Energy Analysis of an Inverter Air Conditioner Connected Directly to Photovoltaic Solar Panels

Pedro V. Quiles
Universidad Miguel Hernández de Elche
pedro.vicente@umh.es
http://dime.umh.es

Francisco J. Aguilar Valero
Universidad Miguel Hernández de Elche
faguilar@umh.es

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

UNIVERSITAS Miguel Hernández

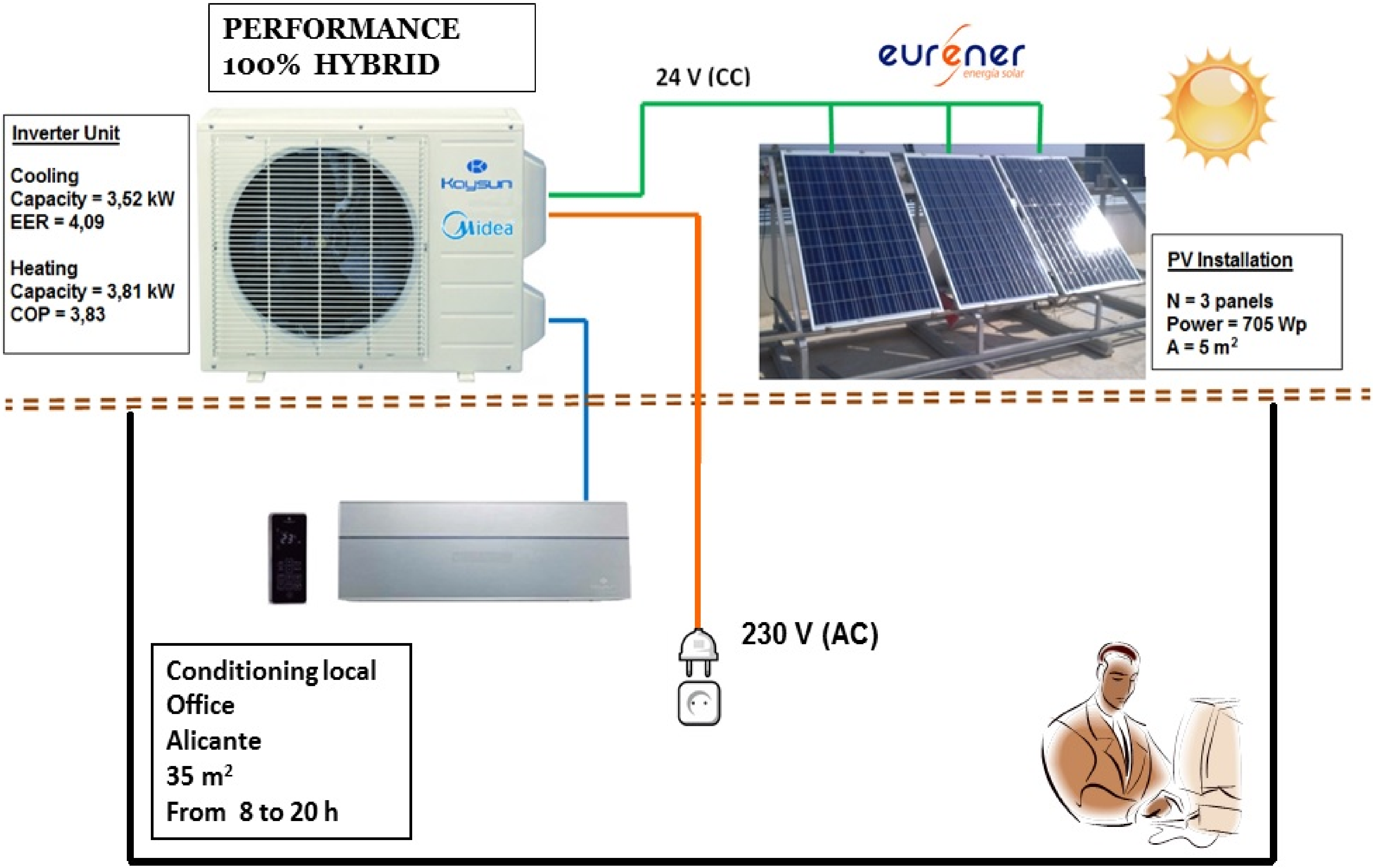
Prointer

Francisco J. Aguilar
faguilar@umh.es

1. PROJECT DESCRIPTION

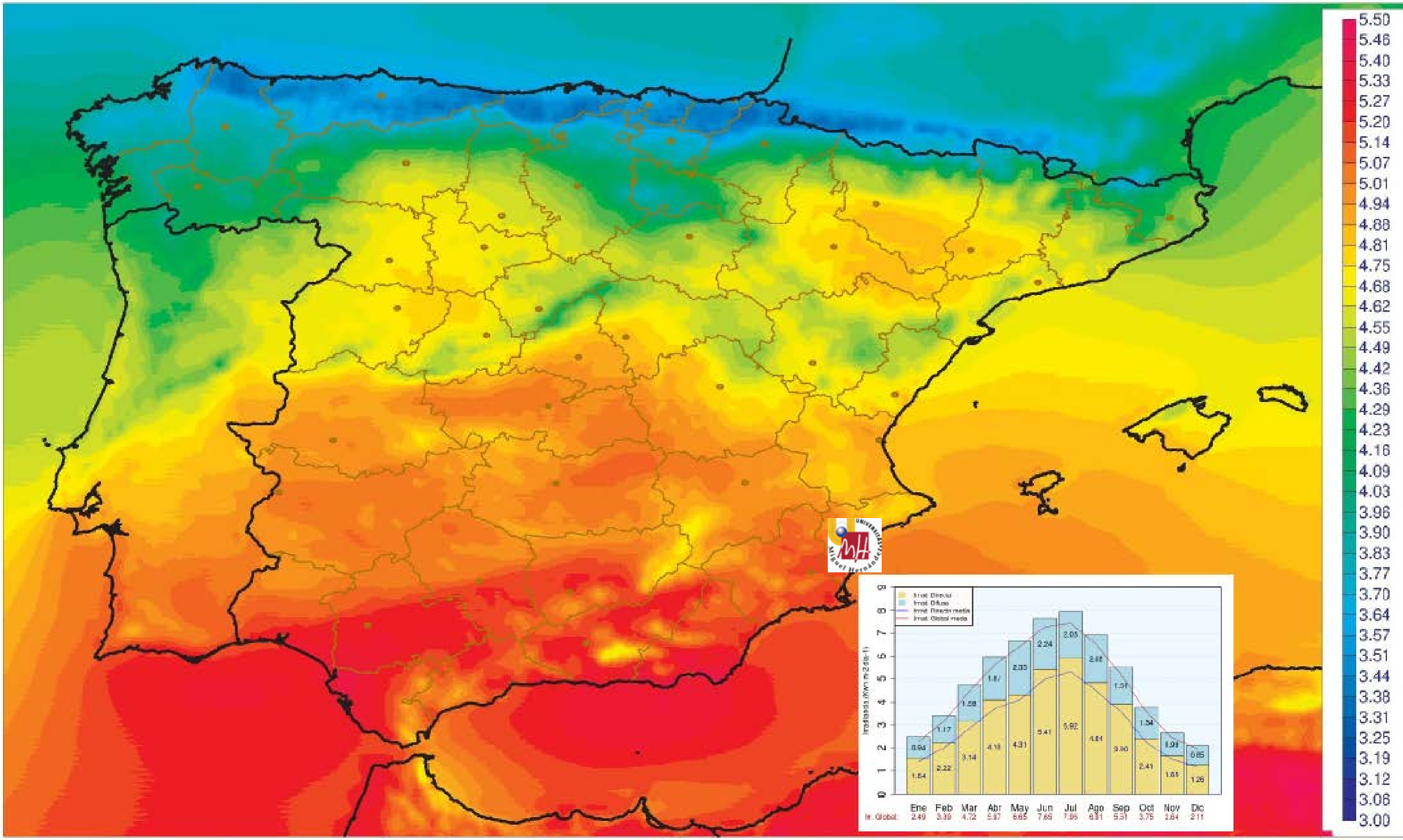
Energy Analysis of an Inverter Air Conditioner Connected Directly to Photovoltaic Solar Panels

Francisco J. Aguilar
faguilar@umh.es



Energy Analysis of an Inverter Air Conditioner Connected Directly to Photovoltaic Solar Panels

Francisco J. Aguilar
faguilar@umh.es



Francisco J. Aguilar
faguilar@umh.es

2. OBJECTIVES OF THE PROJECT

Francisco J. Aguilar
faguilar@umh.es

Main objectives

1. To determine the seasonal energy efficiency of the system (PV+HP) for an entire year
2. To demonstrate real possibilities of using PV panels to produce thermal energy for heating and cooling

Long time objectives

1. To determine the energy efficiency of the system under other working conditions (climate, load, working hours,…)
2. To know the optimum design to each kind of application and working conditions.

Francisco J. Aguilar
faguilar@umh.es

3. EQUIPMENTS AND EXPERIMENTAL FACILITY

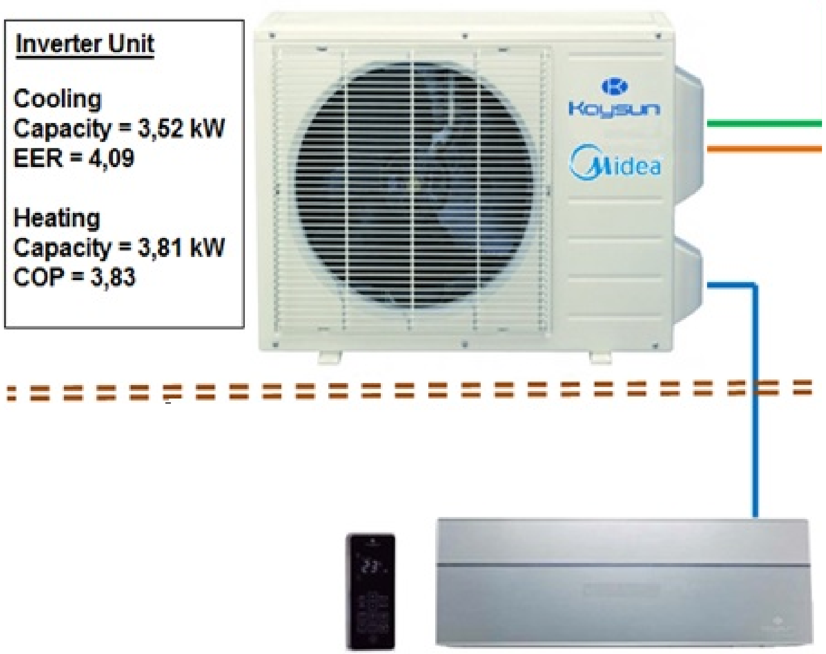
Francisco J. Aguilar
faguilar@umh.es

PERFORMANCE
100% HYBRID

Inverter Unit

Cooling
Capacity = 3,52 kW
EER = 4,09

Heating
Capacity = 3,81 kW
COP = 3,83



24 V (DC)
230 V (AC)

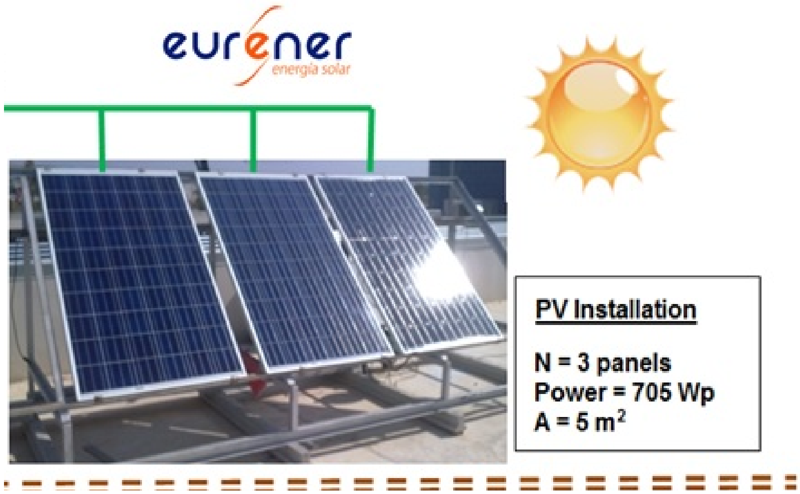
NO BATTERIES !!!

NO EXTERNAL INVERTER !!!

KAYSUN SUITE SOLAR 3D	*Units*	*Min.*	*Nom.*	*Max.*
Cooling Capacity	kW	0.95	3.52	4.15
Cooling Power Supply	kW	0.19	0.86	1.18
EER	---		4.09	
Heating Capacity	kW	1.03	3.81	4.5
Heating Power Supply	kW	0.22	0.99	1.36
COP	---		3.83	
Refrigerant	---		R410A	

Francisco J. Aguilar
faguilar@umh.es

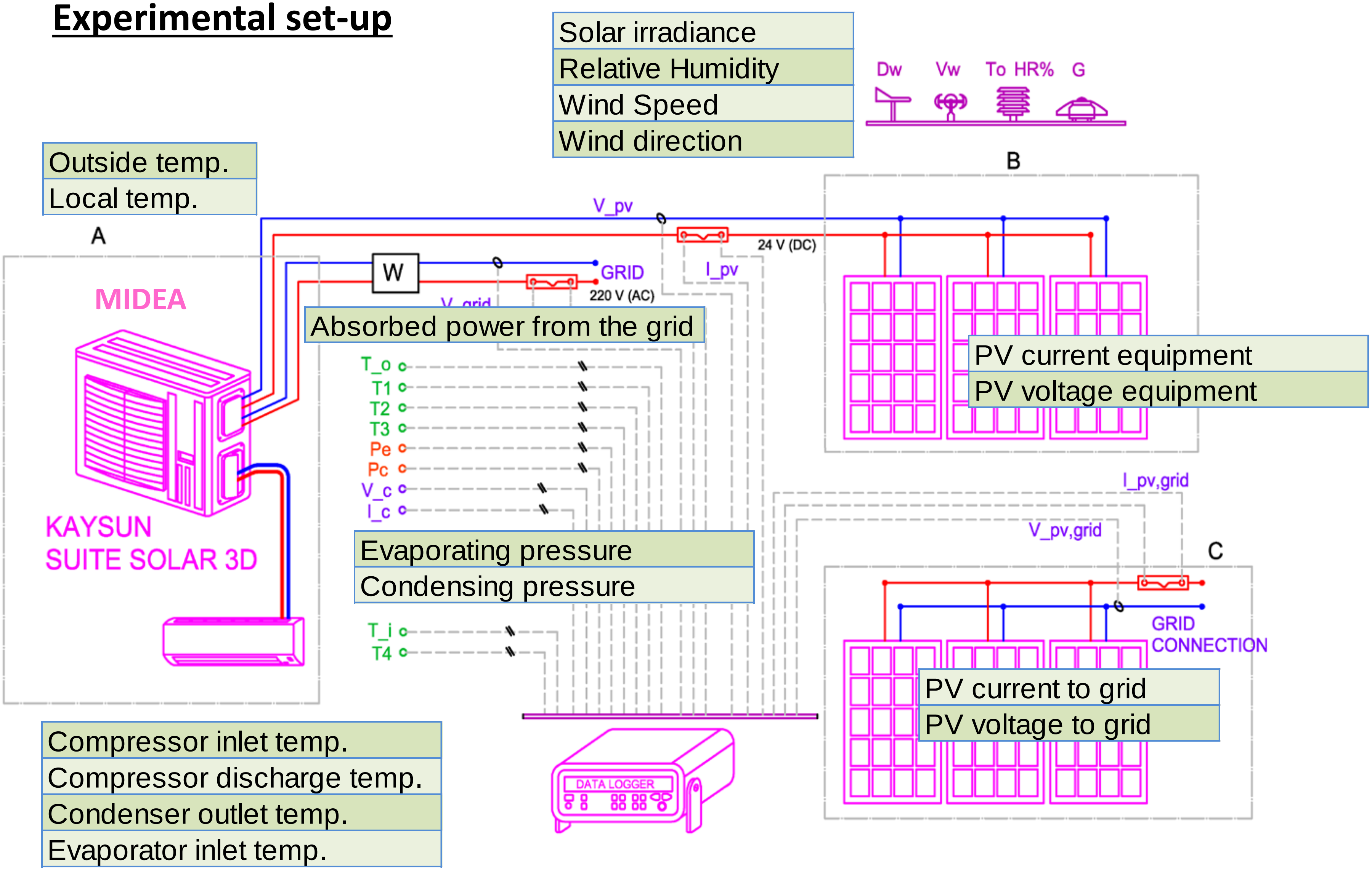
THE STUDY HAS BEEN CARRIED OUT WITH 3 PV PANELS. HOWEVER, THE SYSTEM CAN WORK WITH 1, 2 or 3 PV PANELS.



EURENER 235	***Simb.***	***Unit***	***Nom.***
Nominal Power	$P_{N,PV}$	W	235
Panel Area	A_{PV}	m^2	1.67
Efficiency	EF_{PV}	%	13.74
Short Circuit Current	I_{SC}	A	8.25
Open Circuit Voltage	V_{OC}	V	37.08
Nominal Current	$I_{N,PV}$	A	7.66
Nominal Voltage	$V_{N,PV}$	V	30.01

Francisco J. Aguilar
faguilar@umh.es

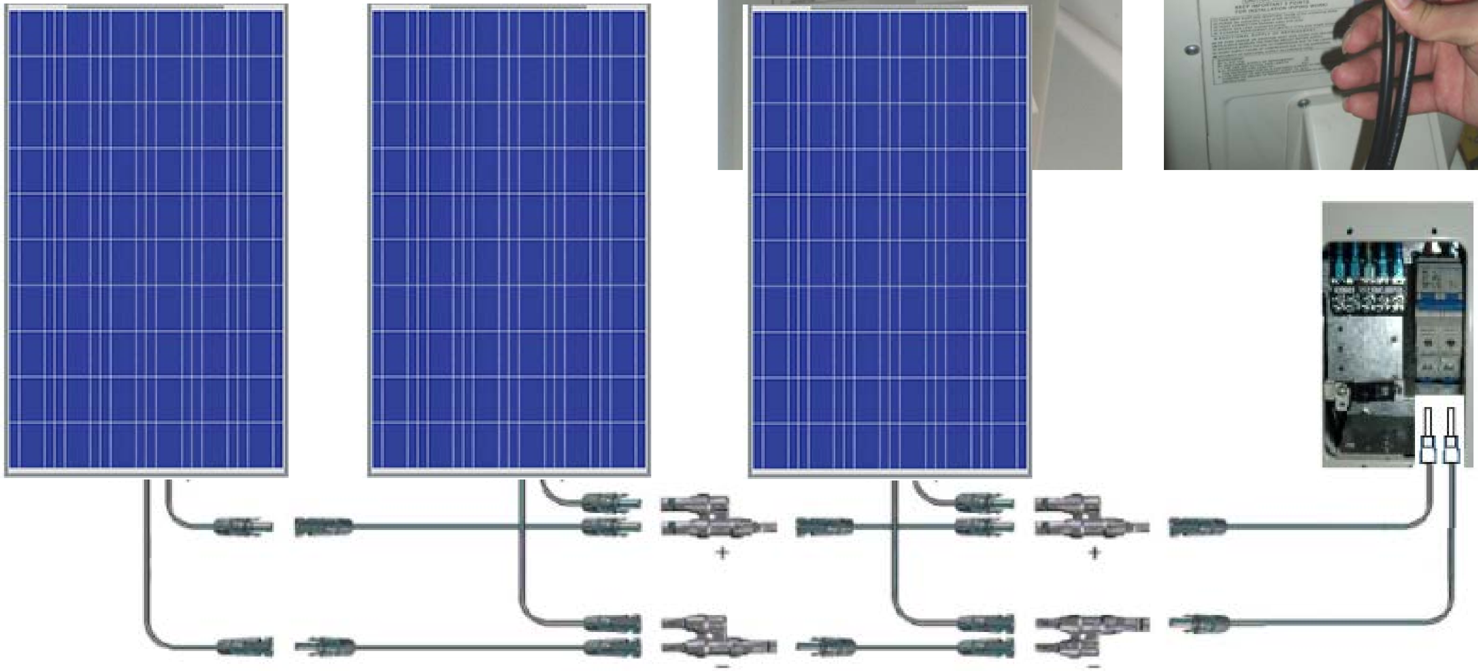
Experimental set-up



Francisco J. Aguilar
faguilar@umh.es

INSTALLATION OF THE EQUIPMENT:

- EASY
- FAST
- RELIABLE



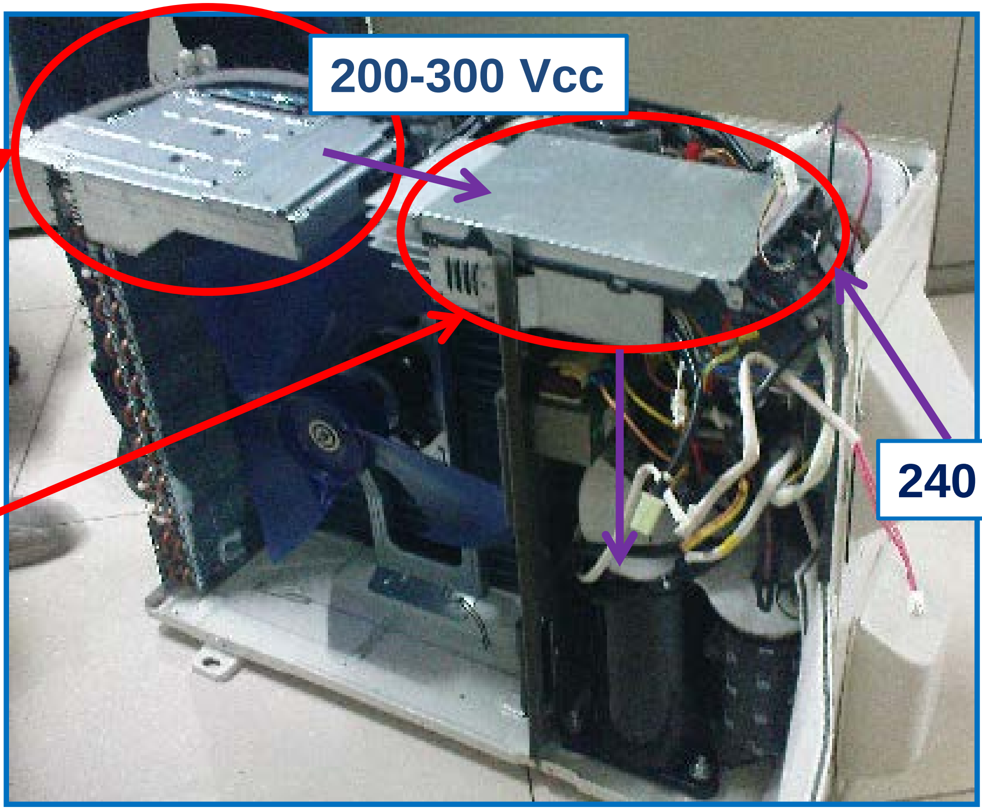
Francisco J. Aguilar
faguilar@umh.es

INSTALLATION OF THE EQUIPMENT:

- EASY
- FAST
- RELIABLE

Solar converter
24 Vcc a 200-300 Vcc

Inverter



Energy Analysis of an Inverter Air Conditioner Connected Directly to Photovoltaic Solar Panels

Francisco J. Aguilar
faguilar@umh.es


PERFORMANCE
100% HYBRID

1 YEAR OF STUDY

PRESENTED ON

5th International Conference

Solar Air Conditioning

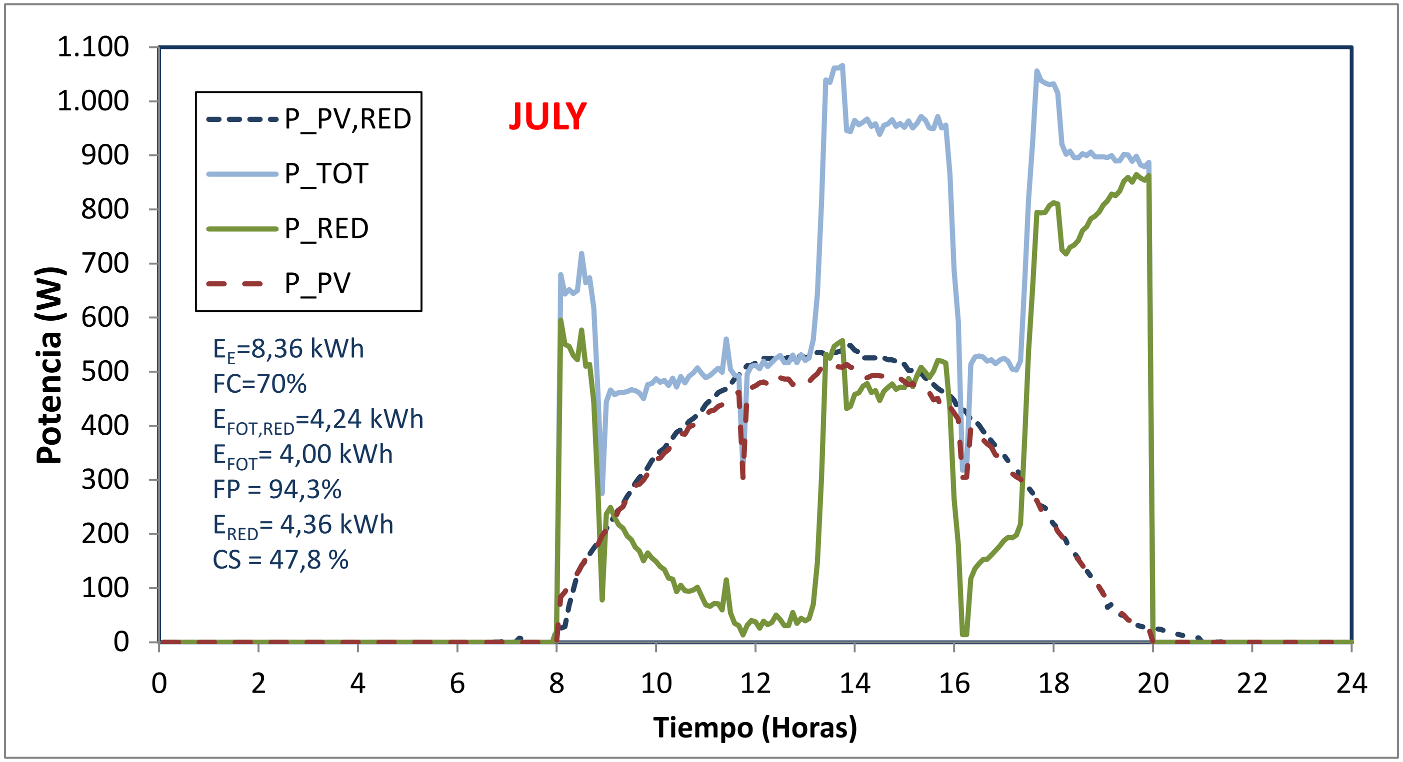
Francisco J. Aguilar
faguilar@umh.es

4. RESULTS ANALYSIS

Francisco J. Aguilar
faguilar@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_l	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

Francisco J. Aguilar
faguilar@umh.es



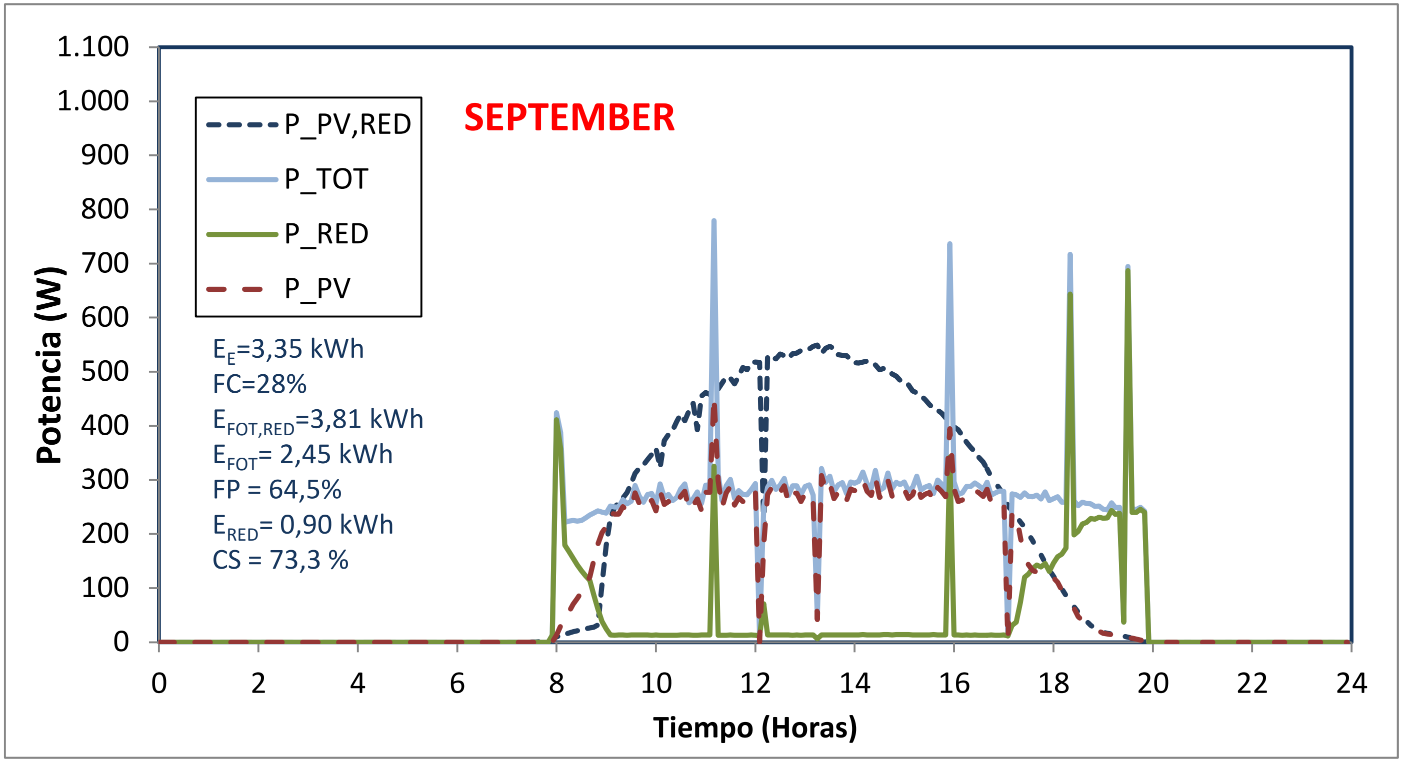
P_{PV} → Electrical power from photovoltaic panels

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

Francisco J. Aguilar
faguilar@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

Francisco J. Aguilar
faguilar@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

$$SC(\%) = \frac{E_{PV}}{E_{TOT}}$$

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

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

Francisco J. Aguilar
faguilar@umh.es

Horario de 8 a 20 h	E_PV (kWh)	E_RED (kWh)	E_TOT (kWh)	E_PV,RED (kWh)	E_U (kWh)	EER_Maq (-)	EER_Inst (-)	Cont. Sol CS (%)	F. Prod F (%)	T_ext (ºC)	T_int (ºC)
MAYO	66,0	25,8	91,8	116,8	519,5	6,50	23,12	82,5%	64,9%	24,0	23,3
							27,54	78,2%	53,6%	26,8	23,1
							9,52	55,7%	73,4%	31,1	25,0
							11,49	59,8%	73,9%	30,6	25,0
SEPTIEMBRE	68,2	29,9	98,2	101,0	545,1	5,55	18,21	69,5%	67,5%	27,8	24,3
OCTUBRE	55,4	32,2	87,7	83,6	524,4	5,98	16,26	63,2%	66,3%	26,1	24,1
MODO FRÍO	436,5	239,3	675,8	670,7	3478,4	5,15	14,54	64,6%	65,1%	27,7	24,2

$DEMAND_{TOTAL} = 186,5\ kWh_T/m^2\text{-year}$

$CONSUMPTION\_EP_{TOTAL} = 48,5\ kWh_{EP}/m^2\text{-year}$

Horario de 8 a 20 h	E_PV (kWh)	E_RED (kWh)	E_TOT (kWh)	E_PV,RED (kWh)	E_U (kWh)	COP_Maq (-)	COP_Inst (-)	Cont. Sol CS (%)	F. Prod F (%)	T_ext (ºC)	T_int (ºC)
NOVIEMBRE	49,36	65,31	114,64	56,49	465,24	4,06	7,12	43,1%	87,4%	14,9	25,9
							6,17	36,6%	91,7%	15,2	24,1
							6,77	42,1%	87,9%	15,1	25,4
							6,42	43,5%	84,5%	13,6	25,2
							7,38	48,9%	74,0%	16,8	25,7
ABRIL	58,53	44,79	103,32	101,76	387,67	3,75	8,65	56,6%	57,5%	19,1	24,0
MODO CALOR	354,4	439,6	793,8	453,8	3044,3	3,83	6,93	44,6%	78,1%	15,8	25,0
TOTAL	790,9	678,9	1469,7	1124,5	6522,7	4,44	9,61	53,8%	70,3%	21,7	24,6

ELECTRICITY COST (WITHOUT PV PANELS)	264,4	€
ELECTRICITY COST (WITH 3 PHOTOVOLTAIC PANELS	122,2	€
ELECTRICITY COST WITH A HP OF EER_M=2,5	469,6	€
SAVINGS	142,2	€

Francisco J. Aguilar
faguilar@umh.es

5. CONCLUSIONS

Francisco J. Aguilar
faguilar@umh.es

Main conclusions

1. The seasonal energy efficiency of the system (PV+HP) in cooling mode was higher than 14 with an seasonal energy efficiency of air conditioning equipment of 5.15
2. The seasonal COP of the system (PV+HP) was almost 10 while the seasonal COP of air conditioning equipment was 4.44
3. The yearly solar contribution was 53.8%
4. Cooling and heating with PV panels are a real option with this kind of systems

Francisco J. Aguilar
faguilar@umh.es

6. FUTURE LINES OF RESEARCH


Kaysun
26

Energy Analysis of an Inverter Air Conditioner Connected Directly to Photovoltaic Solar Panels

Pedro V. Quiles
Universidad Miguel Hernández de Elche
pedro.vicente@umh.es
http://dime.umh.es

Francisco J. Aguilar Valero
Universidad Miguel Hernández de Elche
faguilar@umh.es

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