Pre-design sheet for an exergy optimised building design

IEA ECBCS Annex 37

Steady state calculations for heating case

Version 2.3

Object: *CASA ARIAS, RONCAL (NAVARRA)*

1	**1. Project data, boundary conditions**		
2	Volume (inside) [m³]	V =	*600*
3	Net floor area [m²]	A_N =	*90*
4	Indoor air temperature [°C]	θ_i =	*20*
5	Exterior air temperature [°C]	θ_e =	*10* = θ_{ref} Reference temperature
6	**2. Heat losses**		
7	**2.1 Transmission losses Φ_T[W]**		

8	Building part	Symbols	Area A_i [m²]	Thermal transmittance U_i [W/(m²K)]	$U_i * A_i$ [W/K]	Temperature-correction-factor F_{xi} [-]	$U_i * A_i * F_{xi}$ [W/K]
9	Exterior wall	EW 1	*85,00*	*0,17*	*14,45*	1	*14,45*
10		EW 2	*85,00*	*0,17*	*14,45*	1	*14,45*
11		EW 3	*40,00*	*0,17*	*6,80*	1	*6,80*
12		EW 4	*40,00*	*0,17*	*6,80*	1	*6,80*
13	Window	W 1	*9,90*	*1,04*	*10,30*	1	*10,30*
14		W 2	*9,90*	*1,04*	*10,30*	1	*10,30*
15		W 3	*19,80*	*1,04*	*20,59*	1	*20,59*
16		W 4	*13,20*	*1,04*	*13,73*	1	*13,73*
17	Door	D 1	*2,00*	*0,90*	*1,80*	1	*1,80*
18	Roof	R 1	*100,00*	*0,23*	*23,00*	1	*23,00*
19		R 2				1	
20		R 3				1	
21	Upper story floor	R 4				0,8	
22		R 5				0,8	
23	Wall to roof rooms	RW 1				0,8	
24		RW 2				0,8	
25	Walls and floors to unheated rooms	uhW 1				0,5	
26		uhW 2				0,5	
27	Floors to ground. Areas of unheated cellar to ground	G 1	*90,00*	*0,20*	*18,00*	0,6	*10,80*
28		G 2				0,6	
29		G 3				0,6	
30		G 4				0,6	
31		G 5				0,6	
32		**Σ A_i = A =**	*494,80*	**Specific transmission heat loss Σ $U_i * A_i * F_{xi}$ =**			*133,01*

33	Transmission heat losses [W]	$\Phi_T = \Sigma (U_i * A_i * F_{xi}) * (\theta_i - \theta_e)$ Φ_T = *133,01* * *10,00*	Φ_T = *1.330,12*
34	**2.2 Ventilation heat losses Φ_V [W]**		
35	Air exchange rate [ach/h]	n_d = *0,4*	
36	Heat exchanger efficiency [-]	η_V = *83%*	
37	Ventilation heat losses [W]	$\Phi_V = (cp * \rho * V * n_d * (1-\eta_V)) * (\theta_i - \theta_e)$ Φ_V = *13,67* * *10,00*	Φ_V = *136,68*
38	**3. Heat gains**		
39	**3.1 Solar heat gains Φ_s [W]**		
40	Window frame fraction [-]	F_f = *0,71*	

41	Orientation	Solar radiation $I_{s,j}$ [W/m²]	Window area $A_{W,j}$ [m²]	Total trans-mittance gj [-]	$I_{s,j} * (1-F_f) * 0.9 * 0.9 * A_{W,j} * g_j$ 1) [W]
42	south-east to south-west	20	*19,80*	*1,04*	*96,74*
43					
44	north-west to north-east	20	*9,90*	*1,04*	*48,37*
45					
46	other directions	50	*13,20*	*1,04*	*161,24*
47			*9,90*	*1,04*	*120,93*
48	Dormer window with slope < 30°	5			
49	Solar heat gains: $\Phi_s = \Sigma (I_{s,j} * (1-F_f) * A_{W,j} * g_j)$			Φ_s =	*427,27*

50	**3.2 Internal Heat Gains Φ_i [W]**		
51	Number of occupants [-]:	no_o = *3,00*	
52	Internal gains of occupants [W]:	$\Phi_{i,o} = no_o * \Phi''_{i,o}$ $\Phi_{i,o}$ = *3,00* * *50,00*	$\Phi_{i,o}$ = *150,00*
53	Spec. internal gains of equipmen	$\Phi''_{i,e}$ = *2,00*	
54	Internal gains of equipment [W]:	$\Phi_{i,e} = \Phi''_{i,e} * A_N$ $\Phi_{i,e}$ = *4,22* * *90,00*	$\Phi_{i,e}$ = *379,80*

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55	**4. Other uses**									
56	Spec. lighting power [W/m²]:	p_l =	*5*							
57	Lighting power [W]:	P_l =	p_l	*	A_N		=	$\Phi_{i,l}$		
		P_l =	*5,00*	*	*90,00*				**P_l =**	*450,00*
58	Spec. ventilation power [Wh/m³]:	p_v =	*0,1*							
59	Ventilation power [W]:	P_v =	pv	*	V	*	n_d			
		P_v =	*0,10*	*	*600,00*	*	*0,40*		**P_v =**	*24,00*

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No.	Item	Calculation	Result
60	**5. Heat demand Φ_h [W]**		
61	Heat demand [W]:	$\Phi_h = (\Phi_T + \Phi_V) - (\Phi_s + \Phi_{i,o} + \Phi_{i,e} + \Phi_{i,l})$ $\Phi_h =$ *1.466,80 - 1.407,07*	**Φ_h =** *59,73*
62	Specific heat demand [W/m²]	$\Phi''_h = \Phi_h / A_N$ $\Phi''_h =$ *59,73 / 90,00*	**Φ''_h =** *0,66*
63	**6. Heat production and emission**		
64	Generation / Conversion:	Condensing boiler Efficiency η_G [-] Primary energy factor source F_P [-] Quality factor of source $F_{q,S}$ [-] Max. supply temperature $\theta_{S,max}$ [°C] Auxiliary energy $p_{aux,ge}$ [W/kW $_{heat}$] Auxiliary energy $p_{aux,ge,const}$ [W] Part. environmental energy F_{renew} [-]	*0,95* *1,30* *0,95* *70,00* *1,80* *20,00*
65	Storage:	Small / day storage Heat loss / efficiency η_S [-] Auxiliary energy $p_{aux,S}$ [W/kW $_{heat}$] Solar fraction F_S [-]	*0,95* *2,00*
66	Distribution system:	Boiler position: Outside envelope Insulation: Good insulation Design temperature: Middle (<50°C) Temperature drop: Middle (<10K) Heat loss / efficiency η_D [-] Auxiliary energy $p_{aux,D}$ [W/kW $_{heat}$]	*0,83* *3,35*
67	Emission system:	Air heating/cooling Inlet temperature θ_{in} [°C] Return temperature θ_{ret} [°C] Auxiliary energy $p_{aux,E}$ [W/kW $_{heat}$] Max. heat emission $p_{heat,max}$ [W/m²] Heat loss / efficiency η_E [-]	*35,00* *25,00* *6,03* *34,00* *0,95*
68	DHW production system:	Dwelling; same boiler as for heating system DHW demand V_W [l/pers·d] Efficiency $\eta_{G,DHW}$ [-] Primary energy factor source $F_{P,DHW}$ [-] Quality factor of source $F_{q,S,DHW}$ [-]	*45,00* *0,90* *1,30* *0,95*
69	**7. Results of exergy calculation**		
70	Quality factor room air [-]:	$F_{q,room} = 1 - T_e / T_i$ $F_{q,room} =$ *0,03*	**$F_{q,room}$ =** *0,03*
71	Exergy load room [W]:	$Ex_{room} = \Phi_h * F_{q,room}$ $Ex_{room} =$ *59,73 * 0,03*	**Ex_{room} =** *2,04*
72	Heating temperature [°C]:	$\theta_{heat} = \Delta\log\theta /2 + \theta_i$ $\theta_{heat} =$ *4,55 * 20,00*	**θ_{heat} =** *24,55*
73	Quality factor air at heater [-]:	$F_{q,heater} = 1 - T_e / T_{heat}$ $F_{q,heater} =$ *0,05*	**$F_{q,heater}$ =** *0,05*
74	Exergy load at heater [W]:	$Ex_{heat} = \Phi_h * F_{q,heater}$ $Ex_{heat} =$ *59,73 * 0,05*	**Ex_{heat} =** *2,92*
75	Heat loss emission [W]:	$\Phi_{loss,E} = \Phi_h * (1/\eta_E - 1)$ $\Phi_{loss,E} =$ *59,73 * 0,05*	**$\Phi_{loss,E}$ =** *3,14*
76	Auxiliary energy emission [W]:	$P_{aux,E} = p_{aux,E} * \Phi_h$ $P_{aux,E} =$ *0,01 * 59,73*	**$P_{aux,E}$ =** *0,36*
77	Exergy demand emission [W]:	$\Delta Ex_{emis} = \{ (\Phi_h + \Phi_{loss,E}) / (T_{in} - T_{ret}) \} * \{ (T_{in} - T_{ret}) - T_{ref} * \ln (T_{in} / T_{ret}) \}$ $\Delta Ex_{emis} =$ *6,29 * 0,66*	**ΔEx_{emis} =** *4,14*
78	Heat loss distributon [W]:	$\Phi_{loss,D} = (\Phi_h + \Phi_{loss,E}) * (1/\eta_D - 1)$ $\Phi_{loss,D} =$ *62,87 * 0,20551499*	**$\Phi_{loss,D}$ =** *12,92*
79	Auxiliary energy distribution [W]:	$P_{aux,D} = p_{aux,D} * (\Phi_h + \Phi_{loss,E})$ $P_{aux,D} =$ *0,00 * 62,87*	**$P_{aux,D}$ =** *0,21*
80	Exergy demand distribution [W]:	$\Delta Ex_{dis} = \{ \Phi_{loss,D} / \Delta T_{dis} \} * \{ (\Delta T_{dis} - T_{ref} * \ln (T_{dis} / T_{dis} - \Delta T_{dis}) \}$ $\Delta Ex_{dis} =$ *1,29 * 1,10*	**ΔEx_{dis} =** *1,42*
81	Heat loss storage [W]:	$\Phi_{loss,S} = (\Phi_h + \Phi_{loss,E} + \Phi_{loss,D}) * (1/\eta_S - 1)$ $\Phi_{loss,S} =$ *75,79 * 0,05*	**$\Phi_{loss,S}$ =** *3,99*
82	Auxiliary energy storage [W]:	$P_{aux,S} = p_{aux,S} * (\Phi_h + \Phi_{loss,E} + \Phi_{loss,D})$ $P_{aux,S} =$ *0,00 * 75,79*	**$P_{aux,S}$ =** *0,15*
83	Exergy demand storage [W]:	$\Delta Ex_{stor} = \{ \Phi_{loss,S} / \Delta T_{sto} \} * \{ \Delta T_{sto} - T_{ref} * \ln (T_{dis} + \Delta T_{dis} / T_{dis} + \Delta T_{dis} - \Delta T_{sto}) \}$ $\Delta Ex_{stor} =$ *1,33 * 0,44*	**ΔEx_{stor} =** *0,58*
84	Req. energy of generation [W]:	$\Phi_{ge} = (\Phi_h + \Phi_{loss,E} + \Phi_{loss,D} + \Phi_{loss,S}) * (1 - F_S) / \eta_B$ $\Phi_{ge} =$ *79,78 * 1,00 / 0,95*	**Φ_{ge} =** *83,98*
85	Auxiliary energy generation [W]:	$P_{aux,ge} = p_{aux,ge} * (\Phi_h + \Phi_{loss,E} + \Phi_{loss,D} + \Phi_{loss,S}) + p_{aus,ge,const}$ $P_{aux,ge} =$ *0,00 * 79,78 + 20,00*	**$P_{aux,ge}$ =** *20,14*
86	Exergy load generation [W]:	$Ex_{ge} = \Phi_{Ge} * F_{q,S}$ $Ex_{ge} =$ *83,98 * 0,95*	**Ex_{ge} =** *79,78*
87	DHW energy demand [W]	$P_W = V_W * c_p * \rho * \Delta T * no_o / \eta_{G,DHW}$ $P_W =$ *2,19 * 147,00 / 0,90*	**P_W =** *357,29*
88	Exergy load plant [W]:	$Ex_{plant} = (P_l + P_V) * F_{q,electricity} + P_W * F_{q,s,DHW}$ $Ex_{plant} =$ *474,00 + 339,43*	**Ex_{plant} =** *813,43*
89	Req. primary energy input [W]:	$E_{prim,tot} = \Phi_{ge} * F_P + (P_l + P_V + \Sigma P_{aux}) * F_{P,electricity} + P_W * F_{P,DHW}$	

89		$E_{prim,tot}$ = *109,17* + *1.276,75* + *464,48*	$\mathbf{E_{prim,tot}}$ **=**	*1.850,41*
90	Add. renew. energy input [W]:	$E_{renew} = \Phi_{ge} * F_{renew} + E_{environment}$		
		E_{renew} =	$\mathbf{E_{renew}}$ **=**	
91	Total exergy input [W]:	$Ex_{tot} = \Phi_{ge}*F_P*F_{q,S}+(P_I+P_V+\Sigma P_{aux})*F_{P,elec}*F_{q,elec}+P_W*F_{P,DHW}*F_{q,S,DHW}+E_{renew}*F_{q,renew}$		
		Ex_{tot} = *1.380,47* + *441,26* +	$\mathbf{Ex_{tot}}$ **=**	*1.821,72*

1) 0.9 for shading and 0.9 for not orthogonal radiation

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Results in key figures	total	per Area	per Volume
Energy input (primary and renewable energy + internal and solar gains)	3257,48 W	36,19 W/m²	5,43 W/m³
Energy quality of envelope (heat demand + internal and solar gains)	1466,80 W	16,30 W/m²	2,44 W/m³
Total exergy system efficiency (exergy demand room / total exergy input)	0,001118		
Exergy flexibility factor (exergy demand emission / total exergy input)	0,004074		

Error messages

Results of the calculation:

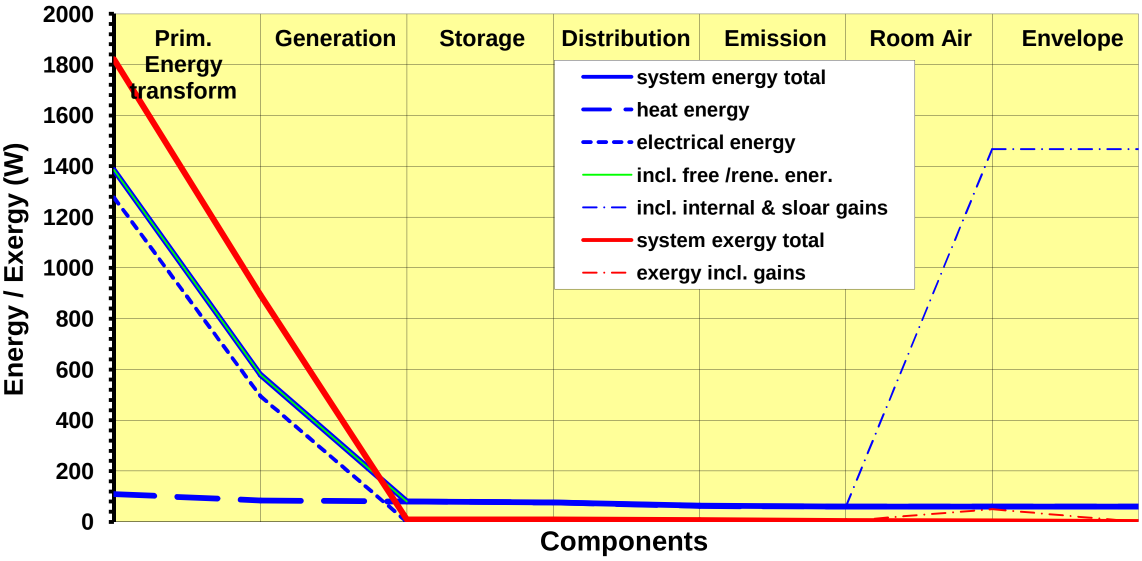

Figure 1: Exergy and energy flows through components

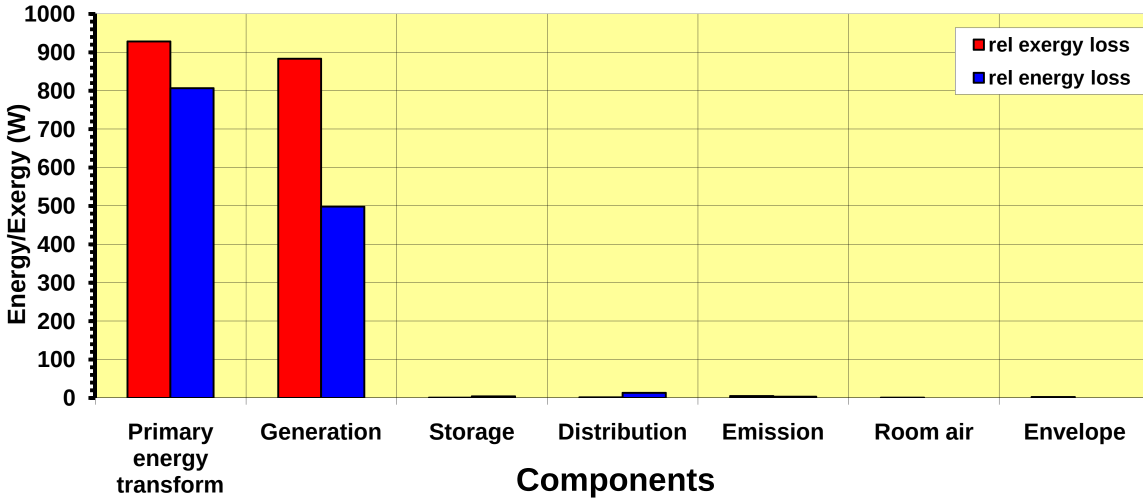

Figure 2: Exergy losses / consumption by components

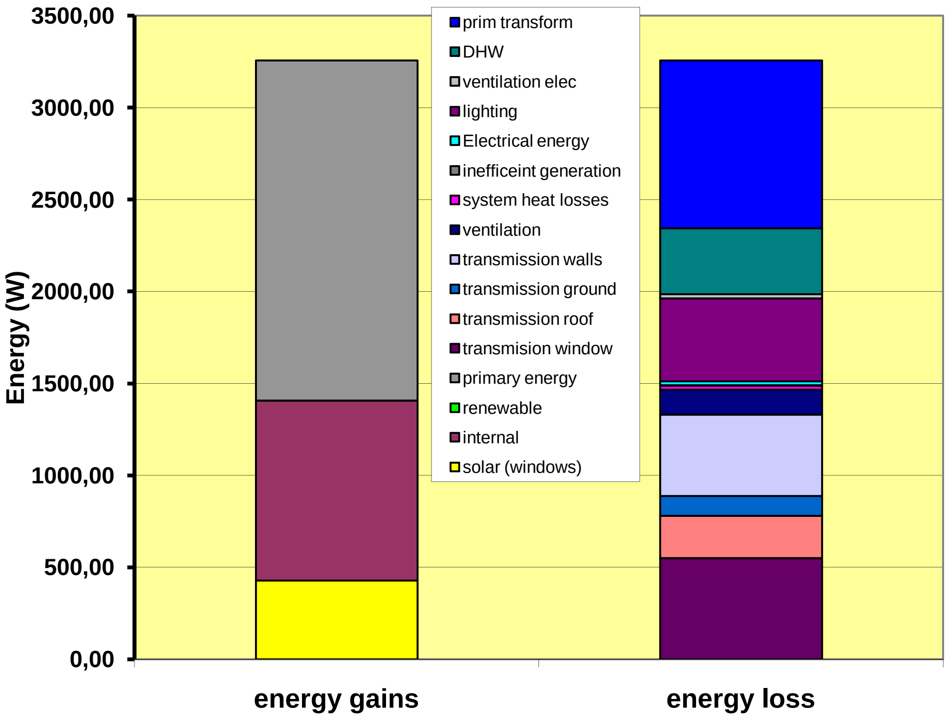

Figure 3: Energy gains and losses

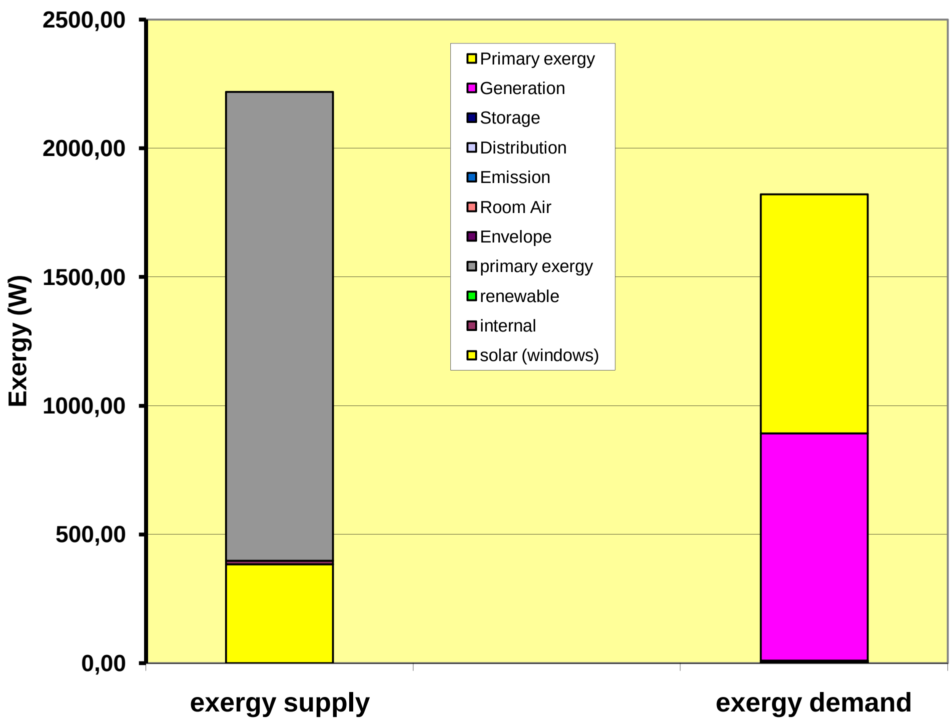

Figure 4: Exergy supply and demand

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