Course Summary Solar Power for Africa

Gave a little bit of information about Africa

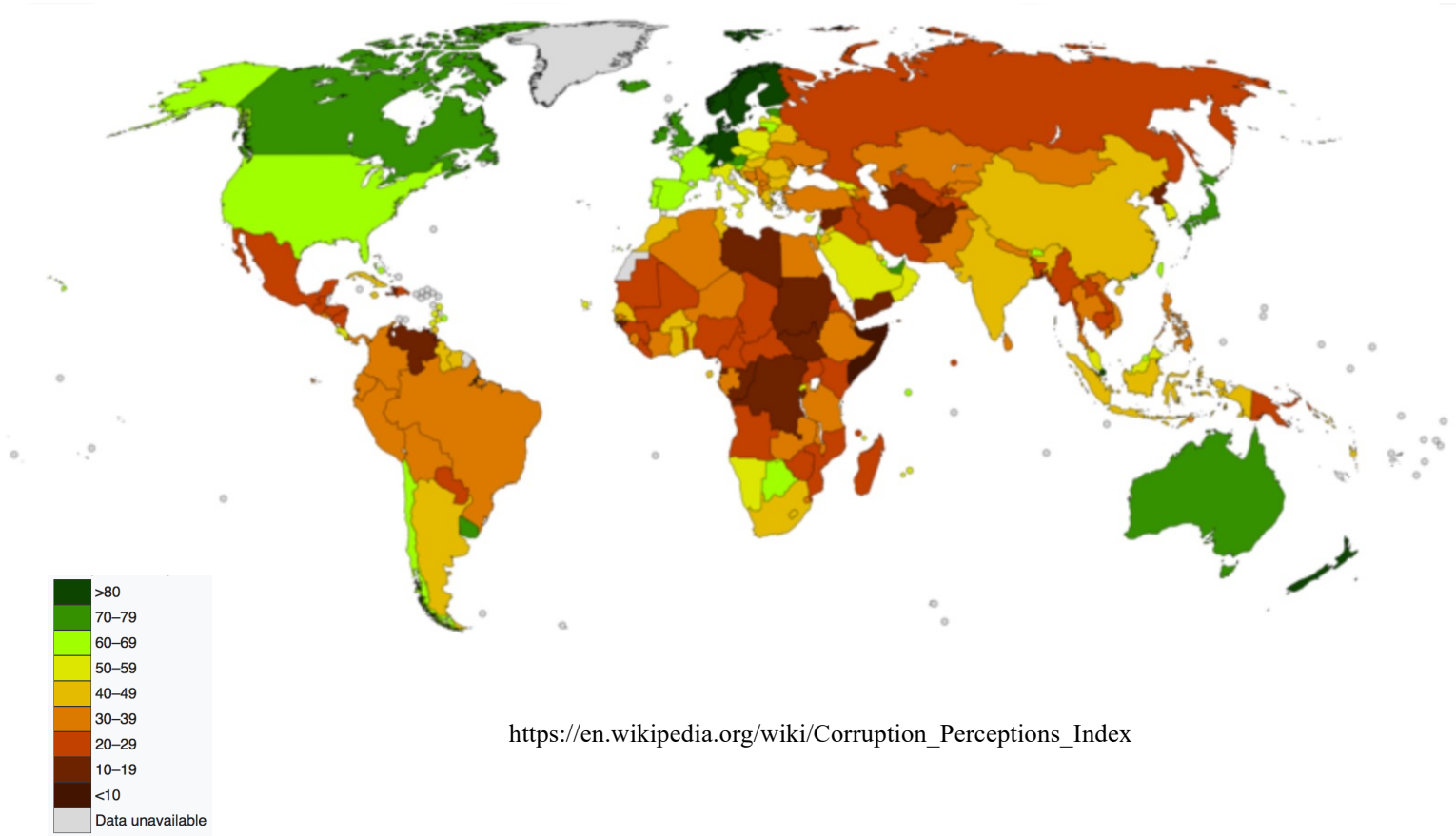
Went through some possible technologies that could be implemented to improve life

Looked into your possible roles in using what you have learned to try to impact the world

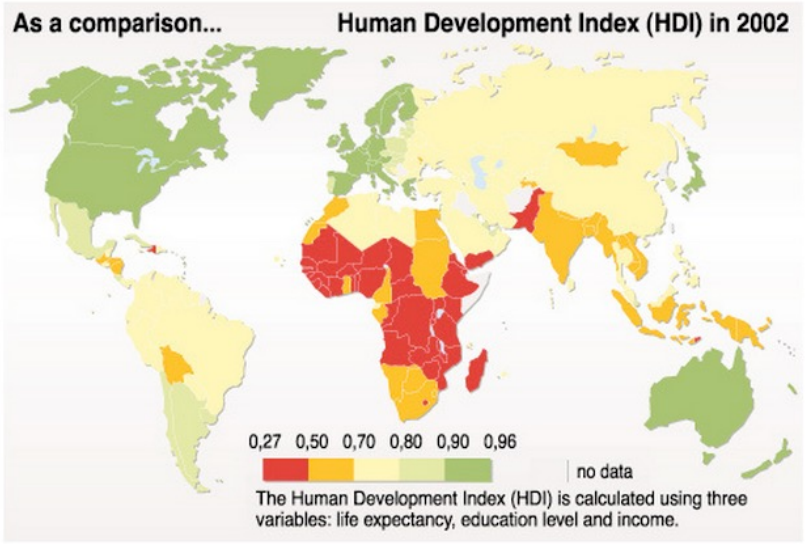
Most of Africa is near the equator, this distorts the size in a 2d projection.

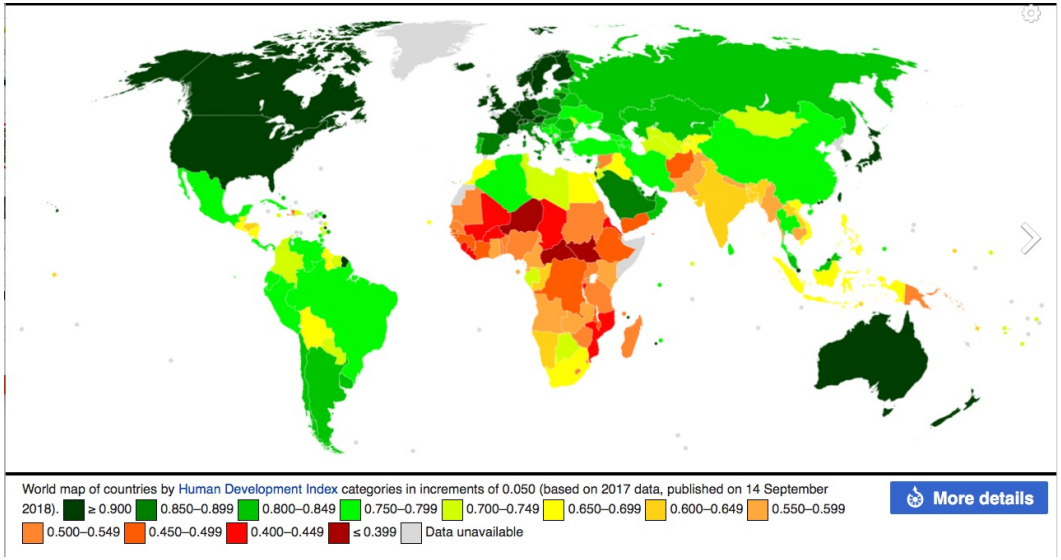
Corruption Index

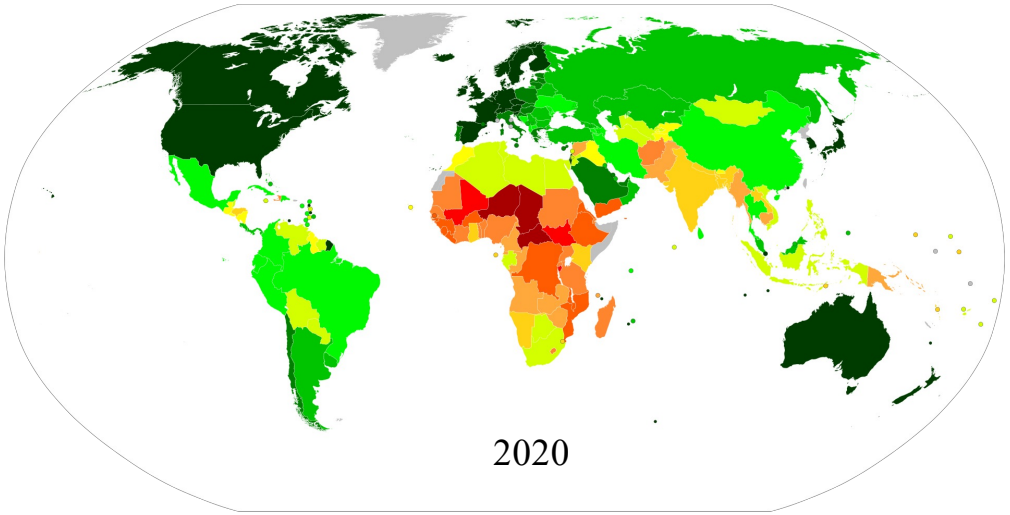
"the misuse of public power for private benefit"



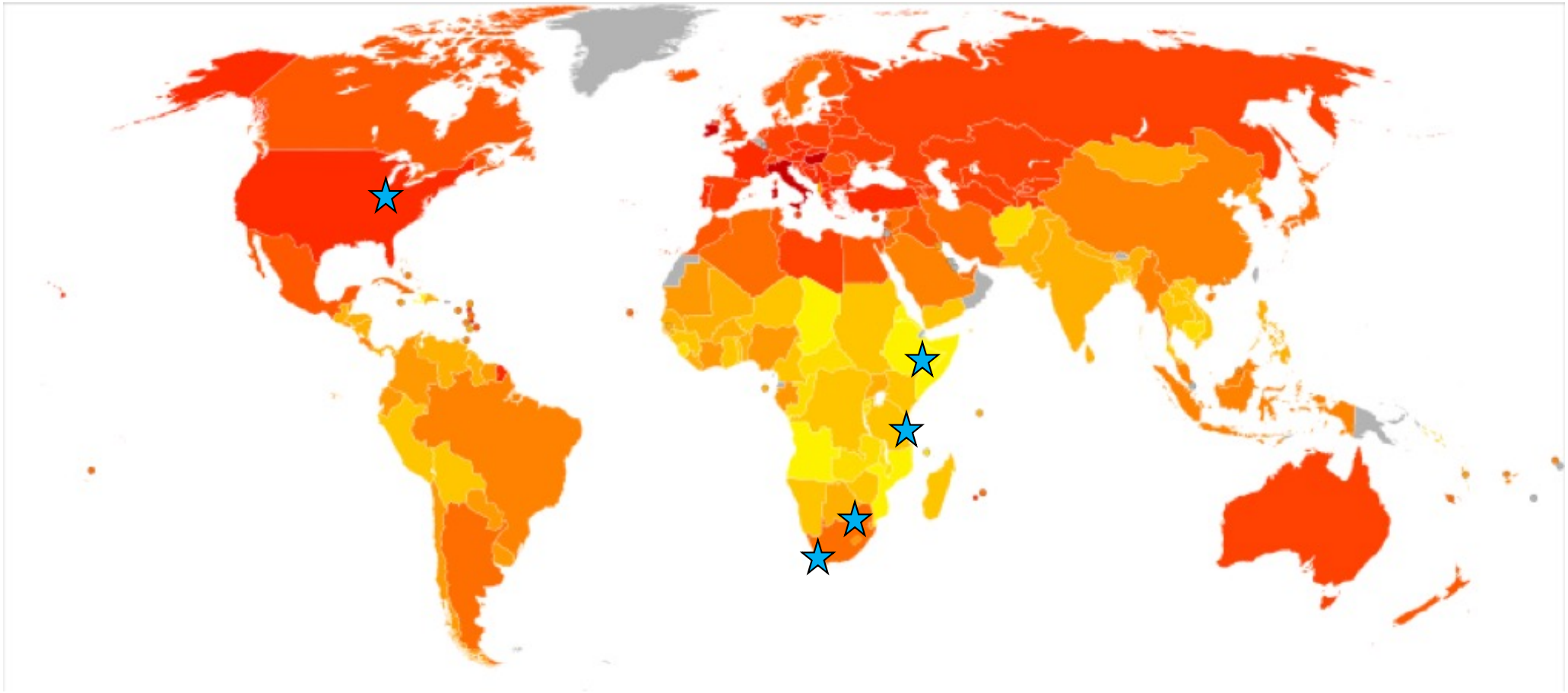
https://en.wikipedia.org/wiki/Corruption_Perceptions_Index


As a comparison...
Human Development Index (HDI) in 2002
0,27 0,50 0,70 0,80 0,90 0,96
no data
The Human Development Index (HDI) is calculated using three variables: life expectancy, education level and income.


World map of countries by Human Development Index categories in increments of 0.050 (based on 2017 data, published on 14 September 2018). ≥ 0.900 0.850–0.899 0.800–0.849 0.750–0.799 0.700–0.749 0.650–0.699 0.600–0.649 0.550–0.599 0.500–0.549 0.450–0.499 0.400–0.449 ≤ 0.399 Data unavailable
More details

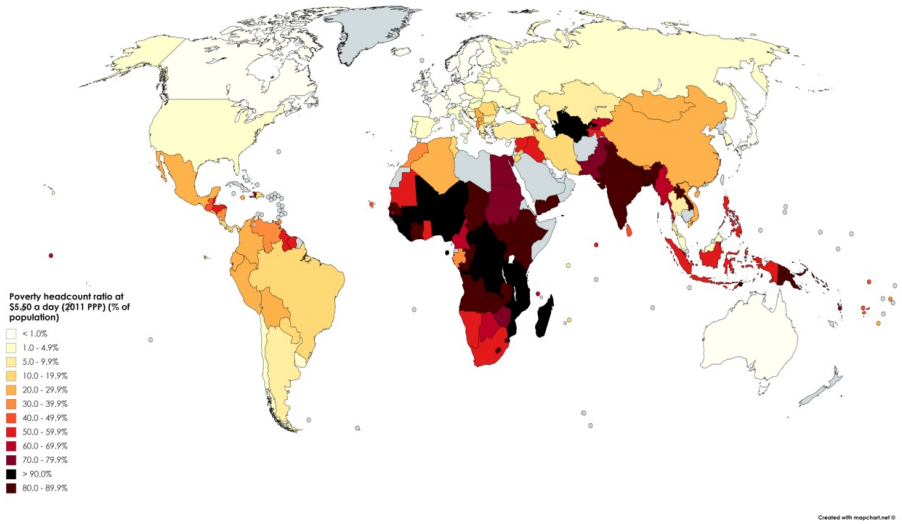

2020

Energy Consumption in the World



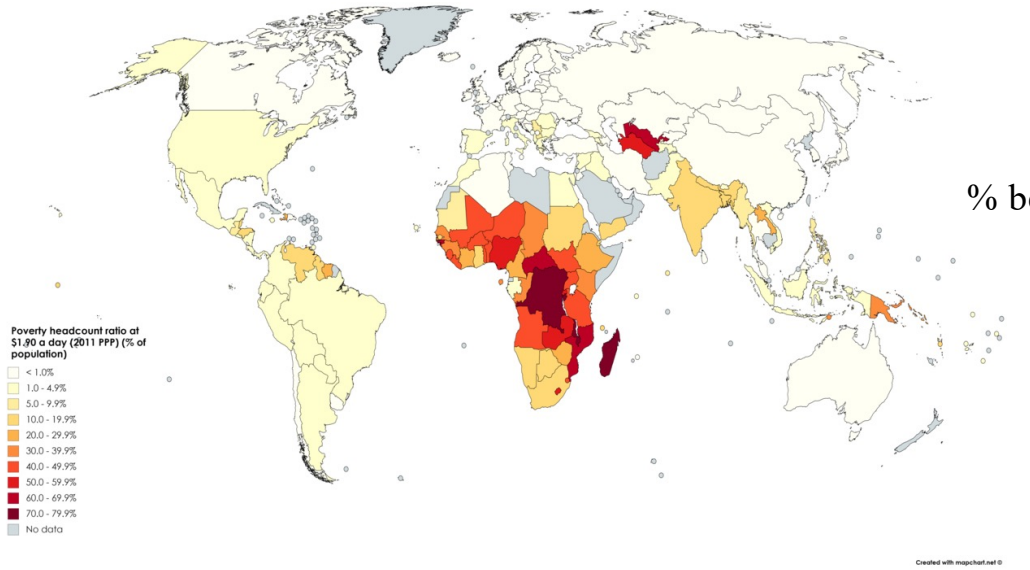
Poverty

One cup of rice ~ $0.22
One cup of beans ~ $0.30
A wage of $2/day is a survival wage
Typically 12 hour work 7 days a week (Possibly 10 on Sunday)



% below $5.50/day

2011



% below $1.90/day

The world's largest cities in 2100

From 2018
2 in Africa
13 drop

According to the report, human geography will look completely unfamili
projected for 2100:

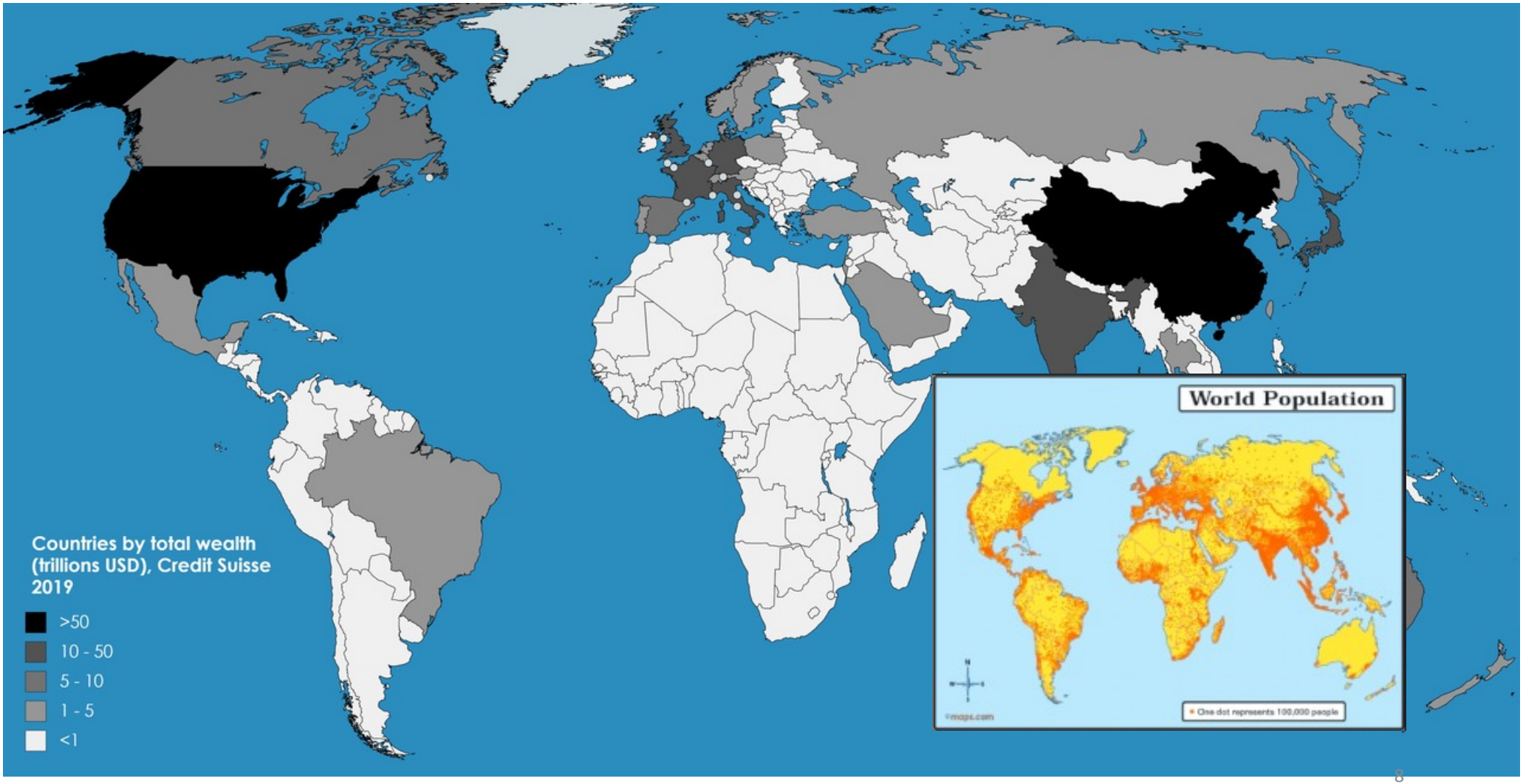
	Population (2100)	City	Country
#1	88.3 million	Lagos	Nigeria
#2	83.5 million	Kinshasa	DRC
#3	73.7 million	Dar Es Salaam	Tanzania
#4	67.2 million	Mumbai	India
#5	57.3 million	Delhi	India
#6	56.6 million	Khartoum	Sudan
#7	56.1 million	Niamey	Niger
#8	54.3 million	Dhaka	Bangladesh
#9	52.4 million	Kolkata	India
#10	50.3 million	Kabul	Afghanistan
#11	49.1 million	Karachi	Pakistan
#12	46.7 million	Nairobi	Kenya
#13	41.4 million	Lilongwe	Malawi
#14	40.9 million	Blantyre City	Malawi
#15	40.5 million	Cairo	Egypt
#16	40.1 million	Kampala	Uganda
#17	40.0 million	Manila	Philippines
#18	37.7 million	Lusaka	Zambia
#19	36.4 million	Mogadishu	Somalia
#20	35.8 million	Addis Ababa	Ethiopia

None in US
None in China
None in Europe

13 in Africa

	City[a]	Country	UN 2018 population estimates[b]	City proper[c]				Metropolitan area[d]			Urban area[g]		
				Definition	Population	Area (km²)	Density (/km²)	Population	Area (km²)	Density (/km²)	Population	Area (km²)	Density (/km²)
1	Tokyo	Japan	37,400,068	Metropolis prefecture	13,515,271	2,191	6,169 [14]	37,274,000	13,452	2,771 [15]	39,105,000	8,231	4,751 [e]
2	Delhi	India	28,514,000	Capital City	16,753,235	1,484	11,289 [16]	29,000,000	3,483	8,326 [17]	31,870,000	2,233	14,272 [f]
3	Shanghai	China	25,582,000	Municipality	24,870,895	6,341	3,922 [18][19]	N/A	N/A	N/A	22,118,000	4,069	5,436 [g]
4	São Paulo	Brazil	21,650,000	Municipality	12,252,023	1,521	8,055 [20]	21,734,682	7,947	2,735 [21]	22,495,000	3,237	6,949 [h]
5	Mexico City	Mexico	21,581,000	City-state	9,209,944	1,485	6,202 [22]	21,804,515	7,866	2,772 [23]	21,505,000	2,385	9,017
6	Cairo	Egypt	20,076,000	Urban governorate	9,500,000	3,085	3,079 [24]	N/A	N/A	N/A	19,787,000	2,010	9,844
7	Mumbai	India	19,980,000	Municipality	12,478,447	603	20,694 [25]	24,400,000	4,355	5,603 [26]	22,186,000	1,008	22,010 [27][i]
8	Beijing	China	19,618,000	Municipality	21,893,095	16,411	1,334 [18][19]	N/A	N/A	N/A	19,437,000	4,172	4,659
9	Dhaka	Bangladesh	19,578,000	Capital city	8,906,039	338	26,349 [28][29]	14,543,124 [30]	N/A	N/A	16,839,000	456	36,928
10	Osaka	Japan	19,281,000	Designated city	2,725,006	225	12,111 [14]	19,303,000	13,228	1,459 [15]	15,490,000	3,020	5,129 [j]
11	New York	United States	18,819,000	City	8,804,190	778	11,316 [31]	20,140,470	12,093	1,665 [32]	23,582,649	34,493	684 [k]
12	Karachi	Pakistan	15,400,000	Metropolitan city	14,910,352	3,530	4,224 [33][34]	16,051,521	3,780	4,246 [35]	15,292,000	1,044	14,648 [36]
13	Buenos Aires	Argentina	14,967,000	Autonomous city	3,054,300	203	15,046 [37]	12,806,866 [38]	N/A	N/A	16,216,000	3,222	5,033
14	Chongqing	China	14,838,000	Municipality	32,054,159	82,403	389 [39][19]	N/A	N/A	N/A	8,261,000	1,536	5,378
15	Istanbul	Turkey	14,751,000	Metropolitan municipality	15,519,267	5,196	2,987 [40]	N/A	N/A	N/A	15,311,000	1,375	11,135
16	Kolkata	India	14,681,000	Municipality	4,496,694	205	21,935 [41]	14,035,959	1,851	7,583 [42]	18,698,000	1,352	13,830 [43]
17	Manila	Philippines	13,482,000	Capital city	1,780,148	43	41,399 [44]	12,877,253	620	20,770 [44]	23,971,000	1,873	12,798 [l]
18	Lagos	Nigeria	13,463,000	[m]	N/A	N/A	N/A	21,000,000	1,171	17,933 [45]	15,487,000	1,966	7,877
19	Rio de Janeiro	Brazil	13,293,000	Municipality	6,520,000	1,221	5,340 [46]	12,644,321	5,327	2,374 [47]	12,486,000	2,020	6,181
20	Tianjin	China	13,215,000	Municipality	13,866,009	11,920	1,163 [18][19]	N/A	N/A	N/A	10,932,000	2,813	3,886

By the year 2100, it's estimated that 13 of the world's largest megacities will be located in Africa. Meanwhile, India will hold three of them – and there will be zero of them found in the Americas, China, or Europe.


Countries by total wealth (trillions USD), Credit Suisse 2019
>50
10 - 50
5 - 10
1 - 5
<1
World Population
One dot represents 100,000 people

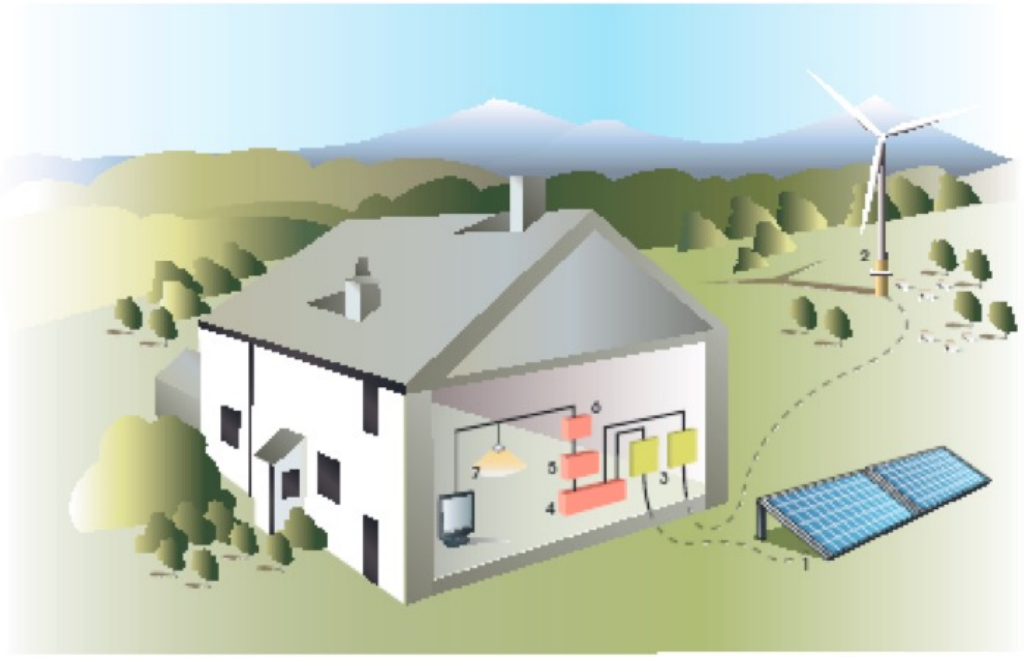


Figure 5.1 Remote and independent: a stand-alone system for a farmhouse.

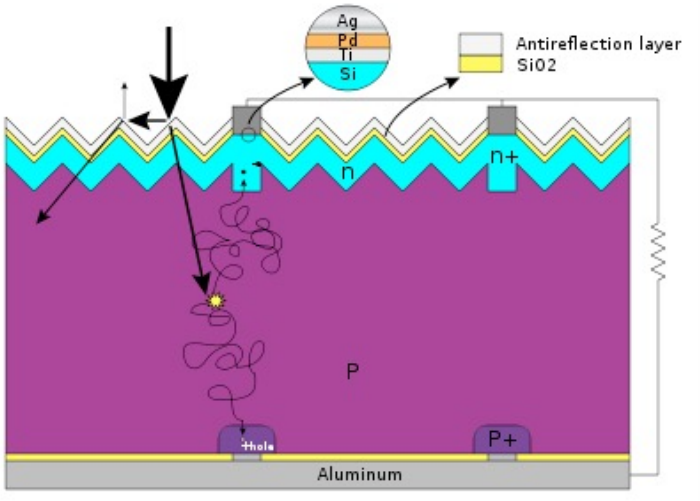
1) PV Panels
2) Other sources of Power: Wind Turbine, Diesel or Gasoline Generator, Hydropower
3) Charge Controllers
4) Battery Bank
5) AC Inverter/Direct DC systems
6) Fuse box(es)
7) Appliances/Loads

50 Solar Street Lights Installed in Village in 2015
Improved Design Installed in 2016 by DDIT Students and Faculty
(Commercialization was not followed through to date)

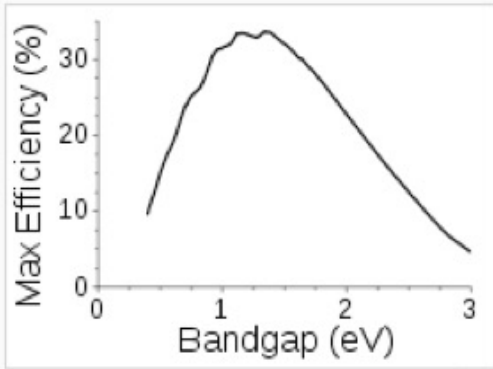
Power Ethiopia

-Photovoltaics are missing in Ethiopia
    high import tariffs
    no financing
    architectural adaption
    no technical support
    aversion to new technology
    no sales team
-Solve these issues using University Resources
    manufacture (assemble) PV panels
    train technologists/business people
    profit for faculty and students
-HU/DDU area is unique for this opportunity

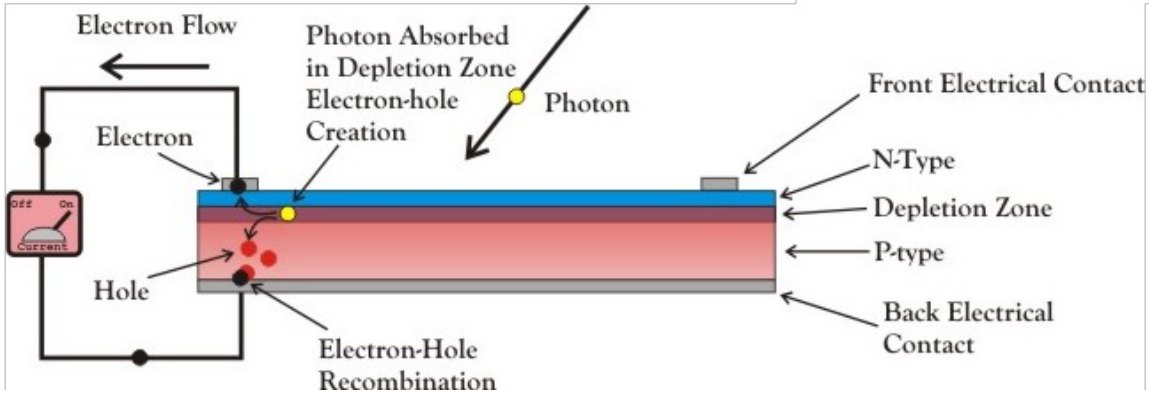
Solar Cell



Basic structure of a silicon based solar cell and its working mechanism.



The Shockley-Queisser limit for the theoretical maximum efficiency of a solar cell. Semiconductors with band gap between 1 and 1.5eV have the greatest potential to form an efficient cell. (The efficiency "limit" shown here can be exceeded by multijunction solar cells.)



Oxidation/Reduction Metal Displacement Reaction

Metal displacement [edit]

In this type of reaction, a metal atom in a compound (or in a solution) is replaced by an atom of another metal. For example, copper is deposited when zinc metal is placed in a copper(II) sulfate solution:

$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

In the above reaction, zinc metal displaces the copper(II) ion from copper sulfate solution and thus liberates free copper metal.

The ionic equation for this reaction is:

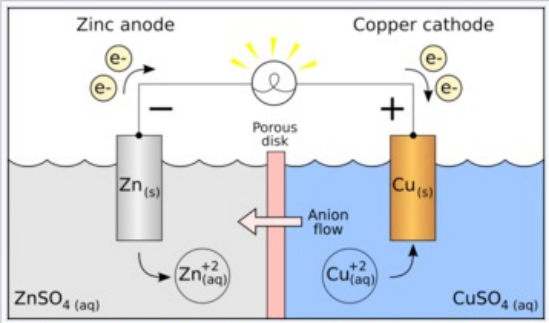
$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

As two half-reactions, it is seen that the zinc is oxidized:

$Zn \rightarrow Zn^{2+} + 2\,e^-$ oxidation

And the copper is reduced:

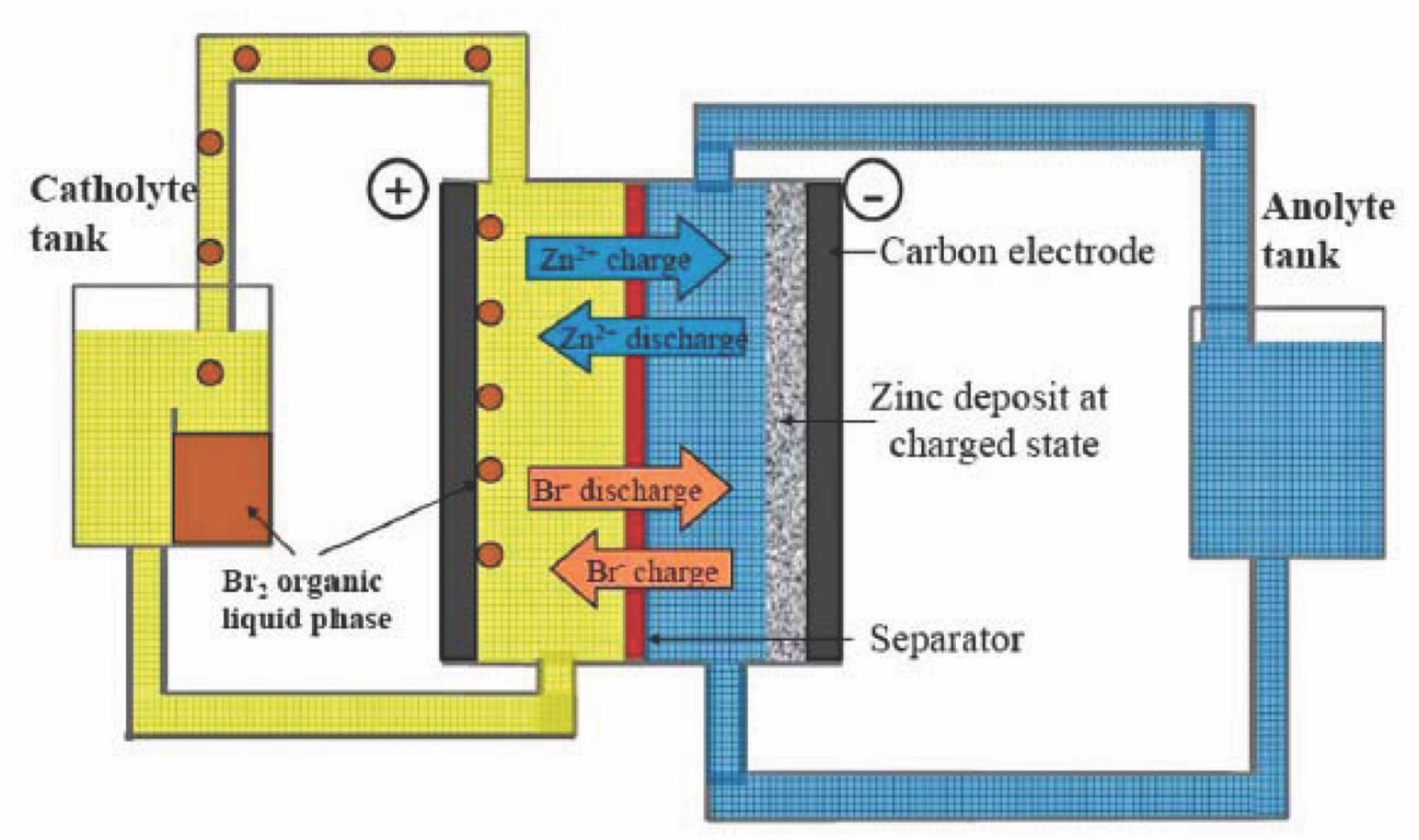
$Cu^{2+} + 2\,e^- \rightarrow Cu$ reduction



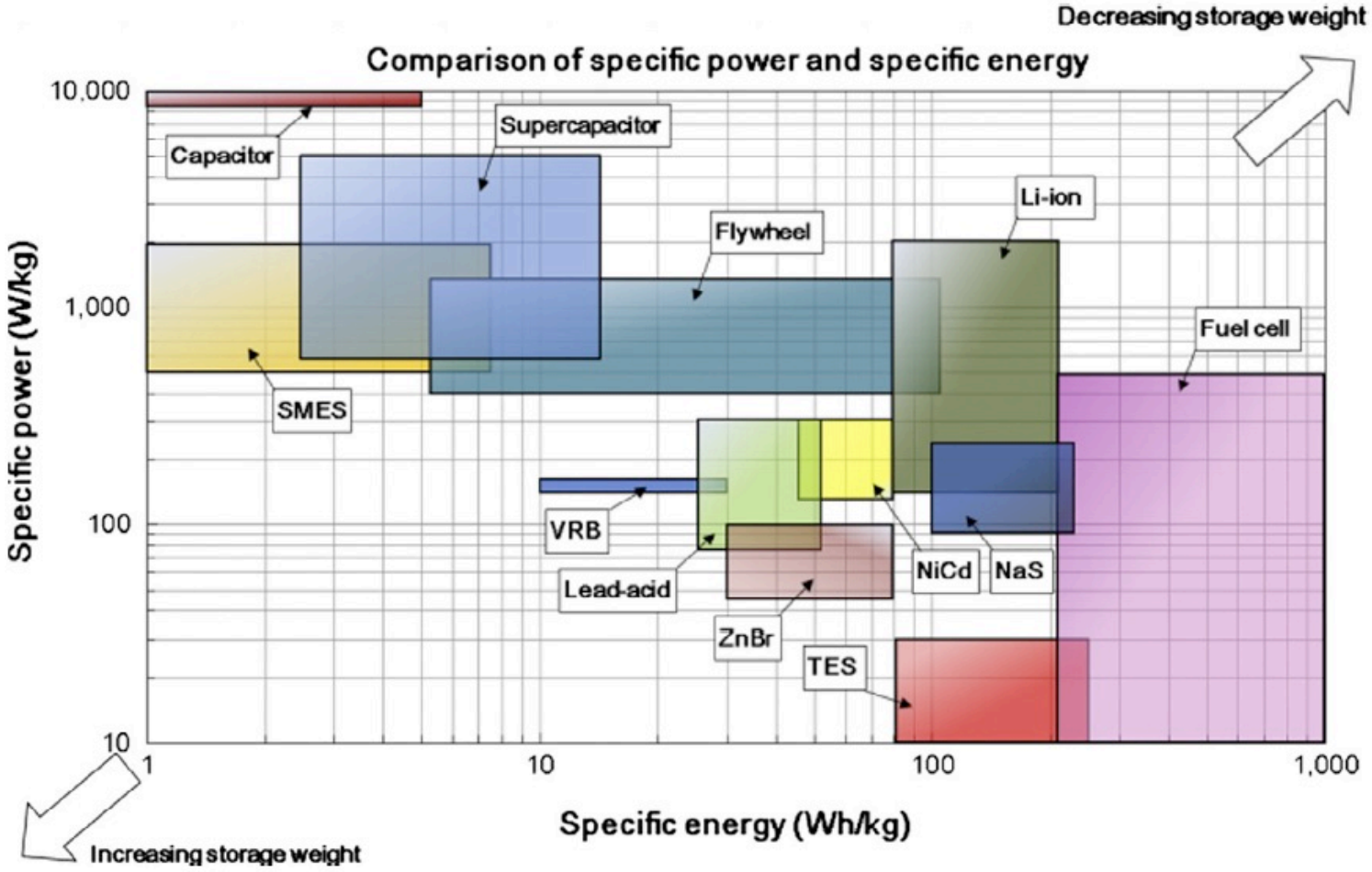
A redox reaction is the force behind an electrochemical cell like the Galvanic cell pictured. The battery is made out of a zinc electrode in a $ZnSO_4$ solution connected with a wire and a porous disk to a copper electrode in a $CuSO_4$ solution.

1.10 Volts for each cell

Zinc Bromide Flow Cell



Comparing energy storage techniques



Luo, X., Wang, J., Dooner, M., Clarke, J., 2015. Appl. Energy.

Lithium ion battery

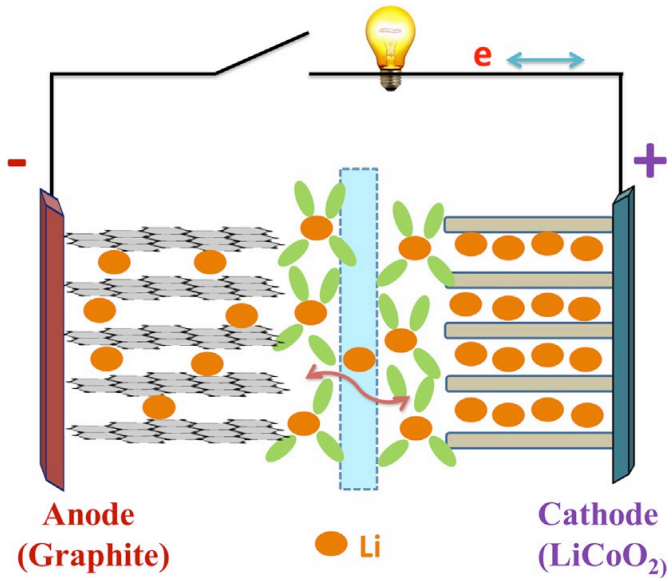
Intercalation reactions occur

Lithium-ions move into material lattices

Lithium ions shuttle back and forth

Graphite stores lithium when fully charged

Cathode accepts lithium during discharge




UZZI

[King Abdullah's Desalinization Plant]

Seawatergreenhouse.com

A restorative approach to agriculture

Photo 3.1 **The Gemasolar power tower near Sevilla (Spain)**

Source: Torresol Energy.

Key point

Molten-salts solar towers can generate electricity round the clock.

Solar Chimney's

Enviromission (Australia)

http://www.enviromission.com.au/EVM/content/about_companyprofile.html

Solar Chimney Spain (Madrid)

http://www.youtube.com/watch?v=XCGVTYtJEFk

Industrial Solar Water Heating Mek'elle Ethiopia

http://www.solarthermalworld.org/sites/gstec/files/Kahsay_ISES%20Kassel.pdf

No.	Factory	Process	Working Temperature (°C)	Consumption (m^3/day)	Current Source of Energy
1.	Sheba Tannery	Skin Tanning	35	18.4	Furnace oil for a steam boiler
		Skin Re-tanning	50	66.6	
		Hide Tanning	40	29.3	
		Hide Re-tanning	65	27.0	
2.	Maichew Particleboard	Glue preparation	40	6.0	Furnace oil, fire wood
		Impregnation	55	1.2	
3.	Bahirdar Textile	Pre-heater	60	36.0	Furnace oil for a steam boiler
		Washing	70	7.8	
		Chemical Preparation	80	5.2	
4.	Ashraf Edible Oil	Conditioning	85	6.0	Furnace oil for a steam boiler
		Degumming	90	5.0	
		Neutralization	90	5.0	
		Washing	70	7.7	

Swamp Cooler (http://www.youtube.com/watch?v=6ooAAcsbf_0)

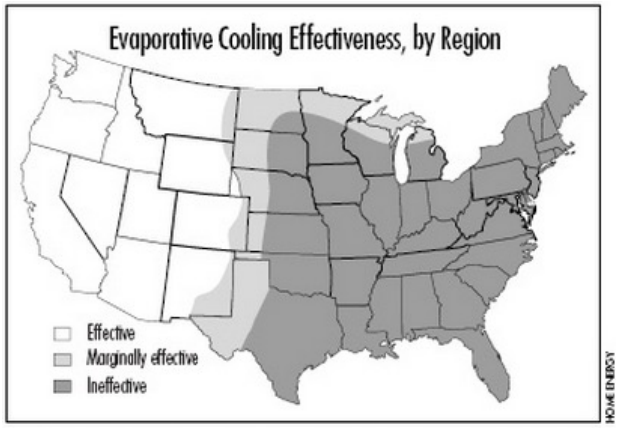


Figure 2. In areas of the United States where humidity tends to run high in the summertime, evaporative cooling is not the best way to stay cool; in the West, it's a very good choice.

A Simple Solar Ice Maker (Anthony Tong/Amanda)

Methanol/Carbon Based Absorption Refrigerator/Ice Maker

Georgia Tech

https://www.engineeringforchange.org/wp-content/uploads/2015/10/sol_r_final_report.pdf

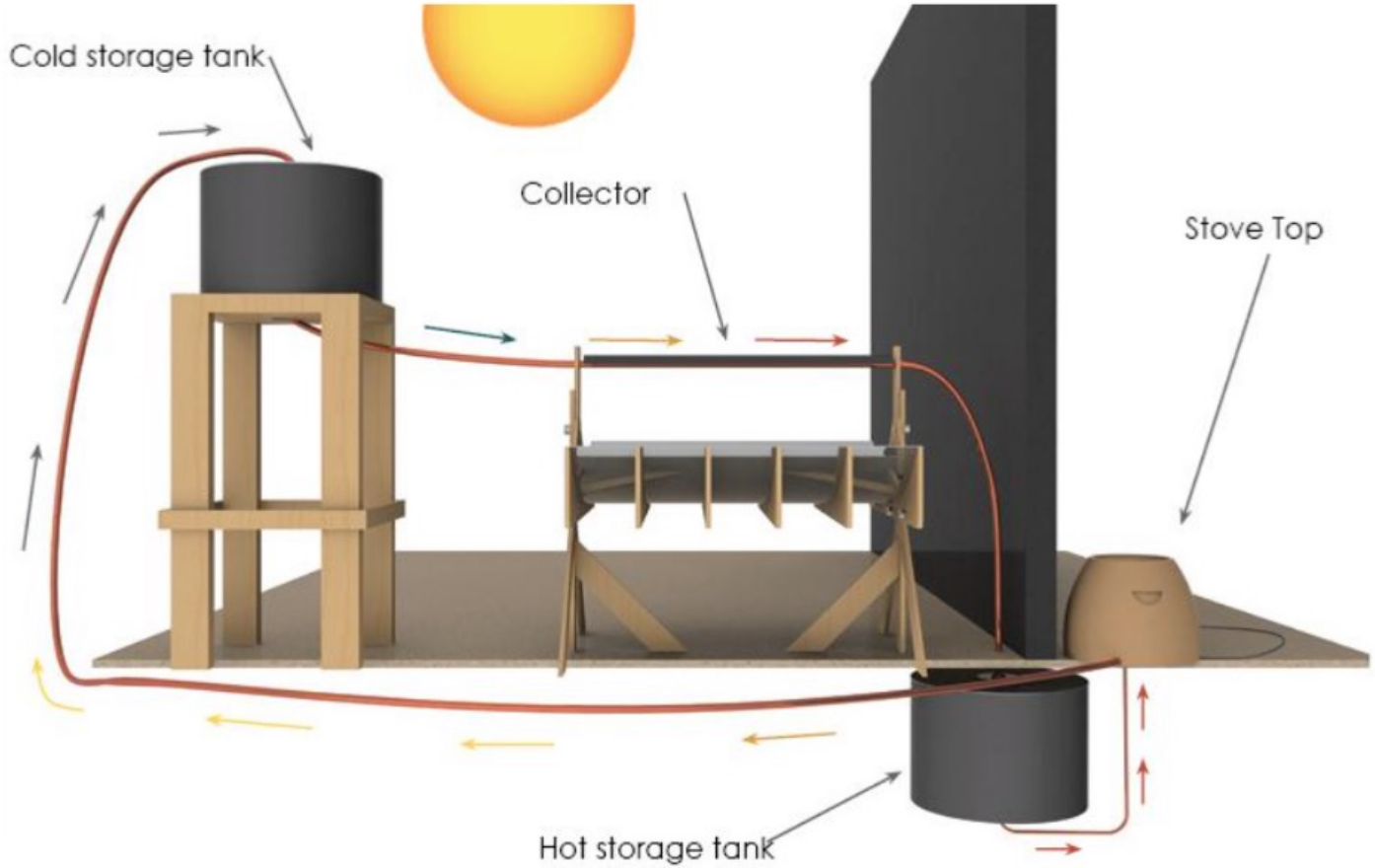


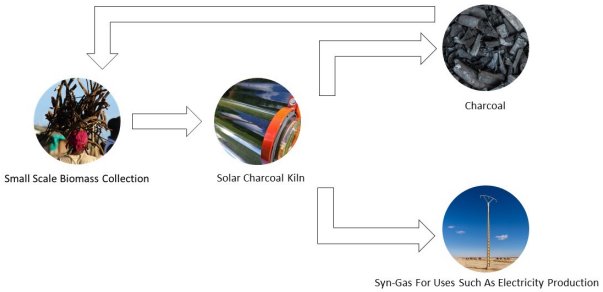
Figure VII.1. Depiction of the entire system

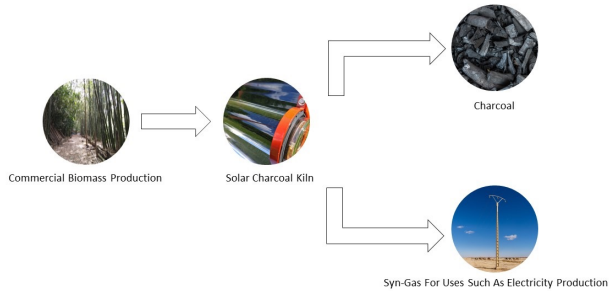
Go Sun Stove (http://www.kickstarter.com/projects/707808908/gosun-stove-portable-high-efficiency-solar-cooker)

Go Sun Fusion

Figure 8 Picture of the prototype in its final version with the evacuated tube receiver.

Figure 9 Picture of the prototype in its final version with the evacuated tube receiver.


Charcoal
Small Scale Biomass Collection
Solar Charcoal Kiln
Syn-Gas For Uses Such As Electricity Production


Charcoal
Commercial Biomass Production
Solar Charcoal Kiln
Syn-Gas For Uses Such As Electricity Production

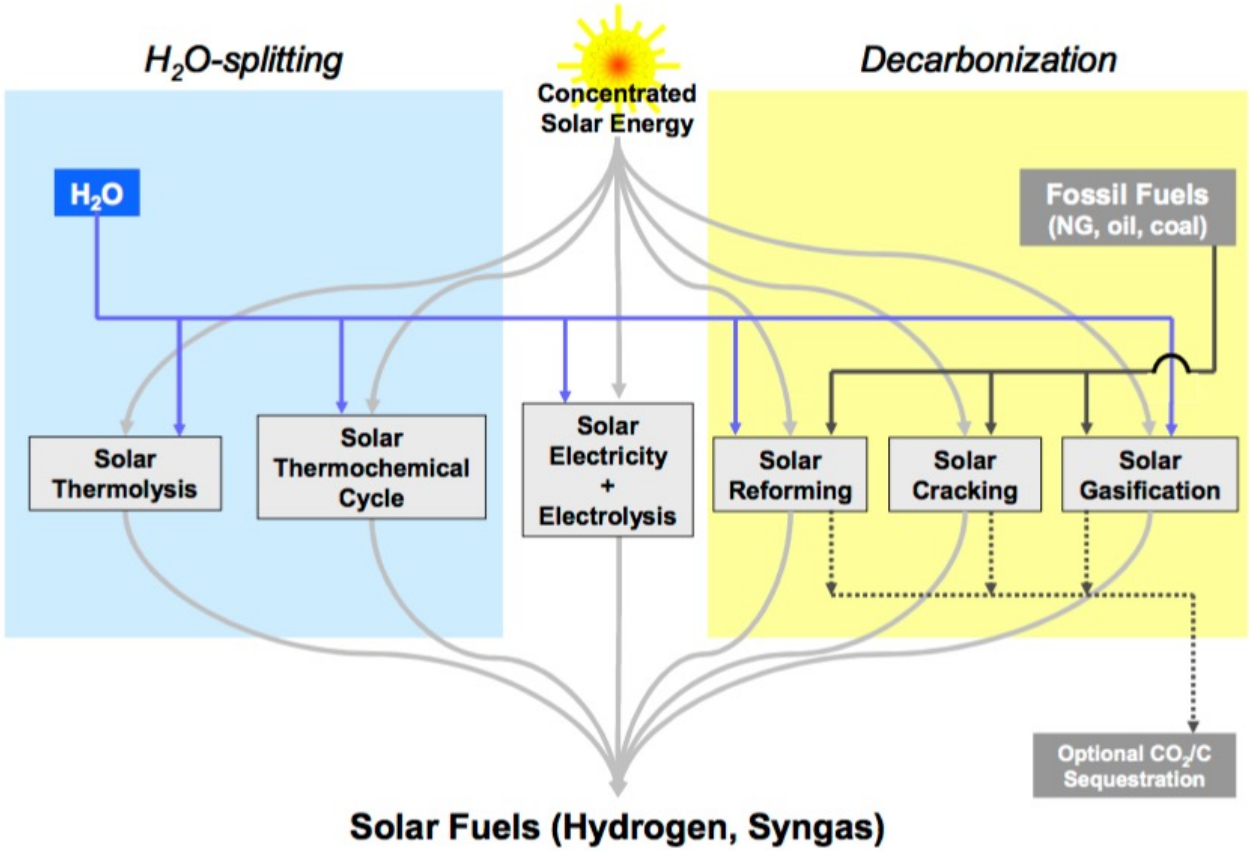
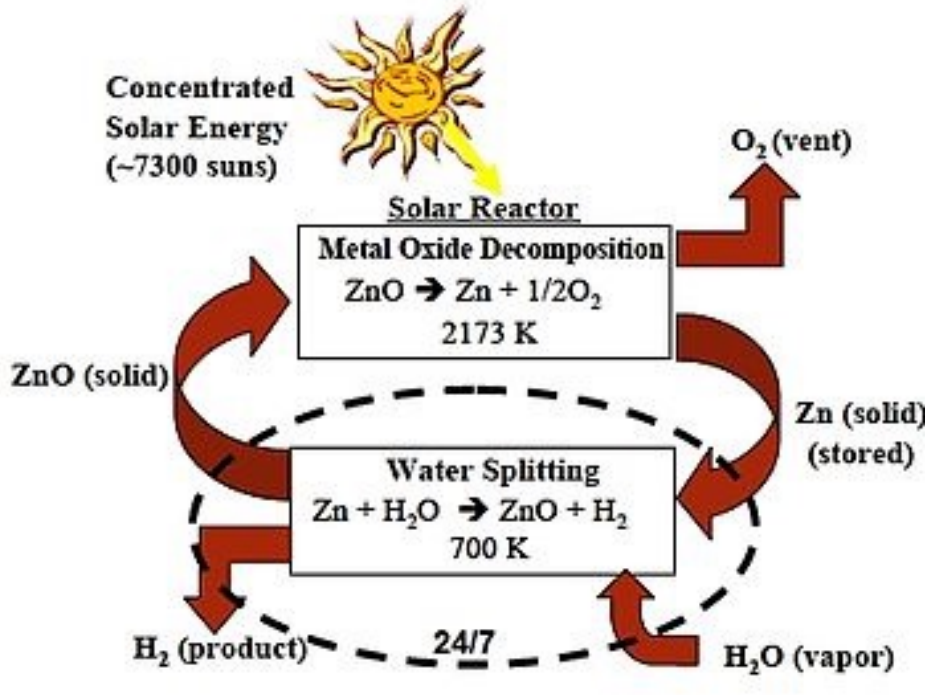


Fig. 2: Thermochemical routes for solar hydrogen production – Indicated is the chemical source of H_2: H_2O for the solar thermolysis and the solar thermochemical cycles; fossil fuels for the solar cracking, and a combination of fossil fuels and H_2O for the solar reforming and gasification. For the solar de-carbonization processes, optional CO_2/C sequestration is considered. All of those routes involve energy consuming (endothermic) reactions that make use of concentrated solar radiation as the energy source of high-temperature process heat. Adapted from [1,2].

Zn => ZnO Cycle (http://en.wikipedia.org/wiki/Zinc%E2%80%93zinc_oxide_cycle)



UNLV (http://www.hydrogen.energy.gov/pdfs/review06/pd_10_weimer.pdf)

PSI/ETHZ (https://www.psi.ch/media/producing-pure-recycling-zinc-with-concentrated-solar-energy)

France Solar Furnace Talk (http://sfera.sollab.eu/downloads/Conferences/SolarPACES_2012_SFERA_Meier.pdf)

http://sfera.sollab.eu/downloads/Conferences/SolarPACES_2012_SFERA_Meier.pdf

Outline

100 kW Pilot Plant at MWSF

- Installation
- Commissioning

Scientific Background

- Solar ZnO dissociation at 2000 K
- Solar reactor technology

Experimental Results

- Solar reactor experiments
- Flux measurements

Outlook / Acknowledgements

CNRS 1 MW Solar Furnace
Odeillo, France

Biomass/Syngas

Steam Reforming Reaction: CH_4 to H_2 and CO

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

At high temperatures (700 – 1100 °C) and in the presence of a metal-based catalyst (nickel), **steam** reacts with methane to yield carbon monoxide and hydrogen. ...

Water Shift Gas Reaction: CO to H_2

$$CO + H_2O \rightarrow CO_2 + H_2$$

The shift reaction will operate with a variety of catalysts between 400°F and 90

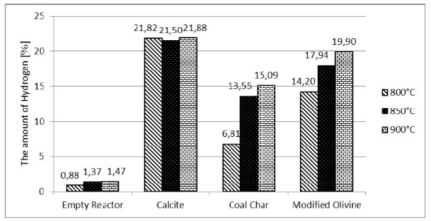


Fig. 3. Average percentage representation of hydrogen for the studied catalysts at t=800, 850 and 900°C

Fischer-Tropsch Reaction: H_2 and CO to Liquid Fuel

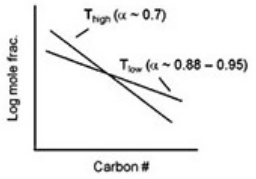
Reaction mechanism [edit]

The Fischer–Tropsch process involves a series of chemical reactions that produce a variety of hydrocarbons, ideally having the formula (C_nH_{2n+2}). The more useful reactions produce alkanes as follows:

$$(2n + 1)\ H_2 + n\ CO \rightarrow C_nH_{2n+2} + n\ H_2O$$

where n is typically 10–20. The formation of methane ($n = 1$) is unwanted. Most of the alkanes produced tend to be straight-chain, suitable as diesel fuel. In addition to alkane formation, competing reactions give small amounts of alkenes, as well as alcohols and other oxygenated hydrocarbons.[4]

- Nickel (Ni) tends to promote methane formation, as in a methanation process; thus generally it is no desirable
- Iron (Fe) is relatively low cost and has a higher water-gas-shift activity, and is therefore more suitab a lower hydrogen/carbon monoxide ratio (H_2/CO) syngas such as those derived from coal gasificatio
- Cobalt (Co) is more active, and generally preferred over ruthenium (Ru) because of the prohibitively cost of Ru
- In comparison to iron, Co has much less water-gas-shift activity, and is much more costly.



Low T	Sasol Arge	High T	Sasol Synthol
• low $C_1 - C_4$	13.3	• higher $C_1 - C_4$	43.0
• low $C_5 - C_{11}$	17.9	• higher $C_5 - C_{11}$	40.0
• low C_{12}-C_{19}	13.9	• less C_{12}-C_{19}	7.0
• 50-70% wax	51.7	• low wax	4.0
• 220-270°C		• 325 – 350°C	
• α: 0.87+		• α: ~0.7	
• gasoline/diesel: 1:2		• gasoline/diesel: 2:1	
• 80° Cetane #		• 50-60 Cetane #	
• 0-20 Octane #		• 0-60 Octane #	

Dependency of Fischer–Tropsch synthesis ASF distribution on temperature. Product selectivities (in %) of the Sasol Arge (220 °C) and Sasol Synthol (325 °C) processes are on a C-atom basis. Reprinted with permission from the author.[6]

India Biogas Reactor (https://www.youtube.com/watch?v=9kKRdlAFuZw)

Titania as a photocatalyst

- *Irradiation of semiconductors having a band gap (2 - 4 eV) with UV light energy ≥ energy of the band gap E_g*
- *Generation of charge carriers*

$$TiO_2 \xrightarrow{h\nu} TiO_2\,(e^- + h^+)$$

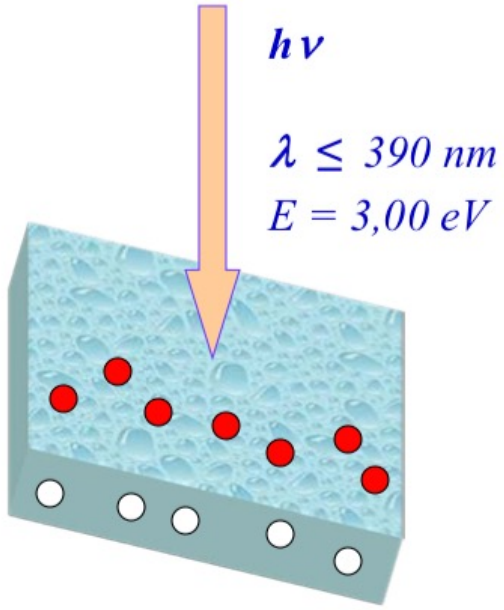
- *Formation of active radicals (OH*, O_2*)*

$$OH^- + h^+ \longrightarrow OH^{\bullet}$$

$$O^{2-} + e^- \longrightarrow {}^{\bullet}O^{2-}$$

- *Recombination process*

$$e^- + h^+ \longrightarrow Heat$$



Solar Thermolysis

Titania as a photocatalyst

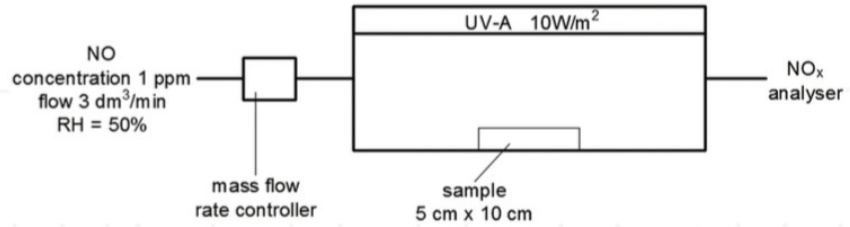
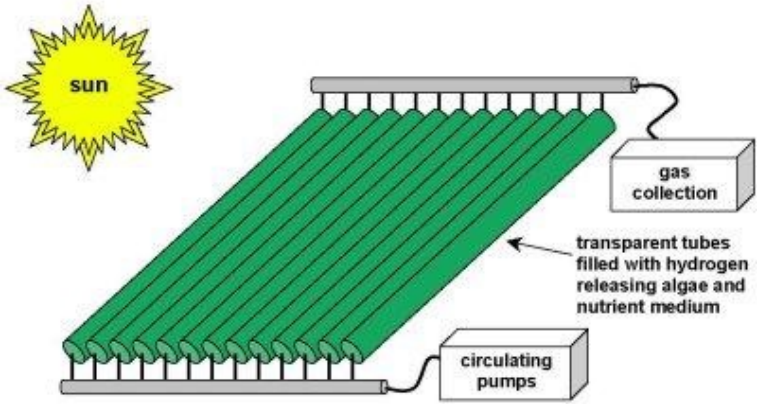


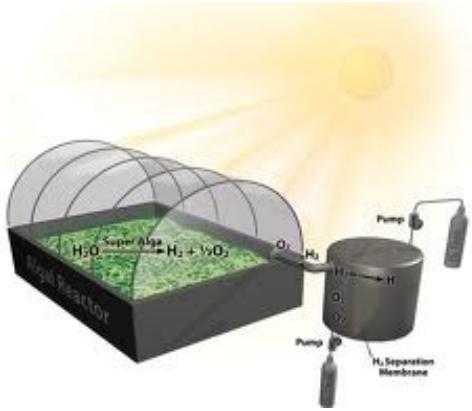
Figure 3. Photoreactor according to ISO 22197-1.

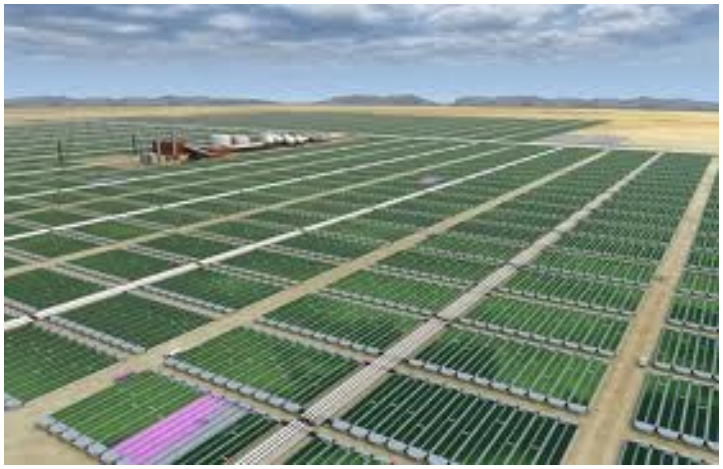
Figure 4. Separate parking lanes at the Leien of Antwerp with photocatalytic pavement blocks [15].

Spirulina Algae in West Africa (https://www.youtube.com/watch?v=CxSA5iiGgiY)

Simple schematic for biological hydrogen production

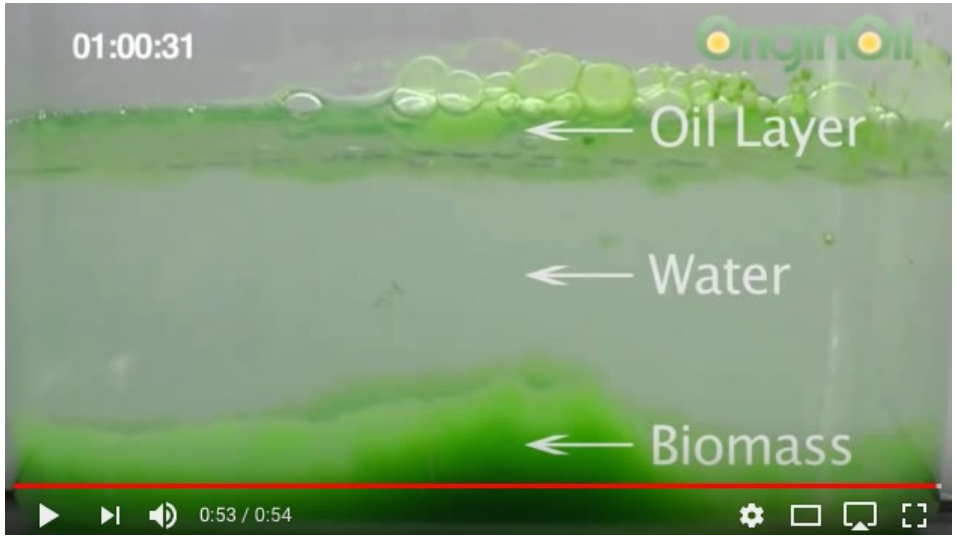






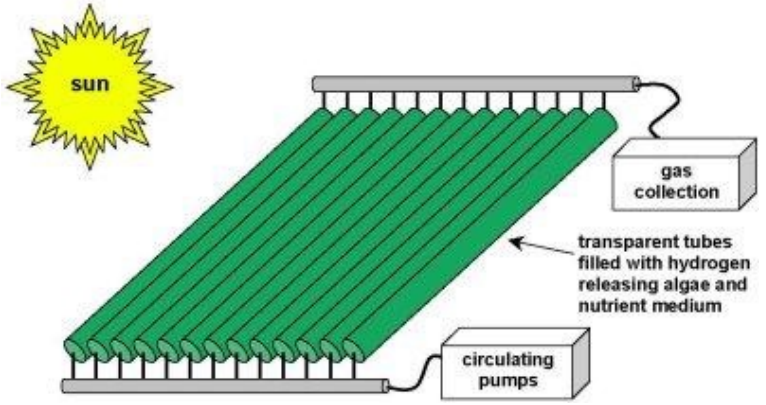
Algae oil extraction

https://www.youtube.com/watch?v=aEZTAJNIxjQ



Algae Tower

Simple schematic for biological hydrogen production



[Hydrogen from Algae](http://www.youtube.com/watch?v=Or_F6qC0sK4)
(http://www.youtube.com/watch?v=Or_F6qC0sK4)

[Hydrogen from Algae Imperial College](https://www.youtube.com/watch?v=OFByDMRbucs)
(https://www.youtube.com/watch?v=OFByDMRbucs)

Vertical Farming in Cincinnati

Offshore Wind Power

Wind Turbine Engineer

Course Summary Solar Power for Africa

Hopefully, you learned something about the situation faced by most people on earth, more than half live on less than $10 per day, 1 billion live on less than $1/day about 10%. Africa has the poorest countries so it could be a place to start.

We are technologists. Our skill set is technological solutions to economic development and improvement of quality of life. Hopefully you got some ideas on how this could be reasonably implemented.

China thinks that the future is in Africa as evidenced by their investment $110 billion in 2019 or 20% of Africa's economic growth. We should consider the business opportunities especially those that could benefit both parties in a partnership.