Monitoring Procedure for Compression Heat Pumps Driven by Photovoltaic Energy. Draft initial version

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O B J E C T I V E S

1. To determine the primary energy savings, solar contribution, self consumed electricity

2. To identify the best practices hence of best design solutions in relationship with the climate conditions, the building features and use, occupation conditions and so on.

3. To calibrate numerical models that may be employed to achieve objectives 1 and 2 with minimum cost.

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APLICATIONS

The methodology presented in this document has been proposed with these restrictions:

1. To use on Heat Pumps driven by PV energy
2. The compressor should be hermetic
3. The method is for use on field applications
4. The unit capacity is lower to 12 kW.

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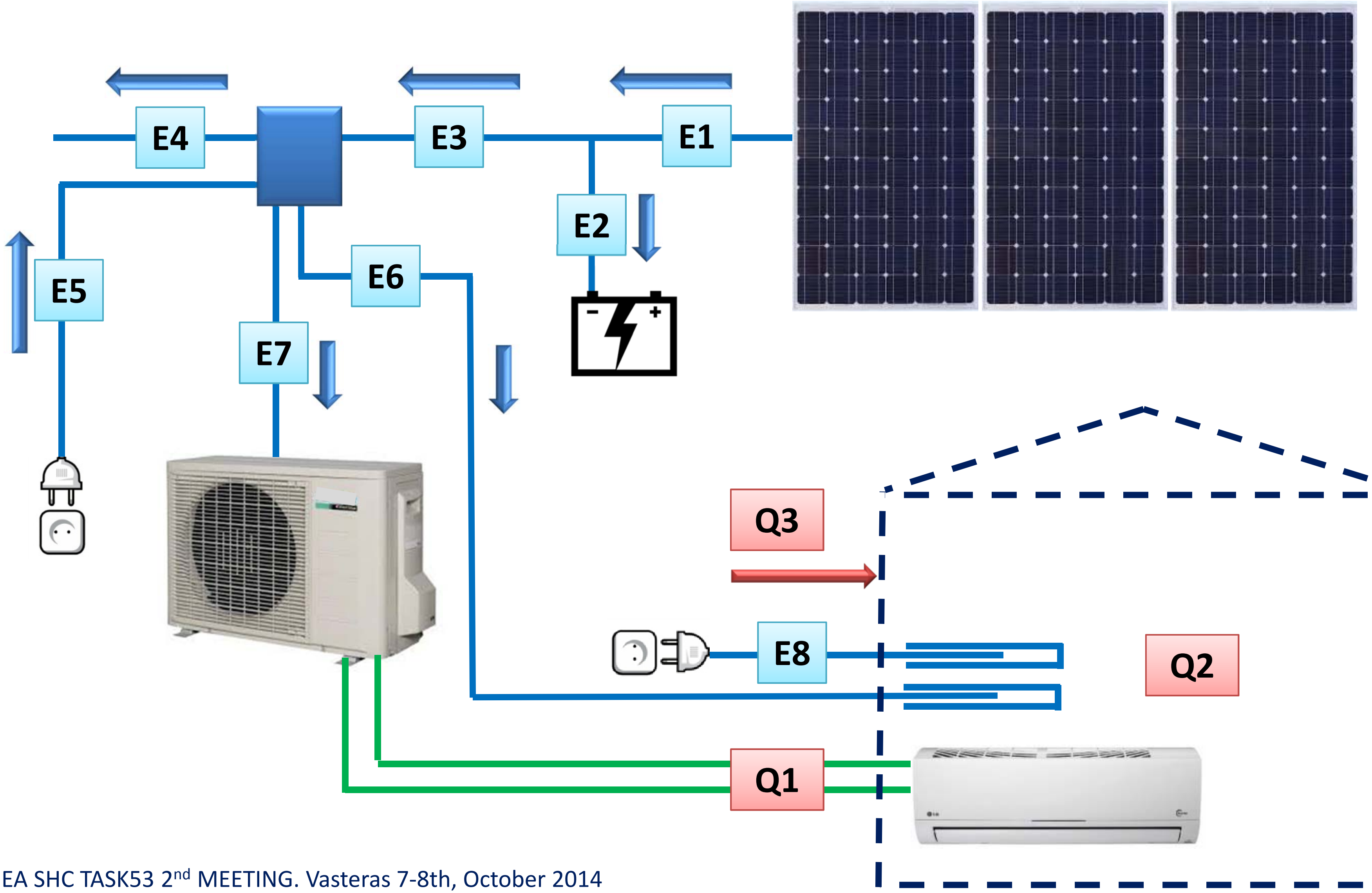
PV driven solar heating and cooling system of a HVAC installation



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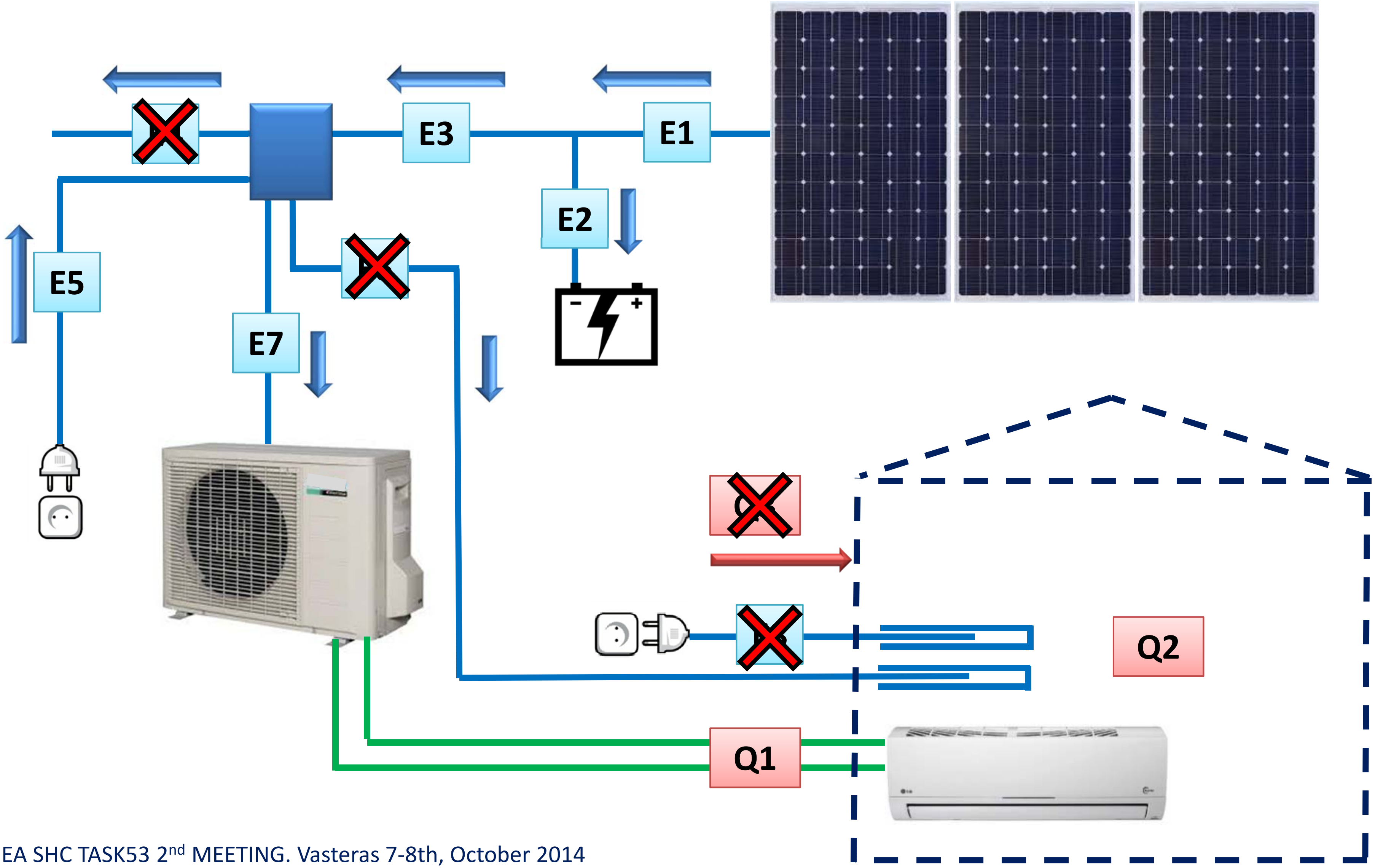

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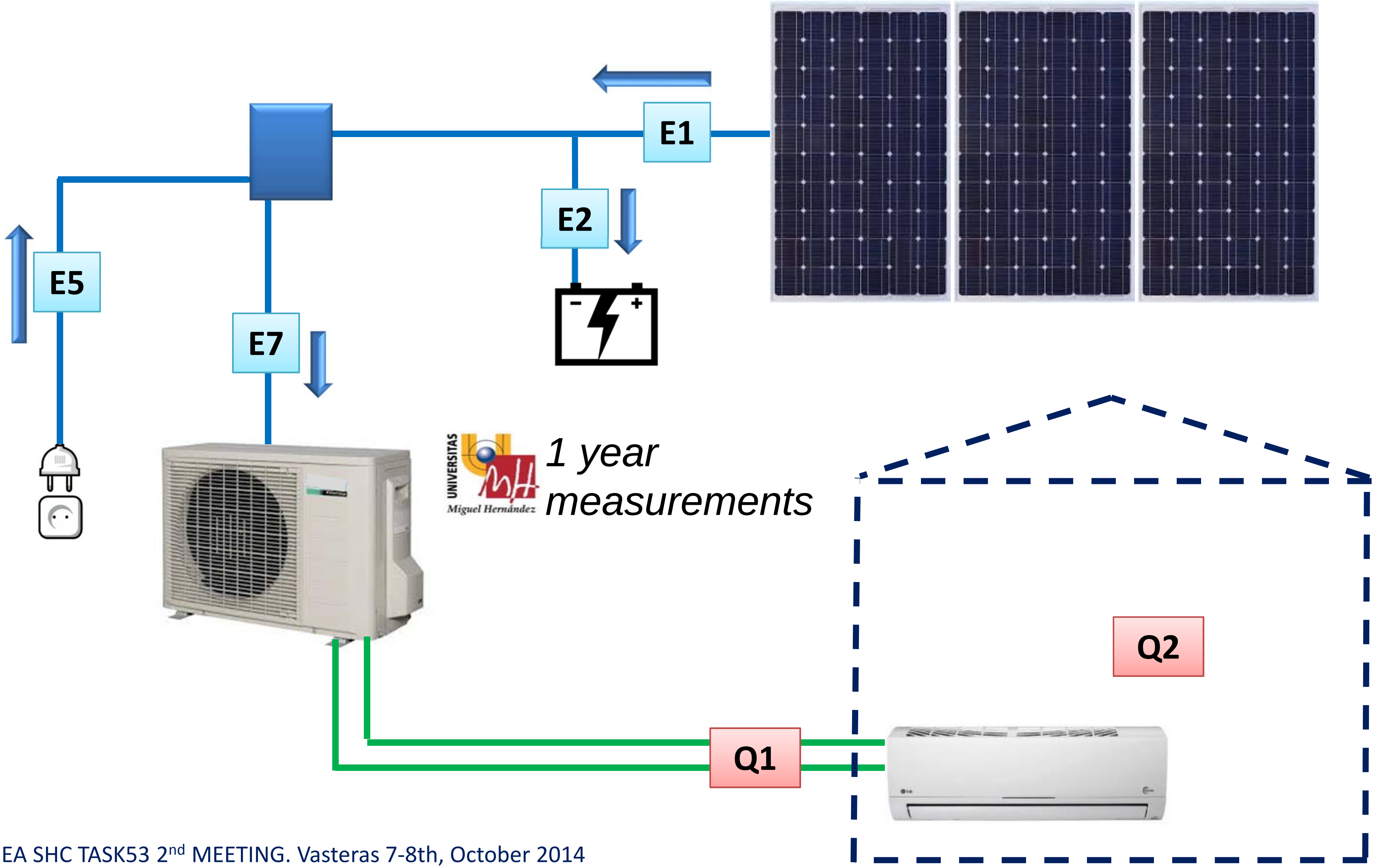

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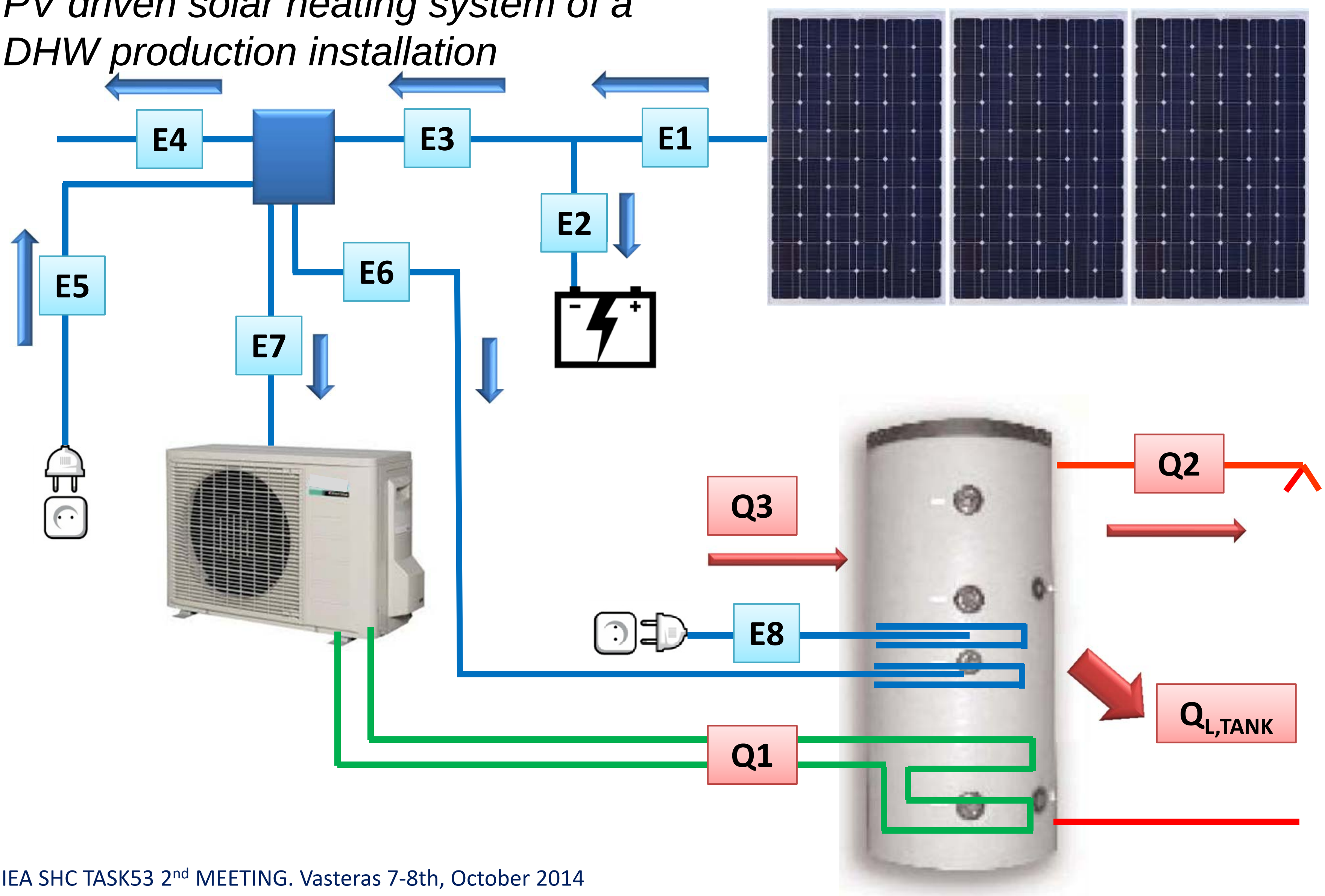
PV driven solar heating system of a DHW production installation



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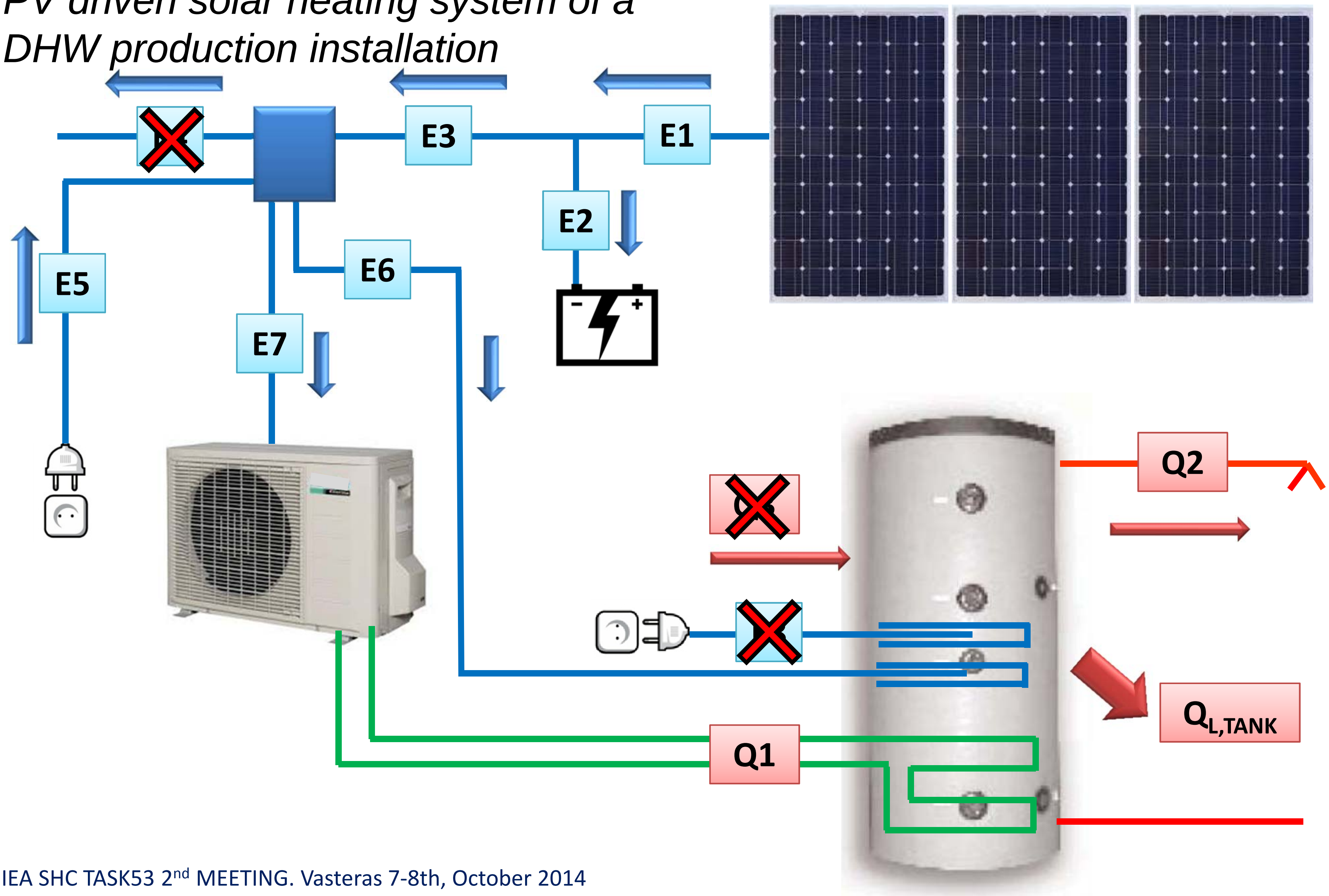

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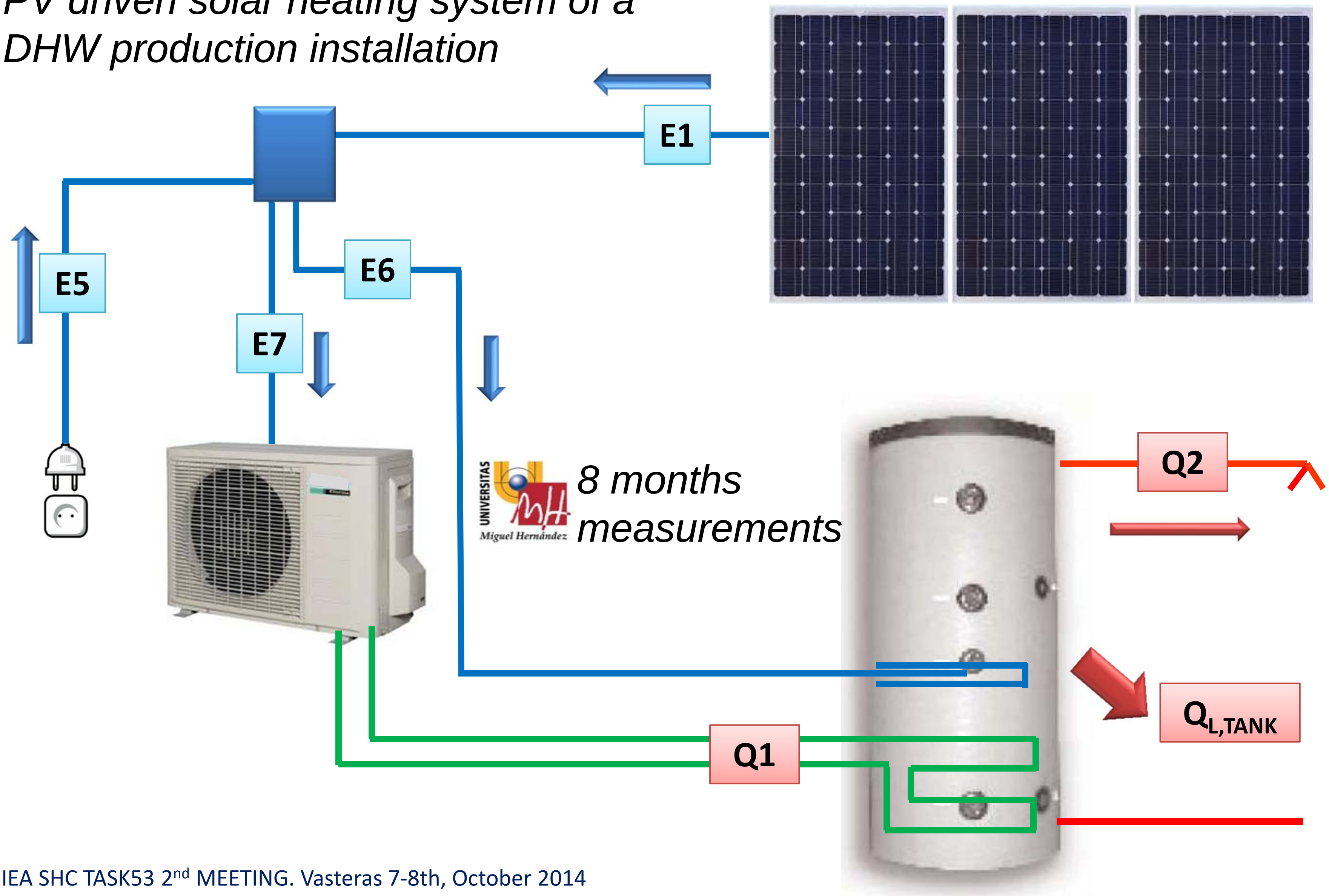

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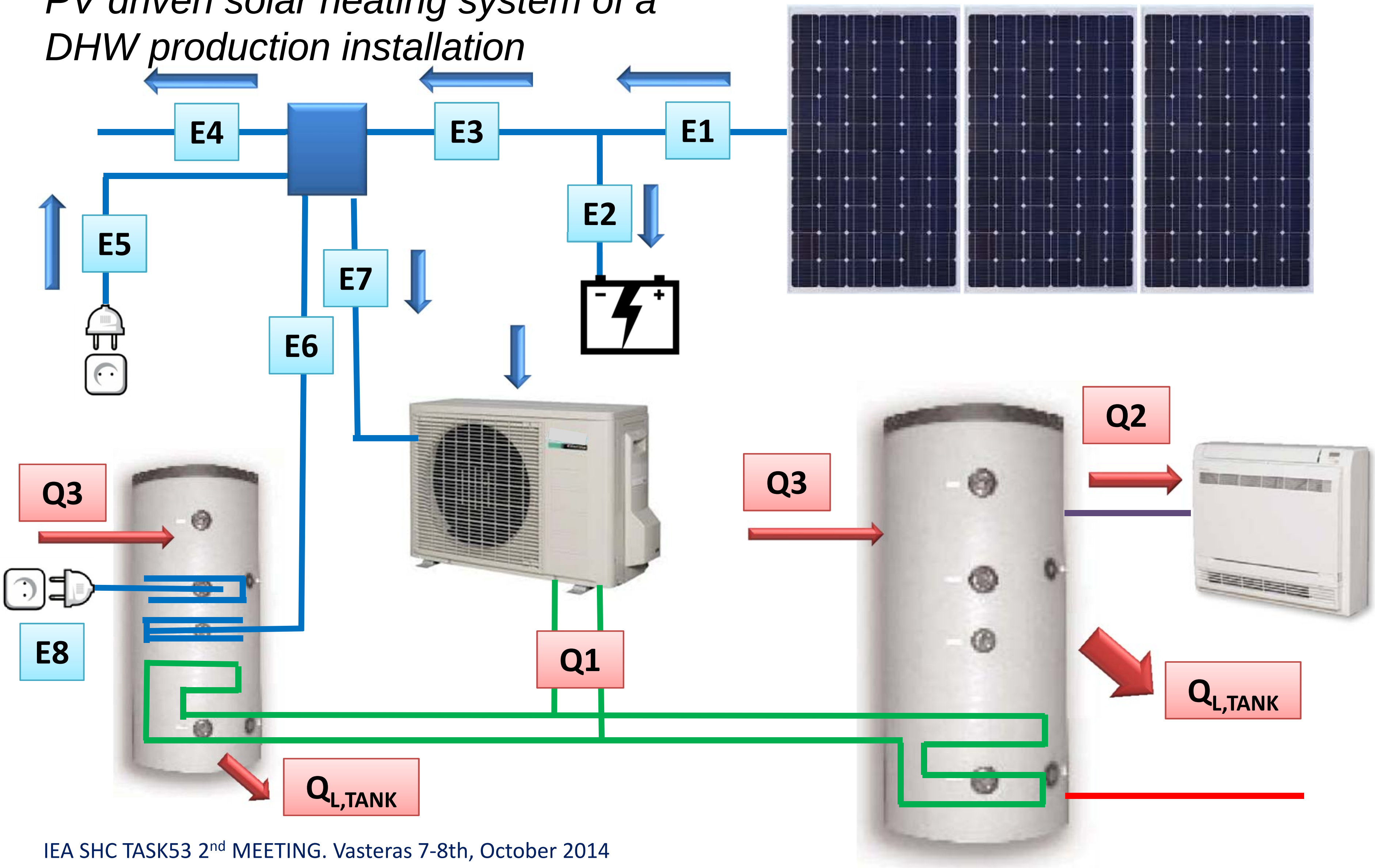

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MONITORING PROCEDURE

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PARAMETERS

Natural gas boiler seasonal efficiency:

$$\eta_{BOILER} = 0.95\,kWh_{TH} / kWh_{FOSSIL}$$

Seasonal Performance Factor of vapor compression unit in cooling mode:

$$SPF_{REF,COOLING} = 2.4\,kWh_{TH} / kWh_{ELEC}$$

Seasonal Performance Factor of vapor compression unit in heating mode:

$$SPF_{REF,HEATING} = 2.8\,kWh_{TH} / kWh_{ELEC}$$

The following "primary energy factors (PEF)" defined according to the EN 15603 can be used:

$$PEF_{ELEC} = 2.5\,kWh_{PE} / kWh_{ELEC}$$

$$PEF_{FOSSIL} = 1.11\,kWh_{PE} / kWh_{FOSSIL}$$

If the Country Regulation specifies other values, then it would be recommended to use those ones.

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COMMISSION DECISION

of 1 March 2013

establishing the guidelines for Member States on calculating renewable energy from heat pumps from different heat pump technologies pursuant to Article 5 of Directive 2009/28/EC of the European Parliament and of the Council

(notified under document C(2013) 1082)

(Text with EEA relevance)

(2013/114/EU)

		Climate conditions					
		Warmer climate		Average climate		Colder climate	
Heat Pump Energy source:	Energy source and distribution medium	H_{HP}	SPF ($SCOP_{net}$)	H_{HP}	SPF ($SCOP_{net}$)	H_{HP}	SPF ($SCOP_{net}$)
Aerothermal energy	Air-Air	1 200	2,7	1 770	2,6	1 970	2,5
	Air-Water	1 170	2,7	1 640	2,6	1 710	2,5
	Air-Air (reversible)	480	2,7	710	2,6	1 970	2,5
	Air-Water (reversible)	470	2,7	660	2,6	1 710	2,5
	Exhaust Air-Air	760	2,7	660	2,6	600	2,5
	Exhaust Air-Water	760	2,7	660	2,6	600	2,5
Geothermal energy	Ground-Air	1 340	3,2	2 070	3,2	2 470	3,2
	Ground-Water	1 340	3,5	2 070	3,5	2 470	3,5
Hydrothermal heat	Water-Air	1 340	3,2	2 070	3,2	2 470	3,2
	Water-Water	1 340	3,5	2 070	3,5	2 470	3,5

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SYSTEM DESCRIPTION

General data on the system have to be entered. The following minimum date are proposed:

- Name:
- Final use:
- Location:
- Mean solar energy radiation in the horizontal at the location: (kWh/m^2)
- Mean temperature at the location: (ºC)
- Nominal characteristics of the heat pump (Eurovent):
- Peak power of the PV panels
- A scheme of the facility (similar to Figure 2, 3 or 4)
- A description of the control strategy of the system

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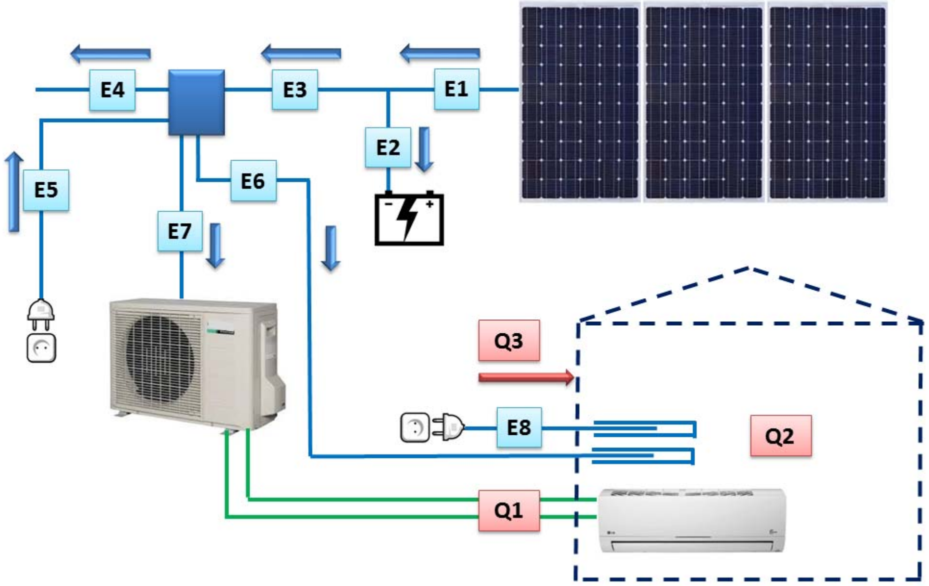
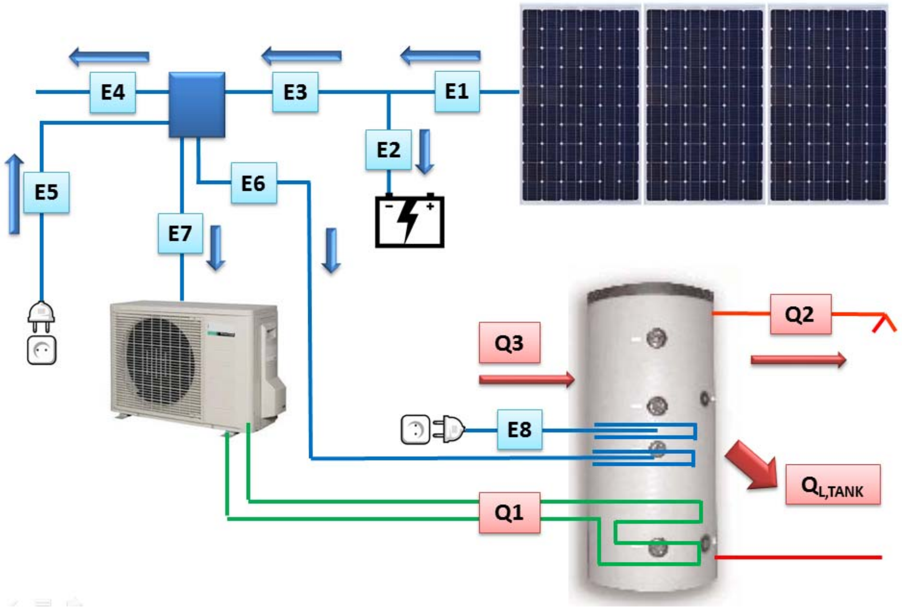
KEY PERFORMANCE INDICATORS

HEAT PUMP

$$COP_{UNIT,TOT} = \frac{Q1}{E7}$$

$$COP_{UNIT,GRID} = \frac{Q1}{E5}$$





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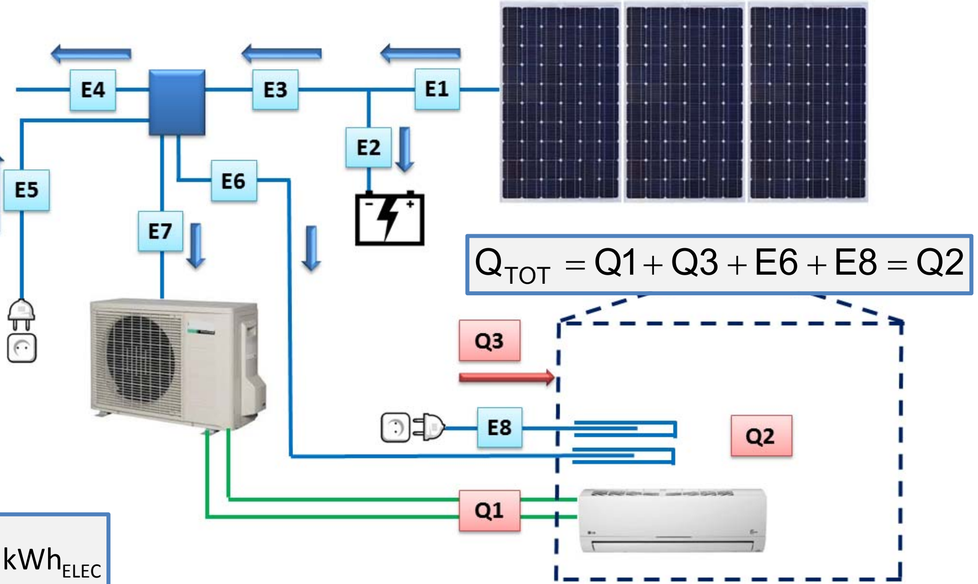
KEY PERFORMANCE INDICATORS



$$Q_{TOT} = Q1 + Q3 + E6 + E8 = Q2$$

SYSTEM

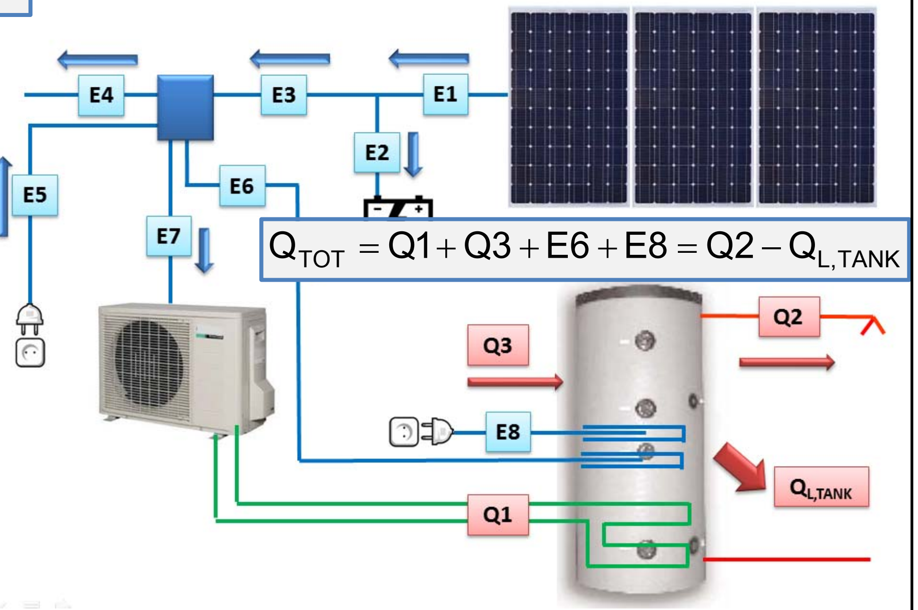
$$EeQ3 = \frac{Q3}{0.95} kWh_{FOSSIL} \cdot 1.11 \frac{kWh_{PE}}{kWh_{FOSSIL}} \cdot \frac{1}{2.5} \frac{kWh_{ELEC}}{kWh_{PE}} = 0.463 \cdot Q3\, kWh_{ELEC}$$

$$E_{TOT} = E7 + EeQ3 + E6 + E8$$

$$COP_{SYSTEM,TOT} = \frac{Q_{TOT}}{E_{TOT}} = \frac{Q1 + Q3 + E6 + E8}{E7 + EeQ3 + E6 + E8}$$

$$COP_{SYSTEM,GRID} = \frac{Q_{TOT}}{E_{GRID}} = \frac{Q1 + Q3 + E6 + E8}{E5 + EeQ3 + E8}$$

$$PER = (1/2.5) \cdot COP_{SYSTEM,GRID}$$



$$Q_{TOT} = Q1 + Q3 + E6 + E8 = Q2 - Q_{L,TANK}$$

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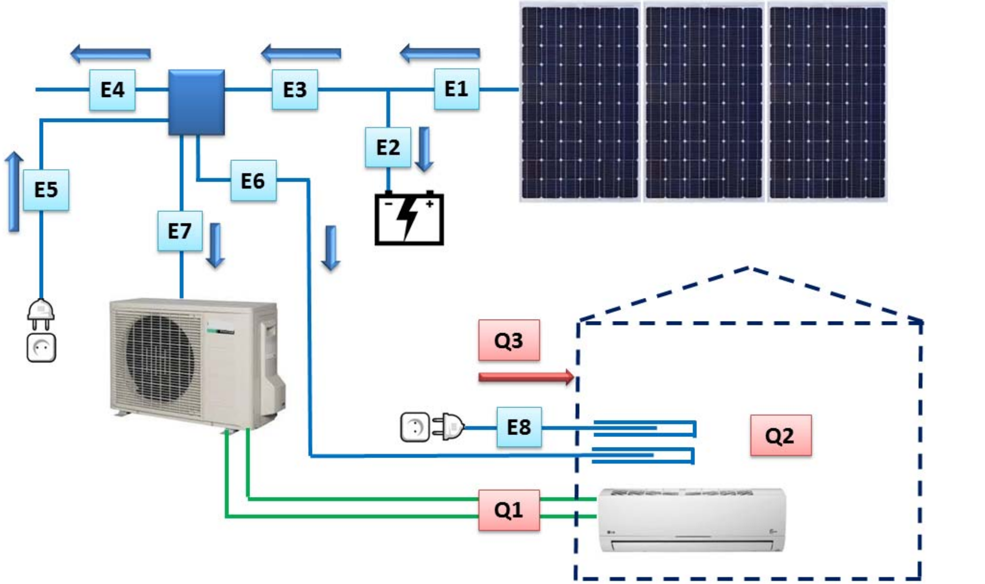
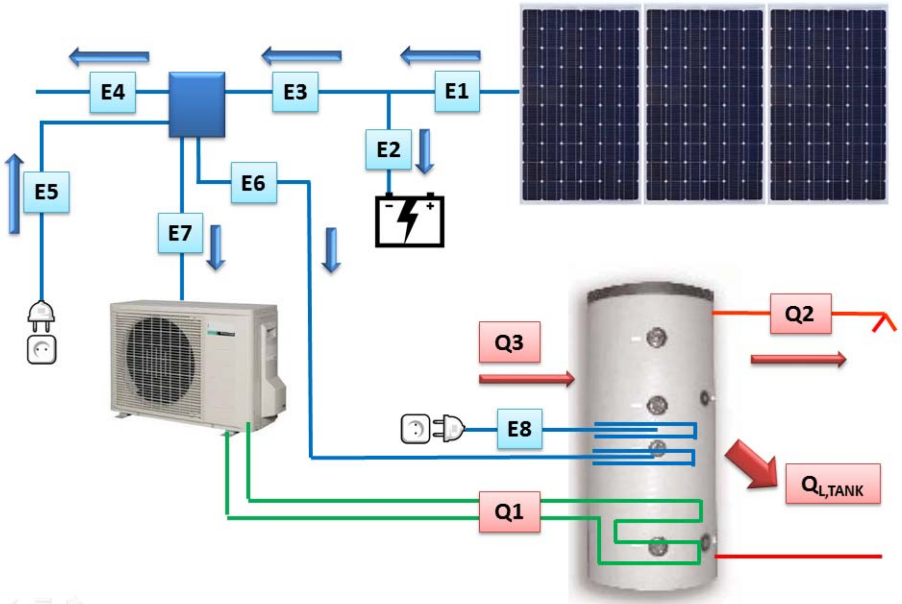
KEY PERFORMANCE INDICATORS

SOLAR CONTRIBUTION

$$SC(\%)_{UNIT} = 1 - \frac{E5}{E7}$$

$$SC(\%)_{SYSTEM} = 1 - \frac{E_{GRID}}{E_{TOTAL}} = 1 - \frac{E5 + EeQ3 + E8}{E7 + EeQ3 + E6/2{,}8 + E8}$$





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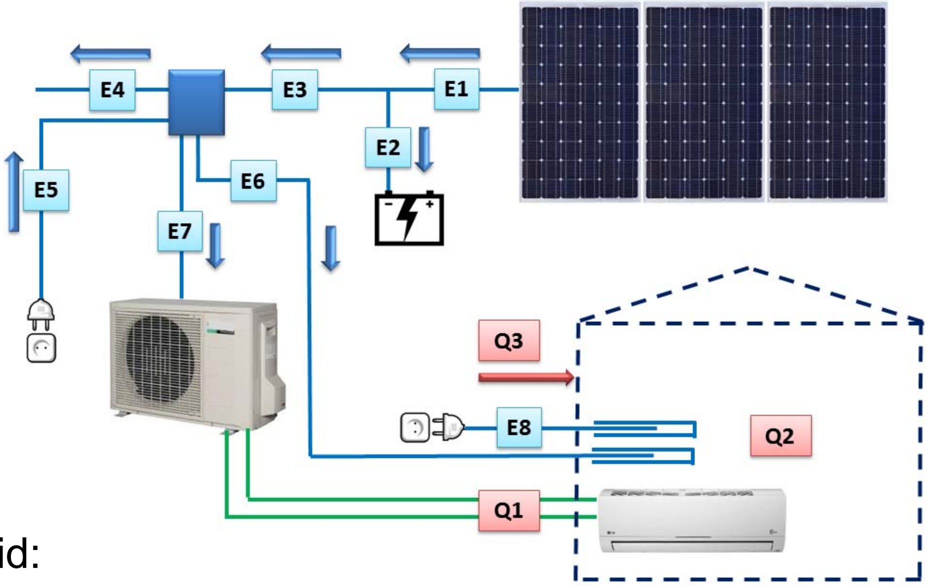
KEY PERFORMANCE RATIOS



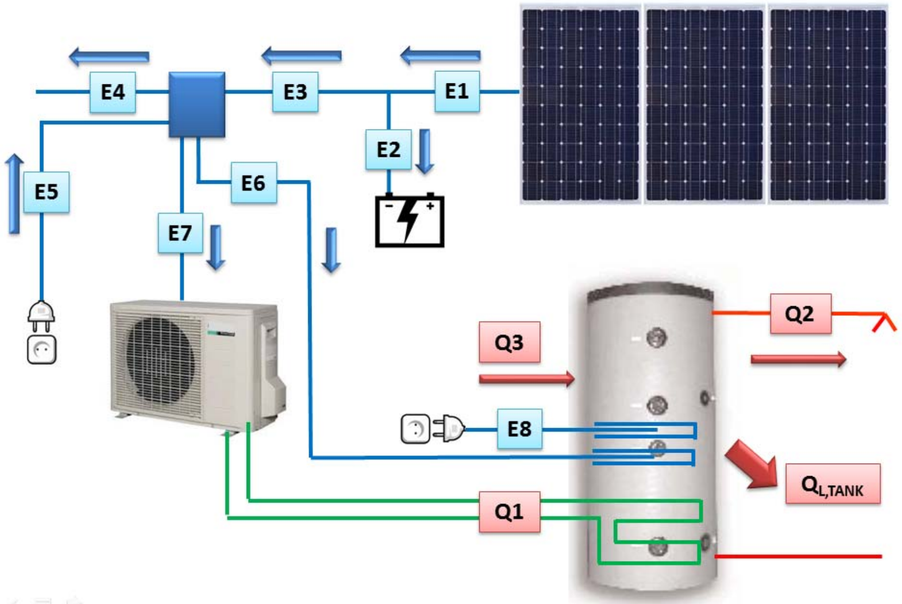
PRODUCTION FACTOR

If PV electricity is not exported to the grid:

$$PF(\%) = \frac{(E7 - E5) + E6/2.8}{\eta_{PV} \cdot Esol}$$

If PV electricity is exported to the grid:

$$PF(\%) = \frac{E4 + E7 + E6/2.8}{\eta_{PV} \cdot Esol}$$



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REFERENCE CONDITIONS

Climatic conditions:

- $T_{M,24h}$ Mean outlet temperature in 24 hours.
- $RH_{M,24h}$ Mean relative humidity in 24 hours.
- $T_{M,HPon}$ Mean outlet temperature when the heat pump is ON
- $RH_{M,HPon}$ Mean relative humidity when the heat pump is ON
- E_{SOL}/A_{PV} Solar energy radiation kWh/m^2 day
- V_W Mean wind velocity in 24 hours.
- D_W Mean wind direction in 24 hours.

In HVAC air to air heat pumps:

- T_{LOCAL} Mean temperature in the space that is being cooled or heated
- RH_{LOCAL} Mean relative humidity in the space that is being cooled or heated.

In air to air heat pumps for DHW production

- $T_{M,IN}$ Mean water temperature in the inlet
- $T_{M,OUT}$ Mean water temperature in the outlet (DHW preparation temperature)

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EXAMPLE

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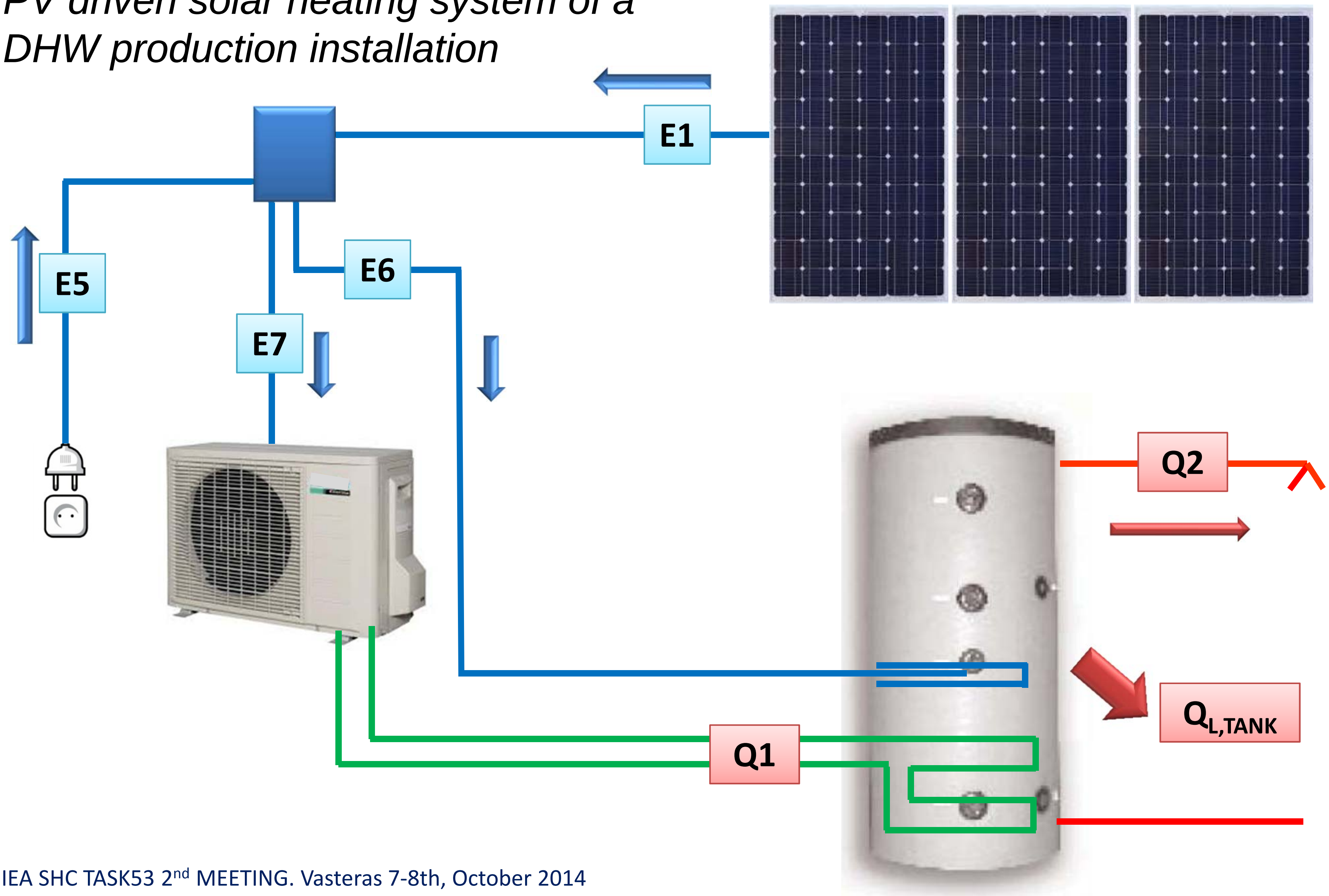
PV driven solar heating system of a DHW production installation



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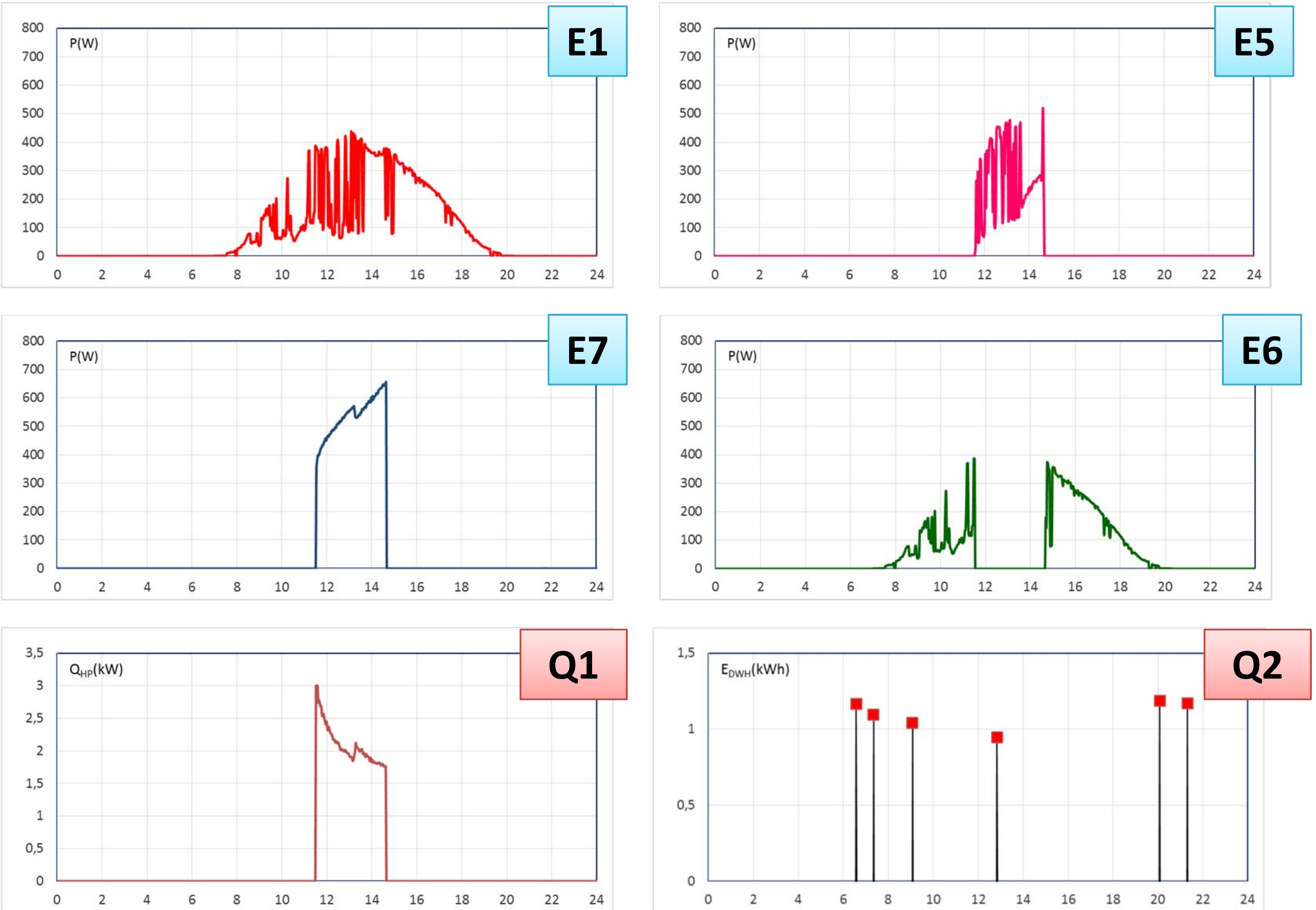

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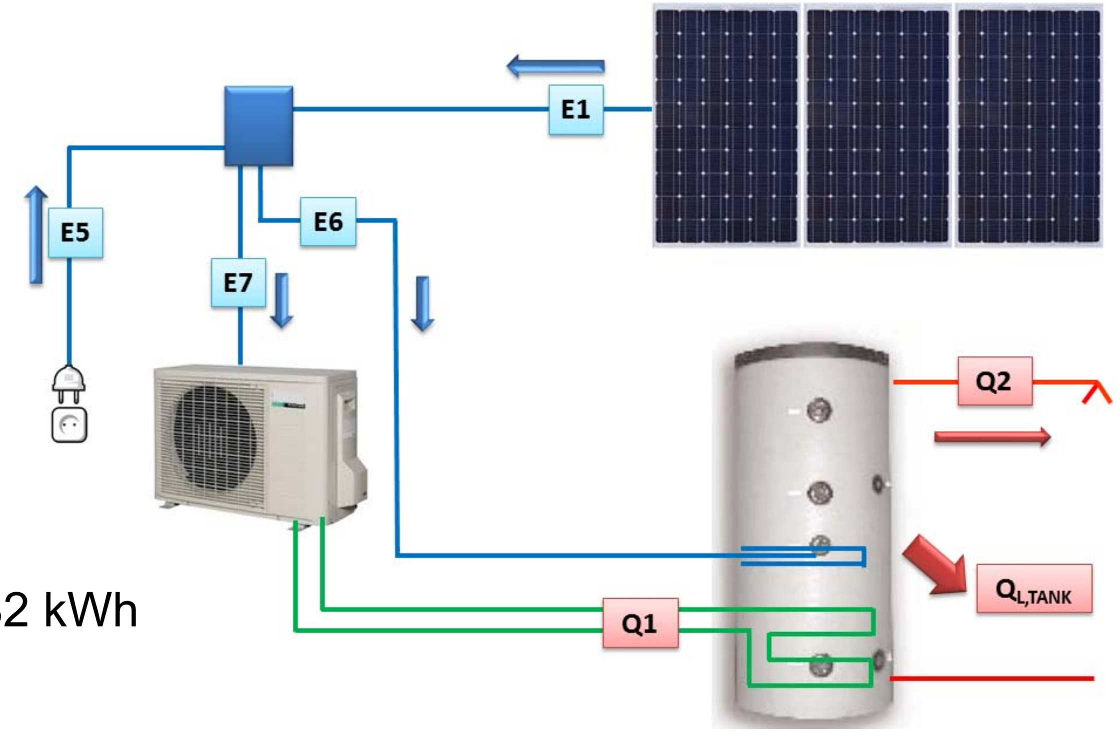
E1=2.077 kWh
E5=0.836 kWh

E6=1.235 kWh
E7=1.678 kWh

Q1=6.547 kWh
E6=1.235 kWh
Q_{TOT}= Q1+E6= 7.782 kWh

Q2=6,603. kWh
$Q_{L,TANK}$=1.152 kWh
Q_{TOT}= Q2+$Q_{L,TANK}$= 7.755 kWh



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KEY PERFORMANCE INDICATORS

The COP of the system (without taken into account the PV contribution) is:

$$COP_{SYSTEM,TOT} = \frac{Q_{TOT}}{E_{TOT}} = \frac{Q1 + E6}{E7 + E6} = \frac{6.547 + 1.235}{1.678 + 1.235} = \frac{7.782}{2.913} = 2.67$$

The COP of the heat pump (without taken into account the PV contribution) is:

$$COP_{UNIT,TOT} = \frac{Q1}{E7} = \frac{6.547}{1.678} = 3.90$$

When only the electricity taken from the grid is considered (E5), the COP is:

$$COP_{SYSTEM,GRID} = \frac{Q_{TOT}}{E_{GRID}} = \frac{Q1 + E6}{E5} = \frac{6.547 + 1.235}{0.836} = 9.30$$

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KEY PERFORMANCE INDICATORS

Solar contribution of the system:

$$SC(\%)_{SYSTEM} = 1 - \frac{E_{GRID}}{E_{NEEDED}} = 1 - \frac{E5}{E7 + E6/2.8} = 1 - \frac{0.836}{1.678 + 1.235/2.8} = 60.5\%,$$

Solar contribution of the unit:

$$SC(\%)_{UNIT} = 1 - \frac{E5}{E7} = 1 - \frac{0.836}{1.678} = 50.2\%$$

Production Factor. In this facility, the maximum electricity production of the panels is measured directly (E1= 2.077 kWh).

$$PF(\%) = \frac{(E7 - E5) + E6/2.8}{E1} = \frac{(1.678 - 0.835) + 1.235/2.8}{2.077} = 61.8\%$$

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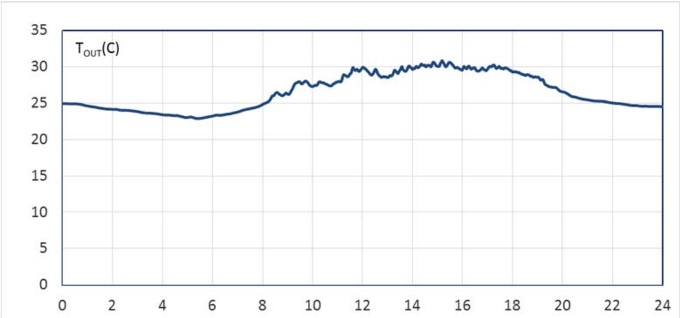
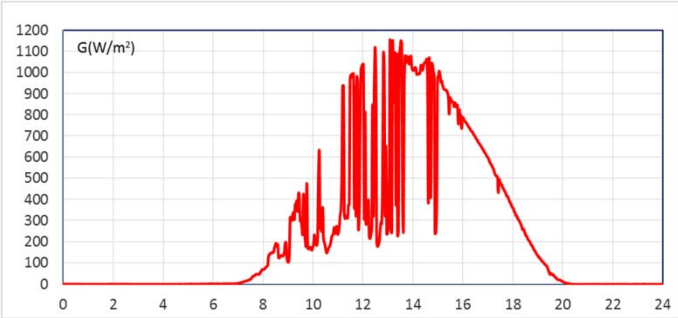
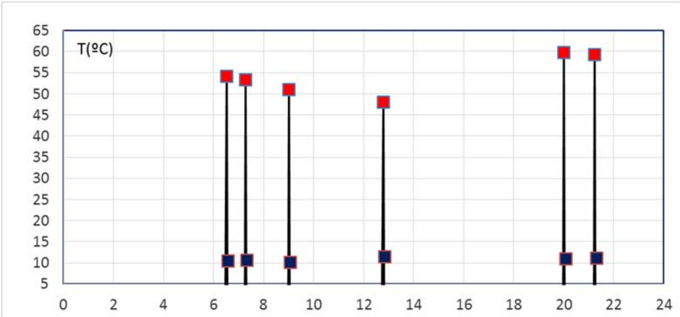
REFERENCE CONDITIONS



$T_{M,24h}$ = 26.5ºC; $T_{M,HPon}$ = 29.9ºC



E_{SOL}/A_{PV}= 5.85 kWh/m^2 day



$T_{W,IN}$ = 10.8º; $T_{W,OUT}$= 53.8ºC

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ANNEX A

THE INTERNAL METHOD

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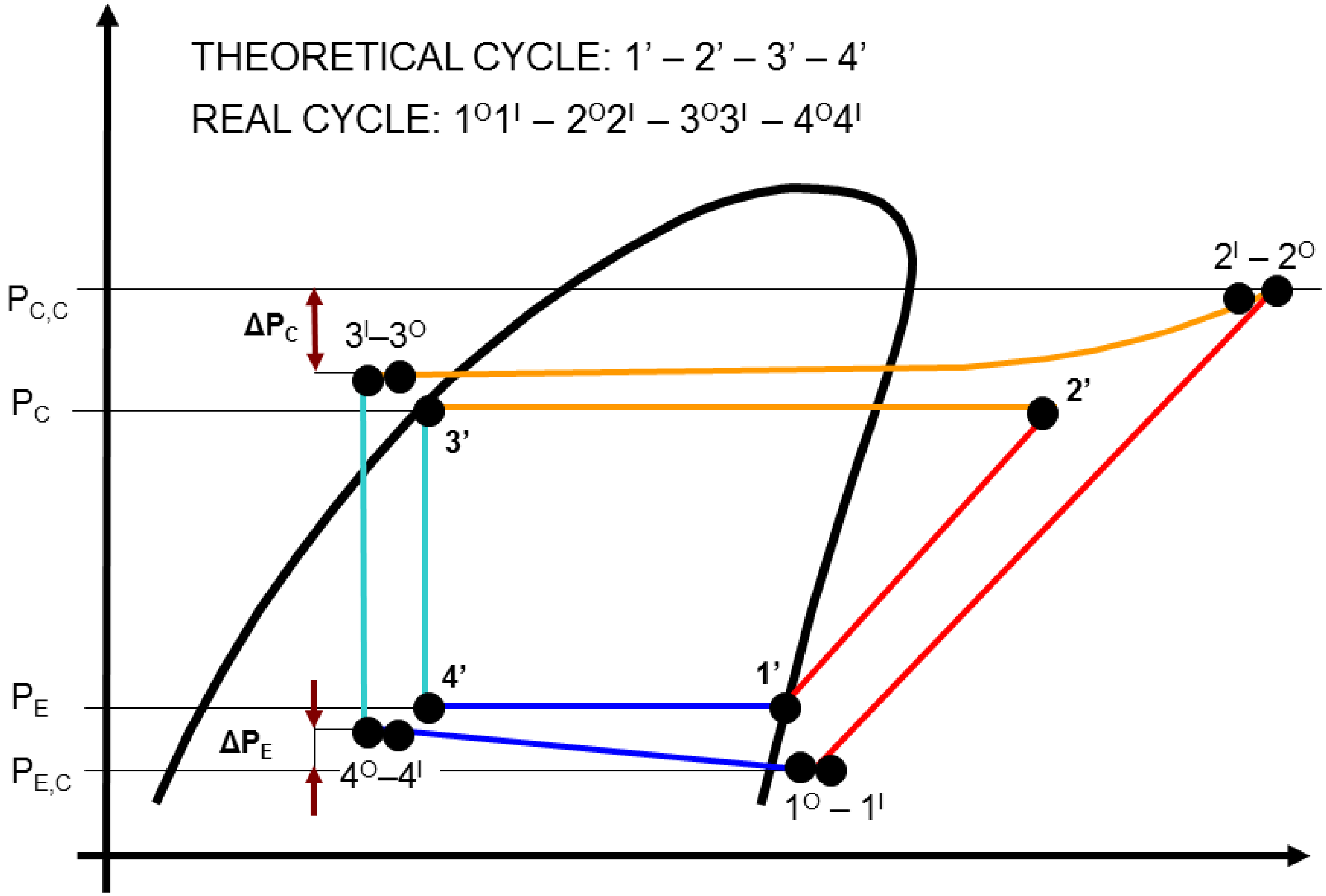
THE REAL THERMODYNAMICAL CYCLE



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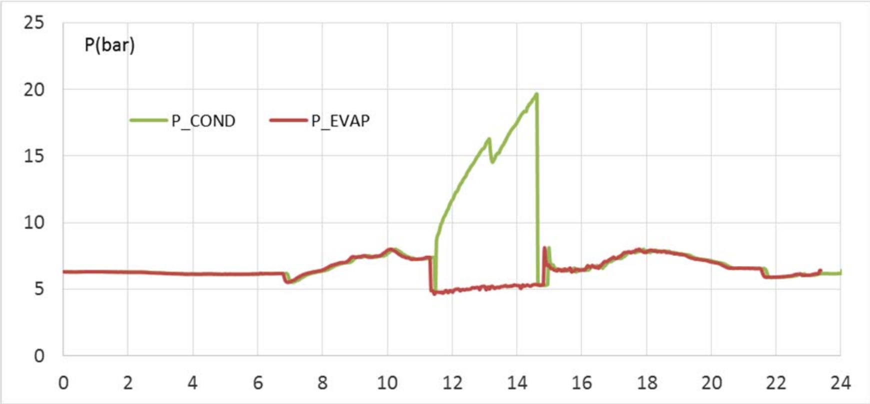
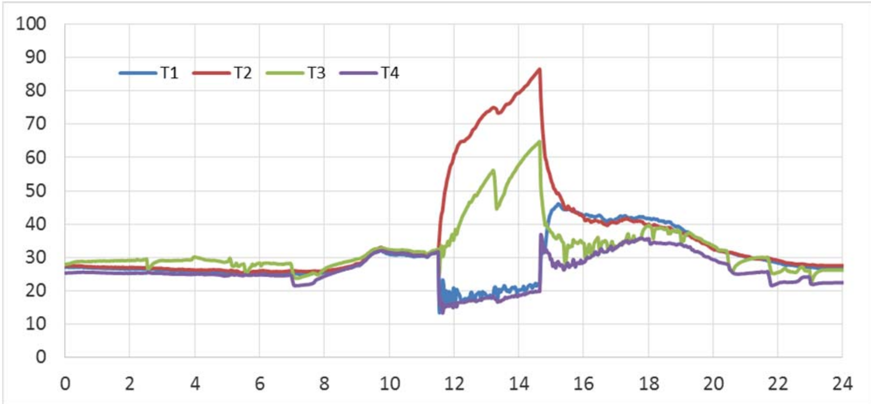
THE REAL THERMODYNAMICAL CYCLE





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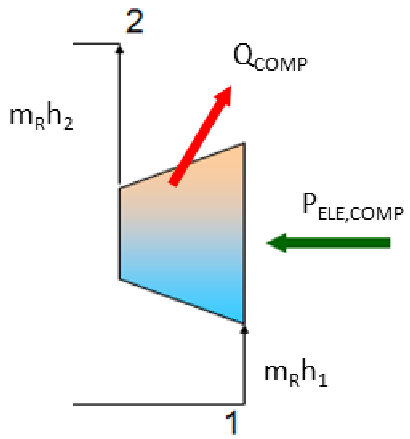
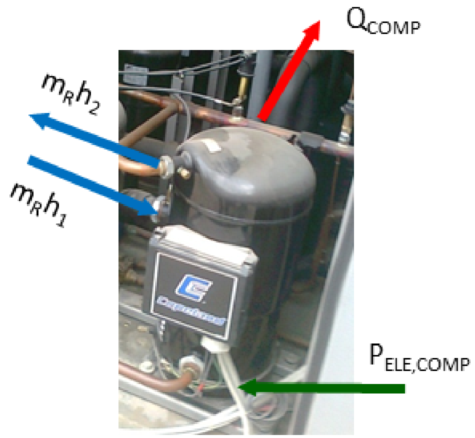
Calculation of m_R

1. Energy Conservation on the compressor





$$P_{ELE,COMP} = m_R \cdot (h_{2O} - h_{1I}) + Q_{COMP}$$

$$\eta_{ISO} = 0.775 - 0.05 \cdot (P_{COND} / P_{EVAP})$$

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Calculation of m_R

2. Volumetric Efficiency of the compressor

To be done for the final document

3. Equation of m_R given by the manufacturer

To be done for the final document

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