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SOLAR ENERGY Webinar- Solar Heat for Industrial Processes (SHIP), and more

Experiences with Small Scale Solar Heat Collection and Storage

- Motivation and Background
- Heat collection
- Heat storage
- Examples

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Motivation and Background

- 10 years of university collaboration in Norad projects on Renewable Energy Education and Research.

  Current projects (Norpart, Erasmus+, NorhedII) include:

  - Univ. Dar es Salaam, Tanzania
  - Dodoma university, Tanzania
  - Makerere University, Uganda
  - Busitema University,Uganda
  - Mekelle University, Ethiopia
  - Addis Ababa University, Ethiopia
  - Eduardo Mondlane University, Mozambique
  - SAVE university, Mozambique
  - Malawi University, Malawi
  - Juba University, South Sudan

- Motivation for the solar thermal part:
  Development of off-grid energy storage solutions for cooking
  - Electrical batteries are not optimal solutions
    - It is costly to design a battery bank for the high power needed for cooking
  - Heat batteries for cooking are needed

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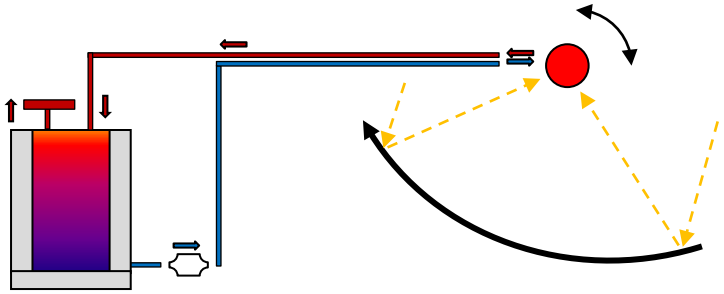
Heat collection concepts

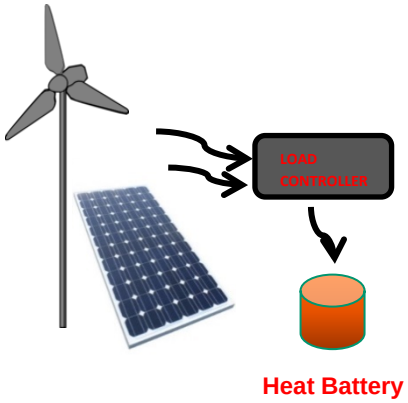
Solar heat collectors

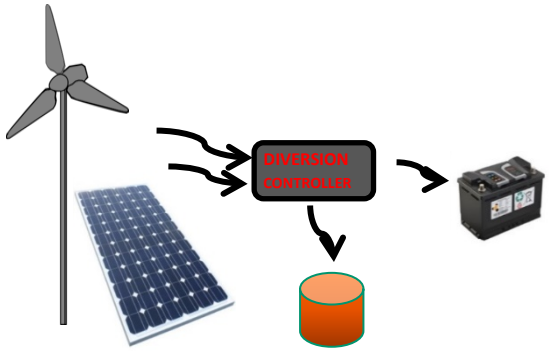
- Trough or dish concentrators with heat transfer loop to heat storage
- Direct illumination of storage

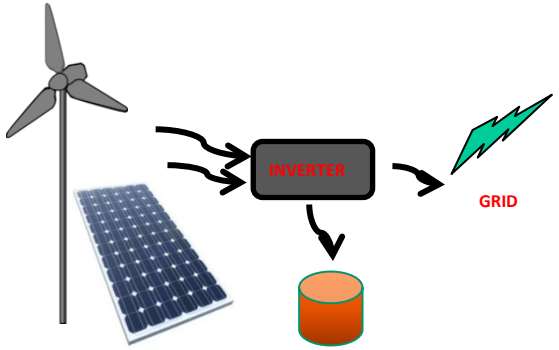


Electrical heating

- Connect heat storage to PV, wind, hydro and use excess, or all power to charge the storage







- Stand alone thermal

Off-grid with batteries

Grid connected

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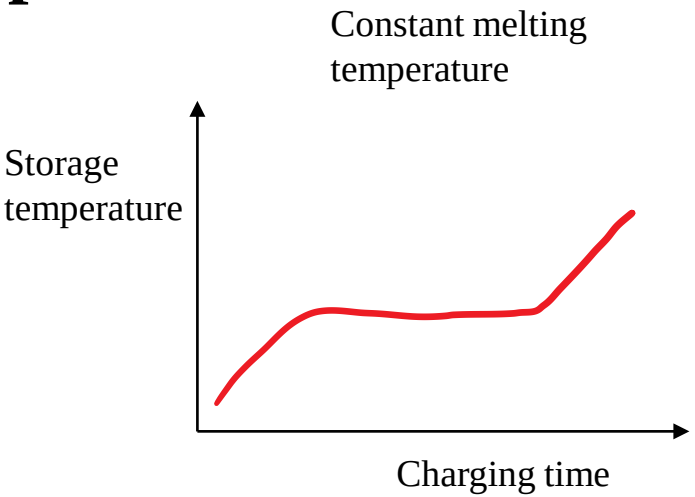
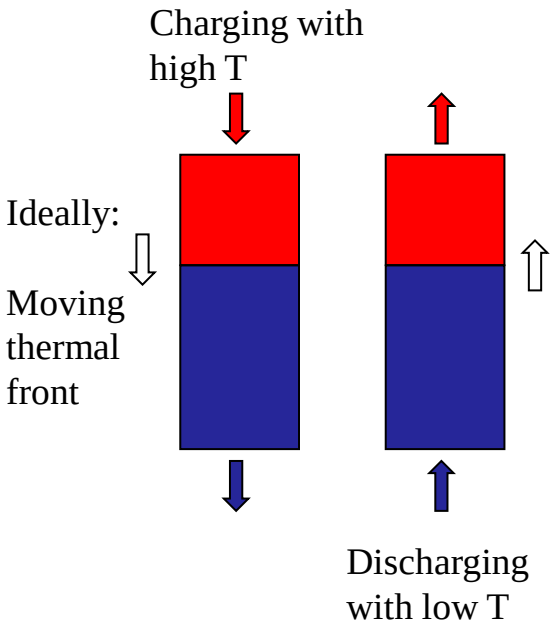
Heat storage concepts

- Latent heat with PCM (Phase Change Material)
  - Storage operation at the phase change temperature
  - Nitrate salts suitable for cooking temperatures (220 degrees C, “Solar Salt”)
  - Some challenges:
    Heat transfer in/out of storage
    Safety



- Sensible heat
  - Thermal stratification can provide heat in/out at constant temperature
  - Some challenges:
    Simplified and robust temperature control
    Maintain thermal stratification



- Thermochemical systems

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Rock bed and air

- Rock bed heat storage: container with rocks
  Air for heat transfer from solar concentrator

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  Inexpensive, safe material, can tolerate very high temperatures
  Possible to regulate heat extraction by fan speed

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  Need careful absorber design to get high air temperatures
  Need high temperature fan for charging and discharging
  Difficult to avoid air leakages
  Poor thermocline properties in short storages
  Require fan control for constant temperature

(Denis Okello, Kardewa Nyeinga, Habtamu, Amos Veremachi, Trygve Veslum)

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PCM storage with heat transfer loop

- Steam or oil for heat transfer loop

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  Stationary absorbers (pipe or spherical)
  Can use polar mount and single axis solar tracking
  Self circulating: no pump

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  Steam: high pressure (about 30 bar)
  Self circulating oil: low efficiency at high temperatures
  Trough: require high optical accuracy and insulated absorber
  Cooking on storage at higher elevations

(Asfafaw H Tesfay)

(Maxime Mussard)

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PCM storage with direct electrical heating

- Heating at top plate and heat transfer by conducting fins

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  No heat transfer loop

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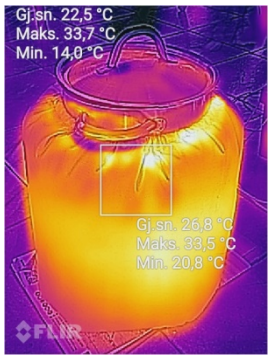
  Heat extraction through conducting fins is difficult to control



PCM bean cooker from excess PV power (Tanzania)

PCM fryer

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PCM with electrical heating

- Heating elements in oil for heat transfer to PCM cylinders
- Evaporator in oil and condenser in frying plate

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Heat transfer can be shut off
No moving parts
One storage can serve several frying pans

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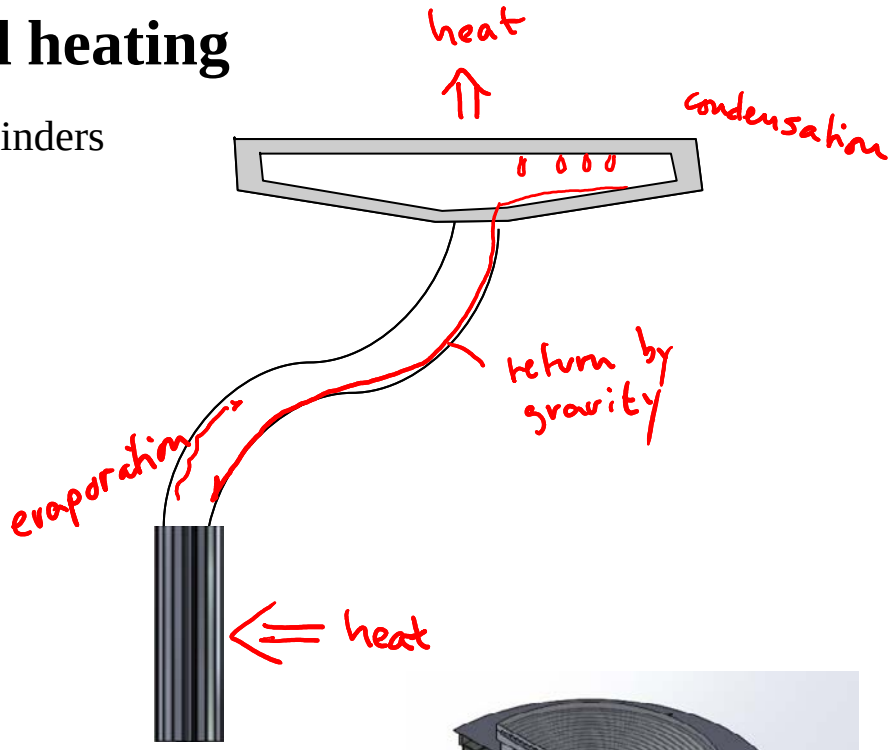
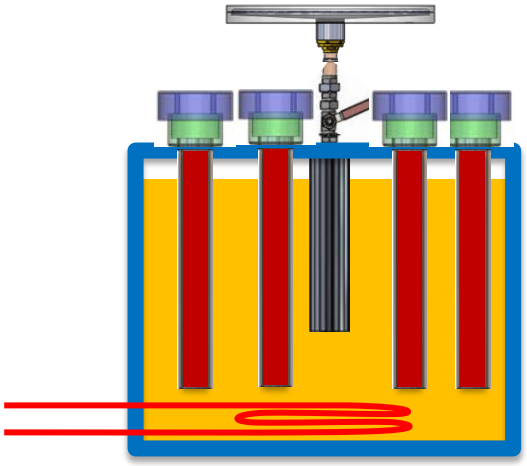
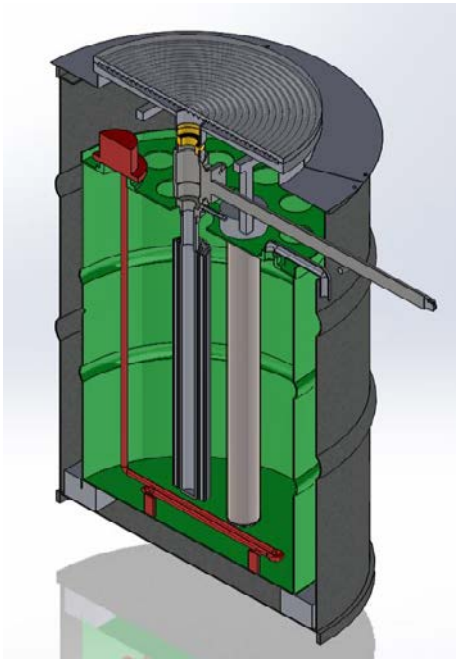
Difficult to get leak proof valve





(Abraham Parra, Martin Systad Geiran)



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Oil/rock bed storage and electrical heating

- Single tank or two tank system
- Thermocline in storage part
- Natural circulation between cooker part and storage part during charging and discharging

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Simple system design with only one tank
Rock bed reduces the amounts of oil needed

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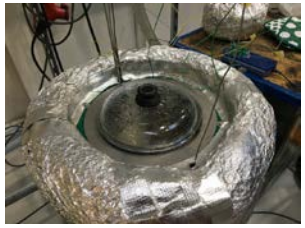
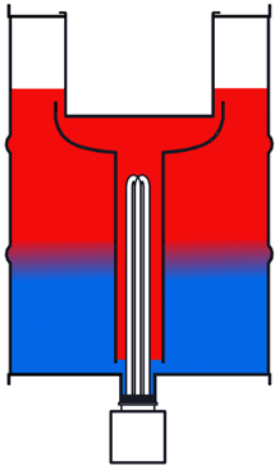
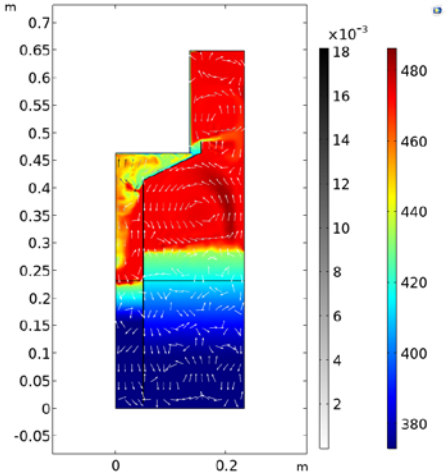
Difficult to control cooking rate
Thermocline will degrade in time



(Oda Fjeldsæter, Vilde Stordal, Gunn Helen Nylund, Andreas Bjørshol)



Principle



Simulations (Comsol)

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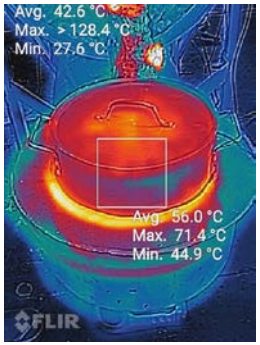
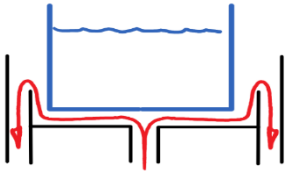
Separate hot and cold storage and electrical heating





- Heating elements in middle tank
- At a set temperature (250 degrees C), a thermostat valve opens for cold oil from upper tank
- Hot oil accumulates in middle tank during sunshine hours
- Cooker is powered by hot oil, drainage into lower tank
- Hand pump oil from lower to upper tank

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Passive and simple system, no electric pump
Hot oil at constant temperature
Can use bulky pots and control the cooking rate

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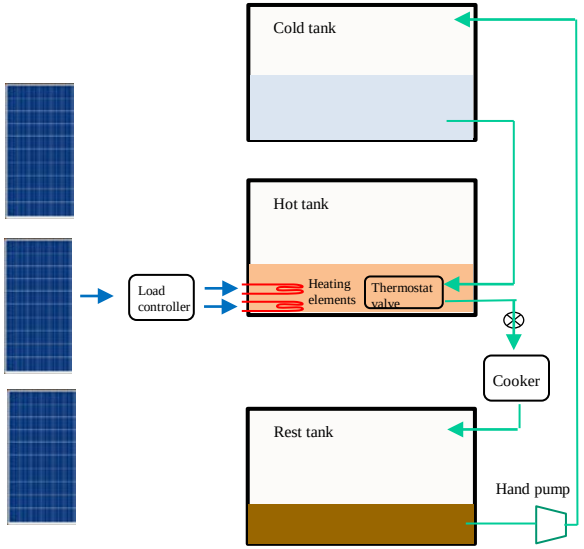
Require large amounts of oil for upscaling
Not suitable for rock bed



(Per Bjerre, Tanzania)

(Marie, Kaja, Sigurd) (Oda, Vilde)

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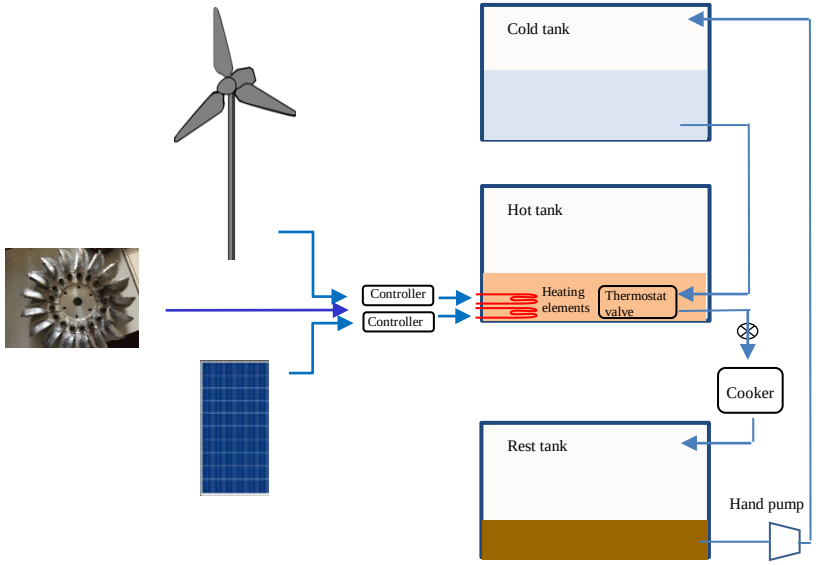
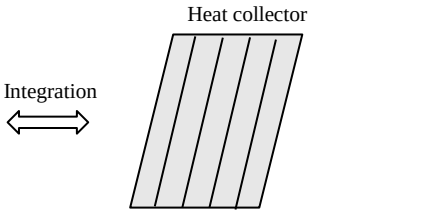
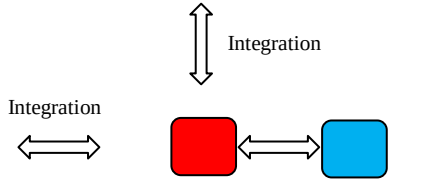
Hybrid system

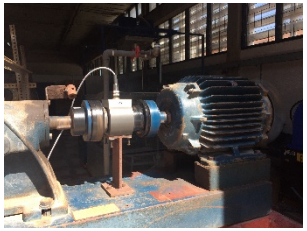
- Heating thermal and electrical systems for heat storage







(Thermal panel, Thomas Nhabetse, UEM, Mozambique)



(Pump as turbine, Ombeni Mdee, UDSM Tanzania)

(Refrigeration, Michael John, UDSM Tanzania)

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Summary

- Several options for solar heat collection and storage have been tested in collaboration projects between NTNU and African universities
- Heat storage solutions at about 250 degrees C would be useful in off-grid energy systems
- The aim is to reduce the use of wood fuel for cooking
- Current work includes hybrid thermal and electrical systems
- Further: field tests

- **Acknowledgements**
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  - NUFU - The Norwegian Programme for Development, Research and Education 1991-2012
  - NORHED and EnPe - the Norwegian Programme for Capacity Development in Higher Education and Research for Development 2013-2020
  - NORHEDII 2021-2026
  - Quota Scheme 2001-2012
  - NORPART Norwegian Partnership Programme for Global Academic Cooperation

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