





THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

COMPETITION - AFRICA BASED MANUFACTURERS

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Whilst many African countries have an active Solar Industry, most are owned and operated by overseas entities and import the required technology.

In no particular order, here are the top ten African Solar Companies and following are details of the African Based Manufacturing plants we have identified.

Off Grid Electric

Based in Tanzania, this solar company is run by Xiaver Helgesen, Erica Mackey and Joshua Pierce. The company was started in 2011. Off Grid Electric provides solar electricity at an affordable price which is less than the price of kerosene, electricity bill, batteries.

Recently, the solar company won a 5 million dollars grant from USAID after raising 25 million dollars from international investors.

M-Kopa Solar

Launched in 2011, the Kenya based solar company now has over 300,000 customers and counting.

M-Kopa Solar was founded by M- Pesa, the founders are Nike Hughes, Chad Larson and Jesse Moore. The founders contribute to society by making finance for everyday essentials very accessible.

M-Kopa helps many underbanked customers have access to power and become owners in the long run. They have attracted 40 million investment backed by the bill and the Melinda Gates Foundation Safaricom.

Atlantic Waste and Power System

A Nigeria-based enterprise launched in 2013 by Chris Onwusanya, Atlantic Waste and Power System is a developer of microgrid and utility scale solar projects.

Having returned to Nigeria and experienced the unreliable power supply and the constant power outage, Onwusanya partnered with a French electricity project developer to address this. The solar company was to help Nigeria achieve a clean and reliable power supply.

Powerhive

In 2015, Powerhive became the first private company in Kenya to receive a utility concession to generate, distribute and sell electricity to Kenyans.

Founded by Christopher Hornor in 2011, the company's goal is to grant everyone clean energy and its opportunities.

Helvetic Solar

Founded by Patric Ngowi, Helvetic Solar services range from solar panels to solar heater, back-up unit etc.

The company serves customers across countries in East Africa. Helvetic Solar ranked at the top of the East Africa Survey of top 100 Mid-size companies in Tanzania in 2012. A year later, the company made up to 5 million dollars

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

ARED

An acronym for African Renewable Energy Distributor, ARED was founded by Henri Nyakarundi. The Rwanda based startup developed a mobile solar kiosk that comes with built-in solar panels that could generate power to charge more than a dozen phones at once.

ARED's power solution has helped a lot of people to earn a living and create job opportunities for ordinary people. It also a supplier of clean energy to charge phones.

Quaint Global

Lunched in 2010, this Nigeria-based company is a provider of solar energy solutions to rural communities in Nigeria.

Quaint Global, co-founded by Seun Solesi, was recognized by Forbes as one of Africa's most cleantech startups in 2015. Also, the solar company received a grant of 1.3 million dollars grant as part of Obama's Power Africa Initiative.

Karibu Solar Power

This innovative company models itself as a social enterprise that supplies energy at kerosene price. Founded by Sameer Gulamani in 2012, the Tanzania based startup aims to bring sustainable energy to Africa.

This it does by designing, manufacturing and distributing solar pay as you go 'business in a box'. In 2014, Karibu solar emerged of the Cornerstone International Business SEED award.

Ugesi Gold

Ugesi Gold is a South African solar company whose goal is to use its solar turtle, a shipping container that is converted into a solar battery charging station where local individuals can buy power.

The solar enterprise won the award for Climate Saver in 2014 and has been awarded a 110% Green Flagship Initiative by the South African Western Cape Government.

Sunny Money

A social enterprise, Sunny Money is owned by a UK-based charity called Solar Aid, which operates in Malawi, Kenya, Uganda, Malawi, Zambia and Tanzania.

Its goal is to provide solar power to the rural communities thereby eradicating the kerosene lamp for good.

These companies provide solar for Africa and will grow to eliminate power issues, save the African economy and reduce fossil fuels emission.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

ARTsolar was established in 2010 in Durban, South Africa, and remains one of the pioneers of the South African Photovoltaic (PV) solar panel manufacturing industry.

They are 100% locally owned and are currently the only South African PV manufacturer that specialises in high volume production for the Utility Scale PV farms. Their production facility is fully capable of laminating, testing and framing PV modules, with a capacity up to 325MW annually.

They also have the facilities to perform complete quality assurance tests on all imported PV modules, this involves complete testing of each and every module in a shipment to ensure that the quality has not been compromised during shipping or by manufacturing defects.

Their business model has further evolved to incorporate the wholesale/retail of PV modules and related equipment directly to specialist installers and general consumers.

ARTsolar's state of the ART Swiss built production facility in Durban (which has been completely funded by its shareholders) was originally designed to manufacture for Bosch in Germany, and became South Africa's first company to produce significant quantities of solar panels for the Renewable Energy Independent Power Producer Programme (REIPPP).

Production and quality assurance facilities are controlled, managed and overseen by our in-house developed, AI powered, MES system: PVflow®.



ARTsolar provide quality assurance reports and perform re-works/repairs on modules to ensure your return of investment.

They also provide local guarantees/warranties and are backed by local shareholders who are committed to the success of the South African renewable energy sector.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Faso Energy

In September 2020 Burkina Faso inaugurated a solar panel production and assembly plant, At a cost of 3,2 billion CFA francs (4,9 million euros) and called “Faso Energy”, the first in West Africa, according to a statement from the Prime Minister

According to the promoter of Faso Energy, Moussa Kouanda, the annual production will install a power of 30 megawatts, or 3% of the country’s consumption.

The Faso Energy solar panel production unit is located in the industrial zone of the Kossodo district of Ouagadougou. There, the latest generation machines of European origin cover the entire production chain.

As a result, solar panels from 260W to more than 330W are produced. The plant’s production capacity is 80 to 120 MW per year and a daily production capacity of 200 photovoltaic panels per day.

daily production of 60 to 100 photovoltaic panels per day. Faso Energy’s solar panels comply with international standards. We use the latest technology of the panels that we find on the market, with a technology of 5 bus bars on the cells.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Ener-G-Africa

In 2017 Ener-G-Africa (EGA) was founded in Malawi as a solar wholesale company after recognizing the demand for quality sustainable energy products outpaced supplies in the country.

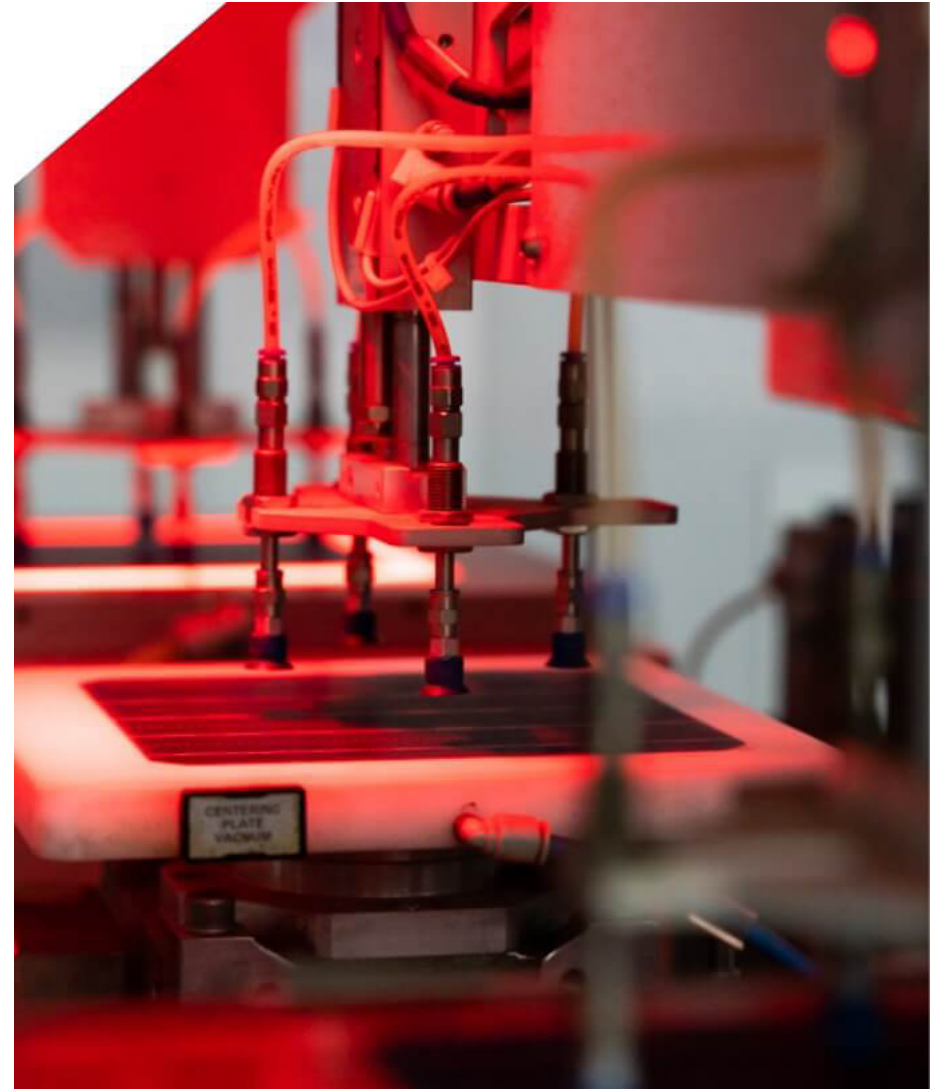
While expanding the company's solar wholesaling capacity, we also started ABS stove distribution and started our first rural stove implementation programme with CQC.

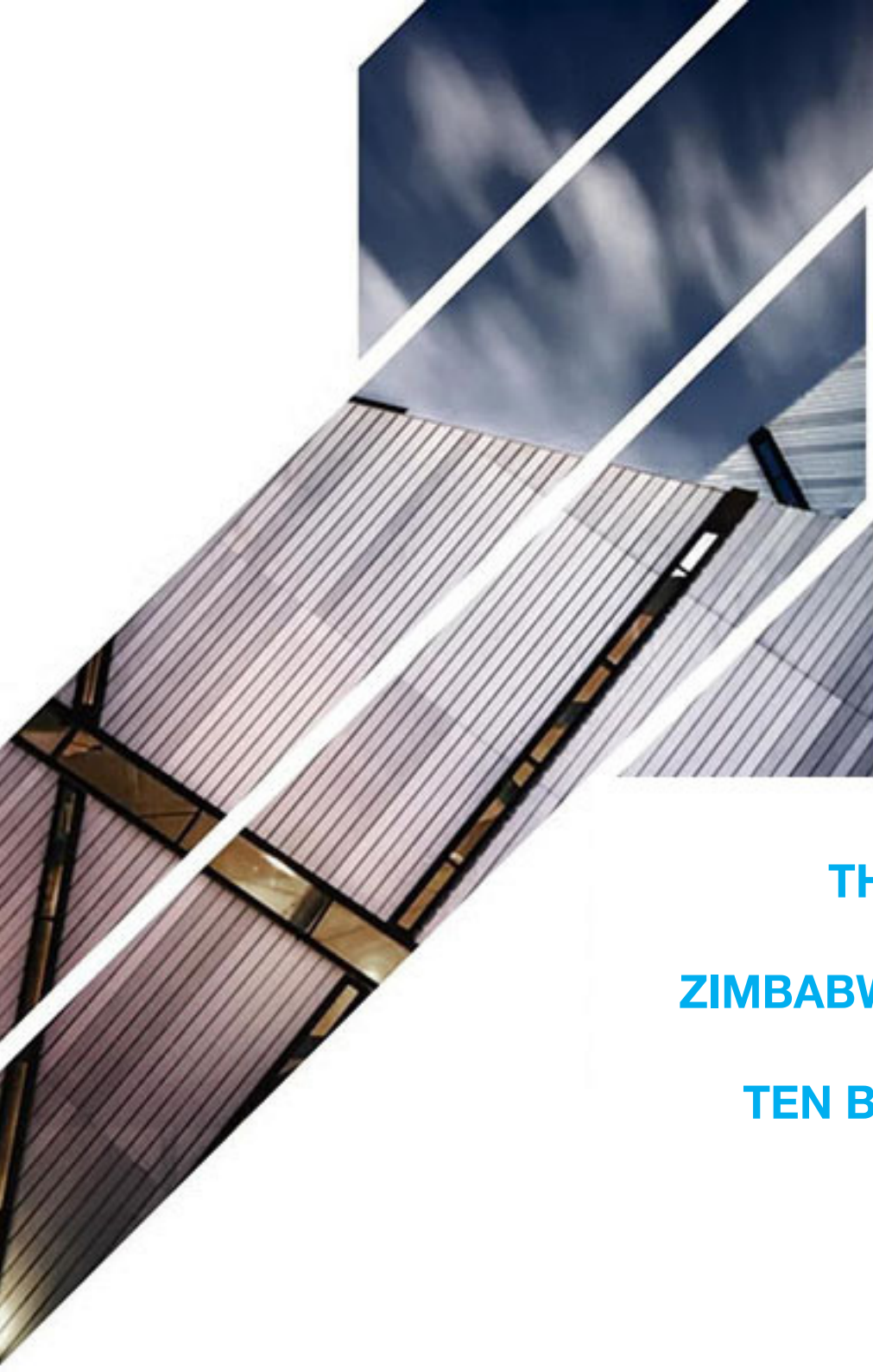
Ener-G-Africa (EGA) furthered the partnership with CQC, resulting in an investment in the first manufacturing line of the TLCRS stove.

In 2020 Stove manufacturing capacity increased by 500%, solar product sales doubled, and stove implementation programs increased by 300%. A year later Ener-G-Africa (EGA) launched another stove manufacturing facility in Cape Town, South Africa, the location of our new headquarters. The new line doubled production output.

More recently, in 2022 Ener-G-Africa (EGA) commissioned a 15 MW per annum solar panel assembly plant at the Cape Town HQ, only the second such facility in Sub-Saharan Africa.

Based at the Cape Town premises, EGA's women-led Solar Plant assembles solar panels for use with Advanced Biomass Stoves, as well as for the regional African market and overseas exports.





THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

TEN BIGGEST AFRICAN SOLAR PROJECTS

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

The biggest solar projects in Africa

Morocco is home to Africa's biggest solar project Noor whereas South Africa hosts eight of the ten largest solar plants in Africa. Power-technology listed Africa's biggest operational solar projects by installed capacity as:

The Noor Solar Complex is a 500MW solar park located in the municipality of Ouarzazate in the Agadir district of Morocco. It is the biggest concentrated solar power plant project in the world. The location of the project offers 2,635kWh/m² of sunlight a year, which is considered to be one of the highest in the world. The solar park integrates multiple utility-scale solar power plants equipped with various solar technologies.

The Noor solar park includes Noor I, Noor II and Noor III projects, which occupy an area of 2,500ha. The three power plants were grid connected by 2018. The Noor Solar Complex offsets 760,000t of CO₂ emissions a year.



Solar Capital De Aar Project – 175MW

Located in the Northern Cape, South Africa, the De Aar solar project was developed by Solar Capital.

The project encompasses two phases (De Aar 1 and De Aar 3) with a combined installed capacity of 175MW.

De Aar 1 was commissioned in 2014 and became operational in 2016.

The project was developed under the South African Government's Renewable Energy Independent Power Producers Procurement Programme (REIPPPP).

The De Aar solar project supplies green electricity to power up to 100,000 South African homes, making it the largest solar farm in the country.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Benban Solar Project – 165.5MW

The 165.5MW Benban photovoltaic (PV) solar park is located in the Aswan Province in Benban, Egypt.

The solar park is med up of three solar power plants with an individual installed capacity of 67.5MW, 70MW and 28MW, respectively.

The 165.5MW project was constructed by CHINT Solar by August 2018.

ACWA Power is the developer, financier and operator of the solar park, which involved an investment of \$190m.

The Benban PV solar park generates enough electricity to power 80,000 homes while offsetting approximately 156,000t of CO2 a year.

KaXu Solar One – 100MW

KaXu Solar One is a 100MW solar power plant near Pofadder in the Northern Cape Province of South Africa.

It is the first commercially operated solar thermal electric power plant in South Africa.

Commissioned in March 2015, the public-private partnership (PPP) project supplies sustainable energy to South Africa's power utility Eskom, under a 20-year power purchase agreement.

Abengoa holds a 51% stake in the project while the IDC and KaXu Community Trust respectively own 29% and 20%.

The KaXu Solar One power plant is capable of delivering clean and green power to approximately 80,000 South African households.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Xina Solar One – 100MW

Xina Solar One is located in Pofadder, South Africa and a 100MW concentrated solar power (CSP) plant built by Abengoa with a \$880m investment. The plant commenced its commercial operations in September 2017.

The CSP plant employs parabolic trough technology and offers 5.5 hours of thermal energy storage.

The parabolic trough collector of the plant is touted to be the world's biggest commercial CSP project to date.

The plant is anticipated to produce approximately 400GWh of energy, which is enough to power 95,000 homes while eliminating 348,000t of CO2 emissions per annum.



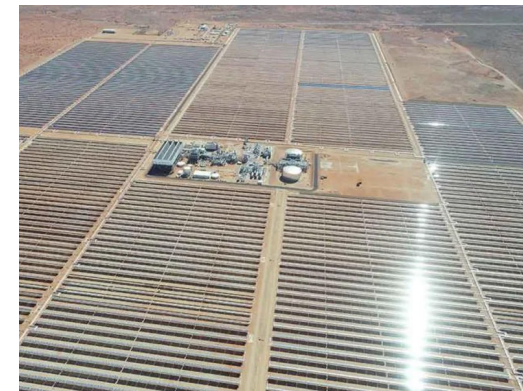
Ilanga-1 CSP Plant – 100MW

SENER and its partners Emvelo and Cobra completed the commissioning and testing of the 100MW Ilanga-1 CSP plant in November 2018.

Located in Karoshhoek in the Northern Cape province of South Africa, the plant is owned by Karoshhoek Solar One (RF) Proprietary.

The Ilanga-1 CSP plant features 266 SENERtrough® loops. The molten salt storage system installed at the plant ensures five hours of thermal energy storage to generate thermal energy in the absence of solar radiation.

The solar power plant is anticipated to provide clean energy to approximately 100,000 South African homes while annually cutting down 90,000t of CO2 emissions over 20 years.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Kathu Solar Park – 100MW

The Kathu Solar Park (KSP) is a 100MW CSP project in Kathu in the province of Northern Cape, South Africa.

The solar park started commercial operations in January 2019.

The KSP project is owned by Engie, SIOC Community Development Trust, the Public Investment Corporation, the Lereko Metier REIPPP Fund Trust, Investec Bank and the Kathu LCT Trust.

The greenfield project integrates parabolic trough and molten salt storage technology, ensuring 4.5 hours of thermal energy storage.

It supplies 179,000 households in South Africa during their peak demand period.



Jasper Solar Power Project – 96MW

With a 96MW-DC installed capacity, Jasper is one of the most significant solar energy projects in Continental Africa.

The solar plant is located in Postmasburg in the Northern Cape Province in South Africa.

The solar power project was developed by SolarReserve and its consortium partners Kensani and Intikon Energy.

Construction on the Jasper plant began in October 2013, while the project became fully operational in October 2014.

Jasper generates approximately 180GWh of renewable energy annually, which is sufficient to power 80,000 homes in South Africa.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Mulilo-Sonnedix-Prieska PV Project – 86MW

The 86MW Mulilo-Sonnedix-Prieska solar photovoltaic (PV) project is located across 125ha of land area in the Northern Cape Province, South Africa.

The solar plant began commercial operations in July 2016.

This project was developed by Mulilo Renewable Project Developments (Pty) in partnership with Mulilo Renewable Energy and Ixowave Women in Power, for Mulilo Sonnedix Prieska PV (Pty).

The Mulilo-Sonnedix-Prieska PV project supplies enough power to 40,000 South African households through the Eskom grid, during its life span of 20 years.

Kalkbult Solar Plant – 75MW

The 75MW Kalkbult solar PV plant is situated near Petrusville in the Northern Cape Province, South Africa.

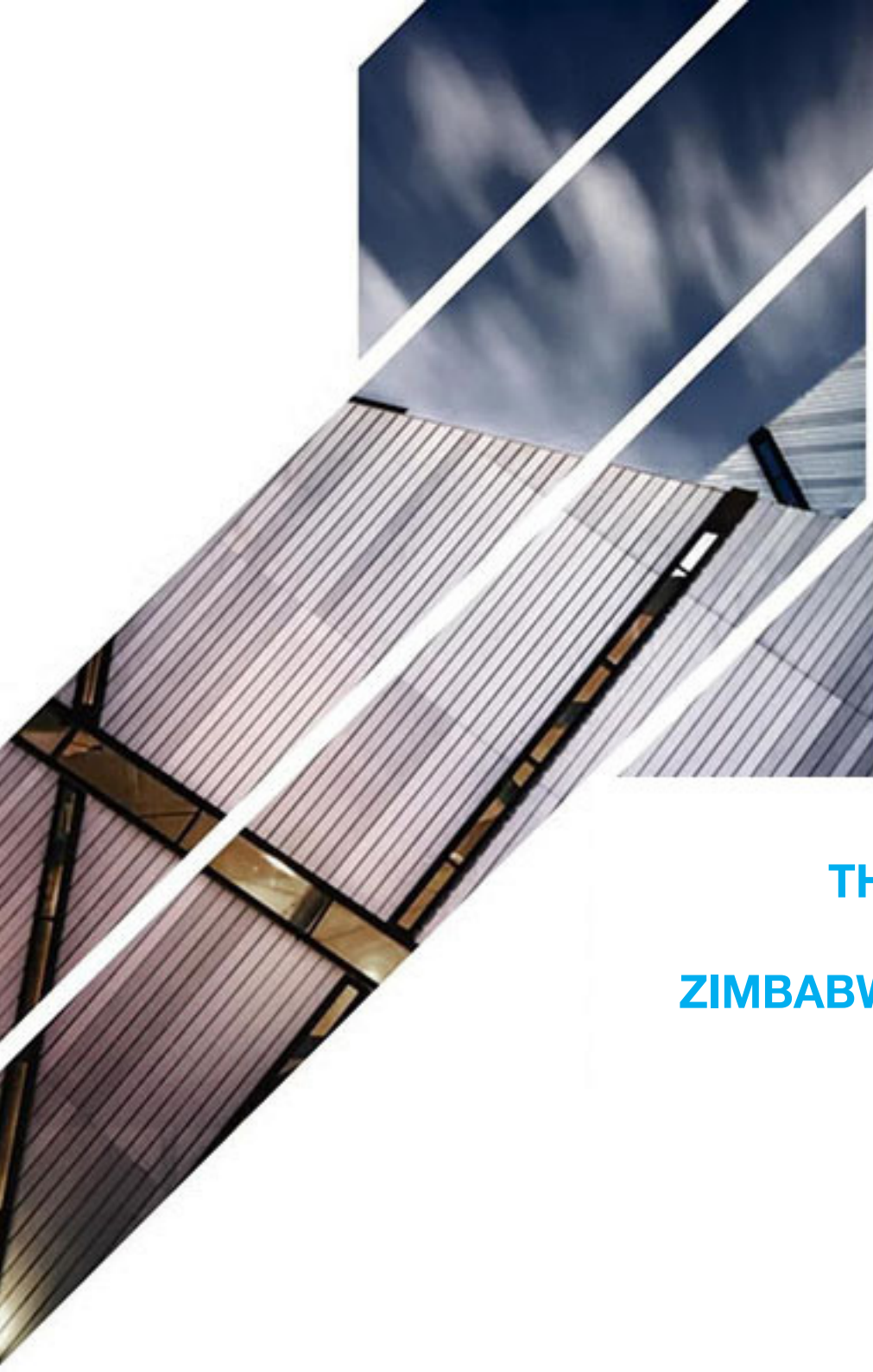
Developed by Scatec Solar, the plant was officially inaugurated in November 2013.

Construction of the Kalkbult solar plant began in November 2012 and the facility was grid-connected in September 2013.

The PV plant features 312,000 solar panels spread across 105ha of land.

The Kalkbult plant generates 135GWh of renewable energy a year, which is enough to feed 33,000 households.

It will also offset 115,000t of greenhouse gas emissions annually.



THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

AGRIVOLTAICS

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Agrivoltaics

“Agri-” relating to food production

“-Voltaic” relating to electricity production

Agrivoltaics: Combining solar panels and agriculture into a win-win result. Solar farms are space-intensive and can sometimes compete for land which would otherwise be used for other purposes. In several countries, attempts are now being made to combine agriculture with solar energy.

Agriculture uses an enormous amount of resources. It takes A LOT of water and energy to grow all of our food! 85% of global water consumption is used for irrigation, and over one-third of all greenhouse gases are attributed to agriculture.

At the same time, our demand for food is only growing. The global population, now at 7.5 billion, is estimated to reach 9.8 billion people by 2050.

We will need to nearly double our current food production to meet that demand. We will also need to improve access to food, reduce food waste, and address inequities related to food deserts.

Food is complicated and approach to a dynamic and sustainable food system is multifaceted.

Let's focus on the future production and resource management side of the equation.

Looking at the water issue alone, with current agricultural methods, there will be nowhere near enough water to grow even the current level of food production by 2050.

And we are all aware of the high cost of fossil fuels on both our wallets and the environment.

If the status quo remains, we will likely be looking at food shortages which in turn could cause social unrest and potential economic collapse.

Agriculture has always adapted to meet the dynamic needs of a changing society.

Innovations in technology have driven incredible progress over time – from tractors and pest management to breeding and genomics.

Today, most growers are accustomed to exploring new methods of addressing emerging challenges in agriculture, and continue to look for ways to mitigate risks brought on by a changing climate.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

AGRIVOLTAICS

Water, energy, and agriculture are the bedrock of modern civilization. And while many technologies have advanced these components separately, few have aimed to address all three components at once. It is time to step back and reimagine their relationship.

This new technology promises to improve food production and reduce water use, while also creating energy and additional revenue. Essentially, the solar panels placed on the same land where crops are grown allow growers to harvest the power of the sun twice.

A recent OSU study estimates that converting just 1% of farmland to agrivoltaics could meet national renewable energy targets and save water and create a sustainable long-term food system.

It will also create new revenue opportunities for family farms which are currently facing increasing economic challenges.

The solar panels also help plants grow more efficiently by needing less water.

plants have a limit to how much sun they can actually use. It's called the light saturation point. Once reached, any light beyond that point does not increase photosynthesis or help the plant grow, it only increases the plant's water demand.

It simply makes the plant sweat, which in turn makes it more thirsty.



Solar panels can be positioned to allow plants just the right amount of sunlight, and then the excess sunlight can be harvested for electricity—and produce more than they would without crops below them.

Plants help keep the solar panels cool, which makes them more productive.

Studies have shown that panels positioned above plants produce up to 10% more electricity.

Agrivoltaics is a symbiotic relationship where both the solar panels and the crops benefit because they help each other perform better.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Wide-scale installation of agrivoltaic systems could lead to an annual reduction of 330,000 tons of carbon dioxide emissions – the equivalent of 75,000 cars off the road per year – and the creation of more than 100,000 jobs in rural communities, while minimally impacting crop yield, researchers say.

“Agrivoltaics provide a rare chance for true synergy: more food, more energy, lower water demand, lower carbon emissions, and more prosperous rural communities,” said Chad Higgins, an associate professor in Oregon State’s College of Agricultural Sciences and the senior author of the paper published in the journal Sustainability.

Wide-scale installation of agrivoltaic systems opens the door for other technologies. The surplus energy generated by the solar arrays could be used to power electric tractors or to generate fertilizer on a farm. Inexpensive sensors could be installed on the solar panel platforms to support artificial intelligence-based decisions to improve agricultural productivity.

Different types of agrivoltaic farms

Generally speaking, there are three major variations of agrivoltaic farms:

1) Spaced: Solar PV arrays that are typically installed at a steep angle (in high/low latitudes) and leave large gaps between rows for crops or grazing.

2) Stilted: Solar PV arrays that are lifted from the ground with stilts, leaving large spaces to overlie crops that require limited sunlight/temperature regulation/water retention.

Roofed: Solar PV arrays that are placed on top of greenhouses or livestock sheds, providing insulation and electricity for heating.

These methods aren’t mutually exclusive and may be used simultaneously within different parts of a single project. The effectiveness of each method depends on the specific setting of the project and its aims.

What are the determining factors of an agrivoltaic project?

The factors affecting the design or even the viability of any agrivoltaic project depend on both human and physical factors.

Human factors

Legislation: Local land use laws may be problematic when regulating two contrasting activities in the same land area.

Public Opinion: Solar farms may be unpopular with local farmers (as may be the case in the UK, with recent political debacles against ground-based solar).

Expertise: Both agriculture and operating solar panels require expertise.

A solar energy producer may need to hire a farming specialist and farmers would need to hire a solar engineer or technician capable of doing maintenance.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Existing practices: Much of the land in developed nations is already being used for farming or energy production, which means there is already a bias for one activity over the other.

Subsidies: Some governments like the Netherlands and Germany have been subsidising solar energy implementation, making agrivoltaic projects potentially very lucrative for farmers.

Feed-in-Tariffs: Each government has a different system for selling energy to the grid, which may affect the attractiveness of putting up solar panels or scaling them for this purpose.

Physical factors

Sunlight intensity: If solar panels can produce a lot of energy in your area, then this becomes a more obvious choice. As the price of solar panels keeps decreasing (it has decreased over 80% since 2010) agrivoltaics is becoming increasingly viable in areas of less solar potential (see global solar potential map) such as the UK.

Terrain: The accessibility, stability and steepness of the land determine both the type of agriculture possible as well as the viability of solar panels.

What are the advantages of agrivoltaics?

Solar panel installation on farmland brings numerous advantages both in terms of farming and risk management opportunities.



It can improve agriculture and animal husbandry by synergetically providing temperature regulation, moisture retention, shade and cheap electricity for heating.

And in business terms, installing solar panels may bring a reliable base source of income to a farm's often unpredictable earnings, which are heavily reliant on nature and which climate change and environmental decline are making increasingly erratic

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Temperature Regulation

Photovoltaic systems work optimally at cool temperatures (between 15C and 35C), and so installing them over agricultural land with temperature-regulating properties is more effective than doing so over barren land.

This is due to the higher moisture and humidity due to having plants and moisture-retaining soil.

It's the same reason why floating solar power systems that are cooled by the underlying water bodies are becoming increasingly popular.

And this works synergetically in reverse, as the cover provided by solar panels helps crops and soil retain moisture and, therefore a more stable temperature less prone to deadly shocks, particularly during anomalous heat waves.

Water Management

One of the consequences of climate change is the higher frequency and intensity of droughts, with even temperate countries like the UK at risk.

Solar panels can help retain water in at-risk agricultural land by reducing exposure to sunlight and providing an impermeable barrier to retain humidity.

This is particularly effective with stilted solar panels, which may act as shade during the day and capture moisture that condenses on its rapidly cooling surface at night, and drips back into the fields, forming a closed water loop.

Moisture-absorbing hydrogels can enhance this moisture-retaining cycle by absorbing the condensed water, which can be collected and used for targetted irrigation (while making the panels even more efficient by keeping them cool while they retain water).

Pilot projects using stilted panels in California have successfully grown shade-resistant crops such as cucumbers, lettuce, kale, and broccoli (i.e. plants that evolved near the ground in covered forests) with reduced water use compared to existing methods.

And the large-scale Solar Garden installed in Colorado is also successfully doing agriculture and producing solar energy while experiencing record revenue. Experiments in Arizona have also shown that these systems can save up to 50% of water in arid climates.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Shade

The shade and protection from the elements provided by solar panels may be a valuable resource for grazing animals during heat waves and inclement weather.

In return, grazing animals like sheep can keep tall grasses from interfering with the panel's sun exposure by grazing, reducing the need for additional maintenance costs.

Plants also have a maximum amount of photons they can absorb for photosynthesis which means that much of the sunlight in agricultural land is actually surplus to requirements.

Dynamic agrivoltaics, developed in Japan by Akira Nagashima leverages this concept by using a system of portable solar PVs that are rotated to cover different crops at different times of the year and maximize yields based on their optimal sunlight exposure.

Additionally, this project in Canada has been using the panel's shade to grow flowers to support pollinator populations and for beekeeping.

Dual revenue for farmers

Farms that combine their activities with solar arrays effectively diversify their income and hedge against the risk of drought, floods, disease and soil loss which leads to bad harvests or animal population reductions.

This is increasingly relevant as climate change is making global weather more extreme and unpredictable, making farming revenue equally volatile.

Also, solar energy production is relatively stable on a year-on-year basis, giving a base income that farms can rely on.

Dual revenue for solar energy producers

Existing land-based solar farms are introducing agriculture and animal husbandry to give more utility to their land, while hedging against changes to the energy market, energy legislation, sabotage, etc.

Also as discussed earlier, the thermal properties of moisture may ultimately improve the yields of solar panels.

This is especially the case in areas where expanding is not an option due to land unavailability (i.e. UK and Europe) or new legislation.

Are agrivoltaic farms the best use for solar panels?

The cost, adaptability and modularity of solar panels have made them a popular solution for decarbonising electricity production.

However, solar panel production is limited and has a carbon and water footprint, so some argue that they should be placed where they make the highest impact.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

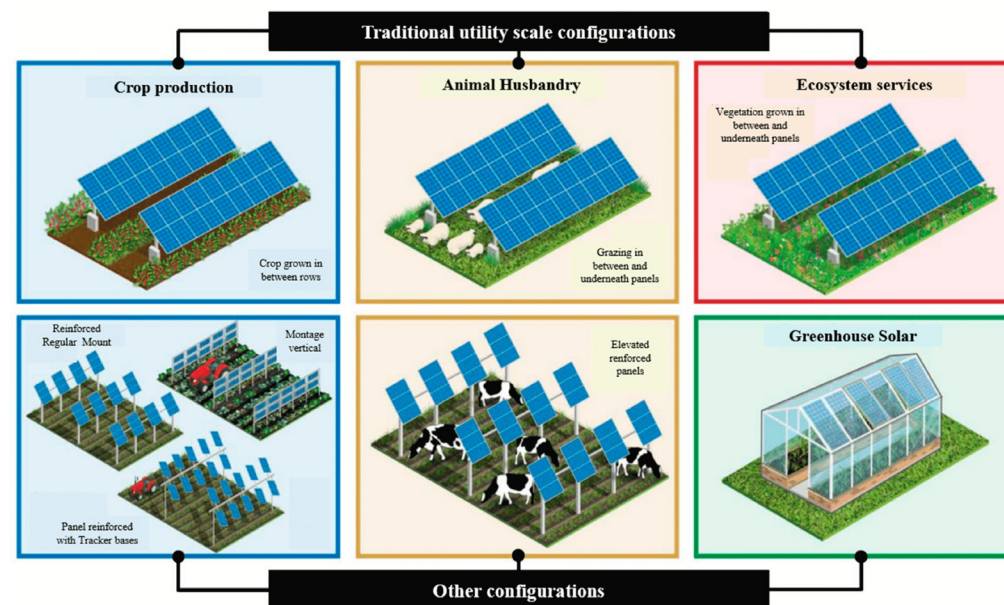
Some would argue that solar panels are best suited to the unused parts of the built infrastructure to produce energy in proximity to where it is most needed and without causing any visual pollution or interference with productive land.

Others argue that floating solar power is an overall more efficient use of panels as the underlying water body regulates temperature while the panels help retain the reservoir's water which is used for drinking, agriculture, hydropower, etc.

However, it is clear from this article that there is also much utility within agriculture, particularly in regions of high solar irradiance and water management issues.

Also, some governments make this practice easier by means of government subsidies and feed-in-tariff schemes (Also known as smart export guarantees in the UK) and legislative conditions.

Also, the development of transparent PV glass may shift the debate as it enables tailored use of the incoming solar frequencies not needed for photosynthesis to produce energy and make energy-producing greenhouses.





THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

FLOATOVOLTAIC (FPV) & SOLAR CANALS

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Floating Photovoltaic and Solar Canals

Floating photovoltaic, commonly known as floatovoltaic, systems and solar canals, are photovoltaic solar energy generating systems designed to float on reservoirs, lakes etc, or by spanning rivers and canals.

Unlike land-based PV systems, FPV systems do not occupy large land areas. In addition, installing PV panels on water bodies increases the efficiency of the PV system, due to the cooling effect of the evaporated water.

According to researchers, covering of only 1% of the natural water surfaces bodies in the world with PV panels would provide around 25% of the global demand of electricity.

Solar canals or floating photovoltaic (FPV) were applied for the first time in 2007 in Aichi, Japan, for research purposes with a capacity of 20 kW.

In 2013, the University of Valencia experimented by covering irrigation reservoirs with photovoltaic panels to ascertain the feasibility of FPV to decrease evaporation whilst generating electricity.

In this study, Santafé et al., 2014, covered an agricultural reservoir with 4490 m² of photovoltaic panels.

The results showed that the covering could save around 25% of the reservoir's storage (5000 m³ of water) from evaporation.

In the Gujarat region, in India, there are two solar canal photovoltaic power plants currently in service.

The first one was constructed over a water body length of 750 m with a capacity of 1 MW and the other one was constructed over a water body length of 3.5 km with a capacity of 10 MW.

The Value of Saving Land

One of the most appealing aspects of solar canals is their use of already built or natural environments, such as rivers, thus reducing the land needs associated with solar power and potentially avoiding the tensions that can arise from renewable energy development.



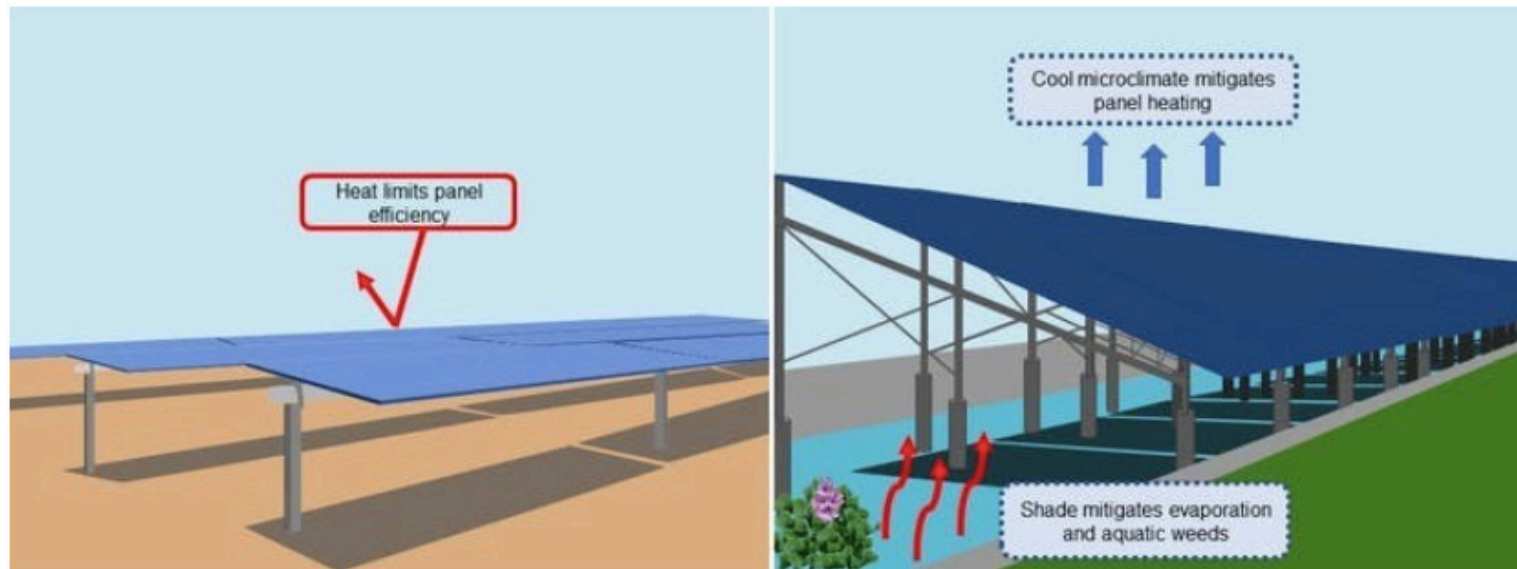
The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

The Value of Saving Land cont...

The installation of large solar farms has become a point of tension between renewable energy developers, farmers, and conservationists.

The Great Plains Institute reports that it takes up to 10 acres of land on a conventional solar farm to produce one megawatt of electricity, enough to power one average U.S. home for about 1.2 months.

Remote, sunny, deserts locations without trees or high buildings that obstruct sunlight are especially suitable for solar farms. However conservationists are increasingly concerned about the impact that solar farms, as well as the infrastructure associated with their installation and maintenance, have on fragile ecosystems.



Solar panels installed over canals increase the efficiency of both systems. Image: The Conversation/Brandi McKuin

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Solar canals come at a higher cost of installation and maintenance because they require customized support structures with galvanized steel to prevent rusting due to increased humidity. Maintenance also requires more trained workers, increasing costs further. However, a peer-reviewed study led by the University of California, Merced and published in Nature Sustainability indicates that these costs would be offset by the benefits of solar canals.

The Indian Solar Canal Example

India has been using solar canals since 2014, according to the BBC, supplying electricity for rural areas while taking advantage of lower evaporation rates and improved water quality.

A pilot 750m stretch in Gujarat in 2014 led to the first large-scale canal-top solar power plant in the Vadodara district of Gujarat in 2015, at a cost of \$18.3 million.

The long stretch of the canals leading off the Narmada River enables electricity to be extracted at multiple points.

The energy generated from the solar canal can provide electricity for farmers during the energy-intensive irrigation season, and out of season the electricity can be fed into the state grid, sold to distribution companies or used by the canal authority.

Power is generated in a rural area, the transmission losses are reduced and the local grid is strengthened.

A 100MW canal-top solar power project atop the branch canals off the Narmada River, stretching for a distance of 40km, at an estimated cost of 1bn Indian rupees (\$13.9m/£9.3m).

Overall, Gujarat has more than 80,000km of canals meandering through the state. According to Gujarat State Electricity Corporation, if 30% of this were converted to solar, 18,000MW of power could be produced, saving 90,000 acres of land.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Advantages of Solar Canals

The advantages of solar plants atop canals are not just about local energy production and land saved.

Solar power plants can be built much faster than large coal or gas power stations. For another, the covering over the canal helps to prevent evaporation of water, leaving more available for crops and people.

In states like Gujarat, Rajasthan and Maharashtra, where canals are mainly used for irrigation, evaporation is a big problem.

Problems associated with land use were a driving factor in India's adoption of solar canals. High land prices made it more economical to install solar panels over canals, and these installations demonstrated multiple other benefits.

Nilesh Kumar, senior project officer at the Gujarat Energy Research and Management Institute, which oversaw the installation of solar canals in the state of Gujarat, stated in a BBC article that the panels also improve water quality. "With the installation of the solar panels, and absence of direct sunlight, algae growth is drastically minimized," he said.

And algae growth is not just an inconvenience. The Environmental Working Group published a study on the cost of algal blooms in the United States, which found that California spent nearly \$53 million to recover from toxic algal blooms between 2010 and 2020.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

And while the water can benefit from the solar panels above, so do the panels from the water below. The running water helps the panels to remain cool, which increases their efficiency by at least 2.5-5%. There are some drawbacks, however. Canal-top plants are more expensive to construct than normal solar plants. The supports have to be galvanised with a protective zinc layer because the water below increases the risk of corrosion.

Solar panels placed over canals are relatively easy to clean and maintain.

Solar panels do not require a lot of maintenance, solar panels over canals will lower the maintenance needs on the canals, but operators will still need access for basic cleaning and maintenance. On the smaller canals, the design must present access at least on one side. For some intermediate-sized canals, access from both sides is likely to be necessary.



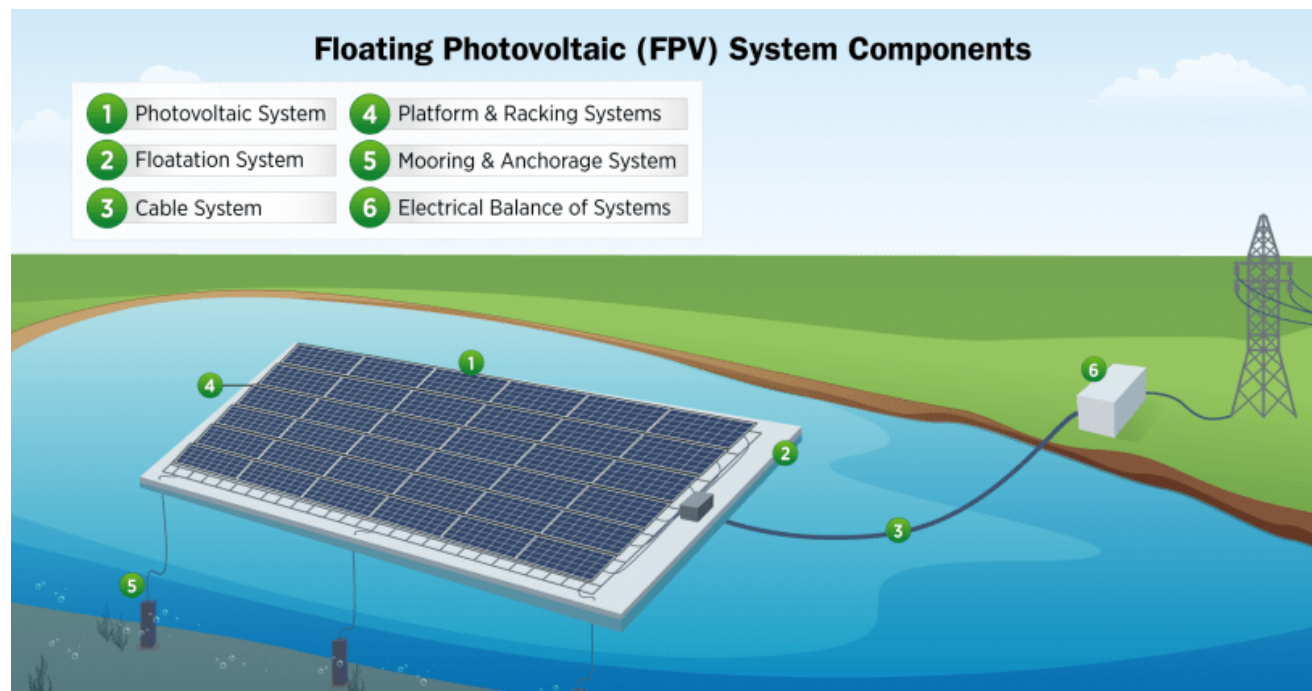
Like conventional solar panels, those above canals also require frequent washing to ensure their capacity isn't reduced by dust (Credit: Getty Images)

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Floating Photovoltaic

Floating photovoltaics (FPV), often called floatovoltaics, are solar panels mounted on a structure that floats on a body of water, typically a reservoir or a lake such as drinking water reservoirs, quarry lakes, irrigation canals or remediation and tailing ponds.

The FPV systems have advantages over photovoltaics (PV) on land. Water surfaces may be less expensive than the cost of land, and there are fewer rules and regulations for structures built on bodies of water not used for recreation. Life cycle analysis indicates that foam-based FPV have some of the lowest energy payback times (1.3 years) and the lowest greenhouse gas emissions to energy ratio (11 kg CO₂ eq/MWh) in crystalline silicon solar photovoltaic technologies reported. Floating photovoltaic systems can achieve higher efficiencies than PV panels on land because water cools the panels, researches have estimated FPV systems are approximately 20% more efficient.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Floatovoltaics technology features

No land occupancy: The main advantage of floating PV plants is that they do not take up any land, except the limited surfaces necessary for electric cabinet and grid connections. The price is comparable with land based plants, but floatovoltaics provide a good way to avoid land consumption.

Installation, decommissioning and maintenance: Floating PV plants are more compact than land-based plants, their management is simpler and their construction and decommissioning is straightforward.

The main feature is that there are no fixed structures, such as foundations as used for a land-based plant and their installation can be totally reversible. Furthermore panels installed on water surfaces require less maintenance than when compared with ground installations in dusty conditions.

Water conservation and water quality: Partial coverage of water surfaces can reduce water evaporation. This result depends on climate conditions and on the percentage of the surface covered.

In arid climates such as parts of India this is an important advantage since about 30% of the evaporation of the covered surface is prevented, which is a useful feature if the water area is used for irrigation purposes.

Water conservation from FPV is substantial and can be used to protect natural lakes and other bodies of fresh water.

Increased panel efficiency due to cooling: the cooling effect of the water close to the PV panels leads to an energy gain that ranges from 5% to 15%.

Natural cooling can be increased by a water layer on the PV modules or by submerging them, the so-called SP2 (Submerged Photovoltaic Solar Panel).

Tracking: Large floating platforms can be rotated horizontally and vertically to enable Sun-tracking. Moving solar arrays uses little energy and doesn't need a complex mechanical apparatus like land-based PV plants. Equipping a floating PV plant with a tracking system costs little extra while the energy gain can range from 15% to 25%.

Environment control: Algal blooms, a serious problem in industrialised areas, can be reduced and in some cases eradicated entirely.

Utilisation of hydropower plant water basins: Floating solar plants can be installed over water basins created by the development of hydropower plants.

This allows for cost reductions by using the existing transmission lines and distribution infrastructure.

The hybridisation of solar photovoltaic with pumped storage is beneficial in raising the capability of the combined plants, as the pumped hydropower plant is used to store the generated electricity from the FPV.

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Challenges

Floatovoltaics presents several challenges to designers:

Long-term reliability of system components: Operating on water over its entire service life, the system is required to have significantly increased corrosion resistance and long-term floatation capabilities, particularly when installed over salt water.

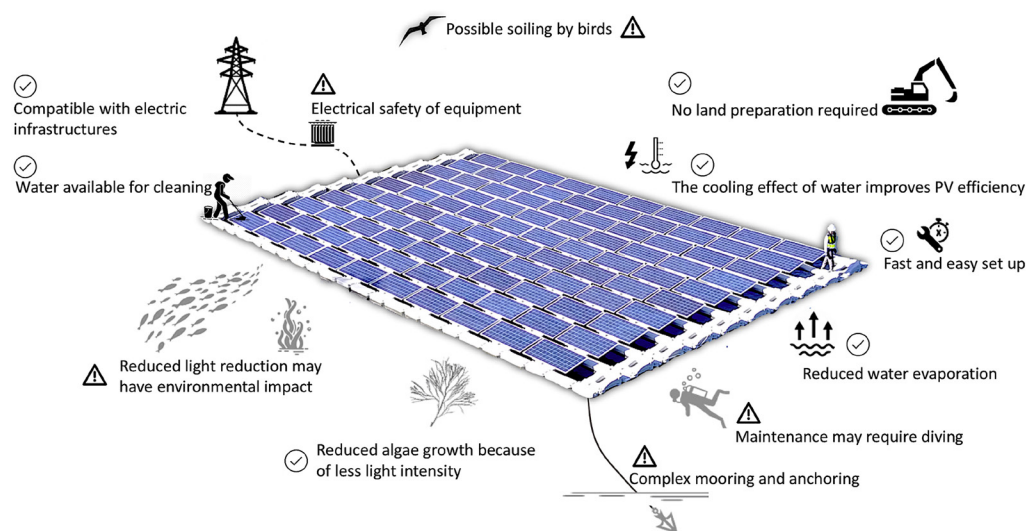
Wind and waves: The floating PV system, such as wires, physical connections, floats, panels etc., requires to withstand higher winds than land based systems and heavy waves, particularly in off-shore or near-shore installations.

Maintenance complexity: Operation and maintenance activities are, as a general rule, more difficult to perform on water than on land.

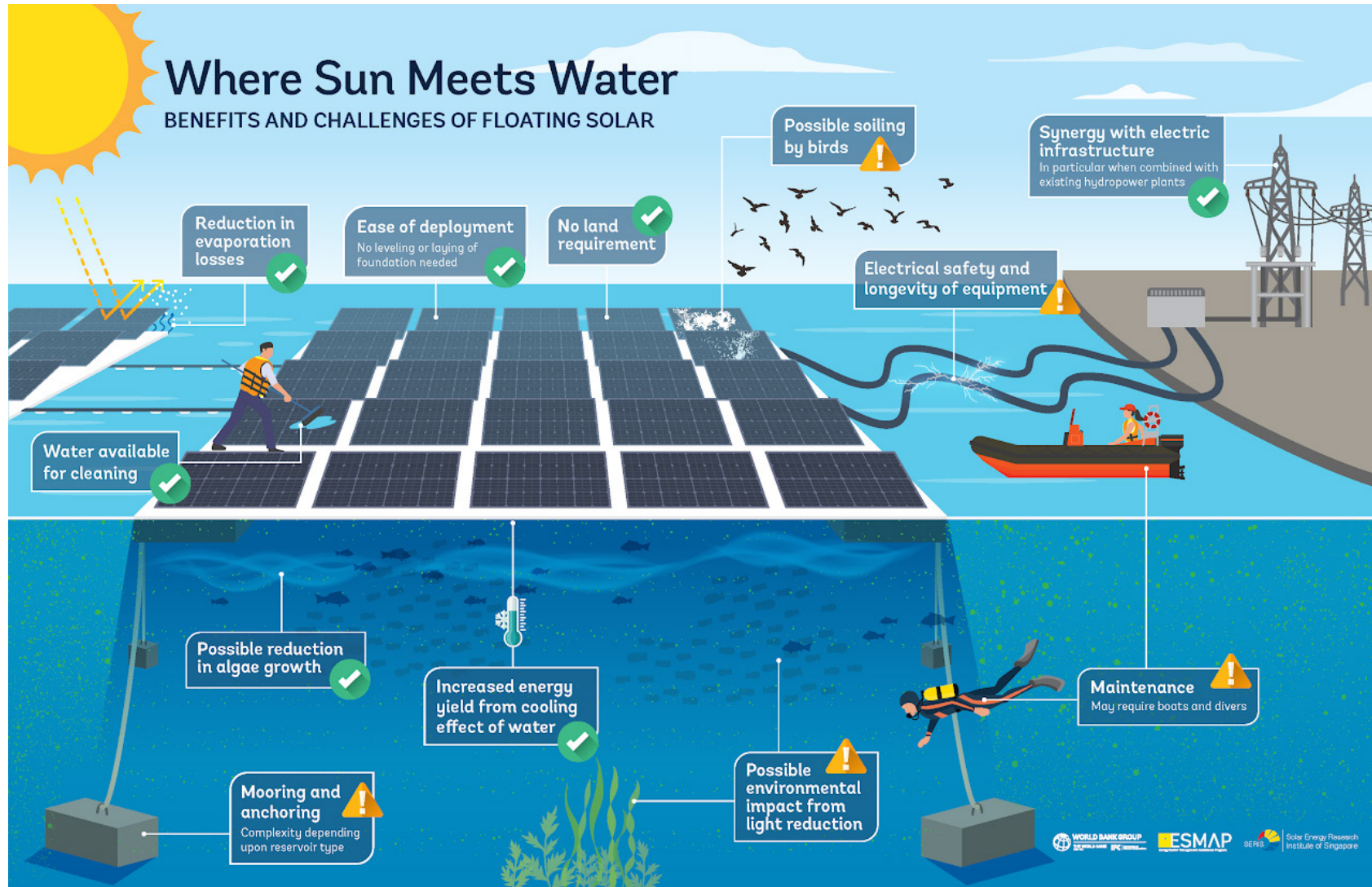
Floating technology complexity: Floating PV panels have to be installed over floating platforms such as pontoons or floating piers, and has to do so for up to 25 years, so it also requires the racking system that has high corrosion resistance, long lifespan, high load capacity, etc.

Anchoring technology complexity: Anchoring the floating panels is necessary to avoid abrupt variation of panel position, which will lead to power production reduction.

Cost: A floatovoltaics installation requires specialised solar power equipment and more niche solar panel installation knowledge.



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Floatovoltaic platforms:

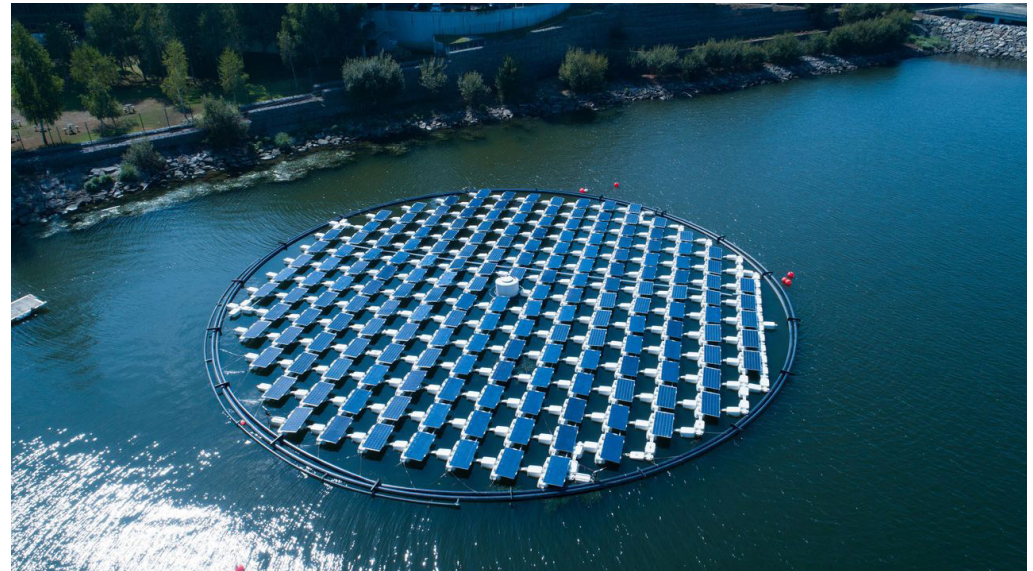
Whilst there are various solar floating platforms available, the Universiti Tenaga Nasional (UNITEN), in Malaysia have developed a floating platform system that can smartly move according to the sun's position.

The development team estimate a 40% improvement in energy harvesting and a more effective use of underutilised water surfaces.

How it works:

- 1) Modular platforms with a detachable solar panel. The number of platforms can be increased by demand due to its modular concept. The platforms can be easily assembled using a slot locking system.
- 2) The Brain platform houses the main controller of the whole system and all the electrical and electronic components.
- 3) The single anchoring pole acts as the rotational point and structural support for the floating platforms. The diameter of the anchoring pole needs to be increased when the number of platform increases. The anchoring pole allows platforms to slide vertically along the single structure while still maintaining the electrical connection.
- 4) A stepper motor for each platform is used to tilt the solar panels. It has 45° tilting angle for each side (both sides will be 90° degree).

- 5) Two paddles with motors at the bottom of two platforms allow 360° rotation either in clockwise or counterclockwise direction.



The passive vertical motion (sliding along the anchor pole) allows the platform to overcome small waves, avoiding any external torque or strong vibration issues.

The platforms can be easily assembled using the slot locking system and the modular design offers easy maintenance, cleaning and repair work.

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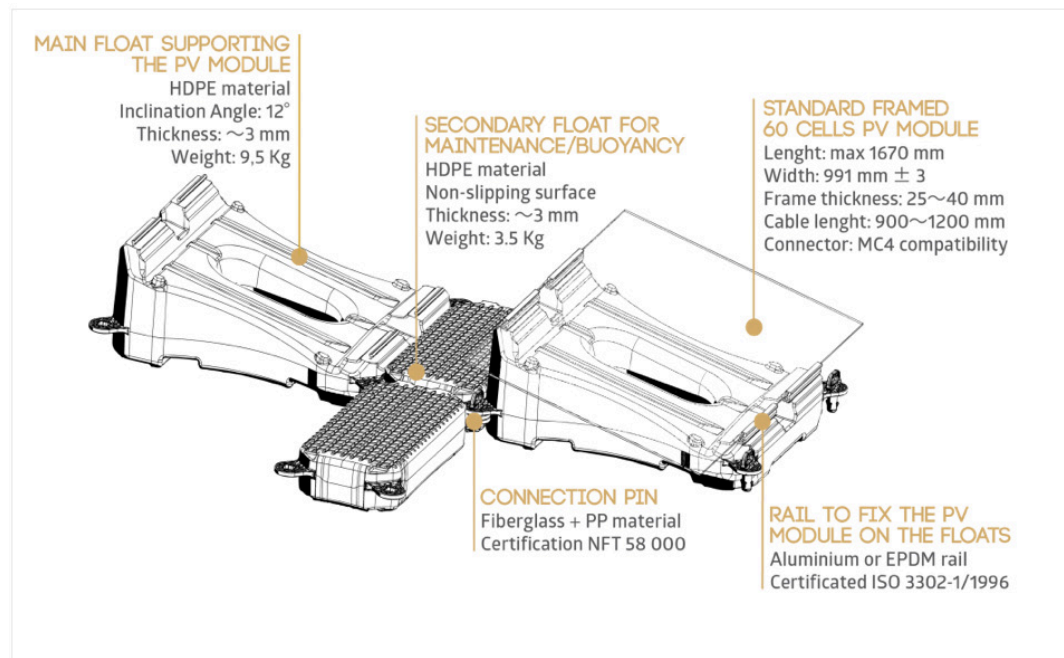
Floatovoltaic platforms cont...

Hydrelion is another innovative floating solar platform that allows standard PV panels to be installed on large bodies of water such as drinking water reservoirs, quarry lakes, irrigation canals or remediation and tailing ponds.

This particular floating solar platform is particularly suitable for energy and water-intensive industries, such as wineries, dairy farms, fish farms, mining companies, wastewater treatment plants, irrigation districts and water agencies, who cannot afford to waste either land or water.

Benefits:

- * Easy to adapt to any electrical configuration
- * Scalable from low to high power generation
- * No tools or heavy equipment needed
- * All materials can be recycled
- * Reduction of water evaporation to conserve irrigation or drinking water
- * Slower algae growth thanks to the shielding of the water by the floating island
- * Low environmental impact: no excavation work, no impact on water quality
- * Reduced erosion of reservoir embankments by reducing waves



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Floatovoltaic In Africa Studies:

Several studies have shown that some reservoirs in Africa, including Lake Kariba in Zimbabwe, present some of the best opportunities for floating PV plants.

A study covering 146 hydropower reservoirs in Africa by Rocio Gonzalez Sanchez et al, indicates that with just 1% coverage, the installed capacity of existing hydropower plants could be doubled, producing an additional 46.04 TWh per year. They add that water savings could be up to 743 million m³/year.

The study also looks at optimising existing grid infrastructure through the Equal Installed Capacity (EQIC) scenario where the FPV is sized to match the existing installed hydro capacity. In this way, the FPV can feed the maximum possible electricity into the existing grid infrastructure.

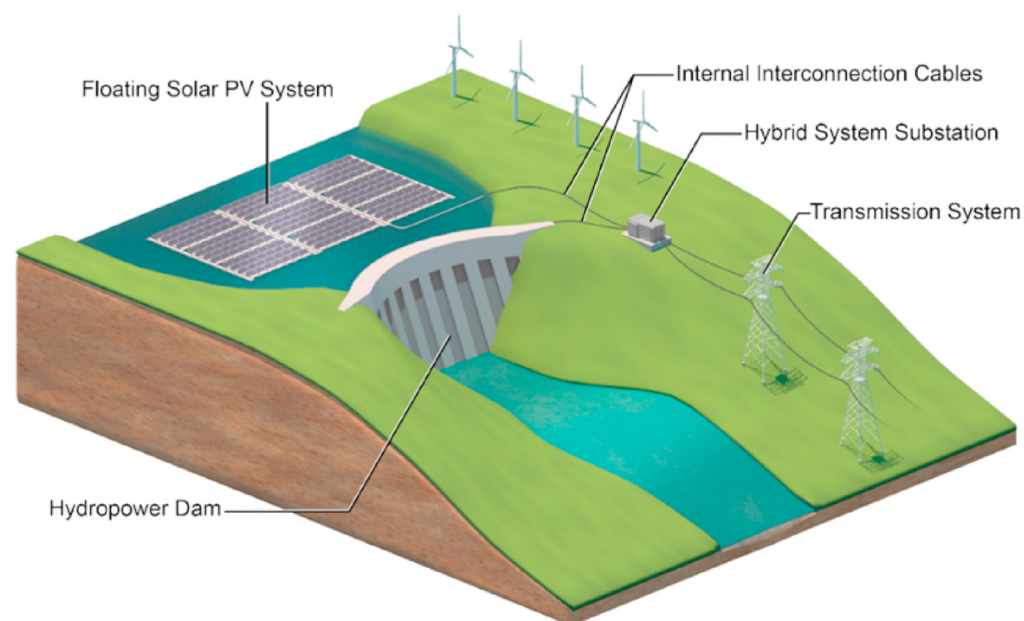
Rocio Gonzalez Sanchez et al, also looked into a case study for Zimbabwe. The data is looking into the period before the recent addition of 300 MW at Kariba to bring the installed capacity to 1,050 MW and thus uses an EQIC scenario of about 680 MW.

This study provides some very interesting insights into the power of FPV. For a scenario covering just 8.42 km², which is just 0.45% of the area considered as the “total reservoir’s area” (1,862.3 km²), they found that there will be an additional generation from the FPV of 1,595.2 GWh of electricity which works out to be 34% of the 4,686.3 GWh from the hydropower plant during that period.

The proposed 1,200 MW (DC)/ 1,200 (AC) floating solar plant for Kariba will cover 25km² (about 1.34%) of the total reservoir’s area using the figures considered by Rocio Gonzalez Sanchez et al., providing an estimated annual production of 2,640 GWh.

In 2021, Kariba generated 6,067 GWh on the Zimbabwe side, according to the Zimbabwe Energy Regulator’s (ZERA) annual report.

The annual production from the proposed FPV would work out to be 44% of that, excluding any extra generated from reduced evaporation.



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Proposed 1,200 MW Floating Solar PV Plant In Zimbabwe

In April 2023 China Energy Engineering Group announced that it had proposed to construct a 1,200 MW DC Floating Solar PV (FPV) plant on Lake Kariba

Kariba Dam is shared between Zambia and Zimbabwe and was constructed between 1955 and 1959. The dam extends for about 280 km.

It holds about 185km³ of water. On the Zimbabwe side, (Kariba South), the hydropower plant now has an installed generation capacity of 1,050 MW.

The dam is a major tourist attraction for the country, second only to Victoria Falls.

Lake Kariba is home to the world's most productive reservoir fishery, and therefore a source of employment for the artisanal fishing industry. Any floating solar PV plant would need to take this into consideration in order to ensure their business continuity.

Other environmental considerations for FPV that have been discussed in a paper by Rafael M. Almeida et al., include shading from floating panels resulting in reduced light disturbing photosynthetic organisms such as aquatic plants and phytoplankton.

However, this shading could also help reduce the proliferation of harmful algae in reservoirs.

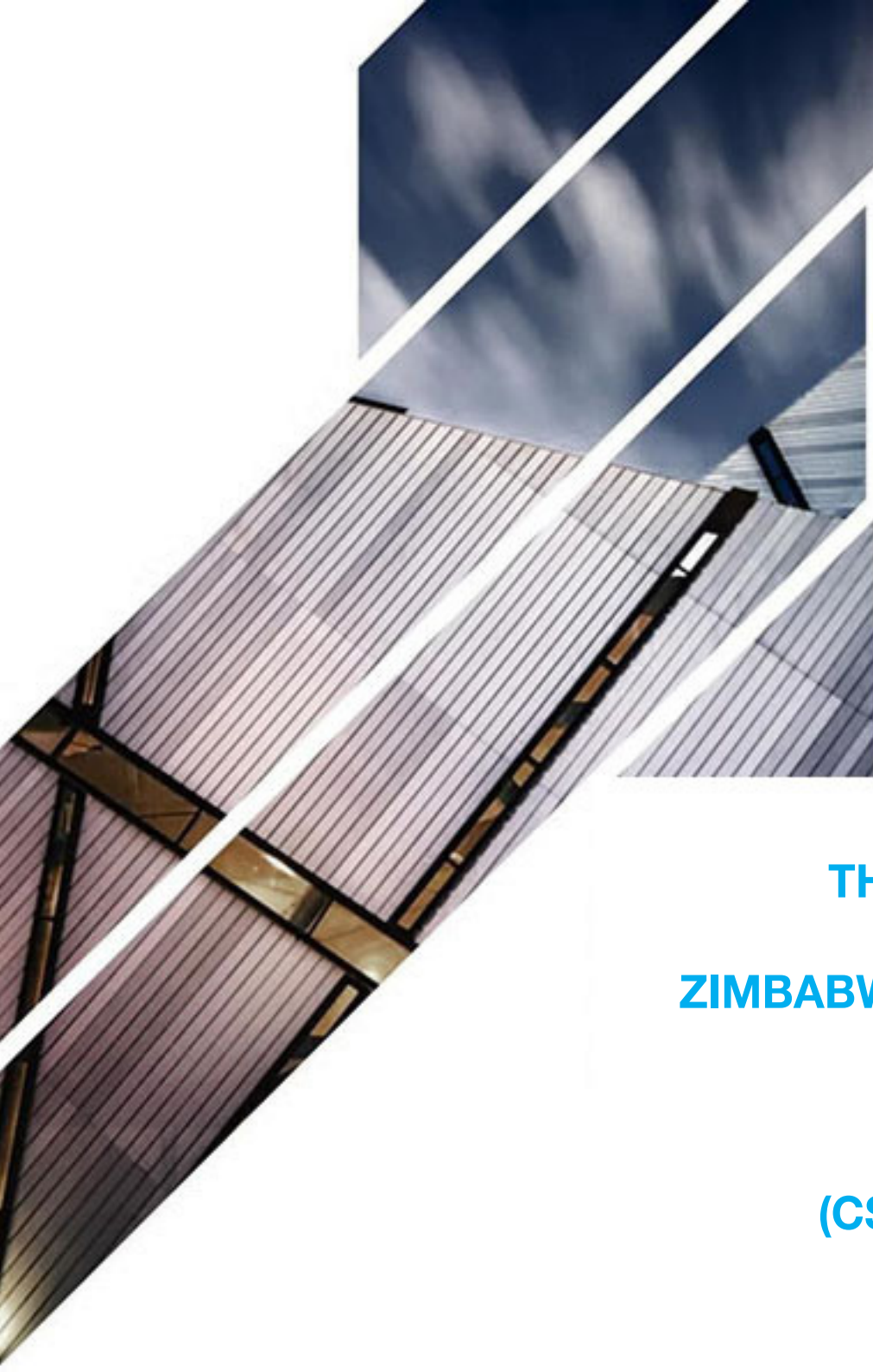


Kariba dam was primarily built for power generation and there are several significant opportunities to optimize power generation from the installation of FPV, bringing wide ranging economic benefits as listed in a paper by Javier Farfan et al. These include:

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- * Providing cooling effect for solar panels increasing their efficiency
- * Panels will provide shading, reducing evaporation from the reservoir and also reducing algae growth, improving water quality. Reducing evaporation also provides the potential to produce additional power from the water saved.
- * Reduced soiling in water environment compared to dusty land based areas
- * Less shading on PV panels as they will be placed away from trees, buildings and other objects that are usually a source of significant shading.
- * Co-location of FPV plants with already existing hydropower plants provides significant cost reductions through maximising existing grid connectivity infrastructure such as transformers and transmission lines.
- * The reservoir will now act as a virtual battery, unlocking more value from the colocated floating variable renewable solar energy. During the day, the power generated from the floating solar plant be could be used directly whilst the water in the reservoir will be allowed to accumulate from inflows and/or saved for later use during the evenings and at times of lower PV production due to cloud cover etc.

The proposed 1,00 MW (AC) (1,200 MW DC), FPV for Kariba dam will use 1,832,069 PV panels covering 25km². These will be 655Wp mono crystalline bifacial dual glass modules. This will be for a 25-year period. The initial estimated annual production is 2,640 GWh. The total project price is estimated to be around \$987 million.



THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

**Proposed Establishment of a
Climate Smart Agriculture
(CSA) Regional College in Zimbabwe**

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Projects such as the proposed Climate Smart Agricultural Regional College, which would be an essential element for the development of AgriVoltaics projects, would be incorporated into the Zimbabwe National Solar Program

Pre-feasibility study for the establishment of a Climate Smart Agriculture (CSA) Regional College in Zimbabwe

The context of the study.

- * The strategic importance of the agricultural sector in Zimbabwe (food security, employment, linkages with agroindustry, etc.) but a growing vulnerability to climate change
- * A Strategic framework has been defined by the Government of Zimbabwe to address these challenges by promoting climate-smart agriculture practices and also contribute to the national priorities defined in the NDCs
- * A central component of this strategy is the transversal reinforcement of agricultural training on the application of these types of practices at vocational and university level. Actions already made (CSA Manual for university and professional level agriculture education and the World Bank-funded CSA Investment Plan

Establishment of a CSA Regional College in Zimbabwe based on a Public - Private Partnership: Ministry of Lands, Agriculture, Fisheries, Water and Rural Development; Green Impact Trust; Makaholi Research Institute, Donors and Private sector)

The objectives of the study (deliverables)

- * A stakeholder mapping of investors/donors/partnerships interested in the establishment of the CSA Regional College in Zimbabwe / Masvingo.
- * An identification, based on existing bibliographic references (in particular the CSA manual) of the main CSA practices adapted to the different agro-ecological conditions of the Masvingo region
- * One or several viable proposals for formalizing a public-private partnership that governs the implementation of the CSA Regional College and its technical and administrative modalities of implementation
- * The elaboration of an economic/financial model that takes into account the possible contributions of the different actors and stakeholders, and in particular the private sector, in order to achieve an economically and financially viable mode of operation
- * A cartographic analysis of the Makoholi Research Institute station with a proposal for the location of the college
- * Draft curricula to train different types of target audiences: students in initial technical and/or higher education; AGRITEX field agents and small farmers in short training courses

An exploratory study: preliminary analysis of the feasibility of moving forward in the CSA Masvingo College project

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Highlights of the Field phase

Revision and analysis of key documents

- * CSA Manual and other related documents (effect of CC, CSA practices, etc.)
- * New curriculum of Diploma in Agriculture – General Academic regulations (2021)
- * Buildings plans of Shamva Colleges of Agriculture
- * Case study of existing infrastructure (strength and weaknesses) of 4 agricultural colleges
- * Typical building costs in Zimbabwe - march 2022
- * Cartographic information of Makoholi Research Institute territory

Meetings and interviews with key stakeholders

- * Representatives of government
- * MLAFWRD: livestock and agriculture and education departments; AGRITEX extensionist; livestock healthservice
- * Ministry of Environment: Climate Change Management Department
- * Masvingo Provincial secretary
- * UN organisations: UNDP
- * International cooperation organisations: HEIFER, SNV
- * International investigation/Research Centres : CIRAD
- * Private sector: MC Meats Pvt Ltd
- * Experts: Chief sustainability consultant of Toxiconsol, and in Extension and Research
- * AGRITEX: Makoholi area Extension Officer
- * Masvingo District Veterinary Office

Highlights of the Field phase cont...

Visits and interviews to existing colleges and universities

- * Shamva Agriculture College (Principal & Heads of Departments)
- * Great Zimbabwe University (Crops, livestock, natural sciences sections & Civil Engineering)

Visit to Makaholi Research Institute

- * Meeting with Researchers (Crops and Livestock)
- * Tour of MRI infrastructure (Livestock area)
- * Tour of the area allocated for the CSA Regional College

Planned visits that could not succeed

- * European Union (EU)
- * World Bank (WB)
- * Food and Agriculture Organization (FAO)



Location of the CSA Regional College in Zimbabwe: **Makoholi Research Institute, Masvingo Province**

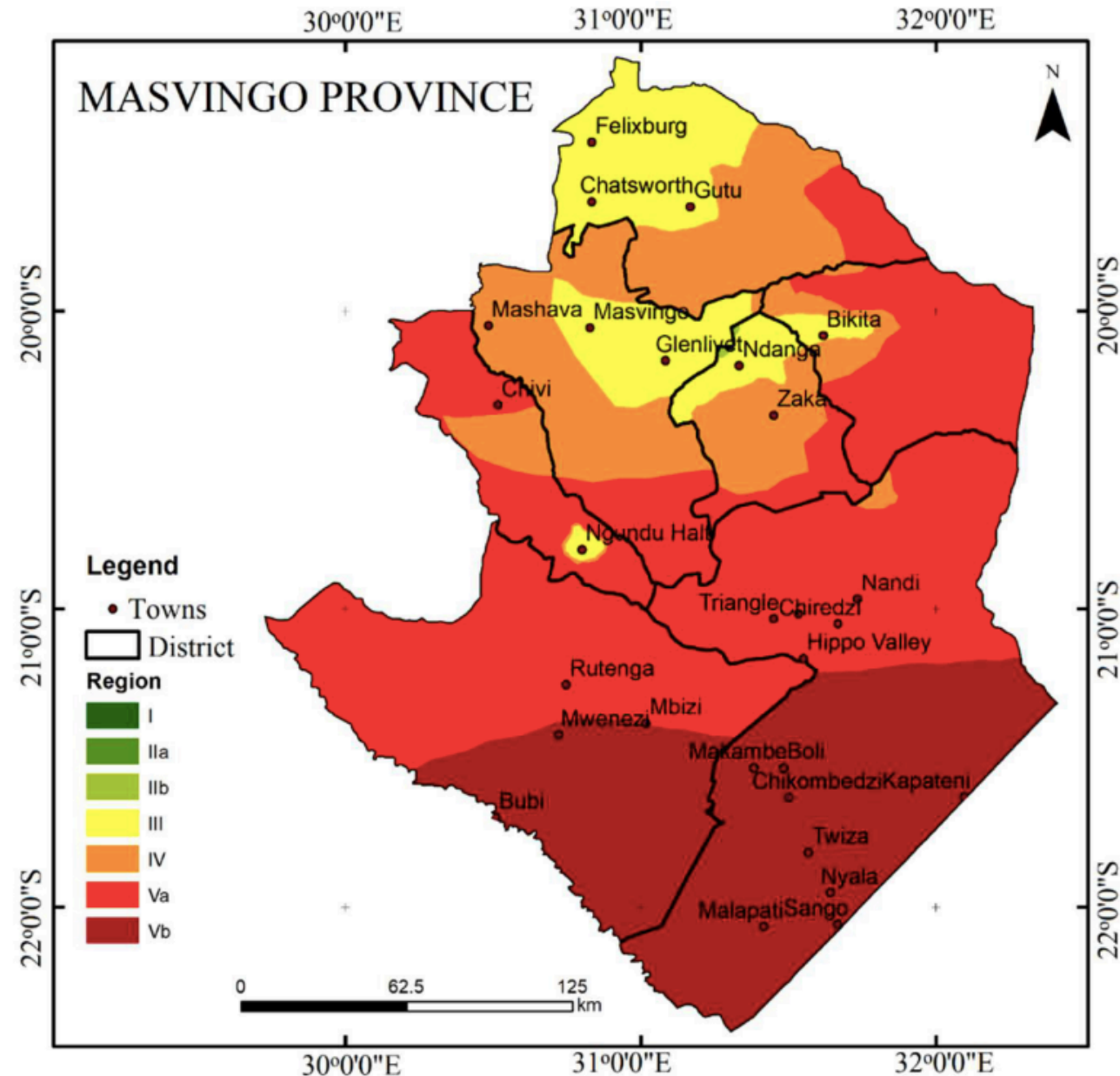
1/3 provinces without a agriculture college

With **20%** of the national herd, the highest in the country.

Over **72%** of the cattle is owned by 82% of smallholder farmers who typically own 3 to 5 animals.

Composed of different agro-ecological regions that experience low rainfall conditions

AEZ	Characteristics of production systems
III	Dominated by semi-intensive smallholder farming. Maize and cotton comprise the primary production systems in this region, in addition to drought-tolerant crops and semi-intensive livestock farming.
IV	Mainly a semi-extensive livestock region. Smallholder farmers grow also drought-tolerant varieties of maize, sorghum, pearl millet and finger millet.
V	Cattle and goats: main form of livelihood for farmers Cropping is nearly impossible without irrigation because of the harsh climate but farmers still plant maize, cowpeas, and small grains such as sorghum and millet The biggest threat to livestock production is the shortage of fodder during the dry season



Climate change effects in Masvingo province's agriculture

Increase of temperature
(between 1.3 and 4.6 C by
2100)

Decrease of rainfall
(between 5 and 18% by 2080)

Increase of inter-annual rainfall
variability (shorter rainy season,
more droughts and risk of floods)

A semi-arid climate more and more predominant

Crop production

Yield of maize
decreasing between
18 and 30 % by
2050

Groundnuts and
cassava may benefit
from increased CO2
levels

Decrease of suitable
areas for maize
cultivation by 2080

Increase of suitable
areas for growing
sorghum and cotton
by 2080

Livestock production

Reduction of net
Primary Production
(NPP) from 5 to 8
T/ha per year by
2080

Increased spread of
vector-borne
livestock diseases
and disease vectors,
and heat stress

Decrease in the
rangeland carrying
capacity for livestock

Reduced dry-season
natural grass and
browsing resources

Increase of vulnerability of small holders involved in crop-livestock production

Key points / transversal skills required

- **“Avoiding quick thinking” about CC** : Ability to effectively and transversally integrate the 3 pillars of CSA // strengthening the mitigation pillar.
- **“To be focused on mixed (small holder) farming systems”** (articulating crops and livestock production)
- **“Has to know available CSA practices and to propose the appropriate ones to each situation”**
- **“Must be technically solid, and not only be theoretical”**
- **“be able to solve problems”**: Identifying problems, constraints that limited the application of CSA practices (complexity of mixed farming systems, gender issues, chain value constraints, etc.) and to propose adapted solutions
- **“To integrate bio-physical /technical and socio-economical dimensions”**

- **A global understanding of climate change, its causes and effects**
- **Management of tools and methods to analyse the effect of the practices on the 3 pillars**
- **Holistic approach of farming systems**
- **Approach based on problems solutions**
- **Gender sensitivity/approach**
- **Value chain approach**
- **Entrepreneurial skills / Competency-based**

An effective theory-practice articulation



Possible/available CSA practices

CSA practices in crops

- Crop Diversification
- Selection, improvement, introduction of varieties / germplasm
- Integrated soil fertility management: Soil conservation/ erosion control, Reduced Tillage, Mulching and residue management, Nutrient management
- Water management practices: Use of efficient Irrigation systems, Water Harvesting, to collect and store water
- Integrated pest and disease management
- Adaptation of the crop calendar and timeliness of cultivation practices

CSA practices in livestock

- Feed Management: rangeland or pasture development and management/protection strategy, grazing management, introduction of multi-purpose crops, improving the storage of feed in dry season, feed supplementation
- Selection of animal types and breeds better adapted to heat stress and dry conditions
- Herd management for a sustainable increase in productivity and reduction of GHG
- Health management to reduce the spread of notifiable diseases, particularly foot and mouth disease

Conservation agriculture, which combines reduced tillage with permanent soil cover using crop residues or growing plants and crop rotation

Practices with multiple positive effects: agroforestry, others

Intensification of cropping systems by combining inputs of organic matter (mulch, compost, crop residues, green manure) with carefully-selected fertilisers

Integrated aquaculture in farming systems: a potential viable investment option for diversifying rural livelihoods in the face of a changing climate

The access to climate information services and early warning systems

The access to Weather index-based insurance

The implementation of Efficient Energy management



Community
rangelands + free
movement of animals

Different (limited) availability of
production means (land, soils,
water, workforce, financial
resources, etc.)

Different types of land
tenure (ownership,
tenancy, commons,
concession,...)

(Smallholder) farming systems :
different situations and
constraints for the application of
CSA practices ("communal
farmers", commercial farmers,
etc.)

Different access to
market / value
chains
opportunities

Increasing risks and
different capacities to
face them

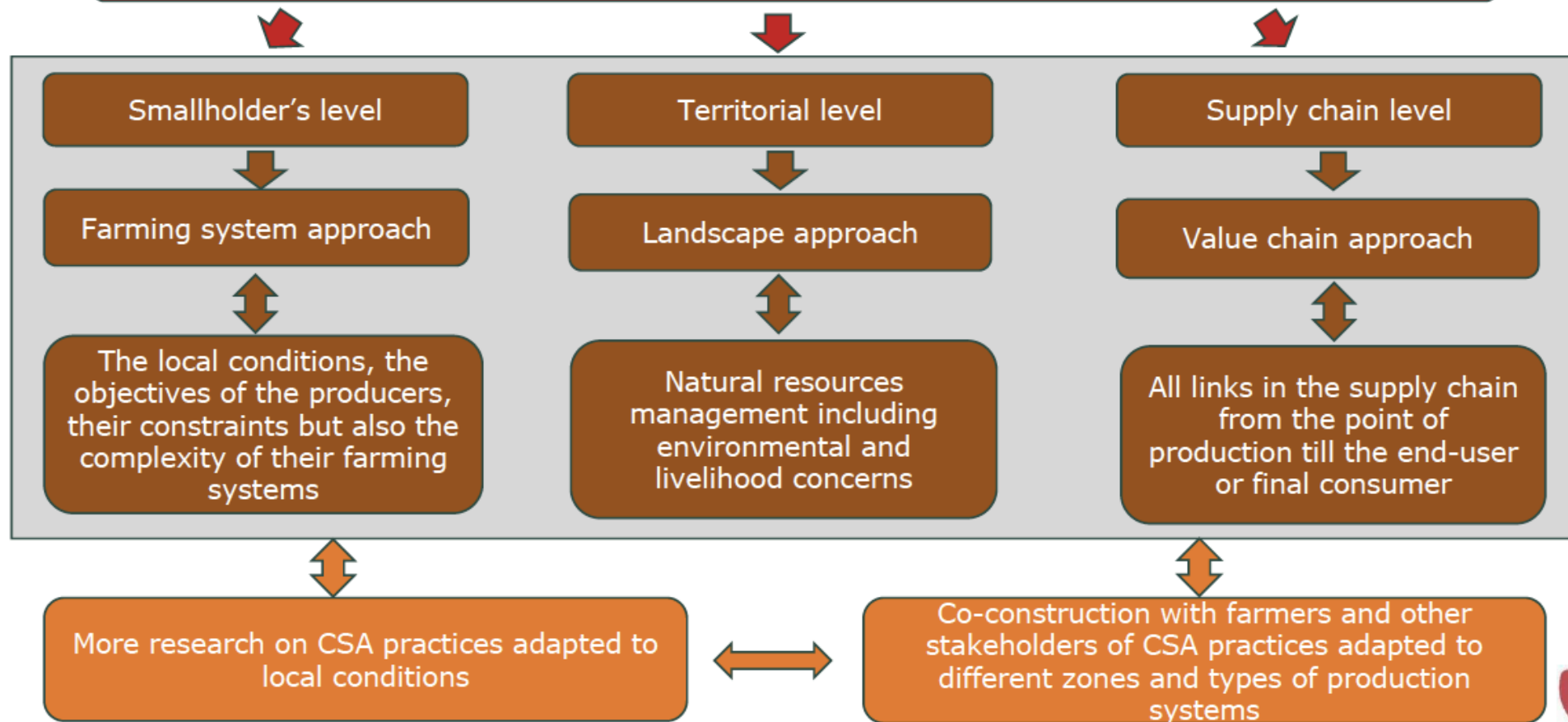
Different gender
issues

Urgent cash needs



The importance of systemic and participative approach to define adapted CSA practices

CSA can't be simply prescriptive: requires spatio-temporal-specific agricultural production technologies and practices



The necessity to take into account gender issue to define CSA practices

Women: 43% of the agricultural labour force, and 70% of agricultural labour in Zimbabwe

Lower levels of access to and control of key productive assets such as land, information and technology



Lower levels of decision-making in households and communities

Lesser control over their own and family labour, and over the proceeds of household production

Men and Women perceive climate change differently and are affected by it in different ways

Women farmers particularly affected by climate change:

- Lower adaptive capacity
- Greater barriers in responding and adapting to climate impacts

Women farmers face specific barriers in adopting CSA practices (unequal access to credit, technology, agricultural inputs, capacity-building)

Strategies for implementation need to be developed in consultation and continuous assessment with women smallholders

In implementing CSA, it is important to understand the needs, priorities and challenges of different stakeholders

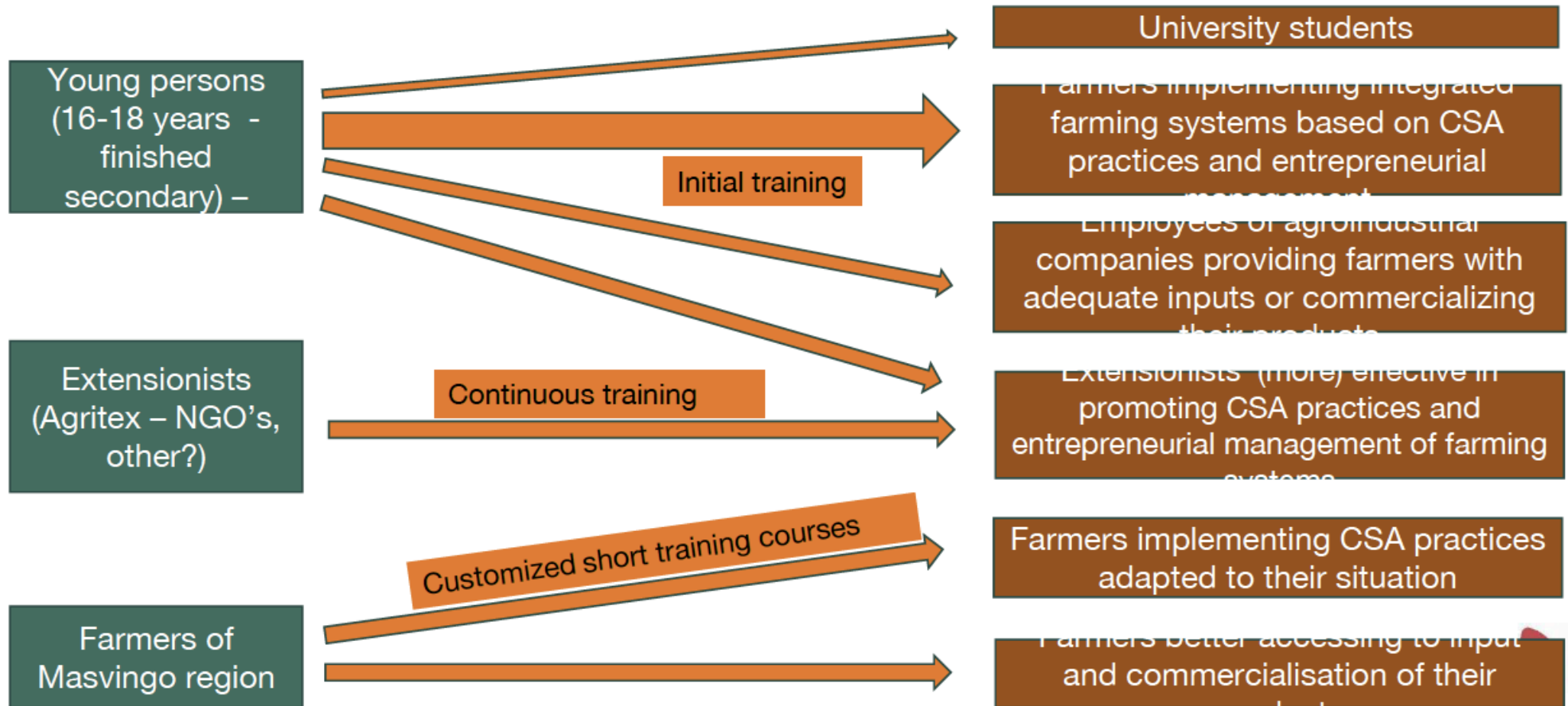
Solutions developed to support women farmers need to take into account these constraints and address them: access to resources, assets and decision-making at the household level

If implemented without consideration of gender and social inequalities, CSA practices will fail to take advantage of opportunities to improve livelihoods and may instead increase these inequalities



CURRICULUM DESIGN BASED ON STAKEHOLDER RECOMMENDATIONS

Target groups of the CSA college and targeted professional profiles



Contents: Articulating 3 yearly /progressive levels

Level 1: Knowing available CSA practices and their effects on CSA Pillars

- **Developing a global understanding of climate change**, his causes and effects / the key importance and implications of implementing CSA practices.
- **Managing tools and methods to analyse the effects of agricultural practices on the 3 CSA pillars** (in crops and breeding's)
- **Knowing and being able**



Level 2: Being able to propose CSA practices adapted to mixed (small holders) farming systems conditions.

- **Integrated management of farming systems and determining factors** (a groecological, socioeconomic, resources available, goals and rationality, etc.)
- **Efficient energy / recycling / articulating crops-livestock management** in farming systems
- **Integration of gender issues** in farming systems management / implementation of CSA practices.
- **Formulation farming development plan** based on integrated / combined CSA practices and entrepreneurial



Level 3a: Implementing farming development based on CSA practices in own entrepreneurial project (specific technical/entrepreneurial assessments)

Level 3b: Supporting the implementation of adapted CSA practices by farmers (innovative extension methods, research development, land scape approach, climate information, etc.)

Level 3c: Enabling value chains conditions for the implementation of CSA practices (access to inputs, commercialisation, addition of value, insurance, etc.)

Contents: Articulating 3 yearly /progressive levels

Level 1: Knowing available CSA practices and their effects on CSA Pillars

Crops and livestock level



Level 2: Being able to propose CSA practices adapted to mixed (small holders) farming systems conditions.

Farming system level



Level 3a: Implementing farming development based on CSA practices in own entrepreneurial project

Farming system level
(implementation)



Level 3b: Supporting the implementation of adapted CSA practices by farmers

Territorial/
landscape level

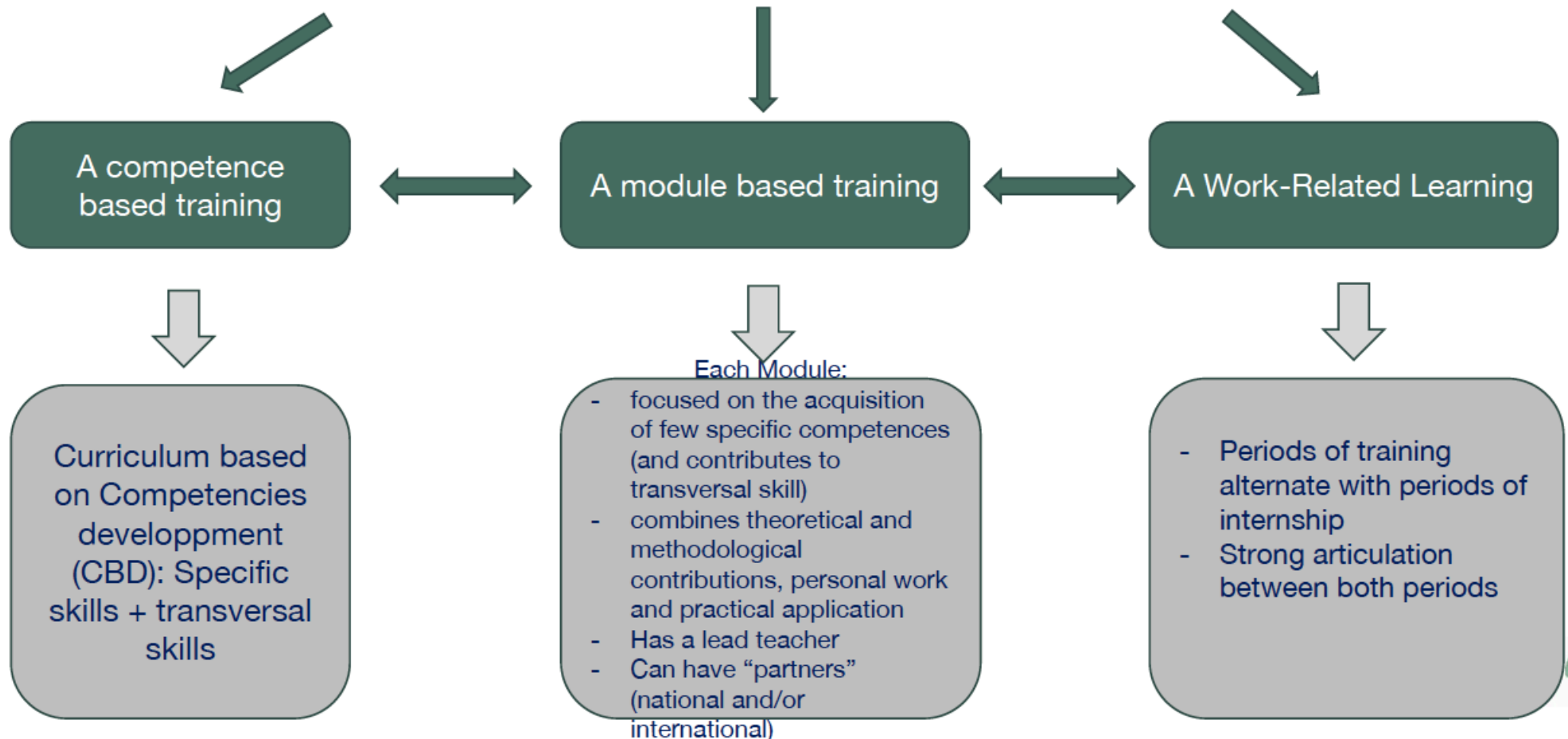


Level 3c: Enabling value chains conditions for the implementation of CSA

Value chain level



Methodology: To reach a strong theory-practice articulation



A work-related learning / module based training

Theoretical/
methodological
contributions

Orientation
s for field
phase
(internship)

Internship: work + data collection/practice
application/observations + elaboration of
reports

Presentation of
reports of field
phase,
exchanges
between
students, etc.

(theoretical
elaboration
based on
practice)
Conclusion

A Module of training

1 Week

2 Week

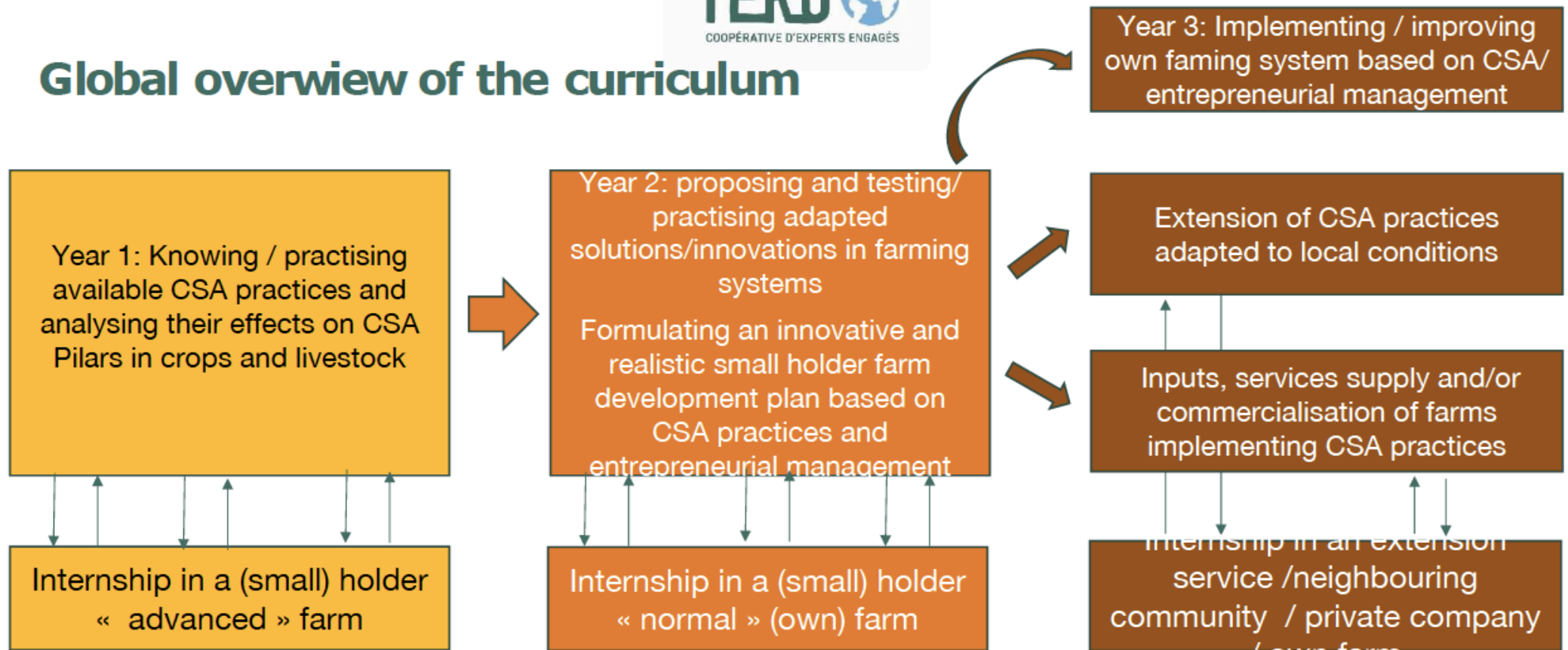
1 Week

Example: Module of Integrated Soil Fertility Management (level 1):

Skill developed: Carry out analyses and integral interpretation of soil characteristics and the effects of agricultural practices on them in order to propose/implement appropriate alternative CSA practices



Global overview of the curriculum



Aternating 2 weeks in CSA college and 2 weeks in internship (in Masvingo Province)

During training in the college: on college farm practices, visit of significant local experiences, practices in direct neighbour hood, etc.

A Diploma in Climate Smart Agriculture

•Based on the General academic regulations of the diploma in agriculture

- **The same general functioning:** entry requirement, mechanisms of admission and registration, boards of examiners and studies, validation and review, etc.
- **The same academic structure:** 3 years training, one level/year, credit system, total of credits and weeks of study, etc.
- **The same final approval mechanism of the curriculum** (by the department of agriculture and education)

•A specific study plan

- **Specific modules and/or contents**
- **Major weight of internship in the training (from 33% to 50 %)**
- **Different modality of articulation** between training and internship periods
- **Wide consultation with** interested stakeholders for the formulation of the study plan
- **Pilot implementation experience + participative capitalisation** before final formulation and approval

Academic/institutional feasibility?

No need to reinvent the Wheel when not necessary

Mwasvingo CSA diploma: a pilot experience reproducible by other colleges (once validated)

Year 1: Knowing / practising available CSA practices and analysing their effects on CSA Pillars in crops and livestock

Modules	Credits
Level 1 Semester 1	
1.- Climate change challenges and CSA	5
2.- Selection, improvement, introduction of adapted varieties / germplasm	5
3.- Integrated soil fertility management	5
4.- Efficient water management	5
5.- Selection of animal types and breeds better adapted to heat stress and dry conditions	5
6.- Integrated Feed Management	5
"Advanced" farm internship	30
Total Credits	60
Level 1 Semester 2	
1.- Analysis of Effects of agricultural practices on the 3 CSA pillars	5
2.- Integrated pest and disease management	5
3.- Integrated crops Management	5
4.- Herd management for a sustainable increase in productivity and reduction of GHG	5
5.- Health management to reduce the spread of notifiable diseases in crop and livestock systems	5
6.- Integrated livestock systems management	5
"Advanced" farm internship	30
Total Credits	60



Year 2: Being able to propose CSA practices adapted to mixed (small holders) farming systems conditions.

Modules	Credits
Level 2 Semester 1	
1.- Diversification of farming systems	4
2.- Agroforestry and agro-sylvopastoral systems	5
3.- Analysis of socio-economic environment of farming systems	5
4.- Microeconomic analysis of farming systems	5
5.- Integration of gender issues in farming systems management / implementation of CSA practices	5
6.- ICTs and climate information systems in agriculture	3
7.- Research and innovation skills	3
"Normal" farm internship	30
Total Credits	60
Level 2 Semester 1	
1.- Optimization of crops-livestock integrated management in farming systems	5
2.- Efficient energy management in farming systems	5
3.- Integrated management of farming systems	5
4.- Farm business, agri-entrepreneurship and CSA	5
5.- Farm budgeting and formulation of farming development plan based on integrated / combined CSA practices and entrepreneurial vision	7
6.- Professional communications skills	3
"Normal" farm internship	30
Total Credits	60



Level 3a: Implementing farming development based on CSA practices in own entrepreneurial project

Modules	Credits
Level 3a Semester 1	
1.- Specific technical and entrepreneurial assessment	5
2.- Solving problems that arise in the implementation of the plan	5
3.- Monitoring and evaluation of the effects of the implementation of the plan on the 3 CSA pillars	5
"Own farm" internship	45
Total Credits	60
Level 3a Semester 2	
1.- Specific technical and entrepreneurial assessment (continues)	5
2.- Solving problems that arise in the implementation of the plan (continues)	5
3.- Monitoring and evaluation of the effects of the implementation of the plan on the 3 CSA pillars (continues)	5
"Own farm" internship	45
Total Credits	60



Level 3b: Supporting the implementation of adapted CSA practices by farmers

Modules	Credits
Level 3a Semester 1	
1.- Analysis of sociological dimensions of change processes in rural areas and definition of relevant / innovative extension methods/strategies	8
2.- Facilitation of collective problem-solving processes	8
3.- Facilitation of capacity building processes based on principles and theories of adult education	7
4.- Implementation of innovative research-development processes with farmers	7
"Extension service" internship	30
Total Credits	60
Level 3a Semester 2	
1.- Facilitation of access to climate information services and early warning systems	8
2.- Concertation on land use planning and communal rangeland management	8
3.- The strengthening of producers / communal organizations	7
4.- Facilitation of individual and collective better integration of farmers in value chains	7
"Extension service" internship	30
Total Credits	60



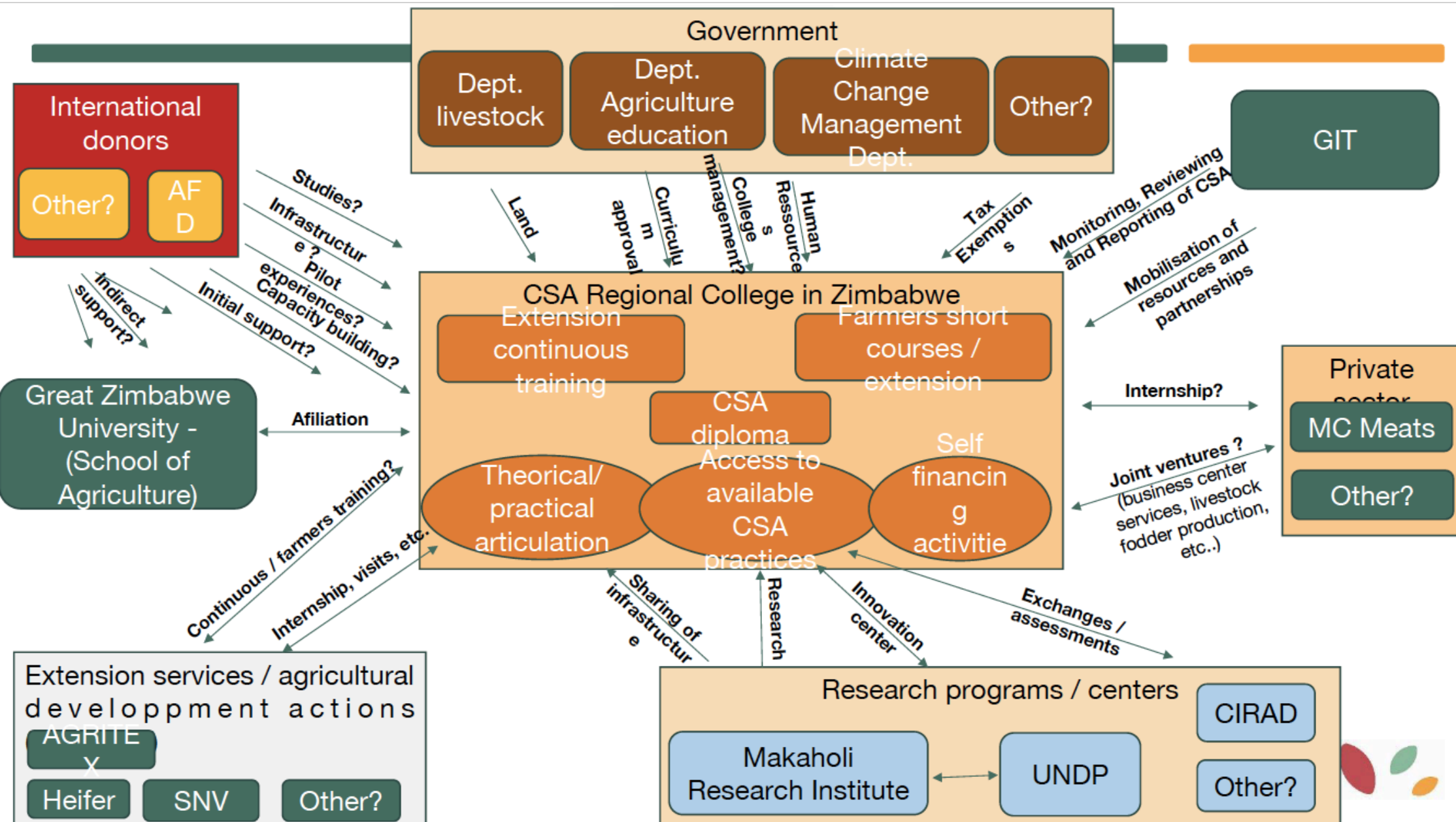
Level 3c: Enabling value chains conditions for the implementation of CSA practices

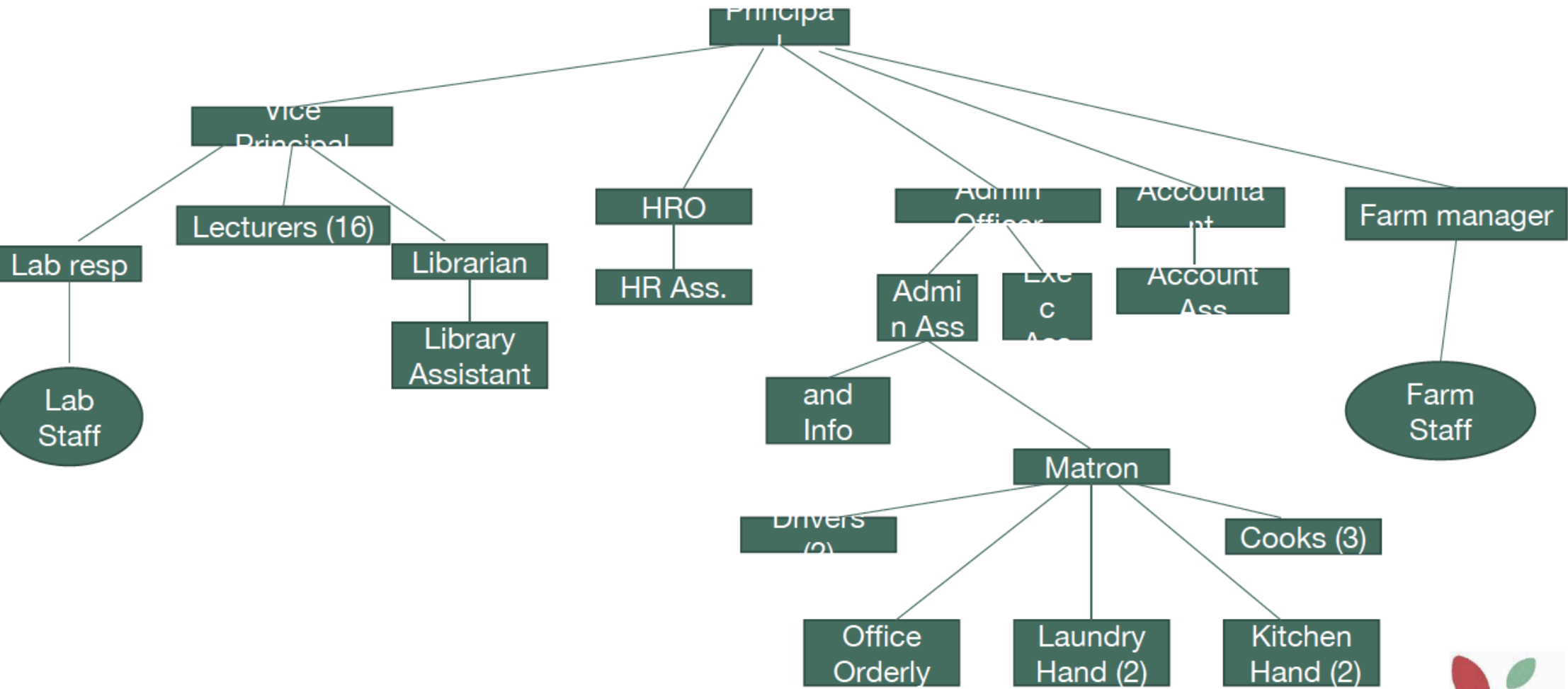
Modules	Credits
Level 3a Semester 1	
1.- Identification of farmers' needs and demands of services	7
2.- Identification and analysis of key value chains	8
3.- Management of post-harvest technology and agro-industries	7
4.- Marketing of agricultural and food products	8
"Private agro-industrial company" internship	30
Total Credits	60
Level 3a Semester 2	
1.- Facilitation of access to green credit and weather index-based insurance services	8
2.- Production and sale of inputs to farmers (seeds, plants, fodder, biofertilizers, biopesticides, etc.)	8
3.- Formulation of business plans to develop specific services	14
"Private agro-industrial company" internship	30
Total Credits	60

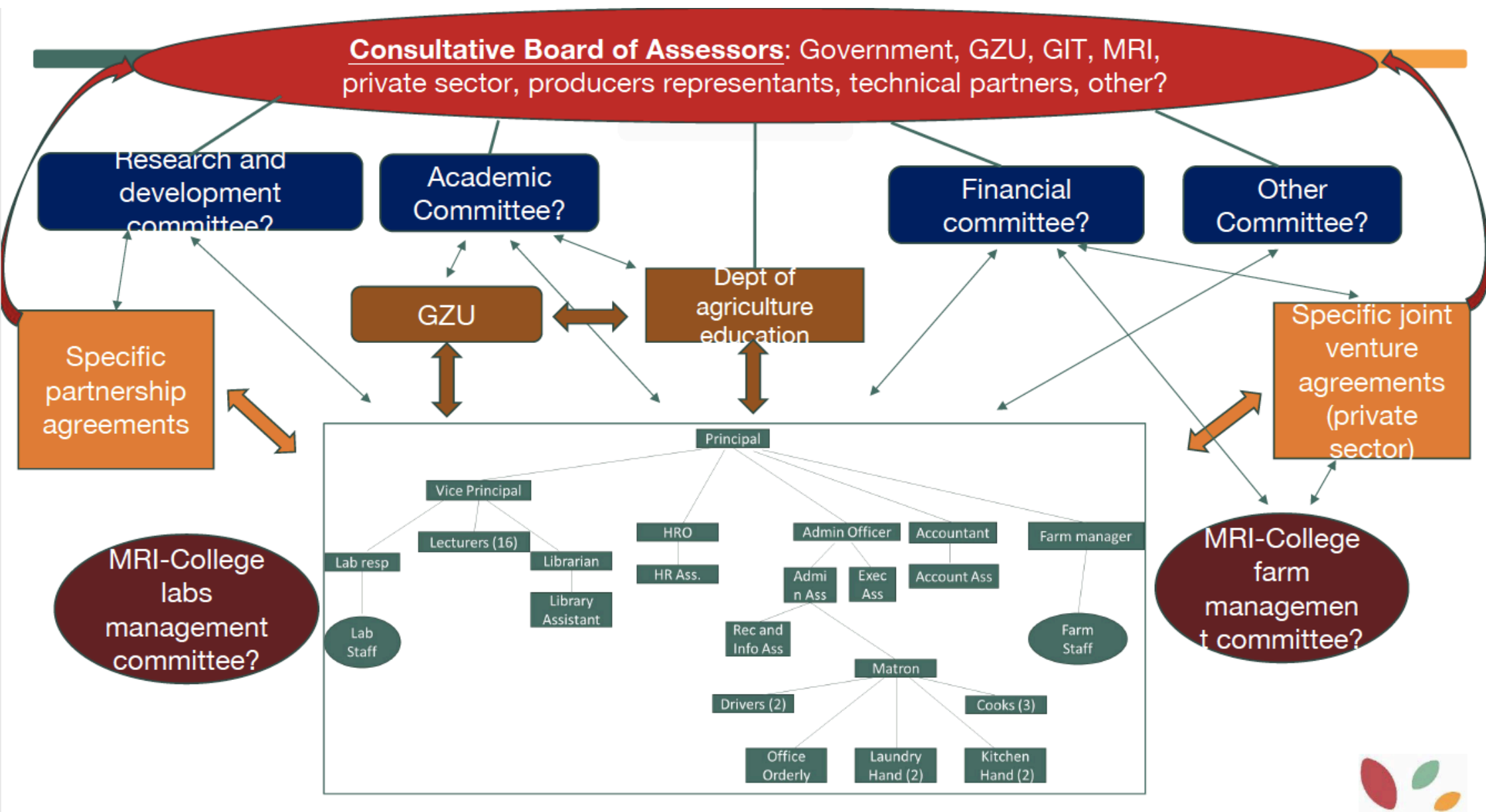




STAKEHOLDERS, PARTNERSHIPS AND GOVERNANCE MODEL







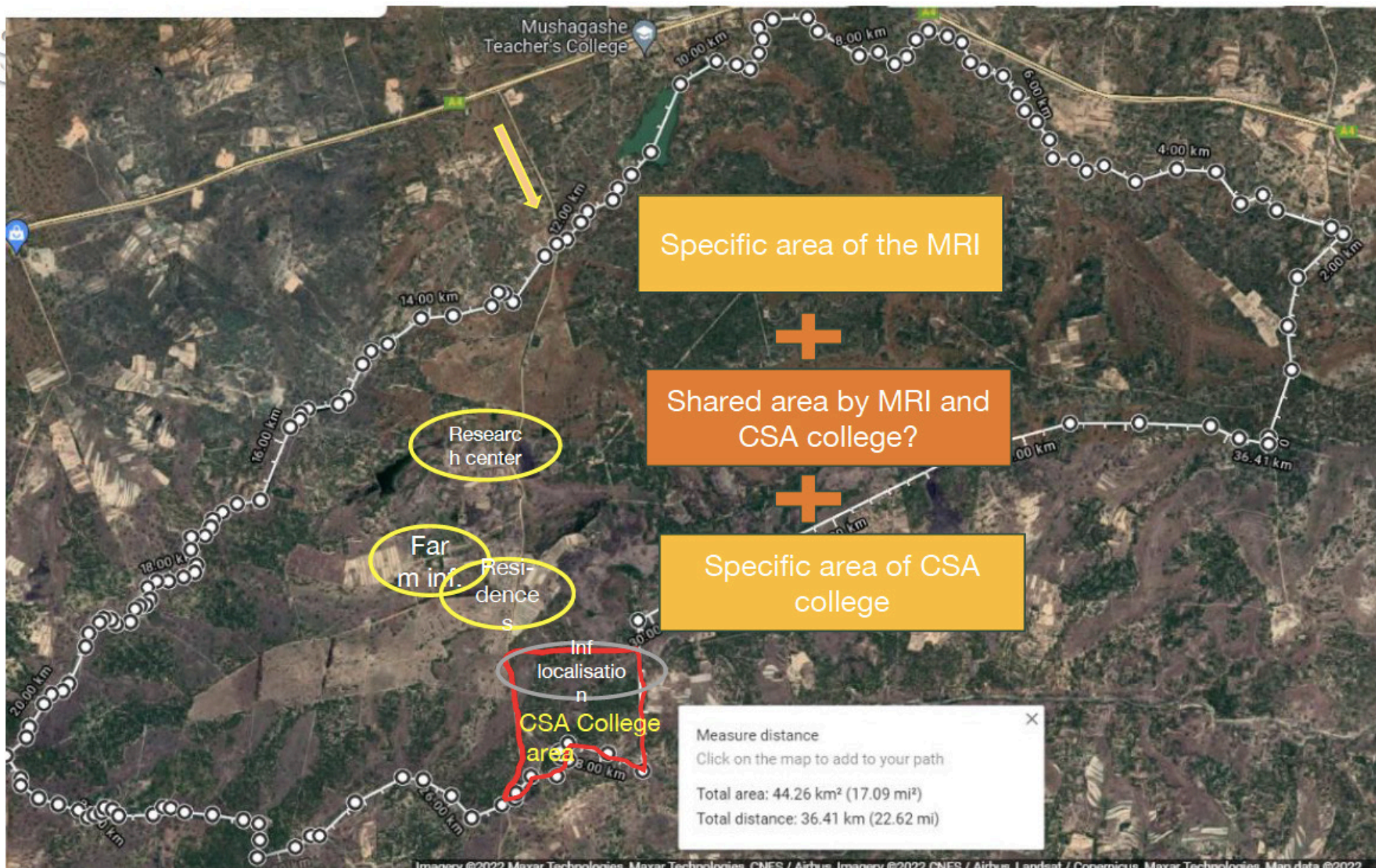


CSA REGIONAL COLLEGE LOCATION & INFRASTRUCTURE SHARING WITH MAKOHOLI RESEARCH INSTITUTE











ECONOMIC/FINANCIAL MODEL AND IMPLEMENTATION STRATEGY

Sizing the college...

150 students

50 students / year

75 at the same time in the college

(based on existing colleges + curriculum proposal)

Assessment of costs based on 3 options

- **OPTION A:** 50 registered students/year over a 3-years cursus; that is 75 to 80 students residing at the same time in the college premises;
- **OPTION B:** 80 students/year over a 3-years cursus; that is 120 to 130 students residing at the same time;
- **OPTION C:** 100 students/year over a 3-years cursus; that is 150 to 160 students residing at the same time.



INFRASTRUCTURE REQUIREMENTS: rough estimations

Basic Infrastructure	Number			Unit	Unitarian price (€)	Total			Description
	Option A	Option B	Option C			Option A	Option B	Option C	
Staff houses	40	50	60	houses	38500	1 540 000	1 925 000	2 310 000	70 m2 each
Students' accommodation	80	130	160	students	2200	176 000	286 000	352 000	4 m2 por student / 4 students per room (12 m2) / 2 watercloset and 2 showers per room / cubicles equipped with desk and tea corner
Guest house	1	1	1	house	55000	55 000	55 000	66 000	100 m2
Kitchen	70	90	100	m2	700	49 000	63 000	70 000	Cooking area and preparation area: 4m x 8m; Matron's office 3m x 4m; warden office 3m x 4m, storage 14 m2
Dining facility	120	180	225	m2	700	84 000	126 000	157 500	Dining area: 10 x 12; 1,5 m2 / student
Administration block (120 m2)	120	150	180	m2	700	84 000	105 000	126 000	for 15/25/35 persons (4 m2 / person) + boardroom (8 x 4 m) + reception (2 x 3) + tea rooms and kitchen (2 x 3) + toilets (2 x 4) + storeroom (2 x 2)
Guardroom	30	30	30	m2	550	16 500	16 500	16 500	with toilets, kitchenette or resting area
Lecture room (3) + Laboratory (1)	240	300	360	m2	700	168 000	210 000	252 000	2 m2 /student; each classroom for 30 students
Hall	120	180	225	m2	550	66 000	99 000	123 750	1,5 m2 /student
Board room/offices for lecturers	100	100	120	m2	550	55 000	55 000	66 000	3 m2 / lecturer + 8 x 4 m boardroom + toilets
Library	100	120	150	m2	700	70 000	84 000	105 000	Library and reading area librarian office, book stacks
Equipped Computer lab	60	120	180	m2	1000	60 000	120 000	180 000	1/2/3 rooms with 2 m2 per student for 30 students and 35 / 45 / 60 computers + ...
Clinic	70	80	100	m2	700	49 000	56 000	70 000	Equipped ward (reception-waiting area, office, procedure room, drug storage, administration office and counselling room (also to serve surrounding communities)
Mechanics shop & storage + tools	50	80	100	m2	700	35 000	56 000	70 000	
Water treatment plant	1	1	1	plant	125000	125 000	180 000	220 000	1,000 US\$ / person served
Total direct costs						2 632 500	3 436 500	4 184 750	
Studies & supervision costs (10%)						263 250	343 650	418 475	
TOTAL Infrastructure costs						2 895 750	3 780 150	4 603 225	



Additional costs for years 1 and 2 at the start of the CSA College

Designation	Euros (TTC)
International and national expertise to assist in:	
-Elaboration of curricula	
-Backstopping for the monitoring of constructions and equipment procurement	
-Training of trainers and other staff	
-Implementation of curricula	
-Development of continuous training, and on-the-job training by alternance	
Equipment procurement (incl. Vehicles – 1 bus, 4 pickups – as well as appropriate agricultural machinery and tools)	0,4 million
Airfares for external experts (10 return trips)	0,8 million
Per diems for experts (200 days total)	0,02 million
Costs to mobilize local stakeholders / governance-related costs	0,02 million
Sub total	0,01 million
Contingencies (5%)	1,25 million
TOTAL ADDITIONAL BUDGET for YEARS 1 & 2	0,06 million
	1,31 million



Recapitulation of direct investment costs for a CSA College in Masvingo

	Initial investment cost (€)	Additional costs for year 1 & 2 and full-fledged feasibility (€)	TOTAL Investment (€)	Unit investment per yearly registered student (€)	Unit investment per graduated technician (€)
OPTION A 50 students/yr	2,900,000	1,400,000	4,300,000	86,000	3,400
OPTION B 80 students/yr	3,800,000	1,500,000	5,300,000	66,000	2,650
OPTION C 100 students/yr	4,600,000	1,600,000	6,200,000	62,000	2,500



INFRASTRUCTURE REQUIREMENTS: rough estimations

- **Equipment?**
- **Sports infrastructure and equipment (external / internal)?**
- **Renovation / improvement of laboratories,**
- **Renovation / improvement of farm :**
 - Livestock and pasture rehabilitation: 92800 US \$
 - Other?
- **Possibilities of rehabilitation of existing infrastructures?**
- **Climate Smart infrastructure (solar energy, water harvesting, recycling, etc.)?**
- **Other?**

Progressive realisation of infrastructure and Equipment of the CSA College (Donors Support):

- Gradual increase in the number of students
- Initially use of existing, underused infrastructure by rehabilitating it



Wages: estimates for option A

1.Function	2.Number	3.Monthly salary (Z\$)	4.Covid Monthly Allowance - CMA (US \$)	5.Annual total incl. CMA (US \$)	6. Social security & other benefits (20 % of col.3) (US\$)	Annual TOTAL incl. CMA (col.5+6) (US\$)	Annual TOTAL without CMA (US\$)	Annual TOTAL without CMA (€)
Principal	1	140,000	200	7,618	1,044	8,662	6,262	6,387
Vice Principal	1	140,000	200	7,618	1,044	8,662	6,262	6,387
Lecturers	16	90,000	200	92,072	10,734	102,806	64,406	65,694
HRO	1	80,000	200	5,382	596	5,978	3,578	3,650
Admin Officer	1	80,000	200	5,382	596	5,978	3,578	3,650
Accountant	1	80,000	200	5,382	596	5,978	3,578	3,650
Farm Manager	1	80,000	200	5,382	596	5,978	3,578	3,650
Lab manager	1	80,000	200	5,382	596	5,978	3,578	3,650
Librarian	1	80,000	200	5,382	596	5,978	3,578	3,650
HR assistant	1	60,000	200	4,636	447	5,084	2,684	2,737
Admin assistant	1	60,000	200	4,636	447	5,084	2,684	2,737
Accountant assistant	1	60,000	200	4,636	447	5,084	2,684	2,737
Executive assistant	1	60,000	200	4,636	447	5,084	2,684	2,737
Recreation and information assistant	1	60,000	200	4,636	447	5,084	2,684	2,737
Library assistant	1	60,000	200	4,636	447	5,084	2,684	2,737
Matron	1	50,000	200	4,264	373	4,636	2,236	2,281
Driver	3	50,000	200	12,791	1,118	13,909	6,709	6,843
Cook	2	50,000	200	8,527	745	9,273	4,473	4,562
Kitchen Hand	2	45,000	200	8,154	671	8,825	4,025	4,106
Laundry Hand	2	45,000	200	8,154	671	8,825	4,025	4,106
Office Orderly	1	45,000	200	4,077	335	4,413	2,013	2,053
Warden	4	45,000	200	16,309	1,342	17,651	8,051	8,212
Total	45			920,000	94,000	1,014,000	440,000	474,000



Number of staff required for the three hypotheses regarding registered students

Number of students in the yearly cohort	Number of lecturers	Number of administrative /non-teaching staff	Total number of staff	Additional staffing needs (Compared to the precedent option)
50	16	29	45	N/A
80	21	36	57	5 lecturers 2 administrative assistants 1 kitchen hand 1 driver 1 library assistant 1 laboratory assistant 1 executive assistant
100	26	44	70	5 lecturers 2 administrative assistants 1 accountant assistant 1 matron 1 driver 1 cook 1 kitchen hand 1 laundry hand



Recapitulation of operating and global costs for the CSA College at full throttle

	Total number of students	Total staff number	Staff-related yearly cost: salaries, bonuses and benefits (€)	Other operating costs	Total yearly operating costs, training only (€)	Yearly boarding and feeding costs (€)	TOTAL yearly recurrent costs, including student feeding (€)
OPTION A	150	45	148,952	223,428	380,000	31,250	411,250
OPTION B	240	57	187,502	281,253	470,000	50,000	520,000
OPTION C	300	70	229,017	343,526	573,000	93,750	663,750

	1.TOTAL initial investment (€)	2.Unit investment per graduated technician (€)	3.TOTAL yearly recurrent costs, including student feeding (€)	4.Average total yearly recurrent costs per student, € (rounded)	5.Total Cost per student over the 3 years cursus (= col 2 + (3 x col 4))
OPTION A	4,300,000	3,400	411,250	2,800	11,800
OPTION B	5,300,000	2,650	520,000	2,200	9,250
OPTION C	6,200,000	2,500	663,750	2,200	9,100



Initial economic/financial model

Costs

Renabilitation /equipment of existing infrastructure, progressive construction of new facilities

Capacity building, partnerships setup, joint ventures, etc.

Cost of operating the farm and other economic activities

Costs of linking theorical with practical training

Students alimentation and accomodation

Reccurent operating costs (electricity, water, fuel communications, etc.)

Wages

Incomes

Donors support

Incomes from farm and other economic activities (consulting services, other?)

Donors support

Students fees + scholarship programs

Government support



Future economic/financial model

Costs

Maintenance of infrastructure and renovation of equipment

Cost of operating the farm and other economic activities

Theoretical / practical articulation

Students alimentation and accomodation

Reccurent operating costs

Wages

Incomes

Government support

Donors support

Incomes from farm and other economic activities

Students fees + scholarship programs

Government support

Projected financing structure of the CSA College

Costs	External donors share	Local partners share	GoZ share	Students' fees and tuition	Farm revenues	Provision of Services
Initial investment	85 %	5%	15%	N/A	N/A	N/A
Operation Short-term (year 1 to 4)	25%	5%	35-50%	10%	0-5%	0-5%
Operation Long-term (year 5 +)	0-5%	5%	60%	10-15%	5-10%	10%



Expected financing contributions (in millions €)

Option A

Costs	External donors' contribution	Partner's contribution	GoZ contribution	Students' fees and tuition	Farm revenues	Provision of Services	Total
Initial investment	3,74	0,22	0,44	N/A	N/A	N/A	4,40
Operation Short-term (year 1 to 4)	0,105	0,021	0,210	0,042	0,021	0,021	0,42
Operation Long-term (year 5 +)	0,021	0,021	0,252	0,063	0,021	0,042	0,42

Option B

Costs	External donors share	Partners share	GoZ share	Students' fees and tuition	Farm revenues	Provision of Services	Total
Initial investment	4,57	0,27	0,54	N/A	N/A	N/A	5.38
Operation Short-term (year 1 to 4)	0,136	0,027	0,272	0,054	0,027	0,027	0.54
Operation Long-term (year 5 +)	0,027	0,027	0,326	0,082	0,027	0,054	0.54

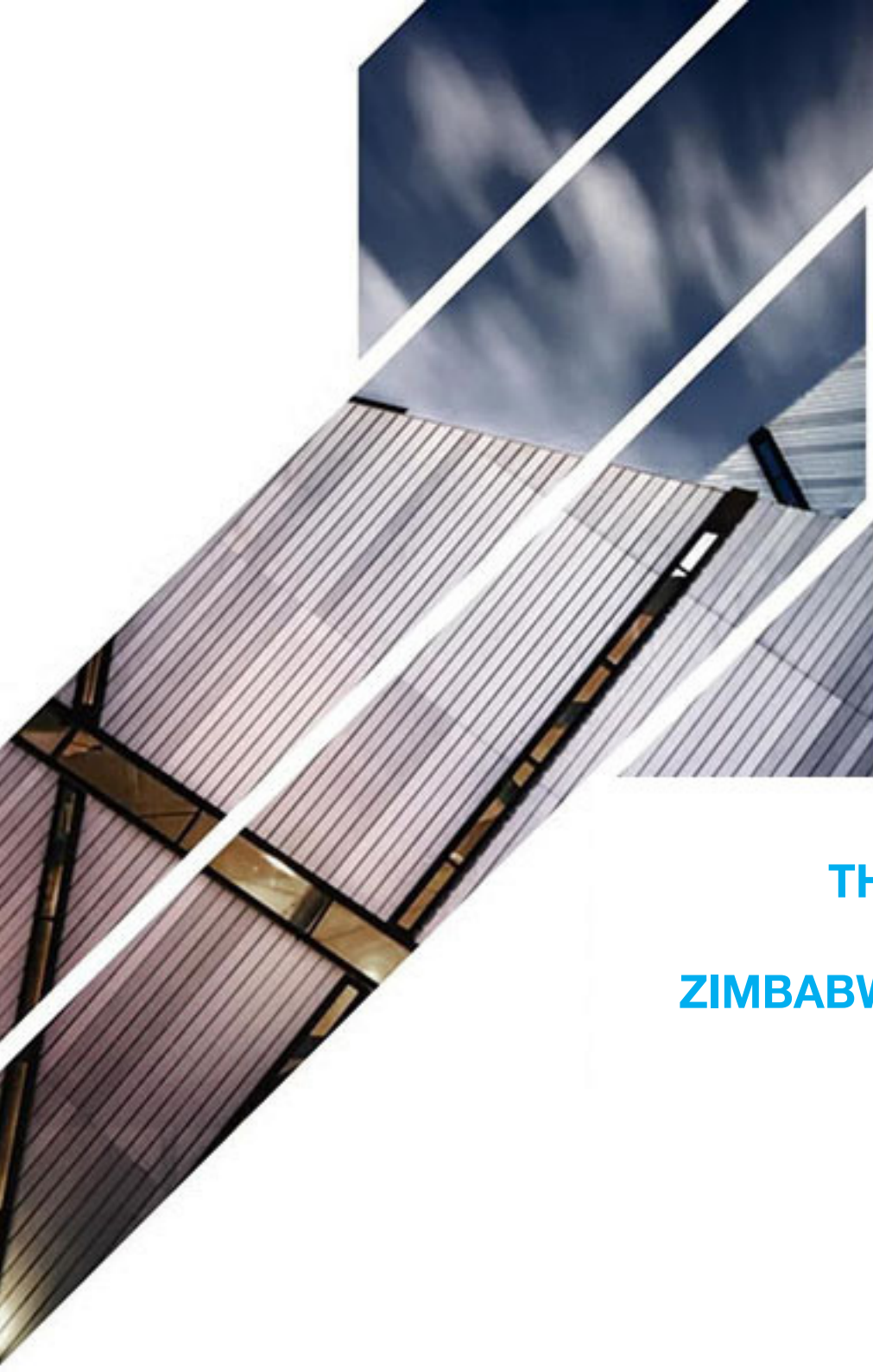
Option C

Costs	External donors share	Partners share	GoZ share	Students' fees and tuition	Farm revenues	Provision of Services	TOTAL
Initial investment	5,38	0,32	0,63	N/A	N/A	N/A	6,33
Operation Short-term (year 1 to 4)	0,167	0,033	0,333	0,067	0,033	0,033	0.67
Operation Long-term (year 5 +)	0,033	0,033	0,400	0,100	0,033	0,067	0.67



CONCLUSION AND NEXT STEPS

[illegible]



THE FUTURE OF SOLAR IN AFRICA

ZIMBABWE NATIONAL SOLAR PROGRAM (ZNSP)

EDUCATION & TRAINING

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Last but not least, **Education & Training**, as to ensure a pool of qualified engineers, technicians and other personnel for the Zimbabwe National Solar Program (ZNSP) over the coming years, a critical element is Renewable Energy courses as part of the College and University syllabus. Due to the foresight by the Zimbabwean College and University faculties this element is already well established.

University of Zimbabwe Master of Science in Renewable Energy

The purpose of the MSc is to provide high quality postgraduate education in the field of renewable energy so that participants develop proficiency in renewable energy project design, implementation, operation and maintenance, as well as in crucial phases of policy generation. There is also scope for focussed research on renewable energy-related topics.

The masters degree builds on the Mechanical Engineering Department's other efforts towards the achievement of the 2030 Sustainable Development Goals, in particular, its participation in the Solar Thermal Training and Development Initiative (SOLTRAIN).

Through the initiative, the department will be able to capitalise on the programme's regional knowledge network, as well as have the use of the SOLTRAIN solar thermal demonstration trailer as well as access to various solar thermal demonstration sites. This will contribute immensely to solar thermal-related learning and research.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Speciss College Solar Installation Courses

Speciss College is the largest private education institution in Zimbabwe.

The Syllabus

Basic

- * Basic electrical theory
- * Electrical Installations
- * Solar System Installation

Advanced

- * Advanced Electrical Theory
- * Planning, Designing and Installation
- * Testing, Troubleshooting and Commissioning
- * PV System Optimization ,Development and Maintenance
- * Project (Building a 15kva system using 5kva inverters)



Speciss has four campuses: Chitepo, Technical (in Highfield), Chitungwiza and Bulawayo. Each Campus is headed by a Campus Director. Within each Campus are Departments known as Schools headed by Directors of Studies. The Chitepo Campus has four departments namely Business School, High School (teaching the Cambridge O and A level syllabuses), Study Centre and the Computer and Secretarial School. The other campuses have a similar set up though the Chitungwiza and Technical campus High Schools teach the ZIMSEC O and A Level syllabuses. The Technical, Bulawayo and Chitungwiza campuses include Technical and Garment Schools providing a range of technical and vocational qualifications. Tuition is also offered by highly qualified professionals who are experts in their specific area of training

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Green Solar Academy

Solar Basics

This course gives participants fundamental and relevant knowledge to understand solar PV and provides them with a foundational understanding of the industry.

PV Mounter

PV systems installation - Students plan and execute installations , up to commissioning and testing of the system.

eLearning

Online courses have been developed with input from international product manufacturers as well as African solar experts to create content relevant to climate and conditions, and feature an engaging mix of lectures, videos, podcasts, interactive exercises and self-assessments.



The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Institute of Solar Technology

Solar Project Design Master Course

Maximizes efficiency in the implementation of detailed project plans, keeping track of goals, tasks, resources, schedules, costs, and contingencies.

This Course also enables to identify opportunities to reduce costs and minimize risk; develop systems to manage safety and quality assurance on site and also provide technical assistance to contractors, and report on progress to owners, project developers, and financial partners.

Calculation of Electrical Energy with Solar Power Plant Design

Attendees learn the design fundamentals of photovoltaic projects. Gain knowledge and skills from engineers with real-life experience in solar energy and electrical delivery fields.

Gaining an understanding of solar plant components and PV modules; DC system and AC collector design; civil and geotechnical issues; and interconnection to distribution and the bulk power grid

Solar Power EV Charging Station Design Course:

Solar charging stations for electric vehicles have emerged as one of the best ways to reduce India's dependence on fossil fuels. Nearly everyone who owns an Electric vehicle will install a solar charging station in their home. Certificate in Solar Power EV Charging Station (Design and Development) Training Program is a master courses that takes an Engineer, design engineer, installer from site assessment, all the way through power-up and pinpointing.

Solar Operation Maintenance Master Course:

Knowledge - Understand solar designs and solve the site level issues remotely, Maintain the PR for Solar projects and prepare DPR for generation shortfall issues.

Job Skill - Inverter diagnostics and repair, Performing troubleshooting and repairs on site, Daily plant operation in coordination with O&M operator/In house O&M activities, Preventive maintenance and breakdown maintenance, Understanding of solar PV technologies and day to day plant operations

Lithium-ion Battery Pack Assembly course

Techno Commercial Course to setup Lithium-ion battery assembly line for solar application, energy storage and EV 2W, 3W etc.

Practical training - cell selection, cell IR testing, cell balancing, charge discharge testing, module & pack assembling, enclosure selection, all machinery selection, assembly line planning and layout drawing, costing of assembly line, working capital, investment, ROI, business projection making, different product design.

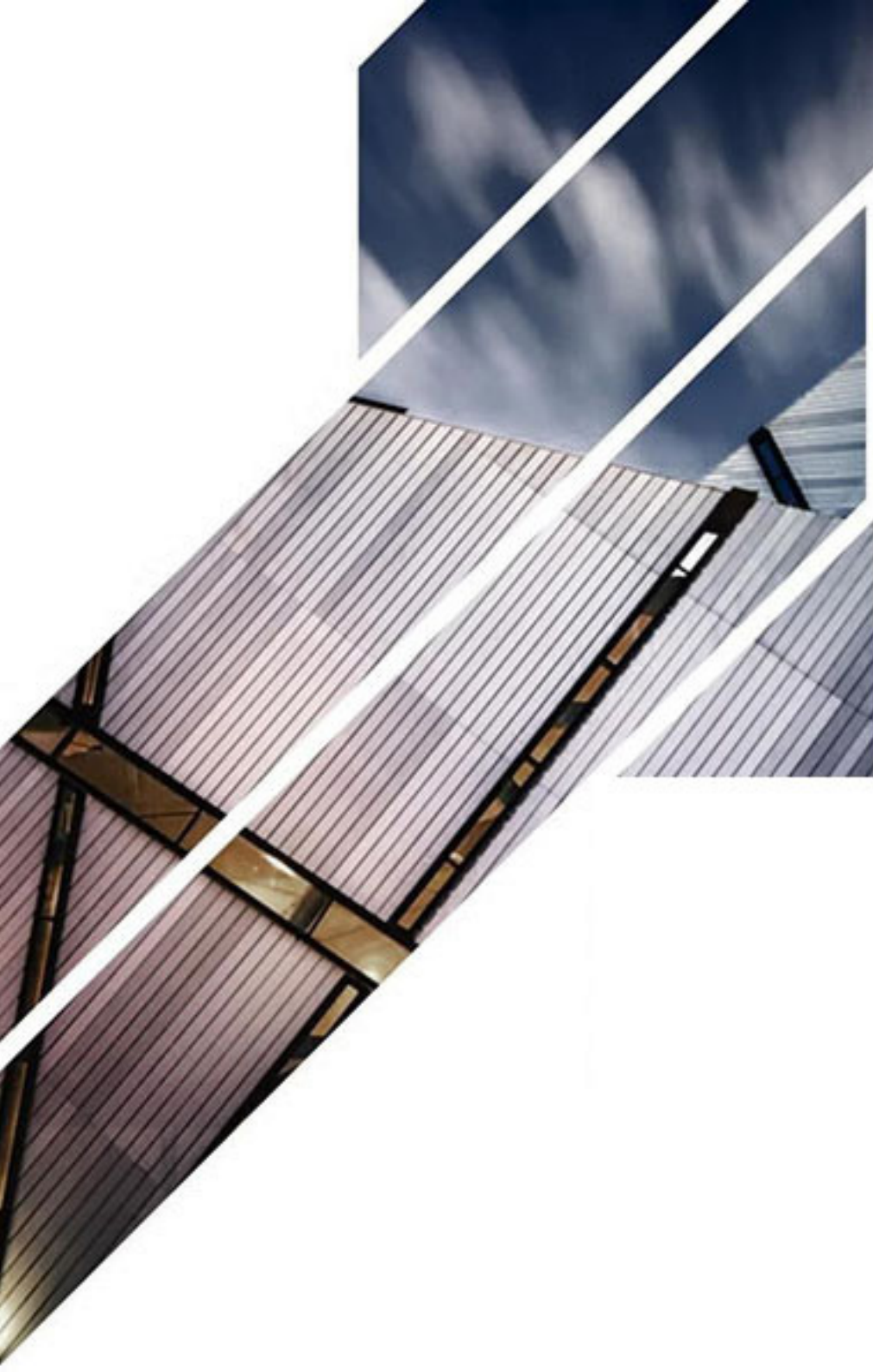
Get the knowledge of Lithium-ion cell parameters, Cell Chemistry, Cell Architecture, Thermal Management, BMS and battery pack assembly technical and commercial detail before setup assembly line.

The future of Solar in Africa - Zimbabwe National Solar Program (ZNSP)

Harare Institute of Technology Solar Photovoltaic Training Course

Course Synopsis

Solar energy fundamentals, Solar system applications, Positioning of the modules, Photovoltaic energy, Photovoltaic illumination, Planning and designing a photovoltaic installation, The electric load, Energy costs and evaluation of the economical solutions, System components, Solar PV system sizing, Solar system maintenance (Performance Analysis and Troubleshooting).



THANK YOU

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