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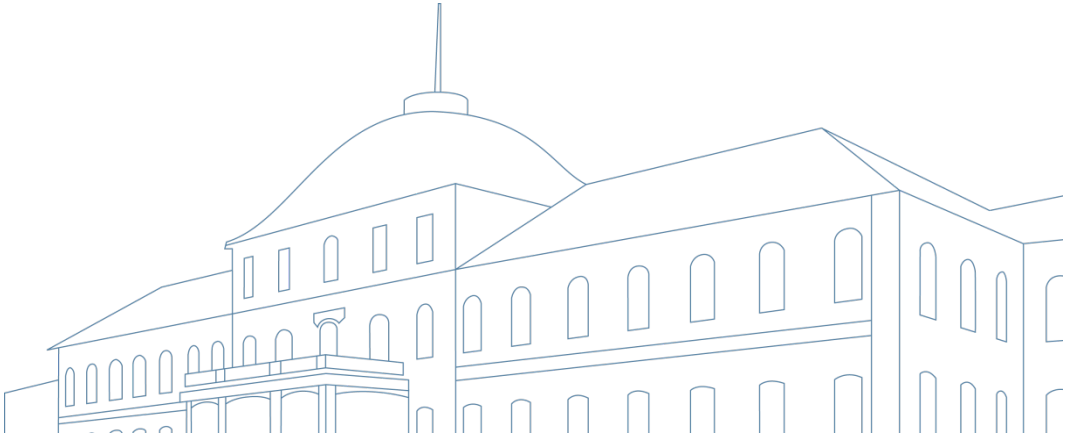
PV-Solar Chillers for Milk Cooling

BSW-Solar Special Exhibition „Off-Grid Power Solutions“

Case studies and technical solutions

Victor Torres Toledo

Universität Hohenheim
Institute of Agricultural Engineering
Tropics and Subtropics Group
Stuttgart, Germany



Institute Profile

Irrigation

- Precision irrigation and fertigation
- Sensors and **control systems for irrigation** scheduling

Energy

- **Extraction of plant oil** from Jatropha curcas
- Development of **plant oil stoves**
- **Biogas as rural household energy**
- Drying and conditioning of biogas digestate

Postharvest technology :

- Energy-efficient systems for high-quality fruit drying
- **Solar drying**
- Increasing energy efficiency in **medicinal plant drying**
- **Non-invasive quality assessment**

Solar Refrigeration:

Design methodology to facilitate **economical evaluation of solar refrigeration as businesses opportunity** in rural areas.

In colaboration with:
Research Group of Applied Thermal Engineering

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https://www.uni-hohenheim.de/einrichtung/fg-agrartechnik-in-den-tropen-und-subtropen

Motivation

Cost competitive cooling technologies are able to **improve economical development** of rural areas of the tropics by adding value to perishable agricultural and animal produce.

In many countries, the evening milk cannot be properly processed because it is highly perishable and cannot be kept fresh until the next morning.

Conventional **vapor-compression cycles refrigeration systems** driven by solar energy are becoming **more attractive** thanks to PV cost reduction.

A **design methodology for solar chillers** is needed for the assessment of **business opportunities** at different climatic conditions and demand scenarios.


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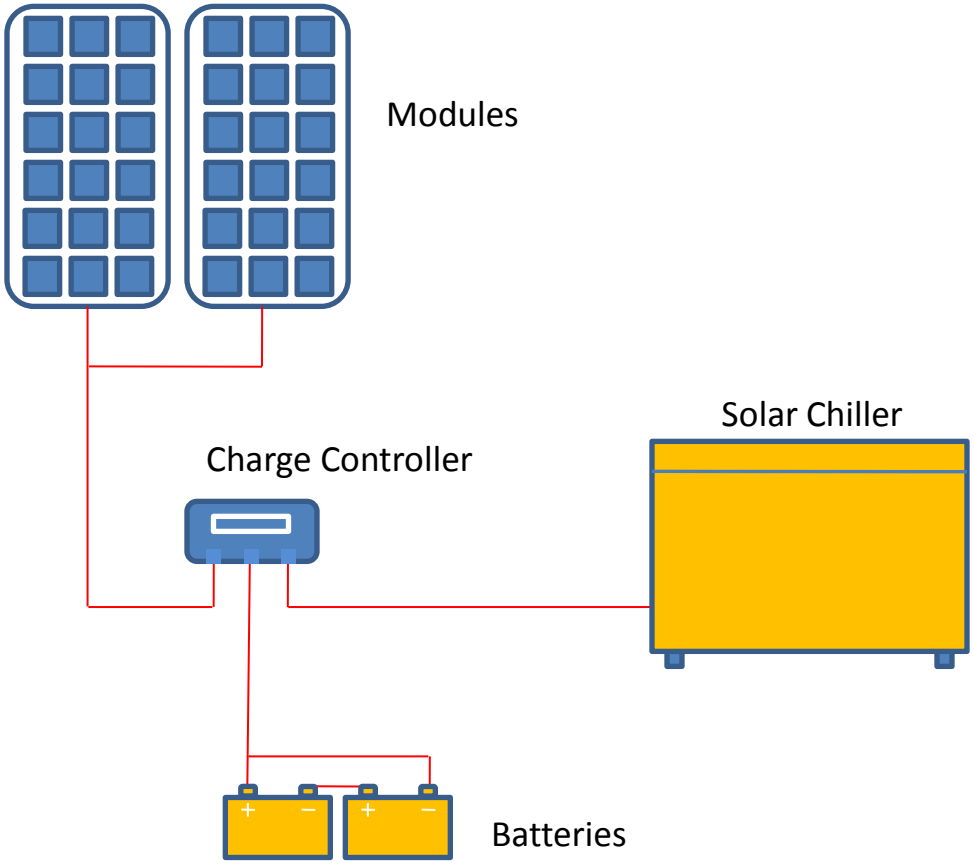
Solar Cooling System



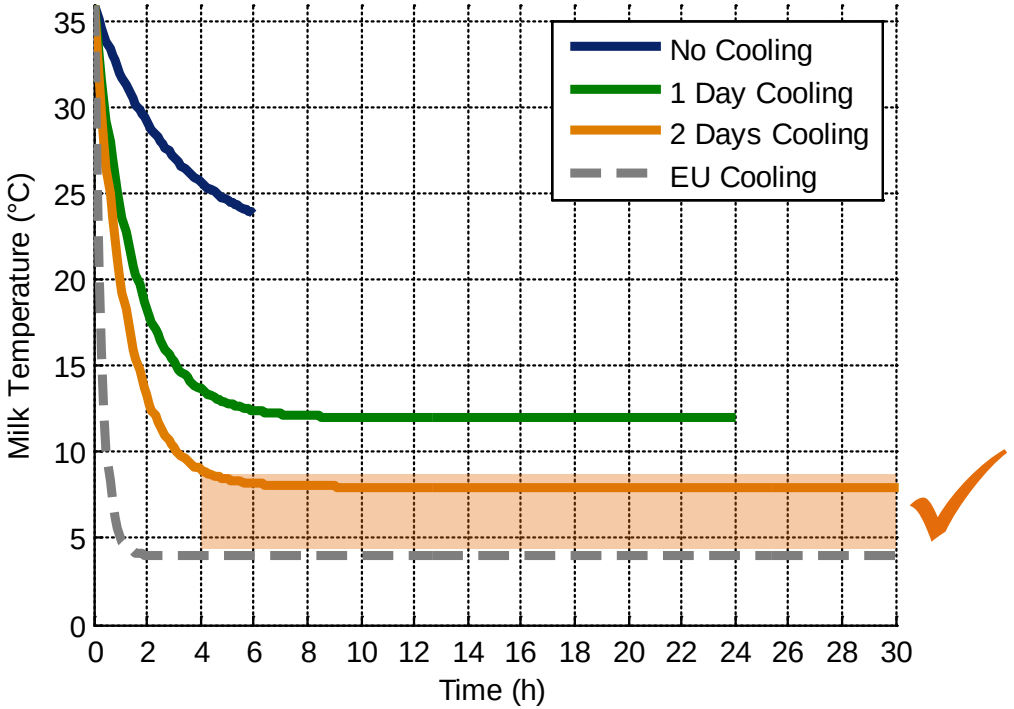
- ✓PV: 70-180 Wp
- ✓Battery: 800-2000 Wh
- ✓Chiller: (Model: Steca-PF166) 166 L
- ✓Working Temp. -20 to 12 °C
- ✓System Cost: 1000 – 1500 €

Milk cooling requirements

Milk Quality improves by:

- Conservation temperature:
  Under 12°C for one day conservation
  Under 8°C for two days conservation

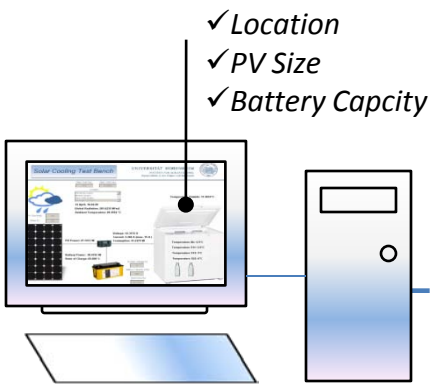
- Fast cooling after milking:
  Under 12°C after 2 hours
  Under 8°C after 4 hours



Testing Bench

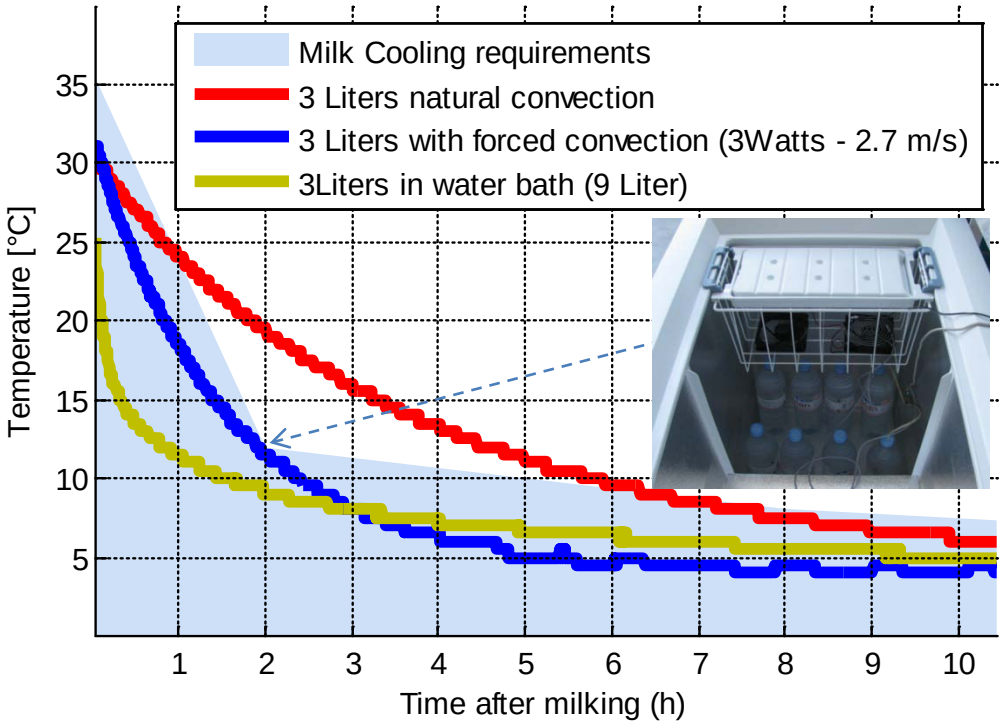
Measurements under real conditions:

- Emulation of PV Power and Ambient Temperature
- Based on Meotonorm Weather data
- Temperature sensors for cooling process
- Fridge electrical consumption
- Operation strategy (Compressor Speed, Fan, Cold Storage)



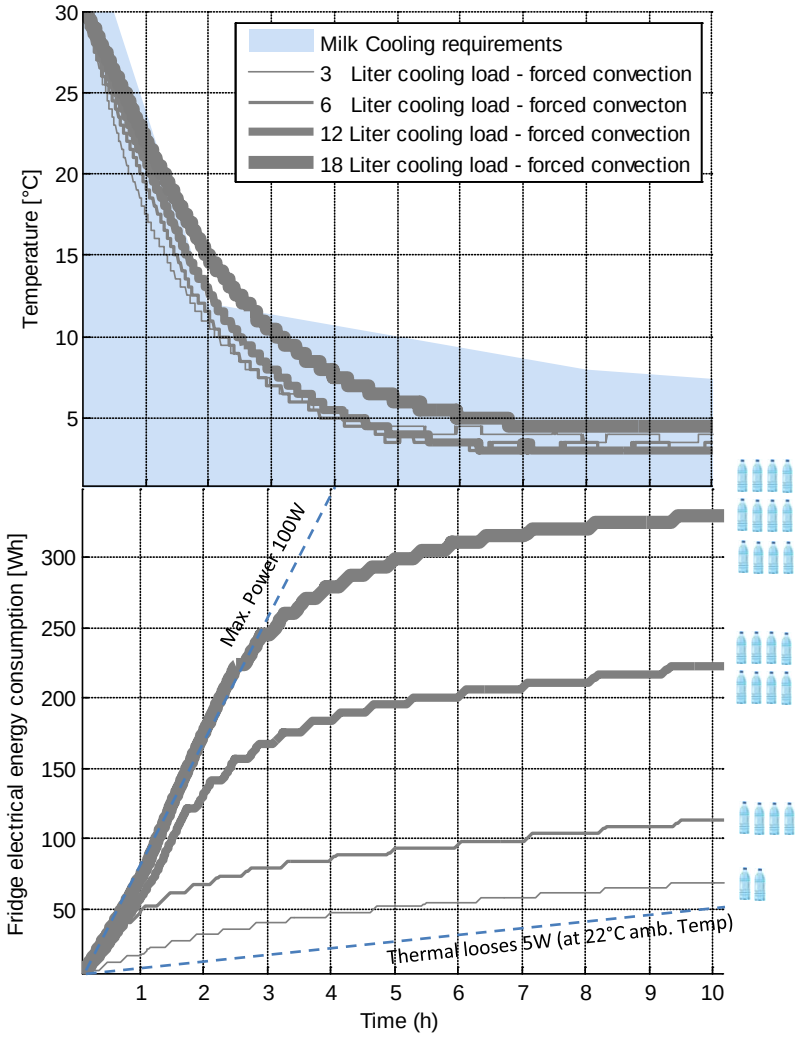
Cooling Method Messurments

Experimental comparison of natural convection, forced convection and water bath:



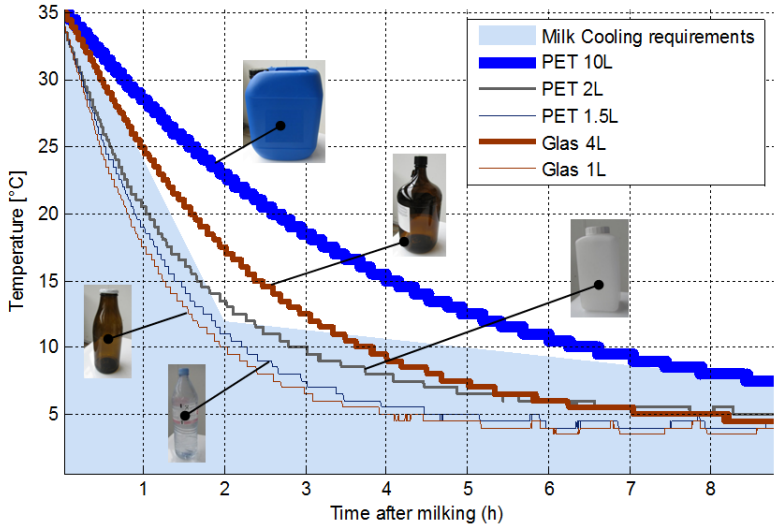
- Testing fluid: Water
- Chiller load: 3 liter
- Cooling temperature: 4°C
- Forced convection needed to meet cooling requiremts
- Low influence of fan position and power (over 1.5 Watt)

Refrigeration Load Messurments



Meets cooling requirements with:

- Forced convection during cooling process.
- Maximal load of 12 Liter simultaneously
- Container volume under 2 liter



Simulation model

Cooling Scenario

- **Cooling Method** (Forced Convection)
- **Container volume** (1.5 PET)
- **Refrigeration load and exchange times**

(10 L at 8 am + 10L at 8 pm)

- **Location** (Outdoors/Indoors)

Real Conditions Messurments
(at different Ambient temperatures)

Fridge + Battery, (Matlab)

PV Simulation (TRNSYS)

Weather Data (Meteonorm)

Optimizer (Matlab)

Economical Optimum Energy Suppy
PV (2€/Wp) – Battery (0.2€/Wh)

- PV Module: 5-Parameter TRNSYS Model based on data sheet (Solar World, *SW Poly RNA*)
- Lead Battery: Consider aging, self discharge and internal resistence based on data sheet (Intact, Block-Power)

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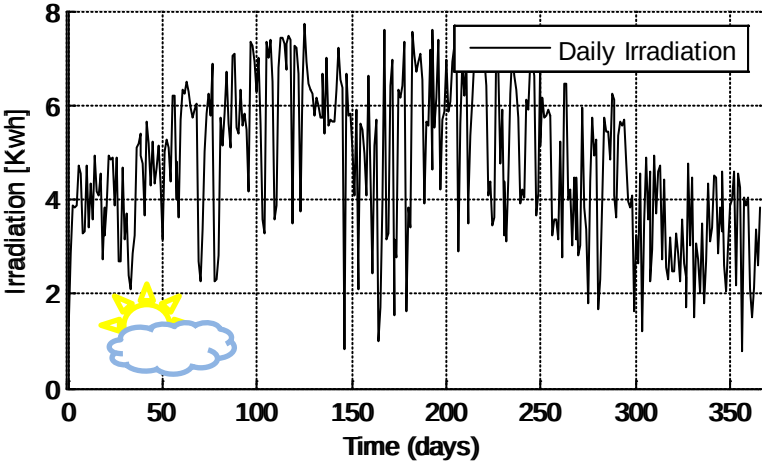
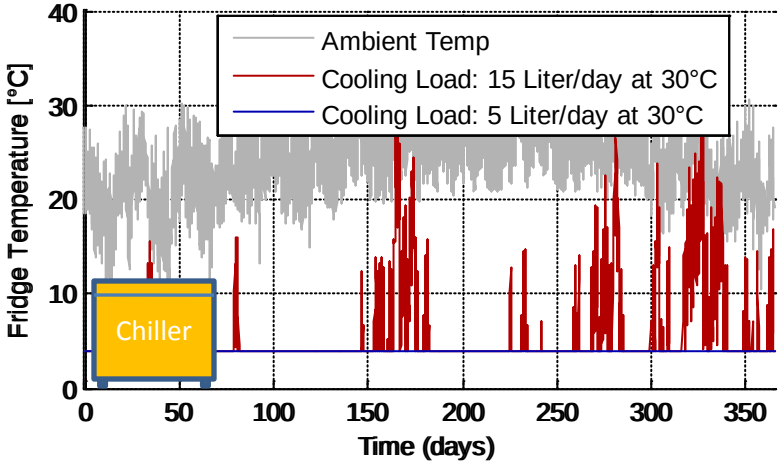
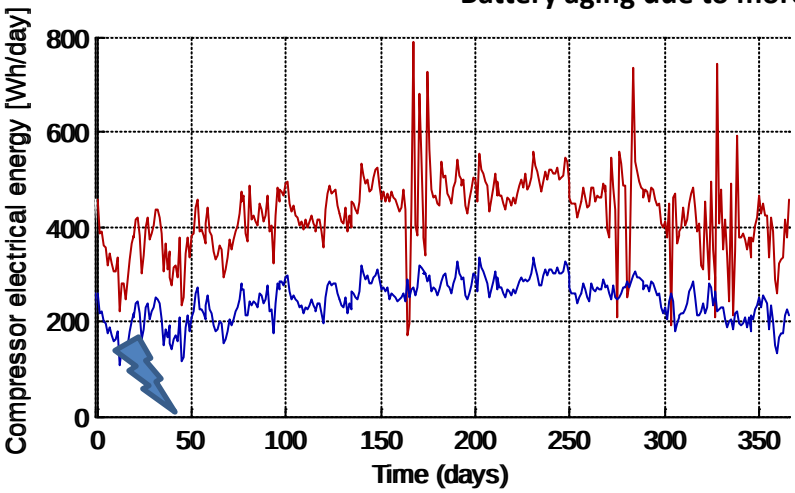
Annual Simulation

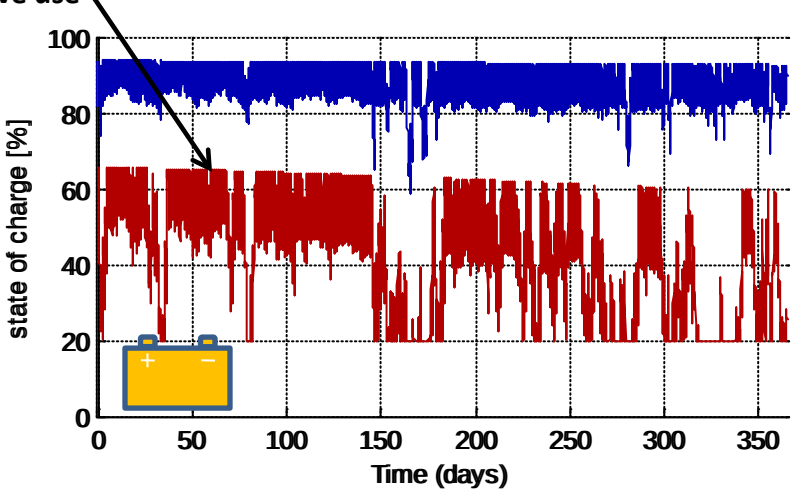
System after 8 Years located outdors at Havana – PV:120 Wp Battery: 1500 Wh





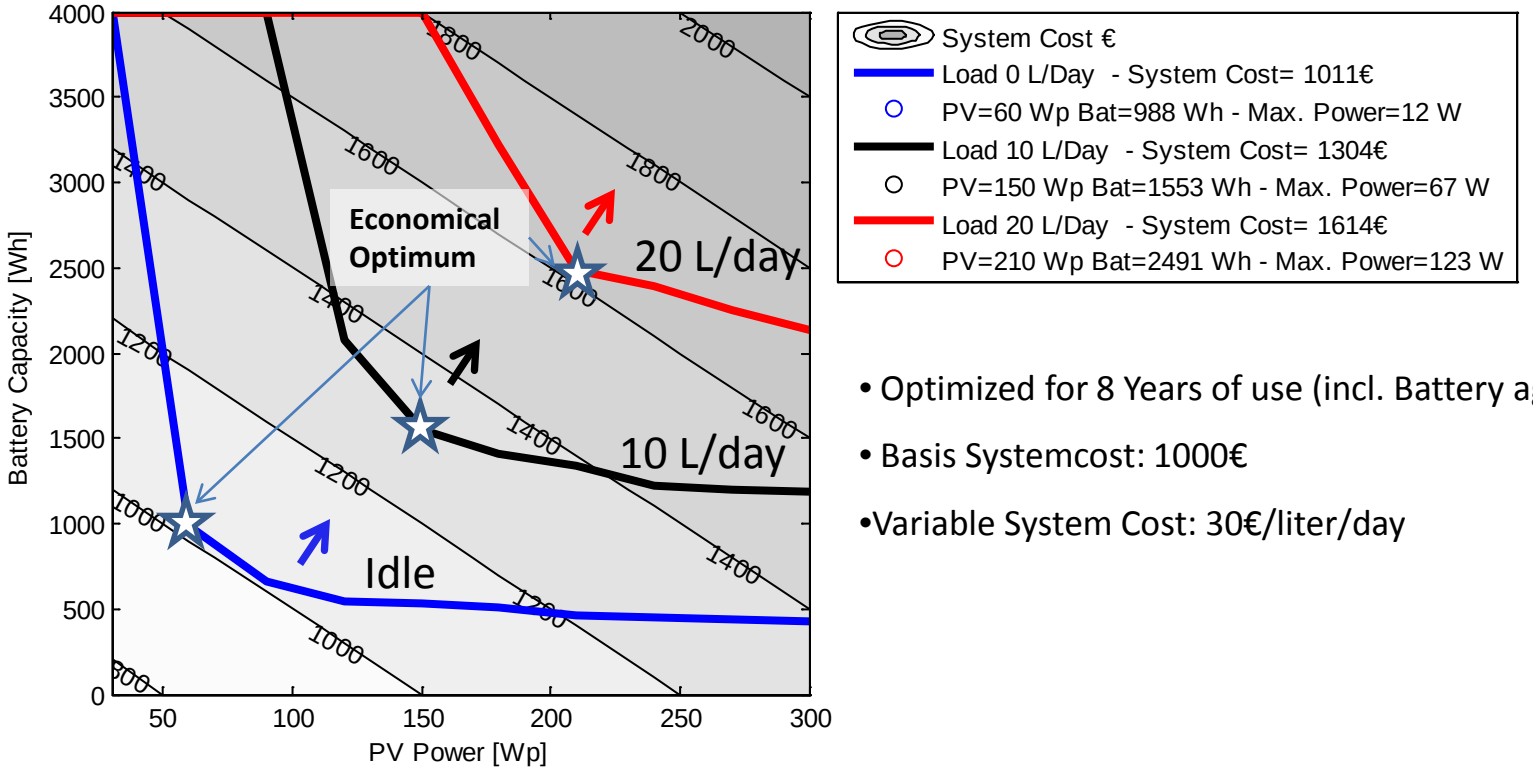
Battery aging due to more intensive use





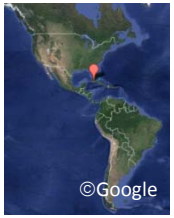
Solar energy supply optimization

Refrigeration load variation: located outdoors at Havana



- Optimized for 8 Years of use (incl. Battery aging)
- Basis Systemcost: 1000€
- Variable System Cost: 30€/liter/day

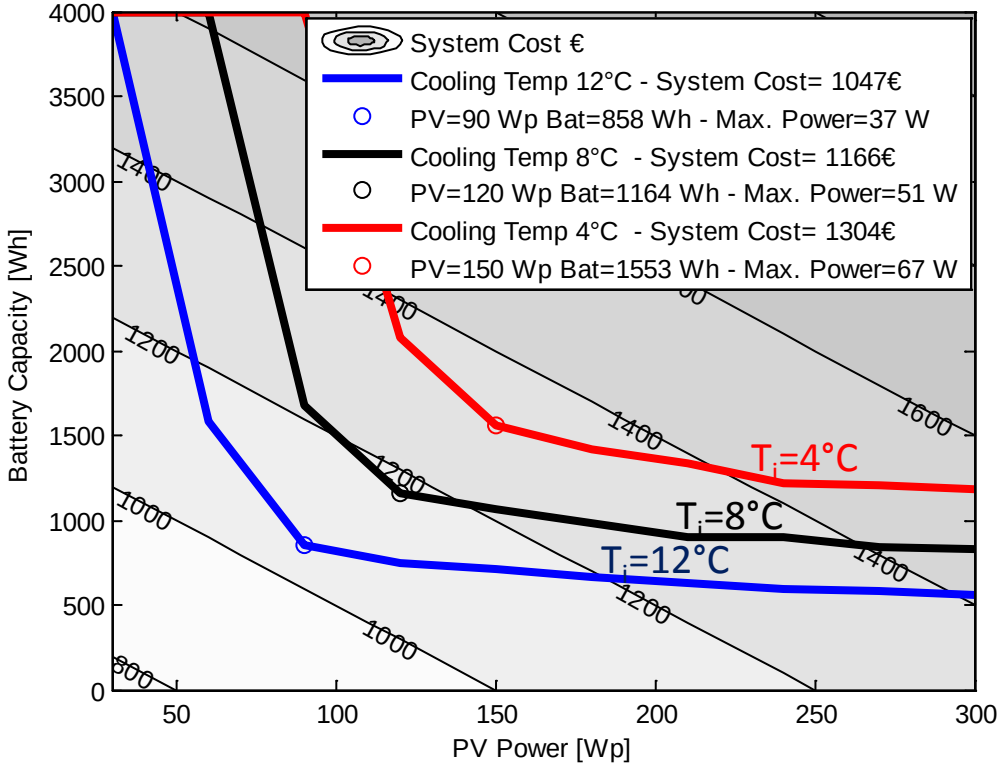
Temperature sensitivity



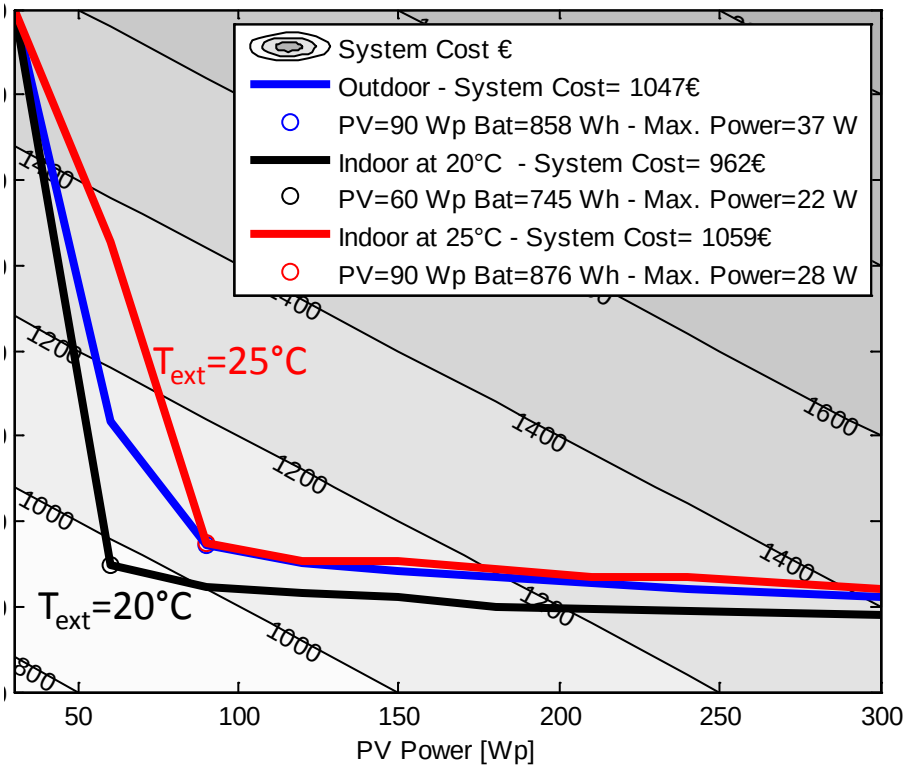
System after 8 Years located at Havana

- Internal Temperature (4-12 °C)
- Refrigeration Load: 10 Liter/day
- Outdoors

- Ambient Temp. (20-25 °C)
- Refrigeration Load: 10 Liter/day
- Cooling Temp. : 4°C



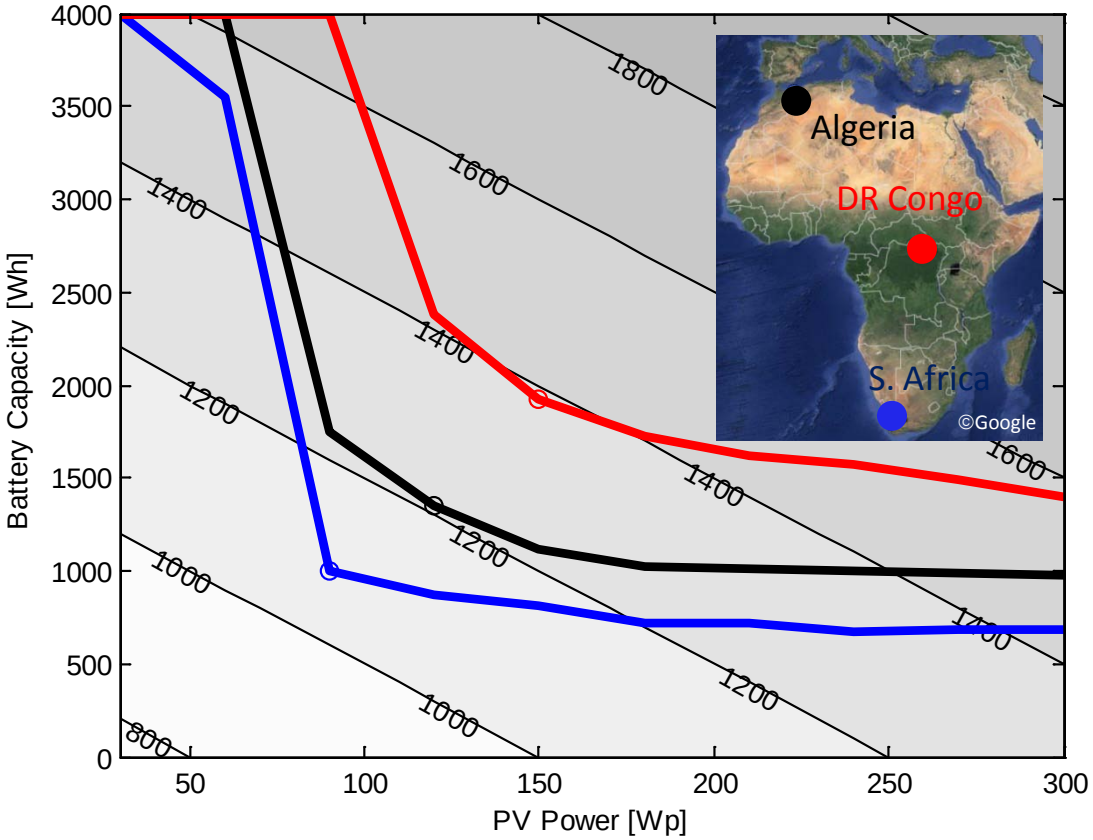
Cost Sensitivity: -32€/°C Ti

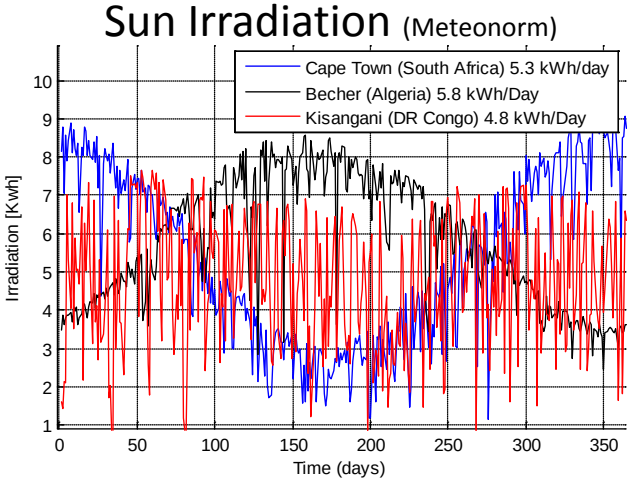


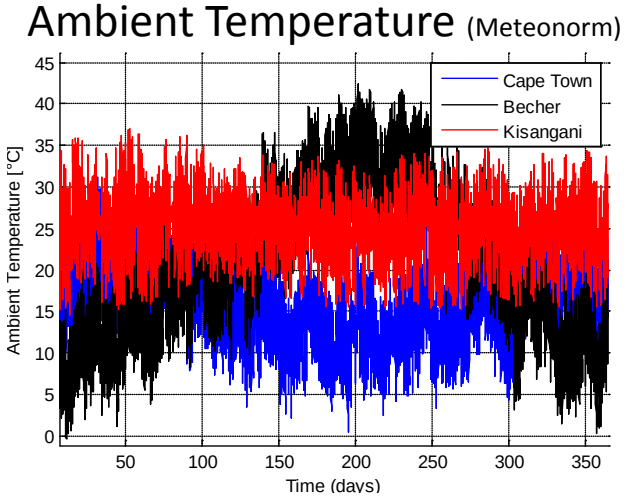
Cost Sensitivity: 19€/°C Text

Location sensitivity

System after 8 Years located outdoors (Cooling load 10 liter/day at 30°C)



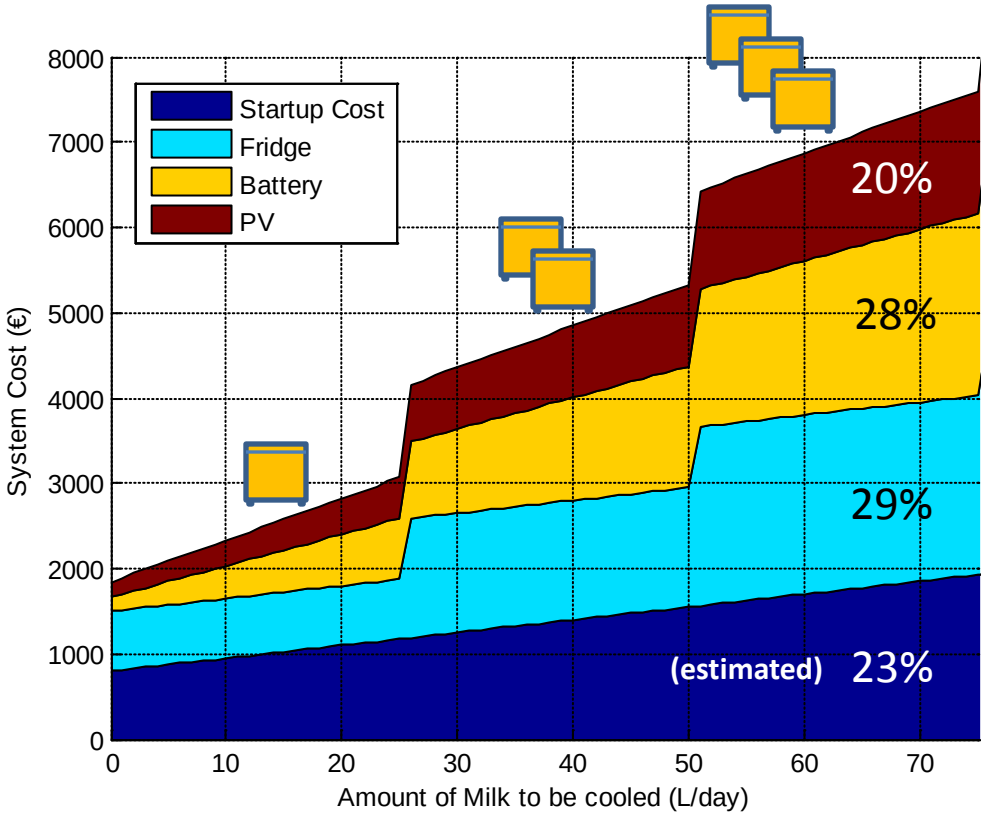




- Hight temperatures increase cooling power
- Tropical weather conditions increase battery cost

Economical evaluation

System cost estimations (location Kisangani , T_i=4°C, placed outdoors)



Added value:

- ❑Milk waste reduction (evening milk)
- ❑Smallholder farms growth
- ❑More efficient milk processing
- ❑Market flexibility (Milk collection centers)

Investment

100€ Invest per liter/day Capacity.

Profitability case:

Payback period set to max. 5 years
(Interest year rate of 10%)
Battery lifetime: 5 years
PV/Chiller Liftetime: 15 years
Usage of Fridge 75%

Minimal added Value : 5 Euro cent / Liter Milk

Conclusion

• The studied chiller is able to cool down **about 12 L milk simultaneously by using forced convection** (1.5W fan) meeting the requirements. (estimated daily load 25 L).

• A **simulation model based on real conditions measurements**, facilitates fundamental **optimisation of the solar system (50% of the investment)**.

• The profitability of **business opportunities with stand-alone refrigeration in the agricultural sector** depends on Location, cooling scenario and added value of the conserved milk.

• Further Work :

1) **Cold Storage** possibilities to improve cost efficiency and reliability.
2) **Evaluation of milk Quality improvement** and marketing chain.
3) Assessment of performance and **acceptability under real field conditions**.

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Thank you for your attention!

Victor Torres Toledo

Universität Hohenheim
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Stuttgart, Germany