Royal Academy for Overseas Sciences

* CBL-ACP = Chambre de Commerce d'Industrie et d'Agriculture Belgique - Luxembourg / Afrique – Caraïbes - Pacifique
* CRAOM = Cercle Royal Africain et de l'Outre-Mer
* MdC = Mémoires du Congo, du Rwanda et du Burundi

CBL ACP

CRAOM

« Quelle énergie pour l'Afrique ? - Une urgence et des défis »

MÉMOIRES DU CONGO du Rwanda et du Burundi asbl

Georges Van Goethem (Dr Ir)

Webinaire, 10 novembre 2020

Royal Academy for Overseas Sciences of Belgium (ARSOM – KAOW)
Formerly with EC DG Research and Innovation / Energy (Brussels)
(georges.m.vangoethem@gmail.com)

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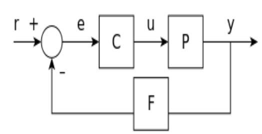
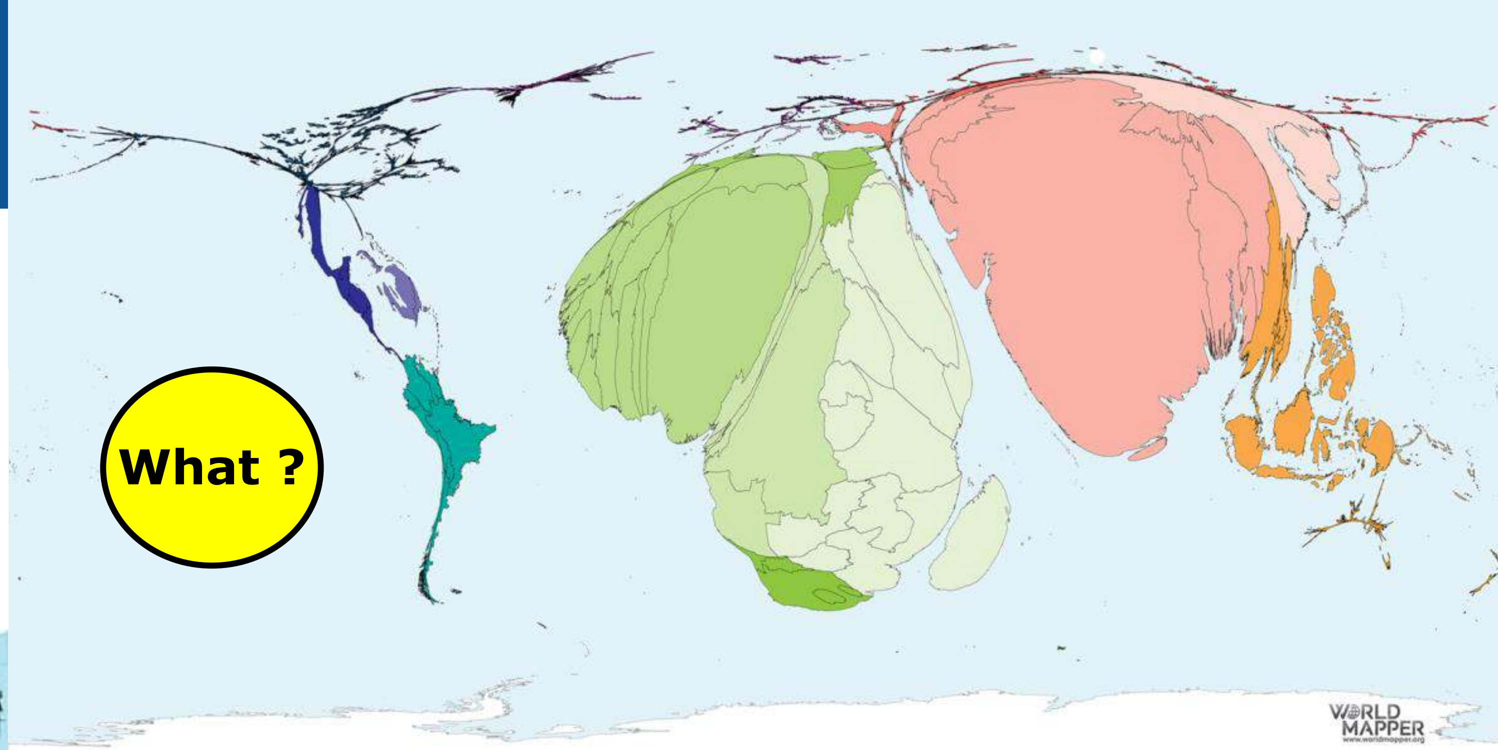


“Quelle énergie pour l’Afrique ?” (1/2)

This map (right) shows the proportion of all people on less than or equal to US$ 1.9 in purchasing power parity a day living there in 2016.

Half of the twenty poorest countries in the world are in sub-Saharan Africa (UNDP).

What ?



Une urgence

et des défis

NO POVERTY

"South Up Map" (left - Hobo-Dyer Equal Area Projection Map)

Main message : maps influence how people see the world and they reflect the political, economic and cultural interests of the people who make and sponsor them.

Source (June 2011) :https://www.transpacificproject.com/index.php/maps/
See also : “Mappa Mundi” exhibition, contemporary art, 5 March – 4 October 2020, Boghossian foundation – Villa Empain, Brussels

“Quelle énergie pour l’Afrique ?”

(2/2)

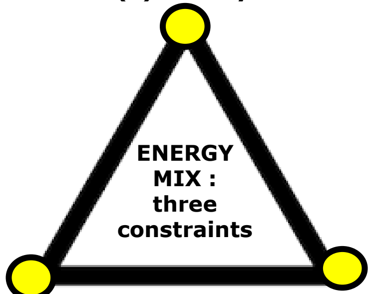
Une urgence et *des défis*

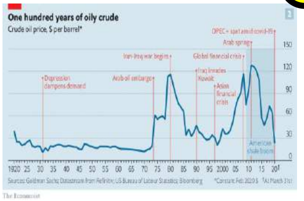
How ?

On the road to sustainable development :

integrating (global) politics and (local) energy services

with distinct space and time horizons





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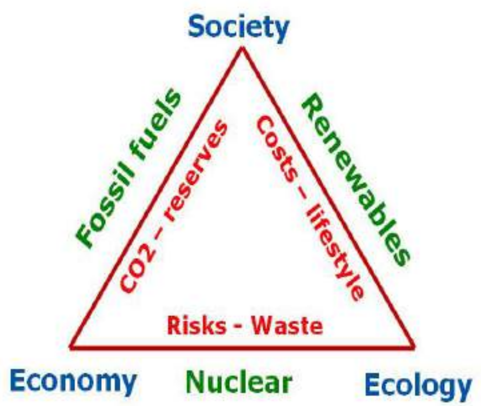
Energy mix : three constraints

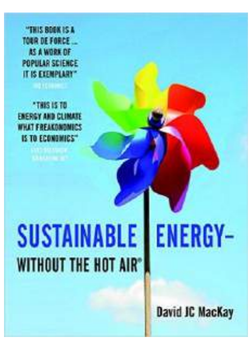
ENERGY MIX TRIANGLE:
three constraints



« Au regard de ce qui nous arrive, certaines oeuvres peuvent être lues sous un nouveau jour »

Le confinement me plonge davantage encore dans la lecture…. Itinéraire au fil des pages… Confinement, confiné, aux confins… - La Libre Belgique le 27-04-2020 - https://www.lalibre.be/debats/opinions/au-regard-de-ce-qui-nous-arrive-certaines-oeuvres-peuvent-etre-lues-sous-un-nouveau-jour-5ea5aad39978e21833e3ba20

Energy Mix within three constraints (Economy – Society – Ecology) with distinct space and time horizons



Humanity faces an immense challenge: providing abundant energy to everyone without wrecking the planet. If we want a high-energy future while protecting the natural world for our children, we must consider the environmental consequences of energy production and use. But money matters too: energy solutions that ignore economic costs are not realistic, particularly in a world where billions of people currently can't afford access to basic energy services. How can we proceed?

Sources : (1) "Energy Within Environmental Constraints", MOOC of Harvard University USA - David Keith and Daniel Thorpe - https://www.edx.org/course/energy-within-environmental-constraints
and (2) "Sustainable Energy: Without the Hot Air", Sir David Mackay, "the low-carbon advisor" of Department of Energy and Climate Change (DECC) UK (2009-2014), UIT Cambridge -www.withouthotair.com - *"At last a book that comprehensively reveals the true facts about sustainable energy in a form that is both highly readable and entertaining." R. Sansom, EDF Energy*

Les énergies en un coup d'œil (1/2)

[L'énergie est présente partout sur notre Planète et sous de multiples formes]: la chaleur et la lumière du soleil, l'eau ou l'air en mouvement, le bois ou les eaux chaudes souterraines, les gisements de charbon ou de pétrole …

On appelle énergies primaires ces différentes sources d'énergie naturelles.

Mais dans bien des cas, nous ne pouvons pas utiliser directement ces énergies pour nos besoins.

Que peut-on faire d'un flacon de pétrole brut ?
Il faut le transformer en carburant pour nos moteurs.

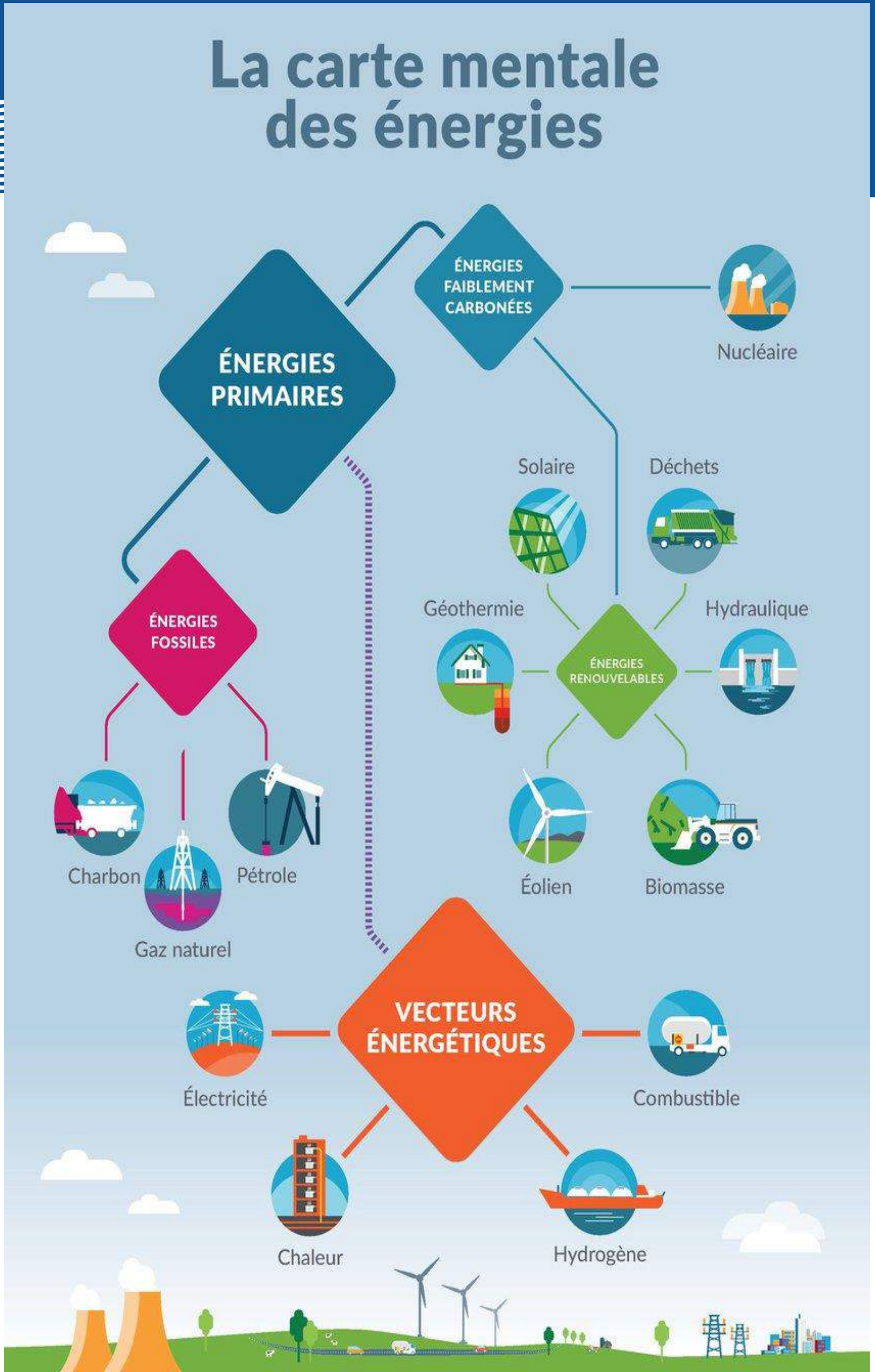
Que peut-on faire du courant d'une rivière ?
Il faut installer un barrage pour créer une chute d'eau artificielle et produire de l'électricité.

Les formes d'énergie produites à partir des énergies primaires, comme l'électricité ou les carburants, sont appelées énergies secondaires ou vecteurs énergétiques.

Ce sont ces vecteurs énergétiques que nous utilisons dans notre vie au quotidien.

planete energies
An initiative by TOTAL FOUNDATION

https://www.planete-energies.com/fr/medias/infographies/la-carte-mentale-des-energies



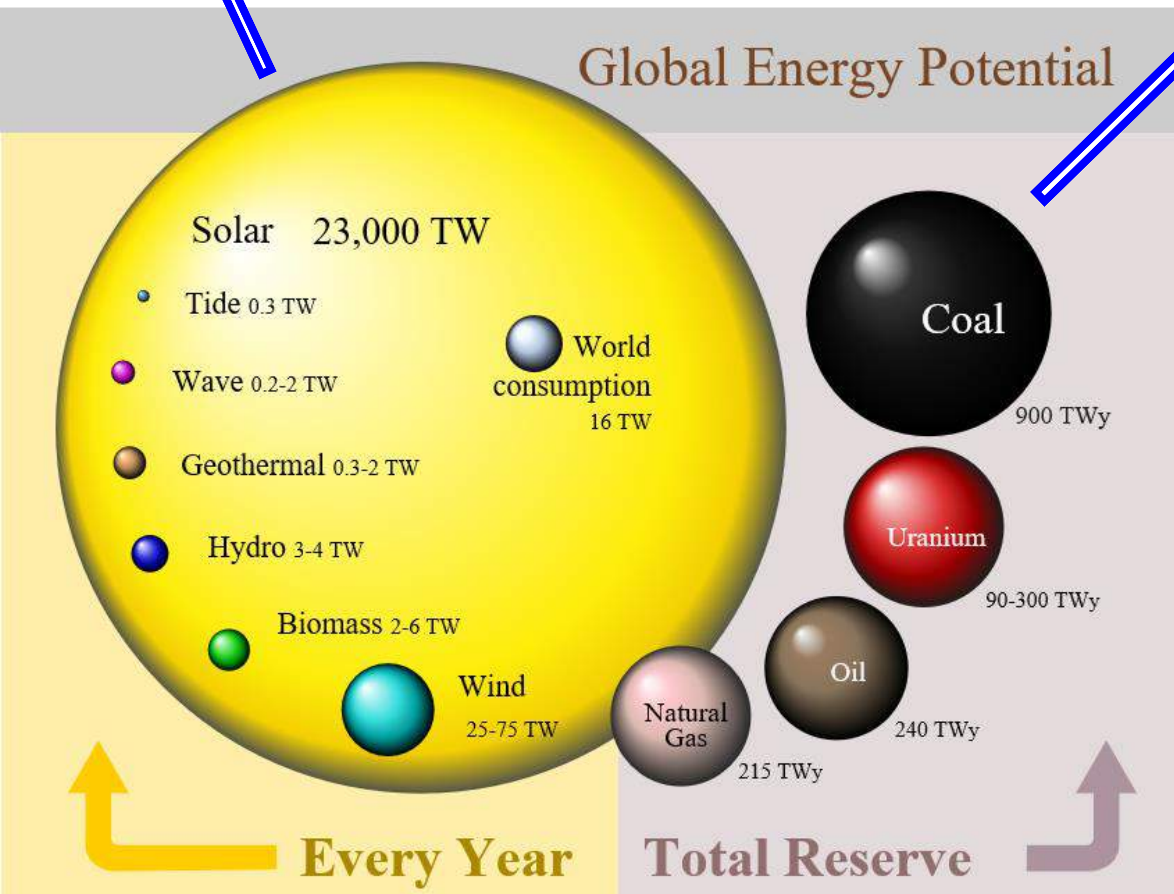
Les énergies en un coup d'œil (2/2)

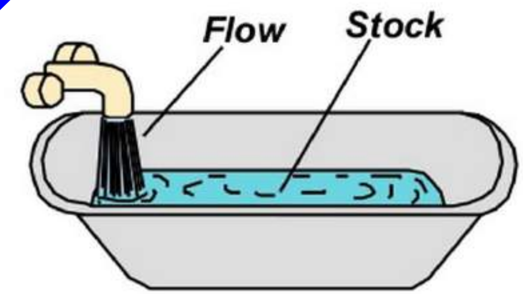
FLOW < = > STOCK

The sun powers almost everything on Earth, but … we do not know how to harness solar energy directly and efficiently (some progress is being made, however)

Energies de flux (vent, soleil): many renewable energy sources are intermittent, unpredictable and non-dispatchable

Energies de stock (charbon, gaz, pétrole, uranium) : réserves limitées dans le temps et l'espace





Grid stability = > Low carbon intermittent renewables ("flow") need a stable low carbon base ("stock")

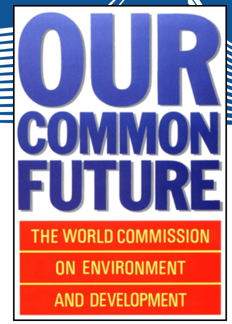
Figure left. All the renewable sources of energy are depicted in this diagram as annual outputs (i.e. power, TW) …………….whereas the non-renewables like fossils and nuclear are shown in their totality (i.e. energy, TWy).

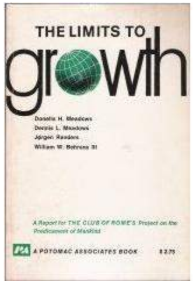
All these energy sources exist on Earth – and they are dwarfed by the monstrous capacity of the one thing that enters our planetary closed system – solar energy.

=> Where should we invest for the long-term ?

Source 2015: http://waitbutwhy.com/2015/06/the-deal-with-solar.html

"Sustainable Development" (UN - Brundtland Report – 1987)





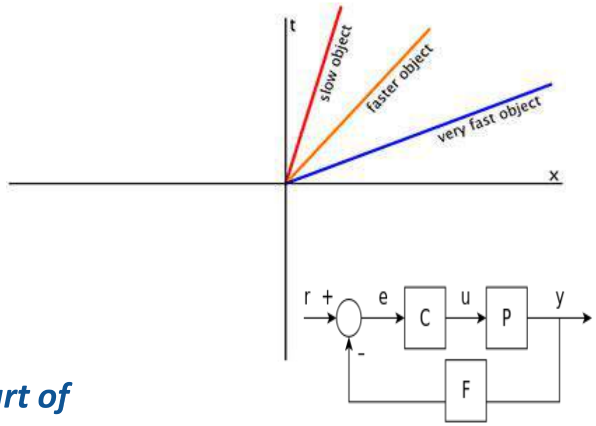
Sustainable Development

Original definition of sustainable development in the so-called Brundtland report :

• [development that] meets the needs of the present without compromising the ability of future generations to meet their own needs;
• but sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfill their aspirations for a better life.

1972 - mal traduit en français par l'interrogation « Halte à la croissance ? »

On the first point, the report reads: «The concept of sustainable development does imply limits—not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities.
But technology and social organization can both be managed and improved to make way for a new era of economic growth.»



On the second point, the report makes clear that poverty eradication is as much part of sustainable development as the environmental part. Even stronger, «A world in which poverty is endemic will always be prone to ecological and other catastrophes.»

One could say that the first point addresses sustainability in time, i.e., intergenerational sustainability, whereas the second point emphasizes the importance of sustainability in space; i.e., more north-south equity and poverty.

Ref : "Our Common Future", Gro Harlem Brundtland et al.

UN - World Commission on Environment and Development, Oxford University Press, NY 1987

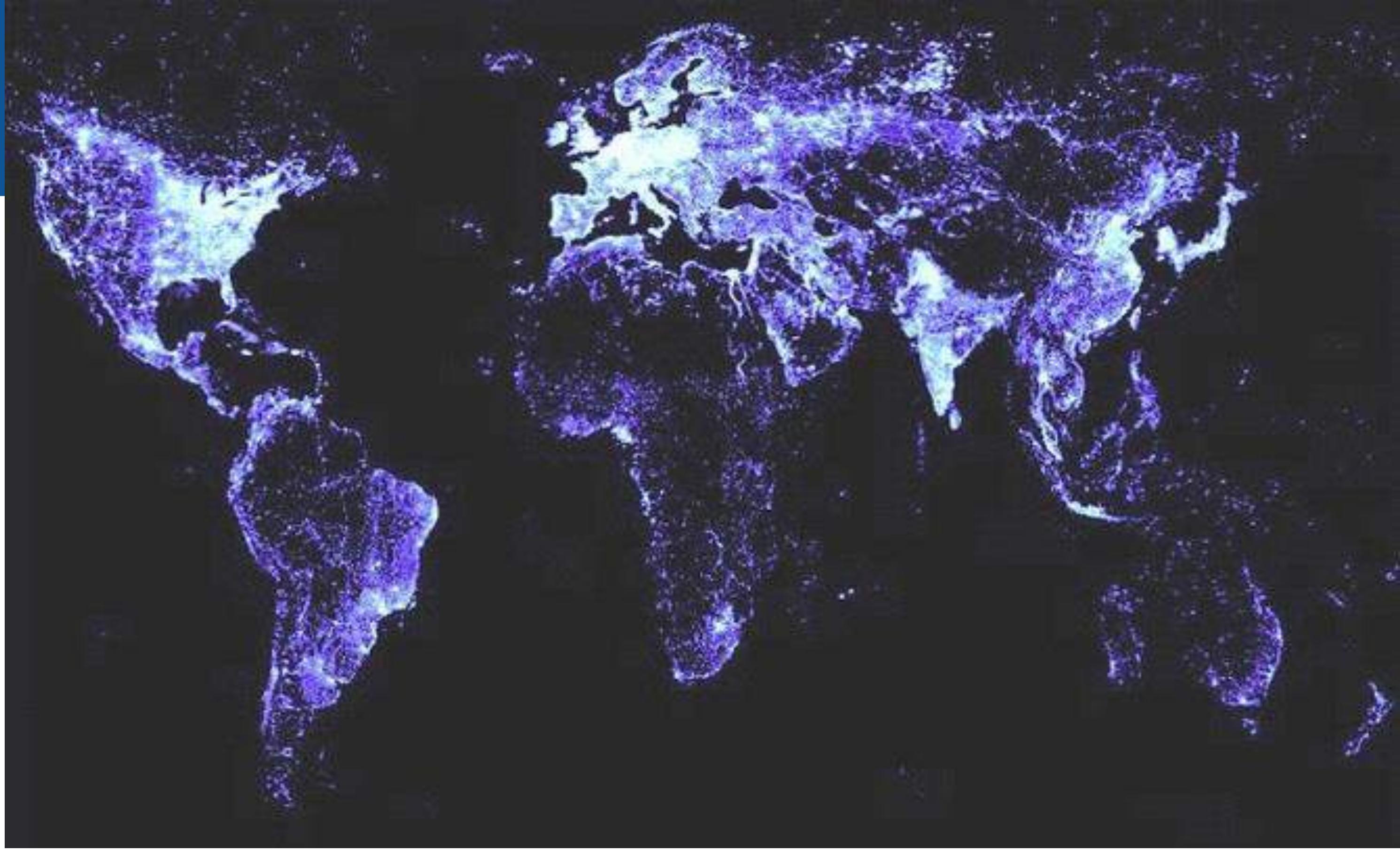
Electricity for developing nations

The amazing image right shows a picture of earth taken at night from outer space.

The street and house lights illuminate the countries and give an idea of <u>how electricity is well or poorly distributed in the world</u>.

Source 2001: The World Atlas of Artificial Night Sky Brightness, by P. Cinzano, F. Falchi (University of Padova) and C. D. Elvidge (NOAA National Geophysical Data Center, Boulder) - Royal Astronomical Society –

https://www3.astronomicalheritage.net/index.php/show-theme?idtheme=21



African Union

Agenda 2063 The Africa we Want

AGENDA 2063 – « *Nos aspirations pour l'Afrique que nous voulons* »

1. <u>une Afrique prospère</u> basée sur une croissance inclusive et un développement durable;
2. <u>un continent intégré</u>, politiquement uni et fondé sur les idéaux du panafricanisme et la vision de la Renaissance de l'Afrique;
3. une Afrique de la bonne gouvernance, la démocratie, le respect des droits de l'homme, la justice et la primauté du droit;
4. une Afrique en paix et sûre;
5. une Afrique ayant une forte identité culturelle, un patrimoine commun, des valeurs et une éthique partagées;
6. une Afrique dont le développement est axé sur les gens, se fondant sur le potentiel des populations africaines, en particulier de ses femmes et de ses jeunes, et prenant soin des enfants;
7. une Afrique en tant qu'acteur et partenaire fort, uni, résistant et influent à l'échelle mondiale.

(https://au.int/agenda2063/aspirations)

Africa, the birthplace of humankind (incl. stone tools and fire)

Where Is the Birthplace of Humankind? East Africa and South Africa Both Lay Claims

(1) Africa's Great Rift Valley, a large lowland area caused by tectonic plate movement that includes parts of present-day Ethiopia, Kenya and Tanzania. Researchers assigned the Lucy skeleton (the famously bipedal ape discovered in 1974 by the team led by Donald Johanson in Hadar, Ethiopia) and some other fossils to a new species, Australopithecus afarensis, dated to 3.2 million years ago.

(2) The high veld country an hour northwest of Johannesburg. In 1924, anatomist Raymond Dart found a skull of a juvenile primate among a box of fossil-bearing rocks sent to him by the manager of a quarry at Taung, on the edge of the Kalahari Desert.

Scientists believe there were numerous migratory routes out of Africa by human ancestors but the latest migration by Homo sapiens is thought to have occurred in the last 60,000-100,000 years.

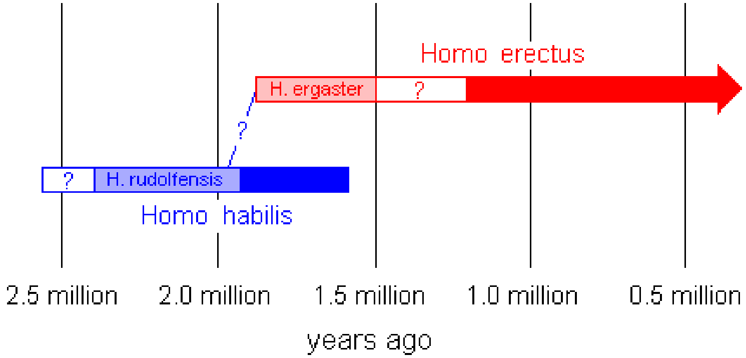
https://www.nationalgeographic.com/news/2015/09/150911-hominin-hominid-berger-homo-naledi-fossils-ancestor-rising-star-human-origins/

Stone tools date back at least 2.6 million years
Humans used fire about 1 million years ago

East Africa is famously the birthplace of humankind and the location where our ancient hominin ancestors first invented sophisticated stone tools. This technology, dating back to 2.6 million years ago, is then thought to have spread around Africa and the rest of the Old World later on.

Homo habilis was named "skillful" because it was considered the earliest tool-using human ancestor (late Australopithecus, inhabited parts of sub-Saharan Africa from roughly 2.6 to 1.5 million years ago) - https://www.britannica.com/topic/Homo-habilis and https://www.sciencealert.com/some-bone-scratches-and-stone-tools-suggest-we-were-in-north-africa-earlier-than-we-thought

At a site called Wonderwerk Cave in South Africa, scientists found evidence that humans used fire about 1 million years ago. In that cave, they found remnants of burned bone and plants and what appear to be hearths. (2012 study in the journal Proceedings of the National Academy of Sciences of the USA - https://www.pnas.org/content/109/20/E1215)



Africa (and EU): demography

How Africa meets the energy needs of a young, fast growing and increasingly urban population is crucial for the continent's – and the world's – economic and energy future.

Africa (54 countries) ranks number 2 among regions of the world (roughly equivalent to "continents"), ordered by population (1.34 billion people) and by land area (30.37 million sq km)

NB : Distance from Cape Town to Algiers = 8000 km (air line)

- **In 2018, Africa's population is 17 % of the world's population. The population density is 45 per sq km.**
- **The median age in Africa is 20 years while children under age 15 accounted for 41% of the population.**

According to UN estimates, the population of Africa may reach 2.5 billion by 2050 (about 26% of the world's total).

Almost 40 % of the population is urban (540 million people)

=> that includes an additional 500 million people who are expected to live in areas requiring some form of cooling.

*** Africa already has three megacities : two in SSA (Kinshasa and Lagos) and another in North Africa (Cairo). There are another five large cities on the continent with a population of between five and ten million each: Alexandria, Dar es Salaam, Johannesburg, Khartoum and Luanda (UNDESA). Of these, Dar es Salaam and Luanda are likely to become sub-Saharan Africa's next megacities.**

=> profound implications for the energy sector (incl. air quality, etc)

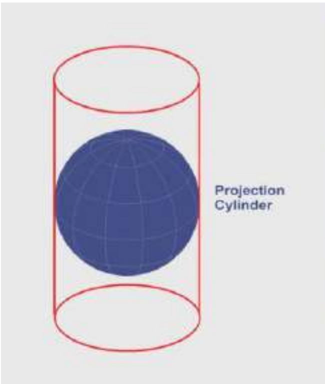
European Union (27 Member States)

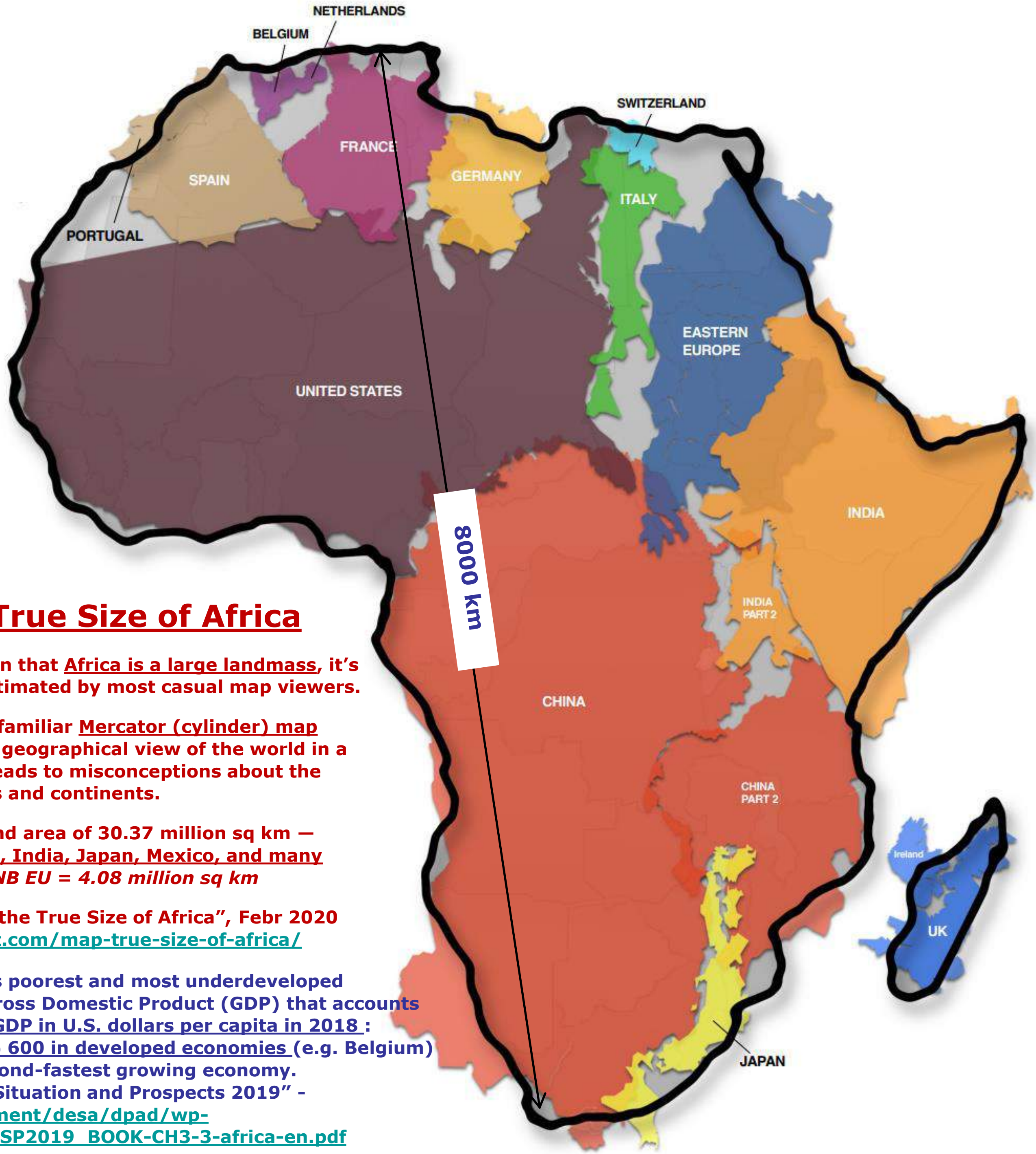
- ***Population is 445 million people (compared to 1 340)***
- ***land area is 4.08 million sq km (compared to 30.37)***
- ***population density is 105 per sq km (compared to 45) ;***
- ***median age is 42 years (compared to 20).***

AFRICAN DEVELOPMENT BANK GROUP

Source : the World Bank's work in Africa - https://www.worldbank.org/en/region/afr/overview and African Development Bank Group - https://www.afdb.org/en

The True Size of Africa + economy (GDP)





Mapped: The True Size of Africa

Despite the common perception that Africa is a large landmass, it's still one that is vastly underestimated by most casual map viewers.

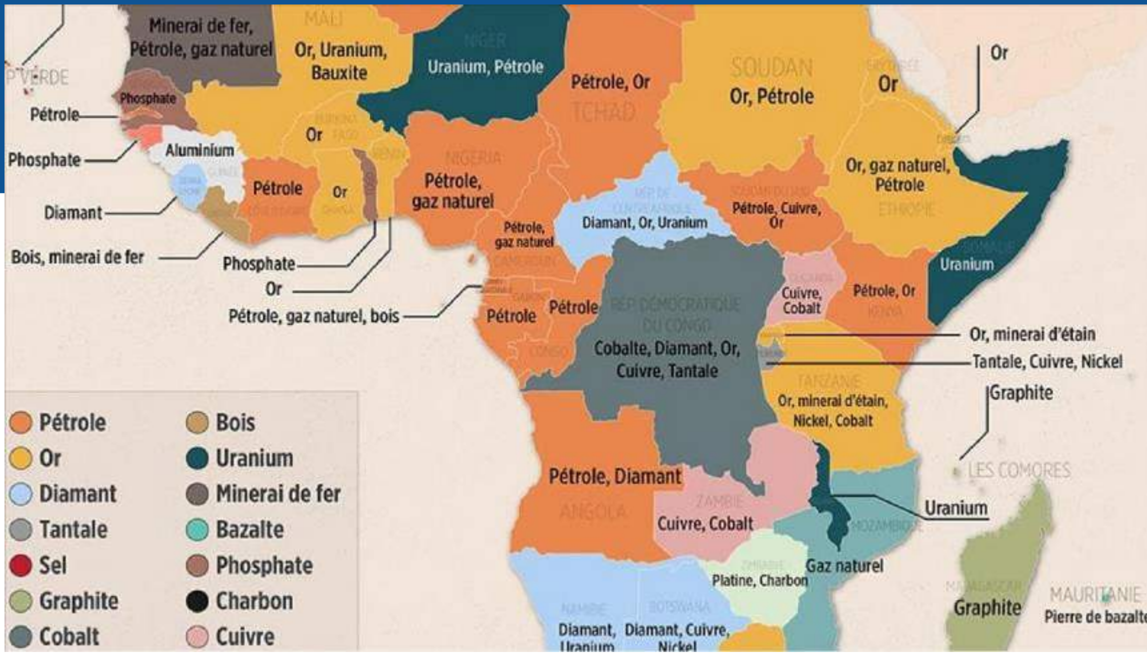
The reason for this is that the familiar Mercator (cylinder) map projection tends to distort our geographical view of the world in a crucial way — one that often leads to misconceptions about the relative sizes of both countries and continents.

The African continent has a land area of 30.37 million sq km — enough to fit in the U.S., China, India, Japan, Mexico, and many European nations, combined. *NB EU = 4.08 million sq km*

Source : "Mapped: Visualizing the True Size of Africa", Febr 2020 - https://www.visualcapitalist.com/map-true-size-of-africa/

Economy - Africa is the world's poorest and most underdeveloped continent with a continental Gross Domestic Product (GDP) that accounts for just 2.4 % of global GDP. GDP in U.S. dollars per capita in 2018 : 1 900 in Africa compared to 46 600 in developed economies (e.g. Belgium) … but it is now the world's second-fastest growing economy. Source : "UN World Economic Situation and Prospects 2019" - https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/WESP2019_BOOK-CH3-3-africa-en.pdf

Africa (and EU) 1/2 : oil, mineral and natural resources



Thanks to natural resource endowments and technology improvements, Africa could pursue a much less carbon-intensive development model than many other parts of the world have.

The challenges and opportunities differ widely across a diverse continent.

- ***But renewables, together with natural gas in many areas, are poised to lead Africa's energy consumption growth as the continent moves away from the traditional use of biomass that currently accounts for almost half of final energy consumption.***
- **Africa has approximately 30% of the earth's remaining mineral resources.**

The continent has the largest reserves of precious metals with over 20% of the gold reserves (mainly in Ghana and ZA), over 60% of the cobalt (in DRC), and 70% of the platinum reserves (in ZA).

- **Africa has the most extensive biomass burning in the world, yet only emits about 4% of the world's total carbon dioxide emissions.**

European Union (27 Member States)

- ***Europe relies on foreign raw materials to power its green and digital future.***
- ***Now (Sept 2020) Europe wants to mine them at home. The plan is to start mining in the EU itself, for battery-related raw materials such as lithium, nickel, cobalt, graphite, and manganese.***

« Les pays africains possèdent une part importante des réserves mondiales de ressources naturelles » - Même si un développement notable est observé dans l'économie africaine grâce à l'exploitation des ressources naturelles, cela à très peu de retentissement sur le quotidien de la population (Source : Radio et Télévision de Turquie /TRT/ - 23.11.2020) https://www.trt.net.tr/francais/economie/2017/07/30/les-pays-africains-possedent-une-part-importante-des-reserves-mondiales-de-ressources-naturelles-780120
See also : CIA The World Fact Book - https://www.cia.gov/library/publications/the-world-factbook/docs/refmaps.html and https://visual.ly/community/Infographics/economy/world-commodities-map-africa

Africa is rich in oil, mineral and natural resources

(Africa's enormous energy and agricultural potential is vastly untapped)

The natural resources in Africa are used practically in many industries and in many countries every day - https://www.miningafrica.net/natural-resources-in-africa/

NB : Coltan (short for columbite–tantalites) from which are extracted the elements niobium and tantalum. Tantalum from coltan is used to manufacture tantalum capacitors which are used for mobile phones, personal computers, automotive electronics, and cameras as well as in high-temperature alloys for jet engines (e.g. Airbus and the 787 Dreamliner). Le coltan est au cœur de la guerre en République démocratique du Congo, l'un des conflits les plus meurtriers depuis la Seconde Guerre mondiale avec plus de 6 millions de morts.

Africa map (2/2): minerals essential to modern energy transitions

Many of the minerals essential to modern energy transitions

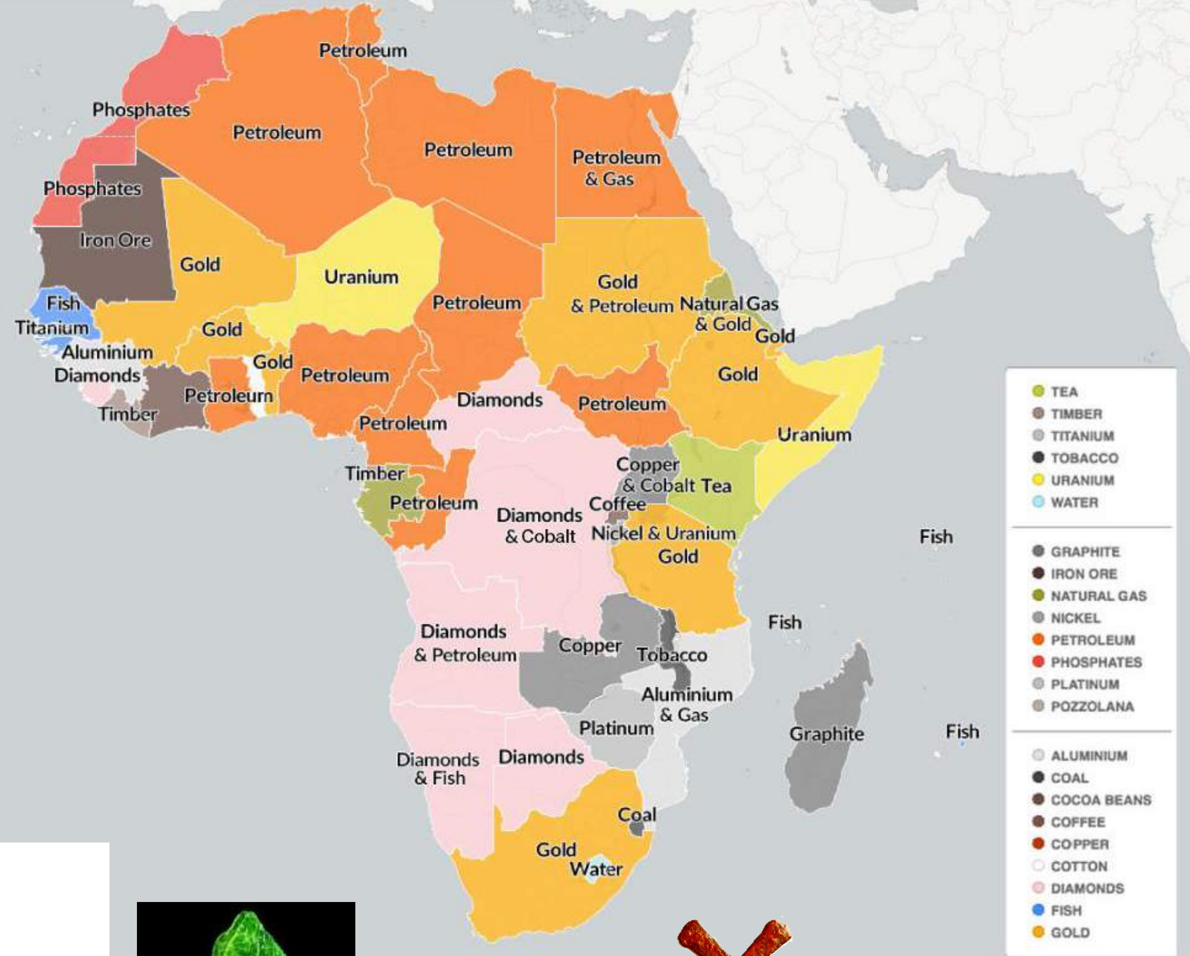
Platinum-Group Metals (PGM):

- **Palladium for autocatalysts, electronics, dental and chemical reagents (South Africa and Ethiopia) ;**
- **Platinum for jewelry and for autocatalysts (South Africa and Zimbabwe) ;**
- **Rhodium for autocatalysts (South Africa an Zimbabwe) ;**
- **Iridium ; Osmium ; Ruthenium (South Africa**

Cobalt is primarily used in lithium-ion batterie and in the manufacture of magnetic, corrosion/wear-resistant and high-strength alloys (e.g. for aircraft engine parts). (*"Le cobalt est le nouveau pétrole »*)

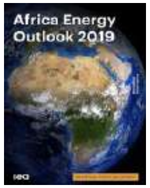
Cobalt is essential to many living creatures and is a component of vitamin B12.

Cobalt-60 is a commercially important radioisotope, used as a radioactive tracer and for the production of high-energy gamma rays.



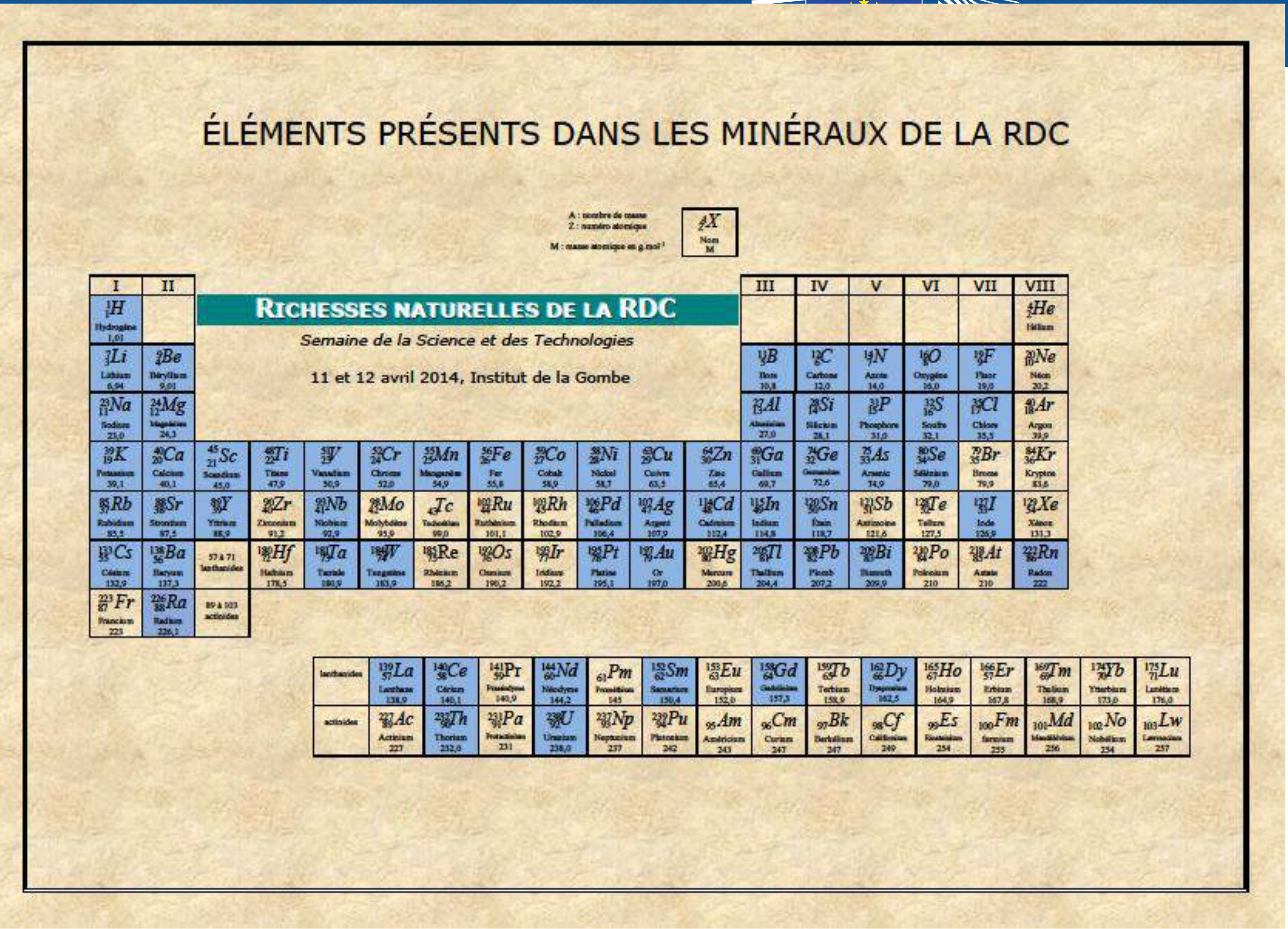
For many African countries, mineral exploration and production constitute significant parts of their economies and remain keys to economic growth. Africa is richly endowed with mineral reserves and ranks first or second in quantity of world reserves of platinum-group metals (PGM) and cobalt, as well as bauxite, industrial diamond, phosphate rock, vermiculite, and zirconium. Many other minerals are present in quantity.

The 2012 share of world production from African soil was platinum 70% and cobalt 60%, followed by uranium 18% and copper 9%; and also chromite 38%; gold 20%; bauxite 7%; aluminium 5%; iron ore 2% (and steel 1%); lead (Pb) 2%; manganese 38%; zinc 1%; natural diamond 56%; graphite 2%; phosphate rock 21%; coal 4%; mineral fuels (including coal) and petroleum 47%.



Source : https://en.wikipedia.org/wiki/Mineral_industry_of_Africa and https://www.miningafrica.net/mining-countries-africa/

RD Congo, un énorme potentiel de matières premières “un véritable scandale géologique” (1920)



Tous les métaux mentionnés dans le célèbre «tableau des éléments chimiques» du russe Mendeleïev se trouvent bel bien dans le sous sol de la République Démocratique du Congo (RDC).

C'est « un véritable scandale géologique » comme s'écrièrent les géologues belges au début des années 1900 (découvertes successives de cuivre, plomb, fer, or, platine, diamant, étain, charbon, cobalt, radium autour de 1920, uranium, zinc, cadmium, germanium, manganèse, etc)

Voir par ex. expédition Cornet-Bia-Franqui 1891-1893 au Katanga – Union Minière du Haut Katanga 1906-1981 (wikipedia).

« Saviez-vous que près de 56% des éléments chimiques du tableau périodique de Mendeleïev se retrouvent sous forme de richesses naturelles en RDC ? Il n'y a probablement que la Russie qui fait mieux. Le tableau ci-joint, présenté lors de la première édition de la Semaine de la Science et des Technologies de Kinshasa, reprend les éléments présents en RDC. »
Raissa Malu, Professeure de sciences, Ambassadrice du Next Einstein Forum (Semaine de la Science et des Technologies en RDC - décembre 2014)

https://www.facebook.com/semainedelasciencerdc/photos/a.685820258116590.1073741827.685419751489974/860498713982076/?type=1&theater
* **African shapers** - https://africanshapers.com/raissa-malu-les-stim-ne-sont-pas-plus-difficiles-que-les-langues-leconomie-ou-les-sciences-humaines/

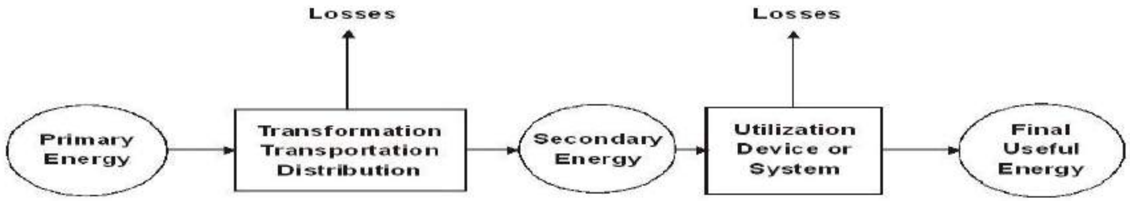
« Si les besoins en investissements dans toutes les énergies et dans les réseaux concernent tous les pays, il est remarquable que deux tiers d'entre eux auront lieu hors OCDE »

Pierre Gadonneix, président du Conseil Mondial de l'Energie, Académie des Sciences Morales et Politiques, Paris, 23 janvier 2012
https://www.asmp.fr/travaux/communications/2012_01_23_gadonneix.htm

"It is indefensible that Africa's poorest people are paying among the world's highest prices for energy. A woman living in a village in northern Nigeria spends around 60 to 80 times per unit more for her energy than a resident of New York City, or of London."
Kofi Annan (UN SG 1997 - 2006), in his introduction to 2015 report from the Africa Progress Panel on energy use in Africa.

« Le sujet central pour le développement de l'Afrique, c'est l'énergie » (Jean-Louis Borloo, ministre FR 2002 - 2010)
L'urgence d'agir : "Si la croissance des pays africains passe de 5 % à 15 % par an, cela accroîtra la nôtre de 2 %.
L'Afrique est, pour l'Europe en particulier, un relais de croissance formidable."

Table of contents (details)



Cinq étapes dans la chaîne de valeur du secteur de l'énergie, depuis l'extraction des ressources naturelles jusqu'à l'utilisation finale dans les services exigés par toute société moderne

(1) Les trois sources d'énergies primaires en Afrique (çàd disponibles dans l'environnement naturel sans transformation : renouvelables, fossiles et nucléaire), y compris les problèmes d'accès pour tous aux ressources énergétiques et minérales (dites stratégiques)

(2) Les technologies de conversion vers des énergies secondaires (dans le but de rendre les énergies primaires utilisables et transportables facilement – par ex. pour l'électricité : turbines à vapeur ou à gaz, roue hydraulique ou éolienne ; générateurs ; transformateurs)

(3) Les énergies secondaires telles que chaleur, électricité, (cogénération), carburants pétroliers raffinés (kérosène, gasoil, essence, gaz), etc - on les appelle aussi vecteurs énergétiques + stockage de l'énergie (sous forme chimique, thermique, mécanique) + hydrogène

(4) Les technologies de conversion finale vers les services énergétiques utilisés par industrie, commerce, ménages, administration, agriculture, transports, telles que pompes, fours, chaudières ; chauffage, climatisation, éclairage, électroménager ; voiture, train, avion, bateau

(5) La mise en œuvre des services énergétiques pour que l'économie soit prospère, que les maisons soient confortables, et que les services essentiels fonctionnent (tels que écoles; hôpitaux et pharmacies; transports publics; télécommunications; distribution eau, gaz, électricité, pétrole)

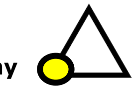
On traitera également les aspects (6) efficacité énergétique (pour parvenir à une sécurité d'approvisionnement, à une réduction des émissions de gaz à effet de serre, et à une réduction des coûts d'une manière stable et systématique, et (7) économie circulaire (visant à limiter la consommation et le gaspillage des matières premières, de l'eau et des sources d'énergie).

Republic of South Africa

(message 1/4) **ENERGY VALUE CHAIN**

Integrated energy planning seeks to consider all the key elements of the energy value-chain

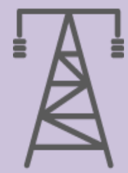
(1) Economy



PRIMARY ENERGY/ RESOURCES
- **RENEWABLES**
- Solar
- Wind
- Biomass
- Hydro
- **FOSSIL FUELS**
- Coal
- Crude Oil
- Natural Gas
- **NUCLEAR FUELS**
- Uranium
- Resources extraction and sourcing

CONVERSION TECHNOLOGIES
- **POWER GENERATION**
- Conventional Coal Plant
- Nuclear
- CCGT
- OCGT
- Solar
- Wind
- **FUEL PROCESSING**
- Oil refineries
- GTL
- CTL
- **REGASIFICATION**

SECONDARY ENERGY CARRIERS
- Electricity
- Heat
- Refined Petroleum Products



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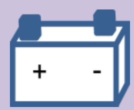
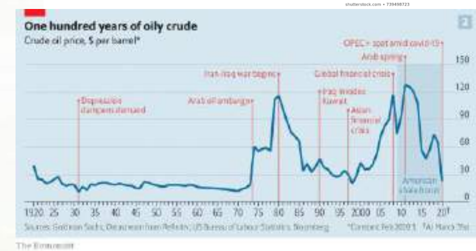
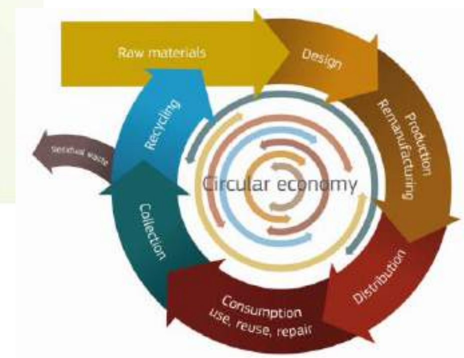


END-USE TECHNOLOGIES
- **INDUSTRY**
- Steam boilers
- Furnace
- Machinery
- **COMMERCE**
- Air Conditioning
- Light Bulbs
- **HOUSEHOLDS**
- Space Heaters
- Refrigerators
- Stoves
- Geysers
- **AGRICULTURE**
- Irrigation pumps
- **TRANSPORT**
- Vehicles
- Aircraft
- Rail

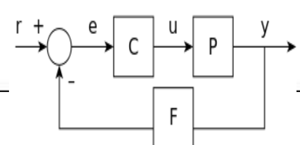
DEMAND FOR ENERGY SERVICES
- **INDUSTRIAL SECTOR**
- Process Steam
- Motive Power
- **COMMERCIAL SECTOR**
- Electronic Communication
- Cooling
- **RESIDENTIAL SECTOR**
- Space Heat
- Refrigeration
- Cooking
- Hot water
- **AGRICULTURAL SECTOR**
- Water supply
- **TRANSPORT SECTOR**
- Person kms





Economie circulaire

Department:
Energy
REPUBLIC OF SOUTH AFRICA



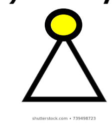
"The Energy Planning Framework considers all energy carriers, all technology options and all key national policy imperatives and proposes an energy mix and policy recommendations which ensures that the energy sector can help achieve these in the most optimal manner." (IEA)

Source : INTEGRATED ENERGY PLAN (IEP), Republic of South Africa, Dep't of Energy, 22 November 2016 - http://www.energy.gov.za/files/IEP/presentations/Integrated-Energy-Plan-22-Nov-2016.pdf and IEP Report, 20 August 2013 - http://slideplayer.com/slide/8307179/ - see also International Energy Agency (IEA, Paris) yearly "World Energy Outlook" projections

Despite its large and growing population, Africa accounts for a very small share of global energy sector investment. In 2018, around $100 billion was invested in the energy sector in Africa, or about 5.5% of the global total. Of this, $70 billion was invested in fossil fuels and $13 billion in renewables. Another $13 billion was spent on electricity networks.

"Energy, a primary driver for human development"

(2) Society



The multiplier effect of energy access - Energy as an enabler

***Energy** is an enabler to foster economic development, create jobs, facilitate education and health services, empower women, ensure **food** production and **water** supply and perform many other actions required for overall development of societies (**NEXUS**). The relationship of energy with "Human Development Index" (HDI) is well known and established.*

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD

UN Agenda-2030 (Sept 2015) : 17 "Sustainable Development Goals"
The proposed 17 "SDGs for people and planet" cut across all of the most critical social, economic and environmental issues of our time.

(message 3/4) "We need all energy conversion technologies" (+ energy triangle)

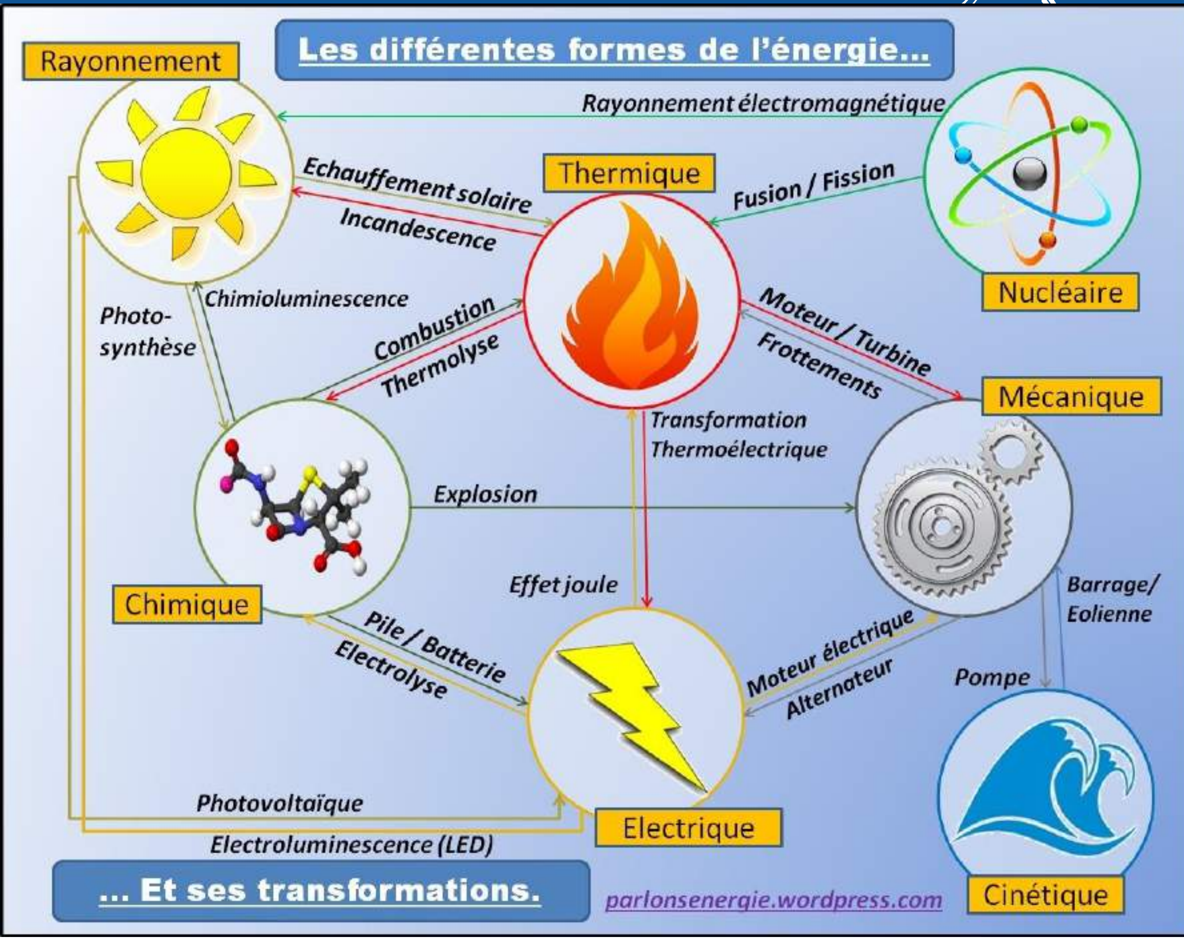
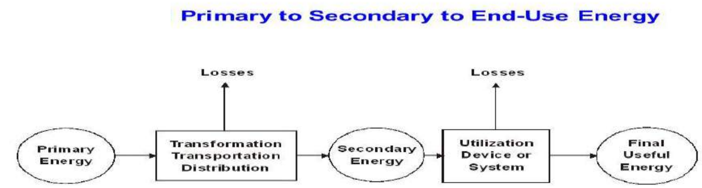
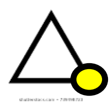


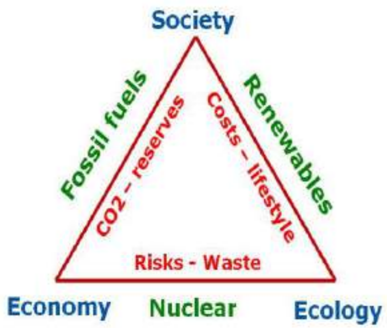
Figure à gauche - Différentes formes d' « énergies libres » (sept au total): gravitation ; cinétique ; thermique ; radiative ; chimique ; électrique ; nucléaire



Améliorer l'efficacité énergétique tout au long des chaînes de valeur



(3) Ecology

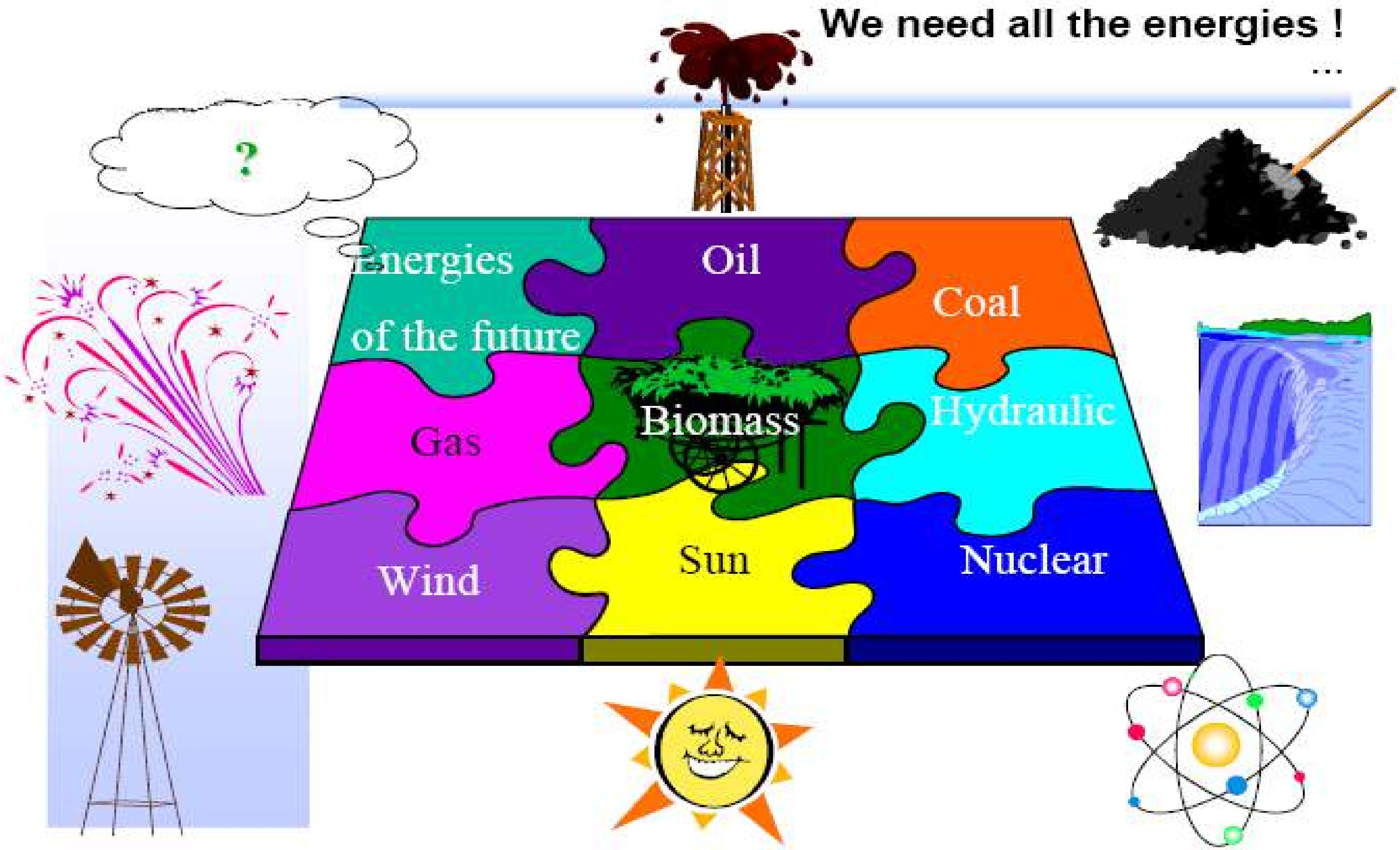


In supplying society with energy, a balance must be struck between (1) economy (competitiveness), (2) society (security of supply) and (3) ecology (environment).

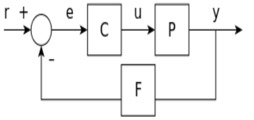
No single energy source is optimal from all dimensions (optimum within energy triangle).

Understanding the pros and cons of each primary energy source (renewables, fossil, nuclear) can help us make a more informed decision about our own energy use.

(message 4/4) **All energy sources have positive and negative effects**



In 2018, total primary energy demand (TPED) in Africa was more than 830 million tonnes of oil equivalent (Mtoe) /or 9650 TWh/. IEA prospects in 2040 : TPED reaches 1350 Mtoe */or 15700 TWh/* in the IEA “Stated Policies Scenario” (STEPS) and 1200 Mtoe /or 13950 TWh/ in the IEA “Africa Case” (AC). *NB : 2018 TPED in Africa = 21 times that in Belgium*



including electricity demand in Africa which is today circa 700 terawatt-hours (TWh), with the North African economies and South Africa accounting for over 70% of the total. IEA prospects in 2040 : Electricity demand more than doubles in STEPS to over 1 600 TWh, and reaches 2 300 TWh in AC, with most of the additional demand stemming from productive uses and emerging middle- and higher-income households.

NB : 2018 total electricity demand in Africa = 8 times that in Belgium.

= > Electricity today accounts for less than 10 % of Africa’s total final energy consumption.

Agenda 2063

the future that Africa wants

In 2015, the Heads of State and Governments of the African Union adopted Agenda 2063.
It sets out a vision for "an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena".
Closely linked to the United Nations "Sustainable Development Goals" (SDGs), it is an ambitious vision and one which will require significant political will if its goals are to be realised.

Agenda 2063, the continent's inclusive and sustainable vision for accelerated economic and industrial development

Agenda 2063 builds on previous Pan-African initiatives, but is distinct in many respects:

- it sets out clear goals, implementation plans and targets alongside elements of accountability;
- it identifies key flagship programmes as well as monitoring and review mechanisms;
- and it proposes a clear resource mobilisation strategy.

Successful delivery of Agenda 2063 is likely to depend on good governance, transparency and effective intra-African co-ordination, among other things.
It will also depend on resources being available to implement it and in particular on the mobilisation of private sector resources.

Energy-related targets contained in the framework for the first ten years include increasing access to electricity by at least 50% compared to 2013 levels and increasing the efficiency of household energy use by at least 30% before 2023.
As a reminder, the SDGs include full access to electricity and clean cooking by 2030 and a significant reduction in premature deaths related to pollution.

"Africa Energy Outlook 2019", World Energy Outlook special report, Nov 2019 - https://www.iea.org/reports/africa-energy-outlook-2019

"Sustainable Development Goals" (world) and "Agenda 2063" (Africa)

"Sustainable Development Goals" (17 SDGs)

1 End poverty in all its forms everywhere
2 End hunger, achieve food security and improve nutrition and promote sustainable agriculture
3 Ensure healthy lives and promote well-being for all at all ages
4 Ensure inclusive and equitable education and promote lifelong learning opportunities for all
5 Achieve gender equality and empower all women and girls
6 Ensure availability and sustainability management of water and sanitation for all
7 Ensure access to affordable, reliable, sustainable and modern energy for all
8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10 Reduce inequality within and among countries
11 Make cities and human settlement inclusive, safe, resilient and sustainable
12 Ensure sustainable consumption and production patterns
13 Take urgent action to combat climate change and its impacts
14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15 Protect, restore & promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, & halt and reverse land degradation & halt biodiversity loss
16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17 Strengthen the means of implementation and revitalize the global partnership for sustainable development

"Agenda 2063 Goals" (20 Goals)

1 A high standard of living, quality of life and wellbeing for all
2 Well educated citizens and skills revolution underpinned by science, technology & innovation
3 Healthy and well-nourished citizens
4 Transformed economies and job creation
5 Modern agriculture for increased productivity and production
6 Blue ocean economy for accelerated economic growth
7 Environmentally sustainable climate resilient economies and communities
8 United Africa (Federal or Confederate)
10 World class infrastructure criss-crosses Africa
11 Democratic values, practices, universal principles of human rights, justice & the rule of law entrenched
12 Capable institutions and transformed leadership in place at all levels
13 Peace, security and stability are preserved
16 African cultural renaissance is pre-eminent
17 Full gender equality in all spheres of life
18 Engaged and empowered youth and children
19 Africa as a major partner in global affairs and peaceful co-existence
20 Africa takes full responsibility for financing her development

Source : https://sdgcafrica.org/wp-content/uploads/2018/09/AFRICA-SDGS-2018-Report-WEB-V6-220818-1.pdf

Flagship projects of Agenda 2063 (1/2)

Agenda 2063

THE AFRICAN WE WANT

PROUDLY MADE IN AFRICA

The flagship projects of Agenda 2063 (15 in total) refers to key programmes and initiatives which have been identified as key to accelerating Africa's economic growth and development as well as promoting our common identity by celebrating our history and our vibrant culture. The Flagship projects encompass amongst others infrastructure, education, science, technology, arts and culture as well as initiatives to secure peace on the continent.

1. INTEGRATED HIGH SPEED TRAIN NETWORK

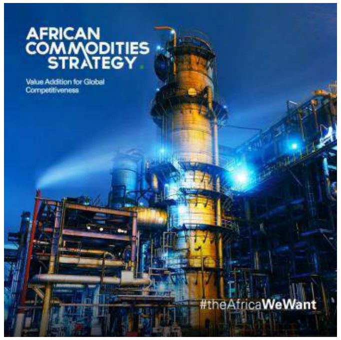
The project aims to connect all African capitals and commercial centres through an African High Speed Train Network thereby facilitating the movement of goods, factor services and people. The increased connectivity by rail also aims to reduce transport costs and relieve congestion of current and future systems.

Ref : The Department of infrastructure and energy - https://au.int/en/flagships/integrated-high-speed-train-network

2. FORMULATION OF AN AFRICAN COMMODITIES STRATEGY (resources and raw materials)

The development of a continental commodities strategy is seen as key to enabling African countries to add value, extract higher rents from their commodities, integrate into the Global Value chains, and promote vertical and horizontal diversification anchored in value addition and local content development. The strategy aims to transform Africa from simply being a raw materials supplier for the rest of the world to a continent that actively uses its own resources to ensure the economic development of Africans.

Ref : The Department of Trade and Industry (DTI) - https://au.int/en/ti



6. IMPLEMENTATION OF THE GRAND INGA DAM PROJECT

The development of the Inga Dam is expected to generate 43,200 MW of power, to support current regional power pools and their combined service to transform Africa from traditional to modern sources of energy and ensure access of all Africans to clean and affordable electricity.

Ref : Department of Trade and Industry (DTI) - https://au.int/en/flagships/grand-inga-dam-project

Flagship projects of Agenda 2063 (2/2)

Agenda 2063

THE AFRICAN WE WANT

PROUDLY MADE IN AFRICA

<u>10. THE PAN-AFRICAN E-NETWORK</u>

This aims to put in place policies and strategies that will lead to transformative e-applications and services in Africa; especially <u>the intra-African broad band terrestrial infrastructure</u>; and <u>cyber security</u>, making the information revolution the basis for service delivery in the bio and nanotechnology industries and ultimately <u>transform Africa into an e-Society</u>. Ref : https://au.int/en/ie

<u>11. AFRICA OUTER SPACE STRATEGY</u>

The Africa outer space strategy aims to strengthen Africa's use of outer space to bolster its development. Outer space is of critical importance to the development of Africa in all fields: <u>agriculture</u>, <u>disaster management</u>, <u>remote sensing</u>, <u>climate forecast</u>, <u>banking and finance</u>, as well as <u>defence and security</u>. Africa's access to space technology products is no longer a matter of luxury and there is a need to speed up access to these technologies and products. New developments in satellite technologies make these accessible to African countries and appropriate policies and strategies are required to develop a regional market for space products in Africa.

Ref : Human Resources, Science & Technology Department (HRST) : https://au.int/en/hrst

<u>12. AN AFRICAN VIRTUAL AND E-UNIVERSITY</u>

This project aims to use ICT based programmes to <u>increase access to tertiary and continuing education</u> in Africa by reaching large numbers of students and professionals in multiple sites simultaneously. It aims to develop relevant and high quality <u>Open, Distance and eLearning resources</u> to offer students guaranteed access to the University from anywhere in the world and anytime (24 hours a day, 7 days a week).

Ref : Human Resources, Science & Technology Department (HRST) : https://au.int/en/hrst

Source : Flagship Projects of Agenda 2063 (African Union) - https://au.int/agenda2063/flagship-projects

Aspiration 1: A Prosperous Africa

The Seven Aspirations (https://au.int/agenda2063/aspirations)

- Aspiration 1: A prosperous Africa based on inclusive growth and sustainable development
- Aspiration 2: An integrated continent; politically united and based on the ideals of Pan-Africanism and the vision of Africa's Renaissance
- Aspiration 3: An Africa of good governance, democracy, respect for human rights, justice and the rule of law
- Aspiration 4: A peaceful and secure Africa
- Aspiration 5: An Africa with a strong cultural identity, common heritage, shared values and ethics
- Aspiration 6: An Africa, whose development is people-driven, relying on the potential of African people, especially its women and youth, and caring for children
- Aspiration 7: Africa as a strong, united, resilient and influential global player and partner.

Aspiration 1: A Prosperous Africa based on inclusive Growth and Sustainable Development:

- ending poverty, inequalities of income and opportunity;
- job creation, especially addressing youth unemployment;
- facing up to the challenges of rapid population growth and urbanization, improvement of habitats and access to basic necessities of life – water, sanitation, electricity;
- providing social security and protection;
- developing Africa's human and social capital (through an education and skills revolution emphasizing science and technology) and expanding access to quality health care services, particularly for women and girls;
- transforming Africa's economies through beneficiation from Africa's natural resources, manufacturing, industrialization and value addition, as well as raising productivity and competitiveness;
- radically transforming African agriculture to enable the continent to feed itself and be a major player as a net food exporter;
- exploiting the vast potential of Africa's blue/ocean economy;
- and finally putting in place measures to sustainably manage the continent's rich biodiversity, forests, land and waters and using mainly adaptive measures to address Climate change risks.

Source : "AGENDA 2063 - The Africa We Want - A Shared Strategic Framework for Inclusive Growth and Sustainable Development" – "First Ten Year Implementation Plan of Agenda 2063 (2013 – 2023)" - September 2015, AUC African Union Commission - https://au.int/en/agenda2063/ftyip and NEPAD (143 pages) - https://www.nepad.org/agenda-2063/publication/agenda-2063-first-ten-year-implementation-plan-2014-2023-0

"Agenda 2063" - First Ten Year Implementation Plan (2013 – 2023) 2/3

Aspiration 1 (cont'd): A Prosperous Africa

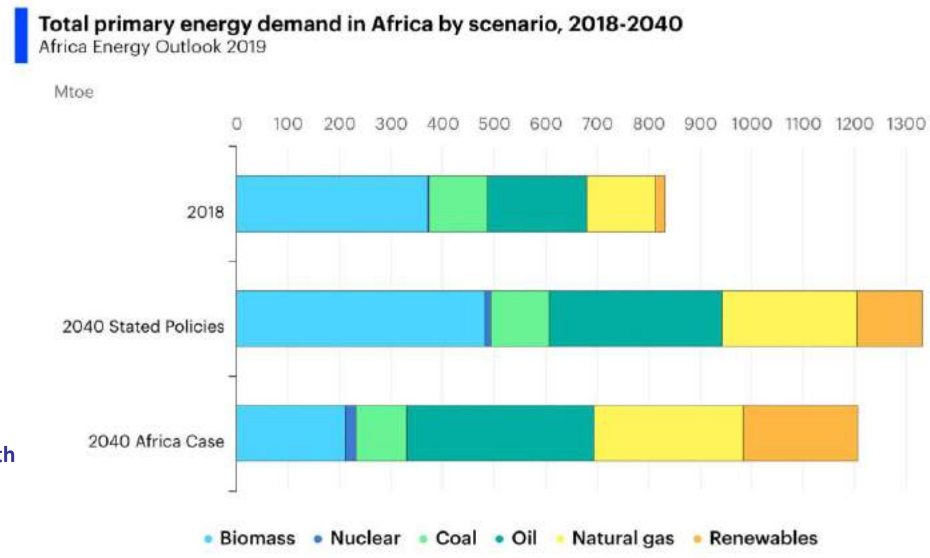


Figure - A major shift towards modern and efficient energy mix

Africa could be the first continent where <u>renewables and gas</u> play a prominent role in supporting <u>a shift away from bioenergy</u> and underpinning economic and industrial growth

<u>Aspiration 1. A prosperous Africa</u> based on inclusive growth and sustainable development

There are seven goals under this aspiration with seventeen priority areas.
The goals under this aspiration are numbered as goals 1-7 in the results framework.

…………

<u>Goal 7: Environmentally sustainable climate resilient economies and communities</u>
(aligned with SDG 7 - Ensure access to affordable, reliable, sustainable and modern energy for all) ……

<u>Priority area (3) : Climate Resilience and Natural Disasters and preparedness</u> …………

2023 Target

4. Reduce proportion of fossil fuel in total energy production by at least 20%
5. All Cities meet the WHO's Ambient Air Quality Standards (AAQS) by 2025

………………………

<u>Priority area (4) : Renewable Energy</u>

2023 Target

1. Raise the share of renewable energy (wind, solar, hydro, bio and geothermal) in total energy production by at least <u>10%</u>
2. At least <u>10%</u> of all urban buildings are certified as energy smart
3. At least <u>15%</u> of all urban mass transport operate on low renewable and low emissions fuel Indicative Strategies

Quantitative targets

To achieve the above targets, the following <u>indicative strategies</u> will have to be considered

1. Develop and implement policies, strategies and regulations to promote <u>sustainable growth of the energy sector</u>
2. Promote the development and dissemination of <u>energy efficient technologies</u> and use clean energy sources
3. Ensure financing of education, adoption and use of <u>renewable energy technologies</u>

Aspiration 2:
An integrated continent

Agenda 2063

THE AFRICAN WE WANT

Aspiration 2. An integrated continent, politically united and based on the ideals of Pan Africanism and vision of Africa's Renaissance

There are two goals under this aspiration with three priority areas.
The goals under this aspiration are numbered as goals 8-10 in the results framework………….

Goal 10: World Class Infrastructure crisscrosses Africa

Priority Area (1) - Communications and Infrastructure Connectivity

2023 Target – Continental/Regional

1. Regional Power Pools fully operational by 2020
2. INGA Dam is commissioned by 2025

INGA Dam

1. ADEPI with mandate to develop and promote Grand Inga Dam is established in 2015; technical studies, preparation of tender documents and resource mobilization are also completed in the same year
2. Design work and field preparation is completed by 2016 with commencement of work in 2017
3. Commissioning is expected in 2024

Other PIDA Initiatives on Energy *(NB PIDA = Programme for Infrastructural Development in Africa)*

1. Increase in generation of electricity by 42,000 MW through hydro and renewable energy initiatives achieved by 2020
2. Additional 10,000 MW in partnership with Power Africa is attained by 2020
3. Feasibility Studies for PIDA 2021-2030 completed by 2020

Quantitative targets

Uganda–Tanzania East African Crude Oil Pipeline (EACOP)

Lake Albert is an on-shore development in the north west of Uganda. The site has seen many significant discoveries and appraisals and is estimated to hold around 1.7 billion barrels of oil in place. The EACOP is a 1,443km, 24-inch diameter heated and buried crude oil pipeline that will start from Hoima in Uganda to Tanga in Tanzania. Albertine Graben Refinery Consortium (AGRC), is a consortium of international companies that have agreed with the government of Uganda, to invest in, construct, operate and co-own the Uganda Oil Refinery (60,000 b/d).

ANNEX 5: CRITICAL SUCCESS FACTORS,
POTENTIAL RISKS AND MITIGATION STRATEGIES

…. 2. Risks, Threats and Mitigation Strategies …

…… External Shocks …Disruptive Technologies:

…For example in the area of oil, Africa still has the responsibility

- to provide power to homes, factories and offices;
- to provide petrol to the growing middle class that will be owning their own cars.

Africa can therefore in the medium term not be bothered by a declining demand for her oil by the rest of the world as a result of a replacement of oil through a disruptive technology.

Indicative Strategies

To achieve the above targets, the following indicative strategies have to be considered

National ……………………

7. Implement high capacity oil refinery and oil and gas pipeline strategy
8. Ensure provision of ICT infrastructure and alternative infrastructure roll out
9. Develop / implement renewable energy generation policy and increase generation capacity
10. Prepare/ implement geothermal projects to increase generation by 200% through GRMF
11. Implement Summit Decision on Africa Bio Energy Policy Framework and Guidelines and increase electricity generation in the bio-energy component in the African energy mix ………..
13. Develop / implement policies for sustainable energy development / usage capacities, research and development and financing *(NB GRMF = Geothermal Risk Mitigation Facility)*

Continental / Regional

1. Promote Think Tanks for ICT and Energy ……….
7. Develop/implement continental legal framework to promote integrated energy market ……

"Le Grand Inga – 40 GW"

Hydro-electricity
(reliable, predictable and dispatchable … but)

"Le Grand Inga", méga-barrage, sur le deuxième fleuve du Monde,
40 GW (2 x le barrage chinois des Trois Gorges),
coût total estimé à environ 80 milliards USD
(including 10 billion USD, cost of the transmission lines needed to carry its power across Africa and potentially to Europe)

« Parmi toutes les énergies renouvelables, c'est l'hydro-électricité qui est la plus économique, car compétitive sans subventions couteuses, et sans problème d'intermittence ni de stockage pour les gestionnaires des réseaux électriques. Elle offre de plus des avantages uniques pour la gestion du réseau électrique (réglage de la fréquence et de la tension). Par ailleurs les besoins en eau douce, en eau potable et en irrigation, vont aussi beaucoup augmenter, avec le changement climatique annoncé. …Les infrastructures de stockage d'eau sont considérées comme des outils indispensables à la fois pour le développement durable et pour l'adaptation au changement climatique.
Pourtant le développement des barrages est controversé, au Nord comme au Sud, du fait des impacts potentiels, et les projets nouveaux se heurtent souvent à des oppositions parfois fortes. »

Source : Henri Boyé, US-AID Electrification Advisor

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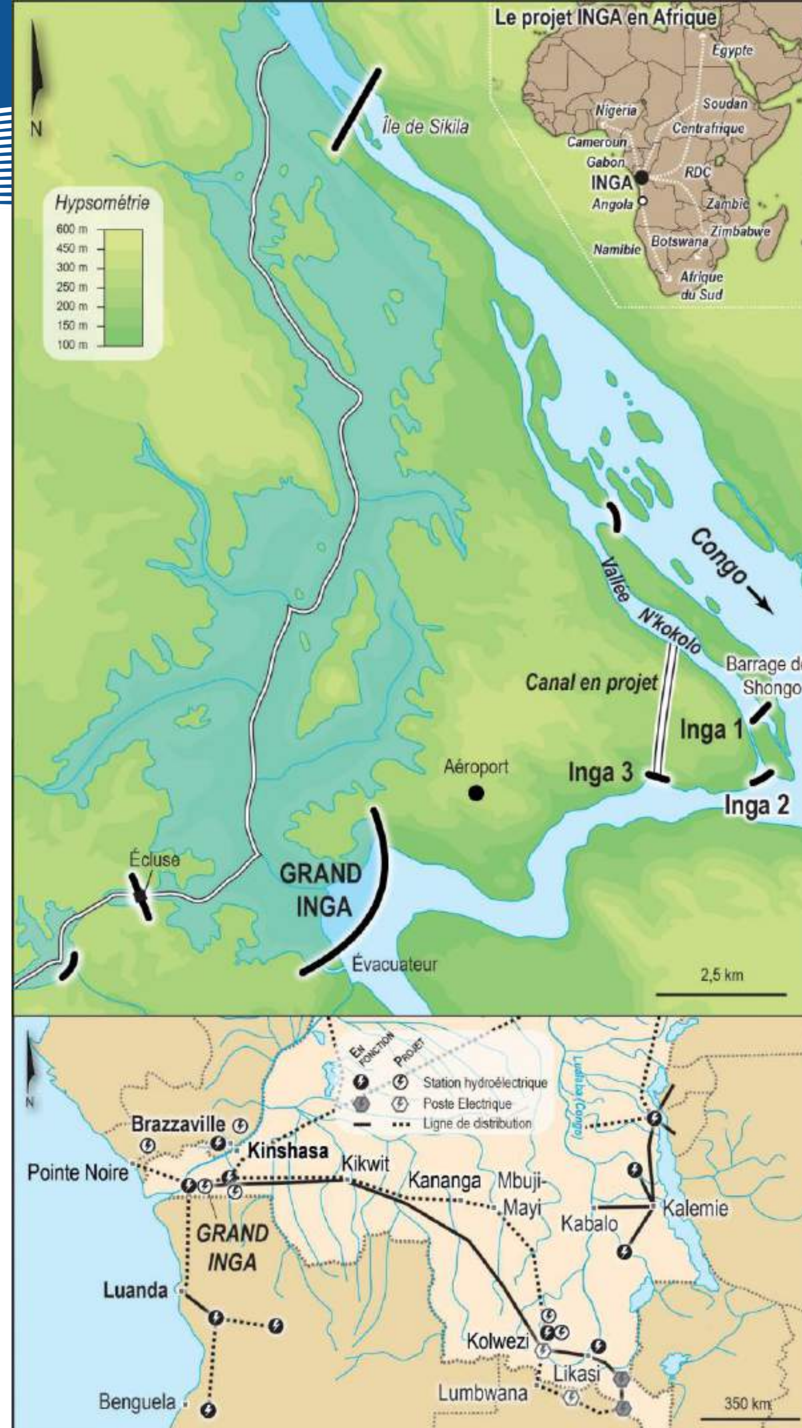
ABUNDANT RENEWABLE ENERGY RESOURCES LOCATED CLOSE TO POTENTIAL DEMAND CLUSTERS

DRC has rich hydro resources distributed across the territory and some of this potential is in close proximity to extractive industries and population centers. The DRC hydrological technical potential is estimated to be around 100 GW among which 70 GW have already been specifically localized and most of this potential (64 GW) being concentrated in Bas Congo Province.
………… Unfortunately, the focus on expanding the Inga power plant has tended to delay the development of other hydro-power sites, especially smaller ones.

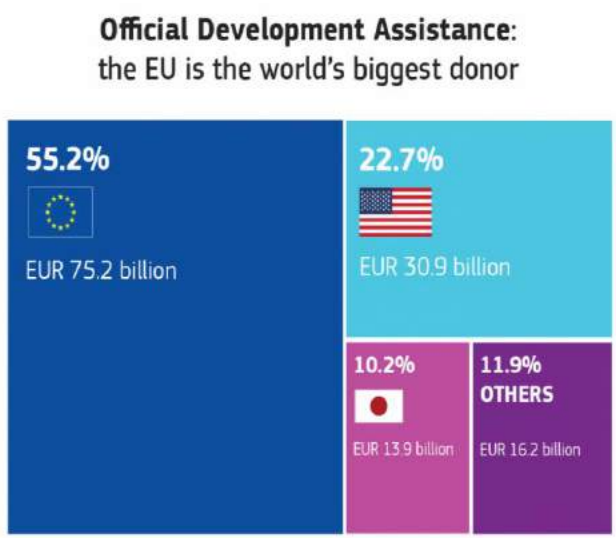
Source : "Increasing access to electricity in the Democratic Republic of Congo - Opportunities and challenges", Washington, DC - World Bank 2020 - http://documents1.worldbank.org/curated/en/743721586836810203/pdf/Increasing-Access-to-Electricity-in-the-Democratic-Republic-of-Congo-Opportunities-and-Challenges.pdf ***and*** https://www.petroleum-economist.com/articles/low-carbon-energy/energy-transition/2020/germany-eyes-drc-hydrogen-project



"Le Grand Inga et les projets de connexion internationale - https://dei.hypotheses.org/494

Lire aussi : "Inga III: Nous sommes en train de nous préparer pour que la première pierre soit posée par le président de la République en 2021", 16 novembre 2020 – Extrait : « Nous travaillons pour que l'énergie d'Inga III soit disponible (…) avant 2030. Inga III va générer 11.000 MW qui vont être repartis comme suit: 3.500 MW sont réservés à l'Afrique du Sud, 4000 MW reviendront à Aluminium corporation of China, une des plus grandes entreprises chinoises de production d'aluminium qui va produire, tout près d'Inga, dans le Bas-Fleuve, dans un premier temps, 1 million de tonnes d'aluminium pour un investissement de 6 milliards de dollars » - https://www.politico.cd/encontinu/2020/11/16/inga-iii-nous-sommes-en-train-de-nous-preparer-pour-que-la-premiere-pierre-soit-posee-par-le-oresident-de-la-republique-en-2021-bruno-kapandji.html/72218/

EuropeAID - The EU is the largest donor in the world



The European Union remains world's leading donor of Official Development Assistance with € 75.2 billion in 2019

NEWS 16 April 2020 Brussels
https://ec.europa.eu/international-partnerships/news/european-union-remains-worlds-leading-donor-official-development-assistance_en

The collective Official Development Assistance (ODA) from the European Union and its Member States amounted to € 75.2 billion in 2019, representing 55.2 % of global assistance, according to preliminary figures released today by the Organisation for Economic Co-operation and Development's Development Assistance Committee (OECD-DAC).

The EU's and its Member States collective assistance represented 0.46 % of EU Gross National Income (GNI), slightly lower than the 0.47 % in 2018, but remains significantly above the 0.21% average of the non-EU members of the DAC.

Source : EU Aid Explorer - a one-stop shop for funding information: it facilitates donor coordination, ensures transparency and improves accountability to citizens - https://euaidexplorer.ec.europa.eu/

EUROPEAID

USAID FROM THE AMERICAN PEOPLE

EU BUDGET FOR THE FUTURE 2021-2027 : THE "*NEIGHBOURHOOD, DEVELOPMENT AND INTERNATIONAL COOPERATION INSTRUMENT*" (NDICI)

The European Union, with its Member States, is the world's biggest donor of development assistance and among the first global trading partners and foreign investors (*).
As a Union promoting peace, stability and a rules-based global order, it is faced with many challenges as well as opportunities in an increasingly complex and inter-connected world. Prosperity and peace in the EU's neighbourhood and beyond are crucial for the EU's own stability and security. This is why the European Union is proposing an increase in its current budget for the next Multiannual Financial Framework. The Commission's 2021-2027 budget proposal of May 2020 earmarks € 86 billion (in 2018 prices) for the "Neighbourhood, Development and International Cooperation Instrument" (NDICI) …, more than an 8% increase to the 2018 proposal. The NDICI will be the EU's main financial tool to contribute to eradicating poverty and promoting sustainable development, prosperity, peace and stability.

(https://ec.europa.eu/international-partnerships/system/files/factsheet-mff-multiannual-financial-framework-v08-clean_0.pdf)

*(*) **Sustainable investments - Public and private investments are crucial to stimulating entrepreneurship and sustainable economic diversification.** ….*

*With a foreign direct investment stock reaching EUR 222 billion, **the EU is the largest investor in Africa**, well ahead of the United States (EUR 42 billion) or China (EUR 38 billion). Under the umbrella of the **Africa-Europe Alliance for Sustainable Investment and Jobs**, EU instruments, such as the External Lending Mandate, the African, Caribbean and Pacific Investment Facility and, more recently, the European External Investment Plan, have unlocked considerable investments in Africa. These include investments in **transport**, **clean energy** and **agricultural sectors** and in **private sector development**. (Source : :"Africa-Europe Green Energy Initiative")*

UE-UA « l'Europe sera au rendez-vous. C'est une priorité pour mon nouveau mandat … Que vive l'alliance entre l'Europe et l'Afrique » 2020

Addis Abeba - 8 décembre 2019 - Ursula Von der Leyen, la présidente de la CE, rencontre la seule cheffe d'Etat africaine du moment, Sahle-Work Zewde (élue en 2018)

Ursula von der Leyen, la nouvelle présidente de la Commission de l'Union européenne, a choisi Addis Abeba (la capitale éthiopienne et le siège de l'Union africaine) pour son tout premier déplacement après sa prise de fonction le 1 décembre 2019.
Elle est venue pour prendre la température et pour essayer de comprendre pourquoi la coopération entre l'UE et l'UA marche encore au ralenti : "*Il y a des progrès, c'est certain, même si les choses n'avancent pas toujours aussi vite que nous le souhaiterions ou n'ont pas toujours la qualité que nous aimerions*", admet Ursula von der Leyen. "*Je souhaite savoir quels sont les projets qui fonctionnent. Quels sont ceux qui ne marchent pas. Autrement dit : séparer les vrais succès des tigres de papier*."
https://www.dw.com/fr/von-der-leyen-en-afrique-pour-son-premier-déplacement-hors-ue/a-51581915

« La RDC et M. Tshisekedi à la présidence de l'Union africaine en 2021 », LLB - 10 février 2020
https://afrique.lalibre.be/46542/la-rdc-et-m-tshisekedi-a-la-presidence-de-lunion-africaine-en-2021/

Reminder : Chairs of Assembly of the African Union :
- *Feb 2020 to Feb 2021 - Cyril Ramaphosa, South Africa*
- *Feb 2019 to Feb 2020 - Abdel Fattah el-Sisi, Egypt*
- *Jan 2018 to Feb 2019 - Paul Kagame, Rwanda*

Conseil européen - Conseil de l'Union européenne - 9 février 2020

Discours du président Charles Michel lors du dîner officiel du 33-ème sommet de l'Union africaine à Addis-Abeba

…. Votre voisin du nord change de visage. Je suis ce soir le porte-voix de vingt-sept pays européens, dont vingt et un n'ont jamais eu de colonies.
Une nouvelle génération de dirigeants arrive au pouvoir. Ils ne sont pas encombrés par le poids de la nostalgie.
Nous voulons nous tourner vers l'avenir, et vers nos voisins. Nous voulons prendre à bras-le-corps le changement climatique et la révolution numérique, les deux principaux défis auxquels nous sommes confrontés.
L'Europe veut se faire entendre davantage sur la scène internationale, où ses valeurs inspirent son action.
…………. Je le dis avec solennité, l'Europe sera au rendez-vous. C'est une priorité pour mon nouveau mandat comme président du Conseil européen.
Nous sommes à l'aube d'une nouvelle décennie. Nous sommes prêts à échanger, partager et coopérer.
Que vive l'alliance entre l'Europe et l'Afrique.
https://www.consilium.europa.eu/fr/press/press-releases/2020/02/09/speech-by-president-charles-michel-at-the-official-dinner-of-the-african-union-summit-in-addis-ababa/

Africa-Europe Green Energy Initiative (March 2020)

EC Communication "Towards a comprehensive Strategy with Africa" (09.03.2020)

European Union
EXTERNAL ACTION

To strengthen the EU's strategic alliance with Africa, the European Commission and the High Representative of the Union are proposing to engage discussions with African partners in view of jointly defining at the upcoming EU-AU Summit a new comprehensive EU strategy with Africa that could be built on five partnerships:

1. **A partnership for green transition and energy access;**
2. **A partnership for digital transformation;**
3. **A partnership for sustainable growth and jobs;**
4. **A partnership for peace and governance; and**
5. **A partnership on migration and mobility.**

I. Partners for green transition and energy access

***The fight against climate change and environmental degradation is this generation's defining task*. Therefore, Europe and Africa are allies in the development of sustainable energy, transport solutions, farming, circular and blue economies which can underpin Africa's economic growth.**
To achieve the Sustainable Development Goals, the EU and Africa alike need to opt for a low-carbon, resource efficient and climate-resilient future in line with the Paris Agreement. African countries are particularly vulnerable to climate change as it risks jeopardising ongoing progress on sustainable development…………

I.1 Innovation is key to drive green transition.
Investments should therefore be geared towards strengthening scientific capacities in Africa by providing access and local adaptation to technologies. This will enable African countries to pursue a low-carbon, climate resilient and green growth trajectory, that avoids inefficient technologies and resists new investment in coal power generation, deploying instead new renewable energy sources and hydrogen production. Trade should also facilitate the adoption of innovative, sustainable business models and play a leading role to shape a climate-neutral future.

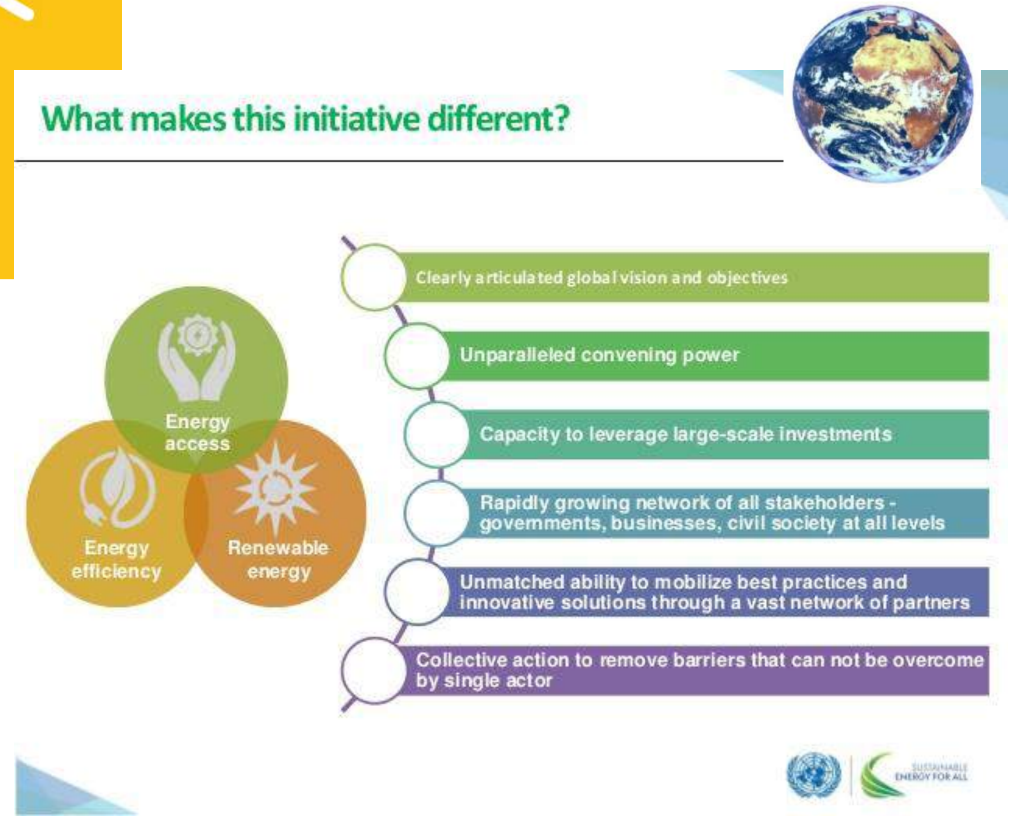
I.2 Africa is home to vast natural capital, unique biodiversity and ecosystems such as forests.
This offers significant opportunities for social and economic development and can contribute to lasting nature-based solutions to climate change mitigation and adaptation.
At the same time, there is a risk of overexploitation and depletion in addition to the threats posed by unsustainable fishing and management of water resources, pollution, desertification, and, in the case of coastal areas, rising sea levels.

I.3 A clean circular economy with sustainable and fair value chains will be key for the transition to a sustainable economic model.
This means that the value of products, materials and resources are maintained in the economy for as long as possible. It also implies that waste is minimised, while natural resources, wastewater and sanitation are managed in a sustainable way.
This requires enhanced cooperation between the EU and Africa on a responsible raw materials sector, secure and clean industrial value chains, respecting ambitious environmental and climate standards.

I.4 African cities have a key role to play in the green transition; the EU should support the development of green and smart urbanisation models and businesses in Africa, thereby tackling pollution.
To address the needs of its growing population and economy, Africa needs to double its energy supply by 2040 while ensuring access to electricity for 600 million people. This means putting the focus on resilient infrastructure, cleaner, more sustainable and secure energy access, maximising renewable energy sources, energy transition and efficiency across all value chains, as well as regional integration for energy security. The EU should build with Africa a strong partnership on sustainable energy for both rural and urban populations.

Source :"Africa-Europe Green Energy Initiative", laid out in the EC Communication 'Towards a comprehensive Strategy with Africa' JOIN(2020) 4 (09.03.2020) - https://ec.europa.eu/international-partnerships/system/files/communication-eu-africa-strategy-join-2020-4-final_en.pdf

SDG-7 : Ensure universal access to affordable, reliable, and modern energy services 1/2



Importance of Sustainable Energy for Sustainable Development

- Globally, 1.2 billion people had no access to electricity in 2010, and more than 95% of these people are either in sub-Saharan Africa or developing Asia.
- 2.8 billion people still (in 2018) burn wood, dung, coal and other traditional fuels inside their homes, resulting in 1.5 million deaths per year.
- Extensive energy use, especially in high-income countries, creates pollution, emits greenhouse gases and depletes non-renewable fossil fuels.
- The scarcity of energy resources will grow ever greater.
- By 2050, when the planet reaches around 9 billion people, there will be 2 billion more people using more energy.

SDG-7 : Ensure universal access to affordable, reliable, and modern energy services 2/2

Goal 7:
Ensure access to affordable, reliable, sustainable and modern energy for all.

SDG-7 : Targets and Indicators

TARGETS

7.1 By 2030, ensure universal access to affordable, reliable, and modern energy services

7.2 By 2030, increase substantially the share of renewable energy in the global energy mix

7.3 By 2030, double the global rate of improvement in energy efficiency

7.A By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced and cleaner fossil fuel technology, and promote investment in energy infrastructure and clean energy technology

7.B By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support

INDICATORS

7.1.1 Proportion of population with access to electricity

7.1.2 Proportion of population with primary reliance on clean fuels and technology for cooking

7.2.1 Renewable energy share in total final energy consumption

7.3.1 Energy intensity measured as a ratio of primary energy supply to gross domestic product

7.A.1 International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems (NB : remember the original international commitment to mobilize up to 100 billion United States dollars per year starting in 2020 with a Financial Mechanism accountable to the COP – Paris Agreement 2015 – COP 21)

7.B.1 Investments in energy efficiency as a percentage of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services

Source : https://sustainabledevelopment.un.org/sdg7

Source :"How data gaps affect global businesses in Africa", Kemdi Ebi, Versus Africa, CEO and Founder, October 16, 2019 - https://www.versus.africa/post/how-data-gaps-affect-global-businesses-in-africa-part-1-of-series

CHAPTER 6 - TRACKING SDG 7 PROGRESS ACROSS TARGETS: INDICATORS AND DATA
Comprehensive and accurate data are a prerequisite for making evidence-based decisions, monitoring trends, and tracking progress toward policy goals. In developed and developing countries alike, well-designed and appropriately resourced statistical systems play a fundamental role in monitoring progress toward Sustainable Development Goal 7 (SDG 7).
(Source : 2020 edition of "Tracking SDG 7: The Energy Progress Report" - p 145)

…………………………………

Data gaps.
Weak statistical systems threaten achievement of SDGs in African countries in ensuring that no one is left behind, especially marginalized groups.
A review of the UN metadata revealed that data disaggregation is inadequate for vulnerable groups i.e. children, youth, persons with disabilities, people living with HIV, older persons, indigenous peoples, refugees, internally displaced persons and migrants.
In addition, some of the SDGs indicators still do not have a methodology. Despite limited updated data since the SDGs were adopted in 2015 globally, it is clear that the benefits of development are not equally shared among different sub-populations.

SDG Index 2020 for Africa (51 out of 54 countries) + COVID-19 impact

2020 Africa SDG Index and Dashboards Report (Sep 30, 2020)

The "2020 Africa SDG Index and Dashboards Report" is a call for action not only to meet the 17 SDGs but also to ensure timely and high-quality data on SDG indicators (aligned with elements of the Agenda 2063). The report focuses on the efforts that African governments are taking to incorporate the SDGs into their national strategies, budgets, public engagements, and coordination among branches of government.
This 2020 Report provides an assessment of where African countries stand with respect to the SDGs and their progress toward the goals, with the additional lens of "leave no one behind."
51 countries are included in the Index ranking and all 54 African countries have country dashboards.
NB : One of the key findings = overall, North Africa is the best-performing region on average, while Central Africa is the worst-performing. Tunisia has replaced Mauritius as the top-ranking country.

The report also includes a preliminary analysis of the impact of COVID-19 on the SDGs in Africa.
Summary of COVID-19 impacts on the SDGs related to Energy, Industry, Innovation and Infrastructure :
+ reduced energy demand led to decrease in energy costs, which increases access
- reduces incentives for renewables.

https://sdgindex.org/reports/2020-africa-sdg-index-and-dashboards-report/ (248 pages)
and "Africa SDG Index 2020 - select a country to see its full profile" - https://countries.africasdgindex.org/#/

Focus on SDG-7, SDG-11 and SDG-13

Indicators of SDG-7 – Affordable and Clean Energy

- Proportion of population with access to electricity
- Proportion of population with primary reliance on clean fuels and technology for cooking
- Renewable energy share in total final energy consumption
- Energy intensity measured as a ratio of primary energy supply to gross domestic product

ACCESS TO ELECTRICITY - INDICATORS
- Electricity access rate, Total (%)
- Electricity access rate, Urban (%)
- Electricity access rate, Rural (%)
- Population with access to electricity, millions of people (Total)
- Population with access to electricity, millions of people (Urban)
- Population with access to electricity, millions of people (Rural)

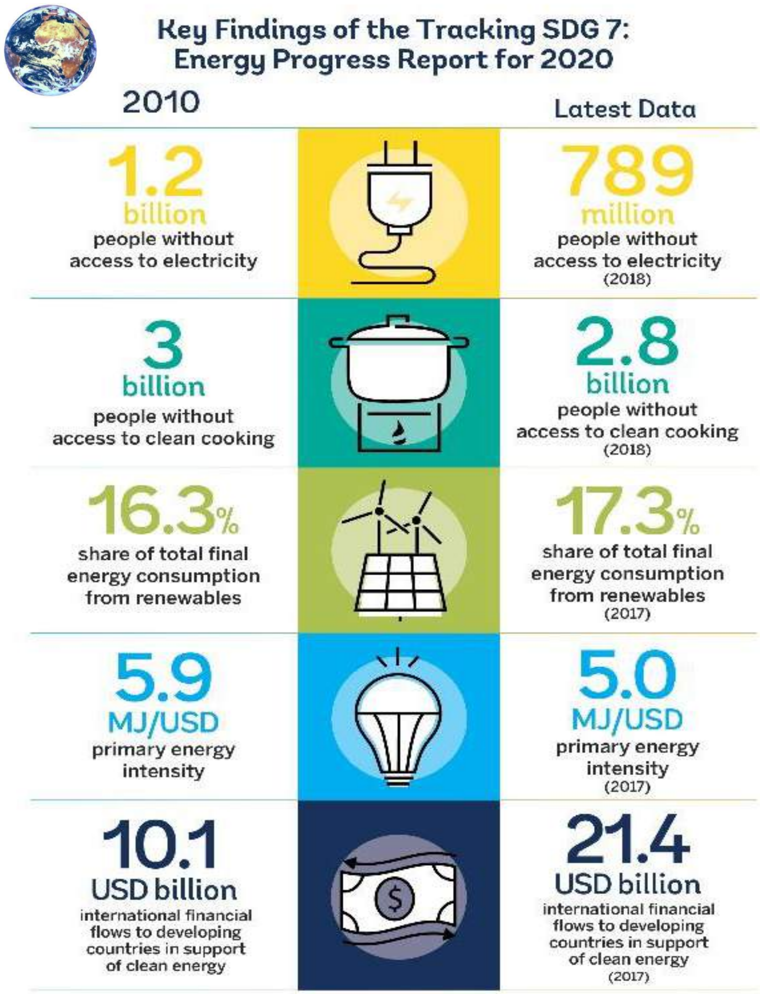
Indicators of SDG-11 – Sustainable Cities and Communities

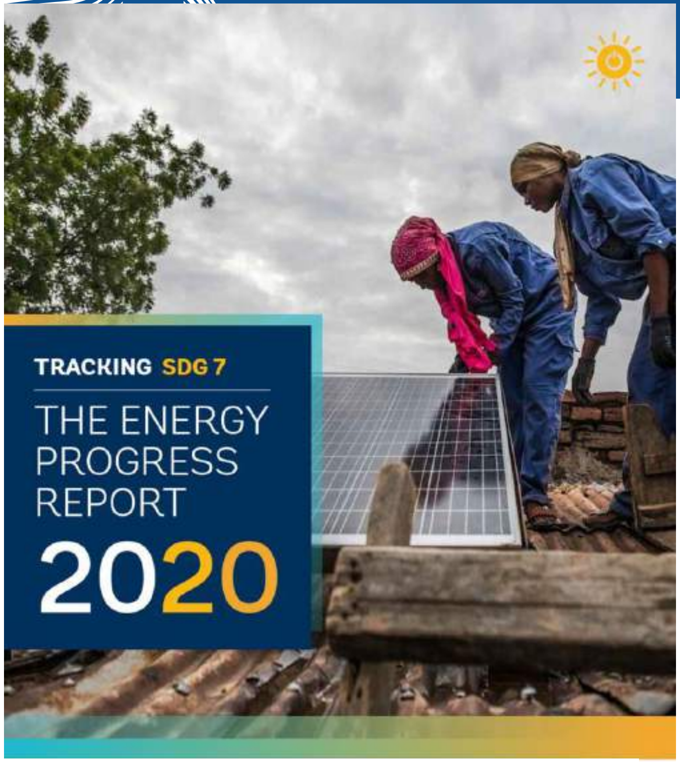
- Proportion of urban population living in slums
- Improved water source, piped (% urban population with access)
- Satisfaction with public transport (%)
- Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5) in urban areas (µg/m3)

Indicators of SDG-13 – Climate Action

- Climate Change Vulnerability Monitor
- Energy-related CO_2 emissions per capita (tCO2/capita)
- Imported CO_2 emissions, technology-adjusted (tCO2/capita)
- CO_2 emissions embodied in fossil fuel exports (kg/capita)

Tracking SDG 7 : Access to energy / Renewable energy / Energy efficiency / Access to clean cooking / International financial flows 1/2





International Energy Agency
United Nations Statistics Division
World Health Organization
IRENA International Renewable Energy Agency
THE WORLD BANK IBRD • IDA | WORLD BANK GROUP
ESMAP Energy Sector Management Assistance Program

Source : World Bank 2020 "Tracking SDG 7: The Energy Progress Report" - Summary (country results) in https://trackingsdg7.esmap.org/ and website tracking - https://trackingsdg7.esmap.org/data/files/download-documents/tracking_sdg_7_2020-full_report_-_web_0.pdf and World Bank full report (6 chapters) May 2020 - https://www.worldbank.org/en/topic/energy/publication/the-tracking-sdg-7-report-the-last-decade-to-leave-no-one-behind

OUTLOOK FOR EFFICIENCY (SDG 7.3 - p 147). For purposes of SDG 7, energy efficiency is tracked as energy intensity, the ratio of total energy supply to economic output (MJ/USD).
Recent world-wide estimates indicate that annual improvements in global energy intensity is low for 2018 (1.3 %) and 2019 (2.0 %), moving the world further from achieving SDG 7.3.
Determining the total energy supply requires robust information on production of and trade in all types of energy. The supply information may be collected from administrative sources or by surveying the key energy suppliers. Reasonably good information on supplies of most energy sources is available in most countries, with the notable exception of supplies of solid biofuels in several countries. Thus, where solid biofuels are a significant part of the overall energy mix, estimates of total energy supply may be less certain.
To analyze sectoral progress in energy efficiency, countries are encouraged to monitor intensities at the end-use level, at least for priority sectors. Examples of energy efficiency indicators include,

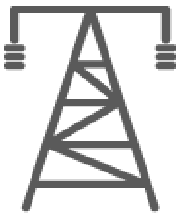
- **for transport, energy per passenger-kilometer (or tonne-kilometer for freight), by vehicle type;**
- **for buildings, energy for space heating and cooling as a function of area; and**
- **for industry, energy by quantity of physical production of a given good.**

Goal 7:
Ensure access to affordable, reliable, sustainable and modern energy for all.

Focus on "Access to energy" (2020)

ACCESS TO ELECTRICITY

Tracking electrification efforts has been a complex process that has raised many challenges, the first being to devise a universally applicable and transparent approach. Measuring access to electricity requires tracking cumulative progress across interventions by a variety of players—governments, energy utilities, private sector companies, funding agencies, and development organizations at the national and international levels. Particularly challenging are the socioeconomic complexities of low-access countries. Measuring access also implicates a variety of technologies—not only national grids but mini grids and off-grid solutions, such as solar home systems. Finally, it requires assessing the number of people who actually benefit from these interventions, as well as the nature and degree of improvement they provide. But however difficult it may be, measuring access is critical to enable governments and practitioners to understand the current status of access, to identify bottlenecks to further electrification, and to achieve universal access goals in more efficient ways.



The definition and measurement of access to electricity should focus not only on the number of users benefitting from improved energy access, but also on the nature and degree of improvement across various attributes: capacity (adequacy), availability, reliability, affordability, quality, legality, health impact, safety, and convenience, among others. To provide this fuller picture, and to help prioritize investment and track progress, a set of international agencies joined together to produce a multi-tier framework (MTF) for household surveys. The MTF has been rolled out by national statistical offices and the World Bank in about 16 countries since 2016. Given the paucity of data for multi-tier metrics, however, standardized country-level surveys and supply-side data from governments and utilities must still be used to complement the MTF approach.

Additional methods of improving the tracking of access to electricity are:

(i) developing the capacity of national statistical offices to collect energy data (for example, through workshops organized by development partners on data collection and analysis for the energy sector);
(ii) helping governments apply new technology and data analytics, since survey design can be challenging if the national census is outdated or if a census has never been conducted;
(iii) improving and adapting the usability of existing datasets for energy practitioners;
(iv) exploring the use of largescale open databases, such as satellite data.

Most microdata (including household surveys, enterprise surveys, and agricultural surveys) contain information useful for energy practitioners and the ministries of energy. However, significant time and effort are usually required to extract from such sources data related to energy access, including socioeconomic status, electrification status, and village-level information. Data harmonization and standardization could help more end users access and use such datasets for project design and policy formulation.
(Source : 2020 edition of "Tracking SDG 7: The Energy Progress Report", p 146)

Democratic Republic of the Congo

ACCESS TO ELECTRICITY (% of population with access) Year : 2018 — 19

ACCESS TO CLEAN COOKING (% of population with access) Year : 2018 — 3

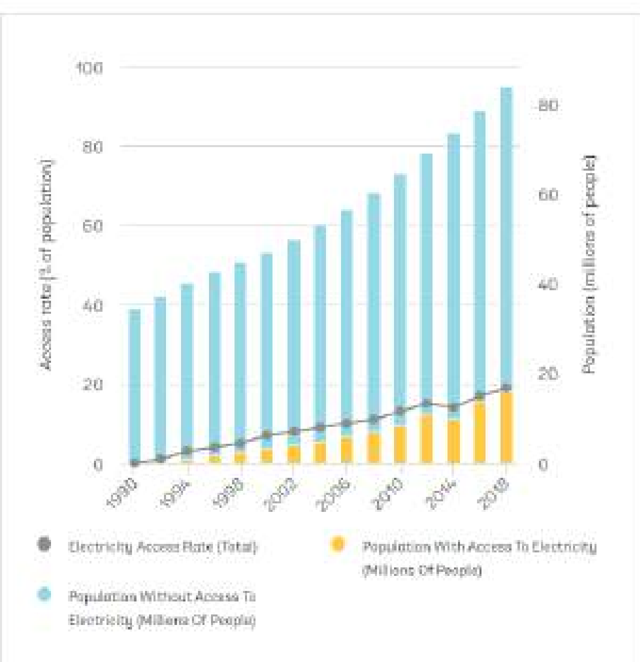
REGION	Sub-Saharan Africa
SUBREGION	Middle Africa
INCOME GROUP	Low income
POPULATION (MILLION)	84.07

RENEWABLE ENERGY (% of Total Final Energy Consumption) Year : 2017 — 97

ENERGY EFFICIENCY (MJ per US$ PPP 2011) Year : 2017 — Country Value 19; 5.0 Global Average

INTERNATIONAL FINANCIAL FLOWS (USD million, 2017 PPP) Year : 2017 — 42.7

Access to electricity, 1990-2018 (Total)



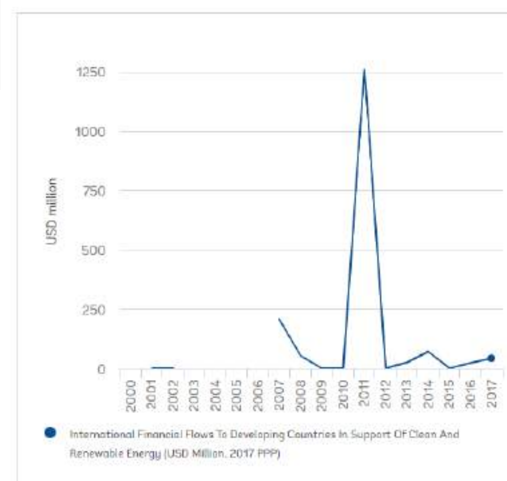
DRC 2018 - Access to electricity :

- **total = = 16 million people (i.e. 19 % of total population 84 million people)**
  - **urban = 16 million people (i.e. 51 % of urban population)**
  - **rural = N/A**

Source :"2019 THE ENERGY PROGRESS REPORT - TRACKING SDG7" - https://trackingsdg7.esmap.org/country/democratic-republic-congo
and "Enerdata's Global Energy Research" - https://estore.enerdata.net/congo-dr-energy.html
and World Bank full report (6 chapters) May 2020 - https://www.worldbank.org/en/topic/energy/publication/the-tracking-sdg-7-report-the-last-decade-to-leave-no-one-behind

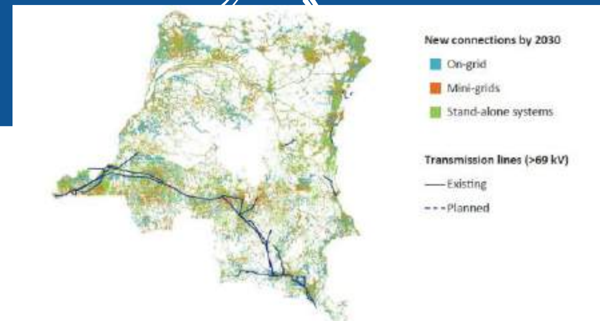
Democratic Republic of the Congo

International financial flows, 2000-2017



RDC - International Financial Flows To Developing Countries In Support Of Clean And Renewable Energy (USD Million, 2017 PPP) = max 1258 USD million in 2011

DRC (2/3) : Tracking (2019) / SDG2 – Zero Hunger / SDG7 – Affordable and Clean Energy / SDG9 – Industry, Innovation and Infrastructure



SDG2 – Zero Hunger

- **Prevalence of stunting in children under 5 years of age (%) 42.6 (year 2013)**
- **Prevalence of wasting in children under 5 years of age (%) 8.1 (year 2013)**
- **Prevalence of obesity, BMI ≥ 30 (% of adult population) 6.7 (year 2016)**
- **Cereal yield (tonnes per hectare of harvested land) 0.8 (year 2017)**
- **Fertilizer consumption (kg per hectare of arable land) 2.5 (year 2016)**

Source : 2020 Africa SDG Index and Dashboards Report (Sept 30, 2020)

https://sdgindex.org/reports/2020-africa-sdg-index-and-dashboards-report/ (248 pages)

and "Democratic Republic of the Congo - Energy Outlook Analysis" from Africa Energy Outlook 2019 https://www.iea.org/articles/democratic-republic-of-the-congo-energy-outlook

SDG7 – Affordable and Clean Energy

- **Population with access to electricity (%) 19.1 (year 2017)**
- **Population with access to clean fuels and technology for cooking (%) 4.0 (year 2016)**
- **Renewable energy consumption (% of total final energy consumption) 97.1 (year 2017)**
- **Consumer affordability of electricity (worst 0–100 best) 51 (year 2017)**

SDG9 – Industry, Innovation and Infrastructure

- **Infrastructure score (worst 0–100 best) 24.7 (year 2017)**
- **Logistics performance index: Quality of trade and transport-related infrastructure (worst 1–5 best) 2.1 (year 2018)**
- **Expenditure on research and development (% of GDP) 0.4 (year 2015)**
- **Scientific and technical journal articles (per 1,000 population) 0.0 (year 2018)**
- **Mobile broadband subscriptions (per 100 population) 15.9 (year 2018)**
- **Population using the internet (%) 8.6 (year 2017)**

DRC (3/3): Tracking (2019) / SDG11 – Sustainable Cities & Communities / SDG13 – Climate Action

SDG11 – Sustainable Cities and Communities

- Proportion of urban population living in slums (%) 79.1 (year 2016)
- Access to improved water source, piped (% of urban population) 62.9 (year 2017)
- Satisfaction with public transport (%) 40.8 (year 2017)
- Annual mean concentration of particulate matter of less than 2.5 microns in diameter (PM2.5) (µg/m3) 44.9 (year 2017)

SDG13 – Climate Action

- People affected by climate-related disasters (per 100,000 population) 193.2 (year 2019)
- Energy-related CO2 emissions (tCO2/capita) n.a. (year 2017)
- CO2 emissions embodied in imports (tCO2/capita) n.a. (year 2015)

Reminder. The Democratic Republic of the Congo (DRC) is the 11th largest country in the world, with a land area equivalent to that of Western Europe. The population is 84 million, of which 12 million people live in the capital Kinshasa. GDP in 2019 was estimated at $10.82 billion, which represents 0.01 percent of the world economy (source: World Bank). The DRC has one of the lowest rates of electrification in the world.

Main challenges regarding the SDGs in Africa:

Prioritization of challenges in implementing the SDGs differs from one country to the other,

but the most important challenge are :

- lack of funding or resources
- lack of statistical capacity (mainly in Comoros, Democratic Republic of Congo, Kenya, Libya, Mauritania, Niger and Tunisia).

Benin

REGION	Sub-Saharan Africa
SUBREGION	Western Africa
INCOME GROUP	Low income
POPULATION (MILLION)	11.49

ACCESS TO ELECTRICITY (% of population with access) Year : 2018 — 42

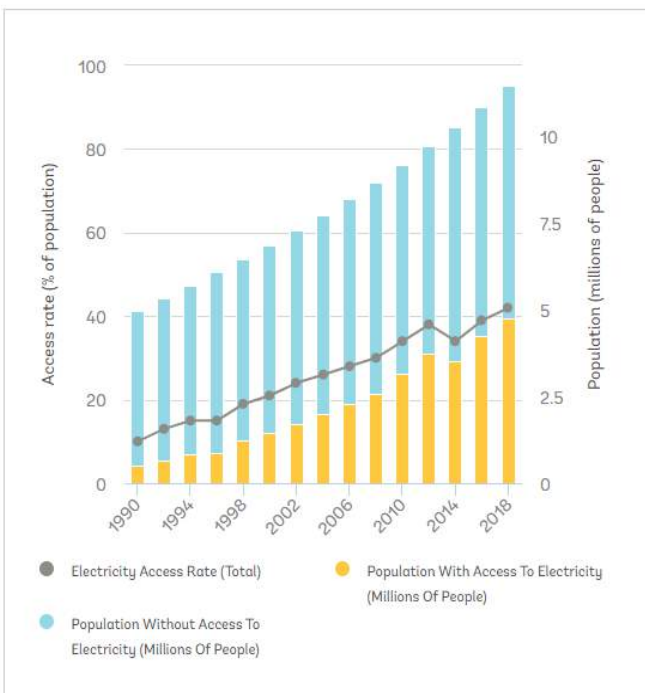
ACCESS TO CLEAN COOKING (% of population with access) Year : 2018 — 5

RENEWABLE ENERGY (% of Total Final Energy Consumption) Year : 2017 — 46

ENERGY EFFICIENCY (MJ per US$ PPP 2011) Year : 2017 — Country Value 9.2 / Global Average 5.0

INTERNATIONAL FINANCIAL FLOWS (USD million, 2017 PPP) Year : 2017 — 316.5

Access to electricity, 1990-2018 (Total)



© World Bank.

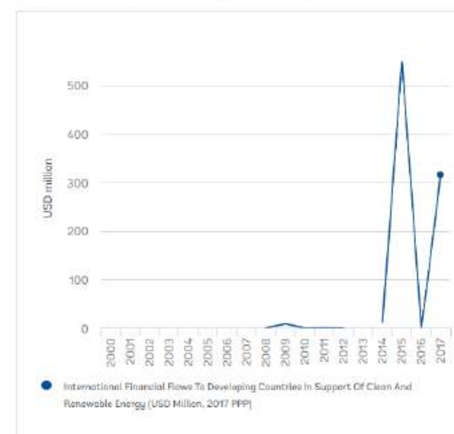
BENIN 2018 - Access to electricity :

- **total = 4.8 million people (i.e. 42 % of total population)**
  - **urban = 3.7 million people (i.e. 67 % of urban population)**
  - **rural = 1.1 million people (i.e. 18 % of rural population)**

Source : World Bank "2019 THE ENERGY PROGRESS REPORT - TRACKING SDG7" - https://trackingsdg7.esmap.org/country/benin and World Bank full report (6 chapters) May 2020 https://www.worldbank.org/en/topic/energy/publication/the-tracking-sdg-7-report-the-last-decade-to-leave-no-one-behind

Benin

International financial flows, 2000-2017



International Renewable Energy Agency (IRENA), Organisation for Economic Co-operation and Development (OECD)

BENIN - International Financial Flows To Developing Countries In Support Of Clean And Renewable Energy (USD Million, 2017 PPP) = max 549 USD million in 2015

BENIN (2/3) : Politique et projets de développement du secteur de l'électricité (PDE 2017)


BENIN - Vue d'ensemble du secteur et contexte de la décision

L'Energie est un des secteurs clés pour le développement socio-économique du pays. L'Economie Béninoise est en effet extrêmement sensible aux grands problèmes énergétiques. Le pays est particulièrement confronté à certaines contraintes. Entre autres:

- **une facture énergétique contraignante, les importations énergétiques étant une proportion non négligeable du volume total des dépenses d'importation;**
- **un déficit de l'offre d'énergie électrique par rapport à la demande; en raison de la faible production nationale par rapport au besoin (moins du tiers en 2019) ;**
- **la faible efficacité énergétique dans tous les secteurs d'activités ;**
- **l'impact des activités de production et de consommation d'énergies sur l'environnement.**

Politique et projets de développement du secteur de l'électricité

Avec le rythme de plus en plus élevé des électrifications annuelles de localités par raccordement au réseau électrique et l'objectif fixé par le Gouvernement de garantir l'accès de tous les ménages béninois à l'électricité d'ici 2030, la demande devrait connaître une croissance soutenue les prochaines années.

Suivant le plan directeur de développement du sous-secteur de l'énergie électrique (PDE) adopté en 2017 par le Gouvernement, la demande nationale d'électricité pourrait s'accroitre de 966 GWh en 2014 à 5229 GWh en 2035 (scénario moyen des prévisions de la demande). La puissance à la pointe passera de 197 MW en 2014 à 1014 MW en 2035.

Or l'offre d'énergie reste présentement déficitaire, et le Bénin n'est pas sorti de sa grande dépendance des pays voisins pour ses approvisionnements en électricité.

Vue succincte du secteur de l'électricité

La production nationale d'électricité est caractérisée par une prédominance de la filière thermique qui assure la grande part de la production nationale.

Elle représentait environ 75% de la production totale nationale en 2017 (soit 325 GWh sur 434 GWh).

Globalement la production à partir des sources d'énergies renouvelables est encore faible en dépit de ressources primaires renouvelables dont le pays dispose (ressources hydraulique, solaire et les possibilités de valorisations modernes de la biomasse énergie). Leur part dans la production nationale d'électricité, est encore modeste (25% en 2017).

Source « EVALUATION DES BESOINS DE TECHNOLOGIES POUR L'ATTENUATION DES GES - RAPPORT SUR LA PRIORISATION DES TECHNOLOGIES » « BENIN - MINISTERE DU CADRE DE VIE ET DU DEVELOPPEMENT DURABLE (DIRECTION GENERALE DES CHANGEMENTS CLIMATIQUES) » - Avril 2020 (projet financé par UNEP DTU, GEF et ENDA) - https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2020/07/tna-attenuation-benin.pdf

Voir aussi : « 2020 Africa SDG Index and Dashboards Report" - https://countries.africasdgindex.org/#/benin

BENIN (3/3) : Projets en cours de réalisation et 4 technologies retenues dans le secteur de l'énergie

Projets en cours de réalisation dans le cadre du Programme d'Action (2016 – 2021) du Gouvernement

- la construction à Maria-Gléta de trois centrales thermiques bicombustibles (fioul et gaz naturel) pour une capacité totale de 240 MW (2 x120 MW) ;
- la construction au port de Cotonou d'une unité de regazéification du gaz naturel liquéfié importé pour alimenter les centrales électriques installées dans l'optique de les tourner au gaz plutôt qu'au fioul ;
- l'aménagement hydro-électrique des sites (i) de Adjarala (147 MW) sur le fleuve Mono et (ii) de Dogo – bis (128 MW) sur le fleuve Ouémé ;
- l'installation de fermes solaires photovoltaïque (capacité totale projetée sur la base des projets existants 95 MWc) sur différents sites identifiés à Kétou (au Sud du pays), Bohicon (au centre du pays) et Parakou, Kandi, Natitingou et Djougou (au Nord du pays) ;
- l'introduction à titre expérimental dans le système électrique national de la production d'électricité à partir de la biomasse.

C'est dans ce cadre que s'inscrit également le Programme MCA – Bénin II principalement pour ces composantes relatives au :

- Projet de distribution d'électricité qui vise à moderniser les infrastructures de distribution d'électricité du Bénin afin d'étendre la capacité du réseau pour s'adapter à la croissance future, améliorer la fiabilité, et réduire les pertes ;
- Projet d'accès à l'électricité hors-réseau avec un financement destiné à soutenir

(i) l'électrification hors réseau y compris pour des systèmes de panneaux solaires photovoltaïques au niveau institutionnel et des ménages, des mini-réseaux, ainsi que

(ii) (ii) des activités d'efficacité énergétique à l'échelle nationale.

Quatre technologies retenues dans le secteur de l'énergie (pp 80 – 90)

- **Mini centrale solaire photovoltaïque (PV) et réseau local de distribution**
- **Systèmes d'éclairage public par lampadaires solaires PV**
- **Bateaux-bus pour transport fluvio-lagunaire et infrastructures associées (embarcadères / débarcadères)**
- **Trains diesel-électrique légers pour transport interurbain et réseau ferroviaire Ouidah-Cotonou-Porto Novo réhabilité)**

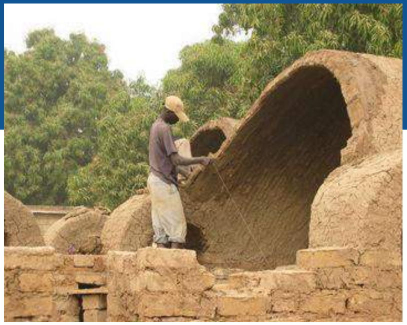
++++++++++++++++++++++++++

et quatre technologies retenues dans le secteur Agriculture, Foresterie et autres Affectations des terres (pp 91 – 103) :

- *Gestion intégrée de la fertilité des sols*
- *Production et utilisation du fumier*
- *Reboisement des terres forestières*
- *Petits équipements de cuisson au gaz butane*

Ces technologies sont toutes en cohérence avec la politique définie par le Gouvernement dans chacun de ces secteurs.

la Voûte Nubienne (la chaînette) : un modèle de construction simple et d'efficacité énergétique



Pour la fabrication des briquettes des murs et de la voûte, il faut : Paille de riz ; Terre de barre ; Infusion de Néré ; Eau de gâchage

Un concept architectural à la fois ancestral et innovant : la Voûte Nubienne. Cette technique constructive sans bois, ni tôle (çàd sans coffrage) utilise la terre crue comme matériau et permet la formation professionnelle d'une main d'œuvre locale et souvent précaire à un métier d'avenir.

Rappel historique : les magasins du Ramésseum à Louxor (Ramsès II, nécropole thébaine) qui ont été construits avec la même technique, datent de circa 1300 ans av. JC, attestant ainsi de la durabilité de telles constructions.

Le résultat ? L'accès aux populations à des bâtiments abordables et adaptés, confortables et résistants face aux conséquences des changements climatiques, la création d'emplois verts, le renforcement des économies à toutes échelles et le développement d'une filière « habitat adapté » dans une économie verte, efficace (énergétiquement) et résiliente face aux crises (par ex. le climat).

(https://www.mediaterre.org/afrique/actu,20170316141610.html)

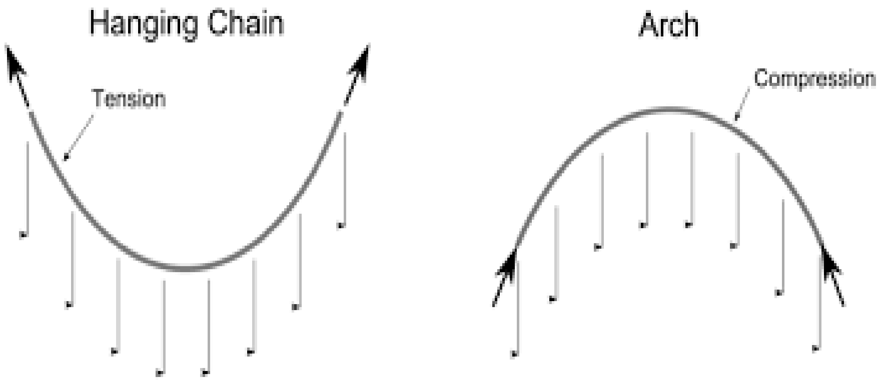


Figure: Analogy between hanging chain in tension and arch in compression

La théorie de la chaînette

La courbe décrite par un collier ou une corde pesant sous son propre poids, et tendue entre ses deux extrémités, est à base de la théorie de la chaînette. Du point de vue mathématique, il s'agit d'une fonction cosinus hyperbolique. La chaînette est un ensemble de maillons articulés entre eux et de ce fait toute autre sollicitation à part celle de la traction, s'avère impossible.

En assimilant l'allure de la voûte nubienne à celle de la chaînette renversée, nous voulons assurer dans la voûte nubienne la présence rien que des efforts de compression. En effet la technique mise en œuvre dans la réalisation de la voûte nubienne ne tolèrerait nul autre effort que celui de la compression.

La fonction cosinus hyperbolique peut s'écrire de deux façons : une plus simplifiée, exprimée par le symbole mathématique « ch(x) » et l'autre, plus élaborée, exprimée en termes de fonction exponentielle « $[(e^{x} + e^{-x}) / 2]$ ».

Source « Optimisation de la portée d'une voûte nubienne avec la théorie de la chaînette renversée, en tenant compte des conditions aux états limites » AHOSSI A. D., 2016, Ecole Supérieure de Génie Civil VAK (http://www.verechaguine.com/), Cotonou https://www.lavoutenubienne.org/IMG/pdf/17_optimisation-porte_e-vn_me_moire-ahossi.pdf

Enabel au Bénin (programme 2019 – 2023) : priorité pour secteurs agroalimentaire et portuaire

Enabel

Agence belge de développement

enabel.be

__À propos d'Enabel__

Enabel est l'Agence belge de développement. Elle exécute et coordonne la politique belge de développement international, et travaille principalement pour le compte de l'État belge. L'Agence met également en œuvre des actions pour d'autres organisations nationales et internationales. Avec 1.500 collaborateurs·rices, dont plus de 70 % de personnel local, Enabel gère quelque 150 projets, essentiellement dans des États fragiles d'Afrique.

Bureaux à l'étranger : Bénin ; Burkina Faso ; Burundi ; RD Congo ; Guinée ; Mali ; Maroc ; Mozambique ; Niger ; Palestine ; Rwanda ; Sénégal ; Tanzanie ; Ouganda.

__Enabel au Bénin (présente à Cotonou depuis 1999)__

**Programme de coopération gouvernementale
Belgique – Bénin 2019-2023**

Active depuis plus de vingt ans au Bénin, Enabel se focalise sur l'appui au développement des secteurs de l'agriculture et de la santé. Dans ce pays, le programme de coopération 2019-2023 dispose d'un __budget total de soixante millions d'euros__. La Belgique y met également en œuvre des projets pour le compte d'autres bailleurs, pour un montant avoisinant les __vingt millions d'euros__. Le programme de coopération privilégie le partenariat, le transfert de compétences, la durabilité et l'innovation.

__Le programme de coopération conclu entre la Belgique et le Bénin pour la période 2019-2023 rejoint les priorités et orientations du Bénin__, en particulier la stimulation du développement économique focalisé sur le secteur de __l'agroalimentaire__ et de __l'activité portuaire__, ainsi que le droit à la santé sexuelle et reproductive. (representation.benin@enabel.be)

https://www.enabel.be/sites/default/files/enabel_au_benin_web.pdf

(1) Développement des chaînes de valeur et de l'entrepreneuriat dans l'agroalimentaire (42 % des engagements financiers de Enabel)

Objectif : Meilleurs revenus pour 50 PME de transformation, 60 entreprises de commercialisation, 100 entreprises de services (transport, emballage) et 3.000 producteurs et productrices.

(2) Appui au développement du secteur portuaire (17 % des engagements financiers de Enabel)

Le Port de Cotonou est l'un des plus grands ports de l'Afrique de l'Ouest. Enabel l'appuie dans sa modernisation pour le rendre plus compétitif et performant. L'ambition est de renforcer son positionnement concurrentiel en facilitant les investissements, en renforçant les compétences de différents acteurs du port et en travaillant sur l'aspect environnemental.

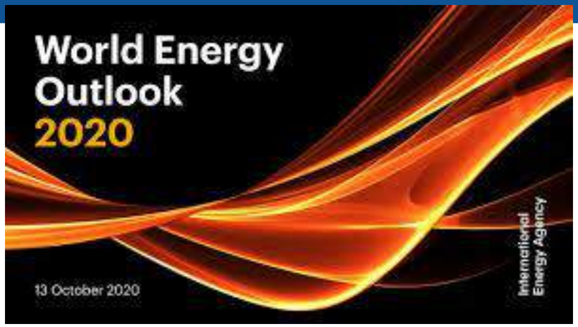
Objectifs : * Évolution du nombre d'emplois décents parmi les emplois précaires : de 20 à 60 %
**** Evolution du tonnage global traitées par le port : augmentation de 20 % d'ici fin 2023 (base line 10 millions de tonnes).***

International Energy Agency (IEA, Paris)

Energy Security + Economic Development + Environmental Awareness + Engagement

International Energy Agency

Secure • Sustainable • Together



IEA - Our mission

Founded in 1974, the IEA was initially designed to help countries co-ordinate a collective response to major disruptions in the supply of oil, such as the crisis of 1973/4. While this remains a key aspect of its work, the IEA has evolved and expanded significantly. The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries.

Today, the IEA is at the heart of global dialogue on energy, providing authoritative analysis through a wide range of publications, including the flagship World Energy Outlook (Figure : release of 2020 version on 13 October 2020) and the IEA Market Reports; data and statistics, such as Key World Energy Statistics and the Monthly Oil Data Service; and a series of training and capacity building workshops, presentations, and resources. - https://www.iea.org/about/ourmission/

The four main areas of IEA focus are:

- **Energy Security: Promoting diversity, efficiency, flexibility and reliability for all fuels and energy sources;**
- **Economic Development: Supporting free markets to foster economic growth and eliminate energy poverty;**
- **Environmental Awareness: Analysing policy options to offset the impact of energy production and use on the environment, especially for tackling climate change and air pollution; and**
- **Engagement Worldwide: Working closely with partner countries, especially major emerging economies, to find solutions to shared energy and environmental concerns.**

IEA, "Africa Energy Outlook 2019", World Energy Outlook special report - 2019 edition (WEO-2019)

The International Energy Agency's (IEA's) "Stated Policies" scenario /STEPS/ factors in current and already announced policies, (a WEO-2019 scenario that was formerly known as the "New Policies Scenario), …………

whereas the "Africa Case" /AC/ (or "Sustainable Development") scenario is an analysis of how the energy sector can deliver the key sustainable development goals by 2030 and spur economic growth ambitions of Agenda 2063, fully aligned with the Paris Agreement, which has an objective of holding the increase in the global average temperature to well below 2C above pre-industrial levels. The AC scenario includes full access to electricity and clean cooking and a significant reduction in premature deaths related to pollution.

NB About 100 experts contributed to this remarkable IEA 2019 report (about half originating from Africa)

Source : "IEA - Africa Energy Outlook 2019", Paris, 8 Nov. 2019 - https://www.iea.org/news/africas-energy-future-matters-for-the-world

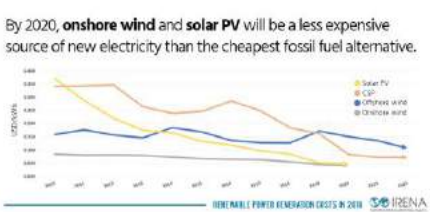
Power Sector Insights from the IEA's World Energy Outlook 2019 1/2

The Next Big Market: Africa

The Next Big Market: Africa.

Electricity demand in sub-Saharan Africa (SSA), where more than half the population have no access to power, is set to soar, and the IEA is optimistic that African countries will make progress to improve access rates. However, it notes, achieving full access by 2040 will require a significant expansion of the power system. By 2040, electricity output in the SSA region could expand from 225 TWh today to more than 900 TWh. It will likely be supplied mainly by on-grid power, but decentralized solutions could also be heavily adopted. "*Although on-grid solutions have traditionally served as the most cost-effective option to supply electricity in areas close to an existing grid, the falling costs of stand-alone solar PV and battery storage technologies as well as new business models using digital and appliance innovations are making these solutions more competitive*," the WEO-2019 says.

Technology Costs May Favor Renewables (mainly solar PV).



Using a value-adjusted levelized cost of electricity (LCOE), which does not include environmental externalities or network integration costs, the WEO-2019 suggests solar PV will become the most competitive source of power in 2020 in China and India, and largely close the gap with other sources by 2030 in the EU and U.S. It suggests the global average LCOE of solar PV will fall by about 50 % from 2018 to 2030. The competitiveness of conventional power plants could depend heavily on the availability of low-cost resources and market conditions. However, "*In general, existing conventional power plants are more competitive with renewables than new builds, because they usually need to cover only their short-run fuel and maintenance costs to continue operations, and capital investment for refurbishment is lower than for new construction*," it says.

A Gust for Off-shore Wind.

The IEA is especially optimistic about off-shore wind's potential to tackle the separate challenges facing energy transitions, noting that it is competitive (and could therefore enable low-carbon power and hydrogen production), flexible, affordable, and reliable. It projects that off-shore wind capacity is set to grow into a $1 trillion business as current installed capacity expands from 23 GW installed in 2018 to 345 GW in 2040. Of specific note is that new off-shore wind projects already have annual capacity factors of 40 % to 50 % or above, matching those of gas-fired plants in many markets, and significantly exceeding that of solar PV. Innovation in technology has improved turbine capacities and platform options. However, the sector may still face challenges without long-term plans that emphasize effective system integration, including for transmission infrastructure.

Power Sector Insights from the IEA's World Energy Outlook 2019 2/2

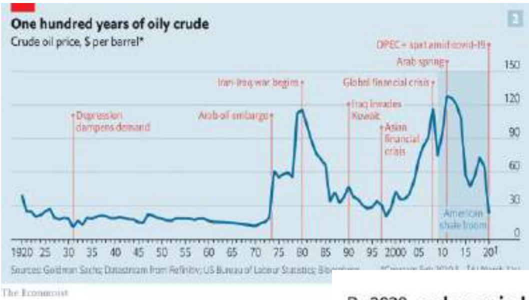
Interest in electrification

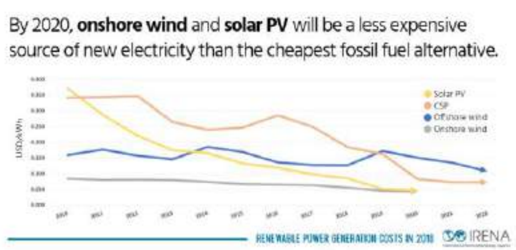
<u>Gas Infrastructure Decarbonization Ramping Up.</u>

The WEO-2019 also dedicates an entire chapter to gas infrastructure, noting the next decade will be "critical," because short-term decisions on whether to invest could have major implications. The reason: <u>Interest in electrification</u>, which promises to provide "modern energy services with no emissions at the point of use." The trend is tangible: global power demand has risen 60% faster than gas demand in final energy consumption since 2000, says the IEA.

But while <u>electrification has a huge potential</u>, the WEO-2019 emphasizes there are limits to how quickly and extensively it could occur. It says <u>current electricity infrastructure is not well-suited to deliver all types of energy services, such as to shipping, aviation, heavy-freight trucks, and certain industrial processes</u>, and a future switch would depend heavily on variable generation, which raises practical issues, such as <u>meeting demand for large-scale high-temperature heat</u>.

<u>To secure a role in a low-emissions energy system, gas infrastructure must adapt to decarbonized gases, such as low-carbon hydrogen and synthetic methane (produced from fossil fuels with carbon capture or via electrolysis using renewables or nuclear) or biomethane (such as landfill gas).</u> These aren't currently competitive with the natural gas supply today, but the IEA still urges policymakers to consider them in long-term strategies.





<u>Affordability Will Be a Concern in the Age of Electrification</u>.

According to the IEA, policymakers are specifically concerned about affordability as the emphasis on electrification continues.
A WEO-2019 sensitivity analysis identified three of the largest uncertainties that could affect future affordability:

- **fossil fuel (oil and gas) prices,**
- **the cost of wind and solar PV,**
- **and the cost of capital for all power generation technologies.**

NB about energy prices. The combined net income from oil and gas production of the top-ten producing countries in Africa declined by 70% between 2014 and 2016.

Source : "Power Sector Insights from the IEA's World Energy Outlook 2019" - by POWER magazine - Jan 2, 2020 - <u>https://www.powermag.com/10-power-sector-insights-from-the-ieas-world-energy-outlook-2019/</u> and The Economist (8 April 2020) - <u>https://www.economist.com/briefing/2020/04/08/an-unprecedented-plunge-in-oil-demand-will-turn-the-industry-upside-down</u>

About 20 % of the world's energy is consumed in the form of electricity (IEA)

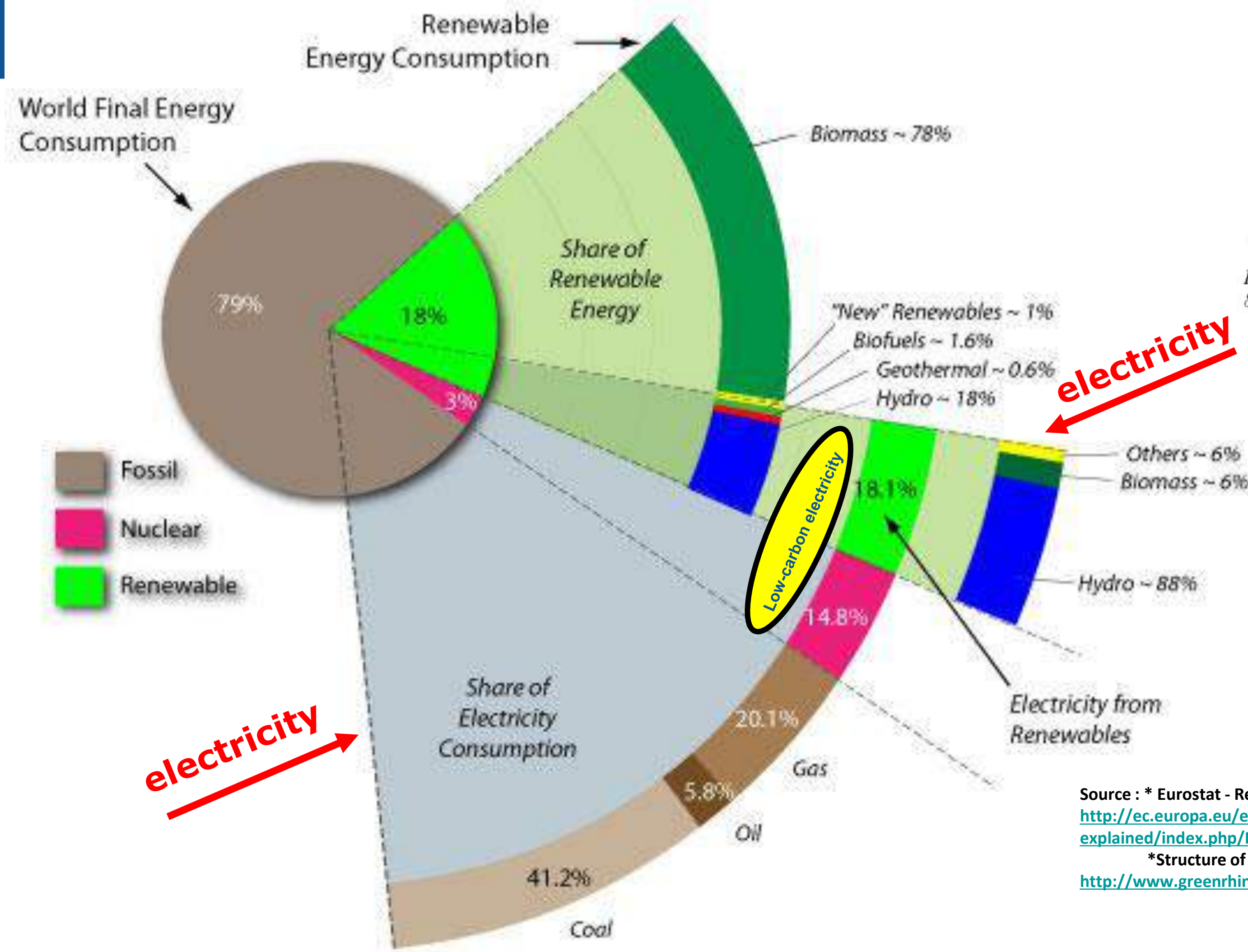
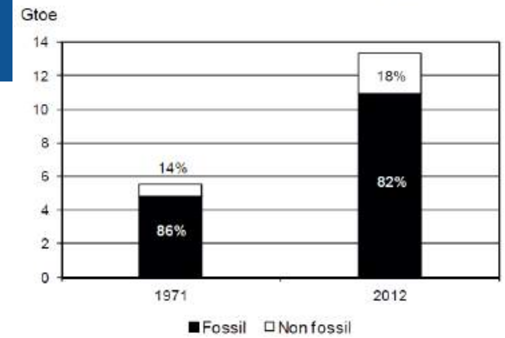


Figure 2. World primary energy supply*



* World primary energy supply includes international bunkers.

Key point: Fossil fuels still account for most – over 80% – of the world energy supply.

Source : * Eurostat - Renewable energy statistics - http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics

*Structure of Global Energy (2007) - Worldwide statistics - http://www.greenrhinoenergy.com/renewable/context/uses_and_sources.php

National energy use is categorized in most countries world-wide in four broad sectors:

- transportation (passenger, freight, and pipeline)
- residential (heating, lighting, and appliances)
- industrial users (agriculture, mining, manufacturing, and construction)
- commercial (lighting, heating and cooling of buildings, and provision of water and sewer services)

Most of the energy used in the four broad sectors world-wide comes from fossil energy (about 80 %). It has been so over the last 50 years (above graph).

A small fraction of the primary energy sources - approximately 20 % - is consumed in the form of electricity but this fraction may grow dramatically in the coming decades because of the upcoming massive electrification of society (IEA outlook).

National energy use - four broad sectors : transportation ; residential ; industrial ; commercial

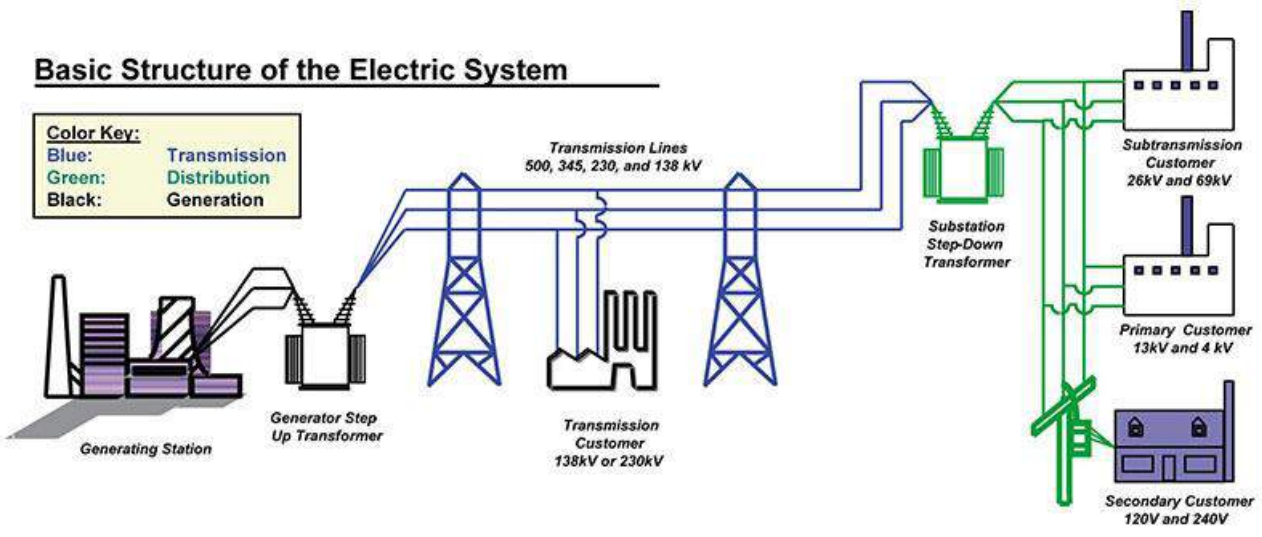
(1) Transportation : e.g. African High Speed Train Network (Agenda 2063 – Flagship project no 1)

(2) Residential (e.g. heating, lighting, and appliances)

(3) Industry (e.g. mining, manufacturing, and construction)

(4) Commercial and services (e.g. lighting, heating and cooling of buildings, and provision of water and sewer services)

Traditional power grid and future smart grid: paradigm change - from linear to more complex power generation



Today

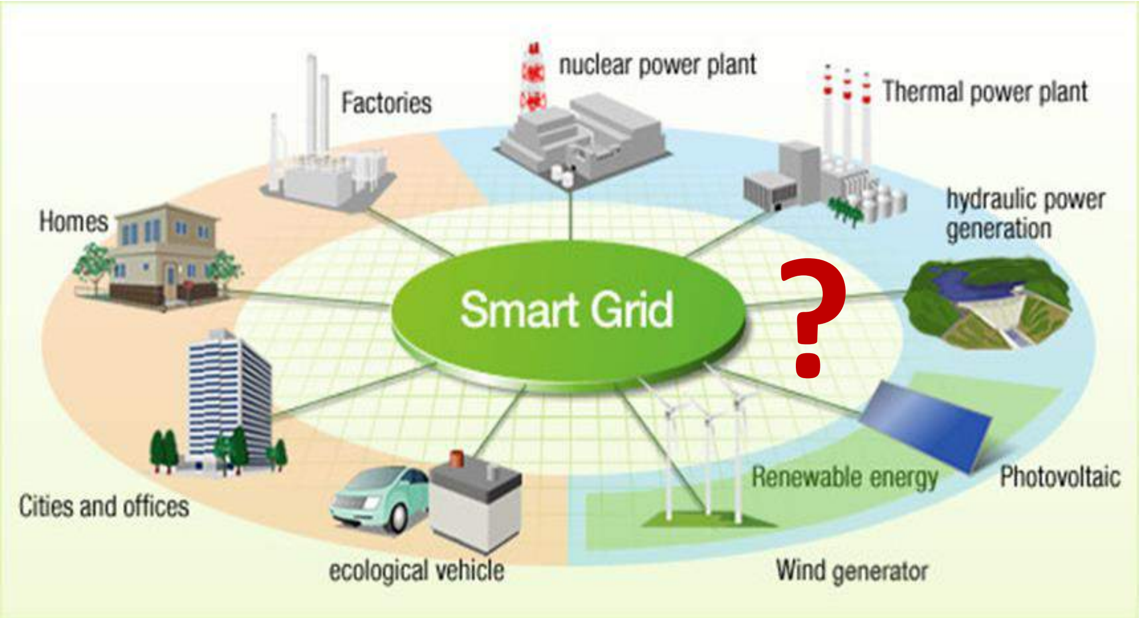
Traditional centralized model of linear power generation and delivery through limited market or monopoly conditions

Linear : from "generation" = > to "transmission" => to "distribution"

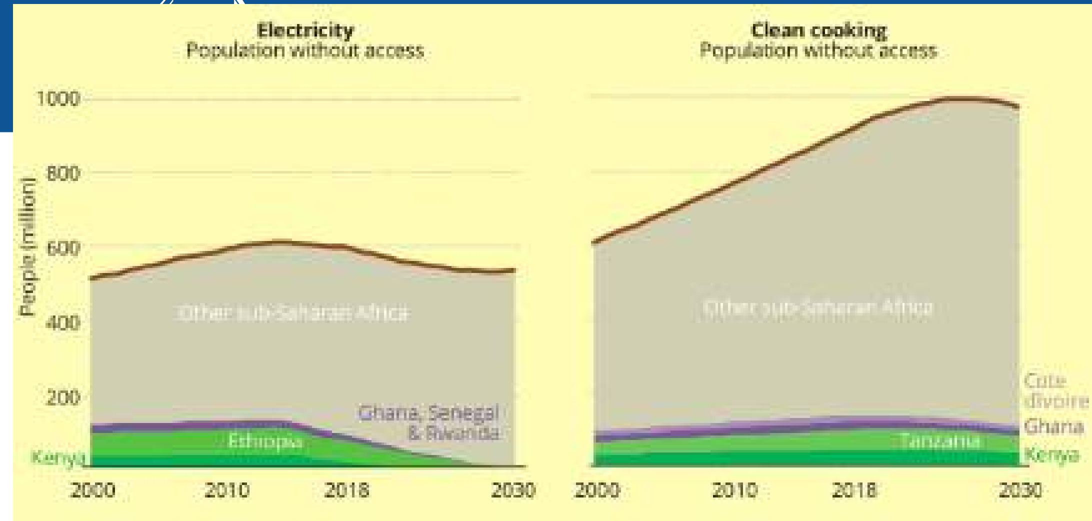
Tomorrow ?

A more diverse, dynamic and complex system with multiple actors and multilayered energy, information and money flows ?

Complex system with paradigm change : from "supply follows load" to "load follows supply" (users become "prosumers" = PROducer - conSUMER)



Access to electricity and clean cooking remains elusive



- With <u>rising population, urbanisation and industrialisation</u>, Africa is increasingly influential for global energy trends.

- <u>Renewables and natural gas</u> are acting as an accelerator to development in a few countries, but in many others, <u>energy remains a brake to development</u>:

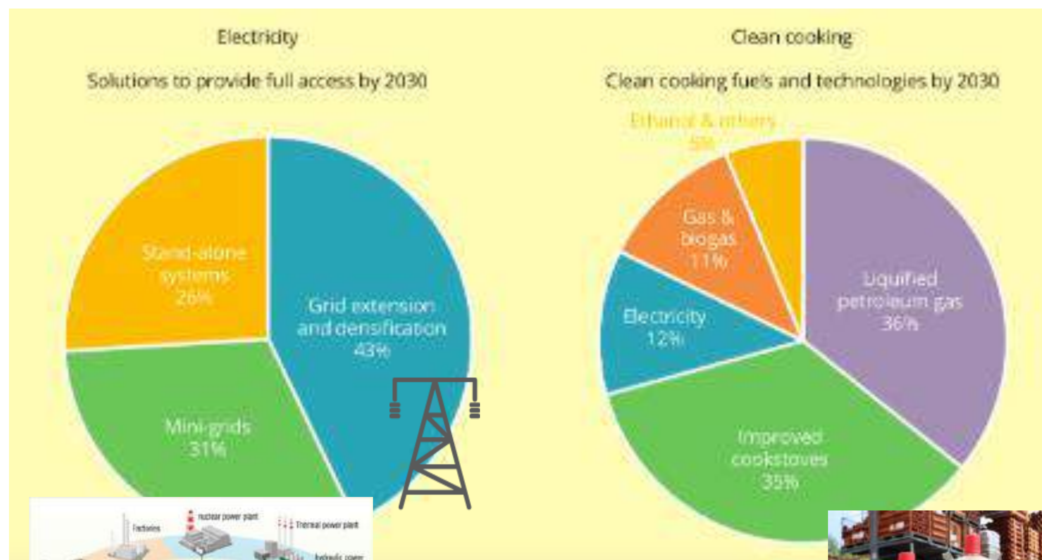
- <u>Access to electricity and clean cooking</u> remains elusive.
- <u>Investment in power infrastructures</u> among the lowest in the world.
- <u>Traditional use of biomass</u> dominates the energy mix.

As a reminder, <u>nearly half of Africans (600 million people) did not have access to electricity in 2018</u>,
while <u>around 80% of sub-Saharan African companies suffered frequent electricity disruptions leading</u> to economic losses.

In addition, more than 70% of the population, <u>around 900 million people, lack access to clean cooking</u>. The resulting household air pollution from traditional uses of biomass is causing <u>500 000 premature deaths a year</u>. It also contributes to <u>forest depletion</u> resulting from unsustainable harvesting of fuelwood, as well as <u>imposing a considerable burden and loss of productive time</u>, mostly on women.

Access to electricity and clean cooking remains elusive

Despite progress in several countries, current and planned efforts to provide access to electricity barely outpace population growth; efforts for clean cooking need to accelerate even more



What is required to achieve full energy access by 2030 ?

* <u>Access to electricity</u> means <u>grid densification and grid extension</u> (43 %) - often the least-cost solution), <u>mini-grids</u> (31 %) and <u>stand-alone systems</u> (26 %).

* <u>Access to clean cooking facilities</u> means access to (and primary use of) <u>modern fuels and technologies</u>, including natural gas, liquefied petroleum gas (LPG), electricity, bioethanol and biogas, or improved biomass cookstoves.

Three increasing levels of energy access (scale of grid system)

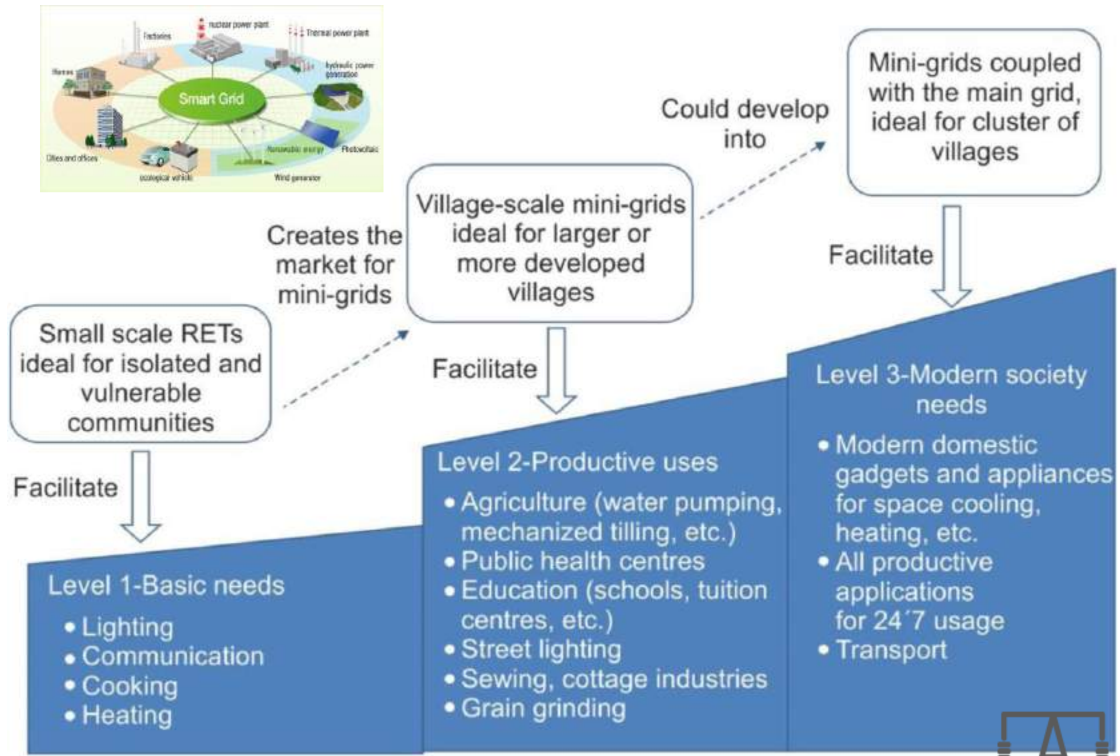
Of particular interest in electric system's strategy is the issue of scales: off-grid, mini-grid or major grid.

A distinction should be made between

- **<u>off-grid systems</u> at the scale of a household (< 500 We) :**
  appropriate for small populations living in remote rural areas distant from existing electrical grids (small-scale renewable energy technologies /RETs/, e.g. solar home systems)

- **<u>mini-grid systems</u> at the community level (30 – 500 kWe) :**
  appropriate for communities of a dozen to several thousand households in a rural area (particularly if the grid is far away from the target populations) (e.g. biomass power plants)

- **the <u>major grid systems</u> needed for industrialised societies (up to several hundreds of MWe) :**
  generally preferred in highly-populated urban and peri-urban areas, where population density allows economies of scale (e.g. thermal power using fossil fuels or hydro-power).



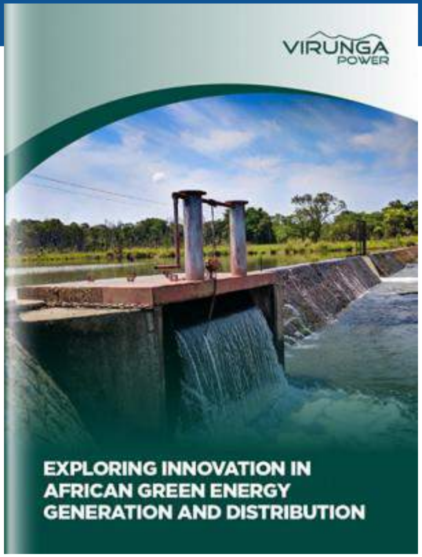
<u>Emerging countries - One size does not fit all</u>
A progressive development path, over a period of time, will ensure the transition from basic to conditions suitable for modern living.

"Mini-grid based off-grid electrification to enhance electricity access in developing countries: What policies may be required?"
http://www.sciencedirect.com/science/article/pii/S0301421516301781

"Virunga Alliance" – a project of sustainable development for the benefit of the local populations of the Virunga National Park (1/2)

"Every MW of electricity generated empowers the community, by creating 1.000 jobs, 5–10% of which go to ex-combatants. When people are empowered, they have the choice to control their future and move into productive society, away from armed groups".
Emmanuel de Merode, director, Virunga National Park.

(http://blog.lesoir.be/colette-braeckman/2015/12/28/la-centrale-de-matebe-nord-kivu-contre-la-guerre-et-la-deforestation/)



(1) Mutwanga Hydro-power Station

• mini to small hydro-power technology : Run-of-the-river (normal elevation 1,290 m)

• Capacity : Mutwanga I with 0.38 MW ("mini-hydro"), upgraded to Mutwanga II (completed in 2019) with 1.35 MW ("small hydro")

• Estimated Investment : financed by EU

• Announced : Commission date 2013, now operational

The power station is located in North Kivu, the Democratic Republic of the Congo, near the village of Mutwanga, on one of the rivers in Virunga National Park, a Unesco World Heritage Site.

At Mutwanga, the plant has spawned a soap factory and papaya factory (400 jobs).

(https://www.africaoutlookmag.com/company-profiles/1293-virunga-power/reader)

EU- AID

(2) Rutshuru Hydro-power Station (also called Matebe)

• small hydro-power technology : Run-of-the-river (elevation 1,600 m)

• Capacity : 13.8 MW (max. planned) – 2 turbines ("large hydro")

• Estimated Investment : a additional US $ 20 million (financed by the Howard G Buffett Foundation, an USA philanthropic organization)

• Announced : start in 2013, commission date 2016, now operational

This project is envisioned to kick-start the green economy in the country, while bringing over 12,000 sustainable employments for those in the region of Rutshuru.

The hydro-electric plant is expected to supply 600 000 people with clean, accessible and affordable electricity (including Goma which is a huge consumer of charcoal, most of it illegally sourced in the southern sector of the park).

(Source 2017 - https://www.esi-africa.com/industry-sectors/generation/drcs-matebe-hydropower-plant-qualifies-for-carbon-certification/

+ "L'hydro-électricité pour l'habitat des gorilles" - Climate Partners - https://www.climatepartner.com/fr/projets/hydraulique-virunga-congo)

"Virunga Alliance" – a project of sustainable development for the benefit of the local populations of the Virunga National Park (2/2)

(3) A third site at Lubero is being developed with a hydro-electric capacity of 12.8 MW

The three power plants, financed in particular by the European Union, cost more than 60 million USD, it is reported.

These projects belong to Virunga Sarl, a company that constructs and operates hydro plants and distribution systems in the Virunga National Park area.

The company offers incentive schemes for commercial / industrial (medium voltage) and residential (low voltage) customers.

The scheme involves a lump-sum payment for the first year ($292 for medium voltage and $223 for low voltage) and a consumption-based tariff for subsequent years (20.26 cents/kWh for medium and 21.50 cents/kWh for low voltage customers).

By early 2018, Virunga had around 4,300 customers.

Power Africa is working with Virunga to expand its network into the Nyirigonga district of Goma, which has up to 20,000 households without power.

Source : US-Aid April 16, 2020 - https://www.usaid.gov/powerafrica/democratic-republic-congo

Read also : "World Small Hydropower Development Report 2019 : Case Studies", LIU, D., LIU, H., WANG, X., and Kremere, E., eds. (2019) - United Nations Industrial Development Organization (UNIDO); International Center on Small Hydro Power (https://www.unido.org/our-focus-safeguarding-environment-clean-energy-access-productive-use-renewable-energy-focus-areas-small-hydro-power/world-small-hydropower-development-report)

"Difficult Times for Virunga and its Hydro-power Plants"

December 18, 2017, by Save Virunga

… It is time to bring the facts to the table, and let them speak for themselves:

- **The Price of the Connection ....**
- **The Price of Electricity ....**
- **The Current Situation of the Project**
- **As of November 30, 2017, 3,669 households and 220 companies have been connected to the Matebe hydro-power plant network. ....**
- **The Other Dimensions of Virunga's Hydro-power Project .... public lighting .... free electricity to social infrastructure .... an experimental microcredit program to facilitate the entrepreneurship of the poorest, … employs 273 people (direct jobs), … provides work for around 2,000 daily workers ....Other sectors of activity in the Virunga National Park (security, tourism, etc.) provide direct employment to about 1000 people.**
- **The Objectives of the Virunga Alliance .... sustainable development for the benefit of the local populations of the Virunga National Park – "Virunga Alliance" – is supported by the park, but also and above all by the public authorities, the civil society and the private sector of North Kivu.**

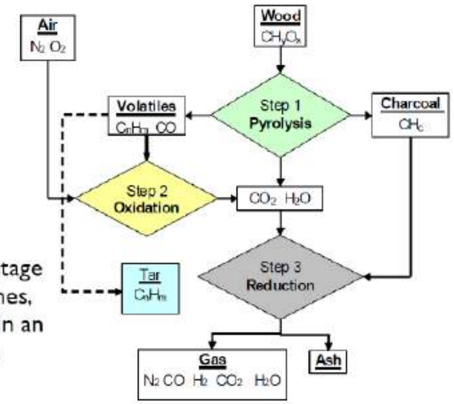
(https://savevirunga.com/2017/12/18/difficult-times-for-virunga-and-its-hydropower-plants-time-to-get-the-facts-right/)

Recycling - gasification of agricultural residues : not only heat but also electricity (1/2)

Rural populations in Africa depend nearly exclusively on woody biomass to satisfy their energy needs that are usually limited to cooking and some food processing.
Nevertheless, this limited use together with the biomass exported to the cities lead to an unsustainable pressure on the resources.
At the same time, agricultural activities lead to the production of large quantities of residues (cotton stalk, rice husks, etc.).

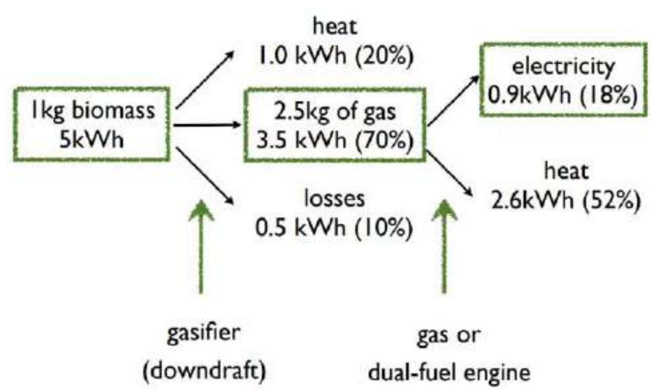
These wastes have an energetic potential that could be exploited locally.
But, contrary to woody biomass, the combustion of these residues is complex.
Gasification could help converting efficiently these residues into more useful forms of energy: not only heat but also electricity.
Downdraft fixed bed gasifiers are the most suitable technology for the range of power (50…200 kWth) and feedstocks considered.

Gasification is a high efficiency conversion of a solid into a combustible gas, mainly composed of CO and H2.



In single-stage approaches, tars remain an issue

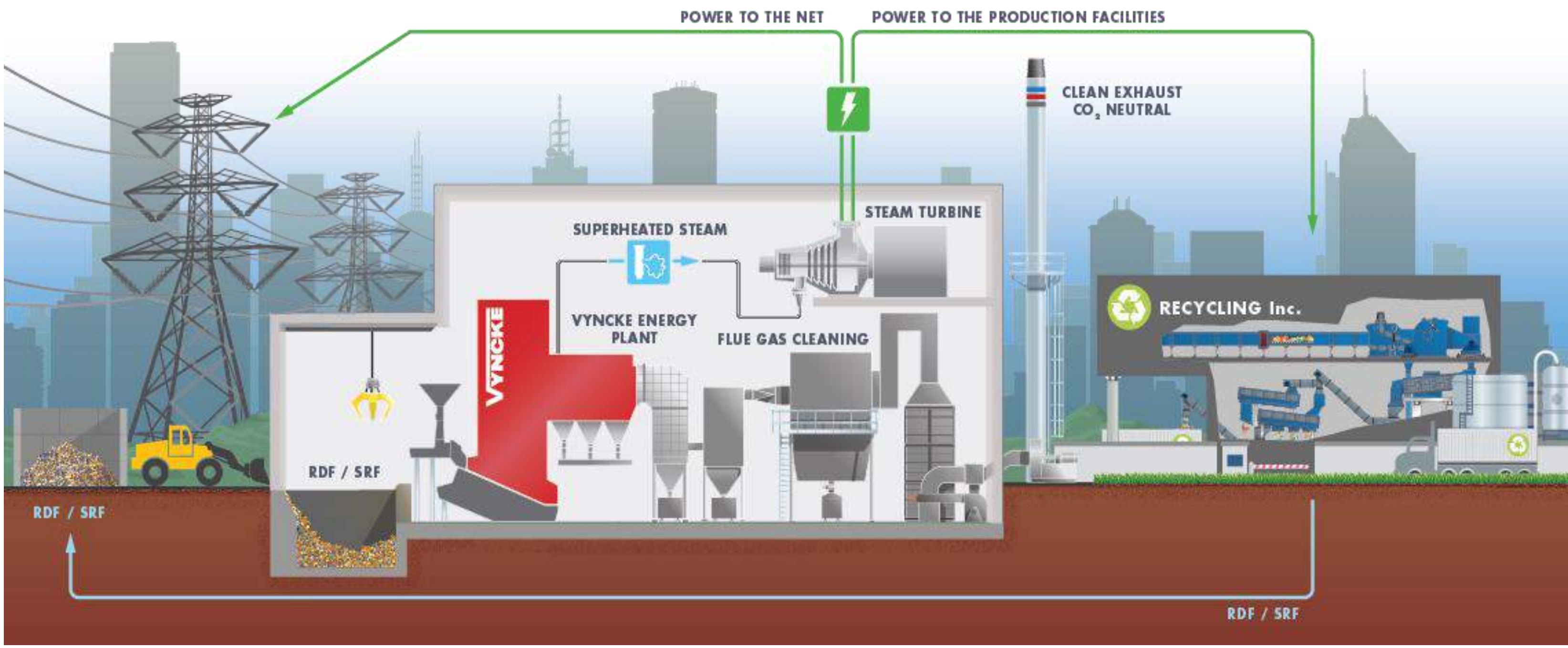
Cold gas efficiency is 70%. The gas can be further converted into electricity with an efficiency of around 20%



Rappel. Les procédés de conversion utilisés pour transformer la biomasse en combustible peuvent être:

- *** soit thermo-chimique (ou voie sèche) : il s'agit de la combustion, de la pyrolyse, de la gazéification et du craquage catalytique.**
  - **la combustion - ou incinération pure et simple (par ex. balle de riz, coque d'arachide ..) s'effectue dans des chaudières industrielles pour produire de la vapeur et parfois de l'électricité;**
  - **la pyrolyse - ou thermo-décomposition en atmosphère pauvre en oxygène - est utilisée e.a. pour la production de charbon de bois à usage domestique (par ex. à partir d'eucalyptus).**
- *** soit bio-chimique (ou voie humide) : il s'agit de la fermentation alcoolique et de la fermentation méthanique.**

Recycling – gasification of agricultural residues : not only heat but also electricity (2/2)



RECYCLING INDUSTRY - WASTE FROM RECYCLING TO MAKE ENERGY FOR ALL INDUSTRIES
In the eighties, industry began to take an interest in recovering solid fuels from waste streams in order to reduce disposal costs and energy costs. As it is difficult to identify the fuels as monostreams (e.g. recycled wood), these streams were in general referred to as 'Refuse Derived Fuels" (RDF) or "Solid recovered fuels" (SRF).

The cement kilns are an important market for these fuels. There is however a huge unused potential to use these recovered fuels to produce energy for district heating, power generation and other industry. This will help to decarbonize the industry by replacing fossils fuels. (Manufacturers : e.g. biomass boilers - Harelbeke, Belgium - https://www.vyncke.com/industries/renewables/waste/)

"WE TURN BIOMASS INTO CLEAN ENERGY - VYNCKE designs and builds green and clean energy plants burning biomass and waste to produce thermal energy from 1 – 100 MWth and electrical power from 0.5 – 15 MWe. The energy comes individually or in any combination of steam, hot water, thermal oil and hot gas … with or without electrical power generation."

Source: RAOS Conference SE4A 2017 - "Sustainable energy for Africa", 2017, October 23 – 25, Brussels (Royal Academy for Overseas Sciences of Belgium) - "A locally manufactured gasification technology for the valorization of agricultural wastes in West African countries" by Prof Hervé Jeanmart (UCLouvain), Séverin Tanoh, Wilfried Ouedraogo, Yohan - Richardson, Sayon Sidibe, Frédéric Bourgois and François Pinta - https://www.kaowarsom.be/en/SustainableEnergy4Africa_presentations%26vid%C3%A9os

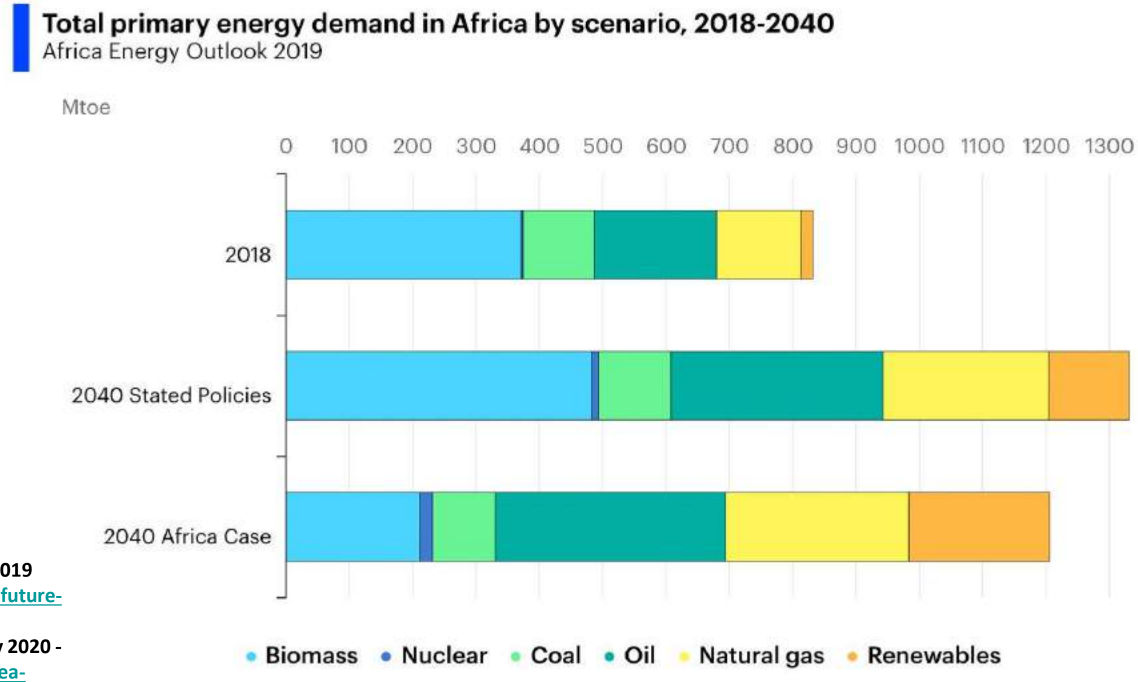
SOLARIMPULSE EFFICIENT SOLUTION NOVEMBER 2019

* See also "BCH biomass condensing boilers (capacity of 150kW, generation of 20 MWh/year)" - https://solarimpulse.com/efficient-solutions/bch-biomass-condensing-boilers
Applications in greenhouses, industrial processes, dryers, food processing, where low cost solid biomass fuel is available (granulated up to 30 mm).

A huge opportunity for renewables and natural gas

A major shift towards modern and efficient energy mix

Africa could be the first continent where renewable energy technologies /RETs/ and gas play a prominent role in supporting a shift away from bioenergy and underpinning economic and industrial growth



Source : "IEA - Africa Energy Outlook 2019", Paris, 8 Nov. 2019 Press Release -https://www.iea.org/news/africas-energy-future-matters-for-the-world and "A huge opportunity for renewables and natural gas", May 2020 - https://www.modernpowersystems.com/features/featurea-huge-opportunity-for-renewables-and-natural-gas-7912686/

In 2018, total primary energy demand (TPED) in Africa was more than 830 million tonnes of oil equivalent (Mtoe) /or 9650 TWh/: North Africa (24%), Nigeria (19%), and South Africa (16%) together accounted for almost 60% of this despite making up only 35% of the population.
Average energy consumption per person in most African countries is close to 0.6 toe/capita (well below the world average of around 2 toe/capita).
In most SSA countries, a large part of energy consumption consists of the inefficient use of solid biomass (mostly for cooking but also in industry).
Prospects for Africa in 2040 : TPED reaches 1350 Mtoe /or 15700 TWh/ in the IEA "Stated Policies Scenario" (STEPS) and 1200 Mtoe /or 13950 TWh/ in the IEA "Africa Case" (AC).

- Between 2010 and 2018, total installed electricity generation capacity in Africa increased from around 155 gigawatts (GW) to almost 245 GW, or about a quarter of the capacity in European Union countries. Breakdown : 100 GW of gas-fired power plants ; 50 GW of coal-fired capacity ; 40 GW of oil-fired capacity ; 50 GW of renewable power capacity (including 35 GW of hydropower) ; 5.5 GW for wind power ; 4.5 GW for solar ; 0.6 GW of geothermal.

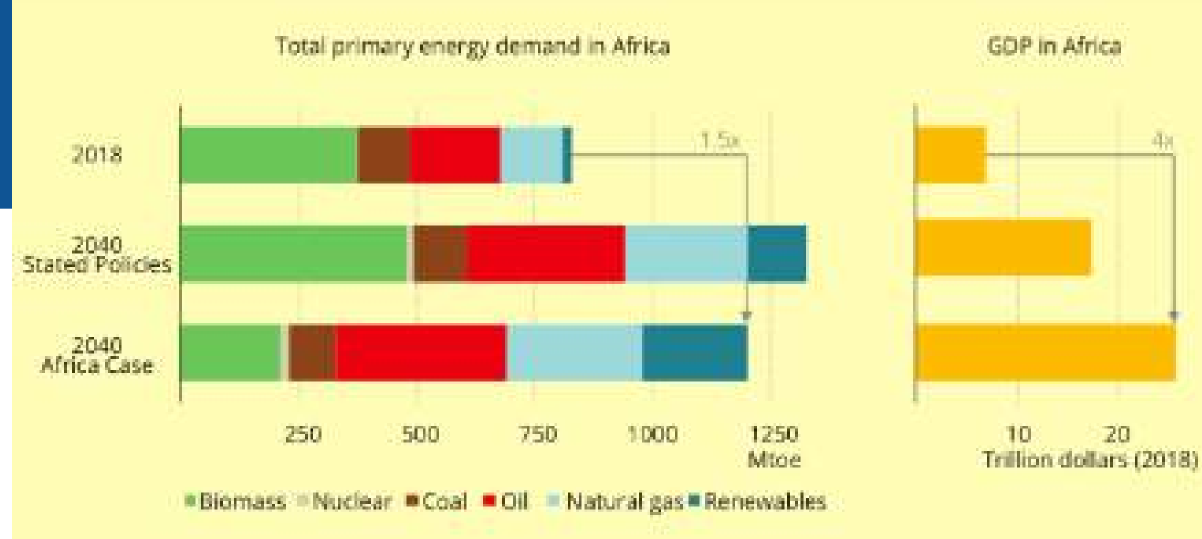
- Africa's young, fast growing and increasingly urban population is set to drive the continent's economic and energy development as well as global energy trends.

- A critical task for policymakers is to address the persistent lack of access to electricity and clean cooking, and the unreliability of electricity supply.

Building a reliable power system requires a significant scale-up in investment; mobilising capital is a challenging undertaking, but can be achievable with adequate policy measures.

NB - In 2018, energy consumption in the European Union of 27 Member States (EU) : Primary energy consumption reached 1 376 Mtoe, while final energy consumption reached 990 Mtoe (Eurostat). The difference (28 %) relates mainly to what the energy sector needs itself and to transformation and distribution losses -the EU has an energy efficiency target of reducing energy consumption by 20% by 2020.

The future of natural gas in Africa 1/2



ENERGY EFFICIENCY. The continent could fuel an economy four times larger than today with only 50% more energy, if there is a major shift towards modern energy sources such as renewables and natural gas and efficiency improvements

Oil and gas

Africa is home to five of the world's top oil-producing countries, with an estimated 57 percent of Africa's export earnings from hydrocarbons.

Algeria, Angola, Cameroon, Chad, Republic of Congo, Egypt, Eritrea, Gabon, Ghana, Kenya, Libya, Nigeria, South Sudan, Sudan, Tunisia, and Mozambique are all rich in oil and gas.

Proven oil reserves have grown by almost 150 %, increasing from 53.4 billion barrels since 1980, to 130.3 billion barrels by the end of 2012.

The region is home to five of the top 30 oil-producing countries in the world, and nearly $2tn of investments are expected by 2036.

The future of natural gas in Africa is at an important juncture.

Since 2010, there have been major gas discoveries in every part of the continent: immense finds in East Africa (Mozambique and Tanzania) were followed by more in Egypt, West Africa (Mauritania and Senegal) and South Africa.

While Africa in 2018 accounts for 7.3 % of all oil reserves across the globe (125 billion barrels of proven oil reserves), over 40% of global gas discoveries between 2011 and 2018 were in Africa.

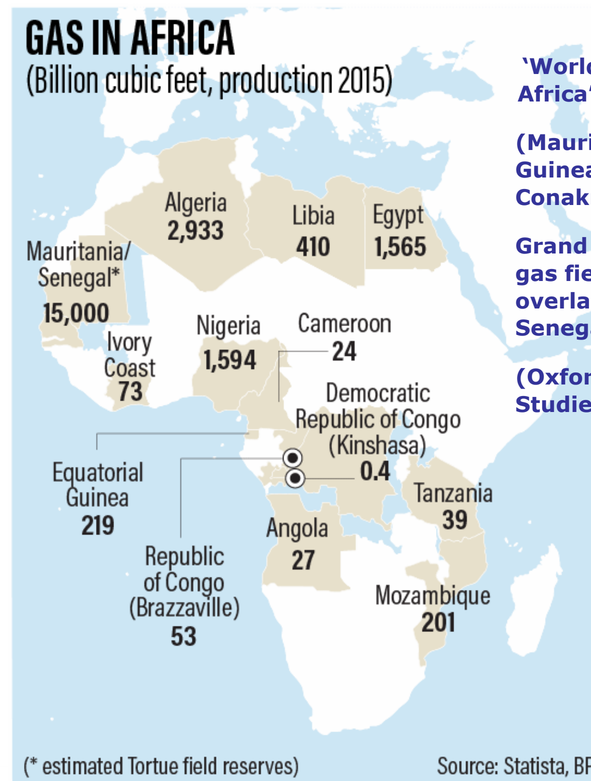
These resources offer new opportunities for Africa's energy and industrial development.

The prospects for gas, however, hinge upon well-articulated strategies to bring the discoveries into production and build infrastructure to deliver gas to consumers at competitive prices.

Two main issues:

(1) There are national oil or gas companies (NOCs) because of limited financial capacity and lack of technical expertise in handling complex projects

(2) most spending in oil and gas has been directed at export-oriented projects (e.g. upstream and liquefied natural gas) rather than projects geared towards domestic markets (e.g. gas pipeline, refineries).



'World class' gas discoveries in Africa's MSGBC geological basin

(Mauritania, Senegal, Gambia, Guinea Bissau, and Guinea Conakry).

Grand Tortue Ahmeyim (GTA) gas field development project, overlapping Mauritania and Senegal's off-shore waters.

(Oxford Institute for Energy Studies – 2020)

The future of natural gas in Africa 2/2

The Organization of the Petroleum Exporting Countries (OPEC) has a strong base in the gas industry, even though the focus of the Organization is on the oil market.

As of January 2020, OPEC has 13 member countries: five in the Middle East (Western Asia), seven in Africa (namely : Algeria, Angola, Equatorial Guinea, Gabon, Libya, Nigeria, the Republic of the Congo), and one in South America.

This map illustrates the current state of Africa's LNG projects together with the distribution of natural gas reserves, 2018

Map : Countries by natural gas proven reserves (2014) and LNG projects (2018)
https://en.wikipedia.org/wiki/List_of_countries_by_natural_gas_proven_reserves

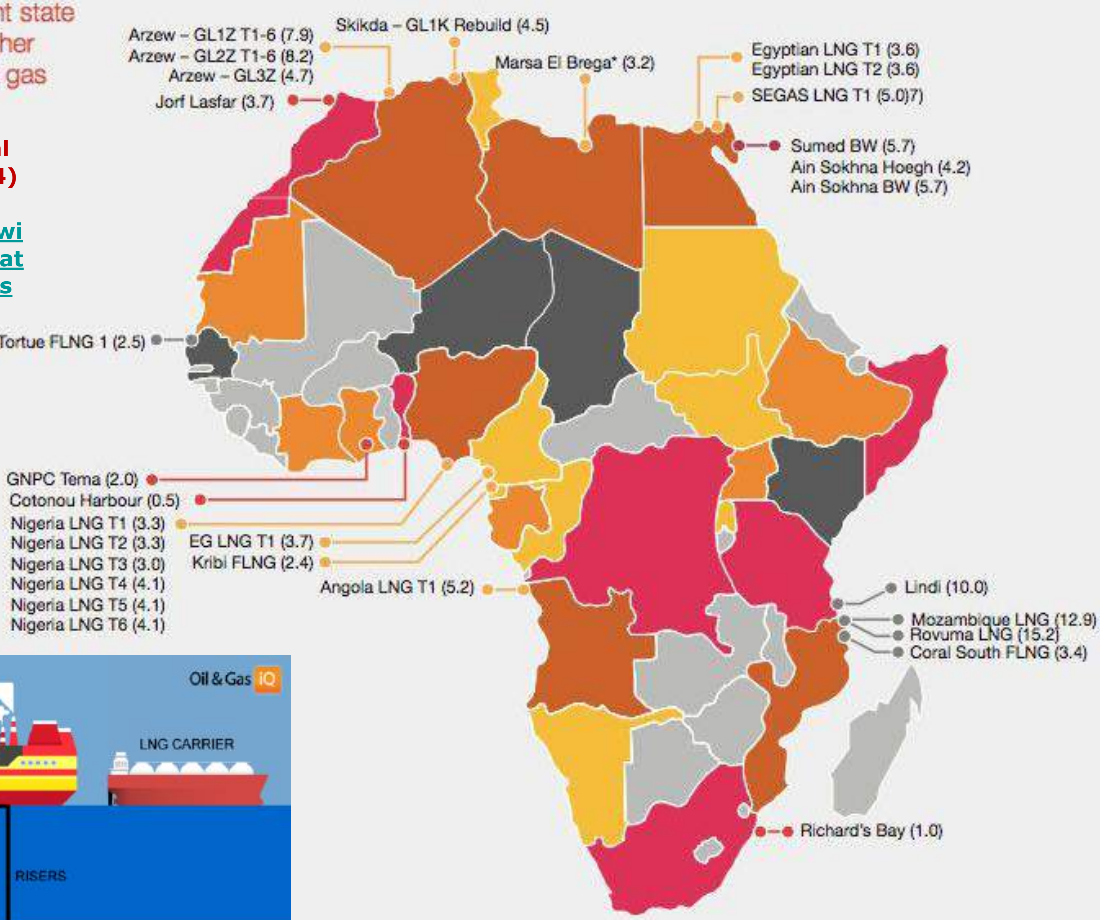
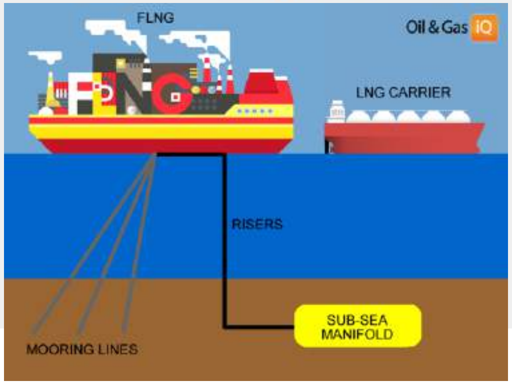


Figure : Floating Liquefied Natural Gas (FLNG) - "A guide to FLNG", August 2018
FLNG facilities can be up to 450 metres long, can be located 500 km from the nearest land, can store more than 170,000 m³ of LNG, can generate 100 MW on board.
https://www.oilandgasiq.com/fpso-flng/articles/guide-to-flng



Aside from oil reserves, many African countries enjoy a surplus of natural gas and coal reserves, which have a considerable role to play in the energy sector. Where coal has been among the most stable commodities and sources of income, changes in the energy sector are shifting the focus away from coal.

One sign of encouragement is that the global shift towards natural gas has been accompanied by an increase in proven natural gas reserves across Africa.

The continent's share of global gas reserves is currently at 7.2 % (509 tcf of gas), aided by a substantial discovery made in Mozambique in recent years.

According to PwC, the new discovery "has already unlocked the first three large-scale LNG projects. These projects, together with project expansion phases and additional exploration, have the potential to position Mozambique as the third largest global LNG producer after Qatar and Australia by 2030."

Source : "Natural gas is the way forward for the African resources sector", Consultancy.Africa, 11 Nov 2019
https://www.consultancy.africa/news/1865/natural-gas-is-the-way-forward-for-the-african-resources-sector

AFRICAN ENERGY CHAMBER

Africa Should be Allowed to Use its Resources

(African Energy Chamber, Johannesburg, South Africa, 29 Nov 2019)

The African Energy Chamber launches a petition against the idea that the continent should not explore its full hydrocarbon potential in the wake of the climate change debate.

On the backdrop of the climate change debate, Africa finds itself in an unfortunate position where it is required by the global energy industry to slow down its progress and not explore its hydrocarbons potential to its fullest. This is not right.

At the African Energy Chamber (https://EnergyChamber.org/) we do not deny the impacts and severity of climate change. We recognize the role and significance of the Paris Agreement which over 30 African countries have signed. However, we believe the energy transition should be gradual and considerate of the power gap that exists in Africa.

On the continent, our foremost obligation as industry leaders is to ensure that Africa's people have access to energy. We are determined to address the everyday issues that the continent is faced with.

Energy poverty is Africa's most critical concern

For us, it is a life and death situation. In Africa, over 600 million people still do not have access to power. And, we remain a net importer of energy yet we boast 125 billion barrels of proven oil reserves, accounting for 7.3 percent of global oil reserves and 509 tcf (trillion cubic feet) of gas – accounting for 7.2 percent of global reserves.

Our natural resources are important for our development. We cannot ignore what the continent needs, in the interest of supporting global trends when our economies remain underdeveloped. Our hydrocarbon potential is vast and Africa is home to a number of emerging economies who are steadfast on taking their rightful place in the global energy sector, our time to industrialize is now.

We applaud our brothers, sisters and friends in the west such as Norway and Germany for having used their oil and gas resources to develop their countries and build thriving economies. But, Africa deserves the same opportunity to build world-class economies.

"Africa Should be Allowed to Use its Resources" (call against "environmental colonization") 2/2

AFRICAN ENERGY CHAMBER

Environmental colonization

"At the African Energy Chamber, we understand that issues of climate change are important but, this new drive for environmental colonization bullies African countries to leave their resources and depend on the sun," said NJ Ayuk Executive Chairman of the African Energy Chamber and author of "Billions at Play: The Future of African Energy and Doing Deals" (October 2019).

In the past, Africa has been far too reliant on foreign aid and while in some ways it has been extremely helpful and beneficial, it has also taken away our independence. In several instances, Africa has always taken the passenger seat when it comes to deciding its future but, it must end now.

Our continent needs to be left alone to decide its own fate.

The African Energy Chamber strongly stands against the idea that Africa should ignore its potential and ability to leverage its resources as a means to drive growth, create opportunities for investment and development.

As the voice of the African energy industry, we are proud to announce our counter-campaign on the insistence that the continent should pursue a less carbon-intensive energy future as a way to support global interests which Africa has not yet benefitted from.

NB In above book, NJ Ayuk points the way to a more powerful African presence on the world stage through African OPEC membership and through energy value chain development.

Steelmaking boom in Algeria likely to end billet imports

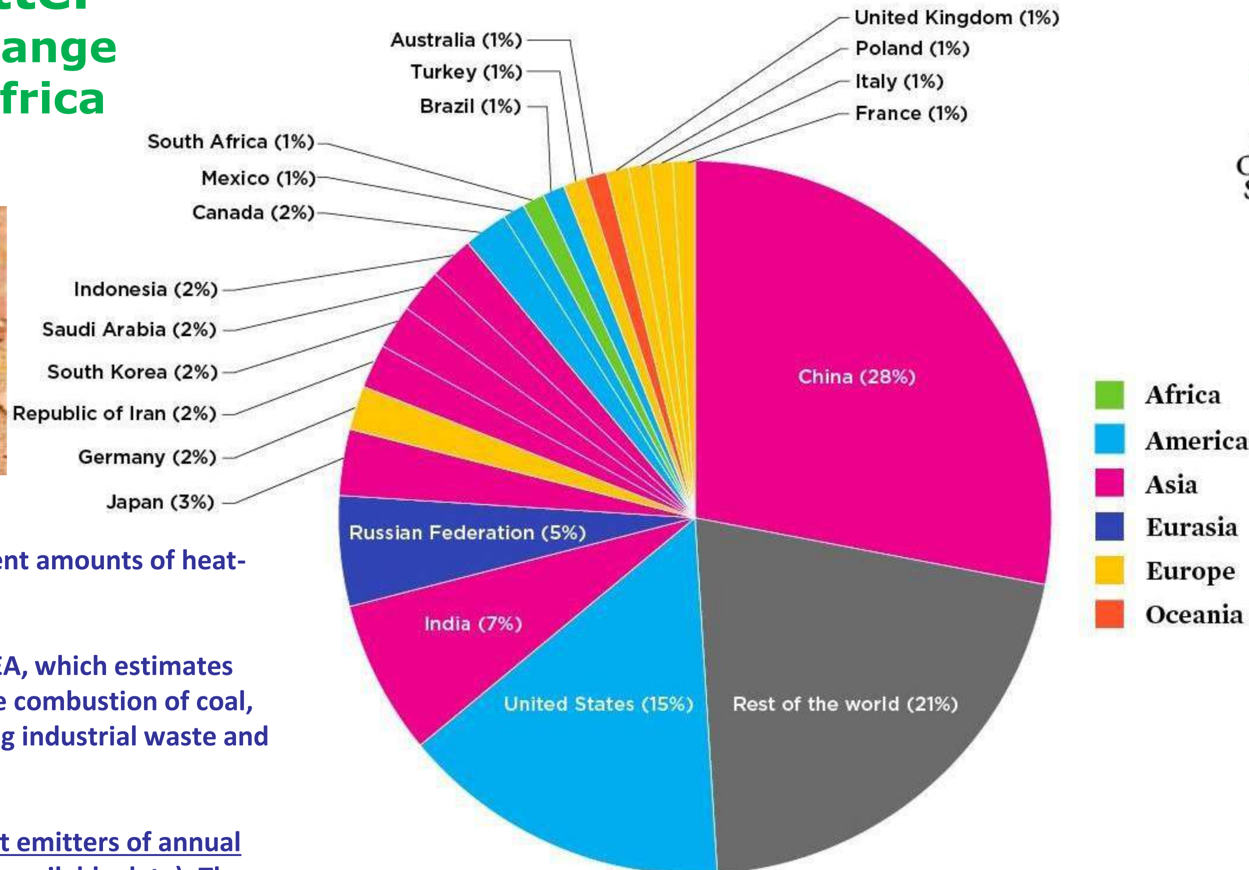
The country's steelmaking capacity is expected to grow by around 7 million tonnes by the end of 2020, which will lead to significant reduction in, if not the total elimination of, billet imports, sources told Metal Bulletin (July 19, 2018)
https://www.metalbulletin.com/Article/3821672/FOCUS-Steelmaking-boom-in-Algeria-likely-to-end-billet-imports.html

– see, in particular, Oran-based subsidiary of Turkey's Tosyali Holding and Bellara-based Algerian Qatari Steel

- Reminder : Algeria's predicted steel requirement in 2020 is of 10 million mt/y

Source : "Africa Should be Allowed to Use its Resources", Maravi Post Reporter, South Africa, 29 Nov 2019 – https://www.maravipost.com/africa-should-be-allowed-to-use-its-resources/ and "Top 25 Movers and Shakers to Watch" - https://energychamber.org/news/top-25-movers-and-shakers-list/

Not a major emitter
(4 %), but climate change matters greatly for Africa



Union of Concerned Scientists

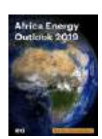
The world's countries emit vastly different amounts of heat-trapping gases into the atmosphere.

The chart shows data compiled by the IEA, which estimates carbon dioxide (CO2) emissions from the combustion of coal, natural gas, oil, and other fuels, including industrial waste and non-renewable municipal waste.

Picture right : we rank the top 20 highest emitters of annual carbon dioxide in 2018 (the most recent available data). The picture that emerges from these figures is one where—in general—developed countries and major emerging economy nations lead in total carbon dioxide emissions.

Africa accounts for a relatively small, but nonetheless growing share of the world's CO_2 emissions. In 2018, the continent accounted for 3.7% of global energy-related CO_2 emissions or around 1.2 gigatonnes (Gt) CO_2. North Africa accounted for the largest share with 40% and South Africa accounted for 35%.

Source : "Each Country's Share of CO2 Emissions", Union of Concerned Scientists, Aug 12, 2020 - https://www.ucsusa.org/resources/each-countrys-share-co2-emissions



- Achieving the outcomes of the Africa Case would be neither energy-intensive nor emissions-intensive thanks to stronger roles of energy efficiency and clean energies.

- Although not a major emitter, Africa is in the front line for the effects of a changing climate. Energy infrastructure planning must be climate-resilient.

NB Cumulated energy-related CO2 emissions:
** 1890-2018 : 2 % in Africa and 98 % in rest of the world*
** 1890 – 2040 (Stated Policies) : 3 % in Africa and 97 % in rest of the world*

African planned and existing electricity lines

The Electrification Situation

According to Power Africa, there is a long way to go to 100% electrification.

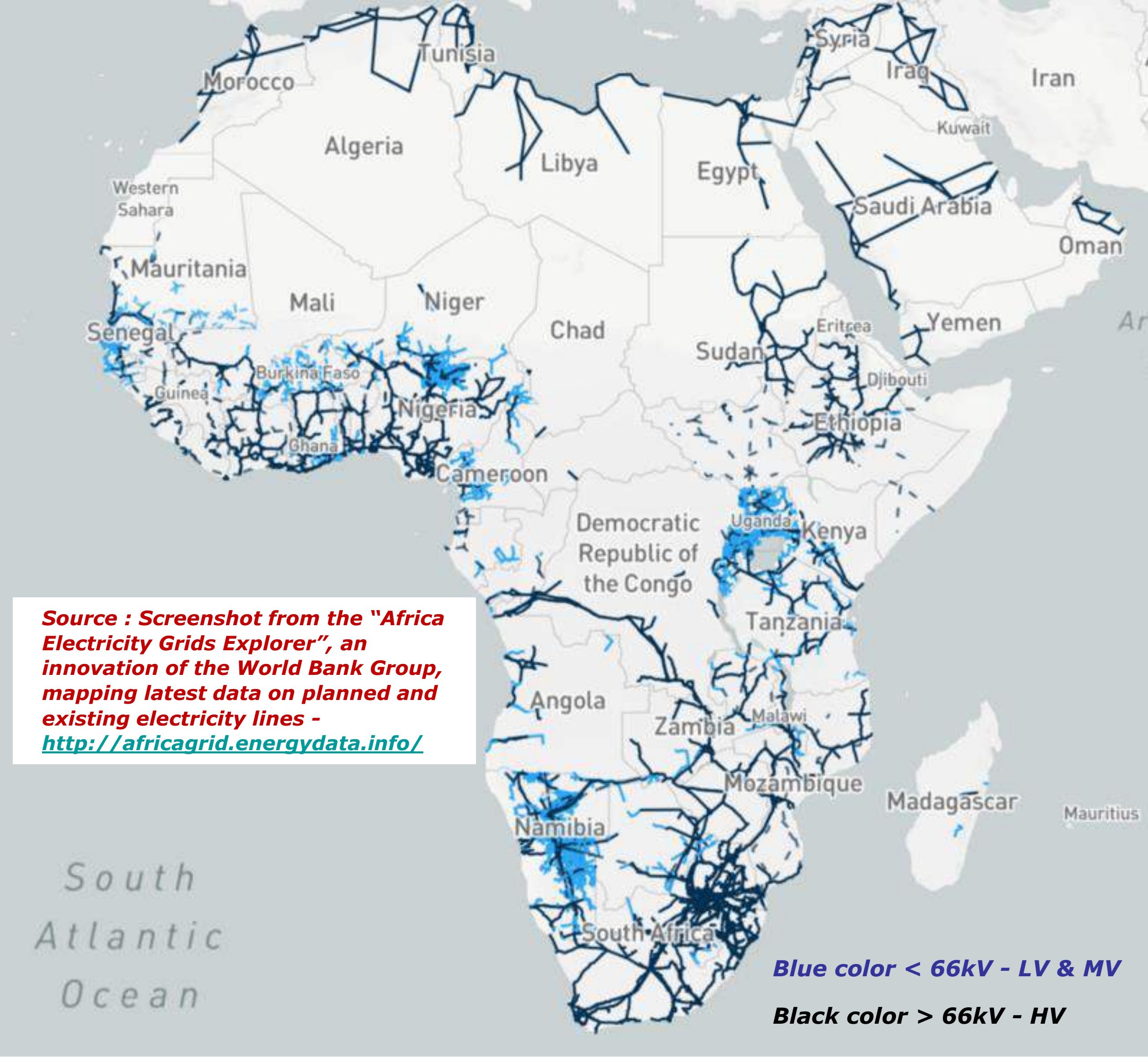
* Kenya is only 65% electrified by the national grid, run by Kenya Power & Electric (KPLC); this percentage is significantly higher than neighboring countries…and still far from the Vision 2030 target of 100% of the population with electricity access

* In contrast, Nigeria (45%), Ethiopia (40%) and Rwanda (30%)

* South Africa takes the lead with 86% electrification

* At only 22%, Uganda has one of the lowest electrification rates in Africa.

Source : "Electrifying Africa: A Brief Introduction to Solar & the Opportunities", Feb 7, 2019, I-DEV International - https://medium.com/i-dev-insights/electrifying-africa-a-brief-introduction-to-solar-the-opportunities-article-1-of-3-9604dc450301



Source : Screenshot from the "Africa Electricity Grids Explorer", an innovation of the World Bank Group, mapping latest data on planned and existing electricity lines - http://africagrid.energydata.info/

Focus on DRC's transmission network

The commissioning of the Inga 2 hydro-electric plant (1,424 MW) in 1982, which alone still accounts for more than 50% of the country's generation capacity, was followed by the construction of a 500 kV DC line of 1,774 km between Inga and Kolwezi, allowing the interconnection of the West and South grids and the transfer of energy to Kolwezi to cope with growing mining demand…
The Inga-Kolwezi HVDC line was rehabilitated over the period 2012-2019 and work is currently underway to increase the transit capacity from 560 MW to 1,000 MW to the southern transport network thanks to funding from multilateral and private (mainly mining) partners.

Source : "Increasing access to electricity in the Democratic Republic of Congo - Opportunities and challenges", Washington, DC - World Bank. 2020 - http://documents1.worldbank.org/curated/en/743721586836810203/pdf/Increasing-Access-to-Electricity-in-the-Democratic-Republic-of-Congo-Opportunities-and-Challenges.pdf

Electricity demand in Africa (TWh)

- With a fifth of the world's population, Africa accounts for only 6% of global energy demand and little more than 3% of electricity demand. Bioenergy is the largest source of energy in Africa today, meeting 45% of primary energy demand and over half of final energy consumption.

- To date, limited use has been made of this vast potential of renewable energy resources: Africa has only 50 gigawatts (GW) of renewable capacity, mostly hydropower (36 GW).

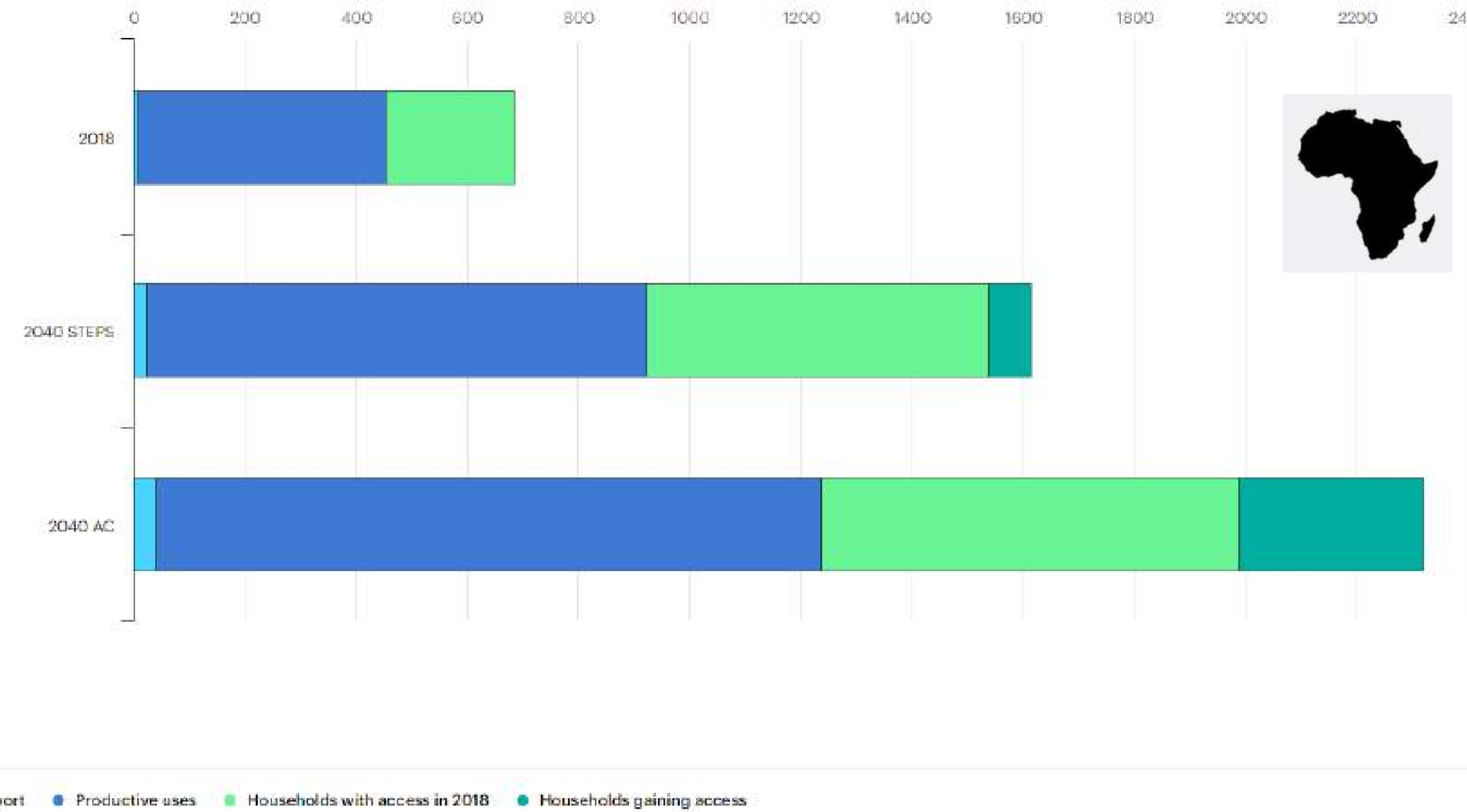


Figure : Electricity demand (TWh) in Africa by scenario, 2018-2040

Transport – Productive uses – Households with access in 2018 – Households gaining access

700 TWh = Electricity demand in Africa in 2019 (= 550 kWh per capita)

700 TWh is equivalent to a fifth of electricity demand in Europe in 2018.
Electricity accounts for less than 10 % of Africa's total final energy consumption, but per capita electricity demand in Africa remains very low at around 550 kWh (370 kWh in sub-Saharan Africa) compared with 920 kWh in India and 2 300 kWh in Developing Asia.

Electricity generation in Africa increased to 870 TWh in 2018 from 670 TWh in 2010.

"Sub-saharan Africa (SSA) is the world's region with the lowest access rate to electricity, only 35% in average, with a stark disparity between urban (69%) and rural areas (15%).

NB : Comparison with electricity demand in the EU in 2019 - EU-wide consumption average varied greatly between countries: from Romania (2550 kWh/capita) to Finland (14 951 kWh/capita). In Belgium, electric power consumption was reported at 7 250 kWh/pers/yr. (source : Enerdata's Global Energy Research - https://estore.enerdata.net/)

Renewables push ahead to power Africa's brighter future

Electricity demand in Africa today is 700 terawatt-hours (TWh), with the North African economies and South Africa accounting for over 70% of the total. Yet it is the other sub-Saharan Africa countries that see the fastest growth to 2040. Electricity demand more than doubles in the "Stated Policies Scenario" to over 1 600 TWh in 2040, and reaches 2 300 TWh in the "Africa Case", with most of the additional demand stemming from productive uses and emerging middle- and higher-income households.

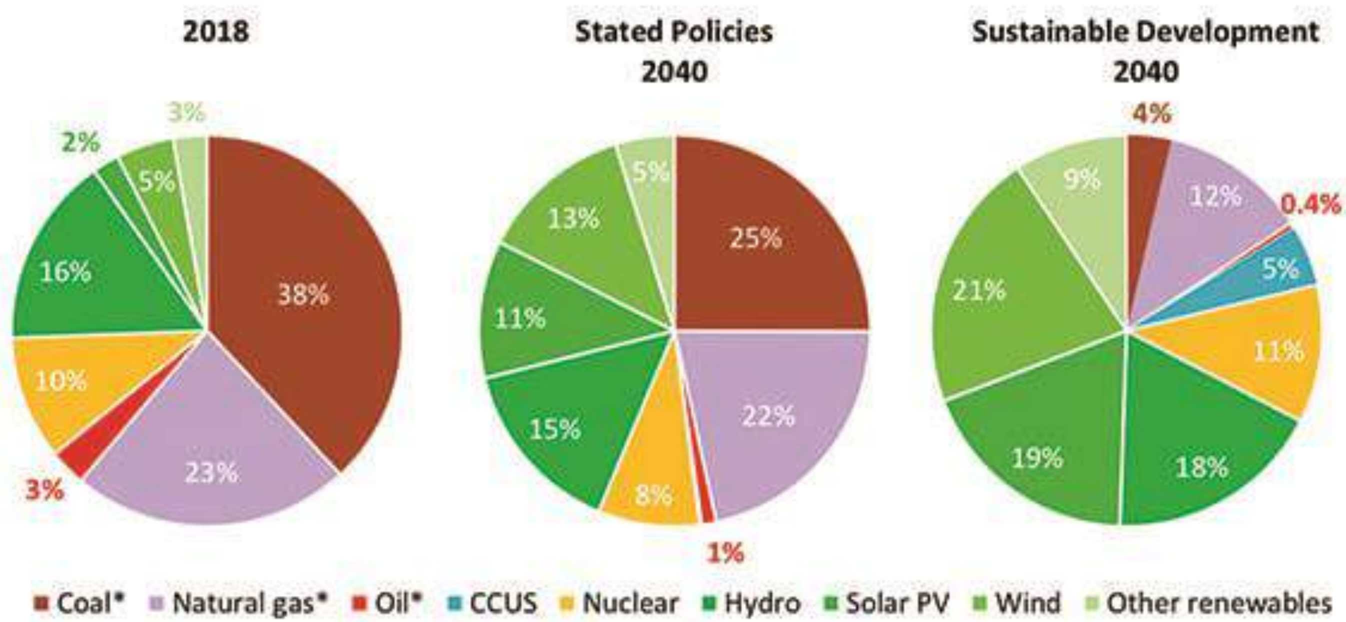
Source :"IEA - Africa Energy Outlook 2019" – overview , Paris, 8 Nov. 2019
https://www.iea.org/reports/africa-energy-outlook-2019

NB 1 Mtoe = 11,63 TWh => total primary energy demand 820 Mtoe = 9500 TWh
=> Africa total electricity demand / total energy demand = 700 / 9500 = 7 %

Electricity generation world-wide by scenario, 2018-2040

Figure : world-wide, the global electricity generation mix in 2018 compared to what it could be in 2040 under two possible scenarios :
(1) Stated Policies and
(2) Sustainable Development

Source : "IEA – World Energy Outlook 2019" and https://www.powermag.com/10-power-sector-insights-from-the-ieas-world-energy-outlook-2019/

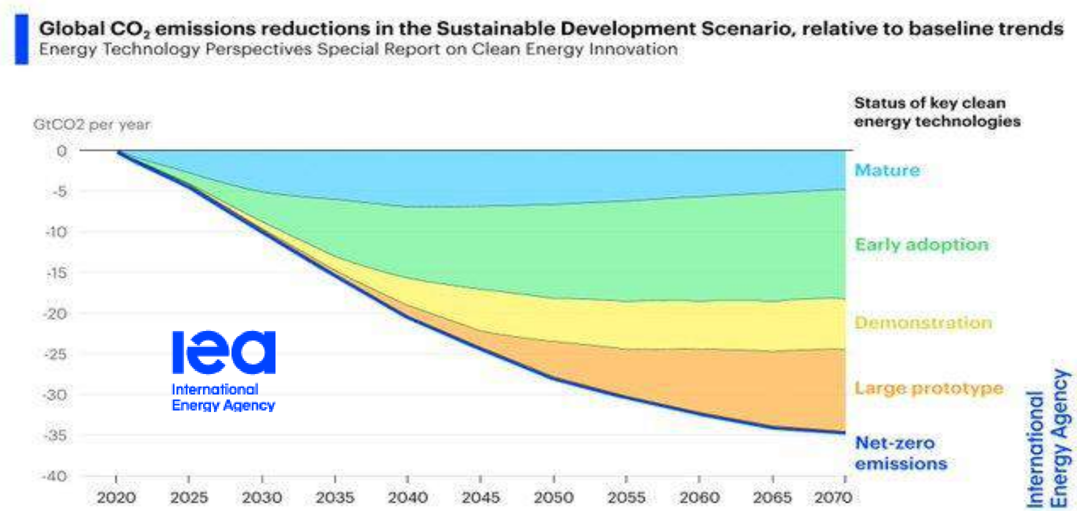


Renewable generation plays a leading role in meeting the electricity demand

Perhaps the most stunning finding is that IEA expects world-wide explosive growth for solar energy capacity through 2040 (NB -solar energy is composed of photovoltaic /PV/ and concentrated solar power /CSP/).

Overall world-wide, the report suggests the share of renewable generation—not capacity—could nearly double, from 26% today to 44% in 2040, surpassing coal as early as 2026. Combined, solar energy and wind generation's share could surge from 7% to 24% in the Stated Policies Scenario.

Comparatively (above Figure), the share of fossil-fired generation could fall in 2040—down from two-thirds, where it has hovered for decades. Coal's generation share, which grew fivefold between 1970 and 2013, could decline from 38% today to 25% by 2040, though natural gas-fired generation, which has tripled over the past 22 years, is set to surge nearly 50% by 2040, owing largely to the cheap shale gas supply.



Technologies that are mature today will cover only 15 % of the cumulative CO2 emissions abatement needed in 2050 and less than 15 % by 2070

Electricity generation in Africa (TWh) 1/2

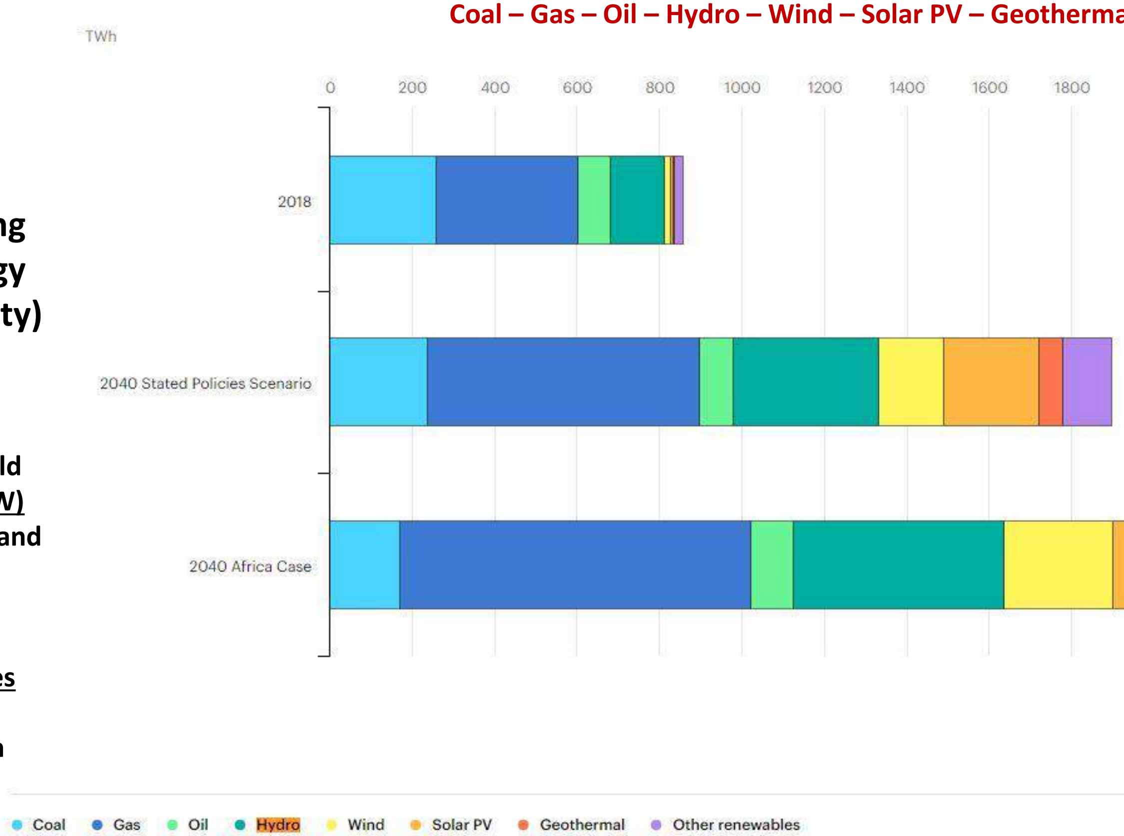
Renewables play a leading role in meeting the energy (in particular, the electricity) demand.

To date, the continent with the richest solar resources in the world has installed only 5 gigawatts (GW) of solar energy (i.e. : 4 GW of PV and 1 GW of CSP), less than 1% of the global total.

However, Africa's vast renewables resources and falling technology costs drive double-digit growth in deployment of utility-scale and distributed PV, and other renewables, across the continent.

Electricity generation (TWh) in Africa by scenario, 2018-2040

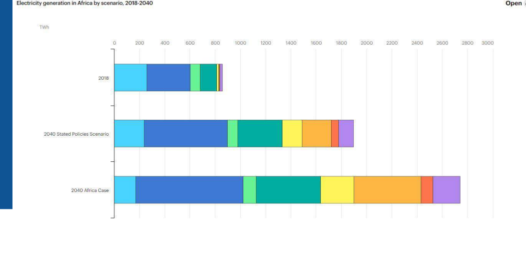
Coal – Gas – Oil – Hydro – Wind – Solar PV – Geothermal – Other renewables



In Africa, in the "Stated Policies Scenario" /STEPS/, global installed solar capacity could surge from 5 GW in 2018 to 145 GW by 2040 (or even to 342 GW in the "Africa Case" /AC/ or "Sustainable Development" scenario), and in just 15 years it could surpass coal and gas to become the largest source of installed capacity.
If considered in terms of generation, the IEA suggests solar energy will grow from 8 TWh in 2018 to 275 TWh in 2040 in the STEPS scenario (or even 620 TWh in the AC scenario)—from a 2% share of global electricity generation today to 11% in 2040.

In Africa, the IEA is optimistic about other renewables too, especially wind, which could make up 13% of global generation in 2040, buoyed by off-shore installations, but also geothermal, which could grow from 5 TWh in 2018 to 59 (STEPS) or even 95 (AC) TWh in 2040 (when it could make up 3 % of global generation) – or, in terms of capacity, from 1 GW in 2018 to 10 (STEPS) or even 14 (AC) GW in 2040 .

Electricity generation in Africa (TWh) 2/2



In the Africa Case, solar PV deployment averages almost 15 GW a year, reaching 320 GW in 2040, overtaking hydropower and natural gas to become the largest electricity source in Africa in terms of installed capacity.

Wind also expands rapidly in several countries that benefit from high quality wind resources, most notably Ethiopia, Kenya, Senegal and South Africa while Kenya is also at the forefront of geothermal deployment.

The Africa Case requires building a more reliable power system and greater focus on transmission and distribution assets. A key priority is targeted investment and maintenance to reduce power outages, a major obstacle to enterprise, and to decrease losses from 16% today to a level approaching advanced economies (less than 10%). There is also a need to build up the regulation and capacity to support Africa's power pools and strengthen regional electricity markets.

Africa needs a significant scale-up in electricity sector investment in generation and grids, for which it currently ranks among the lowest in the world. Despite being home to 17% of the world's population, Africa currently accounts for just 4% of global power supply investment.

Achieving reliable electricity supply for all would require an almost fourfold increase, to around $120 billion a year through 2040. Mobilising this level of investment is a significant undertaking, but can be done if policy and regulatory measures are put in place to improve the financial and operational efficiency of utilities and to facilitate a more effective use of public funds to catalyse private capital. Nurturing Africa's own financial sector is also critical to ensure a sustained flow of long-term financing to energy projects.

Focus on hydro.

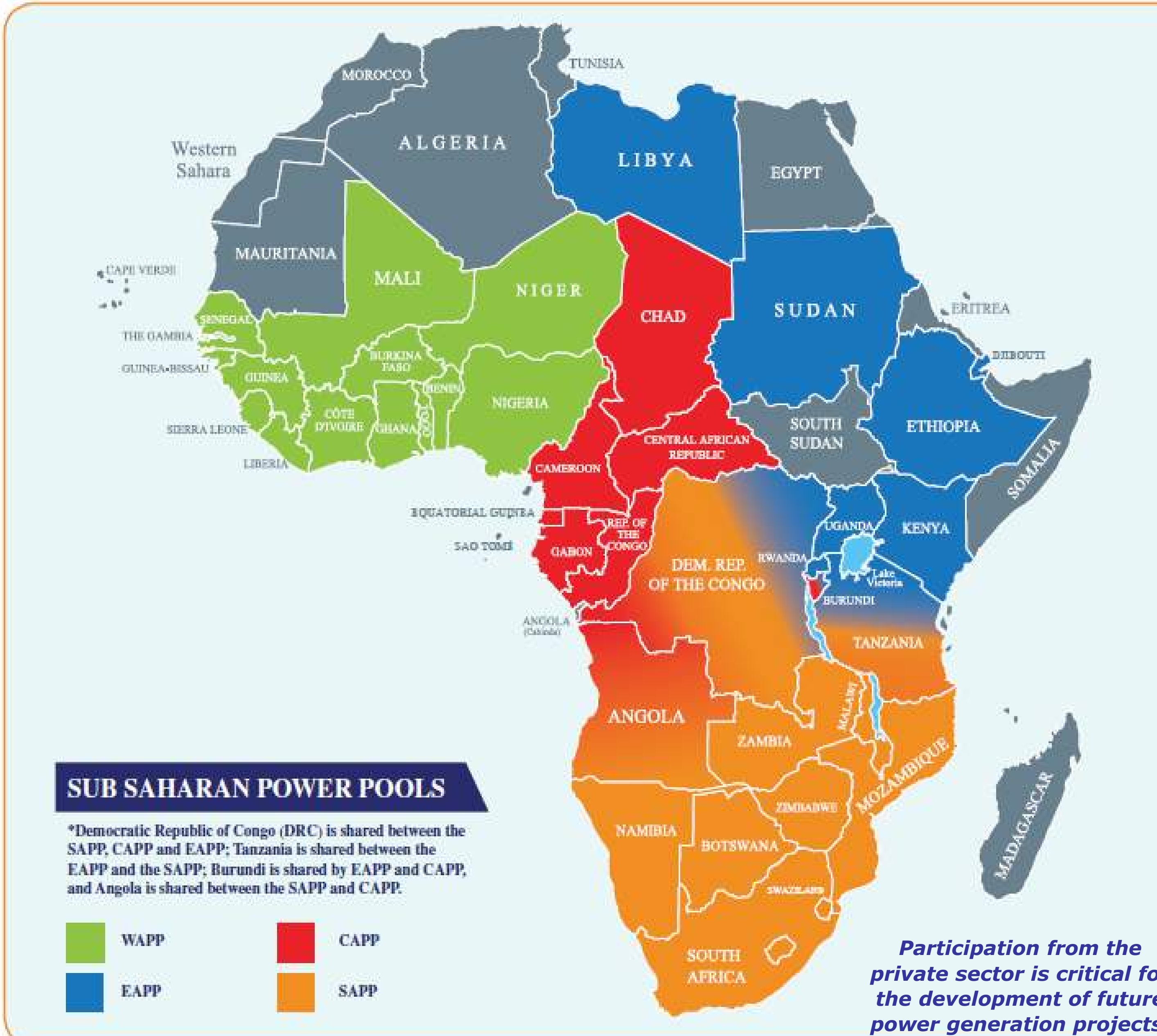
** This IEA Outlook indicated electricity generation from hydropower in Africa was 131 TWh in 2018.*
** If a more reliable power system is built with a greater focus on transmission and distribution assets, hydropower generation in Africa could reach 512 TWh by 2040, according to the "Africa Case" scenario in the Africa Energy Outlook 2019.*
** Under IEA's "Stated Policies Scenario", hydropower would contribute 351 TWh to the continent's total electricity generation by 2040.*

Power pools enabling SSA's transmission corridors (1/5) - improve generation capacity and transmission infrastructure

Sub-Saharan Africa's power pools were established to improve generation capacity and transmission infrastructure for greater cross-border trade and ultimately address a cost-effective way of evacuating excess capacity between countries to offset peak demands.

NB The Comité Maghrébin de l'Electricité (COMELEC), also North African Power Pool (NAPP), is an association of five North African countries aiming at interconnecting the electricity grids of the member countries in order to facilitate the trading of electric power between the members.

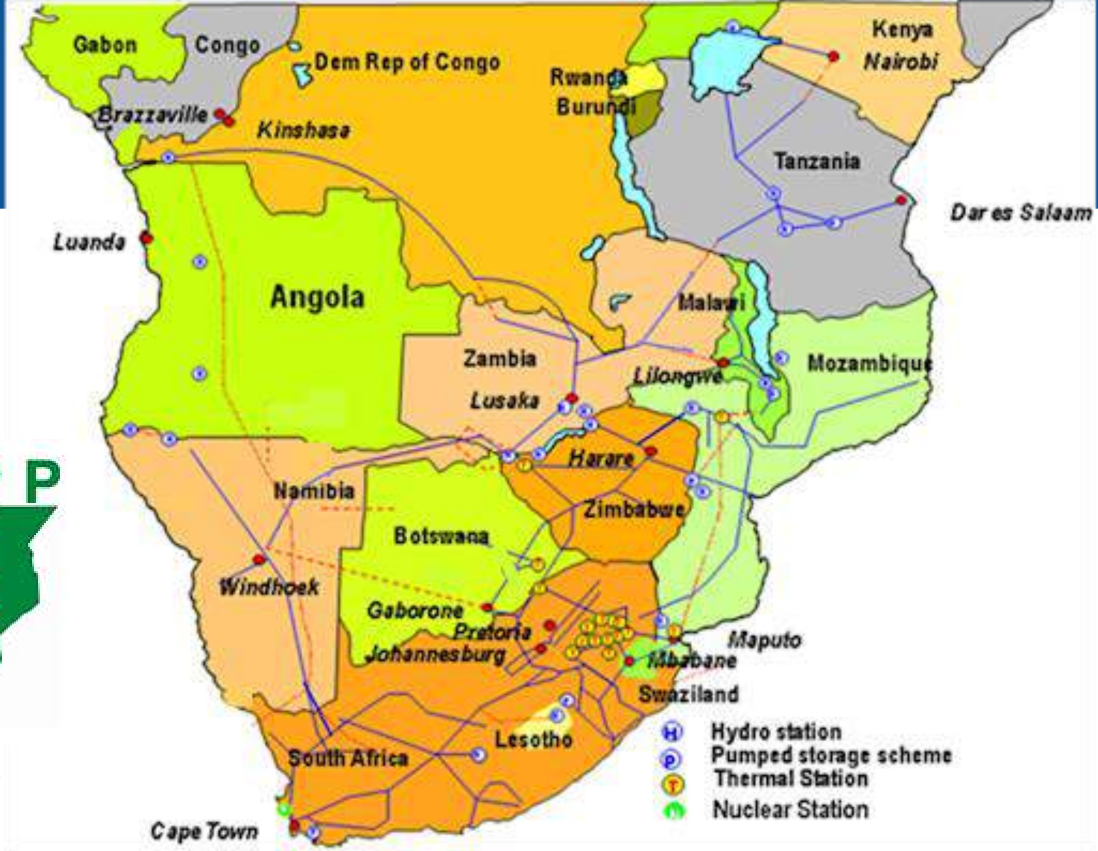
NAPP is one of the five regional power pools in Africa (NAPP, SAPP, EAPP, CAPP and WAPP).



Participation from the private sector is critical fo[r] the development of futur[e] power generation project[s]

Southern African Power Pool (SAPP) (2/5)

The demand for electricity in sub-Saharan Africa (SSA) is expected to grow at an average annual rate of 4.6% by 2030, which will be more than double the current electricity production.



Currently, the Southern African Power Pool (SAPP) is operating at a capacity of 60.8 GW, exceeding a peak demand of 50.1 GW.

- **The SAPP comprises 12 member states, of which nine member countries are already interconnected.**
- **Notably, SAPP has evolved into the only fully functioning regional energy market in SSA.**
- **According to a study by Frost & Sullivan, the cost of addressing the region's power needs has been estimated at $40.8 billion per annum (equating to 6.35% of the African continent's GDP). Approximately 40% of this funding will be needed for improving the transmission and distribution infrastructure alone.**

Despite SAPP being a role model for other African power pools, it, too, faces many challenges and setbacks, including :

- **semi-frequent power outages and**
- **aged power infrastructure.**

SAPP has set the pace with its establishment of a successful electricity trade market, which has been replicated by other power pools.

NB : SAPP electricity trade in 2018 = 939 GWh (IEA)
Source : SAPP Co-ordination Center, Harare, Zimbabwe - http://www.sapp.co.zw/

East African Power Pool (EAPP) (3/5)

The East African Power Pool (EAPP) was established by the Common Market for Eastern and Southern Africa (COMESA) in 2015 with 11 member states.

- **Despite its setbacks, the EAPP has achieved great progress in bridging the access gap in recent years through a number of start-ups that focus on providing access to electricity in rural areas. The Eastern electricity highway connecting Ethiopia with Kenya will drive this region's electricity market going forward.**

- **All EAPP members began electricity trading in 2018, both within and beyond the region, upon the completion of six major cross-border transmission lines.**
- **The Chinese are becoming increasingly involved in EAPP power transmission with a recent project between a Chinese firm and Ethiopian Electric Power for interconnectors to Kenya.**
- **Kenya leads the African market for off-grid solar deployments.**

NB : EAPP electricity trade in 2018 = 275 GWh (IEA)
Source : EAPP, Eastern Africa Power Pool - Addis Ababa, Ethiopia - https://www.ea-energianalyse.dk/wp-content/uploads/2020/02/1332_eapp_master_plan_2014_volume_1_main_report.pdf

Central African Power Pool (CAPP) (4/5)

The Central African Power Pool (CAPP) was established in 2003 to combat the infrastructure across all aspects of the power value chain and comprises 10 m

- **It is the least developed power pool in Africa with 75% of Central Africa lac electricity. CAPP still has a long way to go in terms of operating as a power African countries engage in minimal trading due to limited transmission int infrastructure.**
- **Lack of regional framework for electricity trading, lack of regional regulatio management, difficulty in gathering investment, and low interconnection b are among the challenges facing CAPP.**
- **The power pool aims to establish an electric power market between its member countries by 2025 and requires a total of over $60 billion if it is to keep pace with increasing electricity demand by 2030.**

NB : CAPP electricity trade in 2018 = 81 GWh (IEA)
Source : Pool Energétique de l'Afrique Centrale (PEAC) - Secrétariat - Brazzaville, the Republic of Congo - http://www.peac-ac.org/

West African Power Pool (WAPP) (5/5)

The West African Power Pool (WAPP) was created by ECOWAS (*), a regional economic union, in 1999.

- **WAPP is a cooperation of the national electricity companies in Western Africa under the auspices of the Economic Community of West African States (ECOWAS).**
- **The members of WAPP are working for establishing a reliable power grid for the region and a common market for electricity. Member countries are Benin, Burkina Faso, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Mali, Niger, Nigeria, The Gambia, Togo, Senegal, and Sierra Leone. Since 2006, the headquarters of WAPP are located in Cotonou, Benin.**
- **Approximately 7% of regional power is traded through WAPP, surpassing that of EAPP and the Central Power Pool (CAPP).**
- **Nigeria has pioneered the privatisation of its power sector by privatising all T&D distribution companies owned by the government, which resulted in WAPP countries altering legislation to support purchasing power parity (PPP) initiatives.**
- **The biggest challenge for WAPP lies in the inability to finance big generation and T&D projects in smaller regions. The power pool requires a total investment of over $60 billion to meet transmission and distribution goals by 2030.**

(*) NB : WAPP = EEEOA, « West African Power Pool » WAPP = EEEOA « Système d'Échanges d'Énergie Électrique Ouest Africain »). Il s'agit d'une institution spécialisée de la « Communauté économique des États de l'Afrique de l'Ouest » (CÉDÉAO) - en anglais "Economic Community of West African States" (ECOWAS) - qui a pour but d'intégrer les réseaux électriques nationaux dans un marché régional unifié de l'électricité.

NB : WAPP electricity trade in 2018 = 2926 GWh (IEA)
Source : Système d'Echanges d'Energie Electrique Ouest Africain – Cotonou, Bénin - https://www.ecowapp.org/fr/file/ecowas

West African Power Pool

(socio-economic development – facts and figures) 1/2

In spite of the region's abundant energy potential and progress achieved in the establishment of the regional power pool, the West African Power Pool (WAPP), the region's electricity sector is underpowered with inadequate generation and transmission systems, leaving about 175 million people (48%) in the region un-electrified in 2016. Further, the total population relying on biomass for cooking was 263 million (75%) in 2015.

Studies on energy consumption and economic growth nexus conclude that energy is a critical parameter for socio-economic development.

NB In the subject study, West Africa was structured into 20 defined sub-regions based on the existing cooperation.

The different sub-regions of West Africa

The socio-economic development of most WA countries is hampered by its underdeveloped energy sector. Most ECOWAS countries rank among the poorest, having Low Human Development. Access to electricity in the region is at 52%, with shortages of up to 80 h/month and yet electricity prices in WA remain among the costliest in the world, at 0.21 €/kWh, more than twice of the global average. In 2016, the electrification rate was below 40% in 10 of the 15 countries, with Guinea-Bissau, Liberia, Niger and Sierra Leone occupying the bottom: with 13%, 12%, 11% and 9% respectively. The average annual electricity consumption in WA was about 145 kWh/capita in 2015.

Nonetheless, the electricity supply gap is likely to increase as population, urbanisation and income are expected to rise, driving up electricity demand in the nearest future. Electricity demand in the region is projected to increase fivefold by 2030, to 250 TWh, based on the ECOWAS Master plan.

The current grid capacity is not sufficient to cover the demand. Implying load shedding is becoming more prominent, driving consumers towards large-scale use of costly backup generation. Due to significant under-capacity in electricity generation, some countries in the region such as Benin, Burkina Faso, Niger and Togo rely on electricity imports for a substantial share of their supply.

As of 2015, the power generation capacity in the ECOWAS region is about 21 GW, producing about 57 TWh of electricity. As shown in above Figure, more than half of the grid-connected capacities in the region are natural gas powered thermal plants, mostly in Nigeria, where it is the main power generation technology. Nigeria, Ghana and Côte d'Ivoire account for more than 80% of installed capacity and generation. In addition, the operating capacity is low in comparison to the overall existing capacity in most of the countries in the region.

Source : « Transition towards decarbonised power systems and its socio-economic impacts in West Africa », by LUT University, Lappeenranta, Finland), in Renewable Energy - Volume 154, July 2020 - https://www.sciencedirect.com/science/article/pii/S0960148120304109#fig6

West African Power Pool

(socio-economic development – facts and figures) 2/2

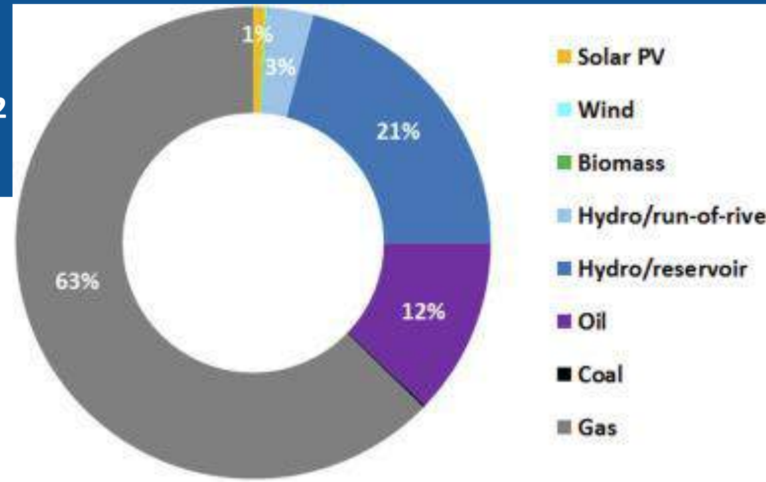
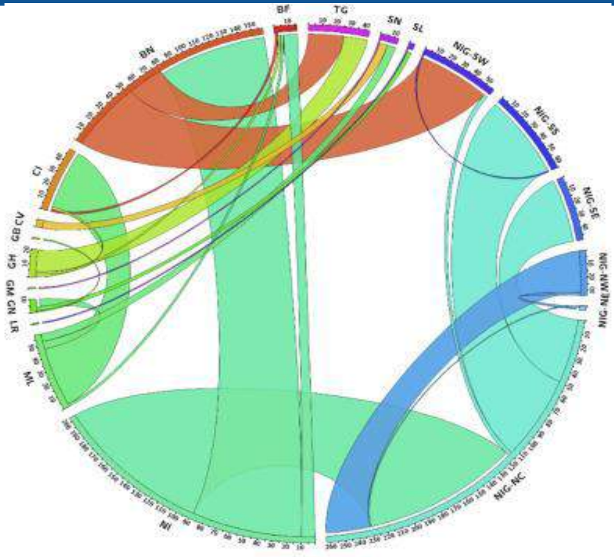
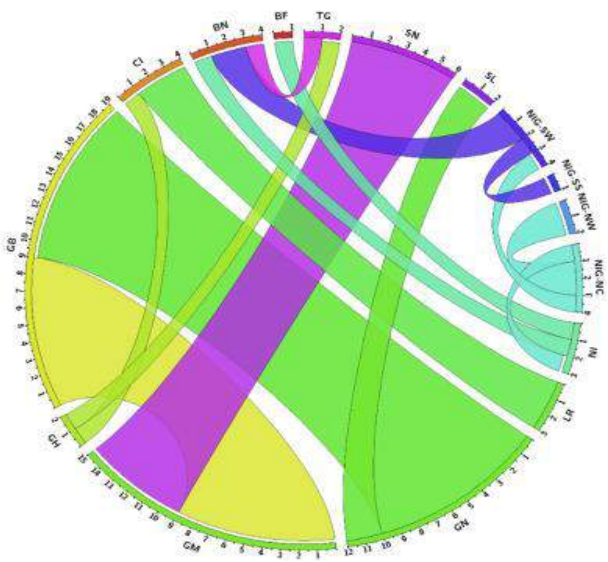


Figure left - West Africa power plant installed capacity by 2015





Regional grid exchange within West Africa in the BPS-A (top) and CPS-A (bottom) in 2050.

OBJECTIVE : determine the cost optimal generation mix by 2050 to meet the demand based on assumed costs and technologies

Methodology - abstract

Pathways towards a defossilated sustainable power system for West Africa within the time horizon of 2015-2050 is researched, by applying linear optimisation modelling to determine the cost optimal generation mix to meet the demand based on assumed costs and technologies in 5-year intervals.

Six scenarios were developed, which aimed at examining the impact of various policy constraints such as cross-border electricity trade and greenhouse gas emissions costs. Solar PV emerges as the prime source of West Africa's future power system, supplying about 81-85% of the demand in the Best Policy Scenarios for 2050. The resulting optimisation suggests that the costs of electricity could fall from 70 Euro/MWh in 2015 to 36 Euro/MWh in 2050 with interconnection, and to 41 Euro/MWh without interconnection in the Best Policy Scenarios by 2050. Whereas, the levelised cost of electricity without greenhouse gas emission costs in the Current Policy Scenario is 70 Euro/MWh.

Results of the optimisation indicate that a fully renewables based power system is the least-cost, least-GHG emitting and most job-rich option for West Africa. This study is the first of its kind study for the West African power sector from a long-term perspective.

Figure left shows the cross-border electricity trade directions and amounts (in TWh) among the sub-regions in the Best Policy Scenario (BPS)-A and Current Policy Scenario (CPS)-A. The thickness of the flow illustrates the amount of electricity transferred between the regions in TWh. Niger dominates the net electricity trade with 204 TWh (68%) in BPS-A, whereas, Guinea dominates the electricity trade in the CPS-A with 12 TWh (31%). Benin and NIG-NC emerge as the main transit conduit in the regional electricity trade in the BPS-A. The regional electricity trade depicts the role of grid interconnections, particularly in scenario with high shares of RE, in comparison to the one dominated by thermal dispatchable generators.

Grand Ethiopian Renaissance Dam (GERD)

The largest hydro-electric power generation facility in Africa and the fifth largest in the world

Grand Ethiopian Renaissance Dam on the Blue Nile River

- **Hydropower technology : Gravity, roller-compacted concrete dam (reservoir surface area = 1 874 sq km)**
- **Capacity : 6.35 GW (max. planned) –Turbines 14 x 400 MW + 2 x 375 MW (Francis turbines)**
- **Annual net output : 16.15 TWh (= > max capacity factor of around 28.6 %)**
- **Estimated Investment : US $ 4.8 bn**
- **Announced : Construction began in April 2011 / Commission date 2020–2022**

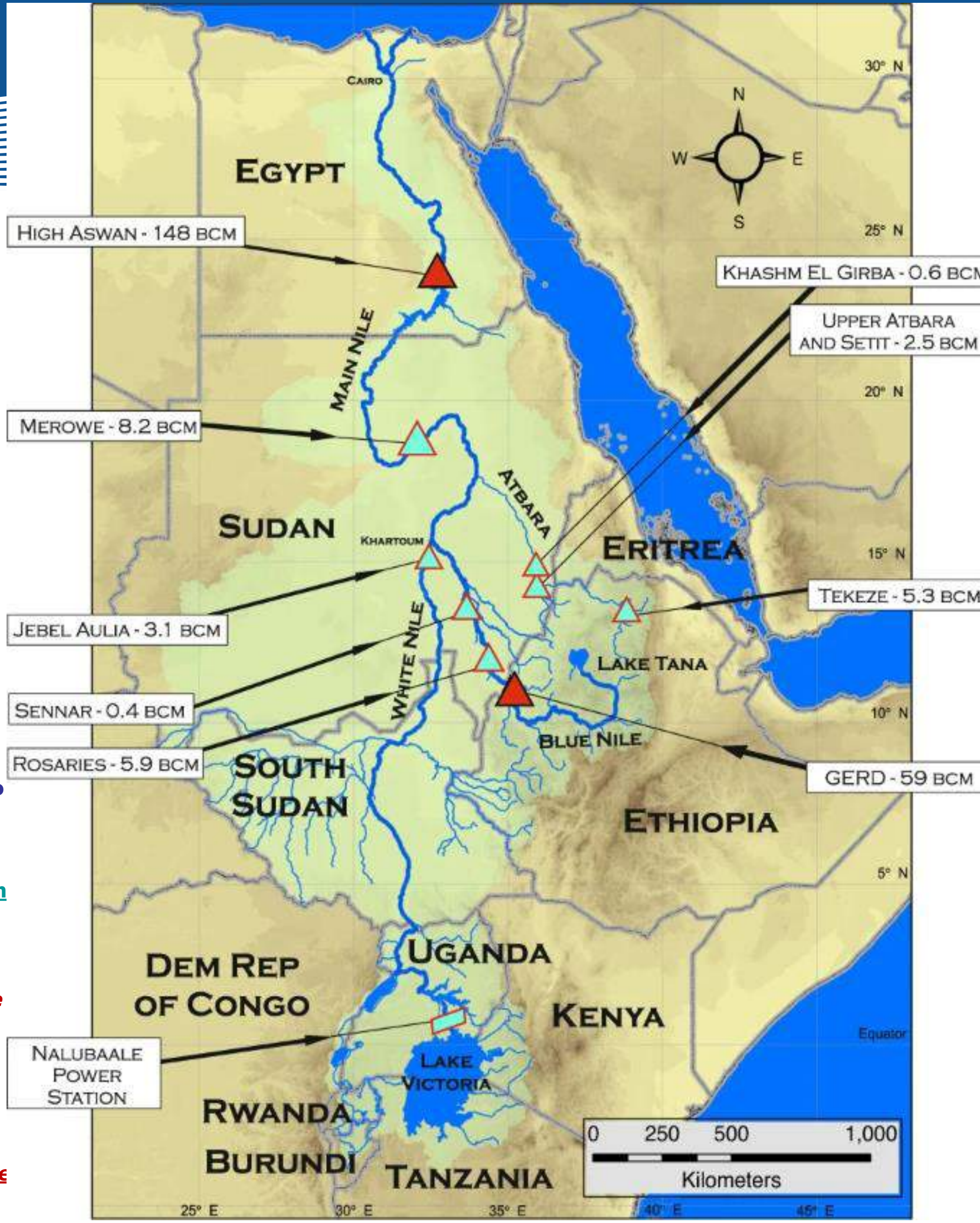
The main contractor is the Italian Multinational Construction Company Webuild (formerly Salini Impregilo). As of August 2020, construction of the GERD was over 70% percent complete, and Ethiopia has completed the first year filling of the reservoir by impounding 4.9 billion cubic meters (bcm).

When construction of the GERD is completed, the Nile will have two of the world's largest dams—the High Aswan Dam (HAD – built 1960-1970, Lake Nasser, yearly production 10 042 GWh in 2004) and the GERD—in two different countries (Egypt and Ethiopia).
https://en.wikipedia.org/wiki/Grand_Ethiopian_Renaissance_Dam

Cost and financing

The Ethiopian government has stated that it intends to fund the entire cost of the dam by itself in order to prevent relying on foreign countries who may be brought under pressure by Egypt to withdraw their support. Ethiopia has issued a bond targeted at Ethiopians in the country and abroad to that end.

The turbines and associated electrical equipment of the hydropower plants costing about US$ 1.8 billion are reportedly financed by Chinese banks. This would leave US$ 3 billion to be financed by the Ethiopian government through other means. The estimated US$ 4.8 billion construction cost, apparently excluding the cost of power transmission lines, corresponds to about 5% of Ethiopia's gross domestic product of US $87 billion in 2017.



Ethiopia's move to fill the dam's reservoir could reduce Nile flows by as much as 25%

Benban solar photovoltaics (PV) park, Aswan, Egypt (1.8 GWp or 4.3 TWh/yr) The largest in the world

Benban Solar power Park, the world's largest solar farm, a vast collection of more than 7 million photovoltaic panels - Aerial view – AfDB - June 2020 (https://www.afdb.org/en/news-and-events/infrastructure-fund-africa50-helps-egypts-solar-power-sector-take-36247)

Africa's vast natural resources mean that low-cost clean energy technologies have plenty of potential. Solar is rightly seen as a huge opportunity for Africa, both at utility-scale and off-grid. Deployment is low today, but it is expanding fast.

Benban Solar power Park

- **Photovoltaics technology**
- **Capacity : 1.8 GWp (which corresponds to an annual production of approximately 4.3 TWh = > max capacity factor of around 26 %)**
- **Estimated Investment : US $ 4 bn**
- **Announced : Sept 2014 / Commissioning : 2019**

Benban solar power park is a power complex of 41 solar power plants being developed in Benban, located in the Aswan governorate, Egypt. It is part of Egypt's landmark solar Feed-in-Tariff (FiT) Programme mobilising private investments.

Benban is touted to become the biggest solar photovoltaic generation park in the world, upon completion.

The 41 solar power plants (total area of 37 km²) will be developed on plots ranging from 0.3 km² to 1.0 km² in size. The arrays will be connected to inverters for converting the direct current (DC) power to alternating current (AC) power, which will be transferred by a transformer to the nearby power grid for distribution.

NB – remember : Electricity demand in Africa today is 700 TWh. IEA prospects in 2040 : Electricity demand more than doubles in STEPS to over 1 600 TWh => ratio Benban 4.3 TWh / total Africa 1600 TWh = 0.003

Financing for Benban solar park : International Financial Corporation (IFC) including the Africa Development Bank, the Asian Infrastructure Investment Bank (AIIB), Arab Bank of Bahrain, CDC of the United Kingdom, Europe Arab Bank, Green for Growth Fund, FinnFund, ICBC, and OeEB of Austria + the European Bank for Reconstruction and Development (EBRD) + the United Nations' Green Climate Fund (GCF), the Dutch Development Bank, FMO, the Islamic Development Bank (IsDB) and Islamic Corporation for the Development of the Private Sector (ICD) + Bayerische Landesbank and Arab African International Bank
Source : https://www.nsenergybusiness.com/projects/benban-solar-park/

Olkaria Geothermal Power Station
in the Rift Valley, Nakuru County, Kenya
The largest geothermal producer in Africa

All of Kenya's high temperature prospects are located in the Kenya Rift Valley, where they are closely associated with the late quaternary volcanoes (≤1 m.y.)

Olkaria Geothermal Power Station (six stations)

- **Geothermal Power Station technology**
- **Capacity : 510 MW (Olkaria I to V Units operational 45+105+140+140+80 MW)**
- **Annual net output of Olkaria II : 0.85 TWh** (source : KFW Entwicklungsbank 2011 - Ex Post-Evaluation Brief)
- **Announced : Kenya has a long history of developing geothermal resources / Olkaria I was completed in 1985 / Olkaria VI is planned for 2021**
- **efficient production :** works on single flash plant cycle with a steam consumption of 7.5 t/h/MW (the turbines are single flow six stage condensing with direct contact spray jet condenser). Geothermal power plants have been quoted to have capacity factors around 73 %. When compared to a coal fired power plant with a capacity factor typically averaging around 60% or a natural gas plant at 45%, it is apparent that geothermal power plants have the potential to be more efficient than traditionally fueled power plants.

Source : "The role of geothermal and coal in Kenya's electricity sector and implications for sustainable development", November 2019, L. Kahlen, M-J. Kurdziel, T. Day, T. Schiefer (NewClimate Institute – study report based on a decision by the German Bundestag) *https://ambitiontoaction.net/wp-content/uploads/2019/11/A2A-Kenya_Geothermal-study_201911.pdf*

Geothermal versus coal : implications for sustainable development

A major challenge for planners and policymakers in the electricity sector is identifying the optimal combination of electricity generation technologies within different load-factor categories in order to achieve the best match at the lowest cost. This study aims at supporting decision making in the electricity sector by comparing the two main power generation technologies that are considered baseload electricity supply options in Kenya, namely, geothermal and coal, and the role that they can play in Kenya's future electricity supply mix. This role is determined by a number of factors, including technical considerations, resource availability, environmental characteristics, economics, and other issues that may act as drivers or pose barriers or risks to the development of this source. ……

While Kenya has a long history of developing geothermal resources, coal has not yet been exploited. Kenya has a high geothermal resource potential of around 10,000 MW along the Kenyan Rift Valley. The current installed geothermal capacity in Kenya is 745 MW, with most of it in the Olkaria fields. However, the Government of Kenya plans to build two coal power plants over the next 30 years: one in Lamu, a 981 MW power plant divided into three units of 327 MW each, to be commissioned by 2024, and a 960 MW power plant in Kitui, which is scheduled for 2034-36. While the plant in Lamu will run on imported coal, the plant in Kitui is predicted to use domestic coal.

The development of these two generation technologies will have a considerable impact on the electricity sector in Kenya, affecting the generation costs, affordability of electricity, and overall flexibility and reliability of electricity supply.

Lake Turkana Wind Power Project (LTWP)
wind farm, 545 km north of Nairobi, Kenya
The largest wind farm project in Africa

Lake Turkana Wind Power Project - a big leap to Kenya's off-grid energy efforts

Lake Turkana Wind Power Project (LTWP)

. Wind farm technology : 365 wind turbines, each with a capacity of 850 kilowatts

- **Capacity : 310 MW (wind farm over 160 sq km)**
- **Annual net output : 2 TWh**
  (= > max capacity factor of around 70 %)
- **Estimated Investment : US $ 0.85 bn**
- **Announced : Commissioning in October 2018, however the line evacuating the power generated was not completed until July 2019 (i.e. : 428 km transmission line from Lake Turkana to Susua sub-station)**

Developers and funding (https://fr.wikipedia.org/wiki/Parc_%C3%A9olien_du_lac_Turkana)

The company that owns and is developing the wind farm is called Lake Turkana Wind Power Limited (LTWP). It is the single largest private investment in Kenya's history. LTWP, which has 20-year Power Purchase Agreement (PPA) with Kenya Power (KPLC), sells electricity to the national grid based on a low-cost initial tariff of $ cent 10 per kWh for the first six years, that will be adjusted downwards to $ cent 8 per kWh for the remaining 14 years.

The consortium which owns LTWP Limited includes the following entities:

● Equity partners : e.g. KP&P BV Africa; Wind Power A.S. (Vestas - turbine supplier) ; (Google inc ?), etc

● Financial partners : African Development Bank, Standard Bank and Nedbank Capital of South Africa ; European Investment Bank ; Triodos Bank ; etc

● Donors : Government of the Netherlands (€10 million) ; EU Africa Infrastructure Trust Fund (part of the European Commission - €25 million).

NB "Last year /2019/ the wind farm operated at an average capacity factor of 57 per cent and hit a peak of 99 per cent (307 MW) in January"

- ***The cost of electricity in Kenya remains high at $0.217 per kWh for households and $0.167 for businesses compared to world average of $0.14 per kWh for households and $0.13 for businesses.***
- ***In Uganda, the cost for households stands at $0.183 and $0.161 for businesses while in Tanzania it is at $0.099 and $0.102 respectively.***

Source : Newspaper The East African, 14 Sept 2020 - https://www.theeastafrican.co.ke/tea/business/consumers-pay-the-price-as-covid-electricity-cuts-hit-turkana-project-1939124

Ouarzazate Concentrated Solar Power (CSP) also called Noor Power Station (Arabic for light), Drâa-Tafilalet region, Ouarzazate, Morocco
The largest in the world

The Ouarzazate solar power station Noor I is eight times as large as the Gemasolar (Solar Tres, 20 MWe) concentrated solar plant in Sevilla, Spain

Ouarzazate Concentrated Solar Power (OCSP) Station

- **CSP technology : Parabolic-through, Solar power tower**
- **Capacity : 160 MW (Noor I), 200 MW (Noor II) and 150 MW (Noor III) / that is : 510 MW total capacity /**
- **Annual net output : 370 GWh (Noor I), 600 GWh (Noor II), 500 GWh (Noor III) / that is : 1.47 TWh in total (= > max capacity factor of around 33 %)**
- **Estimated Investment : US $ 3.9 bn**
- **Announced : start August 2013 / Commissioning : Phase 1 in February 2016 and Phases 2 and 3 in 2018**

Phase 1, also referred to as Noor I CSP, comes with a full-load molten salt storage capacity of 3 hours of low-light producing capacity and has an installed capacity of 160 MW. The plant is able to store solar energy in the form of heated molten salt, allowing for production of electricity into the night. The molten salt is heated to 150–350 °C as it flows through the receiver and is then used as a heat source for a power generation system. Noor I CSP was connected to the Moroccan power grid in 2016. The plant covers 450 hectares and uses half a million mirrors.

Noor II, commissioned in 2018, and Noor III, commissioned in January 2019, store energy for up to eight hours. They cover an area of 2,5 sq km. Azelio installed renewable energy storage at the Noor Ouarzazate solar complex in March 2020.

Ouarzazate Concentrated Solar Power Station is the largest concentrated solar power plant in the world. NB - Noor IV will be a 72 MW photovoltaic power station.

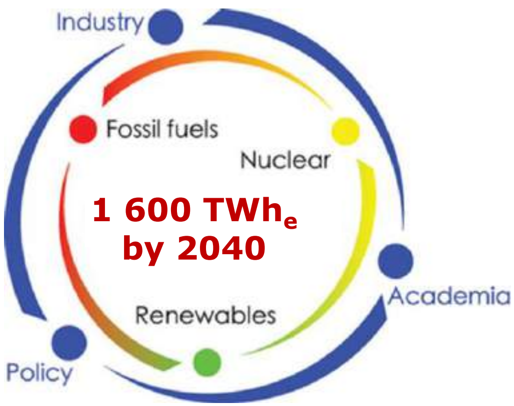
Financing of OCSP - The project was developed on a build, own, operate and transfer (BOOT) basis by ACWA Power Ouarzazate, a consortium of ACWA Power, the Moroccan Agency for Solar Energy (Masen), ARIES Ingeneria y Sistemas as well as TSK Electrónica y Electicidad and Sener Ingeniería y Sistemas. Around $3.9bn has been invested in the Ouarzazate solar complex, including $1bn from the German investment bank KfW, $596m from the European Investment Bank and $400m from the World Bank.The Noor complex is operated and maintained by a consortium led by NOMAC, a subsidiary of ACWA Power, and Masen. Source : https://www.power-technology.com/projects/noor-ouarzazate-solar-complex/

A little over 10 years ago David MacKay drew attention by saying "*All the world's power could be provided by a square 100km by 100km area in the Sahara*". Kevin McCann reviews the updated numbers and looks at the current renewable energy plans of the MENA nations. The potential is far greater still, but to deliver power across borders and outside the region in future will clearly require a step change in storage and transportation, as well as long term political stability. https://energypost.eu/10000-sq-km-of-solar-in-the-sahara-could-provide-all-the-worlds-energy-needs/

Conclusion - On the road to sustainable development : integrating (global) <u>politics</u> and (local) <u>energy services with</u> distinct space and time horizons

<u>Agenda 2063 (African Union)</u>

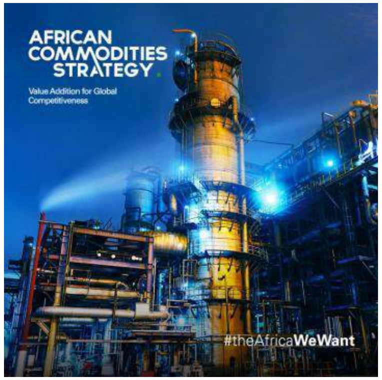
the continent's <u>inclusive</u> and <u>sustainable</u> vision for accelerated <u>economic and industrial development</u>



2040 energy demand per year in Africa (IEA prospect)

- **total primary energy demand : 15 700 TWh (or 1 350 Mtoe)**
- **incl. total electricity needed : 1 600 TWh$_e$**

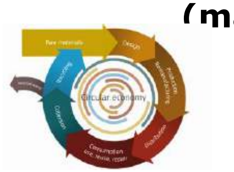
(= 15 times electricity expected to be needed in Belgium in 2040)



<u>Primary energies</u> : renewables – fossil fuels – nuclear

<u>Stakeholders</u> : policy – industry – academia

+ <u>circular economy</u>
(material recycling and energy recovery)
and <u>energy efficiency</u>
(stable reduction of cost and GHG)



Recherche, innovation et formation en / avec l'Afrique - une partie de la solution 1/2

PROUDLY MADE IN AFRICA

"Scientific African" is owned by the Next Einstein Forum (NEF) and operated by the NEF Community of Scientists - https://www.journals.elsevier.com/scientific-african/

"the next Einstein would be from Africa"

"My wish is that you help us unlock and nurture scientific talent across Africa, so that within our lifetimes we are celebrating an African Einstein", said Neil Turok. https://blog.ted.com/the-next-einstein-forum-begins/ and https://www.nexteinstein.org/

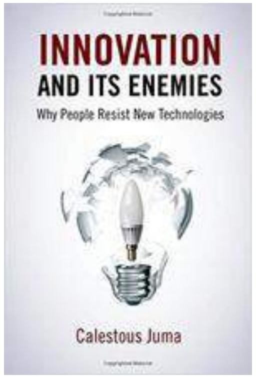
"Can you imagine a thinker who combines the brilliance of Einstein and the compassion of Mandela?" - TED 2008 talk (February 2008, 25 min duration, with transcript in 27 languages) : https://www.ted.com/talks/neil_turok_makes_his_ted_prize_wish

Neil Turok (1958 -), founded in 2003 the "African Institute for Mathematical Sciences" (AIMS) in Muizenberg (a small seaside suburb of Cape Town, South Africa). AIMS centre of excellence offers a creative STEM education to African students and aims to improve the statistic that less that 1% of global research is done in Africa. Since then, through the AIMS Next Einstein Initiative (AIMS-NEI), AIMS centres have opened Cape Town (2003), in Sénégal (2011), Ghana (2012), Cameroon (2013), Tanzania (2014) and Rwanda (2016). "Our goal is to have 15 AIMS centres of excellence in operation across Africa by 2023."

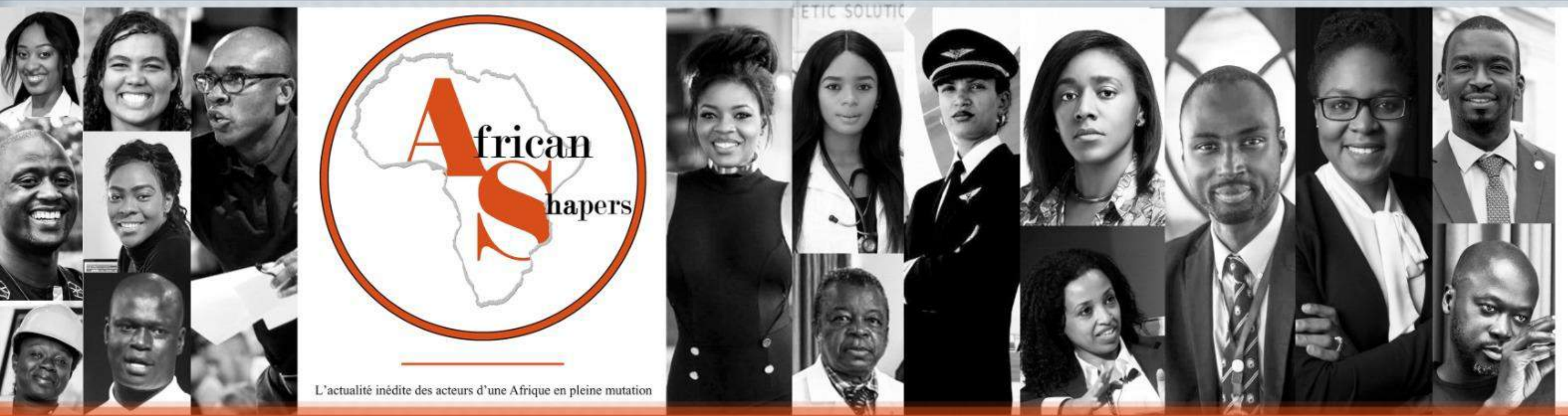
****

"Innovation and Its Enemies: Why People Resist New Technologies"

Calestous Juma (1953-2017) was a Kenyan professor and an internationally recognised authority in the application of science and technology to sustainable development worldwide. Juma created in 1988 the African Centre for Technology Studies (ACTS) in Nairobi. He set out the threats of modern biotechnology and its potential for solving food insecurity, especially in developing nations. His book "Innovation and Its Enemies: Why People Resist New Technologies" (Oxford Univ. Press, 2016) charted the battle between "innovation and incumbency" throughout human history.



Recherche, innovation et formation en / avec l'Afrique - une partie de la solution 2/2



Towards a joint AU-EU (ERASMUS) programme to support research, education, training, culture, youth and sport ?

Picture from EU Horizon 2020 project : IGD-TP 3rd MIND Annual Project Meeting, 7-9 May 2018, Lausanne, Switzerland (15 countries involved)
https://igdtp.eu/event/3rd-mind-annual-project-meeting/

Références bibliographiques

Goal 7:
Ensure access to affordable, reliable, sustainable and modern energy for all.

(1) "Africa Energy Outlook 2019", IEA World Energy Outlook special report, Nov 2019 (*the IEA's most comprehensive and detailed work to date on energy across the African continent, with a particular emphasis on sub-Saharan Africa*)
- https://www.iea.org/reports/africa-energy-outlook-2019

(2) "2020 Africa SDG Index and Dashboards Report (leave no one behind)", UN Sustainable Development Solutions Network, Sep 30, 2020 (248 pages)
https://sdgindex.org/reports/2020-africa-sdg-index-and-dashboards-report/

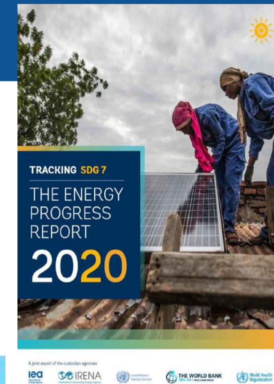
(3) "Tracking SDG 7: The Energy Progress Report", World Bank full report (6 chapters) May 2020 -
https://www.worldbank.org/en/topic/energy/publication/the-tracking-sdg-7-report-the-last-decade-to-leave-no-one-behind

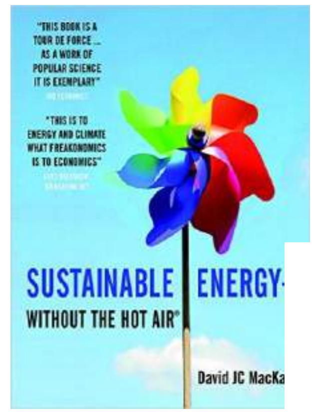
(4) "Sustainable Energy: Without the Hot Air", Sir David Mackay, 2009, UIT Cambridge (download pdf file for free / read translations in 15 languages) - www.withouthotair.com

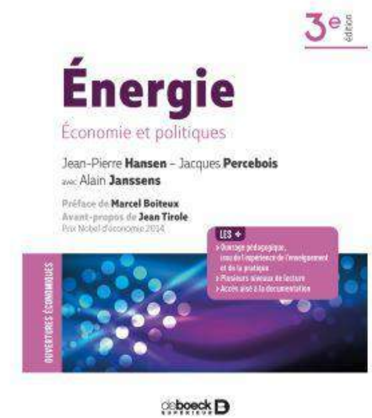
(5) « Energie : Economie et politiques » de Jean-Pierre Hansen (Auteur), Jacques Percebois (Auteur), Marcel Boiteux (Préface), Jean Tirole (prix Nobel d'économie 2014, Introduction), Editions De Boeck, 2010, ré-éditions 2015 et 2019 - 756 pages

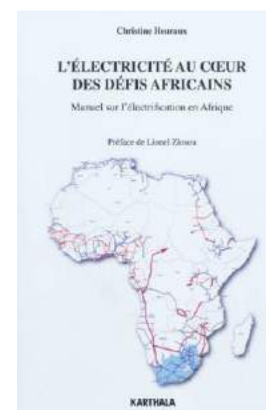
(6) « L'électricité au coeur des défis africains - manuel sur l'électrification en Afrique », Christine Heuraux, EDF 2010

(7) « La guerre des métaux rares : La face cachée de la transition énergétique et numérique », Guillaume Pitron, 2018 (293 pages)









ANNEXES

SE4A 2017 - « Sustainable Energy for Africa » – 2017, October 23 – 25, Palace of the Academies, Brussels

Royal Academy for Overseas Sciences

SE4A 2017 - International Conference organized by RAOS
(RAOS = Royal Academy for Overseas Sciences of Belgium)

(= Académie Royale des Sciences d'Outre-Mer /ARSOM/
and Koninklijke Academie voor Overzeese Wetenschappen /KAOW/)
http://www.kaowarsom.be/en/Sustainable_Energy_for_Africa

The aim of this three-day conference is to raise public and private awareness of the opportunities and challenges of sustainable energy in Africa by bringing together a number of high-level experts who will discuss energy policy topics from a political, socio-economic, scientific and/or technical point of view. Three topics, with focus on Africa, will be successively treated, namely:

(1) Energy is crucial for achieving the Sustainable Development Goals /SDGs/ (2030 Agenda, UN September 2015). Energy is a prerequisite for reaching many of the SDGs. The focus is on SDG 7 ("Ensure access to affordable, reliable, sustainable and modern energy for all").

(2) Towards an ideal energy mix. The challenge is threefold: security of supply (24/7/365) of an energy mix that is physically and economically accessible to all, and whose environmental impact is limited.

(3) Research, innovation and education (RIE). Very important to support any energy policy is to continuously improve RIE programmes, aiming at providing robust solutions to the many energy challenges.

Programme : 5 keynote speeches, 27 invited lectures, 36 invited posters (65 % from EU, 35 % from abroad, all peer reviewed)
Participation : more than 200 registrations from 25 countries

Programme and audio/video recordings of all presentations

- https://www.kaowarsom.be/documents/Conferences/Energy/RAOS_programme_sustainability_energy4Africa.pdf
- https://www.kaowarsom.be/en/SustainableEnergy4Africa_presentations%26videos

Royal Academy for Overseas Sciences of Belgium (RAOS)
"Promoting scientific knowledge in overseas regions"

Main organisers (RAOS committee):

- **Dr. Ir. Georges VAN GOETHEM (georges.m.vangoethem@gmail.com)**
- **Prof. Dr. med. Philippe GOYENS, Permanent Secretary of RAOS**
- **Prof. Dr. Jan RAMMELOO, former Director National Botanic Garden**

- **Tel. 32 (0)2 790.39.02 // Fax. : + 32 (0)2 374.98.22**
- **Website: http://www.kaowarsom.be/en/home**
- **E-mail: contact_raos@kaowarsom.be**

SE4A 2021 - « Sustainable Energy for Africa »

2021, November 8-11, National Academy, Cotonou, Benin

You're invited

SE4A 2021 - International Conference organized jointly by RAOS (Royal Academy for Overseas Sciences of Belgium) and ANSALB (National Academy of Sciences, Arts and Letters of Benin)

Sustainable Energy for Africa
Cotonou, 8-11 Nov. 2021
mail : contact@se4a.africa
http://www.se4a.africa

• ***Energy is crucial for achieving the Sustainable Development Goals in Africa*** *: "Agenda 2030", UN 2015 and "AGENDA 2063 - The Africa We Want", AU 2015) - Energy systems that are secure, sustainable, competitive and affordable for all - how can Africa's natural resources benefit all citizens ?*

• ***Energy value chain (including conversion and end-use technologies)*** *: Power and storage technologies, aiming at providing energy services for all - Development and economics of power system*

• ***Research, innovation & education*** *in connection with the energy-intensive sectors : Exploring the role of scientific resources and capacity building as a response to the needs of emerging countries in the sectors of transport, residential, industry, services.*

Six seminars

1 - Energy, climate and sustainable development in Africa: Local Institutional Capacity Development
2 - Solar energy - tapping into solar energy resources to drive electricity access in Sub-Saharan Africa
3 - Modular energy production (e.g. mobile gas turbines in response to sudden demands) and/or cogeneration plants
4 - Design and development of small hydropower plants, taking advantage of the untapped potential of rivers and small dams
5 - Exploring the role of scientific resources and capacity building in the sectors of transport, residential, industry and services
6 - Innovative financing mechanisms in Africa for projects related to energy access, including circular economy.

Main organisers from RAOS and ANSALB:

• Dr. Ir. Georges VAN GOETHEM (georges.m.vangoethem@gmail.com)
• Prof. Dr. med. Philippe GOYENS, Permanent Secretary of RAOS
+ Bernard MAIRY (Ir - SEII) and Marc LOBELLE (Prof. Dr Ir Emeritus UCL)
Website: http://www.kaowarsom.be/en/home
E-mail: contact_raos@kaowarsom.be
+
• Prof. Dr. Mahouton Norbert HOUNKONNOU, President of ANSALB
• Prof. Dr. med. Hippolyte AGBOTON, Secrétaire Perpétuel de ANSALB
+ Mr Arnaud Y. ZANNOU (UC/PDER) and Dr. Thierry d'ALMEIDA (Sèmè city)
Website: https://academie-sciences.bj/
E-mail: ansalb@academie-sciences.bj

Bertrand Piccard (https://solarimpulse.com/)

A voice to encourage the implementation of solutions

A pioneering vision, considering ecology through the lens of profitability

As an influential voice on progress and sustainability, Bertrand Piccard is now working to develop collaborations with governments, institutions and large companies to give them practical tools to reconcile ecology and economy and prove that solving climate change – rather than an expensive problem – is a fantastic market opportunity.

For the first time a label proves the economic profitability of solutions that protect the environment. The Solar Impulse Foundation is selecting 1,000 solutions that protect the environment in a profitable way and awarding them the "Solar Impulse Efficient Solutions Label".
https://solarimpulse.com/energy-crisis-solutions

Collaborating with independent experts and with renowned institutions, the World Alliance proposes to evaluate its members solutions free of charge. The "Solar Impulse Efficient Solutions" label will offer a competitive edge to innovators and a guarantee of quality to solution seekers (investors). WORLD ALLIANCE NETWORK - An ever-expanding network (3073 members)
https://solarimpulse.com/alliance-network

PowerCorner - Mini-Grid for off-grid areas (Engie) 2/4

Source : PowerCorner - https://solarimpulse.com/efficient-solutions/powercorner
Video (47 sec) : https://youtu.be/nSWvZFN2mQs?list=PL-tY-9eGABwxBttHVtWResvO6_9CLpvLZ

PowerCorner - Mini-grids for affordable, reliable, sustainable energy-services for rural and off-grid populations

PowerCorner energy solution includes a containerised generation unit comprised of photovoltaic panels, a lithium-ion battery bank for storage and a back-up genset, providing electricity 24-hours a day.
In developing countries, many rural villages are off-grid, forcing populations to use polluting energy generation devices. PowerCorner units, through a 230V single phase overhead distribution network, can provide power for LED lightbulbs, phone chargers and fridges, as well as power tools and milling machines. Households and businesses who wish to be connected pay a nominal connection fee and are able to benefit from using electricity through a pay as you go technology thanks to smart meters and a Micro Utility Platform developed by ENGIE.

Key features
- Replacement of old, polluting energy generators with clean energy for off-grid customers
- Provision of basic services for households (lighting, refrigeration, communications, entertainment), capacity building for uses of appliances.

Profitability
- Easily deployable and replicable
- The Micro Utility Platform (MUP) manages notifications, payments, information tracking and all the digital aspects of the company

Categories of Application : Photovoltaic ; Smart grid ; Smart metering

Activity regions : Senegal, Ghana, Togo, Benin, Nigeria, Zambia, Tanzania, Uganda, Kenya

Maturity Stage:

- Medium and large scale commercialization
- **Small scale commercialization**
- Initial market commercialization
- Prototype testing in the real world
- Prototype testing 1:1 in the lab

Villaya - A containerized microgrids that provides solar electricity for off-grid needs (Schneider Electric) 3/4

Source : Schneider Electric - https://solarimpulse.com/efficient-solutions/schneider-electric-villaya
See also Press Release - 9 June 2020 : https://www.se.com/ww/en/assets/564/document/140848/press-release-solar-impulse-efficient-solution-label-award.pdf

Villaya can ideally complement or replace diesel gensets.

It consists of a maintenance-free plug and play solar microgrid embedded in a shipping container, and enables remote control and monitoring. The Villaya offer range is split into two containerized microgrids solutions ideally answering two distinctive market needs.
Villaya Emergency, a game changer, containerized technology, including pre-mounted and rectractable solar modules for disaster relief and refugee camps. Is is a system providing safe and reliable sustainable energy for rural electrification, schools, small businesses and hospitals.
Both ranges are standardized along 5 pre-defined power outputs (ranging from 7 up to 63 kW), enabling cost-effective industrialization. As plug and play solution fully factory tested, the Villaya range can be installed in remote areas without requiring specific skills for installation. Operation can be done remotely and it is maintenance free.

Key features
- PV panel and NiNa battery are all recyclable *(NiNa is a "hot" sodium nickel chloride battery that can operate at high temperature)*

Profitability
- A payback time estimated at 2.8 years

Categories of Application : Photovoltaic ; Solar thermal ; Smart grid ; Smart metering ; Power conservation ; Collaborative electricity consumption systems ; Demand-side management

Activity : Sub-Saharan Africa

TROPICALISATION
(résilience p. r. à chaleur, sable, poussière, eau, humidité, sel, vent, pollution, etc)

Maturity Stage:
- Medium and large scale commercialization
- **Small scale commercialization**
- Initial market commercialization
- Prototype testing in the real world
- Prototype testing 1:1 in the lab

Heliatek (Dresden, DE)
in collaboration with

Source : Heliasol - https://solarimpulse.com/efficient-solutions/heliasol

HeliaSol - HeliaSol is a flexible, ultra-lightweight, ultra-thin organic ready-to-use solar solution for various applications.

HeliaSol® is an organic solar solution that helps customers to virtually convert any surface into a power-generating solar surface, helping the customers to become less susceptible to increasing energy prices.
HeliaSol® is flexible, ultra-lightweight and ultra-thin, which enables more surfaces to become energy generator. The film is perfectly suited on curved or non-straight rooftops, ones with low static conditions like old buildings or lightweight industrial buildings, which usually cannot take traditional PV solutions. Even Façade installations can be realised with HeliaSol®. The solar film is a ready-to-use product with a specific adhesive on the back, which is glued directly to surfaces like steel, concrete and rooftop membranes.

Key features
- A carbon footprint of 5-7 g CO2e/kWh for central Europe in comparaison to 1000g CO2e/kWh for brown coal
- Ultra-lightweight (less than 2 kg/m²), very thin (less than 2 mm - excluding junction box), and flexible (minimum bending radius of 20 cm)

Profitability
- Energy Payback Time and Carbon Payback Time of less than 6 months

Categories of Application : Photovoltaic ; Structural building material ; Building ; House

Activity region : Egypt

Maturity Stage:

- Medium and large scale commercialization
- Small scale commercialization
- Initial market commercialization
- **Prototype testing in the real world**
- Prototype testing 1:1 in the lab

"Chrysalis, the machine that converts plastic waste into fuel" (1/2)

"Chrysalis, the machine that converts plastic waste into fuel"
A concrete solution to make plastic waste valuable and thus encourage its collection and contribute to its elimination from our coastlines.

172 millions de tonnes de plastique qui s'accumulent dans les océans depuis 1950

Plus de 8 millions de tonnes de plastiques ménagers continuent de se déverser chaque année dans les océans, en provenance à 80% des terres émergées !

A l'heure où les risques climatiques et les pollutions menacent la survie de nombreuses espèces – dont l'humanité – certains pensent que <u>la technologie va sauver le monde</u>… d'autres considèrent qu'elle nous a menés dans le mur et que la seule issue désormais est de s'en libérer, en changeant radicalement de système.

Mais pendant que l'on débat sur l'avenir, une majorité de la population vit dans un présent cruel : réchauffement, disparition des ressources, destruction des habitats, insécurité, pollution et migration forcée vers le Nord ou les villes.

Et l'occident ne peut plus se contenter de repousser le problème. Les déchets que nous déversions au Sud nous reviennent en pleine face. Ici aussi, les plus modestes, les plus éloignés des métropoles sont les premiers à en subir les conséquences. Et leur colère gronde…

Given that <u>plastic pollution damages are higher in developing countries</u> and primarily affect countries that lack the resources to effectively tackle the issue, the use of Chrysalis machines also <u>aims to assist countries in the global south and remote regions</u> by converting this waste in to a fuel.

Notre constat est simple :
Pour pouvoir penser sereinement notre avenir commun, nous devons d'abord agir pour le présent.
La mission que l'association Earthwake s'est donnée est de <u>mettre la technologie au service de cette urgence</u> :

<u>Etre un laboratoire et un incubateur d'innovations low-tech, accessibles à tous, au service de la valorisation des déchets dans le monde.</u>

Ces technologies seront mises à la disposition des populations avec pour objectif de <u>reconstruire leur autonomie écologique et économique</u>, et à terme, <u>contribuer à réduire les inégalités sociales</u>.

SOLARIMPULSE EFFICIENT SOLUTIONS OUR CHALLENGE 1000

"Chrysalis, the machine that converts plastic waste into fuel" (2/2)

pyrolysis + precision distillation

The latest version of our machine, the Chrysalis 40 (40 kg of plastic wastes transfomed per cycle), was presented in September 2019 on the World Clean-up day in Nice, France.
This low-tech pyrolysis machine is capable of converting 160 kg of plastics per day into 120 L of diesel fuel.

Five main advantages can be found in Chrysalis :

- A solution that converts plastic wastes (even those which are not recyclable) into energy.
- A human-scale solution providing alternatives to landfilling and incineration.
- A mobile solution that can be installed easily and quickly in communities that need the most.
- A machine self-sufficient in energy that provides vulnerable populations energy through their plastic wastes
- A profitable solution.

The machine is visible here (in French) – 1min28: https://www.youtube.com/watch?v=JboxVrm53i0 in Oct 2019, and Sept 2018 (2min13) in Antibes - https://www.youtube.com/watch?v=6eG99wbABlg

La Chrysalis : une machine permettant aux populations de traiter la pollution en amont, en valorisant les déchets plastiques.

Basée sur la pyrolyse, une combustion sans oxygène bien connue, la Chrysalis est la première machine permettant de recycler les déchets plastiques en carburant, dans un format réduit, mobile, et pour un prix abordable.

The device combines two technologies- the pyrolysis and precision distillation. This integrated system makes the Chrysalis 40 (a 450 degrees Celsius reactor) significantly innovative compared to other pyrolysis systems.
Crucially, Pyrolysis is a combustion without oxygen and thus without a flame, which allows the plastic to become another material.
The plastic is melted and distilled, then cooled and recovered in various states, including diesel.
This enables the production of a high-quality fuel directly usable in generators, agricultural machinery, boats...
Another impressive quality of Chrysalis is its energy self-sufficiency. Indeed, the gas produced during the process is used to power the machine. Also, Chrysalis does not emit toxic smokes because the combustion takes place in an hermetic oven.
Chrysalis has a 95% energy yield : 65% of diesel that can be used for generators or boat motors, 15% of gasoline and 15% of gas for heating. The 5% left are a residue of black carbon that can be enhanced (can be used for crayons or colorants).

Sources : website of Earthwake (created in France in 2014) - https://www.earthwake.fr/ and Reuters Dec 2018 - https://reuters.screenocean.com/record/1368764 and Solar Impulse (member – Earthwake) - https://solarimpulse.com/companies/earthwake and https://www.businessinsider.com/r-french-pair-invent-plastic-to-fuel-recycler-fit-for-african-bush-2018-12?IR=T

Small and micro-hydropower : reliable access to electricity, in particular in rural areas (1/2)

* micro-hydro (<100 kW)

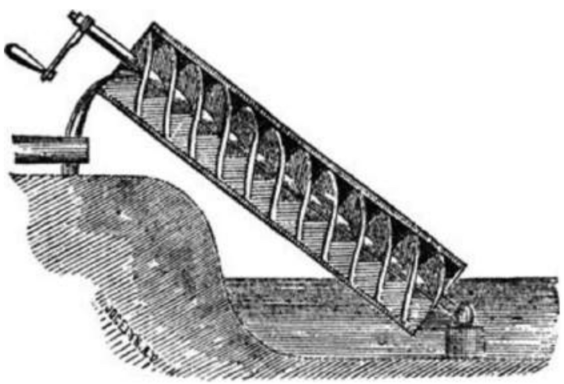
e.g. Archimedes screw turbine

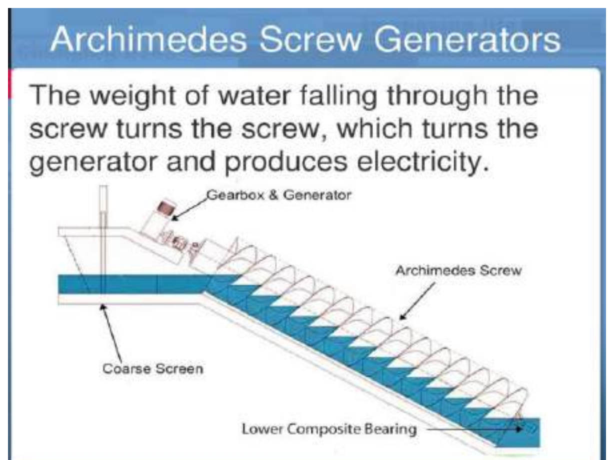
New ROR (run-of-river) hydropower technologies such as <u>Archimedes Screw Turbines</u> can be particularly advantageous.

<u>Classification of hydropower plants</u>

Hydropower plants can be classified based on their installed electrical generating capacity. Typical categories and associated capacities are: large hydro (>10 MW), <u>small hydro (<10 MW)</u>, mini-hydro (<1 MW), <u>micro-hydro (<100 kW)</u>, and pico-hydro (<5 kW). It is estimated that about 10% of global hydropower is generated from powerplants with less than 10 MW of capacity. Micro-hydroplants often utilize the natural flow of water in a run-of-river (ROR) configuration .

<u>ROR plants</u> include little or no controlled water storage, meaning that ROR typically has small or no reservoirs. The lack of a large reservoir formed by a dam, or significant control of river flow, avoids or minimizes the disadvantages associated with large reservoirs, at a cost of having to accept more variable or poorly timed power generation. Micro hydropower plants can often be considered as a sustainable development option for generating electricity in both developing and developed countries. There is often no need to build expensive dams and flood massive areas for the reservoir. This minimizes land and soil destruction, threats to wildlife, climate change effects, and other environmental impacts, especially on ecosystems as well as the social impacts of ROR hydropower plants.





See also: RAOS Conference SE4A 2017 - "Sustainable energy for Africa", 2017, October 23 – 25, Brussels (Royal Academy for Overseas Sciences of Belgium) - "Using small low cost, robust and easily maintained decentralized hydraulic power stations in Central Africa" by Patrick Hendrick (ULB), Jean Paul Katond Mbay (DR Congo, Univ. Lubumbashi), Jean Bosco Niyonzima (ULB and Burundi)
Excerpt : Archimedes screw micro-hydro Lubumbashi : Power 18 kW ; Length 4,5 m ; Ext Diam 1,9 m ; Nr blades 2
https://www.kaowarsom.be/en/SustainableEnergy4Africa_presentations%26vid%C3%A9os

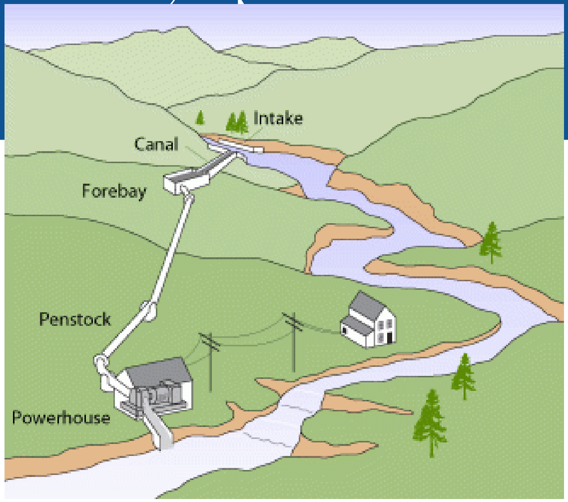
Figure. Archimedes screw pump (left) and an Archimedes screw hydropower plant (right)

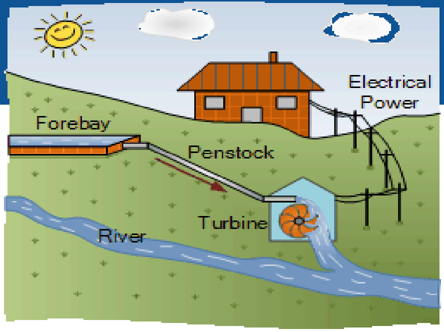
Source : "Archimedes Screw Turbines: A Sustainable Development Solution for Green and Renewable Energy Generation—A Review of Potential and Design Procedures", A. Y. Doost and W. D. Lubitz, University of Guelph, Canada, 8 Sept 2020 - https://www.researchgate.net/publication/344192874_Archimedes_Screw_Turbines_A_Sustainable_Development_Solution_for_Green_and_Renewable_Energy_Generation-A_Review_of_Potential_and_Design_Procedures

Small and micro-hydropower : reliable access to electricity, in particular in rural areas (2/2)

* micro-hydro (<100 kW)

* small hydro (<10 MW)





Source : "Micro-hydropower systems", US DOE - ENERGY SAVER - Office of Energy Efficiency & Renewable Energy - https://www.energy.gov/energysaver/buying-and-making-electricity/microhydropower-systems

Micro-hydropower System Components (ROR) :

- Water conveyance - channel, pipeline, or pressurized pipeline (penstock) that delivers the water
- Turbine or pump (incl. Archimedes screw) or waterwheel - transforms the energy of flowing water into rotational energy
- Alternator or generator - transforms the rotational energy into electricity (<100 kW)
- If high voltage AC electricity (e.g. 240 volts) is needed, add inverter to convert the low-voltage DC electricity produced
- Regulator - controls the generator
- Wiring - delivers the electricity.

Small hydropower (SHP) for productive use (e.g. Gura SHP project)

Generation of electricity to increase energy access in tea-growing areas by Kenya Tea Development Agency: 5.8 MW Gura SHP project in Central Kenya

Successfully installed in 2016 by KTPC (KTDA subsidiary), the total cost was over US$ 9 million. The development of the Gura SHP has had direct impacts in terms of providing green electricity from SHP for productive use. Annually, the project delivers a total of 18 GWh of reliable, alternating current (AC) electricity to four factories (see NB below), freeing them from the national grid, thereby improving the efficiency of the tea factories and reducing the emissions that harm the environment. NB - Name of factory - Amount of power supplied in (kWh/month) : Chinga - 220,000 ; Gathuthi 200,000 ; Iriaini 180,000 ; Gitugi 140,000

Technical features of the Gura SHP:

The Gura SHP is a small-scale ROR hydropower plant, which is made up of: a weir, settling tanks, channel, forebay tanks, penstock pipe, turbine and generator. More specifically:

- *Its installation involved the horizontal mounting of two 2,830 kW Francis turbines with the output power supplying the four tea factories.*
- *The weir is located upstream in the forest. The level of the weir is 2,066 metres.*
- *The settling tank (upstream of the waterway) has the following characteristics – size 34.6 x 5.55 metres, height circa 5.0 m, storage volume 231 cubic metres*
- *Penstock with an approximate length of 400 metres*
- *Power house (delivering 18 GWh/y of reliable, alternating current (AC) electricity)*

Lessons for future SHP development

The successful implementation of the Gura hydropower mini-grid project may also serve as a useful model for private investors and other stakeholders interested in developing SHP for productive use in Kenya. Here are some specific lessons learnt:

- Lesson 1: A practical and mature technology, SHP can contribute green electricity directly and effectively for productive use in Kenya
- Lesson 2: The importance of the integrated ownership model
- Lesson 3: The benefits of building a local community
- Lesson 4: Using the private sector to fill in the infrastructure gap.

Source : "World Small Hydropower Development Report 2019: Case Studies", LIU, D., LIU, H., WANG, X., and Kremere, E., eds. (2019) - United Nations Industrial Development Organization (UNIDO); International Center on Small Hydro Power (https://www.unido.org/our-focus-safeguarding-environment-clean-energy-access-productive-use-renewable-energy-focus-areas-small-hydro-power/world-small-hydropower-development-report).

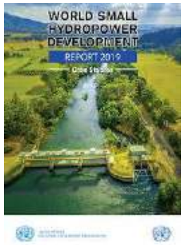
Hydro-Electricity and Climate Change – Energy Planning in Africa (1/3)

Africa has vast untapped sources of hydroelectricity but climate change, particularly droughts, raises questions about sustainability.

While Africa produces just 2% of the world's energy-related CO_2 emissions, climate-related effects are disproportionately higher in the region, which highlights the importance of a diverse power mix and regional interconnections.

- **Hydropower is a clean power source, which helps to offset the impacts of fossil fuels.**
- **Hydropower infrastructure also provides essential adaptation services to reduce the impacts of climate change such as floods and drought.**

The Democratic Republic of Congo (DRC) has Africa's largest hydropower potential, estimated to be 100,000 MW – that is, almost half of the current installed generation capacity on the entire continent. An estimated $ 14 billion is required to complete the Inga III hydroelectric mega- dam in the DRC, according to an October 2019 report by the NGO Resource Matters and the Congo Study Group. On completion, the Inga III will become the largest hydropower plant in sub-Saharan Africa. But the DRC, Namibia, Zambia, Ethiopia, Togo, and Sudan are the only African nations that get more than 90% of their power from hydro.



While developing the hydro potential in places where the rain patterns are still good is important, there is a need for long-term thinking on how Africa will manage the energy- water nexus.

Apart from adapting to climate change through diversifying the energy mix to include solar, wind, and geothermal, the continent has to be more interconnected.

Source : "Has the time for hydropower passed ? ", by Munyaradzi Makoni, a journalist based in Cape Town, South Africa, 15 Sep 2020 (This article was originally published in Good Governance Africa (gga.org) - https://africa-energy-portal.org/blogs/has-time-hydropower-passed

Hydro-Electricity and Climate Change – Energy Planning in Africa (2/3)

The Kariba Dam is failing. Since the late 1950s, it has sat on the Zambezi River. It provides 1,830 megawatts of hydroelectric power to both countries and holds back the world's largest reservoir.

For the last decade, scientists and reporters have issued warnings about the dam's potential to cause ecological disasters — of opposite kinds. On one hand, low rainfall has yielded water levels that barely reach the minimum necessary to generate electricity. On the other hand, heavy rainfall has threatened to flood the surrounding areas. When the floodgates were opened in 2010, 6,000 people had to be evacuated. …

Whether the water is too high or too low, the lives of millions of people are at stake, to say nothing of the natural ecosystem. It's a familiar, seemingly inevitable tale of human folly: One of our most ambitious efforts to harness the power of nature has left us exposed to nature's vagaries.

"Learning From the Kariba Dam" (Figure) – Climate change and neglect have brought the mammoth structure at the border of Zambia and Zimbabwe to the brink of calamity

- Namwali Serpell, The New York Times, July 22, 2020 - https://www.nytimes.com/interactive/2020/07/22/magazine/zambia-kariba-dam.html

Renewable energies such as solar and wind are associated with issues of variability, due to the constantly changing nature of weather patterns. These sources of renewable energy need to be coupled with sources that are more reliable, such as hydro, where flowing water is available.

Pairing hydro and renewable sources of power could help manage the effects of climate change.

- In Scandinavia, for example, Norway has plenty of hydropower plants, while a neighbouring country, Denmark, has wind. Each of these countries can switch off its own form of generation and rely on electricity from the other's source, depending on environmental and other conditions.
- = > The hydro potential in the African region could be managed in the same way.

?

Regional integration can also play a role by enabling nations to exchange electricity from regions of plenty to regions of scarcity.

- For example, when its dry in one region, it may be raining in another.
- Endeavours to interconnect the power systems of Kenya, Tanzania and Zambia such as the Southern African Power Pool (SAPP), begun in 1995, and the Eastern Africa Power Pool (EAPP), begun in 2005, facilitate this type of trade.

Hydro-Electricity and Climate Change – Energy Planning in Africa (3/3)

Though "cheap and clean", not everybody thinks hydropower is the right path for Africa.

Figure. The Cahora Bassa Dam (5 turbines of 415 MW each) is a dam in Mozambique.

It is one of the three major dams on the Zambezi river system, the others being the Kariba and the Itezhi-Tezhi (2 turbines of 60 MW each).

"As large dams continue being constructed on the continent, the destruction of river ecosystems and displacement of communities, destruction of livelihoods, and an increase in countries' debt burden is experienced".

"Dams also fall short of achieving their intended purpose, especially in the face of climate change and increasingly erratic rainfall, which can reduce energy and water benefits from dams and increase the risks."

"Hydropower's time has passed, even though Africa has developed only about 11% percent of its potential".

- **The amount of hydropower under construction or in the planning stages in sub-Saharan Africa far exceeds its needs for the next decade or two.**
- **Some of those under construction, such as the Grand Renaissance dam in Ethiopia, will become white elephants.**

Facing the future should involve energy policy planning that is inclusive of communities and addresses their water and energy needs, while addressing broader social, economic and environmental concerns.

"The key challenge for Africa is not merely to increase energy consumption, but to also ensure equitable access to cleaner energy sources, guided by good energy planning".

NB The AfDB works with regional power pools to ensure that the sustainable development of hydropower resources is underpinned by strong policy, regulatory frameworks, developed regional power markets, sustainable financial and operational performance in the face of climate change challenges.

Demand for hydrogen continues to rise (1/2)

standard and "green" H_2

Supplying hydrogen to industrial users is now a major business around the world. Demand for hydrogen has grown more than threefold since 1975.

Hydrogen can be extracted from fossil fuels and biomass, from water, or from a mix of both.

Natural gas is currently the primary source of hydrogen production, accounting for around three quarters of the annual global dedicated hydrogen production of around 70 million tonnes. This accounts for about 6% of global natural gas use.

Gas is followed by coal (2%), due to its dominant role in China, and a small fraction is produced from the use of oil and electricity.

As a consequence, production of hydrogen is responsible for CO2 emissions of around 830 million tonnes of carbon dioxide per year, equivalent to the CO2 emissions of UK and Indonesia combined.

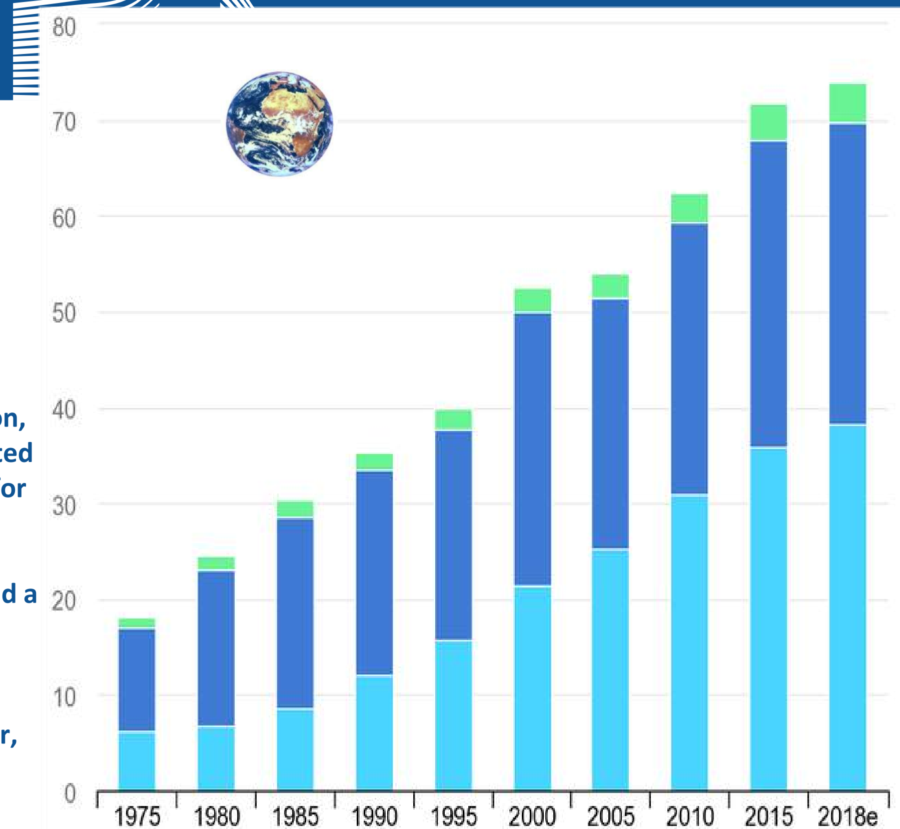


Figure (IEA 2019) : Global demand for pure hydrogen in Mt, 1975-2018
Demand for pure hydrogen was 18 Mt in 1975. Today (2018) it is around 70 Mt per year, mostly for oil refining (light blue) and chemical production (ammonia – dark blue). This hydrogen currently is produced from natural gas and coal, and associated CO2 emissions are significant.

Hydrogen Production, splitting water into hydrogen and oxygen ("green H2" - two main low-carbon technologies)

(1) Electrolytic processes for water splitting

Like fuel cells, electrolyzers are based on electrical processes and consist of an anode and a cathode separated by an electrolyte. This technology is well developed and available commercially. Alkaline electrolyzers operate via transport of hydroxide ions (OH-) through the electrolyte from the cathode to the anode with hydrogen being generated on the cathode side. In a "polymer electrolyte membrane" (PEM) electrolyzer, the electrolyte is a solid specialty plastic material (transport of positively charged hydrogen ions /protons/). https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis

(2) Thermochemical water splitting

Thermochemical water splitting uses high temperature heat (500°–2,000°C) —from concentrated solar power or from the waste heat of nuclear power reactions—and chemical reactions to produce hydrogen and oxygen from water. This is a long-term technology pathway, with potentially low or no greenhouse gas emissions. Source : US-DOE website - https://www.energy.gov/eere/fuelcells/hydrogen-production-thermochemical-water-splitting

Reminder - " standard H2 " - Today, 95% of the hydrogen in the world is produced in large central fossil fuel plants (natural gas, oil and coal) . Natural gas contains methane (CH4) that can be used to produce hydrogen with thermal processes, such as steam-methane reformation and partial oxidation.
https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming

CertifHy

Demand for hydrogen continues to rise (2/2)

standard and "green" H_2

On 8 July 2020, the EC released its hydrogen strategy, which clearly sets ambitious targets for the development of the clean hydrogen sector: 6 GW of electrolysis capacity installed by 2025 and 40 GW by 2030.

This is four to five times more than the investments currently planned in the national development strategies.
(https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf)

New wind farms in North Sea with a capacity of 10 GW can provide the electricity for an electrolysis plant capable of producing 800 kiloton/y of green hydrogen. That, in turn, would reduce CO2 emissions by 7 megaton/y. ("European Hydrogen Valley")
Source : "Hydrogen Gives Electrolysis a Lift" (June 2020)
https://www.chemicalprocessing.com/articles/2020/hydrogen-gives-electrolysis-a-lift/

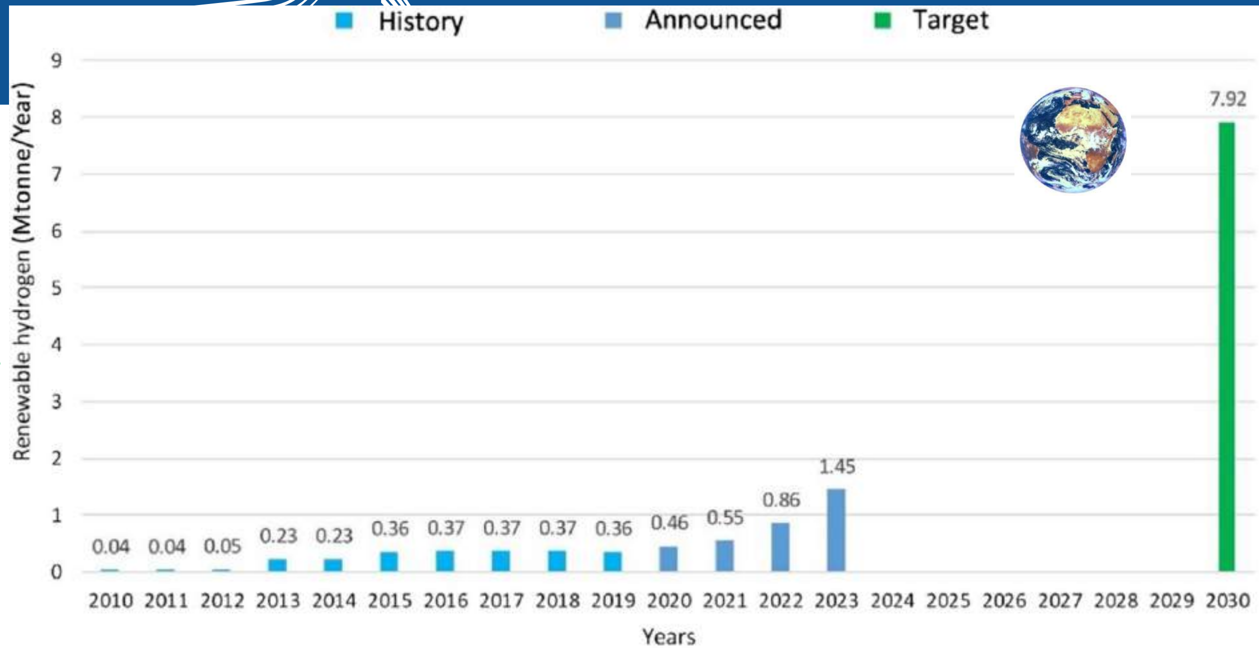


Figure (IEA 2019) : global low-carbon (renewable) hydrogen production, 2010-2030
"historical", "announced" and "in the SDS 2030" (details : 0.5 Mt/y in 2020 and 8 in 2030)

VARIOUS USES FOR HYDROGEN (standard or green)

- Hydrogen use today is dominated by industry, namely: oil refining, ammonia production, methanol production and steel production. Virtually all of this hydrogen is supplied using fossil fuels, so there is significant potential for emissions reductions from clean hydrogen.
- In transport, the competitiveness of hydrogen fuel cell cars depends on fuel cell costs and refuelling stations while for trucks the priority is to reduce the delivered price of hydrogen. Shipping and aviation have limited low-carbon fuel options available and represent an opportunity for hydrogen-based fuels.
- In buildings, hydrogen could be blended into existing natural gas networks, with the highest potential in multifamily and commercial buildings, particularly in dense cities while longer-term prospects could include the direct use of hydrogen in hydrogen boilers or fuel cells.
- In power generation, hydrogen is one of the leading options for storing renewable energy, and hydrogen and ammonia can be used in gas turbines to increase power system flexibility. Ammonia could also be used in coal-fired power plants to reduce emissions.

CertifHy

Source :"The Future of Hydrogen - Seizing today's opportunities", IEA Technology report — June 2019 - https://www.iea.org/reports/the-future-of-hydrogen

La production d'"hydrogène vert" n'est pas encore une réalité. Une transformation des systèmes énergétiques et du contexte technico-économique seront nécessaires pour y parvenir. Institut Français du Pétrole - https://www.ifpenergiesnouvelles.fr/enjeux-et-prospective/decryptages/energies-renouvelables/tout-savoir-lhydrogene

Nuclear fission in Africa (under IAEA auspices) : 11 research reactors and 15 countries considering nuclear power programmes

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Atoms for Peace and Development

Research reactors in Africa

Eleven research reactors currently exist across the African continent, covering a wide power range, from 0.1 kW to 22 MW. Common designs include the TRIGA model ("Training, Research, Isotopes, General Atomics") and the miniature neutron source reactor (MNSR). Other, unique, designs exist, as shown below.

Country - Facility name - Type - Thermal power (kW) - Neutron flux (cm-2 s-1)

- Algeria - NUR - Pool - 1000 - 5.0×10 13
  and Es-Salam - Heavy water - 15 000 - 2.0×10 14
- Democratic Republic of the Congo - TRICO II(1)
  - TRIGA Mark II - 1000 - 3.0×10 13
- Egypt - ETRR-1(1) - Tank - WWR 2000 - 3.6×10 13
  and ETRR-2 - Pool - 22 000 - 2.7×10 14
- Ghana - GHARR-1 - MNSR - 30 - 1.0×10 12
- Libya - IRT-1(2) - Pool, IRT - 10 000 - 2.0×10 14
  and TNRC - Critical assembly - 0.1 - 1×107
- Morocco - MA-R1 - TRIGA Mark II - 2000 - 7.1×10 13
- Nigeria - NIRR-1 - MNSR - 34 - 1.2×10 12
- South Africa - SAFARI-1 - Tank-in-pool - 20 000 - 4.0×10 14

(1) In extended shutdown.
(2) In temporary shutdown as of November 2019

(Source : IAEA - "Research Reactors in Africa - 2020 directory" - https://www.iaea.org/sites/default/files/20/07/research-reactors-in-africa-2020.pdf)

South Africa Koeberg (Cape Town)
Two PWRs – Framatome (1984)
Power generation 2 x 970 MW
Annual net output 13,7 TW·h

Emerging Nuclear Energy Countries in Africa

World-wide, about 30 countries are considering, planning or starting nuclear power programmes under strict control of IAEA (Vienna)

including 15 countries in Africa: Egypt, Tunisia, Libya, Algeria, Morocco, Sudan, Nigeria, Ghana, Senegal, Kenya, Uganda, Tanzania, Zambia, Namibia, Rwanda, Ethiopia.

(WNA website - August 2020 - https://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx)

Russia	China	Other
Jordan	Sudan	Poland
Egypt	Kenya	Lithuania
Tunisia	Thailand	Philippines
Algeria	Uganda	Kenya
Morocco	Cambodia	
Nigeria		
Ghana		
Ethiopia		
Sudan		
Zambia		
Kazakhstan		
Venezuela		
Bolivia		
Paraguay		
Myanmar		
Indonesia		
Vietnam		
Laos		
Cambodia		
Philippines		
Cuba		
Uzbekistan		
Rwanda		
Azerbaijan		
Congo		
Cuba		
Sri Lanka		

Le Rwanda a franchi une nouvelle étape en vue de la création de son « Centre national des sciences et technologies nucléaires » (CNST) d'ici 2024

- 2018 : le gouvernement rwandais avait entamé des discussions avec l'Agence fédérale russe pour l'énergie atomique ROSATOM pour la mise en place du CNST dans le parc industriel de Bugesera (sud de Kigali).
- Juillet 2020 : le parlement rwandais a approuvé un projet de loi portant sur la création au Rwanda d'un CNST, qui aura pour mission de développer des solutions d'énergie nucléaire intégrées.
- Six domaines sont concernés par les réacteurs de recherche (production de neutrons libres ou d'isotopes radioactifs) : la médecine nucléaire, l'agriculture, l'éducation, la radiobiologie, la science des matériaux.
  Source : Agence marocaine de Presse - 26/10/2020 - http://mapecology.ma/actualites/rwanda-avance-vers-creation-dun-centre-sciences-technologies-nucleaires/

IAEA : Nuclear science and technology contribute directly to nine of the 17 SDGs 1/3

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International Atomic Energy Agency

The IAEA, in line with its 'Atoms for Peace and Development' mandate, supports countries in their efforts to reach the 17 Sustainable Development Goals (SDGs) set out in the United Nations (UN) 2030 Agenda for Sustainable Development. Many countries use nuclear science and technology to contribute to and meet their development objectives in areas including energy, human health, food production, water management and environmental protection. The use of these techniques contributes directly to nine of the 17 SDGs.

The 2030 Agenda was adopted in 2015. The Agenda's 17 SDGs and their associated 169 targets aim at stimulating action over the next 15 years in areas of critical importance for humanity and the planet. They are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental.

https://www.iaea.org/about/overview/sustainable-development-goals

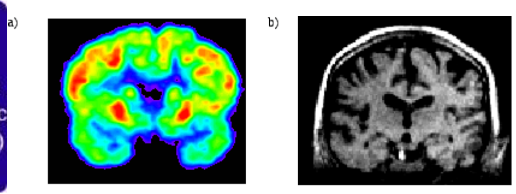
(1) SDG 2: Zero hunger

Nuclear science and technology can help fight hunger and malnutrition and improve food security and food safety, in particular, through the use of isotopic techniques.

*** to develop sustainable agricultural practices : e.g. help farmers conserve soil, water and crop resources, protect plants from damaging insect pests and grow more food using new plant varieties that are diseases resistant, thrive under changing climate conditions such as drought and increased soil salinity.**

*** establish and improve nutrition programmes and ensure stable supplies of quality food : e.g. produce food rich in key vitamins and minerals.**

[^{99m}Tc]-Technetium
Half-life : 6.01 Hrs
^{99}Mo (β decay) ^{99m}Tc
Decay : γ (141 keV)
Diagnostic



(2) SDG 3: Good health and well-being

The use of nuclear technology in medicine has become one of the most widespread uses of nuclear energy.

Nuclear techniques play an important role in diagnosing and treating various health conditions, in particular non-communicable diseases such as cancer and cardiovascular diseases.

Reminder - More than 80% of all nuclear medicine Single Photon Emission Computerized Tomography (SPECT) scans used each year to detect diseases like cancer and cardiovascular diseases require Technetium-99m (Tc-99m) – the most widely used radioisotope in radiopharmaceuticals. Tc-99m is the decay product of Molybdenum-99 (Mo-99), which is mainly generated in research reactors.

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(3) SDG 6: Clean water and sanitation

Finding, studying and protecting water resources

By using isotopic techniques, scientists can study the quality and quantity of water resources. They use naturally occurring isotopes in water to determine the water's origin, age, vulnerability to pollution, as well as how water resources move and interact with each other both above and below ground.

Fighting water pollution

Water sources can be polluted by heavy metals, complex organic compounds such as petroleum by-products or pharmaceuticals, radioactive isotopes and trace elements. Through IAEA support, scientists use nuclear and isotopic techniques to detect and analyse pollutants and track their movement. They can also use techniques, such as irradiation with electron beams, to destroy certain pollutants from wastewater generated from industrial processes.

(4) SDG 7: Affordable and clean energy

Nuclear power is a reliable, low-carbon energy source many countries are now considering or adopting as part of their energy mix.

The IAEA helps countries to meet the growing energy demand for development, while improving energy security, reducing environmental and health impacts and mitigating climate change.

For countries considering or setting up a nuclear power programme, the IAEA, upon request, provides guidance and support on establishing and maintaining a nuclear power programme in line with internationally recognized safety standards and security guidelines. The IAEA also assists countries new to nuclear technology in developing the proper infrastructure to help them build their way to sustainable energy.

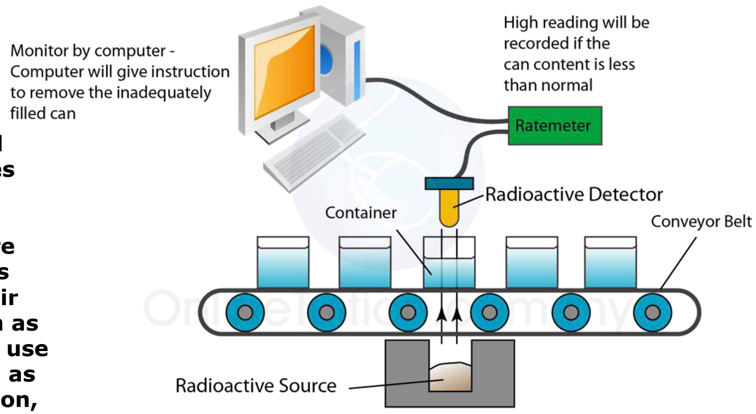
The IAEA provides technical support in all aspects of the nuclear fuel cycle and the life cycle of nuclear facilities, as well as support related to emerging innovative technologies.

(5) SDG 9: Industry, innovation and infrastructure

How industry benefits from nuclear technology

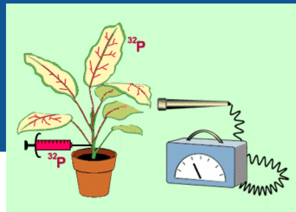
Experts develop and use nuclear technology to make products safer and better quality and also to boost industrial productivity. These technologies can also make industrial processes more efficient, environmentally friendly and cost-effective.

Radiation, such as electron beams or gamma rays, can be used to sterilize products, ensure food safety and quality, preserve and restore cultural artefacts, and clean up contaminants from industrial wastewater and air. It can also be used to modify materials to improve their quality and lifespans, such as making cables fire-resistant, and create new materials, such as biodegradable food packaging and hydrogels for use in medicine to heal wounds. With the use of radiotracers, experts can also diagnose and improve industrial processes (Figure), such as tracking and monitoring the movement and distribution of sediments caused by construction, dredging or dumping in coastal areas or finding valuable natural resources in the ground.



Non-destructive testing using X-rays, gamma rays or neutrons, such as industrial radiography, can help experts check for cracks and flaws to ensure the quality and integrity of materials and structures, such as airplanes, gas and oil pipelines. They are also used to verify the safety of buildings and bridges, particularly after natural disasters. Innovative non-electrical uses of nuclear power plants also offer cost-effective and efficient solutions by integrating energy production with other systems and applications. This includes using left over heat from nuclear power plants to desalinate seawater, extract and produce hydrogen and provide heating and cooling.

IAEA : Nuclear science and technology contribute directly to nine of the 17 SDGs 3/3



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Atoms for Peace and Development

Food and Agriculture Organization of the United Nations

(6) SDG 13: Climate action

Fighting climate change with nuclear science and technology

Climate change has made water scarcity, food shortages, biodiversity loss and natural disasters more common worldwide. Researchers use nuclear and isotopic techniques to collect data on and monitor how climate change affects the environment — from the ocean and freshwater to mountains and soil — and identify sources of pollutants and greenhouse gas emissions. This data can help policymakers take science-based decisions for mitigating and adapting to climate change.

As greenhouse gas emissions, such as carbon dioxide, nitrous oxide and methane, accelerate the rate of climate change, countries are working to mitigating these emissions by developing sustainable energy plans, many of which include nuclear power. They are also taking steps to improve the agriculture sector — a major source of greenhouse gas emissions — by using nuclear science and technology to study and develop new methods for growing food that also reduce emissions, such as carbon sequestration, which uses certain types of plants and harvesting methods to encourage soil to take in and hold onto more carbon dioxide from the atmosphere.

(7) SDG 14: Life below water

Oceans cover more than 70% of the planet and are a source of food and income for more than 10% of the world's population. Pollution and climate change continue to have a major impact on the ocean.

One of the major changes to the marine environment is ocean acidification. This is caused by the ocean absorbing excess amounts of carbon dioxide from the atmosphere, mainly coming from human activities. This results in an increase in the acidity of the oceanwater. Scientists are monitoring and studying ocean acidification using isotopic and other techniques to understand how it affects marine life and ecosystems and identify ways to protect the ocean and the coastal communities.

(8) SDG 15: Life on land

Land degradation affects more than 60% of global soil resources, due mostly to intensive agriculture and deforestation. Degraded land influences the lives of more than 1 billion people who rely on this land for food production.

Experts use nuclear techniques involving isotopes, such as nitrogen-15 and carbon-13, to assess soil quality and study how crops take up nutrients, as well as how soil moves. This information helps them to develop efficient soil management and crop production methods. These methods, such as intercropping and terrace building, help people to continue to grow food while conserving soil resources, and in some cases, reversing erosion and preventing soil from polluting water resources.

With the help of nuclear science, experts can also track and stop contaminants from harming the environment. They can identify certain isotopes in different contaminants, such as chemical fertilizers or industrial pollutants, to measure their concentration and trace their source. This kind of data can help decision makers to understand the impact of contaminants and develop policies to protect the environment. See also FAO website (Food and Agriculture Organization of the United Nations) – "Seven examples of nuclear technology improving food and agriculture" - http://www.fao.org/zhc/detail-events/en/c/1039633/

Protecting the environment from radiation contamination is another focus area of the IAEA's work. In such cases – for example during a nuclear or radiological incident or accident or at former uranium production sites – experts work with the IAEA to assess and safely and effectively remediate the areas. This involves, among others, addressing immediate safety concerns, removing or immobilizing radionuclides and modifying their pathways. The aim is to restore the affected land while protecting the public.

(9) SDG 17: Partnerships for the goals

As governments implement. their national development strategies and plans, many turn to the IAEA and its partners to help them use nuclear science and technology to meet their objectives. Longstanding IAEA partnerships, such as with the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), the United Nations Educational, Scientific and Cultural Organization (UNESCO) allow international organizations to contribute their skills and resources to support development worldwide.

(Philosophical question) : Should Energy Access Be a Human Right ?

UNITED NATIONS
HUMAN RIGHTS
OFFICE OF THE HIGH COMMISSIONER

Some Philosophical achievements

- Energy does not determine **human dignity.**
- With zero/poor access, **fundamental rights** may not be guaranteed.

→ Energy comes to be an **instrumental right**

Source: RAOS Conference SE4A 2017 - "Sustainable energy for Africa", 2017, October 23 – 25, Palace of the Academies, Brussels (Royal Academy for Overseas Sciences (RAOS) of Belgium - "Measuring sustainable energy projects to orient strategies for access to energy: why does it matters?", Prof Emanuela Colombo, UNESCO Chair in Energy for Sustainable Development; Dr Lorenzo Mattarolo, both with Department of Energy, Politecnico di Milano ; Dr Mariano Morazzo, Head of Climate Change and Renewable Energy Policies at Enel - https://www.kaowarsom.be/en/SustainableEnergy4Africa_presentations%26vid%C3%A9os
NB for clarification : the right to energy access is an instrumental right in that respecting this is the best means of protecting the fundamental rights, thereby ensuring human dignity.