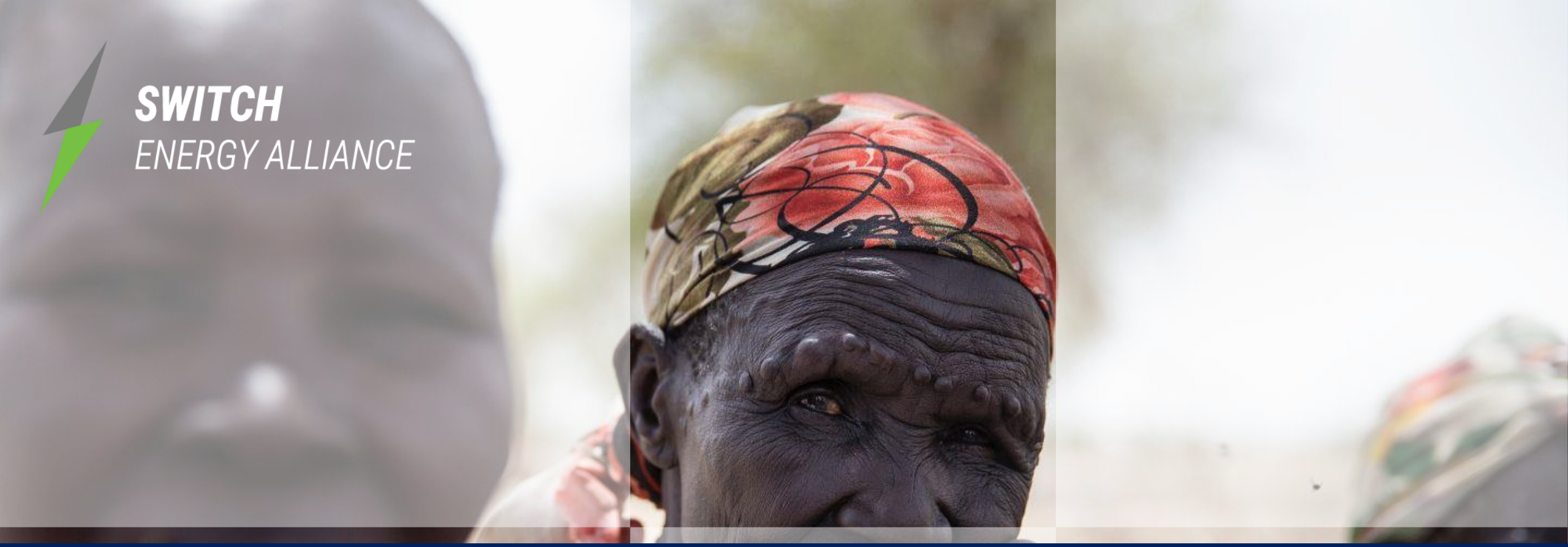


South Sudan – Vision 2051

(Energizers IIII)

Team members:
Abdullah Mohamed Hamed
Youssef Mahmoud
Yasmine Abd-Elmoniem El-Feky
Mariem Elkholy

Mentor:
Eng/ Silvia Pizzigoni

Home Country:
Egypt

- East-central Africa; the most recently formed country in the world.

- Political struggles:
  -independence from North Sudan in **2011**
  -A civil war in **2013.**

- Mostly with **rural subsistence lifestyles** affecting their energy needs, access and consumption.

- **10 states** –Juba, Malakal and Wau

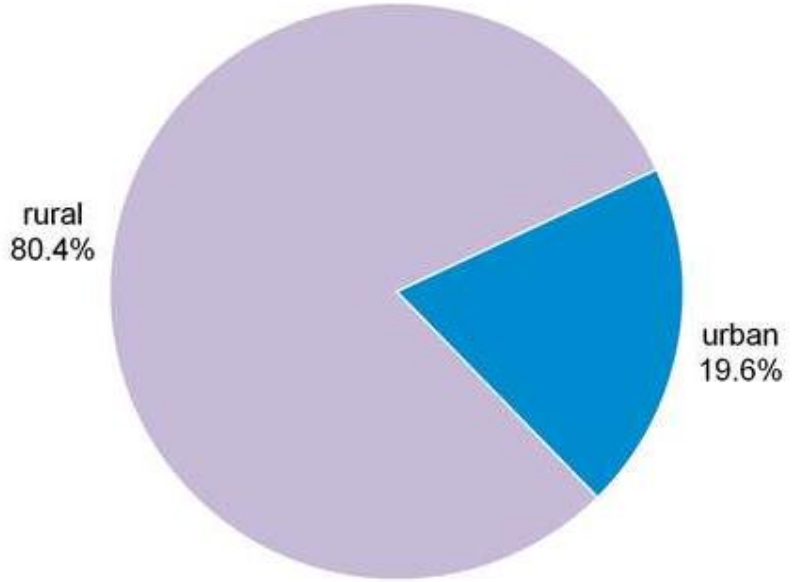
- Heavy dependence on the **Oil sector** while having **abundant natural resources**; mineral resources aquatic and forest resources as well as fertile rain fed agricultural land

South Sudan Population

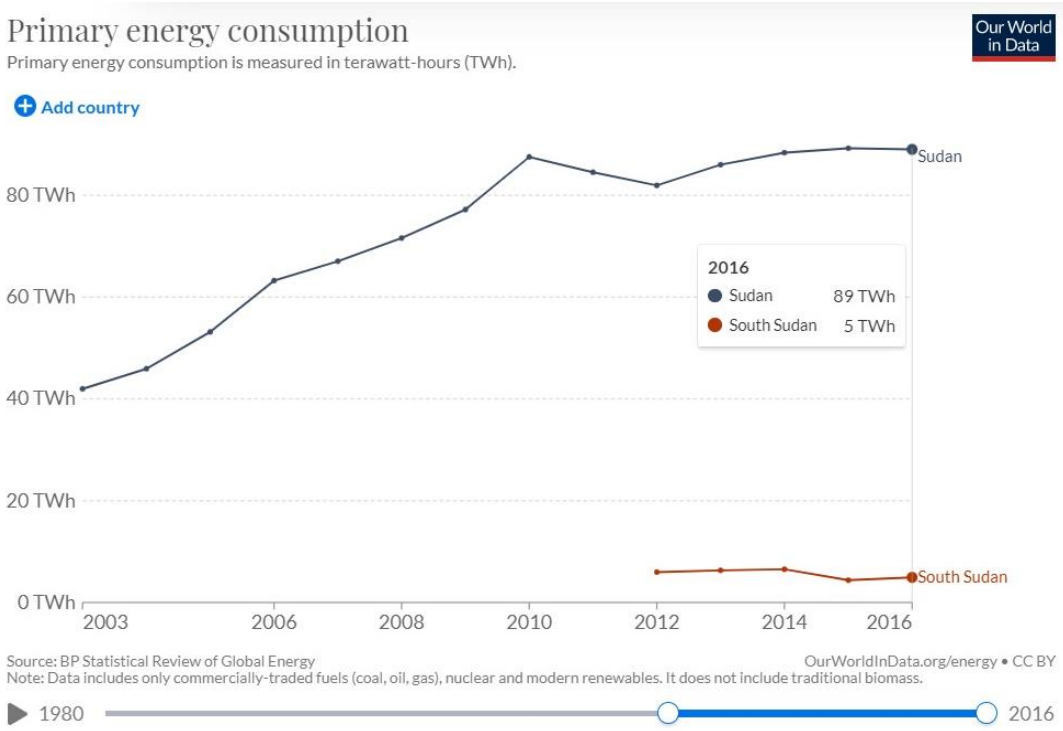
South Sudan Population Clock

South Sudan Population (as of 10/28/2021)	11,443,778
Last UN Estimate (July 1, 2021)	11,381,378
Births per Day	1,071
Deaths per Day	319
Migrations per Day	-232
Net Change per Day	520
Population Change Since Jan. 1	156,520

Adapted from: https://worldpopulationreview.com/countries/south-sudan-population

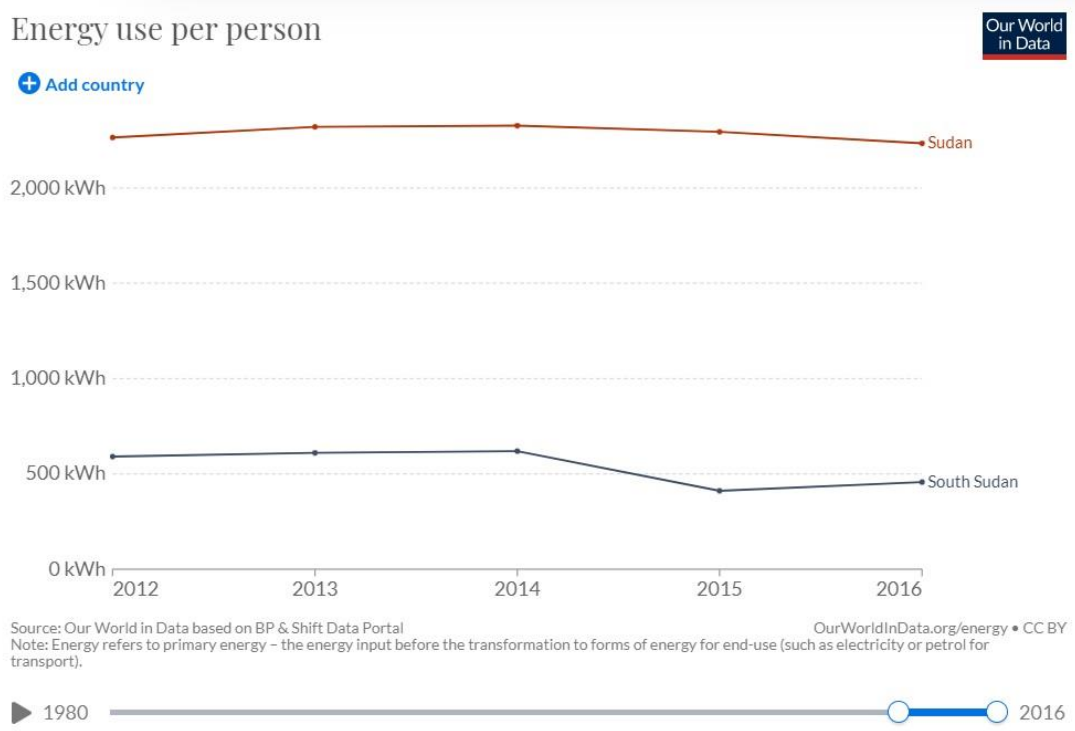


Landlocked - 44,000 Km^2
Population ~11 million



Adapted from: https://ourworldindata.org/energy/country/south-sudan?country=~SSD

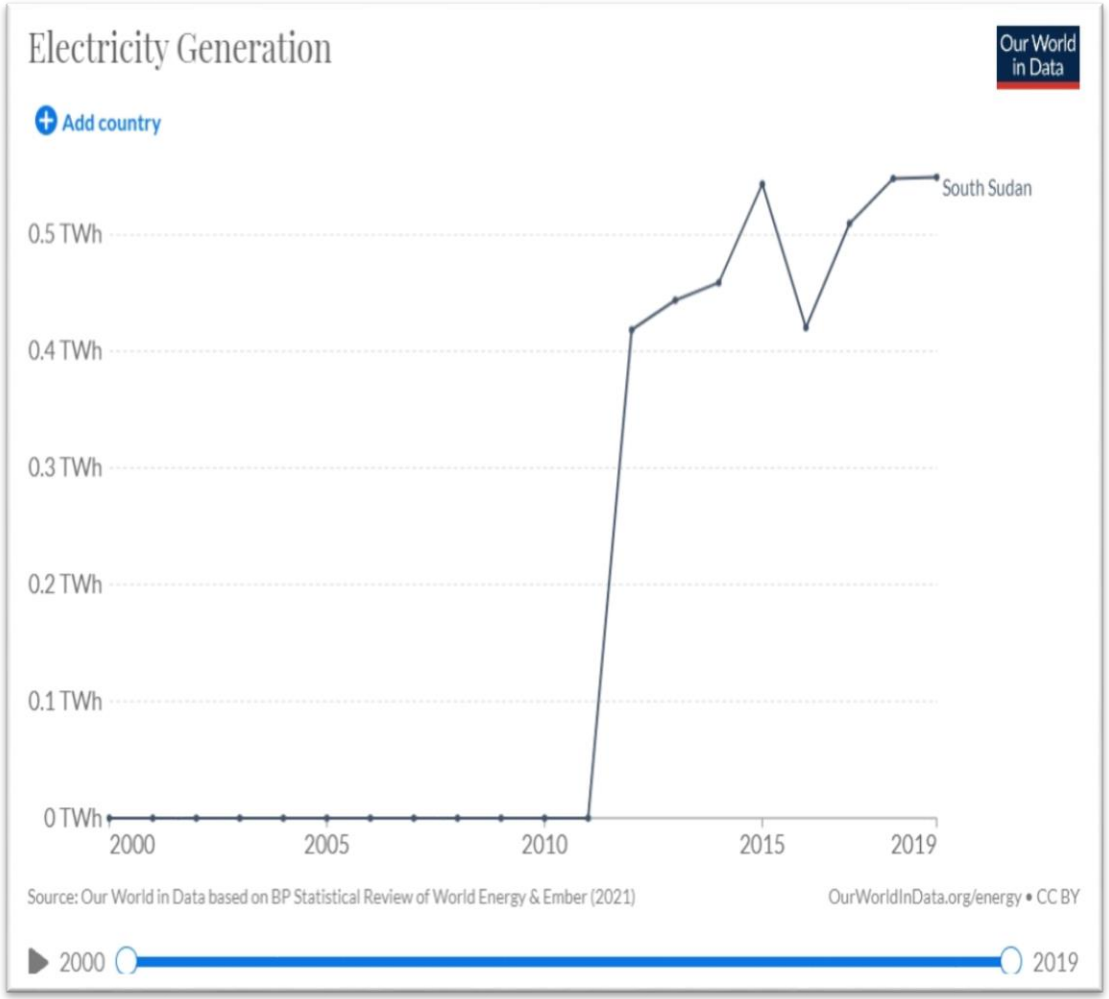
South Sudan: How much **energy** does the country consume each year?
(=0.06 of Average Sudan Per Capita)



Adapted from: https://ourworldindata.org/energy/country/south-sudan?country=~SSD

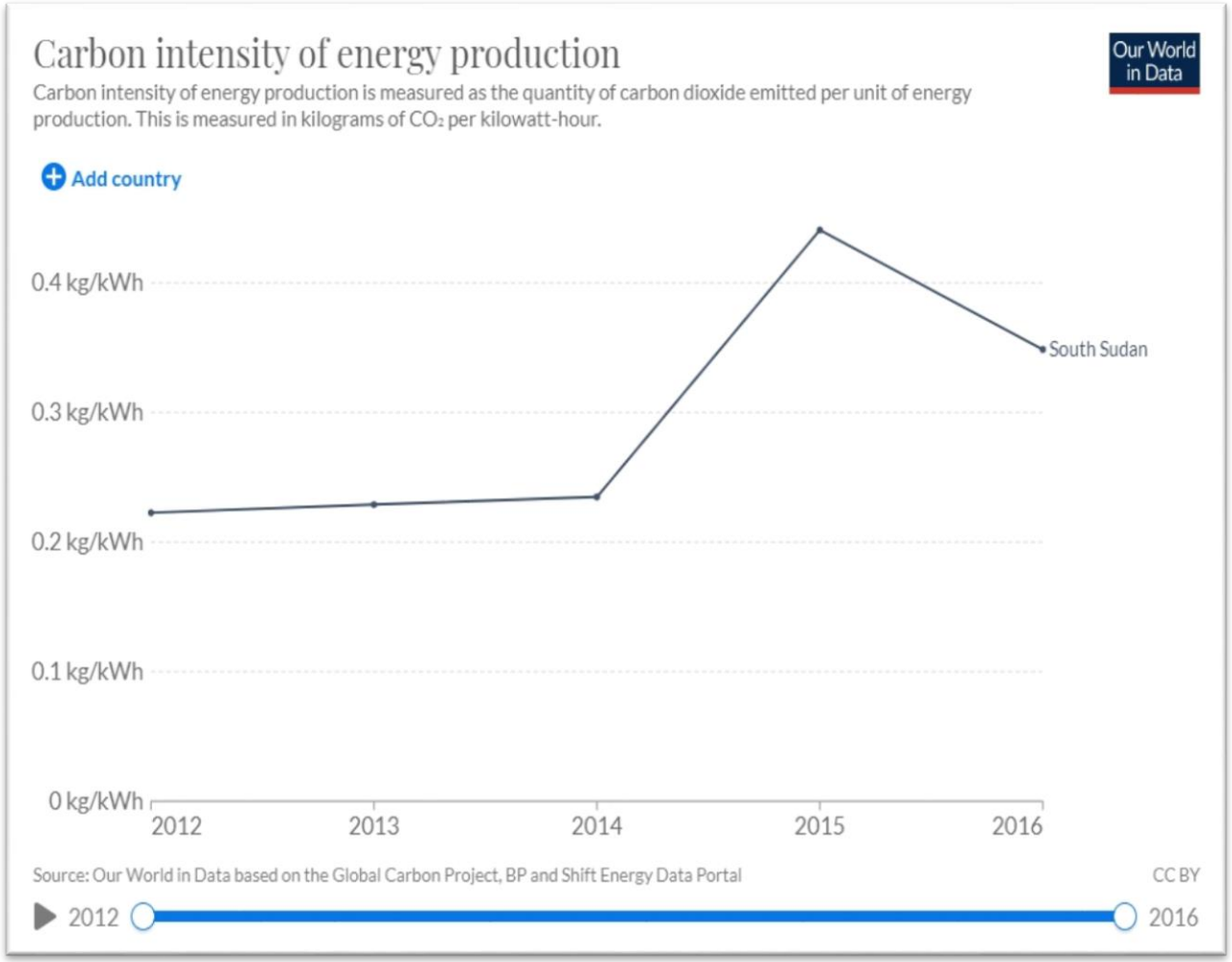
South Sudan: **Per capita**: how much energy does the average person consume?

South Sudan: How much **electricity** does the country consume each year?



Adapted from: https://ourworldindata.org/energy/country/south-sudan?country=~SSD

South Sudan: Carbon intensity: how much carbon does it emit per unit of energy?



Adapted from: https://ourworldindata.org/energy/country/south-sudan?country=~SSD

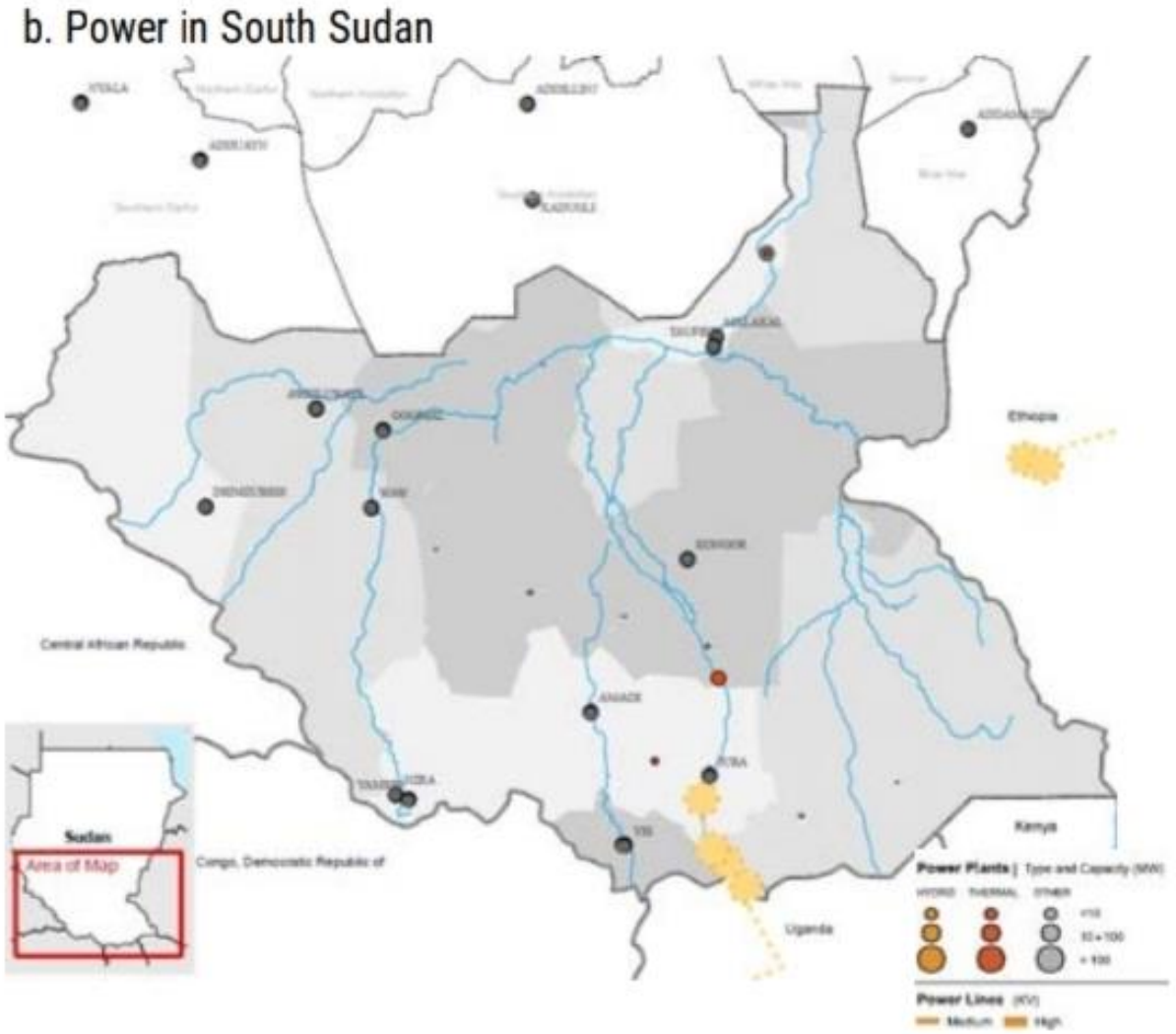
Infrastructure

South Sudan is yet to develop infrastructure backbones.

- Spending needs: 1.4 billion → 23% of GDP

During the six year interim:

2005-10, South Sudan benefited from the strong support of donors Estimates indicate spending needs on the order of 1.4 billion per year over a decade more than three times as much as the country has been spending in recent years.



Economy

- Economy grew with gross domestic product (GDP) estimated at 9.5% in FY2019/20.
- oil production → 62.1 million barrels in FY2019/20 -*representing a 26.5% increase on the 49.1 million barrels realized in FY2018/19.*
- Falling oil prices → GDP growth in FY2020/21 is projected to contract by -4.1%.
- In the agricultural sector, cultivated area increased by 6% in 2020 compared to the previous year.

Economy

Extreme levels of acute food insecurity persist across the country :

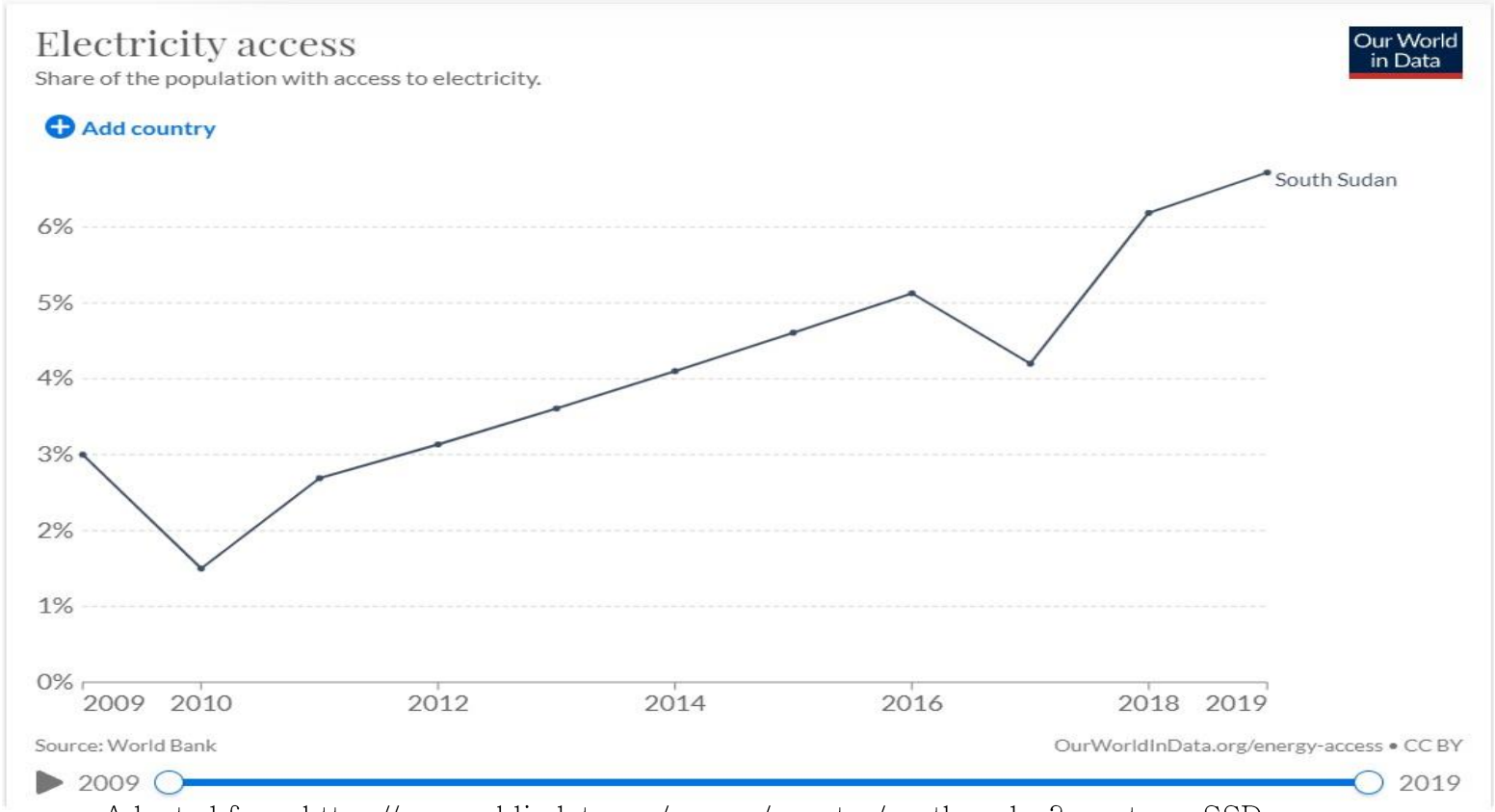
- *> 6 million are facing crisis-level food insecurity -1.4 million children <5 years expected to be acutely malnourished this year.*
- *~ 4 million people remain displaced by the humanitarian crisis -1.6 million people displaced internally and some 2.2 million refugees in six neighbouring countries.*
- *About 82% of the population in South Sudan is poor according to the most recent estimates.*

Solutions implemented

- 100-megawatts (MW) power plant to supply Juba and other areas.
- Connect power from Uganda's 400 MW Karuma dam by 2023.
- Source power from its northern Sudan to supply the northern areas of Renk and Malakal.
- A deal with General Electric aimed at increasing power generation by 470 megawatts.
- Increase imports from neighbors Egypt and Ethiopia.
- Large hydropower

South Sudan: What share of the population have access to electricity?

Despite being the newest country, it is the least electrified.

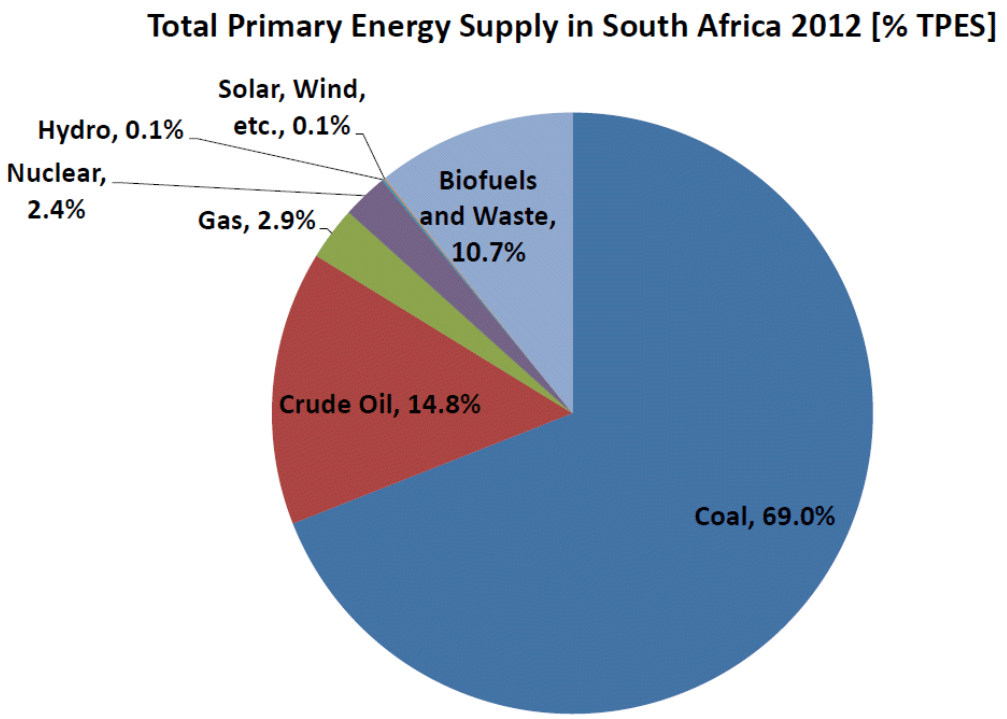


Adapted from: https://ourworldindata.org/energy/country/south-sudan?country=~SSD

Population with access to electricity, 2019

URBAN	RURAL	NATIONAL
5.1 %	7.1 %	6.7 %

Electricity



Access to electricity (% of population)	6.0
Access to clean cooking (% of population)	<5

Adapted from: South Sudan: An Infrastructure Action Plan
A program for Sustained Strong Economic Growth

Existing electric power transmission grid for the region

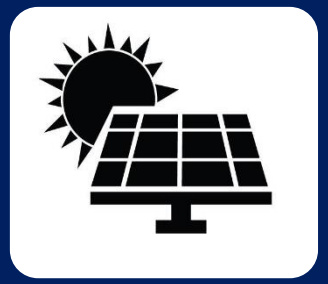
A recent Study:

On more than 121,000 health facilities, in 46 low and middle-income countries:

- 60% lacked access to reliable electricity

Solution Methodology

Available Sources



Solar (On/ Off-Grid)

- Good potential allover the country (6.1 kWh/m^2/day).
- Yet no significant production, due to lack of assistance, setup and maintenance costs.
- Used in rural and peri-urban settings (Water pumping in agriculture and lighting).

Geothermal

- 400 MW of potential in different regions around the country.
- No electricity from geothermal sources due to lack of guidance. Government is looking forward to partnerships with the experienced neighboring Kenya.

Oil

- Was the key player in South Sudan economy up to 2011.
- Sharply declined after 2011 due to the independence from the Republic of Sudan.
- Main source of generated electricity in 2015 (33.6 % of produced electricity was generated from fossil fuels).

Electricity Consumption by institution

(Average in developed countries/ Targeted consumption after electrification)

Targets:

- Self sufficiency by 2040. No more importing or usage of crude oil to invest in healthcare improvements; moreover, reduce pollution and birth defects resulting from it.
- Significant dependence on renewable supplies by 2051.
- Full revival of educational and industrial services.

5 ~ 15 kWh/ day	(Targeted = 30 kWh/ day as per international average)
N/A	(Targeted = 5 kWh on average to refine Gasoline)
N/A	(Targeted = 10 kWh as per average school usage)
N/A	(Targeted = 31 kWh as per average hospital usage)

Power Generation plan

(On/Off-Grid - Supply type & population)

1st Stage

- Supply type — population density coupling.
- Off Grid systems in rural parts.

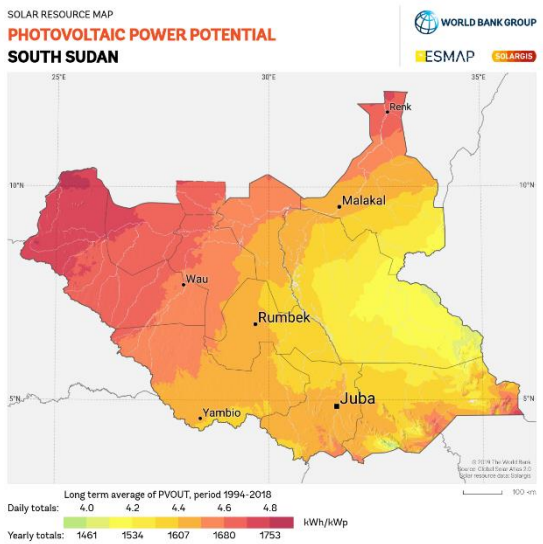
2nd Stage

- On Grid at central areas of the country.
- Off Grid extension.

3rd Stage

- Full On Grid systems after infrastructure revival.

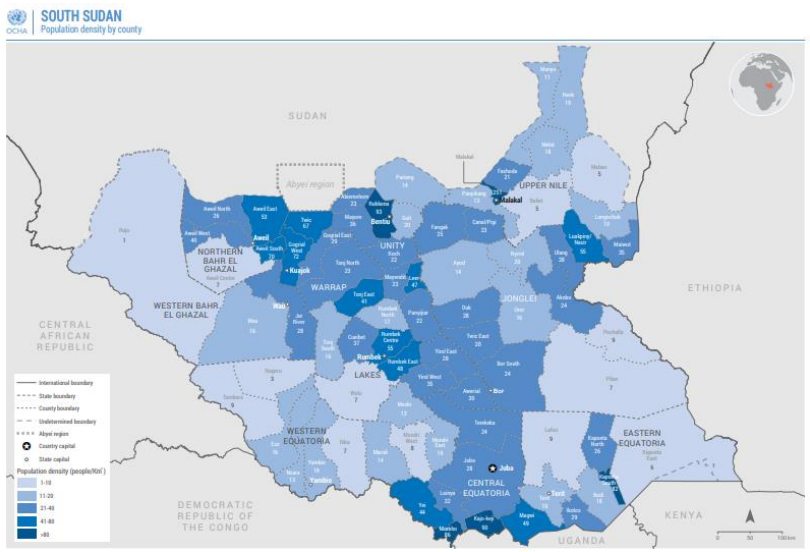
Supply type-Population density coupling (Solar)



Retrieved from: Global Solar Atlas

- Off Grid is better to start with, for several reasons:

1- Weak infrastructure of the country.
2- Absence of energy security.
3- Allows energy storage and reuse; therefore, ensures self sustainability when the grid is down.
4- Effective in powering remote areas.

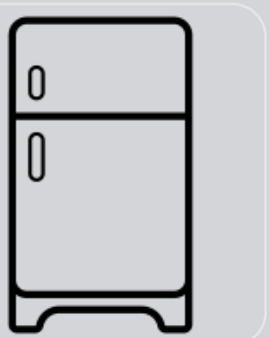


Retrieved from United Nations Office for the Coordination of Humanitarian Affairs

Capital Expenditure Cost (CAPEX) & Fixed Operating and Maintenance Cost (OPEX):

Among all the energy sources, solar PV midscale projects ranges from 1300 ~ 2000 $/kW (CAPEX) and 1.5 ~ 2.5% (OPEX)

Household basic appliances power consumption



1200 kWh

2x

150 kWh

(8 hours/day)

180 kWh

(1 hour/day)

1460 kWh

(2 hours/day)

2x

160 kWh

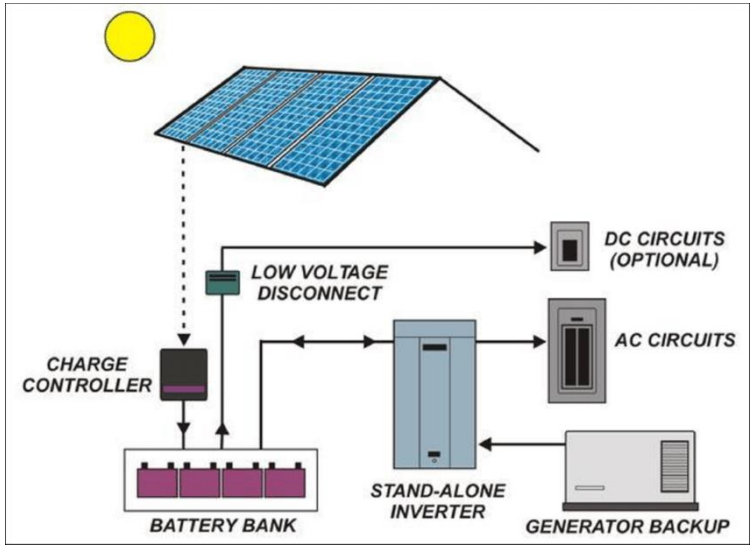
(7 hours/day)

5~6 kWh

(2 hours/day)

Min Generation needed & incremental annual needs

Annual Electricity Needs (Family)	kWh/ year
A Fridge	1200
2x 75W bulbs	150
Washing Machine	180
Electric Oven	1460
2x 100W Fan	160
Phone Charger	5~6
Total	3156
Total (Daily Basis)	8.64
Average daily sunlight hours	8
Panel Rated Power Needed (W)	1080 W
Number of 355W solar panels needed	3
Price	$355
Other equipment	~ $100
2 kWh battery	~ $550
Total	$1005/ household

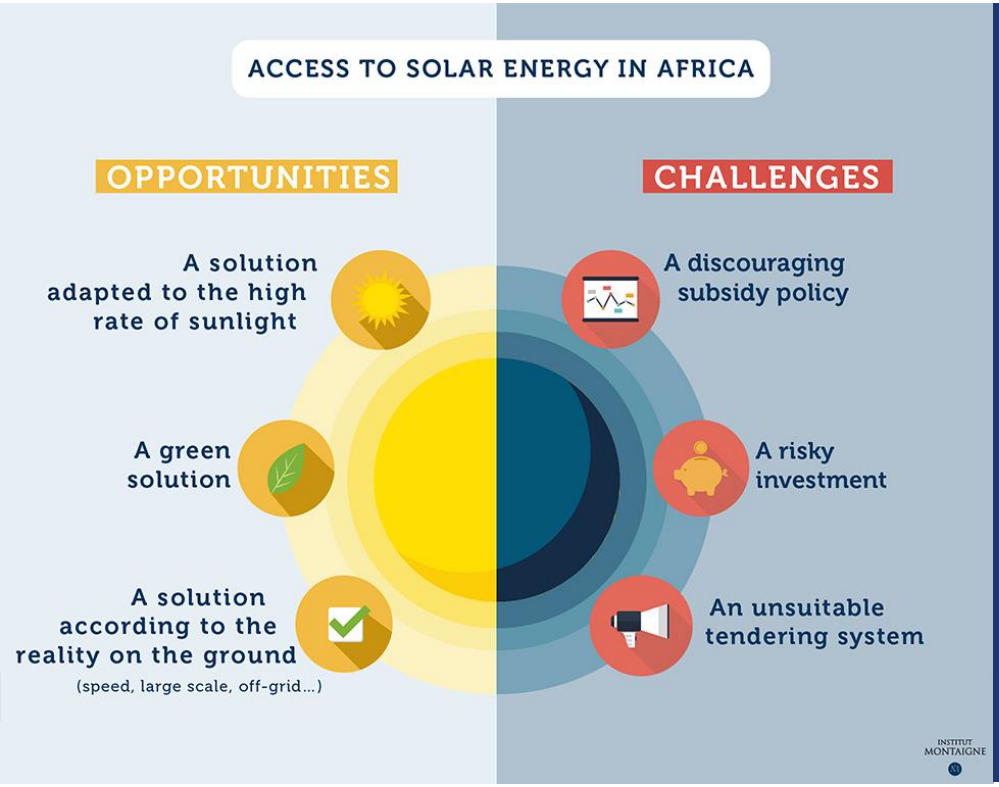


Retrieved from: [(23) (PDF) Design of an Off-Grid Solar PV System for a Rural Shelter (researchgate.net)]

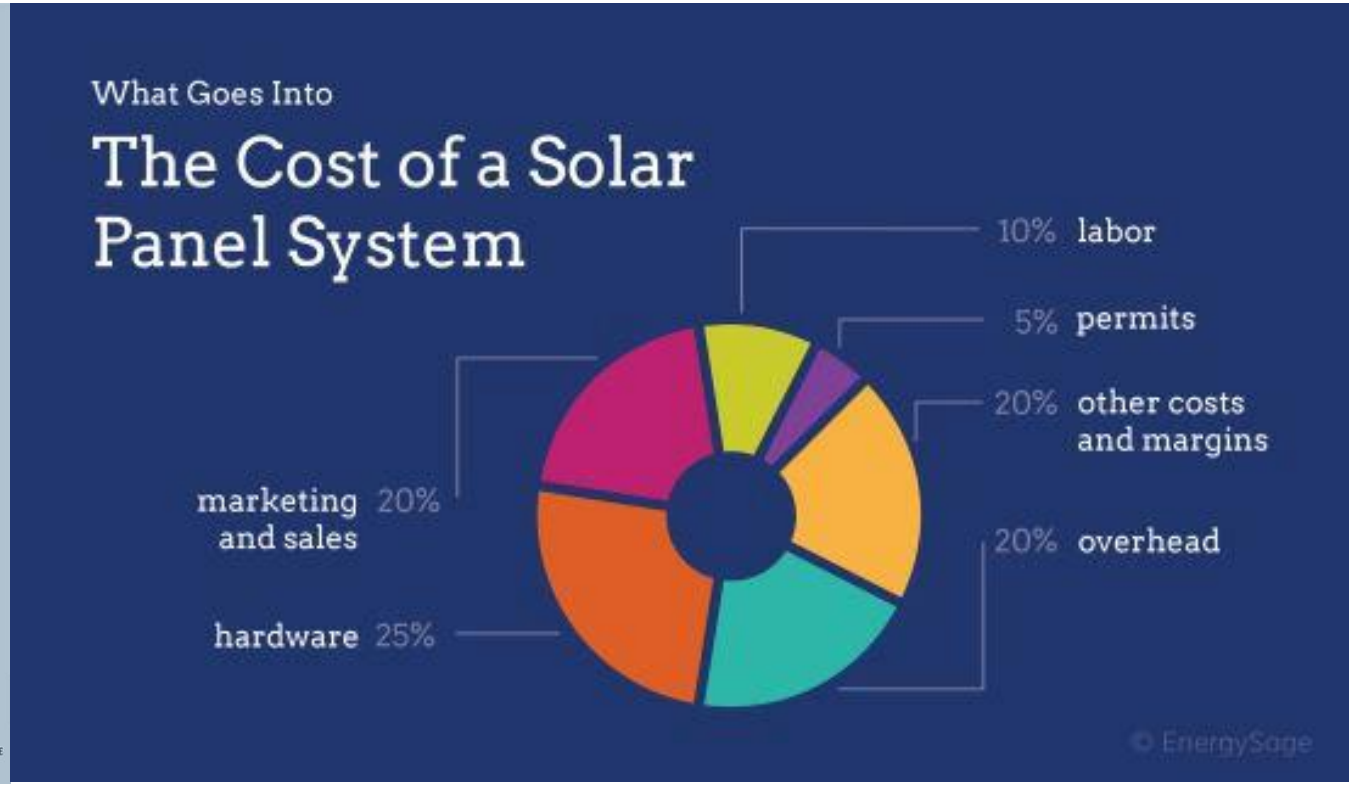
Year	Expected annual population growth	Estimated households (Average family is 4 members)	Estimated additional generation needed /day (kWh)
2030	1.84 m	46,000	397,440
2040	4.94 m	1,235,000	106.7 e5
2050	8.04 m	2,010,000	173.6 e5

Challenges

- Despite hitting bottom lines (cost-wise), solar PVs needs to be cheaper to be affordable by anyone.
- Uncertainty of how much sun is available depending on the location.
- No consistent generation is guaranteed, and thus expensive energy storage mechanisms are needed.
- Little or no knowledge of how to maintain or install for most people.



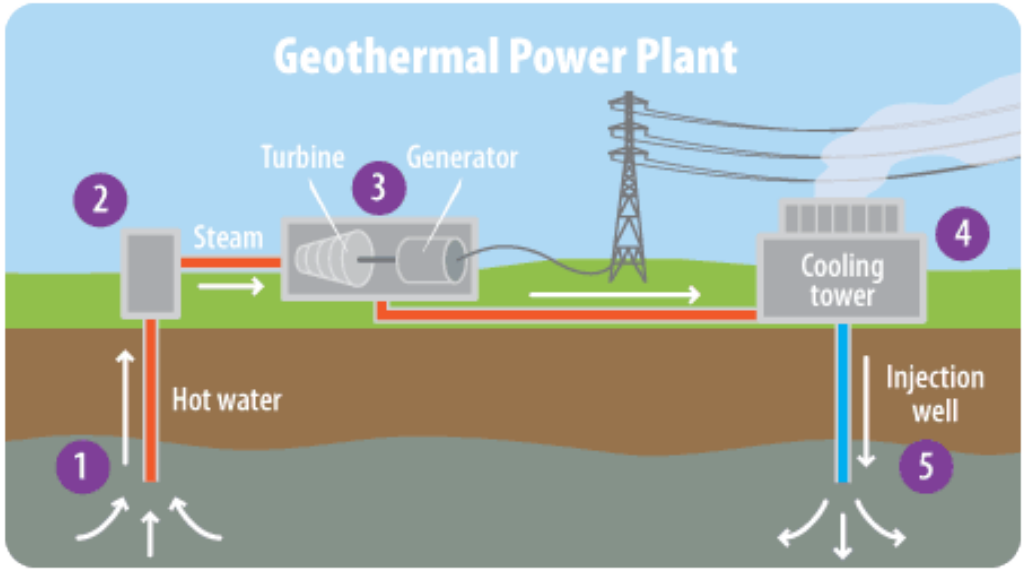
Retrieved from: Bright Perspectives for Solar Power in Africa? | Institut Montaigne



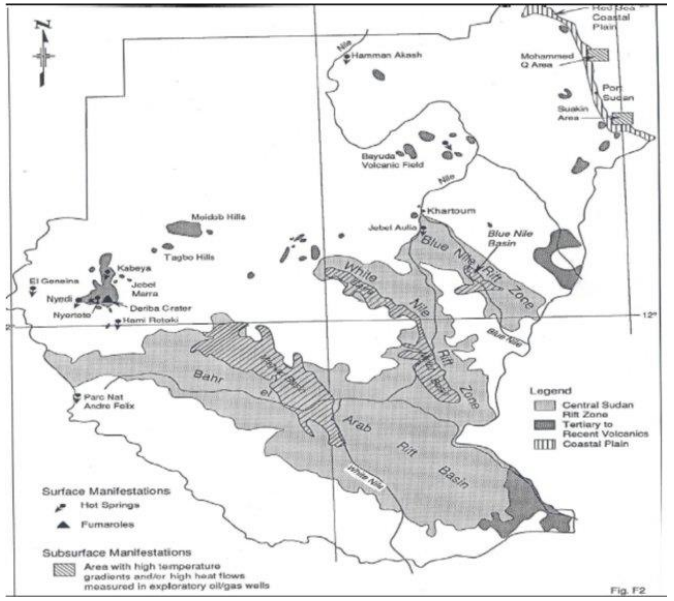
Retrieved from: Why Are Solar Panels So Expensive? | EnergySage

Geothermal

- Estimated 400 MW potential of geothermal energy in South Sudan, yet no efficient studies have been performed to exploit this type.
- Cooperation with experienced countries is underway under the supervision of ministry of electricity and dams.
- Very challenging, as the drilling operations requires equipment that is extraordinarily expensive.
- Hesitant investment in providing large scale energy facilities due to unpredictable and tectonically active sites.
- Training is costly and time consuming even for developed countries.
- Mistakes in reinjection of water into the wells again can have devastating geological effects.



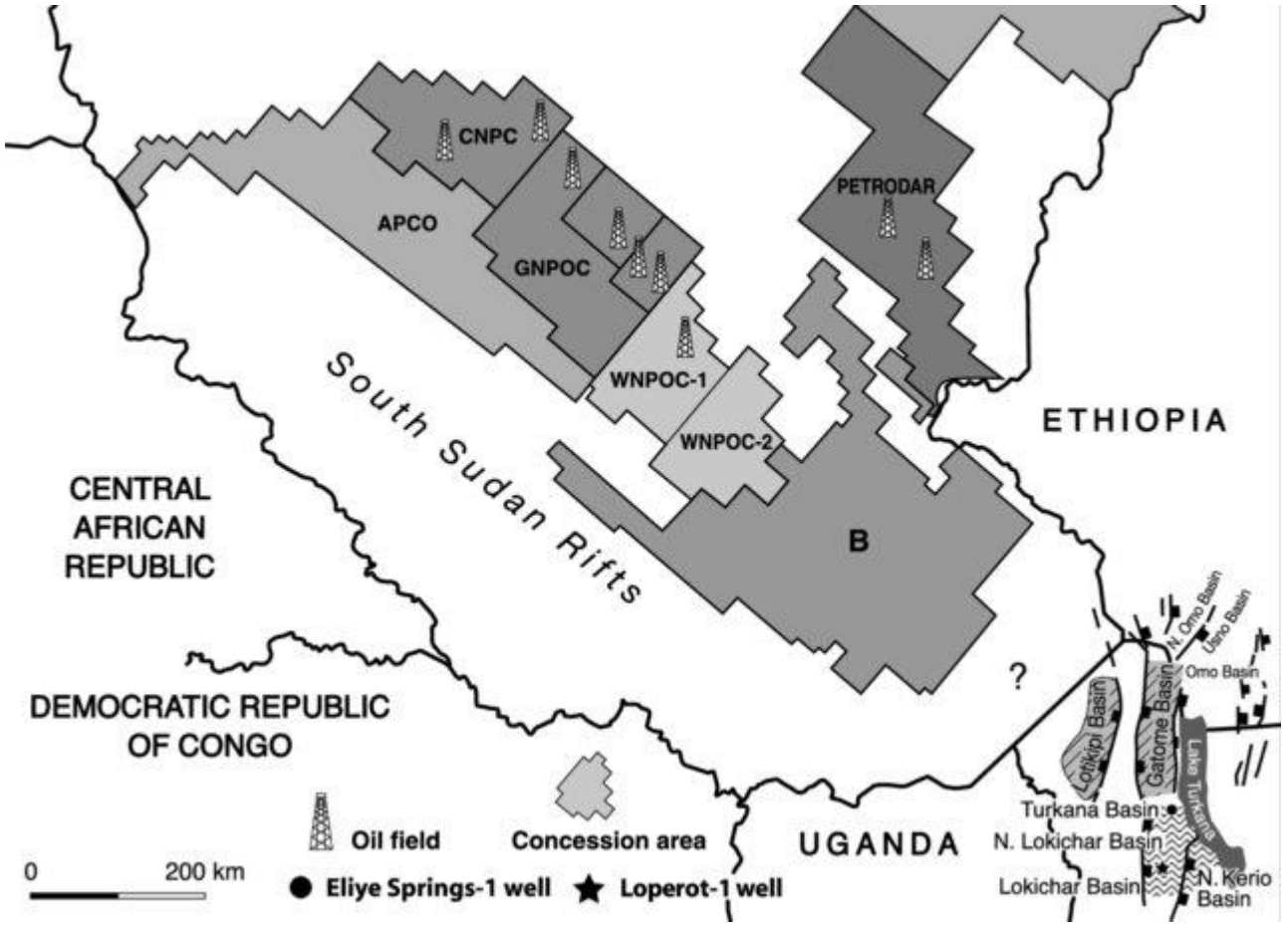
Retrieved from: Geothermal Energy | A Student's Guide to Global Climate Change | US EPA



Retrieved from: (23) (PDF) Geothermal Mainstream Adoption through Risk Mitigation in Sudan (researchgate.net)

Oil

- Dominant energy provider in South Sudan with nearly 77% contribution in energy production.
- South Sudan comes third in oil reserves in the Sub — Saharan region with 3.5 billion barrel as annual production.
- Most of the reserves are not yet untapped, waiting for foreign investors.
- Due to the novelty of South Sudan in the field, catastrophic effects results from oil-related operations, like birth defects, waste pits, toxic wastes.
- Licensing rounds have begun lately, training and data storage control is on the spot for the South Sudanese government.



Retrieved from: [(23) (PDF) Hydrocarbon Prospectivity in Mesozoic and Early—Middle Cenozoic Rift Basins of Central and Northern Kenya, Eastern Africa (researchgate.net)]

Wind

- The wind potential is generally higher in the north-north eastern parts at Girbana, having The highest long term annual average wind speed:
- 5.08 m/s at height 10m AGL.
- 5.94 m/s at height 30m AGL.
- 6.39 m/s at height 50 m AGL.
- Other locations with reasonable wind potential included Geigar and Renk in the north-north eastern part of the country.

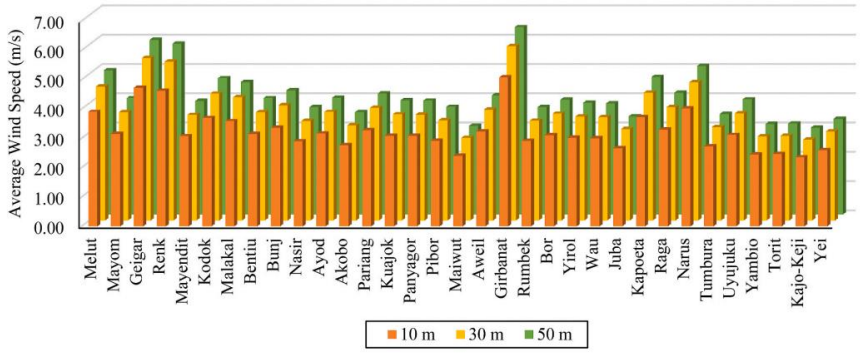
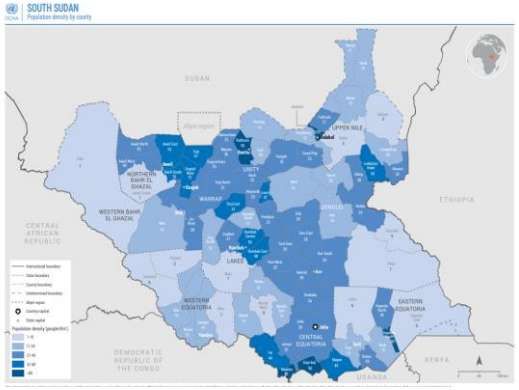


Fig. 6. Long-term annual average wind speeds at 10 m, 30 m and 50 mAGL



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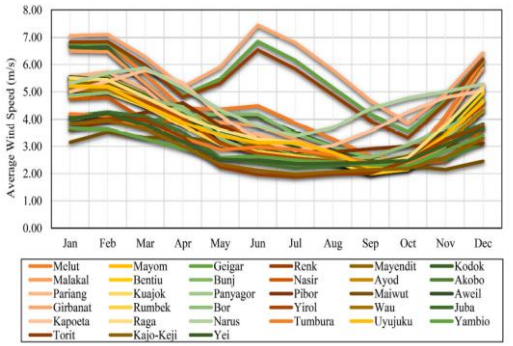


Fig. 4. Long-term monthly average wind speeds (30 m AGL).

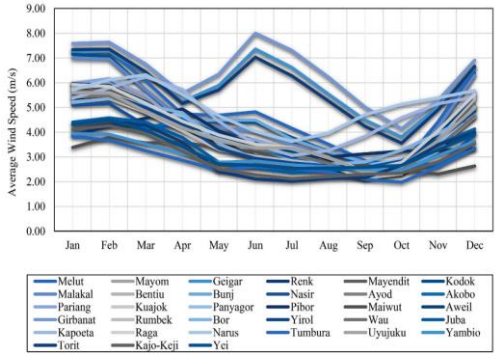
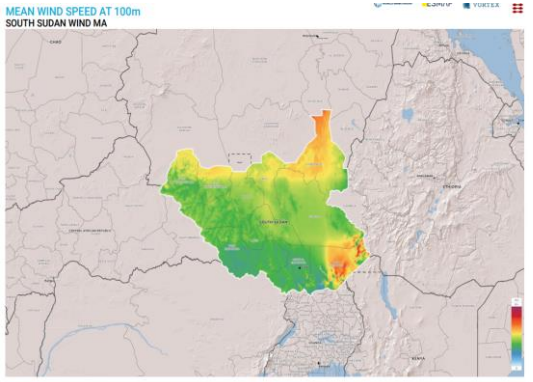


Fig. 5. Long-term monthly average wind speeds (50 m AGL).



https://globalwindatlas.info

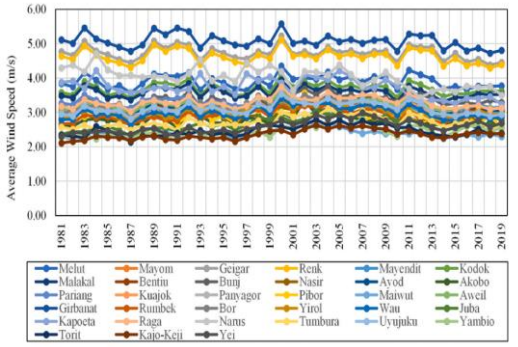


Fig. 3. Long-term annual average wind speeds (10 m AGL).

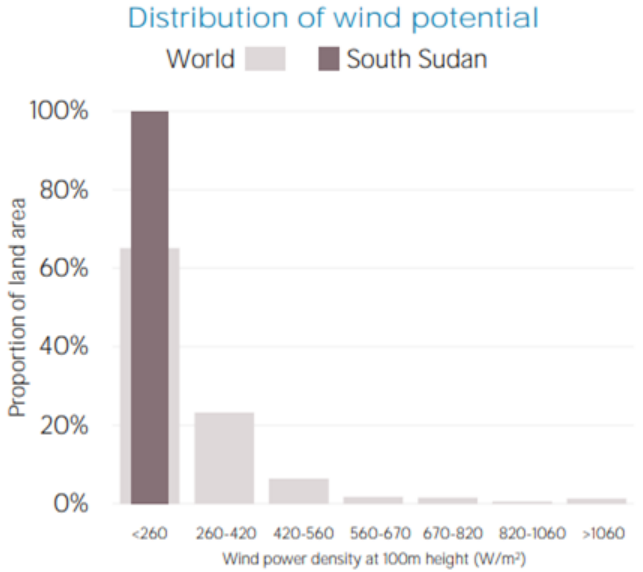
Figures 3, 4, 5, and 6 were retrieved from https://www.sciencedirect.com/science/article/pii/S1364032120309059

Wind (Proposed)

Micro/small scale wind turbines

Benefits:

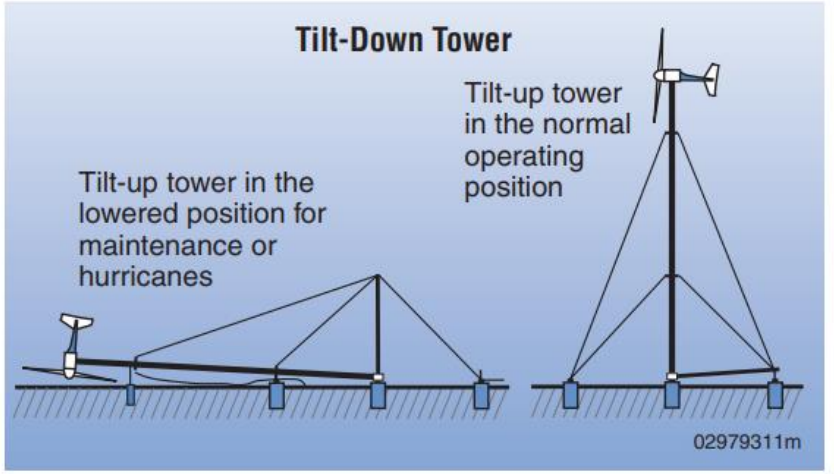
- Capacity from 20 watts to 100 kilowatts (kW)
- Lower electricity cost by 50%—90% compared to traditional energy sources
- Possibility of on-grid and off-grid.
- Simple equipment and easy operation
- Few affection to nature environment
- No air, water, or thermal pollution, No greenhouse gases
- With average capacity and household consumption, one turbine under operation conditions can generate energy to more than 16 households.
- Scalability
- Turbines can last from 10~15 years
- Short installation time (2 months)
- Cost effective
  - Small wind energy systems cost from $3,000 to $5,000 for every kilowatt of generating capacity.



Retrieved from IRENA "energy profile of South Sudan".

https://www.bsg-ecology.com/bats-micro-wind-energy-schemes/

Challenges	Solution
Required wind speed	The required Cut-in wind speed from 3 to 4 m/s; it is a suitable speed as the wind speed can reach to more than 6 m/s for 50m heights
Land area and required heights	The country is characterized by vast areas of land and relatively low storey buildings
Maintenance	Tilt-down tower design can be used for easier maintenance with lower cost
Cost	Signing agreements to fund the project

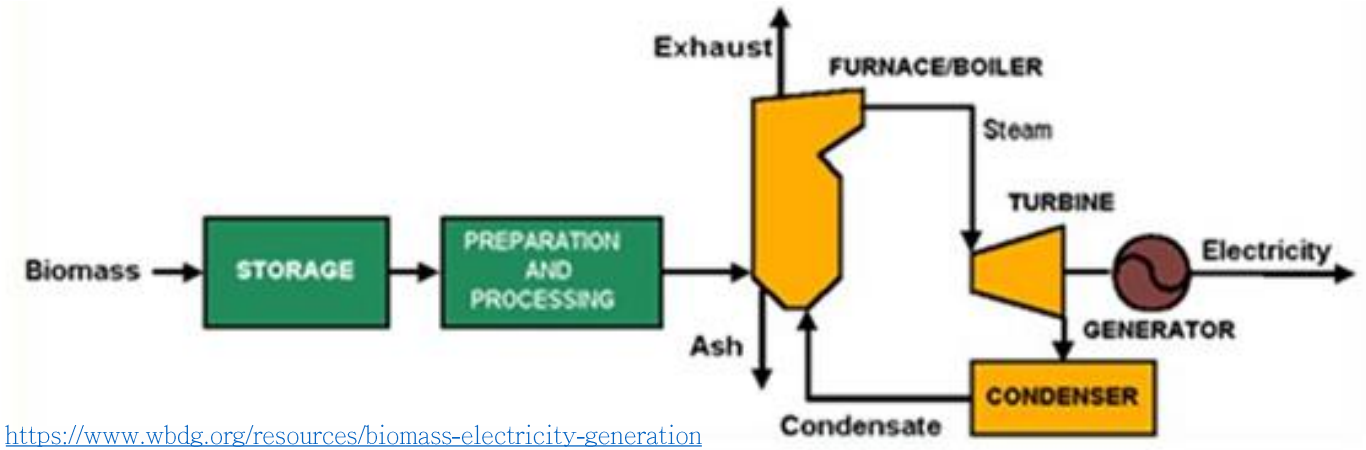


https://windexchange.energy.gov/small-wind-guidebook#parts

Biomass (Proposed)

A biomass plant

- How it works?



https://www.wbdg.org/resources/biomass-electricity-generation

Biomass	Example	Capacity(MWe)
Waste	Organic MSW	0.5 — 50
	Sewage sludge / animal waste	
Process Residues	Timber residues	0.5 — 5
	Rice husks	
	Food waste	
Locally Collected Feedstock	Forestry residues	10 — 50
	Energy crops	
	Roundwood thin	
	Forestry residues	
Internat. Feedstock Trading	Biomass pellets	> 50
	Biomethane	
	Pyrolysis oil	
	Roundwood	

Adapted from Biomass for Heat and Power Technology Brief by IEA-ETSAP and IRENA© Technology Brief E05 — January 2015

Fermentation	Burning	Bacterial decay	conversion to gas/liquid fuel
microorganisms are used biologically to produce biofuels chemicals, materials, or combustible gases from biofeedstock.	It is a direct combustion using a boiler to produce high-pressure steam, the steam enter a turbine, and the turbine connected to a generator to produce electricity. It is the most common way and the cheapest ranges between USD 140-850/kW.	the waste is collected in oxygen-free tanks and it is decomposed by anaerobic bacteria that produce methane and other byproducts to form a renewable natural gas then it’s purified and used to generate electricity	the solid biomass is exposed to high temperatures with very little oxygen present, synthesis gas is produced: “a mixture that consists mostly of carbon monoxide and hydrogen” that burned by a boiler to produce electricity

- Benefits:
  - Clean and renewable energy source from existed resources
  - Greenhouse Gas Emissions Reduction.
  - Oil Dependence Reduction
  - Can be converted into useful products such as plastics and fertilizers
  - Can be used to make transportation fuels
  - Biomass energy is stored within the organism, and can be harvested when it is needed.
  - The typical power plant capacity is on the order of 10 MW
  - Long lifetime (15 years)

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.margamgreenenergy.co.uk%2Fabout-the-plant&psig=AOvVaw3UEFqZcAXXNgy2JEsvIprk&ust=1635343817772000&source=images&cd=vfe&ved=0CAwQjhxqFwoTCKD-1N2g6PMCFQAAAAAdAAAAABAj

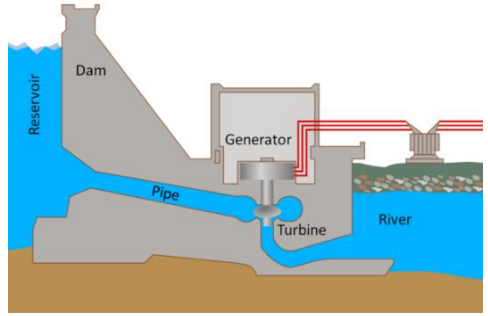
Biomass (Proposed)

Challenges	Description	Solution
Resource availability	Quality assurance for feedstock	applying pre-processing techniques such as fracturing, drying, densifying, and blending
	Long term contract for the raw materials	Replacing an annual crop with a fast-growing perennial, South Sudan has about 45.2% of the land is agricultural land and 11.3 % is a forest land
	Logistics for feedstock collection/transport	Build the station near the city and plant crops near the station. In addition to signing agreements to provide the necessary means of transportation and equipment.
	Competing land/water demand for non-energy purpose	Selected location should be nearby rivers or having a suitable rain rate: near to juba (Rejaf), the lowland areas of Eastern Equatoria, Jonglei, the Upper Nile and Bahr el Ghazal, and Western Equatoria and highland parts of Eastern Equatoria.
Cost	Higher cost of feedstock than fossil fuel	signing agreements to fund the project
	Higher upfront capital investment	
Sustainability	Land ownership	country potential match with the proposed projects, so it will seeks to facilitate the requirements through the compacts
	Employment opportunity	The agriculture sector employs 80% of the population.

Hydro (Ongoing)

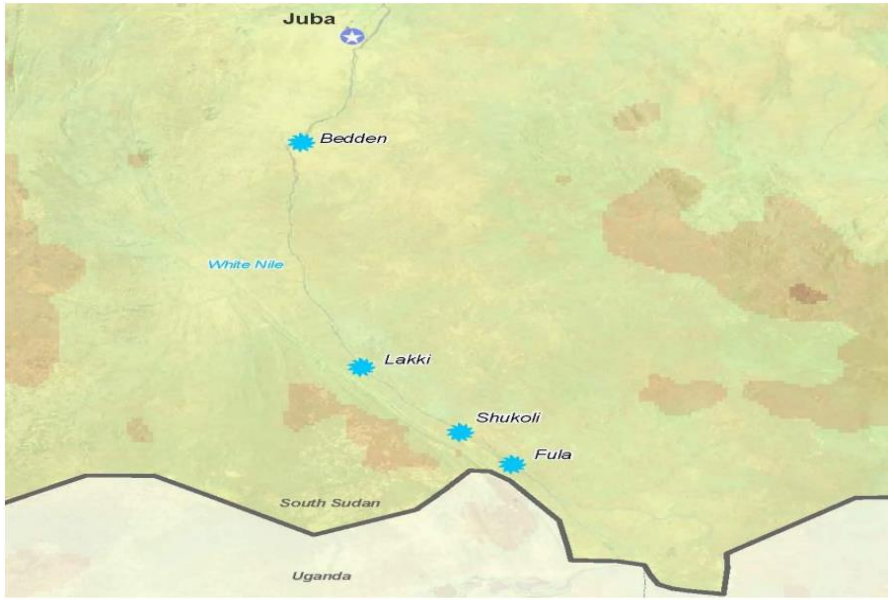
Project name	power Capacity (MW)	location	type	expected time for completion	Expected time to operate
Grand Fula	700 to 1080	White Nile river	Dam	8 — 12 years.	2035 (long-term)
Fula rapids	40	bahr-al jabal	Run of river	2.5 — 3 years	—
Shukoli	210 to 280	White Nile river	Run of river	5 — 7 years	2040 (long-term)
Lakki	240 to 420	White nile river	Run of river	5 — 7 years.	2033 (long-term)
Bedden	400 to 570	White nile river	Run of river	6 - 7 years	2028 (long-term)
Juba barrage	120	White nile river	Low-head dam	—	2026

These projects have the potential to deliver more than a total of 2,927 MW, 11,852 GWh of average energy, and 7,634 GWh of firm energy.



https://www.keystagewiki.com/index.php/Hydroelectric

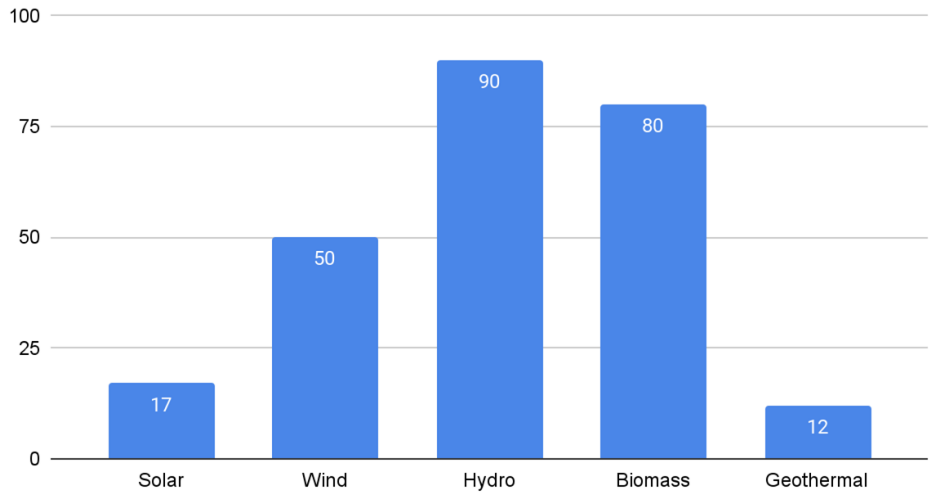
https://www.researchgate.net/figure/Typical-run-of-river-hydropower-components_fig1_330325483



Adapted from: https://energycapitalpower.com/wp-content/uploads/Oil-Power.pdf

- Small hydro plants may generate up to 40 MW of electricity and so far about 18 potential locations have been identified
- Main challenge is funding

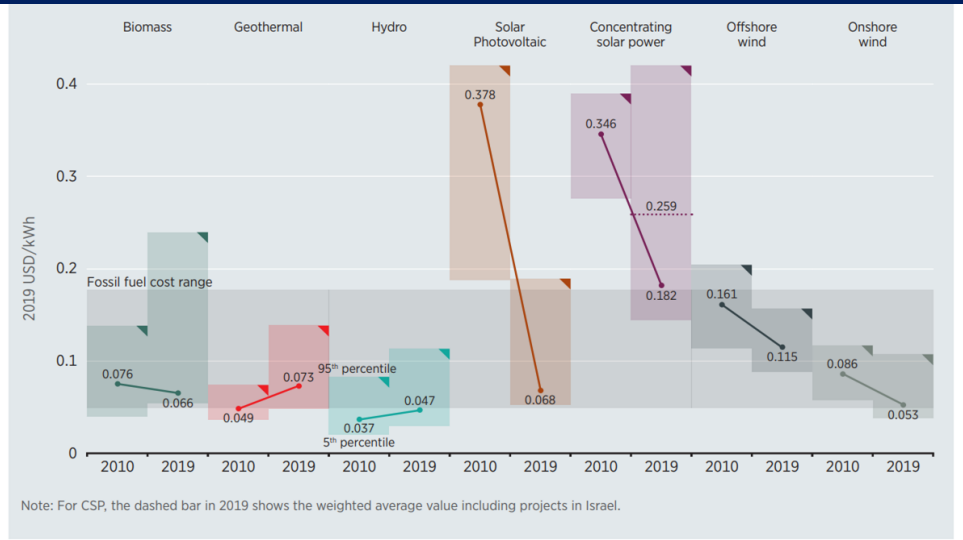
Efficiency



Rough estimation for power generation contribution development by source for 30 years

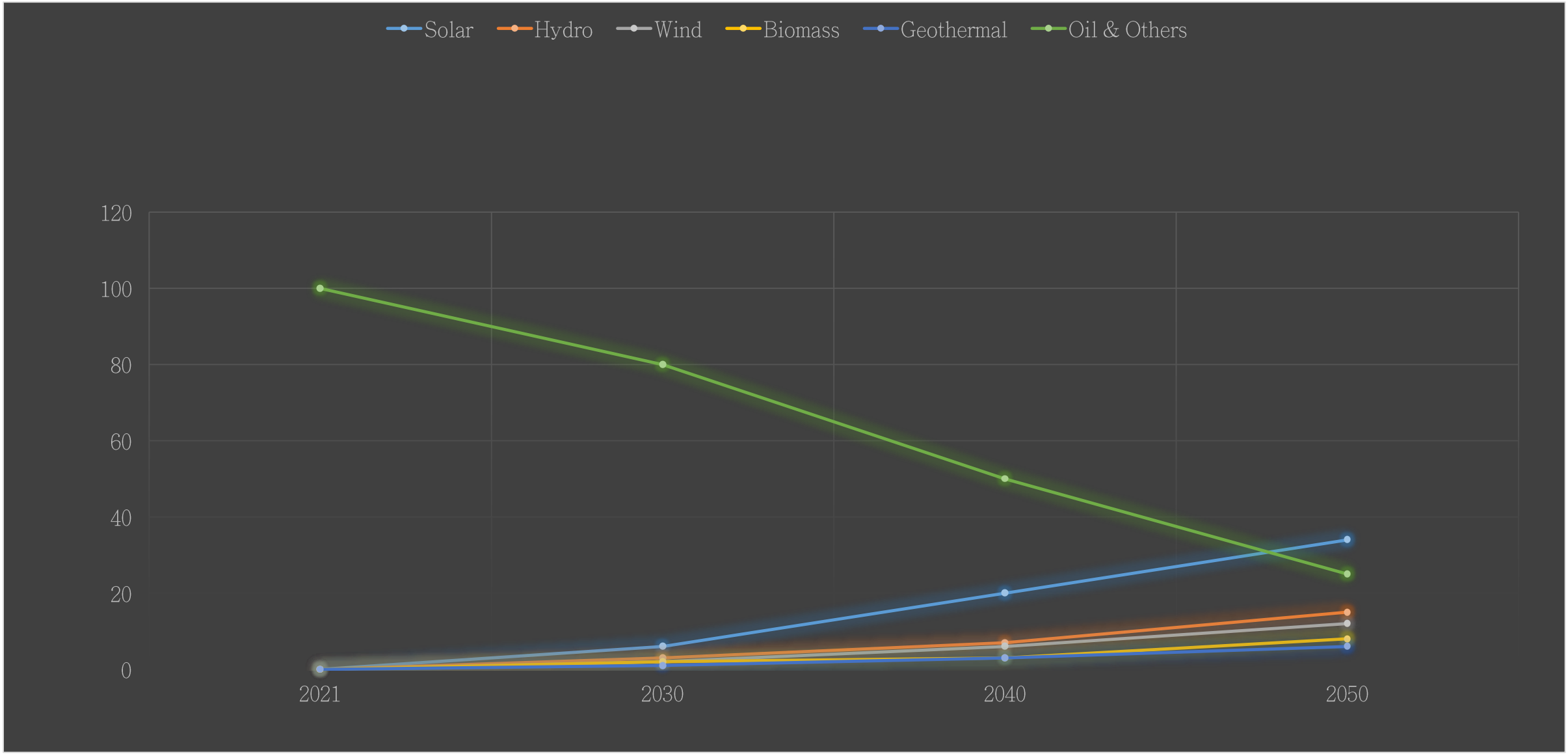
	2021	2030	2040	2050
Solar	0%	6%	20%	34%
Hydro	0%	3%	7%	15%
Wind	0%	2%	6%	12%
Biomass	0%	2%	3%	8%
Geothermal	0%	1%	3%	6%
Oil & others	100%	80%	50%	25%

Cost



adapted from the International Renewable Energy Agency (IRENA) "RENEWABLE POWER GENERATION COSTS IN 2019"

Power Generation Contribution by Source (Estimated)



Economic Analysis

The energy consumption per capita is around 50 KWh annually, so the total energy generation needed in 2050 is 974.18 GWh annually

Energy source	Energy generation	Number of plants	Capital expenditure cost (CAPEX) M$	Operating and maintenance cost (OPEX) M$	Total M$	Beneficial per dollar
Solar	331.2 GWh	260407	184	4.6	188.6	42.9
Hydro	146.1 GWh	6	202.9 + 1.5 billion$ (Dam)	14.2	1717.1	312.2
Wind	116.9 GWh	3248 (avg capacity)	84.427	5.065	89.49	190.77
Biomass	77.93 GWh	5 plants (avg capacity)	97.425	5.845	103.27	12.72
Oil & others	243.54 GWh	—	—	—	—	—

Factors taken into consideration:

- Construction time
- Lifetime
- Operating hours
- Population and energy generation growth

		Run-of-river Hydro	On shore wind	Solar PV	Biomass combustion electricity plant	Biogas digester and electricity generator	Diesel generator
Range in KW							
CAPEX ($/kW)	from	2000	2200	1300	2500	3000	1000
	to	5000	2600	2000	4500	6500	1300

		Run-of-river Hydro	On shore wind	Solar PV	Biomass	Biogas	Diesel
Fixed OPEX (% capex)	from	3,0%	4,4%	1,5%	4,0%	5,0%	2,0%
	to	7,0%	6,0%	2,5%	6,0%	8,0%	4,0%
variable non fuel OPEX ($/kWh)	from	0,000	0,002	0,000	0,002	0,020	0,014
	to	0,000	0,005	0,000	0,004	0,030	0,028
Variable fuel OPEX ($/kWh)	from	0,000	0,000	0,000	0,005	0,014	0,300
	to	0,000	0,000	0,000	0,022	0,058	0,500

"Sustainable Energy Handbook"

Year	Expected population
2030	13283778
2040	16383778
2050	19483778

Timeline

Stage 1

- Training and rising awareness for renewables via workshops and sessions.
- Introducing different technologies with assistance.
- Purchasing essential equipment.
- Beginning of funding campaigns

Stage 2

- Elimination of household harmful lightening fuels.
- Installing Off Grid systems — country outer parts.
- Achieving self sustainability of Oil.

Stage 3

- Off Grid extension.
- Preparing for On Grid installation
- Renewable & effective electrification marketing

Stage 4

- Cutting down dependence on oil to the least.
- Distribution of electric cooking devices to fully eliminate household fuels
- Initiating private sectors for renewable concerns.

2021

2031

2041

2051

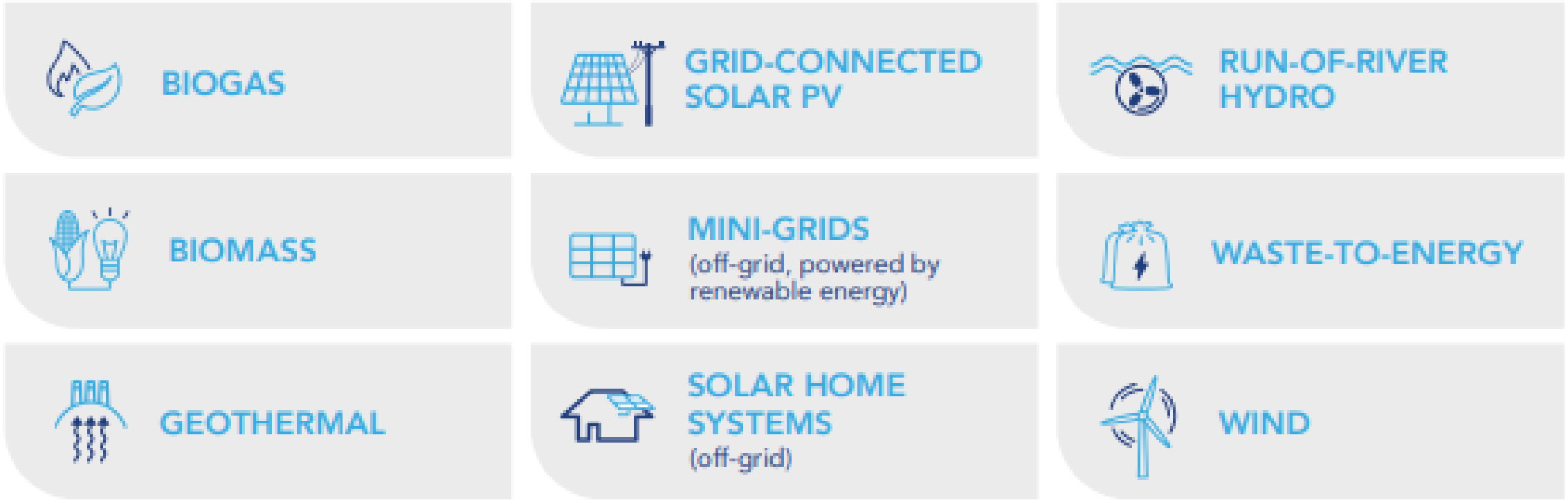
Providers

1- A lot of neighboring African startups would facilitate providing solar panels and installation experts, as the knowledge about Off-Grid systems among the South Sudanese people needs to be taken care of.

2- Such initiatives and cooperation would strengthen continental relations and rapidly stabilize infrastructure plans.

Funding organizations

- African export-import bank
- African development bank (AFDB)
- European investment bank
- World bank
- The Renewable Energy Performance Platform — REPP



Supported Energy Fields

Juba Solar Project

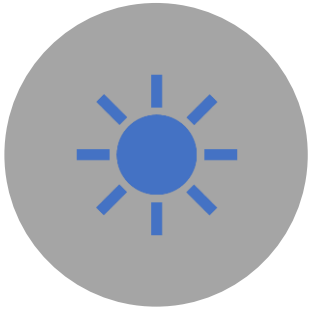
- The AFDB with **$1.5 million** supported the 170km 400kV Nimule-Juba Power Transmission Line between South Sudan and Uganda minimizing dependency on non-renewable energy and contribute to climate change resilience and reduce CO2 emissions under the coordination of the Nile Equatorial Lakes Subsidiary Action Program.

Nimule-Juba Power Transmission Line

- The African export-import bank with **$ 45 million** funded the Juba Solar Project with a 20 megawatts solar park (to be scaled up to 80 MW in the future) and a 35 megawatt-hour storage system
- United Arab Emirates-based PV system integrator Asunim Solar and renewable energy solutions consultancy I-kWh have formed a consortium to support Egyptian energy services company Elsewedy Electric.

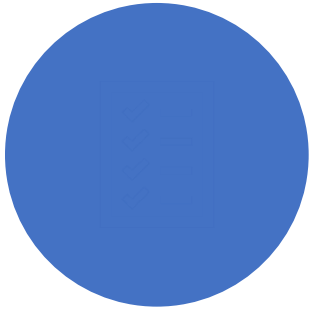
Project Criteria Satisfaction

FEASIBILITY



DIVERSE ENERGY SOURCES PLAN

SUSTAINABILITY

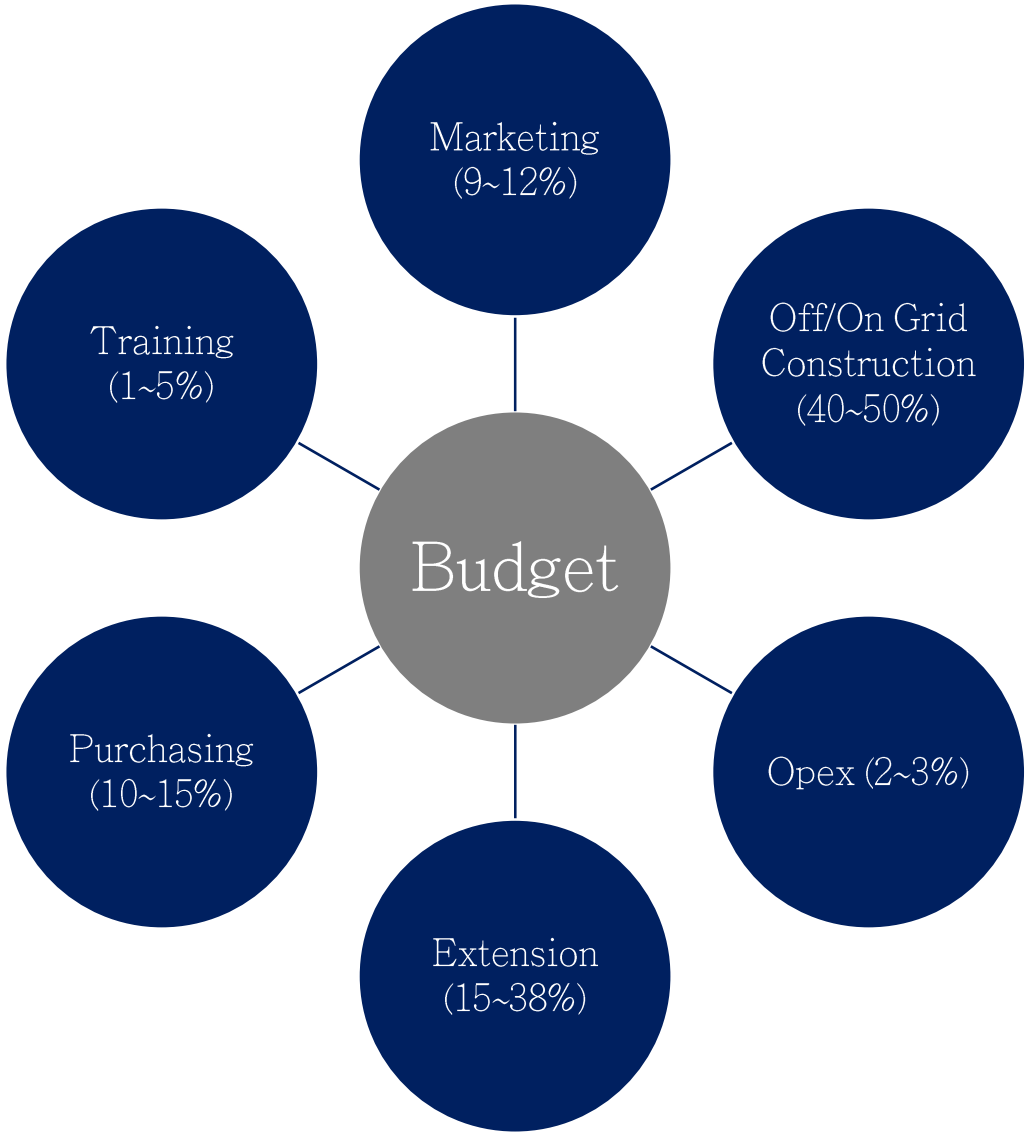


COP26 AGENDA

Funding organizations & fund percentage

Organization	Investment Share In Renewable Energy	Project Budget %
African export-import bank	Min fund: $ 30 million	15 %
African development bank	In 2019: $ 28 million	10 %
World bank	In 2020: $ 3.7 billion	30 %
European investment bank	2015 - 2020: EUR 21 billion	40 %
The Renewable Energy Performance Platform — REPP	$ 200,000 - $ 2000,000	5 %

Budget Distribution ($250,000,000)



Considerations:

- Optimum usage of the budget = Max revenue.
- Least cost/higher beneficial per dollar value is a priority.
- In our plan, hydropower has the highest beneficial/dollar value; however, due to scalability concerns and the nature of South Sudan besides water share of the neighboring countries, more obstacles would appear on their way and their locked-land nature will force distant planning for power projects.
- Wind and Solar are better potentials for their abundance and scalability.
- Along the first 10~15 years of the plan, expansion of solar systems (On/Off Grid) will be easier and revenue will be more guaranteed; however, in the next 10 years, extension of hydro and wind plants will be needed to meet the growing energy demand.

Impacts

Financial	Environmental	Public Health
- Better use of resources due to renewable systems installation instead of using Oil and fossil fuels in the long run. - Additional energy generated can be stored and shipped to the surrounding developing countries.	- Sharp reduction of air, water and soil pollution, besides eliminating the effects of greenhouse gasses to contribute to the international plans of facing global warming.	- Reducing the number of deaths or birth defects resulting from pollution, thus decreasing mortality rate. - Better healthcare services.

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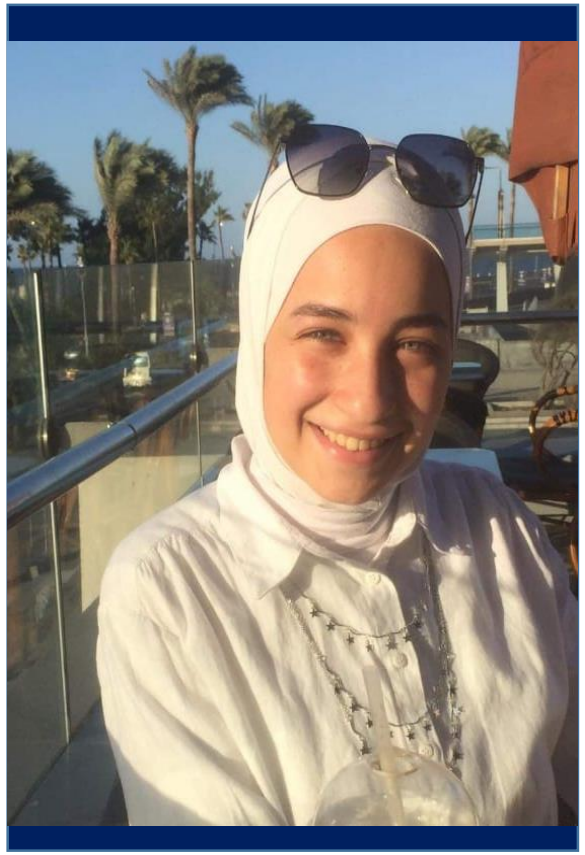
TEAM 101

SWITCH ENERGY ALLIANCE



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