CENTRE FOR RENEWABLE & SUSTAINABLE ENERGY STUDIES

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT

# ISEC 2026

# Thermal energy options for residences

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# Overview

- At Stellenbosch University, 20-30% of the electricity used in residences is to heat water using large heat pump systems in each building.
- Large heat losses were identified, specifically with Simonsberg residence, due to poor pipe insulation, sub-optimal control strategy and ring-main design.
- PV-driven systems can reduce heat pump electricity costs by 20-40%, with investment return of up to 30% and payback of 3.5-4.0 years.
- Solar thermal technologies can reduce electricity costs further, but would require subsidies for the project’s IRR to meet the cost of capital

# Current Systems Overview

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| | | Simonsberg | Metanoia | Sonop |
|---|---|---|---|---|
| Building & Occupancy | Gross Internal Area | 5 927 $m^2$ | 13 776 $m^2$ | 4 425 $m^2$ |
| Heat Pump (HP) | # Student | 276 | 500 | 264 |
| | Heat Pump Capacity | 2 x 36 kW | 4 x 47.3 kW | 2 x 36 kW |
| | Est. Annual HP Electricity Consumption | 111 655 kWh | 89 155 kWh | 101 546 kWh |
| Domestic Hot Water (DHW) | Seasonal Performance Factor (COP) | 3.5 | 5.4 | 3.4 |
| | Storage Capacity | 2 x 8600 Litres | 4 x 7500 Litres | 2 x 6000 Litres |
| | Est. DHW per Student | 177 Litres/student | 87 Litres/student | 113 Litres/student |
| Thermal Demand & Losses | Est. Annual Thermal Demand | 393 324 $kWh_{th}$ | 478 387 $kWh_{th}$ | 347 151 $kWh_{th}$ |
| | Losses Ratio | 2.5:1 | 0.8:1 | 1.3:1 |

# Simonsberg – Thermal Demand Profile & Electricity Consumption Overview

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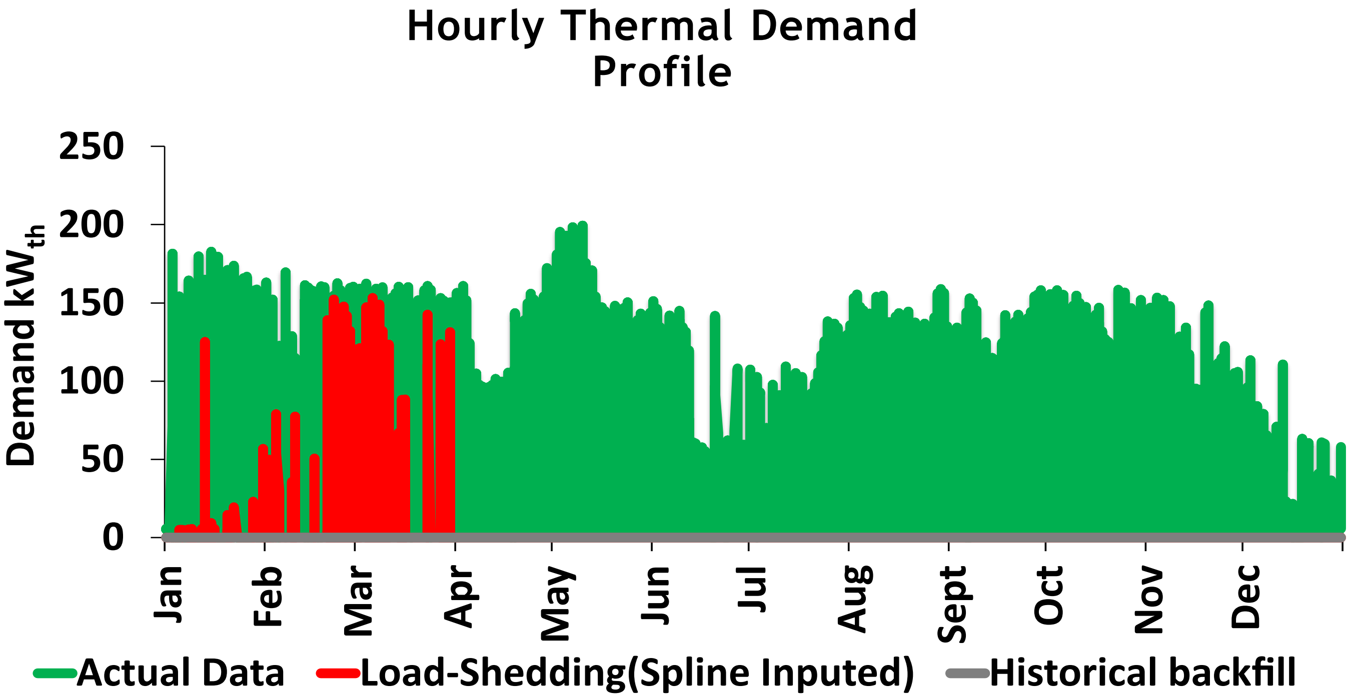


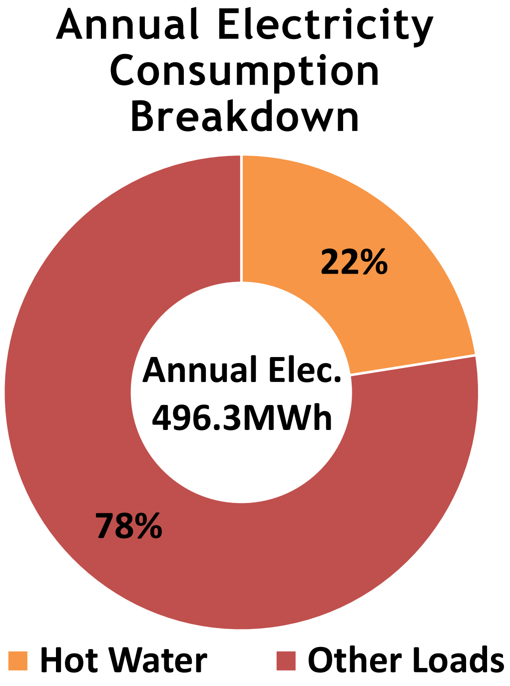

# Simonsberg – Annual hourly thermal-demand heatmap

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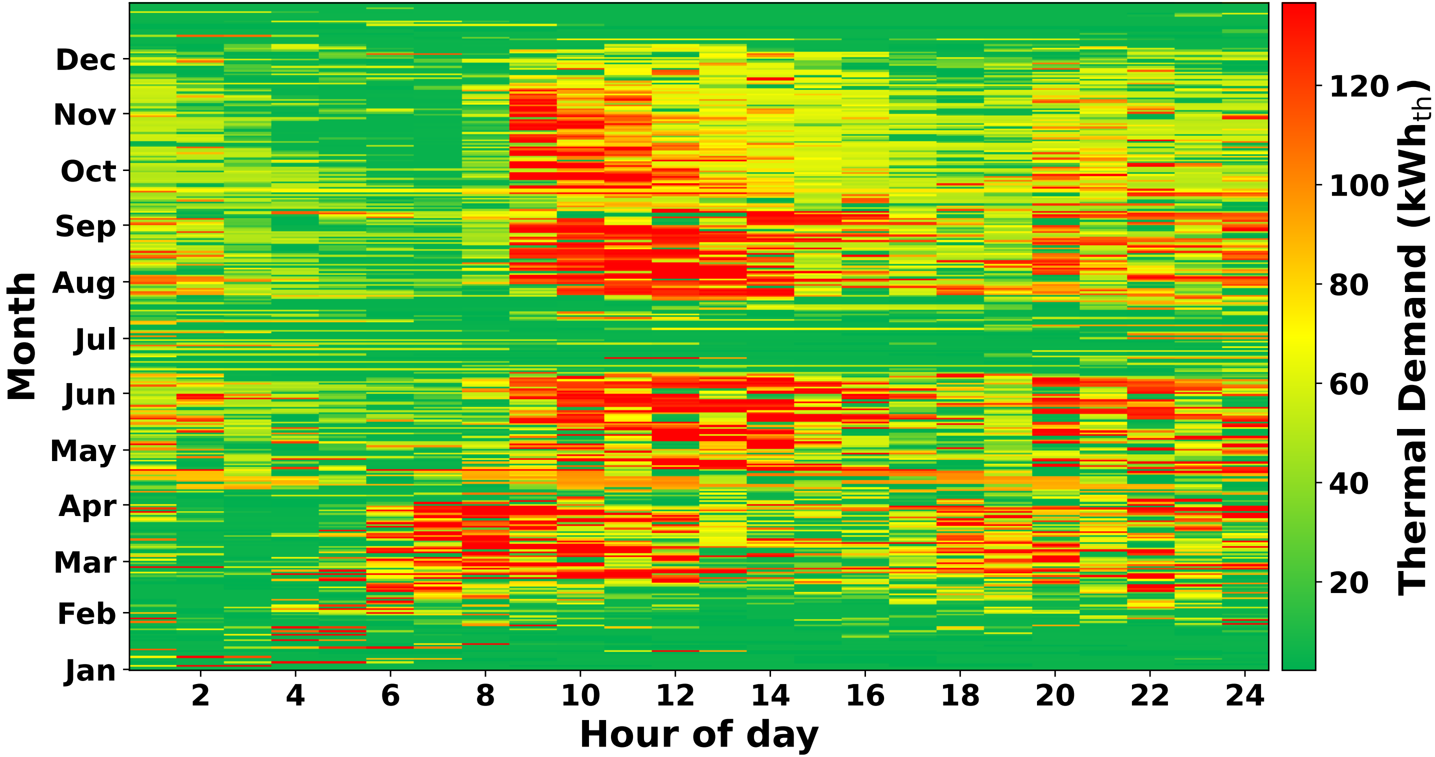


- Demand is linked to term attendance
- Morning has the highest demand (8:00-12:00) with a late evening spike (20:00-midnight)

**This includes both Hot Water Consumption and standing losses from the ringmain

# Modelling Assumptions

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## Design and Operational Assumptions

- Available area: 300 $m^2$
- Heat pump off during peak hours
- Turns on only if water temperature drops below 45 °C
- Electricity Inflation: (12% 2025-2028, 6% thereafter)
- Seasonal time-of-use (ToU) electricity tariffs:

| | High Demand Season | Low Demand Season |
|---|---|---|
| Peak | 8.35 R/kWh (0.43 €/kWh) | 2.53 R/kWh (0.13 €/kWh) |
| Standard | 2.37 R/kWh (0.12 €/kWh) | 1.65 R/kWh (0.085€/kWh) |
| Off-Peak | 1.39 R/kWh (0.071 €/kWh) | 1.24 R/kWh (0.064 €/kWh) |

### PV+HP

**Cost per unit:** 10 R/$W_p$ (0.51 €/$W_p$)
**O&M:** R 0.255 /Wp/year

### ST+HP

**Cost per unit (incl. Storage):** 13 867 R/$m^2$ (707 €/$m^2$)
**Cost per unit (excl. Storage) :** 8 502 R/$m^2$ (433 €/$m^2$)
**O&M:** 1.15% of Capital Cost

### PVT+HP

**Cost per unit (incl. Storage):** 20 000 R/$m^2$ (1025 €/$m^2$)
**Cost per unit (excl. Storage):** 16 460 R/$m^2$ (844 €/$m^2$)
**O&M:** 1.15% of Capital Cost

# Comparison of Alternative Peak-Load Shifting Strategies

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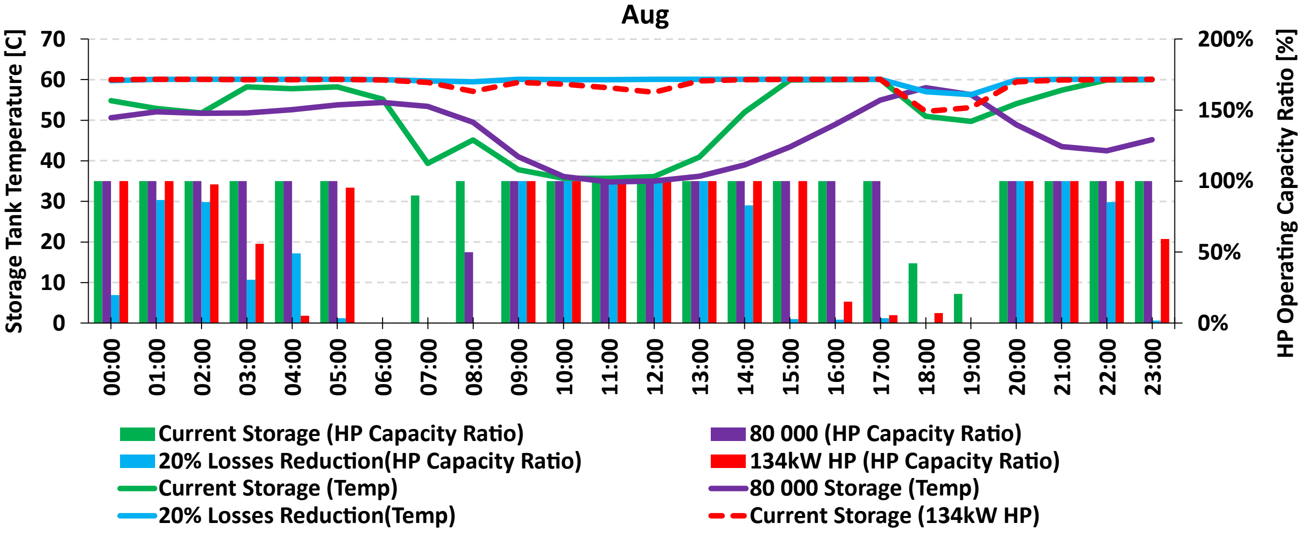
## Peak-Load Shifting Options:

1. Energy efficiency (~20% demand reduction through insulation and circulation controls)

2. Larger heat pump (replace 2x36kW with 3x47 kW)

3. Larger storage (from 17,200L to 80,000L)




**Conclusion:**

Energy efficiency should be implemented first. Among the capacity options, increasing **heat-pump capacity** is more cost-effective than increasing storage.

# Polysun PVT Model and Adaptation for PV and ST

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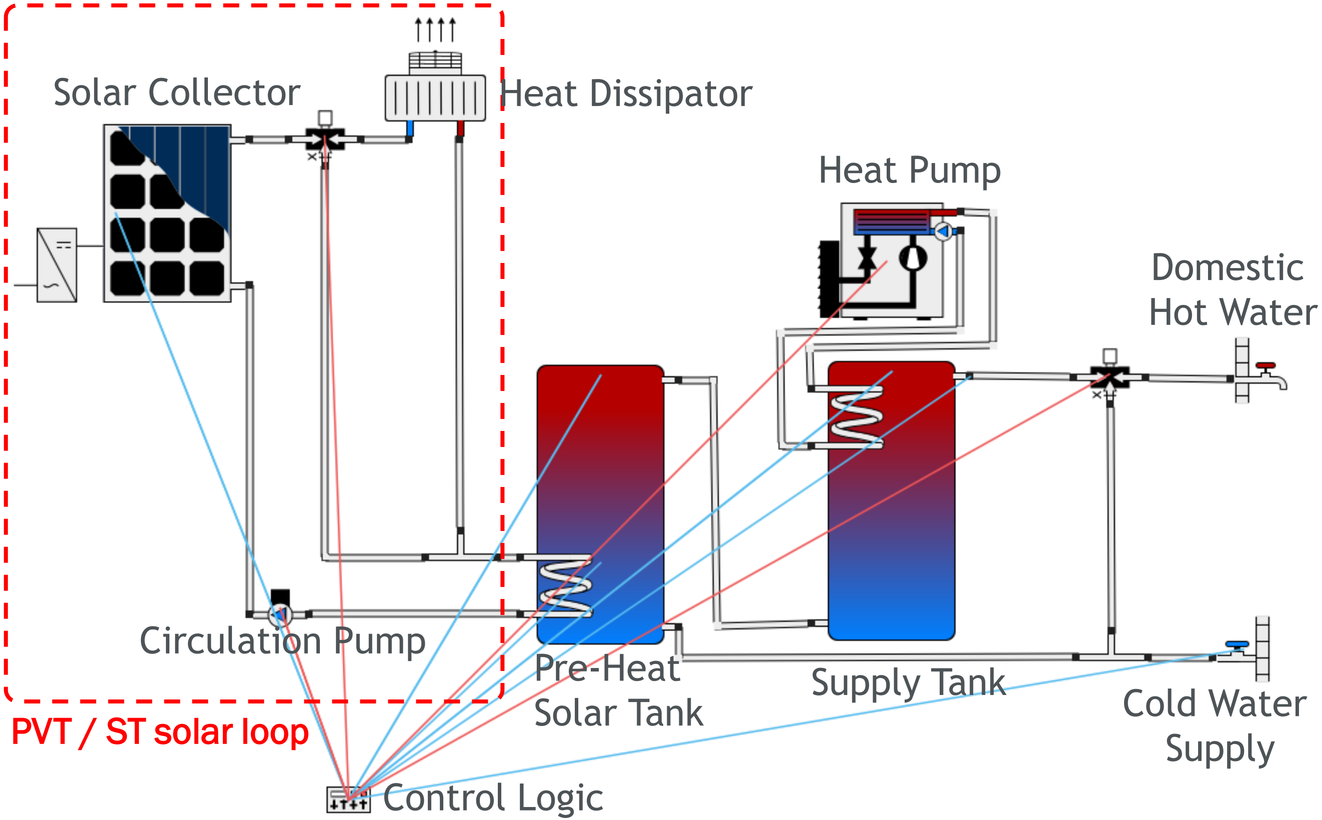


- In ST/PVT systems, the solar loop preheats the water.
- The heat pump raises the water temperature to the required level.
- In the PV system, the solar loop is replaced by a heat pump.
- PV generation offsets grid electricity for the heat pump, circulation pumps, and other auxiliary systems.
- In ST/PVT systems, a heat dissipator rejects excess heat during periods of high solar input and low hot-water demand.

# Simonsberg – Monthly Energy Supply Breakdown

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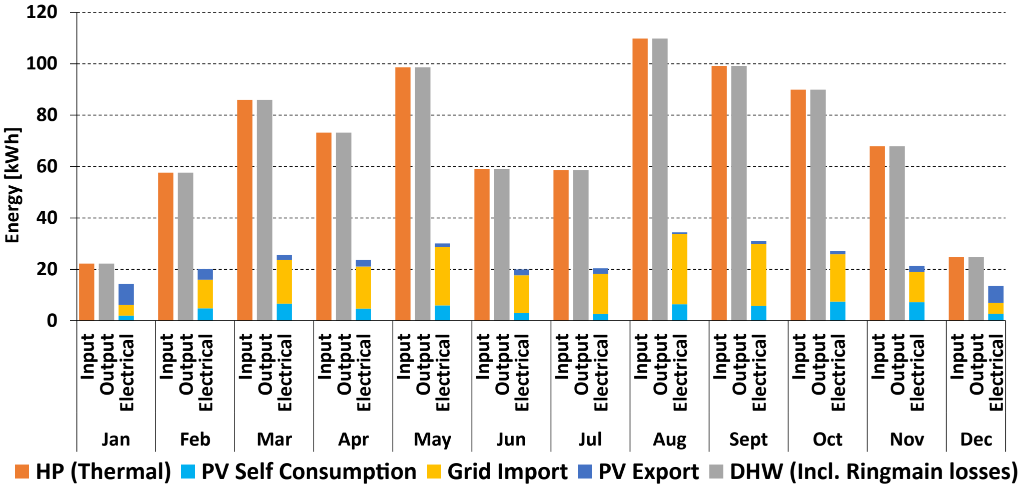
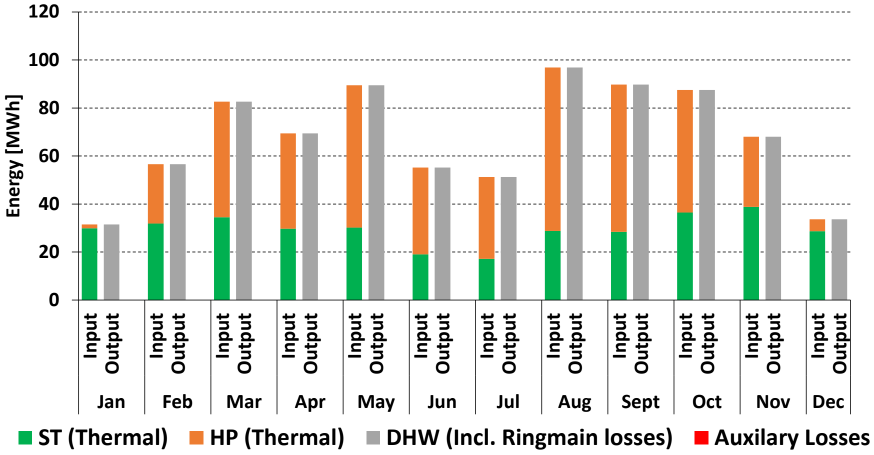
## PV HP + Grid HP




## ST + Grid HP




Solar Fraction (Excl. PV Export): 24%
Solar Fraction (Incl. PV Export): 33%

Solar Fraction : 44%

# Simonsberg – Hourly Energy Usage (Winter Aug 20, 2023)

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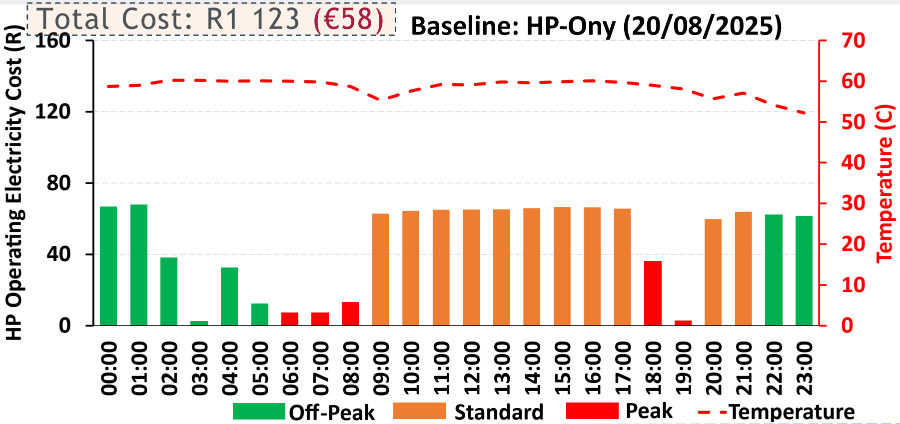


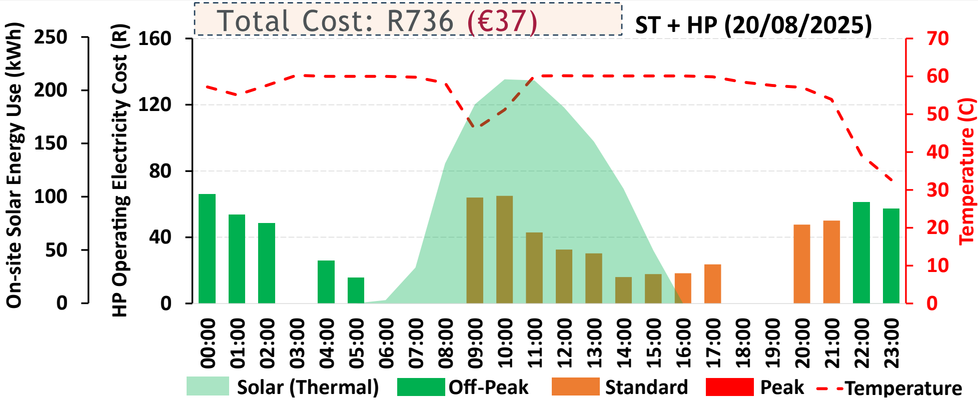


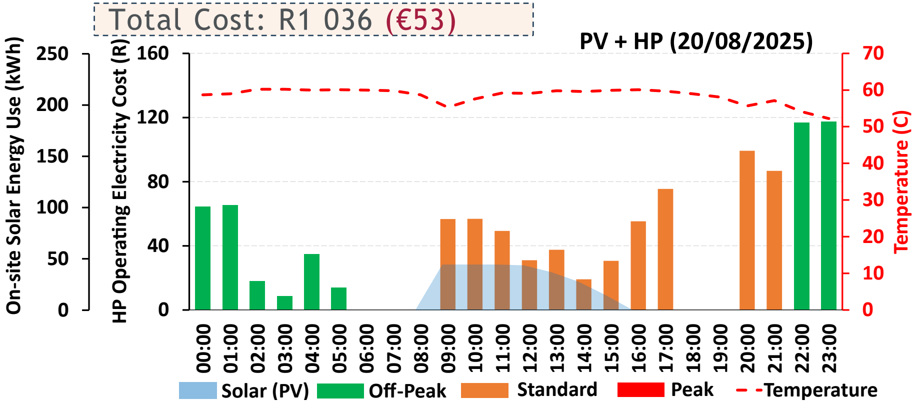


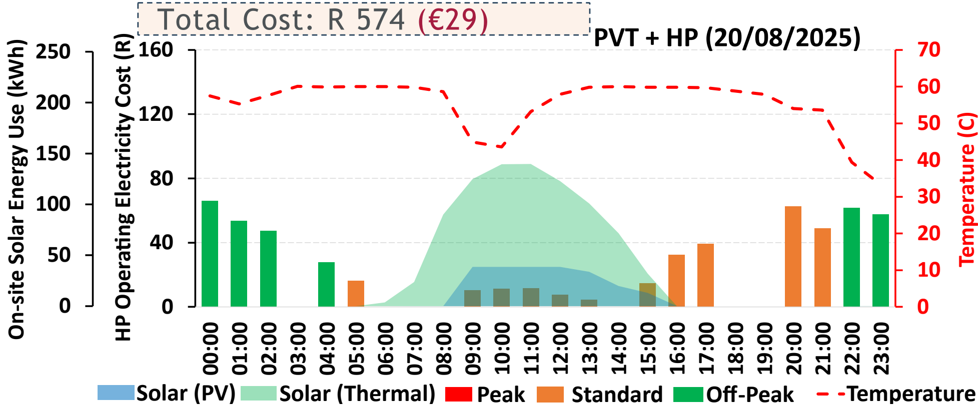

# Result Comparison – Simonsberg

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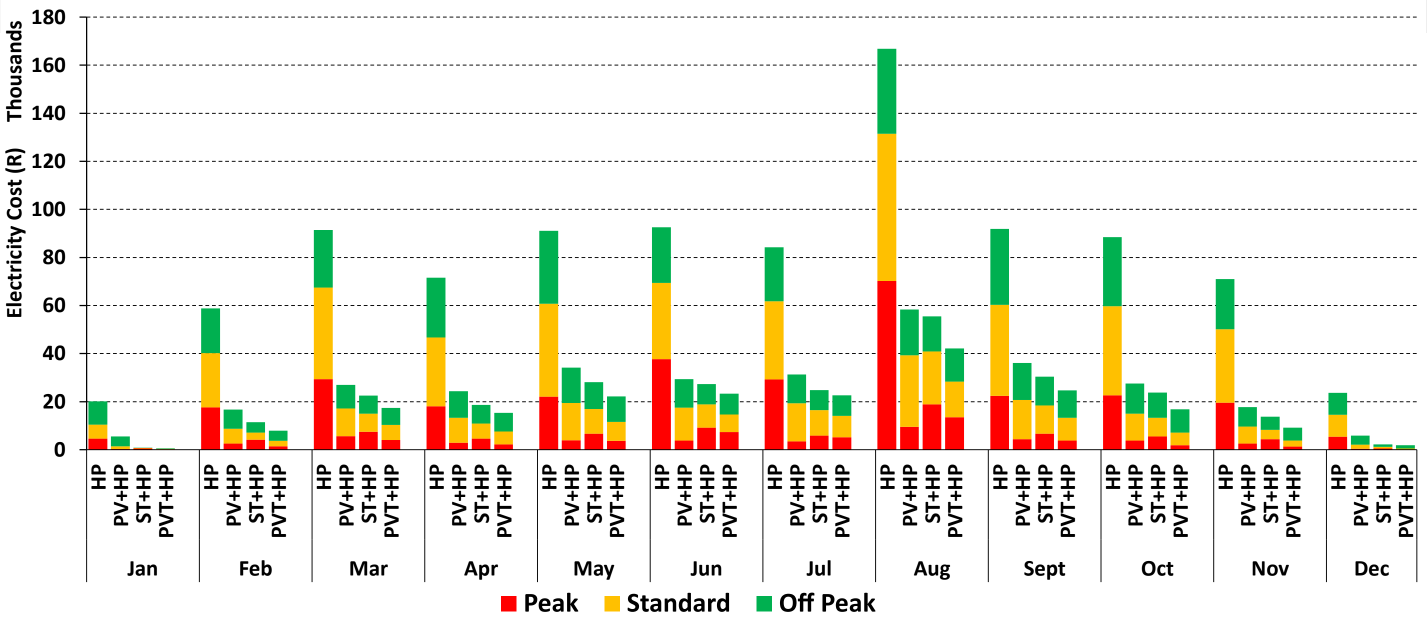
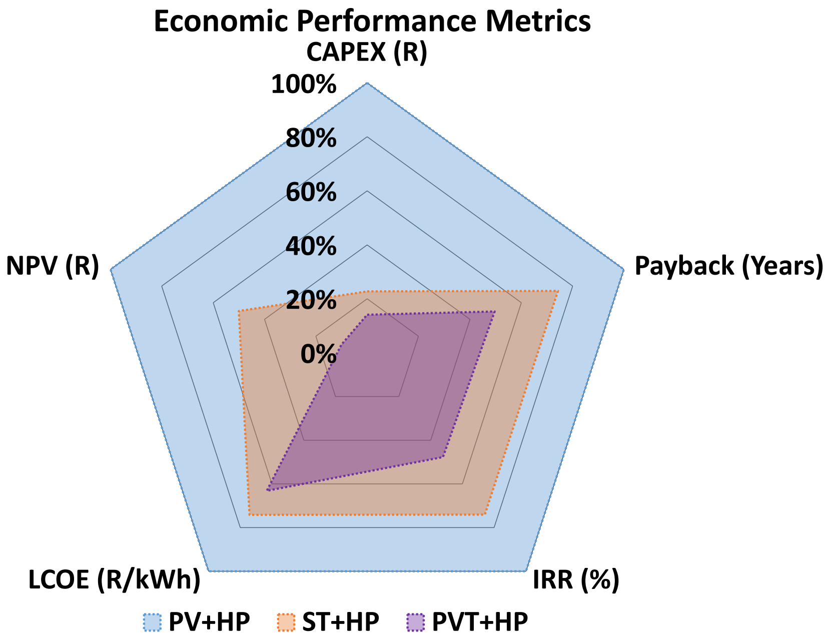
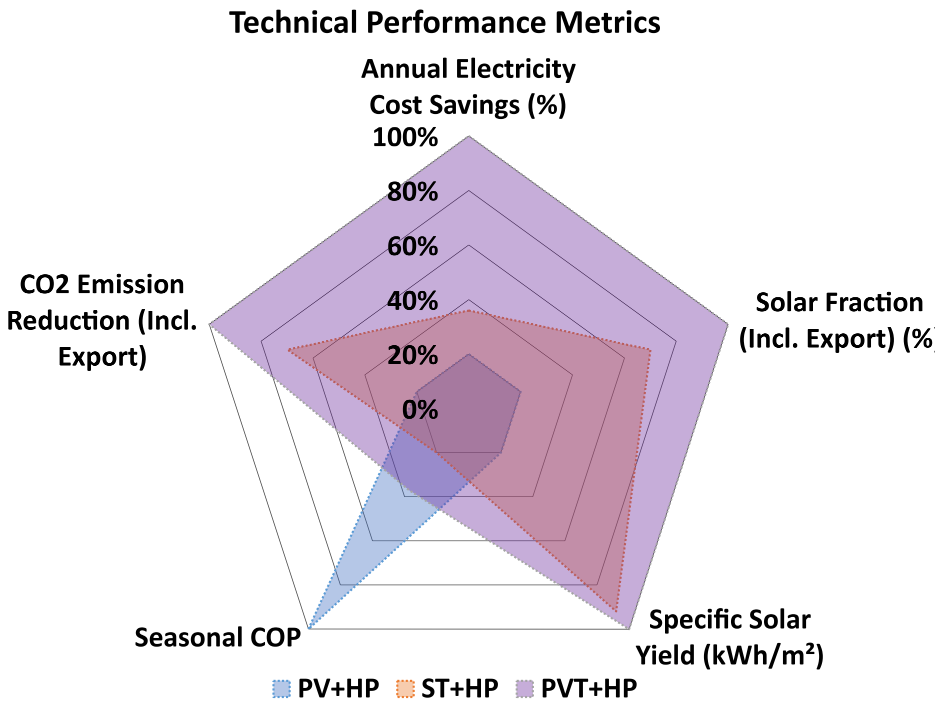



| | PV+HP | ST+HP | PVT+HP |
|---|---|---|---|
| CAPEX | €30,000 | €155,500 | €260,000 |
| IRR | 31% | 9% | 6% |
| Solar Fraction | 24-33% | 44% | 38-52% |

# Economic and Technical Comparison
# PV is economically attractive; PVT delivers more benefits



# Simonsberg—Size Optimization

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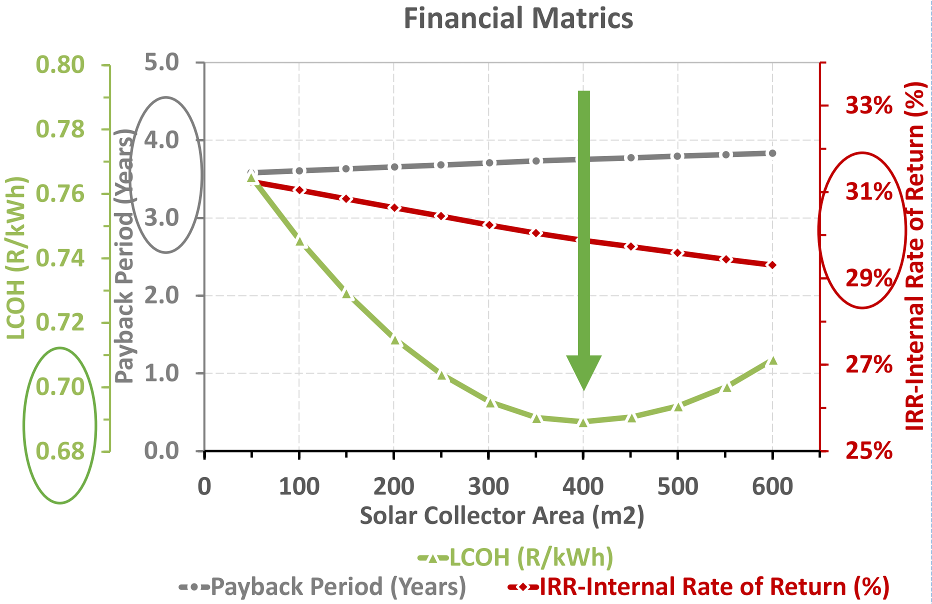
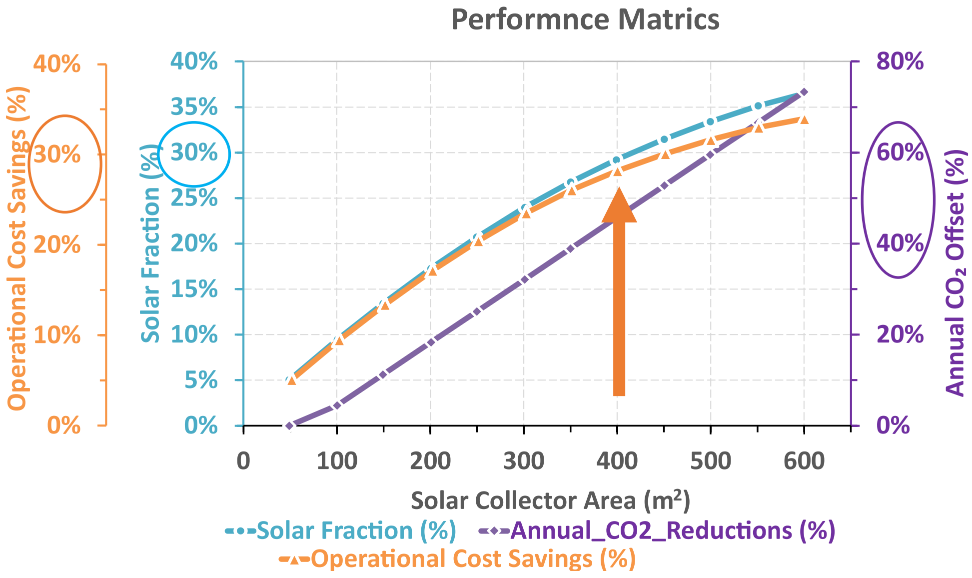
## PV + HP



# Cost of Abatement — Simonsberg

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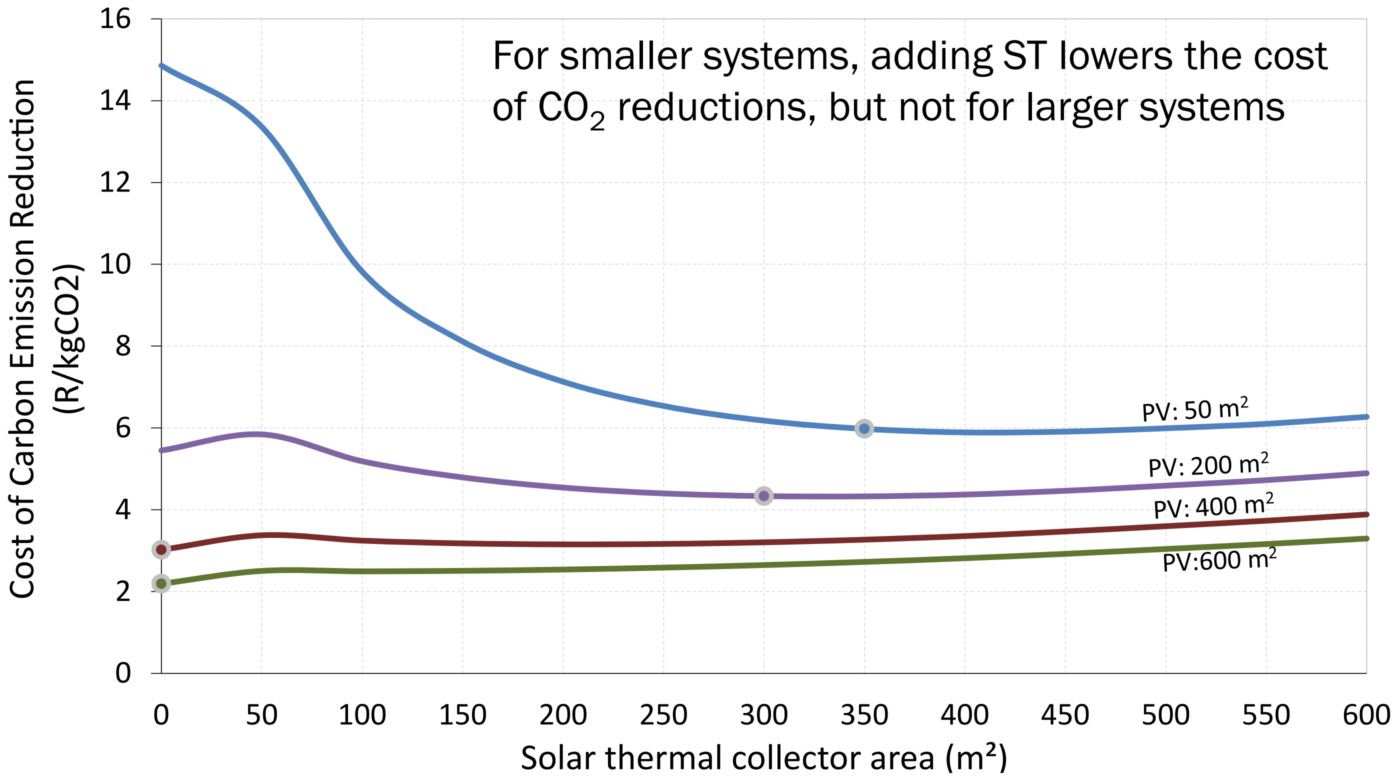

# Conclusion

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- Prioritising energy efficiency is essential.
- PV-driven systems could achieve a return on investment of up to 30%, making it a financially sound solution.
- Adding solar thermal collectors to a PV-driven system can increase overall cost savings to around 50%, but it comes at a cost.
- When assuming that all PV-generated electricity will be used by the campus, the cost of abatement reduces with PV array size, with minimal benefit from ST collectors above 3-400$m^2$.