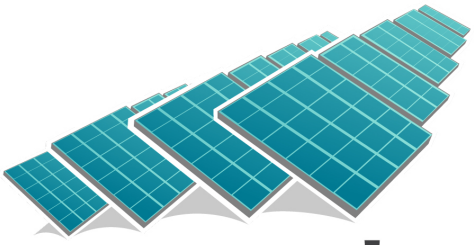

EAST AFRICA'S SOLAR SURGE

The Public Agenda on Productive Use of Solar Energy in Agriculture

DECEMBER 2023

A·C·M·E AFRICAN CENTRE FOR MEDIA EXCELLENCE

CHARLES STEWART MOTT FOUNDATION

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List of Abbreviations

Abbreviation	Term in Full
A2EI	Access 2 energy institute
ACE TAF	Africa Clean Energy Technical Assistance Facility
ACME	African Centre for Media Excellence
AECF	Africa Enterprise Challenge Fund
AFD	Agence Française de Développement (French Development Agency)
AfDB	African Development Bank
BGFA	Beyond the Grid Foundation Africa
CLASP	Collaborative Labelling and Appliance Standards Program
CREEC	Centre for Research in Energy and Energy Conservation
DBVTI	Don Bosco Vocational Training Institute
DFI	Development Finance Institution
DFID	United Kingdom Department for International Development
EAC	East African Community
EASP	Energy Access Scale Up Project
EEP Africa	Energy and Environment Partnership Trust Fund
EnDev	Energizing Development Program
EPRA	Energising Development Program
EPR	Energy and Petroleum Regulatory Authority
ERA	Electricity Regulatory Authority
ESMAP	Energy Sector Management Assistance Programme
EU	European Union
EWURA	Energy and Water Utilities Regulatory Authority
FCDO	Foreign, Commonwealth and Development Office
GDC	Global Distributors Collective
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
Global LEAP	Global Lighting and Energy Access Partnership
GMG	Green Mini-Grid

GOGLA	Global Off-Grid Lighting Association
IFC	International Finance Corporation
IRENA	International Renewable Energy Agency
IMED	Institute of Management and Entrepreneurship Development
IOS	International Organisation for Standardisation
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KCIC	Kenya Climate Innovation Centre
KEBS	Kenya Bureau of Standards
KEPSA	Kenya Private Sector Alliance
KEREA	Kenya Renewable Energy Association
KNES	Kenya National Electrification Strategy
kWh	Kilowatt hour
LEIA	Low energy inclusive appliances
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
MEM	Ministry of Energy and Minerals
MEMD	Ministry of Energy and Minerals Development
MFI	Microfinance institution
MoA	Ministry of Agriculture
MoE	Ministry of Energy
MoITED	Ministry of Industry, Trade and Economic Development
MSME	Micro-, Small- and Medium-Sized Enterprise
MTIC	Ministry of Trade Industry and Cooperatives
MV	Medium voltage
MW	MegaWatt
MWE	Ministry of Water and Environment
MWh	Megawatt Hour
MWp	Megawatt peak
NBS	National Bureau of Statistics
NDP	National Development Plan

NEECS	National Energy Efficiency and Conservation Strategy
NGO	Non-governmental organisation
NMB	National Microfinancing Bank
NREP	National Renewable Energy Platform
OGS	Off Grid Solar system
OPIC	Overseas Private Investment Corporation
P&P	Plug and play
PAOP	Power Africa Off-grid Project
PAYGO	Pay-As-You-Go
PREO	Powering Renewable Energy Opportunities
PUSE	Productive Use of Solar Energy
PV	Photovoltaic
REA	Rural Energy Agency
REACT	Renewable Energy and Adaptation to Climate Technologies
RESP	Rural Electrification and Plan
RTH	Royal Institute of Technology
SACCO	Savings and credit cooperative organisation
SERC	Strathmore Energy Research Centre
SHS	Solar Home Systems
SIDA	Swedish International Development Cooperation Agency
SME	Small- and Medium-sized Enterprises
SPIS	Solar Pump Irrigation System
SWP	Solar water pump
TAMFI	Tanzania Association of Microfinance Institutions
TAREA	Tanzania Renewable Energy Association
TBS	Tanzania Bureau of Standards
UECCC	Uganda Energy Credit Capitalisation Company
UNBS	Uganda National Bureau of Standards
UNREEEA	Uganda National Renewable Energy and Energy Efficiency Alliance

UOMA	Uganda Off Grid Market Accelerator
URA	Uganda Revenue Authority
USAID	United States Agency for International Development
USEA	Uganda Solar Energy Association
V	Volt
VAT	Value Added Tax
VSLA	Village Saving and Loan Association
Wh	Watt hour

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Introduction

Off-grid solar energy solutions have gained popularity, providing a pathway to achieving the United Nations Sustainable Development Goal 7 (universal access to affordable and reliable energy.)

Between 2019 and 2022, an additional 70 million people gained access to electricity through off-grid solar power, bringing the total number of people accessing energy to reaching 490 million globally[1]. Off-grid solar technologies are cheaper, and environmentally friendly, potentially reducing CO2 emissions[2]. Estimates show that connecting 490 million people to solar mini grids could cut 1.2 billion tonnes of emissions.

Greener energy alternatives such as off-grid solar systems contribute 29 per cent of global electricity[3], and are gaining ground while fossil fuels, which account for 80 per cent of global energy output, and contribute to climate change, and are responsible for over 75 per cent of global greenhouse gas emissions and nearly 90 per cent of all carbon dioxide emissions.

Productive use of solar energy for income generation in either the production of goods or provision of services for job creation, improved livelihoods, food security and economic empowerment[4], offers enormous opportunities to address climate change and increase energy access.

In sub-Saharan Africa, 567 million people lack access to energy and 900 million people lack access to clean cooking energy[5].

In Uganda, Kenya and Tanzania, an estimated 82 million residents lacked reliable

1 https://documents1.worldbank.org/curated/en/099235110062231022/pdf/P175150063801e0860928f00e7131b132de.pdf
2 https://www.worldbank.org/en/news/press-release/2022/09/27/solar-mini-grids-could-power-half-a-billion-people-by-2030-if-action-is-taken-now
3 https://www.iea.org/reports/global-energy-review-2021/renewables
4 https://www.gogla.org/wp-content/uploads/2023/07/Gogla_PURE-Roadmap-Report-Uganda.pdf
5 https://unstats.un.org/sdgs/report/2023/Goal-07/

electricity by 2018[6]. PUSE holds potential in the agriculture sector which employs 70 per cent of the population in East Africa[7].

PUSE applications, which cut across the production, processing, distribution, and consumption value chains of the agriculture sector, would boost primary production and post-harvest processing, while solar powered storage would unlock higher yields and aggregation opportunities, increase incomes, cut losses, and improve climate resilience. Pay-as-you-go solar-powered refrigerators help reduce food waste.

However, over reliance on small-scale and rain-fed farming has for long undermined the sector's potential in the region[8].

Standalone solar photovoltaic irrigation systems can meet more than a third of the water needs for crops in small-scale farms across sub-Saharan Africa[9]. Solar-powered irrigation systems appear to be the most impactful. A study conducted on four hundred farmers across Kenya, Uganda, and Tanzania, who had been in possession of a solar pump for a period of four to five months revealed that these farmers had reduced their expenses by 91 per cent. The majority had switched from diesel or manual pumps, and a substantial 81 per cent reported an improved quality of life, due to increase in the harvest seasons and higher incomes[10].

Off-grid solar systems have the potential to power machinery that adds value to produce, move farmers to higher value commercial crop cultivation and improve post-harvest storage via refrigeration for preservation. The electricity generated also reduces farm operating costs associated with diesel generators[11]. Beyond this, the off-grid solar industry supports hundreds of thousands of green jobs in

6 https://www.wri.org/insights/millions-east-africans-who-need-electricity-most-data-shows-renewable-energy-viable-and
7 https://www.creec.or.ug/wp-content/uploads/2021/07/Agrivoltaics2020_conference_paper_Randle-Boggis.pdf
8 ibid
9 https://www.creec.or.ug/wp-content/uploads/2021/07/Agrivoltaics2020_conference_paper_Randle-Boggis.pdf
10 https://www.ace-taf.org/wp-content/uploads/2019/10/ACE-TAF-UGANDA-SOLAR-WATER-PUMPING-REPORT-SCREEN-1.pdf
11 ibid

sales, distribution, customer services, and management[12]. The off-grid solar value chain reportedly employed over 77,000 in East Africa alone in 2018 and this was projected to have grown to 350,000 by 2022[13].

The development of Productive Use of Solar Energy (PUSE) in East Africa encompasses a multitude of stakeholders: government agencies, private enterprises, international organisations, and investors. The governments of Kenya, Tanzania, and Uganda have created a favourable policy environment, thus sparking innovation and investment from both the local and international private sectors. International lenders and funders bolster these sectors, to improve the affordability and accessibility of off-grid renewable energy solutions. Notably, East Africa accounted for more than half (57 per cent) of the $284 million invested globally in the off-grid solar sector in 2017[14].

This investment has catalysed a wave of innovations that have significantly increased the uptake of off-grid solar technologies. For example, Pay-as-you-go (PAYG) solutions have rendered larger systems more affordable for rural households. Under this model, households make an initial down payment to solar systems suppliers, followed by manageable, periodic payments[15].

These payments collected via mobile money payment platforms, allow for ease and convenience of transactions.

Innovations in solar technology contribute to the high volume of solar units sold in Sub Saharan Africa, with around 70 per cent of these units purchased in East Africa[16].

12 https://blogs.worldbank.org/energy/how-grid-solar-solutions-are-key-climate-adaptation-and-resilience

13 www.smithschool.ox.ac.uk%2Fsites%2Fdefault%2Ffiles%2F2022-03%2FSupporting-the-East-African-Off-grid-Energy.pdf

14 www.gogla.org/sites/default/files/resource_docs/2018_mtr_full_report_lowres_2018.01.15_final.pdf.

15 IRENA, REthinking Energy 2017: Accelerating the global energy transformation, International Renewable Energy Agency, Abu Dhabi: 2017. Accessed August 10, 2023. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/IRENA_REthinking_Energy_2017.pdf

16 GOGLA, Global Off-Grid Solar Market Report Semi Annual Sales and Impact Data July-December 2017. Public Reporthttps://www.gogla.org/wp-content/uploads/2023/05/global_off-grid_solar_market_report_h2_2018_opt.pdf

Study Objective

The goal of this mapping study and situational analysis is to promote greater adoption of sustainable off-grid renewable energy (solar) solutions for agricultural development in Tanzania, Uganda, and Kenya. By examining the current state of the public discourse regarding the Productive Use of off-grid Solar Energy, the study seeks to promote greater adoption of these sustainable off-grid renewable energy solutions.

Methodology

The study employed qualitative methodologies, encompassing a desk review and the PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) analytical framework.

Desk review

This study reviews off-grid solar use globally, the global energy landscape, PUSE developments, the actors, and relevant legal and regulatory frameworks in Kenya, Uganda, and Tanzania.

PESTLE analysis

The study used the PESTLE analytical framework for situational analysis, a tool researchers use to examine external factors that influence the implementation of energy subsectors. This includes examining Indonesia's fossil fuel industry[17], reviewing Malawi's renewable energy sector[18]and assessing Poland's renewable energy potential[19].

Stakeholder mapping

The study, conducted between September and November 2023, used stakeholder mapping to identify interested parties, their interests, and interactions. The data will inform the creation of knowledge products including podcasts, explainers, and story ideas. The products will be part of the package for a journalist's training course on solar energy and its productive use. The course aims to enhance journalists' comprehension of renewable energy technologies and their potential impact on the populations.

17 Yudha, S. W., Tjahjono, B., & Kolios, A. (2018). A PESTLE policy mapping and stakeholder analysis of Indonesia's fossil fuel energy industry. Energies, 11(5), Article 1272. https://doi.org/10.3390/en11051272

18 Zalengera, Collen & Blanchard, Richard & Eames, P.C. & Juma, Alnord & Chitawo, Maxon & Gondwe, Kondwani. (2014). Overview of the Malawi energy situation and A PESTLE analysis for sustainable development of renewable energy. Renewable and Sustainable Energy Reviews. 38. 335–347.

19 Igliński, Bartłomiej & Iglińska, Anna & Cichosz, Marcin & Kujawski, Wojciech & Buczkowski, Roman. (2016). Renewable energy production in the Łódzkie Voivodeship. The PEST analysis of the RES in the voivodeship and in Poland. Renewable and Sustainable Energy Reviews. 58. 737-750.

Country Snapshots and Findings

Kenya

Kenya, the largest economy in East Africa boasting a Gross Domestic Product (GDP) of $112.75 billion, enjoys an annual growth rate of five per cent and is home to 51.5 million people.[20]However, it faces political vulnerability owing to economic and developmental strains, particularly a surging cost of living.[21] In October 2022, inflation peaked at 9.6 percent, the highest since 2017, largely driven by food and fuel prices.[22]

The conflict in Ukraine war and prolonged drought in 2022 disrupted the global supply chains, consequently affecting Kenya's agriculture sector. This sector contributes 20 per cent to the nations GDP[23]and employs 61 per cent of the labour force, underlining the critical need for sustainable, affordable, and reliable electricity.

Solar Energy uptake in Kenya

In June 2022, Kenya's electricity generation totalled 12,652.74 GWh with hydro and geothermal contributing the lion's share at 65.62%, while wind and solar accounted for 18.69 per cent[24].

Access to electricity in urban areas, stands at one hundred per cent, compared to the sixty-five pe cent access in rural areas. Kenya has championed the development of off-grid solar systems through policies such as exemptions from VAT and import tariffs on solar PV products[25], as part of its strategy to realise universal energy access. A prime initiative, the Kenya Off-grid Solar Access project (KOSAP), funded by the World Bank, was set to deliver 250,000 stand-alone solar systems and 150,000 clean cooking stoves to households in designated regions over the 2018-2023 period. Approximately 17 million people in Kenya are connected to an off-grid energy solution, positioning the country as the second most dynamic off-grid market after India[26].

20 https://www.imf.org/external/datamapper/profile/KEN
21 https://www.voanews.com/a/kenya-opposition-leader-raila-odinga-says-protests-will-continue-/7195913.html
22 https://theconversation.com/kenyas-cost-of-living-crisis-expert-unpacks-whats-driving-it-and-what-should-be-done-215487#:~:text=Since%202022%20Kenya%20has%20been,points%20above%20or%20below%205%25.
23 ibid
24 file:///Users/haggai/Downloads/Energy-and-Petroleum-Statistics-Report.pdf
25 Babayomi, et al, A review of renewable off-grid mini-grids in Sub-Saharan Africa, (Frontiers in Energy Research, 2023, 10. 1089025. 10.3389/fenrg.2022.1089025.
26 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/SDG7_Tracking_Progress_2021.pdf.

"Kenya has championed the development of off-grid solar systems through policies such as exemptions from VAT and import tariffs on solar PV products, as part of its strategy to realise universal energy access"

At the level of technology and innovation, Kenya has taken a leading role in adopting off-grid solar solutions. The country is also a trailblazer in the world of mobile money systems boasting over fifty-four million active mobile money accounts and more than fifty diverse lending applications. This widespread adoption has significantly improved the accessibility of credit, making the acquisition of solar products viable for Kenyan citizens.

PUSE applications in Kenya's agriculture value chain

Solar-powered water pumping systems represent the most widespread Productive Use of Solar Energy (PUSE) application in Kenya. Kenya accounted for 65 per cent of solar water pump sales across Sub Saharan Africa from July 2018 to June 2021, as indicated in the GOGLA Sales & Impact Report. As of January 2021[27] there were about 35,000 solar water pumps in operation across Kenya.

Nevertheless, several obstacles including high upfront costs, limited access to finance, low consumer awareness, stiff competition from fossil fuel-powered solutions such as diesel pumps, and lack of repair and maintenance services for solar powered irrigation systems continue to thwart access for millions of smallholder farmers in Kenya[28]. A solar water pump consumer awareness campaign in Kenya's Machakos County, revealed that a staggering 71 per cent of the farmers used diesel-powered water pumps, in a stark contrast to a mere one per cent who employed solar water pumps[29].

27 VeraSol, "Kenya Consumer Experience Study: Insights on Solar Appliances," April 2022, chrome-extension://mhnlakgilnojmhinhkckjpncpbhabphi/pages/pdf/web/viewer.html?file=file%3A%2F%2F%2FUsers%2Fhenry%2FDownloads%2FKenya-Consumer-Experience-Study-Insights-on-Solar-Appliances-April-2022.pdf

28 Yasemin Erboy Ruff, Ruth Kimani and Lisa Kahuthu, Solar Water Pump Consumer Awareness Raising Campaign Readout Machakos, Kenya," CLASP, September-December 2021 chrome-extension://mhnlakgilnojmhinhkckjpncpbhabphi/pages/pdf/web/viewer.html?file=https%3A%2F%2Fefficiencyforaccess.org%2Fwp-content%2Fuploads%2FEfficiency-for-Access-Solar-Water-Pump-Awareness-Raising-Campaign-2021.pdf

29 ibid

However, for those who adopted the system, the impact has been significant. For example, the Catholic Agency for Overseas Development (CAFOD), in partnership with the EU and local partners Dupoto-E-Maa in Kajiado, the Catholic Dioceses of Isiolo and Kitui and Solar Works East Africa Limited, installed customised solar powered irrigation for greenhouse farming used by forty-eight women's' groups. They also added agricultural extension services, enterprise development and other supporting services. The project resulted in improved food security and additional income generation from selling the crops[30]. Apart from irrigation, other PUSE market applications in Kenya cut across a range of agriculture value chains (dairy, livestock, poultry, fisheries), and these are offered by a range of entities, including more than 100 companies[31].

Solar-powered milling

Another sector where solar energy holds substantial potential is in agricultural processing. The maize value chain is significant, as the top most crop cultivated in the region contributing over 50 percent of the national grain supply in Kenya, Tanzania, and Uganda.[32]

The adoption of solar powered mills has previously been hindered by high cost, which can be twice as much as the cost of diesel mills ($2000 vs. $1000), with the latter also providing higher operational throughput[33]. However, in 2022, Agsol, an innovative start-up based in Kenya, launched the "MicroMill," a compact milling device capable of producing edible- quality flour at a rate of 60 kg/hr, while consuming only 800W of power[34].

30 https://access-coalition.org/wp-content/uploads/2016/07/powering-agriculture-for-sustainable-and-inclusive-economic-development.pdf

31 https://kerea.org/wp-content/uploads/2021/12/The-Market-for-Productive-Uses-of-Solar-Energy-in-Kenya-Status-Report-2021_web.pdf

31 https://fews.net/sites/default/files/documents/reports/East_Africa__Maize_Supply%20Outlook_Oct_2021_6.pdf

32 Energy4Impact (2020), "Solar milling: Exploring market requirements to close the commercial viability gap", https://storage.googleapis.com/e4a-website-assets/SolarMilling_Market-Requirements.pdf.

33 https://www.renac.de/fileadmin/renac/media/Projects/Soaring/Soaring_Fact_sheet_Grain.pdf

Preservation and cooling systems

Pay-As-You-Go models for solar-powered cold storage facilities have also been introduced in Kenya, enabling farmers to significantly mitigate post-harvest losses, which can sometimes be as high as 40 percent[35]. One such innovation, SokoFresh, established cold storage infrastructure in regions with dense concentrations of agriculture produce[36].

Farmers store their produce for $0.2 per kilo for a period of one to three days. In addition to preserving the farmers' produce, these facilities also support aggregation, facilitating buyers to collect goods directly from the storage points. Consequently, co-operatives and other aggregators can use these cold storage services for a monthly access fee. By streamlining the value chain and promoting aggregation, farmers have been able to unlock additional revenue, with increases of up to 30 per cent.

At the consumer level, a ***'Pay-as-You-go'*** solar-powered refrigerator retains the freshness of food stuffs and other perishables for an extended period[37]. The 100-liter fridge, tailored for off-grid use, consumes a quarter of the energy of a conventional fridge and can be powered by a smaller solar panel and a smaller battery[38]. Customers pay for the fridge in daily instalments via mobile phones, through M-Kopa, a Kenyan solar energy company. New customers pay a $100 deposit and daily payments ranging from US$1 to US$1.50 for a package that includes solar lighting and covers the installation of a rooftop solar panel[39].

Dairy

The dairy sector contributes 14 per cent to the agricultural gross domestic product (GDP) and accounts for 6-8 per cent of the nation's overall GDP[40]. Diary is a key component of the livestock sector and serves as an essential means of livelihood for approximately one million small scale farmers[41].

The Kenyan dairy cattle population is estimated at 4.3 million, with an annual milk yield of 3.43 billion litres[42]. About 54 per cent of households with one acre or less keep cattle[43].

35 https://docs.wfp.org/api/documents/WFP-0000150206/download/
36 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Nov/IRENA_FAO_Renewables_Agrifood_2021.pdf
37 https://edition.cnn.com/2020/09/09/business/solar-fridge-youmma-africa-spc-intl/index.html
38 ibid
39 ibid
40 USAID (United States Aid for international development) and GoK (Government of Kenya) 2009 Dairy value chain competitive assessment and action plan development. Final report
41 IFAD 2006 Small Holder Dairy Commercialization Programme- Appraisal Report: Africa Division 11, Programme management Department. Rome, Italy.
42 Republic of Kenya 2015 Central planning and Project monitoring Unit, Ministry of Agriculture Livestock and Fisheries, Economic Review of Agriculture (ERA) Nairobi, Kenya
43 IFAD 2006 Small Holder Dairy Commercialization Programme- Appraisal Report: Africa Division 11, Programme management Department. Rome, Italy.

Notably, smallholder dairy farmers own over 80 per cent of the dairy cattle, produce over 56 per cent of total milk output[44]. The cattle are reared under intensive and semi-intensive systems of livestock production[45].

The remaining 20 per cent of dairy production originates from large-scale dairy farms and indigenous herds[46]. A minimum of 19 per cent of the total milk produced, is wasted[47]. Solar-based cooling systems have the potential to mitigate these losses and bolster the earnings of smallholder farmers. For example, the Kiambu milk cooling plant has helped farmers who previously could not sell 50 per cent of their milk promptly[48]. As a result, these farmers manage to preserve milk valued at $1,000 each month.

Savanna Circuit Technologies has developed solar-powered mobile chilling units that establish an innovative cold chain for dairy operations, preventing microbial proliferation and spillage that often results in milk spoilage and subsequent rejection by cooperatives. This initiative has benefitted over 22,000 smallholder farmers across ten dairy regions in Kenya, facilitating the transportation of approximately 2.4 million litres of milk[49].

44 Peeler E J and Omore A 1997 Manual of livestock Production Systems in Kenya. 2nd Edition. Retrieved March 23, 2017, from http://www.fao.org/docrep/article/agrippa/557_en.htm.

45 Mbugua P N, Gachuiri C K, Wahome R G, Wanyoike M M, Abate A, Kamau J M Z and Munyua S J M 1998 Performance of dairy cattle under two feeding systems, as practiced in Kiambu and Nyandarua districts of Central Kenya. http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/30/042/30042868.pdf.

46 Omore A O, Muriuki H, Kinyanjui M, Owango M and Staal S 1999. The Kenya Dairy sub-sector: A rapid appraisal. Research report of the MoLFD/ KARI/ ILRI. Smallholder dairy (Research and Development) project. International research institute. Nairobi Kenya.

47 https://journalajaees.com/index.php/AJAEES/article/view/1835

48 https://shellfoundation.org/app/uploads/2019/09/UOMA-Dairy-Report.pdf

49 https://sav-circuit.com/about-us/

Poultry

In Kenya, poultry constitutes 30 per cent of the agricultural sector, contributes 7.8 per cent to the Gross Domestic Product (GDP), and provides employment for two to three million people. Poultry is also important as a source of income for smallholder farmers in the region[50].

One of the biggest challenges poultry farmers face is the prohibitive cost of chicken feeds. Like other areas in the region, feed mills in Kenya grapple with erratic power supplies and substantial utility expenses. Beyond powering feed processing mills, solar energy is integral for incubation of chicks, and lighting of chicken coops.

Broilers require constant lighting to stimulate feeding, regulate hormone levels, and manage their short growth cycle. Eco chicks Poultry Limited in Kenya provides solar-powered egg incubators to rural small-scale poultry farmers, enhancing hatching efficiency from 40 per cent to 95 per cent, thereby doubling production[51].

Fishing

Kenya's fishing industry accounts for 0.5 per cent of the national GDP, two per cent of the national export earnings, employs over 60,000 fishers directly, and supports an estimated 1.2 million people directly and indirectly within the fishing, production, and supply chain[52].

Notably, around 80 per cent of the catch is attributable to small-scale artisanal fishers. Solar solutions implemented throughout the value chain, encompass fishing, transportation, storage, and processing activities. For instance, fisher folks were spending an average of 35 per cent to 50 per cent of their total income on kerosene fuel for their light[53]. Solar fishing lights, particularly those manufactured by Omni voltaic, have drastically cut expenditure on kerosene.

Lack of cooling facilities both on-board fishing vessels and landing sites has been another major challenge in the supply chain. Electricity supply and portable water are available at only 26.3 per cent, and 7.4 per cent of the landing sites, respectively[54]. Predictably, post-harvest fish losses (associated to spoilage) account for more than 70 per cent of total losses[55].

50 https://pdf.usaid.gov/pdf_docs/PNADU076.pdf
51 https://ecochickspoultry.com/solar-powered-egg-incubator-in-kenya/
52 https://mahb.stanford.edu/library-item/the-status-of-kenya-fisheries/
53 https://waterjournalistsafrica.com/2021/10/powering-the-ghost-town-of-rusinga-island-fishermen-in-lake-victoria-kenya-take-action-on-climate-change/
54 https://mahb.stanford.edu/wp-content/uploads/2021/08/ThestatusofKenyaFisheriesKMFRI2008.pdf
55 ibid

Solar systems have made powering icemakers and cooler boxes much cheaper and convenient. For example, through a partnership with the private sector, the Green Cooling Initiative designed and built a solar-powered fish cold store as a solution for fishing communities in the area[56]. Additionally, transport crates packed with onsite produced ice flakes have improved the quality of transport and maintenance of the cold chain[57]. Prior to the construction of the store, which has the capacity to preserve five tons of fresh fish for two to three days, local fishermen frequently discarded 40 to 60 per cent of their catch, due to lack of preservation facilities[58].

56 https://www.green-cooling-initiative.org/fileadmin/user_upload/2019_GCI_FishCoolingStore.pdf
57 ibid
58 ibid

Asobo Kenya Limited, an innovative start-up in Kisumu on the shores of Lake Victoria, is helping fishers to transition from diesel-powered boats to electric engines, to combat pollution in the lake[59]. The e-mobility system is equipped with engines and batteries that are charged via solar power.

Still under e-mobility, in 2020, Raino Tech4Impact, a social enterprise trading under the name ***"Keep IT Cool" (KIC)***, started a decentralised cooling-as-a-service model to lower the cold chain access barriers for small-scale fisher folk in Kenya[60]. KIC signed an off-take agreement with Osera Cooperative, a small-scale fishers' association located in Homa Bay County, and developed an online trading platform, which enables retailers across four counties (Nairobi, Kiambu, Machakos and Kajiado) to purchase the fish[61]. KIC ensures the distribution of fish using its fleet of refrigerated lorries. Additionally, KIC provides hybrid solar backup cooler boxes as storage solutions to preserve fish during power outages. The boxes available in various volumes, are hired for KES 500 to 1,000 per week, depending on the size.

The Osera Cooperative consolidates the fish harvest from approximately 20 small-scale fishers, dealing with weekly produce volumes of 7 to 20 tonnes. KIC started transportation of fish from the cooperative in early 2020, initially managing around 1.5 tonnes per week. The volume swiftly increased to 2.5 tonnes, despite the logistical challenges posed by the Covid-19 pandemic[62].

59 https://www.electrive.com/2020/09/03/kenyan-startup-rents-electric-motors-to-fishermen/
60 https://shellfoundation.org/app/uploads/2022/03/IMPACT1.pdf
61 ibid
62 ibid

PUSE regulatory framework in Kenya

Table 1: A snapshot of the legal framework and implementing agencies of PUSE related laws and regulations in Kenya.

Legal Framework	Focus on PUSE	Agency
2019 Energy Act	Outlines obligations of national and county governments for the provision of affordable energy and establishes entities that regulate energy issues including the Energy and Petroleum Regulatory Authority (EPRA)	Ministry of Energy (MoE) EPRA
National Energy Policy 2019 Kenya National Electrification Strategy 2018 (KNES) National Energy Efficiency and Conservation Strategy 2020 (NEECS)	KNES recognises a role for stand-alone solar to electrify 1.9 million households by 2022. NEECS is the main government document on PUSE with a range of recommendations which include for the use of solar electricity.	Ministry of Energy and Petroleum
Draft Energy (Solar PV Systems) Regulations 2020 Draft Energy (Mini grid) Regulations 2021	EPRA regulates the off-grid solar and mini-grid sectors,	Energy and Petroleum Regulatory Authority (EPRA)
Irrigation Act No. 14 of 2019	This act touches on community-based smallholder irrigation and drainage schemes	Ministry of Agriculture (MoA)

Micro and Small Enterprises Act 2012 Micro and Small Enterprises Strategic Plan 2020–2024 – 3rd Draft	The act mandates collaboration with relevant actors in Information and Communications Technology, Mining and Energy. The draft plan acknowledges renewable energy broadly in terms of sensitising MSMEs on its benefits.	Ministry of Industry, Trade and Economic Development
Energy (Appliances Energy Performance and Labelling) Regulations 2016 Draft Energy (Solar PV Systems) Regulations 2020: Builds on the Energy-Solar PV Systems Regulations 2012		Kenya Bureau of Standards (KEBS)
Finance Act 2021	In 2020, the Treasury re-introduced 14 per cent VAT on solar equipment. In January 2021, it increased to 16 per cent as the temporary COVID-related 2 percent VAT relief expired. Effective 1 July 2021, VAT exemption was reinstated on specialised equipment for the development and generation of solar energy, including PV modules, DC charge controllers, DC inverters and deep cycle batteries that use or store solar power.	National Treasury

Key Actors

Table 2: The key government agencies and their role in Kenya's energy sector

Institution	Role
Ministry of Energy and Petroleum	Oversees policies, strategies, and laws.
Energy and Petroleum Regulatory Authority (EPRA)	Sector regulator
Kenya Power	Sole power distributor
Kenya Electricity Transmission Company (KETRACO)	Plans, designs, builds, and maintains electricity transmission lines and associated substations.
Kenya Electricity Generation Company (KenGen)	Develops and manages all public power generation facilities.
Rural Electrification and Renewable Energy Corporation	Implements rural electrification through grid extension and off-grid projects.
Geothermal Development Company	Fast-tracks development of geothermal resources, including providing steam to power plant developers for electricity generation

Donors

USAID

Through its premier energy initiative, Power Africa, USAID has contributed to the development of 779 megawatts (MW) of electricity generation capacity, which includes off-grid solar projects in Kenya. With the aid of USAID funding, providers of agricultural and off-grid solar products, as well as microfinance institutions, have introduced innovative products and services. These initiatives have empowered a greater number of Kenyans to use clean energy, thereby enhancing their income and overall quality of life.

GIZ

GIZ facilitates the alignment of Kenyan market players with German expertise by initiating and overseeing renewable energy projects. It also contributes to knowledge exchange, capacity building, and the establishment of business partnerships.

World Bank

The World Bank is the principal financier of the Kenya Off-grid Solar Access Project (KOSAP), which was launched in 2017. KOSAP's aim is to expand access to clean energy to underserved counties within the nation. The project aspires to reach an estimated 1.3 million individuals across 277,000 households in fourteen counties.

GCF

The Green Climate Fund has committed funds to clean energy companies that are developing decarbonised energy

infrastructure. Notably, GCF has provided seed capital to KawiSafi, which focusses on investments in consumer finance, mobile payment, and metering/monitoring technologies.

SIDA

The Swedish International Development Authority seeks to reduce poverty through the increased adoption of renewable energy in off-grid households. In Kenya, SIDA invests in energy companies to accelerate access, particularly for unserved and underserved low-income households.

FCDO

The Foreign, Commonwealth, and Development Office funds projects which enable carbon emission reductions. For example, FCDO has jointly funded the Low Energy Inclusive Appliances (LEIA) Programme. This research and innovation program aims to double the efficiency and halve the cost of a variety of electrical appliances that are suitable for off-grid and weak-grid households, small businesses, and industrial consumers in Kenya.

EU

The European Union has funded a technical assistance program that provides institutional and other types of support to public and private sector stakeholders to identify and implement renewable energy, energy access, and energy efficiency projects.

AECF

The Africa Enterprise Challenge Fund, through the Renewable Energy and Climate Technologies Sub-Saharan Africa (REACT SSA) programme, supports private companies that promote the use of renewable energy.

Industry Groups

KEREA

The Kenya Renewable Energy Association (KEREA) is a non-profit organisation that promotes and facilitates the growth and development of the renewable energy sector in Kenya.

NON-GOVERNMENT ORGANISATIONS

SNV

SNV extends financing within the off-grid energy sector, designed to surmount market barriers that hinder the private sector's provision of modern energy services to remote communities.

CLASP

The Collaborative Labelling and Appliance Standards (CLASP) program assists to build robust markets for off-grid solar products by driving innovation and sales within nascent markets, revealing data and research on product performance, market trends, and consumer preferences, establishing technical foundations for consumer protection, and aligning sector stakeholders throughout the value-chain.

EnDev

EnDev Kenya supports solar companies in distributing Solar Home Systems (SHS) and picoPV to households, social institutions, and SMEs primarily employing the Results-based financing (RBF). EnDev also provides policy advisory, promotes awareness creation (including demonstration sites -demos), support to and close collaboration with relevant sector associations and a pilot linking PAYG companies to the credit reference system (CRS).

EEP

The Energy and Environment Partnership Trust Fund (EEP Africa) is a clean energy financing facility hosted and managed by the Nordic Development Fund (NDF) with funding from Austria, Denmark, Finland, Iceland, NDF, Norway and Switzerland. EEP Africa provides early-stage grant and catalytic financing to innovative clean energy projects, technologies, and business models in countries across Southern and Eastern Africa.

LEIA

The LEIA (Low Energy Inclusive Appliances) Programme is a research and innovation programme that seeks to double the efficiency and half the cost of a range of electrical appliances suited for off- and weak-grid households, small business, and industrial consumers. The programme also aims to address market barriers for efficient end-use electrical appliances to improve energy access, increase incomes, reduce greenhouse gas emissions, increase reliability of access to health services, and improve agricultural efficiency and food security.

KCIC

Kenya Climate Innovation Centre (KCIC) offers incubation, capacity building, and financing options to new, small, and medium business ventures and Kenyan entrepreneurs that are developing innovations to address the challenges of climate change. KCIC is currently implementing the Productive Use of Solar Energy (PUSE) Program, across Kenya, Uganda, and Tanzania with funding from the Charles Stewart Mott Foundation. The programme aims to enhance energy access through productive use of solar energy.

PRIVATE COMPANIES

Table 3: The key private companies and their products/services in Kenya's energy sector.

Company	Product/Services
M-KOPA	Financing for solar products
Mwezi	Solar solutions distributor
OvoSolar	Off-grid solar products
Powerpoint Systems	Supplies & installs solar technologies.
Raino Tech4Impact	Cold-chain solutions for farmers
Suntech Power Ltd	Supplies solar energy equipment.
Agsol	Solar solutions for agro-processing machines
Suntech Power Ltd	Solar energy equipment
Greenlight Planet	Designs, distributes, and finances solar home energy products

Tanzania

Tanzania boasts a Gross Domestic Product (GDP) valued at $84 billion and experienced a 5.2 percent growth in 2023[63]. The country's population has been growing rapidly, recording a 37 percent increase to almost 63 million over the past decade. Projections indicate that Tanzania will be one of eight countries contributing to more than half of the global population growth over the next thirty years[64].

To cater for the development needs of this burgeoning populace, access to sustainable, affordable, and reliable electricity is critical. The African Development Bank (ADB) has observed that despite the upward trajectory in Tanzania's total energy and electricity consumption, the supply side signal that energy deficit could pose a significant challenge in the future[65].

As of June 2022, Tanzania's installed electricity capacity stood at 1,740MW, with 1,695MW (97.36 per cent) connected to the main-grid, and 45.8MW (2.64 per cent) to off-grid systems[66]. Of this capacity, hydro contributes 581 MW, Gas 876 MW, wind 2 MW, solar 2 MW, biomass 63 MW, and other sources 240 MW[67].

Although solar energy accounts for a small percentage of Tanzania's energy portfolio, it has the most potential. Research by the Division of Energy Systems Analysis at the Royal Institute of Technology (KTH) on behalf of the International Renewable Energy Agency (IRENA) estimated Tanzania's annual technical solar power potential at 31,482 TWh for Concentrated Solar Power (CSP) technology and 38,804 TWh for Photovoltaic (PV) technology, the highest potential in the East African region[68].

The Government of Tanzania has collaborated with partners to exploit the immense potential of the country's solar resources, through interventions such as Exemption of VAT and import taxes on major solar panels, batteries, and inverters.

" Research by the Division of Energy Systems Analysis at the Royal Institute of Technology (KTH) on behalf of the International Renewable Energy Agency (IRENA) estimated Tanzania's annual technical solar power potential at 31,482 TWh for Concentrated Solar Power (CSP) technology and 38,804 TWh for Photovoltaic (PV) technology, the highest potential in the East African region."

63 https://www.imf.org/external/datamapper/profile/TZA
64 https://www.theguardian.com/global-development/2022/nov/15/focus-turns-to-africa-as-world-population-reaches-8bn
65 https://www.afdb.org/en/documents/working-paper-370-outlook-tanzanias-energy-demand-supply-and-cost-2030
66 https://www.ewura.go.tz/wp-content/uploads/2023/06/Regulatory-Performance-Report-for-Electricity-Sub-sector-for-FY-2021-22.pdf
67 https://www.usaid.gov/powerafrica/tanzania
68 https://www.sciencedirect.com/science/article/abs/pii/S0960148117304718

The World Bank has extended financing towards access to a sustainable water supply through improved solar pumping systems in 165 rural Tanzanian villages[69]. With over all access at 37.7%[70], Tanzania plans to achieve universal access to modern energy services by 2030, with 25 per cent of this effort through quality verified off-grid solutions[71]. The 2019/2020 Energy Access and Use Situation Survey revealed that only 30.4 per cent of the 37.7 per cent of households connected to electricity in 2019, were using off-grid Solar[72].

The Tanzania Renewable Energy Association (TAREA) and the Tanzania Association of Microfinance Institutions (TAMFI) are leading advocates for reforms that enhance the viability of the off grid solar sector[73]. Their efforts stretch beyond lobbying for reforms to bolster the capabilities of solar and renewable energy installers. TAREA, with a membership exceeding eight hundred – over half of whom engage in solar technologies and services - has supported training for microfinance institutions (MFIs) in collaboration with TAMFI. The training aims to foster MFI involvement in both the supply-side and end user financing of solar systems[74].

Key impediments to the expansion of Tanzania's solar market include limited access to financing, an absence of stringent quality control standards and enforcement, unclear tax exemption policies for the import of solar photovoltaic (PV) products, inadequate policies and regulations for small scale solar PV technologies, and insufficient technical capacity within off-grid solar companies operating in the country. PUSE opportunities exist in fisheries, dairy, maize growing and processing value chains.

69 https://www.trade.gov/country-commercial-guides/tanzania-energy#:~:text=In%202019%2C%20the%20World%20Bank,in%20165%20rural%20Tanzanian%20villages.

70 https://www.worldbank.org/en/news/feature/2022/06/28/changing-lives-and-livelihoods-in-tanzania-one-electricity-connection-at-a-time#:~:text=Over%20the%20past%20decade%2C%20electricity,rates%20in%20Sub%2DSaharan%20Africa

71 ibid

72 United Republic of Tanzania (2020). Energy access and use situation survey II in Tanzania mainland 2019/2020.

73 ibid

74 ibid

Solar-powered irrigation in Tanzania

Solar powered irrigation is proving transformative for Tanzanian farmers. For instance, the Don Bosco Vocational Training Institute (DBVTI) in Dodoma, supported by the Charles Stewart Mott Foundation, has shown that solar PV-powered drip irrigation systems, when paired with optimal agronomical best practices on just a quarter an acre of tomatoes, can substantially increase farmers' incomes[75].

In Lupembe village, within the Iringa region, the ELICO Foundation – also supported by the Charles Stewart Mott Foundation, has innovated a solar-powered mobile pump that helps about one hundred farmers to irrigate their farms faster and effectively. The pump installed on a two-or three-wheeled handcart fitted with solar panels and an electric pump, propels water from the source directly to the fields.

Farmers, who have adopted this technology have more than doubled their agriculture output and nearly tripled their incomes. Encouraged by the success, ELICO has embarked on plans to train thirty people to fabricate their solar trolley to further promote the adoption of this sustainable agriculture solution[76].

Beyond these examples, Jitume Group operates a 26-acre solar irrigation scheme in Lupembe Lwasenga. They transitioned from expensive diesel pumps, which cost TZS 70,000 per day, to solar photovoltaic irrigation system with the support of the ELICO Foundation. Kibidula Farm, owned by the Seventh Day Church, spans a large estate of which 200-hectare of the one thousand hectares of irrigated land.

The farm grows avocados for export and local markets and relies on solar photovoltaic electricity for 95% of its irrigation needs.

Pinos Farm, which covers sixteen acres in the Iringa district, benefited from the support of the ELICO Foundation, switching from petrol-diesel water pumps. This change has resulted in a daily fuel cost saving of TZS 50,000. Comparatively, the annual cost of operating a petroleum generator-powered pump is TZS 3,810,000 over its 4-year lifespan. In contrast, the cost of using a 3 Hp solar pump, with a lifespan of 20 years costs TZS 10,000,000.

75 https://www.linkedin.com/posts/ddamulira_dbvti-waterformercy-cultivaid-activity-7119961375027695616-GrUQ
76 https://sun-connect.org/how-mobile-solar-powered-pumps-are-improving-agriculture-in-rural-tanzania/

Therefore, the solar pump becomes financially viable after just 2.6 years, surpassing the petroleum generator. Additionally, the petroleum generator pump is responsible for an average emission of 487 kg of CO2, making the solar option not only more cost-effective but also environmentally friendly.

The primary obstacle for smallholder farmers in Tanzania is the substantial initial investment required to acquire a solar irrigation pump. To tackle this issue, TAREA has partnered with donors and has actively advocated for government support to create a more accessible market for affordable solar irrigation pumps for smallholders.

TAREA has campaigned for the granting of fiscal incentives to smallholder farmers, to allow them to acquire solar-powered irrigation pumps.

TAREA has also engaged with the Tanzania Bureau of Standards (TBS) to urge the development of minimum performance standards for solar irrigation pumps. TBS has adopted standards for solar pumps aligned to International Electrotechnical Committee, ensuring that the pumps meet international quality benchmarks. The country has set a goal to extend its irrigation coverage to 1,243,230 hectares by 2025, up from the existing 694,715 hectares.

Off-grid solar in other Agriculture value chains

Access to Energy Institute (A2EI) assessed ten agricultural processes to identify opportunities where solar energy can be used profitably in agriculture-related businesses.[77] The study concluded that two applications—oil extraction and peanut shelling – have high potential to scale up. Six more applications – spice grinding, rice hulling, fruit juicing, sugarcane juicing, fruit drying and flour milling – showed potential under certain circumstances.[78] Maize shelling and coffee pulping had limited potential for generating a stable income through solar power.

Maize milling in Tanzania

Eighty per cent of Tanzania's population is engaged in agriculture and 90 per cent of these farms grow maize for human consumption. Maize milling for human and animal consumption is an important activity. Ninety-three per cent of maize production takes place on small farms, implying that grid electricity or diesel engines process 95 per cent of maize flour at decentralised small-scale hammer mills. The throughput of solar energy maize mills in Tanzania improved by 50 per cent, making them four times more efficient than diesel-powered alternatives[79].

77 https://a2ei.org/resources/uploads/2020/09/A2EI_Productive_Use_Report_Agricultural_Technologies.pdf
78 ibid
79 https://nextbillion.net/milling-on-mini-grids-africa-maize/

Fishing

Small-scale fishing in Tanzania, employs more than 300,000 people, majority of whom are women and youth[80]. The small sardine like fish locally known as 'dagaa' is widely consumed across East Africa and a popular commercial fish product. More than 300,000 tonnes of dagaa are consumed in Tanzania annually with a third destined for human consumption, and the reminder primarily used as animal feed[81]. The production of dagaa has seen a significant increase, rising from 289,873 tonnes in 2010 to 433,845 tonnes in 2015, and has generated over $2 million, spurred by growing demand in neighbouring countries[82].

Despite this substantial economic potential, small-scale fish processors, distributors, and traders face high post-harvest losses. Traditional fish processing practices like open sun drying - where harvested dagaa is laid on the bare ground for hours, results in up to 40 per cent post-harvest losses due to contamination from sand and other external contaminants[83]. These losses are exacerbated during the rainy season when consistent sunshine is scarce, further impeding the drying process. Since most fishing communities in Lake Victoria are in off-grid areas, adopting simple, locally made, and affordable solar dryers would help small-scale fish processors avoid spoilage and deliver clean and safe dagaa to consumers.

Since 2022, MAVUNOLAB, has partnered with the Karume Institute of Science and Technology (KIST) and the government of Tanzania fisheries agencies, including the Fisheries Education and Training Agency (FETA), to promote the adoption and use of solar dryers in two Lake Victoria fishing communities: Kayenze Ndogo and Mswahili, in the Mwanza region of Western Tanzania.

80 https://agrilinks.org/post/affordable-solar-dryers-fish-communities-lake-victoria-tanzania-can-avoid-postharvest-fish
81 ibid
82 ibid
83 ibid

MAVUNOLAB has developed a solar dryer - an affordable solution that offers efficient and high-quality preservation, capable of processing up to 200 kilograms of dagaa in under six hours—a significant improvement over the 12 hours required for traditional smoking or open sun drying methods[84]. The solar dryers ensure that food products like dagaa are processed in a hygienic and controlled environment, reducing spoilage and loss. This enables fishers to supply cleaner, higher quality dagaa that meets international export standards, thus potentially increasing their earnings.

To strengthen local expertise and bridge the knowledge gap, MAVUNOLAB has trained 10 young graduate engineers in solar drying technology and plans to extend the training to Lake Tanganyika and other areas facing postharvest challenges. Moreover, the introduction of solar-powered fishing lights has helped eliminate the need for kerosene and enabled the fishers to fish during the rainy season, which is not feasible with traditional fuel-powered lighting[85].

Dairy

Tanzania's dairy sector primarily operates on traditional farming systems that involve grazing on communal land. Of the 2.5 billion litres of milk produced annually in Tanzania, only 12 billion litres are sold through small-scale milk traders and collective bulking centres[86]. Approximately 90 per cent of rural households lack electricity. Market access, poor handling practices and the absence of modern cooling technologies result in the loss of between 30 to 40 per cent of milk[87].

84 ibid
85 https://www.nilebasindiscourse.org/news-blog/community-blog/tanzania/tanzania-harnessing-solar-energy-for-sardines-fishing.html
86 https://www.fao.org/fao-stories/article/en/c/1170760/
87 ibid

A notable initiative in Njombe, demonstrates the transformative potential of off-grid solar power solutions in overcoming these challenges. A cooperative run milk factory in the area pasteurizes and supplies milk weekly to approximately 25,000 schoolchildren, helping to cut back on child malnutrition. In 2014, as part of an energy initiative by SEVA for Africa, an 11 KWP off-grid was installed at the dairy, providing reliable green energy and paving the way for smoother operations[88].

Legal and institutional framework

The existing laws and regulations focus on the hydro standards, and do not focus specifically on PUSE regulation in Tanzania.

Table 4: A snapshot of the legal framework and implementing agencies of PUSE related laws and regulations in Tanzania.

Legal Framework	Focus on PUSE	Agency
Energy and Water Utilities Authority Act, 2001 and 2006, Rural Energy Act, 2005, Electricity Act, 2008	Broadly address off-grid energy policies.	Ministry of Energy and Minerals Energy and Water Utilities Regulatory Authority Rural Energy Agency
Electricity Act, 2008 EWURA Act	Regulation of entities in the energy sector	Ministry of Energy and Minerals Energy and Water Utilities Regulatory Authority

88 https://offgridsun.com/en/tanzania-our-solar-panels-on-the-milk-factory-of-njombe/

Tanzania Communication and Regulatory Authority Electronic and Postal Communications (Licensing) Regulations 2011 ElectronicPayment Schemes Guidelines 2007 Bank of Tanzania Act 2006 Tanzania Communication and Regulatory Authority Act 2003	Through mobile money, solar companies that can partner with Telkom and intermediaries are able to offer PAYGO options to their customers	Tanzania Communication and Regulatory Authority
Tax Laws The VAT (General) Regulations, 2015 The VAT General Regulation, Amendments, 2018 East African Community (EAC) Customs Management (Compliance and Enforcement) Regulations, 2016 EAC Customs Management Regulations, 2010 EAC Customs Management (Duty Remission) Regulations, 2008 Regulations under the EAC Customs Management Act:	Previously, the government provided exemptions of import taxes (import duty and VAT) on main solar components (panels, batteries, inverters, and regulators) to make SHS more affordable. The 2015 VAT Act and 2016 Customs Law amendments removed exemptions for some items that make up a solar system. For example, no exemption applies to wire/cables, switches, light emitting diode (LED) lights, and other solar energy system components.	Tanzania Revenue Authority

Quality Control In 2018, the Tanzanian Bureau of Standards (TBS) announced the basic standards for solar products. Through TBS, quality of pico-PV products are assessed, verified, and registered.	TBS adopted the Lighting Global Standard for small renewable energy and hy brid systems for rural electrification. The basic standards involve all solar power and related products manufactured in the country or imported	Tanzanian Bureau of Standards (TBS)

Players

Government

Table 5: The government agencies and their roles in Tanzania's energy sector

Institution	Role played
Ministry of Energy and Minerals	Oversees policies, strategies and laws governing the electricity sector.
Tanzania Electric Supply Company Limited (TANESCO)	In charge of power generation, transmission, and distribution
Energy and Water Utilities Regulatory Authority (EWURA)	Sector regulator
Rural Energy Agency	Supports the government to accelerate access to rural areas.
Tanzania Investment Centre	Co-ordinates & promotes investment in Tanzania

DONORS

USAID

Through Power Africa, USAID has supported the development of 671 megawatts (MW) of electricity generation projects in Tanzania. Firms such as Simusolar offers solar-powered equipment water pumps and fishing lights designed for night fishers and financing for the same, have been able to expand exponentially owing to Power Africa support.

DFID

DFID has supported a range of energy access activities in Tanzania including the Africa Enterprise Challenge Fund, Renewable Energy and Adaption to Climate Technologies, the Energy & Environment Partnership programme, the Green Mini-Grids programme implemented by REA, and EnDev Tanzania programme for Results-Based Financing (RBF) in Lake and Central Zones.

GIZ

Working with Energy 4 Impact, GIZ has supported efforts to extend solar irrigation systems to smallholder farmers in the least developed regions of Tanzania. These efforts have enabled access to support services, access to finance, and increased the uptake of small-scale solar irrigation equipment.

World Bank

The World Bank through programmes like the Tanzania Rural Electrification Expansion Program (TREEP) has been facilitating grid connections as well as renewable energy options and clean cooking solutions to rural households. With co-financing from the Energy Sector Management Assistance Program (ESMAP), in addition to expanding grid connections, TREEP has supported the implementation of the National Renewable Energy Strategy and the piloting of a Solar Home System (SHSs) and clean cooking results-based financing programs for rural households.

SIDA

SIDA has funded projects aimed at increasing access to electricity in rural areas. These projects involved scaling up the supply of renewable energy in rural areas, while strengthening sector institutional capacity.

Charles Stewart Mott Foundation

The Charles Stewart Mott Foundation funds efforts that build future leaders and entrepreneurs working in the off-grid solar energy sector in Uganda, Kenya, and Tanzania.

Non-Government Organisations

Elico

E-LICO Foundation collaborates with rural communities to co-design and implement off-grid renewable energy initiatives which create jobs, while reducing greenhouse gas emissions that cause climate change.

CLASP

The Collaborative Labeling and Appliance Standards Program (CLASP) helps build healthy markets for off-grid solar products by driving innovation and sales in early-stage product markets, surfacing data and research on product performance, market trends, and consumer preferences, establishing technical foundations for consumer protection, and aligning sector stakeholders across the value chain.

EnDev

EnDev has established a dedicated national off-grid solar Green Economic Recovery Fund based on a result-based financing (RBF) scheme in Tanzania. EnDev has successfully operated an off-grid solar RBF Fund for years, focused on the Lake and Central Zone regions.

INDUSTRY GROUPS

Tanzania Renewable Energy Association (TAREA), formerly the Tanzania Solar Energy Association, brings together actors in the renewable energy sector. Established in 2000, TAREA works to promote the accessibility and use of renewable energy technologies in Tanzania.

PRIVATE COMPANIES

Table 6: The key private companies and their products/services in Tanzania's energy sector.

Company	Product/services
Simusolar	Provides & finances solar water pumps, solar fishing.
Redavia	mini-grid developer
Ensol	Sells & installs water pumps.
Mobisol	Sells appliances.
Jumeme	Cold storage, milling, grinding, welding, water pumping.
Agsol	Solar mills
Imara Tech	Multi-crop solar threshers
Power corner	Milling, grinding, welding, water pumping

UGANDA

Uganda is East Africa's third largest economy, with a gross domestic product (GDP) worth $52.39 billion, growing at 4.6 per cent per annum, and a population of 45.05 million people[89]. Given that 27 per cent of this population live in urban areas, and 54 per cent are younger than 18 years, there are major demands for jobs, education, food, health, and energy, which present both a challenge and opportunity for the country.

Uganda's installed electricity capacity stands at 1,402.0 MW as of 2023.[90] Most of the country's energy is generated from hydro-power plants accounting for 78 percent, followed by Bagasse/cogeneration (10 per cent), thermal plants (7 percent) , and solar plants (5 percent).[91] With year-round sunshine, estimates indicate that Uganda's total renewable energy potential is 5.3 GW.[92] However, solar photovoltaic (PV) mini grids are few, the most notable one being the Kitobo solar power plant in Kalangala district.

In a country where electricity is accessible to 57 per cent of the population, predominantly in urban areas, the Rural Electrification Programme aims to achieve 300,000 new connections annually, with about a third of these expected to come from the off-grid sector[94]. As Uganda pursues its goal of universal electricity access by 2030[95], the potential for off-grid solar technologies such as solar PV systems is increasingly important.

" With year-round sunshine, estimates indicate that Uganda's total renewable energy potential is 5.3 GW "

The adoption of Solar House Systems (SHS) in rural areas rose from 18 per cent in 2017 to 38 per cent in 2020[96]. This growth aligns with the presence of more than 210 solar companies in the Ugandan market as of December 2020[97]. These companies sold more than 482,100 off-grid solar products in 2019 and 128,242 off-grid solar products in the first half of 2019, ranking Uganda as the third largest market in East Africa after Kenya and Ethiopia[98]. Keen to tap into opportunities offered by solar energy, Uganda has established the National Roadmap for Productive Use of Solar Energy (NR-PUSE)[99].

89 https://www.imf.org/external/datamapper/profile/UGA
90 https://www.era.go.ug/index.php/stats/generation-statistics/installed-capacity
91 https://www.era.go.ug/index.php/stats/generation-statistics/energy-generated#:~:text=Energy%20Generated%20by%20type%20of,was%20obtained%20from%20Solar%20plants.
92 https://www.usaid.gov/sites/default/files/2022-12/Power-Africa-Market_Assessment-Brief-Uganda.pdf
93 ibid
94 https://www.gogla.org/wp-content/uploads/2023/07/Gogla_PURE-Roadmap-Report-Uganda.pdf
95 https://www.newvision.co.ug/category/news/all-ugandans-will-have-access-to-power-by-203-137560
96 www.ubos.org/wp-content/uploads/publications/06_2021UNHS2019-20_presentation.pdf.
97 https://documents1.worldbank.org/curated/en/722961612536168002/pdf/Project-Information-Document-Uganda-Electricity-Access-Scale-up-Project-EASP-P166685.pdf
98 ibid
99 https://www.gogla.org/wp-content/uploads/2023/07/Gogla_PURE-Roadmap-Report-Uganda.pdf

The Ministry of Energy and Mineral Development (MEMD) in partnership with the Uganda Solar Energy Association (USEA) and GOGLA, with the financial support of the Germany's BMZ and the European Union (EU), through the international initiative Water and Energy for Food (WE4F), spell out a clear and comprehensive strategy for scaling up PUSE to meet energy needs in a sustainable way.

The National Roadmap for Solar energy applications in Uganda, encompasses a range of technologies, including solar PV, water heating, cooling, and crop drying. Estimates show that the market potential for solar energy extends to over six million households currently without access to electricity[100]. The roadmap also shows that small-sized off grid solar systems such as water pumps and sprinklers, milling machines, and refrigeration, could benefit more than 80 per cent of Uganda's smallholder farmers across the various crop value chains.

As part of the initiatives to scale up access from 2022 to 2027, the World Bank has allocated $107 million to the Uganda Energy Credit Capitalisation Company to support financial intermediation services for providers of Productive Use of Solar Energy (PUSE) equipment, facilitating broader access to essential solar technologies.[101]

The Ministry of Agriculture, Animal Industry, and Fisheries has implemented a subsidy for solar irrigation pumps in forty districts, under the World Bank funded Micro-Scale Irrigation Program[102]. The program subsidizes 25 to 75 per cent of the cost of the irrigation equipment, subject to a maximum amount per acre. Farmers access the subsidized credit through financial institutions. The program aims to support up to 2.5 acres (1 hectare) per beneficiary, helping smallholder farmers to shift from subsistence farming to commercial agriculture.

In 2022, the government completed the construction of 135 solar powered small-scale irrigation schemes countrywide, expanding the country's irrigable area by 723 acres directly benefiting 9,214 farmers and creating labour opportunities[103]. Concurrently, construction was underway for thirty-one solar-powered irrigation schemes across twenty-six districts. Additionally, the government had procured forty-four sets of solar-powered water-pumping systems, capable of providing 3-7 m3 of energy per hour, in 44 sites across 41 districts, to support crop cultivation and livestock.

100 ibid
101 https://beyondthegrid.africa/wp-content/uploads/Nefco-PUE-Market-Assessment-March-2023.pdf
102 https://www.worldbank.org/en/news/feature/2020/09/14/uganda-micro-scale-irrigation-program
103 https://budget.finance.go.ug/sites/default/files/Sector%20Spending%20Agency%20Budgets%20and%20Performance/Ministry%20of%20Agriculture%2C%20Animal%20Industry%20and%20Fisheries_2.pdf

PUSE in Uganda's agriculture value chain

Coffee

Coffee is Uganda's top commodity for international trade, with export earnings reaching $940.3 million for the fiscal year ending September 30, 2023[104]. The majority of Uganda's coffee farmers are smallholders, accounting for 85 per cent of all coffee farmers. An estimated 1.7 million households grow coffee on plots typically smaller than one acre[105]. Small scale and industrial scale farmers are using Stand Alone Solar (SAS) systems in the coffee value chain specifically in milling, husking, and drying.

Tumusiime Godfrey, a farmer from Bubare Sub County in Mbarara, successfully operates his 30-acre coffee farm year-round with the support of a solar irrigation system. He has built a solar-powered dryer and storage facility to ensure the maintenance of high-quality coffee beans[106].

In 2020, the National Union of Coffee Agribusiness and Farm Enterprises (NUCAFE)—representing more than 216 farmer organisations across Uganda's coffee-producing regions—installed solar panels at their coffee production sites to support environmentally sustainable coffee production[107].

NUCAFE made history as the first coffee organisation in East and Central Africa to commission an Industrial Solar Power Plant at their coffee processing factory in Namanve, a Kampala suburb.

The solar plant a component of the broader initiative titled: 'Enhancing the Quality and Profitability of coffee by smallholder farmers through improved

104 https://www.independent.co.ug/uganda-achieves-record-coffee-export-revenues-generates-940-3-million/

105 https://globalpressjournal.com/africa/uganda/big-ambitions-ugandas-small-scale-coffee-farms/

106 https://twitter.com/CoffeeUganda/status/1547108509975724033

107 https://nucafe.org/nucafes-first-industrial-solar-power-plant/

storage, grading, and marketing services,' aims to improve the livelihoods of smallholder coffee farmers. The Agribusiness Initiative Trust (aBi), NCF/NDF, NIRAS, and other partners support the solar plant.

The solar (PV) system installed at the coffee processing factory consists of 442 panels, each with a capacity of 390Wp, covering a roof area of 1,800 square meters. This solar plant will enable the production and export of Uganda's first carbon Neutral coffees, signifying a major step towards eco-friendly practices in the industry. The plant is expected to reduce carbon dioxide emissions by 241.3 tons annually, contributing to environmental conservation.

Since its inauguration in August 2020, the project has led to a substantial decrease in electricity costs, with the factory experiencing more than 70 per cent in power bills. The Ugandan government plans to construct fifty solar powered small scale irrigation coffee irrigation schemes[108].

Dairy

As of February 2023, Uganda's annual milk production was estimated at 3.22 billion litres, according to the Dairy Development Authority (DDA)[109]. 20 to 40 per cent of all milk production in Uganda is wasted due to lack of cooling facilities[110]. In regions with cooling facilities at milk collection points, farmers still rely entirely on diesel-run generators, which account for 40 per cent of the dairy producer organisations' operating costs.

The adoption of solar cooling technologies is on the rise, offering a more cost-effective and environmentally friendly alternative. In December 2022, Heifer International Uganda initiated the engineering phase for the installation of solar power systems at five dairy cooperatives milk collection centres. These installations, part of the PREO-supported Solar for Sustainable Income in Dairy project, are spread across central and southwestern Uganda.[111] The solar facilities will replace inefficient, polluting, and expensive diesel generator thereby reducing post-harvest losses and increasing profitability for smallholder farmers.

Poultry

The cost of chicken feeds is a challenge within the poultry value chain. Farmers are

108 https://budget.finance.go.ug/sites/default/files/Sector%20Spending%20Agency%20Budgets%20and%20Performance/Ministry%20of%20Agriculture%2C%20Animal%20Industry%20and%20Fisheries_2.pdf

109 https://www.mediacentre.go.ug/sites/default/files/media/Diary%20Devpt%20Authority%20Performance%20Report.pdf

110 https://shellfoundation.org/learning/productive-use-of-off-grid-energy-the-business-case-in-ugandas-dairy-value-chain/

111 https://www.preo.org/heifer-international-uganda-kicks-off-construction-of-solar-power-for-chilling-facilities-to-improve-profitability-of-rural-dairy-producers/

reducing these costs by using solar-powered mills to produce their own feeds[112]. Farmers are investing in comprehensive solar systems on their poultry farms. Aptech Africa installed a 22.78kWp of solar PV system at Geza poultry farm located in Katosi-Mukono District. This system supplies power to eight chicken coops, which collectively accommodate over 50,000 chickens[113].

Fisheries

In January 2017, GRS commodities undertook an initiative to address the shortfall in the supply of flake-ice to the fishing community on Lake Victoria's Ssese Islands. The goal was to improve the local fish value chain[114]. The company revamped the district flake ice plants in Mweena Kalangala District to mitigate waste and support the fishermen's livelihoods[115]. Flake ice is critical for preserving and transporting fresh fish to markets. Scarcity of local flake ice supply makes it difficult for the fish dealers to preserve unsold fish.

112 https://www.monitor.co.ug/uganda/special-reports/will-solar-milling-technology-take-root-in-africa--3338902
113 https://aptechafrica.com/de-commissioning-and-re-installation-of-solar-system-at-geza-poultry-farm/
114 https://growthafrica.com/impacting-lives-using-renewable-energy-technology-flake-ice-production-uganda/
115 ibid

Legal and regulatory framework

Table 7: Policies and regulations common in the off-grid energy sector in Uganda

Legal Framework	Focus on PUSE	Agency
Electricity Amendment Act	Makes it possible for isolated grid operators to sell power directly to customers.	Ministry of Energy and Mineral Development
Uganda National Bureau of Standards Act	Monitors standards of solar equipment coming into the country.	Uganda National Bureau of Standards.
Microfinance Institutions and Money Lenders Act 2016	SACCOs and microfinance institutions that extend credit to end users and solar companies fall under this law.	Uganda Micro finance Regulatory Authority
The Hire Purchase Act, 2018	Companies dealing in hire purchase business are required to have a licence, stipulating penalties for default. PAYGo companies that sell products on credit fall under this law.	Ministry of trade, industry, and cooperatives
National Environment Management Act	Regulation of the disposal of waste including e-waste generated by off grid companies to protect the environment.	National Environment Management Authority
Isolated Grid Regulation, 2020	Aimed at encouraging further private sector investment and achieving the national electrification target of 80% electricity access by 2040.	Electricity Regulatory Authority
Rural Electrification Strategy and Plan (RESP II) 2013-2022	This is a guiding document for rural electrification. It targeted access and service penetration of 26% for rural households, businesses, and institutions by 2022, 1.28 million new on-grid connections, and 14,000 new off-grid connections leveraging solar and mini-grid technologies.	Ministry of Energy and Mineral Development

The Ministry of Energy and Mineral Development (MEMD) holds the primary responsibility for creating a conducive environment for the Productive Use of Solar Energy (PUSE) in Uganda. Alongside MEMD, there are other agencies, each with specific roles in this sector, as outlined in Table 8 below.

Table 8: The government agencies and their roles in Uganda's energy sector

Institution	Key Role
Ministry of Energy and Mineral Development (MEMD)	Creates an enabling for scaling up productive use of energy in Uganda through policies, regulations, tax exemptions, and extending subsidies to the end-user.
Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)	Develops policies to scale up or support the growth of or mechanisation of agriculture through use of solar powered water pumps, tax exemption on agricultural inputs including solar powered pumps.
Electricity Regulatory Authority	Regulates, licences, and supervises the generation, transmission, distribution, sale, export, and importation of electrical energy in Uganda.
Uganda Electricity Distribution Limited	In charge of electricity distribution to domestic and commercial end-users in Uganda. Sub-leased this role to Umeme for a 20-year concession.
Uganda Electricity Generation Limited	In charge of electricity generation for use in Uganda and for sale to neighbouring countries.
Uganda Electricity Transmission Company Limited	Purchases electricity in bulk from generating companies and sells the electricity to distribution companies throughout Uganda.
Ministry of Water and Environment (MWE)	Developed policies to promote water for production including establishment of irrigation using solar powered water pumps.

DONORS

World Bank

The World Bank is bolstering Uganda's shift towards sustainable energy with financial support for key projects. Through the Electricity Access Scale-up Project, which will run from 2022 to 2027, the World Bank has funded the Uganda Energy Credit Capitalisation Company. This investment is aimed at offering financial services that facilitate the distribution of Productive Use of Solar Energy (PUSE) equipment. The World Bank is also financing a subsidy scheme for solar-powered irrigation pumps within the ambit of the Micro-Scale Irrigation Program, demonstrating its commitment to advancing solar energy solutions in Uganda's agricultural sector.

USAID

Through Power Africa, USAID has supported the development of 196.25 megawatts (MW) of electricity generation projects in Uganda. Solar projects aimed at facilitating productive use of energy in off-grid locations.

DFID

Energy Africa, a UK Government-led initiative, has been supporting the growth of the solar market by establishing a suitable enabling environment. DfID has also supported capacity building efforts for the Uganda Solar Energy Association.

GIZ

GIZ has supported the electrification of Uganda's rural areas with solar energy through the Get Access mini grid solar programme. The goal is to provide first time access to modern, affordable, and clean electricity to more than 110, 000 people, eight hundred public institutions, including schools and health centres, and at least seven hundred businesses in rural areas through solar-powered mini grids.

EnDev

EnDev Uganda supports solar companies in the dissemination of Solar Home Systems (SHS) and picoPV for households, social institutions, and SMEs using the Results-based financing (RBF) as the primary mechanism. EnDev also offers policy advisory, awareness creation (including demonstration sites -demos), support to and close collaboration with relevant sector associations and a pilot linking PAYG companies to the Credit Reference System (CRS).

Non-Government Organisations

UOMA

The Uganda Off-Grid Energy Market Accelerator (UOMA), founded in 2017, is a dedicated and neutral intermediary, focused on accelerating the growth of off-grid energy in Uganda to enable universal energy access. It emerged out of a partnership between USAID / Power Africa, DFID, and the Shell Foundation under their Scaling Off-Grid Energy: Grand Challenge for Development (SOGE) partnership.

Energy4Impact

Energy4Impact enables companies to expand access to climate-smart energy and create the innovation and jobs that drive local economies forward.

CLASP

The Collaborative Labelling and Appliance Standards Program (CLASP) builds healthy markets for off-grid solar products by driving innovation and sales in early-stage product markets, surfacing data and research on product performance, market trends, and consumer preferences, establishing technical foundations for consumer protection, and aligning sector stakeholders across the value chain.

CREEC

The Centre for Research in energy and Energy Conservation (CREEC) advocates for clean energy through actionable research and renewable energy product testing, training, and innovation. The centre engages with communities in the design and development of renewable energy interventions. This ensures ownership of the interventions co-developed with the centre to ensure sustainability of interventions.

INDUSTRY GROUPS

UNREEEA

UNREEEA provides a platform that brings together all private sector players specialising in Renewable Energy and Energy Efficiency through government engagement and programmes.

USEA

Uganda Solar Energy Association is an independent non-profit association dedicated to facilitating the growth and development of solar energy business in Uganda and the East African region.

PRIVATE COMPANIES

Table 9: The key private companies and their products/services in Uganda's energy sector

Company	Product/Services
Tulima Solar	Solar water pumps
Aptech	Solar water pump
Energrow	Multiple PUE appliances
Winch Energy	Mini grid
Azuri Technologies	Solar water pumps
Village Energy	Solar irrigation
Water Pumps International	Solar irrigation solutions
Sunculture	Solar irrigation pumps
Futurepump	Solar Water pumps
Davis & Shirtliff	Solar Water Pumping systems
East African Power	Solar milling solutions
One Lamp	Solar milk Chillers

CONCLUSION

This analysis and mapping study on the adoption of Productive Use of Solar Energy (PUSE) within agricultural value chains in Kenya, Uganda, and Tanzania has uncovered positive impacts on farmers' livelihoods. The integration of PUSE applications has led to increased agricultural yields and incomes, job creation through agro-processing, and the diversification of farming activities.

The study shows that PUSE technologies are used throughout the agricultural lifecycle, including production, processing, distribution, and consumption phases. While solar-powered irrigation stands out as the predominant PUSE application in agriculture, other technologies such as e-mobility, cold storage, and agri-processing are gaining traction. For example, the KIC refrigerated e-trucks in Kenya show how e-mobility is streamlining the distribution of agricultural goods.

Although PUSE applications often entail higher initial costs compared to traditional fossil fuel-based methods, financial innovations such as pay-as-you-go (PAYGo) systems are making solar energy solutions more accessible to smallholder farmers. To capitalize on these benefits, the study suggests that development partners continue to encourage innovation through funding.

Concurrently, it is imperative for governments to enact reforms to mitigate the challenges faced such as limited consumer awareness, absence of targeted policy in the sector, and restricted access to financial resources, which currently hinder wider adoption of PUSE in these countries.

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