ENERGY PERFORMANCE OF BUILDINGS BEFORE RENOVATION.

D.4.3

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1 EXECUTIVE SUMMARY

The following document includes the information, procedure and explanations to characterize the energy consumption of the different Pilot Buildings considered in the Dreeam Project.
The report are divided in three main chapters corresponding to the pilot building of each Housing Company Partner: Ater Treviso, Places for People, Landskronahem
The information of each Pilot building it is described with the same structure in three main sections:

- Summary of information available and information collected.

For each building it is provided a table that indicate the typology of the data and the agent or procedure to collect the historic Data. The minimum information requested is one year but in some cases there are more than one year and in other there is no data at all. Regarding with the information initially available and the different agents that can provide the information it is important to remark that in general terms it is very difficult to collect information through utilities and most of the tenants. Finally in order to collect information from tenants it has been needed to select a group of collaborative tenants that are willing to participate in the interviews (social evaluation) and providing their energy bills.

- Energy Consumption Description.

This section describes the use of the energy from the different active systems. There is a description of the equipment of the different systems that are the main energy consumers. The main systems are Heating, Domestic Hot Water, Electric consumption in communal areas and Tenants electric consumption. The objective of this section is to determine the use of energy of each system. Every pilot has different systems: District Heating, Central Boilers, electric heating, individual boilers… but in all of them SinCeO2 have analysed the data in order to get a detailed and accurate breakdown for each system.

- Energy Baseline.

In all the pilot Buildings, it is being calculated the consumption Energy Baseline for the main systems: Heating, Domestic hot Water, Electric consumption in communal areas and Tenants electric consumption. The objective of the energy baseline is to calculate the mathematical function that includes the variables that affect the consumption. This energy baseline is a normalised consumption that allows the comparison of the energy consumption in different periods (before and after renovations). The variables that mainly affect the consumption is weather conditions and the variable most representative is Heating Degree Days. For Each Baseline we have considered different HDD bases due to for each service, tenant or room it is very different the set point that starts the operation of the system.

Regarding with the tenant's electric consumption different from heating and domestic hot water, additional analysis it is performed in order to identify if they are using auxiliary heating systems.

The highlights and the working process of consumptions energy baseline in each pilot is summarized in the following points:

Ater Treviso 1^{St} Pilot Building

- In this pilot Building there is an accurate baseline for heating and domestic Hot Water.
- The electric consumption of Communal Heating system is possible to relate it to the weather variability during winter time but not for the rest of the year.
- The tenant's electric consumption it has not been completed because the plan for monitoring equipment was stopped when Ater had to change the pilot building.

Ater Treviso 2nd Pilot Building

- In this pilot, there is few initial available data from some tenants. This report includes an initial description of the energy consumption of tenants. The production of heating and DHW is performed by an individual Boiler, therefore the information from tenants meters are essential. The necessary additional data will be collected in the following months by the installation of monitoring equipment and through gas meters readings. Through the analysis of those additional data will be possible to calculate the energy baseline for some selected tenants.

PfP Pilot Building.

- In this Pilot Building there were not initial available information about energy consumption of the Dwellings. Thanks to the monitoring equipment it has been possible to collect detailed information of the energy consumption for the different active systems. The period evaluated in this report is from mid-September to mid-February, being necessary to continuing with the analysis more months after this winter period. In this initial evaluation for winter time it has been calculated baselines for the different systems in nine selected dwellings.

LandsKronahem Pilot Building.

- In this pilot, there is complete information to evaluate the whole consumption of the four buildings included in the project. This buildings are supplied by district heating and its heating substation is equipped with a BMS that have registered the consumption Data during last three years. In addition the electric consumption of the communal areas and the aggregated consumption of the tenants have been collected through the collaboration of Landskrona-energy and Landskronahem, being the only pilot where the utility has been collaborative.
- The energy baseline for the whole buildings and the different systems have been calculated.

2 ENERGY PERFORMANCE ATER 1st BUILDING BEFORE RENOVATION.

2.1 INITIAL INFORMATION.

The following Table summarize the information collected to perform the calculations of the baseline.

Table 1: ATER Treviso pilot initial information requested

ATER TREVISO PILOT INITIAL INFORMATION REQUESTED.				
Information	**Initial Availability**	**Agent involved**	**Other Agent requested**	**information Provided**
ENERGY CONSUMPTIONS				
Electric consumptions communal Areas	NO	Ater/building manager	Eon (utility) Without no results	3 years
Electric consumptions tenants	NO	Ater/	Aggregate consumptions requested to Eon (utility) Without no results.	8 Tenants 1 year
Gas consumptions Central Heating.	NO	Ater/ Syram (Esco)		3 Years
Gas consumptions Central Heating.	NO	Ater/ Syram (Esco)		3 Years
Tenants heating bills (from electronic allocators)	NO	Ater/Syram/tenants		1 Year (7 tenants)
BUILDING DESCRIPTION. (drawings technical description)				
Arquitectonical	YES			Basic description.
Electric installation	NO			Information collected in field visit.
HAVC installation.	YES			Basic description
SOCIOLOGICAL CHARACTERISITC				
Number of tenants per dwelling	NO	Ater/Savills		Ater/
Family status.	NO	Ater/Savills		Savills Interviews

2.2 ENERGY CONSUMPTION DESCRIPTION.

- HEATING SYSTEM.

This section describes the evolution of the energy consumption during the year. One first analysis is developed looking for the variables that affects the energy evolution and explains the variations.

The data collected is from the utility gas meter in two variables: gas m3 and Normalised gas m3. the value of Gross Calorific value has been estimated , average value= 11,5

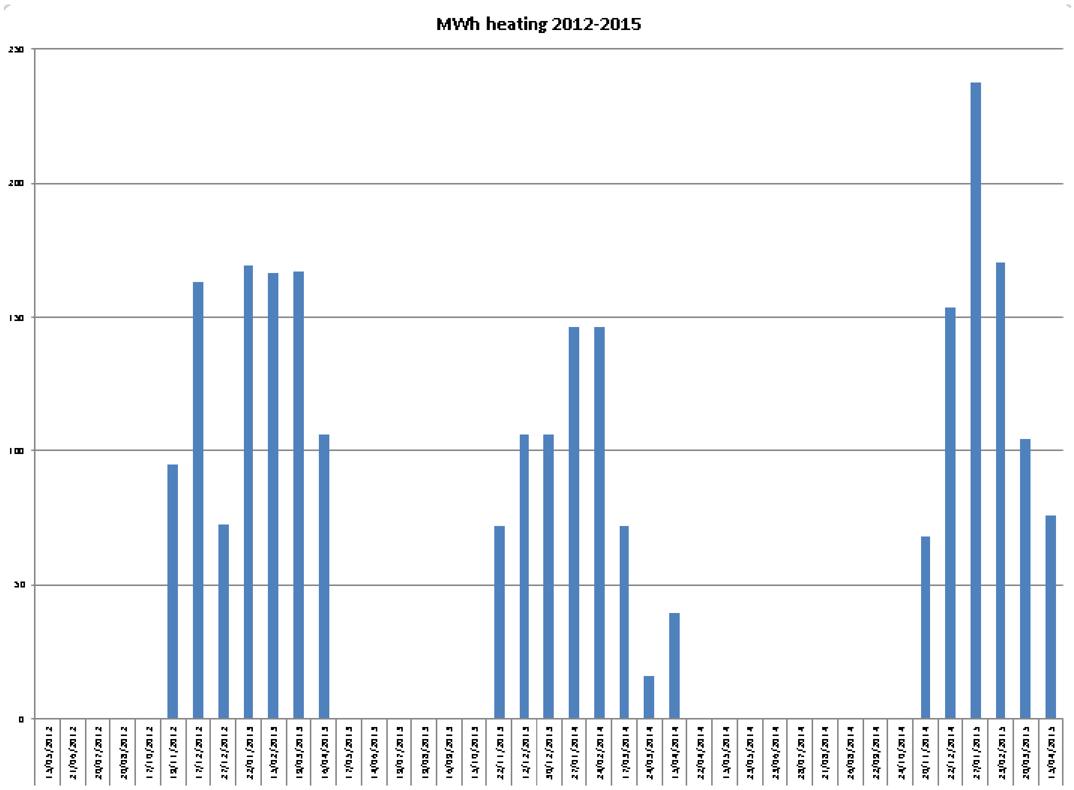


Figure 1: MWh heating 2012-2015

The period of use for central heating system is fixed from mid-October to mid-April. The central heating system produces the heating needed for whole building.

The variations for the different months will be compared with climatologic data, the most representative variable is Heating Degree Days. We have developed an analysis on different bases from (10C -22C) in order to find out the one that better fits with the consumption pattern.

- DOMESTIC HOT WATER.

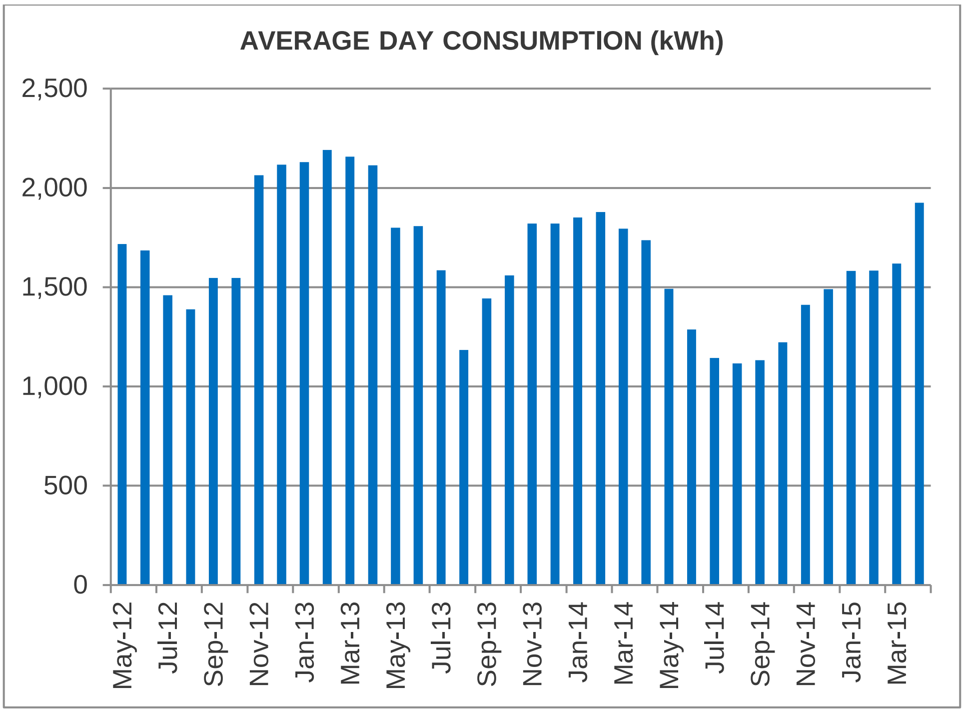


Figure 2: Average day consumption (whole Building)

The year evolution shows that there is relation between the Energy produced for domestic hot water and the ambient temperature, during winter is needed more energy because of the influence of outside temperature on the supplied water temperature.

- COMMUNAL ELECTRIC CONSUMPTION

The following data has been collected from the utility bills for the years 2012-2015 (kWh). There is an utility meter for each block and one more for the electric consumption in the heating room. The electric consumption in each block is demanded by the elevator and the lighting system.

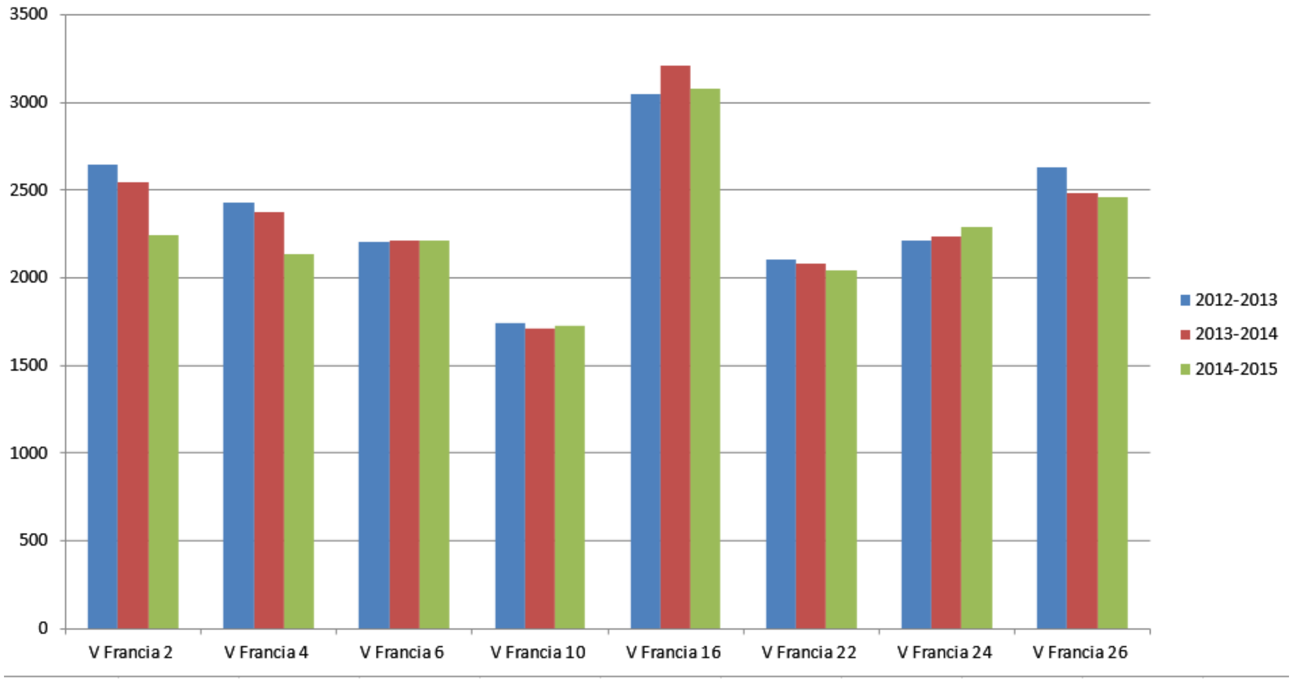


Figure 3: Communal electric consumption

Considering that all the blocks have a similar distribution, the above table show an unusual high consumption in block 16, due to an inefficiency in the elevator or in the lighting system. The average electric consumption considered per Block is 2.342,6 kWH/year

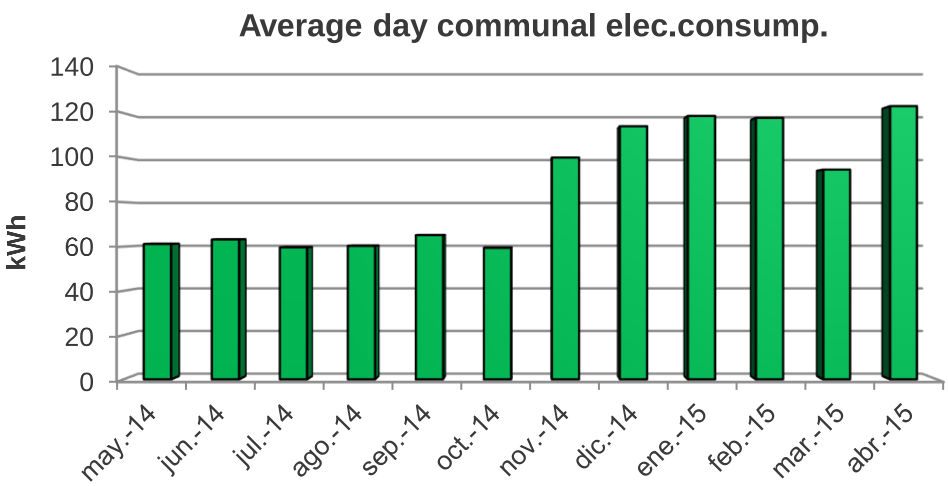


Figure 4: Average day electric consumption communal services

- TENANTS ELECTRIC CONSUMPTION,

The electric bills collected from tenants is showed in the below table. There are the information from 11 tenants, but only 4 of them can provide the bills for a complete year.

Table 2: Flats electric bills

FLATS ELECTRIC BILLS (kWh)											
BLOCK	FLOOR	COOLING	TENANTS	oct- nov 15	Ag-Sept 15	Jun-Jul 15	Apr-May 15	Feb-Mar 15	Dic 14 -Ene 15	oct- nov 14	AVER 2015
T4	P6	Y	4		228	245	211	253	484		1701
T4	P5	N	4	165	80	258					1548
T4	P4	Y	3	240		686	381,4	337	371		2415,4
T4	P3	Y	4	515	874	668	585	544	547		3733
T4	P3	N	1							255	1530
T4	P2	Y	2	151	263	206	181	213	293	241	1307
T4	P1	Y	1	118	127	128	181	211			1025
T2	P4 R	Y	4	303	530	406	381	393	389	373	2402
T2	P2 R	N	2	213	570	402	258	286	346	343	2412
T2	P2L	N	6			190					1596
T2	P6R	N	2	158							1327,2

There are few data to obtain conclusions, for this reason is planned to complete this data with the data provided by the monitoring equipment, 12 dwellings.

However, with this data it is possible to estimate a gross average consumption for 2015 (see last column of the table) and it shows to two initial groups with similarities:

- Flat with few tenants <2 and without no cooling system with a yearly consumption: 1000-1600kwh/year.
- Flat with tenants >2 and cooling system with a yearly consumption >1600 Kwh/year

With the data of a standard flat with cooling system, it is possible to calculate an initial estimation for this system.

Table 3: Electric consumption 1 flat floor 3th B24 T2 (Bills)

	ELECTRIC CONSUMPTION 1 FLAT FLOOR 3th B24 T2 (BILLS)					
	2014	2015				
(kWh)	**16/11-16/01**	**16/01-16/03**	**16/03-16/05**	**16/05/16-07**	**16/07-16/09**	**16/09-16/11**
P1	150	145	173	171	223	121
P2	397	399	412	497	651	284
TOTAL	**547**	**544**	**585**	**668**	**874**	**515**
AVERAGE (NO SUMMER)	**548**	**548**	**548**	**548**	**548**	**548**
COOLING CONSUMP.				**120**	**326**	

Table 4: Flats with cooling system per block

Flats with cooling system per Block					
	B24-B26	B2-B4	B6-B10	B16-B22	TOTAL
Flats with AC	3	4	2	1	10
Total.	24	30	24	24	102
%	12,50%	13,33%	8,33%	4,17%	9,80%

- BUILDING ENERGY CONSUMPTION.

Adding the year consumption of each system, the total year consumption is calculated as well as the percentage of the each facility.

Table 5: Building energy consumption

	Total	**Block 26 & 24**		
	kWh/year	kWh/year	kWh/m2 year	%
Space heating	886.753	206.317	97,4	48%
Domestic hot water	574.332	133.627	63,1	31%
Electricty Heating	8.453	1.967	0,9	0%
Electricity DHW	22.431	5.219	2,5	1%
Electricty common space	18.741	4.685	2,2	1%
Electricity Households	310.607	72.267	34,1	17%
Electricity Cooling	18.434	4.289	2,0	1%

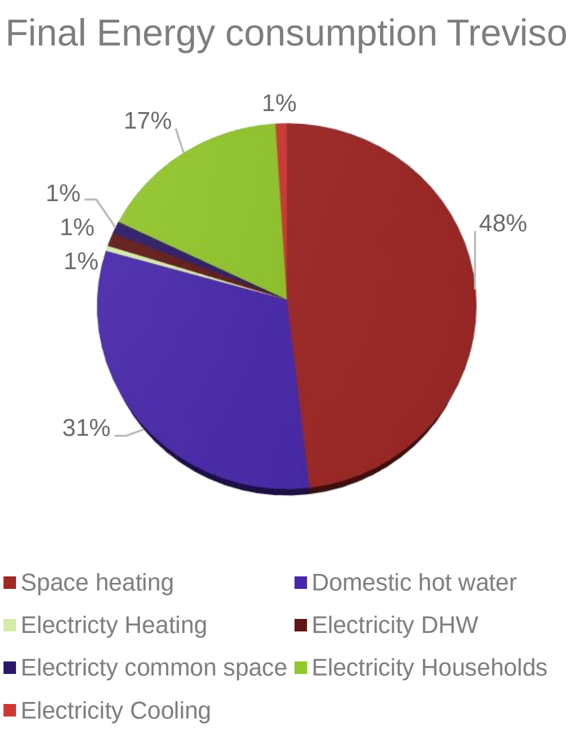


Figure 5: Final energy consumption

2.2.1 BASELINE CALCULATION

This section includes the different baselines calculations. The analysis and procedures followed in order to obtain these baselines will be also displayed. The objective is to get the mathematical model that define the energy consumption pattern considering the variables that affects the consumption. This model will permit to determine the difference between both consumptions: before and after renovations.

In general terms, the baselines have been calculated comparing consumption and climatologic data, concretely the Heating Degree Days, which is the most representative variable for the weather variations.

- HEATING SYSTEM BASELINE CALCULATION

The heating system at these buildings is supplied with natural gas. Through the collected information and the available data, it has been possible to develop a baseline calculation for the heating system consumption.

The heating System, "Centrale Termica" currently is operating by an Esco Company. In this heating system, there are two Gas Boilers systems that produce heated water for heating and domestic hot water network. The energy baseline for each system have been calculated separately.

The heating system meter readings are registered in m^3 of natural gas. Therefore, in order to normalize this measure, it has been converted into Standard cubic meters (Sm^3). This conversion permits to easily calculate the consumption of the heating system in kWh, relating the consumption in Sm3 with the Gross Calorific Value of natural gas.

Additionally, with the climate data collected and specifically with daily average temperature, it has been possible to calculate the Heating Degree Days, with different bases, from 12 ºC to 22ºC.

This climate information has been researched at Weather Underground website, concretely extracting the available data from the meteorological station of LIPH (no. 16099), located at Treviso/Sant'Angelo Mil (45.65º N, 12.19º E).

Thus, with the total HDD per month and its associated monthly consumption by the heating system during 2013 and 2014, it has been possible to develop different plots relating the climatologic variable and the natural gas consumption in Sm^3. These plots are all shown down below in the next page:

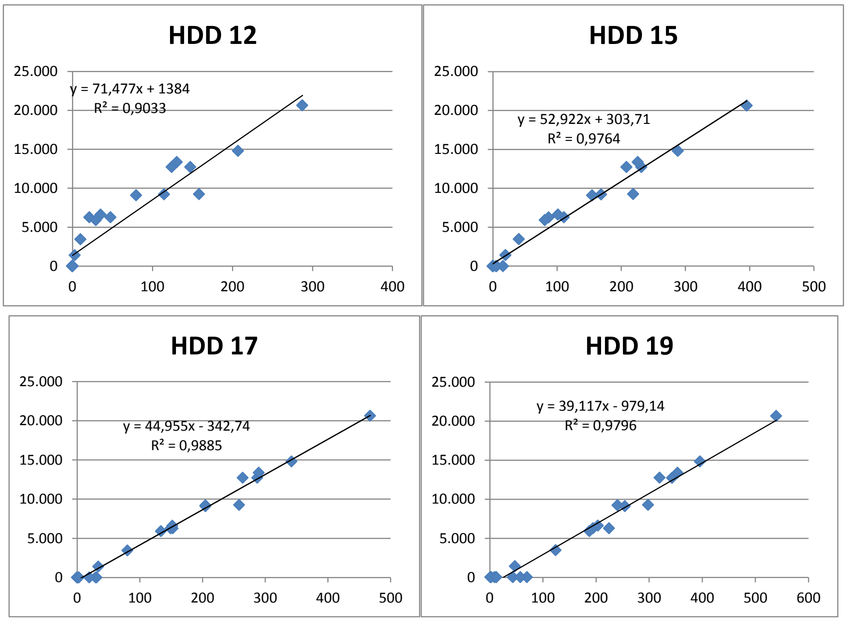


Figure 6: Natural gas consumption per month against different heating degree days

As it can be noted, the charts include both the linear function that describes the evolution of the heating system consumption according to the climate fluctuations and the value for R-Square. Thus, the nearest of R-Square to 1, the more accurate the model it is. Then, observing again the previous plots, it can be said that most of all the models presented are quite accurate, with R-Square values really close to 1.

However, it will be assumed that the one related with HDD 17 is the model that better describes the evolution of the heating system consumption according to weather variability as is the one with higher R-Square value.

So, developing now a new regression model for the data consumption of 2012/13 in order to extend it to year 2015, it has been obtained the following chart, which includes the linear function and R-Square value for this new model:

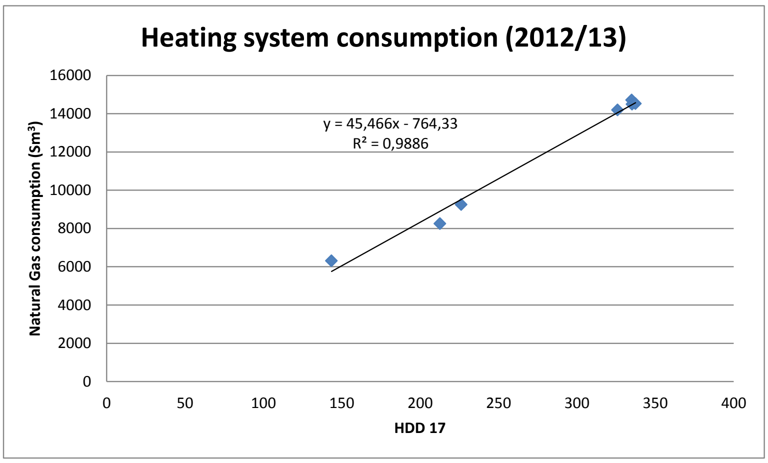


Figure 7: Natural gas consumption by the heating system for 2012/13

Focusing now at this figure, it is possible to read the expression that may be used in order to estimate the natural gas consumption in Sm^3 for the near future.

$$y = 45,47x - 764,33$$

Where the dependent variable '*y*' represents the natural gas consumption by the heating system in Sm^3, and the independent one, '*x*', the heating degree days per month.

Thus, this expression has been applied to the latest available climatologic data in order to estimate the natural gas consumption and compare it with the real one, as it is shown at the next table.

Table 6: Real and expected district heating consumption for 2015

	Base Line (Sm^3)	Real Consumpt. (Sm^3)	DIF	% Err
oct-13	6.014,65	6.260,10	245,45	3,92
nov-13	10.984,08	9.251,00	-1.733,08	18,73
dic-13	8.542,56	9.214,70	672,14	7,29
ene-14	12.302,60	12.717,10	414,50	3,26
feb-14	11.243,24	12.725,90	1.482,66	11,65
mar-14	6.937,11	7.672,50	735,39	9,58
abr-14	2.882,04	3.448,50	566,46	16,43
-	-	-	-	-
nov-14	5.314,47	5.903,70	589,23	9,98
dec-14	12.407,17	13.356,20	949,03	7,11
jan-15	20.491,03	20.638,20	147,18	0,71
feb-15	14.789,59	14.803,80	14,21	0,10
mar-15	8.542,56	9.084,90	542,34	5,97
abr-15	6.141,96	6.603,30	461,34	6,99
	126.593,06	131.679,90	5.086,84	3,86

In conclusion, it can be said that the baseline purposed at this section may be used to estimate the natural gas consumption by the heating system.

Therefore, the regression model developed at this section has been also applied for the latest available data. If the monthly consumption meters are represented in a plot against the estimated consumption with the established baseline, it can be seen that there are some few differences but in general terms and as it was expected, both lines presents the same tendency and quite similar values.

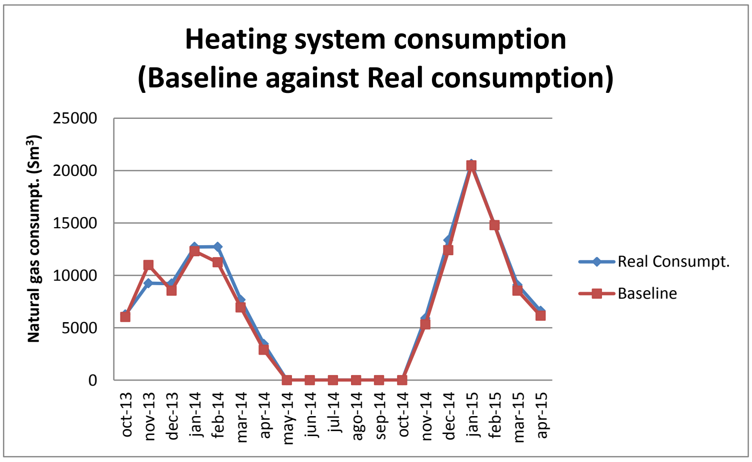


Figure 8: Heating system consumption during 2014 and 2016

On the other hand, there is also available information about the energy production by the heating system. So, in the same way as it has been done with the natural gas consumption, a regression model has been developed for the energy production. This variable has been also analyzed against the climatologic variable, obtaining, as it was expected, similar models as the ones obtained for the natural gas consumption.

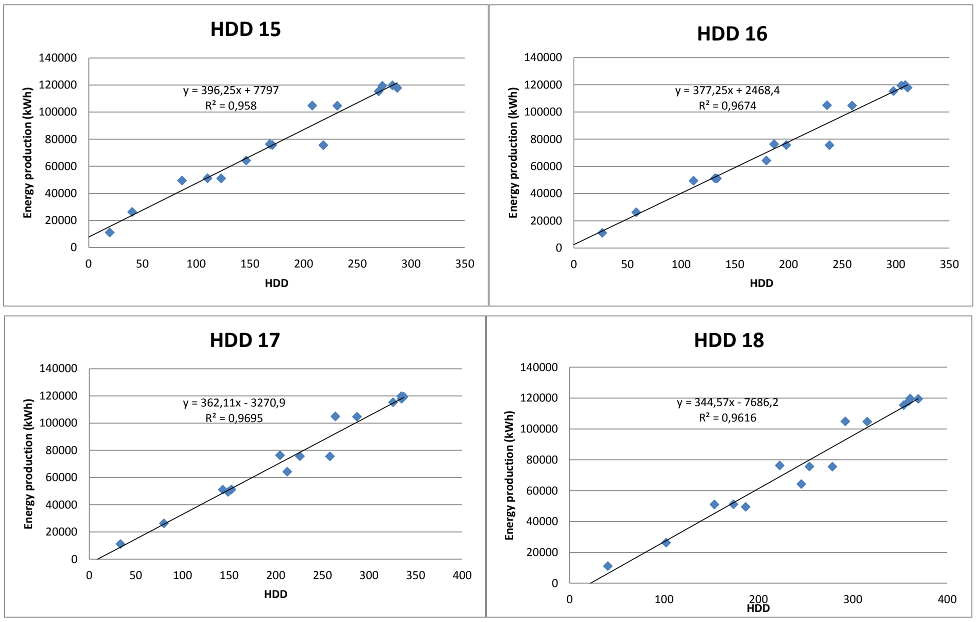


Figure 9: Energy production against heating degree days

These models have been developed with the available data for 2012/13, and as it is showed all of them present similar R-Square values near to 1, being all of them appropriate to describe the energy production related with the heating degree days. Thus, selecting the model HDD 17, and applying it to the latest available data, it has been possible to compare the real energy production with the one estimated thanks to the baseline purposed.

$$y = 362,11x - 3270,9$$

Where the variable 'y' represents /month consumption by the heating system in kWh, and the independent one, 'x', the heating degree days base17 per month.

Table 7: Real and expected energy production by the heating system.

	Base Line (kWh)	Real Consumpt. (kWh)	DIF	% Err
oct.-13	50.719,70	49.430,00	- 1.289,70	2,61
nov.-13	90.298,32	75.530,00	- 14.768,32	19,55
dec-13	70.853,02	76.320,00	5.466,98	7,16
jan-14	100.799,51	104.660,00	3.860,49	3,69
feb.-14	92.362,35	104.850,00	12.487,65	11,91
mar.-14	60.883,08	62.190,00	1.306,92	2,10
apr-14	25.770,32	26.210,00	439,68	1,68
-	-	-	-	-
nov.-14	45.143,21	47.150,00	2.006,79	4,26
dec-14	101.632,37	110.900,00	9.267,63	8,36
jan-15	166.015,53	168.140,00	2.124,48	1,26
feb.-15	120.606,93	121.260,00	653,07	0,54
mar-15	70.853,02	75.470,00	4.616,98	6,12
apr-15	51.733,61	53.790,00	2.056,39	3,82
	1.047.670,97	1.075.900,00	28.229,03	2,62

If the values of the previous table are represented in a plot, it is possible to observe the differences between both real consumption and expected one.

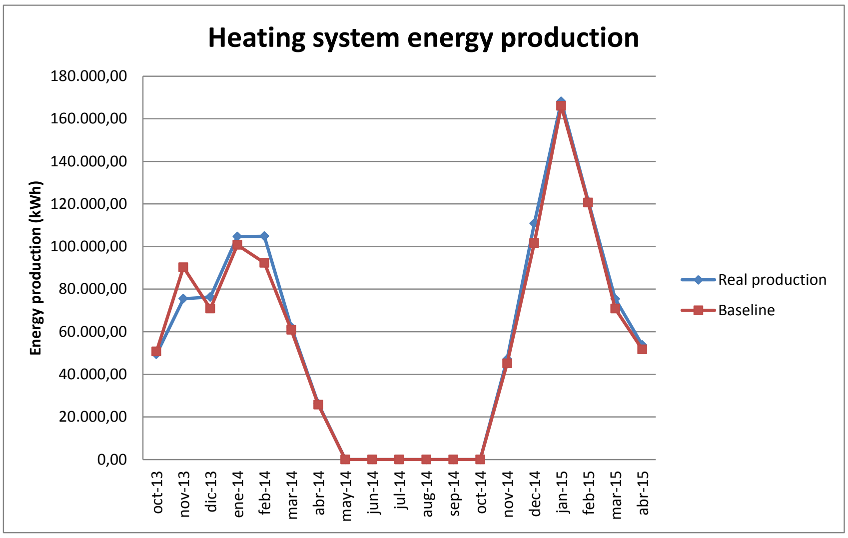
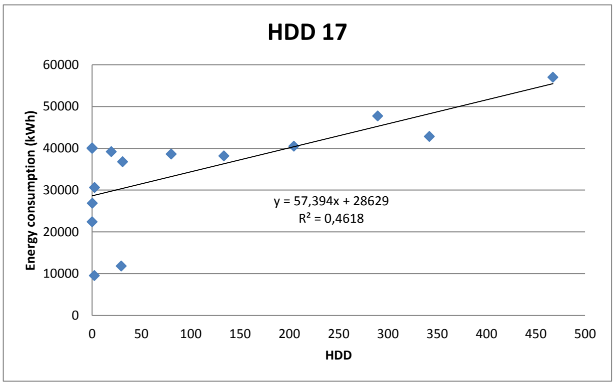


Figure 10: heating energy production (real vs baseline)

In general terms, both real and estimated energy production by the heating system present similar values and tendency, concluding that the consumption due to the heating system may be predicted in an accurate way thanks to the baseline purposed all along this section.

- **DOMESTIC HOT WATER BASELINE CALCULATION**

Another important energy consumption that must be analyzed is the one associated to domestic hot water system. The domestic hot water system is also supplied with natural gas. One initial analysis has been performed in order to look for the relation between the consumption with the weather variability. Down below are shown two of the many models developed.



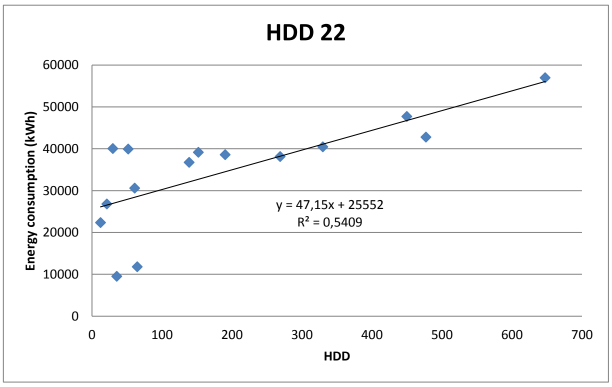


Figure 11: DHW consumption against HDD

There is not such a clear relation between the domestic hot water consumption and the climatologic variable as it occurred with the heating system, which is logically more influenced by the weather than the domestic hot water. Therefore, in order to establish a baseline that may allow to calculate and to predict this consumption another analysis has been done by adding a new variable to the regression model. Thus, considering the billing period as another variable it has been possible to develop a more complex model, which is shown down below:

Table 8: Summary of the regression model for DHW consumption

Regression Statistics	
Multiple R	0,944565065
R Square	0,892203161
Adjusted R Square	0,874237021
Standard Error	4504,932143
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.015.651.684,90	1.007.825.842,45	49,66	1,56905E-06
Residual	12	243.532.963,31	20.294.413,61		
Total	14	2.259.184.648,21			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	8.801,03	3.152,21	2,79	0,016283396	1.932,96	15.669,11
Variable X 1	25,98	6,96	3,73	0,002850932	10,82	41,13
Variable X 2	867,87	138,78	6,25	4,2312E-05	565,50	1.170,24

As it can be seen, the R-Square value is now quite more acceptable. Then, the model is represented by the following expression:

$$y(x_{1,}x_2) = 8801{,}03 + 25{,}98 \cdot x_1 + 867{,}87 \cdot x_2$$

Where the dependent variable represents the energy consumption by the domestic hot water and both independent variables symbolize respectively the Heating Degree Days in base 22ºC and the billing periods, in days. Thus, this model has been applied to the latest data available in order to test if the obtained model can be used as the baseline for the domestic hot water consumption.

Table 9: DHW consumption, baseline and real consumption

	Baseline (kWh)	Real Consumpt. (kWh)	DIF	% Err
15/04/2014	32.549,24	38.566,40	6.017,16	15,60
22/04/2014	16.410,21	11.789,80	- 4.620,41	39,19
15/05/2014	32.085,99	36.724,56	4.638,57	12,63
23/05/2014	16.521,19	9.521,19	- 7.000,00	73,52
23/06/2014	36.728,26	39.913,17	3.184,90	7,98
28/07/2014	39.603,03	40.031,39	428,36	1,07
21/08/2014	29.918,07	26.801,67	- 3.116,40	11,63
26/08/2014	13.340,25	22.348,99	9.008,73	40,31
22/09/2014	33.521,31	30.586,44	- 2.934,88	9,60
24/10/2014	40.166,19	39.146,58	- 1.019,61	2,60
20/11/2014	38.872,23	38.119,63	- 752,61	1,97
22/12/2014	47.834,64	47.690,50	- 144,14	0,30
27/01/2015	56.369,33	56.962,95	593,62	1,04
23/02/2015	44.238,60	42.757,00	- 1.481,60	3,47
20/03/2015	38.722,36	40.454,70	1.732,34	4,28
	516.880,90	521.414,95	4.534,04	0,87

As it can be noted, there is a significant difference between some of the values presented at the previous table. However, attending to the global error it can be said that in general terms the model is quite accurate and may be used to establish a baseline for the domestic hot water consumption. The following figure represents both real and expected consumption, where it is possible to see that although some of the consumption values are quite different, in general terms they present similar values and same tendency.

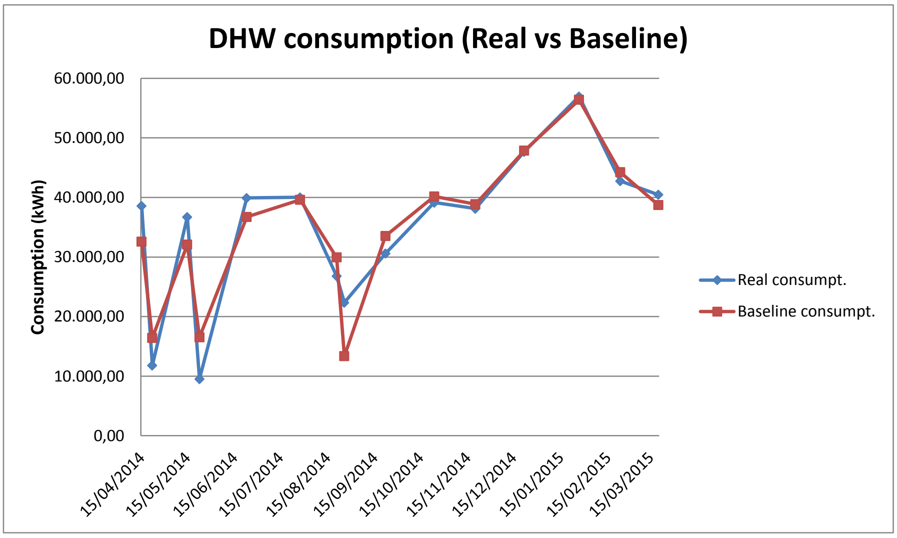


Figure 12: DHW consumption, real vs baseline

However, in order to make sure that the baseline purposed at this section can be used to estimate near future consumptions by the domestic hot water it would be interesting to extend the comparison between both real and estimated consumption with more recent data.

- **ELECTRIC CONSUMPTION IN HEATING SYSTEM BASELINE CALCULATION.**

Another important energy consumer is the one associated to the electric consumption of the Heating System, “Centrale termica”. This electric consumption have to be breakdown in two systems heating and Domestic Hot water, this can be calculated considering the consumptions during the two periods of the year: with heating system running (winter) and without Heating system running. In the same way as it has been performed before, the data available for the electric consumption may be used to establish a baseline in order to explain actual consumptions and compare with near future consumptions.

Table 10: Heating system electric consumption

		ELECTRIC CONSUMPTION (kWh)	
		Days	TOTAL
02/05/2012	15/05/2012	13	882,2
15/05/2012	21/06/2012	37	2424,4
21/06/2012	20/07/2012	29	1914
20/07/2012	20/08/2012	31	1776,5
20/08/2012	17/10/2012	58	1655,5
17/10/2012	19/11/2012	33	4956,6
19/11/2012	17/12/2012	28	4162,4
17/12/2012	27/12/2012	10	1344,2
27/12/2012	22/01/2013	26	3411,1
22/01/2013	15/02/2013	24	3168
15/02/2013	19/03/2013	32	3949
19/03/2013	16/04/2013	28	3248,3
16/04/2013	17/05/2013	31	2105,4
17/05/2013	14/06/2013	28	1866,7
14/06/2013	19/07/2013	35	2226,4
19/07/2013	19/08/2013	31	2461,8
19/08/2013	16/09/2013	28	1434,4
16/09/2013	15/10/2013	29	1760
15/10/2013	12/12/2013	58	3006,3
12/12/2013	30/12/2013	18	2263,8
30/12/2013	27/01/2014	28	2121,9
27/01/2014	24/02/2014	28	3037,1
24/02/2014	17/03/2014	21	3212
17/03/2014	24/03/2014	7	2966,7
24/03/2014	15/04/2014	22	2202,2
15/04/2014	22/04/2014	7	464,2
22/04/2014	23/05/2014	31	1896,4
23/05/2014	23/06/2014	31	1960,2
23/06/2014	28/07/2014	35	2086,7
28/07/2014	21/08/2014	24	1447,6
21/08/2014	22/09/2014	32	2084,5
22/09/2014	24/10/2014	32	1900,8
24/10/2014	20/11/2014	27	2701,6
20/11/2014	22/12/2014	32	3652
22/12/2014	27/01/2015	36	4273,5
27/01/2015	23/02/2015	27	3182,3
23/02/2015	24/03/2015	29	2744,5
24/03/2015	15/04/2015	22	2709,3

With the information shown above, it has been possible to calculate the average electric consumption per day. Thus, attending to the warmest months, when heating is not operating, it is possible to determine the average consumption only for DHW. Then, extending this calculation to the rest of the year, the difference between the total electric consumption and the one calculated represents the consumption due to the electric heating. All these calculations are shown at the next table.

Table 11: Breakdown of the electric consumption

		ELECTRIC CONSUMPTION (kWh)							
				Daily				Absolute	
		Days	TOTAL	Av./Day	Non heating period	EL. During Heating	EL. DHW	EL. During Heating	EL. DHW
02/05/2012	15/05/2012	13	882,2	67,9	67,9	0,0	67,9	0,0	882,2
15/05/2012	21/06/2012	37	2424,4	65,5	65,5	0,0	65,5	0,0	2424,4
21/06/2012	20/07/2012	29	1914	66,0	66,0	0,0	66,0	0,0	1914,0
20/07/2012	20/08/2012	31	1776,5	57,3	57,3	0,0	57,3	0,0	1776,5
20/08/2012	17/10/2012	58	1655,5	28,5	28,5	0,0	28,5	0,0	1655,5
17/10/2012	19/11/2012	33	4956,6	150,2	0,0	89,1	61,1	2938,7	2017,9
19/11/2012	17/12/2012	28	4162,4	148,7	0,0	87,5	61,1	2450,3	1712,1
17/12/2012	27/12/2012	10	1344,2	134,4	0,0	73,3	61,1	732,7	611,5
27/12/2012	22/01/2013	26	3411,1	131,2	0,0	70,0	61,1	1821,3	1589,8
22/01/2013	15/02/2013	24	3168	132,0	0,0	70,9	61,1	1700,5	1467,5
15/02/2013	19/03/2013	32	3949	123,4	0,0	62,3	61,1	1992,3	1956,7
19/03/2013	16/04/2013	28	3248,3	116,0	0,0	54,9	61,1	1536,2	1712,1
16/04/2013	17/05/2013	31	2105,4	67,9	67,9	0,0	67,9	0,0	2105,4
17/05/2013	14/06/2013	28	1866,7	66,7	66,7	0,0	66,7	0,0	1866,7
14/06/2013	19/07/2013	35	2226,4	63,6	63,6	0,0	63,6	0,0	2226,4
19/07/2013	19/08/2013	31	2461,8	79,4	79,4	0,0	79,4	0,0	2461,8
19/08/2013	16/09/2013	28	1434,4	51,2	51,2	0,0	51,2	0,0	1434,4
16/09/2013	15/10/2013	29	1760	60,7	60,7	0,0	60,7	0,0	1760,0
15/10/2013	12/12/2013	58	3006,3	51,8	51,8	0,0	51,8	0,0	3006,3
12/12/2013	30/12/2013	18	2263,8	125,8	0,0	64,6	61,1	1163,2	1100,6
30/12/2013	27/01/2014	28	2121,9	75,8	0,0	14,6	61,1	409,8	1712,1
27/01/2014	24/02/2014	28	3037,1	108,5	0,0	47,3	61,1	1325,0	1712,1
24/02/2014	17/03/2014	21	3212	153,0	0,0	91,8	61,1	1927,9	1284,1
17/03/2014	24/03/2014	7	2966,7	423,8	0,0	362,7	61,1	2538,7	428,0
24/03/2014	15/04/2014	22	2202,2	100,1	0,0	39,0	61,1	857,0	1345,2
15/04/2014	22/04/2014	7	464,2	66,3	66,3	0,0	66,3	0,0	464,2
22/04/2014	23/05/2014	31	1896,4	61,2	61,2	0,0	61,2	0,0	1896,4
23/05/2014	23/06/2014	31	1960,2	63,2	63,2	0,0	63,2	0,0	1960,2
23/06/2014	28/07/2014	35	2086,7	59,6	59,6	0,0	59,6	0,0	2086,7
28/07/2014	21/08/2014	24	1447,6	60,3	60,3	0,0	60,3	0,0	1447,6
21/08/2014	22/09/2014	32	2084,5	65,1	65,1	0,0	65,1	0,0	2084,5
22/09/2014	24/10/2014	32	1900,8	59,4	59,4	0,0	59,4	0,0	1900,8
24/10/2014	20/11/2014	27	2701,6	100,1	0,0	38,9	61,1	1050,6	1651,0
20/11/2014	22/12/2014	32	3652	114,1	0,0	53,0	61,1	1695,3	1956,7
22/12/2014	27/01/2015	36	4273,5	118,7	0,0	57,6	61,1	2072,2	2201,3
27/01/2015	23/02/2015	27	3182,3	117,9	0,0	56,7	61,1	1531,3	1651,0
23/02/2015	24/03/2015	29	2744,5	94,6	0,0	33,5	61,1	971,2	1773,3
24/03/2015	15/04/2015	22	2709,3	123,2	0,0	62,0	61,1	1364,1	1345,2

Finally, once the separation has been done, it is possible to develop the baseline for the consumption due to the electric heating and the consumption due to the electric DHW. Then, the electric heating consumption has been related with different heating degree days in order to find a relation between both variables. It must be said that this regression models have been developed with 2013 and 2014 data, in order to extend it to the latest consumption meters.

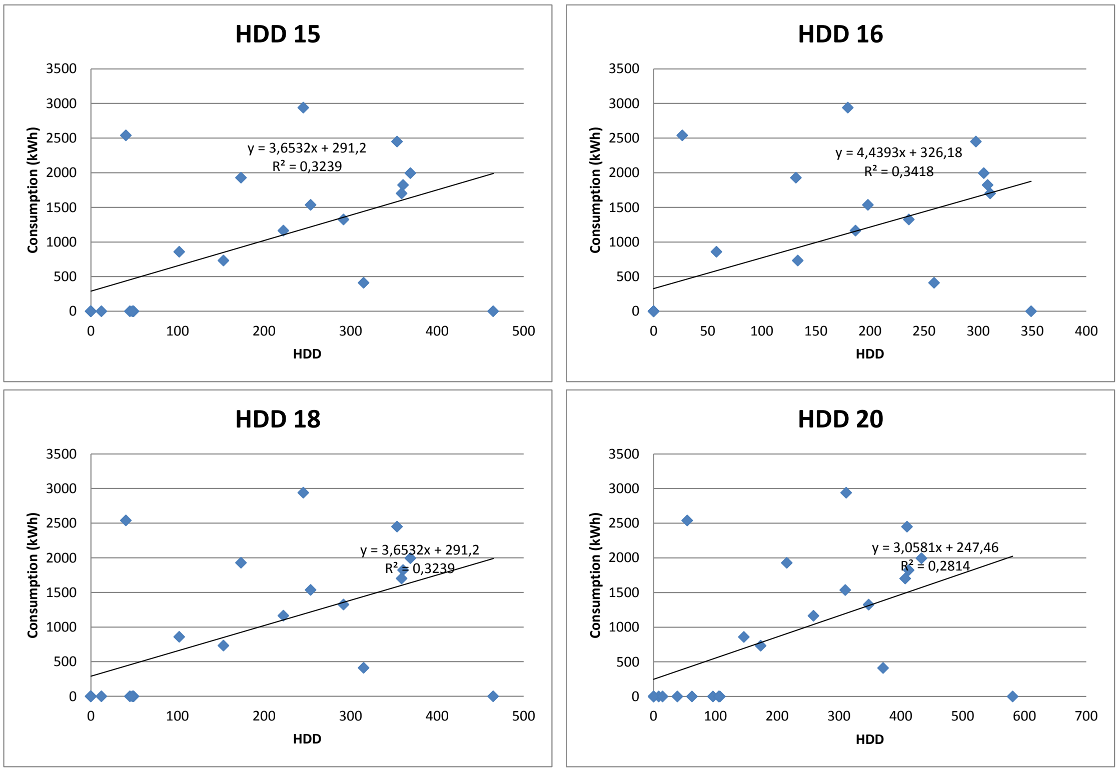


Figure 13: Electric heating consumption against different HDD

Attending to these figures, All of them present a low R-Square value. This is caused because some strange values do not correspond with the rest of meters. Therefore, in order to establish an accurate baseline these values have been removed, obtaining another regression model as it is shown down below.

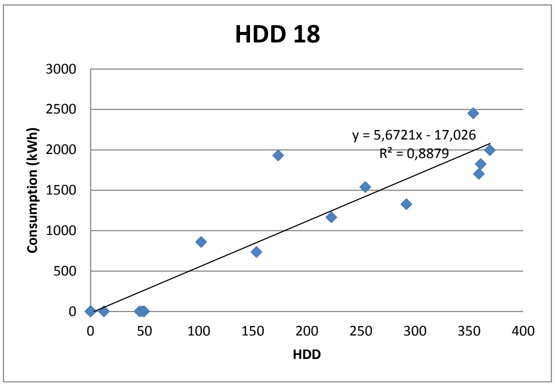


Figure 14: Regression model for HDD 18

As it can be seen, the R-Square takes now a quite more acceptable value. Then, the linear equation that describes this model is:

$$y(x) = 5{,}67x - 17{,}03$$

Where the dependent variable represents the electric heating consumption and the independent one is related with the heating degree days. Therefore, the following graphic has been obtained by extending this regression model to the latest available data.

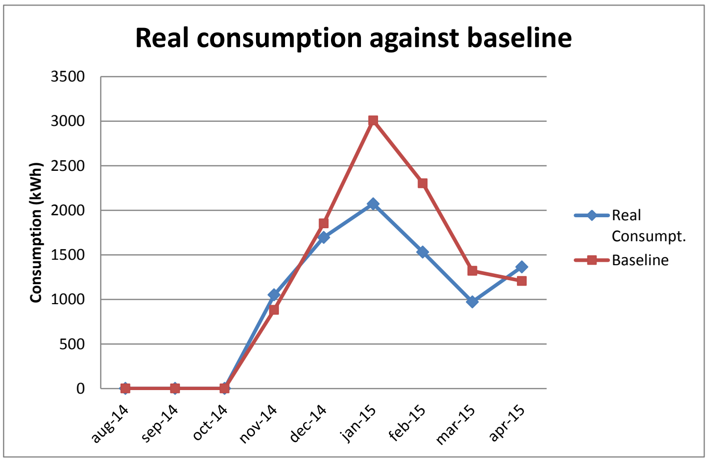


Figure 15: Real electric heating consumption against baseline

Attending to the previous graph, it can be said that in general terms both real and baseline consumptions present similar values and practically the same tendency. However, it would be interesting to collect more data in order to make a more exhaustive and accurate analysis.

On the other hand, another regression model has been developed for the electric consumption by DHW only. As it was expected, and as it can be seen down below, the obtained model shows no relation, (R-Square value close to zero), between this electric consumption and the climatologic variable as the usage of the pumping system for DHW it is not related with the weather.

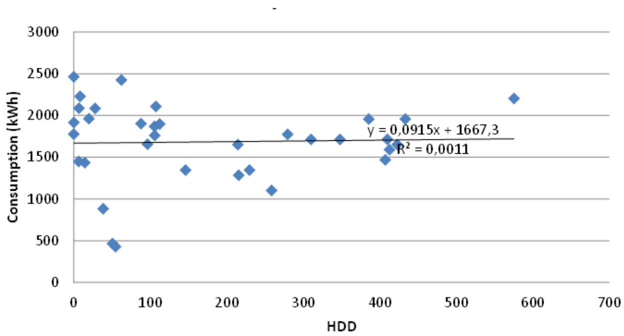


Figure 16: Electric consumption for DHW

- AGGRAGATED ELECTRIC CONSUMPTION

In this section it is shown the electric consumption by the householders of blocks 24 & 26 By the little information provided from tenants bills. The following table summarized all this data.

Table 12: Electric consumption during 2015 (kWh)

BLOCK	FLOOR	COOLING	TENANTS	Oct- Nov 15	Aug-Sept 15	Jun-Jul 15	Apr-May 15	Feb-Mar 15	Dec 14 -Ene 15	Oct- Nov 14	AVER. 2015
T4	P6	Y	4		228	245	211	253	484		1701
T4	P5	N	4	165	80	258					1548
T4	P4	Y	3	240		686	381,4	337	371		2415,4
T4	P3	Y	4	515	874	668	585	544	547		3733
T4	P3	N	1							255	1530
T4	P2	Y	2	151	263	206	181	213	293	241	1307
T4	P1	Y	1	118	127	128	181	211			1025
T2	P4 R	Y	4	303	530	406	381	393	389	373	2402
T2	P2 R	N	2	213	570	402	258	286	346	343	2412
T2	P2L	N	6			190					1596
T2	P6R	N	2	158							1327,2

There is not enough information to establish a baseline for the electric consumption by householders of both buildings. However, with the available data, it has been possible to make a first gross estimation for the electric consumption by householders for 2015, although it is impossible to establish a baseline which relates the weather variability at Treviso with the electric consumption.

On the other hand, and as it is known, there are some flats that count with air conditioner and other that lack of it, because of this and in order to develop an accurate baseline, it would be necessary to attend just to the flats with AC system installed as they would be the only ones whom electric consumption were related with the weather variability.

Therefore, it would be essential to relate this electric consumption with the Cooling Degree Days, (instead of Heating Degree Days), as the air conditioner is only used for refrigeration and not for heating operation. But looking at the available information it can be concluded that there is not enough data for establish a clear baseline between these flats and the climatologic variable.

However, there are also some bills available for two whole years of one flat at block 24. Therefore, in an attempt of establishing a baseline for predicting the electric consumption by householders it has been tried to relate the electric consumption at this flat with the climatologic variable.

Table 13: Electric consumption for one flat of block 24

Period	Consumption (kWh)
Oct - Nov 2015	213
Aug - Sept 2015	570
Jun - Jul 2015	402
Apr - May 2015	258
Feb - Mar 2015	286
Dec 2014 - Jan 2015	346
Oct - Nov 2014	343
Aug - Sept 2014	390
Jun - Jul 2014	309
Apr - May 2014	292
Feb - Mar 2014	292
Dec 2013 - Jan 2014	320
Oct - Nov 2013	294
Aug - Sept 2013	252
Jun - Jul 2013	223
Apr - May 2013	235
Feb - Mar 2013	160
Dec 2012 - Jan 2013	158

Thus, relating these monthly consumptions with the corresponding cooling degree days it has been possible to develop the following calculations.

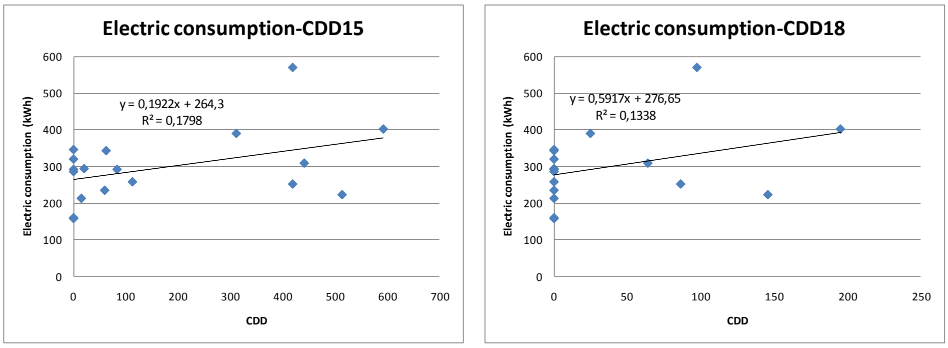


Figure 17: Electric consumption against different Cooling Degree Days

In view of the results, it can be concluded that it does not exist a clear relation between the Cooling Degree Days and the electric consumption by householders. Then, in order to establish an accurate baseline for this consumption it would be necessary to gather more information about the number of tenants and their manners. The monitoring Plan was designed to solve this lack of information regarding with the tenants energy consumption and indoor comfort conditions.

3 ENERGY PERFORMANCE ATER 2nd BUILDING BEFORE RENOVATION.

3.1 INITIAL INFORMATION.

The following Table summarize the information collected to perform the calculations of the baseline.

Table 14: ATER Treviso 2nd pilot Initial information.

ATER TREVISO 2nd PILOT INITIAL INFORMATION REQUESTED.				
Information	**Initial Availability**	**Agent involved**	**Other Agent requested**	**information Provided**
ENERGY CONSUMPTIONS				
Electric consumptions comunal Areas	NO	Ater/building manager	NA	1 year
Electric consumptions tenants	NO	Ater	NA	11 Tenants 1 year
Gas consumptions tenants	NO	Ater	NA	10 Tenants 1 year
BUILDING DESCRIPTION. (drawings technical description)				
Arquitectonical	YES			Basic description.
Electric installation	NO			Information collected in field visit.
HAVC installation.	YES			Basic description
SOCIOLOGICAL CHARACTERISITC				
Number of tenants per dwelling	NO	Ater/Savills		Ater/
Family status.	NO	Ater/Savills		Savills Interviews

The initial available data of energy consumption from energy bills it is not enough to develop an analysis with definitive conclusions about the energy use of the buildings. In collaboration with Ater it has been implemented some actions in order to collect relevant information from gas meters and energy Bills from a group of selected tenants. This data will be collected along 2017 year, therefore, at this time it is only possible to report a basic description of the energy use of the building. The final conclusions will be obtained after the analysis with the data including 2017 summer.

3.2 ENERGY CONSUMPTION DESCRIPTION.

- HEATING AND DOMESTIC HOT WATER.

Each apartment has an independent heating system for the production of hot water for heating and DHW. The independent boiler is running with gas natural and 25 kW of thermal power. The boiler is connected to the apartment Gas net that also supply the cooking system. The first objective of this section is to calculate the energy consumption for each component: Heating, DHW and cooking. Initially the monitoring plan was developed to get the data for the gas meters every 15 min. With such a detailed data it would be possible to calculate accurately the consumption of the three systems that are supplied by gas. Due to the lack of collaboration from the Gas Supplier. It has not been possible to install the gas monitoring equipment, so the following procedure will be used for calculate the energy of the different systems:

Getting the monthly gas consumption of at least 10 months it is possible to identify the DHW consumption during the months when heating system is off. Considering that the pattern of use for DHW it is similar along the year and it only could have some variations regarding with the net water temperature we will calculate the monthly DHW consumption.

For heating system, thanks to the collaboration of Ater the gas meter readings have been collected during this winter in order to have some daily gas consumption in with different weather conditions.

Finally the gas consumption due too cooking system will be analysed through the information provided during the tenants interviews they had to answer some question regarding with their pattern of gas usage for cooking. However in order to perform the comparison before and after renovations this consumption it will be considered as not variable parameter.

The following tables shows and initial basic estimation for a year of the energy consumption from gas supplied in each apartment, according with the few data available from bills.

Table 15: ENERGY CONSUMPTION DATA FROM GAS BILLS A TOWER

COD.	n Persons	TYPE	FLOOR	BOW WINDOW	SQM	AIR COND	1 YEAR GAS BILLS	SOME MONTHS GAS BILLS	KWht/year (Estimation)
AT1FA1	1	A1	1	X	79,44			6	6.554
AT1FA2	3	A2	1	X	94,35			11	29.712
AT1FA3	2	A3	1	X	82,97	1		2	11.291
AT2FA1	1	A1	2	X	79,44	1			
AT2FA2	4	A2	2	X	94,35			4	15.640
AT2FA3	1	A3	2	X	82,97			10	20.215
AT3FA1	1	A1	3		79,44	1		2	7.780
AT3FA2	3	A2	3	X	94,35	1		8	11.404
AT3FA3	4	A3	3	X	82,97			10	10.770
AT4FA1	3	A1	4	X	79,44			11	10.203
AT4FA2	2	A2	4	X	94,35			11	18.949
AT4FA3	2	A3	4	X	82,97		X		11.168
AT5FA1	1	A1	5	X	79,44	1		10	13.924
AT5FA2	2	A2	5	X	94,35			10	10.952
AT5FA3	2	A3	5	X	82,97	1		3	10.939
AT6FA1	2	A1	6		79,44	1		4	24.654
AT6FA2	2	A2	6	X	94,35	1			
AT6FA3	6	A3	6		82,97				

Table 16: ENERGY CONSUMPTION DATA FROM GAS BILLS B TOWER

COD	n Persons	TYPE	FLOOR	BOW WINDOW	air cond	SQM	1 YEAR GAS BILLS	SOME MONTHS GAS BILLS	KWht/year (estimation)
BT1FA1		B1	1	X		79,44			
BT1FA2	4	B2	1	X	1	94,35	X		1.658
BT1FA3	3	B3	1			82,97			
BT2FA1	5	B1	2		1	79,44			
BT2FA2	1	B2	2	X	1	94,35	X		20.536
BT2FA3	2	B3	2	X	1	82,97			
BT3FA1	2	B1	3	X		79,44	X		14.551
BT3FA2	3	B2	3		1	94,35			
BT3FA3	2	B3	3		1	82,97		10	18.883
BT4FA1	1	B1	4	X		79,44		10	12.240
BT4FA2	5	B2	4	X	1	94,35	X		9.122
BT4FA3	2	B3	4	X	1	82,97	X		13.939
BT5FA1	3	B1	5			79,44		8	9.065
BT5FA2	3	B2	5	X	1	94,35		10	1.380
BT5FA3	2	B3	5		1	82,97		10	7.513
BT6FA1	1	B1	6	X	1	79,44			
BT6FA2	2	B2	6	X		94,35			
BT6FA3	4	B3	6	X	1	82,97	X		16.332

- TENANTS ELECTRIC CONSUMPTION.

The electric consumption of the apartments is due to appliances, lighting system and Air conditioning. The electric consumption of each apartment will be monitored through monitoring equipment, therefore there will be available data to characterize the electric consumption of the tenants. The consumption of the Air Conditioning will be registered during summer period.

The following tables shows and initial basic estimation for a year of the energy consumption from electric consumption in each apartment, according with the few data available from bills.

Table 17: ENERGY CONSUMPTION DATA FROM ELECTRIC BILLS A TOWER

COD.	n Persons	TYPE	FLOOR	BOW WINDOW	SQM	AIR COND	1 YEAR ELECTRIC BILLS	SOME MONTHS ELECTRIC BILLS	kWhe/YEAR (Estimation)	kWhe/year (BILL)
AT1FA1	1	A1	1	X	79,44					
AT1FA2	3	A2	1	X	94,35			11	1.950	
AT1FA3	2	A3	1	X	82,97	1		1	1.940	
AT2FA1	1	A1	2	X	79,44	1				
AT2FA2	4	A2	2	X	94,35			9	1.762	1.794
AT2FA3	1	A3	2	X	82,97			10	3.380	
AT3FA1	1	A1	3		79,44	1		2	1.461	
AT3FA2	3	A2	3	X	94,35	1		4	374	
AT3FA3	4	A3	3	X	82,97			10	3.898	
AT4FA1	3	A1	4	X	79,44			2	1.217	
AT4FA2	2	A2	4	X	94,35			2	1.624	1.556
AT4FA3	2	A3	4	X	82,97		X		1.537	
AT5FA1	1	A1	5	X	79,44	1		10	1.169	1.339
AT5FA2	2	A2	5	X	94,35			1	2.790	
AT5FA3	2	A3	5	X	82,97	1		2	3.723	
AT6FA1	2	A1	6		79,44	1				
AT6FA2	2	A2	6	X	94,35	1		11	2.427	
AT6FA3	6	A3	6		82,97					

Table 18: ENERGY CONSUMPTION DATA FROM ELECTRIC BILLS B TOWER

COD	n Persons	TYPE	FLOOR	BOW WINDOW	air cond	SQM	1 YEAR ELECTRIC BILLS	SOME MONTHS ELECTRIC BILLS	kWhe/year (estimation)	KWhe/year (BILLS)
BT1FA1		B1	1	X		79,44				
BT1FA2	4	B2	1	X	1	94,35	X		3.045	
BT1FA3	3	B3	1			82,97				
BT2FA1	5	B1	2		1	79,44				
BT2FA2	1	B2	2	X	1	94,35		4	894	
BT2FA3	2	B3	2	X	1	82,97				
BT3FA1	2	B1	3	X		79,44	X		2.242	
BT3FA2	3	B2	3		1	94,35				
BT3FA3	2	B3	3		1	82,97		11	1.759	1.901
BT4FA1	1	B1	4	X		79,44		10	1.467	
BT4FA2	5	B2	4	X	1	94,35	X		2.077	
BT4FA3	2	B3	4	X	1	82,97	X		1.832	1.832
BT5FA1	3	B1	5			79,44		6	2.338	584
BT5FA2	3	B2	5	X	1	94,35		X	1.494	1.820
BT5FA3	2	B3	5		1	82,97		6	1.285	1.476
BT6FA1	1	B1	6	X	1	79,44				
BT6FA2	2	B2	6	X		94,35				
BT6FA3	4	B3	6	X	1	82,97		11	3.136	

- COMMUNAL SERVICES ENERGY CONSUMPTION.

The energy consumption of the communal services it is due to the elevator and the lighting system. This components as well as the future systems implemented during renovations will be monitored with monitoring equipment and there will be enough data for a complete analysis. The consumptions of the current systems it is already available through the billings.

	kWh/year
COMMUNAL SERVICES TOWER A	2.378
COMMUNAL SERVICES TOWER B	2.779

3.3 ENERGY BASELINE CALCULATION.

As it is explained in the previous section there is not enough available data to perform the analysis in order to obtain the normalized energy base line that will allow to compare the two different scenarios before and after renovations.

The next version of this report will include the analysis of different energy baselines:

- Individual Heating baseline for a selected group of tenants
- Individual DHW baseline for a selected group of tenants
- Individual Electric consumption baseline for a selected group of tenants
- Communal Services energy Baseline

4 ENERGY PERFORMANCE PADIHAM PILOT BEFORE RENOVATIONS

4.1 INITIAL INFORMATION

The initial information is based on the following:

- Characteristics of the dwellings according to the information provided by PFP and field visit.
- Heating systems installed.
- Line diagrams.
- Monitoring equipment installed.
- Data collected from the monitoring system through the Open Domo platform.

In the map it is showed the location of the dwellings.

Figure 18 Pilot site map and Dwellings with monitoring kit Installed

The table below shows the different types of dwelling the monitoring is based on.

Table 19: Dwelling characteristics

	Tipology	Supplies	Floors	Bedroom	Tenants	Auxiliary electric panel	Lighting
D1	Ground Floor flat	El. and Gas	1	1	1	-	Low consumpt.
D2	Mid Terrace	Electric	2	2	2	700 W (4)	-
D3	Mid Terrace	Electric	2	2	2	1	Low consumpt. And LED
D4	Ground Floor flat	Electric	1	1	1	2000 W (1)	Incandescense
D5	End terrace	El. and Gas	2	3	1	-	-
D6	First Floor Flat	Electric	1	1	1	2500 W (1)	Low consumpt. And LED
D7	End terrace	Electric	2	3	3	2000 W (1)	-
D8	End terrace	Electric	2	2	3	2000 W (1)	-
D9	Mid Terrace	Electric	2	3	2	-	-

4.2 ENERGY CONSUMPTION DESCRIPTION

In this section it will be included the calculation based on the data collected for the period from the installation date on September 22nd to February 14TH.

There are two dwellings (named as D1 and D5) that have gas supply for heating and domestic hot water. There is not gas consumption data up to now, however they are included on the report for analysing their electric consumption. When their gas consumption data will be available they will be taking into account for the calculations.

4.2.1 ENERGY CONSUMPTION DISTRIBUTION

This section is a summary of the different systems that contribute to the total energy consumption.

For the study, the consumptions have been divided in the following groups:

- Heating. It includes the heating system for off peak hours and heaters installed in the bathroom
- Domestic Hot Water (DHW). It includes the immersion heater system and the shower heater system
- Sockets. It is measured the consumption in sockets of different rooms of the dwellings. The reason behind these measurements is to check whether there are other heating systems that are being used such as electric heaters. According with the results of the analysis when there is no relation between socket consumption and weather parameters, it is being considering that this dwelling do not use auxiliary heating system.

- Appliances and Lighting "others". It includes the rest of the consumption, and includes the lighting system, the kitchen appliances and other devices such as T.V and might include electric heaters as well.

In the following chart it is showed the distribution of each group during the observation period.

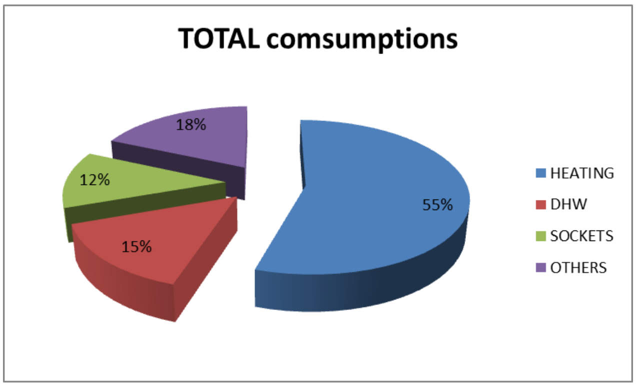


Figure 19: Total consumption

As it showed in the graft, the 'heating consumption' is 55% being the 'DHW' the third one with 15%.

The following figure shows the total consumption on a per monthly basis.

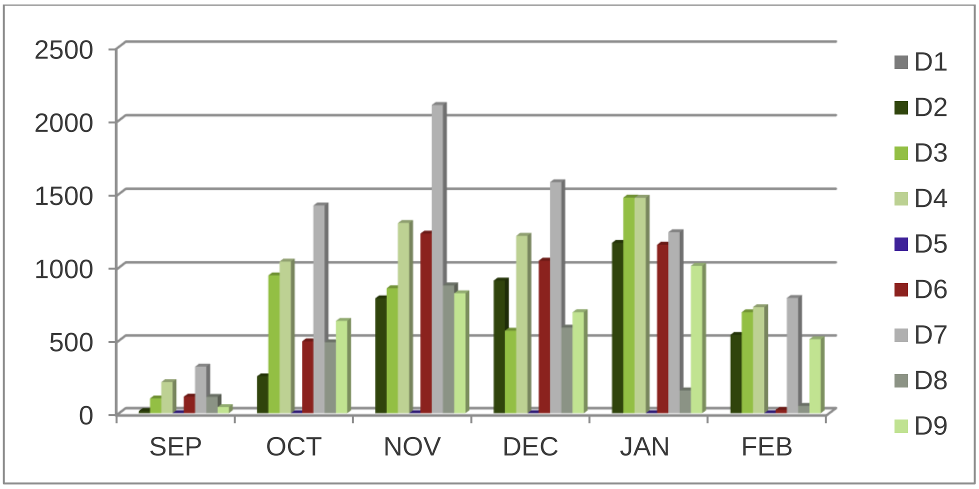


Figure 20: Monthly total consumption (kWh)

It has to be taken into account that the observation period is mostly during winter period when the heating systems are on.

The dwellings D8 have not got data in February since the tenants have left and similar circumstance seems to happen in D6.

4.2.2 HEATING SYSTEM

This section describes the energy consumption related to the heating system. For all the electric dwellings the heating consumption is due to the electric storage heating systems and other heaters located at the bathroom.

The electric storage heating system is only charged during night time, (at the Off Peak hours), and it stores heat during the whole night in order to release it gradually during the rest of the day.

There is also an energetic consumption due to the bathroom heater; however, this consumption is practically inconsiderable comparing to the Off Peak heater consumption. The next graph shows the consumption distribution for the off peak heating system and the bathroom heating one. As mentioned, in these calculations data belonging to dwelling D1 and D5 are not included.

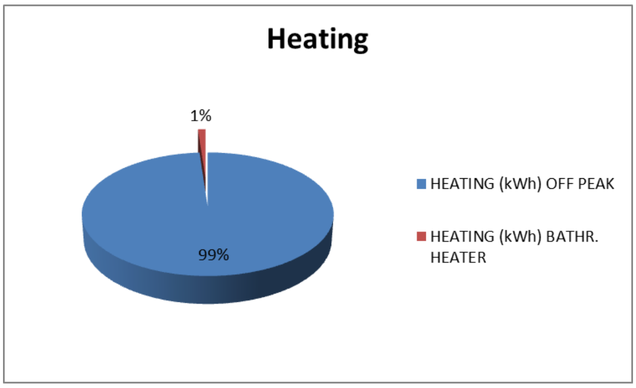


Figure 21: Heating system breakdown

In addition the following chart shows the difference on heating system consumption along the months.

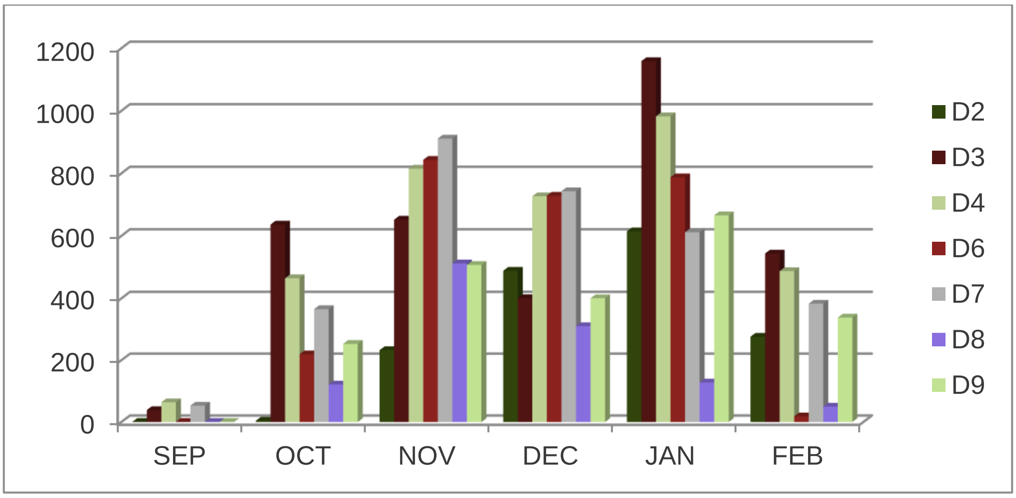


Figure 22: Monthly heating system consumption (kWh)

Note that the observation period in September is only 9 days and it is supposed that no heating system was being used, and the one for February is fifteen days.

4.2.3 DOMESTIC HOT WATER (DHW)

The domestic hot water system is supplied by an immersion heater and a shower heater located at the bathroom. These systems are based on a resistance. A strong electric current is passed through it to heat it up and it heats the water around it.

The immersion heater system operates generally during night time, at the off peak tariff, storing the heat and releasing it later during the day when domestic hot water is needed.

The immersion heater for DHW can be programmed by a timer which is shown in the next image.

Figure 23: DHW Off Peak Timer

The other energy consumer of the DHW system is the one related to the Shower heater.

Figure 24: Shower heater thermostat

However, taking a look over the available data it is possible to observe that the consumption due to the shower is, in general terms, lower than the immersion heater consumption. Thus, the next graph shows the distribution for DHW consumption by the immersion and shower heater for the sum of all the electric dwellings during October and November 2016.

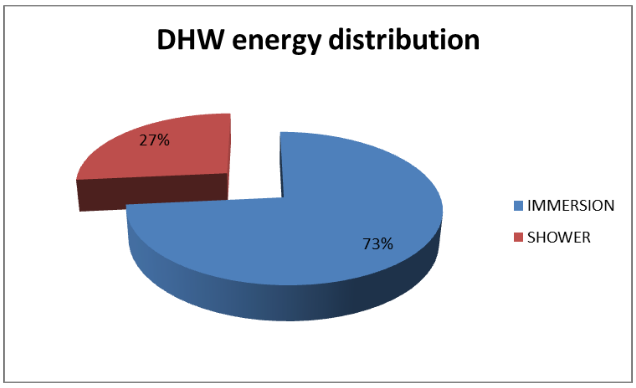


Figure 25: Domestic Hot Water distribution

The immersion heater consumption is more than two times greater than of the shower heater consumption.

In the following figure, it is shown the DHW consumption by each dwelling from September 2016 to February 2017.

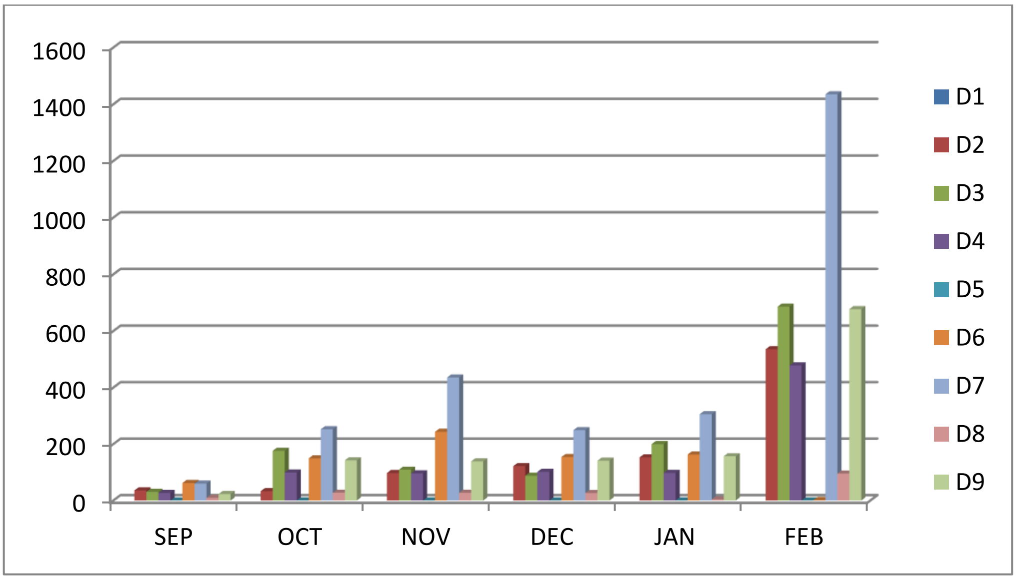


Figure 26: Monthly DHW consumption (kWh)

With the available data, it cannot be confirmed yet that there exists any relation between the DHW consumption and the climatologic variable. However, this will be tested later in this study relating this consumption with the Heating Degree Days in order to establish a baseline for estimate near future consumptions.

4.2.4 Appliances and lighting (Others)

There is an important part of the energy consumption which corresponds directly to the electric consumption not related to heating systems or DHW. This consumption includes the one due to the lighting system, kitchen appliances and other devices such as T.V and electric stoves.

Therefore, the 'Others' consumption will be analyzed separately dwelling by dwelling, as it will be quite different depending on the number of tenants or on the use of appliances.

In the next figure it is shown the consumption distribution over the months.

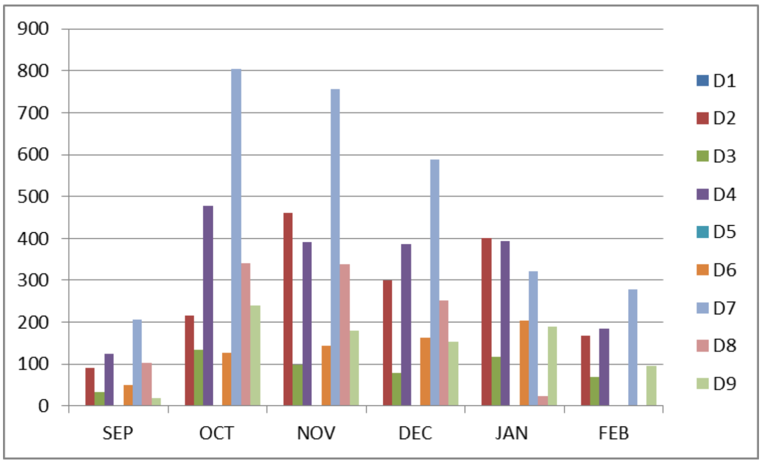


Figure 27: Monthly Appliances and Ligthing consumption (kWh)

As it can be seen from the graft, the greatest consumption corresponds to dwelling D7 that have three tenants.

In general terms, it can be said that the consumption regarding "others" is not dependent on the external temperature. In the case there may be some relationship with it, it will be explicitly mentioned.

4.3 BASELINE CALCULATION

The data related to consumption has been compared to Heating Degree Days on different bases, from 10 ºC to 20ºC.

Thanks to the given information and the available data, it has been possible to develop a baseline calculation for the different systems consumption.

The data have been collected from the Monitoring equipment installed whose data have being registered in Open Domo platform. Electric consumption data as well as indoor and outdoor temperature have been got. There is a temperature probe in dwelling D4 that provides temperature information. It has been calculated the Heating Degree Days, (HDD, from now on), with different designated bases, from 10 ºC to 20ºC.

With the total HDD and the consumption per month for the different systems during the observation (From Sep 2016 to Feb 2017), it has been possible to develop different graphs per dwelling for different temperature bases, HDD 10, HDD 11, etc.

The HDD value that represents the best value for the heating systems consumption will be used for all the different consumptions for the corresponding dwelling, unless otherwise specified.

For each Dwelling has been selected a specific HDD base according with the most accurate results for the heating system. This same HDD base it has been used to compare the results of the other systems such as DHW, Total consumption, sockets…

4.3.1 Analysis for dwelling D1

The characteristics of this dwelling are as follow:

- 1 floors
- 1 bedrooms
- 1 tenants

Gas supply is used for heating and Domestic Hot Water.

The variation of the temperature inside the dwelling over the months is showed in the next figure:

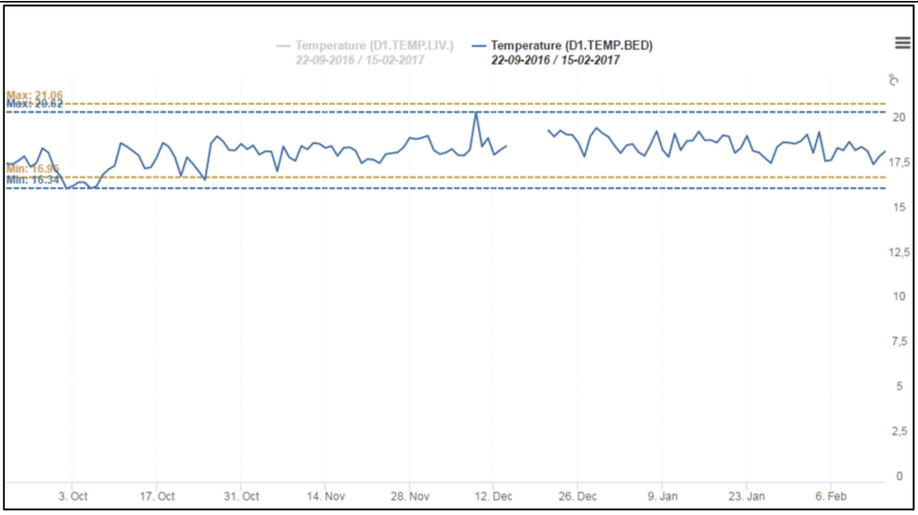


Figure 28: D1. Inside temperature and relative humidity

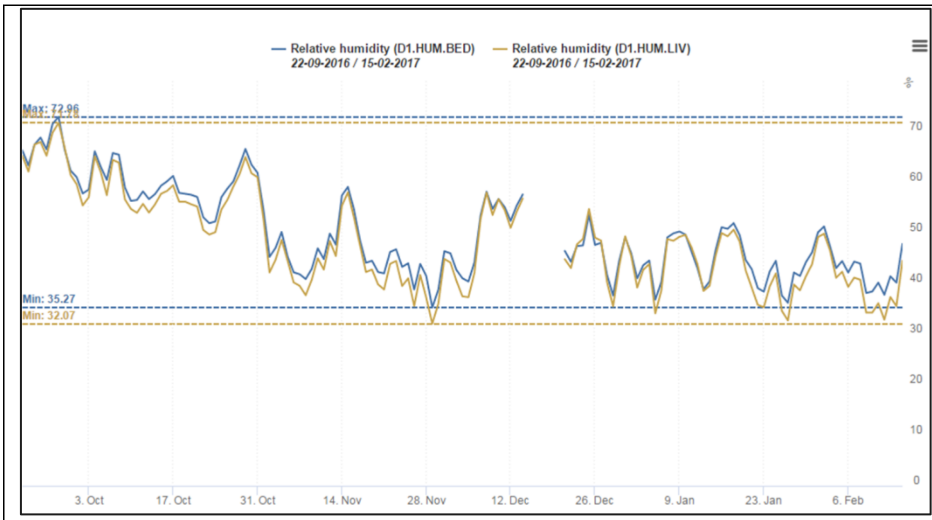


Figure 29: D1. Inside relative humidity

The maximum and minimum values for the temperature and relative humidity inside the dwelling are as follow:

Table 20: D1. Maximum and minimum values for inside temperature and relative humidity

	TEMPERATURE (ºc)		RELATIVE HUMIDITY (%)	
	MAX	MIN	MAX	MIN
LIVINGROOM	21,06	16,96	71,78	32,07
BEDROOM	20,62	16,34	72,96	35,27

The following chart summarizes the consumptions per item and per month.

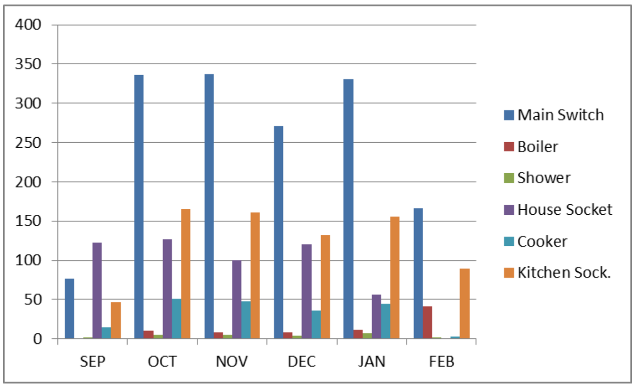
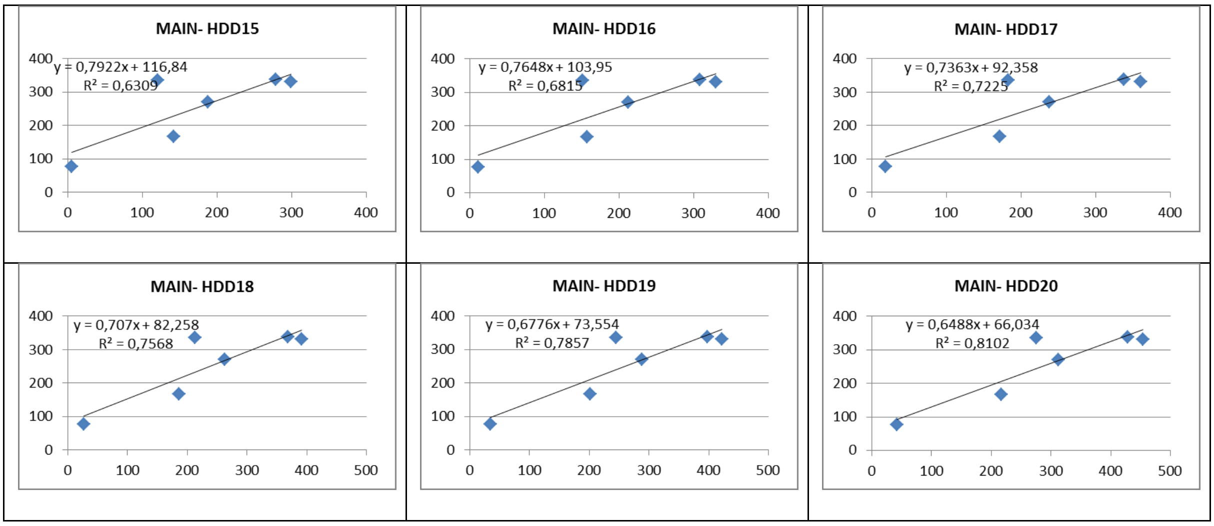


Figure 30: D1. Monthly consumption (kWh)

Since this dwelling has gas supply for heating and domestic hot water, the electric consumption may not follow the exterior temperature.

Following it is showed the charts corresponding to Main switch.



The graph for HDD 20 is the one that describes better the evolution of the energy consumption.

The formula that will be used for predicting the heater systems consumption for D1 is:

$$y = 0{,}6488x + 66{,}034$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 21: D1. 'Total' baseline based values vs. measured values per month

	HDD 20	BS	MEASURED	MEASURED DAYS
SEP	42,48	93,59	76,90	9
OCT	275,39	244,71	335,91	31
NOV	428,13	343,81	336,86	30
DEC	312,64	268,88	271,35	25
JAN	453,59	360,32	330,67	31
FEB	216,77	206,68	166,32	15

Table 22: D1. 'Total' baseline based values vs. measured values in the period

	HDD 20	BS	MEASURED	DIF	% ERROR
TOTAL	1729,01	1517,98	1518,01	-0,03	0

As it can be seen from the table the calculate values are very close to the measurements. Anyway, the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.2 Analysis for dwelling D2

The characteristics of this dwelling are as follow:

- 2 floors.
- 2 bedrooms.
- 2 tenants.
- 4 auxiliary electric panel of 700 W.

The variation of the temperature inside the dwelling over the months is showed in the next figure:

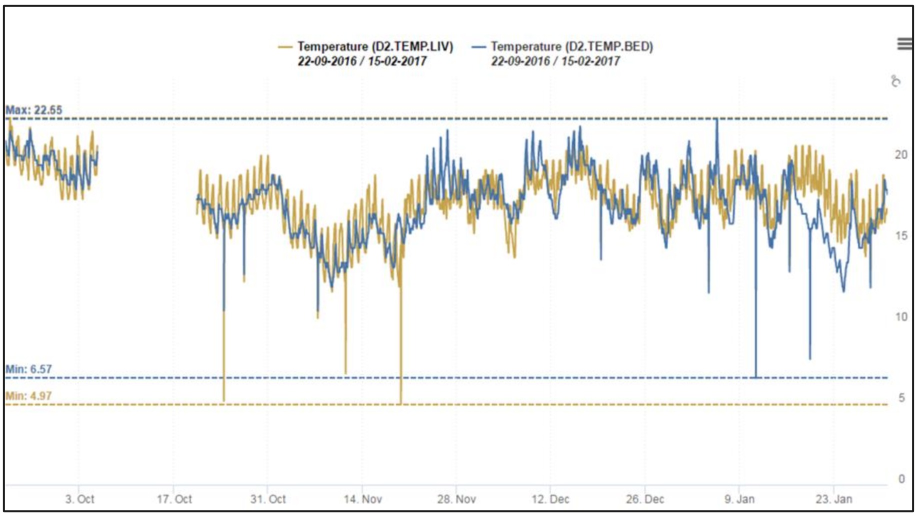


Figure 31: D2. Inside temperature

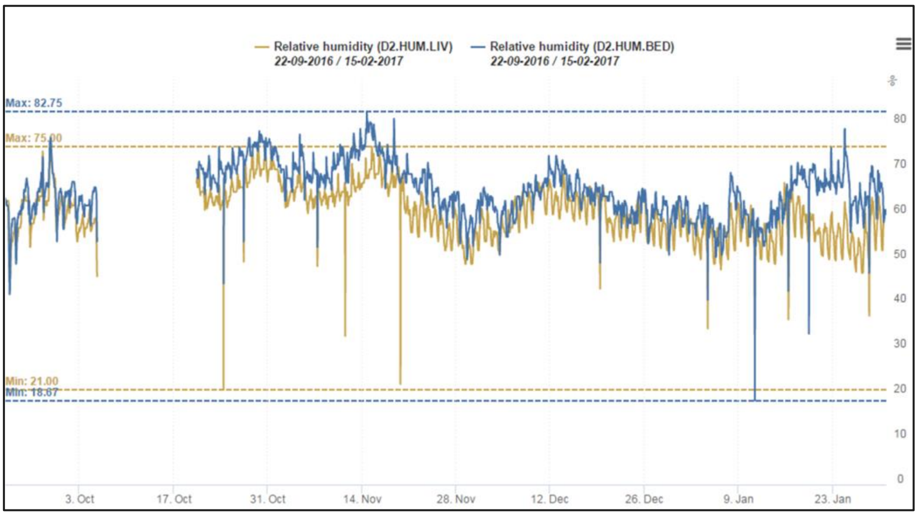


Figure 32: D2. Inside relative humidity

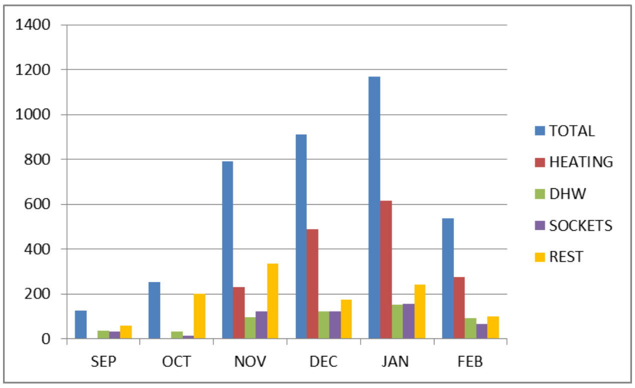
The maximum and minimum values for the temperature and relative humidity inside the dwelling are as follow:

Table 23: D2. *Maximum and minimum values for inside temperature and relative humidity*

	TEMPERATURE (º C)		RELATIVE HUMIDITY (%)	
	MAX	MIN	MAX	MIN
LIVINGROOM	22,55	6,57	75,00	21,00
BEDROOM	22,63	4,97	82,75	18,67

As it can be seen in the graphs, there are some peaks in the minimum temperature and minimum relative humidity. Removing these peaks, the values will be around 13ºC and 45 % respectively.

The following chart summarizes the consumptions per item and per month.



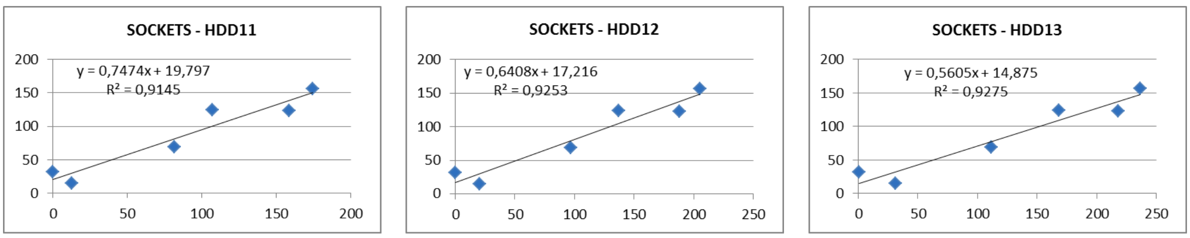
'REST' refers to the consumption that have not been measured i.e. the *difference between the 'TOTAL' value minus the sum of the other monitoring items (heating, DHW and sockets).*

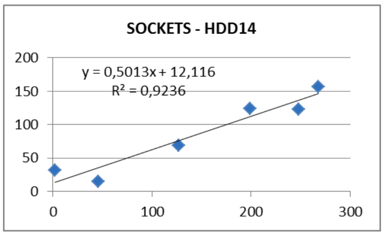
Figure 33: D2. Monthly consumption (kWh)

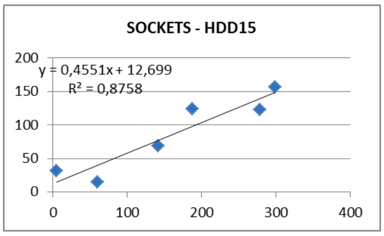
In this case the baseline that shows better value fort R^2 is the one tied to 'Sockets' consumption, so this value will be used for the rest of consumptions. As mentioned in the initial description of the Dwelling, this tenant use 4 auxiliary electric panel for heating that have to be supplied by Sockets circuit.

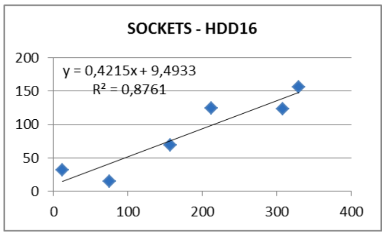
4.3.2.1 D2. SOCKETS CONSUMPTION

The graphs for the Sockets consumption are shown below:









Since the HDD value for heating systems used was HDD 13, the formula that will be used for predicting the Sockets consumption is:

$$y = 0{,}5605x + 14{,}875$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 24: D2. 'Sockets' baseline based values vs. measured values per month

	HDD 13	BS	MEASURED	MEASURED DAYS
SEP	0,41	16,11	31,97	9
OCT	31,13	33,32	14,76	17
NOV	218,13	138,14	123,35	30
DEC	168,11	110,10	124,04	25
JAN	236,59	148,48	156,19	31
FEB	111,77	78,52	68,36	15

Table 25: D2. 'Sockets' baseline based values vs. measured values in the period

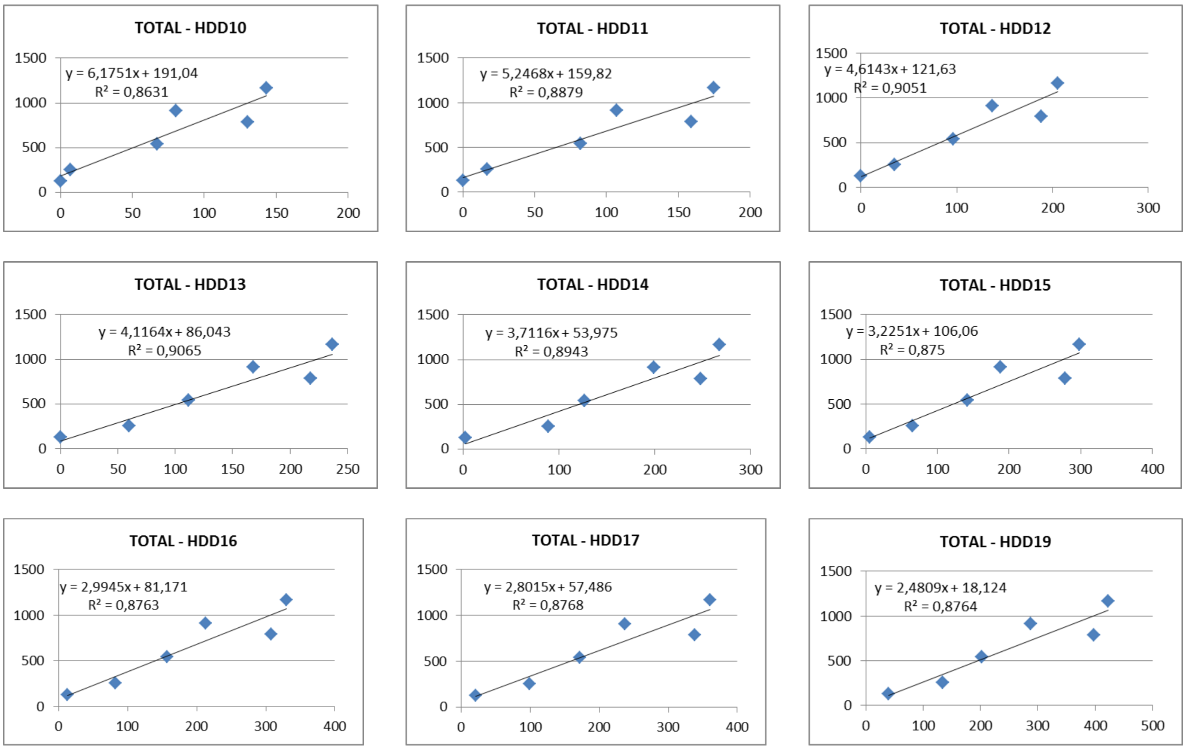
	HDD 13	BS	MEASURED	DIF	% ERROR
TOTAL	766,13	524,67	518,67	6,00	1

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the sockets consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

In this case the baseline that shows better value fort R^2 is the one tied to 'Sockets' consumption, so this value will be used for the rest of consumptions.

4.3.2.2 D2. TOTAL CONSUMPTION

The graphs for the TOTAL consumption are shown below:



Since the HDD value for Sockets used was HDD 13, the formula that will be used for predicting the 'Total' consumption is:

$$y = 3{,}9232x + 130{,}43$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 26: D2. 'Total' baseline based values vs. measured values per month

	HDD 13	BS	MEASURED	MEASURED DAYS
SEP	0,41	132,04	126,98	9
OCT	31,13	252,54	253,92	17
NOV	218,13	986,21	790,37	30
DEC	168,11	789,95	911,04	25
JAN	236,59	1058,61	1167,19	31
FEB	111,77	568,93	538,76	15

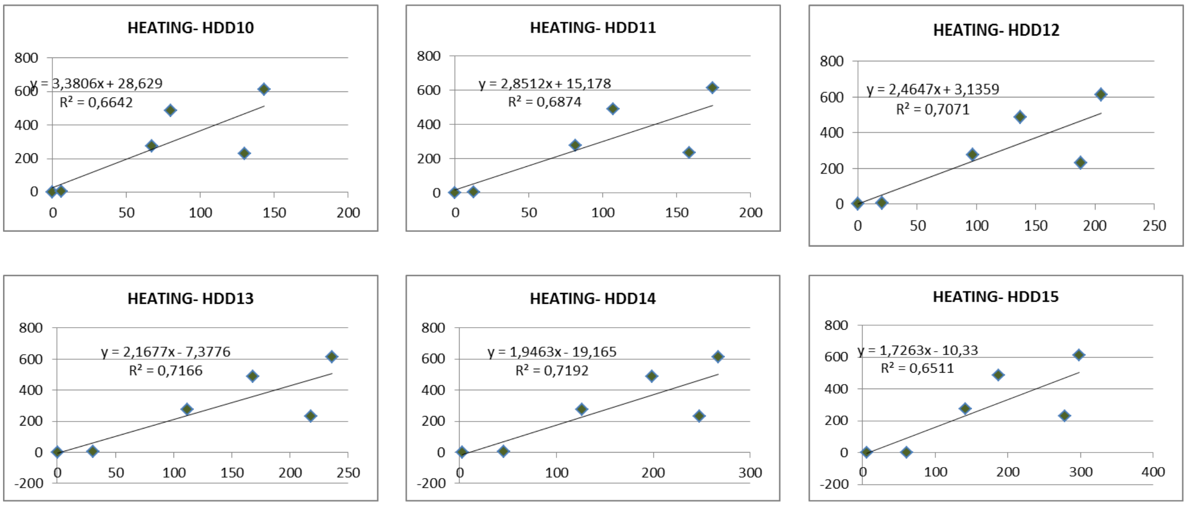
Table 27: D2. 'Total' baseline based values vs. measured values in the period

	HDD 13	BS	MEASURED	DIF	% ERROR
TOTAL	766,13	3788,28	3788,25	0,02	0

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the electricity consumption. Anyway, the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.2.3 D2. HEATING SYSTEMS CONSUMPTION

The graphs for the heating systems are as follow:



Since the HDD value for Sockets used was HDD 13, the formula that will be used for predicting the 'HEATING' consumption is:

$$y = 1{,}857x$$

Were y represents the consumption in kWh and the x the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 28: D2. 'Heating' baseline based values vs. measured values per month

	HDD 13	BS	MEASURED	MEASURED DAYS
SEP	0,41	0,76	0,37	9
OCT	31,13	57,80	4,27	17
NOV	218,13	405,07	232,74	30
DEC	168,11	312,17	488,34	25
JAN	236,59	439,34	614,55	31
FEB	111,77	207,56	276,17	15

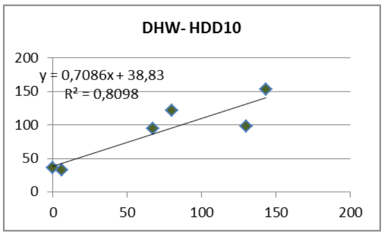
Table 29: D2. 'Heating' baseline based values vs. measured values in the period

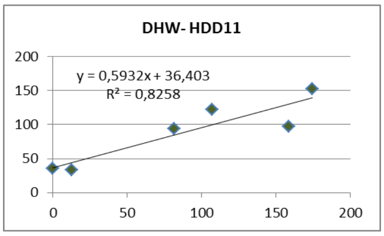
	HDD 13	BS	MEASURED	DIF	% ERROR
TOTAL	766,13	1422,71	1616,45	-193,74	12

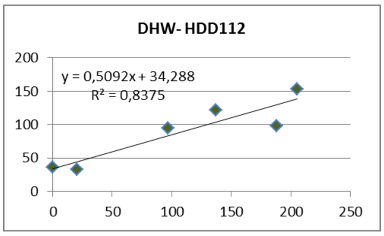
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Heating consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

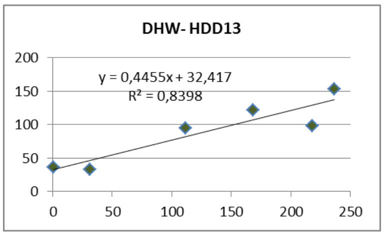
4.3.2.4 Domestic Hot Water

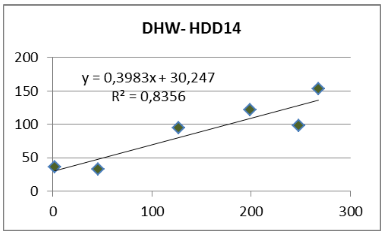
The graphs for the DHW consumption are shown below:

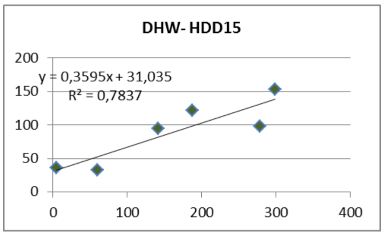












Since the HDD value for Sockets used was HDD 13, the formula that will be used for predicting the 'Total' consumption is:

$$y = 0{,}4455x + 32{,}417$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 30: D2. 'DHW' baseline based values vs. measured values per month

	HDD 13	BS	MEASURED	MEASURED DAYS
SEP	0,41	32,60	35,86	9
OCT	31,13	46,28	33,17	17
NOV	218,13	129,59	97,58	30
DEC	168,11	107,31	121,92	25
JAN	236,59	137,82	152,92	31
FEB	111,77	82,21	94,33	15

Table 31: D2. 'DHW' baseline based values vs. measured values in the period

	HDD 13	BS	MEASURED	DIF	% ERROR
TOTAL	766,13	535,81	535,79	0,03	0

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the DHW consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.3 Analysis for dwelling D3

The characteristics of this dwelling are as follow:

- 2 floors
- 2 bedrooms
- 2 tenants
- 1 auxiliary electric panel

The variation of the temperature inside the dwelling over the months is showed in the next figure:

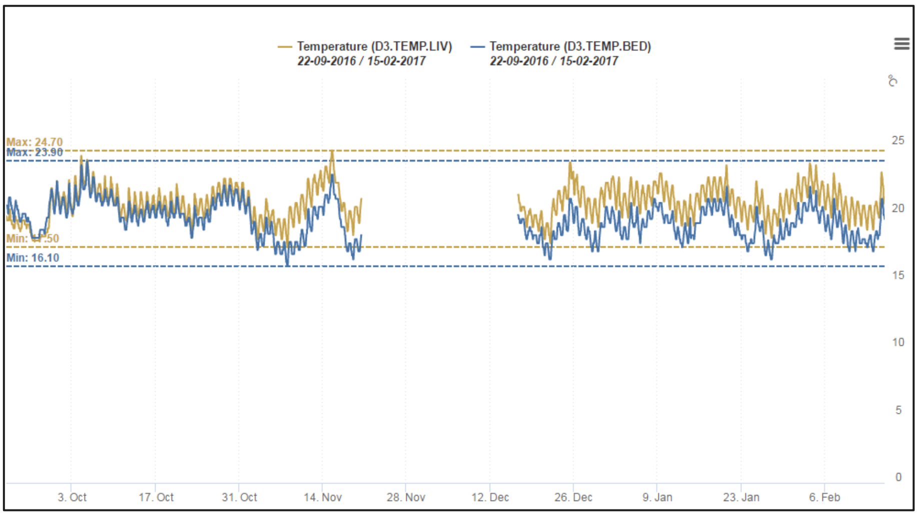


Figure 34: D3. Inside temperature

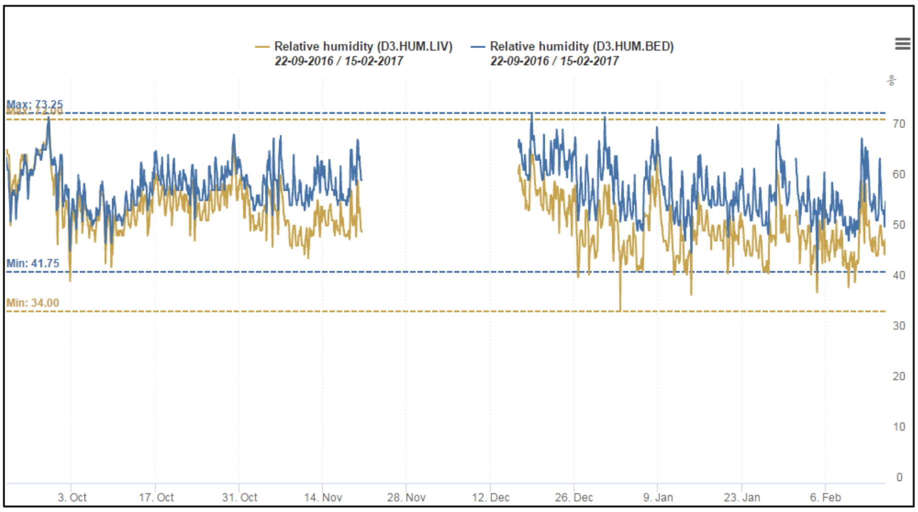


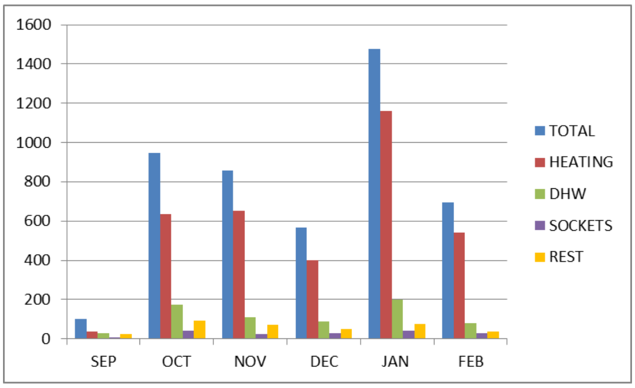
Figure 35: D3. Inside relative humidity

The maximum and minimum values for the temperature and relative humidity inside the dwelling are as follow:

Table 32: D3. Maximum and minimum values for inside temperature and relative humidity

	TEMPERATURE (º C)		RELATIVE HUMIDITY (%)	
	MAX	MIN	MAX	MIN
LIVINGROOM	24,70	17,50	73,00	34,00
BEDROOM	23,90	16,10	73,25	41,75

The following chart summarizes the consumptions per item and per month.

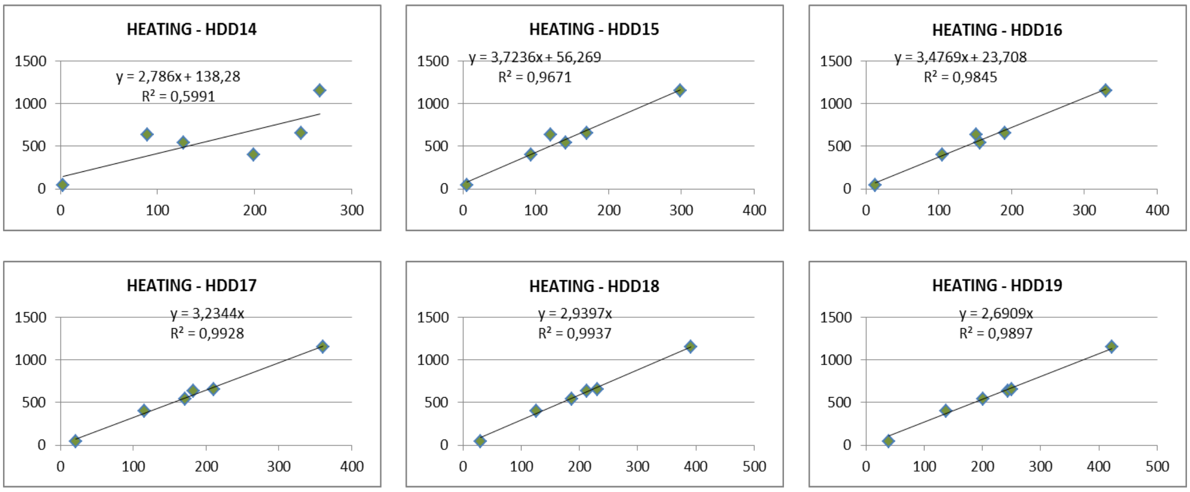


'REST' refers to the consumption that have not been measured i.e. the difference between the 'TOTAL' value minus the sum of the other monitoring items (heating, DHW and sockets).

Figure 36: D3. Monthly consumption (kWh)

4.3.3.1 D3 HEATING SYSTEMS CONSUMPTION

The graphs for the Heating systems consumption are shown below:



The graph for HDD 18 is the one that describes better the evolution of the energy consumption.

The formula that will be used for predicting the heater systems consumption for D3 is:

$$y = 2{,}9397x$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 33: D3. 'Heating' baseline based values vs. measured values per month

	HDD 18	BS	MEASURED	MEASURED DAYS
SEP	30,32	89,14	38,63	9
OCT	213,39	627,31	635,99	31
NOV	230,63	677,98	652,00	20
DEC	126,59	372,14	400,89	11
JAN	391,59	1151,15	1158,92	31
FEB	186,77	549,05	543,64	15

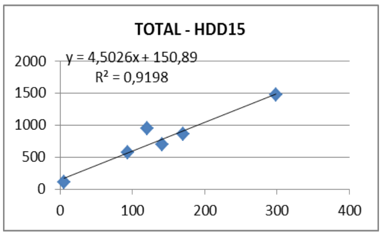
Table 34: D3. 'Heating' baseline based values vs. measured values in the period

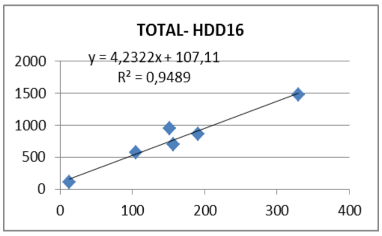
	HDD 18	BS	MEASURED	DIF	% ERROR
TOTAL	1179,30	3466,77	3430,08	36,70	1

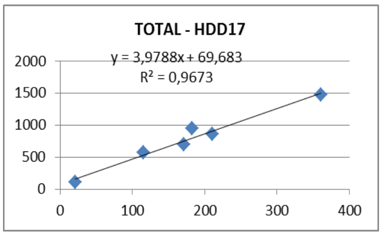
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Heating consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

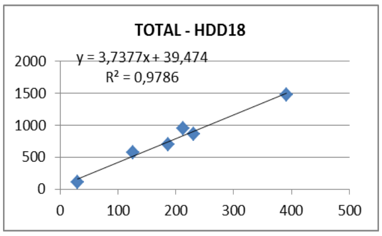
4.3.3.2 D3 TOTAL CONSUMPTION

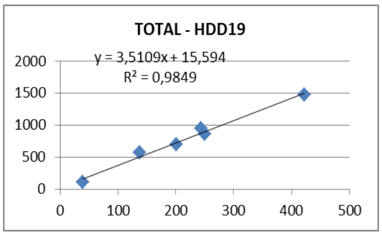
The graphs for the Total consumption are shown below:

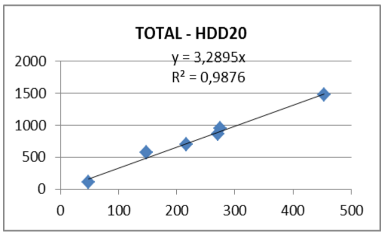












Since the HDD value for heating systems used was HDD 18, the formula that will be used for predicting the 'Total' consumption is:

$$y = 3{,}7377x + 39{,}474$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

	HDD 18	BS	MEASURED	MEASURED DAYS
SEP	30,32	152,82	101,64	9
OCT	213,39	837,07	946,26	31
NOV	230,63	901,50	859,15	20
DEC	126,59	512,63	567,76	11
JAN	391,59	1503,11	1475,10	31
FEB	186,77	737,57	694,81	15

Table 35: D3. 'Total' baseline based values vs. measured values per month

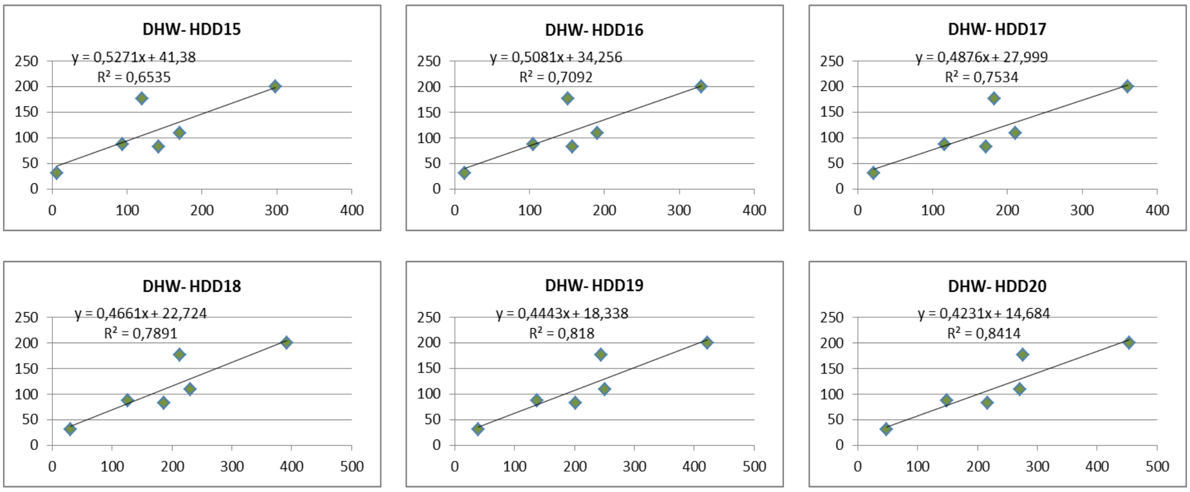
	HDD 18	BS	MEASURED	DIF	% ERROR
TOTAL	1179,30	4644,70	4644,72	-0,02	0

Table 36: D3. 'Total' baseline based values vs. measured values in the period

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Total consumption. Anyway, the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.3.3 D3 DOMESTIC HOT WATER

The graphs for the DHW consumption are shown below:



Since the HDD value for heating systems used was HDD 18, the formula that will be used for predicting the DWH consumption is:

$$y = 0{,}4661x + 22{,}724$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 37: D3. 'DHW' baseline based values vs. measured values per month

	HDD 18	BS	MEASURED	MEASURED DAYS
SEP	30,32	36,86	30,82	9
OCT	213,39	122,19	175,98	31
NOV	230,63	130,22	109,17	20
DEC	126,59	81,73	87,74	11
JAN	391,59	205,24	199,91	31
FEB	186,77	109,78	82,41	15

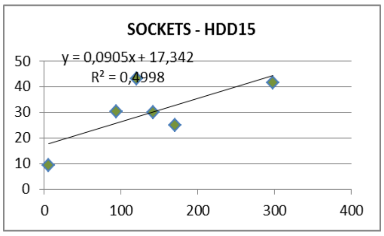
Table 38: D3. 'DHW' baseline based values vs. measured values in the period

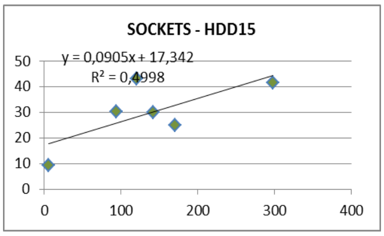
	HDD 18	BS	MEASURED	DIF	% ERROR
TOTAL	1179,30	686,01	686,02	-0,01	0

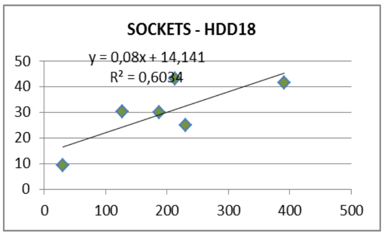
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Heating consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.3.4 D3 SOCKETS CONSUMPTION

The other item that is being monitored i.e. Sockets consumption does not have any relationship with the exterior temperature as it can be seen in the following graphs.







4.3.4 Analysis for dwelling D4

The characteristics of this dwelling are as follow:

- 1 floor.
- 1 bedroom.
- 1 tenant.
- 1 auxiliary electric panel de 2000 W.

The variation of the temperature inside the dwelling over the months is showed in the next figure:

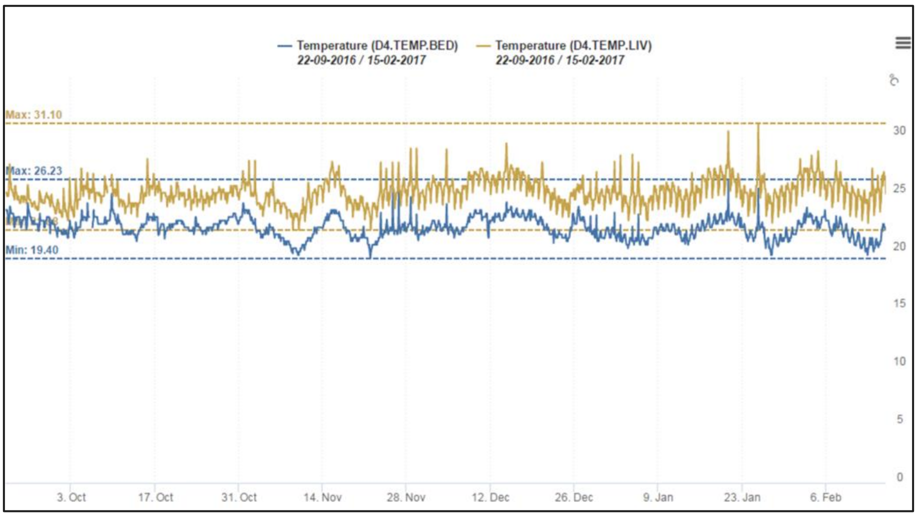


Figure 37: D4. Inside temperature

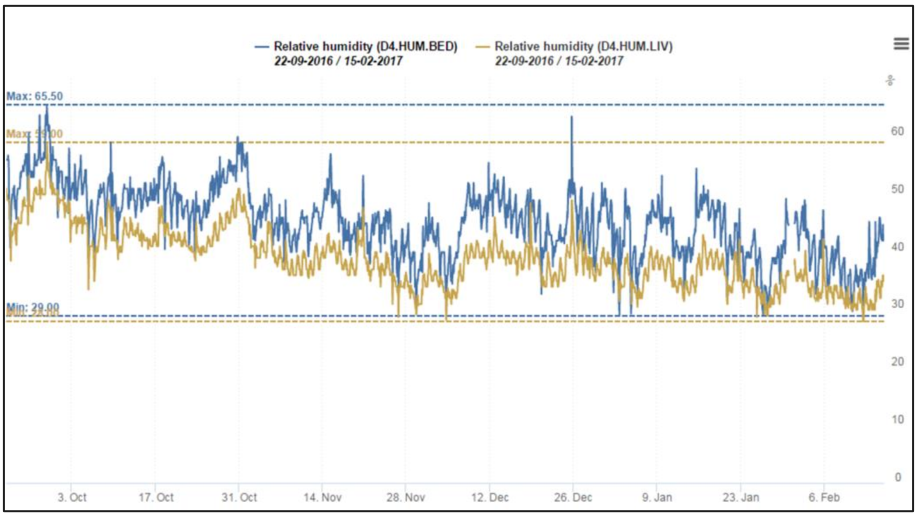


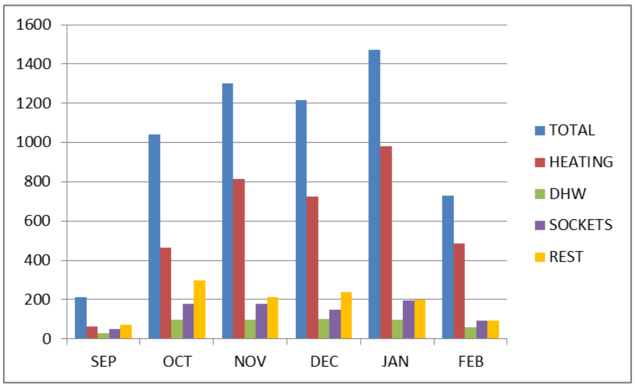
Figure 38: D4. Inside relative humidity

The maximum and minimum values for the temperature and relative humidity inside the dwelling are as follow:

Figure 39: D4. Maximum and minimum values for inside temperature and relative humidity

	TEMPERATURE (º C)		RELATIVE HUMIDITY (%)	
	MAX	MIN	MAX	MIN
LIVINGROOM	25,80	8,93	81,25	32,00
BEDROOM	25,80	10,20	76,75	30,00

The following chart summarizes the consumptions per item and per month.

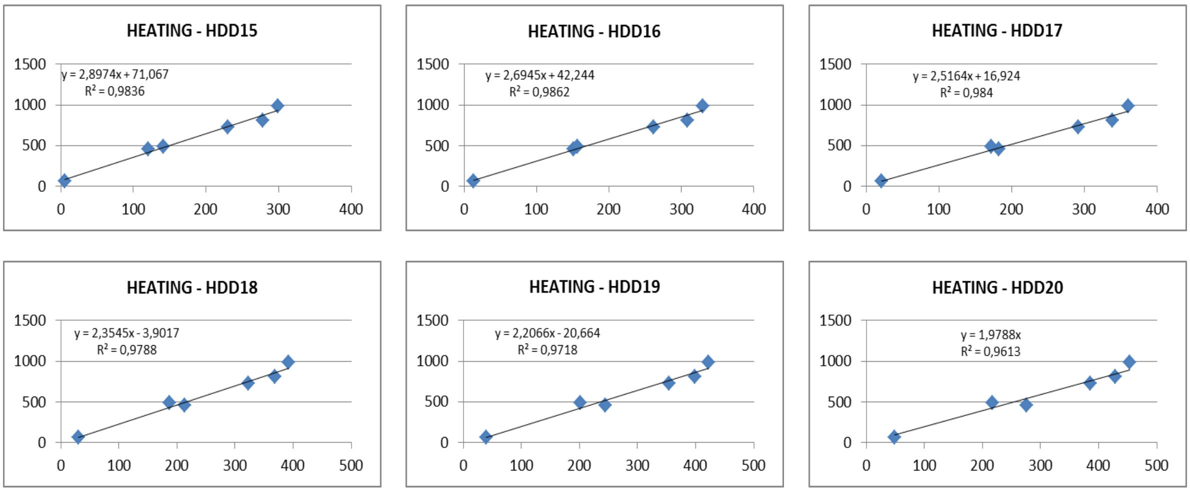


'REST' refers to the consumption that have not been measured i.e. the difference between the 'TOTAL' value minus the sum of the other monitoring items (heating, DHW and sockets).

Figure 40: D4. Monthly consumption (kWh)

4.3.4.1 D4 HEATING SYSTEMS CONSUMPTION

The graphs for the Heating systems consumption are shown below:



The graph for HDD 16 is the one that describes better the evolution of the energy consumption.

The formula that will be used for predicting the heater systems consumption for D4 is:

$$y = 2{,}6945\,x + 42{,}244$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 39: D4. 'Heating' baseline based values vs. measured values per month

	HDD 16	BS	MEASURED	MEASURED DAYS
SEP	12,65	76,34	63,87	9
OCT	151,39	450,17	464,51	31
NOV	308,13	872,51	814,94	30
DEC	261,11	745,80	726,65	25
JAN	329,59	930,32	982,32	31
FEB	156,77	464,67	487,45	15

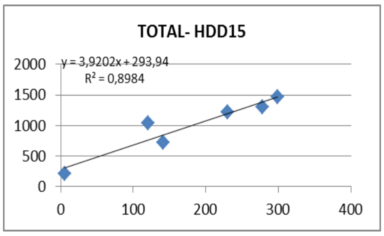
Table 40: D4. 'Heating' baseline based values vs. measured values in the period

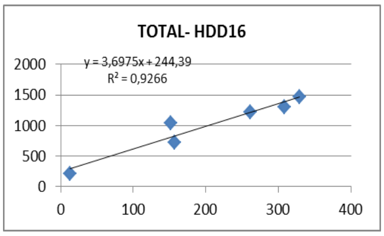
	HDD 16	BS	MEASURED	DIF	% ERROR
TOTAL	1219,64	3539,79	3539,75	0,04	0

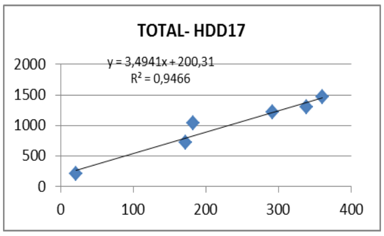
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Heating consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

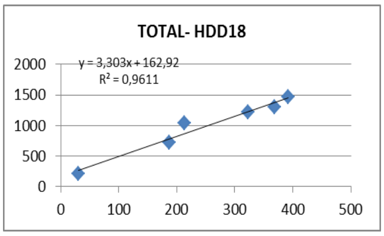
4.3.4.2 Total consumption

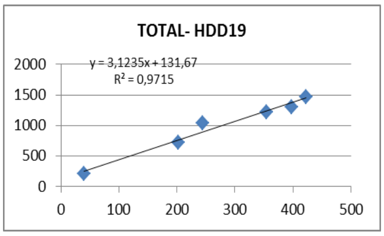
The graphs for the Total consumption are shown below:

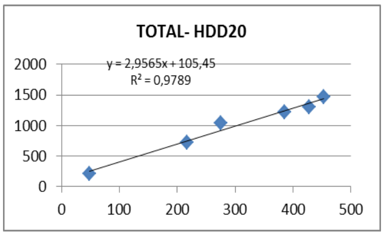












Since the HDD value for heating systems used was HDD 16, the formula that will be used for predicting the 'Total' consumption is:

$$y = 3{,}6975x + 244{,}39$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 41: D4. 'Total' baseline based values vs. measured values per month

	HDD 16	BS	MEASURED	MEASURED DAYS
SEP	12,65	291,17	214,24	9
OCT	151,39	804,16	1040,39	31
NOV	308,13	1383,71	1302,67	30
DEC	261,11	1209,83	1215,30	25
JAN	329,59	1463,04	1473,90	31
FEB	156,77	824,05	729,45	15

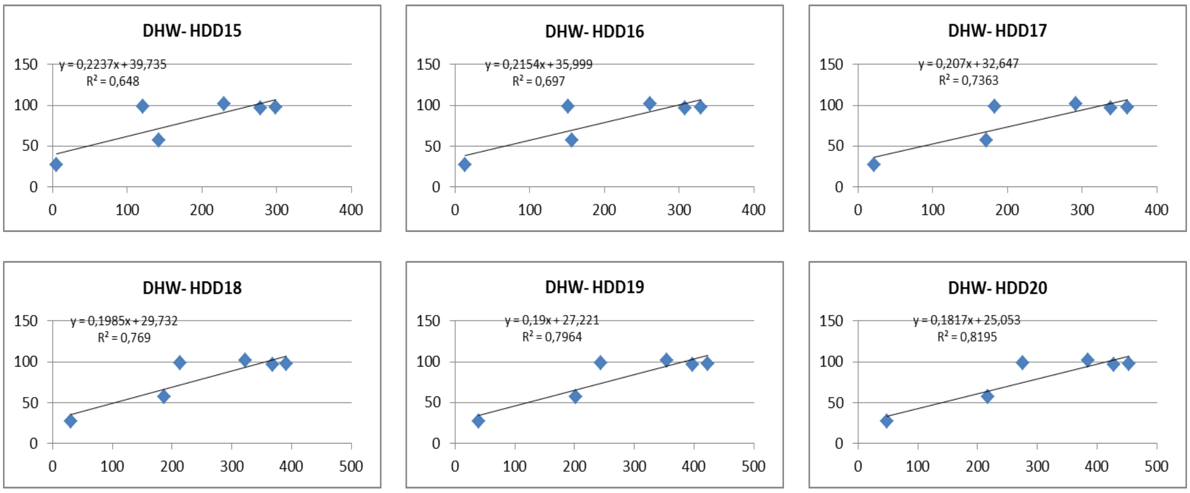
Table 42: D4. 'Total' baseline based values vs. measured values in the period

	HDD 16	BS	MEASURED	DIF	% ERROR
TOTAL	1219,64	5975,97	5975,95	0,02	0

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Total consumption. Anyway, the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.4.3 D4 DOMESTIC HOT WATER

The graphs for the DHW consumption are shown below:



Since the HDD value for heating systems used was HDD 16, the formula that will be used for predicting the DHW consumption would be:

$$y = 0{,}2154x + 35{,}999$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 43: D4. 'DHW' baseline based values vs. measured values per month

	HDD 16	BS	MEASURED	MEASURED DAYS
SEP	12,65	38,72	26,99	9
OCT	151,39	68,61	99,14	31
NOV	308,13	102,37	96,16	30
DEC	261,11	92,24	101,56	25
JAN	329,59	106,99	97,99	31
FEB	156,77	69,77	56,89	15

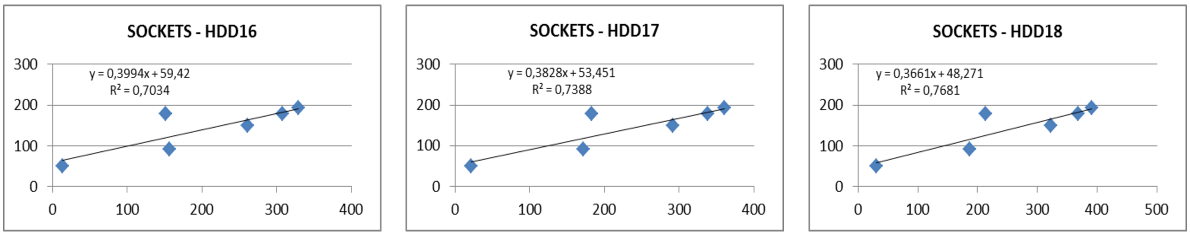
Table 44: D4. 'DHW' baseline based values vs. measured values in the period

	HDD 16	BS	MEASURED	DIF	% ERROR
TOTAL	1219,64	478,71	478,73	-0,03	0

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the DHW consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.4.4 D4 SOCKETS CONSUMPTION

The last item that is being monitored i.e. Sockets consumption does not have any relationship with the exterior temperature as it can be seen in the following graphs.



4.3.5 Analysis for dwelling D5

The characteristics of this dwelling are as follow:

- 2 floors.
- 3 bedrooms.
- 1 tenants.

Gas supply is used for heating and Domestic Hot Water.

The variation of the temperature inside the dwelling over the months is showed in the next figure:

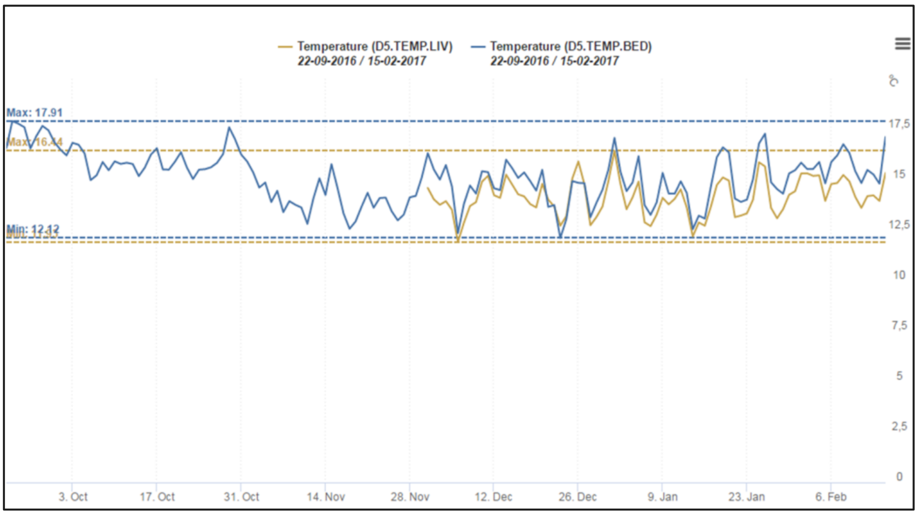


Figure 41: D5. Inside temperature

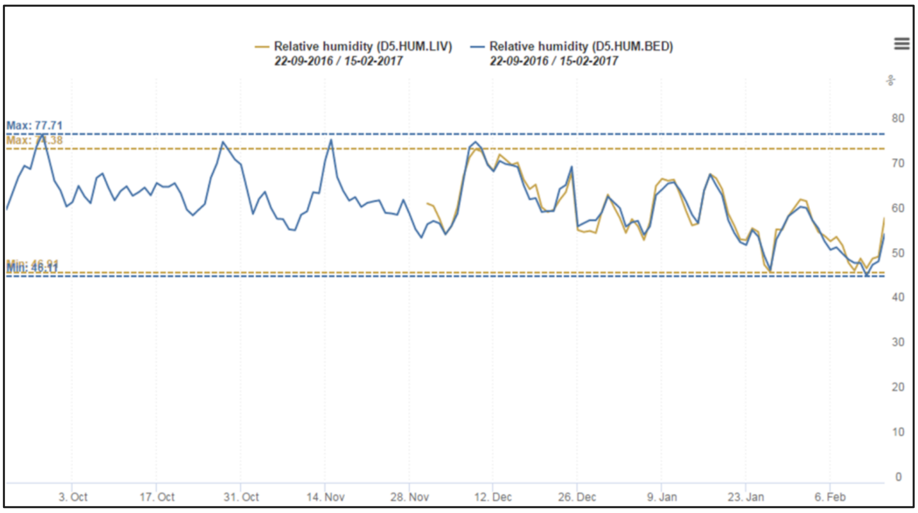


Figure 42: D5. Inside relative humidity

The maximum and minimum values for the temperature and relative humidity inside the dwelling are as follow:

Figure 43: Maximum and minimum values for inside temperature and relative humidity

	TEMPERATURE (ºc)		RELATIVE HUMIDITY (%)	
	MAX	MIN	MAX	MIN
LIVINGROOM	16,44	11,93	74,38	46,91
BEDROOM	17,91	12,12	77,71	46,11

The following chart summarizes the consumptions per item and per month.

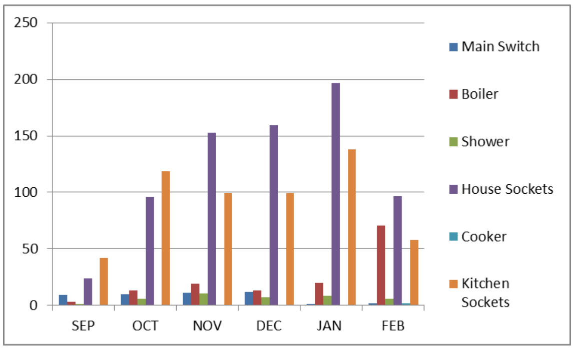
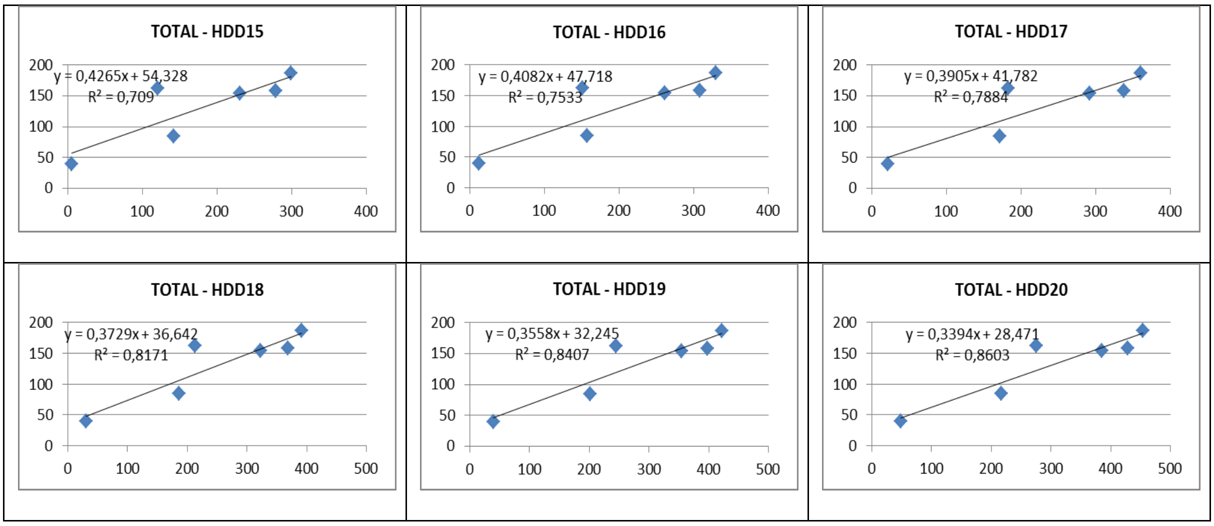


Figure 44: D5. Monthly consumption (kWh)

Following it is showed the charts corresponding to Main switch.



The graph for HDD 20 is the one that describes better the evolution of the energy consumption.

The formula that will be used for predicting the heater systems consumption for D4 is:

$$y = 0{,}3394x + 28{,}471$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table

Table 45: D5. 'Total' baseline based values vs. measured values per month

	HDD 20	BS	MEASURED	MEASURED DAYS
SEP	48,32	44,87	39,49	9
OCT	275,39	121,94	161,66	31
NOV	428,13	173,78	157,83	30
DEC	385,11	159,18	154,19	25
JAN	453,59	182,42	186,54	31
FEB	216,77	102,04	84,52	15

Table 46: D5. 'Total' baseline based values vs. measured values in the period

	HDD 20	BS	MEASURED	DIF	% ERROR
TOTAL	1807,31	784,23	784,22	0,00	0

As it can be seen from the table the calculate values are very close to the measurements. Anyway, the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.6 Analysis for dwelling D6

The characteristics of this dwelling are as follow:

- 1 floor.
- 1 bedroom.
- 1 tenant.
- 1 auxiliary electric panel de 2500 W.

The variation of the temperature inside the dwelling over the months is showed in the next figure:

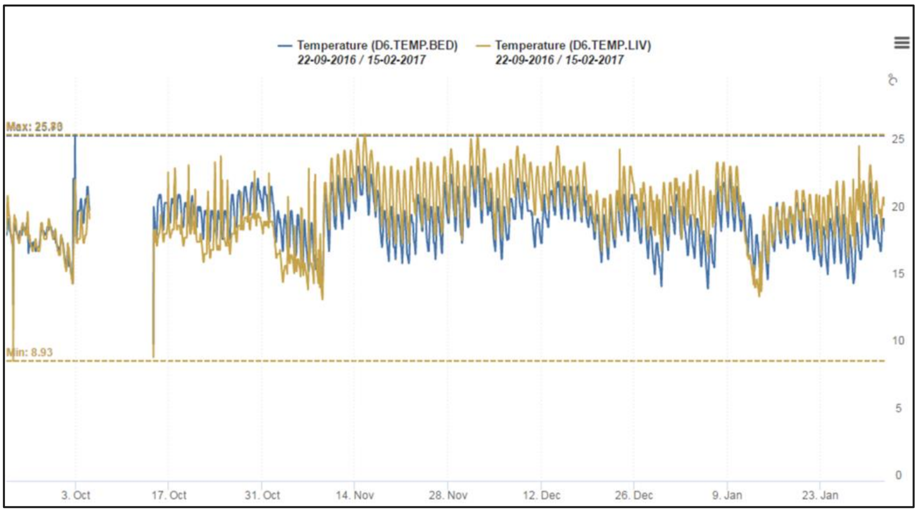


Figure 45: D6. Inside temperature

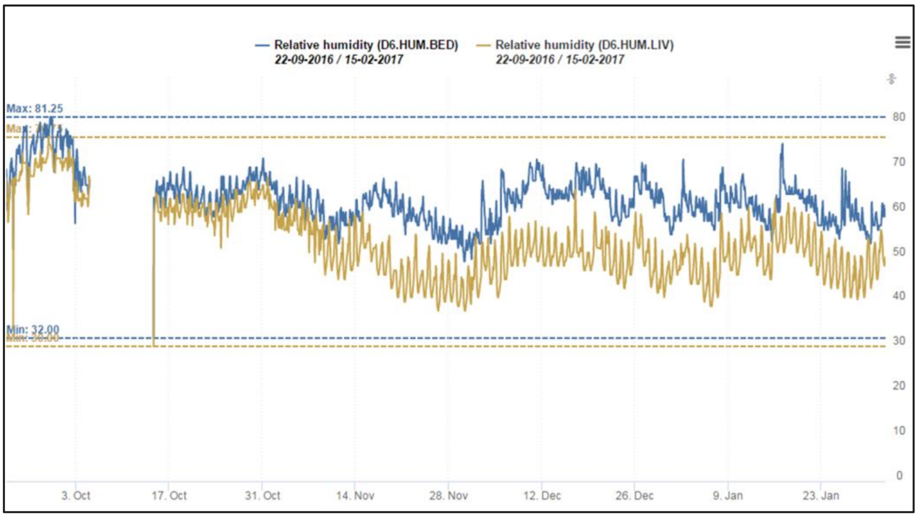


Figure 46: D6. Inside relative humidity

The maximum and minimum values for the temperature and relative humidity inside the dwelling are as follow:

Figure 47: D6. Maximum and minimum values for inside temperature and relative humidity

	TEMPERATURE (º C)		RELATIVE HUMIDITY (%)	
	MAX	MIN	MAX	MIN
LIVINGROOM	25,80	8,93	81,25	32,00
BEDROOM	25,80	10,20	76,75	30,00

As it can be seen in the graphs, there are some peaks in the minimum temperature and minimum relative humidity. Removing these peaks, the values will be around 14ºC and 37 % respectively.

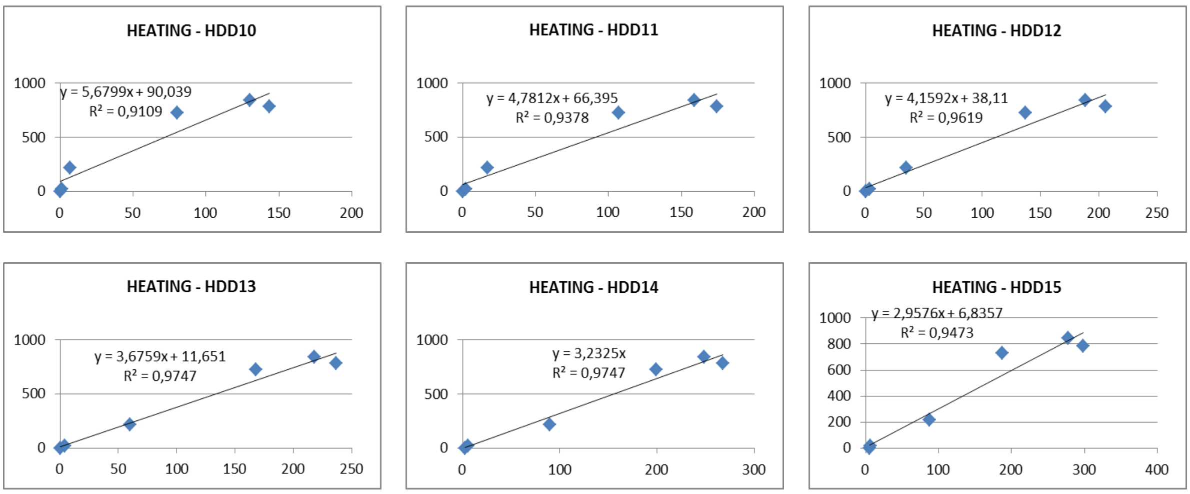
The following chart summarizes the consumptions per item and per month.

	TOTAL	HEATING	DHW
SEP	114,031	0,566	62,349
OCT	494,498	219,193	149,367
NOV	1230,254	843,001	243,766
DEC	1046,471	728,486	154,166
JAN	1154,774	787,206	162,928
FEB	23,036	18,435	1,889

Figure 48: D6. Consumptions per item and per month

4.3.6.1 D6 HEATING SYSTEMS CONSUMPTION

The graphs for the Heating systems consumption are shown below:



The graph for HDD 14 is the one that describes better the evolution of the energy consumption.

The formula that will be used for predicting the heater systems consumption is:

$$y = 3{,}285\ x$$

Were ‘y’ represents the consumption in kWh and the ‘x’ the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 47: D6. ‘Heating’ baseline based values vs. measured values per month

	HDD 14	BS	MEASURED	MEASURED DAYS
SEP	2,40	7,77	0,57	9
OCT	89,39	288,96	219,19	23
NOV	248,13	802,09	843,00	30
DEC	199,11	643,61	728,49	25
JAN	267,59	864,98	787,21	31
FEB	5,34	17,26	18,44	1

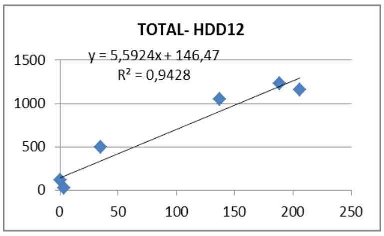
Table 48: D6. ‘Heating’ baseline based values vs. measured values in the period

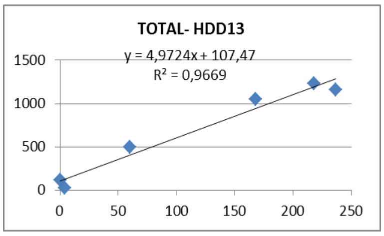
	HDD 14	BS	MEASURED	DIF	% ERROR
TOTAL	811,96	2624,66	2596,89	27,78	1

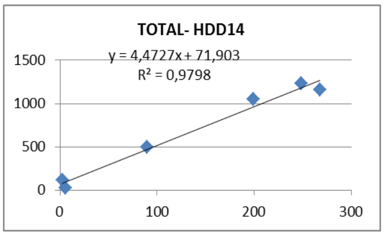
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Heating consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

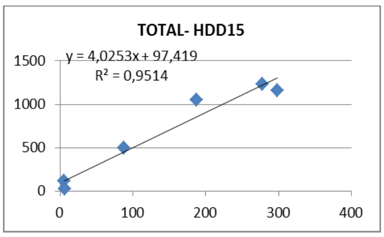
4.3.6.2 D6 TOTAL CONSUMPTION

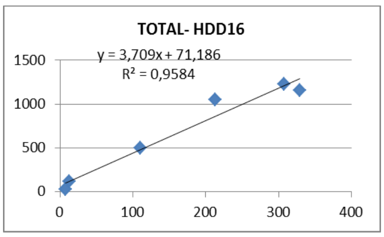
The graphs for the Total consumption are shown below:

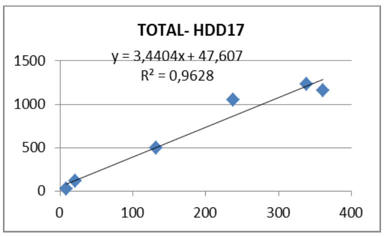












Since the HDD value for heating systems used was HDD 14, the formula that will be used for predicting the 'Total' consumption is:

$$y = 4{,}4727x + 71{,}903$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 49: D6. 'Total' baseline based values vs. measured values per month

	HDD 14	BS	MEASURED	MEASURED DAYS
SEP	2,40	82,65	114,03	9
OCT	89,39	471,73	494,50	23
NOV	248,13	1181,72	1230,25	30
DEC	199,11	962,45	1046,47	25
JAN	267,59	1268,74	1154,77	31
FEB	5,34	95,78	23,04	1

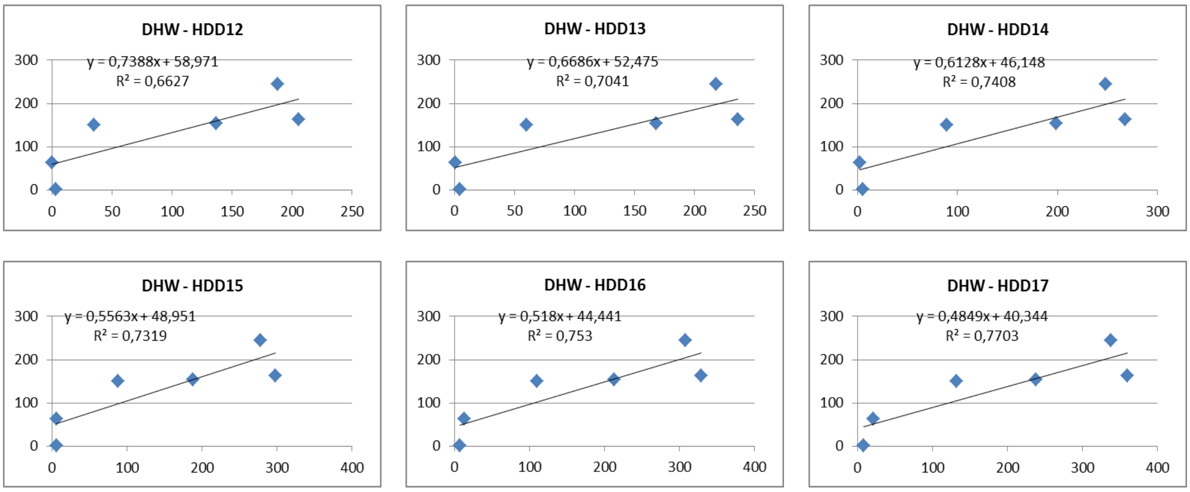
Table 50: D6. 'Total' baseline based values vs. measured values in the period

	HDD 14	BS	MEASURED	DIF	% ERROR
TOTAL	811,96	4063,07	4063,06	0,01	0

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Total consumption. Anyway, the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.6.3 D6 DOMESTIC HOT WATER

The graphs for the DHW consumption are shown below:



Since the HDD value for heating systems used was HDD 14, the formula that will be used for predicting the DHW consumption is:

$$y = 0{,}6128x + 46{,}148$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 51: D6. 'DHW' baseline based values vs. measured values per month

	HDD 14	BS	MEASURED	MEASURED DAYS
SEP	2,40	45,79	55,36	9
OCT	89,39	106,26	161,37	23
NOV	248,13	216,60	232,80	30
DEC	199,11	182,52	166,86	25
JAN	267,59	230,12	209,16	31
FEB	5,34	47,83	3,60	1

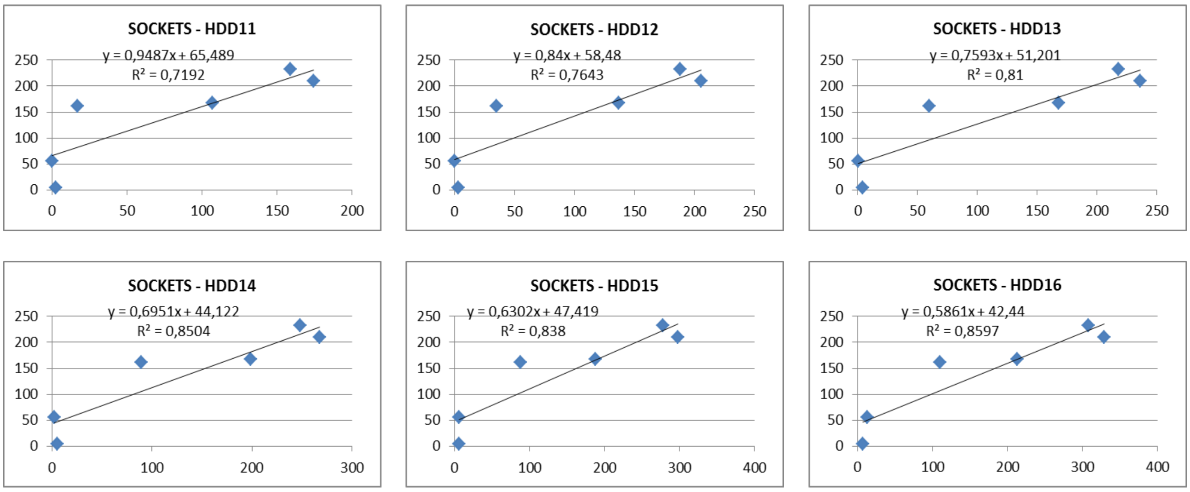
Table 52: D6. 'DHW' baseline based values vs. measured values in the period

	HDD 14	BS	MEASURED	DIF	% ERROR
TOTAL	811,96	829,13	829,15	-0,03	0

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the DHW consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.6.4 D6 SOCKETS CONSUMPTION

The graphs for the Sockets consumption are shown below:



Since the HDD value for heating systems used was HDD 14, the formula that will be used for predicting the Sockets consumption is:

$$y = 0{,}6951x + 44{,}122$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 53: D6. 'Sockets' baseline based values vs. measured values per month

	HDD 14	BS	MEASURED	MEASURED DAYS
SEP	2,40	45,79	55,36	9
OCT	89,39	106,26	161,37	23
NOV	248,13	216,60	232,80	30
DEC	199,11	182,52	166,86	25
JAN	267,59	230,12	209,16	31
FEB	5,34	47,83	3,60	1

Table 54: D6. 'Sockets' baseline based values vs. measured values in the period

	HDD 14	BS	MEASURED	DIF	% ERROR
TOTAL	811,96	829,13	829,15	-0,03	0

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the sockets consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.7 Analysis for dwelling D7

The characteristics of this dwelling are as follow:

- 2 floor.
- 3 bedroom.
- 3 tenant.
- 1 auxiliary electric panel de 2000 W.

The variation of the temperature inside the dwelling over the months is showed in the next figure:

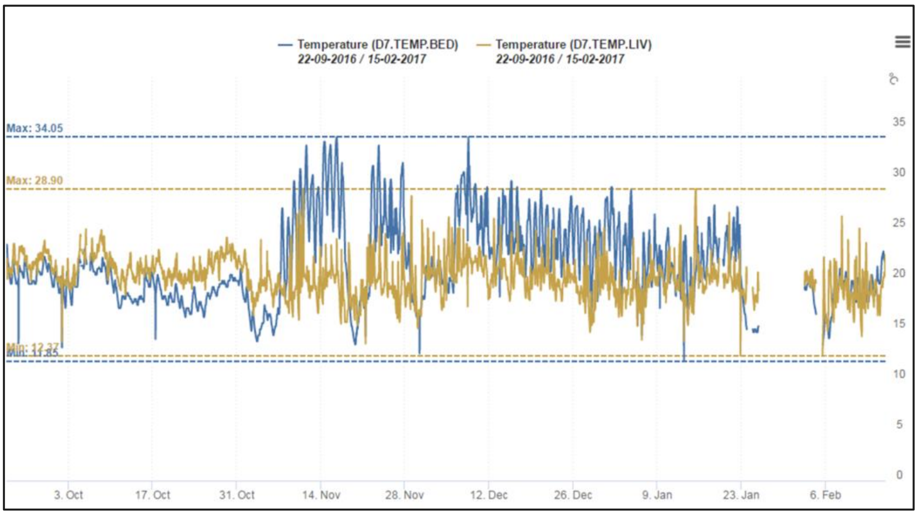


Figure 49: D7. Inside temperature

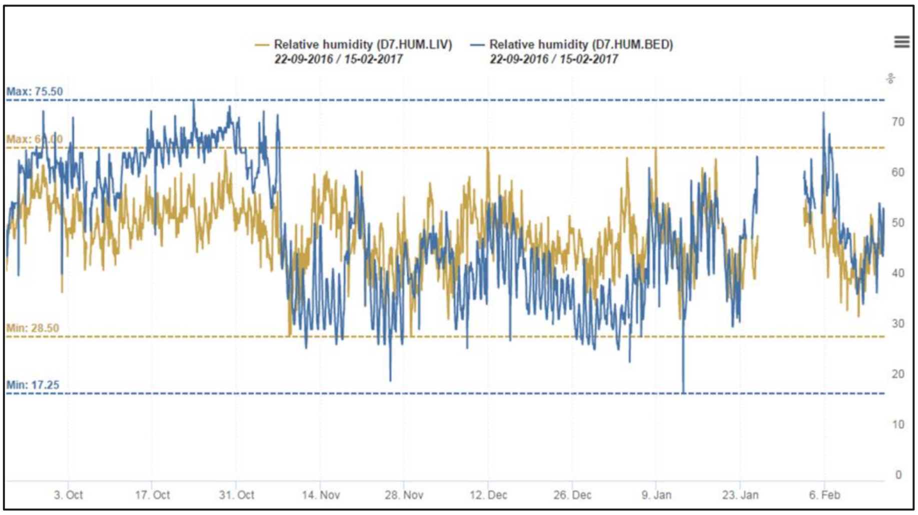


Figure 50: D7. Inside relative humidity

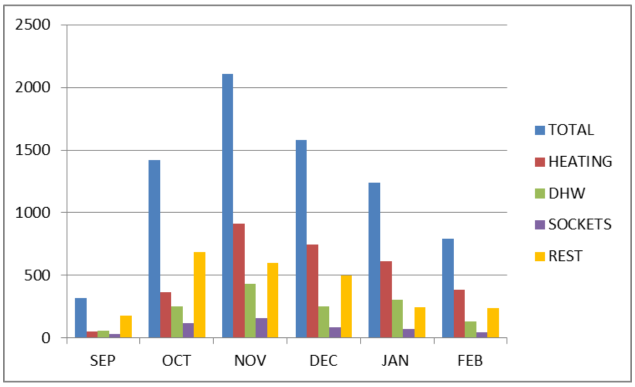
The maximum and minimum values for the temperature and relative humidity inside the dwelling are as follow:

Figure 51: D7. Maximum and minimum values for inside temperature and relative humidity

	TEMPERATURE (º C)		RELATIVE HUMIDITY (%)	
	MAX	MIN	MAX	MIN
LIVINGROOM	28,90	12,37	66,00	28,50
BEDROOM	34,05	11,85	75,50	17,25

As it can be seen in the graphs, there are some peaks in the minimum temperature and minimum relative humidity. Removing these peaks, the values will be around 14ºC and 37 % respectively.

The following chart summarizes the consumptions per item and per month.

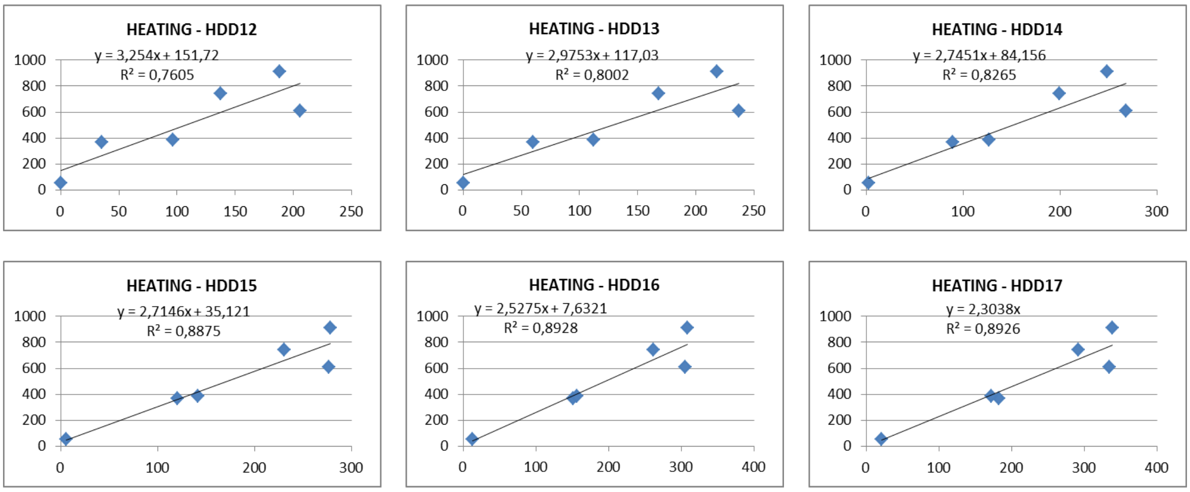


'REST' refers to the consumption that have not been measured i.e. the difference between the 'TOTAL' value minus the sum of the other monitoring items (heating, DHW and sockets).

Figure 52: D7. Monthly consumption (kWh)

4.3.7.1 D7 HEATING SYSTEMS CONSUMPTION

The graphs for the Heating systems consumption are shown below:



The graph for HDD 16 is the one that describes better the evolution of the energy consumption.

The formula that will be used for predicting the heater systems consumption is:

$$y = 2{,}5275x + 7{,}6321$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 55: D7. 'Heating' baseline based values vs. measured values per month

	HDD 16	BS	MEASURED	MEASURED DAYS
SEP	12,65	39,61	53,11	9
OCT	151,39	390,28	365,40	31
NOV	308,13	786,44	911,04	30
DEC	261,11	667,58	742,80	25
JAN	305,33	779,35	611,79	21
FEB	156,77	403,87	383,03	14

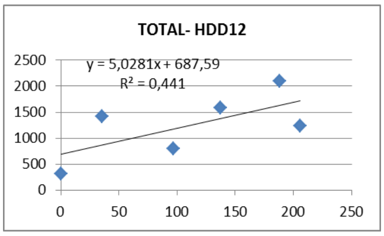
Table 56: D7. 'Heating' baseline based values vs. measured values in the period

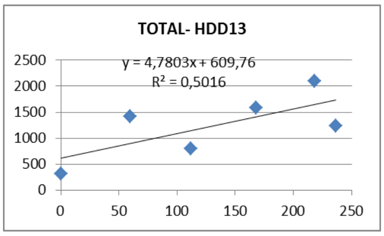
	HDD 16	BS	MEASURED	DIF	% ERROR
TOTAL	1195,38	3067,13	3067,17	-0,04	0

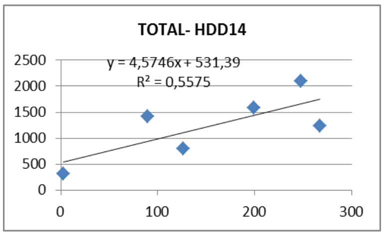
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Heating consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

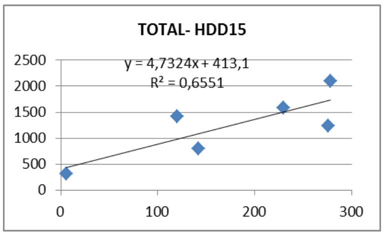
4.3.7.2 D7 TOTAL CONSUMPTION

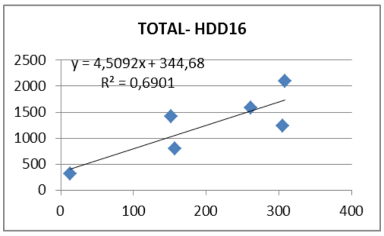
The graphs for the Total consumption are shown below:

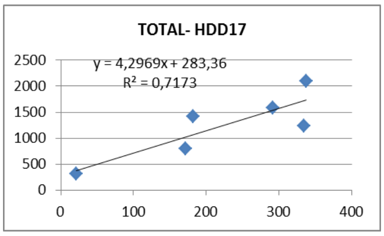












Since the HDD value for heating systems used was HDD 16, the formula that will be used for predicting the 'Total' consumption is:

$$y = 4{,}5092x + 344{,}68$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 57: D7. 'Total' baseline based values vs. measured values per month

	HDD 16	BS	MEASURED	MEASURED DAYS
SEP	12,65	401,73	320,44	9
OCT	151,39	1027,34	1421,55	31
NOV	308,13	1734,11	2104,11	30
DEC	261,11	1522,06	1579,43	25
JAN	305,33	1721,47	1239,60	21
FEB	156,77	1051,60	793,14	14

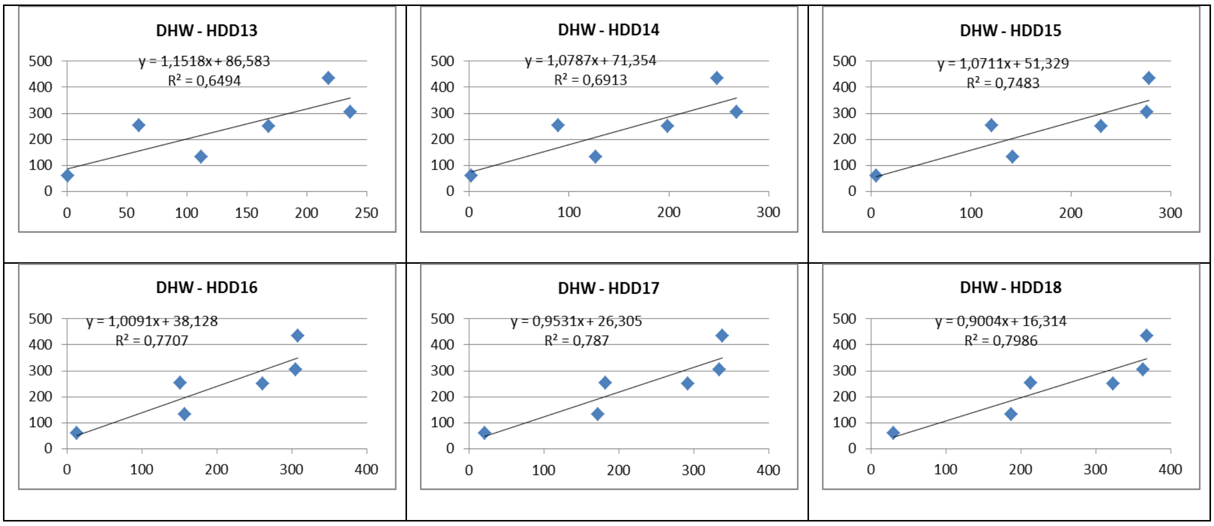
Table 58: D7. 'Total' baseline based values vs. measured values in the period

	HDD 16	BS	MEASURED	DIF	% ERROR
TOTAL	1195,38	7458,31	7458,28	0,00	0

As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Total consumption. Anyway, the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.7.3 D7 DOMESTIC HOT WATER

The graphs for the DHW consumption are shown below:



Since the HDD value for heating systems used was HDD 16, the formula that will be used for predicting the DHW consumption is:

$$y = 1{,}0091x + 38{,}128$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 59: D7. 'DHW' baseline based values vs. measured values per month

	HDD 16	BS	MEASURED	MEASURED DAYS
SEP	12,65	50,90	60,13	9
OCT	151,39	190,90	252,42	31
NOV	308,13	349,06	435,77	30
DEC	261,11	301,61	249,25	25
JAN	305,33	346,24	305,85	21
FEB	156,77	196,33	131,61	14

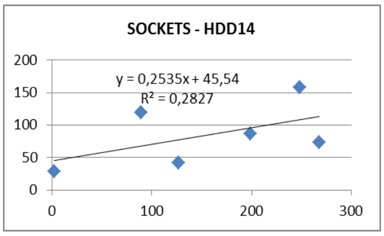
Table 60: D7. 'DHW' baseline based values vs. measured values in the period

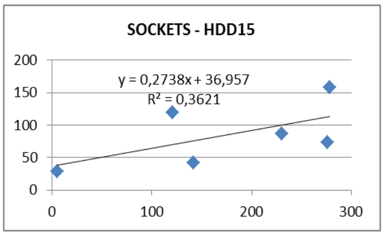
	HDD 16	BS	MEASURED	DIF	% ERROR
TOTAL	1195,38	1435,03	1435,01	0,02	0

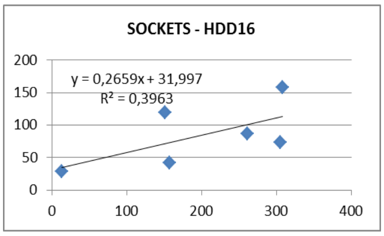
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the DHW consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.7.4 D7 SOCKETS CONSUMPTION

The other item that is being monitored i.e. Sockets consumption does not have any relationship with the exterior temperature as it can be seen in the following graphs.







4.3.8 Analysis for dwelling D8

The characteristics of this dwelling are as follow:

- 2 floor.
- 3 bedroom.
- 3 tenant.
- 1 auxiliary electric panel de 2000 W.

The variation of the temperature inside the dwelling over the months is showed in the next figure:

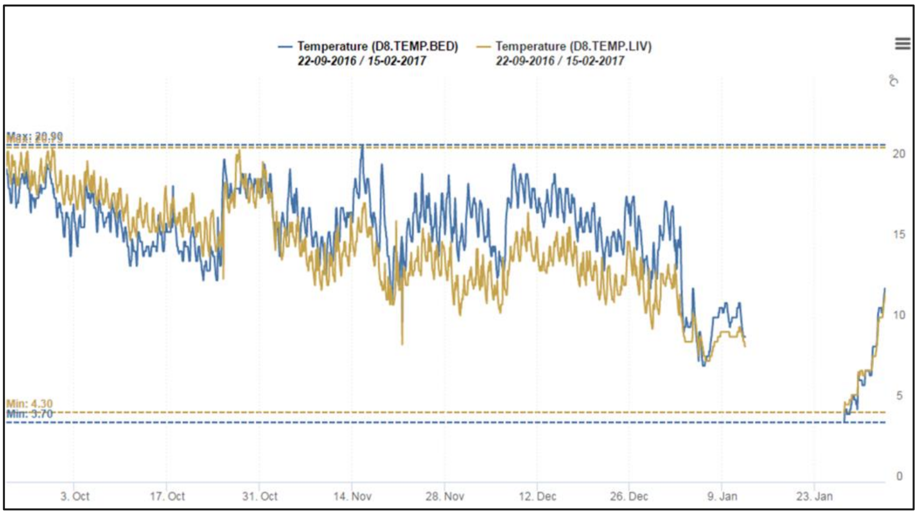


Figure 53: D8. Inside temperature

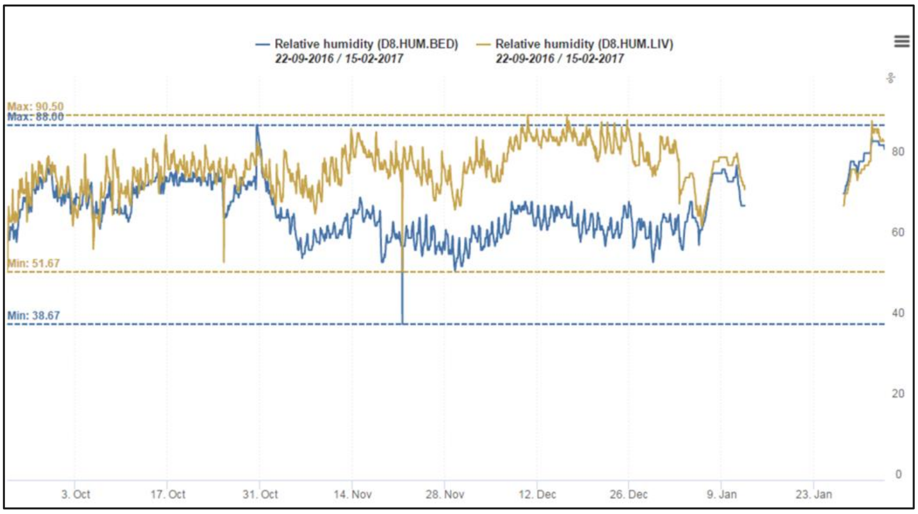


Figure 54: D8. Inside temperature humidity

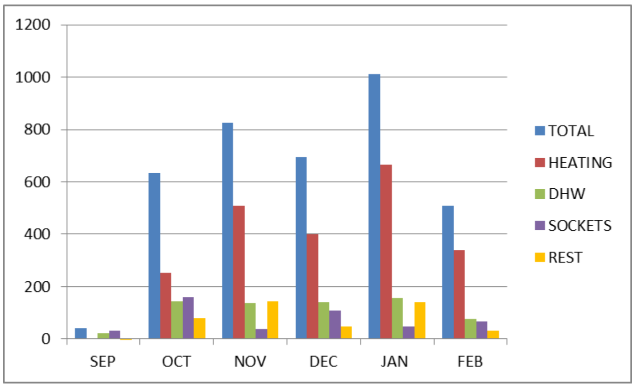
The maximum and minimum values for the temperature and relative humidity inside the dwelling are as follow:

Figure 55: D8. Maximum and minimum values for inside temperature and relative humidity

	TEMPERATURE (º C)		RELATIVE HUMIDITY (%)	
	MAX	MIN	MAX	MIN
LIVINGROOM	28,90	4,30	90,50	51,67
BEDROOM	34,05	3,70	88,00	38,67

Tenants for dwelling D8 left in January 12th so removing the values after that date and the peaks the minimum values for temperature and relative humidity are 11ºC and 51%.

The following chart summarizes the consumptions per item and per month.

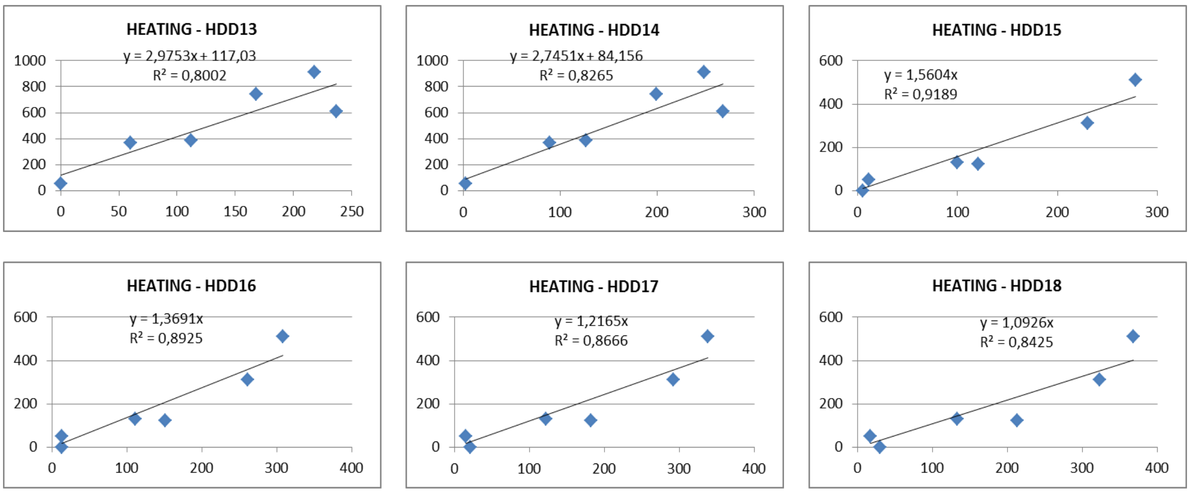


'REST' refers to the consumption that have not been measured i.e. the difference between the 'TOTAL' value minus the sum of the other monitoring items (heating, DHW and sockets).

Figure 56: D4. Monthly consumption (kWh)

4.3.8.1 D8 HEATING SYSTEMS CONSUMPTION

The graphs for the Heating systems consumption are shown below:



The graph for HDD 15 is the one that describes better the evolution of the energy consumption.

The formula that will be used for predicting the heater systems consumption is:

$$y = 1{,}5604x$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 61: D8. 'Heating' baseline based values vs. measured values per month

	HDD 15	BS	MEASURED	MEASURED DAYS
SEP	5,52	8,62	0,53	9
OCT	120,39	187,86	121,34	31
NOV	278,13	434,00	511,94	30
DEC	230,11	359,06	310,30	25
JAN	99,94	155,94	128,25	17
FEB	11,02	17,20	49,71	2

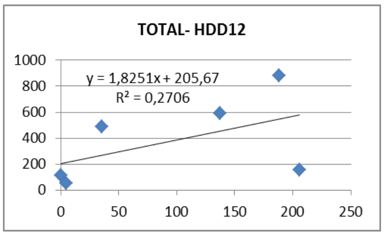
Table 62: D8. 'Heating' baseline based values vs. measured values in the period

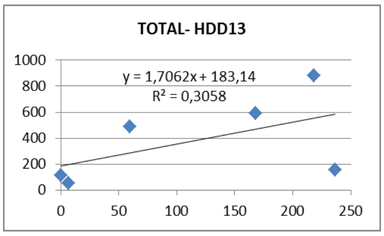
	HDD 15	BS	MEASURED	DIF	% ERROR
TOTAL	745,11	1162,67	1122,06	40,61	4

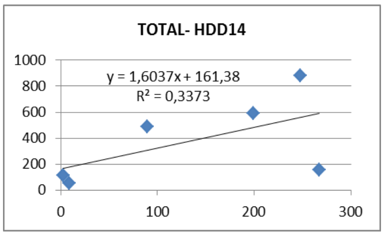
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Heating consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

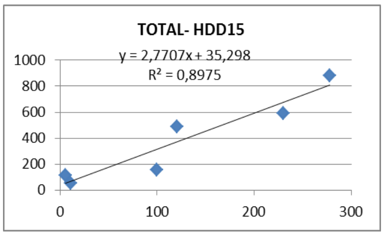
4.3.8.2 D8 TOTAL CONSUMPTION

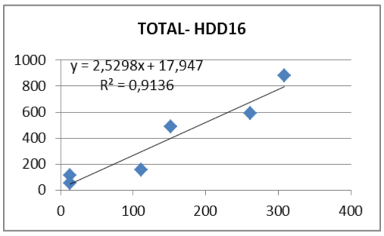
The graphs for the Total consumption are shown below:

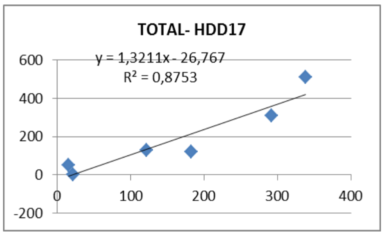












Since the HDD value for heating systems used was HDD 15, the formula that will be used for predicting the 'Total' consumption is:

$$y = 2{,}7707x + 35{,}298$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 63: D8. 'Total' baseline based values vs. measured values per month

	HDD 15	BS	MEASURED	MEASURED DAYS
SEP	5,52	50,60	112,69	9
OCT	120,39	368,87	488,41	31
NOV	278,13	805,92	878,47	30
DEC	230,11	672,85	589,25	25
JAN	99,94	312,19	157,09	17
FEB	11,02	65,84	50,39	2

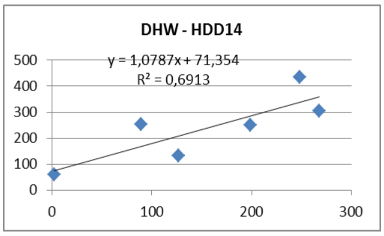
Table 64: D8. 'Total' baseline based values vs. measured values in the period

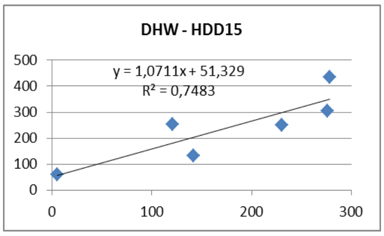
	HDD 15	BS	MEASURED	DIF	% ERROR
TOTAL	745,11	2276,27	2276,30	-0,02	0

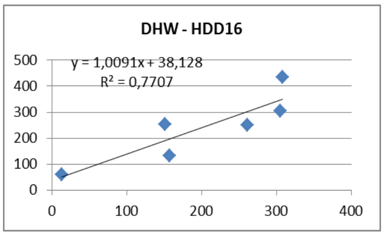
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Total consumption. Anyway, the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.8.3 D8 DOMESTIC HOT WATER

The graphs for the DHW consumption are shown below:







Since the HDD value for heating systems used was HDD 15, the formula that would be used for predicting the DHW consumption is:

$$y = 1{,}0711x + 51{,}329$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 65: D8. 'DHW' baseline based values vs. measured values per month

	HDD 15	BS	MEASURED	MEASURED DAYS
SEP	5,52	57,24	9,64	9
OCT	120,39	180,28	27,57	31
NOV	278,13	349,24	27,47	30
DEC	230,11	297,80	26,53	25
JAN	99,94	158,37	4,18	17
FEB	11,02	63,13	0,09	2

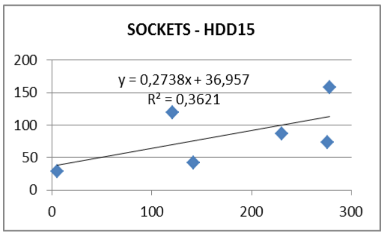
Table 66: D8. 'DHW' baseline based values vs. measured values in the period

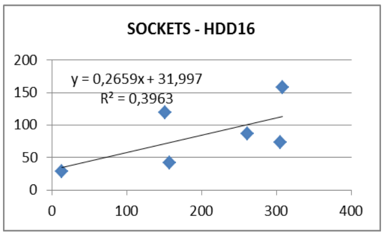
	HDD 16	BS	MEASURED	DIF	% ERROR
TOTAL	745,11	1106,06	95,47	1010,60	1059

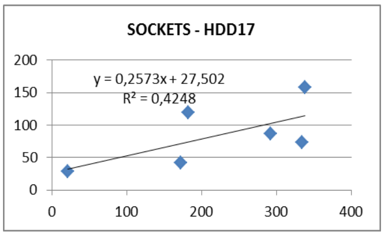
From the table it can be said that DHW consumption is not dependent on the exterior temperature.

4.3.8.4 D8 SOCKETS CONSUMPTION

The other item that is being monitored i.e. Sockets consumption does not have any relationship with the exterior temperature as it can be seen in the following graphs.







4.3.9 Analysis for dwelling D9

The characteristics of this dwelling are as follow:

- 2 floor.
- 3 bedroom.
- 3 tenant.
- 1 auxiliary electric panel de 2000 W.

The variation of the temperature inside the dwelling over the months is showed in the next figure:

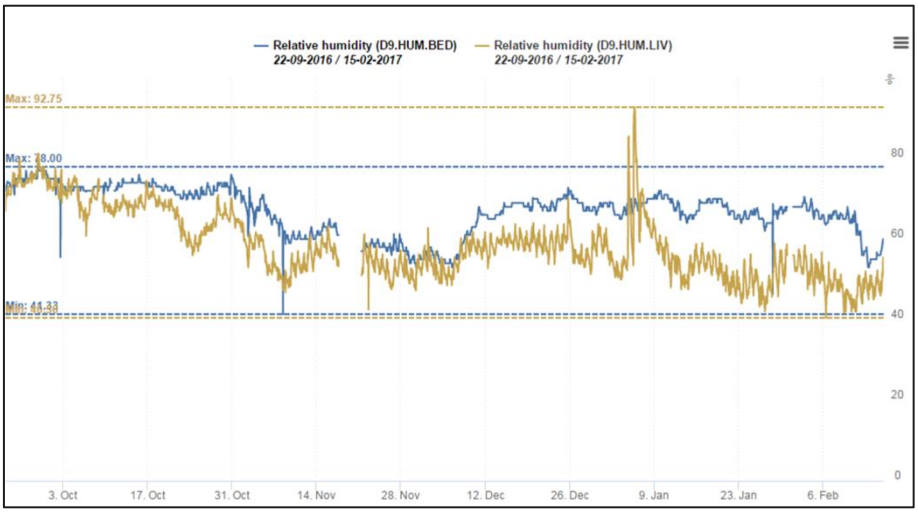


Figure 57: Inside temperature

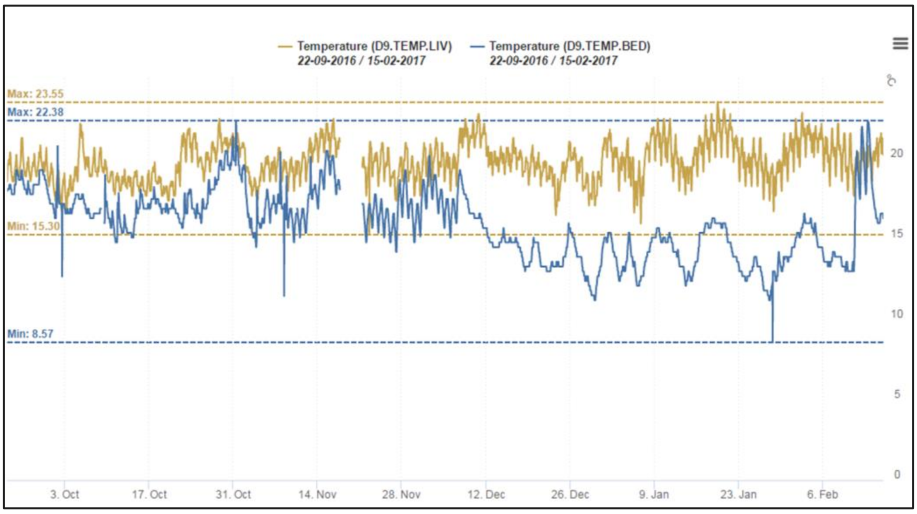


Figure 58: Inside relative humidity

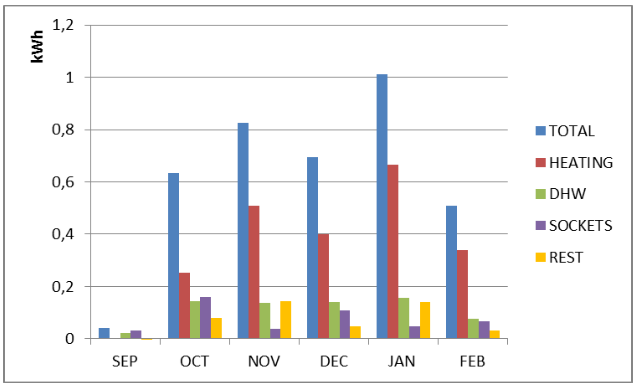
The maximum and minimum values for the temperature and relative humidity inside the dwelling are as follow:

Table 59: D9. Maximum and minimum values for inside temperature and relative humidity

	TEMPERATURE (º C)		RELATIVE HUMIDITY (%)	
	MAX	MIN	MAX	MIN
LIVINGROOM	23,55	15,30	92,75	40,50
BEDROOM	22,38	8,57	78,00	41,33

As it can be seen in the graphs, there are some peaks in the minimum temperature. Removing these peaks, the value will be around 11ºC for the bedroom.

The following chart summarizes the consumptions per item and per month.

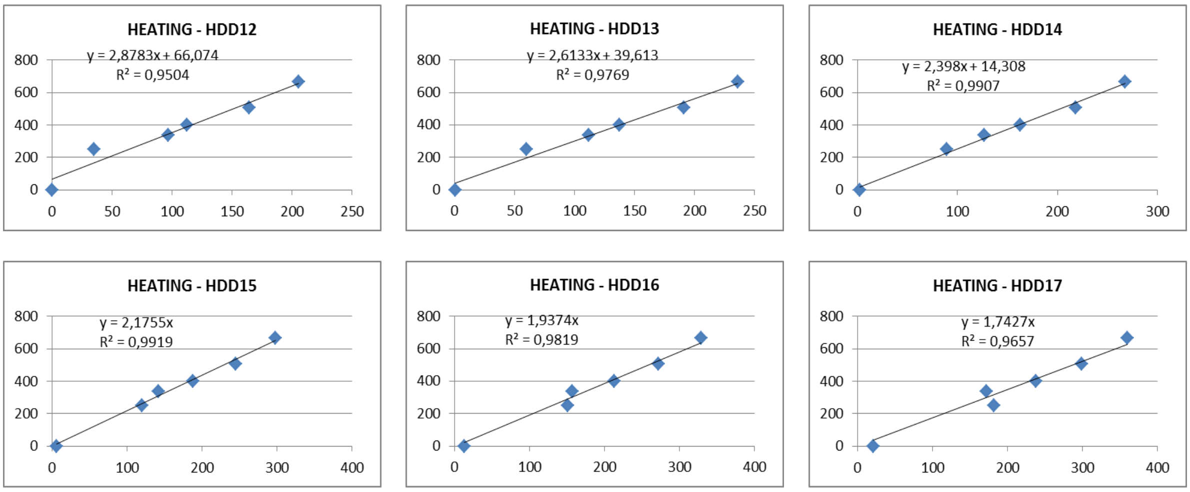


'REST' refers to the consumption that have not been measured i.e. the difference between the 'TOTAL' value minus the sum of the other monitoring items (heating, DHW and sockets).

Figure 60: D9. Monthly consumption (kWh)

4.3.9.1 D9 HEATING SYSTEMS CONSUMPTION

The graphs for the Heating systems consumption are shown below:



The graph for HDD 15 is the one that describes better the evolution of the energy consumption.

The formula that will be used for predicting the heater systems consumption is:

$$y = 2{,}1755x$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 67: D9. 'Heating' baseline based values vs. measured values per month

	HDD 15	BS	% ERROR	MEASURED DAYS
SEP	5,52	12,02	2588	5
OCT	120,39	261,91	4	31
NOV	245,12	533,26	5	27
DEC	187,64	408,22	2	25
JAN	298,59	649,58	2	31
FEB	141,77	308,42	9	15

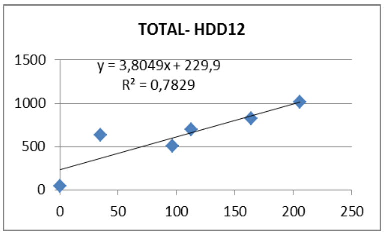
Table 68: D9. 'Heating' baseline based values vs. measured values in the period

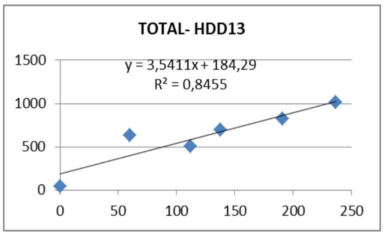
	HDD 16	BS	MEASURED	DIF	% ERROR
TOTAL	999,04	2173,41	2164,74	8,67	0

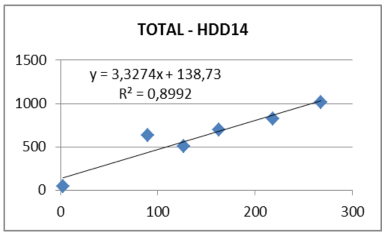
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Heating consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

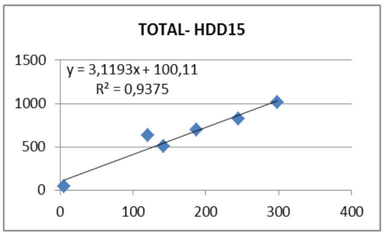
4.3.9.2 D9 TOTAL CONSUMPTION

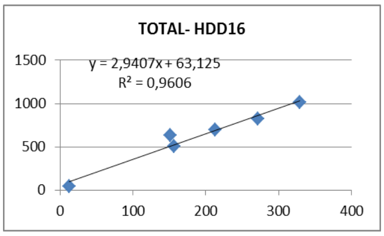
The graphs for the Total consumption are shown below:

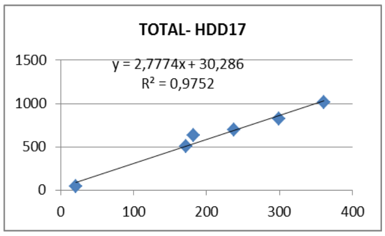












Since the HDD value for heating systems used was HDD 15, the formula that will be used for predicting the 'Total' consumption is:

$$y = 3{,}1193x + 100{,}11$$

Were 'y' represents the consumption in kWh and the 'x' the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 69: D9. 'Total' baseline based values vs. measured values per month

	HDD 15	BS	MEASURED	MEASURED DAYS
SEP	5,52	117,34	42,26	5
OCT	120,39	475,65	634,81	31
NOV	245,12	864,72	825,08	27
DEC	187,64	685,43	694,97	25
JAN	298,59	1031,49	1011,28	31
FEB	141,77	542,34	508,54	15

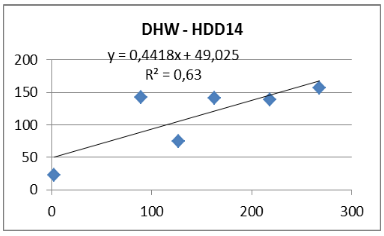
Table 70: D9. 'Total' baseline based values vs. measured values in the period

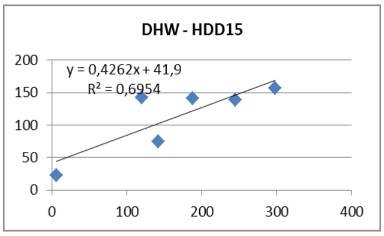
	HDD 15	BS	MEASURED	DIF	% ERROR
TOTAL	999,04	2173,41	2164,74	8,67	0

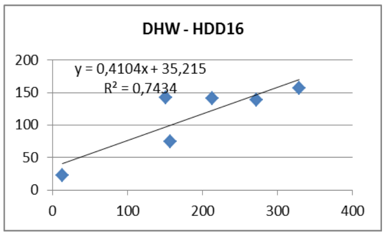
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the Total consumption. Anyway, the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.9.3 D9 DOMESTIC HOT WATER

The graphs for the DHW consumption are shown below:







Since the HDD value for heating systems used was HDD 15, the formula that will be used for predicting the DHW consumption is:

$$y = 0{,}4262x + 41{,}9$$

Were ‘y’ represents the consumption in kWh and the ‘x’ the Heating Degree Days per month.

Applying the formula to the data got during the observation period, the differences between the estimations and the reality are showed in the following table:

Table 71: D9. ‘DHW’ baseline based values vs. measured values per month

	HDD 15	BS	MEASURED	MEASURED DAYS
SEP	5,52	44,25	22,97	5
OCT	120,39	93,21	142,32	31
NOV	245,12	146,37	138,70	27
DEC	187,64	121,87	141,34	25
JAN	298,59	169,16	156,73	31
FEB	141,77	102,32	75,15	15

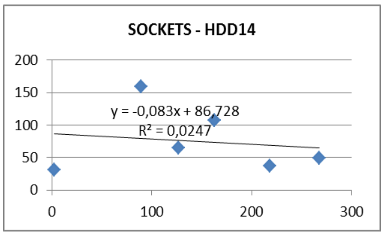
Table 72: D9. ‘DHW’ baseline based values vs. measured values in the period

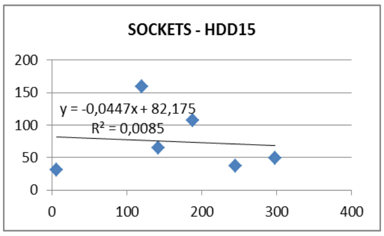
	HDD 15	BS	MEASURED	DIF	% ERROR
TOTAL	999,04	677,19	677,20	-0,01	0

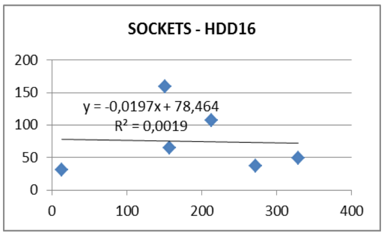
As it can be seen from the table the calculate values are very close to the measurements, that means the formula can be used for estimating the DHW consumption. Anyway the observation period should, at least, cover a year in order to validate correctly the values for the different seasons.

4.3.9.4 D9 SOCKETS CONSUMPTION

The other item that is being monitored i.e. Sockets consumption does not have any relationship with the exterior temperature as it can be seen in the following graphs.







5 ENERGY PERFORMANCE LANDSKRONA-BUILDING BEFORE RENOVATION.

5.1 INITIAL INFORMATION.

Table 73: Landskronahem pilot initial information summary

LANDSKRONAHEM PILOT INITIAL INFORMATION REQUESTED.	Initial Availability	AGENT INVOLVED	SCOPE	TIPOLOGY	FREQUENCY	2012	2013	2014	2015
ENERGY CONSUMPTIONS.									
DISTRICT HEATING. (HEATING&DHW) B11,13,15,17,19	NO	LANDSKRONA ENERGY	Sum 5 Buildings	MEASURED	HOURLY		available	available	available
DISTRICT HEATING. (HEATING&DHW) B11,13,15,17,19	NO	LANDSKRONAHEM (BMS)	Sum 5 Buildings	NORMALIZED	MONTHLY	available	available	available	available
ELECTRIC CONSUMPTION (COMMUNAL INSTALLATIONS)	NO	LANDSKRONA ENERGY	Each Building.	MEASURED	MONTHLY		available	available	available
ELECTRIC CONSUMPTION (COMMUNAL INSTALLATIONS)	NO	LANDSKRONA ENERGY	Each Building.	MEASURED	HOURLY				available
ELECTRIC CONSUMPTION TENANTS AGGREGATE.	NO	LANDSKRONA ENERGY	Each Building.	MEASURED	HOURLY				available
M3 DHW	NO	LANDSKRONA ENERGY	Sum 5 Buildings	MEASURED		available	available	available	available
INDOOR TEMPERATURE	NO	LANDSKRONAHEM (ECOGUARD)	Each Flat,	MEASURED	HOURLY				available from dic2015
	NO		5 Buildings.						
VENTILATION	NO				NONE AVAILABLE DATA				
EXAUSTED AIR HEAT PUMP.	NO	LANDSKRONAHEM	Building 1	ESTIMATION: Through DH Production and Electric Consumption.					
BUILDING DESCRIPTION. (drawings technical description)									
Arquitectonical	YES	LANDSKRONAHEM	Basic description provided						
Electric installation	NO	LANDSKRONAHEM	Basic description provided						
HAVC installation.	NO	LANDSKRONAHEM	Basic description provided						
SOCIOLOGICAL CHARACTERISITC									
Number of tenants per dwelling	NO	LANDSKRONAHEM	Not Provided yet						
Family status.	NO	LANDSKRONAHEM	It is been imposible to perform tenants interviews before renovations.						

5.2 ENERGY CONSUMPTION DESCRIPTION.

In this section, it would be presented the initial data and the calculations for the energy consumption breakdown at the buildings included in this project. The Buildings included in this project are B13, B15, B17, and B19. Building 11 it is not involved in the renovation Program of Dreeam Project but it has to be considered in this analysis because it is included in the same net of District Heating. Therefore, its energy consumption will be included in some of the tables where the different results will be presented.

5.2.1 DISTRICT HEATING SYSTEM.

This section describes the evolution of the energy consumption by the district heating supply system during the last two years. As it is known, the district heating system substation is located at building's 11 basement, which connects the network with the rest of buildings.

It must be remarked that the heating system meter is placed before the network splits into both Heating (DH) and domestic hot water (DHW) pipeline systems. Because of this, the meter readings include both of these consumptions, so the first objective of this study will be to identify and separate both consumptions.

Through the available data and the meter readings it has been possible to obtain the graphics shown below, that reflect the evolution on district heating consumption for 2014 and 2015.

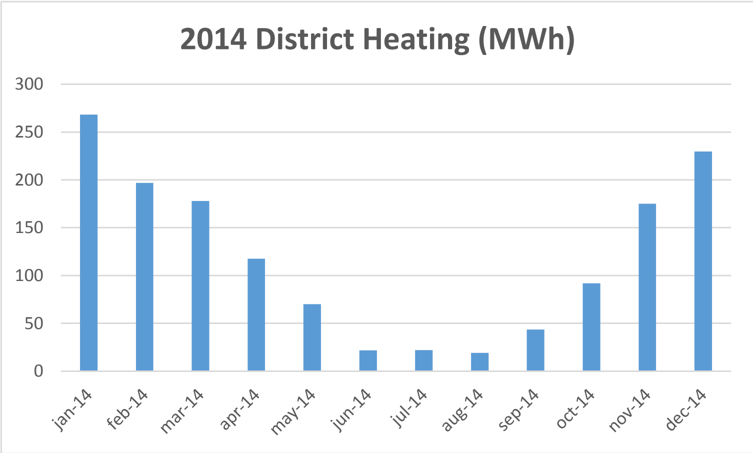


Figure 61: Consumption for heating during 2014

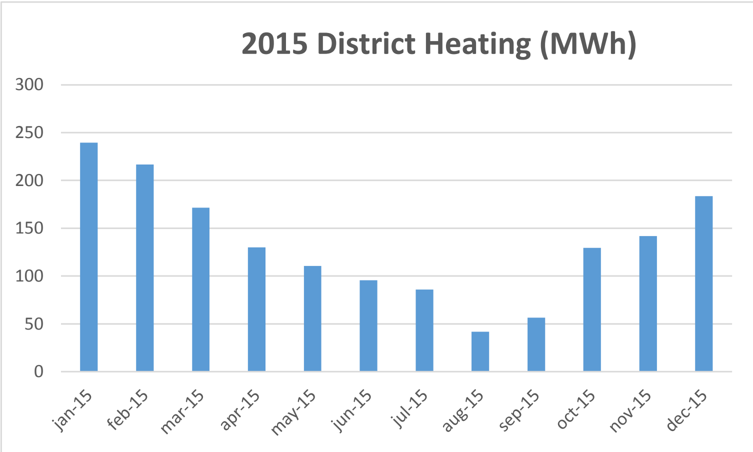


Figure 62: Consumption for heating during 2015

This consumption includes both district heating and domestic hot water consumption. Therefore, attending to the meter readings during summer months and considering that district heating is no needed during this period, the meters read during these months shall correspond directly with the DHW consumption by all the different buildings.

Furthermore, it can be assumed that DHW consumption has similar values for every month, and according to this, if the DHW consumption is subtracted from the rest of monthly readings, it is possible to determine the total amount of energy used by the district heating for each month. Concretely, this DHW consumption has been estimated from summer months of 2014, as it is shown at the figure down below.

Thus, the next graphic have been obtained through this method and they show the total consumption of district heating and domestic hot water separately for 2014 and 2015. The data for 2013 have not been considered because it is not available the data corresponding to January.

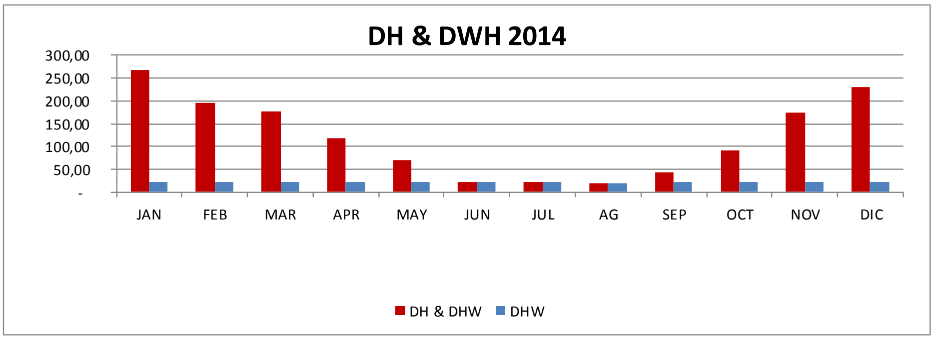


Figure 63: District Heating and Domestic Hot Water consumptions (MWh) for 2014

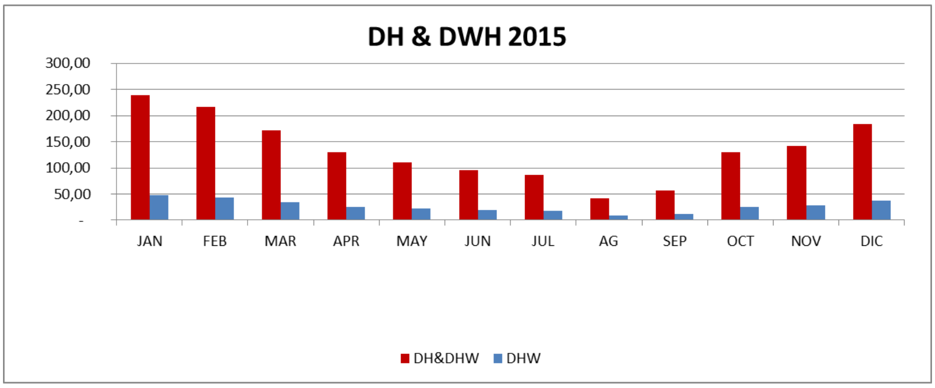


Figure 64: District Heating and Domestic Hot Water consumptions (MWh) for 2015

As it was expected, the consumption during the coolest months is significantly higher than the rest of the year. In order to make this quite more visible, the next graph, extracted from Opendomo platform, shows the consumption by the heating system against the average temperature in Landskrona during 2015.

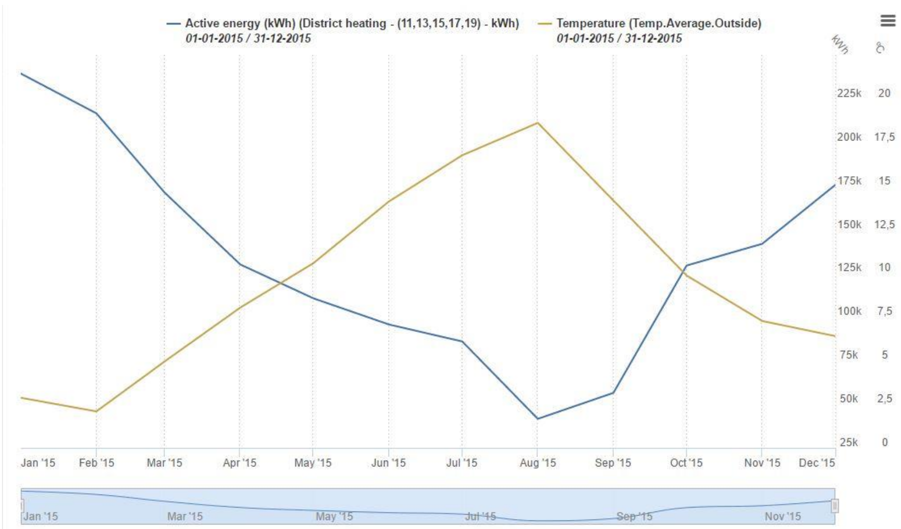


Figure 65: District heating consumption against outside average temperature in 2015

Finally, attending to the different building's areas, heating system consumption can be measured by kWh/m^2 as it is shown at the table down below:

Table 74: DISTRICT HEATING CONSUMPTION 2014

	Area (m^2)	TOT. DISTRICT HEATING (kWh)	HEATING (kWh)	DOMESTIC HOT WATER (kWh)
B11	5196	442.815	362.611	80.204
B13	2144	182.717	149.622	33.094
B15	5196	442.815	362.611	80.204
B17	2144	182.717	149.622	33.094
B19	2144	182.717	149.622	33.094
TOTAL	16.824	1.433.780	1.174.089	259.691
Average kWh/m2		85,22	69,79	15,44

Table 75: DISTRICT HEATING CONSUMPTION 2015

	Area (m^2)	TOT. DISTRICT HEATING (kWh)	HEATING (kWh)	DOMESTIC HOT WATER (kWh)
B11	5.196	494.960	395.968	98.992
B13	2.144	204.233	163.386	40.847
B15	5.196	494.960	395.968	98.992
B17	2.144	204.233	163.386	40.847
B19	2.144	204.233	163.386	40.847
TOTAL	16.824	1.602.620	1.282.096	320.524
Average kWh/m2		95,26	76,21	19,05

As it is explained in the next section Base-line calculation, we considered more representative the data relating to 2014

ELECTRIC CONSUMPTION FOR PUMPING SYSTEM

The heating system substation at building 11' basement is fitted with a Grundfos pump, model MAGNA 3, in order to impulse the heated water all over the rest of the buildings. Comparing electric consumption on communal services at building 11 and 15, which both have lifts and very similar lighting systems, it is possible to estimate the electric consumption for Heating.

Figure 66: GRUNDFOS pump

It must be considered that heating system does not come into operation during the warmest months, because of this, taking a look at differences between electric consumption during winter and summer nights, it is possible to obtain the pump consumption as the only energy consumers are indeed this pump and the night lighting of community areas.

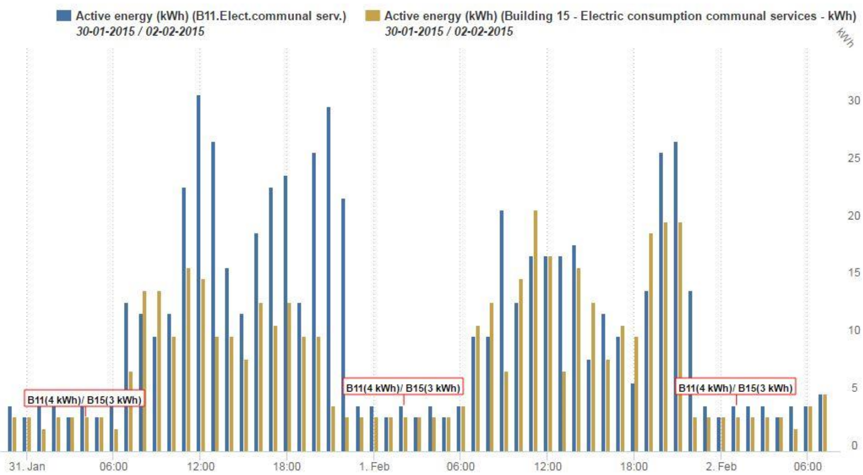


Figure 67: Winter night consumption at communal areas for buildings 11 and 15

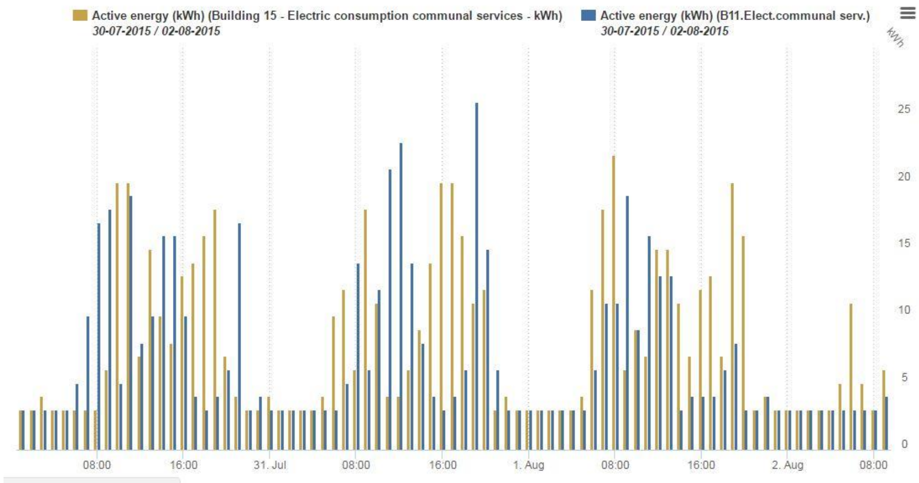


Figure 68: Summer night consumption at communal areas for buildings 11 and 15

The Figures above show that during summer nights, the electric consumption is the same for both buildings 11 and 15, while during winter nights, there is an extra consumption at building 11, caused by the district heating pump operation. Thus, the pump consumption is shown in the previous charts, estimating its power in 1 kW (consumption of 1 kWh operating during one hour).

However, further researches related with the pump model, have shown off that its nominal power is 1.3 kW. Thus, assuming that this pump operates all day during the whole year except a couple of summer months, it has been possible to estimate its associated electric consumption, which is included in the electric consumption on communal services of building 11, as it will be shown in the next table.

This analysis has been performed easily using Opendomo Platform. It is a clear example of the great functionality of Opendomo platform regarding with the graphic analysis of energy consumption comparisons.

Table 76: Electric consumption by the district heating pump

	GRUNDFOS PUMP			
	Power (kW)	Operating hours	Consumpt. (kWh)	Consumpt. /Area (kWh/m^2)
B 11	1,3	7.272,00	9.453,60	1,82

5.2.2 COMMUNAL ELECTRIC CONSUMPTION

The energy consumption on communal services is described throughout this section. Each building has its own meter, which provides the electric consumption by the different communal facilities that can be found in it. Therefore, it would be interesting to break down this consumption into the different systems that contribute to it, such as lifts, lighting system, laundry service, etc.

Lifts

Building 15, which has a total of seven floors, counts with an elevator system that includes two different lifts. Regarding the power installed in both of them, 3.5 kW for staircase A elevator and 5.5 kW for the one of staircase B, providing a total power of 9 kW, it is possible to estimate the consumption of this service by taking a close look at the available data.

Thus, assuming an operating time of about half an hour at the first hours of the morning, it may be possible to determine its associated consumption, which has been estimated in 4-5 kWh according to the installed power.

This first chart, extracted from Opendomo platform, represents a regular working week of June 2015.Thus, it is easy to observe a growth in the electric consumption of around 4-6 kWh, from 3 kWh during the night to 7-9 kWh at the early hours of the morning.

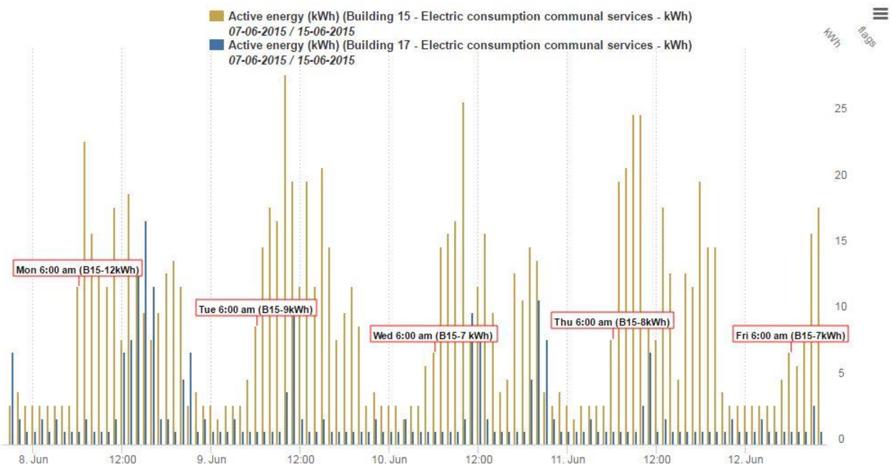


Figure 69: Electric consumption on communal services during a working week, June 2015

In addition, analysing the same hours for a cooler month, it is possible to identify again those consumption peaks due to lifts operation, comparing the basic value of consumption during the night with the one at the early hours of the morning. Thus, as it is shown in the chart of the following page, basic consumption during the night it is around 7-8 kWh, and at around 7:00 AM it gets higher again up to 12-13 kWh, showing off the energy consumption by lifts operation, which is again, around 4-6 kWh.

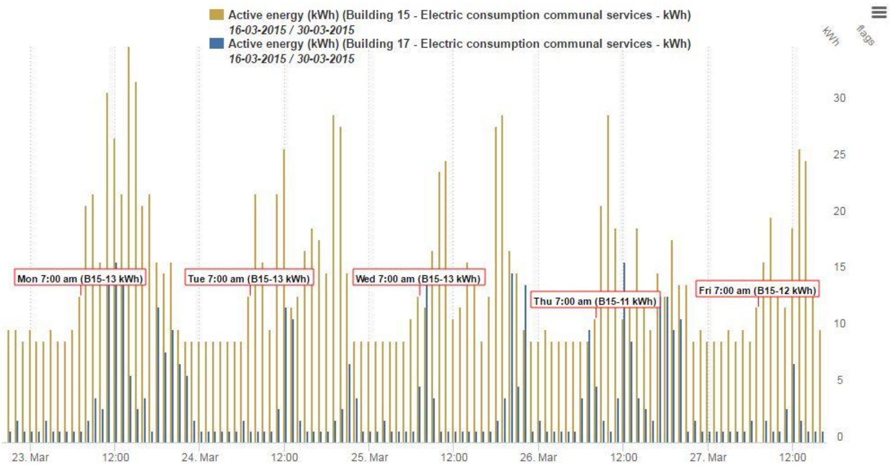


Figure 70: Electric consumption on communal services during a working week, March 2015

Extending this calculation to the whole year, it has been possible to estimate the annual consumption by the lifts usage.

Table 77: Elevator system electric consumption

		LIFTS CONSUMPT. ESTIMATED					
	Area (m^2)	Working day consumpt. (kWh)	No. Days	Weekends consumpt. (kWh)	No. Days	Total Consumpt. (kWh)	Consumpt./Area (kWh/m^2)
B11 & B15	5.196	11	250	5,5	100	3.300,00	0,635

Laundry service

Every building has its own laundry equipment at their basement consisting in a washer machine, a tumble dryer and a cold ironer. All these machines have an associated consumption, which is in fact, an important part of the total electric consumption at communal services. Therefore, it is essential to study these installations.

Thanks to the given information and the data collected during the field visit, it has been possible to make a precise estimation of the energy consumption corresponding to the laundry installations.

All of the equipment belongs to ELECTROLUX brand. Concretely, the washer machines models are W465H and W365H depending of the building while the tumble driers model is T4250. Knowing all these details, it is possible to get the associated power on the laundry service.

Figure 71: Details of the laundry equipment

Thus, handling with the installed power on these machines and other information such as the number of tenants per building, it has been possible to make a first estimation of the electric consumption associated to the laundry usage.

Table 78: laundry consumption

		LAUNDRY								
	Area (m^2)	Washing Machine (kW)	Tumble Dryer (kW)	Hours	Consumpt. /Laundry (kWh)	Days	No. Tenants	No. Laundry	Consumpt. (kWh)	Consumpt. /Area (kWh/m^2)
B11	5196	5,6	9	2	29,2	70	91	20	40.996,80	7,89
B13	2144	5,6	9	2	29,2	70	42	16	32.797,44	15,30
B15	5196	3,6	9	2	25,2	70	102	22	38.918,88	7,49
B17	2144	5,6	9	2	29,2	70	32	11	22.548,24	10,52
B19	2144	3,6	9	2	25,2	70	12	4	7.076,16	3,30
	16824								142.337,52	8,46

Lighting system

The lighting system also represents an important part of the total consumption on communal services for each building, so it is necessary to study it as well. It is essential to separate buildings 11 and 15 from the rest, as these two are quite larger and must have more installed power on their lighting system.

The lighting system consumption of communal areas is represented by the minimum value shown at the following graphic, from Opendomo platform, which is around 1 kWh for buildings 13, 17 and 19. This consumption is measured hour by hour, so it can be said that the total power installed in the lighting system for communal areas at these buildings is around 1 kW.

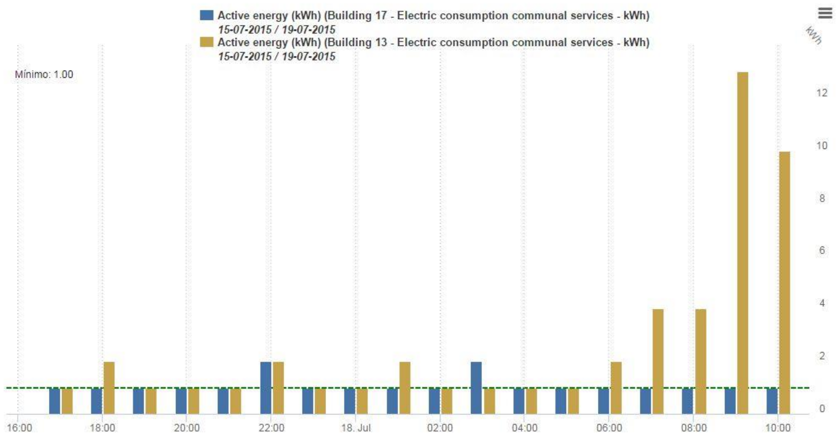


Figure 72: Electric consumption on communal services for buildings 13 and 17

In addition, the following chart shows the electric consumption on communal areas for building 15. As it was expected, the power installed in the lighting system for this building is significantly higher than in the others, around 2-3 kW.

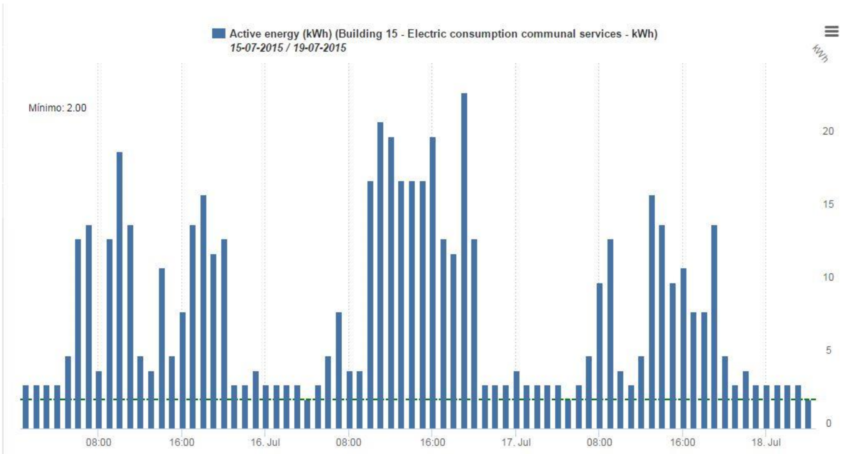


Figure 73: Electric consumption on communal services for building 15

Furthermore, it is possible to calculate the total of hours when the lighting system is operating by looking at the number of annual daylight hours at Landskrona. Therefore, the product of installed power and the number of operating hours by the lighting system provides the total electric consumption on lighting for each building, as it is shown down below:

Table 79: Electric consumption by lighting system

		LIGHTING SYSTEM			
	Area (m^2)	Installed Power (kW)	Lighting hours	Consumpt. (kWh)	Consumpt. /Area (kWh/m^2)
B11	5196	2,5	4265	10.662,50	2,05
B13	2144	1	4265	4.265,00	1,99
B15	5196	2,5	4265	10.662,50	2,05
B17	2144	1	4265	4.265,00	1,99
B19	2144	1	4265	4.265,00	1,99
	16824			34.120,00	2,03

Ventilation

All the buildings counts with a ventilation system, which it is used to renovate the inside air with the outside fresh air. Living-rooms and bedrooms have natural ventilation below the window and behind radiators that ideally heat the fresh air introduced in the apartment, while bathrooms have a ventilation system forced by a little fan, which contribute to the electric consumption on communal services.

Figure 74: Air Intake/ air outlet in the room and forced ventilation at the rooms

It is possible to estimate the power installed in the ventilation system by analysing the electric consumption of communal services. The following chart, extracted also from Opendomo platform, shows this consumption for a couple of days during the month of July 2015, when the only active systems are lighting and ventilation.

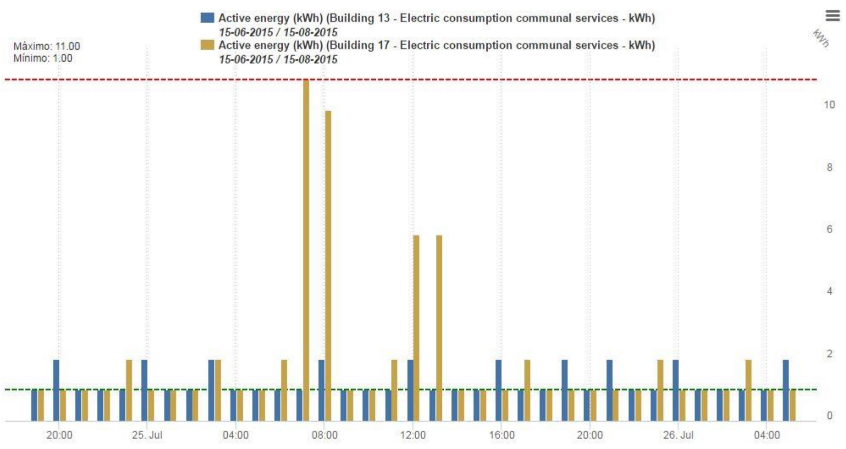


Figure 75: Electric consumption on communal services for buildings 13 and 17. July 2015

Taking a look over this chart, it is easy to observe a regular fluctuation on electric consumption of around 1 kWh during the whole day and night.

This fact is certainly caused by the ventilation system, which comes into operation from time to time. As it can be seen, these time lapses are quite regular and they all have the same value. So, keeping on with this analysis, the lighting system consumption of communal areas is represented by the minimum value shown at the chart as it has been explained before. This means that the value of that fluctuation matches with the consumption of the ventilation system, also 1 kWh per hour, traduced into an installed power on ventilation of around 1 kW for the smaller buildings. .

In addition, the next chart represents the electric consumption at communal areas as well, but now for building 13 and 15. However, it is still possible to notice the same regular fluctuation during night time as in the rest of the buildings, which again corresponds to the ventilation system consumption.

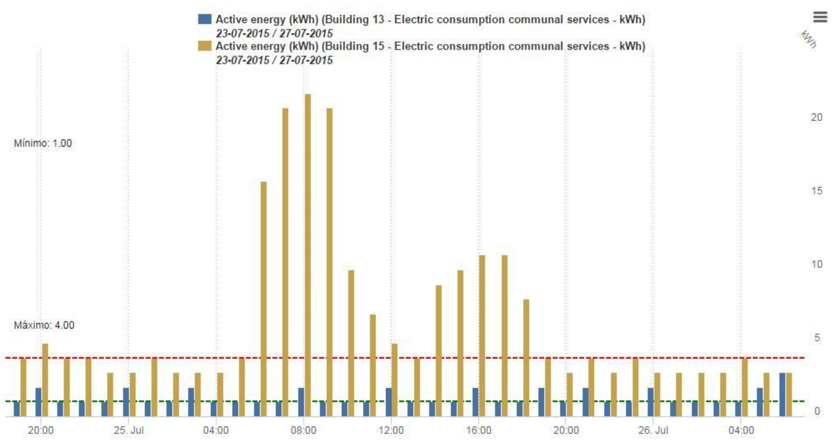


Figure 76: Electric consumption on communal services for buildings 13 and 15. July 2015

Therefore, establishing a total consumption for each operating time of around 1 kWh and 3 kWh for the different buildings, and assuming an interval of 2-3 hours between operation times, it has been possible to estimate the ventilation system consumption as it is shown at the first of the following tables. Furthermore, the second table has been obtained thanks to the electric meter of each building and the data analysis through OD platform. Both of the tables show off a quite similar value for the building consumption.

Table 80: Ventilation system consumption

	Area (m^2)	VENTILATION SYSTEM Operation consumpt. (kWh)	Operating times /day	No. Days	Consumpt. (kWh)	Consumpt. /Area (kWh/m^2)
B11	5196	3	6	365	6570	1,26
B13	2144	1	6	365	2190	1,02
B15	5196	3	6	365	6570	1,26
B17	2144	1	6	365	2190	1,02
B19	2144	1	6	365	2190	1,02
	16824				19710	1,17

	Area (m^2)	VENTILATION SYSTEM Fan power (W)	Fan /lgh	No. Lgh	Operating hours /year	Conumtp. (kWh)	Consumpt. /Area (kWh/m^2)
B11	5196	50	2	56	1095	6132	1,18
B13	2144	50	2	18	1095	1971	0,92
B15	5196	50	2	56	1095	6132	1,18
B17	2144	50	2	18	1095	1971	0,92
B19	2144	50	2	18	1095	1971	0,92
	16824					18177	1,08

Exhaust air heat pump

It should be remarked as well that there is an exhaust air heat pump installed at buildings 11 and 15, which are used for recover part of the heat used by the district heating system, reducing then the total consumption on the heating supply system.

It must be noted that these pump are only used during the months when the district heating is operating. Thus, in order to estimate these pump consumption, it will be necessary to observe the available data for the electric consumption on communal services during those months. In addition, it must be remarked that the pump was set up on 2015, therefore, observing buildings 11 and 15 consumption for 2014 and 2015, there must be a clear difference which is nothing else than the electric consumption by the heat recovery pump.

Finally, this calculation was done with the available data for Koppargården 01, where there is also installed a heat recovery pump. This pump uses the remaining heat of the exhaust air to transfer this energy to the DHW network. Then, the estimated consumption is shown down below:

Table 81: Electric consumption by the heat recovery pump

	HEAT RECOVERY PUMP CONSUMPT.
jan-15	4790
feb-15	4666
mar-15	5114
apr-15	3977
may-15	
jun-15	
jul-15	
aug-15	
sep-15	
oct-15	3057
nov-15	4368
dec-15	4588
	30.560 kWh

According with the available data, although the estimated COP for the Heat recovery pump is COP=5, Lasndskronahem commented that the results obtained with the operation of this equipment are not adequate.

CONCLUSIONS FOR COMMUNAL ELECTRIC CONSUMPTION

The next table presents the total electric consumption per building on communal services, it has been obtained gathering all the different consumptions that have been analyzed along this section and with the available data for each building.

Table 82: Total electric consumption on communal services per building (2015)

		ELECTRIC CONSUMPTION ON COMMUNAL SERVICES	
	Area (m^2)	kWh	kWh/m^2
B11	5196	106.800,00	20,55
B13	2144	40.622,00	18,95
B15	5196	90.951,00	17,50
B17	2144	31.357,00	14,63
B19	2144	55.747,00	26,00
	16824	323.286,00	19,22

It is also interesting to breakdown the previous table into the different consumption by all the systems and facilities for all the buildings, as it is done down below:

Table 83: Breakdown of 2015 electric consumption on communal services per building

	B11	B13	B15	B17	B19	TOTAL
lifts	2.700,00	0,00	2.700,00	0,00	0,00	5.400,00
laundry	40.996,80	32.797,44	38.918,88	22.548,24	7.076,16	182.355,85
lighting	10.662,50	4.265,00	10.662,50	4.265,00	4.265,00	34.120,00
ventilation	6.132,00	1.971,00	6.132,00	1.971,00	1.971,00	18.177,00
heat recovery	30.560,00	0,00	30.560,00	0,00	0,00	61.120,00
dhw pump	3.225,00	0,00	1.290,00	0,00	0,00	4.515,00
dh pump	9.516,00	0,00	0,00	0,00	0,00	9.516,00
others	3.007,70	1.588,56	687,62	2.572,76	42.447,84	8.082,15
Communal services (kWh)	106.800,00	40.622,00	90.951,00	31.357,00	55.760,00	323.286,00

It must be remarked that the table includes the electric consumption due to the different pumps operation. The impulsion pump from building 11 was analyzed at the previous section, and the recirculation pumps from building 11 and 15 which are WILO Perfecta have a nominal power of 300 W. With this data it has been possible to calculate the different pump consumptions according to their operating hours.

On the other hand, building 19 presents a really unusual electric consumption on communal services if compared with the rest of buildings and considering that the number of tenants at building 19 is considerably fewer than in the rest of buildings. This fact may be caused by a malfunction at the reading meter or even to a failure in any of the system. This point it will be analyzed together with Landskronahem.

5.2.3 AGGREGATE ELECTRIC CONSUMPTION BY HOUSEHOLDERS.

An important part of the total energy consumption is due to the total electric consumption by householders in their dwellings. Despite of it has not been possible to have the tenant's interviews, It is possible to develop an analysis through the aggregated tenants consumption data, 2015 hourly consumption, that has been integrated in Opendomo Platform.

Down below it is shown a chart extracted from Opendomo platform, which presents the electric consumption for different buildings relating it with the average outside temperature.

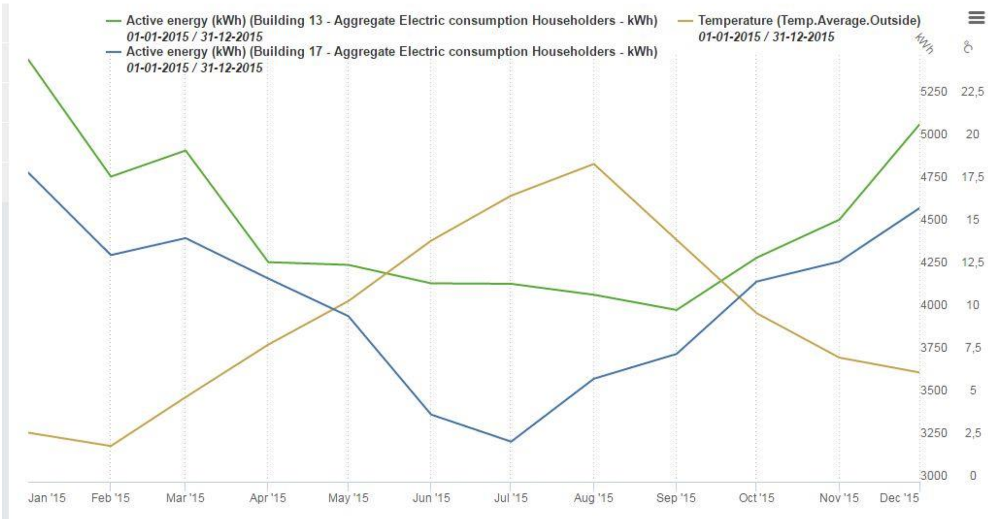


Figure 77: Aggregate electric consumption against outside temperature

As it can be seen at the previous figure, it might be said that it does exist a relation between the climate and the electric consumption by the tenants. However, this hypothesis would be tested in the next section where it is described the calculation of the baseline for the aggregate electric consumption considering the climatologic variable.

Table 84: Aggregate electric consumption by householders (2015)

		AGGREGATE ELECTRIC CONSUMPT. BY TENANTS	
	Area (m^2)	kWh	kWh/m^2
B11	5196	125.516,12	24,16
B13	2144	54.117,00	25,24
B15	5196	113.842,92	21,91
B17	2144	48.767,74	22,75
B19	2144	13.940,00	6,50
	16824	356.183,78	21,17

Building 19 presents a significant lower consumption than the other buildings, this fact is due to the low number of tenants habiting this building, (a total of twelve tenants according to the latest available data).

5.2.4 BUILDING ENERGY CONSUMPTION.

Finally, the next graph will show the energy consumption distribution for all the four buildings which are involved in this project, (excluding building 11). It has been obtained by gathering all the different results calculated all along the previous sections.

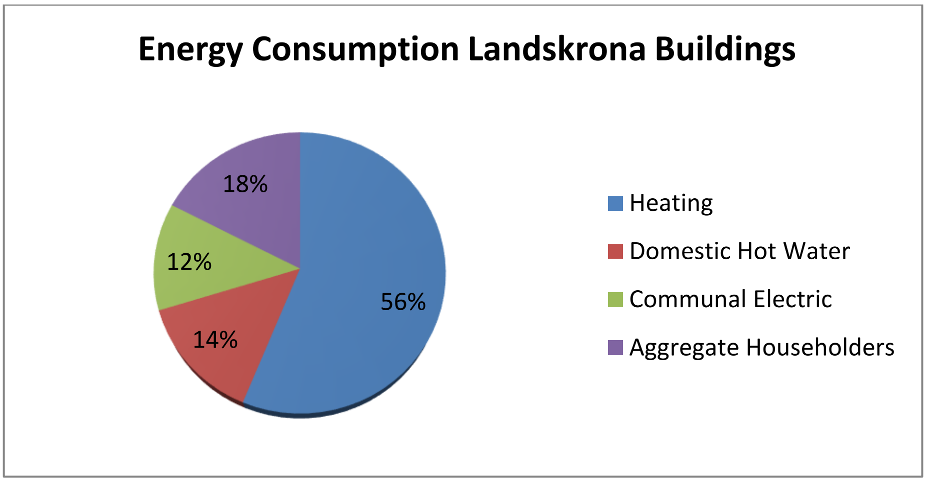


Figure 78: Energy consumption distribution for 2015 B13, B15, B17, B19

As it was expected, the District heating supply system is the largest energy consumer, with a 71% of the total of energy consumption, (56% for heating and 14% for domestic hot water). On the other hand, both electric consumption on communal services and the consumption by the sum of all the householders present quite similar values.

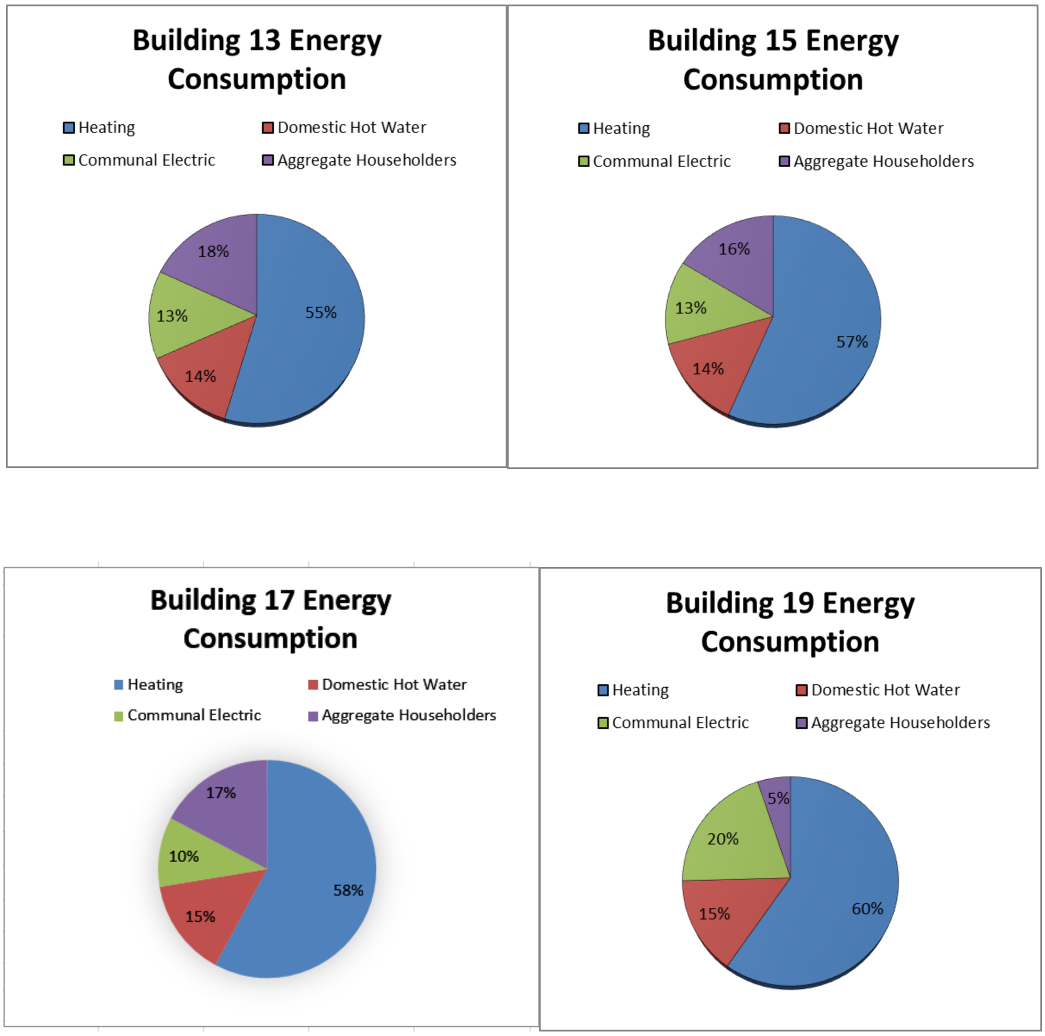


Figure 79: Energy consumption distribution per each building

5.3 ENERGY BASELINE.

The following section includes the Energy Base Line calculation for the different systems: Heating Systems, Domestic Hot Water, Electric communal services and Aggregated tenants Consumption.

5.3.1 DISTRICT HEATING SUPPLY BASELINE CALCULATION

Through to the collected information from 2014 and 2015, it has been possible to develop a baseline calculation for the district heating supply consumption. The data for the DH consumption has been normalized in order to obtain an accurate relation between climate and district heating consumption.

This normalization has been arranged with the available data of district heating consumption from 2014. We have selected 2014 year because during 2015 there were problems on the installations that recommend to use 2014 as base year. Using the climate data specifically daily average temperature, it has been possible to calculate the Heating Degree Days, (HDD, from now on), with different designated bases, from 14 ºC to 22ºC.

Considering the total HDD per month and its associated monthly consumption by the district heating system during 2014, it has been possible to develop different models relating both of those variables for distinct temperature bases, HDD 14, HDD 15, etc. These plots are all shown down below in the next page:

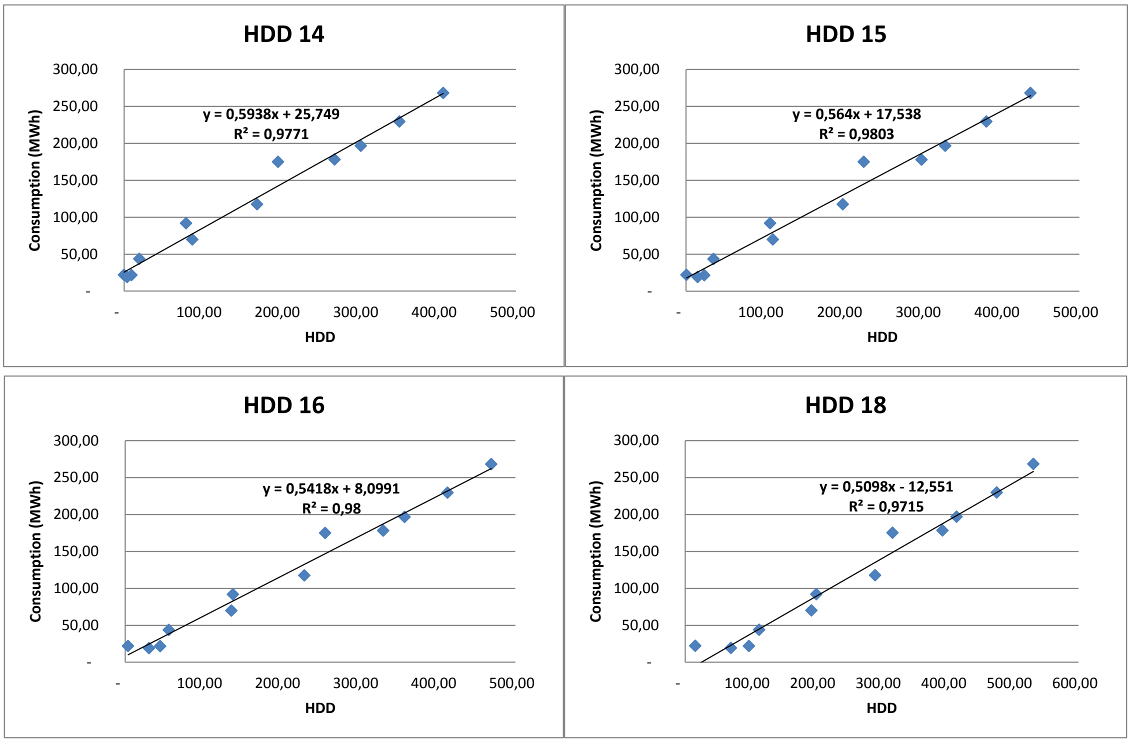


Figure 80: Monthly district heating consumption against different heating degree days

As it can be noted, the charts include both the linear function that describes the evolution of the district heating consumption according to the climate fluctuations and the value for R-Square. Thus, the nearest value to 1 for R-Square, the more accurate the prediction will be. It will be assumed that the one related with HDD 15 is the chart that better describes the evolution of the energy consumption by district heating according to weather variability, although all of the different models could be used to describe a baseline as all of them present values quite close to 1.

So, focusing now at the model of district heating against HDD 15, it is possible to read the expression that can be used in order to predict the district heating consumption for the next years.

$$y = 0,564x + 17,538$$

Where the dependent variable *'y'* represents the district heating consumption in MWh, and the independent one, *'x'* represents the Heating Degree Days per month.

This expression has been applied to year 2015 in order to obtain a prediction for the energy consumption during this year. However, the calculated values do not correspond exactly with the available data for 2015 district heating consumption.

Researches have shown that during the first months of 2015 a heat recovery pump was installed at the heating supply system, causing a variation on the consumption meters. In addition, a leak on the pipeline network caused a malfunction in the district heating system during summer months, giving again some unexpected measures. As it is shown at the next table, the rest of monthly consumptions are quite similar to the predictions made with the baseline purposed.

Table 85: Real and expected district heating consumption for 2015

	base line (SIN2)	Real Consumpt.	DIF	% Err
jan-15	237,50	239,38	1,88	0,79
feb-15	232,25	216,59	-15,66	7,23
mar-15	204,22	171,40	-32,82	19,15
apr-15	153,07	130,04	-23,03	17,71
may-15	106,71	110,64	3,93	3,56
jun-15	50,64	95,65	45,01	47,05
jul-15	23,18	85,95	62,77	73,03
aug-15	18,50	41,63	23,13	55,57
sep-15	52,00	56,52	4,52	8,00
oct.15	121,88	129,43	7,55	5,83
nov-15	152,67	141,87	-10,80	7,61
dec-15	177,66	183,52	5,86	3,19
	1530,27	1602,62	72,35	4,51

difference due to heat pumps

difference due to leaks

difference due to heat pumps

The influence of the Heat Pump can be also visualized in the following graphic from Opendomo Platform.

In conclusion, it can be considered that the baseline purposed at this section may be used to estimate the district heating consumption, as long as no setbacks would take place affecting the normal operation of the installations.

Therefore, the regression model developed at this section has been applied also for the available data from 2016. If the monthly consumption meters are represented in a graphic against the estimated consumption with the established baseline, the below chart shows that there are some few differences but in general terms both lines presents the same values and tendency.

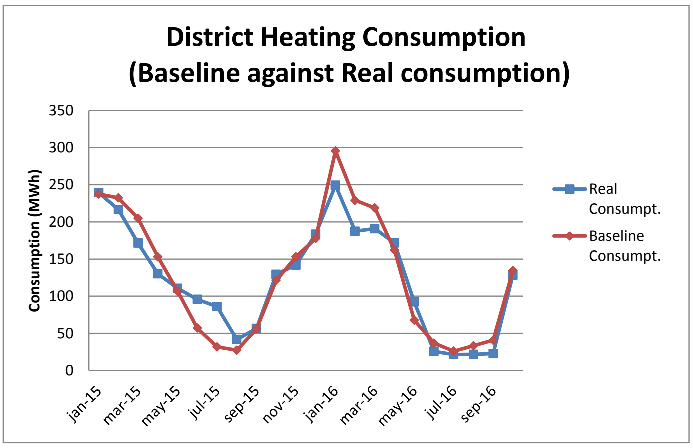


Figure 81: District Heating consumption during 2015 and 2016

In the same way, the daily consumption by district heating system has been analyzed against the climatologic variable, obtaining another regression model, which is shown down below:

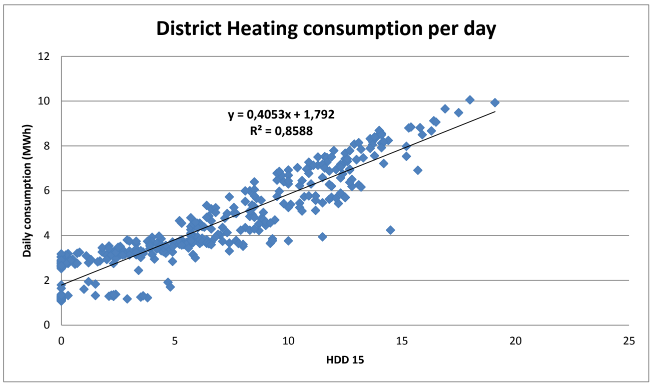


Figure 82: Daily district heating consumption against HDD 15

This model has been developed with the available data for 2015, and as it can be seen it presents an adequate value for R-Square. Thus, it has been applied to the heating degree days of the present year, obtaining some interesting results.

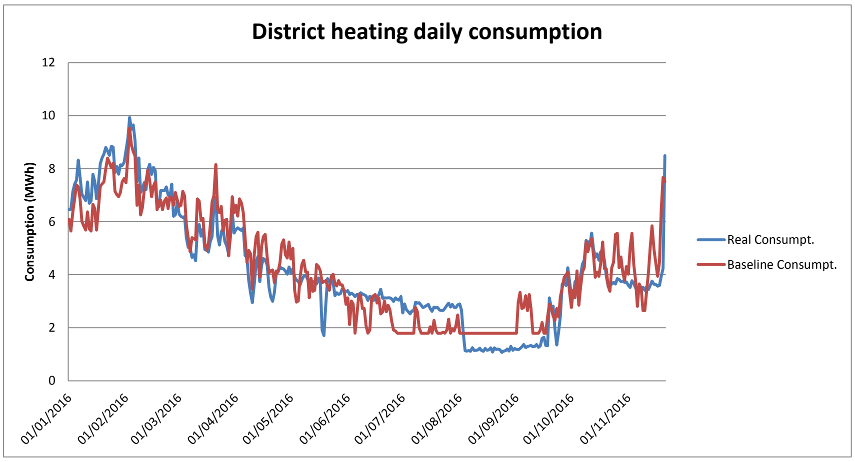


Figure 83: District heating daily consumption (real against baseline)

In general terms, both real and estimated district heating consumption present similar values and tendency, concluding that the consumption due to the district heating system may be predicted in an accurate way thanks to the baseline purposed all along this section.

5.3.2 ELECTRIC COMMUNAL SERVICES CONSUMPTION

Another important energy consumer is the one associated to the communal services, such as lift usage, lighting or laundry service, all of them described previously in this study. In the same way as it has been done for the district heating system, the data available for the electric consumption on communal services may be used to establish a baseline in order to explain actual consumptions and try to predict near future consumptions.

Therefore, considering the available information about the electric consumption for the different buildings it is possible to obtain a regression model. The data that has been used to create this model is shown at the table down below, which includes the monthly consumption for 2014 and 2015, and the Heating Degree Days in base 15ºC:

Table 86: Electric consumption for communal services for 2014 and 2015

		ELECTRIC COMMUNAL CONSUMPT. (kWh)					
	HDD 15	B11	B13	B15	B17	B19	TOTAL
jan-14	438,1	12.293	3.074	6.725	3.005	4.516	29.613
feb-14	330	10.990	2.650	6.621	3.070	4.115	27.446
mar-14	299,7	13.241	3.073	7.560	3.022	4.388	31.284
apr-14	199,7	13.303	3.128	6.907	2.933	3.197	29.468
may-14	110,8	13.543	2.983	7.345	3.323	3.787	30.981
jun-14	23,6	11.697	2.672	6.472	2.768	4.236	27.845
jul-14	0,9	11.888	3.138	6.104	3.122	4.408	28.660
aug-14	15,1	11.916	3.042	6.227	2.719	4.632	28.536
sep-14	35,3	12.552	3.299	6.404	2.683	4.500	29.438
oct-15	107,3	11.660	3.169	6.809	2.724	4.344	28.706
nov-14	226,4	8.023	2.944	6.562	2.711	4.447	24.687
dec-14	382,2	8.310	2.905	7.157	3.127	4.303	25.802
jan-15	390	8.165	3.379	7.056	3.142	4.534	26.276
feb-15	380,7	10.628	3.028	6.574	2.607	4.313	27.150
mar-15	331	13.195	3.634	11.280	2.867	5.360	36.336
apr-15	240,3	12.822	3.234	8.270	2.411	4.380	31.117
may-15	158,1	10.515	3.574	6.838	2.570	5.123	28.620
jun-15	58,7	7.287	3.328	5.914	2.582	4.640	23.751
jul-15	10	7.121	3.091	5.756	2.354	4.429	22.751
aug-15	1,7	6.732	3.393	6.185	2.566	4.337	23.213
sep-15	61,1	7.200	3.109	6.334	2.535	4.457	23.635
oct-15	185	7.865	3.533	6.687	2.634	4.681	25.400
nov-15	239,6	7.872	3.572	9.731	2.484	5.105	28.764
dec-15	283,9	7.419	3.781	10.343	2.432	4.400	28.375

Based on this table, and as it was done before with the district heating consumption, a linear regression model has been developed trying to relate both variables, electric consumption and climatic variability. The following graphs have been obtained by analyzing each building separately and obtaining their regression models.

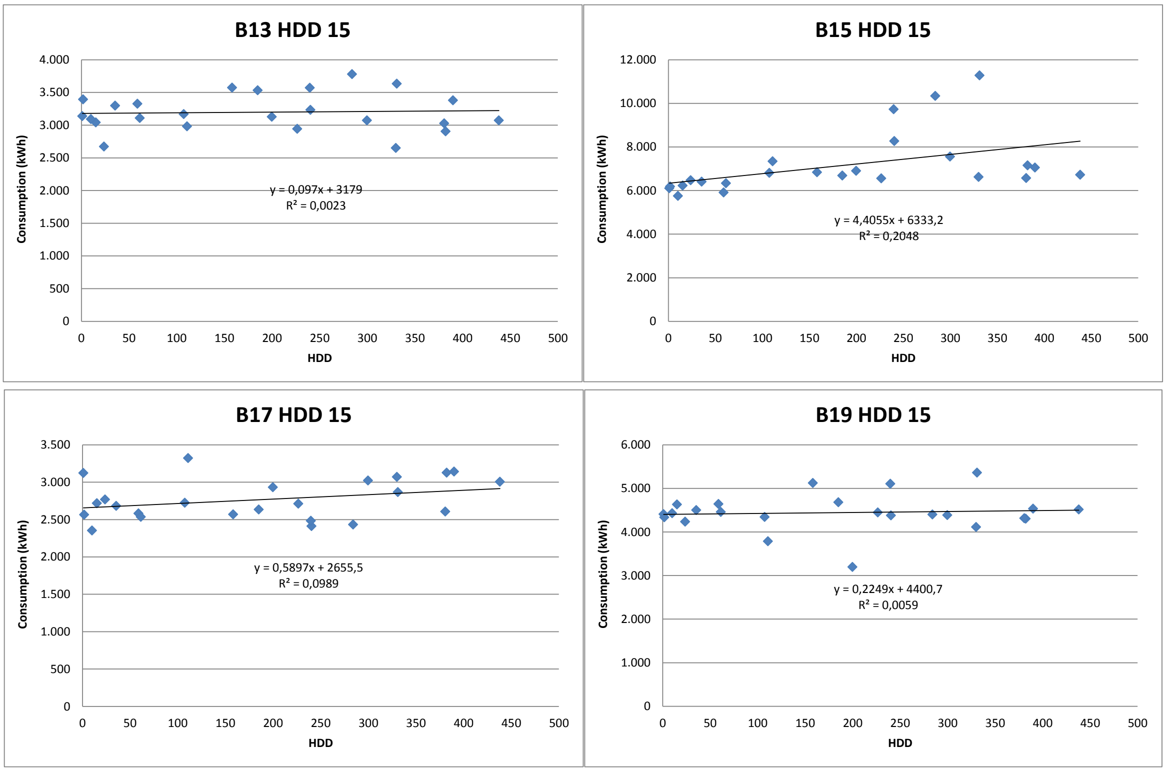


Figure 84: Common electric consumption regression models for different buildings

Those graphs show that it does not exist a clear relation between the electric consumption on communal services for each building and the climatologic variable. Therefore, another analysis has been developed considering the total electric consumption per month by the sum of all the five buildings and 2014 data, in order to extrapolate it for 2015 and compare the baseline calculations with the real consumption.

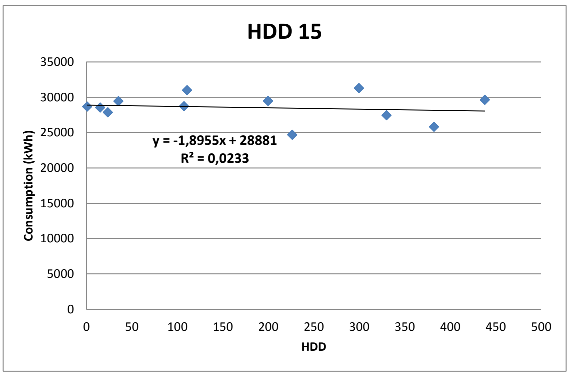


Figure 85: Electric consumption against HDD 15

In view of these results it can be said that, it does not exist a clear relation between both variables, presenting a value for R-Square close to zero. However, in an attempt for establishing a relation between the weather data and the electric consumption, another variable has been added to the regression model. Thus, another analysis has been done including the same variables but adding also the different billing periods associated to the monthly energy consumption, making the regression model a bit more complex.

Table 87: Summary of the analyzed regression model

Regression Statistics	
Multiple R	0,788233943
R Square	0,621312748
Adjusted R Square	0,537160026
Standard Error	2666,296913
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	104975779,6	52487889,8	7,383156822	0,012655027
Residual	9	63982253,07	7109139,23		
Total	11	168958032,7			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	98096,74009	27660,11617	3,54650499	0,006250034	35525,21018	160668,27
Variable X 1	12,27921934	5,27579985	2,32746118	0,044933536	0,344530918	24,2139078
Variable X 2	-2406,596536	903,6695353	-2,66313784	0,025912203	-4450,839048	-362,354024

The equation that describes this regression model it is shown down below:

$$y(x_{1,}x_2) = 98096{,}74 + 12{,}28 \cdot x_1 - 2406{,}60 \cdot x_2$$

The dependent variable represents the electric consumption, while both independent variables are respectively the Heating Degree Days and the billing period measured in days. Despite the R-Square value is not too adequate, this model has been applied to 2015 in order to observe if the expected consumption obtained from the regression model corresponds itself with the real electric consumption value. Thereby, the comparison between both of them it is shown at the next table.

Table 88: Real and expected electric consumption on communal services (2015)

(kWh)	Real Consump	base line (SIN2)	DIF	%Err
jan-15	26276,00	28281,14	-2005,14	7,63
feb-15	27150,00	28166,95	-1016,95	3,75
mar-15	36336,00	34776,46	1559,54	4,29
apr-15	31117,00	26442,94	4674,06	15,02
may-15	28620,00	27840,19	779,81	2,72
jun-15	23751,00	24213,04	-462,04	1,95
jul-15	22751,00	26021,64	-3270,64	14,38
aug-15	23213,00	23513,12	-300,12	1,29
sep-15	23635,00	24242,51	-607,51	2,57
oct-15	25400,00	28170,50	-2770,50	10,91
nov-15	28764,00	26434,35	2329,65	8,10
dec-15	28375,00	29384,91	-1009,91	3,56
	325388	327487,747	-2099,747	0,645

Attending to these results, it can be considered that the regression model developed for predicting the electric consumption in the near future it is reasonably accurate. Although some of the predicted values differ from the real ones, the total amount of the different monthly consumptions are quite similar, with an overall standard error of 0,645%, which is a very acceptable result.

As it can be seen at the following plot, both consumptions, baseline and real one, follow a similar tendency, showing off the acceptability of the baseline model developed for the electric consumption at communal areas.

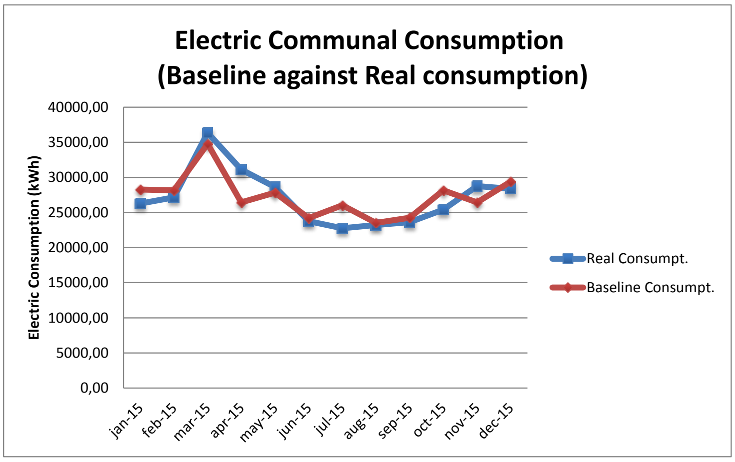


Figure 86: Baseline against real consumption for 2015

In addition, thanks to the latest available data for 2016, it has been possible to extend the baseline calculation, as it is shown in the following table and graph.

Table 89: Real and expected electric consumption on communal services (2016)

	Real Consumpt. (kWh)	Baseline (kWh)	DIF	% Err
jan-16	34.157,00	32.546,18	1.610,82	4,72
feb-16	33.360,00	31.097,14	2.262,86	6,78
mar-16	35.655,00	38.095,90	-2.440,90	6,85
apr-16	30.875,00	29.635,82	1.239,18	4,01
may-16	30.575,00	29.991,66	583,34	1,91
jun-16	28.174,00	26.909,66	1.264,34	4,49
jul-16	29.306,00	29.082,94	223,06	0,76
aug-16	28.935,00	26.835,98	2.099,02	7,25
sep-16	28.784,00	26.995,62	1.788,38	6,21
oct.16	31.493,00	31.440,70	52,30	0,17
	311.314,00	302.631,60	8.682,40	2,79

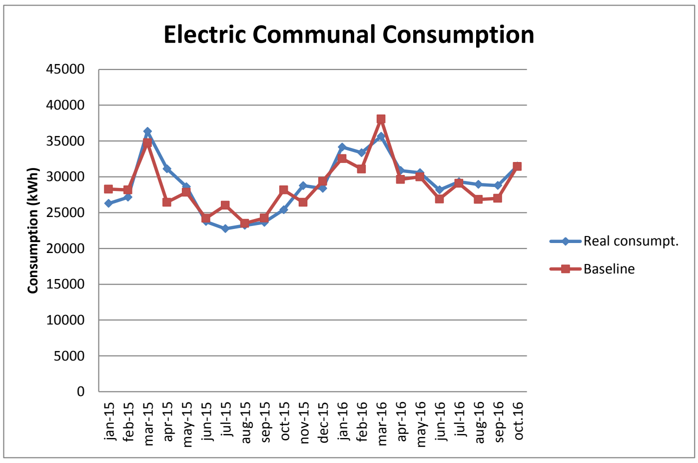


Figure 87: Baseline against real consumption for 2015-16

As it was expected both real and predicted consumption present quite similar values and tendency. Therefore, it can be said that the baseline purposed all along this section can be used in order to estimate near future electric consumptions for communal services.

5.3.3 AGGREGATED ELECTRIC CONSUMPTION

The aggregated electric consumption by tenants of each building will be analyzed at this section. In order to obtain a baseline for this consumption, at first, a regression model for the total aggregated electric consumption has been developed for all the five buildings, while afterwards, the study will focus on each building separately. Thus, as it has been done previously, the aggregate consumption by householders will be studied relating it with the climate variability.

However, So far there is only available information for 2015 consumption. The data corresponding to 2016 are pending to be sent by Landskrona energy. So far, it will not be possible to prove accuracy of the regression model. The data utilized at this section is shown down below:

Table 90: Aggregated electric consumption for 2015

		AGGREGATED TENANTS CONSUMPT. (kWh)					
	HDD 15	B11	B13	B15	B17	B19	TOTAL
jan-15	390	11.484,22	5.476,00	10.619,35	4.805,64	1.308,00	33.693,21
feb-15	380,7	10.398,81	4.791,00	9.360,96	4.331,78	1.230,00	30.112,55
mar-15	331	10.613,38	4.941,00	9.215,17	4.428,29	1.475,00	30.672,84
apr-15	240,3	9.763,75	4.286,00	8.525,15	4.192,03	1.103,00	27.869,93
may-15	158,1	10.155,26	4.271,00	8.885,36	3.968,28	1.065,00	28.344,90
jun-15	58,7	10.158,95	4.162,00	8.006,92	3.394,03	1.167,00	26.888,90
jul-15	10	9.407,51	4.157,00	8.263,29	3.234,42	1.098,00	26.160,22
aug-15	1,7	9.973,14	4.098,00	8.774,39	3.599,02	948,00	27.392,55
sep-15	61,1	9.988,48	4.006,00	9.369,04	3.751,38	867,00	27.981,90
oct-15	185	10.879,84	4.309,00	10.235,55	4.174,32	1.149,00	30.747,71
nov-15	239,6	11.065,13	4.535,00	10.636,39	4.286,12	1.430,00	31.952,64
dec-15	283,9	11.617,08	5.087,00	11.946,66	4.603,69	1.099,00	34.353,43
	TOTAL	125.505,55	54.119,00	113.838,23	48.769,00	13.939,00	

First of all, it can be observed that building 19' consumption presents anomalous values if it is compared with buildings 13 and 17, all of them with the same floors and area. Thus, the explanation for this fact it is that building 19 has fewer tenants than the other two buildings. The following Figure shown the total monthly consumption by householders for the sum of the five buildings relating it with the Heating Degree Days.

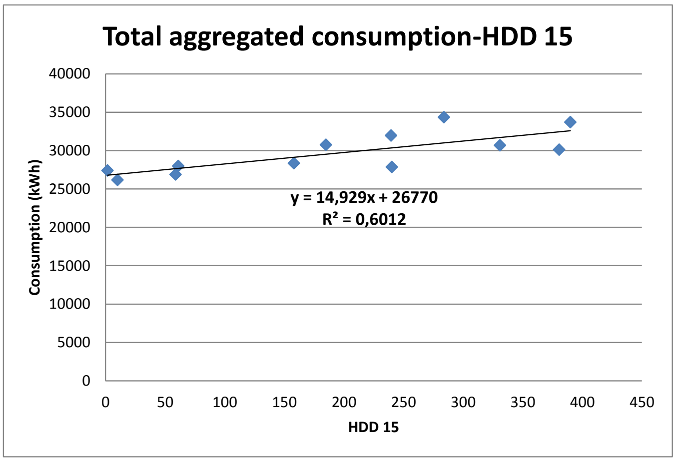


Figure 88: Sum of the aggregated consumption for all the buildings against HDD 15.

The R-Square value for this model presents an intermediate value between zero and one, so it can be assumed that this model is not accurate in order to predict future electric consumptions.

On the other side, with a view to extending the study, the same procedure has been applied for each different building, obtaining diverse regression models, which are all shown down below:

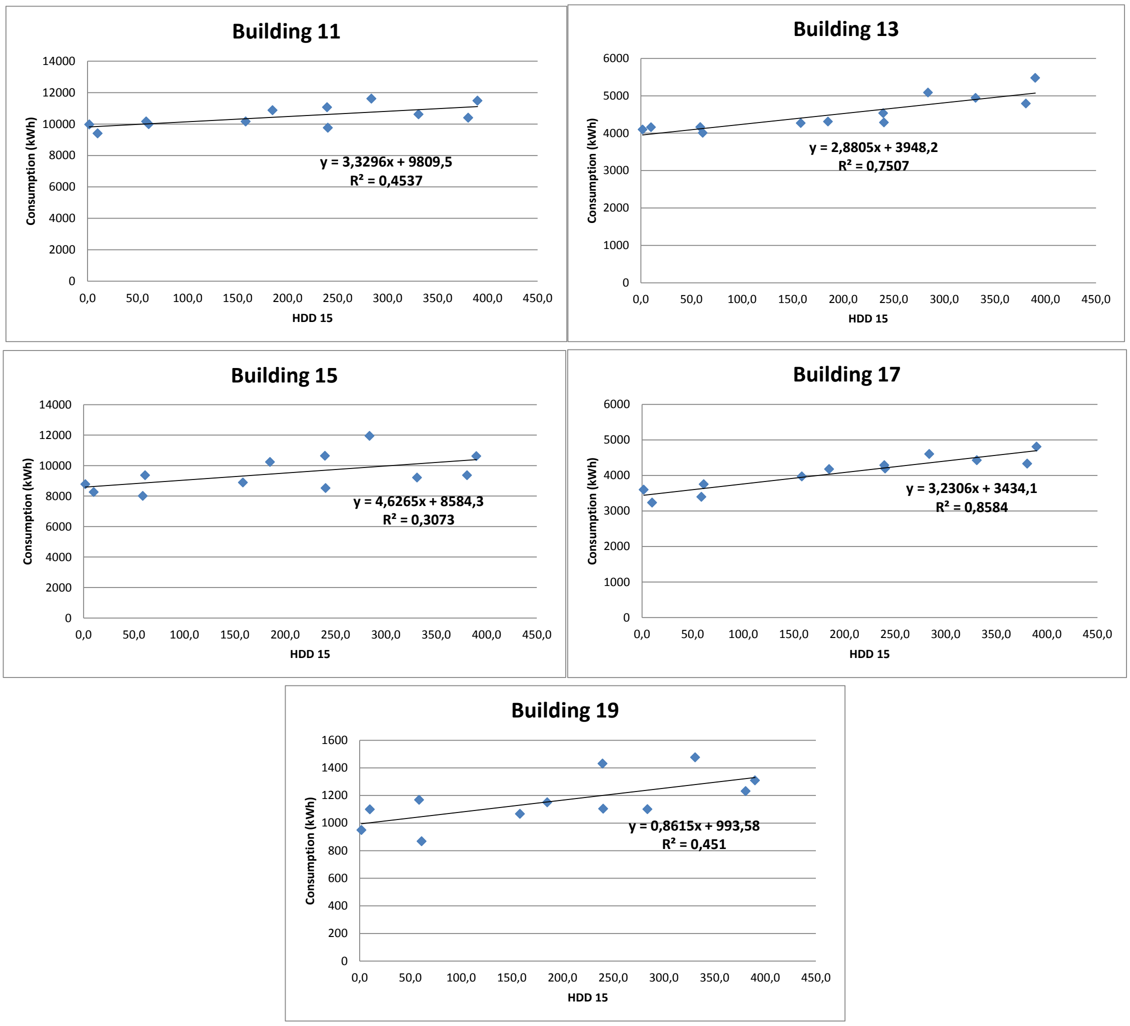


Figure 89: Electric consumption by householders per each building against HDD15

Buildings 13 and 17 presents the best R-Square value, (the closer value to 1, the more accurate the model will be). Therefore these models will be indeed suitable for predicting the electric consumption in those same buildings.

However, these results are not convincing enough, therefore, for getting deeper in this study, the daily electric consumption by tenants has been analyzed against the climatic variable.

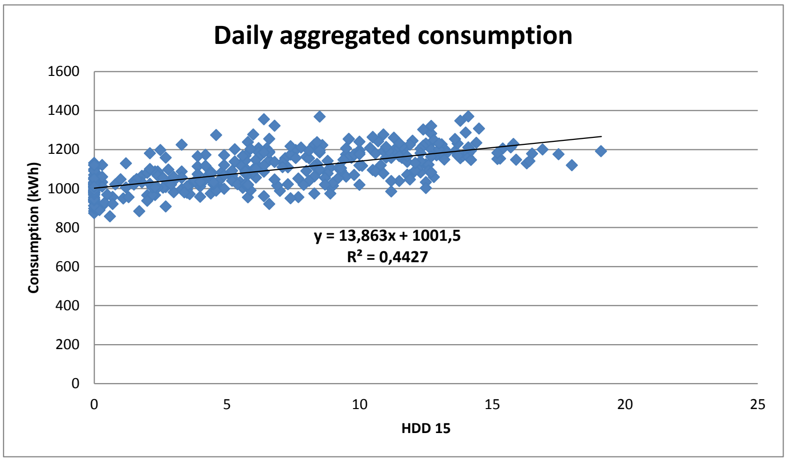


Figure 90: Daily aggregated consumption against heating degree days

The obtained result is once more not enough positive, with the intention of developing a more accurate model, another analysis has been done considering only and exclusively the consumption during weekend days. Thus, it is expected to obtain a model with a better adjusted R-Square as some of the anomalous values have been removed from the analysis.

Therefore, the obtained regression model it is shown at the next page, where it is possible to see that the R-Square value it is now more accurate, although it is still far from the most adequate value, 1.

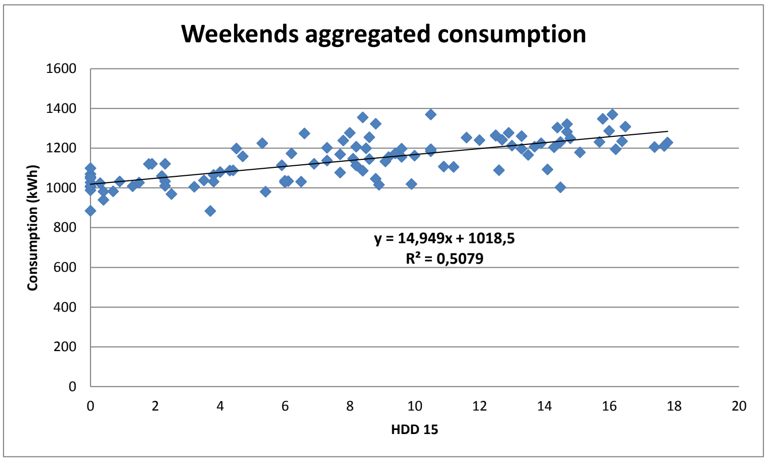


Figure 91: Daily aggregated consumption by tenants on weekends for 2015

In conclusion, and as it was expected, there is not a clear relation between climatologic variables and tenants electric consumption. The first important conclusion is that in general terms tenants do not use auxiliary electric heaters during heating period. Tenants electric consumption is due to the use of appliances and Lighting system and it is not directly related with the energy performance of the building.

Therefore, it would be necessary to carry out a social analysis and with the collected data for the number of tenants for each building and their manners, it could be possible to identify the variables in relation with the electric consumption of the tenants in order to obtain a more accurate baseline.