# Tools and methods

# FROM SCRIBBLED CHEAT SHEETS TO HELPFUL TOOLS

### **Too much information** à **The Passive House Reference Sheet**

For many, entry to the professional Passive House world starts with a CEPH course and exam. Quality training and preparation for the exam as well as for first projects are important. There are many very good providers and publications available to support this.



But open book exams are tricky – the Passive House exam is a battle against the clock with not much time to skim through available material.

Early during the preparation for my own test, I started writing

down formulas, terminology, acronyms, symbols and all kind of notes. Thanks to bad handwriting and my desire to be well prepared for the exam, I transcribed my notes into a digital format. This allowed me to experiment with a few options to present the material. After the exam

## Too many units à The Passive House Converter Tool

Unique to the North American construction industry is the need to work with imperial and metric units – even in Canada where metrication started back in the 1970s. The **Reference Sheet** offers conversion tables.

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									Vin		
Material	Thermal conductivity λ W / mK	$U_{metric} \left[ \frac{W}{m^2 K} \right]$	$= \frac{5.678}{R_{imp.} \left[\frac{ft^2 F h}{Btu}\right]}$	→ W/ n	RSI U-value F n <sup>2</sup> K/ Btu/ f W ft <sup>2</sup> Fh	R-value t <sup>2</sup> F h / Btu			500	• \	$\mathbf{\mathbf{N}}$
Copper	3802		"Imp. Btu	0.055 1	18.18 0.010 1				( UNI		
Aluminium	160 <sup>1,2</sup> - 200 <sup>2</sup>			0.060 1	16.67 0.011	94.64		•			
Mild Steel	40 <sup>2</sup> - 50 <sup>1</sup> - 80 <sup>2</sup>	r W 1	0.1442			87.36 81.12					
Stainless Steel	17 <sup>1</sup>	$\lambda_{\text{metric}}\left[\frac{W}{mK}\right] = -$				75.71					
Concrete (Reinforced)	1.4 <sup>2</sup> - 2.1 <sup>1</sup> - 2.6 <sup>2</sup>		verinch Btu inch			70.98					
Cement Screed	1.4 <sup>1</sup>					66.80				) /	
Lightweight Concrete	0.151 - 0.31					63.09				1/	
Quinn Lite aerated concrete	0.12 <sup>13</sup> - 0.19 <sup>13</sup>	Annual Ener	gy Demand			59.77 56.78		/		1/	
Natural Stone	1.5 <sup>1</sup> - 3.5 <sup>1</sup>	kWh/ kBt				54.08				· /	
Sand-Lime Masonry	11	m²a ft²		0.110	9.09 0.019	51.62		•			
Solid Clay Brick Masonry	0.81 - 1.21	1 0.3	17 0.093	3 0.115	8.70 0.020	49.38	1	~ ~			
Vertically Perforated Lightweight Masonry		15* 4	r								
Adobe	0.41 - 0.82	25* 7	Ann	ual Energ	y Demand	1	1				
Float Glass	11	30** 9	}				1	/			
Solid Plastic (Typical)	0.171 - 0.31	45** 1	kWh /	kBtu		Wh/					NVERSK
Rubber	0.171	60** 1	m <sup>2</sup> a	ft <sup>2</sup> a		ft <sup>2</sup> a				11	AIN CY 24
Linoleum	0.171	120** 3	iii d	ita		ita					
Carpet Gypsum Plaster	0.06 <sup>1</sup> 0.18 <sup>1</sup> - 0.56 <sup>1</sup>	* Heating /coolin EnerPHit ** Prin	1	0.31	7 0	.093					-
Gypsum Plaster Gypsum Plasterboard	0.18' - 0.56' 0.251	L'ENERPHIL Prin	J							N	re'\
For wood and wood products the thermal conduct		Heating Loa	15*	4.75	4.755 1.394			13 <u>-</u>		)) () ()	171
a factor of 2.2 when the heat flow is parallel to the		W / E	}							11	
Hardwood	0.181	m <sup>2</sup>	25*	7.92	5 2	.323					
Softwood	0.131	1 C	30**	0.51	0 0	.787					
Chipboard	0.101 - 0.181	10' 3	30	9.51	0 2	./8/					
Oriented Strand Board (OSB)	0.092 - 0.131	*Heating load cri	45**	14.2	6 4	.181					
Plywood	0.082 - 0.112		}								
Medium Density Fibreboard (MDF)	0.071 - 0.181	North Ame	60**	19.0	2 5	.574					
Wood Wool Lightweight Building Board	0.065 <sup>1</sup> - 0.090 <sup>1</sup>	Dimensiona	J		04 11.15				· · · · · ·		
Fibre Insulating Material	0.035 <sup>1</sup> - 0.050 <sup>1</sup>	nominal a	120**	38.0	4   1	1.15			North	American So	ftwood
Wooden Softboard	0.040 <sup>1</sup> - 0.070 <sup>1</sup>	1"	Allesting /		the state for t						
Agepan DWD Protect	0.090 <sup>s</sup>	2" :	* Heating /	cooling cr	iteria for F	Hand			Dimen	sional Lumb	er sizes
Agepan THD Insulating Wood Fibre Board		3" 2	EnerPHit	** Priman	y Energy c	ritoria					
Agepan THD Static	0.055 <sup>8</sup>	4" :	Lineirint	rinaly	y Lineigy C				nominal	actual	actual
Corkboard	0.0422	5" 4.,		5 0.75 0.74	1.37 0.129 1.35 0.130	1.10			nominal	actual	actual
Coconut Fibre	0.0404 - 0.0504	6" 5-3	4" 140 mm	5 0.74	1.35 0.130	7.67			1"	3/4"	10 man
Flax / hemp board									1 I.	74	19 mm
Mineral wool (roc				17			T			a 1/11	1
Roxul ComfortBoo	г W т	5.67	78	1	U-value	RSI	U-value	R-valu∉	2"	1-1⁄2"	38 mm
Fibreglass (blown	$\frac{W}{m^2 K}$		0				-+				
Expanded perlite ( Sheep wool	netric 21/		2-11		w/	m <sup>2</sup> K/	Btu /	ft <sup>2</sup> Fh	3"	2-1⁄2"	64 mm
Cellulose (blown f	[m~K]	_  ft	<sup>2</sup> Fh		2				·	<b>_</b> /2	
Strawbale		P. I			m <sup>2</sup> K	W	ft <sup>2</sup> F h	Btu	4"	3-1/2"	89 mm
Cellular Glass		inip.	Btu		O OFF	10 10		103.24	<del></del>	<u> </u>	
Foamglas Perinsu		L	1		0.055	18.18	0.010	103.24	5"	4-1/2"	114 mm
Foam glass gravel					0.060	16.67	0.011	94.64	5	4-/2	1 114 mm
Foam glass gravel								1	CII	F 1/H	1.10
Geocell Foam Gla			1		0.065	15.38	0.011	87.36	6"	5-1⁄2"	140 mm
Expanded Rigid Pc	- 14/ -	0 1 1 1 2									+
Extruded Rigid Pol	W	0.1442		l o l	0.070	14.29	0.012	81.12	7"	6-¼"	159 mm
Jackodur Atlas (lo	=			nents					·		+
Rigid Polyurethan	mK	<b>f</b> + <sup>2</sup>	Fh	5	0.075	13.33	0.013	75.71	8"	7-1/4"	184 mm
Low density open-		IL		121-	0.000	10 50	0.011	70.00		1-14	1 104 11111



I kept on improving the document and shared it with others.

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Annual Space Heat Demand		Transmission Heat Losses		Ventilation Heat Losses	Utilization factor for free heat gains			Solar Gains		Internal Heat Gains
Q <sub>H</sub>	=	$\mathbf{Q}_{T}$	+	$\mathbf{Q}_{\mathbf{V}}$	—	η	×	( Q <sub>s</sub>	+	<b>Q</b> ,)
2,211 kWh/a		5,835 kWh/a		759 kWh/a		0.94		2,937 kWh/a		1,722 kWh/a
qн	=	q <sub>T</sub>	+	qv	_	η	×	(qs	+	q, )
$14  kWh/m^2a$		37.4 kWh/m²a		4.9 kWh/m²a		0.94		18.8 kWh/m²a		11.0 kWh/m²a
·····	unt of h		er year		20°C; Spe		l Heat D		<b>₄</b> ≤ 15k	······
<b>Q<sub>H</sub> = [PHPP:124]</b> Amou		eat (fuel) required p		to keep building at 2		ecific Annua		emand $q_{H} = Q_{H} / A_{TF}$		Wh/m <sup>2</sup> a in a PH
$\frac{14 \text{ kWh/m}^2 \text{ a}}{\mathbf{Q}_{H} = [PHPP:124] \text{ Amon}}$ $\mathbf{Q}_{H,window} = \mathbf{Q}_{T,window} - \mathbf{Q}_{\Pi}$ $\mathbf{\eta} = \text{Defined as the fract}$ $\mathbf{\eta}_{G} = (1 - (\mathbf{Q}_{F}/\mathbf{Q}_{L})^5) / (1 - (\mathbf{Q}_{F}$	<b>2</b> s = Wir ction of	eat (fuel) required p ndow energy balance free heat that can be	e; <b>Q<sub>L</sub> = C</b> e utilize	to keep building at 2 I <sub>T</sub> + Q <sub>V</sub> = Total heat I d for space heating.	osses; <b>Q</b> (Surplus	ecific Annua F = Q <sub>I</sub> + Q <sub>S</sub> = S heat, e.g. 6	= Free he excess so	emand <b>q<sub>H</sub> = Q<sub>H</sub> / A<sub>TF</sub></b> , eat (heat gains); <b>Q</b> <sub>G</sub> = blar gains are not or o	• <b>Q<sub>F</sub> x η</b> only pa	Wh/m <sup>2</sup> a in a PH <sub>G</sub> = useful heat gains irtially usable.)

			Solar	Internal Heat Gains		Length of heating peri
Transmission	Area of envelop	be /	Gains	Q	=	t <sub>HEAT</sub>
Heat Losses	· ·· · ·		Qs	1,722 kWh/a		219 d/a x 0.02₄
QT	Ventilation & Infiltration Losses		2,489 kWh/		H <sub>T</sub> = Heating	g days per year [PHPP:1
2,075 kWh/a			g = SHGC = Total	$H_{T,Germany,PHPP-Default} = 21$	19d, H <sub>T,Vancour</sub>	<sub>ver</sub> = 208d, H <sub>T,Yellowknife</sub> =
$\mathbf{Q}_{\mathbf{T}}$ = Calculated for e	Qv	=	A <sub>w</sub> = Rough oper	Default average intern	al heat gains	$\mathbf{q}_i = 2.1 \text{ W/m}^2 \text{ for reside}$
$Q_{T,thermal bridge} = I \times \Psi$	759 kWh/a		windows with th		•	= $3.5 \text{ W/m}^2$ for offices, c
$\Psi$ ( <b>psi</b> ) = Linear ther	V <sub>v</sub> = TFA × average roc	om height	<b>r</b> = Reduction / a			idence-angle · · · Frame L' · · · ·
<b>χ (chi)</b> = Point therm	height of 2.5m is used	for calcula		nt, r <sub>incidence-angle</sub> = 0.85 Cc		$r_{\text{Shading}} = 0.75 \text{ Default }$
$\mathbf{f}_{t} = 1.0$ if exposed to	$\mathbf{n}_{\mathbf{V},\mathbf{Q}}$ = Energetically effective	ective air (	reflection (non-pe	rpendicular incident rad	liation),	<b>r</b> <sub>H</sub> = Continuous horizc
for reduced tempera	$n_{V,Q} = n_{V,System} \times (1 - \phi_{F})$	<sub>IR</sub> ) + n <sub>V,Rest</sub>	r <sub>Frame</sub> = A <sub>Glass</sub> / A <sub>Win</sub>	<sub>ndow</sub> = glazing fraction (C	).60.7 are	wall), <b>r<sub>o</sub></b> = Horizontal
$\mathbf{G}_{T}$ = Time integral of	<b>n</b> <sub>V,system</sub> = Average air e	exchange i	typical values; high	ner value = less frame)		(
$G_{T,monthly,5^{\circ}C} = (20-5)K$	<b>n<sub>V,Rest,Q</sub> = Infiltration ai</b>	ir change t	·	<u> </u>		· · · · · · · · · · · · · · · · · · ·

Now the **Reference Sheet** is much more than just a comforting cheat sheet for the exam. The concise guide presents the relevant terminology and information in such a way that the document can serve as the initial go-to tool to look up information when working on a project or learning about Passive House. References for further reading are included.

Annual S Heat Der		Transmis Heat Los			Ventilation Heat Losses		tilization fact r free heat ga			Sola					
Q⊦	, =	$\mathbf{Q}_{T}$		+	$\mathbf{Q}_{\mathbf{v}}$	-	η	×							
2,211 kV	Nh/a	5,835 kV	Vh/a		759 kWh/a		0.94		2,			Which present value Ko		Which present value Ko	How high is the <u>annuity A</u> , that is
qн	=	q⊤	-	+	qv	—	п	×			capital K <sub>0</sub> have at a future date t?	does one <u>future capital K</u>	, have?	does a <u>constant payment A</u> have?	to be paid from a present value K <sub>0</sub> ?
14 kWh,		37.4 kWh			4.9 kWh/m²a		0.94		18		$K_n = K_0 \times (1+p)^t$	$K_0 = K_n \times (1 + 1)$	p) <sup>-t</sup>	$K_0 = A \times \frac{1 - (1 + p)^{-n}}{n}$	$A = K_0 \times \frac{p}{1 - (1 + p)^{-n}}$
H = [PHPP·1	241 Amount of h	eat (fuel) rec	nuired ner v	vear to	keen huilding a	t 20					Accumulation factor	Diana	 unt factor:	Present value factor B:	Annuity factor a = 1/E
window							HEATING				Accumulation factor	equals the reciprocal va		equals the accumulated discount	reciprocal value of th
= Defin	Space Heating Load		Transmission Heat Losses		Ventilation Heat Losses							accumulation factor =			
= (1-(C	PH	=	P <sub>T</sub>	+	Pv	-	Central Heatin				t = time index = interval from point	l		n = useful life = number of periods = rep	1
	1,558 W		2,188 W		264 W		System Design		h air íe.		p = interest rate [decimal] (use real				a = annuity factor SEE NEXT PAGE
T	рн	=	рт	+	Pv	-			DDA		A = annuity = stream of payments (				present value factor
	9.99 W/m²		14.03 W/m²		1.69 W/m <sup>2</sup>	2010			1		$K_n$ = capital at a given time $t_n$ = futu	re value / final value		annuity A = present value K <sub>0</sub> / present	t value factor $\mathbf{B} = \mathbf{K}_0 \times \text{annuity factor}$
	P <sub>H</sub> = Size of neating sy (f) cold, clear day	stem (maximum d	ally mean power	r) required	to keep the building a	120 C			Exhaust		$K_0$ = capital at a given time $t_0$ = net	present value NPV of annu	uity = curr	rent value of a stream of payments disco	unted by the interest rate
	Specific Heating I						हे। हो		I I					$K_0 = A \times \frac{1 - (1)}{2}$	+ p) <sup>-n</sup>
2	P <sub>II,window</sub> = P <sub>1,winde</sub>	U-VALU	E CALCULAT	<u>ION - 0</u>	PAQUE ELEMENT	[PHP	tion	ney	-		Net Present Value of an Annuity			$K_0 = A \times \frac{1}{F}$	<u>, , , , , , , , , , , , , , , , , , , </u>
Q <sub>T</sub> = (	Transmi			$u = \frac{1}{2}$	1		pus	him	5		Capital to invest today for 3 years,			4 (4 0 005)3	
Q <sub>T.the</sub>	Heat Lo			Ϋ́ R <sub>T</sub>	$R_{si} + \frac{d_1}{2} + \frac{d_2}{2} + \frac{d_3}{3}$	<u>4</u> 3 + 6	com	0	DHW		at an interest rate of 3.5%,		$K_{0} = 500$	$\$ \times \frac{1 - (1 + 0.035)^{-3}}{0.035} = 500\$ \times 2.802 = 1,$	401 \$
Ψ(ps	PT			1	n1 n2 1	-3			DHW		to be able to withdraw 500\$ at the	end of each year?		0.035	9775.027 <b>9</b>
	774 1	U= -	12 m <sup>2</sup> K 0.30	m 0.24	im _ 0.015m _ n.o. m	2 <u>K</u> =		1			What additional mortgage could be	supported		1 (1:0.00)25	
χ (chi	P <sub>T</sub> = Calculate P <sub>T,thermal bridge</sub>		W 0.035	W 0.79	$\frac{km}{mK} + \frac{0.015m}{0.70} + 0.04 \frac{m}{N}$	N		3			by annual savings of 1,500\$ on heat		$K_0 = 1,50$	$00\% \times \frac{1 - (1 + 0.03)^{-25}}{0.03} = 1,500\% \times 17.413$	= 26,119\$
<b>f</b> <sub>t</sub> = 1.	$\Psi$ (osi) = Line				Evomole chow			1 2			at an interest rate of 3% borrowed f	or 25 years?		0.03	



A **Unit Converter** for mobile devices was added for accurate metric-imperial conversions on the go:

U-values, R-values + Heating Demand (kWh/m2.a, kBtU/ft2.a, kWh/ft2.a) + Heat Load (W/m2, BtU/h.ft2) + Vapour Diffusion (Sd-value, metric & US-Perm) + Temperature (°C, °F, K)

Building Physics I SI-Imperial Edit >> HEAT TRANSFER <<						renaij	s I SI-Im		Edit	Building Physics   SI-Imperial Edit						
>> H (U = 1/i		ANSFER	<<			Thermal Resistance (h.ft².F)/Btu					Load					
U (me		ficient W/	(m² K)				CONSU			>> WATER VAPOUR DIFFUSIO (1 US Perm = 3.28 Sd)						
R (me	etric) (R	SI)				kWh/(m <sup>2</sup> .a) Consumption					Sd Diffusion-equivalent air layer thickness in meter					
U (im	perial)	e (m².K)/W			kBtu/(ft².a) Consumption					US Perm Permeance ∆ in: gn/(h.ft².inHG)						
R (im	perial)	ficient Btu			kWh/(ft².a) Consumption >> HEATING LOAD<< (immediate rate of energy consumption, Heatin				SI Perm Permeance ∆ in: ng/(s.m².Pa)							
		e (h.ft².F)/8 CONSU		N <<					>> TEMPERATURE << (degrees)							
C	±	1/x	iana Haatin ÷	X	С	±	1/ x	÷	×	С	±	1/x	÷	×		
MC	1	2	3	-	MC	1	2	3	-	MC	1	2	3	-		
MR	4	5	6	+	MR	4	5	6	+	MR	4	5	6	+		
M+	7	8	9		M+	7	8	9		M+	7	8	9			
~	0		ta ka	=		0		tan ka	-	~	0		ta a constant	_		

#### Less searching à More Passive House

The **Reference Sheet** and **Unit Converter** are currently available in English only (metric and imperial versions as downloadable PDF), with a strong focus on North American user groups.



φ (psi) = cine		Example above is: El	heat generator		· · · · · ·
for r∈ χ (chi) = Poin f, = 1.0 if exp		efficient (heat flow in W through 1:	oil tank heat generator (o	Annui	ity Calculation
GT = for reduced t		ig elements (e.g. framed wall) is cal esistance <b>R</b> , = d, /λ = Thermal res			
$G_{T,mos}$ $\Delta_{11,or12} = Diffe$		vity [PHPP:46] d [m] = thickness	L		h amount can be taken at the end of eac
				for	
Ventilati		nce of the interior surface (PHPP:4 ance of the exterior surface and bel	VENTILATION [PHPP:29]	ata	Evaluation Criteria for residential buildings [PH
V Infiltration		id in Uglass and Uframe for windows.	Dimensioning of Air Quantitie	Ac	Space Heating Demand Q <sub>H</sub> ≤ 15 kWh/m <sup>2</sup> a or al
Infil Pv		due to lower AT and less air movem		of	Peak Heating Load P <sub>H</sub> ≤ 10 W/m <sup>2</sup> (small bu
2641	Re is cypically larger chair Re	de la lover di and less all moven	① Supply Air = 20 to 30m <sup>3</sup> /h p		Useful Cooling Demand ≤ 15 kWh/m <sup>2</sup> a or altern Peak Cooling Load ≤ 10 W/m <sup>2</sup> + see [PHPF
V., = TFA × av			(The CO <sub>2</sub> emissions of a perso	Ho	Primary Energy Demand PE ≤ 120 kWh/m <sup>2</sup> a + se
height of 2.5			Typical values used for energ	Wh	ventilation, cooling, DHW, aux electricity, house
V <sub>V</sub> = 1 P <sub>V</sub> = Heat los: N <sub>VP</sub> = Energet	WINDOWS: U-Values	and Surface Temperatures	② Extract Air = kitchen 60m <sup>3</sup> /	No	Building Airtightness n <sub>s0</sub> ≤ 0.6h <sup>-1</sup> (0.649 is still O
		$= \frac{(A_{glass} \times U_{glass}) + (A_{frame} \times U_{frame})}{4}$	$60m^3/h + 40m^3/h + 20m^3/h +$	Pno	EN 13829 Method A: Envelope in the same cond
heigh	Uwlodow,installed			i =	or ventilation are being used. Difference betwee
n <sub>V.O</sub> = (worst case s			(3) Minimum air change = $V_v \times$	Pres	and negative pressure <10%.
	$G_{\text{mindrer}} = \frac{(3.22)}{2}$	$\frac{4m^2 \times 0.6W/m^2K}{1.820m^2} + \frac{(0.596m^2 \times 1.6W/m^2K)}{1.820m^2}$	$\rightarrow$ n <sub>V,system</sub> = V <sub>average air flow</sub> / V	Pres	Design temperature 20°C (Can be different in ju: Excess temperature ≤ 10% of total yearly hours
n <sub>v,q</sub> =		- <b>x</b> III	Design air flow rate = max. of		Occupancy rate for Verification of residential bu
n <sub>v,syst</sub>	Uwinstalled = Uwindow + Linsta	$= 1.323W/m^2 K + \frac{5.42m}{1}$	Standard / normal flow rate =	1	(PHPPv9: Based on typical occupancy rates for s
n <sub>v,Res</sub>			standard / normal now rate -	Prc	for Planning = 20-50 m <sup>2</sup> /p; entered manually for
1		otal window area (rough opening) :	Infiltration	Ani	New Evaluation Criteria 2015 with PHPPv9 (not
g = SHG	$A_{glass} = w_{glass} \times h_{glass} = Glazing$	area = (1.23-0.117-0.117)m × (1.48		ene	All of the above, except alternative methodolog
$A_{W} = Rc$		window frame area = 1.820m <sup>2</sup> - 1.2	$n_{V,Res} = n_{50} \times e \times \frac{V_{n50}}{V_{cc}} \approx 10\% \text{ o}$	1	and introduction of new classes to address rene
G = Dai		h <sub>glass</sub> = Glazing perimeter (= spacer	V <sub>V</sub>	Ani	Primary Energy Renewable PER is the demand p
r = Red		× h <sub>window</sub> = Window frame perimet	n <sub>v.Rest</sub> = Infiltration air change	wit	energy application and locally available renewat production from PV and wind (and hydro power
r <sub>Dirt</sub> = O		thermal bridge heat loss coefficier lge heat loss coefficient of the insta	$V_{n50} = V_{Air}$ = Pressure test refer	me	
reflecti		laver and 60mm 'over-insulation')	$V_{50}$ = Measured air flow rate at		$PER = \frac{E_{cir} + \frac{E_{tits}}{\eta_{MS}} + \frac{E_{ts}}{\eta_{SS}} + E_{OL}}{PER}$
r <sub>frene</sub> = typical		w certification document, or calcula	v <sub>50</sub> - Weasured an now rate at	-	$PER = \frac{P_{MS}}{E_{ST} + E_{MS} + E_{SS}}$
typical		ial specific parameter, but depends	Efficiency of Heat Recovery (H	Equ	PER Factor for each source and application [kW
					E <sub>dr</sub> Electricity generated by RES used directly
		f a Window (or Wall) Surface temp	Treat Trust Pel 20		E <sub>MS</sub> Electricity from short/medium term storag E <sub>SS</sub> Electricity generated from energy in seaso
		0°C - (2.8W/m²K × 0.13m²K/W × 30° de Ti= Inside air temperature	$n = \frac{r_{EIA} + r_{EAA} + m \times c_p}{m \times c_p} = \frac{r_{EIA} + r_{EAA} + m \times c_p}{m \times c_p}$		End Distribution and other losses
	R <sub>d</sub> = Surface thermal resistance		$\eta_{HR} = \frac{T_{ETA} \cdot T_{EHA} + \frac{P_{el}}{\dot{m} \times c_p}}{T_{ETA} \cdot T_{ODA}} = \frac{20}{-}$	Inv	η <sub>MS</sub> and η <sub>SS</sub> Efficiencies of storage processes (w
		inside and outside $\Delta T = T - T_c = 20^{\circ}$	$\eta_{HR}$ = Efficiency of HRV ( $\geq$ 75%	line	New Passive House Classes: Classic Plus
	bi - remperature unerence	inside and butside 21 - 1 - 16 - 20 h	$\dot{\mathbf{m}}$ = Mass flow [kg/s] $\mathbf{c}_{n}$ = Spe		Renewable PE Demand: ≤60 ≤45
			$c_{p,air} = 0.33 \text{ Wh/m}^3\text{K} = \text{Volumet}$	a =	Renewable Energy Generation: n/a ≥60
	H-VALUE [PHPP:59]	THERMAL BRIDGES [PH	Print .	ladd	Passive House Components (Quality Criteria)
		,	Electricity Demand = Pel / Vflow	R =	Heat protection: U ≤ 0.15 W/m <sup>2</sup> K thermal envelope, opaque eler
Losses ->	H = Temperature specific	The linear transmittance Ψ and			0.15 W/m <sup>2</sup> K); thermal bridge free (to reduce her
	transmission heat losses	compared to adjoining building	Boundary o		interior surfaces) THERMALERIDSES
$Gains \rightarrow \mathbf{P}_{s}$	H = A × U	Compliance Definition ① (requi	ODA	Z =	Heat Recovery Ventilation (HRV, MVHR):
Gains	= 184.23m <sup>2</sup> × 0.138W/m <sup>2</sup> K	building envelope's average U-v		2-	η <sub>HR</sub> ≥ 75% efficiency (to maintain min. 16.5°C su
	= 25.3W/K	of building elements alone, calc	EHA 🗰 🔘 🖉		prefer 85-92%); Low velocity; Electricity demand
	H <sub>α</sub> = I × Ψ	$H_{\rm m} = \Sigma(1 \times \Psi) + \Sigma(\chi) = -3.5W/K +$			Max. 25dB(A) in habitable rooms, 30dB(A) in fur room with ventilation unit;
Sources: Peak-haus Institut: Passinhaus Dienstleistung Gr	= 116.85m × -0.03W/mK	AU <sub>1B</sub> = H <sub>IB</sub> / A <sub>Total thermal envelope</sub> =	/	P =	Balanced (≤ 10% during operation between OD/
	= -3.5W/K	Compliance Definition (2) (prage		Psar	operation (basic / normal / purge: 54 / 77 / 100
$t_{HFAT} = H_T \times 0.024$	$H_{x} = \chi = 0.77W/K$	(to avoid heat losses); and chan	Duct Diameter	In a	Filters for outdoor air ≥ F7 exhaust air ≥ G4;
	1	considered for condensation), la		bec	Frost protection to protect plate HE on exhaust extraction fan is broken (e.g. air subsoil, brine lo
H <sub>T,Germany,PHPP-Defa</sub>	$\Sigma H = 22.57 W/K$	Thermal bridges for window op:	Duct diameter = 2×	Dec	Condensate drain in exhaust air, airtight and in:
Default average		Thermal Bridge Rules:	velocity		Windows*:
$q_i = 4.1 \text{ W/m}^2 \text{ fo}$	$\mathbf{Q}_{1} = \mathbf{\Sigma} \mathbf{H} \times \mathbf{f}_{1} \times \mathbf{G}_{1}$	Avoidance (do not penetrate i	N		$U_{window} \le 0.80 \text{ W/m}^2 \text{K}^{**} \text{ and } U_{winstalled} \le 0.85 \text{ W}$
	= 22.57W/K × 1 × 81.9kKh/a	Pierce-through (if disturbance	V = Volumetric flow rate at sta		temperature asymmetry <4.2K (comfort criterio
	= 1,848kWh/a	<ul> <li>Connection (transfer insulatio</li> </ul>	ideally max. 2m/s (to avoid turbu		PH windows; Triple glazing Uglass ≤ 0.80 W/m <sup>2</sup> K,
0.74	$P_T = \Sigma H \times f_t \times \Delta_{t1 \text{ or } t2}$	Repeating thermal bridges in co	Typical: 100mm with ≤55m³/h, 15	50mm ≤1	g-value = SHGC = 50-55% typical for PH window * Values shown are for cool-temperate climaters
osses → Q <sub>T</sub> Tra	= 22.57W/K × 1 × 30.6K	approximated on the PHPP U-Vi	E		nent certification critera for other climate
South	= 690W	the variation of the $\lambda$ values in $t$	Sources: Passivhaus Institut (PHI), Passivhaus Dienstleistung GmbH (PHD)		classes phA+, phA, phB and phC can be fou
	ferrer and the second s				** For PH certificate: U <sub>w</sub> = 0.80 W/m <sup>2</sup> K verifie
Gains → Qs Solar Gai	Seurons: Passi-Seur Institut (PHI), Passivhaus Dienstleittung GrubH (PHD)	VERm   page 3   © ) All references are reade	to PHPP Manual Version 8 (2013): [PHPP page]		*** Other comfort criteria met by PH: Air spee temperature stratification between head a
ains -> Us Solar Gai					person < 2K; Felt temperature difference in
Free H	eat (not usable heat ani	ns are considered a loss $ ightarrow$ 'r	····		place less than 0.8°C
1 1100	ease processore near gain		11		L
ces: Passivhaus Institut (PHI),	v2.6m	page 1   © André Harrmann   Notia	ble for any errors and omissions		Sources: Passiuhaus Indtitut (PHI), Passiuhaus Dienstleistung Gritith (PHD)
isivhaus Dienstleistung GmbH (PHD)	v2.5m	All references are made to PHPP Manual Vers	ion 8 (2013): [PHPP:page]		

Notice the statement of the each of each yearfor at i at i colspan="2">Construction of the statement							
Process         Cross Ventilation:           A c         Space Heating Domain Q. g. 5 15 WM/m <sup>2</sup> or othermothey/ Pask Heating Load         Process 200 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building, Lings written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building Written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building Written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building Written) Useful Cooling Domain 2 15 00 W/m <sup>2</sup> (and building Written) Useful Cooling Written 2 15 00	$A = K_0 \times \frac{p}{1 - (1 + p)^n}$						
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Renewable P2 Demand: 560 s45 330 kVMrm/m <sup>1</sup> m <sup>2</sup> ad       350 water/day can condense through Imm x Im leak, when outside 0°C, 2018 kVMrm/m <sup>2</sup> mal         Pasive House Components (Quality Criteria)       80% water/day can condense through Imm x Im leak, when outside 0°C, 2018 kVMrm/m <sup>2</sup> mal         Pasive House Components (Quality Criteria)       80% water/day can condense through Imm x Im leak, when outside 0°C, 2018 kVMrm/m <sup>2</sup> mal         Pasive House Components (Quality Criteria)       80% water/day can condense through Imm x Im leak, when outside 0°C, 2018 kVMrm/m <sup>2</sup> mal         I us 0.15 W/m <sup>2</sup> kr; thermal bridge free (to reduce heat loss and avoid cold interior strates) iterwateriation into. IS: 50 capply air temp, at-10°C, and reduce heat loss and avoid cold interior strates).       • exercing the operation of diriting components         Heat Recovery Ventilation (HKV, MWHR):       • exercing the operation and effect/heats is important       • exercing the operation and effect/heats is important.         Max: 559(2k) in abtables from stores, 3068(2k) in functional rooms, 3568(2k)       • exercing air abdat not met       • exercing the operation and effect/heats is important.         Max: based at a in testaway at a constant if and increase       • example able the heat with story ar alone       • exist of comfort will decrease         • first protection to protect plate HC on exhaust at ic 6.1 minutes       0.3 W/m <sup>2</sup> kt* and Quality and insulated.       • exist of mould increase         • Windows**:       • store (mould in crease)       • exist of mould in crease       • estimation of interost log.							
Benewable Energy Generation: In/a 260 2120 KWhyn/M <sup>*</sup> <sub>maxet</sub> BX/BH and inde CC, SD/SH1           Prevention of cold boxs         Prevention of cold boxs           If each protection:         Prevention of cold boxs           If each protection is protecting the protection and the protection is protecting the protection and the protection is protecting.         Prevention of cold boxs           If each protection is protecting between ODA and ENA) and Control will decrease         Prevention is protecting in protection is protecting protection is protecting protecting protecting protecting protecting protection is protecting the ison enables is each protection is protecting it enables is a cold protecting it enables is a cold protection is protectin							
Present House Components (Quality Criteria)         • Prevention of cold floors in the ground floor           • U 40.15 W/m <sup>2</sup> (thermal envelope, opaque elements (typically 0.10- DL 5W/m <sup>2</sup> (thermal envelope, opaque elements (typically 0.10- Preventing air politypically 0.10- Pre							
Heat protection:         Vecanting an output of the some some some some some some some som							
U 5 0.15 W/m <sup>2</sup> K themal envelope, pague elements (typically 0.10 0.15 W/m <sup>2</sup> K; themal envelope, pague elements (typically 0.10 0.15 W/m <sup>2</sup> K; themal envelope, pague elements (typically 0.10 0.15 W/m <sup>2</sup> K; themal envelope, pague elements (typically 0.10 0.15 W/m <sup>2</sup> K; themal envelope, pague elements (typically 0.10 0.15 W/m <sup>2</sup> K; themal envelope, pague elements (typically 0.10 0.15 W/m <sup>2</sup> K; themal envelope, pague elements (typically 0.10 0.15 W/m <sup>2</sup> K; themal envelope, typically 0.10 scuring the source discuss (infiltration) <ul> <li>Sourcing the source discuss (infiltration)</li> <li>Parkite House Statistic of Ventiliation envelope, and the typically 0.10 scuring the insulation effective discuss (infiltration)</li> <li>Parkite House Statistic of Ventiliation envelope (typically 0.10 scuring the insulation effective discuss (infiltration)</li> <li>Passive House Statistic of Ventiliation envelope (typically 0.10 scuring the source of Ventiliation envelope (typically 0.10 typically 0.10</li></ul>							
ID: SW/m/K; thermal bridge free (to reduce heat loss and avoid cold interior surface); Insurance and SW (minimum section); ID: SW/m/K; thermal bridge free (to reduce heat loss and avoid cold interior surface); Insurance and ID: SW/m/K; the invaliance reflect of the external building components							
Heat Recovery Ventilation (HW, MVHR):							
Image 2 75% efficiency (to maintain min. 16.5°C supply air temp. at -10°C, prefer 8 5°2%); Low velocity: Electricity demains. 0.45 W/m/.         For HRV to work efficiently, airtightness is important.           Max. 25dB(A) in habitatie rooms, 35dB(A) in from with ventiliation unit;         How and a supple supp							
Orefer 65-92%: Low wolch; Electricity demand max. 0.43 VM/m <sup>2</sup> ;         What happens if them is a problem (any problem) with the Passive House?           Max. 2548(a) habbalable rooms, 3068(A) in functional rooms, 356(A).         Max happens if them is a problem (any problem) with the Passive House?           Balanced IS JON during operation unit;         Balanced IS JON during operation between ODA and EHA) and Centrolled         I service is conflort will decrease           Poperation (basic, normal / purge: 54 / 77 / 100%; summer bypass);         I Heating load Increases         I Heating load Increases           Filters for outdor air 27 frost protection to protect plate HC on exhaust side and poot-heater if extraction fin is broken (e.g. si subsolt, brin loog, electric);         Supplementary heating might be required         I Heating load Increases           Low during to a subsolt, brin loog, electric);         AN to long; see (PirPP) for symbols & definitions         I Problem 2000 (PIP) For symbols & definitions           During S S SN Um <sup>1</sup> X to keep radiant temperature asymmetry <4.21 (conflort criterion**); typical/ <3 will be the problem 2000 (PIP) For symbols & definitions							
Max. 25dB(A) in habitable rooms, 35dB(A) in functional rooms, 35dB(A) in 6 assiste House Standard not met. <ul> <li>Assiste House Standard not met.</li> <li>Assiste</li></ul>							
Passive House Standart nor met     Passive House Standart Norther     Passive Hou							
Balancel (s 10% during operation between ODA and EHA) and Controlled         + Heating demand increases         Increases           operation (bisk) (normal / purple: 54 / 77 / Dioks, unmore hyposal)         + Heating index increases         Increases           Filters for outdoor all 2 FT exhaust all 2 GG.         Supplementary heating might be required         > No longerable to heat with supply all alone           Interpretation to protect price in a tripted tript all all into structure leads to interstitial         > No longerable to heat with supply all alone           Condensate drain in enhaust all all all into structure leads to interstitial         • Risk of mould increases         • Editivation of internal all into structure leads to interstitial           Ubuncts 2 SBW Um <sup>2</sup> K** and Ubuncted 50.85 W/m <sup>2</sup> K to keep radiant temperature asymmetry <4.24 (comfort criterion***), spically <3.48 with [							
in poperation (basic / normal / purgle: 54, 177 / 100%, summer bypass);     I Heating load increases       if lites for outdoor aix 27 fract and the start is a subsort, into income late is the start is an analysis of the start is subsort, into income late i							
If rost protection to protect plate HE on exhaust side and poot-heater if extraction for is broken (e.g. si subsolt), kind loop, electrici;         Not longer able to heat with supply air alone           Condensate drain in exhaust air, airlight and insulated.         Not longer able to heat with supply air alone         Not longer able to heat with supply air alone           Windows*:         Condensate drain in exhaust air, airlight and insulated.         Not longer able to heat with supply air alone         Not longer able to heat with supply air alone           Ubusitions         Condensate drain in exhaust air, airlight and insulated.         Editization (in, a)         Image: supplementary of a supplementary of air supplementary of a supplementar							
D     extraction fan is broken (e.g. air suboul), brine loop, electric);     • The Original and in subprise and insulated.       Condensate drain in exhaust air, airtight and insulated.     • Extilination of internal air into structure leads to interstitial condensation (n <sub>2</sub> ).       Uwindows *:     • Extilination of internal air into structure leads to interstitial condensation (n <sub>2</sub> ).       Uwindows *:     • Extilination of internal air into structure leads to interstitial condensation (n <sub>2</sub> ).       Uwindows *:     • Extilination of internal air into structure leads to interstitial condensation (n <sub>2</sub> ).       Uwindows *:     • Condensate difference       PH windows:     • Condensate difference       1     gr-value = SHGC = S0-SSX typical for PH windows       1     gr-value = SHGC = S0-SSX typical (interperate climate, (Transparent comport)       0     (theta), T       1     gr-value = SHGC = S0-SSX typical (interperate climate, (Transparent comport)							
Condensate drain in exhaust air, airtight and insulated.     Windows*:     Condensate drain in exhaust air, airtight and insulated.     Windows*:     Condensate drain in exhaust air, airtight and insulated.     Windows*:     Condensate drain in exhaust air, airtight and insulated.     Condensate drain in exhaust airtight a							
Windows*:         Deviation of the conduction (n <sub>i</sub> , )           U_u_value < 0.80 W/m <sup>2</sup> K** and U_u_value < 0.85 W/m <sup>2</sup> K to keep radiant         condension (n <sub>i</sub> , )           U_u_value < 0.80 W/m <sup>2</sup> K** and U_u_value < 0.85 W/m <sup>2</sup> K to keep radiant         (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K** and U_u_value < 0.85 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K**         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue < 0.80 W/m <sup>2</sup> K to keep radiant         (hiscalinancous see (PiPP) for symbols & definitions           U_walue							
U_summer 50.80 W/m <sup>k</sup> t** and U_summer 50.85 W/m <sup>k</sup> to its even radiant temperature symmetry 4.24 (conduct rations <sup>1</sup> ), bypically 4.24 (child, pical) efficiency PH windows; Triple glazing U <sub>start</sub> 50.80 W/m <sup>k</sup> (to 50 W/m <sup>k</sup> is typical; I gravitae =5HGC ± 59.55% typical for PH windows 4. (Limbod) = thermai conductivity         Deviation from North (PHPP 81)           I gravitae =5HGC ± 59.55% typical for PH windows • Values shown are for cool temperature climate. (Transparent compo- t • Values shown are for cool temperature climate. (Transparent compo- t 6 transparent compo- t 7 transparent compo- 7 transparent compo-	90						
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PH windows; Triple glasing U <sub>pins</sub> <b>50.80 W/m</b> K, 0.60 W/m K is typical; <b>1</b> (lambda) = thermal conductivity North: 0' <b>c-value s</b> HOC <b>sol 55%</b> Windows <b>v</b> Values shown are for cool-temperate climate. (Transparent compo- A <b>t</b> = temperature difference East: <b>90</b> '							
Values shown are for cool-temperate climate. (Transparent compo- AT = temperature difference East: 90°							
Δ1 = temperature unreferice case. 30							
classes phA+, phA, phB and phC can be found on www.passiv.de) w (phi) = point thermal transmittance (outby 190)							
** For PH certificate: U <sub>w</sub> = 0.80 W/m <sup>2</sup> K verified with U <sub>gluss</sub> = 0.70 W/m <sup>2</sup> K							
*** Other comfort criteria met by PH: Air speed < 0.08m/s; Room air $A_{crice} = (\pi \times d^6) / 4 = \pi \times r^4 = 0.7854 \times d^2$ West: 270*							
temperature stratification between head and ankles of seated Equilateral triangle = all sides and angles (60 ) equal Northwest: 315'							
person < 2K; Felt temperature difference in a room from place to place less than 0.8°C 1 year = 365 days = 8,760 hours = 8.76 kh/a 1 hour = 2.600 seconds							
place less than 0.8 C I hour = 2,600 seconds  Second Secon							

I hope my brief introduction to the tools will initiate a productive discussion which eventually leads to further developments. The result might be cooperation with others and the development of more customized versions of both tools for specific markets, in different languages and for additional software platforms. I have already received requests to add more conversions, such as for lighting power density, cooling metrics and equipment efficiencies.

#### References

Harrmann, André: Tools for Passive House Exam and Daily Use. Harrmann Consulting, Canada & Germany. www.15kwh10w.com/passive-house-tools/, January 2017

André Harrmann | Harrmann Consulting | 15kwh10w.com Vancouver, Canada + Leipzig, Germany

