Analytical simulation of an inverter heat pump driven simultaneously by the grid and PV panels

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

Francisco J. Aguilar Valero
Universidad Miguel Hernández de Elche

Erika Puigcerver Blanco
Universidad Miguel Hernández de Elche

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

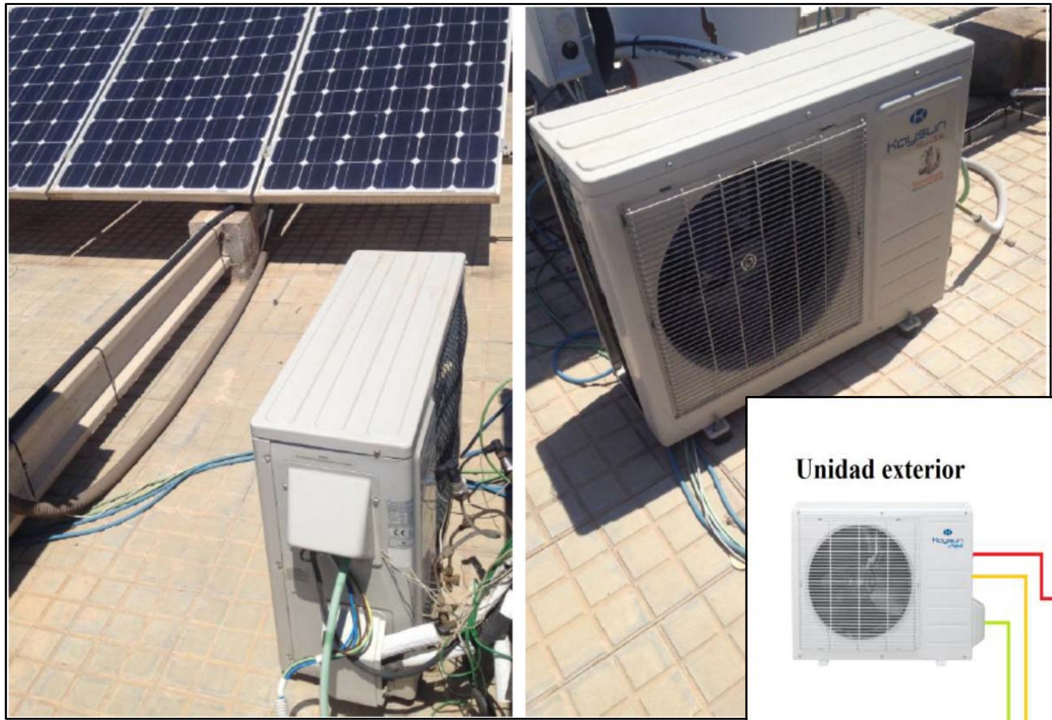
UNIVERSITAS Miguel Hernández

Prointer
CLIMATIZACION Y ENERGIAS RENOVABLES

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

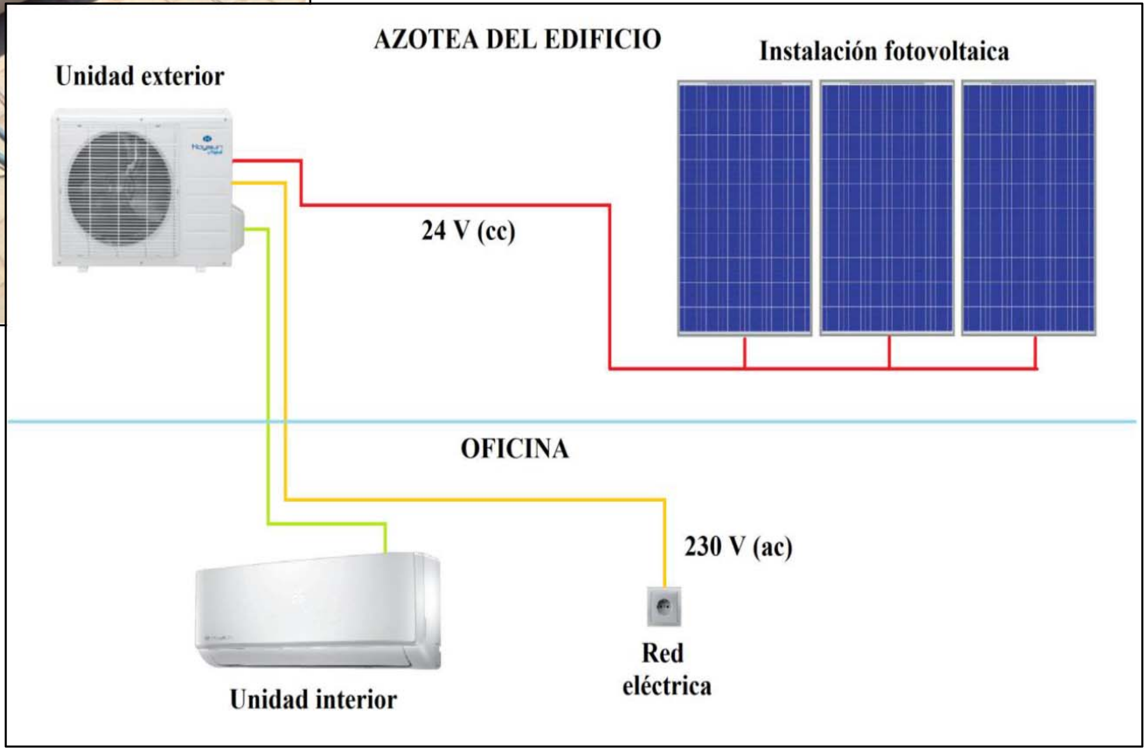
1. EXPERIMENTAL PROJECT DESCRIPTION

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



PERFORMANCE
100% HYBRID

1 YEAR OF STUDY



PRESENTED ON

5th International Conference

Solar Air Conditioning


Koysun

UMH. Pedro Vicente Quiles
pedro.vicente@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)

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	

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

THE STUDY WAS CARRIED OUT WITH 3 PV panels

THE SYSTEM COULD 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

PV Installation

N = 3 panels
Power = 705 Wp
A = 5 m^2

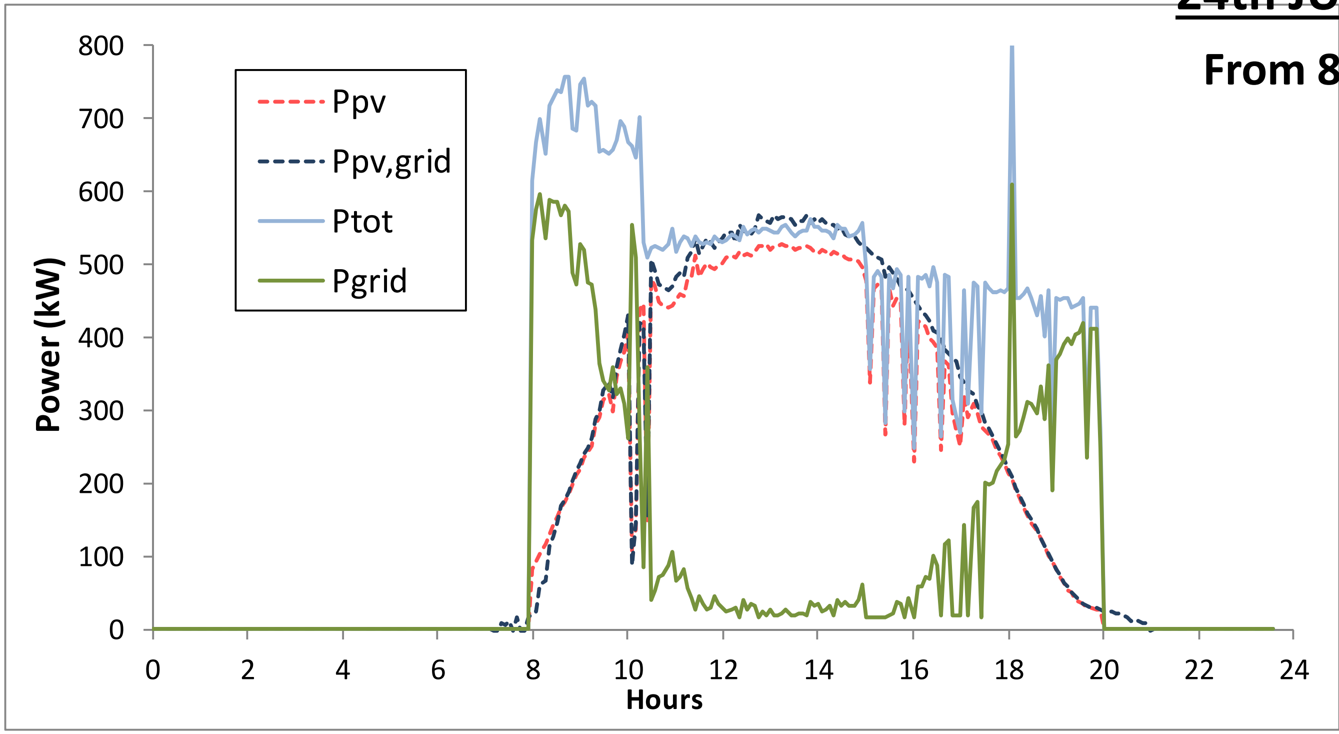
UMH. Pedro Vicente Quiles
pedro.vicente@umh.es

2. EXPERIMENTAL ANALYSIS

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

24th JULY 2012

From 8 to 20h



P_{PV} → Electrical power from photovoltaic panels

P_{GRID} → Electrical power from the electrical grid

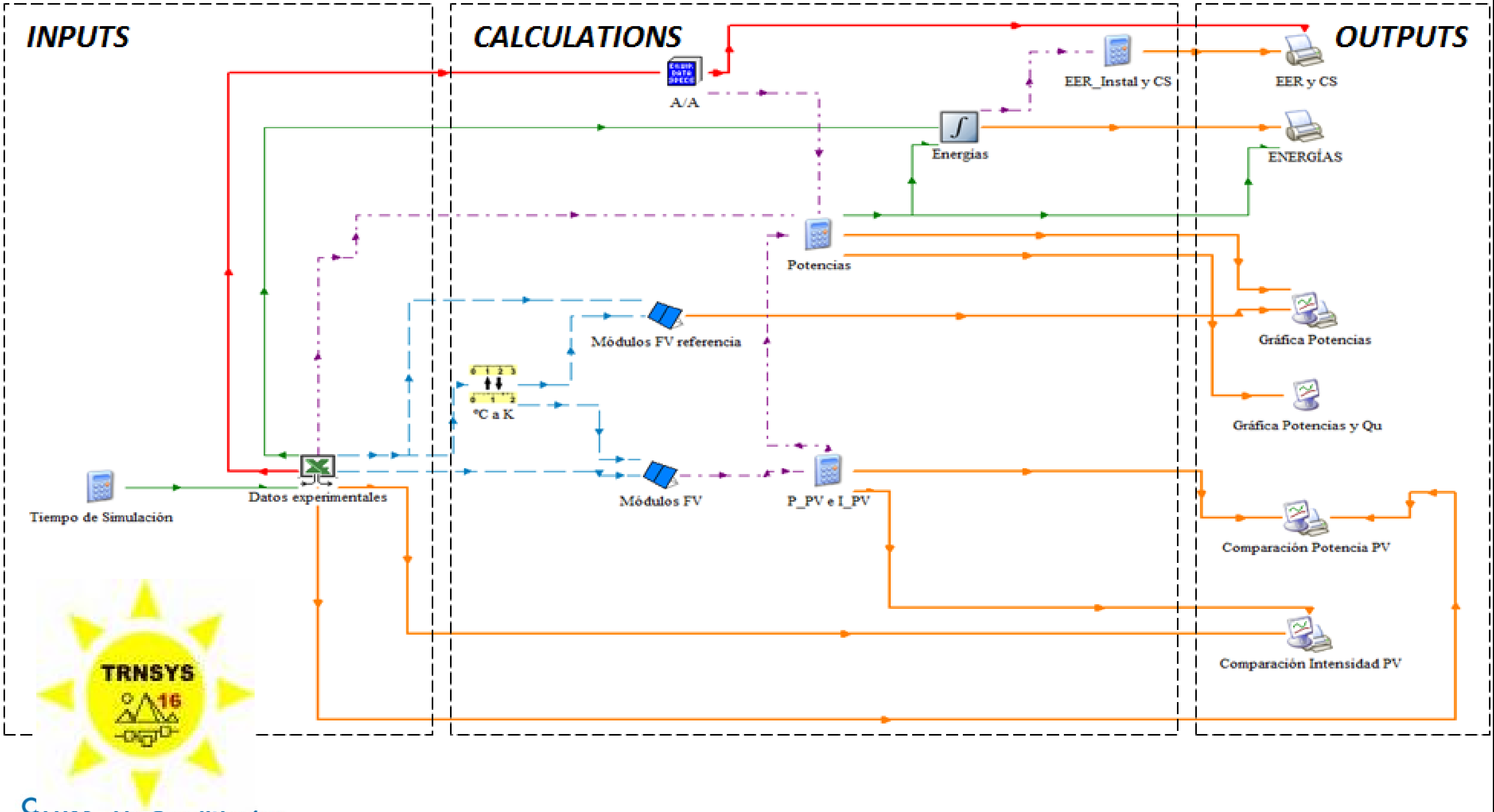
P_{TOT} → Total Electrical power

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

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

3. ANALYTICAL MODEL DEVELOPMENT AND VALIDATION

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



Air-Conditioning

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

Analytical results vs. Experimental results (July, 18th)

	E_{TOT}	E_{PV}	E_{GRID}	E_U	EER_{HP}	EER_{SYST}	SC
	kWh	*kWh*	*kWh*	*kWh*			%
EXPERIMENTAL RESULTS	11.58	3.87	7.71	36.09	3.12	4.68	33.44
TRNSYS RESULTS	11.41	3.95	7.46	36.01	3.16	4.83	34.58
ERROR (%)	1.48	1.94	3.20	0.21	1.17	3.10	3.41

Analytical results vs. Experimental results (July, 26th)

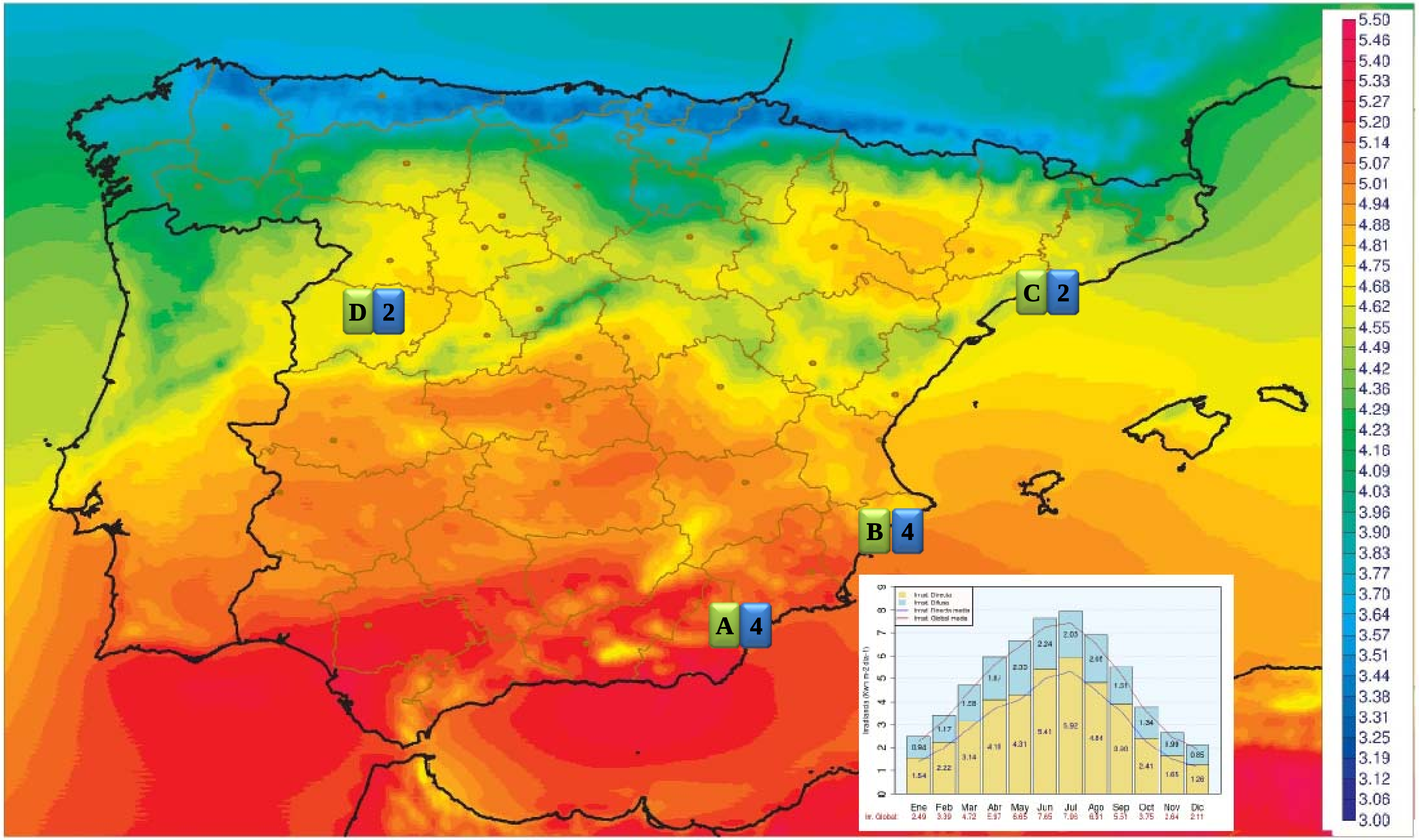
	E_{TOT}	E_{PV}	E_{GRID}	E_U	EER_{HP}	EER_{SYST}	SC
	kWh	*kWh*	*kWh*	*kWh*			%
EXPERIMENTAL RESULTS	6.99	3.22	3.77	27.40	3.92	7.27	46.05
TRNSYS RESULTS	7.01	3.09	3.92	27.47	3.92	7.01	44.06
ERROR (%)	0.22	4.14	3.94	0.24	0.02	3.59	4.32

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

4. ANALYTICAL RESULTS IN DIFFERENT CONDITIONS

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

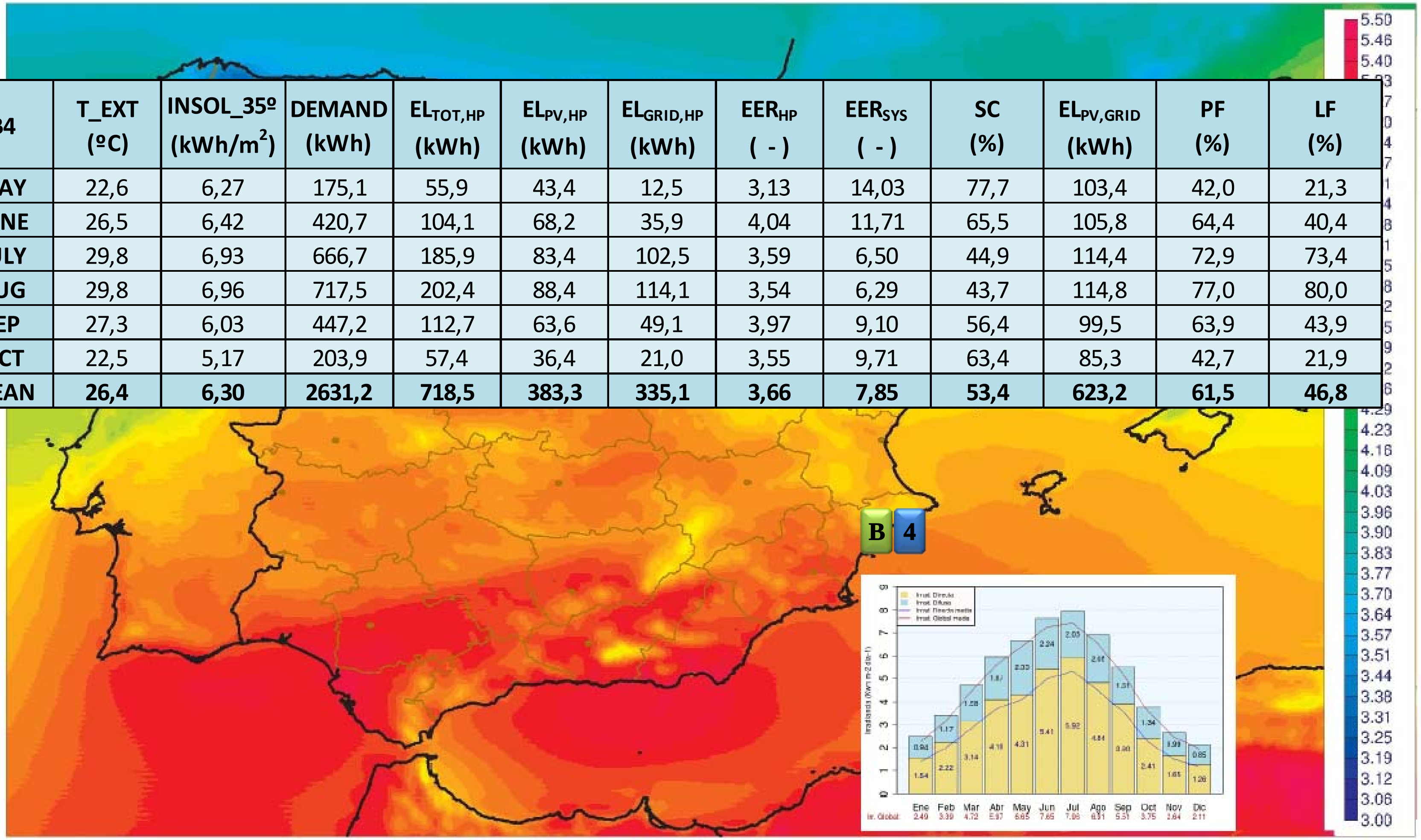
4. DIFFERENT CLIMATE AREAS



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

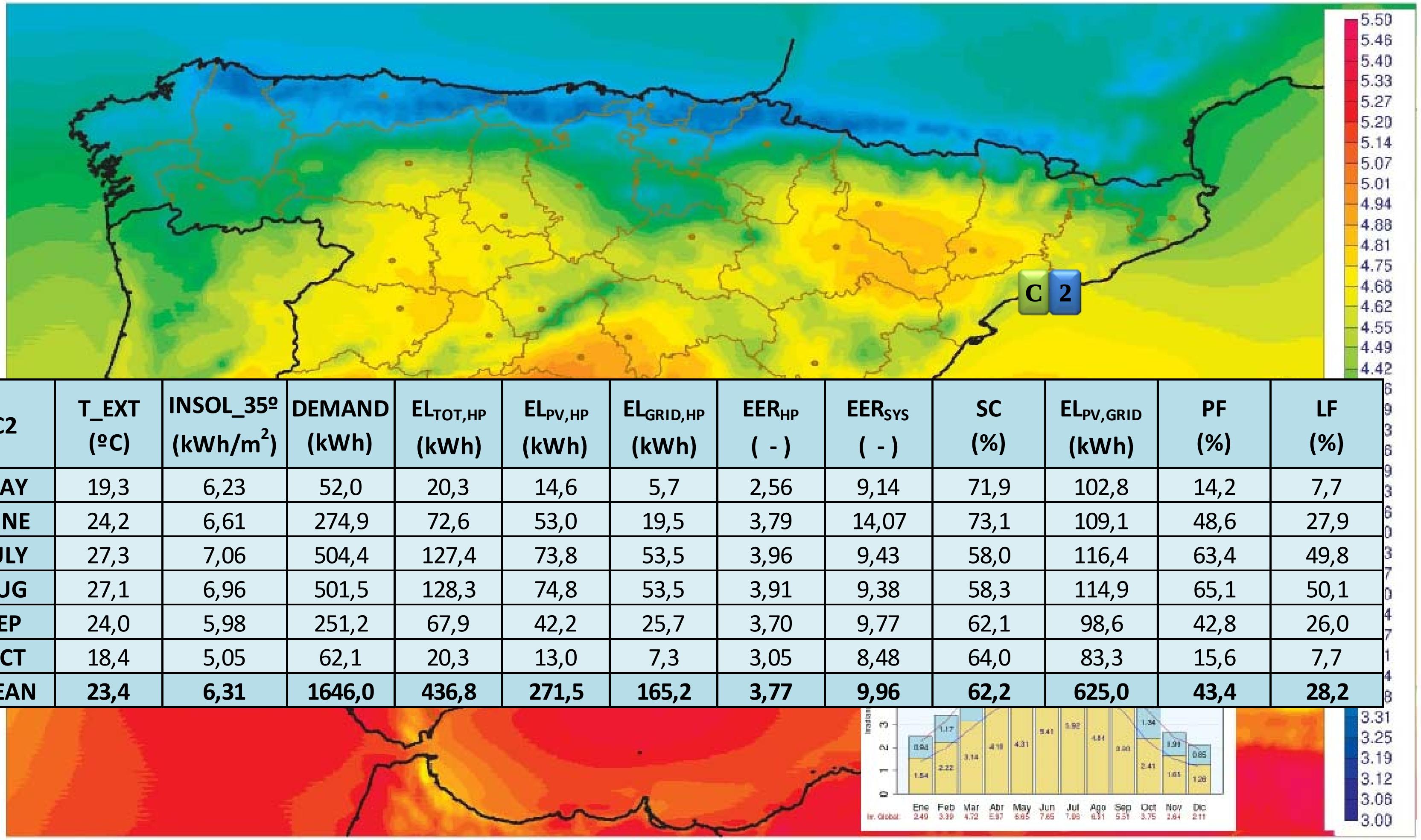
4. DIFFERENT CLIMATE AREAS

B4	T_EXT (ºC)	INSOL_35º (kWh/m^2)	DEMAND (kWh)	$EL_{TOT,HP}$ (kWh)	$EL_{PV,HP}$ (kWh)	$EL_{GRID,HP}$ (kWh)	EER_{HP} (-)	EER_{SYS} (-)	SC (%)	$EL_{PV,GRID}$ (kWh)	PF (%)	LF (%)
MAY	22,6	6,27	175,1	55,9	43,4	12,5	3,13	14,03	77,7	103,4	42,0	21,3
JUNE	26,5	6,42	420,7	104,1	68,2	35,9	4,04	11,71	65,5	105,8	64,4	40,4
JULY	29,8	6,93	666,7	185,9	83,4	102,5	3,59	6,50	44,9	114,4	72,9	73,4
AUG	29,8	6,96	717,5	202,4	88,4	114,1	3,54	6,29	43,7	114,8	77,0	80,0
SEP	27,3	6,03	447,2	112,7	63,6	49,1	3,97	9,10	56,4	99,5	63,9	43,9
OCT	22,5	5,17	203,9	57,4	36,4	21,0	3,55	9,71	63,4	85,3	42,7	21,9
MEAN	**26,4**	**6,30**	**2631,2**	**718,5**	**383,3**	**335,1**	**3,66**	**7,85**	**53,4**	**623,2**	**61,5**	**46,8**



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

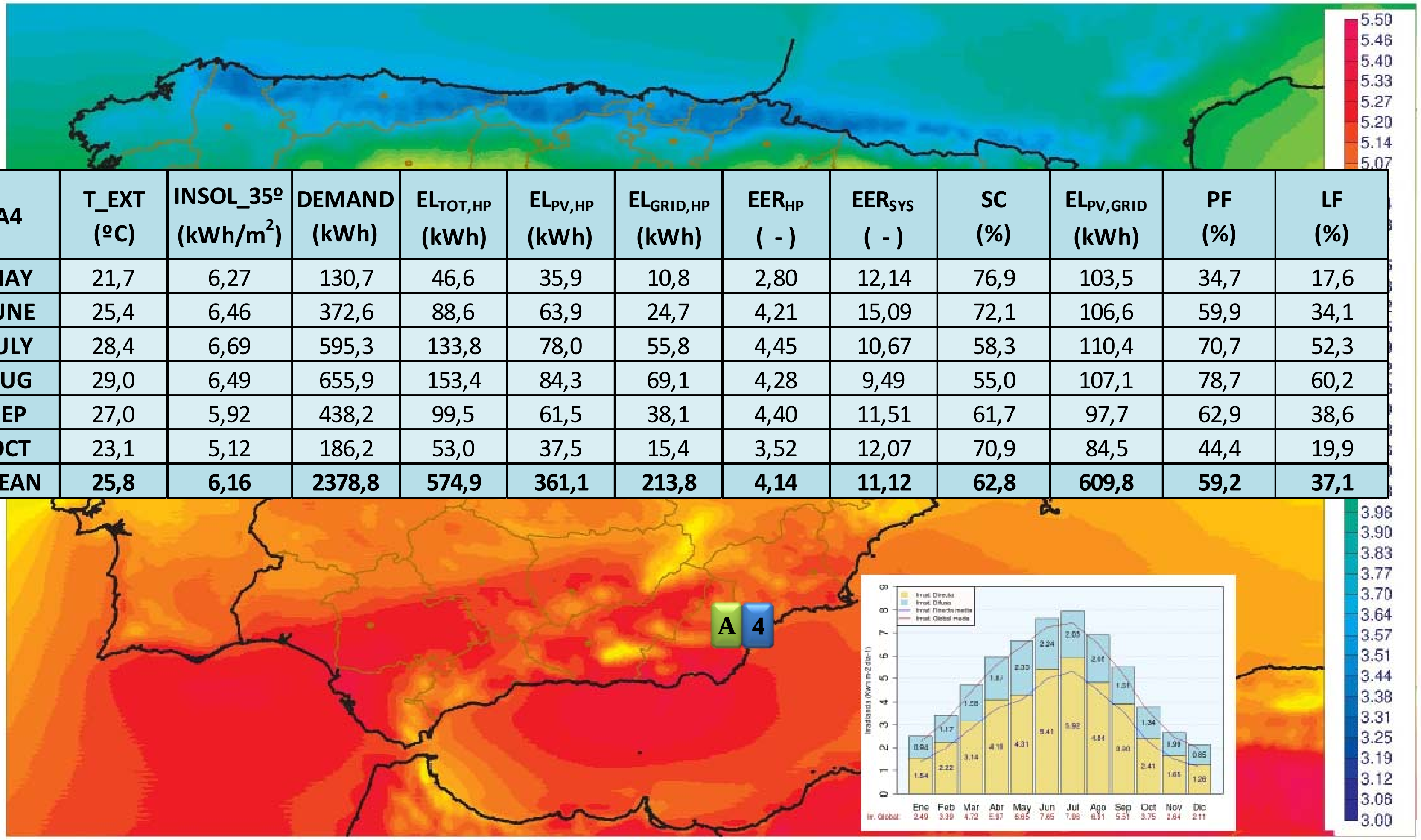
4. DIFFERENT CLIMATE AREAS



C2	T_EXT (ºC)	INSOL_35º (kWh/m^2)	DEMAND (kWh)	$EL_{TOT,HP}$ (kWh)	$EL_{PV,HP}$ (kWh)	$EL_{GRID,HP}$ (kWh)	EER_{HP} (-)	EER_{SYS} (-)	SC (%)	$EL_{PV,GRID}$ (kWh)	PF (%)	LF (%)
MAY	19,3	6,23	52,0	20,3	14,6	5,7	2,56	9,14	71,9	102,8	14,2	7,7
JUNE	24,2	6,61	274,9	72,6	53,0	19,5	3,79	14,07	73,1	109,1	48,6	27,9
JULY	27,3	7,06	504,4	127,4	73,8	53,5	3,96	9,43	58,0	116,4	63,4	49,8
AUG	27,1	6,96	501,5	128,3	74,8	53,5	3,91	9,38	58,3	114,9	65,1	50,1
SEP	24,0	5,98	251,2	67,9	42,2	25,7	3,70	9,77	62,1	98,6	42,8	26,0
OCT	18,4	5,05	62,1	20,3	13,0	7,3	3,05	8,48	64,0	83,3	15,6	7,7
MEAN	**23,4**	**6,31**	**1646,0**	**436,8**	**271,5**	**165,2**	**3,77**	**9,96**	**62,2**	**625,0**	**43,4**	**28,2**

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

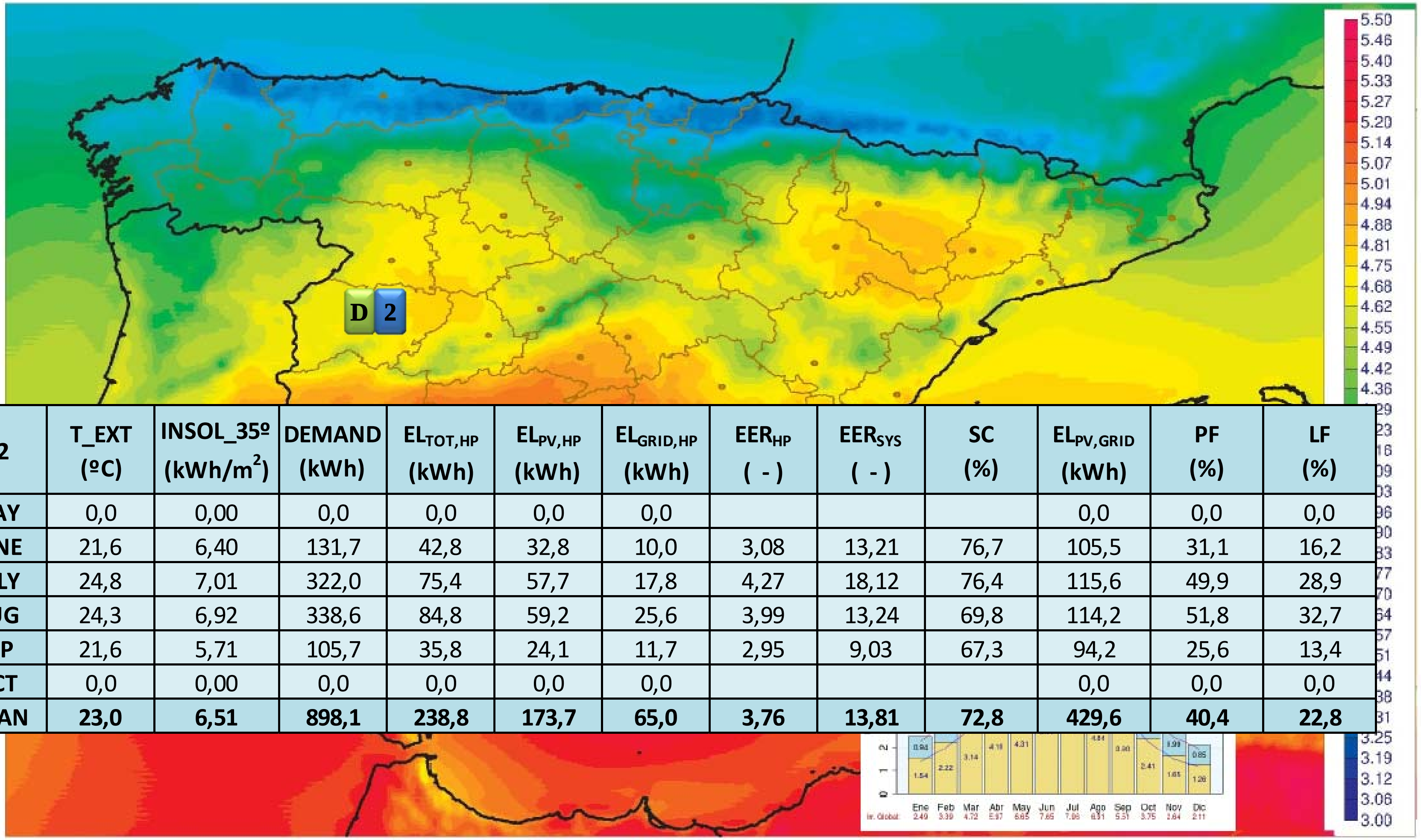
4. DIFFERENT CLIMATE AREAS



A4	T_EXT (ºC)	INSOL_35º (kWh/m^2)	DEMAND (kWh)	$EL_{TOT,HP}$ (kWh)	$EL_{PV,HP}$ (kWh)	$EL_{GRID,HP}$ (kWh)	EER_{HP} (-)	EER_{SYS} (-)	SC (%)	$EL_{PV,GRID}$ (kWh)	PF (%)	LF (%)
MAY	21,7	6,27	130,7	46,6	35,9	10,8	2,80	12,14	76,9	103,5	34,7	17,6
JUNE	25,4	6,46	372,6	88,6	63,9	24,7	4,21	15,09	72,1	106,6	59,9	34,1
JULY	28,4	6,69	595,3	133,8	78,0	55,8	4,45	10,67	58,3	110,4	70,7	52,3
AUG	29,0	6,49	655,9	153,4	84,3	69,1	4,28	9,49	55,0	107,1	78,7	60,2
SEP	27,0	5,92	438,2	99,5	61,5	38,1	4,40	11,51	61,7	97,7	62,9	38,6
OCT	23,1	5,12	186,2	53,0	37,5	15,4	3,52	12,07	70,9	84,5	44,4	19,9
MEAN	**25,8**	**6,16**	**2378,8**	**574,9**	**361,1**	**213,8**	**4,14**	**11,12**	**62,8**	**609,8**	**59,2**	**37,1**

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

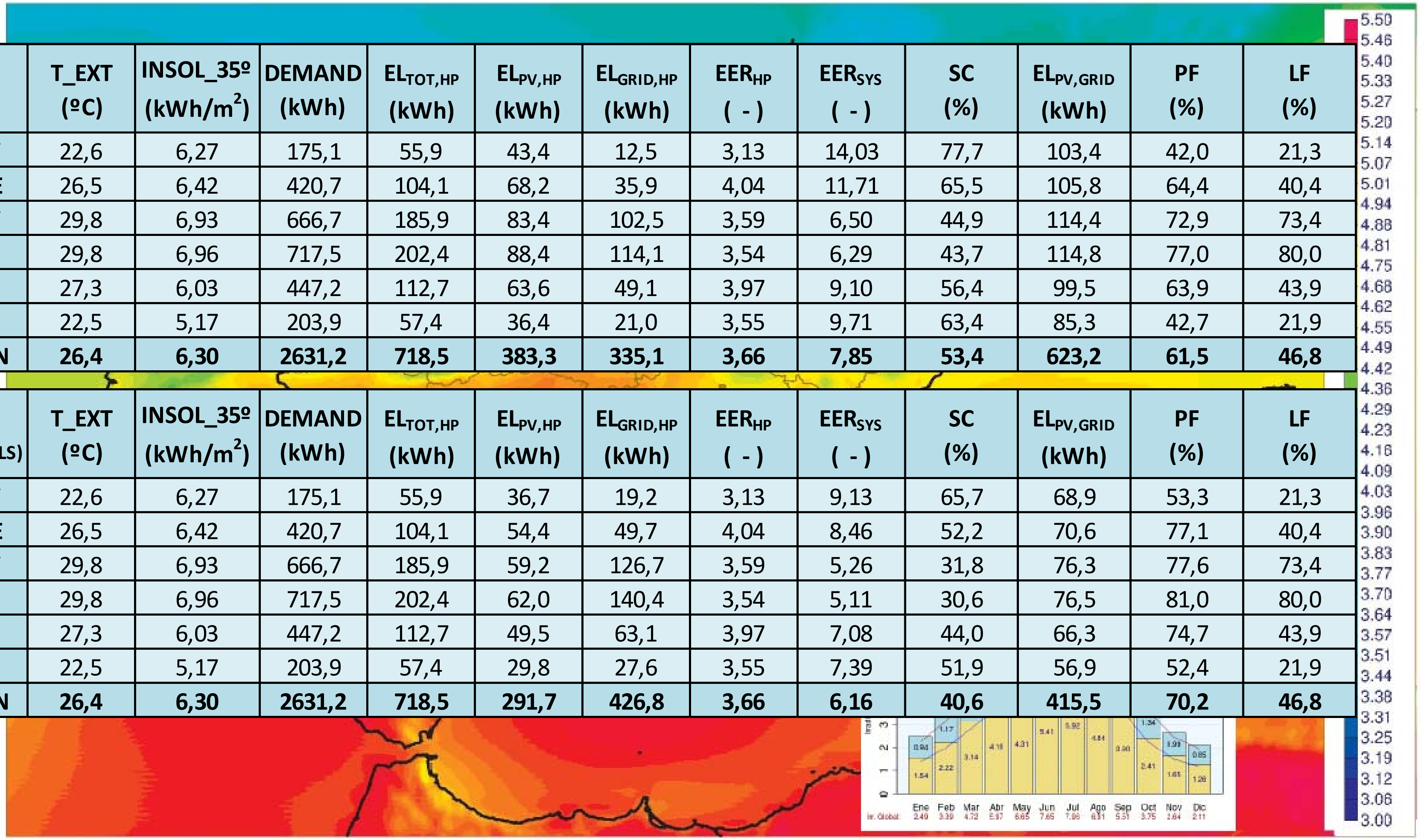
4. DIFFERENT CLIMATE AREAS



D2	T_EXT (ºC)	INSOL_35º (kWh/m^2)	DEMAND (kWh)	$EL_{TOT,HP}$ (kWh)	$EL_{PV,HP}$ (kWh)	$EL_{GRID,HP}$ (kWh)	EER_{HP} (-)	EER_{SYS} (-)	SC (%)	$EL_{PV,GRID}$ (kWh)	PF (%)	LF (%)
MAY	0,0	0,00	0,0	0,0	0,0	0,0				0,0	0,0	0,0
JUNE	21,6	6,40	131,7	42,8	32,8	10,0	3,08	13,21	76,7	105,5	31,1	16,2
JULY	24,8	7,01	322,0	75,4	57,7	17,8	4,27	18,12	76,4	115,6	49,9	28,9
AUG	24,3	6,92	338,6	84,8	59,2	25,6	3,99	13,24	69,8	114,2	51,8	32,7
SEP	21,6	5,71	105,7	35,8	24,1	11,7	2,95	9,03	67,3	94,2	25,6	13,4
OCT	0,0	0,00	0,0	0,0	0,0	0,0				0,0	0,0	0,0
MEAN	**23,0**	**6,51**	**898,1**	**238,8**	**173,7**	**65,0**	**3,76**	**13,81**	**72,8**	**429,6**	**40,4**	**22,8**

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

4. DIFERENT PV PANELS



B4	T_EXT (ºC)	INSOL_35º (kWh/m^2)	DEMAND (kWh)	$EL_{TOT,HP}$ (kWh)	$EL_{PV,HP}$ (kWh)	$EL_{GRID,HP}$ (kWh)	EER_{HP} (-)	EER_{SYS} (-)	SC (%)	$EL_{PV,GRID}$ (kWh)	PF (%)	LF (%)
MAY	22,6	6,27	175,1	55,9	43,4	12,5	3,13	14,03	77,7	103,4	42,0	21,3
JUNE	26,5	6,42	420,7	104,1	68,2	35,9	4,04	11,71	65,5	105,8	64,4	40,4
JULY	29,8	6,93	666,7	185,9	83,4	102,5	3,59	6,50	44,9	114,4	72,9	73,4
AUG	29,8	6,96	717,5	202,4	88,4	114,1	3,54	6,29	43,7	114,8	77,0	80,0
SEP	27,3	6,03	447,2	112,7	63,6	49,1	3,97	9,10	56,4	99,5	63,9	43,9
OCT	22,5	5,17	203,9	57,4	36,4	21,0	3,55	9,71	63,4	85,3	42,7	21,9
MEAN	**26,4**	**6,30**	**2631,2**	**718,5**	**383,3**	**335,1**	**3,66**	**7,85**	**53,4**	**623,2**	**61,5**	**46,8**

B4 (2 PANELS)	T_EXT (ºC)	INSOL_35º (kWh/m^2)	DEMAND (kWh)	$EL_{TOT,HP}$ (kWh)	$EL_{PV,HP}$ (kWh)	$EL_{GRID,HP}$ (kWh)	EER_{HP} (-)	EER_{SYS} (-)	SC (%)	$EL_{PV,GRID}$ (kWh)	PF (%)	LF (%)
MAY	22,6	6,27	175,1	55,9	36,7	19,2	3,13	9,13	65,7	68,9	53,3	21,3
JUNE	26,5	6,42	420,7	104,1	54,4	49,7	4,04	8,46	52,2	70,6	77,1	40,4
JULY	29,8	6,93	666,7	185,9	59,2	126,7	3,59	5,26	31,8	76,3	77,6	73,4
AUG	29,8	6,96	717,5	202,4	62,0	140,4	3,54	5,11	30,6	76,5	81,0	80,0
SEP	27,3	6,03	447,2	112,7	49,5	63,1	3,97	7,08	44,0	66,3	74,7	43,9
OCT	22,5	5,17	203,9	57,4	29,8	27,6	3,55	7,39	51,9	56,9	52,4	21,9
MEAN	**26,4**	**6,30**	**2631,2**	**718,5**	**291,7**	**426,8**	**3,66**	**6,16**	**40,6**	**415,5**	**70,2**	**46,8**

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

CONCLUSIONS

- A heat pump driven simultaneously from the grid and from PV panels has been modelled with Trnsys and the model has been validated using experimental results.

- The modelling has been used in order to know the system behavior in other climate areas and with other building thermal load curves in cooling mode.

- The average energy efficiency of the system ($\overline{EER_{SYST}}$) can vary from 78 to 14 depending on the climate area.

- In climate areas where the load factor is high the solar contribution is the lowest. On the other hand, if the load factor is very low, the solar contribution can reach higher values, although in this case the production factor of the PV panels decreases.

Analytical simulation of an inverter heat pump driven simultaneously by the grid and PV panels

Pedro G. Vicente Quiles

Universidad Miguel Hernández de Elche

pedro.vicente@umh.es

http://dime.umh.e

Francisco J. Aguilar Valero

Universidad Miguel Hernández de Elche

Erika Puigcerver Blanco

Universidad Miguel Hernández de Elche

Simón Aledo Vives

simon@prointer.es

Prointer, S.L.

UNIVERSITAS Miguel Hernández

Prointer CLIMATIZACION Y ENERGIAS RENOVABLES