Decentralised Hydrogen/Battery/Solar Hybrid Energy production & storage system

Report on Provision of clean, sustainable energy solutions for the rural Sub-Saharan region

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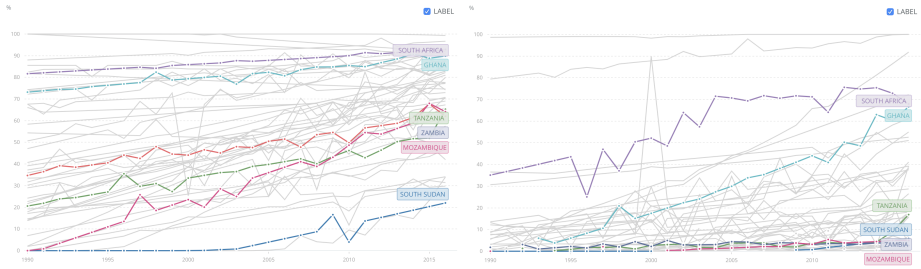
Problems and Pain

The Problem causing most of the pain identified is the lack of electricity in rural areas of the Sub-Saharan Region. To just grasp how much of a problem the lack of electricity is and how much pain it induces, one must consider those involved (quantity), which in this case are many, and the pain induced in qualitative terms. The two graphs below aim at visualising the severity of the problem in terms of lives impacted.



(a) urban (% of urban population) (b) rural (% of rural population)

Figure 1: Access to electricity

When looking at the percentage of the population from urban and rural communities and their access to electricity, incredibly low numbers are the result for rural South-Saharan regions compared to urban communities in the same region. The staggeringly low electricity access coverage becomes even clearer when comparing to rural areas of central Europe, in which the electricity access is so well established as a standard, that it isn't worth considering urban areas, which nearly everywhere reach 100% of the population.

The root cause of having no electricity or water in rural areas causes much pain in many stakeholders associated with the entity in question. Such stakeholders are companies missing out on massive commercial opportunities in the Sub-Saharan region due to the nonexistence of these utilities, those of the many rural community citizens, the governments struggling with changing the circumstances and so many more. For ease of understanding, it is better to view the pains in separate planes, so that there is the one of those living in said rural communities and the one of those wishing for those communities to develop.

Pains of rural communities and their members

There exist many pains on many different levels within Rural Communities. To effectively grasp the many different pains, it is advised to consider multi-perspective viewpoints, including the perceptions of different entities regarding

one or multiple aspects of a situation.

Characteristic pain which is experienced by a particular individual because of his/hers individuality in characteristics - such can be children or teachers who experience pain in a situation that is uncommon to any individual not having characteristics that lead them to be in said situation.

Communal Pain which is induced only when multi-characteristic individuals aggregate and arises because of individual pain not equaling communal pain. Individual pain can also be extrapolated by the existence of communal pain - such can be families or communities as a whole where a common pain point can experience the emergence of a new pain, additional to the aggregated common pain, due to the accumulation of said common pain.

The pains include:

Types of Pain	Pain Owner
So many pains cascading from the lack of electricity/water supply	Families, individuals, communities
Can't use productivity enhancing technology	Labour-force, families, students, communities
Don't have the privilege of electrical home appliances	families
Can't easily research	students, pupils, the curious
Can't communicate with my family members	Family members
Can't stay up-to-date with what's going on nearby or afar	Families, individuals
Can't call an ambulance/help/police if necessary (if even existing)	Families, individuals, communities
Can't simply buy fresh or non-local food	Families
Can't keep food fresh/edible for long in the heat	Families
Boredom Roams much of the day	Individuals
Can't research/learn	Children, teens, curious individuals
Can't buy many things I would like to	Families, individual members of rural communities
Can't expect things to become better without things changing	Communities
Can't *automate* recurring tasks	Families, Labour-force, communities
At day, there's no AC, at night, there's no alternative to fire	Families, communities
A lot of disease/hustle/pain due to *below-standards* sanitation	Communities

Types of Pain	Pain Owner
There's no option for engaging/receiving in politics	Communities, individuals
Safety drops and boredom peaks after sunset	Families, individuals
After sunset, there's so much that can't be done without light	Labour-force, families, individuals, communities

Many of these pains have similar roots, which mostly relate to each other in some way, those *crystallising* in essence are, that there is no commercial availability to buy many things that many would like or that there is no way of communication.

Thus, the root causes of those *pain points* are similar as well, coming down to the lack of electricity and water and the missing funds for communities to locally influence the landscape - missing infrastructure can be included in missing funds, considering the option traditional infrastructure alternatives.

Insert "As is, as needed to be, to be" here

Sample Scenario Mobile phones have immense positive potential in terms of impact on rural communities, ranging from enabling communication, which impacts so many areas, like healthcare, emergency alert, education, policing, safety, family management, shopping, community coordination... The absence of a mobile network boils down to the *classic "Chicken & Egg"* dilemma, where mobile network infrastructure won't be built by commercial or public entities until there's no demand for such an expensive undertaking. If the construction were simpler and cheaper, it would be done - thus, the existence of projects like *Starlink* that aim at providing-low cost global broadband satellite-to-consumer technology. Though, still there are no mobile phones and there won't be until they can be recurrently and preferably sustainably recharged, which requires one essential commodity, electricity.

Pains of those wishing for those communities to develop.

Those wishing for rural communities to develop (also, but not only economically), include the neighboring and regional communities, the government governing these communities, NGO's providing aid, other countries providing aid, commercial firms wishing to generate sales from rural communities, more urban environments wishing more capacity/capability - requiring resources, including rural community members.

Types of Pain	Pain Owner
Can't sell my traditional product to potential customers	Domestic, international businesses
Can't get my cheap, alternative product to those communities	Domestic, international businesses
Can't reach my population for political reasons	Government
Can't utilise domestic labour-force without necessary infrastructure investments	Domestic, international businesses
Can't offer my (charity) services due to missing communication possibilities	NGO's, businesses, charities

These entities have different pains than the rural communities and their constituent members, but again boil down to similar root-causes, missing electricity, infrastructure and economy. *A business cannot sell its products to those communities without any possibility of effectively communicating with them.* From this point of view, it seems as though the introduction of electricity isn't all the pain's root cause, but may be diminishing/hindering development in the root cause identified, including infrastructure.

> *Insert "As is, as needed to be, to be" here*

> *"Most Pains and their root causes are interwoven in a complex network of causality, similar to a poverty-cycle."*

And thus identifying and agreeing on the root-cause for the problem to solve is the first step of fixing it.

A typical Scenario

South-Sudan

Imagine a day in the life of the citizen of a small village community, of not even 50 people, in a Sub-Saharan Country like South Sudan. There is no supermarket, no internet, no running water nor electricity, no way to order anything quickly, but every trip to the closest bigger community for any type of resources/products requires planning and much time in execution - not an easy task.

> *"South Sudan has only 5.1% of its population enjoying access to electricity. It has less than 1% of its roads being paved ones, and less than 1% of the population have formal, Western-style housing as we*

> *would recognize it as well. Such a want for facilities has been the result of 30 years of war and government neglect. The government is now trying to attract foreign investors to conduct their varied business ventures within South Sudan. Many of these will be for power generation and distribution, transportation infrastructure, and property development."* (Comparison of access to electricity in African Countries)

The community is unable to provide electricity to its citizen - That includes light after sunset, heating/cooling of housing in the at day incredibly hot and during night moderately cool biome. They cannot run appliances such as refrigerators, whose absence accounts for much of the already few existing food going to waste. After all, a fish laying around in this region for longer than any given period of time will start to become unenjoyable.

> In developing regions, often the biggest chunk of food loss occurs during the post-harvest phase But in developed regions, the biggest chunk occurs at the retail and consumer levels. (Food & Waste Organisation of the United Nations)

In addition to not being able to keep food stored for long, electric ovens/microwaves/stoves are also missing out and instead used are traditional wood burning or fewer seen gas appliances for cooking.

No electricity means no means to charge any electric device or even use any non *"accumulator/battery"* powered electric device. That means no mobile phones, no radio, no television, no communication method with family members or friends. There is no way to learn anything new other than books and stories. No way to exchange ideas, collaborate - everything seems disconnected. That is in fact the second factor to focus on as disconnectedness is a consequence of the lack of electricity as there's no digital network nor any effective/efficient enough non-digital network and causes many of the other pains mentioned above. Note, that connection can also include physical connection in terms of logistics, thus also addressing the infrastructure problem.

A teacher cannot pull up a video on *youtube* to further explain his point, communicate with students in any other way than them being in the room, require his students to be able to do extensive research and so many more things, knowing that he is most likely to only source of knowledge available. His ability to pursue what he desires and enjoys doing is limited by the non-existence of electricity and the lack of the consequences following electrification.

> Besides requiring energy access being crucial for many basic human needs, the underserved populations represent a massive commercial opportunity for sub-Saharan African utilities. Advances in distributed renewable energy technologies have made utility providing units more affordable, faster to deploy and more transparently/stable. Millions

of urban Africans still don't have electricity: here's what can be done

Considering the percentage of individuals and communities living *under-the-grid* in many rural Sub-Saharan African regions, it seems like there is much potential for the offering of a electricity providing utility service.

Solution Proposal to Problems and Pain

The proposed solution to the cascading problems and pains created by the root-causes is a self-contained, expandable electricity provision and storage unit. This storage unit works by utilising *hydrogen* and solar technologies for energy production and storage.

The Hydrogen-Solar cycle

1. Use electricity generated from solar panel to split *water* into *hydrogen* and *oxygen* gas. The oxygen gas can be release into the atmosphere.
   - The splitting step requires energy, thus the necessity of the solar panel.
   - This whole step should be done close-by water sources or oceans, they require water to split.
2. Get the hydrogen gas to rural communities.
   - The hydrogen gas is super-light and not expensive to store/transport
   - It is less flammable than car-petrol
3. At the rural community, combine the hydrogen gas with oxygen gas (extracted from the atmosphere) to generate electricity and have water as a side-product.
   - The combination of the two gases happens naturally when in proximity, as oxygen is hydrophyllic.
   - The combination of hydrogen and oxygen releases energy for immediate use or storage in buffer batteries.

The concept proposes to use hydrogen as a medium- to long-term energy storage method. For e.g. night-times in which the solar panels don't work, batteries are sufficient, but are expensive and not environmentally friendly in production. Batteries also degrade and are definitely not the sole solution for a medium-term energy storage on community scale. Hydrogen is the *marathon runner* amongst energy storage/release methods. Batteries are more like a 500m sprinter and capacitors are the 100m sprinters. Given that most loads in these rural areas would be relatively *unintensive*, leaves as a good option to choose a hydrogen/battery hybrid system.

The system has to be able to easily withstand heavier loads of energy demand but also be stable enough and should utilise energy storage methods that have longevity in mind. Considering that maintenance et cetera will be harder than

in urban areas of the developed world, these systems should be as self-contained, independent and sustainable as possible.

Effectively reducing pain through the root-cause targeted solution

> *Insert "How the proposed solution effectively minders pain by tackling the root-causes" here*
>
> *So far, I haven't included the graphs from the excel table, as they are in the last Submitted Assignment and I will change them to be more precise to these assumptions.*

References

Water access (may be more important than electricity for sub-Saharan Africa. (2018). The Conversation. Retrieved 11 June 2019, from here

FAO (2019). Fao.org. Retrieved 11 June 2019, from here

> World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program.

Access to electricity, rural (% of rural population) | Data. (2019). Data.worldbank.org. Retrieved 12 June 2019, from here

Access to electricity, urban (% of urban population) | Data. (2019). Data.worldbank.org. Retrieved 12 June 2019, from here

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Notes

Value comes like waves at the beach, the pain relief is the retreat of the wave, which causes value to take its place.

fractional ownership -> lease basis ->

synergy/emergence -> is it worth it?