BIPV enhancement using thermal diodes and integrated heat storage

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BIPV enhancement using thermal diodes and integrated heat storage

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Challenges & opportunities

BIPV/T – Building Integrated Photovoltaic Thermal

- Facades are important solar collection area for achieving NZEB, especially in tall buildings
- Heat “trapped” at back of PV increases cell temperature:
  - ➢ Reduced electrical yield
  - ➢ Heat induced degradation
  - ➢ “Waste” heat could be used for heating and hot water?
  - ➢ Polygeneration:
    BIPV becomes BIPV/T

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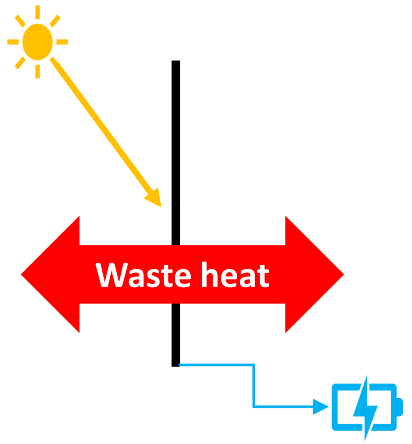
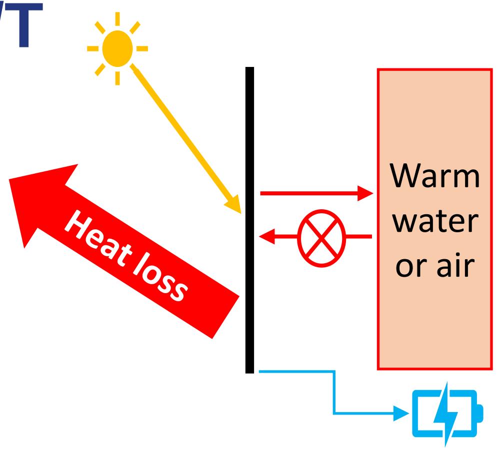
Solar polygeneration compromises

Simple BIPV



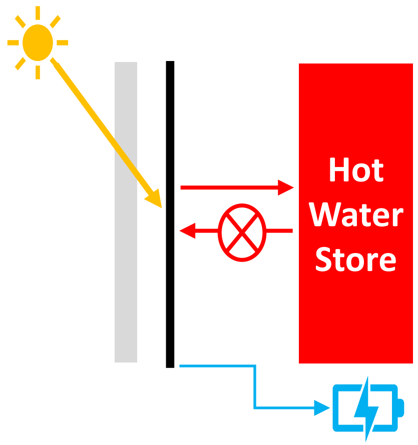
- Electrical output decreases on hot days due to PV temperature effect
- Reduced PV lifetime in sunny and hot climates
- Waste heat can increase building cooling loads

Uncovered BIPV/T



- Electrical output & lifetime unaffected by hot weather,
- Parasitic electricity usage to run pumps and/or fans
- Thermal energy output is warn (not hot) in summer and cold in winter
  Not very useful heat?

Covered BIPV/T



- Electrical output decreases due to optical losses and temperature effect.
- Parasitic electricity usage to run pumps and/or fans
- High temperatures when there is no heat demand can cause damage

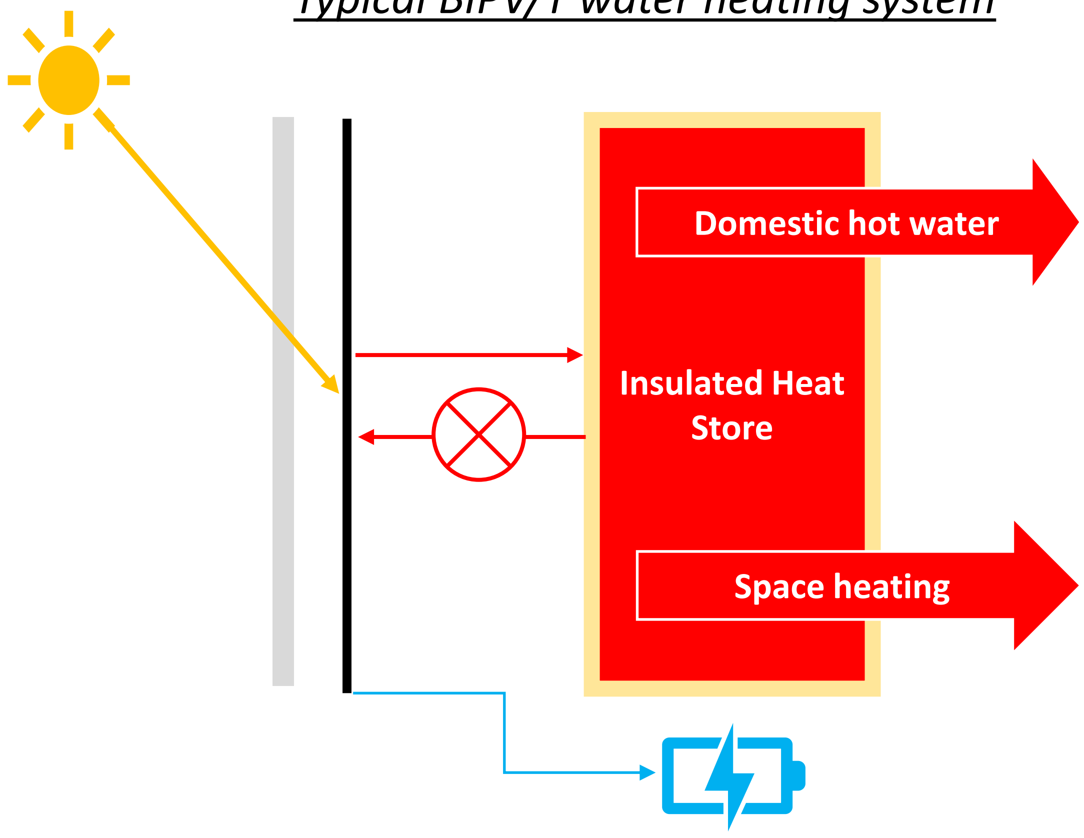
What happens when BIPV gets hot?

PV temperature effect: Causes 0.35%/°C voltage reduction and 0.45%/°C power reduction (monocrystalline silicon)

For a hot sunny summer period with daytime ambient 35°C and 20 MJ/m^2 on façade and no demand for heat output:

- **Uncovered BIPV (or uncovered BIPV/T)**
  Cell temperature ~72°C under stagnation
  - 21% reduction in electrical output due to temperature
- **Covered BIPV/T:**
  Cell temperature ~106°C under stagnation
  Transparent cover gives higher quality heat output but…
  - 36% reduction in electrical output due to temperature
  - 8% reduction in electrical output due to optical loss
  - Denatured heat transfer fluid and high fluid pressures (component damage & fluid loss)
  - Degradation / damage to polymeric components (eg delamination of EVA bonding PV cells to glass)

Typical BIPV/T water heating system

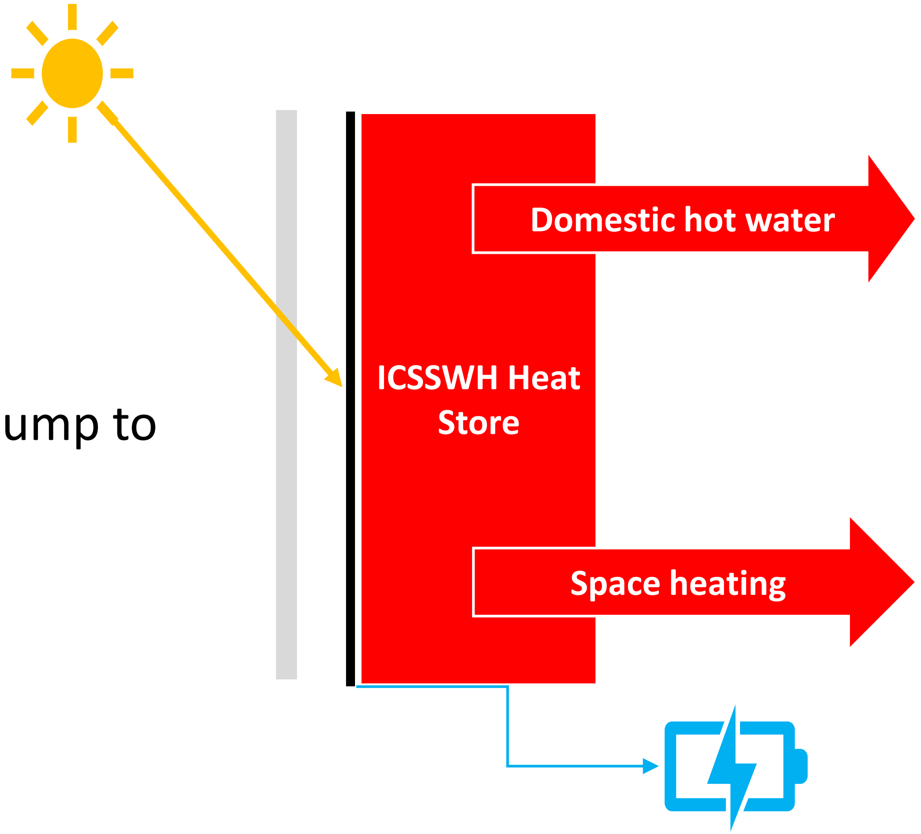


BIPV/T with integrated heat storage

PV + ICSSWH *(ICSSWH = Integrated Collector Storage Solar Water Heater)*

- ✓ Reduces stagnation temperature
- ✓ Reduces parasitic consumption for pumps and fans
- ✓ Saves floor space for hot water storage tanks
- ✗ Suffers from excessive overnight heat loss (U ≈ 4 W·m^{-2} K^{-1}):
    - No heat left in ICSSWH by morning or on cloudy days
    - Rapid heat loss during cold and windy weather
    - Need additional indoor insulated hot water tank and pump to collect and store heat in early evening
- ✗ Additional weight load on façade structures

BIPV/T+ICSSWH water heating



BIPV/T with thermal diode & integrated heat storage

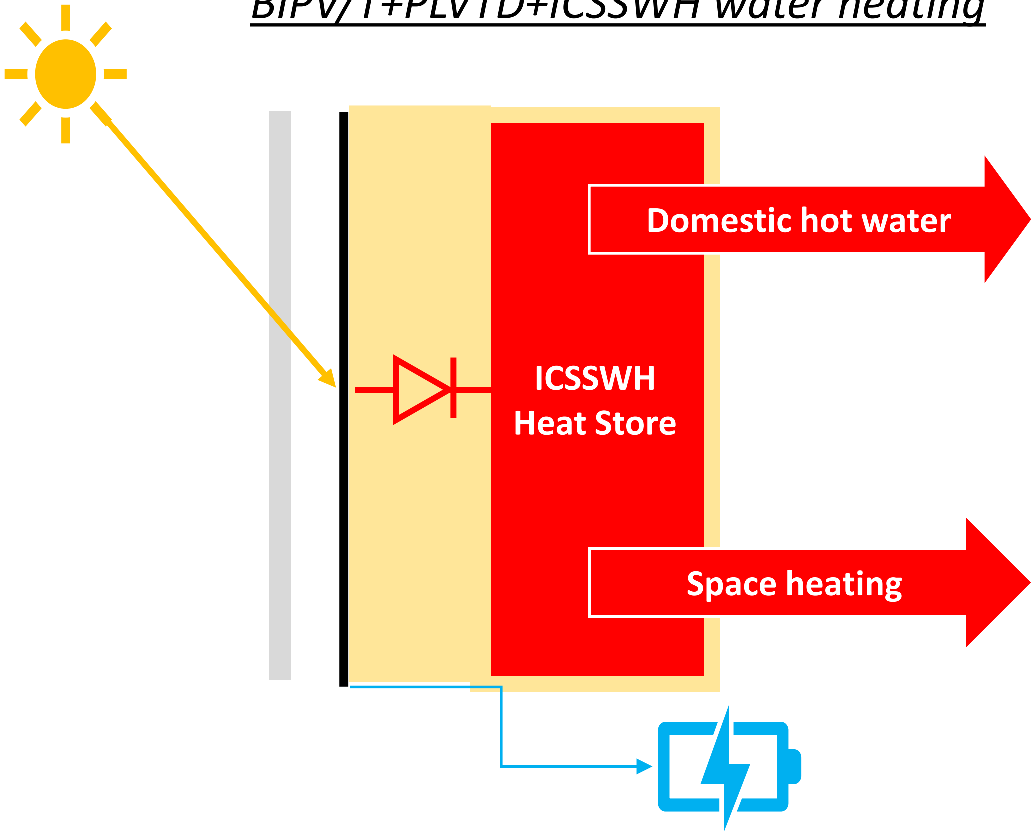
PV + PLVTD + ICSSWH *(PLVTD = Planar Liquid-Vapour Thermal Diode)*

- ✓ Reduces stagnation temperature
- ✓ Reduces parasitic consumption for pumps and fans
- ✓ Saves floor space for hot water storage
- ✓ Minimises overnight heat loss (U ≈ 1 $W \cdot m^{-2} K^{-1}$) about 8 times less heat loss due to PLVTD

- ✗ Additional weight load on façade structures

  Maybe use PCM or thermochemical storage instead of water to reduce weight?

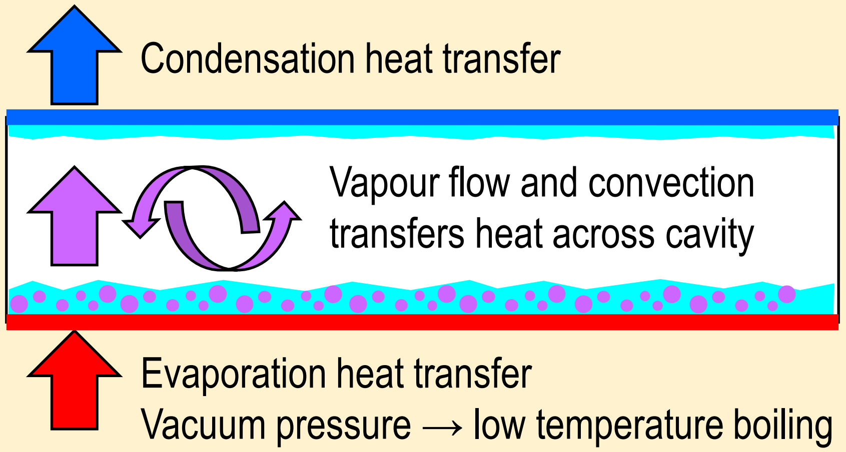
BIPV/T+PLVTD+ICSSWH water heating

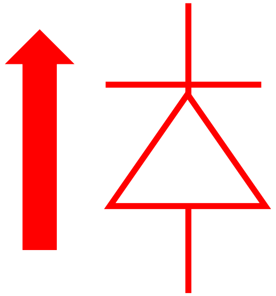


What is a PLVTD and how does it work?

Forward-mode

- Wetted hot surface
- Latent heat flow
- 100 W·m^{-2} K^{-1}

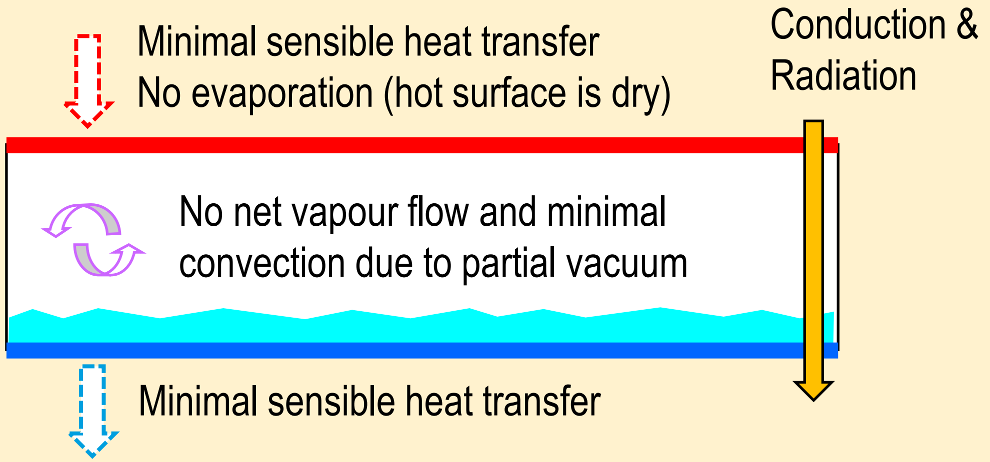


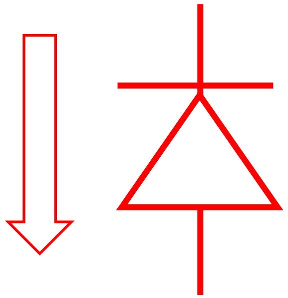


Thermal diode

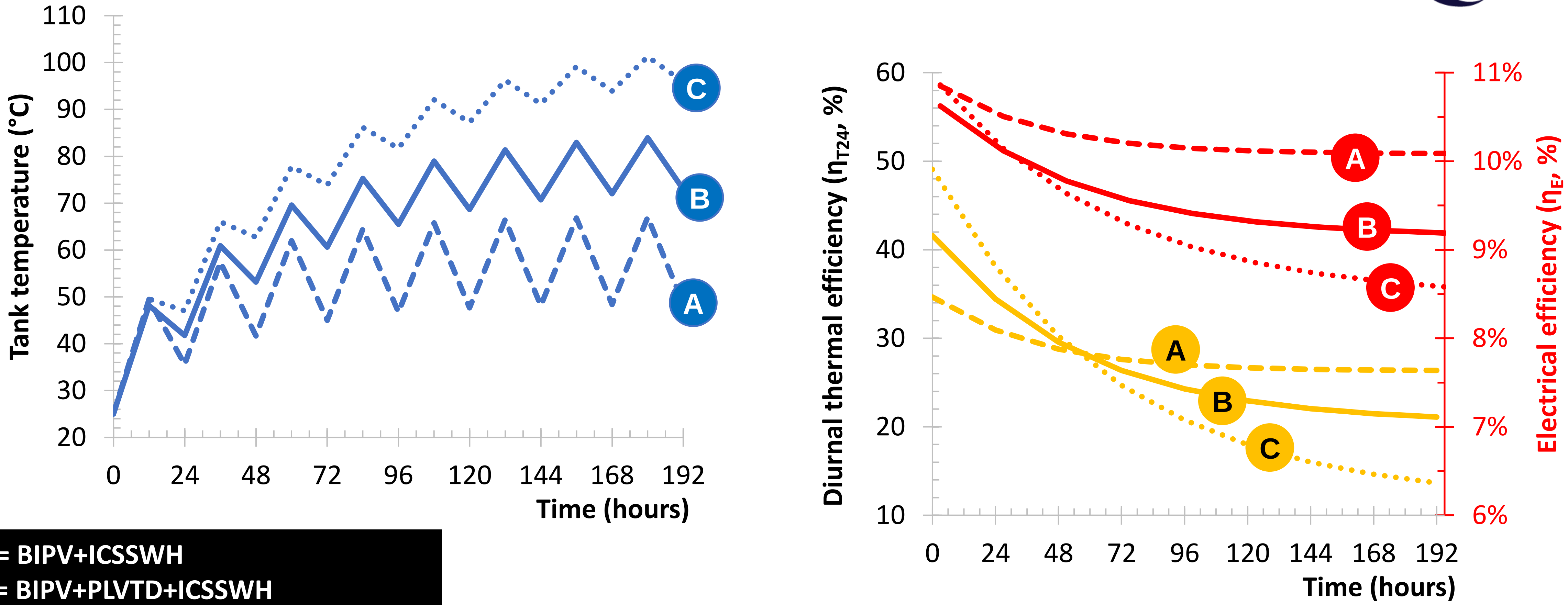
Reverse-mode

- Dry hot surface
- Partial vacuum insulation
- 1 W·m^{-2} K^{-1}





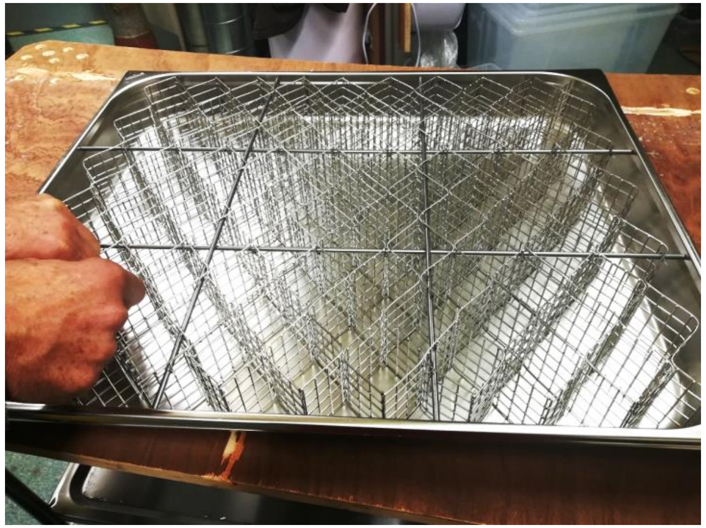
Simulated performance comparison

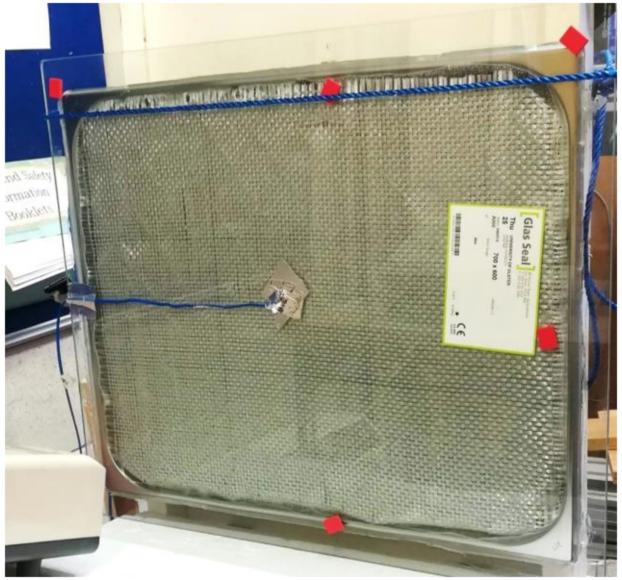


A = BIPV+ICSSWH
B = BIPV+PLVTD+ICSSWH
C = BIPV/T conventional pumped

- Hot summer in Rome: 35°C daytime, 25°C night, no wind, 20MJ/m^2 façade solar flux
- 1m^2 collector, 75% of absorber covered with monocrystalline silicon PV cells, single glazed cover
- 100L well-insulated water storage tank during period of no heat demand

Prototyping and lab testing





Design & fabrication challenges

- Vacuum sealing and outgassing
- Structural support arrangements
- Evaporator wetting mechanisms
- PV integration to absorber-evaporator

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BIPV/T facades – A new opportunity for integrated collector-storage solar water heaters? Part 1: State-of-the-art, theory and potential

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[b] SolaForm Ltd (www.solaform.com) c/o Ulster University, Newtownabbey, BT37 0QB Northern Ireland, UK

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BIPV/T facades – A new opportunity for integrated collector-storage solar water heaters? Part 2: Physical realisation and laboratory testing

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Community Energy from Solar Envelope Architecture

Developing an energy efficient modular façade system incorporating two innovative elements (CoPEG & HyPVT) which enable cost-effective building integrated heat and power generation to decarbonise community energy consumption.

- £200k project realising prototypes to showcase to construction industry stakeholders (26 months from Oct 2020).
- Progressing architectural and building services engineering designs to enable effective building integration.
- Evaluate techno-economics to enable business model development.
- Gain funding for a subsequent full scale demonstrator project

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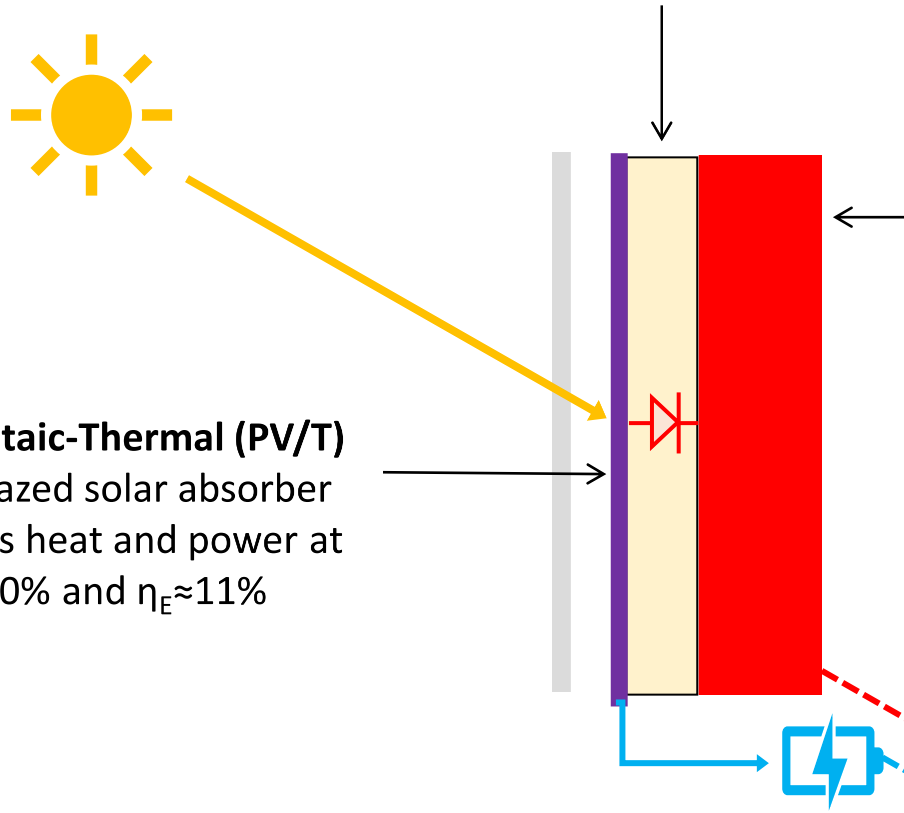
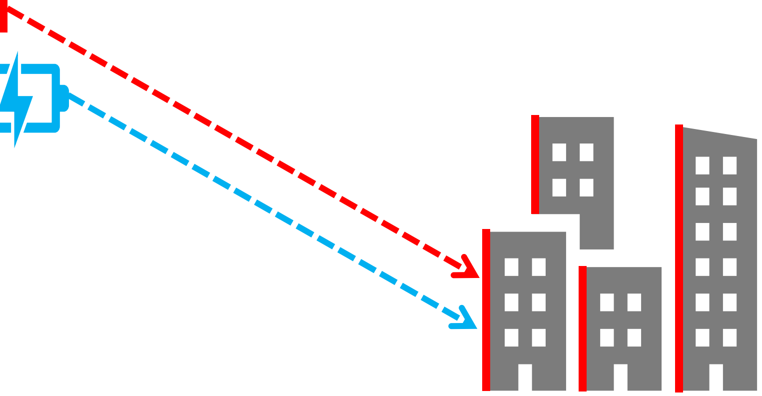
Summary

Planar Liquid-Vapour Thermal Diode (PLVTD)
reduces over-night heat losses enabling
$U_{r,sys}A_{sys}/u \approx 20\ \mathrm{W{\cdot}m^{-3}K^{-1}}$ and $\eta_{T,24} \approx 35\%$

Integrated Collector-Storage Solar Water Heating (ICSSWH)
Built-in storage vessel reduces parasitic energy consumption and reduces maximum stagnation temperature by 20°C



Photovoltaic-Thermal (PV/T)
single glazed solar absorber generates heat and power at $\eta_T \approx 60\%$ and $\eta_E \approx 11\%$



Integrated into NZEB facades to increase solar collection area whilst also reducing demands on valuable floor and roof space