



Solar electricity & hot water for dispersed off-grid households in Botswana

Pugsley, A., Muhumuza, R., Giuzio, G. F., Zacharopoulos, A., Smyth, M., McLarnon, D., & Mondol, J. (2018). Solar electricity & hot water for dispersed off-grid households in Botswana: Demand-based sizing & Prototype testing initial results . In *2nd International Conference on Solar Technologies & Hybrid Mini Grids to improve energy access*

[Link to publication record in Ulster University Research Portal](#)

Published in:

2nd International Conference on Solar Technologies & Hybrid Mini Grids to improve energy access

Publication Status:

Published (in print/issue): 17/10/2018

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Solar electricity & hot water for dispersed off-grid households in Botswana

Demand-based sizing & Prototype testing initial results

Dr Adrian Pugsley
Centre for Sustainable Technologies

Introducing: SolaFin2go

and an overview of presentation content

Addressing challenges of clean & affordable off-grid modern energy to Sub-Saharan African households

- Solar & Storage providing Electricity & Hot water
- Energy-as-a-service business models for the “unbanked”

- 1) Botswana country context
- 2) Household energy demands
- 3) System size & cost
- 4) Concept prototype
- 5) Initial laboratory tests
- 6) Jamataka field trial
- 7) Ongoing & future work



Solar energy research (Project lead)



Robust photovoltaic modules for extreme climates



Fintech PAYG platform based on mobile, cloud & blockchain



Innovative solar thermal diode water storage heater



Joint funders
Energy Catalyst Round 5



Solafin2go technology concept

Key components



1) Botswana context

Dispersed rural communities awaiting a national grid that will never come...

Country and population:

- Low-middle income, natural resources, stable democratic government
- Small population (2.5M) in a large land area (size of France)
- Urban populations served by electricity grid (coal fired)
- Dispersed rural populations (>0.5M) unfeasible to electrify with mains grid

Willing & able to pay:

- Many “unbanked” citizens with limited capital and no access to finance, but...
- Rural communities currently pay for dirty fuels, phone charging & batteries
- Government has budget for electrification but favours incumbent “fossil-grid”
- 130,000 households market (\$47M) for off-grid solar (*World Bank, 2017*)

2.1) Household energy demand variables

HOUSEHOLD INCOME	High	Middle	Low
FAMILY SIZE	Small	Large	
SOCIAL CONTEXT	Urban	Rural	
ELECTRICITY ACCESS	Mains grid	Petrol Generator	Off-grid PV No access!
ELECTRICAL APPLIANCES	Similar to households in Europe & OECD	Fridge / freezer TV & Music systems Fixed lighting	Battery torch / Solar lantern Mobile phones & radios
FUEL AVAILABILITY	LPG	Fuelwood /charcoal	Dirty biomass
HOT WATER APPLIANCES	Electric boiler Solar water heating	Gas boiler	Pot on gas burner Pot on solid fuel stove or open fire

2.2) Household energy demand in SSA



- ELECTRICITY (kWh/day) [Essah & Ofetotse, 2015; IEA, 2014; Prinsloo et al., 2016]
- HOT WATER (kWh/day) [Meyer, 2000; Ferrer, 2017; Curry, 2017]
- COOKING (kWh/day) [Bachelor et al., 2018; Prinsloo et al., 2016]
- TOTAL??? (kWh/day)

3) System size & cost

What is an “entry level” system?

Meet electricity & hot water demand in low/mid income off-grid households:

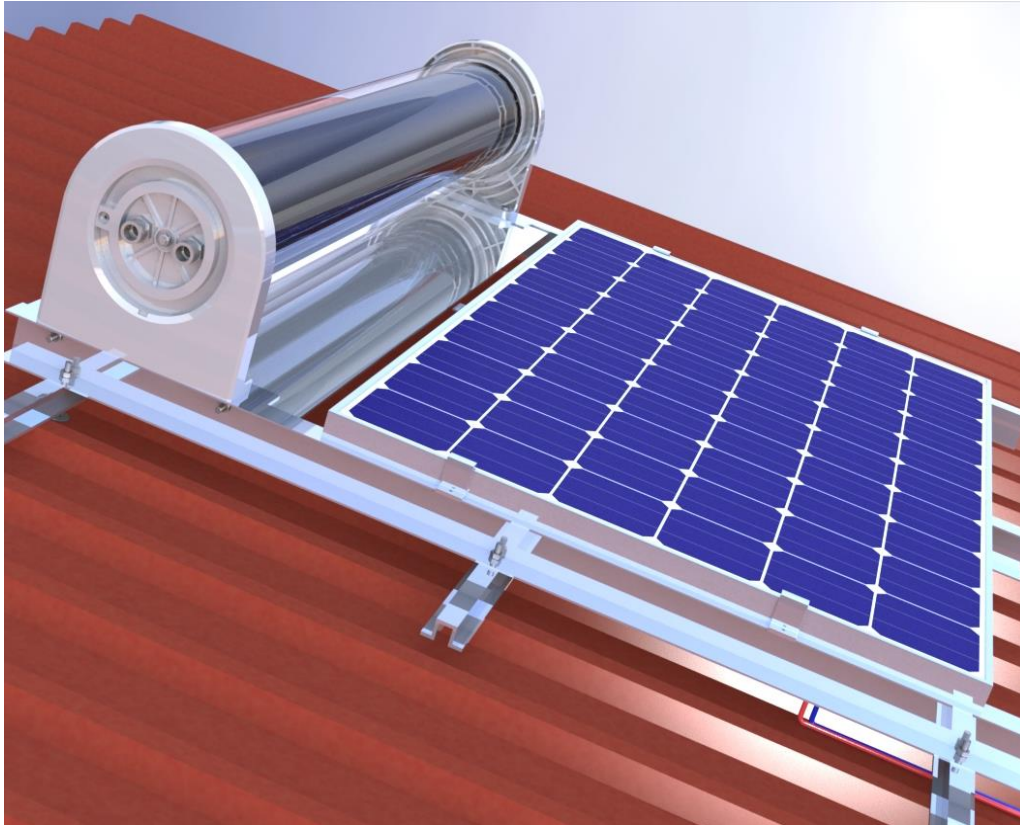
- 0.8 kWh/day electricity (lights, TV, phones, maybe small fridge)
- 1.1 kWh/day hot water (equivalent 20 litres at 65°C)

Affordable for users & viable for investors:

- Capital cost target ~ £600
- End user cost ~ £25/month enables ROI after 2 years
- Modular & upgradable to meet changing (increasing) user demands
- BATTERY COST!!!

4.1) Prototype development

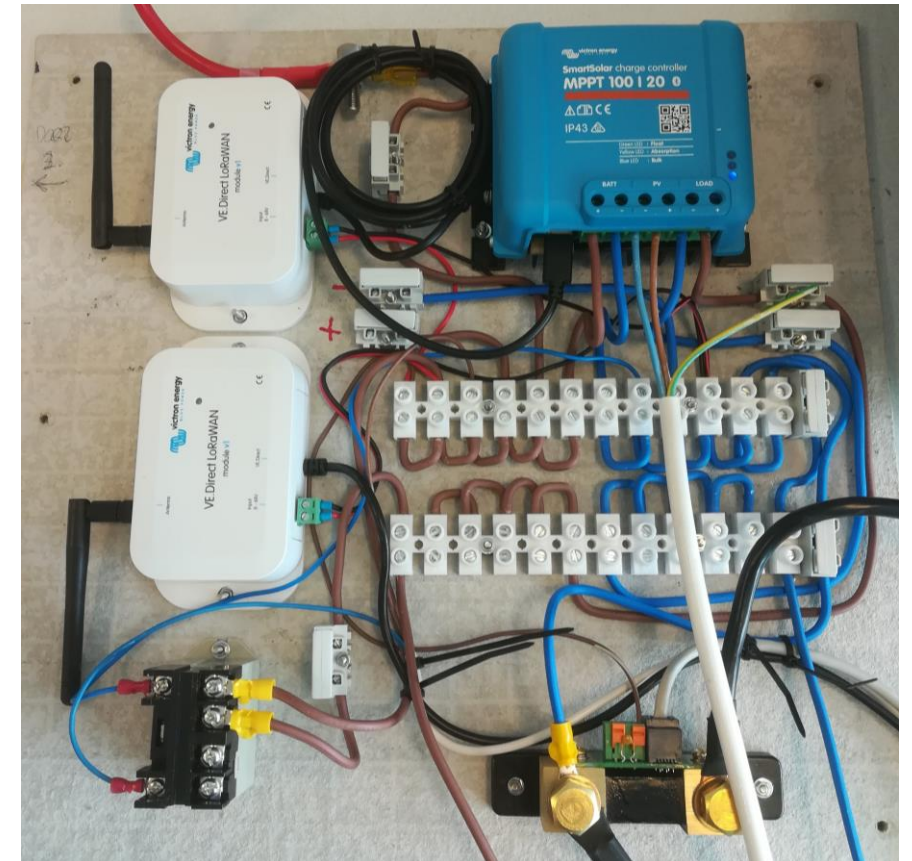
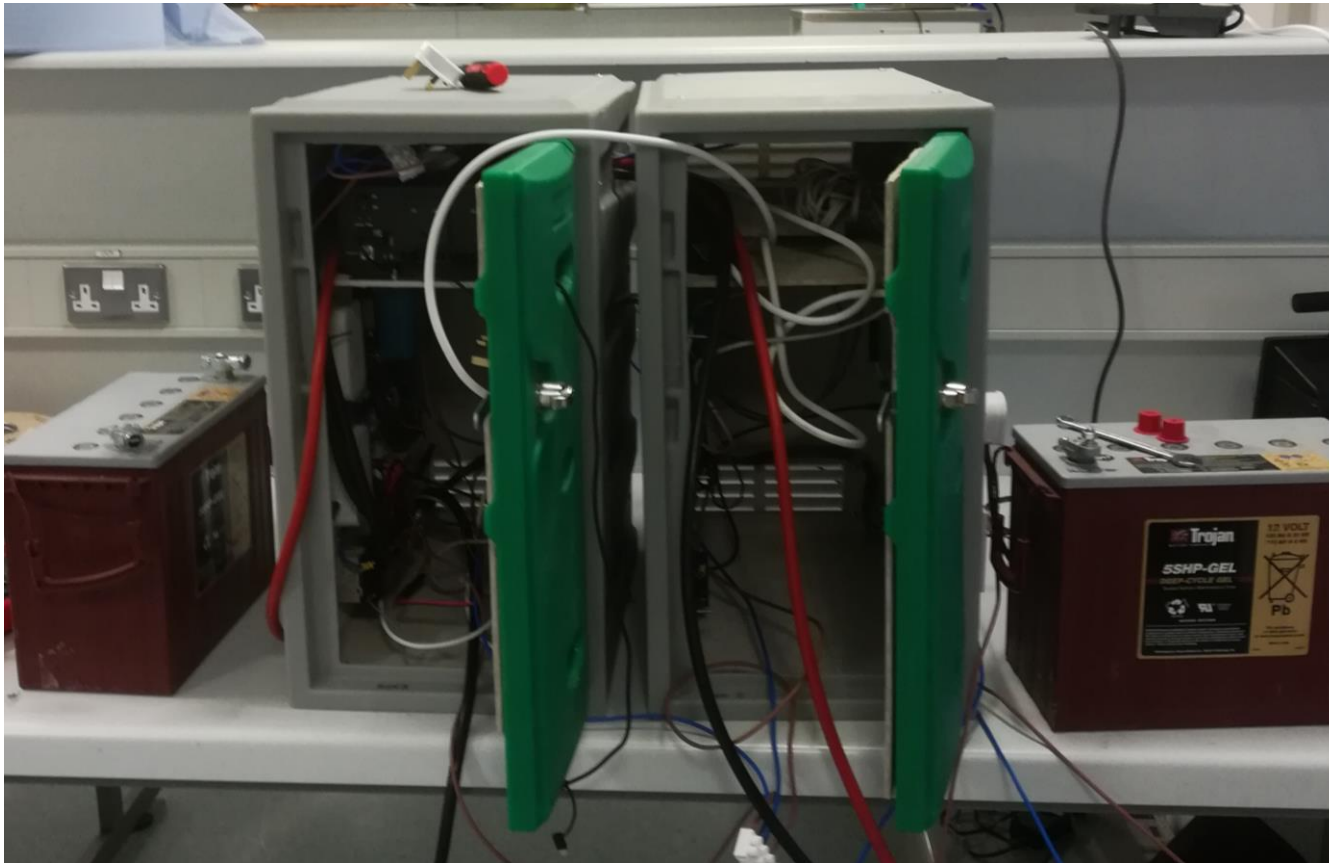
Key components and concepts



- Standard size PV modules (60-cell @ 275Wp) for optimum cost-benefit
- Battery sized for autonomy in typical periods of cloudy weather (125Ah @ 12V)
- 30 Litre integrated-collector-storage “*Solacatcher*” solar water heater with heat retaining thermal diode
- Controller (MPPT): manage battery charging & loads & utilise surplus electricity to boost hot water production
- Communication: energy consumption and system status reported to cloud via LoRaWAN & mobile phone network

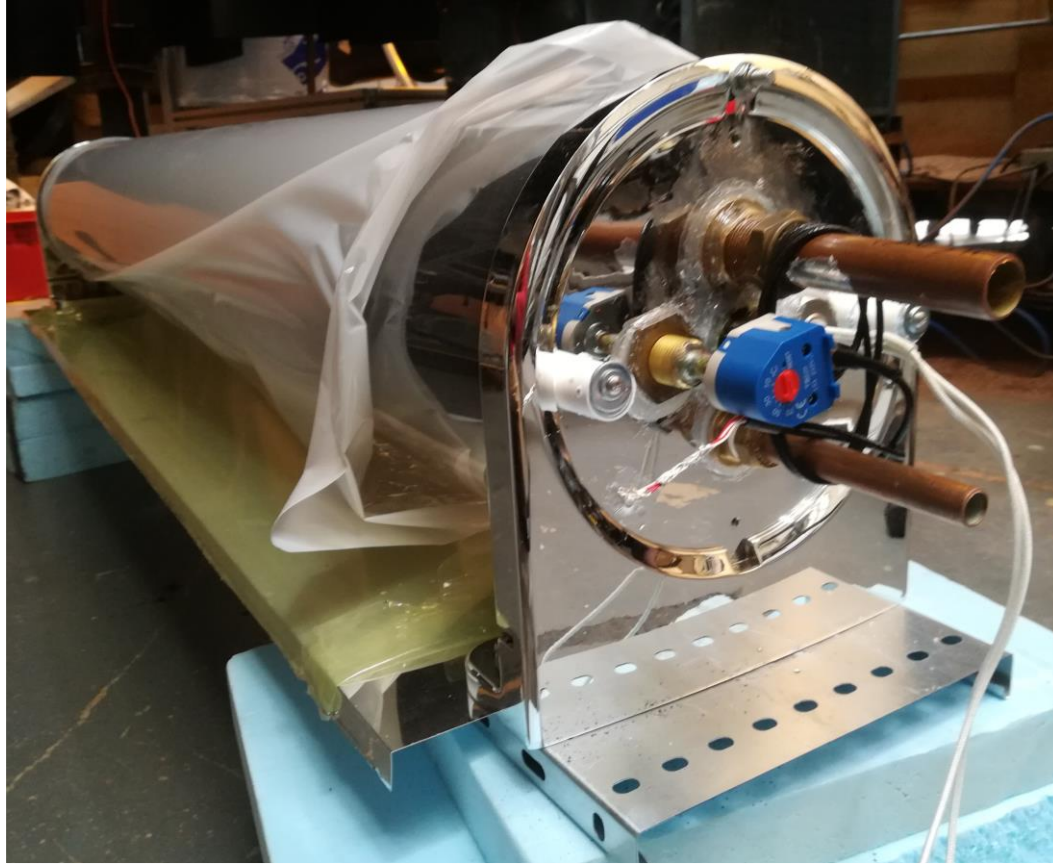
4.2) Prototype development

Batteries, controllers & communications



4.3) Prototype development

Solacatcher fabrication



5.1) Initial laboratory tests

Setup and test conditions

Start test with:

- Battery at close to full charge
- Water tank full & at ambient temperature

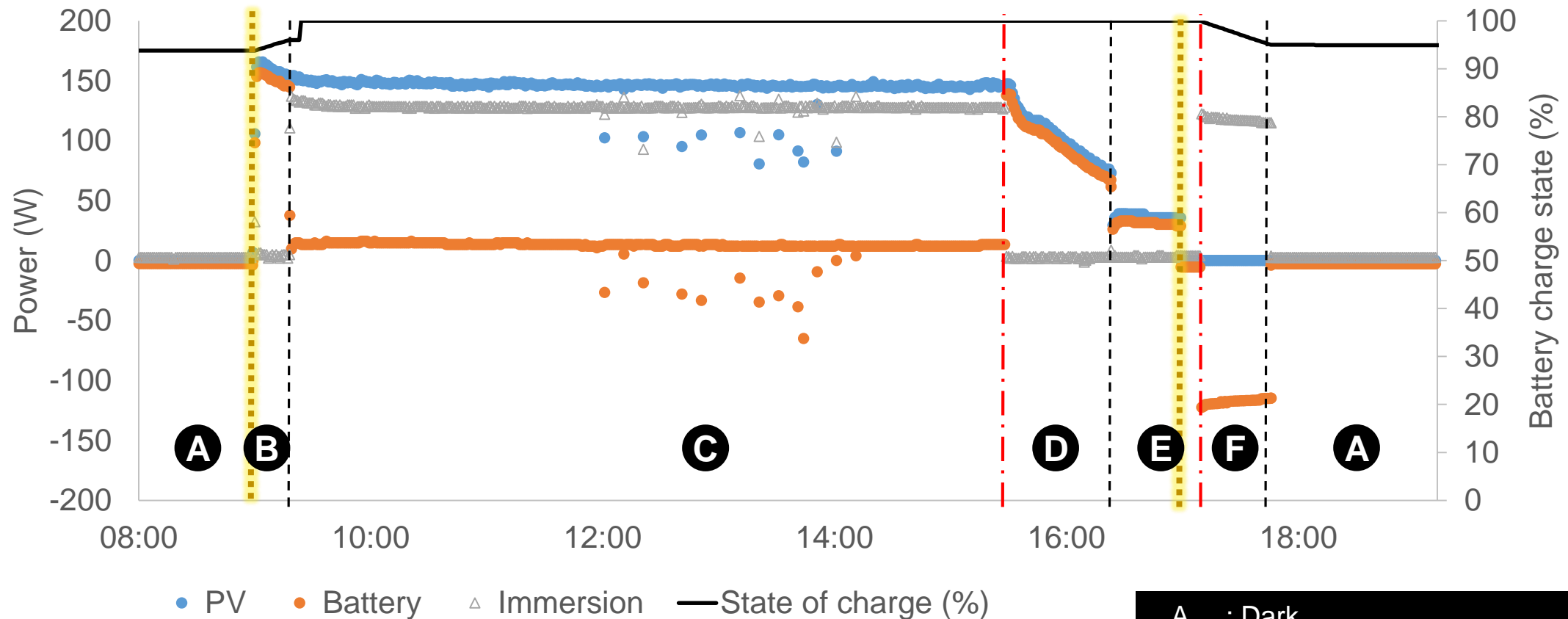
Test for 48hr period:

- 8 hr daytime (6 kWh/m²)
- Simulated solar irradiance ~750 W/m²
- No electrical load except immersion heater
- No hot water draw-offs
- 16 hr darkness to assess overnight heat retention



5.2) Initial laboratory tests

Electrical results

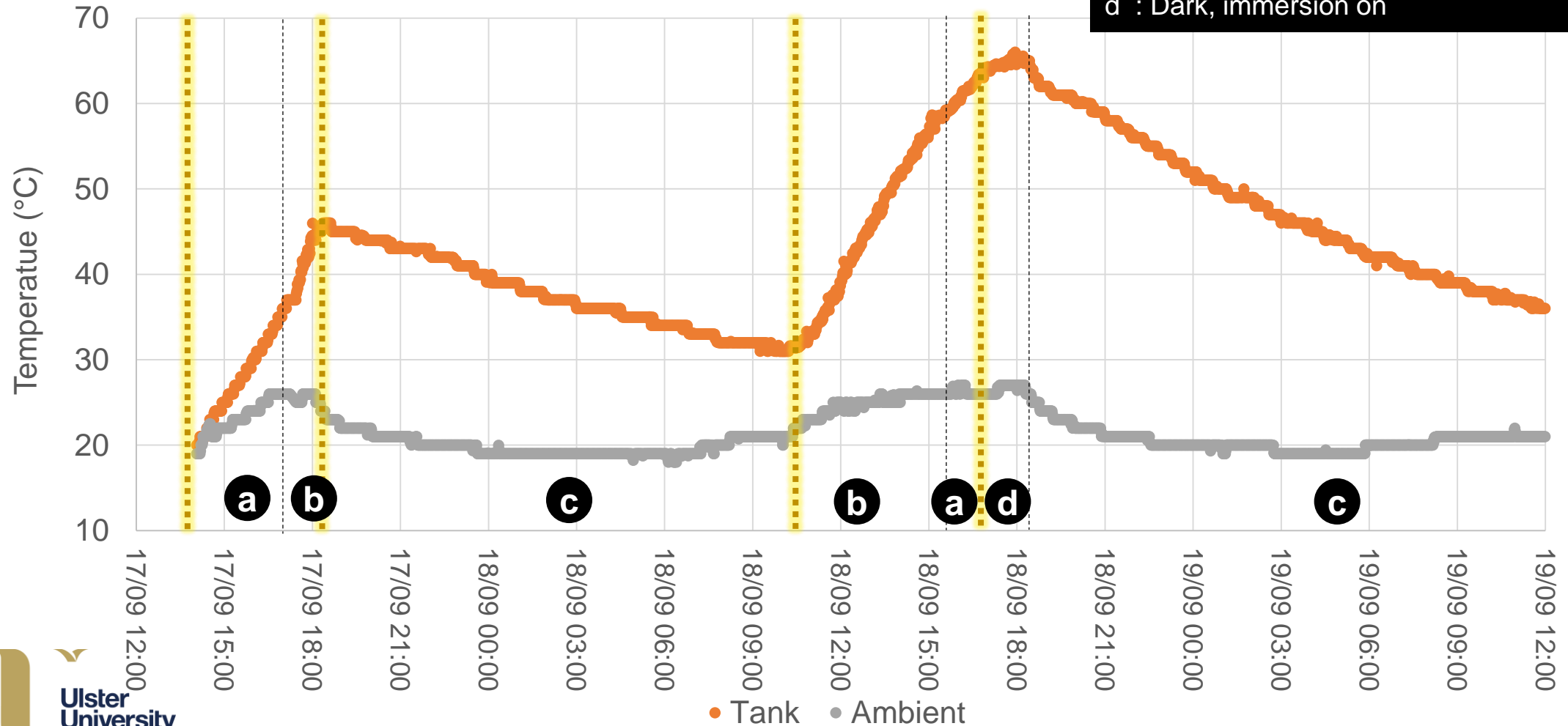


A : Dark
B→E : Simulated sun
A & B : Immersion off (auto)
C & F : Immersion on (auto)
D→E : Immersion off (manual override)

5.3) Initial laboratory tests

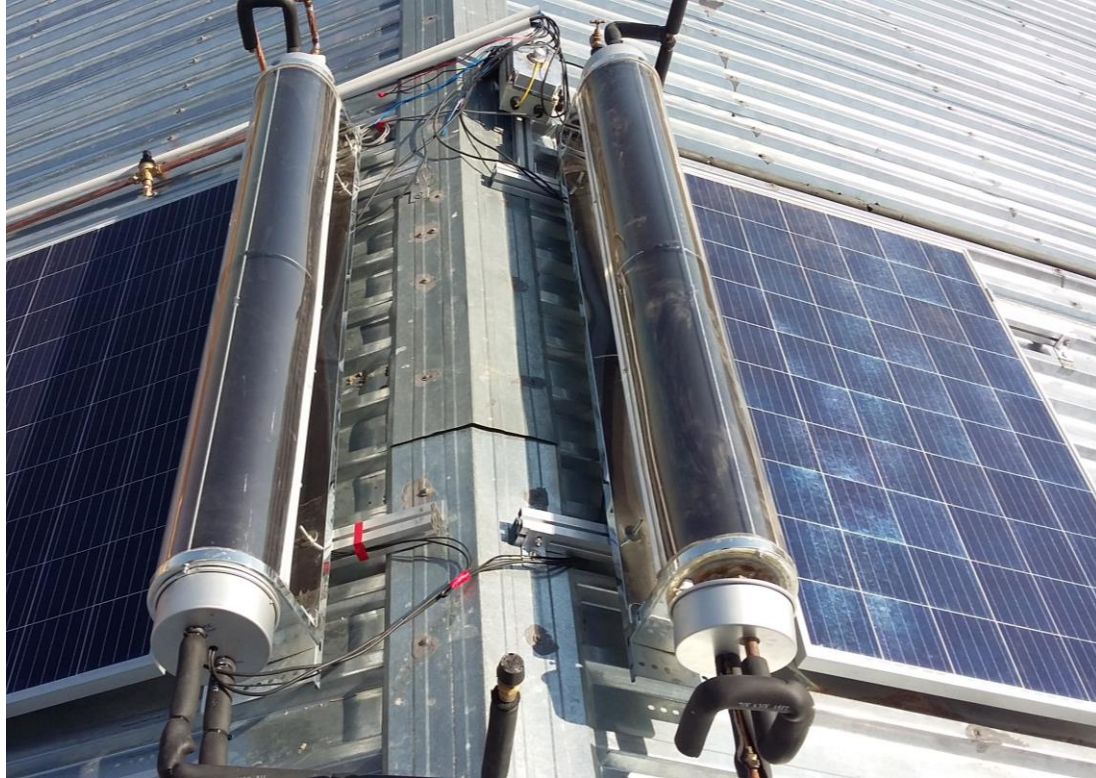
Thermal results

a : Simulated sun, immersion off
b : Simulated sun, immersion on
c : Dark, immersion off
d : Dark, immersion on



6) Jamataka Field trial

Prototype installation October 2018



7) Ongoing & future work

Monitoring and Scaling up

- Feedback from community stakeholders
- Remote monitoring until March 2019 via LoRaWAN and mobile networks
- Energy Catalyst Round 6 funding application
 - Scale-up by installing more systems
 - Organic formation of a prosumer mini-grid network
 - Community empowerment via local DESCo
 - Financial de-risking through business model testing
- Jamataka showcase “solar village”



Solafin2go

Thank you for listening



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