Off Grid Energy for a Brightest Africa

Andy Brauer
Chief Technology Officer
Business Connexion

MY WORLD OF TOMORROW

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Time to Light up Africa

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The Journey Begins

Understanding the Dynamics

Overcoming the Constraints

Getting the ROI right

Getting the timing right

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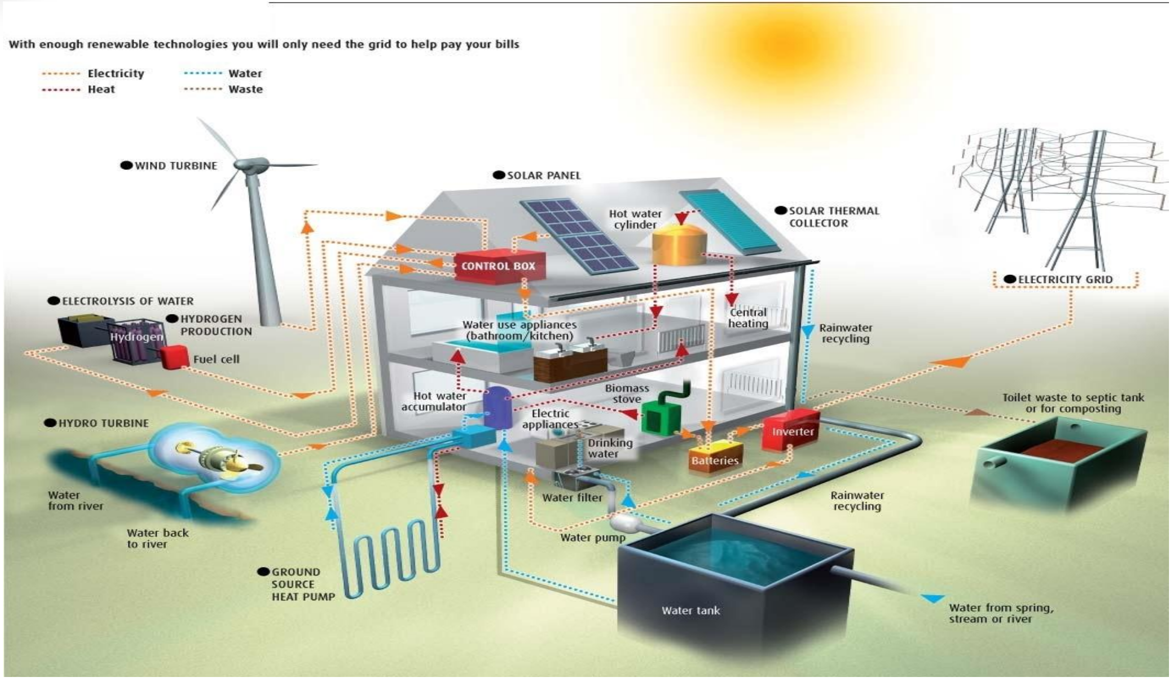
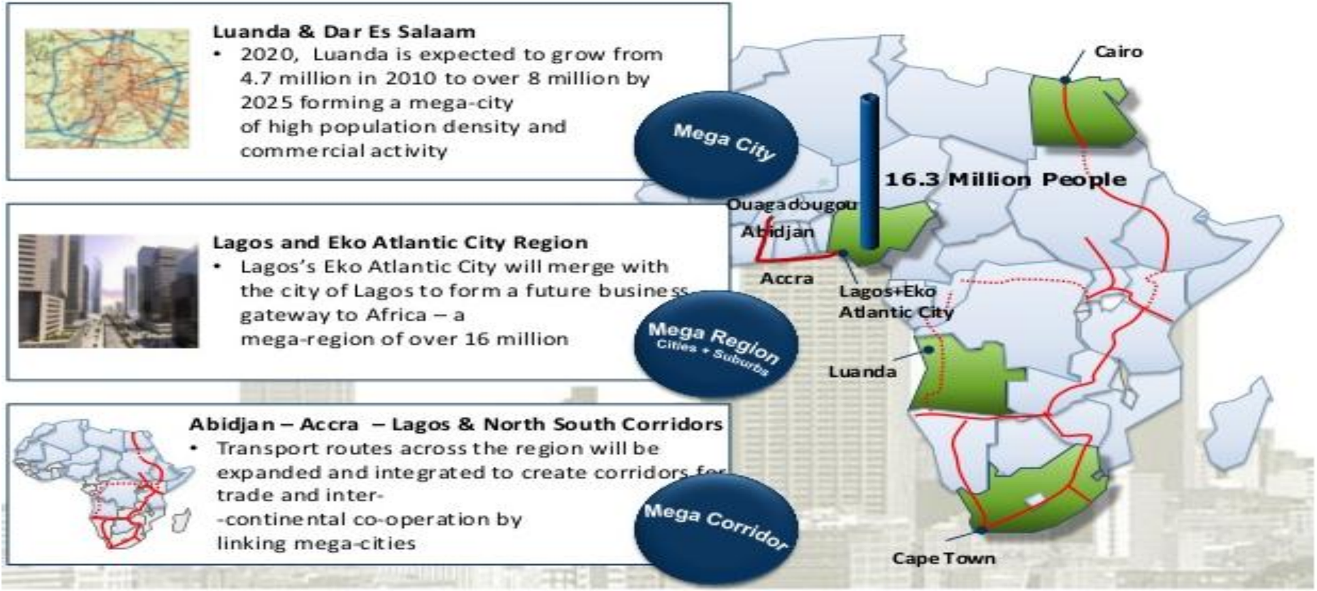
What is Off Grid Energy



The Problem

More than 70% of people in sub-Saharan Africa, do not have access to electricity. Moreover, the majority of this population that lacks access to electricity service lives in rural areas. Renewable energy-based off grid and mini-grids (RE mini-grids) solutions offer a significant opportunity to increase access to reliable electricity services.

Emerging Mega Cities



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Impact of Urbanisation

- Energy demand
- Traffic congestion
- Sanitation and health
- Security
- Slums develop

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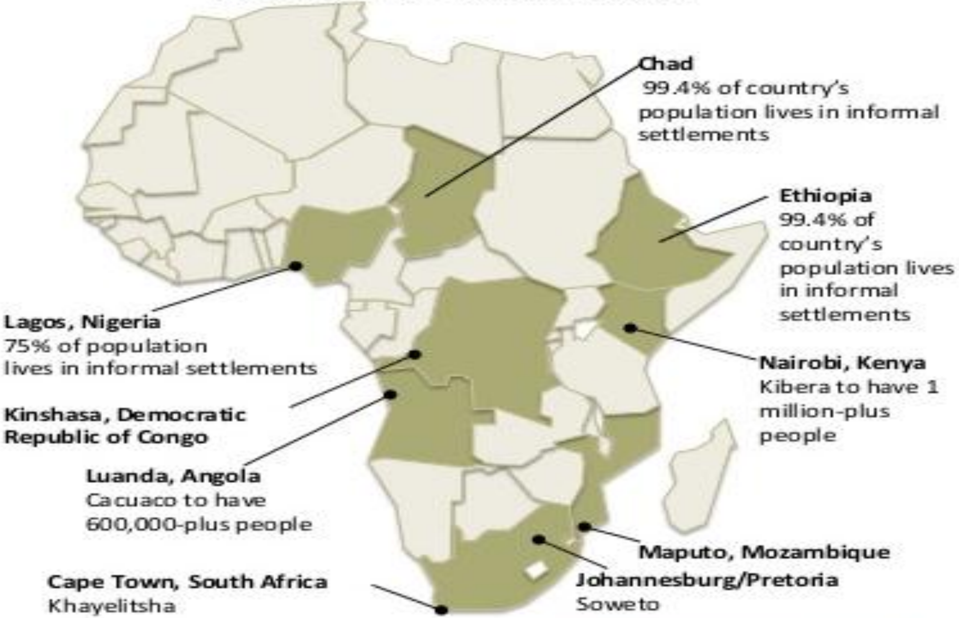
Forecast of Major Slums in Africa

Splintered Urbanization
African urban communities will be comprised of 70% informal settlement dwellers living alongside an emerging middle class, similar to condition in India.

Percent of Urban Residents by Type of Settlement, Africa, 2020

Forecast of Major Slums, Africa, 2050



Source: UN-Habitat and Frost & Sullivan analysis.

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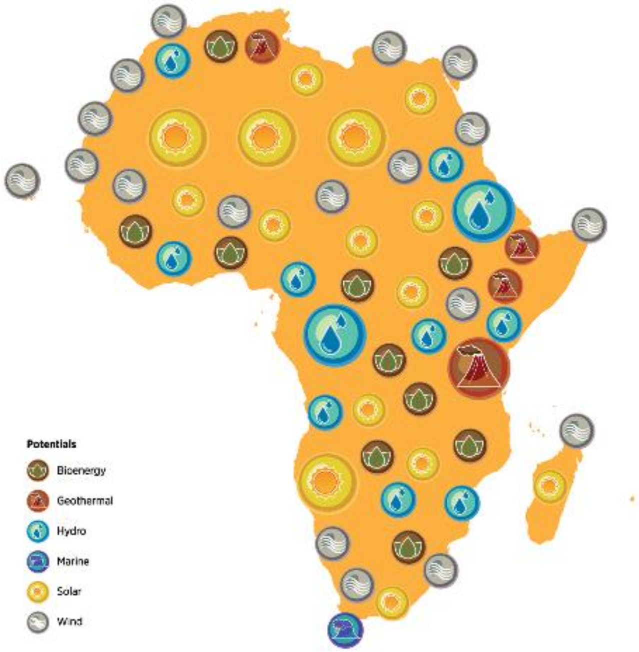
Diverse Energy Projects in Africa



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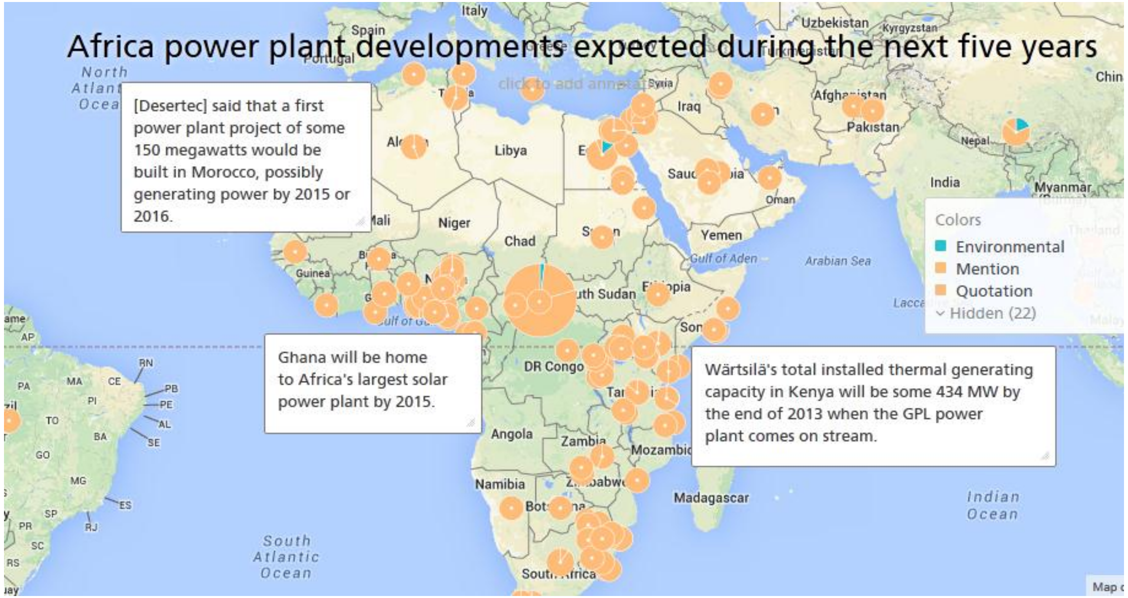
Many Power Projects for Africa



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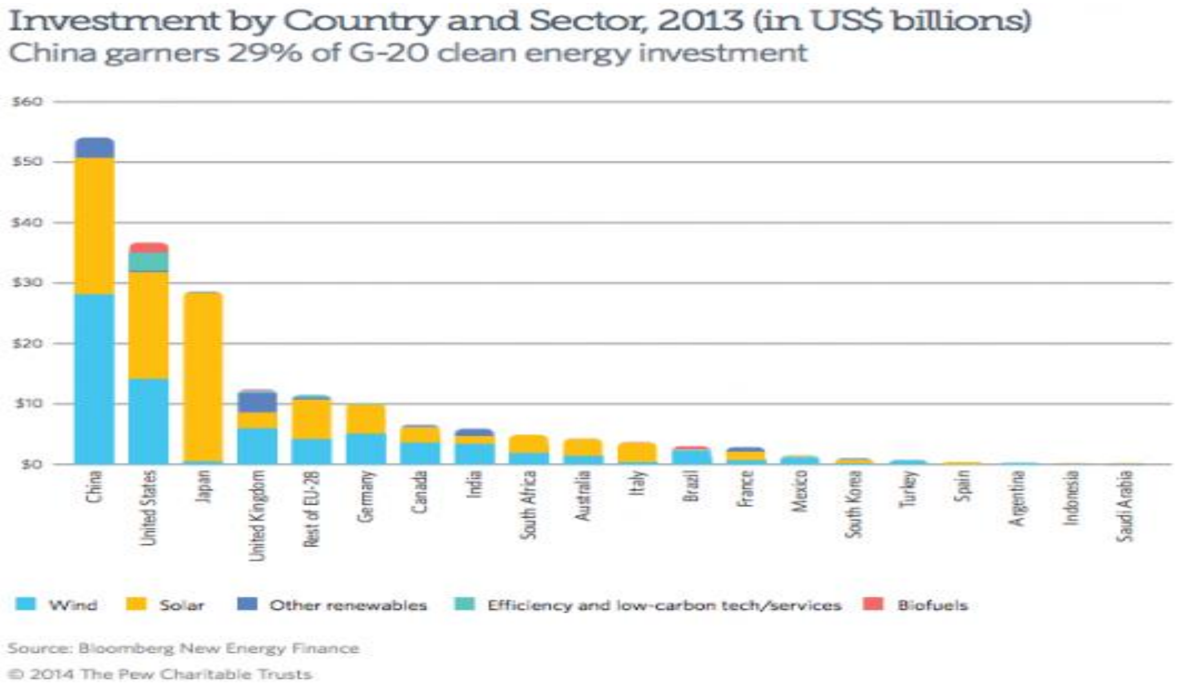
South Africa Wind and Solar



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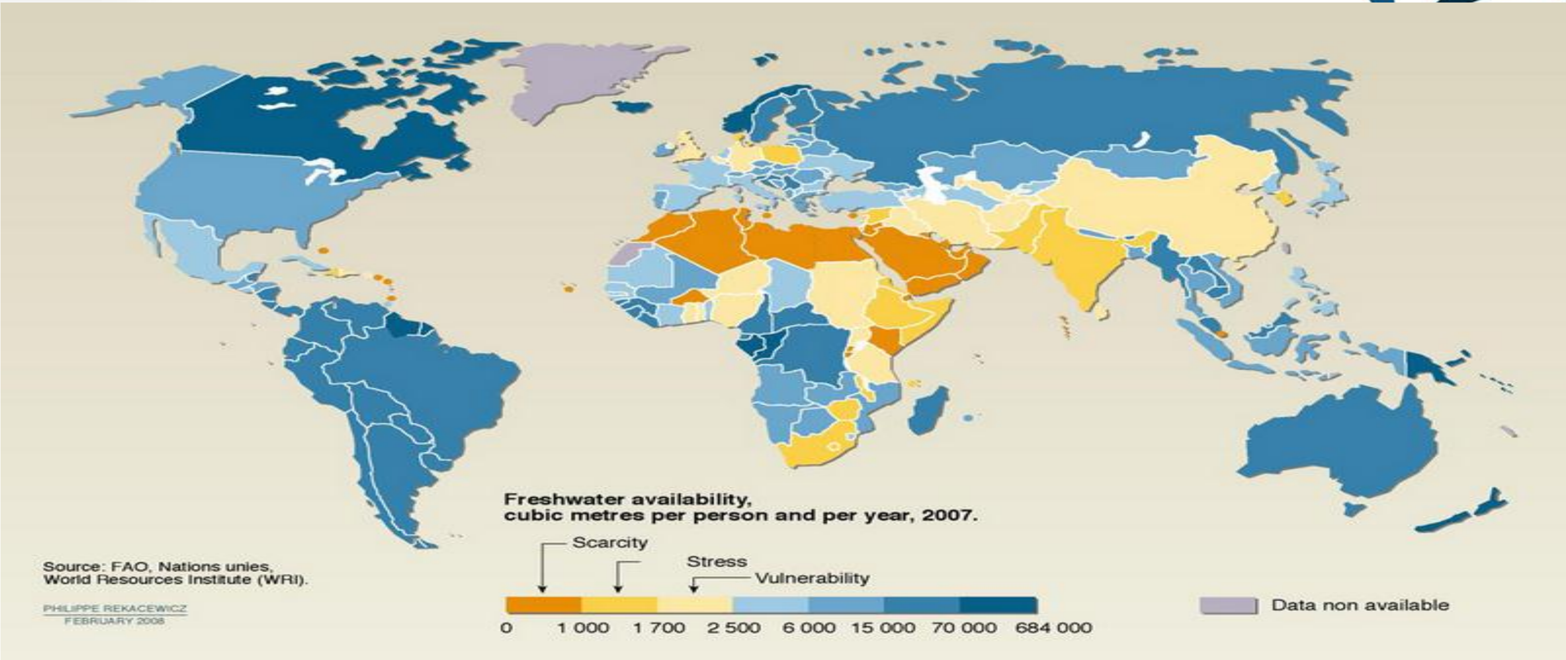
Water Resource



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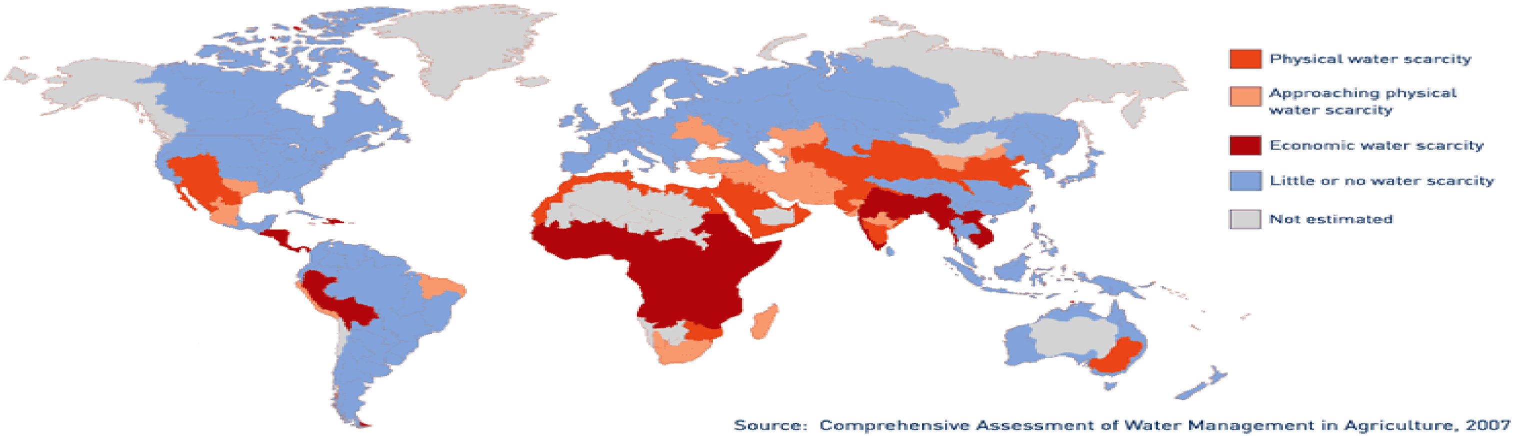
Economic Water Scarcity

Physical water scarcity water resources development is approaching or has exceeded sustainable limits]. More than 75% of the river flows are withdrawn for agriculture, industry, and domestic purposes [accounting for recycling of return flows]. This definition—relating water availability to water demand—implies that dry areas are not necessarily water scarce.

Approaching physical water scarcity. More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.

Economic water scarcity [human, institutional, and financial capital limit access to water even though water in nature is available locally to meet human demands]. Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Little or no water scarcity. Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.



Source: Comprehensive Assessment of Water Management in Agriculture, 2007

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Wind & Solar and Desalination

Big wind power

Energy storage

Renewable Desalination

2013 2014 2015 2016 2017 2018 2019 2020

Innovating to Zero

- Production of water using renewable wind power
- Use of energy storage to stabilize the consumption of energy

Future Infrastructure Development

- Big wind will address desalination's need for high energy consumption
- Contributes towards water security

Industry Initiatives

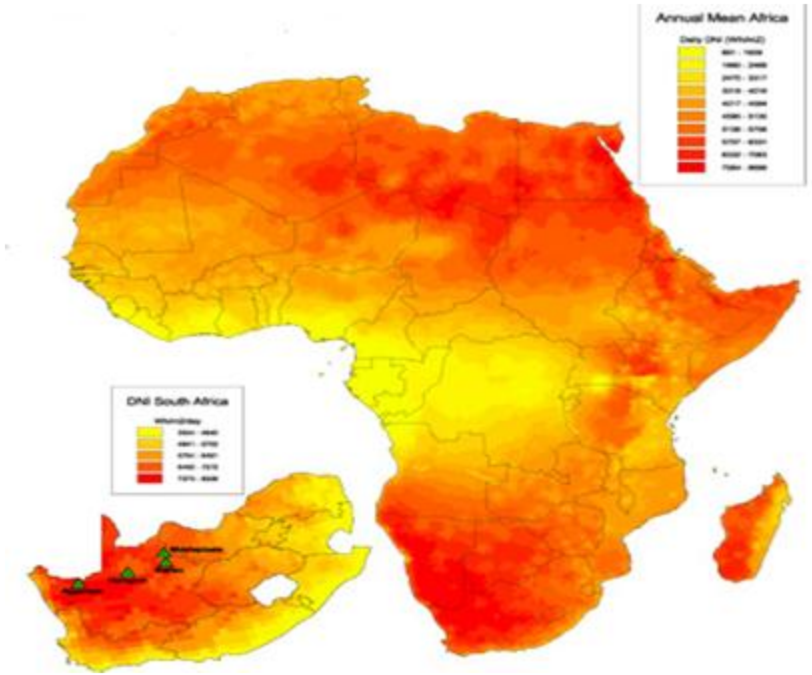
- Multiple studies on renewable desalination have been commissioned by the World Bank, resulting in the publication of 'Renewable Energy Desalination: An Emerging Solution to Close MENA's Water Gap". (MENA = Middle East, North Africa)
- GE and Saudi Aramco has launched a global innovation challenge to improve the energy efficiency of seawater desalination, including the use of renewable energy resources

Year of Impact - 2018-2020

- Feasibility studies have just begun on combining renewable energy and desalination. Thus, YOI will only be after 2018.

FROST & SULLIVAN

Sunshine in Africa



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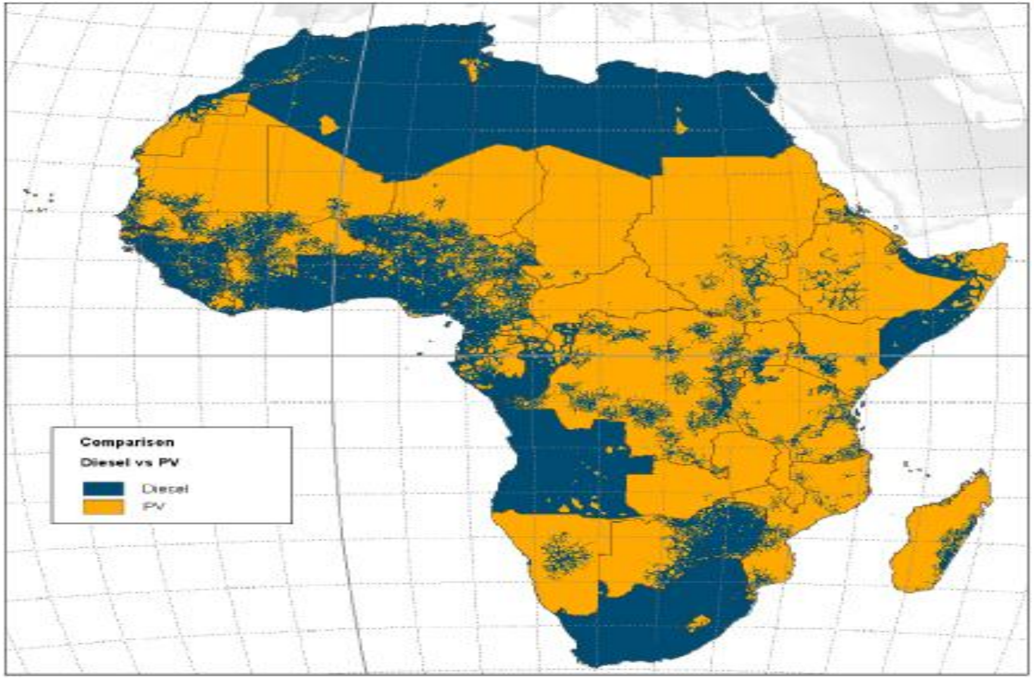
Diesel & Coal vs Solar for now



Yellow is where Solar wins Blue is where Diesel/Coal win at moment

Diesel figures

Approximate Fuel Consumption Chart

This chart approximates the fuel consumption of a diesel generator based on the size of the generator and the load at which the generator is operating at. Please note that this table is intended to be used as an estimate of how much fuel a generator uses during operation and is not an exact representation due to various factors that can increase or decrease the amount of fuel consumed.

Generator Size (kW)	1/4 Load (gal/hr)	1/2 Load (gal/hr)	3/4 Load (gal/hr)	Full Load (gal/hr)
20	0.6	0.9	1.3	1.6
30	1.3	1.8	2.4	2.9
40	1.6	2.3	3.2	4.0
60	1.8	2.9	3.8	4.8
75	2.4	3.4	4.6	6.1
100	2.6	4.1	5.8	7.4
125	3.1	5.0	7.1	9.1
135	3.3	5.4	7.6	9.8
150	3.6	5.9	8.4	10.9
175	4.1	6.8	9.7	12.7
200	4.7	7.7	11.0	14.4
230	5.3	8.8	12.5	16.6
250	5.7	9.5	13.6	18.0
300	6.8	11.3	16.1	21.5
350	7.9	13.1	18.7	25.1
400	8.9	14.9	21.3	28.6
500	11.0	18.5	26.4	35.7
600	13.2	22.0	31.5	42.8
750	16.3	27.4	39.3	53.4

.6 Gal = 2.27125 Litres per Hour for
5KVA Diesel price 1 Oct ZAR 12.13
Electricity 115.32 c/kWh

Real Africa

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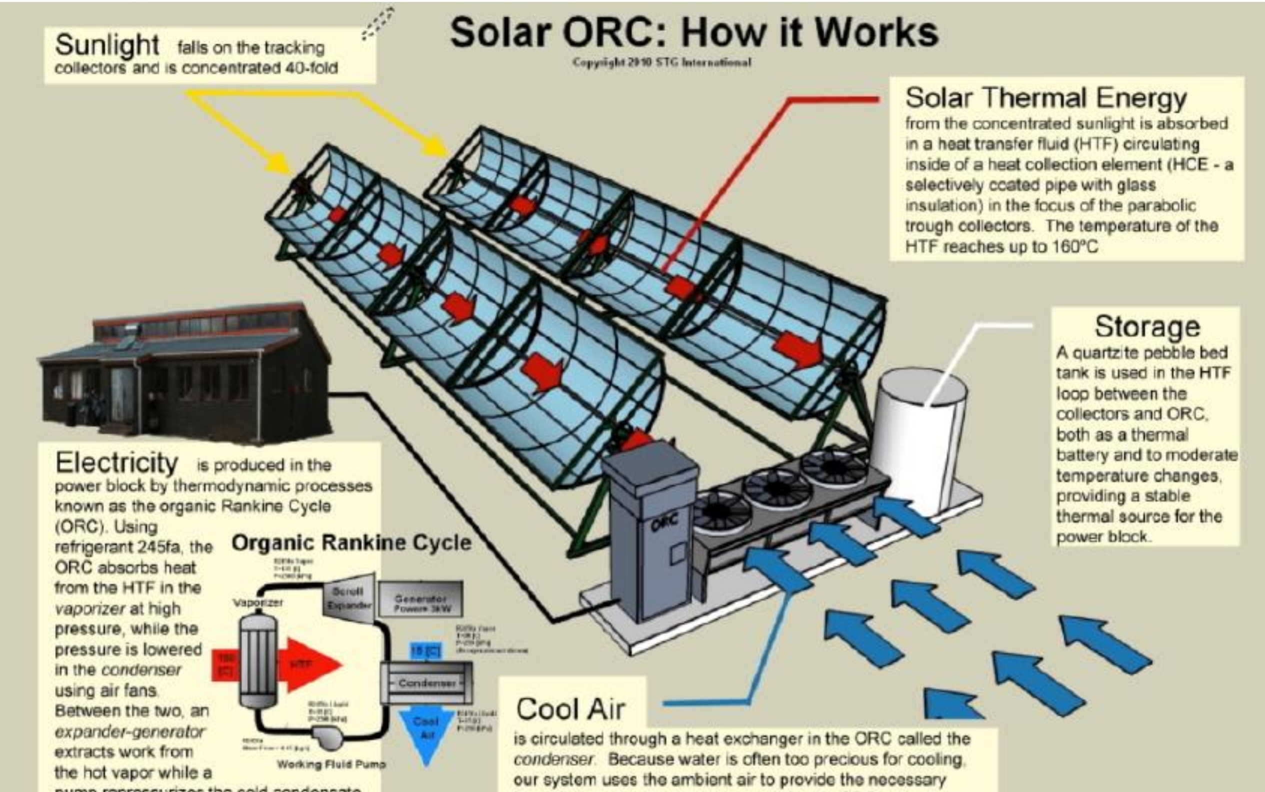
MIT's All-in-One Solar ORC

Provide Heat, Electricity, and Hot Water For African Communities



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CSP Concentrated Solar Power

Khi Solar One, a 50MW power tower plant on the outskirts of Upington

KaXu Solar One, a 100MW parabolic trough plant near Pofadder

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Quick Facts

- Two-thirds of the continent's population are not grid-connected
- Africa has one of the highest solar irradiation levels in the world, up to 200kW m²/year (Source: NASA)
- Kenya has set a target of 16.9GW of solar power by 2030

  Wind plans have changed this
- Uganda targets 61% of energy consumption from renewables by 2017, up from 4% today
- PV sales in Tanzania have been growing at 15% per year from the last 5 years
- The Nigerian government is looking to establish a 'silicon valley' style science park to develop a domestic PV manufacturing industry
- In Ghana, the 155MW Nzema Solar Project, Africa's largest, is in the final stages of financing
- Senegal has allocated 120MW of independent power producer PV capacity to be commissioned before 2017

Hang on a second

- Around 77% of South Africa's energy needs are directly derived from coal and 92% of coal consumed on the African continent is produced in South Africa

- Coal is South Africa's third largest source of foreign exchange; Platinum being the largest and gold second.

- The largest contributor to coal-derived air pollution is household coal usage (65%), followed by industry (30%) and electricity generation (5%).

- Usage of coal and liquid fuel derived from coal accounts for around 86% of the 113 million tons of CO_2 South Africa produces annually and represents around 40% of Africa's total coal derived CO_2 emissions.

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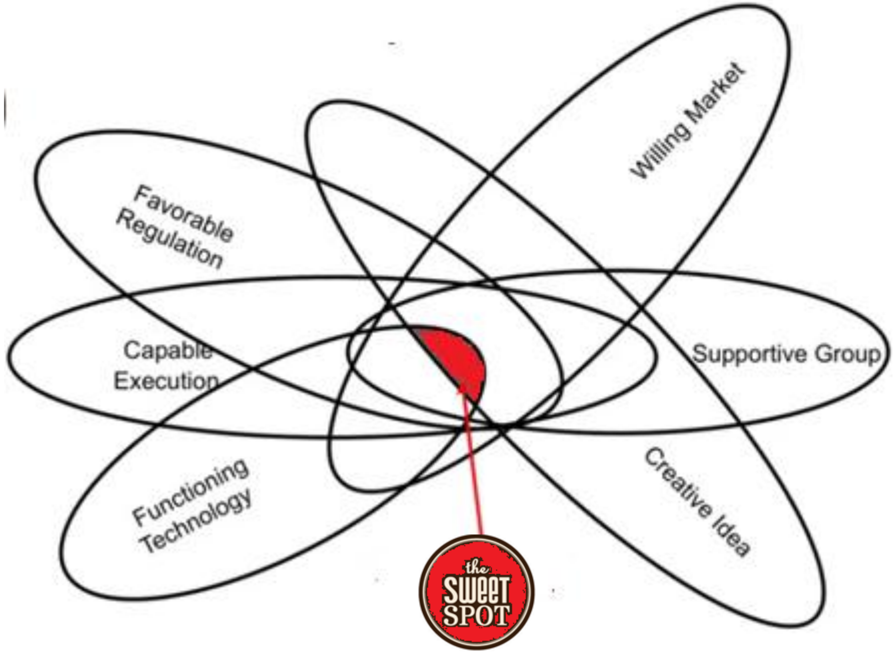
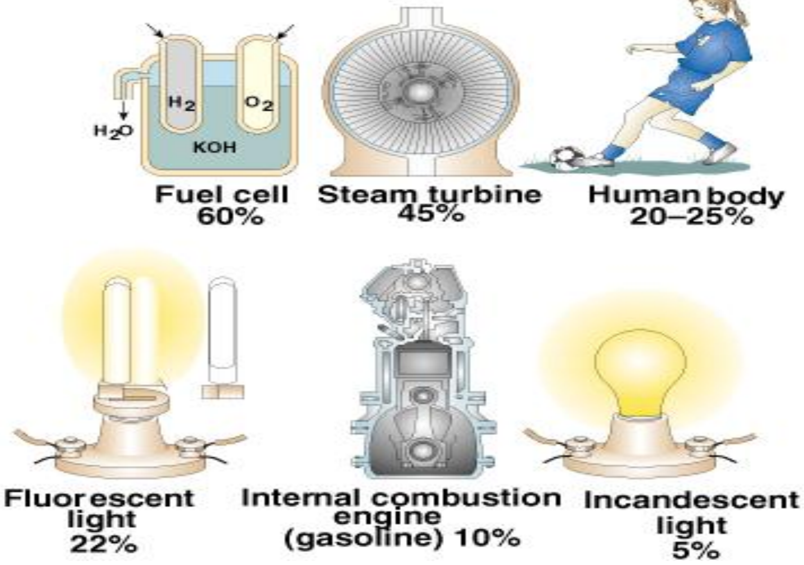
Many factors to consider



Energy Efficiency

Percentage of energy input that does **useful work** in an energy conversion system



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Currently America's large commercial fuel cell producers are:

Plug Power Inc. (PLUG) (market cap: $780M USD)

FuelCell Energy Inc. (FCEL) (market cap: $611M USD)

Ballard Power Systems Inc (BLDP) (market cap: $540M USD)

Hydrogenics Corp. (HYGS) (market cap: $173M USD)

Bloom Energy

All of those fuel cell startups -- targeting the backup power market -- lost money in 2013, despite generating substantial revenue.

Halfway on our Journey

Basis for moving forward.

Solar Bio Wind and Coal have a place

in Hydrogen Generation.

Current Economics has a big influence.

25 Year ROI will not work.

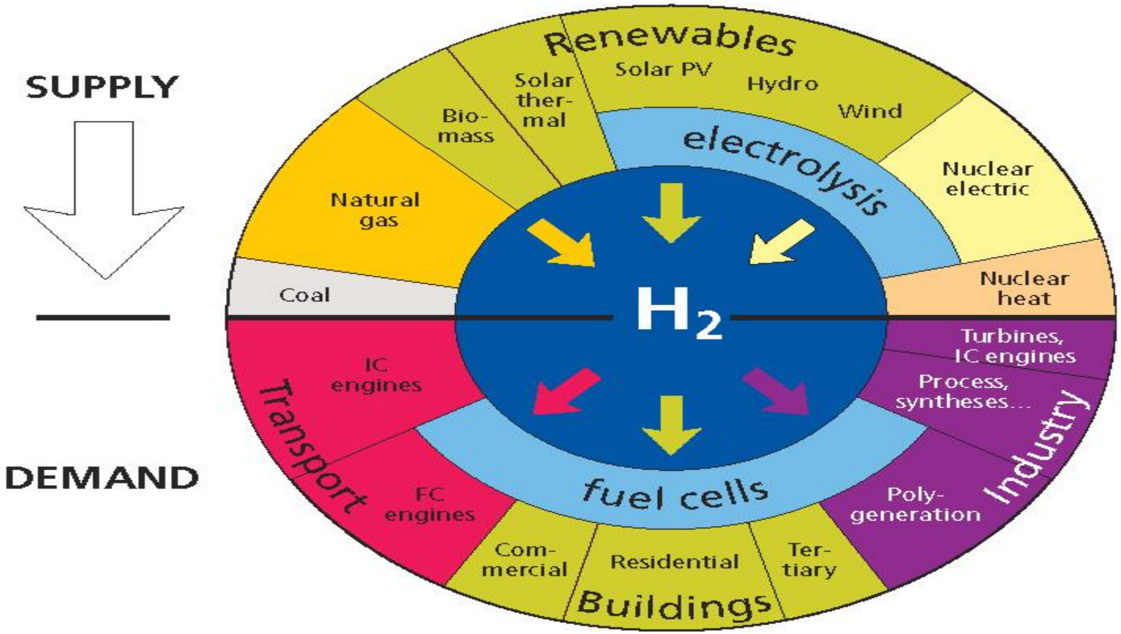
Has to be less expensive than current models.

Fuel Cells seem to be the long term answer.

How is hydrogen produced?

- Hydrogen is not a source of energy; it is an energy carrier.
- Before it can be used, it must be separated from the molecules containing it.
- Hydrogen can be produced from water, from hydrocarbons such as coal, crude oil and natural gas, and from biomass.

Supply Side Demand Side



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Solar Wind Hydrogen Energy Cycle

Source H-TEC

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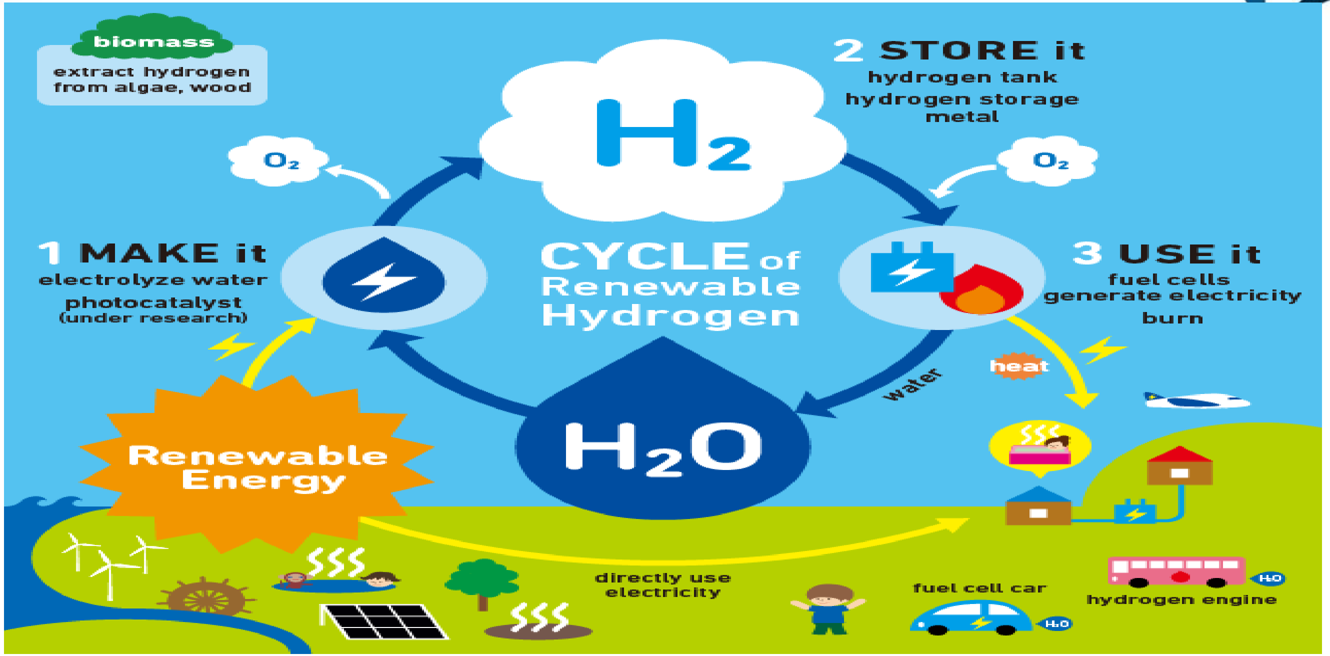
Renewable Energy



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Indicative Costs of Hydrogen Production

Biomass conversion	4.5
CO_2-free from natural gas	4.6 - 6
Surplus nuclear electricity	5 - 7
Wind farms	7.5 - 15
Solar parabolic trough plants	15 - 20

Source: www.hydrogen.org

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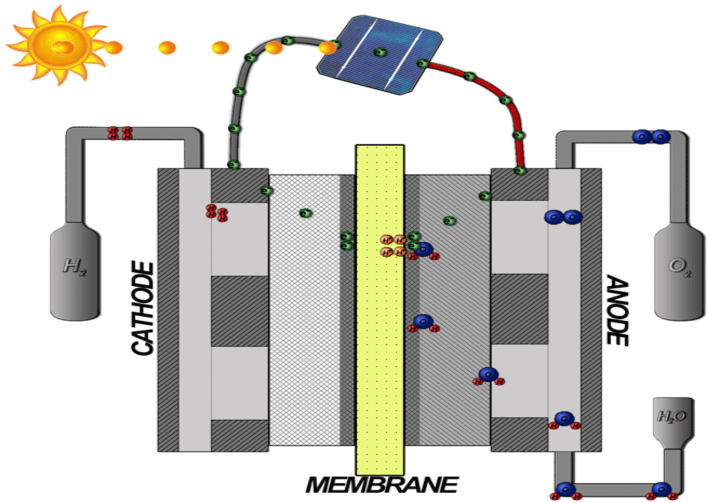
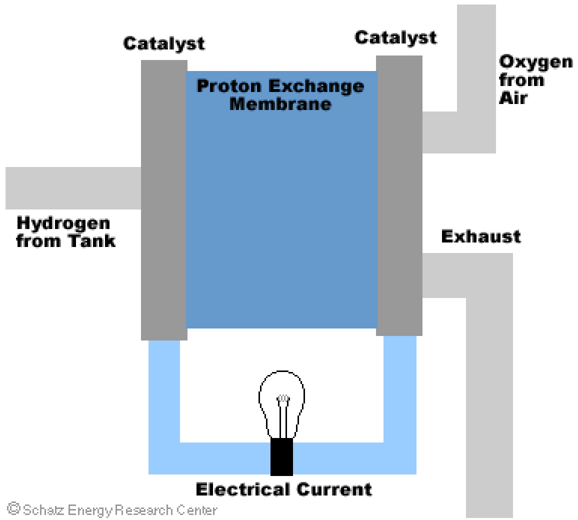
But Wait there is more to consider

Batteries normal have a lifespan of 3 years
The Sun does not shine all the time
Hail damages certain Solar Panels
The Wind does not always blow.
Hydrogen causes embrittlement in many metals

The two Cycles



Creating Hydrogen (Electrolyser)



Generating Electricity (Fuel Cell)

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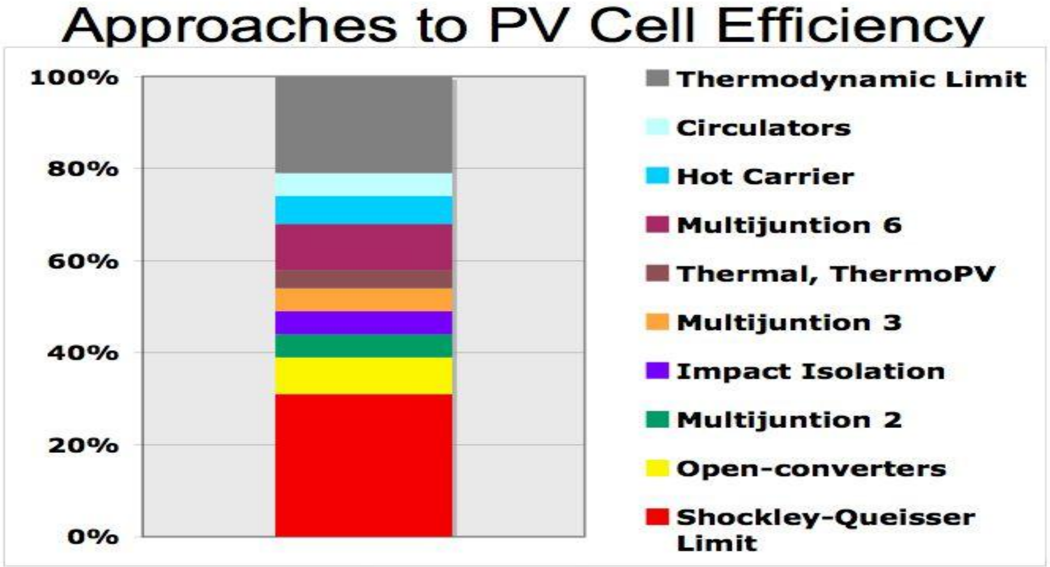
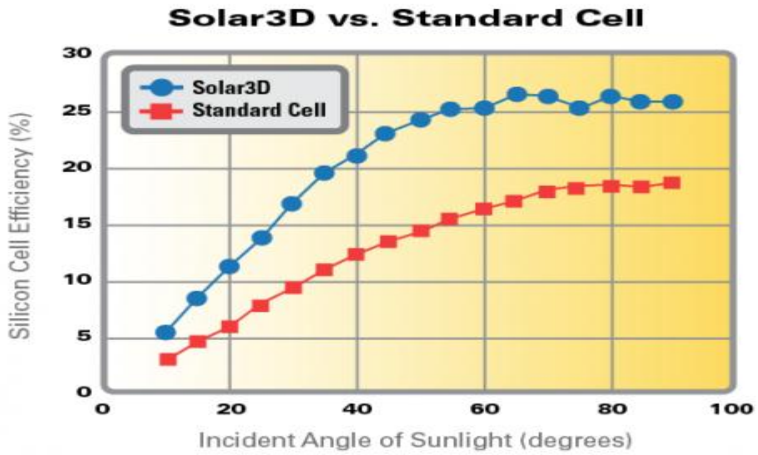
Solar PV Efficiency

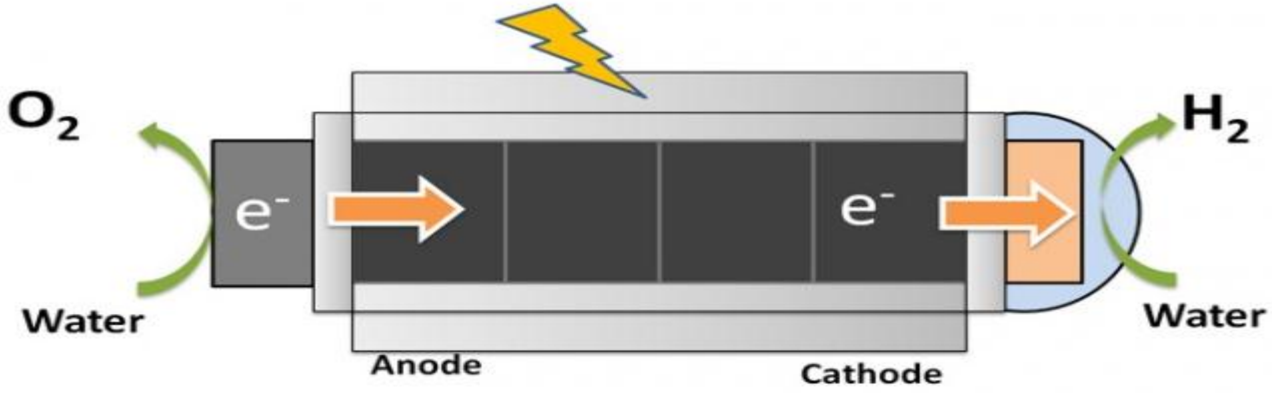


Source: Martin Green, University New South Whales



H2Generator
Eliminates the Need for an Electrolyzer!

Artificial photosynthesis hits milestone in producing cheap, clean hydrogen from water



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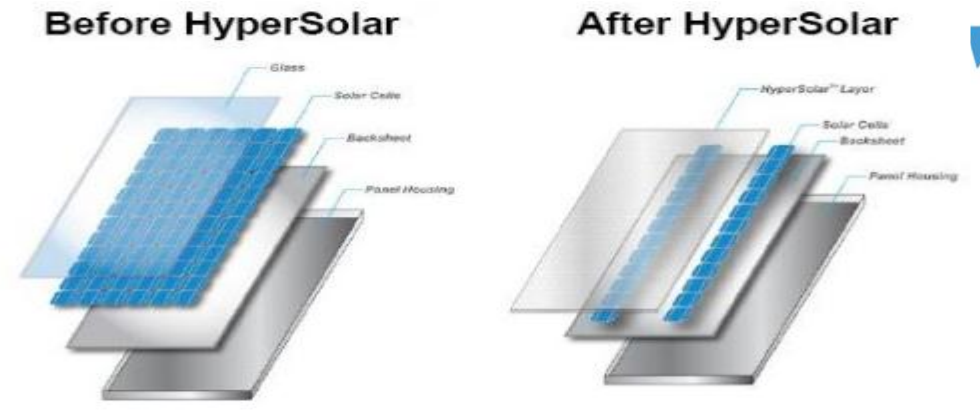
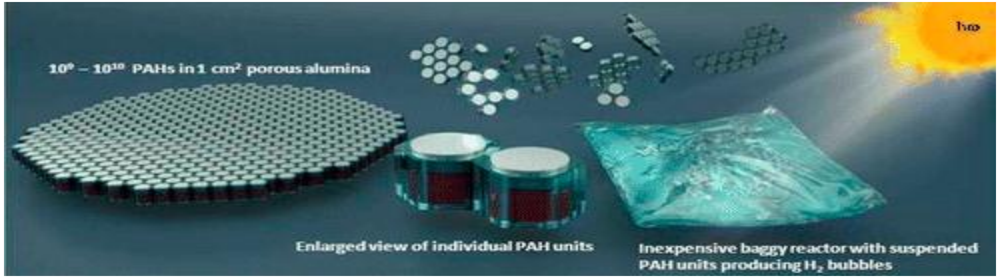
Less Solar Cells



- Lots of solar cells
- High cost

- Fewer solar cells
- Low cost



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Metal-free catalyst outperforms platinum in fuel cell

Source:
Case Western Reserve University

Researchers from South Korea, Case Western Reserve University and University of North Texas have discovered an inexpensive and easily produced catalyst that performs better than platinum in oxygen-reduction reactions.

The finding, detailed in Nature's *Scientific Reports* online today, is a step toward eliminating what industry regards as the largest obstacle to large-scale commercialization of fuel cell technology.

The catalysts are more stable than platinum catalysts and tolerate carbon monoxide poisoning and methanol crossover."

And, in their initial tests, a cathode coated with one form of catalyst -- graphene nanoparticles edged with iodine -- proved more efficient in the oxygen reduction reaction, generating 33 percent more current than a commercial cathode coated with platinum generated.

The research was led by Jong-Beom Baek

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Diesel-like hydrogen breakthrough rekindles platinum fuel-cell excitement

The technology is focused on the safe storage of hydrogen, a frequent energy storage medium.
While existing technologies store hydrogen either under extremely high pressures of up to 700 bar, or in liquid form at –253 °C, this technology binds the hydrogen molecules to LOHCs, which facilitate safe, easy-to-handle, high-density energy storage at ambient conditions, addressing the existing challenges associated with storing gaseous hydrogen.
HydroStore, which stores energy generated from renewables in a power-to-power storage regime, offers flexibility to decouple input and output power from the storage capacity, making it a widely applicable energy storage system, which contributes to electricity grid stabilisation and grid independence.
The breakthrough technology has been developed and optimised by Teichmann and the university's professors **Peter Wasserscheid**, **Wolfgang Arlt** and **Eberhard Schlücker**, together with their research teams at the University of Erlangen–Nuremberg.

A new building at the top of the University of Cape Town's (UCT's) upper campus forms the backdrop to one of the components of Hydrogen South Africa (HySA) Catalysis Centre of Competence, part of the South African government's programme in hydrogen and fuel cells.
UCT Faculty of Engineering and the Built Environment and Mintek, the national research and development organisation for mineral processing, are among the co-hosts of HySA, which hopes to capture 25% of the global fuel-cell and hydrogen catalyst market by 2020.
When the fuel-cell technology industry takes off, it is expected to be a multibillion-dollar market

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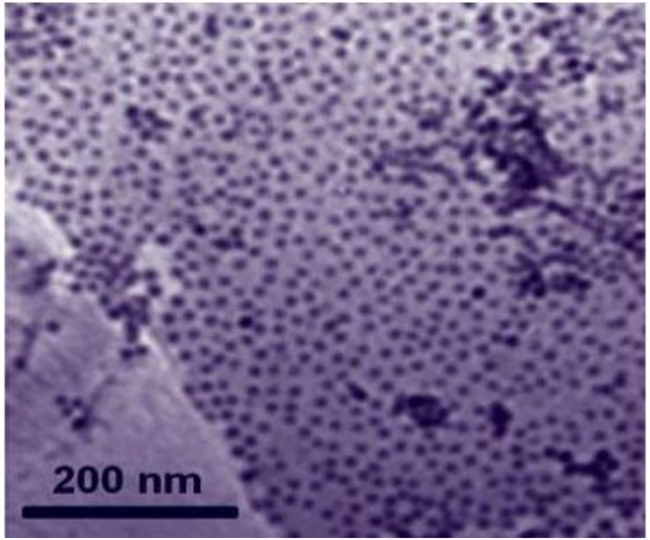
CoBalt-Graphene vs Platinum



A cheaper catalyst alternative

Can cobalt–graphene catalyst beat platinum?

October 16, 2012 Contact: Kevin Stacey 401-863-3766

Platinum works well as a catalyst in hydrogen fuel cells, but it has at least two drawbacks: It is expensive, and it degrades over time. Brown chemists have engineered a cheaper and more durable catalyst using graphene, cobalt, and cobalt-oxide — the best nonplatinum catalyst yet. Their report appears in the journal *Angewandte Chemie International Edition*.

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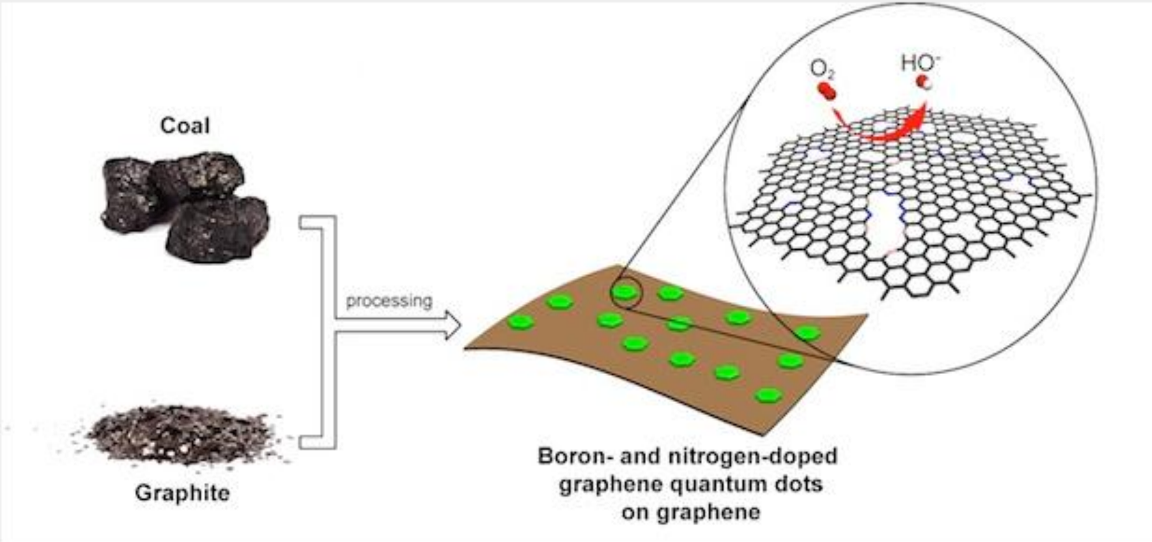
Cheap hybrid outperforms rare metal as fuel-cell catalyst



Rice University scientists combined graphene quantum dots, graphene oxide, nitrogen and boron into a catalyst capable of replacing platinum in fuel cells at a fraction of the cost. Illustration courtesy of the Tour Group

Types of Fuel Cells

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FUEL CELL TECHNOLOGIES PROGRAM

Comparison of Fuel Cell Technologies

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Efficiency	Applications	Advantages	Disadvantages
Polymer Electrolyte Membrane (PEM)	Perfluoro sulfonic acid	50-100°C 122-212° typically 80°C	< 1kW–100kW	60% transportation 35% stationary	• Backup power • Portable power • Distributed generation • Transporation • Specialty vehicles	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up	• Expensive catalysts • Sensitive to fuel impurities • Low temperature waste heat
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90-100°C 194-212°F	10–100 kW	60%	• Military • Space	• Cathode reaction faster in alkaline electrolyte, leads to high performance • Low cost components	• Sensitive to CO_2 in fuel and air • Electrolyte management
Phosphoric Acid (PAFC)	Phosphoric acid soaked in a matrix	150-200°C 302-392°F	400 kW 100 kW module	40%	• Distributed generation	• Higher temperature enables CHP • Increased tolerance to fuel impurities	• Pt catalyst • Long start up time • Low current and power
Molten Carbonate (MCFC)	Solution of lithium, sodium, and/ or potassium carbonates, soaked in a matrix	600-700°C 1112-1292°F	300 kW-3 MW 300 kW module	45-50%	• Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Suitable for CHP	• High temperature corrosion and breakdown of cell components • Long start up time • Low power density
Solid Oxide (SOFC)	Yttria stabilized zirconia	700-1000°C 1202-1832°F	1 kW–2 MW	60%	• Auxiliary power • Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Solid electrolyte • Suitable for CHP & CHHP • Hybrid/GT cycle	• High temperature corrosion and breakdown of cell components • High temperature operation requires long start up time and limits

For More Information

More information on the Fuel Cell Technologies Program is available at *http://www.hydrogenandfuelcells.energy.gov*.

2 to 80 Kw Fuel Cell

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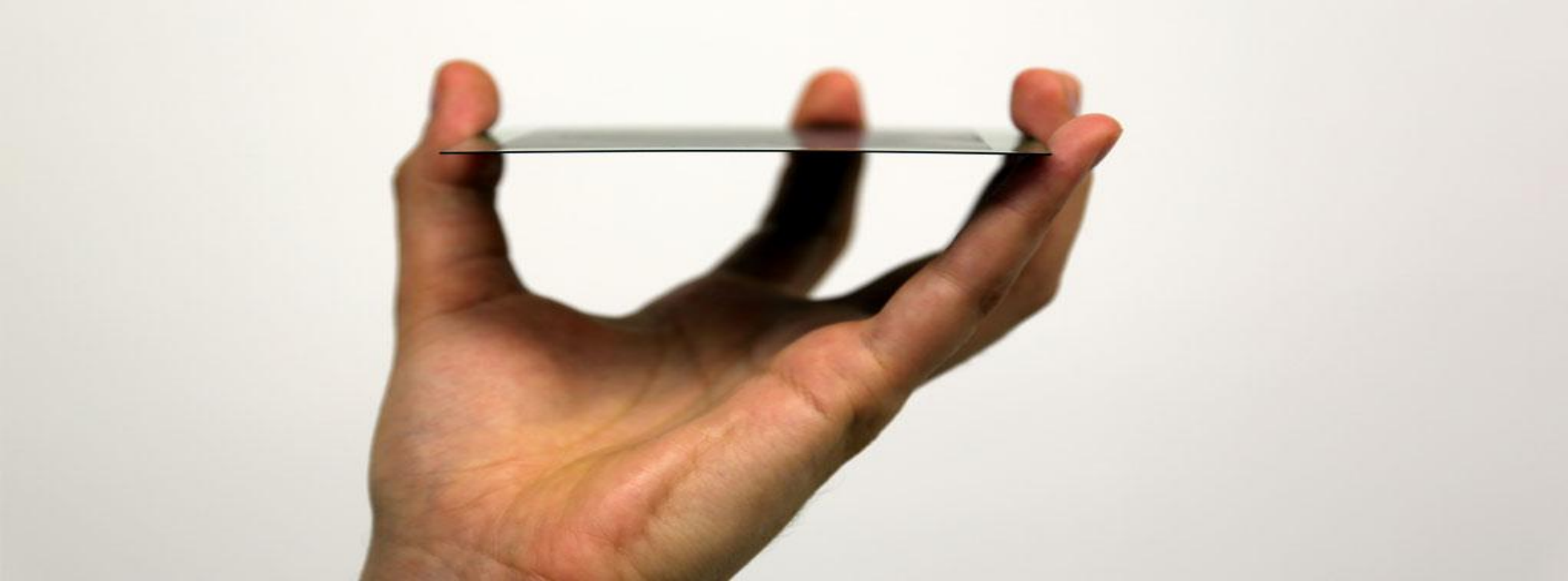
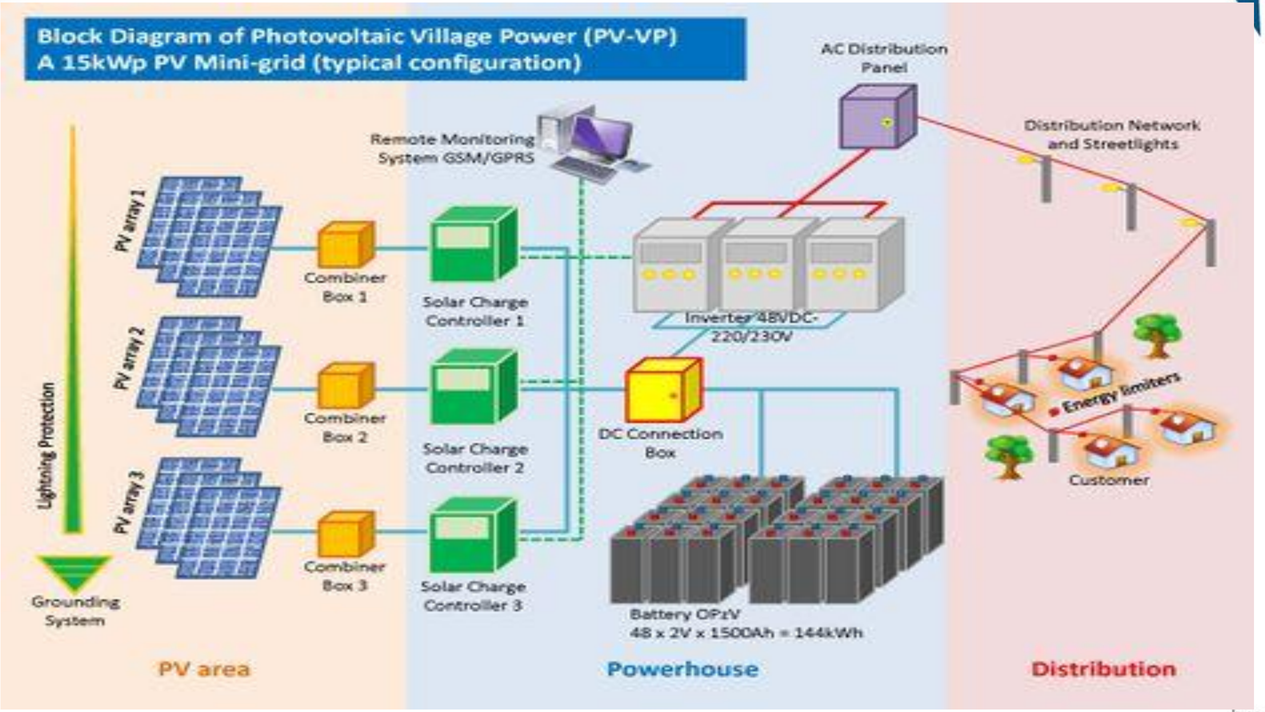
The Catalyst



DC Grid current legislation is for AC



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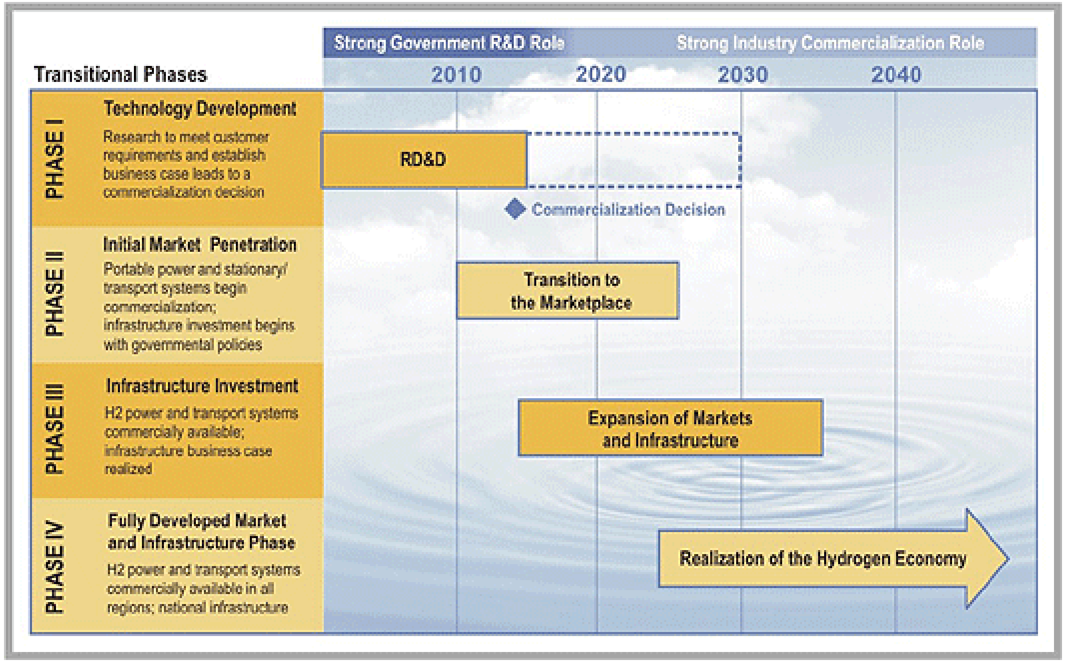
High purity Hydrogen generator

Main Technical Specification:

Price ZAR 23,930.32

(1) The purity of produced hydrogen: 99.999%
(2) The output flow: 0-1000ml/min
(3) The output pressure:0~0.5MPa
(4) The power required: The routine alternating current of 220V/50Hz
(5) The peak power consumed:210w
(6) The size of appearance:520×240×450 mm(L×W×H)
(7) Weight:29kg

Hydrogen Commercialisation



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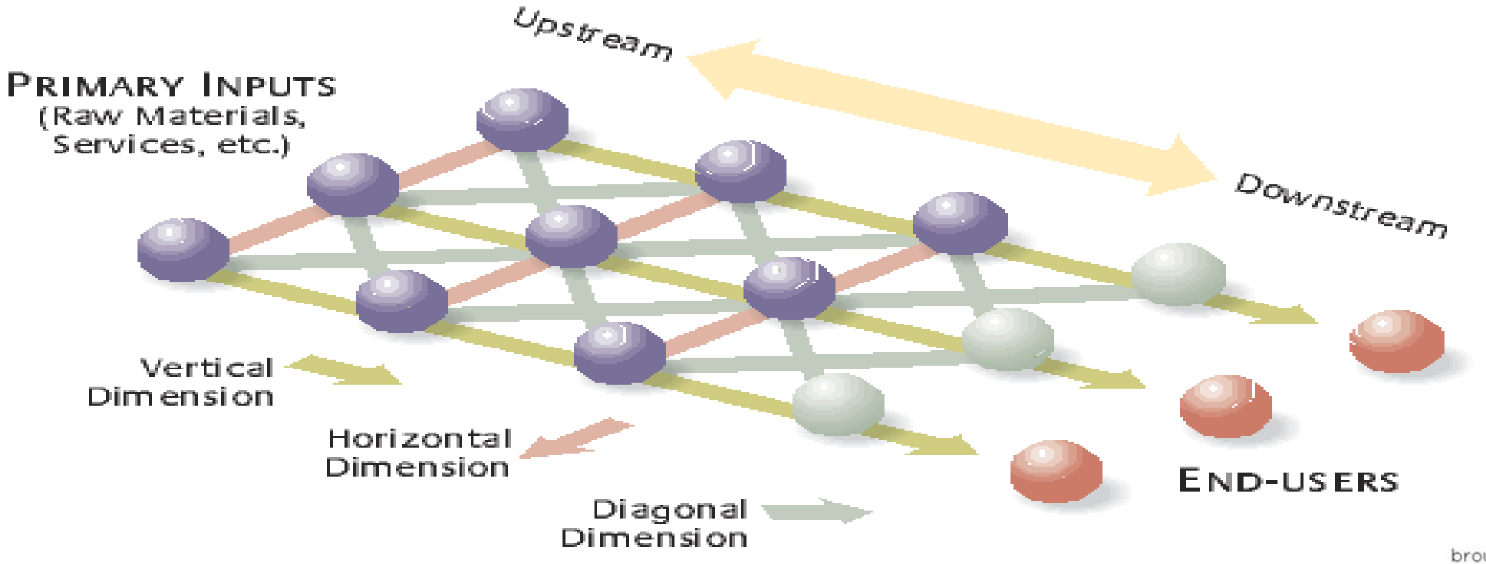
Network Chain - Value Chain

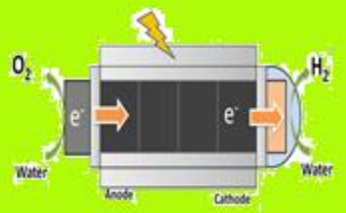
Operating Model



The Green and Red Model

Source

Storage



Fuel Cell

Source

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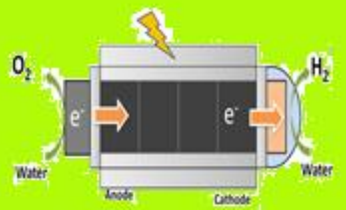
The Green Model over time

Source

Storage



Fuel Cell

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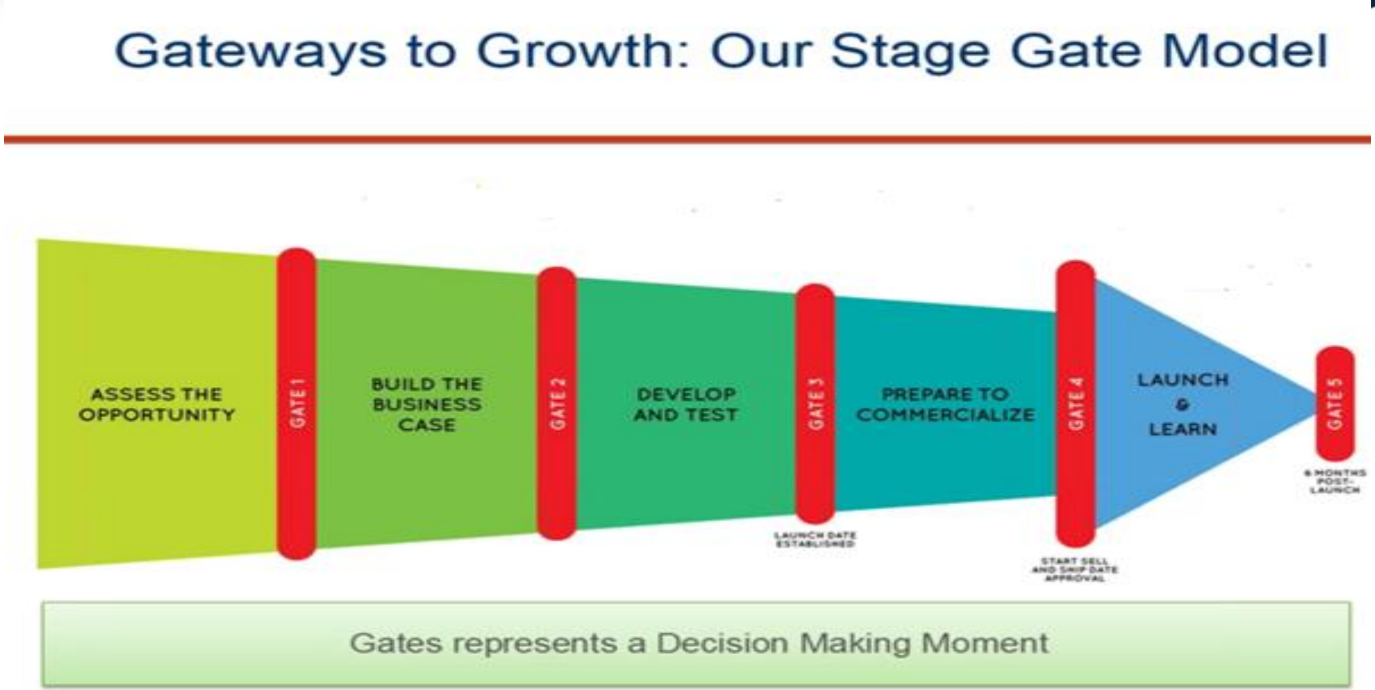
Our Journey to be Continued…..



Thank you

Our Mission

"To enrich communities by making the impossible possible, through technology"

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Current Methods

Steam reforming of natural gas: Natural gas is reacted with steam to initially form hydrogen and carbon monoxide. Further reaction forms more hydrogen and carbon dioxide. Currently, steam reforming of natural gas is the most common method of producing hydrogen; however, it does result in greenhouse gas (GHG) emissions.

Electrolysis of water: An electric current is passed between two electrodes submerged in water. Hydrogen accumulates at the cathode and oxygen at the anode. This method of producing hydrogen results in no GHG emissions. However, if the electricity used was generated by coal-, oil-, or gas-fired thermal processes, some GHG emissions are associated with the hydrogen production life cycle. If the electricity used was generated by hydro, nuclear, solar or wind power, no GHGs are produced or emitted.

Waste stream hydrogen: Hydrogen is a byproduct of some industrial processes such as the manufacture of sodium chlorate via electrolysis of sodium chloride brine.

Hydrogen Methods under development

Hydrogen from coal: Coal is first gasified by exposure to oxygen under high pressure. The resulting synthesis gas is then steam reformed in a process similar to steam reforming of natural gas.

Hydrogen from biomass: Hydrogen is produced from biomass in a process similar to that used for coal. Biomass is both renewable and carbon neutral.

Biological water splitting: Photosynthetic microbes create hydrogen from water as part of their normal metabolic processes.

Photoeletrochemical water splitting: Specialized photovoltaic cells convert sunlight to electricity in sufficient amounts to electrolyse water into hydrogen and oxygen.

Solar thermal splitting: Concentrated sunlight is used to generate temperatures high enough to split methane into hydrogen and carbon.

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Hydrogen Production

Hydrogen can be produced locally, at large central plants or in small distributed units located at or near the point of use.

This means that every community, even remote areas, can become an energy producer.

When produced using renewable energy sources and powering highly efficient fuel cells, the environmental benefits of hydrogen are even greater.

Plus, hydrogen can be produced and stored using off-peak energy produced by renewable energy technologies such as solar, wind and tidal generation.

When used with energy efficient fuel cells, hydrogen will play an important role in extending our current energy supplies as we move forward to a clean energy future

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