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Efficiency for Access Design Challenge Technology Week:
Webinar 3: Refrigeration

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Harini Hewa Dewage,

Battery Research Lead, M-KOPA

- Energy storage background
- PhD in Battery Research at Imperial College London
- Managed multiple research and education projects in the sector

Victor Torres Toledo,

University of Hohenheim

- Studied Mechanical Engineering in Madrid, Spain
- PhD in the field of refrigeration and solar energy, University of Hohenheim in 2012
- Founded Solar Cooling Engineering UG

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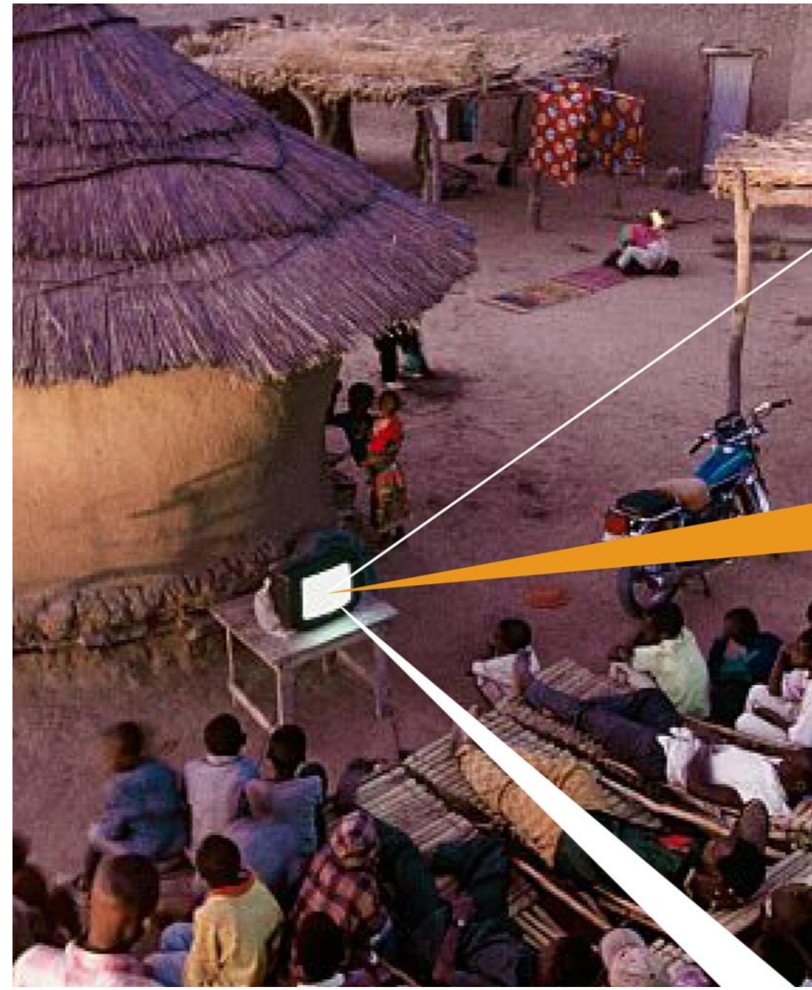
Battery Research Lead, M-KOPA

How does refrigeration link to the Sustainable Development Goals?

- Refrigeration helps save valuable food and potentially increases productivity, therefore reducing risk of poverty and hunger
- Healthier food and ability to store sensitive medicine (insulin, vaccines, etc.) increases well-being and protects health
- Additional spare time can be utilised for children education
- Refrigeration helps women the most – sparing their time (cooking, market visits) and consequently helping reach gender equality
- Renewable energy-based solutions are designed around affordable and clean energy



Demand for refrigeration across sub-Saharan Africa

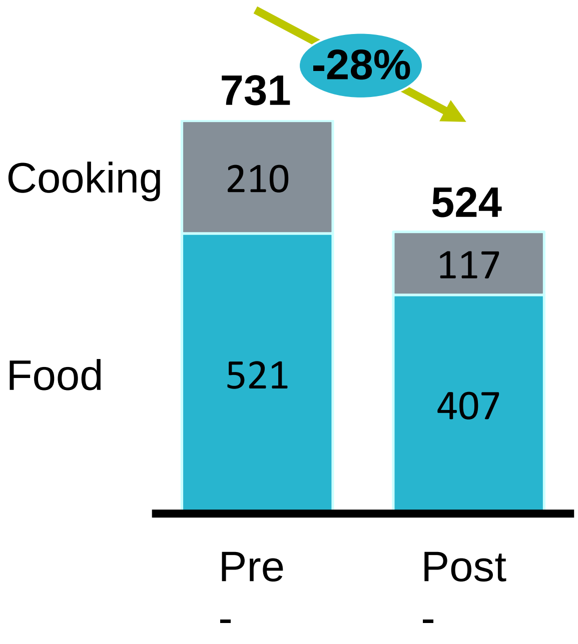
How does refrigeration affect lower income population? (from M-KOPA market tests)

- Saves time and money
  - Bulk buying saves 15% each month
  - Market visits reduced by 30%
  - Spend 40% less time cooking
  - Reduced food spoilage by 33%
- New spare time utilized for family or additional work
- Type 2 diabetes impacts 1-in-17 Kenyans, need for proper / specific medicine storage
- Enables replacing processed food with healthier which would otherwise spoil quickly
- Potential for revenue growth for micro-retailers and smallholder farmers

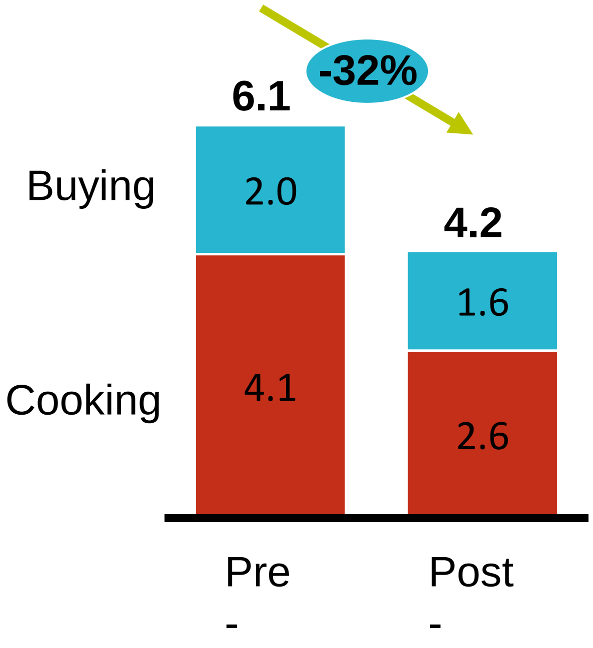
Solar fridge reduced expenditure and time spent by ~30% in our pilot

M-KOPA Solar Fridge customer: “I used to go to the market twice a day. Once I got the M-KOPA Fridge, I only go once. It saves me time and my money.”

Daily Expenditure (KES)



Daily time spent (Hours)



Regions tested were Kisumu, Siaya and Machakos

What are the solutions currently available on the market?

Off grid refrigeration is yet to become mainstream.

- Current solutions are:
  - Optimized for off-grid but expensive
  - Not optimized for off-grid (higher consumption)
- Currently available*:
  - M-KOPA Solar Fridge
  - BBOXX Solar Fridge
  - Engel DC & AC Fridge
  - Etc.
- Sizes up to 150 L

Draw-backs or design problems with current solutions?

- Lack of financing options
  - It is a higher value device / system
  - Not many manufacturers and suppliers choose to offer their appliance on PAYG
- Energy consumption
  - Needs to operate 24/7
  - Larger battery packs needed off-grid
- Traditional compressors need a lot of power to start-up
- Advanced compressors are suitable but expensive as are not widely adopted by the industry

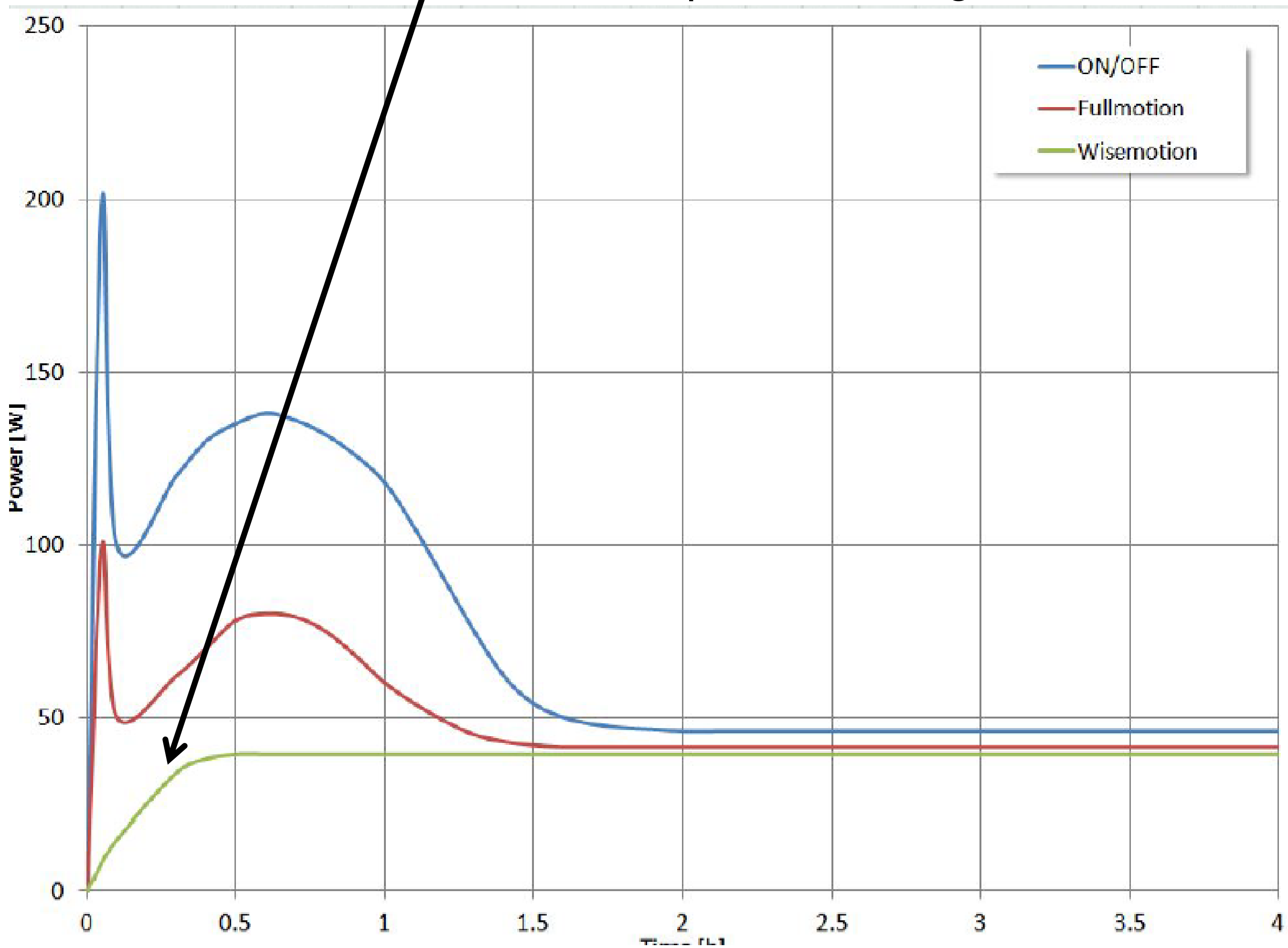
M-KOPA’s current offering

- M-KOPA 100L Solar Fridge
  - Size: 100L
  - Reserve: 36 hours of battery autonomy
  - Avg. power consumption: < 8W
  - Insulation: High density Polyurethane foam (CFC free, Cyclopentane Blown)
  - Cabinet internal temperature: 6ºC
  - Refrigerant: Isobutane (R600a)

The M-KOPA Fridge runs on less daily energy than a 60-watt lightbulb, has a battery autonomy of 36 hours and is sold with LED lights and phone charging capability.

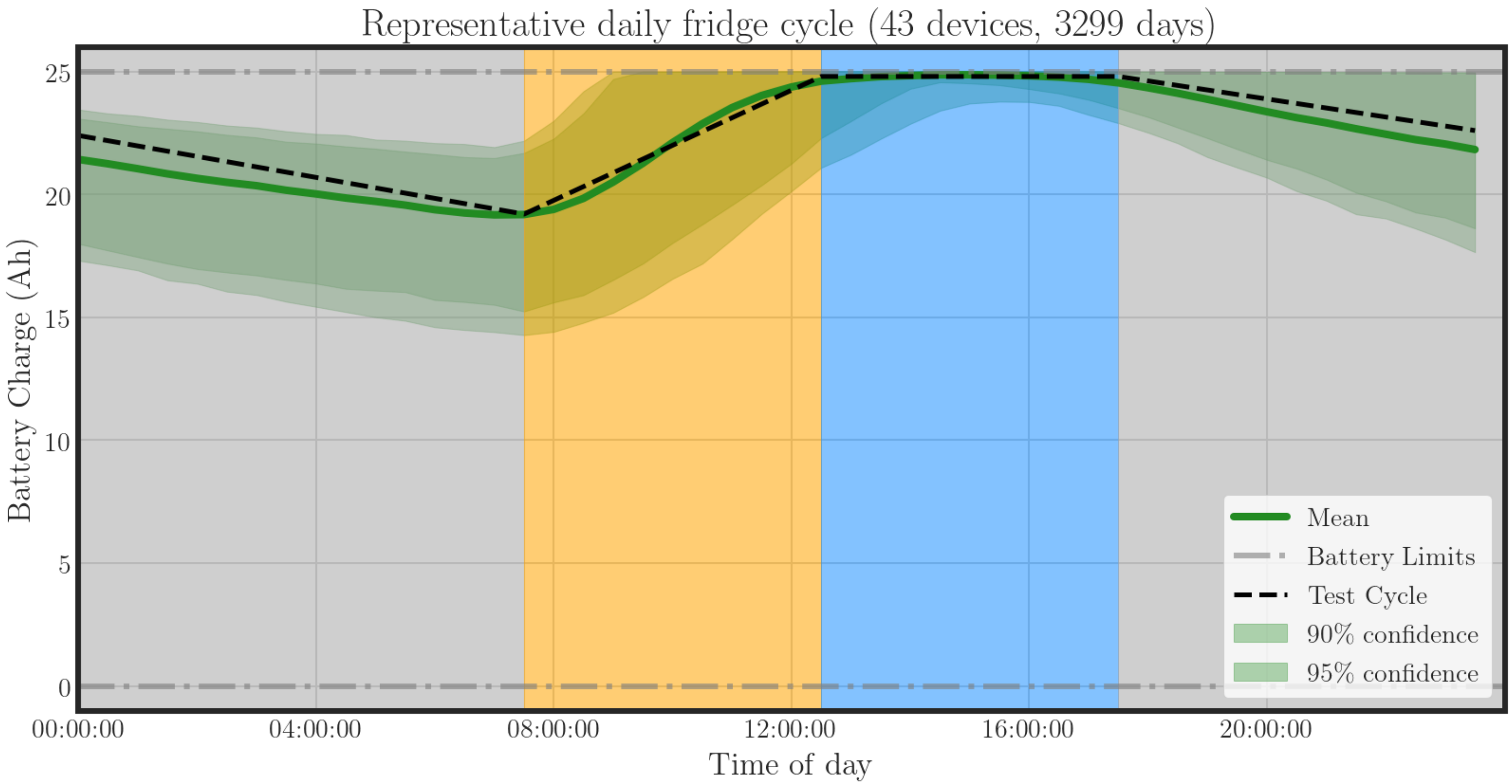
Fridge compressors comparison

No power peak during start-up and lower energy consumption
More expensive though ☹



Fridge Consumption Data

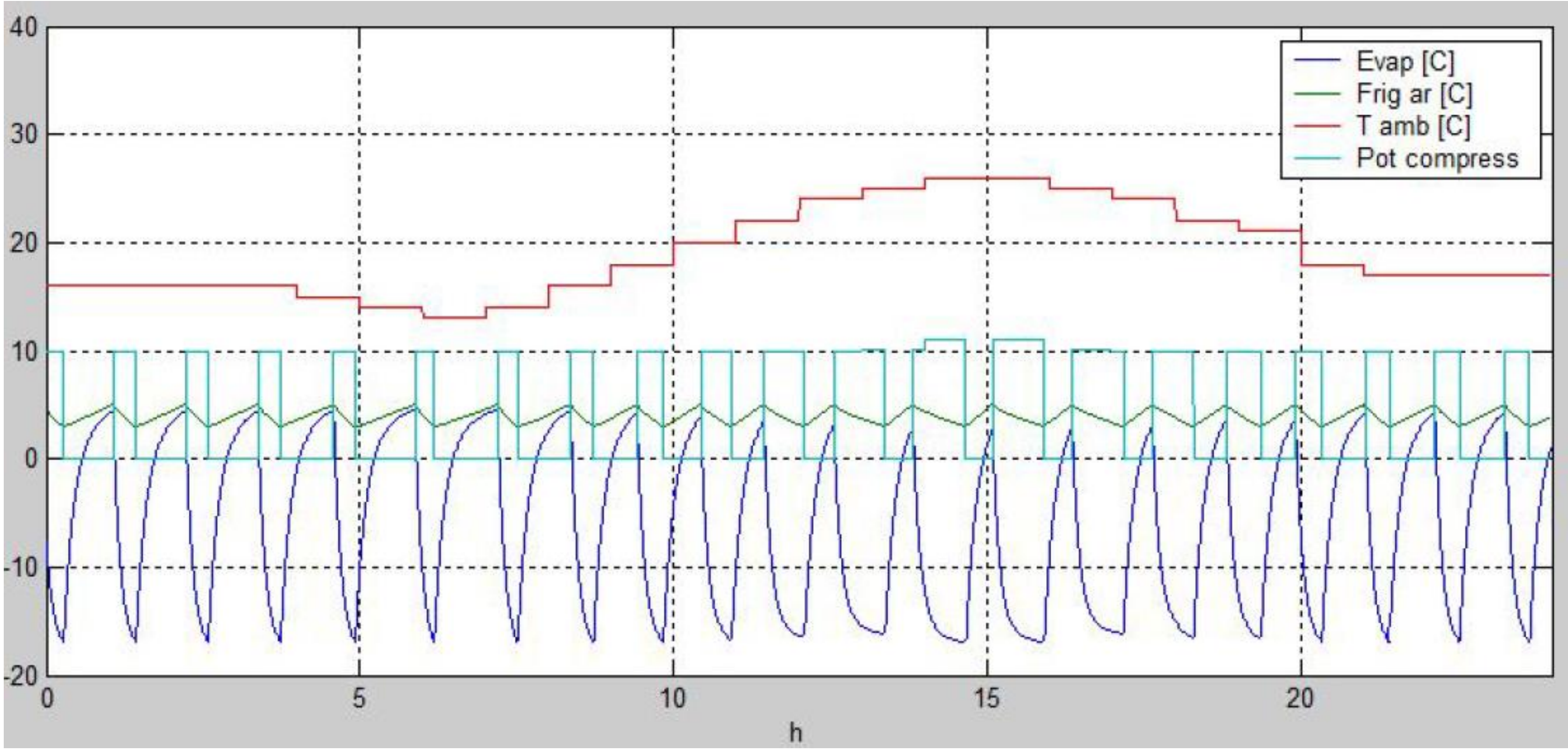
Representative daily battery use based on field observations. Battery charge value distributions are compared to simplified cycle used in laboratory test. Regions represent Night, Charging, and Full Charge.



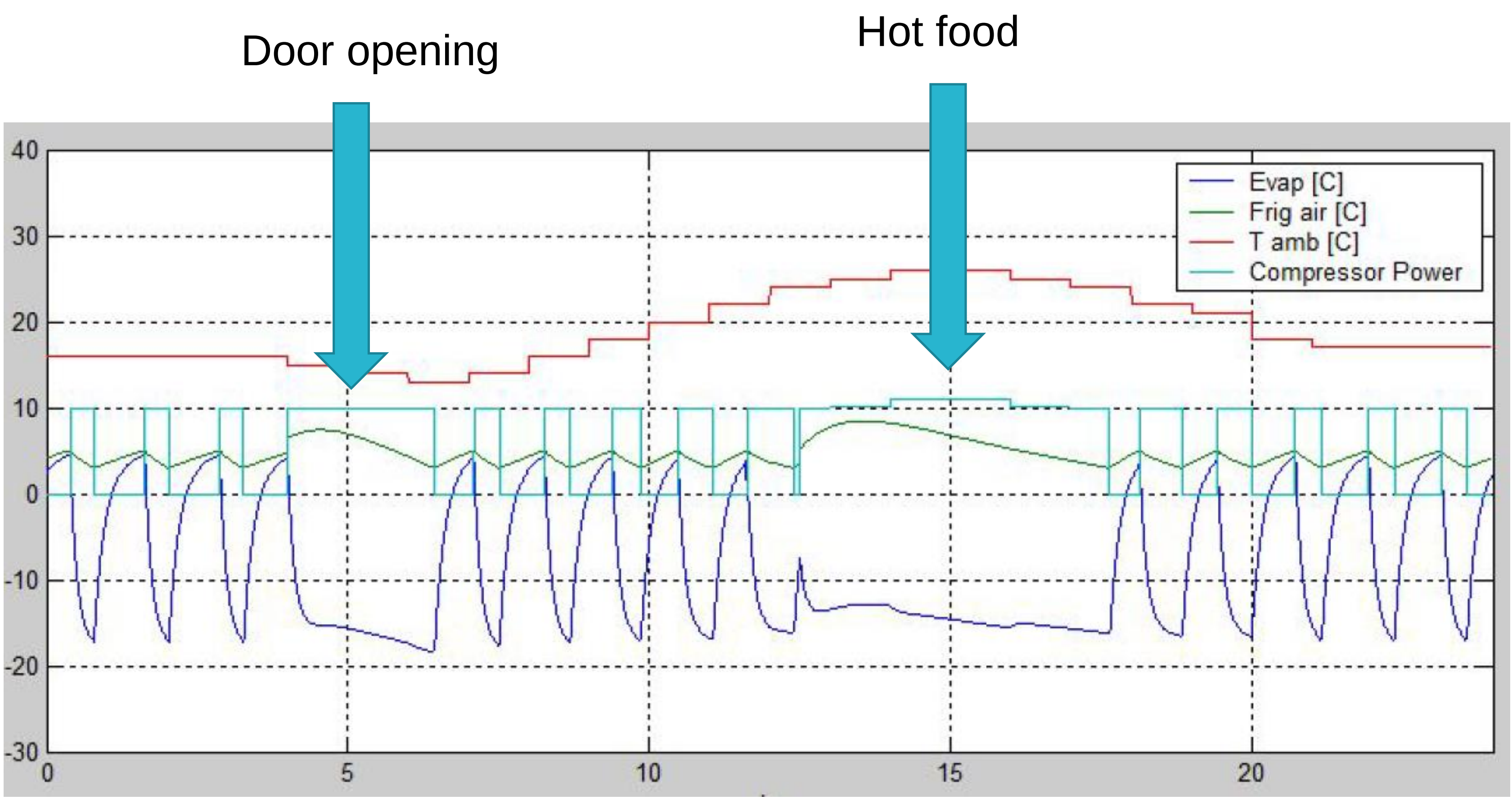
What has failed in the past and what lessons can be learned?

- Fridge size is important
  - Customers want big size fridge since they pay a lot of money for it
- Best solar panel and battery sizing matching
  - Customer behavior have a big impact on fridge performance. (e.g. Leaving the door open for too long, blocking fridge's ventilation, etc).
- Bringing the technology's cost down will help with refrigeration adoption
- Even though concepts of refrigeration are well known, customers may need to be educated on usage

Fridge power and internal temperature during a regular day.



Impacts of customer behavior in the fridge performance



Market direction and current research projects happening in the industry?

- Through a partnership with Embraco (Whirlpool Group company), DFID and Shell Foundation, M-KOPA Solar launched Africa's first made-for-market solar powered, low-power refrigerator in Kenya
- affordable and sold on a PAYG basis to accommodate customers' cash flow constraints
- engineered specifically for the East African environment
- is uniquely suited to solar energy, employing technology to increase energy efficiency and optimize reliability
- Embraco is exploring ways to bring the cost of compressor down

Contact

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Any questions?

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Victor Torres Toledo,

University of Hohenheim

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Solar Cooling for Agriculture

Do it yourself!

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Technology Week Webinars
Refrigeration. October 16th 2019

Dr. Victor Torres Toledo
University of Hohenheim, Germany
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www.solar-cooling-engineering.com

Tropics/Subtropics group (Prof. Dr. Joachim Müller)

- Solar Drying
- Irrigation (Solar)
- Plant oil extraction (Solar)
- Use of biogas/biomass
- Postharvest technologies
- **Solar cooling**




20 PhD Students
6 Post. Docs.
5 Technical staff
2 administrative staff

From 15 countries!

Solar cooling team

Victor Torres-Toledo
R&D

Julian Krüger
R&D - Testing

Farah Mrabet
Milk quality and socio-economic assessments

Muaz Bedru
Development of milk cooling systems

Ana Salvatierra-Rojas
System installation and trainings

Juliet Kariuki
Research Social Scientist

Florian Männer
Testing

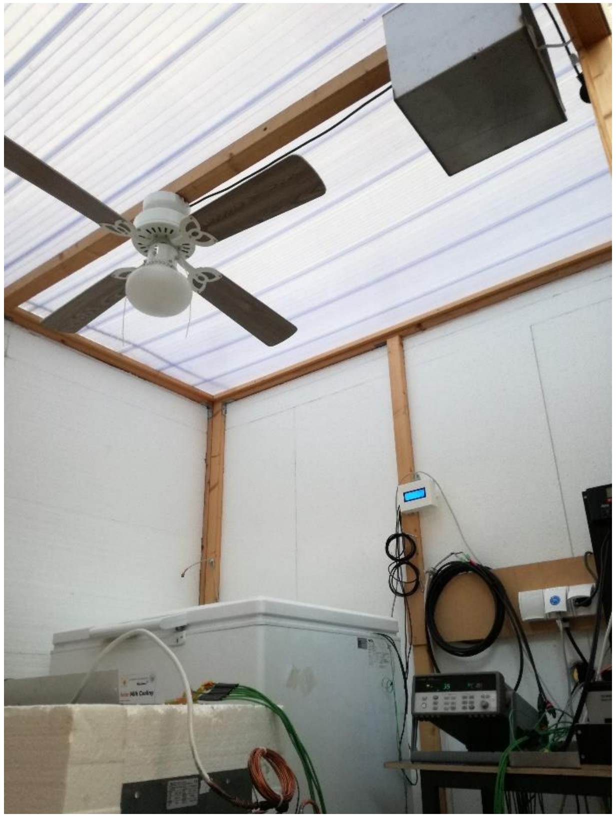
Kilian Blumenthal
Knowledge Management

Solar cooling testing facilities

Weather profile

⇩

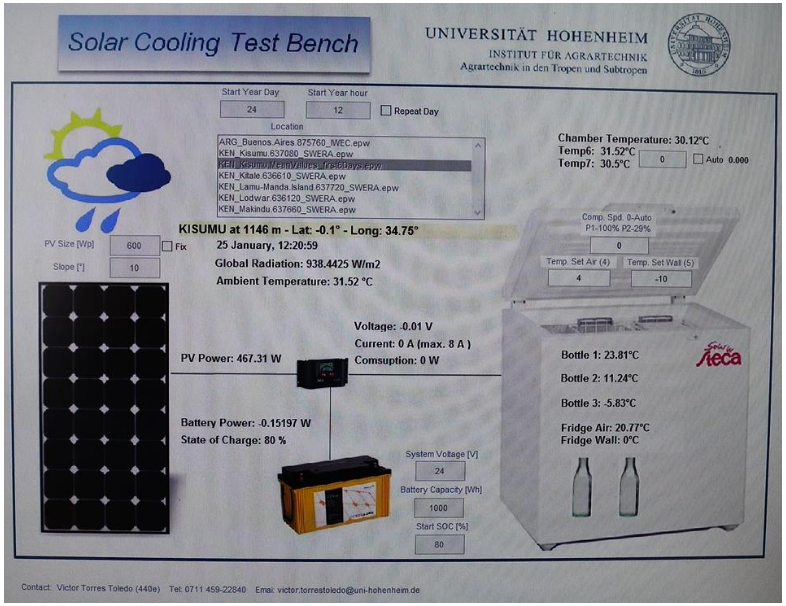
Climate chamber



Solar Power profile

⇩

PV Simulator



Adaptation of local available components


Small-scale solar milk cooling system


Smart ice-maker

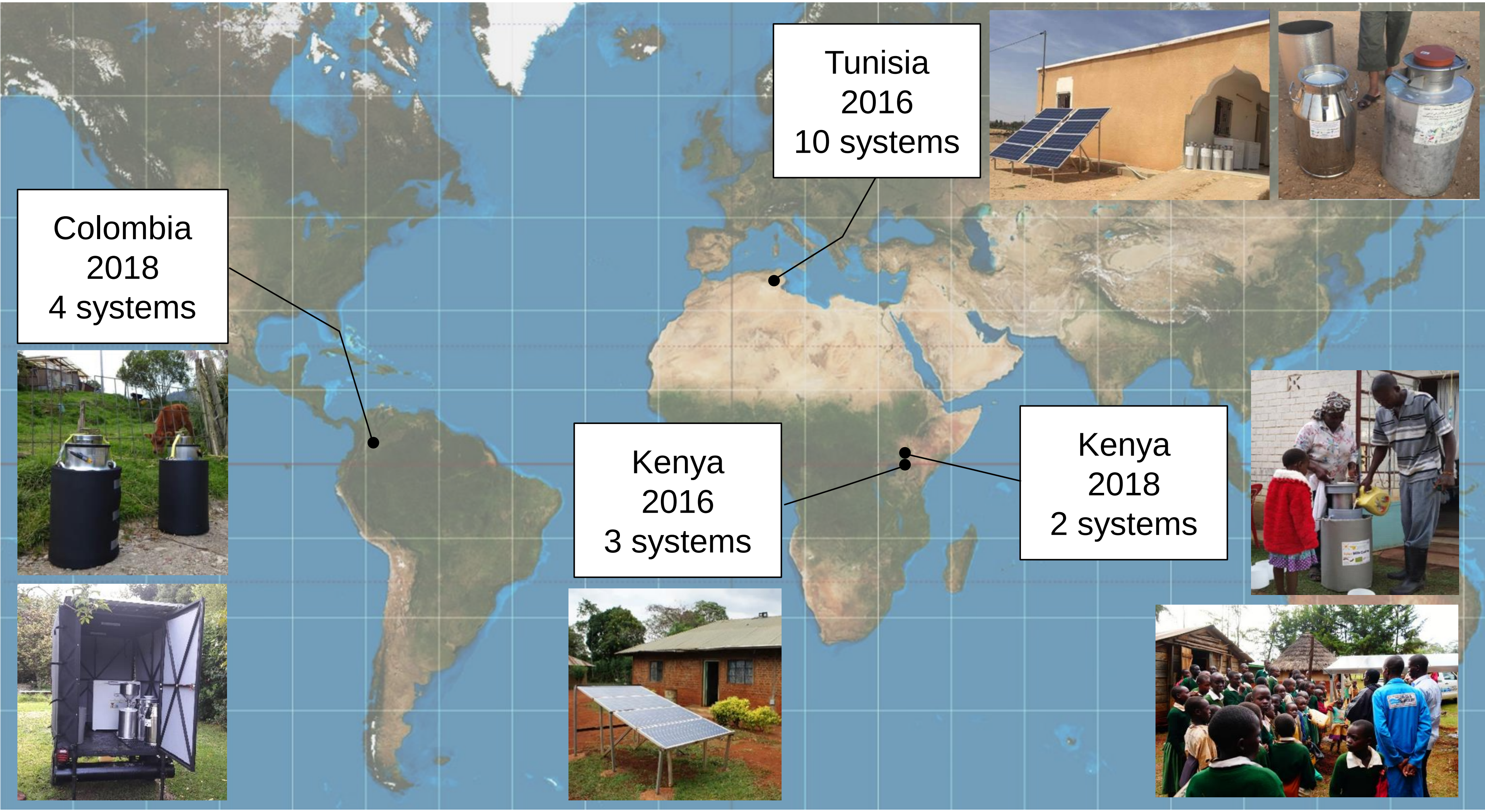

Insulated milk-cans with ice-compartment


Storage of 60 L Milk
up to 16 hours

energypedia

https://energypedia.info/wiki/Solar_Milk_Cooling_with_Insulated_Milk_Cans

Implemented projects



Challenges to promote solar cooling systems in rural areas

Donations negatively influence the willingness to pay

Rotation of pilot systems

Introduction of fees

Maintenance is crucial

Local distribution & Installation

Local assembling and production?

Transport cost + profit margins represent 60% of total cost

Use of local available materials

Local skilled staff

Product doesn´t fit into the local market

Several system configurations

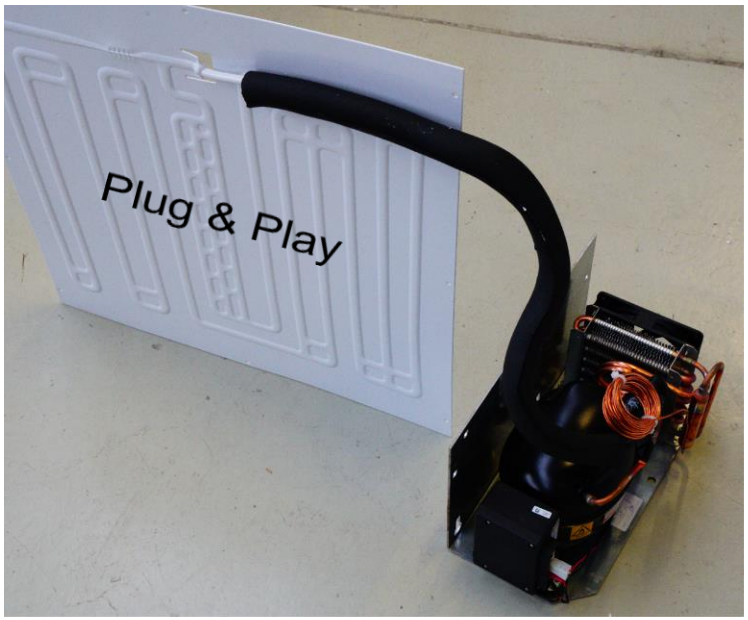
Different sizes (Scalability)

New Approach

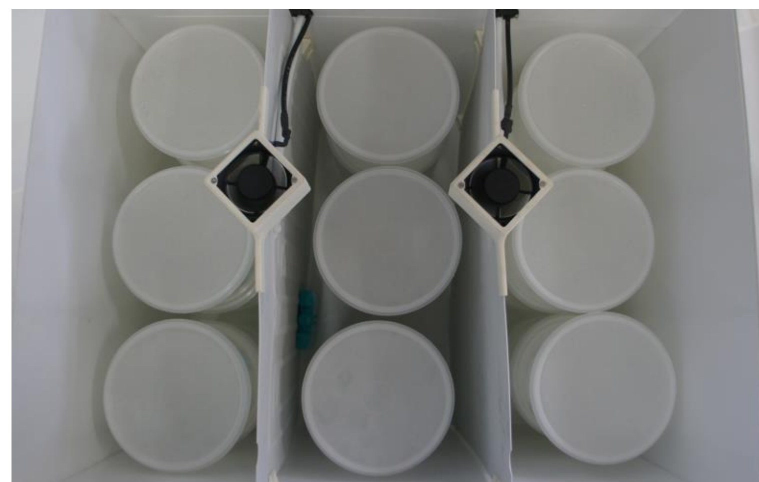
Cooling Units instead of cooling systems

Promoting the use of key components

Solar cooling unit +
electronics and sensors



Locally produced systems



Different configurations

Performance per cooling unit

Ice-Makers

15 kg ice per day
40 L milk per day
80 kg fish per day

Refrigerators

180 L Volume
20 kg food per day

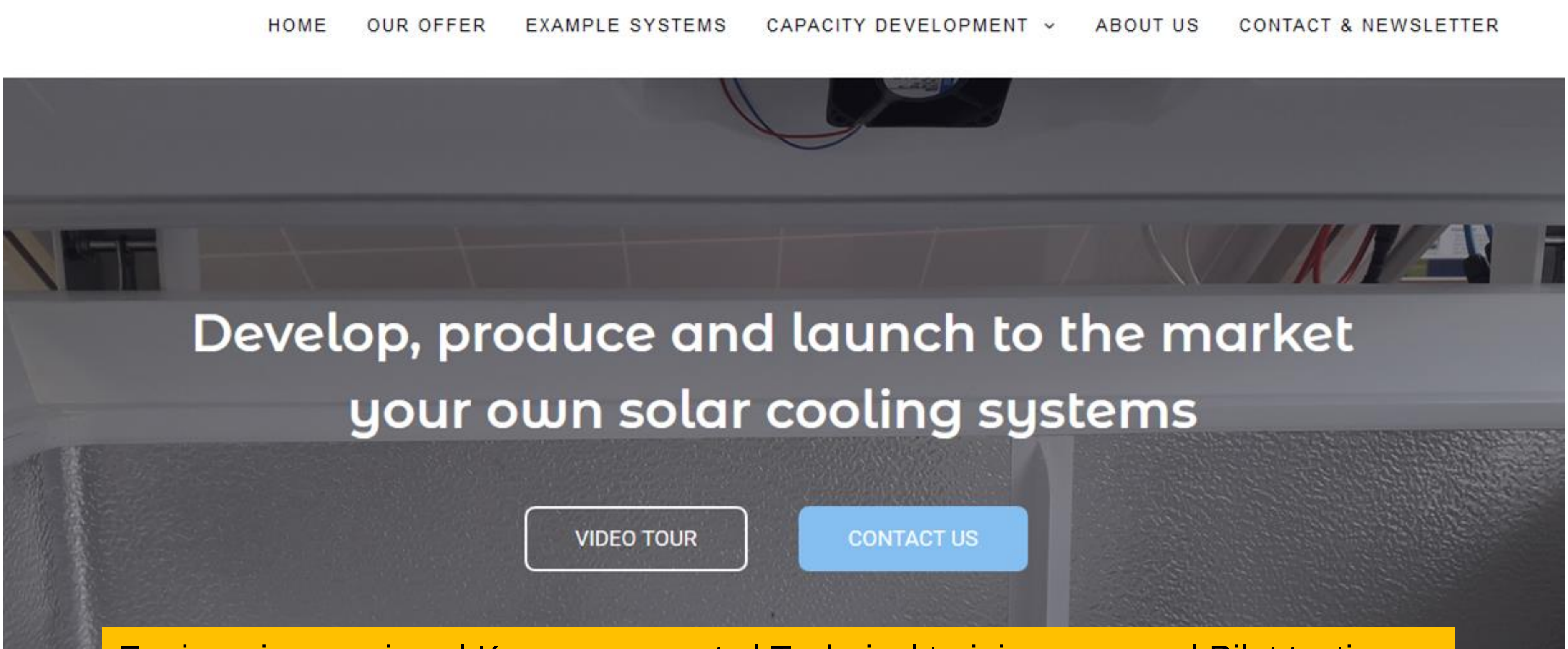
Water Chillers

2.5 kwh per day
80 L milk per day
6 m³ cold rooms

Technology transfer

Solar Cooling Engineering

- Spinoff Company founded in 2018 http://solar-cooling-engineering.com



Engineering services | Key components | Technical training courses | Pilot testing

Technology transfer

Solar Cooling Unit - SelfChill ®

- **Create your own Refrigeration Systems**
- Unbeatable transport cost
- Duty free in most countries
- Battery free compatible (Direct-Drive)
- Natural refrigerant R600a (already filled) with very low global warming potential (GWP)
- Monitoring & PAYG over Smartphone App

Distributed in Germany by:

Phaesun®

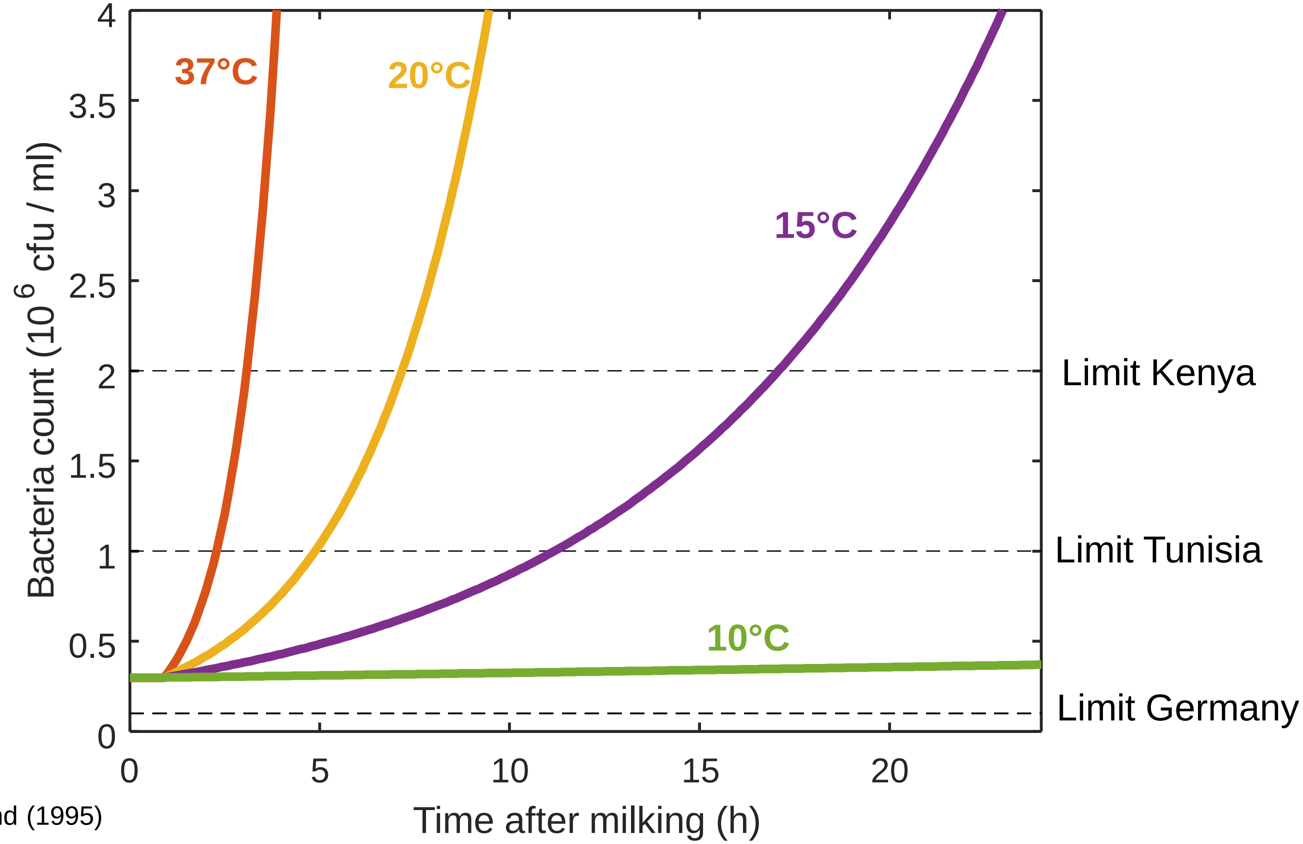
www.Phaesun.com

Design of solar powered refrigeration systems

- Important considerations:
  - Product cooling requirements
  - Value chain context and demand of final users
  - Refrigeration Method
  - Energy demand (Thermal losses and cooling demand)
  - Energy supply configuration (Solar, battery free?)

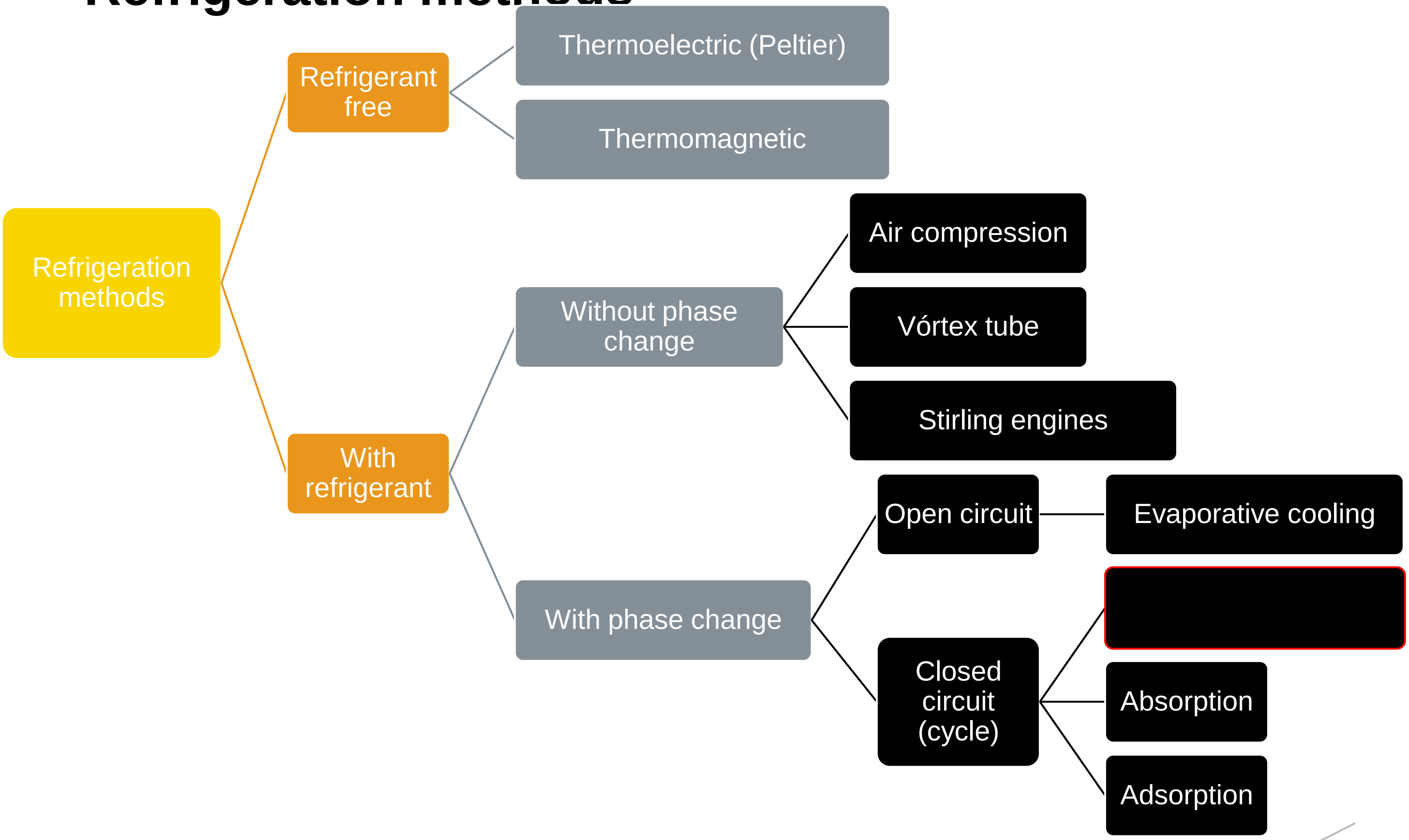
Cooling requirements of raw milk

- Raw milk has around 37°C after milking
- Highly perishable due to rapid bacteria growth



Source: Modified from Bylund (1995)

Refrigeration methods



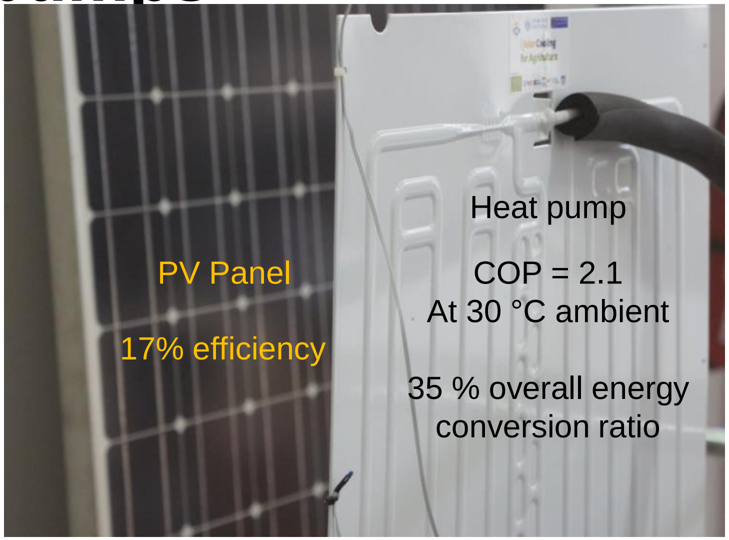
Cooling performance of heat pumps

- **COP** (Coefficient of performance)

$$COP = \frac{Q\ cooling}{P}$$

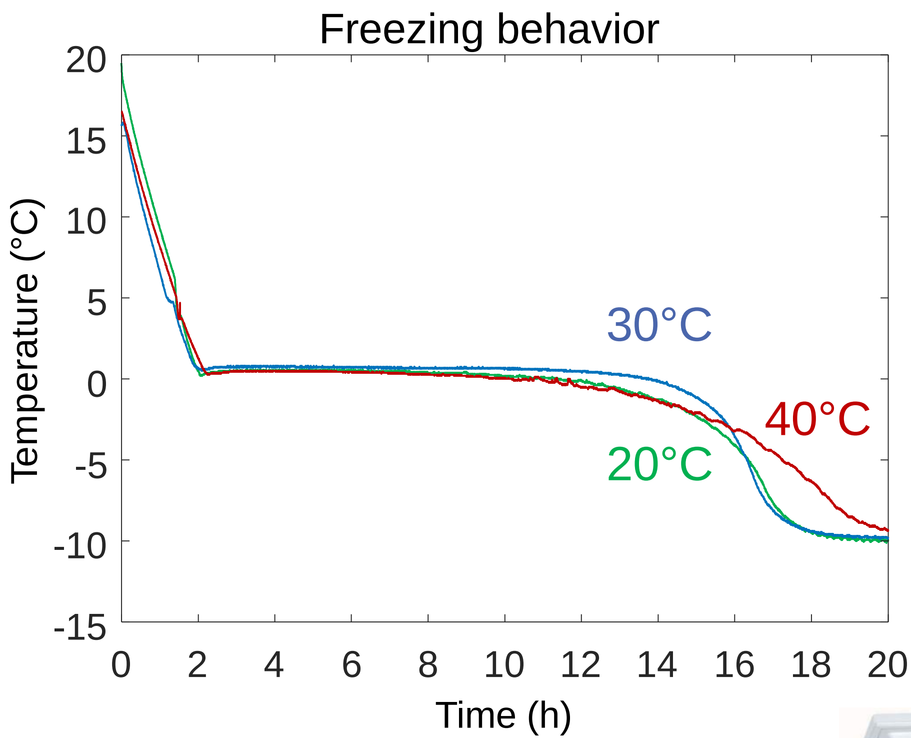
- **COP real ***

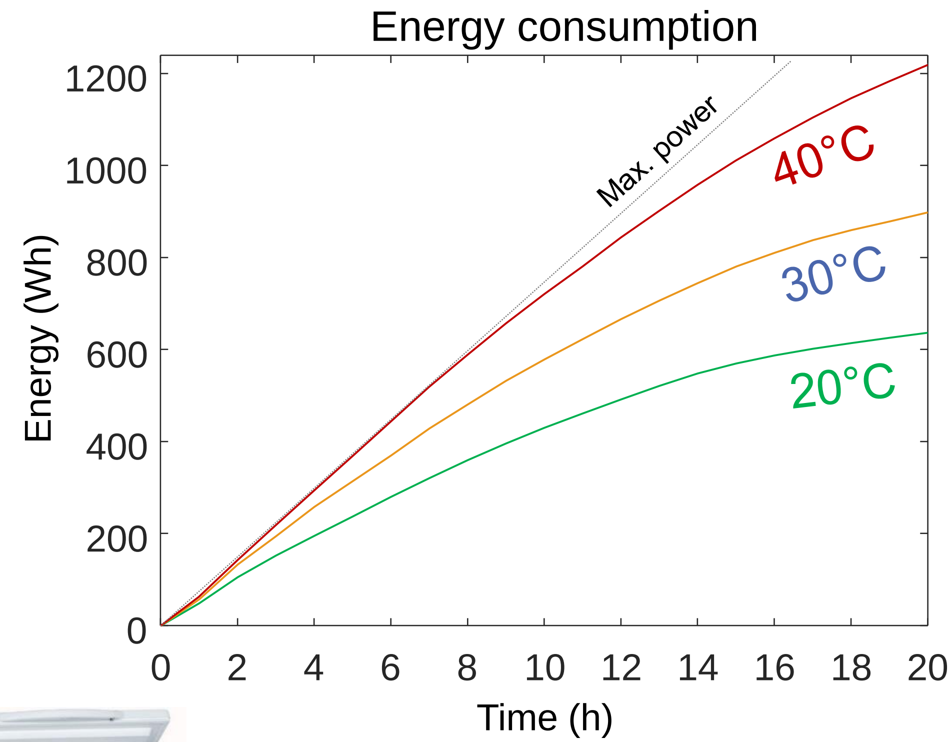
		T warm (°C)		
		20	**30**	**40**
T cold (°C)	**4**	2.6	2.1	1.8
	-10	1.6	1.4	1.1



*Typical refrigerator

Energy consumption





$T_{ambient}$

20°C

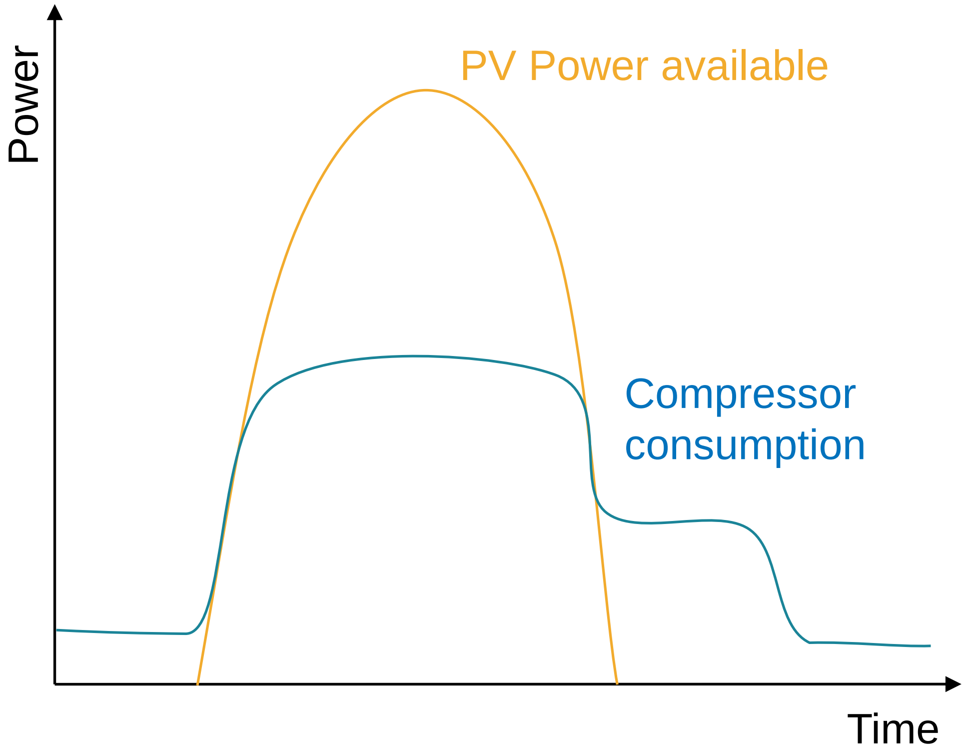
30°C

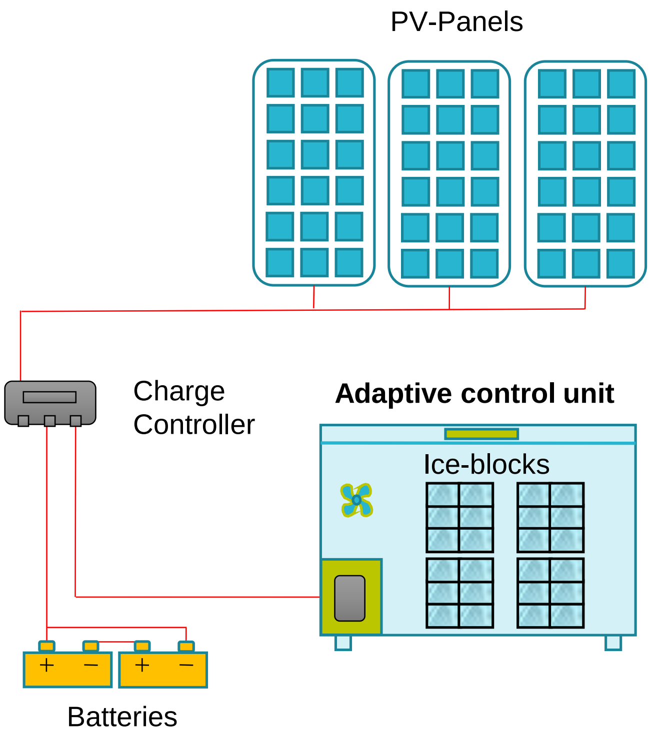
40°C

6 L water → ice

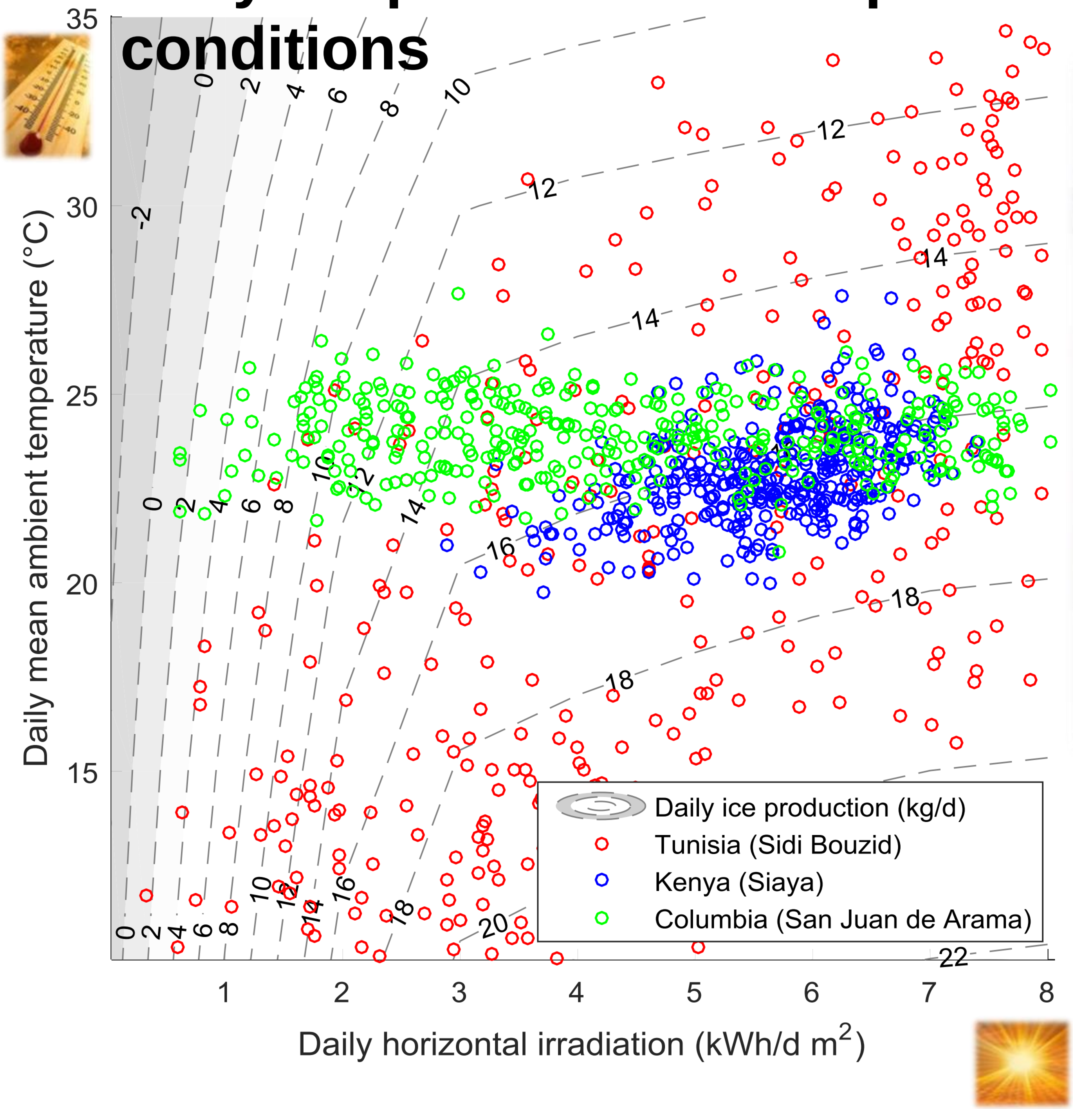
20°C to -10°C

Energy supply configuration





Daily ice production in dependence on weather conditions



50 Kg ice storage
12 kg/day
4 days autonomy

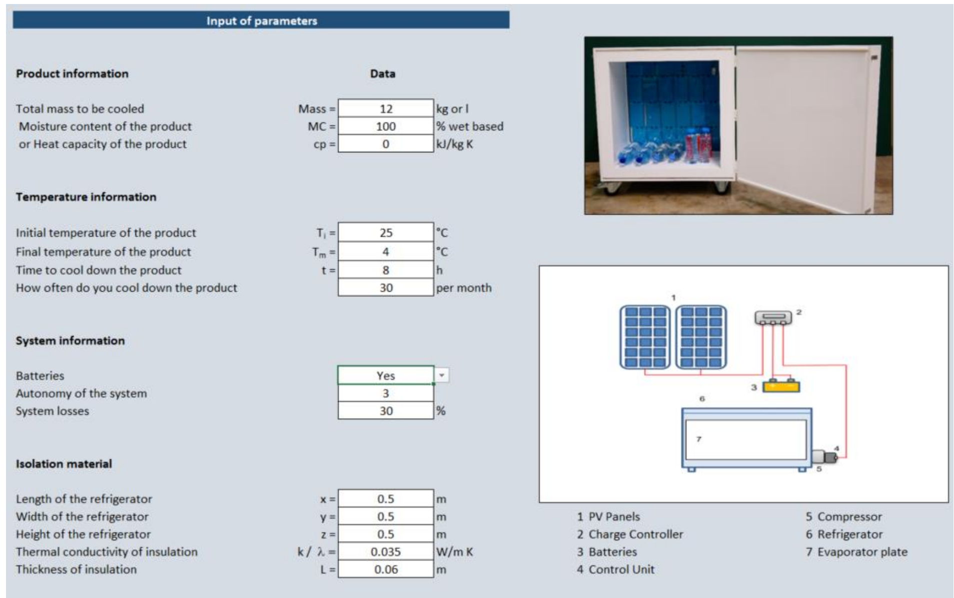
Design Tool box for solar refrigerators and ice-makers

Weather data →

System Type →

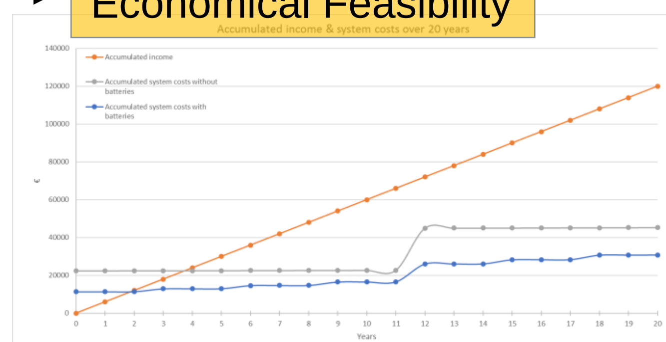
Cooling Demand →

Cost of Components →



→ **Sizing** of:
PV Panels
Batteries

→ Economical Feasibility



Download under
https://energypedia.info/wiki/Do_It_Yourself_-_Solar_Cooling_Units

energypedia

Recommendations for the design challenge

- Consider an overall solution (including PV panels, thermal storage, electrical batteries, control unit and refrigeration system)

- Understand the cost of the solution and its sensibility to:
  - Weather conditions
  - User requirements (Temperatures, cooling speed)
  - Cooling capacity (kg ice/day, L water/day, cold room volume)
  - Production volumes (cost of 1 prototype or first 10,000 Units)

- Consider including:
  - Mass production components available in the market
  - Modularity, local assembling and maintenance
  - Business models for its distribution in rural areas

Thank you for your attention!

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