Kenya Commercial Forestry and Investment Conference & Expo, Muguga Kenya, 23-26 November 2021)

Brunel University London

Solar heat to enable reforestation in Kenya - seed pod drying and seed storage

GCRF Global Challenges Research Fund

UK Research and Innovation

EPSRC Engineering and Physical Sciences Research Council

Newton Fund

UKIERI UK-India Education and Research Initiative

BRITISH COUNCIL

Innovate UK

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62 tonnes to make 120 kg of seed

1 kg seed allows 20000 seedlings/plants

To grow 2 billion trees you will require 1 Mkg of seeds

Cost of producing 1 kg of seed

seed costs to planter £70/kg

Ongoing Externally Funded Projects in Concentrating Solar

research funding > £25 million

- **EPSRC**
  - ➢ SUNRISE project (2017-2021 (UKRI's 'Collaborate to Innovate Award' in 2020; 'International Collaboration of the Year' in the Times Higher Education (THE) Awards 2020); Indian partners: IIT Delhi, Bombay and Kanpur; TATA
- **Newton Fund**
  - ➢ UK-Egypt NoNSToP project (2019-2021); Egyptian partner : NRIAG
- **Innovate UK**
  - ➢ SolCoS project; developing 100% solar energy run cold storage in Kenya (2020-2022)
  - ➢ SoFTS project; developing 100% solar energy run forest seed driers (2020-2021)
  - ➢ InSET4KTI project for drying tea leaves for for Kenyan Tea Industry (2019 – 2021)
- **UKIERI-DST funding**
  - ➢ COSTARMSW project Solar thermophilic anaerobic reactor for valorising the Municipal Solid Waste (2019-2021); Indian partners: IIT Delhi; National Institute of Technology Trichy
- **H2020** funded ReCO2ST and CO2OLHEAT projects (2017-2021)
- **Industry funding** (~$1 Million) for vacuum insulation panels (2017-24)
- **Bill and Melinda Gates Foundation** funding for vaccine storage



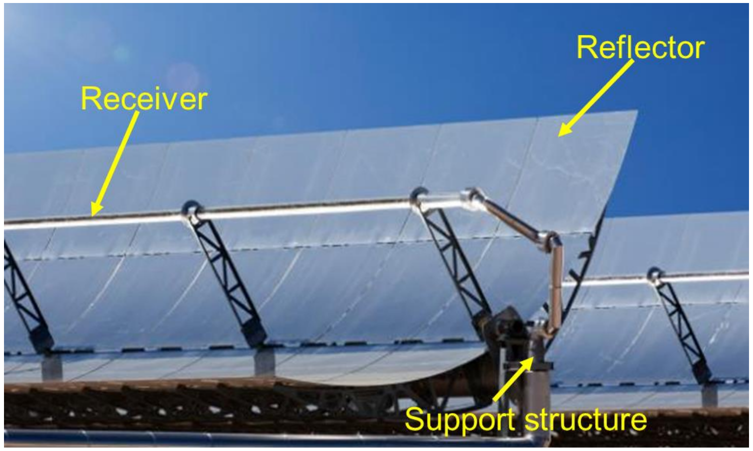
Background

- Kenya has **a target** of reforestation via planting 2 billion seedlings and rehabilitating 5,100,000 hectares of degraded lands by 2023
- KEFRI who supplies 90% of the demand is the biggest supplier of forest tree seeds in Kenya and southern Africa
- They face huge challenge to raise their current seed production from 8 tonnes/yr to 90 tonnes/yr
- **But,** KEFRI owns no active seed drier
- Current seed drying facilities and technology used by KEFRI are **rudimentary;** delays and seed rejection due to high moisture content
  - Open sun drying which takes 6 weeks for the pine cones to open up dry or
  - entirely rely on expensive grid electricity
- There is no reliable solar or other renewable energy technology
- We built on the drawbacks of the existing practices, technologies and systems to develop a new zero carbon impact solar drier **under the SoFTS project**

What was done in the SoFTS project

- Design, manufacture, installation and performance demonstration
- Solar thermal concentrator and storage system to deliver heat at 80-100 ℃ all through the year
  - Pine cone characteristics (moisture content, geometric size, temperature required to dry without damaging them) and climate files for Kenyan locations employed to predict the heat load
  - Computer model led design of optical concentrator, heat exchangers, thermal storage. racking system and balance of plant (pumps, valves etc.)
  - Nanofluid
  - Thermal storage using water as heat storage and transport medium
  - Infrared radiative and convective (air cooled) mixed mode heat exchanger to transfer heat from the thermal storage to drying trays
  - Control and operation strategy and logics
  - Remote data access and operation features

Conventional Solar Thermal Concentrators



- Parabolic trough collector (PTC) system (C~80)
- Large/bulkier in size (6m x 10m) , complex to operate/track long
- Lower optical efficiency, if not tracked
- Nearly impossible to use on **urban** buildings and structures

Drawbacks of Conventional Solar Thermal Concentrators

- Metallic receiver coated with selective material with limited useful life; emissivity rise at high temperatures due to degraded coating (0.11 to 0.3)

- Coated metal surface 50-75 °C above working fluid; resistance to conduction

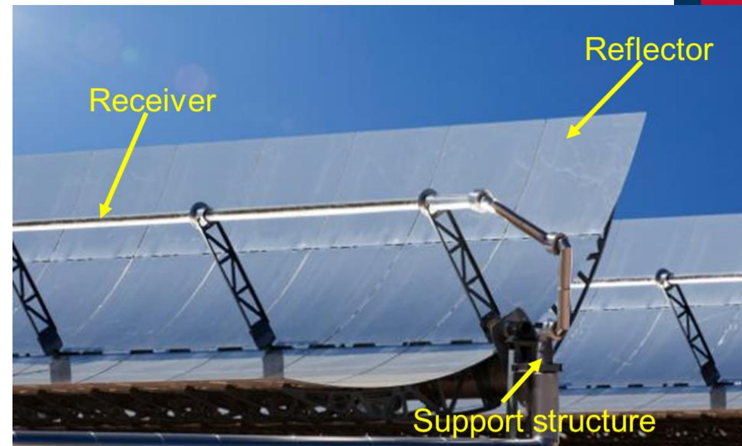
- $Rad\ Loss = \frac{\sigma \pi D_r \left(T_r^4 - T_g^4\right)}{\frac{1}{\varepsilon_r} + \frac{D_r}{\varepsilon_g D_g} - \frac{D_r}{D_g}}$

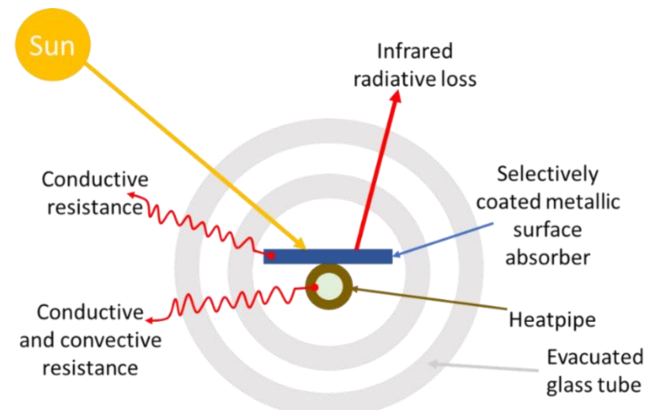
- Selective coatings have high emissivity at elevated temperatures

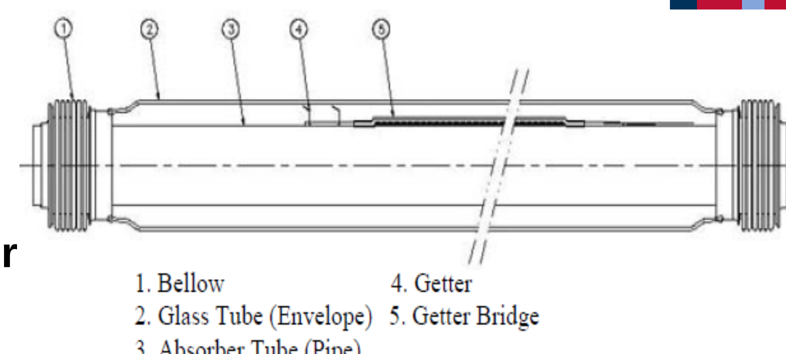
- For a ΔT=50 °C, metallic receiver has up to **three times** higher long wave radiative loss than a **volumetrically** absorbing receiver delivering heat at 200°C

- Our research builds on the drawbacks of the existing system; our solution comprises:

  - ➢ **Least complex and low weight solar concentrator**
  - ➢ **Volumetrically absorbing receiver**

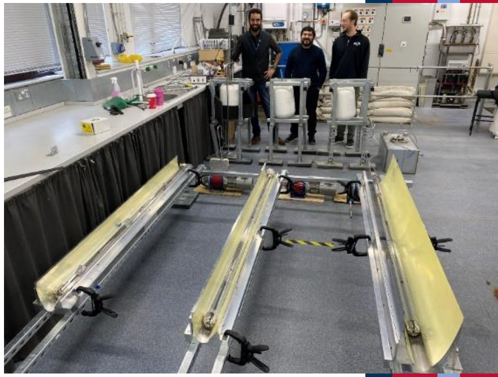


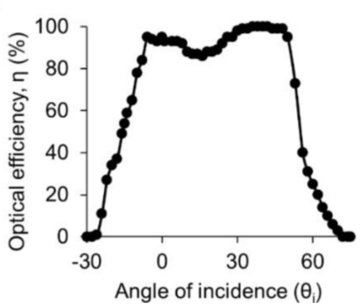


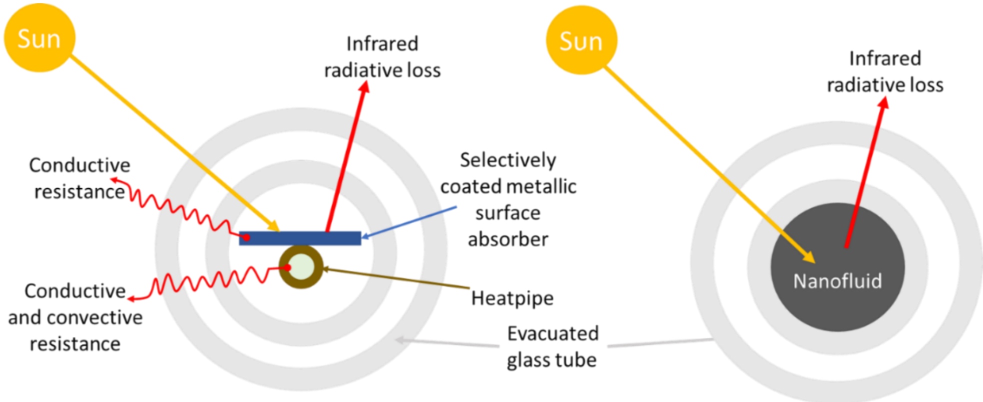


Solar Thermal System Developed

- Line axis focussing solar concentrators
  - ➢ Can harness diffuse as well as direct solar radiation
  - ➢ Simplicity in operation (no tracking); ; optical efficiency >70%
  - ➢ Compaction; 40% smaller footprint (lighter)
- **No metallic receiver** nor selective coatings
  - ➢ Nanoparticles (NPs) suspension in a suitable base fluid
  - ➢ volumetrically absorbing nanofluid; 80-250 ℃; 40% less footprint
  - ➢ Reduced radiative & conductive loss by 50-80%







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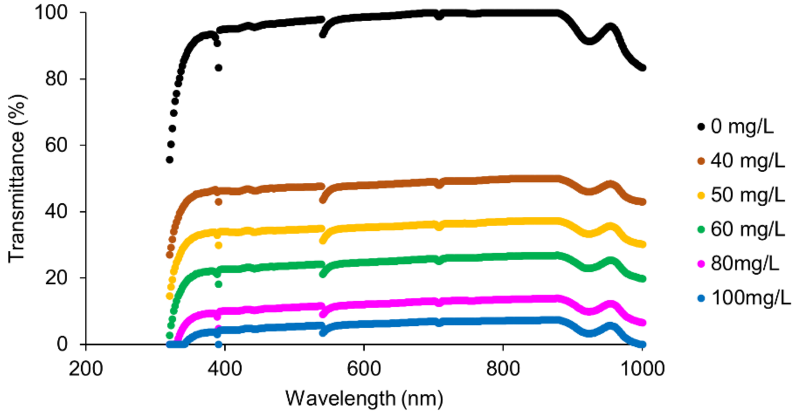
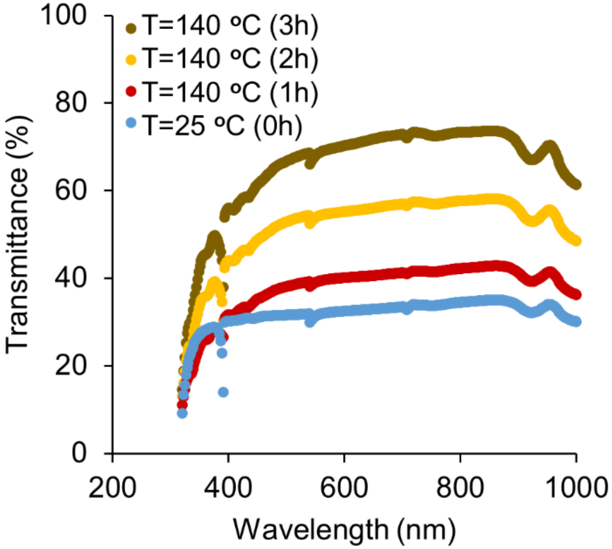
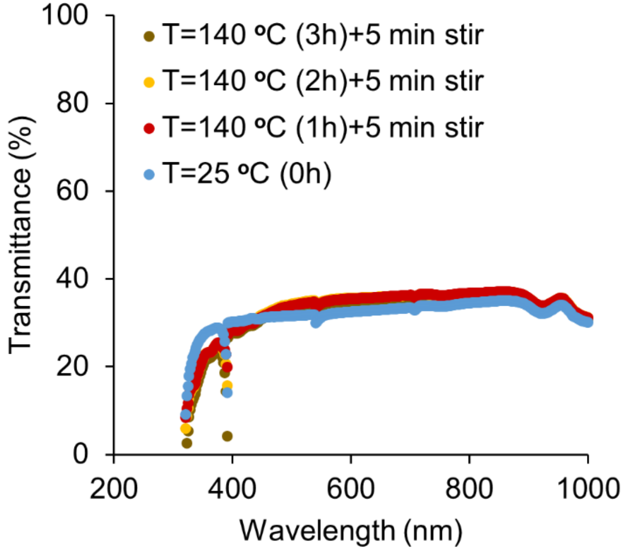
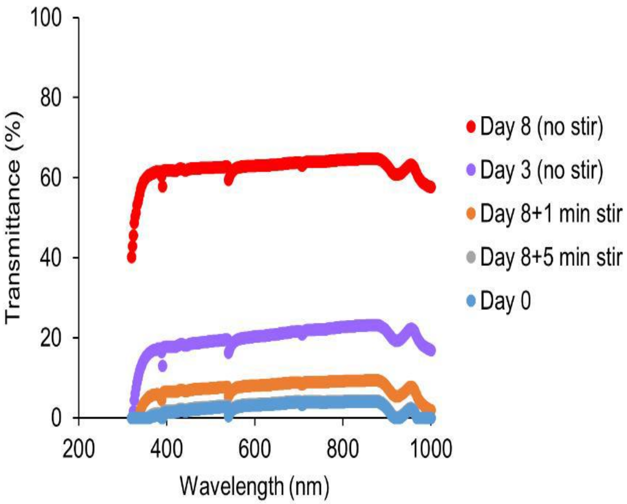
Nanofluid

- Nanoparticle concentration tunes nanofluid properties
- Optical properties of nanofluid are affected by temperature
- Spectral transmittance for nanofluid understood for full range of operating conditions



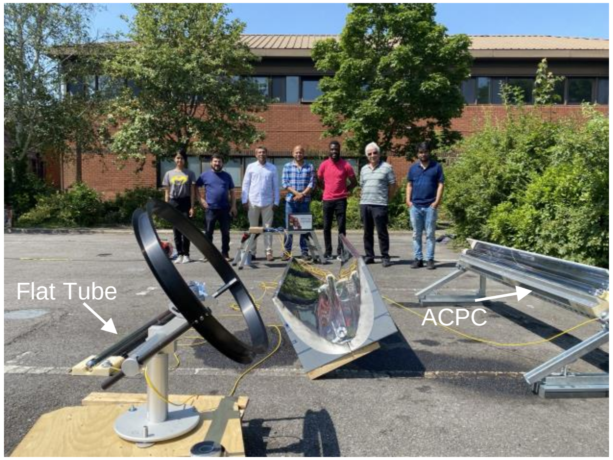


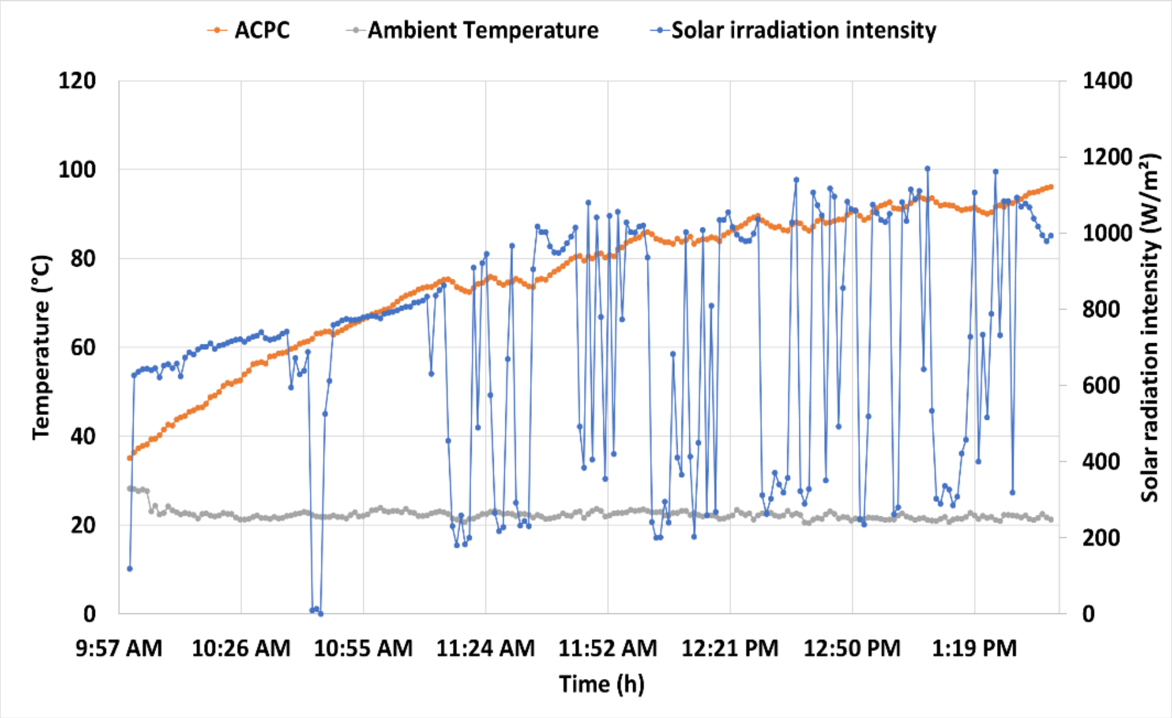




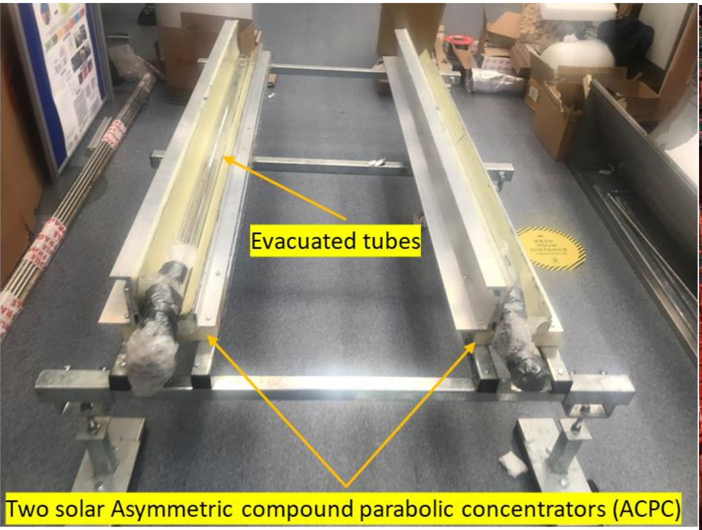
Pramanik A., **Singh H.**, Chandra R, Vijay VK. and Suresh S., 2021. Amorphous Carbon Based Nanofluids for Direct Radiative Absorption in Solar Thermal Concentrators. Available at SSRN: http://dx.doi.org/10.2139/ssrn.3905163

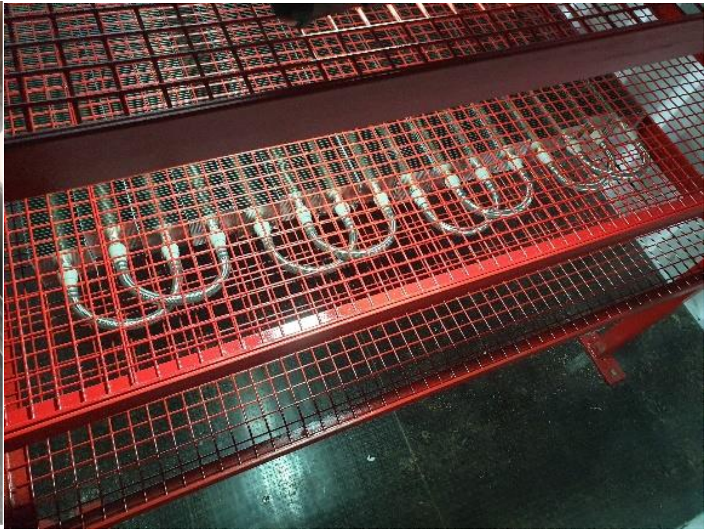
Outdoor Testing at Brunel





In-house design and development





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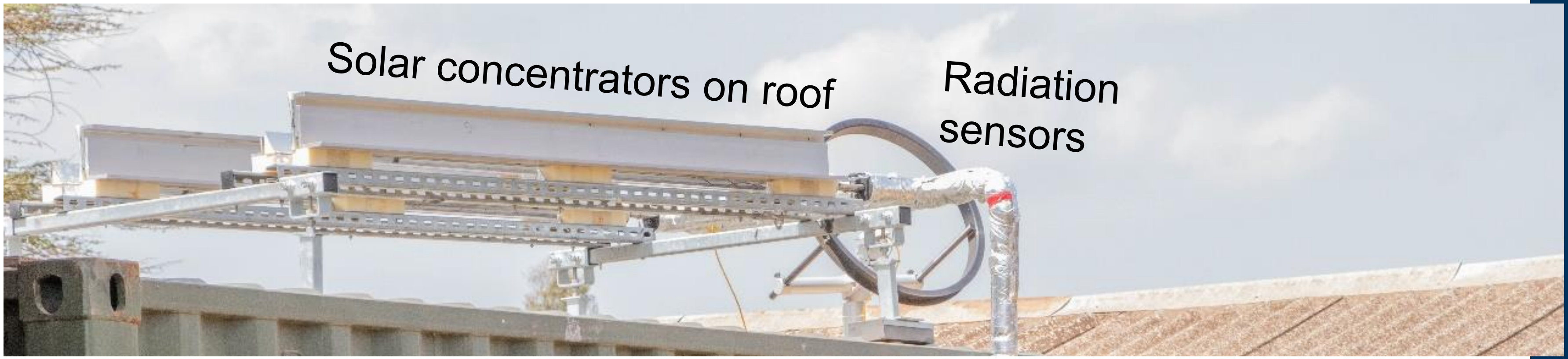
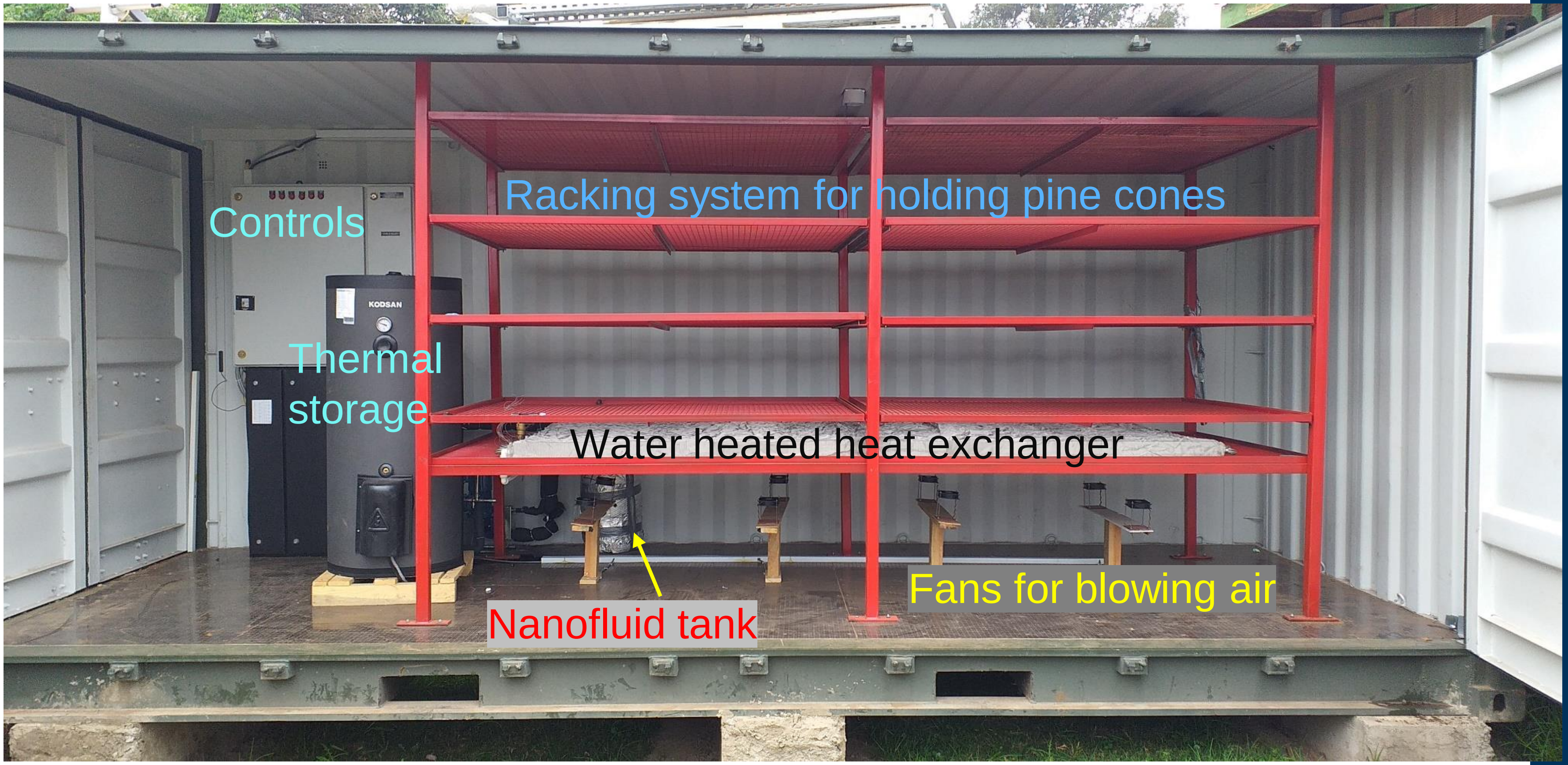
Solar heat storage for drying Forest Tree Seeds (SoFTS)

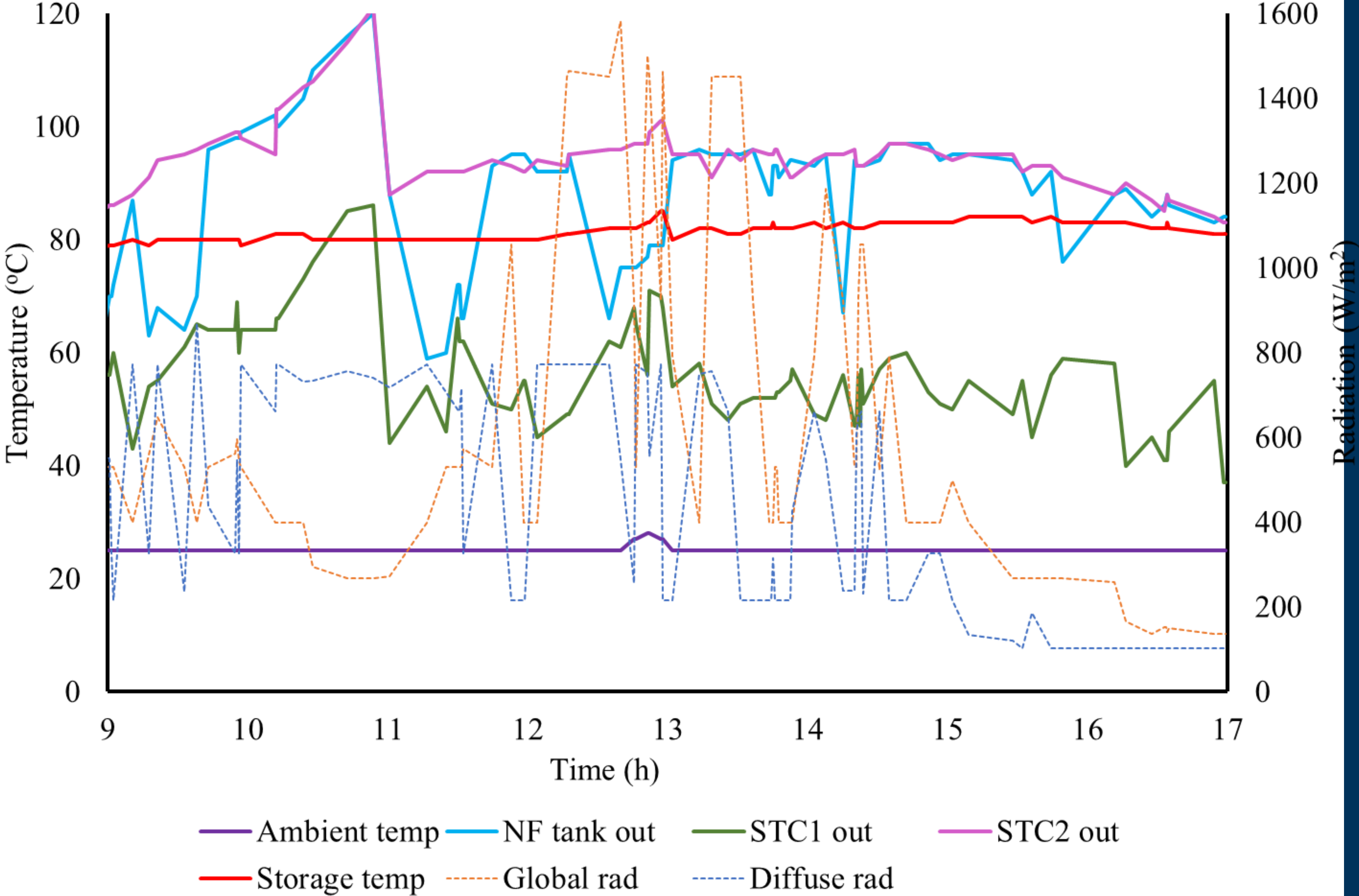
SoFTS System at KEFRI's Muguga Site



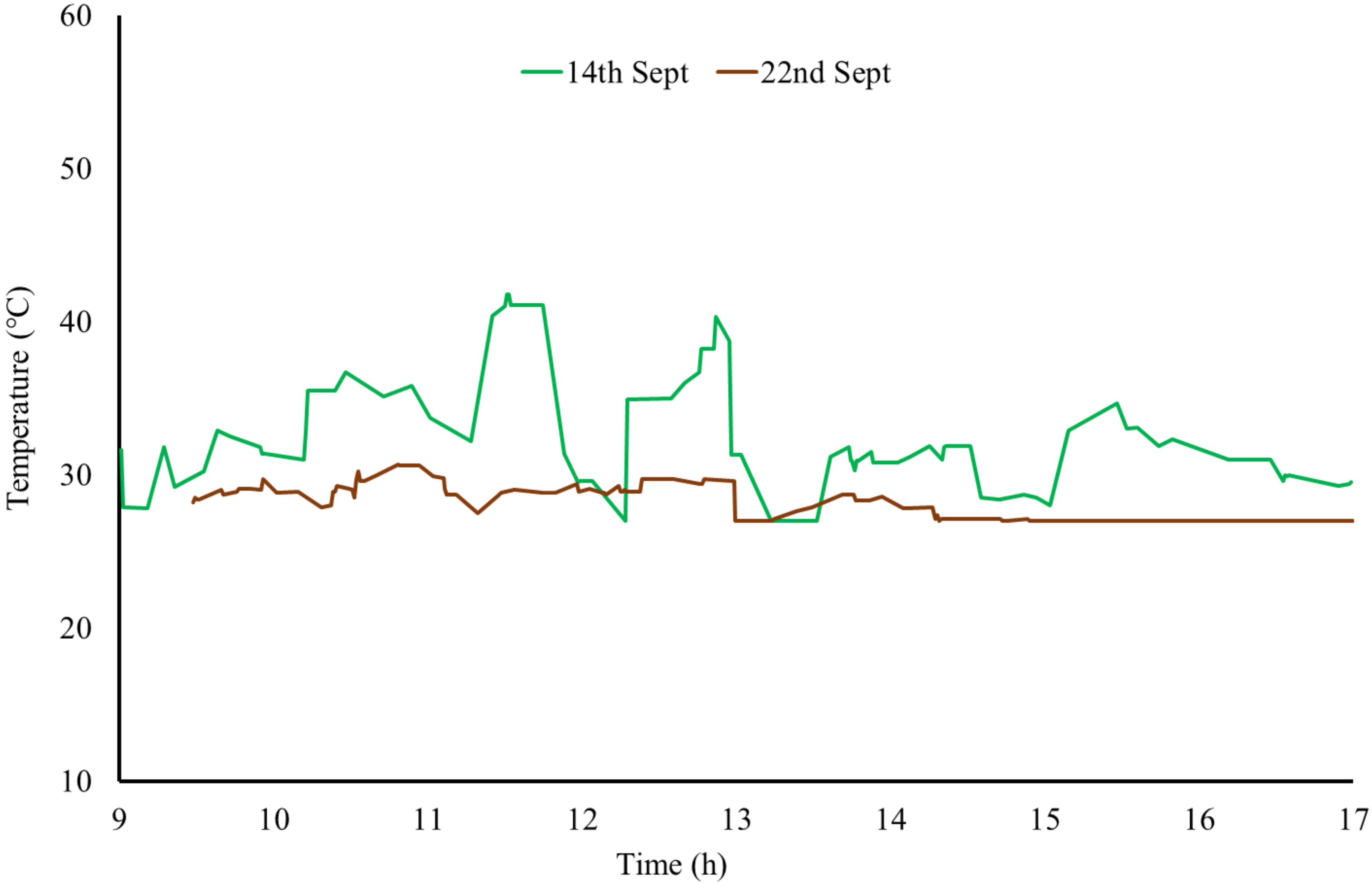


System Performance at Muguga

14th September



Temperature in the racking trays



100% Solar thermal energy run Cold Storage

- Target: deliver heat at 250 ℃ to run diffusion absorption refrigeration unit
- Funder: Innovate UK
- Partner country: Kenya
- Demo-site – Nairobi (Kenya)

- Funder: UKRI (GCRF) UK
- Partner country: Kenya, Tanzania, India
- Demo-sites at least 2 in each partner country
- Local partner: Makerere University, East African Centre of Excellence for Renewable Energy and Efficiency (EACREEE); Tanzania Horticultural Association (TAHA)

Conclusions

- A solar seed drier capable of a 24x7 autonomous operation has been developed and installed at KEFRI
- Our technology will enable sustainable reforestation activities, buildings and industrial and horticultural processes
- KEFRI alone will save 100% heating energy cost which currently stands at circa £30k/yr and is predicted to grow to £400k by 2023
- Enhance competitiveness of KEFRI via cost reduction; currently energy account for 60-70% of total production costs
- Job security and income to approximately 30,000 workers employed in forest tree seed sector; 180,000 in 2023
- Happy to partner on commercial and grant/funding applications offering knowledge and expertise

Thank you for your attention!