NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND
THE BUILT ENVIRONMENT (FEBE)

Off-grid power supply based on green hydrogen storage potential: A case study of the NUST-SEED Living Lab at !Kharoxas

James Katende

08 November 2022

Department of Mechanical, Industrial, and Electrical Engineering

FEBE Faculty Research Day 2022 Theme: Green Hydrogen Future: Challenges and Opportunities for Namibia

Contents

NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

Introduction – TUM SEED Center

- TUM – Technical University of Munich
- SEED – Sustainable Energies and Entrepreneurship for Development in the Global South
- The Center offers higher education at the intersection of sustainable energies and entrepreneurship
- The Center's research contributes to the 2030 Agenda for Sustainable Development – specifically UN SDG 7 ensuring access to affordable, reliable, sustainable and modern energy for all by 2030
- The Center has 8 partner universities located in 8 countries in the Global South
- DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service

exceed EXCELLENCE CENTERS FOR EXCHANGE AND DEVELOPMENT

Federal Ministry for Economic Cooperation and Development

Source: https://www.seed.tum.de/index.php?id=3

Introduction – TUM SEED Center

- Duration: 5 years (2020 – 2024) – (possible extension to 2030)
- Initial Grant: €3.8 million
- Funded by: DAAD, EXCEED and Fed Ministry of Economic Development
- Activities:
  - Conduct joint research with impact – publish in top journals and impact society positively
  - Facilitate international student exchange (Masters and Doctoral)
  - Co-create Living Labs at each partner university to:
    - Provide access to electricity for rural communities (SDG 7) in global South countries
    - Engender productive use of electricity
    - Teach and research in sustainable energies and sustainable entrepreneurship

Introduction – Partner Universities

Kwame Nkrumah University of Science and Technology, Ghana

Namibia University of Science and Technology, Namibia

Indian Institute of Technology, Bombay, India

Bandung Institute of Technology, Indonesia

Pontificia Universidad Catolica del Peru

Bahir Dar University, Ethiopia

Jomo Kenya University of Agriculture and Technology, Kenya

Makerere University, Uganda

Introduction – NUST SEED Team

- Prof James Katende – PI – (TUM SEED Center Scientific Director)
- Mr Robby Tjiwemu – Coordinator
- Mr Teofilus Shiimi – Co-Coordinator
- Prof. Asa Romeo Asa – Member
- Mr Moses Joshua – Member
- Mr Bas Rijnen – Projector monitoring
- Mr Lazarus Willhem – research student
- Mr Johannes Awene – research student
- Mr. Elma Matali – research student

NUST-SEED Living Lab at Farm Kharoxas

- A farm community located 8km south of Groot Aub.
- 20kWp Solar PV plant with 20kWh Lithium-ion battery storage
- Borehole solar water pump installation with water storage tank
- Entrepreneurial activities to include
  - Poultry – house under construction and an egg incubator acquired
  - Marula tree seedlings – acquired and bed is being prepared
  - Bush feed crush machine – to make feedstock – has been acquired
  - Community garden – still under consideration

Community mini grid design – work in progress

- Community load estimation and profiling
- Design of 0.4 kV distribution network
- Assessment of a PV-Battery-Hydrogen storage system

NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

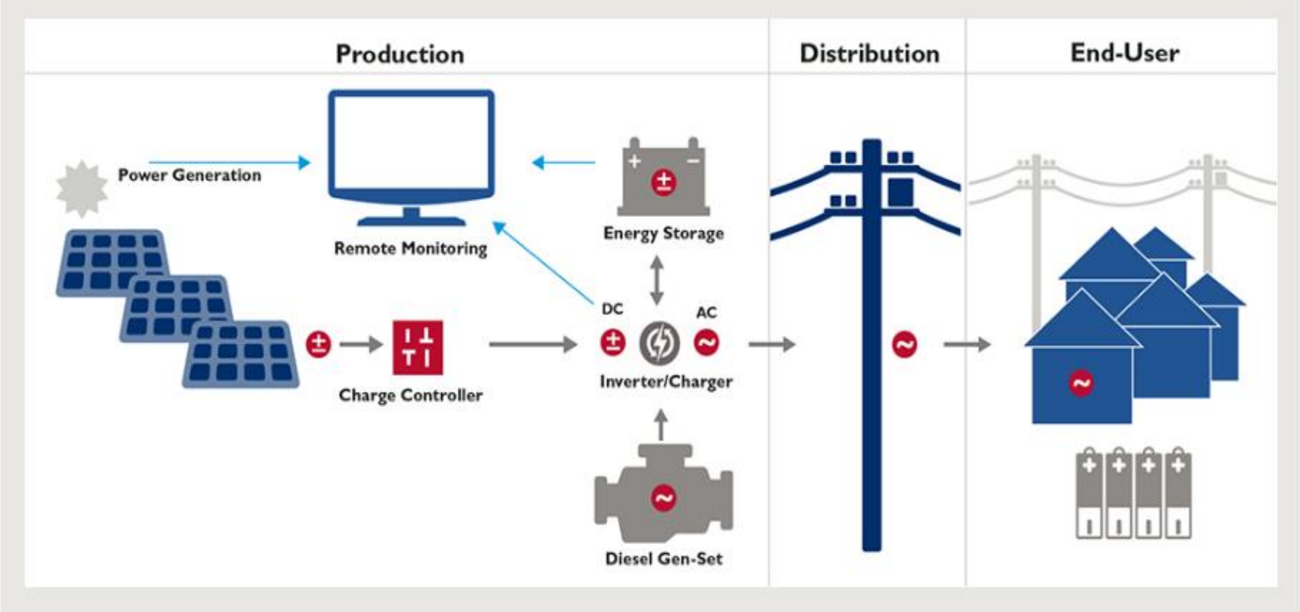
Mini grid technical features

Production – generates electricity

Distribution – moves electricity from generation site to end-users

End user – provides connections that allow customers to use electricity

Energy storage is critical to provide electricity when solar power is not available and to store excess solar generated energy



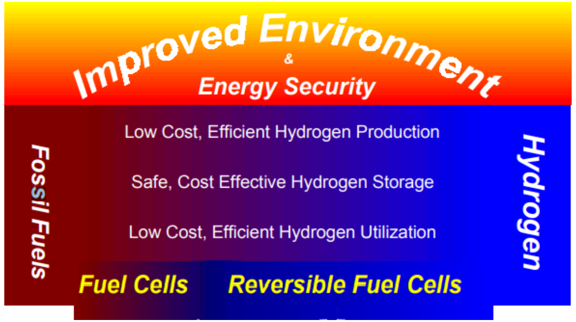
Source: https://www.usaid.gov/energy/mini-grids/technical-design/components

Why green hydrogen storage?

- H_2 is lightest of all elements and most abundant in the universe.
- H_2 has highest energy density of all fuels and reacts cleanly with only heat and water by-products.
- H_2 is an excellent storage medium or energy carrier for excess renewable energy sources.
- H_2 is typically employed as mid- to long-term energy storage, whereas batteries cover short-term energy storage.
- H_2 can be produced by any available electrolyser technology [alkaline electrolysis cell (AEC), polymer electrolyte membrane (PEM), anion exchange membrane (AEM), solid oxide electrolysis cell (SOEC)] if the electrolysis is driven by renewable electricity.
- The most efficient way to generate electricity from hydrogen is by utilizing a fuel cell. PEM fuel cells seem to be the most favourable way to do so.

Why green hydrogen storage?

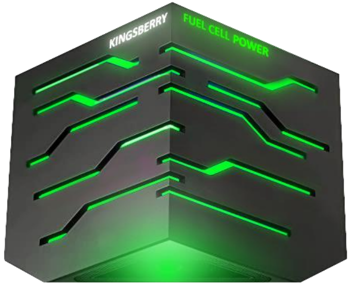
- To increase the capacity factor of fuel cells and electrolysers, both functionalities can be integrated into one device by using the same stack.
- The NASA spacecrafts use fuel cells to provide electric power for everything onboard
- Batteries STORE energy, while fuel cells GENERATE energy by converting chemical energy within fuel. A fuel cell can have a battery as a system component to STORE the electricity it's generating.
- Fuel cells have no moving parts, operate silently with heat and water as by-products



H_2 technology validation

DIESEL GENERATOR:
18% Efficiency, Noisy,
Maintenance, Polluting

$1/kWh Diesel
vs
$0.03/kWh Fuel Cell

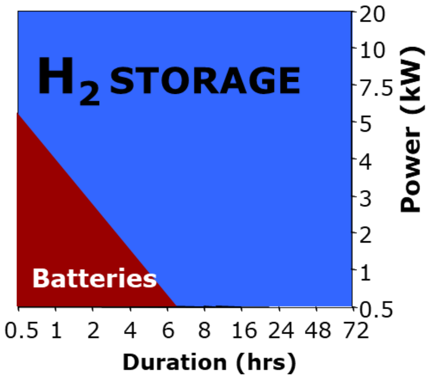


Fuel Cell

- Continuous primary power
- Improves grid resiliency
- 92% CHP efficiency
- High power density
- Low land usage
- Independent of weather
- Minimizes wind /solar land
- Very low maintenance

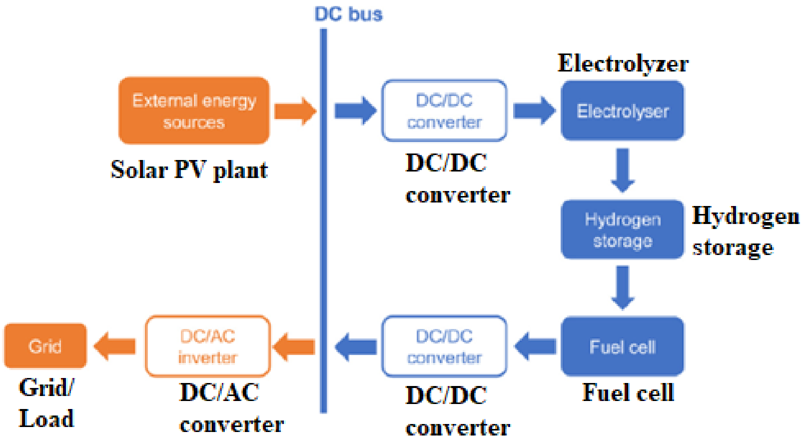
BATTERY: Needs re-charging; Low Power Density; Needs Disposing; Bad in Cold

SOLAR: Non-Steady:
Impacted by Weather;
4-5 Hours/Day Power;
Takes up Land



Our research

- **Initial system architecture design considering cost and environmental impacts**
  - Energy sources
  - Number/size of components
  - Economic evaluation
  - Emissions



HOMER Pro

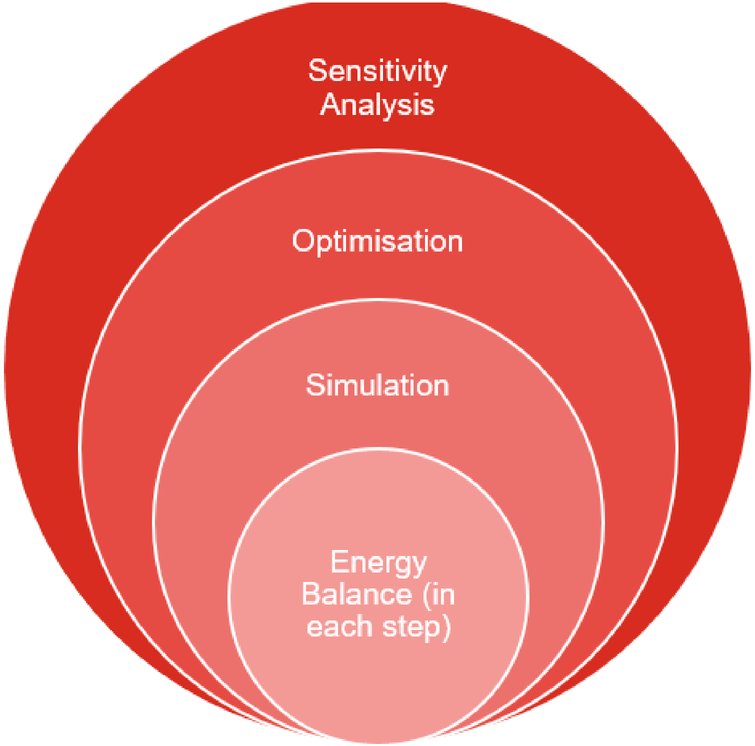
What is Homer Pro?

- HOMER (Hybrid Optimization of Multiple Electric Renewables).
- Developed by NREL (National Renewable Energy Laboratory)
- Initially HOMER and then changed to HOMER Pro since 2014
- Simple and powerful tool for feasibility assessment and design of mini grid systems (both on and off-grid)
- HOMER Grid was developed in 2018 specifically for Grid applications with more capabilities around demand charges and time of use rates

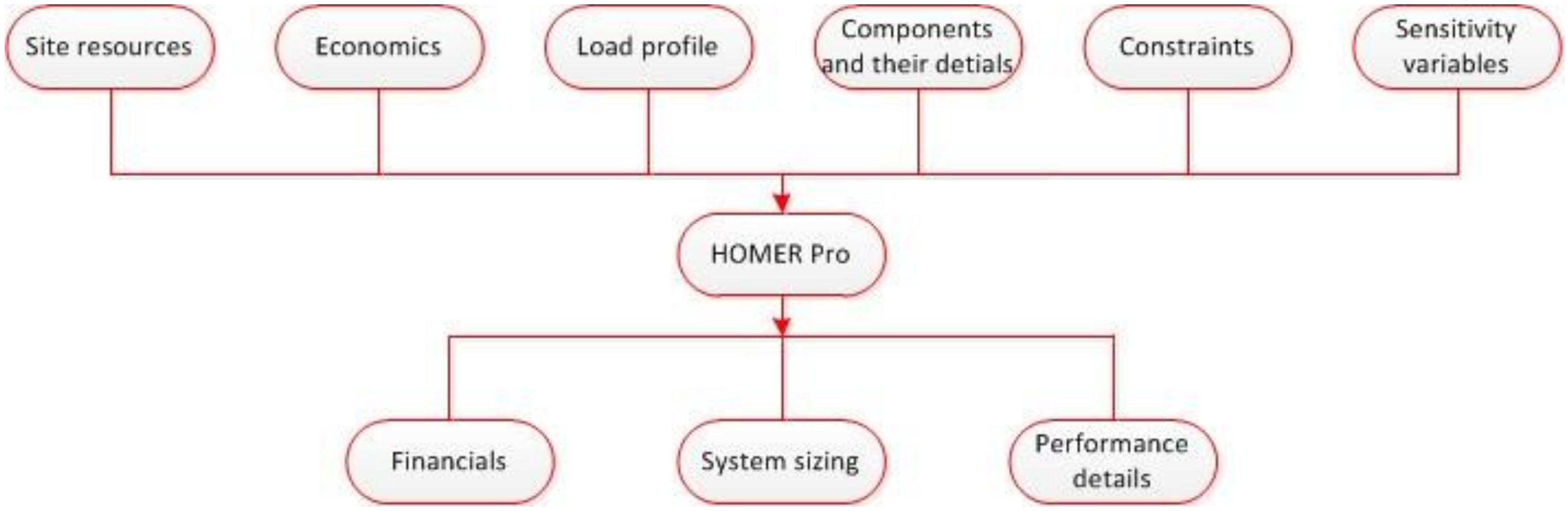
HOMER Pro

HOMER Pro

- **Energy Balance**: managing generation and storage to meet the load in each time step
- **Simulation:** Run each system for one year, every hour or minute
- **Optimisation**: finding the most- cost effect way (i.e. lowest LCoE) to meet the load in each scenario
- **Sensitivity analysis**: analysing the impact of variables that we have no/limited control over (such as capital cost, fuel price, wind and solar resources) on the system configuration and cost



Design and analysis of mini grids with HOMER Pro



HOMER Pro Environment - *inputs*

Hydrogen components in HOMER Pro

- **Fuel cell (It is a generator in HOMER Pro)**
  - Power
  - Cost
  - Fuel curve
  - Lifetime
  - Heat recovery (should be zero if there is no thermal load)
- **Electrolyser**
  - Cost
  - Power
  - Efficiency
- **Hydrogen tank**
  - Cost
  - Capacity
  - Initial hydrogen level

Steps in using HOMER Pro

1. Site selection
2. Defining the load profile: electrical, thermal, hydrogen
3. Resources: wind, solar, temperature, fuel, etc.
4. System design (what components to be considered? Load, generators, batteries, fuel cell, PVs, etc.)
5. Fuel prices
6. Economics: annual interest rate, project lifetime, system fixed capital cost, system fixed O&M cost , capacity shortage penalty, etc.
7. Variables for sensitivity analysis (change in fuel price, average wind speed, capital cost, etc.)
8. Calculate the results

Conclusion

- The on-going TUM SEED Center Project has been presented
- Features of the NUST SEED Living Lab have been described
- Use of Green Hydrogen for a mini grid has been espoused.
- A study of the techno-economic feasibility of using green hydrogen technologies in an off-grid community mini grid with the aid of HOMER Pro software is in progress.
- Detailed results of the study will be availed soon

NAMIBIA UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT (FEBE)

Thank You.

Contact Details FEBE

13 Jackson Kaujeua Street
Private Bag 13388
Windhoek
NAMIBIA

T: ....
F: ....
E: ....
W: www.nust.na

Contact Details Author:

Prof. James Katende
Dept of Mech, Industrial and Electrical Engineering.
NAMIBIA

T: +264 612072537

E: .jkatende@nust.na