Improving energy access in displaced settings

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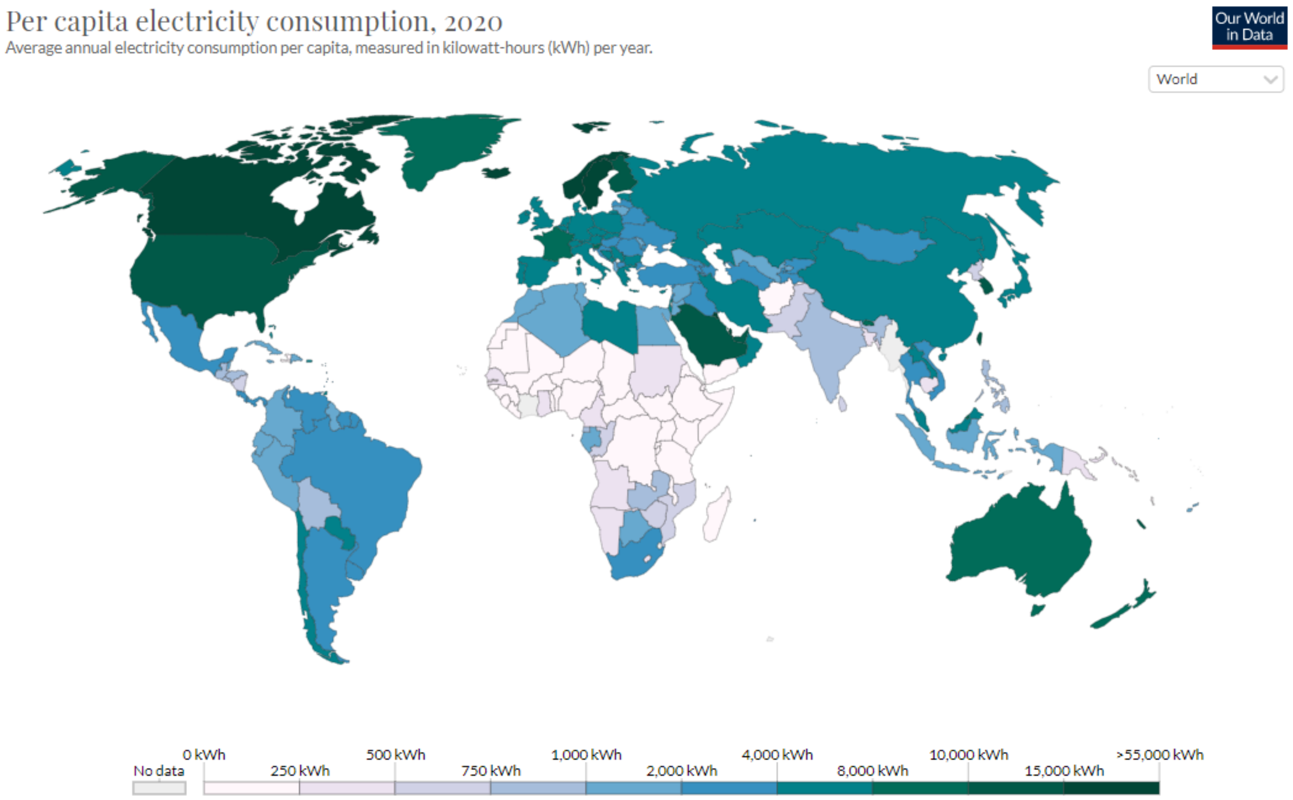
Humanitarian Engineering and Energy for Displacement

Content

- The energy access divide
- The role of solar systems
- The HEED project
- System design
- Performance and evaluation
- What we learnt as engineers

How Much Electricity does the Average Person Consume?

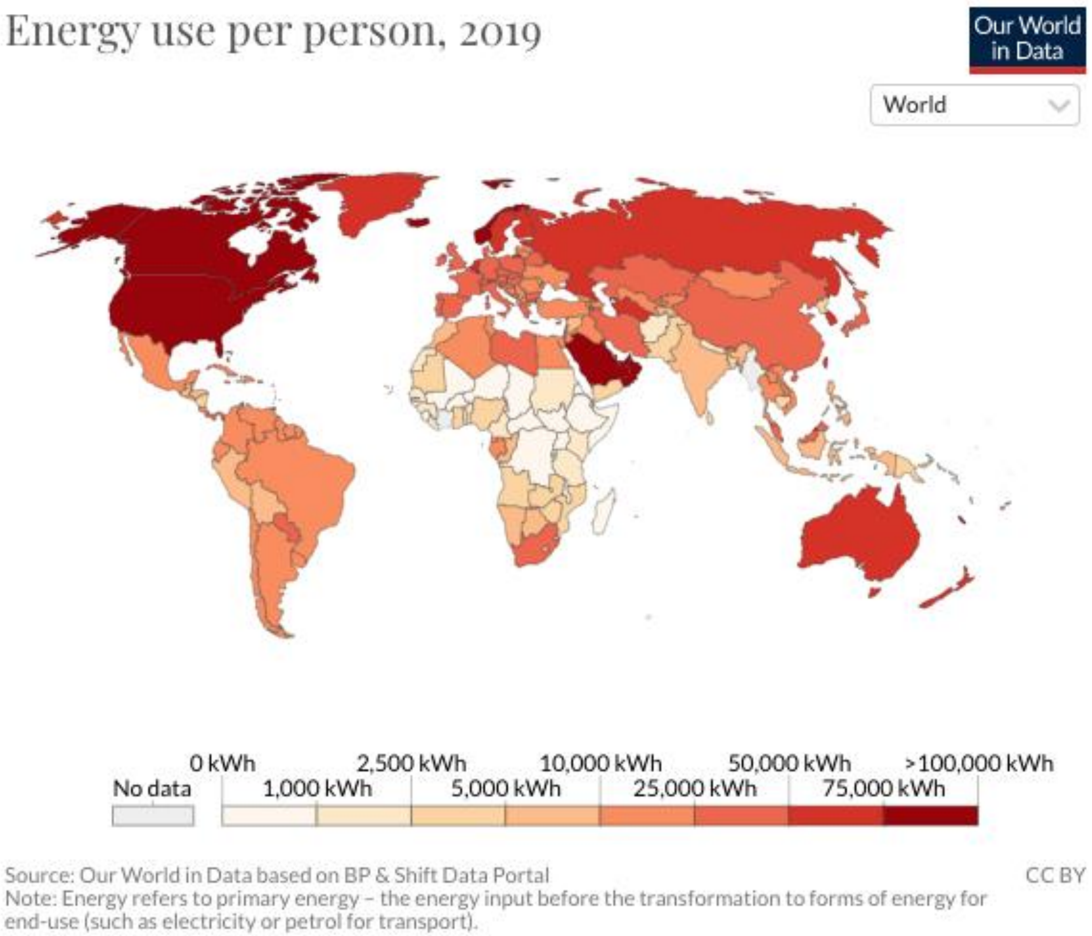


"Having access to the electricity and other forms of energy needed for cooking, heating and lighting is something many of us take for granted"

UK –electricity consumption 12.5 kWh/day

Electricity consumption varies more than 100-fold across the world

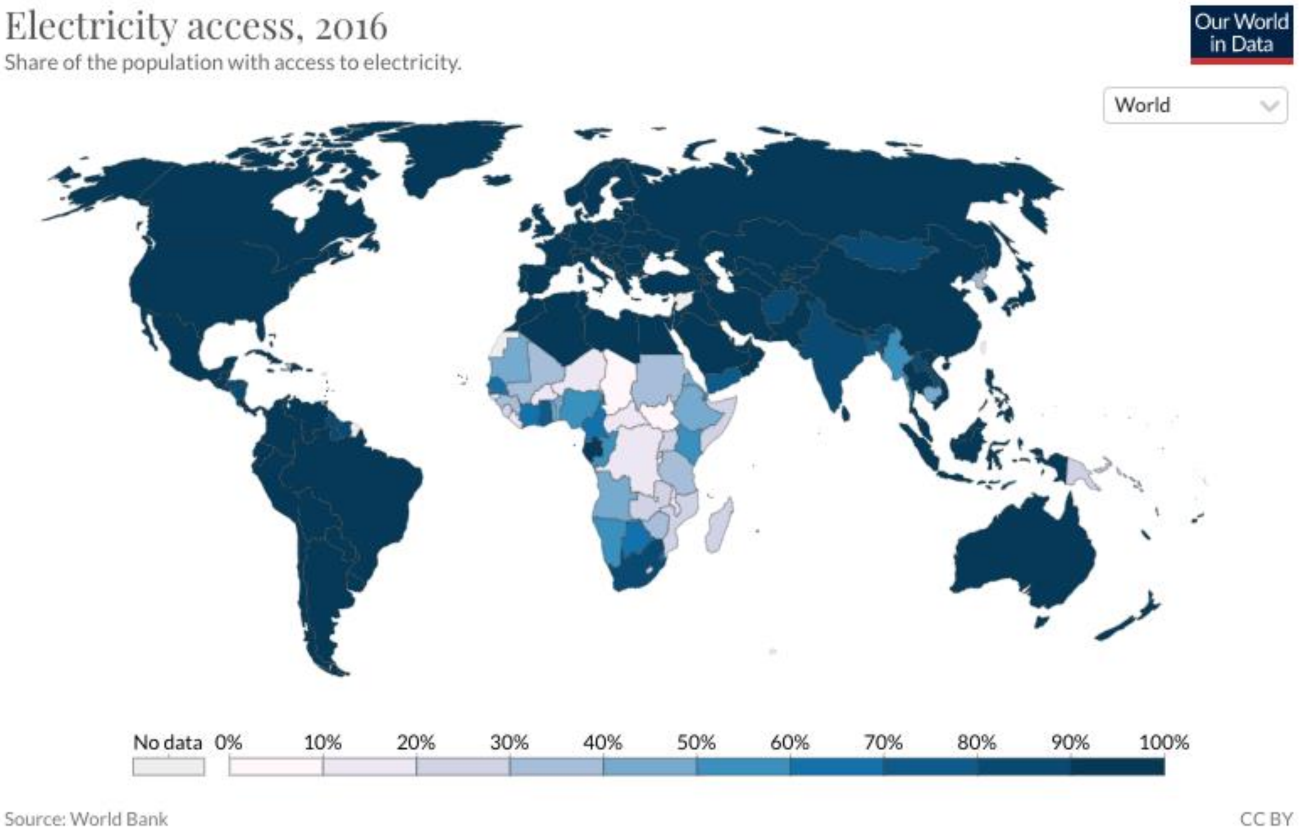
How Much Energy does the Average Person Consume?



Per capita energy consumption varies more than 10-fold across the world

UK – energy consumption
88 kWh/day

Who doesn't have access to electricity?

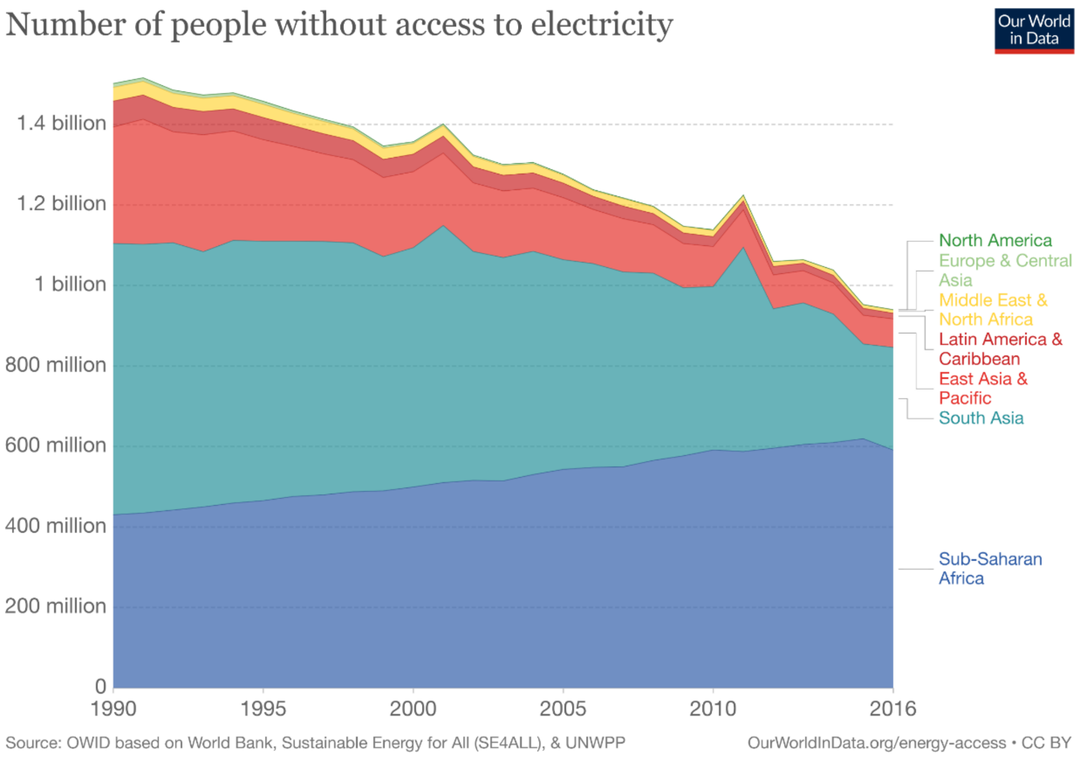


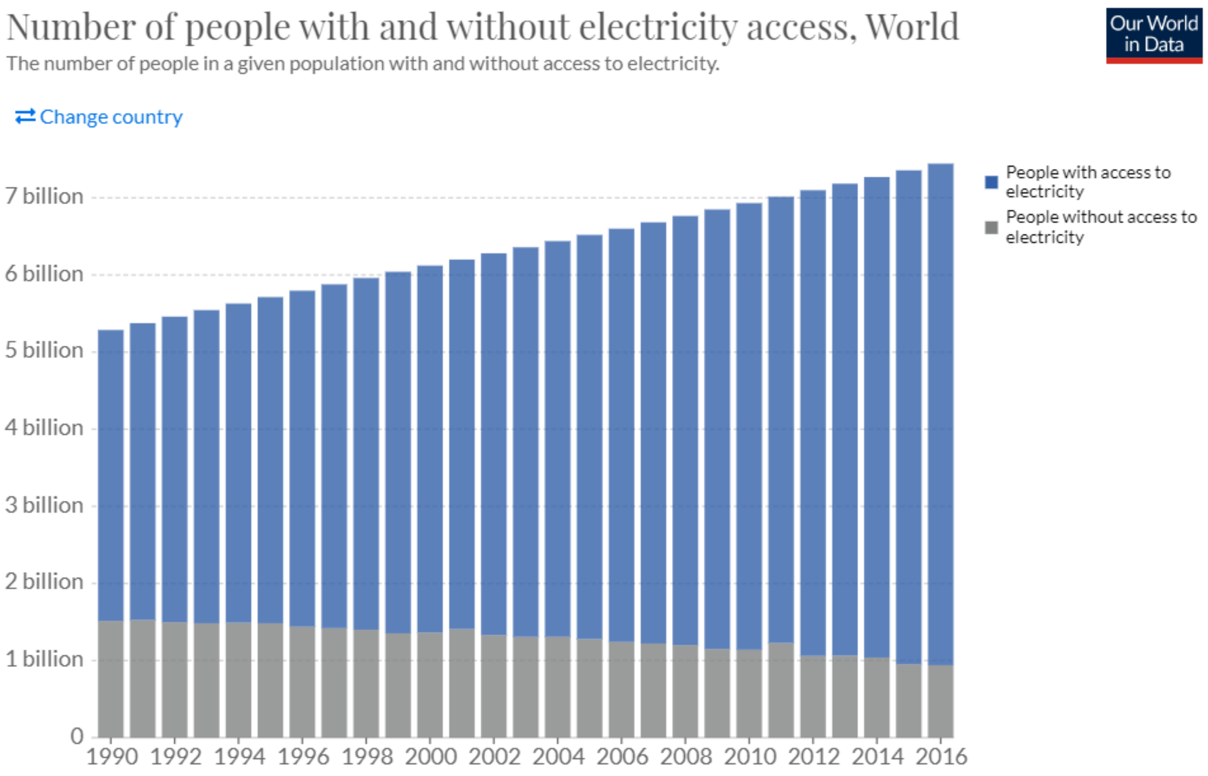
13% of the world did not have access to electricity in 2016 – nearly a billion people!

40% of the world (3 billion) do not have access to clean fuels for cooking.

Around 4 million people per year die as a result from exposure to indoor air pollution.

Available, affordable and safe energy access?





"Poverty levels rising worldwide in 2020 will make basic electricity services unaffordable for more than 100 million people with grid electricity connections."

UN Sustainable Development Goal 7 (2015 - 2030)

Ensure access to affordable, reliable, sustainable and modern energy for all

Will we ensure universal access to affordable, reliable and modern energy services by 2030?

To get there, we need to:

- Devise alternative forms of energy
- Encourage a marketplace for renewable energy suppliers
- Improve access to energy to provide greater opportunities for learning, safer communities and reinforce socio-economic stability

‘Leaving No-one Behind’

- The UN’s Clean Energy Challenge (2019) aims for all refugee settlements to access reliable, sustainable and modern energy by 2030.
- To achieve this goal, engineering and humanitarian responses will need appropriate, creative approaches, tools, skills and new technologies to deliver improved energy solutions in the displacement setting.
- Energy solutions that emerge from conversations with communities, engineers, suppliers and other energy stakeholders, rather than imposed top down, are more likely to succeed in engagement and uptake of renewable energy interventions

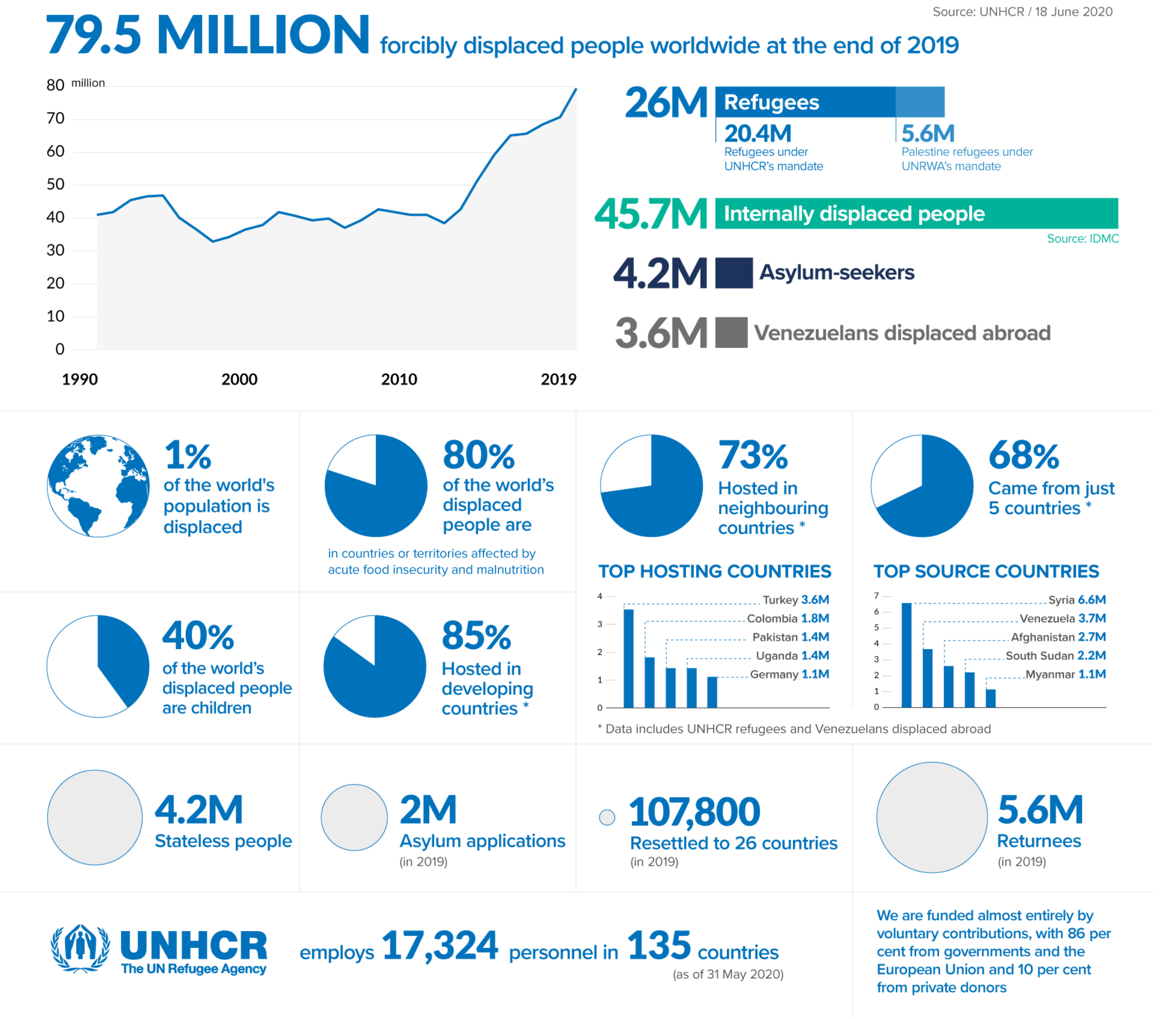
Sustainable Development Goals: Cross Cutting Themes

- GOAL 5: Gender Equality: Energy solutions that recognise not only unequal practices for women as service users but provide opportunities for women to be designers of energy schemes and suppliers of energy services.
- GOAL 8: Decent Work and Economic Growth: Advocate for the salience of skills development that can respond to limitations of camp-based refugees' right to work and freely move between camps and host communities.
- GOAL 10: Reduced Inequality: Energy interventions that seek integration and the sharing of benefits between refugees and host communities.
- GOAL 11: Sustainable Cities and Communities: Refugees as 'prosumers': both users and suppliers of energy

Energy access in displaced settings

- Number of forcibly displaced people /million refugees – **80 million / 26 million**
- Average time spent in refugee camp - **18 years**
- Displaced populations in camps with no access or limited access to electricity – **97%**
- Number of people in camps have access to electricity for less than 4 hours a day - **7 million**
- People living in camps with access to energy for lighting – **11%**

The United Nations High Commissioner for Refugees (UNHCR) are encouraging the provision of clean and affordable energy to refugee camps, with a particular focus on micro-grids and other standalone solutions that use solar power



The role of solar energy

- Can provide affordable energy for critical services (food preservation, medical facilities, lighting for security and safety, water pumping and emergency communications) and other essentials (mobile phone charging, entertainment and educational equipment) when a grid connection is not feasible.
- Refugee camps are often situated in rural areas where a grid connection is not possible due to high investment costs and transmission losses
- Where refugee camps do have electricity provision, it tends to come from costly and inefficiently operated diesel generators
- Even when camps are near national grids, host governments are often reluctant to provide refugees with services that could imply permanence or be negatively perceived by local host communities
- The first photovoltaic (PV) micro-grid supplying a refugee camp was in 2017, which was a 5 MW system deployed in Jordan’s Azraq camp; this was followed by a larger 12.9 MW PV power plant located at Jordan’s Za’atari refugee camp

The challenge for solar systems

Despite the potential of standalone PV systems to cost-effectively provide small-scale energy access solutions, solar energy interventions in refugee camps have largely been unsuccessful.

- There is a lack of data on refugees' energy needs and demands to inform system designs
- No systematic methods or tools to accurately estimate (and forecast) energy usage patterns in communities where there is currently limited or no energy access
- This can lead to oversized/undersized systems (e.g. surplus solar energy is lost when there is no demand or it cannot be stored, which reduces the system's utilisation and viability)
- Limited evidence base for the technical performance of off-grid systems in general regardless of the deployment context
- No systematic analysis of factors for failure, success and gaps between design and actual performance for installations based on renewables in refugee camps
- No renewable system design guidelines and methods to help designers and researchers succeed more often
- Many other challenges… (e.g. theft, vandalism, informal modifications, availability of parts and a lack of local skills, training, ownership, governance and funds for maintenance)
- These issues in humanitarian contexts are compounded by crisis, politics and economic constraints

The Need for Socially Just and Inclusive Energy Systems

- Energy systems power and empower societies
- But do issues around social justice impact engineering priorities?

- Transitions to new energy systems that could be a fairer, more equal way to use and supply energy.
- But are engineering solutions that centre around sustainability and social justice 'too difficult to implement'?

Our Energy Future is Renewables

Renewables have a crucial role in addressing a wider range pf complex challenges— some made even more pressing by inequality in resources, globalisation, climate change, and population issues

But…

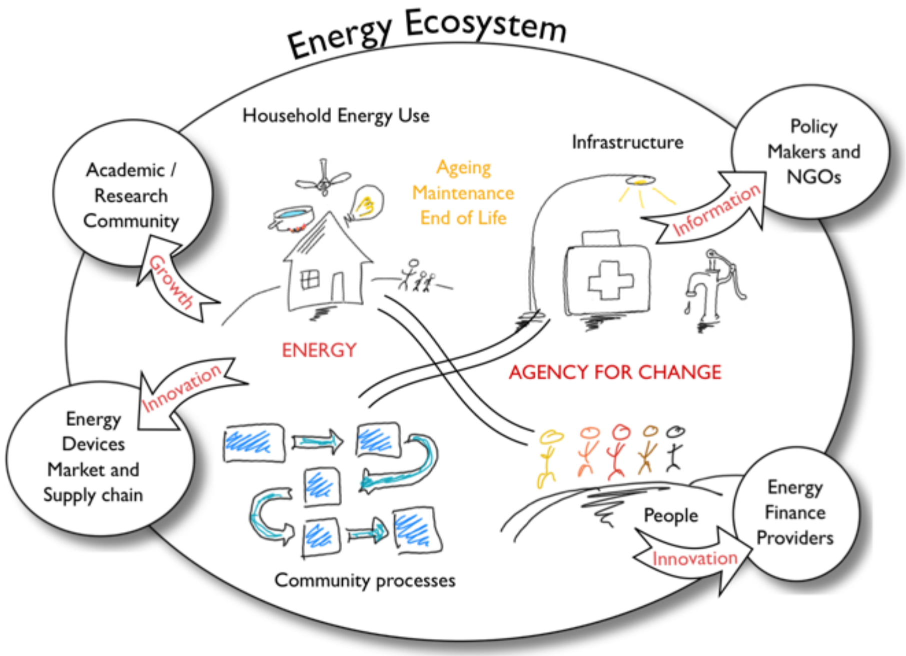
Renewable energy can also reinforce inequality

Humanitarian Engineering and Energy for Displacement (HEED) – Project Vision

An interdisciplinary team based at Coventry University, in partnership with the international development charity, Practical Action and Scene Connect.

The project worked with Congolese refugees in three camps in Rwanda (Gihembe, Kigeme, and Nyabiheke) and internally displaced people in Nepal to understand energy access in refugee camps and displaced settlements.

*To introduce **new principles for the design**, procurement and provision of energy **products and services** that improves **access** to affordable and sustainable energy in the **humanitarian context**.*



HEED’s objectives

The Humanitarian Engineering and Energy for Displacement (HEED) project aimed to understand the energy needs of forcibly displaced people to increase access to safe, sustainable and affordable energy services by asking:

- How do refugees use energy and what are their energy needs and aspirations?
- What principles and processes can be implemented that will deliver energy interventions that respond to and respect the energy needs and aspirations of displaced people?
- How can we think differently about the design of energy interventions, such as microgrids, mobile lanterns, and clean cooking stoves, to produce sustainable, low cost, and cultural appropriate solutions?
- Is it possible to implement structures that improve access to energy that leverage on the local economy of products and skills, and are future proof?

Project Objectives

- Expand the **evidence base** to aid decisions about demand for energy services in the humanitarian context.
- Translate research findings into 'design for displacement' **protocols** and **prototypes**.
- Design, implement and **monitor energy systems** that connect **people**, **products**, **processes** and **policies** .
- Contribute to the scientific **knowledge** base on **energy access**, **energy demand**, **energy provision** and **energy monitoring**.

Research questions

- What is the performance gap between designed and in-situ solar systems in displaced settlement?
- Is anticipated utilisation of a community-based solar energy intervention realised in real-life implementation?
- What are the design, implementation and operational challenges that reduce in-use performance and how can the performance gap be reduced in future solar streetlight interventions?

Humanitarian energy system design

- Humanitarian energy interventions have traditionally followed a top-down design model
- A lack of community engagement has led to oversized systems that are limited to critical services, resulting in high energy costs, low efficiencies and underutilised resources.
- Many energy system interventions are deployed in response to a crises, yet many are in protracted refugee camp settings.
- Bottom-up innovations are now being pioneered to include refugees, host communities, private sectors and aid agencies in the design and implementation process
- Inclusive design approaches and community co-development activities could help to create self-reliance and income generation opportunities and encourage marginalised and disempowered groups (women, youth) to engage with decision making about improved access to energy.

(Rosenberg-Jansen et al., 2019; Groot et al. (2017)

Research approach

Select → **Co-conceive** → **Implement** → **Evaluate**

Select
- Literature reviews
- Site visits
- Surveys

Co-conceive
- Stakeholder workshop
- Conceptulisation
- Load profiling
- Simulation
- Product requirements

Implement
- Supplier selection
- Design revision
- Installation and commissioning

Evaluate
- Community mobilisers
- System monitoring
- Analysis of data
- Training
- Handover

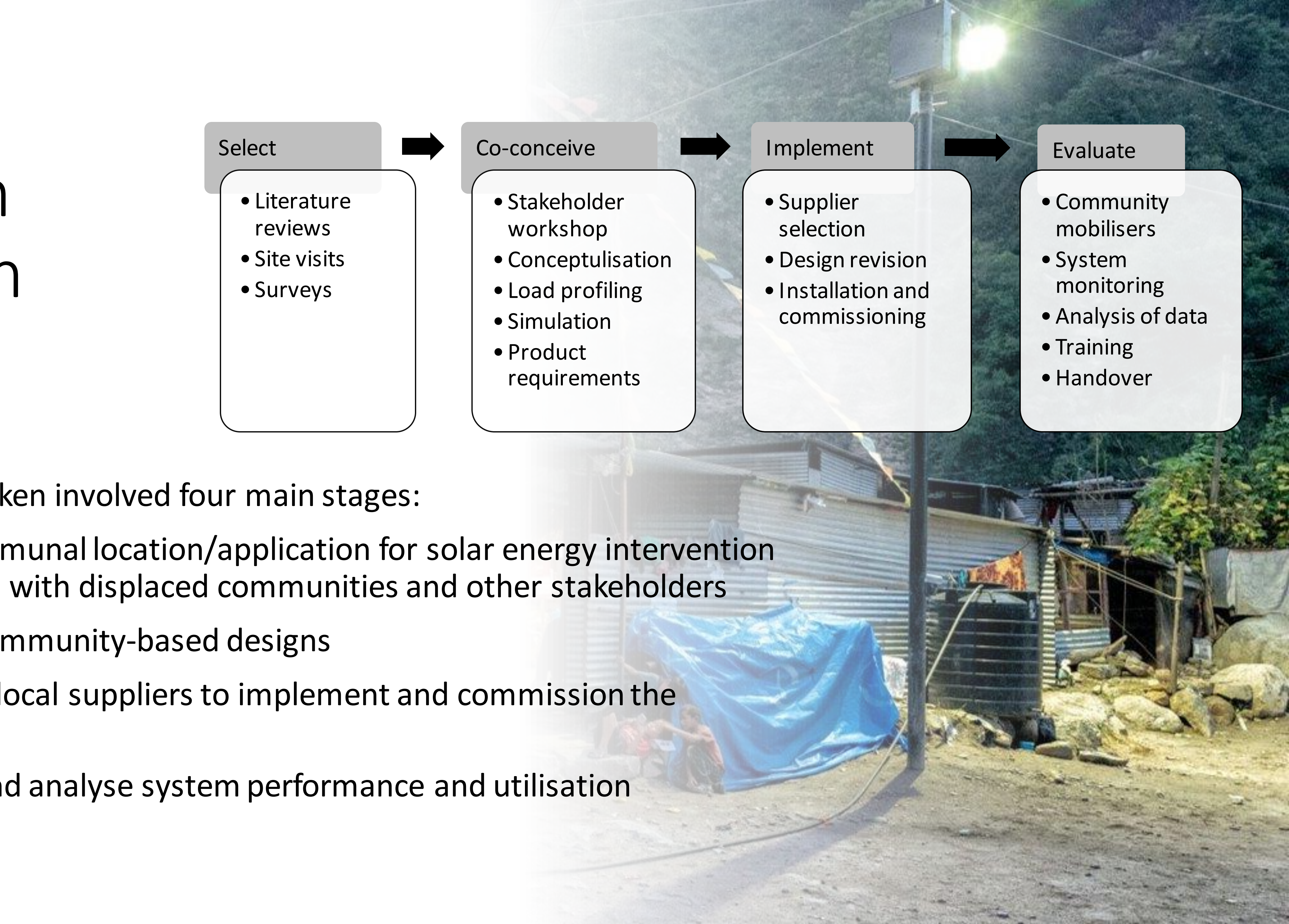
The approach taken involved four main stages:

i) select communal location/application for solar energy intervention by working with displaced communities and other stakeholders

ii) develop community-based designs

iii) work with local suppliers to implement and commission the systems

iv) monitor and analyse system performance and utilisation



Community engagement

- Site assessments (stability, interest in participatory research, relationship with host community, ongoing interventions)
- Baseline surveys of current energy practices and facilities
- Community co-design workshops (e.g. with women, youths, community committees and other stakeholders) to arrive at concept designs

Kigeme Refugee Camp
A micro-grid powering two nurseries and a playground

- 20,000 refugees
- No grid connection
- Very limited use of solar home systems
- Refugees primarily rely on mobile phones and candles for lighting

Nyabiheke refugee camp
Solar electrification of a community hall

- 16,500 Congolese refugees
- No grid connection
- Diesel generator powers camp management/health clinic
- Informal connections made to other communal facilities cut-off
- Primarily rely on mobile phones and candles for lighting

Gihembe refugee camp
8 solar streetlights/4 advanced solar streetlights

- 14,500 refugees
- Solar streetlights previously deployed in Gihembe stopped working within a few months
- Placed for asset security rather than for enhance refugee's safety and mobility

Design process

I. Estimate loads (e.g. desired type, duration and frequency of appliance usage)

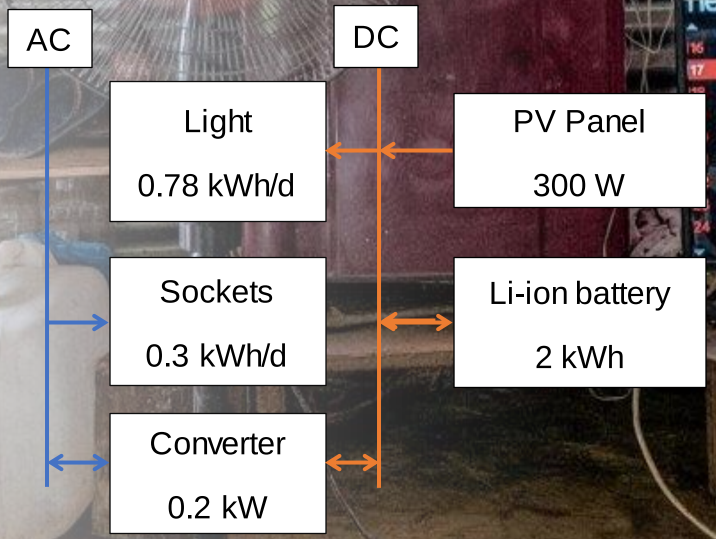
II. Assume performance parameters, variables and constraints

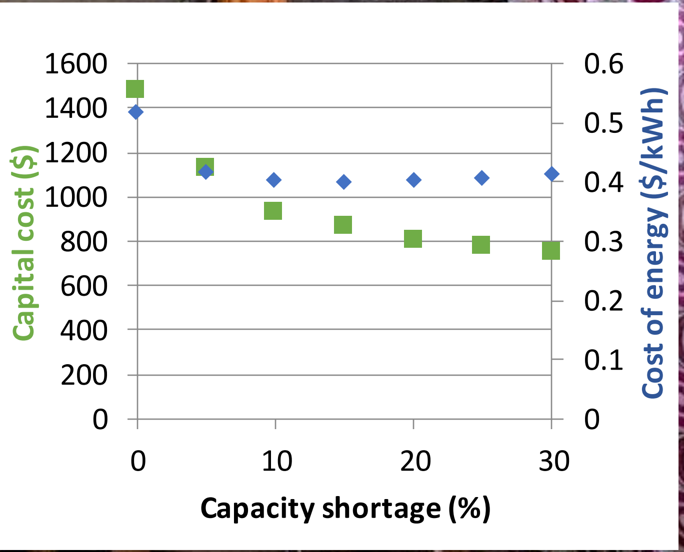
III. Simulation modelling and optimisation

IV. Trade-offs

Input parameter	Micro-grid	Community Hall
Daily average global horizontal irradiance[a]	4.57 kWh/m²/day	5.02 kWh/m²/day
Generic flat plate PV panel location	128° SE, 15° tilt	29° NE, 16° tilt
PV panel derating	90%	90%
MPPT Solar charger efficiency	95%	95%
Socket inverter size and efficiency	1 kW/95%	3 kW/95%
Battery roundtrip efficiency	80%	80%
Initial/Minimum SoC	100%/50%	100%/50%
Load	5.75 kWh/day – 1.18 kWp	4.9 kWh/day – 1.01 kWp
Load timestep and day-to-day variability	10%	10%
PV panel cost		
Battery cost		
Maximum annual capacity shortage		
Location		

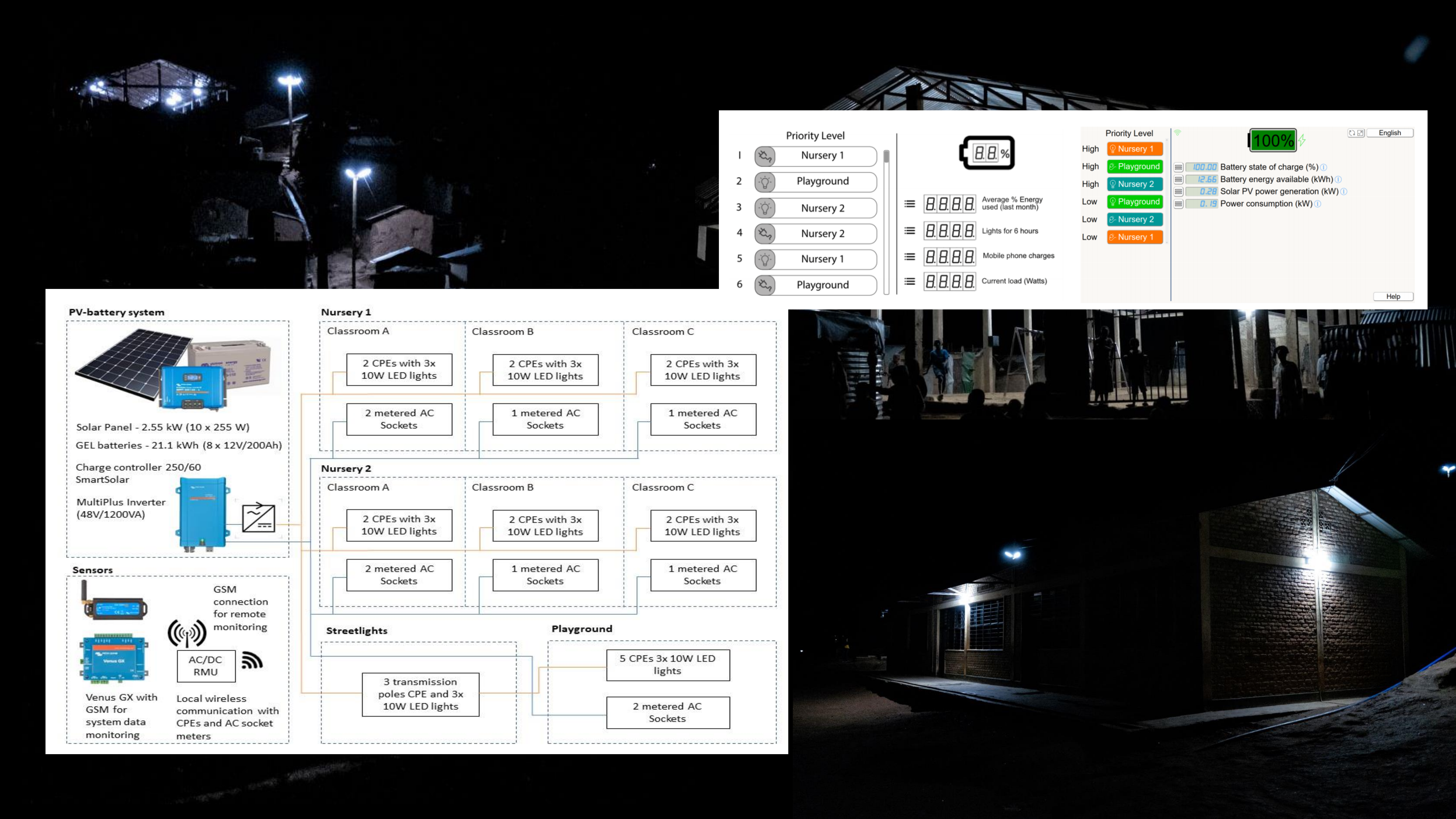
Product	Wattage per unit	Number of units	Hours of use	Estimated kWh used per day
micro-grid				
Playground lighting	10	32	06:00-08:00; 19:00-23:00	1.92
Phone charging	5	4	08:00-14:00; 16:00-19:00	0.18
Torch charging	5	4	08:00-09:00; 18:00-19:00	0.04
Radio	10	2	08:00-09:00	0.02
Small sound system	80	1	09:00-10:00; 17:00-19:00	0.24
Nursery 1 lighting	10	12	06:00-10:00; 15:00-22:00	1.32
Nursery 2 lighting	10	12	06:00-10:00; 15:00-22:00	1.32
Computer	250	2	13:00-14:00	0.5
Phone charging	5	12	12:00-13:00	0.06
Iron	500	1	12:00-12:20	0.15
Hall				
Hall lighting	10	20	06:00-08:00; 16:00-21:00	1.4
Phone charging	5	20	08:00-12:00; 15:00-16:00	0.5
Hall TV	200	1	11:00-15:00; 16:00-18:00	1.2
Music and sound system	300	1	11:00-15:00; 16:00-18:00	1.8

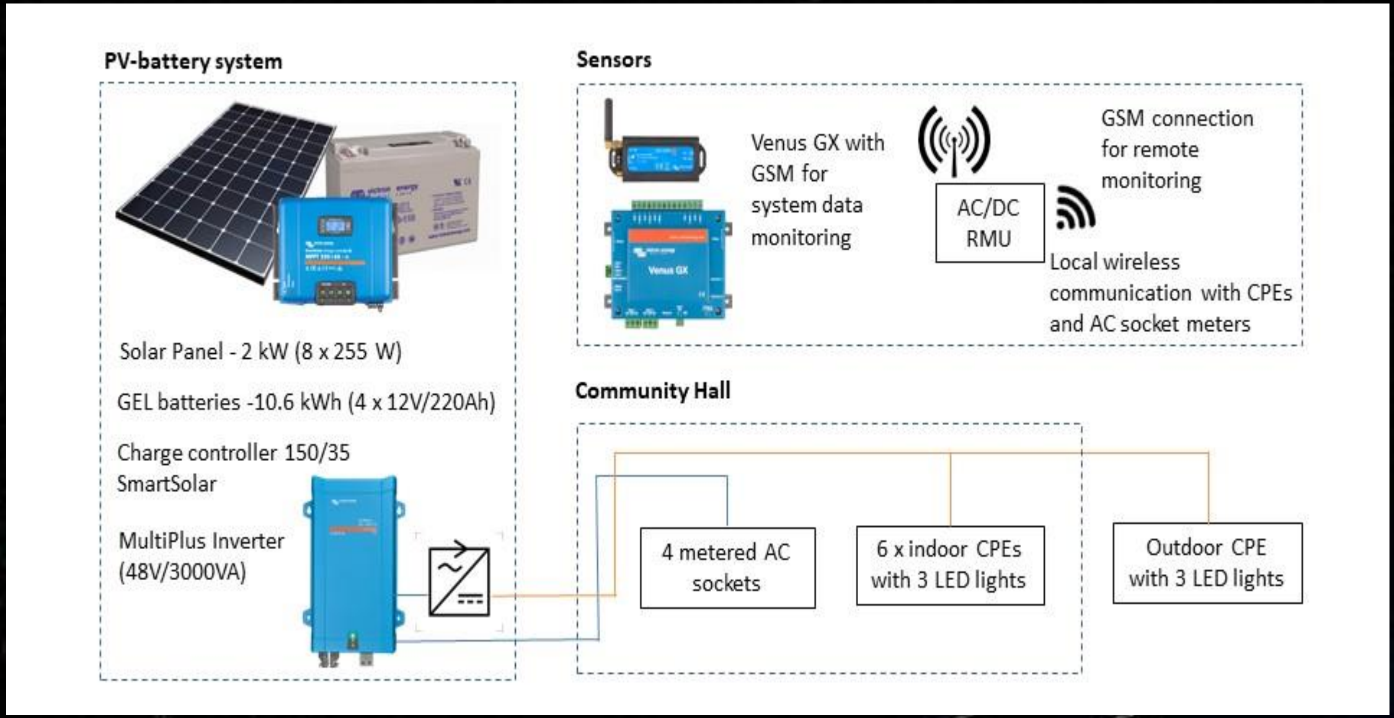




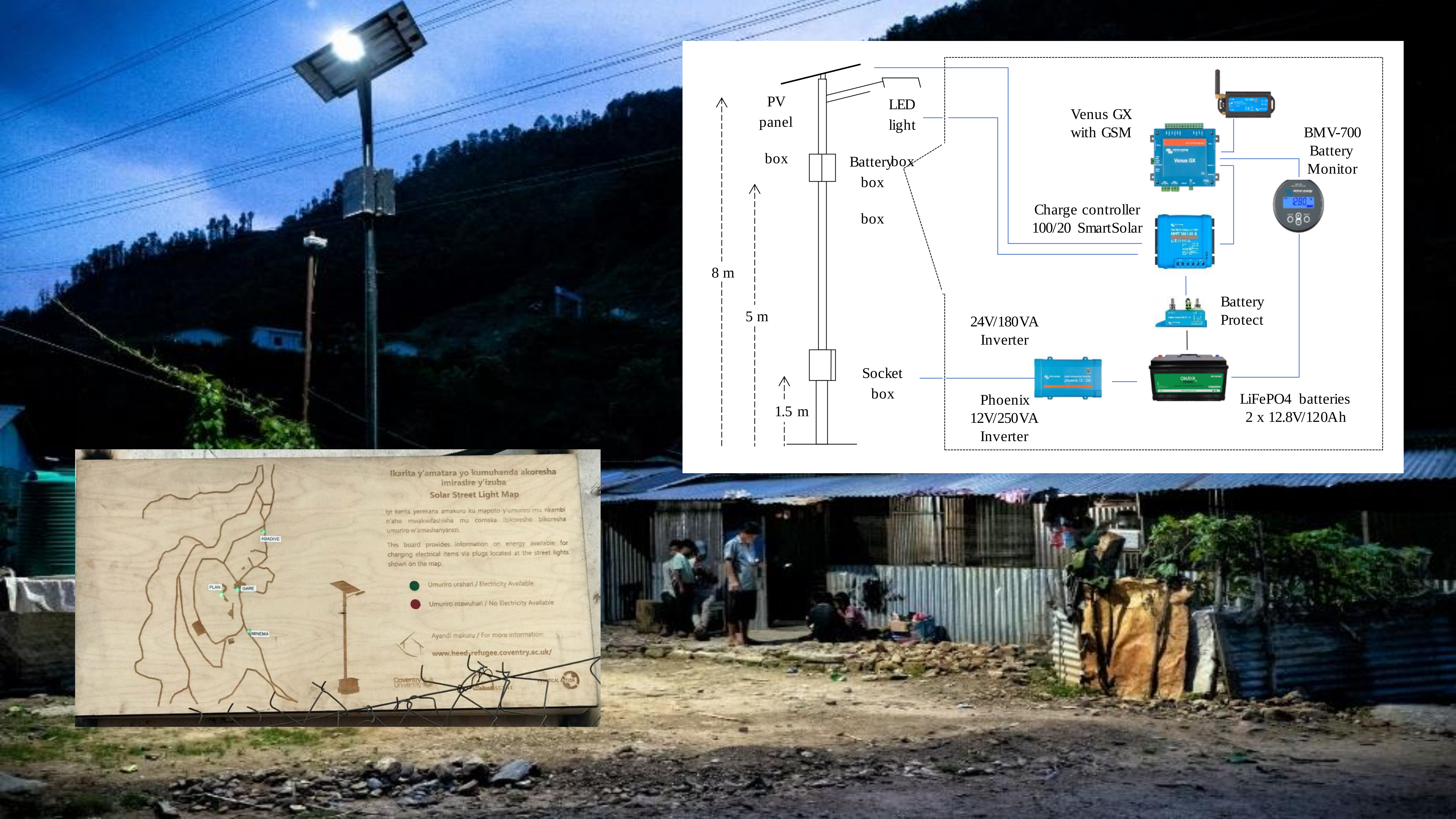
System Design

	Kigeme Micro-grid	Nyabiheke Hall	Gihembe Streetlight
			
System	Solar Panels – 2.55 kW (10 x 255 W) GEL batteries – 21.1 kWh (8 x 12V/200Ah) Inverter – 48V/1200VA	Solar Panels – 2 kW (8 x 255 W) GEL batteries – 10.6 kWh (4 x 12V/220Ah) Inverter – 48V/3000VA	Solar Panel – 320 Watt Li-ion batteries – 3.1 kWh (2 x 12.8V/120Ah) Inverter – 12V/180VA
Output	Two nurseries – 8 sockets/36 lights Playground – 2 sockets/15 lights Streetlights – 3	4 sockets 18 indoor lights /6 outdoor lights	Ground-level AC sockets with USB ports 60 Watt LED light


PV-battery system
Solar Panel - 2.55 kW (10 x 255 W)
GEL batteries - 21.1 kWh (8 x 12V/200Ah)
Charge controller 250/60 SmartSolar
MultiPlus Inverter (48V/1200VA)
Sensors
GSM connection for remote monitoring
AC/DC RMU
Venus GX with GSM for system data monitoring
Local wireless communication with CPEs and AC socket meters
Nursery 1
Classroom A
2 CPEs with 3x 10W LED lights
2 metered AC Sockets
Classroom B
2 CPEs with 3x 10W LED lights
1 metered AC Sockets
Classroom C
2 CPEs with 3x 10W LED lights
1 metered AC Sockets
Nursery 2
Classroom A
2 CPEs with 3x 10W LED lights
2 metered AC Sockets
Classroom B
2 CPEs with 3x 10W LED lights
1 metered AC Sockets
Classroom C
2 CPEs with 3x 10W LED lights
1 metered AC Sockets
Streetlights
3 transmission poles CPE and 3x 10W LED lights
Playground
5 CPEs 3x 10W LED lights
2 metered AC Sockets
Priority Level
1 Nursery 1
2 Playground
3 Nursery 2
4 Nursery 2
5 Nursery 1
6 Playground
Average % Energy used (last month)
Lights for 6 hours
Mobile phone charges
Current load (Watts)
Priority Level
High Nursery 1
High Playground
High Nursery 2
Low Playground
Low Nursery 2
Low Nursery 1
100%
English
100.00 Battery state of charge (%)
12.56 Battery energy available (kWh)
0.28 Solar PV power generation (kW)
0.19 Power consumption (kW)
Help

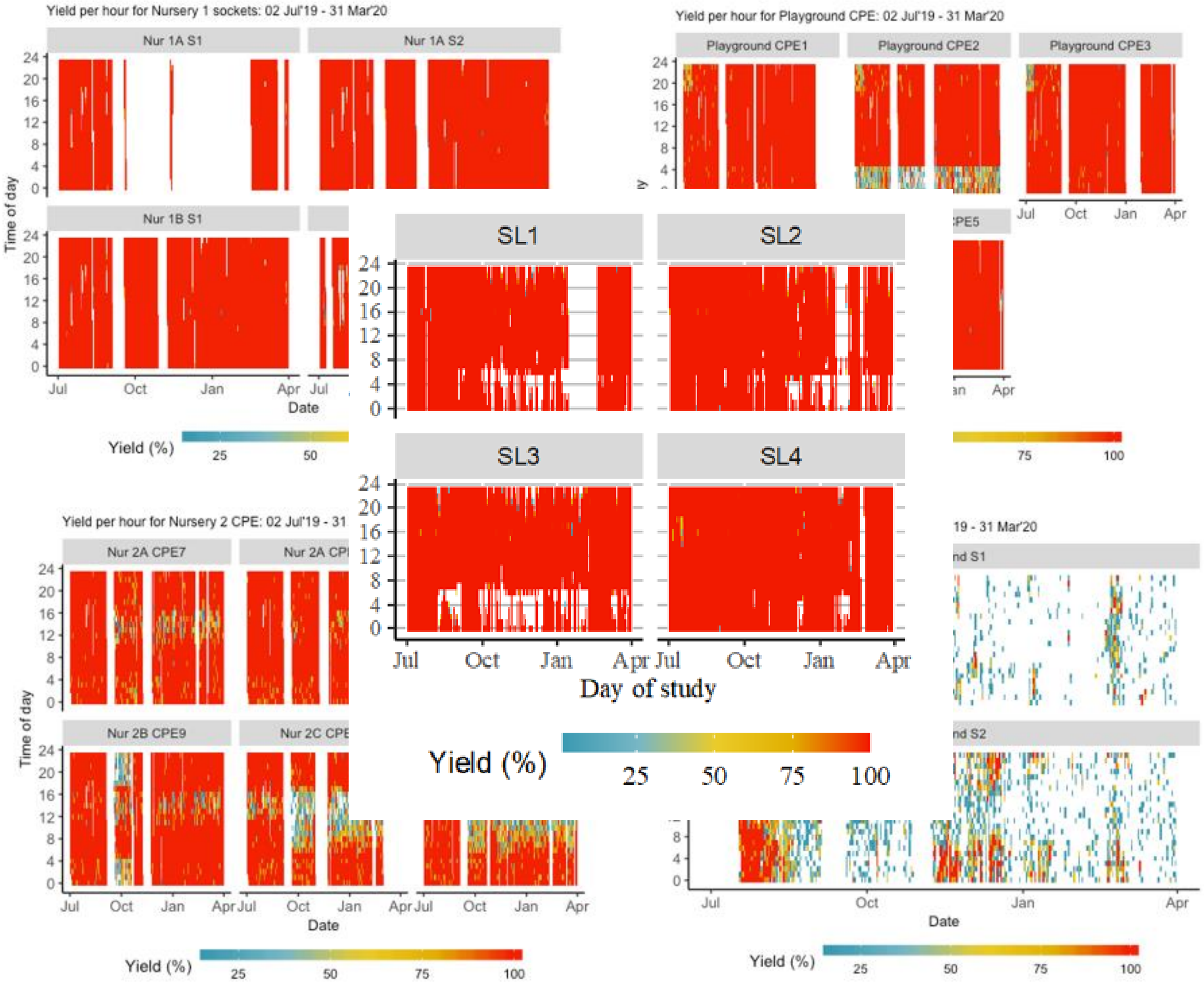


PV-battery system
Solar Panel - 2 kW (8 x 255 W)
GEL batteries -10.6 kWh (4 x 12V/220Ah)
Charge controller 150/35 SmartSolar
MultiPlus Inverter (48V/3000VA)
Sensors
Venus GX with GSM for system data monitoring
AC/DC RMU
GSM connection for remote monitoring
Local wireless communication with CPEs and AC socket meters
Community Hall
4 metered AC sockets
6 x indoor CPEs with 3 LED lights
Outdoor CPE with 3 LED lights

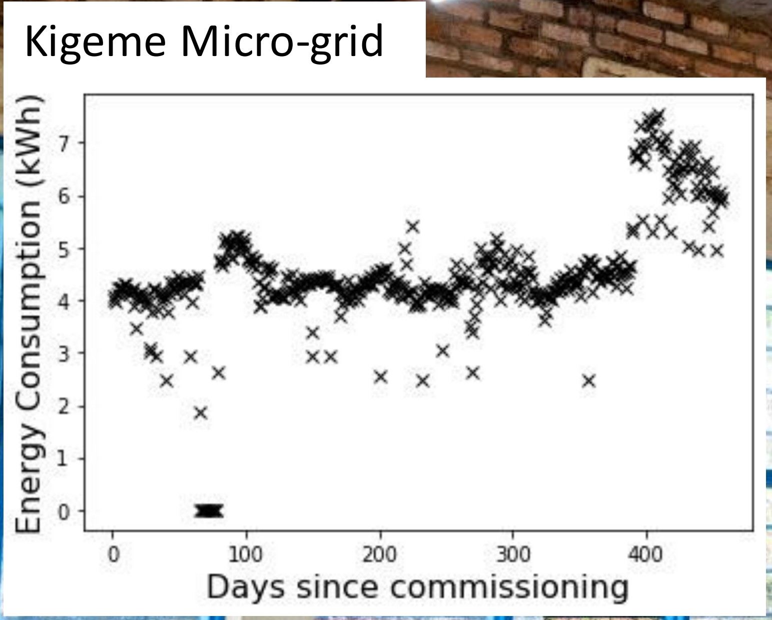

PV
panel
box
LED
light
Battery box
box
box
Socket
box
8 m
5 m
1.5 m
Venus GX
with GSM
BMV-700
Battery
Monitor
Charge controller
100/20 SmartSolar
Battery
Protect
24V/180VA
Inverter
Phoenix
12V/250VA
Inverter
LiFePO4 batteries
2 x 12.8V/120Ah
Ikarita y'amatara yo kumuhanda akoresha
imirasire y'izuba
Solar Street Light Map
Iyi karita yerekana amakuru ku mapoto y'umuriro mu nkambi n'aho mwakwifashisha mu comeka ibikoresho bikoresha umuriro w'amashanyarazi.
This board provides information on energy available for charging electrical items via plugs located at the street lights shown on the map.
Umuriro urahari / Electricity Available
Umuriro ntawuhari / No Electricity Available
Ayandi makuru / For more information:
www.heed-refugee.coventry.ac.uk/
ABADIVE
PLAN
GARE
MINEMA

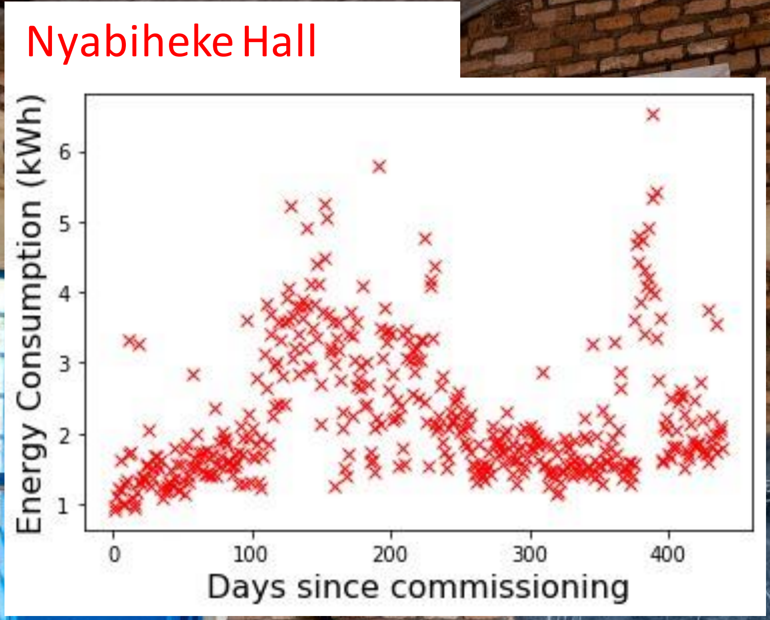
Data availability

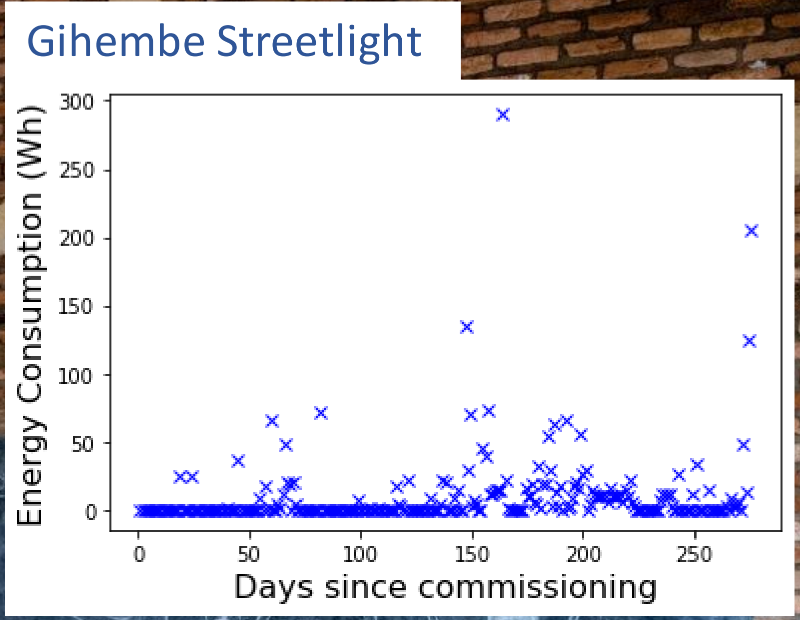
- Incomplete data due to power outages, communication failures and component failures
- Need to avoid bias in analyses due to missing data
- Evaluate behaviour of data as well as the nature of missing data
- Assess options for imputation



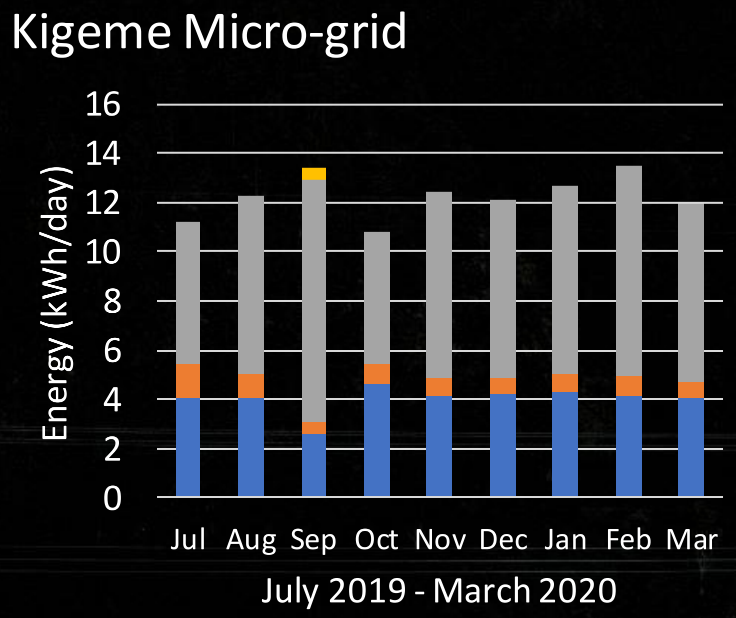
Energy Consumption

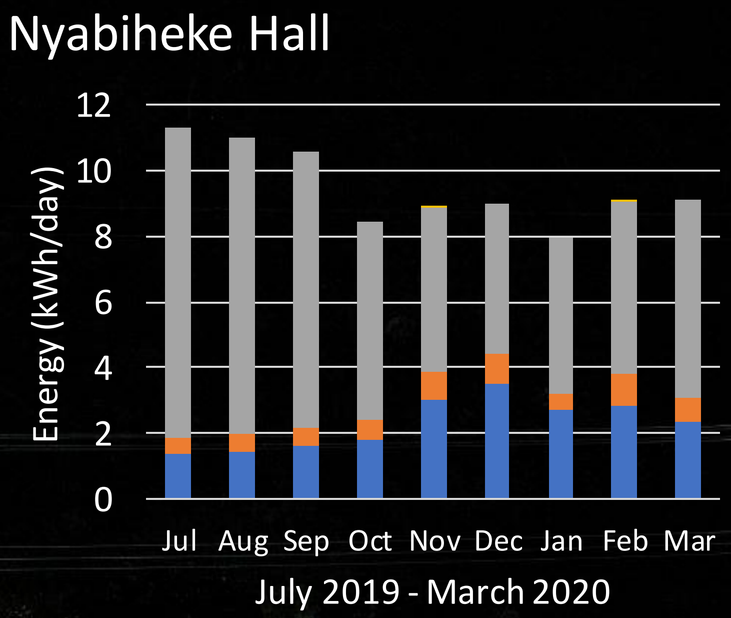


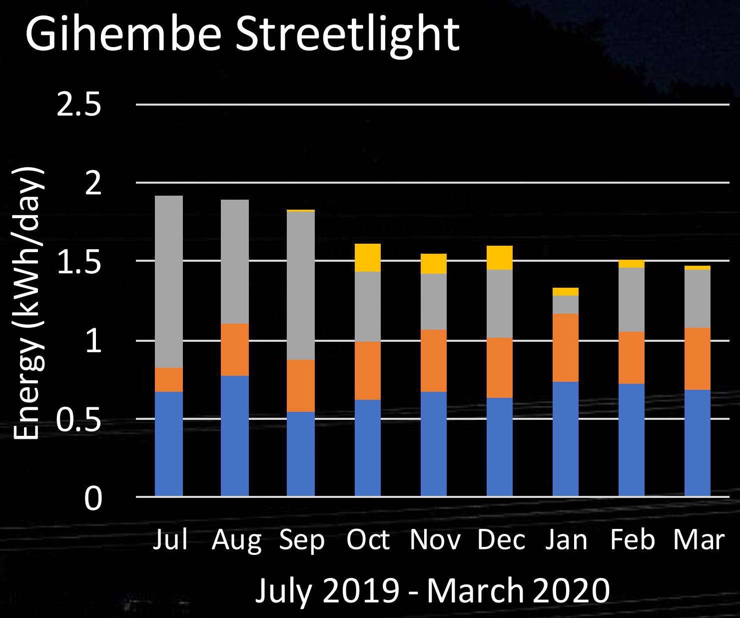




Energy Available

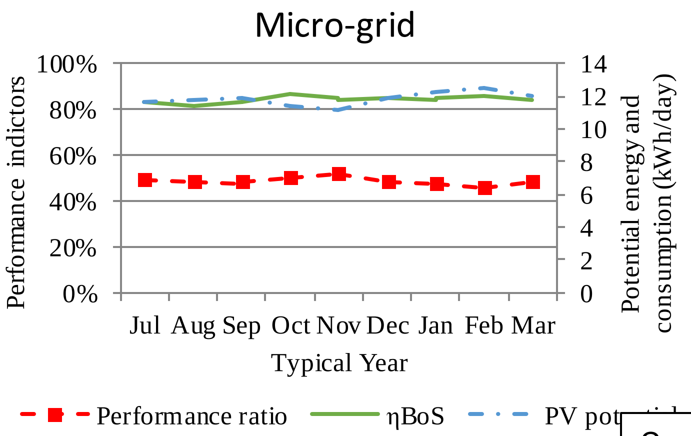


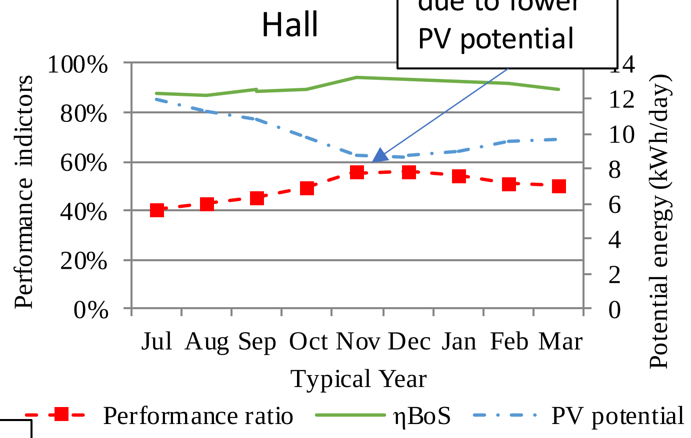




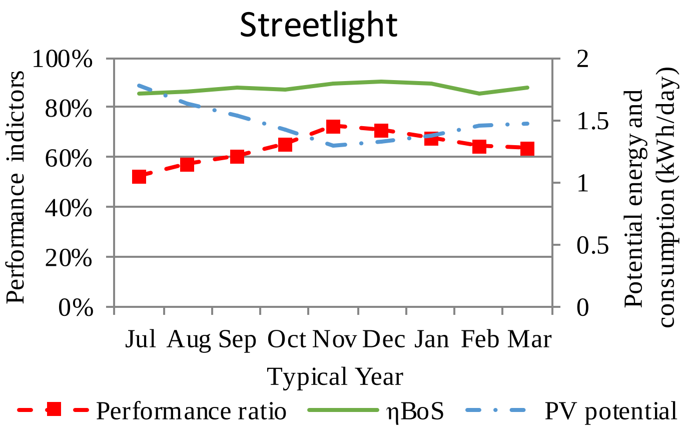
Standalone solar system performance

Design



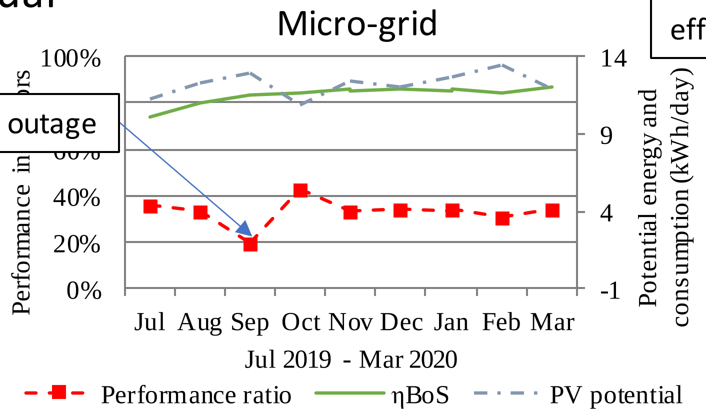


Higher PR due to lower PV potential

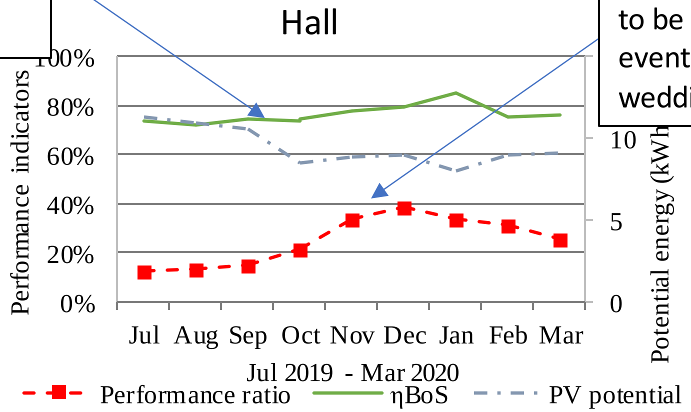


Actual

Power outage

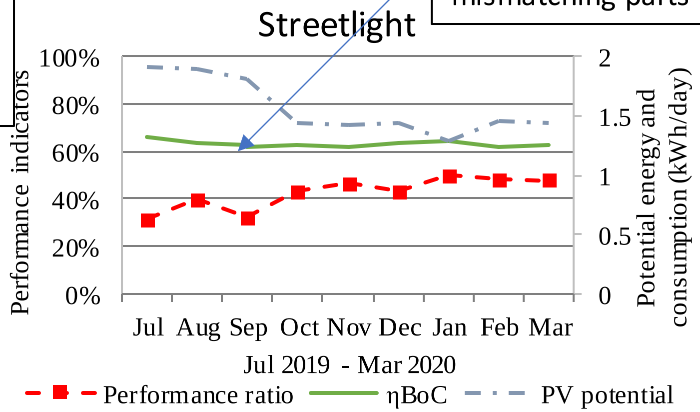


Oversized inverter reduced BoS efficiency



Hall starting to be used for events (e.g. weddings)

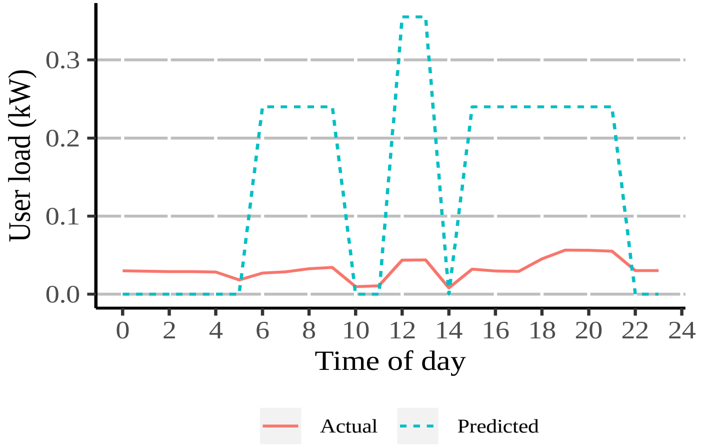
Low system efficiency due to mismatching parts



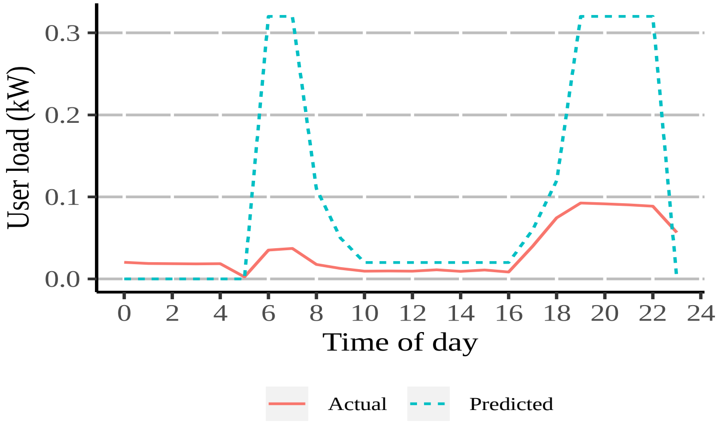
User energy demands

Actual loads were much lower than predicted

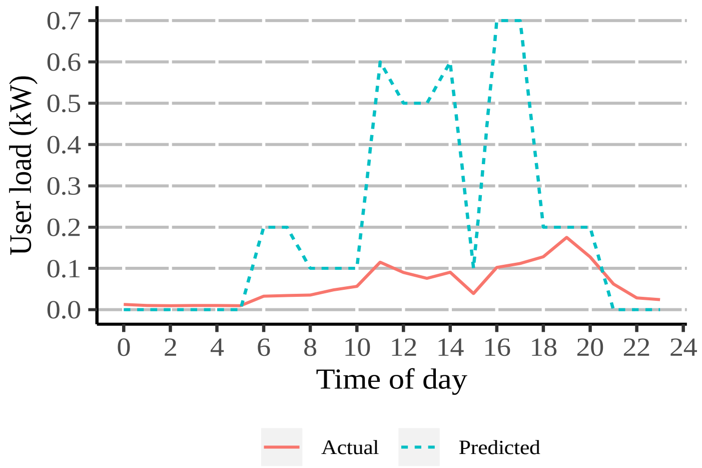
Micro-grid nursery



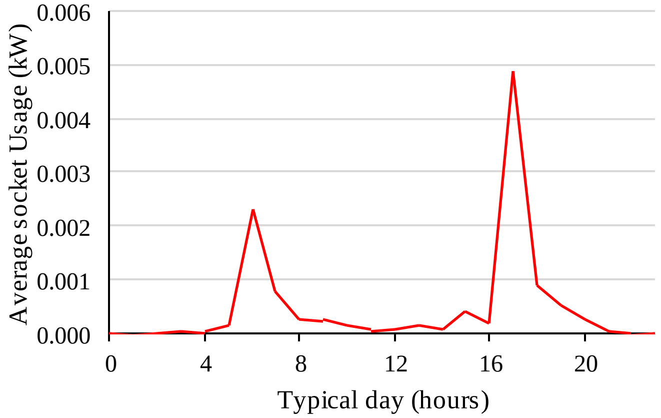
Micro-grid playground



Community hall



Actual socket usage at an advanced streetlight



Energy patterns and trends

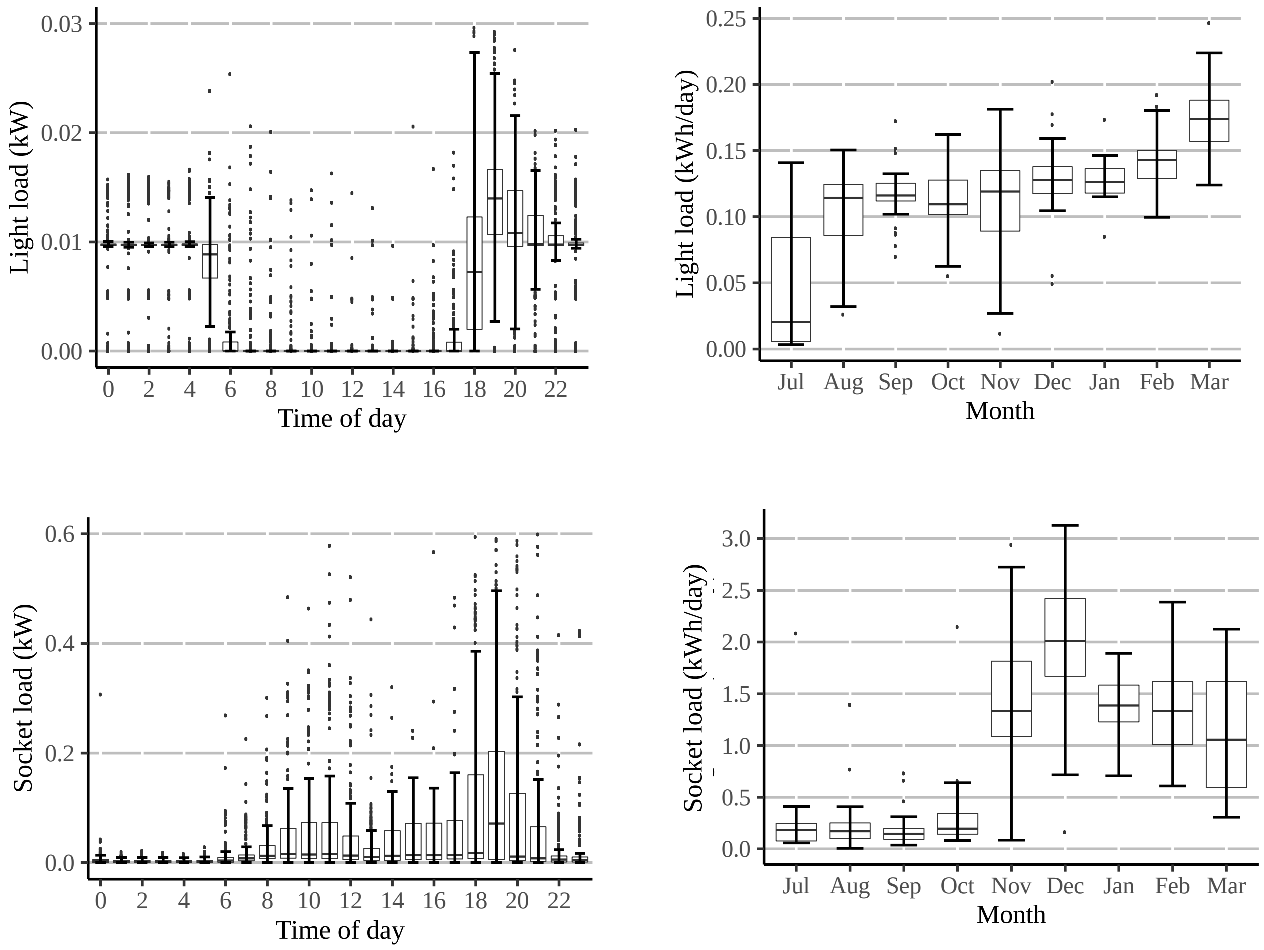
At the micro-grid

- Socket loads fairly constant – around 1-3 Watts per socket
- Light usage at the nurseries decreased

At the hall

- Higher energy consuming devices were used more frequently
- Peak usage at the Hall was 1.2 kW (micro-grid was around 0.7 kW)
- In addition to charging batteries, phones and torches, other devices used included an electric kettle, a television and an entertainment system
- Light usage increased consistently from an average of 0.02 to 0.18 kWh/day

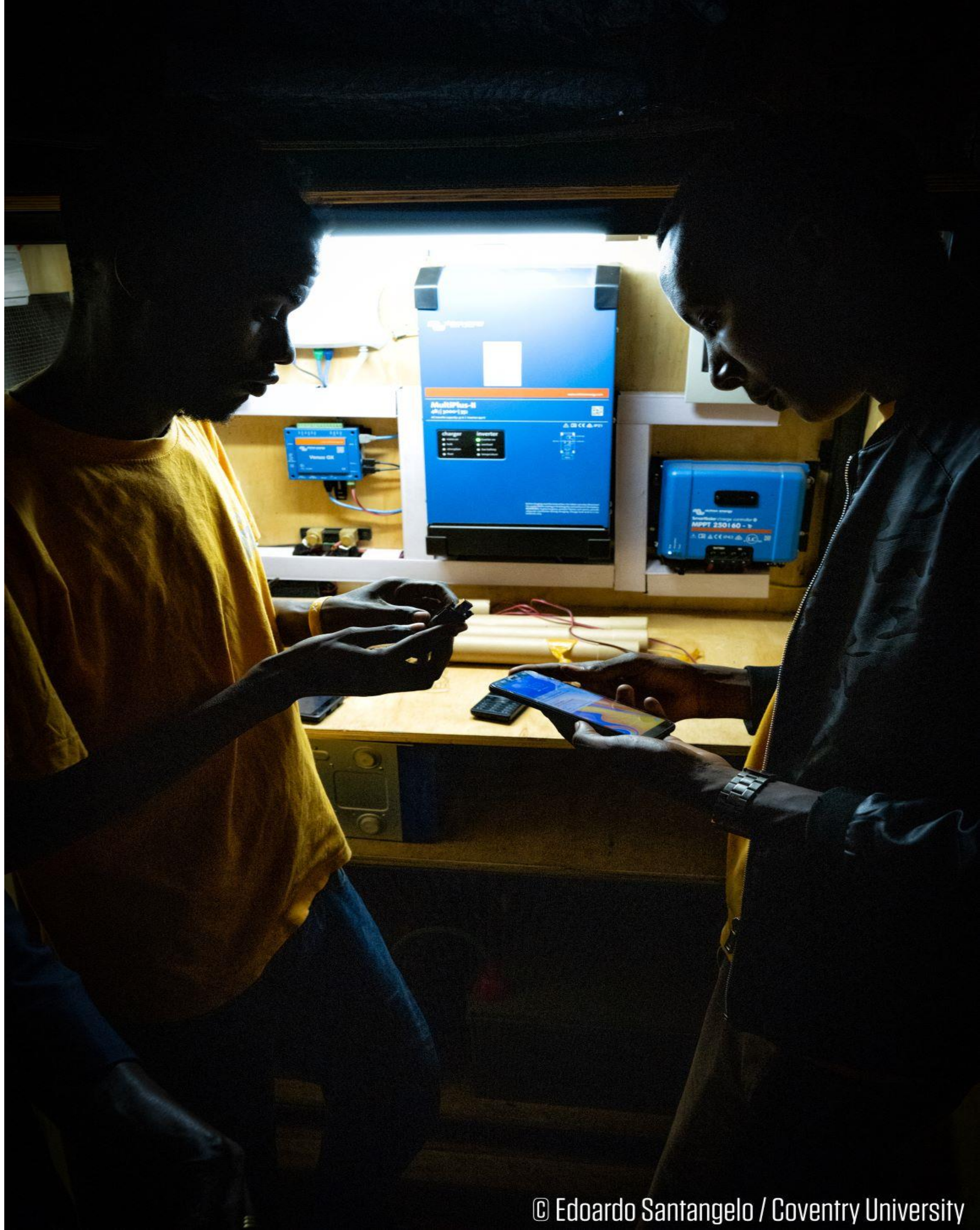
Hall



System Performance

System performance was reduced due to:

- Generation-demand mismatch (supply vs utilisation)
- Component inefficiencies, availability and faults
- Unfulfilled entrepreneurship potential
- Limited access for users and suppliers
- Community perception of outages



Implications for system design

- **Establish, manage and meet community energy demands in new ways**
- Ascertain real energy demands prior to wider deployment where possible
- Understand community use and access to facilities and electronic devices
- Engage marginalised groups, such as young people and women, in the energy discussion
- Frame energy as a service, not only a system to challenges unequal power structures between institutions and displaced communities, as displaced people are seen as service users, rather than dependents
- Develop ownership models that centre on the management of systems as community assets
- Before designing an intervention, promote ownership and self-governance to ensure survivability and effective system utilisation
- Balance reliability (supply to meet demand), longevity of parts, component performance and cost of energy.
- Build flexible into designs to be able to respond to fluid situations and changes in energy demands

- **Implement training/skills development to future proof interventions**
- Engage community to build capacity and capability of displaced people
- ‘Energy apprentices’ for simple repairs, fault reporting and maintenance
- ‘Gatekeepers’, who can work with the community to encourage engagement with new technologies

Implications for system design

- **Perform pre-deployment site and local host market assessments**
- Assess implementation challenges and opportunities for deployment at the design stage
- Make appropriate trade-offs to balance desired functionality with these challenges (access for vehicles and contractors; space for structures; terrain; environment, etc.).
- Balanced use of advanced modern components and market-established products available in local host communities

- **Improve monitoring systems to support communities and improve post-intervention evaluations**
- Implement sensor systems that can distinguish system outages, faults, maintenance and communications issues
- Develop robust data monitoring, handling and analysis approaches to take into account unexpected events (which are likely to be numerous and challenging to track over a long analysis period)
- Use low-power, low-cost independently powered sensors
- Use simple information technology to support fair sharing and access of a community energy resource

A Bright Future?

What are our best chances of providing universal energy access and eliminating energy poverty?

- Interdisciplinary, transdisciplinary, and sociotechnical approaches, with greater inclusivity of communities.
- Greater awareness of structural inequality and the impact on people’s lives (i.e. gender, race, disability, class, sexuality).
- Recognising engineers have a pivotal role in combating tropes around renewable energy, advocating new ways of approaching energy poverty, and creatively responding to solutions.
- Projects that are impactful are often those that communicate directly with communities on an ongoing basis and engage in shared aims, concerns and outcomes.

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For further information, see our website and data portal:

http://heed-refugee.coventry.ac.uk/

https://heed-data-portal.coventry.ac.uk