Operation and energy efficiency of an hybrid air conditioner simultaneously connected to the grid and to photovoltaic panels

Prof. Dr. Pedro Vicente Quiles
Universidad Miguel Hernández de Elche
pedro.vicente@umh.es
http://dime.umh.e

Dipl. Ing. Francisco J. Aguilar Valero
Universidad Miguel Hernández de Elche

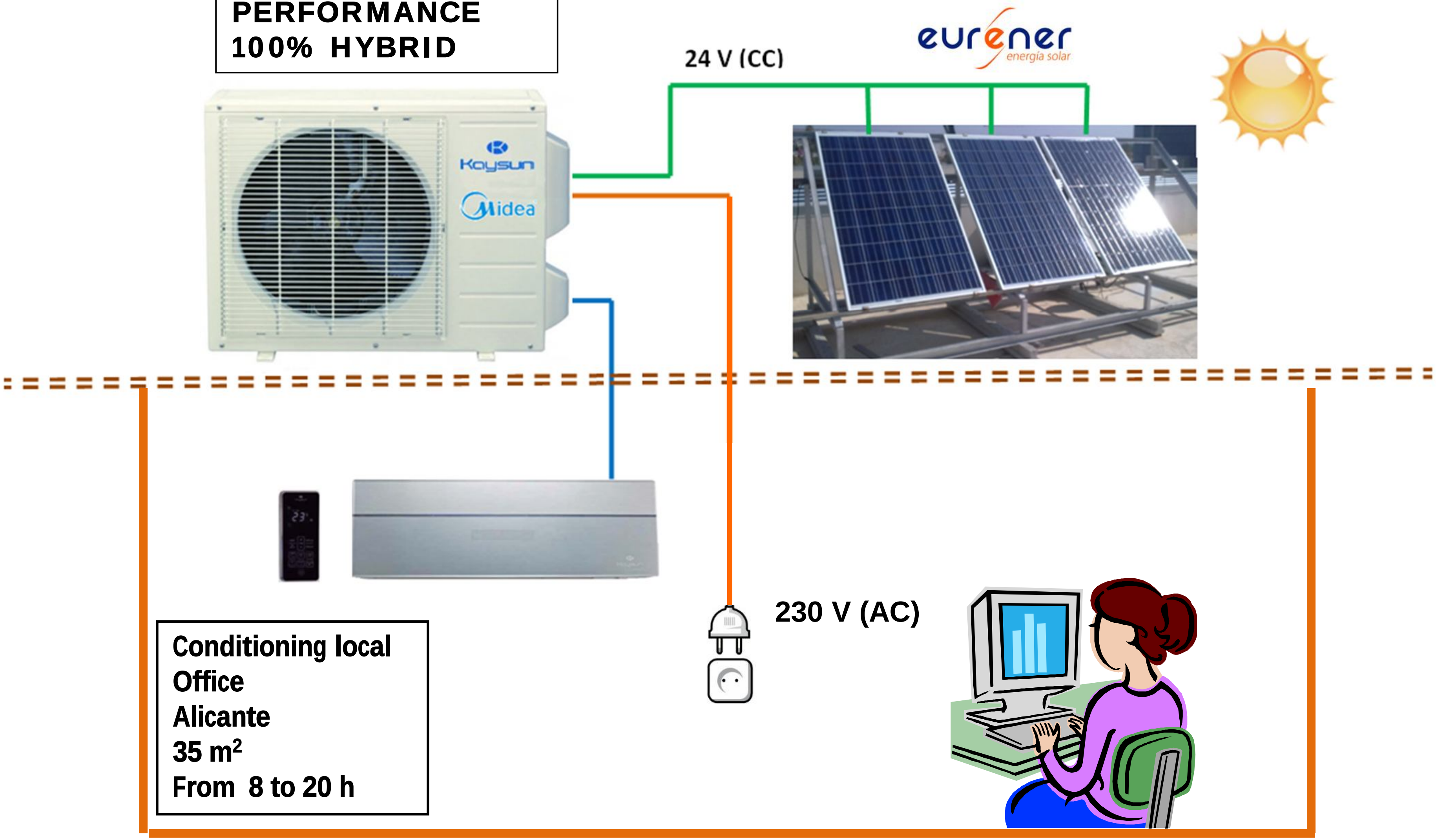
Dipl. Ing. Simón Aledo Vives
simon@prointer.es
Prointer, S.L.

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

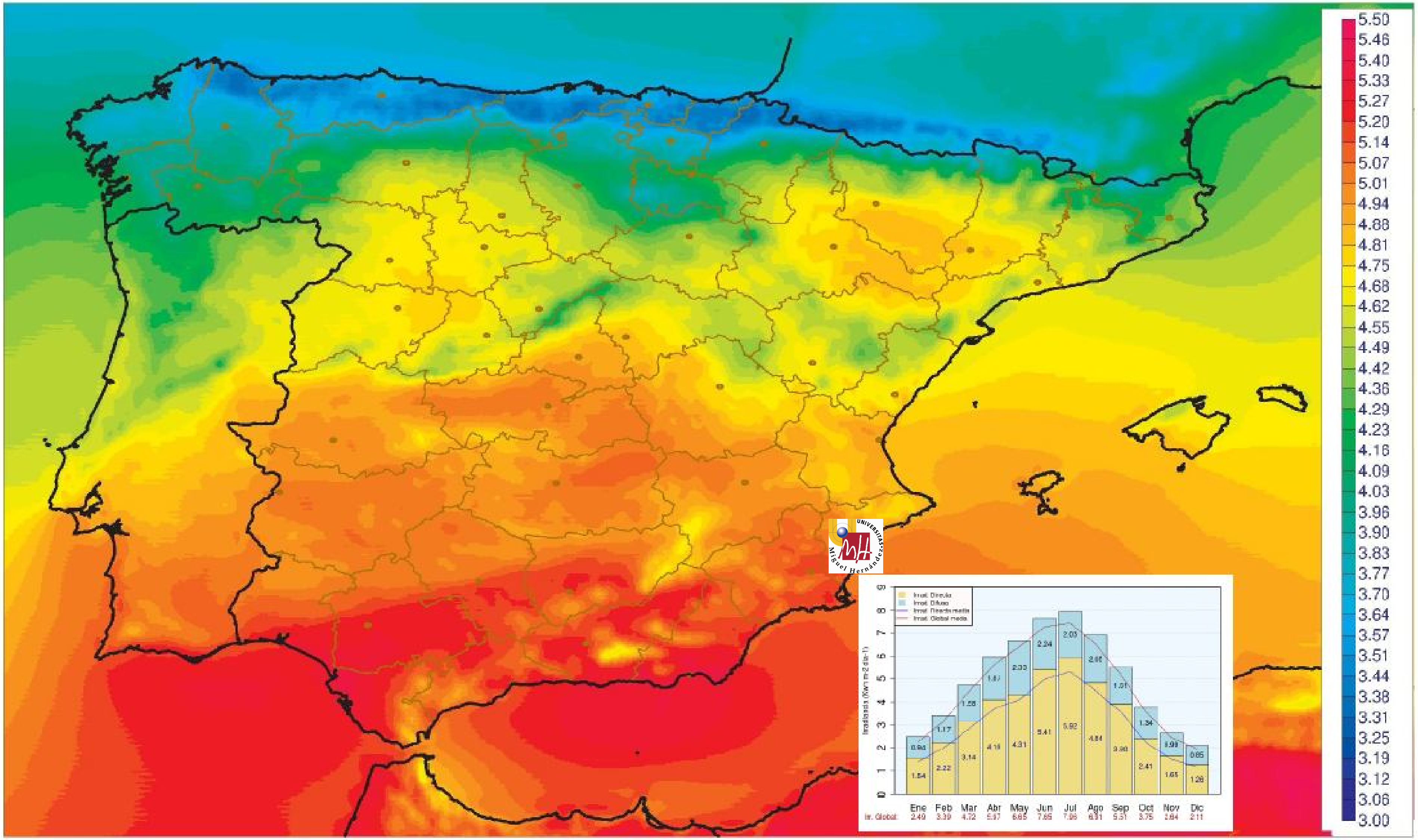
1. PROJECT DESCRIPTION

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

**PERFORMANCE
100% HYBRID**



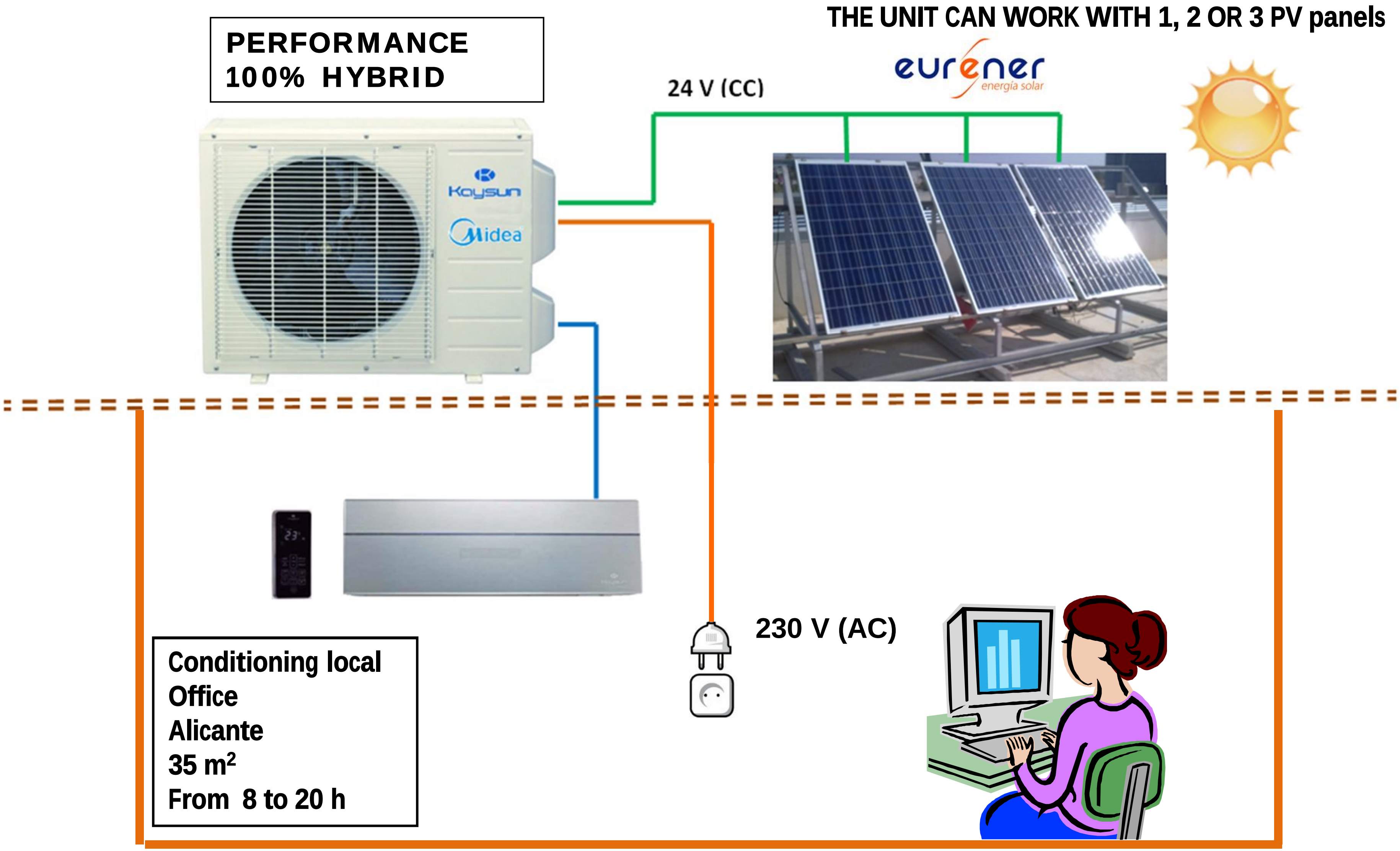
UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



NO BATTERIES !

NO EXTERNAL INVERTER!

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

2. PROJECT OBJECTIVES

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

Main objectives:

- ж To determine the energy efficiency of the equipment monthly and stationally
- ж To demostrate de real posibilities of using aircon units powered simultaneously from the grid and from photovoltaic panels

Long term objectives:

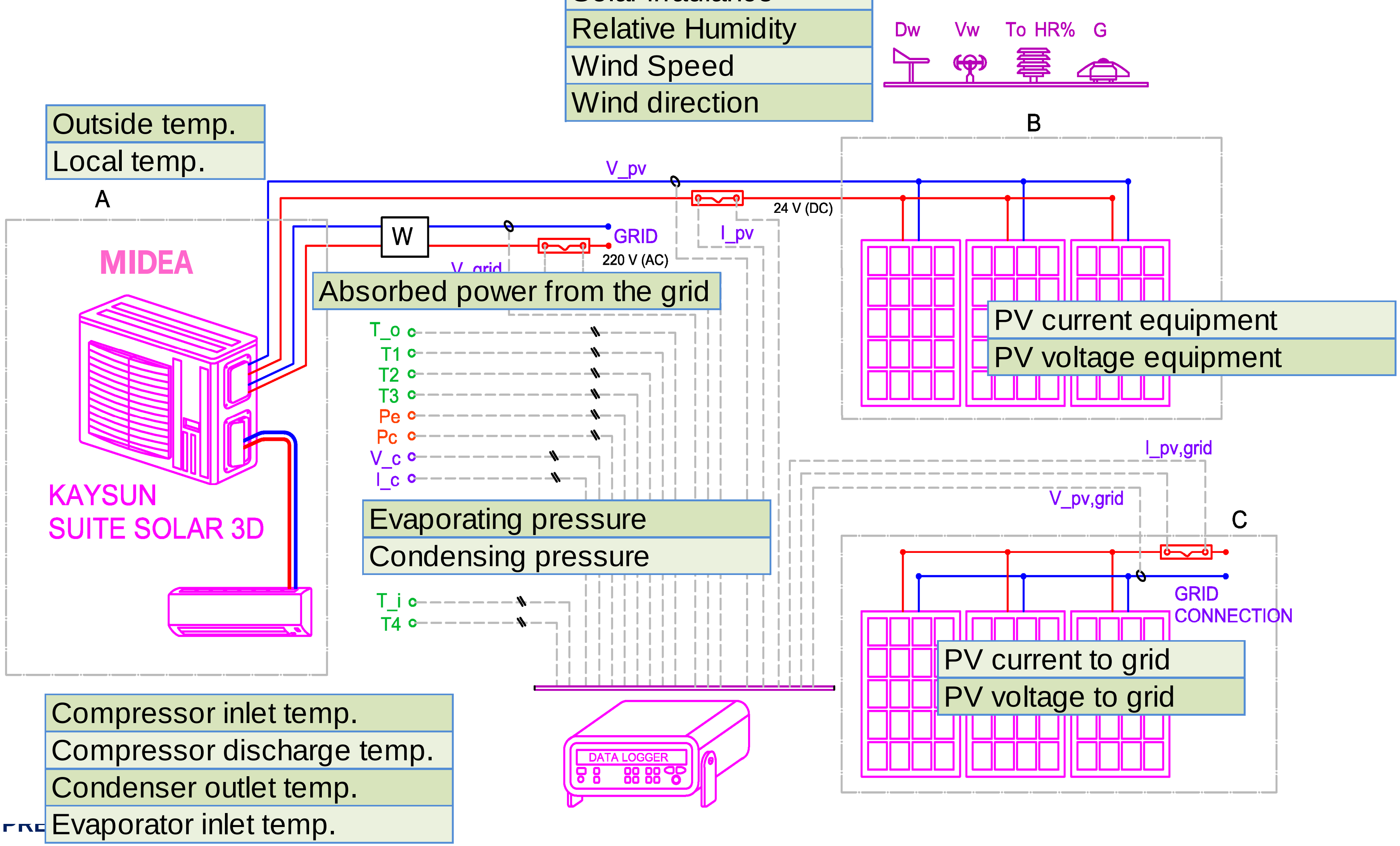
- ж To determine the system efficiency when it works at different conditions (timetable, load, climatic)
- ж To establish the optimum design as a function of the climate region and application:

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

3. EXPERIMENTAL SETUP

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

Experimental set-up



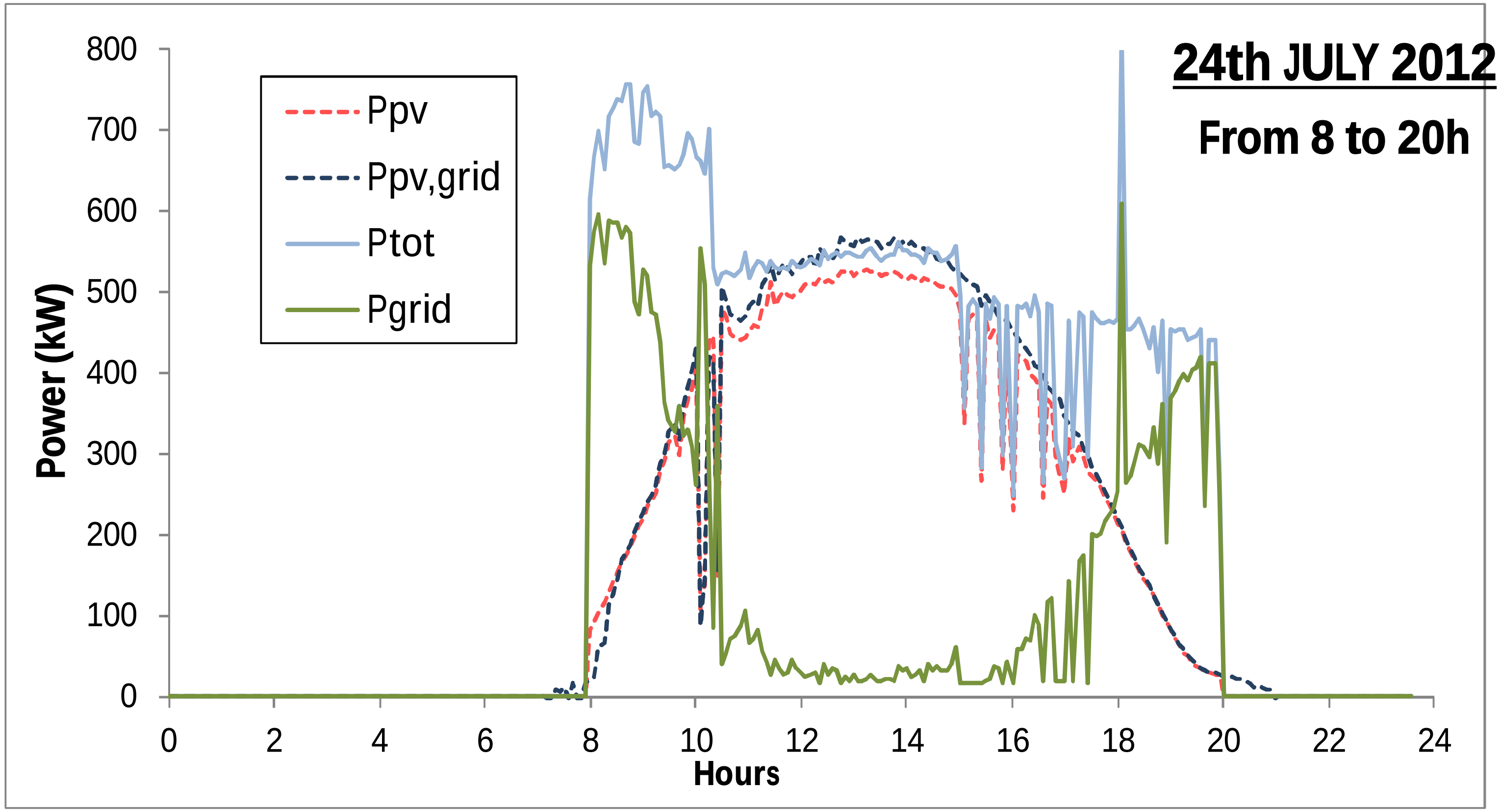
UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

Description	Symbology	14:00 - 24/07	Units
Compressor inlet temp.	T_1	14.27	ºC
Compressor discharge temp.	T_2	63.54	ºC
Condenser outlet temp.	T3	35.97	ºC
Evaporator inlet temp.	T_4	8.08	ºC
Outside temp.	T_O	30.69	ºC
Local temp.	T_I	23.29	ºC
Evaporating pressure	P_E	8.38	bar
Condensing pressure	P_C	22.09	bar
Absorbed power network	P_{GRID}	35.51	kW
PV current equipment	I_{PV}	25.42	A
PV voltage equipment	V_{PV}	20.27	V
PV current network	$I_{PV,GRID}$	26.08	A
PV voltage network	$V_{PV,GRID}$	21.32	V
Solar irradiance	G	962	W/m^2
Relative Humidity	HR	53.1	%
Wind Speed	V_w	1.41	m/s
Wind direction	D_w	43	º

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

4. EXPERIMENTAL RESULTS

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



P_{PV} → Electrical power from photovoltaic panels

P_{GRID} → Electrical power from the electrical grid

P_{TOT} → Total Electrical power

$P_{PV,GRID}$ → Electrical power from photovoltaic panels connected to the electrical grid

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

JULY From 8 to 20 h	E_{PV} kWh	E_{GRID} kWh	E_{TOT} kWh	SC %	$E_{PV,GRID}$ kWh	F %	L %
23/07/2012	3,26	2,90	6,17	52,9%	3,69	88,4%	51,8%
24/07/2012	4,09	2,22	6,31	64,8%	4,41	92,7%	53,0%
25/07/2012	3,64	2,39	6,03	60,4%	4,28	85,1%	50,6%
26/07/2012	3,59	3,71	7,30	49,2%	4,14	86,9%	61,3%
27/07/2012	3,37	4,95	8,32	40,5%	3,69	91,5%	69,9%
30/07/2012	3,52	6,86	10,38	33,9%	3,67	95,9%	87,1%
31/07/2012	3,83	5,73	9,56	40,0%	3,98	96,1%	80,3%
PROMEDIO	3,61	4,11	7,72	46,8%	3,98	90,8%	64,9%

E_{PV} → Energy supplied by PV panels to the inverter unit

E_{RED} → Energy supplied by the grid to the inverter unit

E_{TOT} → Total Energy consumed by the inverter unit

SC(%) → Solar Contribution

$E_{PV,RED}$ → Energy supplied by PV panels to the grid

F → Production factor

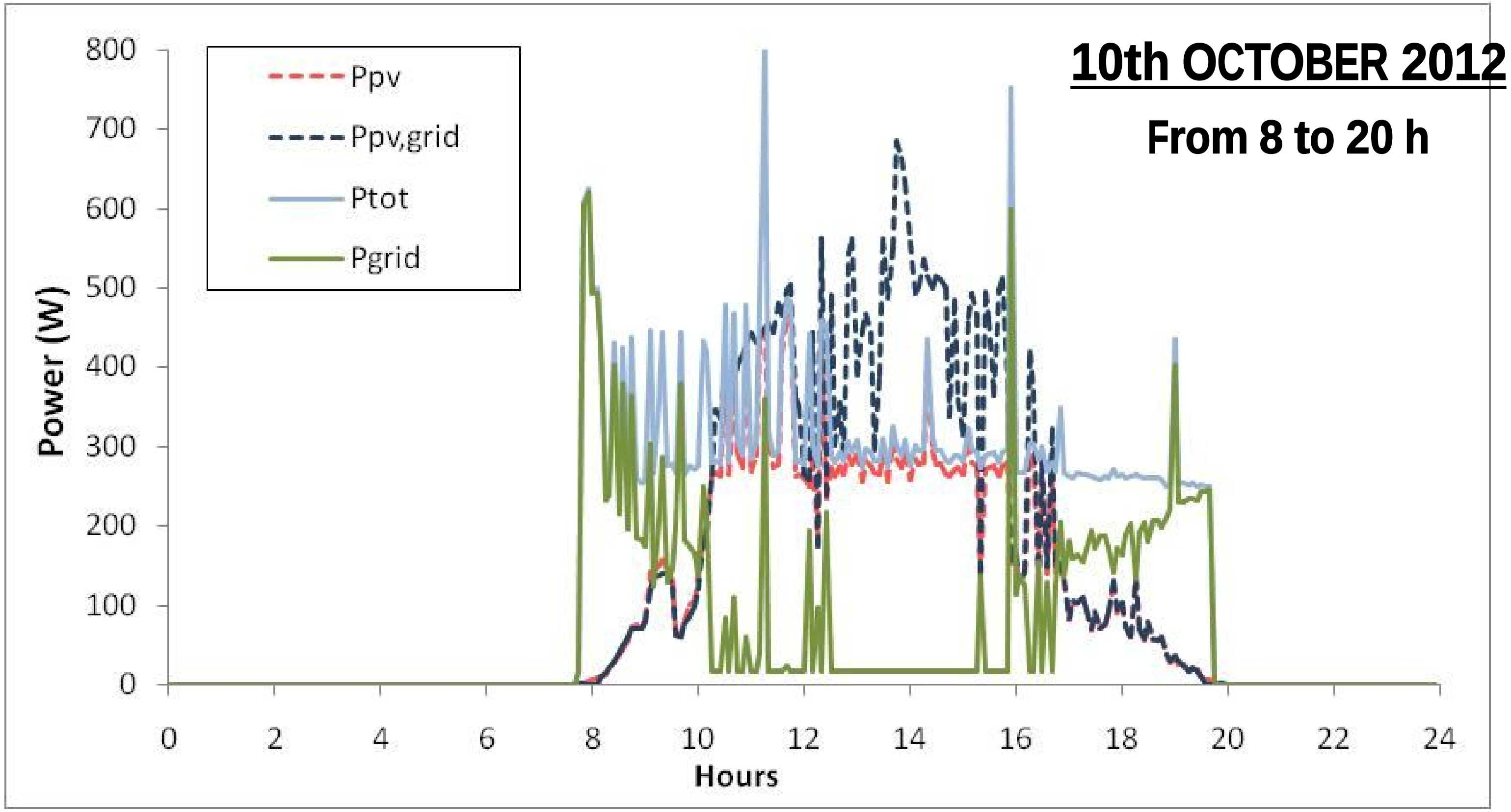
L → Inverter unit mean load

$$SC\,\% = \frac{E_{PV}}{E_{TOT}}$$

$$F\,\% = \frac{E_{PV}}{E_{PV,RED}}$$

$$L\,\% = \frac{E_{TOT}}{E_{TOT,MAX}}$$

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



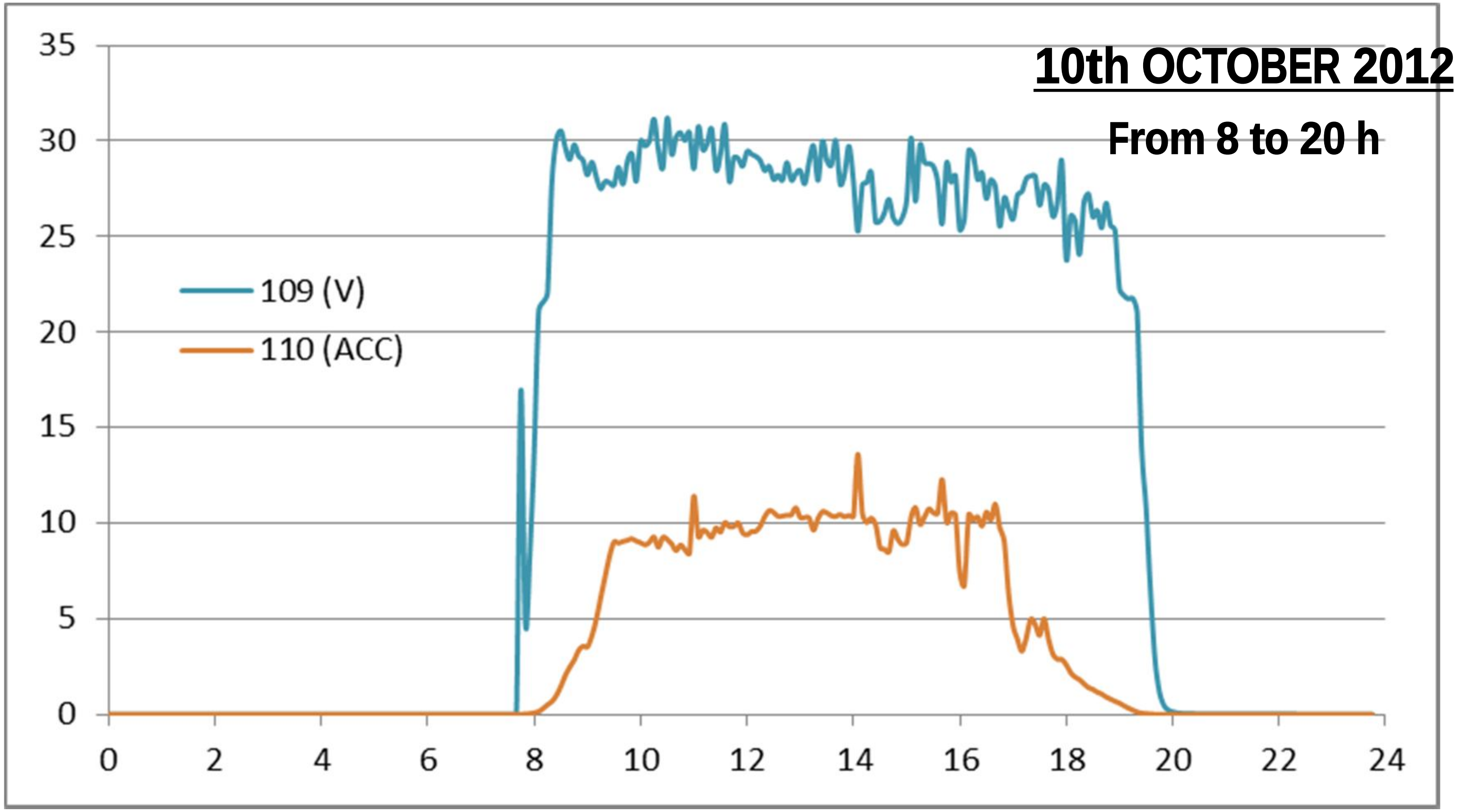
P_{PV} → Electrical power from photovoltaic panels

P_{GRID} → Electrical power from the electrical grid

P_{TOT} → Total Electrical power

$P_{PV,GRID}$ → Electrical power from photovoltaic panels connected to the electrical grid

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



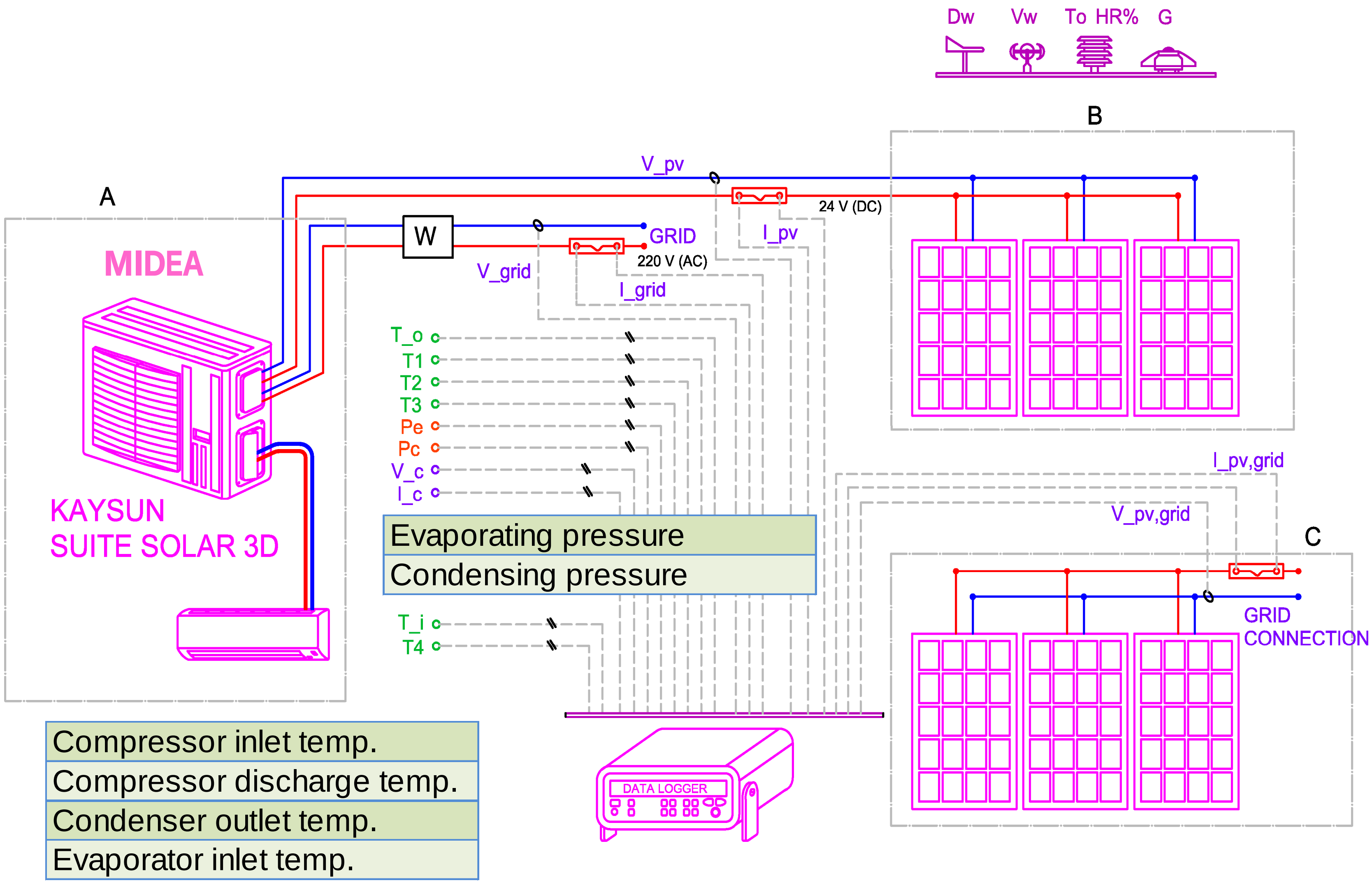
UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

SUMMER	***E_{PV}***	***E_{GRID}***	***E_{TOT}***	***SC***	***$E_{PV,GRID}$***	***F***	***L***
From 8 to 20 h	***kWh***	***kWh***	***kWh***	***%***	***kWh***	***%***	***%***
JULY	3,61	4,11	7,72	46,8	3,98	90,9	64,9
AUGUST	3,42	5,11	8,53	40,0	3,57	95,7	71,7
SEPTEMBER	2,60	1,45	4,05	64,3	3,40	77,4	34
OCTOBER	2,23	1,44	3,67	60,8	3,13	72,7	30,8
AVERAGE				54,5		82,6	47,3

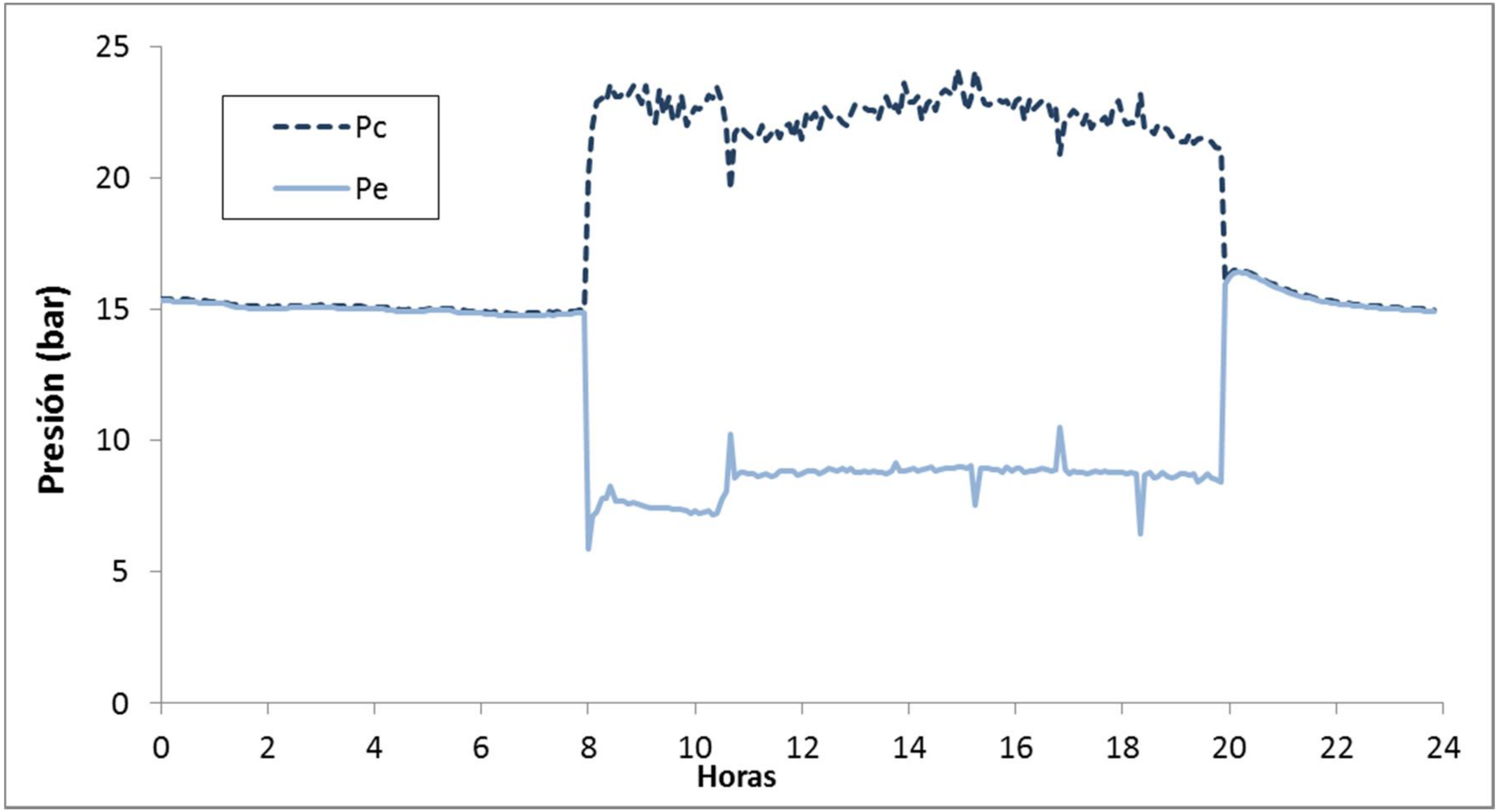
Total consumption = 840 kWhe ; Grid consumption = 378 kWhe; PV contribution= 462 kWhe

- **E_{PV}** → Energy supplied by PV panels to the inverter unit
- **E_{RED}** → Energy supplied by the grid to the inverter unit
- **E_{TOT}** → Total Energy consumed by the inverter unit
- **SC(%)** → Solar Contribution
- **$E_{PV,RED}$** → Energy supplied by PV panels to the grid
- **F** → Production factor
- **L** → Inverter unit mean load

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



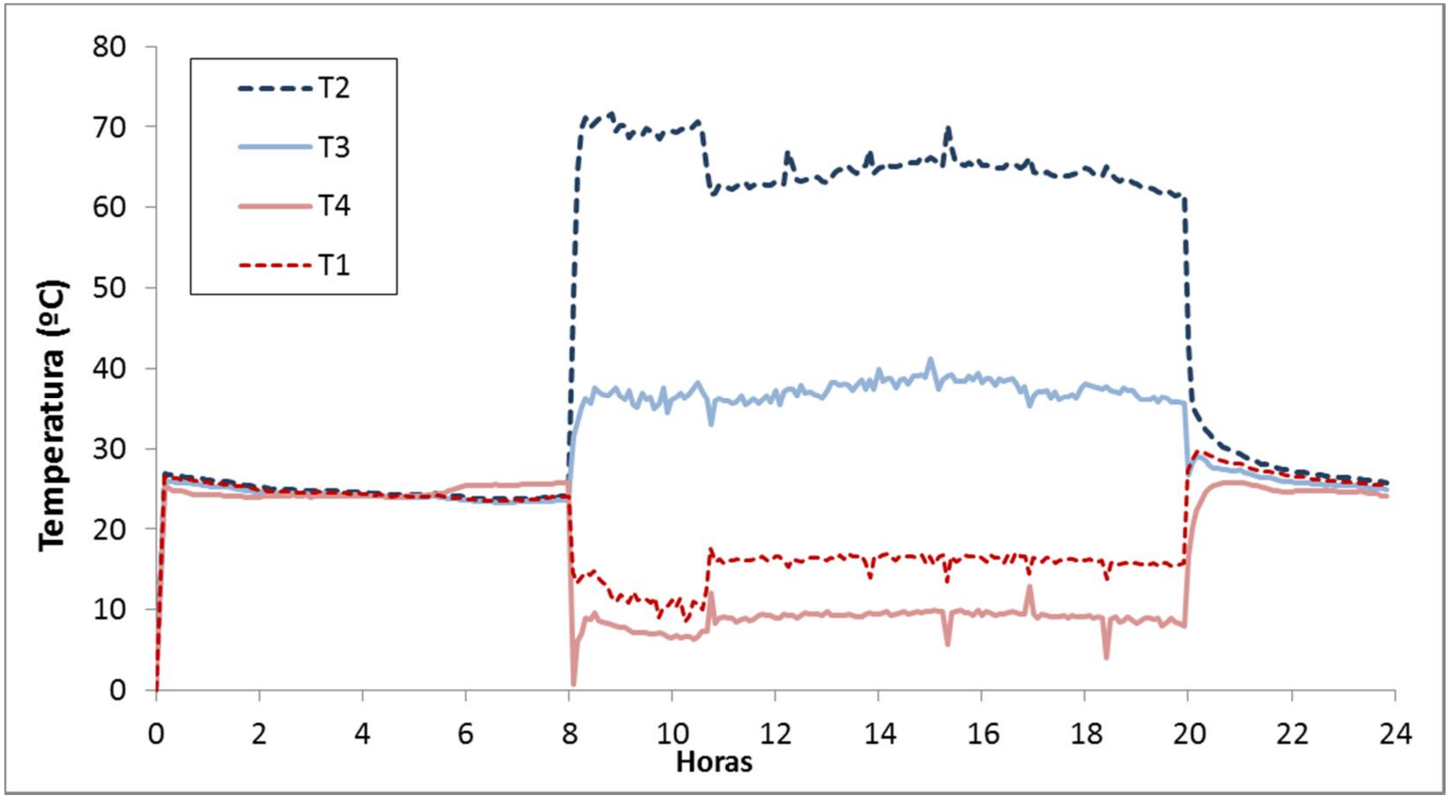
UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



P_C → Condensating pressure

P_E → Evaporating pressure

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



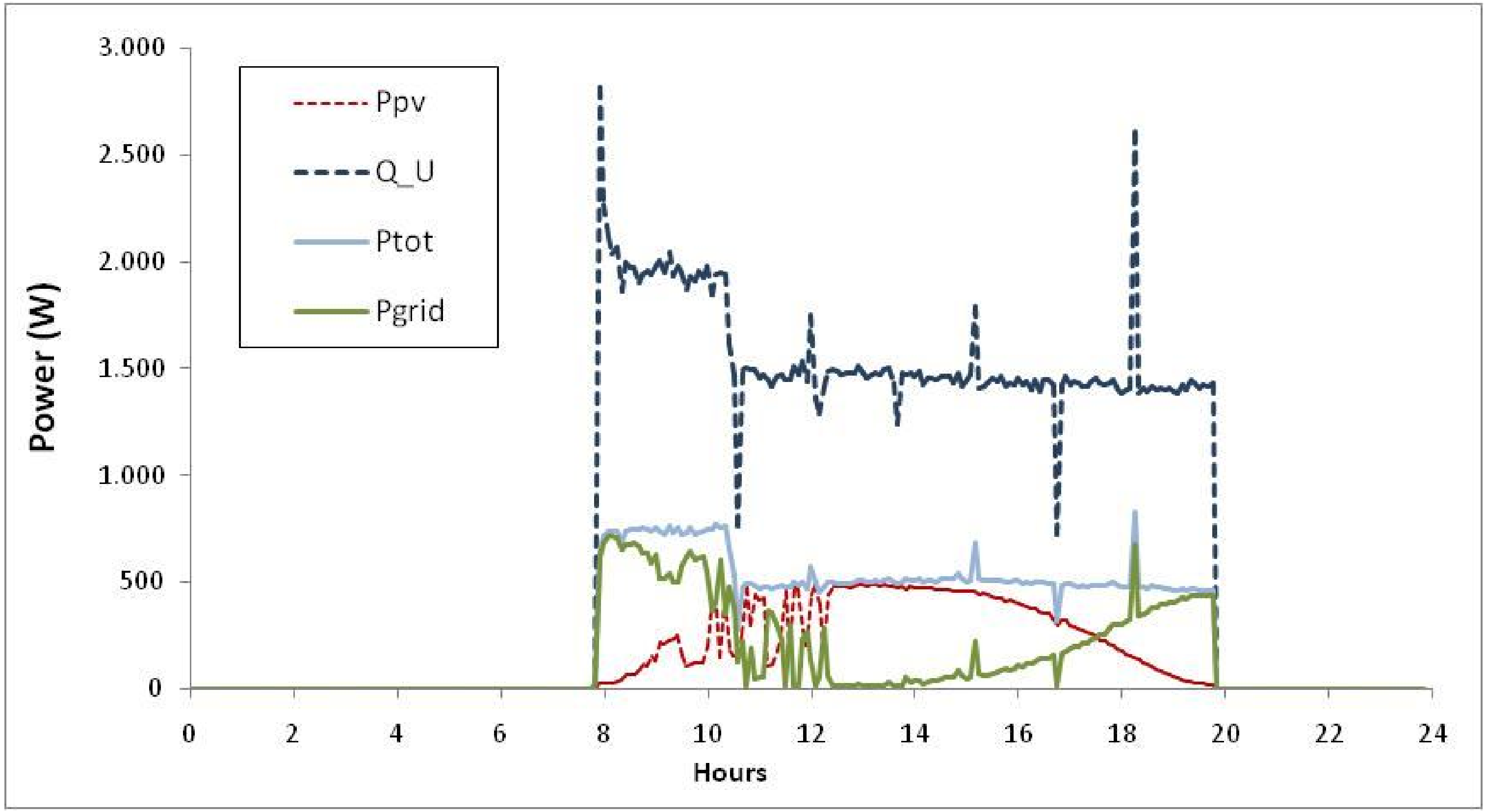
T_1 → Compressor inlet temperature

T_2 → Compressor outlet temperature

T_3 → Condenser outlet temperature

T_4 → Evaporator outlet temperature

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



P_{PV} → Electrical power from photovoltaic panels

P_{GRID} → Electrical power from the electrical grid

P_{TOT} → Total Electrical power

Q_U → Thermal power

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

TIMETABLE FROM 8 TO 20 h

SUMMER	E_{PV}	E_{GRID}	E_{TOT}	E_U	SC	EER_{UNIT}	EER_{SYSTEM}
From 8 to 20 h	kWh	kWh	kWh	kWh	%		
JULY	3,67	4,30	7,97	32,17	46,00	4,04	7,47
AUGUST	3,43	4,88	8,31	32,17	41,27	3,87	6,59
SEPTEMBER	2,54	1,61	4,15	22,28	61,22	5,36	13,83
OCTOBER	2,23	1,44	3,67	19,94	60,76	5,43	13,85
AVERAGE	2,97	3,06	6,03	26,64	49,24	4,75	10,97

E_{PV} → Energy supplied by PV panels to the inverter unit

E_{RED} → Energy supplied by the grid to the inverter unit

E_{TOT} → Total Energy consumed by the inverter unit

E_{COM} → Total Energy consumed by the compressor of the inverter unit

E_U → Useful Thermal Energy

SC(%) → Solar Contribution

ERR_{UNIT} → Mean Energy Efficiency of the inverter unit

EER_{SYSTEM} → Mean Energy Efficiency of the system

$$EER_{UNIT} = \frac{E_U}{E_{TOT}}$$

$$EER_{SYSTEM} = \frac{E_U}{E_{GRID}}$$

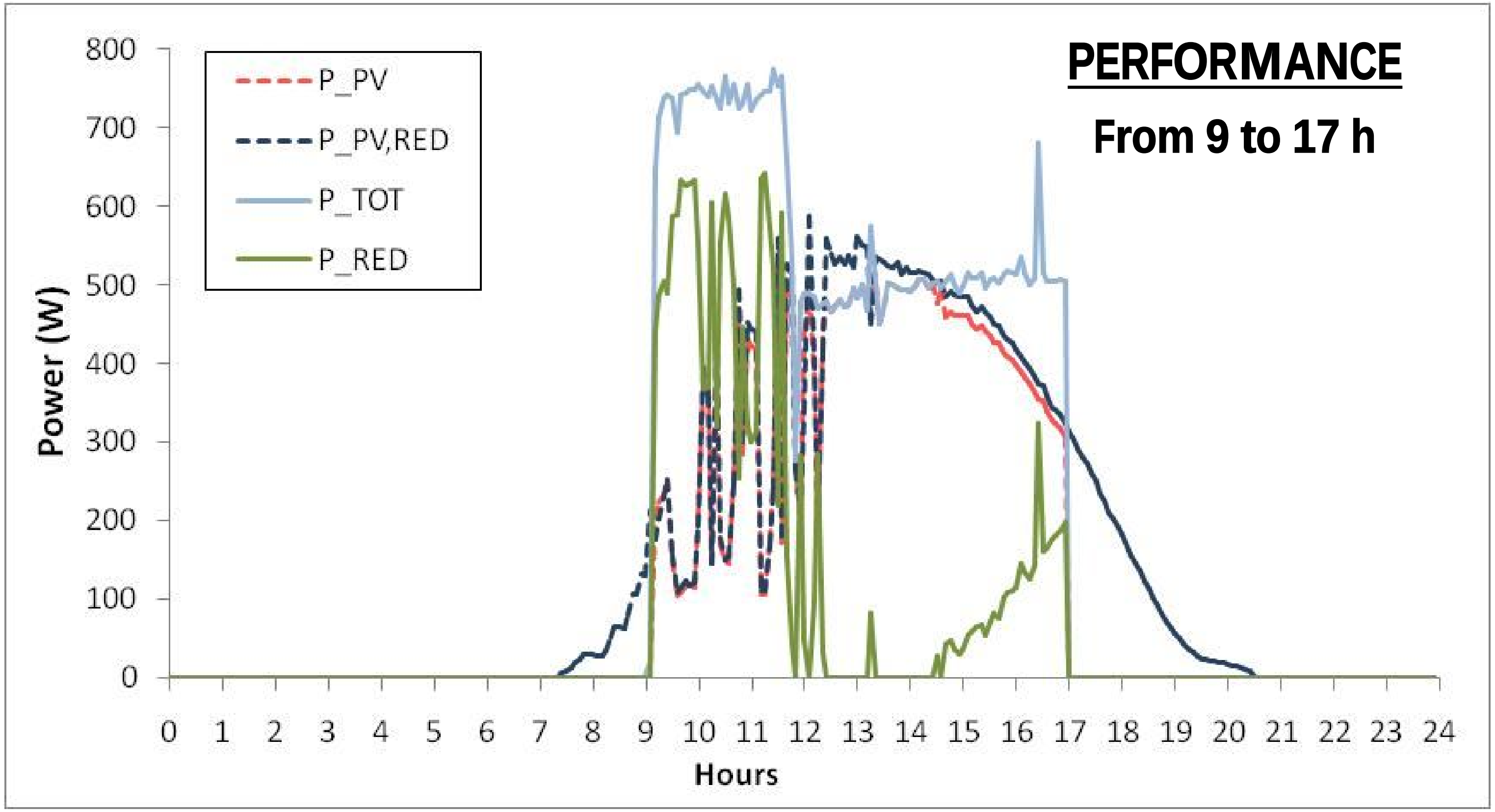
UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

TIMETABLE FROM 8 TO 20 h

SUMMER	E_{PV}	E_{GRID}	E_{TOT}	E_{U}	SC	EER_{UNIT}	EER_{SYSTEM}
From 8 to 20 h	kWh	kWh	kWh	kWh	%		
JULY	3,67	4,30	7,97	32,17	46,00	4,04	7,47
AUGUST	3,43	4,88	8,31	32,17	41,27	3,87	6,59
SEPTEMBER	2,54	1,61	4,15	22,28	61,22	5,36	13,83
OCTOBER	2,23	1,44	3,67	19,94	60,76	5,43	13,85
AVERAGE	2,97	3,06	6,03	26,64	49,24	4,75	10,97

WINTER	E_{PV}	E_{GRID}	E_{TOT}	E_{U}	SC	COP_{UNIT}	COP_{SYSTEM}
From 8 to 20 h	kWh	kWh	kWh	kWh	%		
DECEMBER	1,81	4,43	6,24	24,53	28,97	3,93	5,53
JANUARY	2,04	3,45	5,48	23,24	37,20	4,24	6,73
FEBRUARY	2,24	3,38	5,61	23,51	39,84	4,19	6,96
MARCH	2,30	2,66	4,95	21,25	46,37	4,29	8,00
AVERAGE	2,09	3,48	5,57	23,13	37,60	4,11	6,75

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es



P_{PV} → Electrical power from photovoltaic panels

P_{GRID} → Electrical power from the electrical grid

P_{TOT} → Total Electrical power

$P_{PV,GRID}$ → Electrical power from photovoltaic panels connected to the electrical grid

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

13/12/2012

TIMETABLE FROM 9 TO 17 h

SUMMER	E_{PV}	E_{GRID}	E_{TOT}	E_{U}	SC	EER_{UNIT}	EER_{SYSTEM}
From 9 to 17 h	kWh	kWh	kWh	kWh	%		
JULY	3,36	2,19	5,54	21,96	60,54	3,96	10,04
AUGUST	3,12	2,58	5,70	21,71	54,74	3,81	8,41
SEPTEMBER	2,29	0,84	3,13	14,77	73,19	4,72	17,58
OCTOBER	1,68	0,73	2,41	13,19	69,71	5,47	18,07
AVERAGE	2,61	1,58	4,20	17,91	62,25	4,48	14,15

WINTER	E_{PV}	E_{GRID}	E_{TOT}	E_{U}	SC	COP_{UNIT}	COP_{SYSTEM}
From 9 to 17 h	kWh	kWh	kWh	kWh	%		
DECEMBER	1,81	2,50	4,31	16,78	42,11	3,89	6,71
JANUARY	2,08	1,63	3,71	15,64	56,01	4,22	9,60
FEBRUARY	2,26	1,89	4,15	16,72	54,56	4,03	8,85
MARCH	2,17	1,43	3,6	15	60,40	4,17	10,49
AVERAGE	2,08	1,86	3,94	16,04	52,76	4,01	8,78

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

5. CONCLUSIONS

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

CONCLUSIONS

- An inverter air conditioning unit connected simultaneously to the grid and to 3 PV panels has been monitored.
- Results of the system performance have been obtained for summer and winter conditions and depend on the timetable:
  - Working from 8 to 20:

    Solar Contrib. in summer around 50% and 40% in winter.
  - Working from 9 to 17:

    Solar Contrib. in summer around 60% and 50% in winter.
- The average EER evaluated by the relationship between useful thermal energy and the electricity consumed from the grid is about 11, and it can be higher than 14 if the working hours are from 9 to 17.
- The system has shown a 100% of reliability with no maintenance

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

6. RESULTS DIFFUSION

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

3 NATIONAL CONGRESSES

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

4 INTERNATIONAL CONGRESSES

SHC 2013
CONFERENCE
SEPTEMBER 23-25
FREIBURG, GERMANY

Next Beijing October 2014

OTTI
5th International Conference Solar Air-Conditioning

Climamed'13 Istanbul
Mediterranean Congress of Climatization

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

7. FUTURE WORKS

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

LIFE PROJECT Proposal. 26-JUNE-2013

LIFE+ Environment Policy and Governance

TECHNICAL APPLICATION FORMS

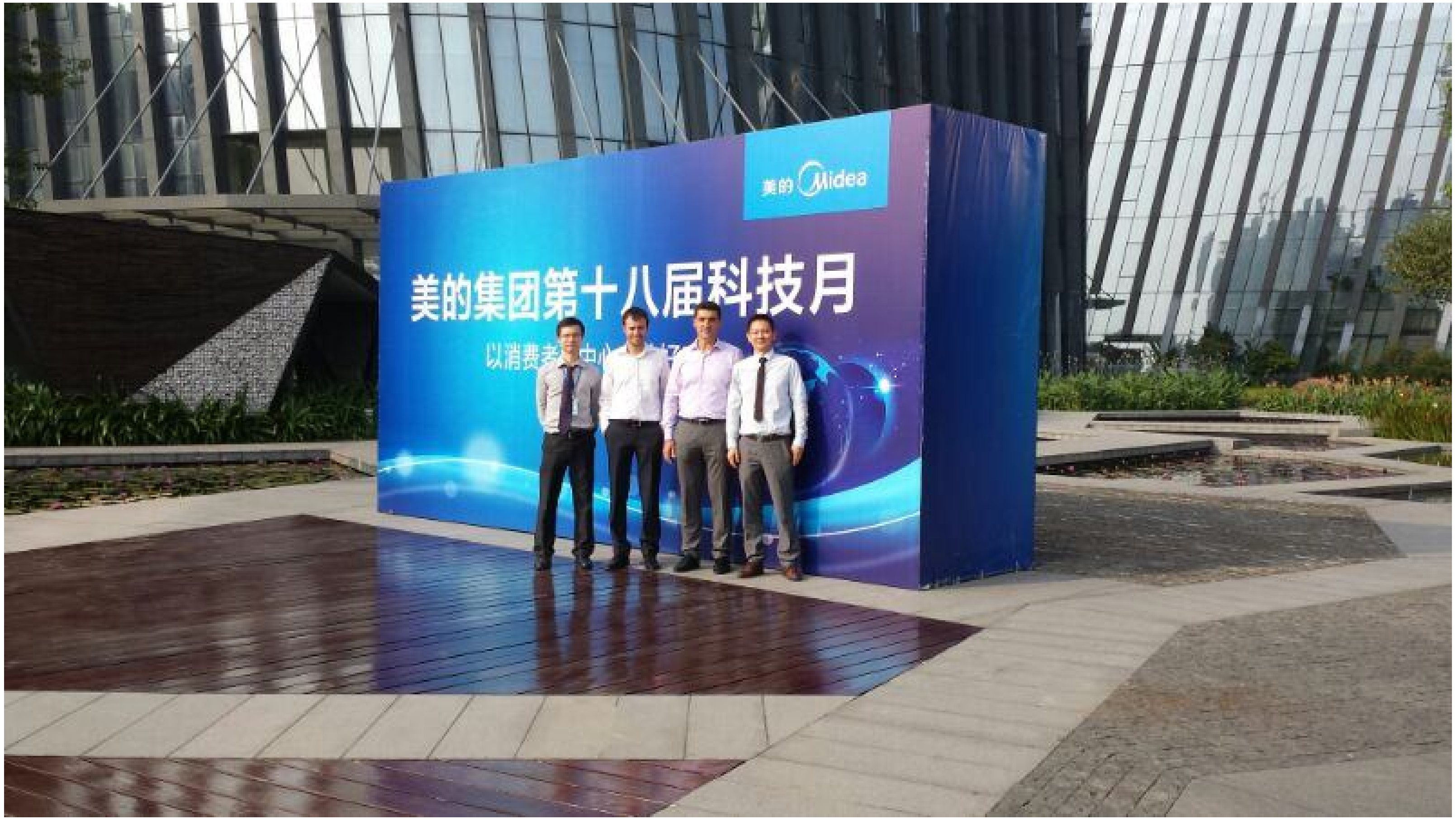
LIFE13 ENV/ES/000623

Reply on Jun 2014

PRESENTATION IN PARIS 22-OCT-2013

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

Proposal to MIDEA. 11-OCT-2013



UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

Midea

Global | Select Country / Region

HOME | ABOUT MIDEA | NEWS ROOM | PRODUCTS & SOLUTIONS | SUPPORT | CONTACT US

- Overview
- History
- Brand
- Major Facilities
- Investor Relations
- Sustainability
- Publications

Home > About Midea > **Overview**

2012 Revenue	People	Export	Innovation
$16.6Bln	135,000	200+	3%
Annual Revenue	Employees Worldwide	Countries & Regions	of Total Revenue Re-invest to R&D

Established in 1968, Midea has grown from what was once a local workshop into a leading consumer appliances and air conditioning systems manufacturer, with operations around the world. Its 40 years of persistent growth has brought its global turnover to $22 billion USD in 2011. Consequently, Midea has created over 150,000 jobs both in China, and throughout the world.

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

EUROPEAN PROJECTS. NOV-DEC-2013

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

FUTURE WORKS

Now

- New unit with eco mode
- New unit with batteries
- New conducts internal unit

Next

- A Domestic Hot Water unit
- A higher power unit up to 10 kW

More research have to be done

- Experimental research
- Demonstrative projects
- Simulations

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

UMH PARTICIPATION IN THE TASK

Subtask C: Testing and demonstration projects

General objective : to stimulate, monitor and analyse performances of field test systems and demonstration projects for new generation solar cooling & heating systems

Specific objectives :
* to create a monitoring procedure for field tests or demo projects
* to select identified projects and organise a complete field test monitoring campaign for it
* to analyse potential technical issues on the monitored systems
* to report on the measured performances of the systems
* to validate and initiate standardised testing methods

UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

UMH PARTICIPATION IN THE TASK

Subtask C: Testing and demonstration projects
C1: Monitoring procedure and monitoring system selection criteria
C2: Definition of energy performance indicators
C3: System description for field test and demo project
C4: Monitoring data analysis on technical issues & on performances
C5: Best practices / feedback (planning+ commissioning + operation/measurements, user and grid utility
C6: Testing method initiation for standards

Operation and energy efficiency of an hybrid air conditioner simultaneously connected to the grid and to photovoltaic panels

Prof. Dr. Pedro Vicente Quiles
Universidad Miguel Hernández de Elche
pedro.vicente@umh.es
http://dime.umh.e

Dipl. Ing. Francisco J. Aguilar Valero
Universidad Miguel Hernández de Elche

Dipl. Ing. Simón Aledo Vives
simon@prointer.es
Prointer, S.L.