MASTER THESIS

COMPARISON OF U.S. AND AUSTRIAN BUILDING STANDARDS FOR A MULTI-STORY TIMBER CONSTRUCTION BUILDING

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Graz, 28th February 2011

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DECLARATION

I declare that this paper is my own work and was written without literature other than the sources indicated in the bibliography. Information used from the published or unpublished work of others has been acknowledged in the text and has been explicitly referred to in the given list of references. This paper has not been submitted in any form for another degree or diploma at any university or other institute of tertiary education.

Christian Kasper

Graz, 28th February 2011

ACKNOWLEDGEMENT

This text would not have been possible without the help of many people. First of all I would like to thank my supervisor DI Dr. Pius Wörle who provided me with the topic of the present Master Thesis and guided me towards the right direction in terms of finding the most interesting spheres to focus on. Furthermore I would like to thank my external supervisor Professor Barry Jones, who made it possible for me to do my research in California by offering a position as a Visiting Scholar at the California Polytechnics State University. He also initiated for me to have my own office on Campus with all the important facilities needed for writing such a paper. Of course I also want to thank Mr. Sämi Behnam for letting me be so flexible about taking classes in advance of my time abroad, which was decisive to become accepted at CalPoly. Furthermore I would like to thank Mike Montoya for providing information about the LEED system, Michael Parolini who helped finding a reference project in San Luis Obispo and Steve Puglisi who agreed on sending me architectural data of his project 'Campus Point'.

I also owe very special thanks to my parents, who guided me through life, let me decide about my future plans and provided the best education to fulfill my career aspiration. My thanks also go to my sister Eva, who with her great amount of diligence to reach her goals, has been a role model for me from back when we were kids until today.
Lastly, I wish to express my gratitude towards my girlfriend Michi, who was always on my side as my partner and best friend and chose to spend more than four months in a foreign country to support me in good and bad times. I am looking forward to building every step of our future together.

Thank you very much!

ABSTRACT

The trend of "green building" is present in industrialized countries throughout the world. Yet, the standards which define a building to be "green" are quite different from country to country and even from state to state. This Master Thesis compares the standards of a multi-story, wooden constructed building in California with those of Austria focusing on building physics and statics.

For comparative reasons the chosen reference project in San Luis Obispo / California was fictitiously built in Austrian climate and calculated according to the Energy Certificate. The part of building physics includes the creation of an energy pass based on thermo technical calculations. The difficulty lies in the comparison of the holistic systems of the mandatory Austrian Energy Certificate and the Title 24 of the California Building Code. Further steps also include a comparison with the LEED for Homes rating system and an outlook about the quality of the Energy Certificate as a prerequisite for a LEED ranking.

The chapter of statics describes the differences within the static calculations by using the relevant building codes and standards in both regions. The selected house in California is being calculated by reference to the "Eurocode" which is applicable in Austria to reveal major distinctions. This contains preliminary structural analysis of the overall concept as well as detailed calculations concerning wind and earthquake forces.

Keywords: structural analysis, wind, seismic, energy efficiency, Eurocode, ASCE

KURZFASSUNG

Der Trend des “grünen Bauens” ist derzeit in der gesamten westlichen Welt präsent und befindet sich gerade in den letzten Jahren auf der Überholspur am Highway der Bautrends. Jedoch unterscheiden sich die definierenden Richtlinien, die ein Gebäude als „grün“ einstufen sehr stark von Land zu Land und sogar von Bundesland zu Bundesland. Diese Master Thesis präsentiert einen Normenvergleich bezogen auf einen mehrgeschossigen Holzbau in der typischen platform frame Bauweise in Kalifornien verglichen mit dem Normenwerk in Österreich, wobei die Themen Bauphysik und Statik in Betracht gezogen wurden.

Aus Gründen der Vergleichbarkeit wurde für das in San Luis Obispo / Kalifornien ausgewählte Referenzprojekt fiktiv ein österreichischer Standort angenommen und danach der Energieausweis erstellt. Der bauphysikalische Teil dieser Master Thesis enthält die Erstellung eines Energieausweises laut OIB Richtlinie 6 sowie einen Vergleich mit den kalifornischen Standards. Die Schwierigkeit dabei lag an der Vergleichbarkeit des in Österreich obligatorischen Energieausweises mit der Normenuntergruppe Title 24 des California Building Codes (CBC). Eine weitere Vertiefung dieses Themas im Zuge der vorliegenden Arbeit illustriert auch eine Gegenüberstellung mit dem international immer mehr an Bedeutung gewinnenden LEED Zertifizierungssystem sowie die Möglichkeit den ohnedies vorgeschriebenen Energieausweis als Voraussetzung dafür zu verwenden.

Das Kapitel der Statik schildert die Unterschiede in den statischen Berechnungen anhand der jeweils relevanten Normenwerke in den beiden Vergleichsregionen. So wurde das ausgewählte Referenzprojekt in Kalifornien nach dem in Österreich zur Anwendung kommendem Normenwerk der Eurocodes berechnet um grundlegende Unterschiede darzulegen. Diese Berechnungen beinhalten neben einer allgemeinen Vorstatik des Gesamtkonzeptes auch Detailkalkulationen wie einer Windkraft- sowie Erdbeben-berechnung.

Stichworte: Statische Berechnung, Wind, Erdbeben, Energieeffizienz, Eurocode, ASCE

CONTENT

1 INTRODUCTION

To illustrate the most widely used construction methods in the Californian residential timber construction sector, this chapter gives a short overview about the history of timber construction and the two most prevalent framing methods called platform- and balloon framing. To understand the in the following chapters immersed context of building codes and regulations within the United States of America and consequently California also a description of that topic is given.

1.1 History of timber construction

Early wood frame construction in the colonies of the United States was realized by creating a heavy timber frame in combination with non load-bearing infill walls. The connections of the main structural posts and beams were executed as mortise and tenon joints which required a lot of manpower to be accomplished. The precursor of the in California nowadays prevalent building system for residential construction was developed in the early 19th century. The first balloon-frame buildings were completed in 1832 and 1833. The first building ever to be erected using this construction method was a storehouse in Chicaco, built by George Washington Snow. One year later Saint Mary's Catholic Church constructed by Augustine Taylor was finished.[1] The term balloon frame can be traced back to a sarcastic expression of the carpenters participating in the construction process of the Church who were certain, that this new building technology would not be more steady than a balloon and that it would be blown away with the first moderate breeze. Both the building, which withstood all stresses and strains, as well as the notation of the framing method persisted over time. Although lumber was sufficiently available in those times it was hard to find skilled labor to erect heavy timber structures. Due to lower costs for the erection of a balloon frame building compared to a heavy timber structure and the simplicity of this construction method, it was soon the predominant building technique in the United States of America. Balloon-frame constructed three-story apartment buildings, so called triple-deckers, were typical apartment buildings in working – class districts during the 19th and early 20th century. Only when in the 1950s the even lighter platform frame method was developed the balloon frame was replaced and resurrected years later within the modern steel construction.[2]

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[1] Spence, William P. / Kultermann, Eva: Construction Materials, Methods and Techniques – Building for a sustainable Future. New York/ USA: Delmar Cengage Learning, 3rd Edition, 2006

[2] Vogt, Floyd: Carpentry. New York/ USA: Thomson Delmar Learning, 4th Edition, 2006

1.2 Construction methods

1.2.1 Balloon frame construction

The balloon frame method utilizes long vertical framing members running uninterrupted from the sill of the first floor all the way to the top plate of the uppermost floor with additional floor constructions nailed to them in between. Due to the low shrinkage of wood in the longitudinal direction and the decoupling of horizontal load-bearing elements, the settling can be reduced to a minimum thanks to a more direct load path in to the foundation. To avoid unequal settlements throughout the building, the load transfer takes place directly between the vertical studs and the girders.

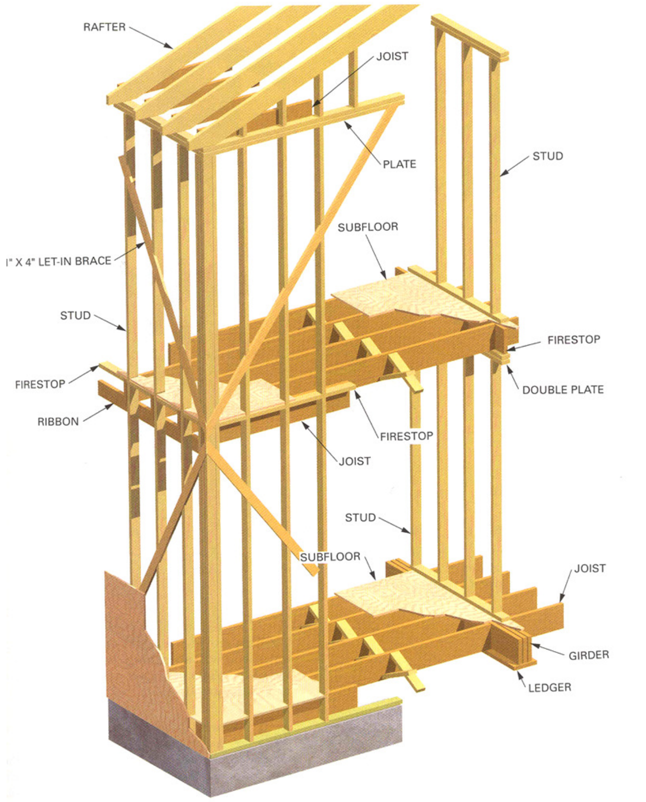


Figure 1: Ballon frame

The disadvantages of balloon framing are:

- Due to the continuous studs a path for fire is created to travel from floor to floor. This danger can be eliminated by the installation of so called firestops.
- Due to a lack of working platforms in comparison to a platform frame structure there is a need of scaffolding during the construction process.
- Variable shrinkage values within the overall structure can lead to a down-slope of floor units in large buildings caused by differential settlements of perimeter- and center walls.
- The demand for long framing components

This type of construction has been replaced by the platform frame in the last 60 years but a remarkable number of objects still exist.[3]

[3] Cf. Vogt, Floyd (2006)

1.2.2 Platform frame construction

The platform frame is the most commonly used method within the North American residential construction. This type of construction uses the different sections when proceeding during a project as a new base for the next one. For example, the walls of the first floor are raised on top of the floor frame. On top of those walls the second floor level is built and the cycle begins again. This way, each floor can be used as a flat working plane and therefore is easier to erect than a balloon frame. A widely used practice is to assemble the wall sections on the floor and tilt them into the right position where they will be fixed.[4]

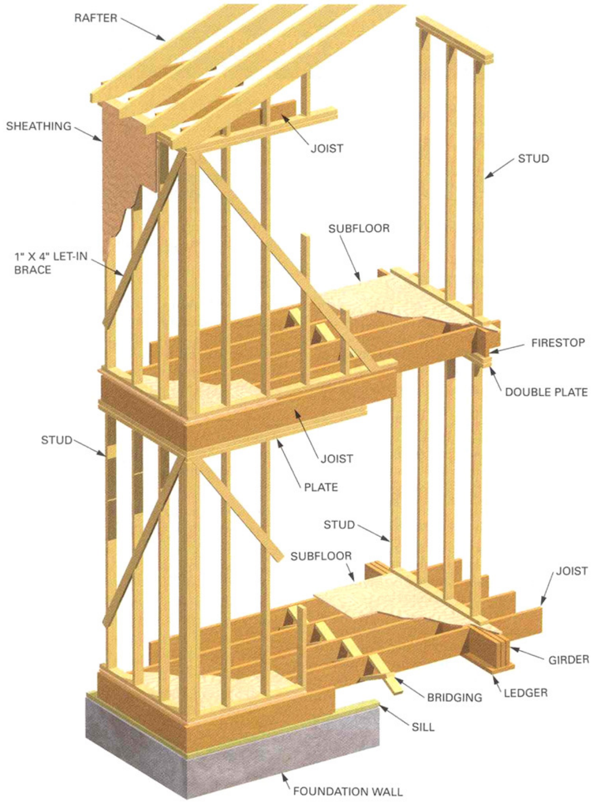


Figure 2: Platform frame

A considerable disadvantage of the platform frame is the unfavorable direction of lumber shrinkage. Since the shrinkage values of wood are most decisive in width and thickness, the horizontal load-bearing frame parts are a crucial component for a relatively large amount of settling. However, due to the equal amount of load-bearing horizontal members the settlement is almost the same throughout a building and can be reduced by only using conditioned lumber with the adequate moisture content.[5]

[4] Cf. Vogt, Floyd (2006)

[5] Cf. Spence, William P.: Construction Materials, Methods and Techniques. New York / USA: Thomson Delmar Learning, 2nd Edition, 2006

1.3 Building codes

"Cities and counties across the United States typically adopt a building code to ensure public welfare and safety. Until recently, most local governments used one of the three regional model codes as the basic framework for their local building code. The three major model codes are the

1. *Uniform Building Code […]*
2. *The BOCA National Building Code […]*
3. *Standard Building Code […]"* [6]

1.3.1 Development

In general, the distribution of those Codes was divided into three parts. The Uniform Building Code was used in the western part of the United States while the BOCA National Building Code was prevalent in the north and the Standard Building Code was the one to refer to in the south. These Codes were revised and updated on a 3-year cycle.

In the 1990s the code development transcended beyond the regional boundaries and a code model that encompassed all regions and states in the United States was created by the International Code Council (ICC). The ICC itself was originated in 1994 to develop a single set of comprehensive and coordinated national model construction codes without regional limitations.

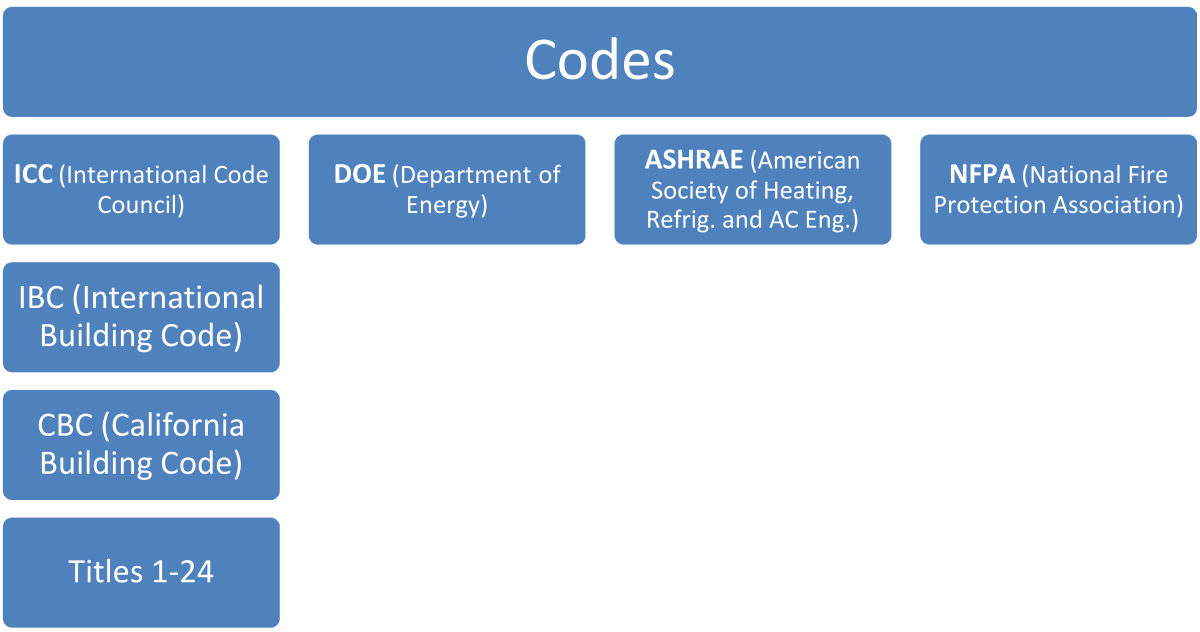


Figure 3: Building Code hierarchy

[6] Breyer, Donald E. et al.: Design of Wood Structures – ASD. 5th Edition, New York et al.: MacGraw-Hill 2003

Within the International Code Council, three representing organizations exist. First of all, the the Building Officials and Code Administrators International, Inc. (BOCA) which is responsible for maintaining the National Building Code. Secondly, the International Conference of Building Officials (ICBO) which monitors the Uniform Building Code. And finally, the Southern Building Code Congress International, Inc. (SBCCI) which administers the Standard Building Code.

The first edition of the International Building Code (IBC) was published in 2000. Since then, most states have adopted all or part of the IBC at either the state or local level.

The standard Minimum Design Loads for Buildings and Other Structures […] is commonly referred to as ASCE 7-02 or simply ASCE 7. It serves as the basics for some of the loading criteria in the IBC and the regional model codes. The IBC directly references ASCE 7 […].[7]

[7] Breyer, Donald E. et al (2003)

2 PRELIMINARY DECLARATIONS

A sensitive subject of the present Master Thesis deals with notations of values with decimal places. While in the United States of America the decimal point is actually written as a dot, a comma is used in this particular paper which is based on the versions of computer programs used for performed calculations. It should be noted, that both European and American software was used to compute decisive data in order to compare the criteria for building envelopes in those two regions. As a basic rule the reader may note, that only commas are used for indicating a decimal point. (Exception: Chapter 7.2)

Secondly, the conversion of imperial to SI units was a tender subject of this Master Thesis. To facilitate traceability of calculations performed in this paper, a conversion table is show below.

Unit	Size	Dimension FPS		Size	Dimension SI
Length	1	inch	=	2,54	cm
	1	foot	=	30,48	cm
Area	1	in^2	=	6,45	cm^2
	1	ft^2	=	0,0929	m^2
Volume	1	in^3	=	16,387	cm^3
	1	ft^3	=	28,317	dm^3
Force	1	lbf = lb(force)	=	4,448	N
	1	kip (=kilo pound)	=	444,8	N
Mass	1	lb/ft^3	=	16,019	kg/m^3
Pressure	1	lbf/in^2 (=psi)	=	6894,76	N/m^2 (=Pa)
	1	ksi (=kip/in^2)	=	6894,76	kN/m^2 (kPa)
	1	lbf/ft^2 (=psf)	=	47,88	N/m^2 (=Pa)
Energy	1	BTU	=	1,05506	kJ
Power	1	BTU/h	=	0,2931	W
Enthalpy	1	BTU/ft^3	=	37,26	kJ/m^3
Heat	1	BTU/ft^2	=	11,357	kJ/m^3
Temperature		5/9°F + 255,38	=		°K
		5/9°F - 17,77	=		°C

Table 1: Conversion table

3 DESCRIPTION OF THE REFERENCE PROJECT

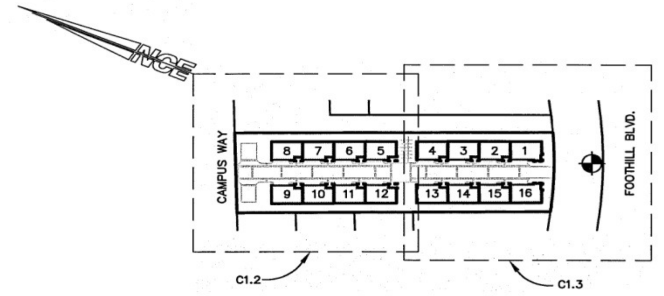
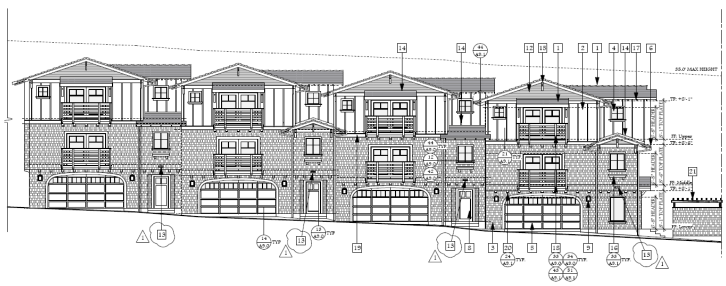
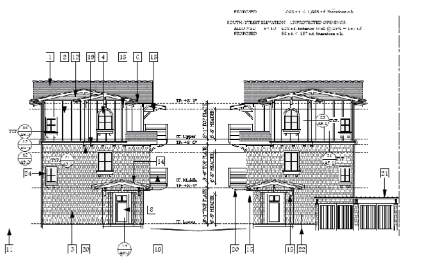
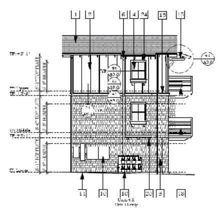
Index map	Adress
	Tract 2969 <u>Campus Point</u> 1310 E.Foothill Blvd. San Luis Obispo CA 93405
Front elevation (WSW)	SSE elevation (units 1 & 16)
	
Rear elevation (ENE)	NNW elevation (units 4, 8, 9 & 13)
	

Table 2: Reference project

At the time this Master Thesis was being written, the reference project “Campus Point” was submitted and approved by the local building authorities in San Luis Obispo, California. The responsible architect agreed to share sets of plans and thermal calculations with the author for the sole use of the research topic the present paper deals with. For the two chapters dealing with structural analysis and building physics, analyses and calculations were conducted on one single unit only, which was established due to the similarity of the units within the whole complex.

4 STRUCTURAL ANALYSIS

The following structural analysis is provided to the author's best knowledge and awareness, using professional approaches with diligence and is subject to error and amendment. The table below shows the relevant codes which were used for all structural analyses conducted within this Master Thesis:

Code distribution	
Europe	**U.S.A**
Eurocode 1: ON EN 1991-1-4	ASCE 7.05
Eurocode 5: ON EN 1995-1-1	ANSI/AF&PA NDS-2001
Eurocode 8: ON EN 1998-1	California Building Code (CBC)

Table 3: Code distribution

The tables revealed on the next two pages show the total loads that have an effect on the building.

4.1 Basis of Design

4.1.1 Total Loads

IMPERIAL UNITS Item / Dead Loads	Roof	2nd/3rd floor	ext. Wall	int. Wall	deck/balcony	cantilevered
	[psf]	[psf]	[psf]	[psf]	[psf]	[psf]
Roofing	6	0	0	0	0	0
Trusses/Rafters	3	0	0	0	0	0
Plywood/Decking	2	3	2	0	3	3
Gypsum board	3	3	2	4	0	0
Insulation	1	1	1	1	0	0
Mechanical/Electrical	1	1	1	1	0	0
Fire sprinklers	1	1	0	0	0	0
Flooring	0	4	0	0	0	0
Floor & ceiling joists	0	3	0	0	6	6
Studs	0	0	2	2	0	0
Decking surface	0	0	0	0	6	6
Exterior surface	0	0	6	0	0	0
Miscallaneous	1	2	0	1	1	1
Total Dead Load	17	15	12	7	15	15
Roof Slope	18	0	0	0	0	0
Live load (red. R2=1)	20	40	0	0	40	60
Total Load	38	55	12	7	55	75

Table 4: Dead Loads - Imperial units

SI UNITS Item / Dead Loads	Roof	2nd/3rd floor	ext. Wall	int. Wall	deck/balcony	cantilevered
	[kN/m²]	[kN/m²]	[kN/m²]	[kN/m²]	[kN/m²]	[kN/m²]
Roofing	0,29					
Trusses/Rafters	0,14					
Plywood/Decking	0,10	0,12	0,07		0,12	0,12
Gypsum board	0,12	0,12	0,10	0,19		
Insulation	0,02	0,02	0,02	0,02		
Mechanical/Electrical	0,05	0,02	0,02	0,02		
Fire sprinklers	0,05	0,05				
Flooring		0,19				
Floor & ceiling joists		0,12			0,26	0,26
Studs			0,07	0,07		
Decking surface					0,29	0,29
Exterior surface			0,29			
Miscallaneous	0,05	0,07		0,02	0,05	0,05
Total Dead Load	0,81	0,72	0,57	0,34	0,72	0,72
Roof Slope	0,86					
Live load (red. R2=1)	0,96	1,92			1,92	2,87
Total Load	1,82	2,63	0,57	0,34	2,63	3,59

Table 5: Dead Loads

4.1.2 Floor weights

Lower Floor Diaphragm Weight				
Area	Load [psf]	length [ft]	width [ft]	Weight [kip]
A	15,00	23,50	22,50	7931,25
	15,00	10,50	6,50	1023,75
	12,00	8,25	47,00	4653,00
	7,00	4,25	15,00	446,25
				14,05 kN
B	15,00	8,50	15,00	1912,50
	12,00	8,25	25,00	2475,00
	7,00	8,25	8,00	462,00
				4,85 kN
			$Sum_{A,B}$ =	18,90 kN
				84,12 kN
Middle Floor Diaphragm Weight				
Area	Load [psf]	length [ft]	width [ft]	Weight [kip]
C	15,00	23,50	22,50	7931,25
	15,00	10,50	5,00	787,50
	12,00	8,25	47,00	4653,00
	7,00	8,25	22,00	1270,50
				14,64
D	15,00	8,50	12,00	1530,00
	18,00	11,50	6,50	1345,50
	12,00	8,25	16,00	1584,00
	7,00	8,25	8,00	462,00
				4,92 kN
			$Sum_{C,D}$ =	19,56 kN
				87,06 kN
Upper Floor Diaphragm Weight				
Area	Load [psf]	length [ft]	width [ft]	Weight [kip]
E	18,00	24,00	25,50	11016,00
	12,00	4,00	47,00	2256,00
	7,00	4,00	30,00	840,00
				14,11 kN
F	18,00	9,00	23,50	3807,00
	12,00	4,00	16,00	768,00
	7,00	4,00	8,00	224,00
				4,80 kN
			$Sum_{E,F}$ =	18,91 kN
				84,15 kN

Table 6: Floor weights

For a description of the areas A to F, see table 28.

4.1.3 Project Specific Load Combinations

4.1.3.1 Basic Load Combinations

a) D + F
b) D + H + F + L + T
c) D + H + F + (L_r or S or R)
d) D + H + F + 0,75*(L+T) + 0,75*(L_r or S or R)
e) 1,13*D + H + F +0,7*E
f) D + H + F + W
g) 1,13*D + H + F + 0,75*(0,7*E) + 0,75*L + 0,75*(L_r or S or R)
h) D + H + F + 0,75*W + 0,75*L + 0,75*(L_r or S or R)
i) 0,6*D + W + H
j) 0,47*D + 0,7*E + H

Where:

D	dead load
E	earthquake load
F	load due to fluids with well-defined pressures and maximum heights
H	load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
L	live load
L_r	roof live Load
R	rain load
S	snow load
T	self-straining force
W	wind load

Because of the geographical location of the reference project, and eliminating factors referring to the building category, not all of the above mentioned load combinations will be taken into consideration but are still shown due to reasons of completeness.

4.2 Preliminary structural analysis

4.2.1 Seismic Analysis according to ASCE 7-05; Section 6.5.3

Site Location: 1310-1318 Foothill Blvd., San Luis Obispo, CA		Source
Longitude	120,66° E	http://google.maps.com
Latitude	35,3° N	
Spectral Response Acceleration:	a_g	Source
SS [Short period (0,2 sec)]:	1,276 m/s²	http://earthquake.usgs.gov/research/hazmaps/design/
S1 [1 sec Period]:	0,477 m/s²	
Site Soil Classification: SD - Stiff soil profile D	[-]	Source
Design Spectral Response Acceleration (5% Damped):		
Short Period: SDS = (2/3)*(Fa)*(SS)		
Fa	1,00	CBC Table 1613.5.3(1)
SDS	0,85	
1 Sec. Period: SD1 = (2/3)*(Fv)*(S1)		
Fv	1,32	CBC Table 1613.5.3(2)
SD1	0,42	
Occupancy Category: II		Source
Seismic Design Category (SDC):		CBC Table 1604.5
- Based on Short Period Response Acceleration:	D	CBC Table 1613.5.6(1)
- Based on 1 Sec. Period Response Acceleration:	D	CBC Table 1613.5.6(2)
Structural System:		Source
North - South		ASCE 7-05 Table 12.2-1
- Bearing Wall Systems		
- Light-framed walls with structural panels:	13	
- R =	6,5	
- Ωo =	2,5	
- Cd =	4	
East - West		
- Bearing Wall Systems		
- Light-framed walls with structural panels:	13	
- R =	6,5	
- Ωo =	2,5	
- Cd =	4	
Diaphragms :	Flexible	Source
Importance Factor (I):	1	ASCE 7-05 Table 11.5-1
Building height (h_n):	35 ft	

Building Period:		
All other structural systems		ASCE 7-05 Table 12.8-2
$T_a = Ct*h_n^x$		
C_t	0,02	ASCE 7-05 Table 12.8-2
x	0,75	ASCE 7-05 Table 12.8-2
T_a	0,29 sec.	
Redundancy Factor:		**Source**
ρ =	1,3	ASCE 7-05; 12.3.4.2
Response Spectra:		**Source**
$T_S = SD_1/SDS =$	0,493	ASCE 7-05; 11.4.5
$T_0 = 0,2*TS =$	0,099	
$T_a > T_0 = 0,29 > 0,099$	o.k.	
$T_a < T_S = 0,29 < 0,493$	o.k.	
--> therefore only ASCE Eq. 12.8-2 applies		
Seismic Response Coefficient:		**Source**
Maximum Considered Earthquake (MCE) used:		ASCE 7-05; 11.4.6
$V = C_S*\omega_d$		ASCE 7-05; Eq. 12.8-1
$C_S = (SDS*\rho)/(R/I)$		ASCE 7-05; Eq. 12.8-2
$V_{north-south} =$	$0,179 *\omega_d$	
$V_{east-west} =$	$0,179 *\omega_d$	
$\omega_d =$	10,25 kip	
$\omega_{d,DL}=$	45,61 kN	
$\omega_{d,tot}=$	75,92 kN	

Table 7: Seismic analysis ASCE 7-05

4.2.1.1 Calculation procedure

a) Definition of site location according to geographical data.

b) Determination of spectral response acceleration in defined area.

c) Determination of the site soil classification depending on an expertise.

d) Calculation of site specific values SDS and SD1 according to CBC tables.

e) Determination of seismic design categories according to CBC tables.

f) Determination of the structural coefficients for both building axes:
R...... Response modification coefficient
Ω_o .... System overstrength factor
C_d .... Deflection amplification factor

g) Determination of the importance factor (I) in coordination with ASCE 7-05.

h) Building height according to set of plans provided by the responsible architect.

i) Determination of values of approximate period parameters C_t and x.

j) Determination of the redundancy factor in coordination with ASCE 7-05.

k) Calculation of the response spectra and synchronization with the applicable equation.

l) Calculation of the seismic response coefficient and maximum considered earthquake force.

4.2.2 Seismic analysis according to EC-8

Roof	Weight [kN]	m²	kN/m²	Weight [kN]	Area [m²]	Total weight [kN]
Construction	55,85	64,94	0,96	62,34	64,94	
		psi2:	0,30			
added up:	55,85	psiE:	1,00	**18,70 kN**		**74,55 kN**
3rd floor		m²	kN/m²	Weight [kN]	Area [m²]	Total weight [kN]
Construction	84,15	64,94	1,92	124,68	64,94	
		psi2:	0,30			
added up:	140,00	psiE:	1,00	**37,41 kN**		**177,40 kN**
2nd floor		m²	kN/m²	Weight [kN]	Area [m²]	Total weight [kN]
Construction	87,06	67,66	1,92	129,91	67,66	
		psi2:	0,30			
added up:	227,06	psiE:	1,00	**38,97 kN**		**303,44 kN**
1st floor		m²	kN/m²	Weight [kN]	Area [m²]	Total weight [kN]
Construction	84,12	64,94	1,92	124,68	64,94	
		psi2:	0,30			
added up:	311,18	psiE:	1,00	**37,41 kN**		**424,96 kN**

Table 8: Seismic analysis EC-8 – No. 1

Value:	Formula	Result	
T_1 =	$T_1 = c_t * H^{(3/4)}$	0,295	m
ct =		0,05	[-]
Bracing frame:	Formula	Result	
l_{wi} =	lwi_max = 0,9*H	9,603	m
A_i =		2,881	m²
A_c =	$A_c = \Sigma[A_i *(0,2 + (0,9))^2]$	3,486	m²
Site Soil Classification: C (equivalent to "D" in ASCE 7-05)	Formula	Result	
T_c =	for: $T1<4*T_c$	0,6	
m=		424,96	kN
λ =	for: $T_1<2*T_c$	0,85	
$S_{d(T)}$ =	$S_{d(T)} = a_g * S* (2,5/q)$	2,13	m/s²
F_b =	$S_{d\,(T1)} * m *\lambda$	76,82	kN
S =		1,00	
q =		1,50	
a_{gR} =	acc. ASCE 7-05	1,276	m/s²
γ_i =	Category II	1,00	
a_g =	$a_g = \gamma_i * a_{gr}$	1,28	m/s²
$E_d=F_b/m$=		18,08%	

Table 9: Seismic analysis EC-8 – No. 2

4.2.3 Wind Analysis according to ASCE 7-05

Design Procedure:

a) Determination of wind speed "V" and wind directionality factor "Kd"
b) Determination of an importance factor "I"
c) Determination of exposure category and velocity pressure coefficient "K_z" or "K_h"
d) Determination of a topographic factor "K_{zt}"
e) Determination of a gust effect factor "G"
f) Determination of an enclosure classification
g) Determination of an internal pressure coefficient "GC_{pi}"
h) Determination of an external pressure coefficient "C_p"
i) Determinatino of the velocity pressure "q_z" or "q_h"
j) Determination of the design wind load "p" or "F"

Basic wind speed (V): V = 85,00 mph (= 38 m/s)

Wind directionality factor: Kd = 0,85

Importance Factor (I): I = 1,00

Exposure Category: B

Surface roughness: B

Velocity pressure exposure coefficient (K_z):

Height [m]	K_z
0 - 4,6	0,7
6,1	0,7
7,6	0,7
9,1	0,7
12,2	0,7
13,75	0,73

Table 10: Wind analysis - K_z

Topographic Factor (K_{zt}): K_{zt} = 1,00

Gust effect factor (G): G= 0,85

Enclosure classification: Enclosed building

Internal pressure coefficient (GC_{pi}): GC_{pi} = +0,18 / -0,18

External pressure coefficient (C_p):

Wall:	C_p
windward wall	0,8
leeward wall	-0,5
side wall	-0,7

Table 11: Wind analysis - C_p

Velocity pressure (q_z) and (q_h): qz = 11,01 psf
qh = 11,48 psf

Design wind load (p):

Windward:	p(z) =	9,46 psf
	p(h) =	9,87 psf
Leeward:	p(z) =	-2,70 psf
	p(h) =	-2,81 psf
Side wall:	p(z) =	-4,57 psf
	p(h) =	-4,76 psf

height [m]	p windward [psf]	p leeward [psf]	p side wall [psf]
0-4,6	9,46	-2,70	-4,57
6,1	9,46	-2,70	-4,57
7,6	9,46	-2,70	-4,57
9,1	9,46	-2,70	-4,57
10,7	9,87	-2,81	-4,76

Table 12: Wind analysis - wind load

height [m]	p windward [psf]	p leeward [psf]	p side wall [psf]
0 - 4,6	0,45	-0,13	-0,22
6,1	0,45	-0,13	-0,22
7,6	0,45	-0,13	-0,22
9,1	0,45	-0,13	-0,22
12,2	0,45	-0,13	-0,22
13,75	0,47	-0,13	-0,23

Table 13: Wind analysis - wind load 2

Wind building load (F): F = 6600,20 lb
F = 29,37 kN

4.2.4 Wind Analysis according to EC1

Data	Value	Unit	Source
Location:	San Luis Obispo / California		
Geometry			
Length:	10,00	m	
Width:	6,86	m	
Height:	9,74	m	
Roof:	gable roof		
Surface category:	III		
Basic Windspeed (vb,0):	38	m/s	ÖNORM EN 1991-1-4:2006, Section 7.2.2 (interpolated)
Basic Windspeed pressure (qb,0):	0,78	kN/m²	
Reference height (h):	9,74	m	
Gust velocity pressure (qb,0):	1,63	kN/m²	

Table 14: Wind analysis - basic data

Total Wind Force - longitudinal direction:

Data	Value	Unit	Source
h/b =	1,42	[-]	
l/b =	1,46	[-]	
c_f =	1,15	[-]	ÖNORM B 1991-1-4; Table 4
z_{e1} =	9,74	m	
z_{e2} =	6,86	m	
c_s*c_d =	1	[-]	ÖNORM EN 1991-1-4:2006, Section 6.2(1)a
$q_{p(z)} = q_{p(h)}$ =	1,63	kN/m²	
$q_{p(z)} = q_{p(b)}$ =	1,50	kN/m²	
$F_{w\_long,1} = c_s c_d * c_f * q_{p(zo)} * A_{ref}$	125,07	kN	
$F_{w\_long,2}$	114,98	kN	ÖNORM EN 1991-1-4, Formula 5.3

Table 15: Wind analysis - longitudinal

Total Wind Force - lateral direction:

Data	Value	Unit
h/l =	0,974	[-]
w/l =	0,686	[-]
c_f =	1,15	[-]
F_{w_lat} =	182,32	kN
F_{w_lat} =	1,87	kN/m²

Table 16: Wind analysis - lateral

4.3 Detail calculation

4.3.1 Vibration behavior of residential ceiling (ÖNORM EN 1995-1-1)

According to EC5 a residential ceiling, with an Eigenfrequency of f_1 > 8 Hz, has to fulfill the following criteria:

$$\frac{\omega}{F} \leq a \left[\frac{mm}{kN}\right]$$

and:

$$\nu \leq b^{(f1 * \zeta - 1)} \left[\frac{mm}{kN}\right]$$

where:

ω ....maximum initial vertical deflection

ν ....characteristic impulse response

ζ ....modal damping ratio

$$f_1 = \frac{\pi}{2 * l^2} * \sqrt{\frac{(EI)_l}{m}}$$

where:

m mass per unit of area [kg/m²]

l ceiling span [m]

$(EI)_l$ equivalent bending stiffness of the ceiling perpendicular to the trusses [Nm²/m]

$$\nu = \frac{4 * (0{,}4 + 0{,}6 * n_{40})}{m * b * l + 200}$$

where:

n_{40} Number of vibrations of 1st order with a maximum resonance frequency of 40 Hz

b Width of ceiling [m]

$$n_{40} = \left\{\left[\left(\frac{40}{f_1}\right)^2\right] - 1 * \left(\frac{b}{l}\right)^4 * \frac{(EI)_l}{(EI)_b}\right\}^{0{,}25}$$

Where:

$(EI)_b$ equivalent bending stiffness of the ceiling in longitudinal direction of trusses [Nm²/m]

Name	Symbol	Value	Unit
Eigenfrequency	f1	16,44	Hz
Characteristic impulse response	v	0,003334	m/(Ns²)
Number of vibrations of 1st order	n_{40}	1,47	[-]
Ceiling span	l	6,86	m
Ceiling width	b	7,16	m
Equivalent bending stiffness_longitudinal	EI_l	6.609.756	Nmm²
Equivalent bending stiffness_perpendicular	EI_b	6.287.417	Nm²/m
Mass per unit of area	m	27,24	kg/m²
Inertial deflection	$w_{\_inst}$	11	mm
Inertial Force	F	3,6	kN
Deflection -Force Ratio	w/F	3,06	mm/kN
Modal Damping ratio	ζ	0,01	[-]

Table 17: Vibration behaviour - input values

Name	Value	Unit
E-Modul (parallel to fibre)	11000	N/mm²
Plywood	0,019	m
lumber S10:		
e	0,41	m [o.c.]
n_trusses	17	[-]
TJI560 14":		
Weight	6,25	kg/m
Trusses per meter	2,44	[-]
Total Mass:	15,24	kg/m²
EI(l)	6.609.756	Nm²/m
EI(b)	6.287.417	Nm²/m

Table 18: Vibration behaviour - calculation values

Synchronizing the requirements of ÖNORM EN 1995-1-1 with the above performed calculations for the reference project, all demands are covered:

$$3{,}06 \leq 4 \left[\frac{\text{mm}}{\text{kN}}\right] \quad \text{and:} \quad 0{,}003 \leq 0{,}19 \left[\frac{\text{mm}}{\text{kN}}\right]$$

5 DISCUSSION – STRUCTURAL ANALYSIS

Due to reasons of comparability the structural part of this thesis was computed by using the input data of the actual location of the reference project in San Luis Obispo, California. Using this procedure, the seismic and wind calculations were first computed by using the applicable California Building Code. Secondly, the values were converted into SI units and used for the calculation according to the relevant Eurocodes.

Comparing the two computation models based on the ASCE 7-05 and EC-8 for the seismic analyses it is striking that both final results are only minimally different, but basically the outcome is mutually the same. The maximum earthquake force is 0,179*ω_d (ASCE) compared to 0,181*ω_d (EC) and therefore only differs by a percentage of approximately 0,2% which is almost neglectable. Hence, although the approaches are not equal to each other, the calculative static effect is the same. It shall be noted, that this result only refers to a very specific building method and no similarities to other projects or methods can be guaranteed.

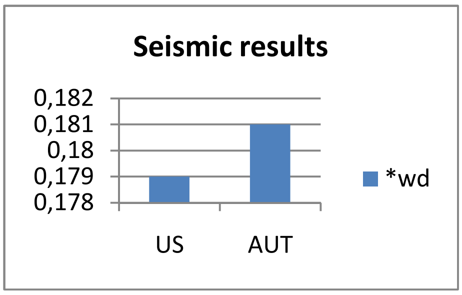


Table 19: Seismic results

Secondly, the ASCE 7-05 method of calculating the total wind force within the static calculations differs fundamentally from those computed using the EC-1 to be applied to the same building, at the same location. The American calculation model is therefore six times less stringent than the European which is alarmingly low considering the high wind speeds at the west coast of the United States of America. Again, this calculation is only valid for this specific reference project at the actual project location but considering the wide distribution and common trend of building methods, this accounts for numerous buildings throughout California.

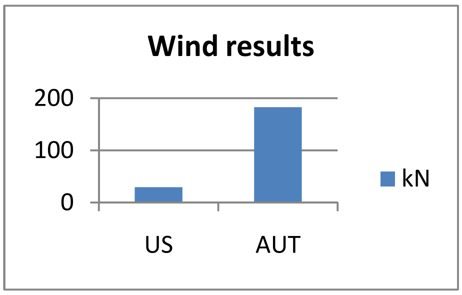


Table 20: Wind results

Due to the not given necessity on the part of the building permit in California to analyze the vibration behavior of a residential ceiling, this detail calculation was only performed according to the Austrian standard ÖNORM EN 1995-1-1 and covered all necessary demands. In principle, it should be noted, that the building method is very light-weighted in general, with a maximum floor load of 2,63 kN/m² and a maximum cantilevered load of 3,59 kN/m². This fact can only be reached by a tremendous economization in terms of weight of the construction, especially the ceiling/floor construction.

6 BUILDING PHYSICS

6.1 Decisive U.S. Energy Data

In this chapter an overview about the prevalent mandatory regulations and additional voluntary measures concerning building physics and green building in general is given. General data about energy consumption, resource use and waste generation is provided to give an overview of the current situation in the United States.

The building sector in the United States accounts for a high proportion of resource use and waste generation:

- 14% of potable water consumption;
- 30% of waste output;
- 38% of carbon dioxide emissions;
- 40% of raw material use;
- 24% to 50% of energy use[8]

The U.S. construction market accounts for 13.4% of the $13.2 trillion U.S. GDP[9] (gross domestic product) and therefore provides sufficient projects to assess green building concepts on a wide range and with enough influence to obtain a noticeable change.

Green building definitely is a growing theme as rating systems, tax incentives and growing social responsibility are increasing more and more. *The overall green building market (both non-residential and residential) is likely to more than double from today's $36-49 billion to $96-140 billion by 2013.*[10]

[8] Energy Information Administration: EIA Annual Energy Review and Energy Information Administration – Emissions of Greenhouse Gases in the United States. Washington: 2005
[9] Department of Commerce: Annual Value of Construction Put in Place. New York: 2008
[10] McGraw Hill Construction: Green Outlook 2009 – Trends Driving Change. New York, 2009

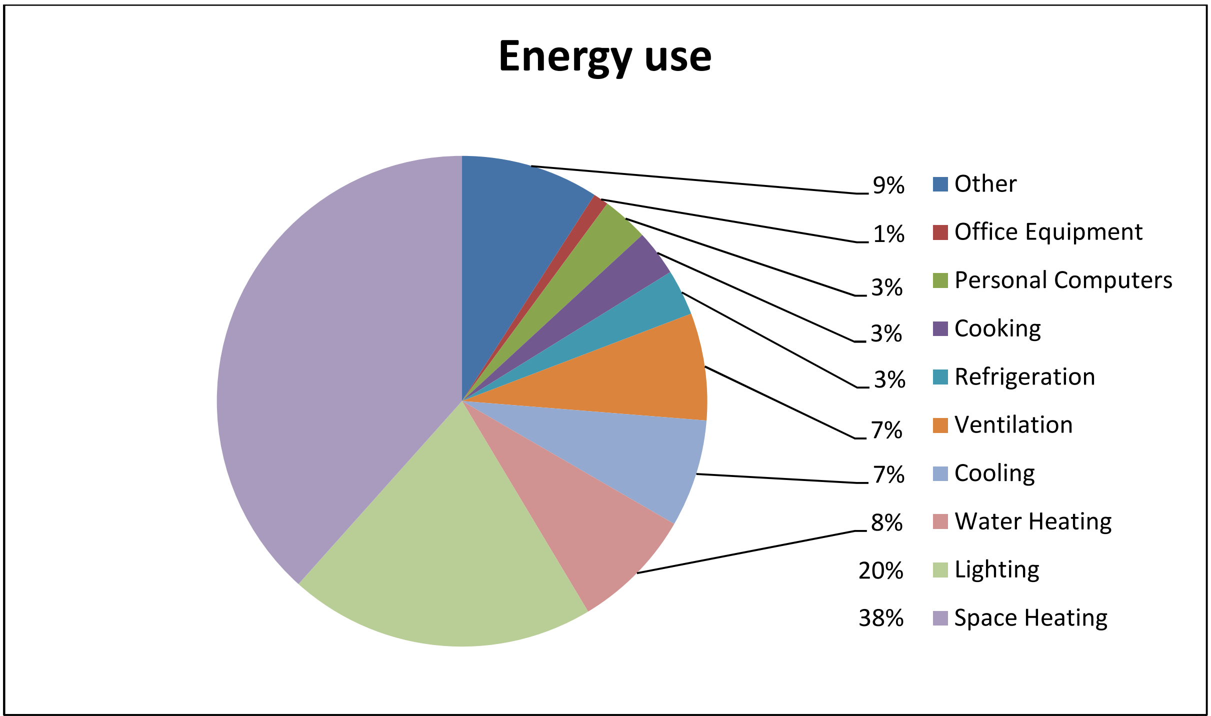


Figure 4: Energy use[11]

Energy consumption:

Buildings represent 38.9% of U.S. primary energy use (includes fuel input for production)[12] and are one of the heaviest consumers of natural resources and account for a significant portion of the greenhouse gas emissions that affect climate change. In the U.S., buildings account for 38% of all CO2 emissions.[13]

Water use:

Buildings use 13.6% of all potable water, or 15 trillion gallons per year.[14]

Materials use:

Buildings use 40% of raw materials globally (3 billion tons annually).[15]

Waste:

The EPA estimates that 136 million tons of building-related construction and demolition (C&D) debris was generated in the U.S. in a single year.[16]

Compare that to 209.7 million tons of municipal solid waste generated in the same year.[17]

[11] U.S. Green Building Council: Green Building and LEED Core Concepts Guide. 1st Edition, Washington, 2010
[12] Environmental Information Administration: EIA Annual Energy Outlook. New York, 2008
[13] Energy Information Administration: Assumptions to the Annual Energy Outlook. Washington, 2008
[14] U.S. Department of Interior: U.S. Geological Survey (2000). USA, 2000
[15] Lenssen and Roodman (1995): A Building Revolution – How Ecology and Health Concerns are Transforming Construction. Worldwatch Institute. Worldwatch Paper 124, 1995
[16] U.S. Environmental Protection Agency: U.S. EPA Characterization of Building-Related Construction and Demolition Debris in the United States. San Francisco, 1997

6.2 Decisive Austrian Energy Data

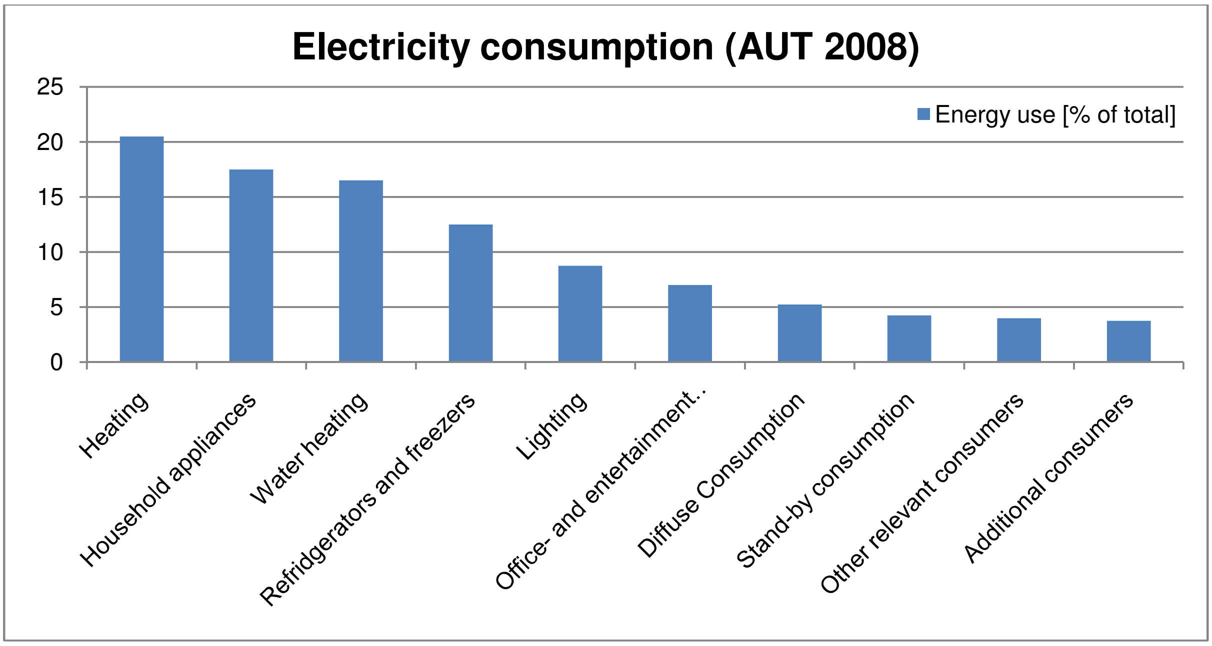


Figure 5: Annual electricity consumption of households in Austria (2008)[18]

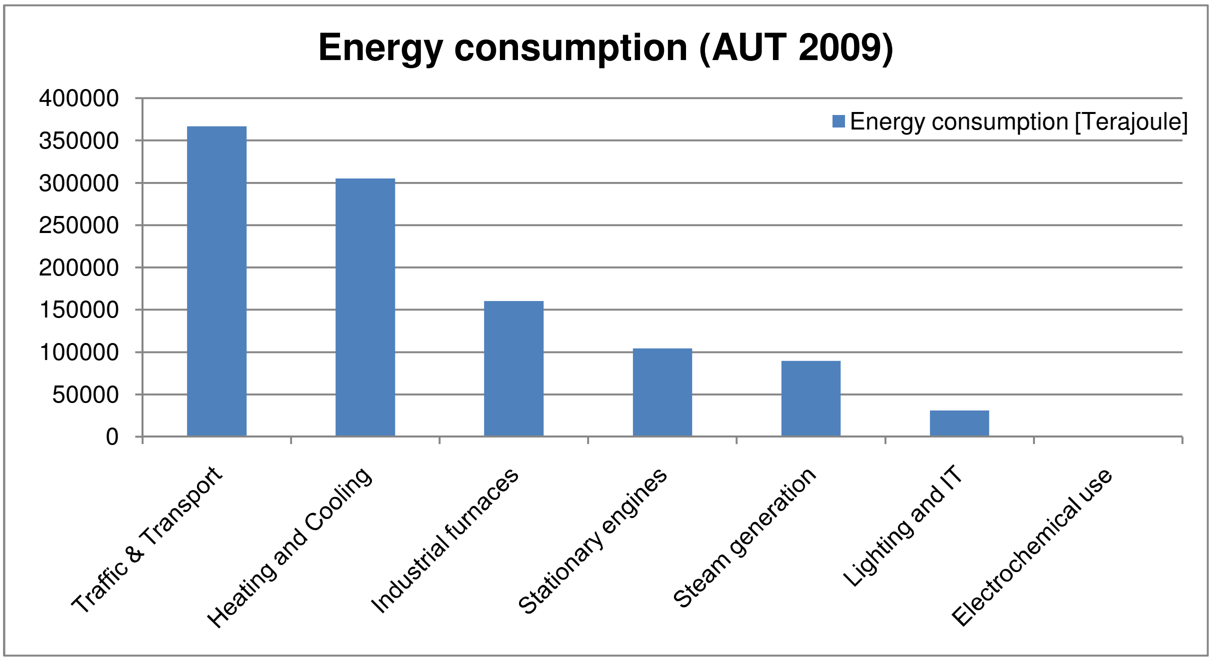


Figure 6: Total energy consumption in Austria (2009)[19]

[17] U.S. Environmental Protection Agency: Characterization of Municipal Solid Waste in the United States. Report No. EPA 530/R-98-007. San Francisco, 1997
[18] URL: http://www.statistik.at/web_de/energie_und_umwelt/energie/energieeinsatz_der_haushalte/[10.02.2011]
[19] URL: http://www.statistik.at/web_de/energie_und_umwelt/energie/nutzenergieanalyse/ [10.02.2011]

6.3 Conclusion

Comparing the local values of the U.S. and Austria it is noticeable that the overall distribution of energy used within a building differs in a great extent (see table below).

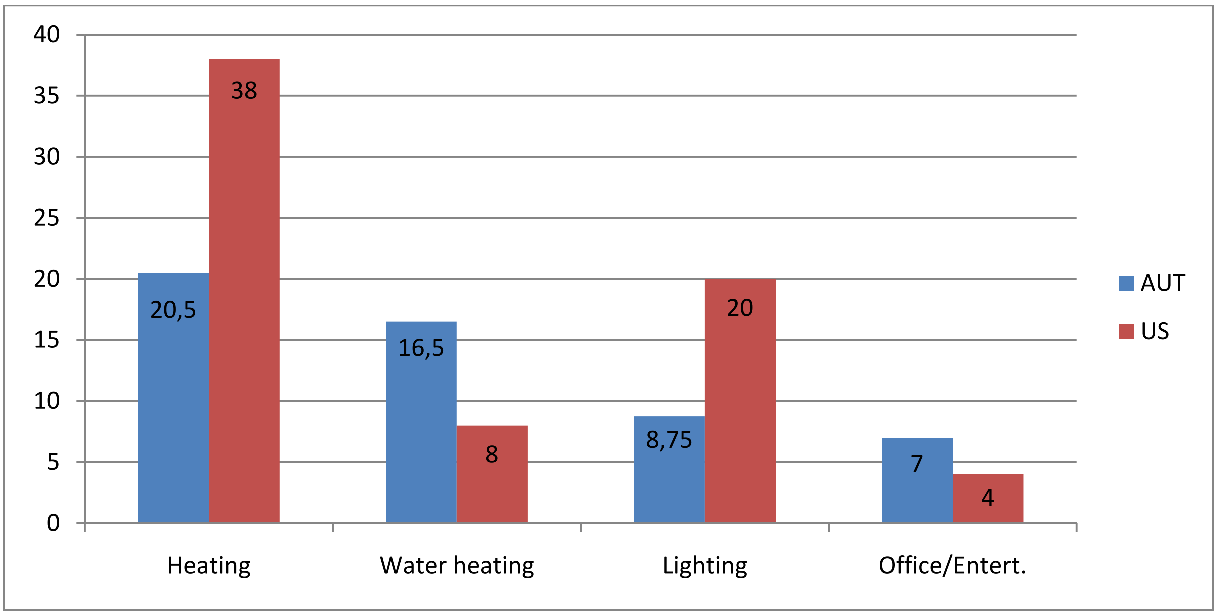


Figure 7: Energy use within a building in %

6.4 LEED

LEED was designed to encourage and accelerate global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted standards, tools, and performance criteria.[20]

> *"LEED (Leadership in Energy and Environmental Design) is a green building certification and rating program in the US and has shown a substantial growth in the last 10 years. This is due to governmental leadership and great efforts from built environment professionals to change the building industry and practice towards sustainable design."*[21]

After years of research and development, LEED version 1 was launched in 1998 with only a handful of projects achieving certification. After repeated review and adjustment, LEED NC (new construction) version 2.2 was released in 2006. Continued development and the incorporation of regional concerns have led to the current standard, LEED version 3, launched in 2009.[22]

[20] URL: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1750 [30.9.2010]
[21] Lee, Young S. / Guerin, Denise A.: Indoor environmental differences between office types in LEED-certified buildings in the US. Michigan/ USA: Elsevier Ltd, 2009
[22] Cf. Spence, William P. / Kultermann, Eva (2006)

When LEED was first established, most of the projects that applied for the certification were public and governmental building projects that had a different financial structure from private and commercial projects.[23] The importance of LEED for private building owners is caused by savings from operating costs and the increased employer satisfaction, in case of private commercial buildings.[24]

6.4.1 LEED Committees

LEED committees are responsible for the improvement and implementation of LEED rating systems either in development or undergoing revisions. They remain in existence until their rating system is fully implemented.

In an effort to harmonize and align credits across LEED, the LEED committee structure has transitioned to include three core committees to oversee the project implementation process, market responsiveness, and technical rigor of LEED.

All LEED core committees have associated corresponding committees made up of USGBC members. Any interested member may join the corresponding committee to receive regular updates and minutes from the core committee and may submit questions or comments to the core committee. Core committee and working group members may be elected or appointed from the corresponding committee member body. Only corresponding committee members are eligible to vote in core committee elections.[25]

6.4.2 Contents of the LEED certification

The measurements a project is undergoing during a LEED certification process are:[26]

- Innovation in Design
- Locations & Linkages
- Sustainable sites
- Water efficiency
- Energy & Atmosphere
- Materials & Resources
- Indoor Environmental Quality
- Awareness & Education
- Regional Priority (extra points)

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[23] Lee, Young S./ Guerin, Denise A.: Indoor environmental quality related to occupant satisfaction and performance in LEED-certified buildings, in: Journal of Indoor & Built Environment 2009, Vol. 18 (4), USA, 2009

[24] Kats, G. a.o.: The costs and financial benefits of green buildings, in: Report to California's Sustainable Building Task Force, USA, 2003

[25] URL: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1750 [30.9.2010]

[26] URL: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1989 [29.9.2010]

To achieve LEED certification for a project, the prerequisites in each category have to be met. Optionally, credits can be earned in addition to the prerequisites to reach an overall LEED rating according to the stated levels:

- Certified (40 – 49 points)
- Silver (50 – 59 points)
- Gold (60 – 79 points)
- Platinum (80+ points)

The USGBC Council decided to make it relatively easy for project applicants to reach the first 20 points of the LEED certification by throwing in some easily earnable categories and sub-chapters. The background of this system is the motivation for project owners to make their buildings more energy efficient by showing them to be very close to a certification, which might still take major modifications to actually reach a certification of having a green building.

6.4.3 USGBC – U.S. Green Building Council

The USGBC (United States Green Building Council) was founded in 1998 and is committed to change the way buildings and communities are designed, built and operated. This goal shall be achieved by promoting environmental and social responsibility to improve the quality of life.[27]

[27] Montoya, Michael: Green Building Fundamentals – Practical Guide to Understanding and Applying Fundamental Sustainable Construction Practices and the LEED System. New Jersey/ USA: Pearson, 2nd Edition, 2009

6.4.3.1 USGBC guiding principles

- **Promote the Triple Bottom Line**
  USGBC will pursue robust triple bottom line solutions that clarify and strengthen a healthy and dynamic balance between environmental, social and economic prosperity.

- **Establish Leadership**
  USGBC will take responsibility for both revolutionary and evolutionary leadership by championing societal models that achieve a more robust triple bottom line.

- **Reconcile Humanity with Nature**
  USGBS will endeavor to create and restore harmony between human activities and natural systems.

- **Maintain Integrity**
  USGBC will be guided by the precautionary principle in utilizing technical and scientific data to protect, preserve and restore the health of the global environment, ecosystems and species.

- **Ensure Inclusiveness**
  USGBC will ensure inclusive, interdisciplinary, democratic decision-making with the objective of building understanding and shared commitments toward a greater common good.

- **Exhibit Transparency**
  USGBC will strive for honesty, openness, and transparency.

- **Foster Social Security**
  USGBC will respect all communities and cultures and aspire to an equal opportunity for all. [28]

[28] URL: http://communicate.usgbc.org/usgbc/2006/08.15.06_guiding_principles/guidingPrinciples [30.9.2010]

6.4.4 Advantages of the LEED certification

LEED certified buildings are designed to have:

- Lower operating costs and increased asset value

  The LEED certification does not only involve lower operating costs due to increased energy efficiency but also outperform conventional buildings in sale value, rental rates, and occupancy rates.

  > *"A recent report by the CoStar Group indicates that LEED-certified buildings average square foot higher rent generation and a 3.8% higher occupancy rate when compared to conventional buildings. This study also indicates that LEED-certified buildings are selling for an average of $171 more per square foot than their peers."*[29]

- Less waste sent to landfills
- Better conservation of energy and water
- Healthier and safer environment for occupants
- Reduced amount of harmful greenhouse gas emissions
- Qualification for tax rebates, zoning allowances and other incentives in hundreds of cities
- Demonstration of an owner's commitment to environmental stewardship and social responsibility.

6.4.5 Weaknesses and Problems of LEED

With the creation of the LEED system the United States Green Building Council wanted to give a definition to what defines a building to be green. Yet, some certified projects show features that were only installed to reach a better certification, but are not utilized by the building operators. One example for that phenomenon is the North Boulder Recreation Center in Colorado, which is silver-certified because the project team decided to install six 110-Volt electric car charging stations, with which one single car was charged one time within the first 12 months.

Incidents like this may lead to an increased loss of plausibility of LEED projects to actually be green buildings. On the other hand a project team which certifies a building according to the LEED standards should not be made responsible for an underutilization of features by the building operators and occupants.

Another major weakness of the LEED certification is the rating system, which is based on a checklist and the awarding of points for categories and single features. The difficulty lies in a

[29] Montoya, Michael (2009)

fair, logical and traceable distribution of points, so a project is not built based on the checklist but will rather be qualitatively constructed to be as green as possible.

Another weakness of the system which should be existent in order to be fulfilling a holistic green building rating is the absence of a post construction follow-up examination, which allows the designer to use legal loopholes for the purpose of summing up more points and possibly collecting incentives for a project.

Furthermore, the cost of registration and the additional expenses for architects and engineers which make up the larger part of cost expenditures for a LEED certification might discourage building owners to take the step of certification. The costs for LEED certification might also use funds which could actually be of better use if put into the improvement of a buildings energy efficiency.

Critical voices also excoriate the minimum standards necessary for reaching a certification and the associated remote efforts to actually make a building energy efficient, but much rather putting a green stamp on a building. This way for an average building the certification can be the primary goal instead of the environmental responsibility, the LEED system generally stands for.

> *"Some critics also argue that basic certification is too low a hurdle to merit the green stamp of approval. They say developers can rack up the minimum number of needed points without going much beyond the requirements of local building codes and the efficiency standards of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers."* [30]

To sum up the LEED system in general, it is important to state that the Green Building Council tries to implement a valuable idea but has not been able to generate the perfect execution system to fully realize its goals yet. Despite all the above mentioned problems of the LEED certification the system is spreading fast around the world, and the USGBC as well as local authorities are constantly striving to improve the holistic system, expand and adopt it to more and more sectors of the construction industry to make the LEED system applicable to standards in countries and regions around the world.

[30] URL: http://www.grist.org/article/leed1/ [26.11.2010]

6.5 CalGreen

Besides the topics planning and design, water efficiency, material conservation and resource efficiency as well as environmental quality, it includes a short chapter about mandatory measures concerning energy efficiency. However, the CalGreen itself does not contain more stringent regulations than Title 24 of the California Energy Code.

> *"The department of Housing and Community Development does not regulate mandatory energy efficiency standards in residential buildings. For the purposes of mandatory energy efficiency standards in this code, the California Energy Commission will continue to adopt mandatory building standards."* [31]

6.6 Title 24 (California Energy Code 2010)

Title 24 is part of the California Code of Regulations and regulates the mandatory and voluntary measures that have to be implemented for construction projects. Table 21 shows the application of Standards. The highlighted areas are the crucial chapters for the analysis and comparison of energy efficiency standards. Although the chosen reference object is a low-rise residential building, the following analysis and assessment are taking the high-rise residential into consideration. This can mainly be attributed to the lack of mandatory energy efficiency standards for conditioned building envelopes of low-rise residential buildings.

<table>
<tr><th>Occupancies</th><th>Application</th><th>Mandatory</th><th>Prescriptive</th><th>Performance</th><th>Additions/ Alterations</th></tr>
<tr><td colspan="2">General Provisions</td><td colspan="4">100, 101, 102, 110, 111</td></tr>
<tr><td rowspan="8">Nonresidential, High-rise Residential, And Hotels/Motels</td><td>General</td><td>140</td><td>142</td><td rowspan="6">141</td><td rowspan="8">149</td></tr>
<tr><td>Envelope (conditioned)</td><td>116, 117, 118</td><td>143</td></tr>
<tr><td>Envelope (unconditioned, process spaces)</td><td></td><td>143(c)</td></tr>
<tr><td>HVAC (conditioned)</td><td>112, 115, 120-125</td><td>144</td></tr>
<tr><td>Water Heating (conditioned)</td><td>113, 123</td><td>145</td></tr>
<tr><td>Indoor Lighting (conditioned, process spaces)</td><td>119, 130, 131, 134</td><td>143(c), 146</td></tr>
<tr><td>Indoor Lighting (unconditioned)</td><td>119, 130, 131, 134</td><td>143(c), 146</td><td rowspan="2">N.A.</td></tr>
<tr><td>Outdoor Lighting</td><td>119, 130, 132, 134</td><td>147</td></tr>
<tr><td rowspan="7">Low-rise Residential</td><td>General</td><td>150</td><td rowspan="6">151(a,f)</td><td rowspan="6">151(a-e)</td><td rowspan="6">152</td></tr>
<tr><td>Envelope (conditioned)</td><td>116, 117, 118, 150(a-g, 1)</td></tr>
<tr><td>HVAC (conditioned)</td><td>112, 115, 150(h, i, m, o)</td></tr>
<tr><td>Water heating (conditioned)</td><td>113, 150(j, n)</td></tr>
<tr><td>Indoor lighting (conditioned, unconditioned and parking garages)</td><td>119, 150(k)</td></tr>
<tr><td>Outdoor Lighting</td><td>119, 150(k)</td></tr>
<tr><td>Pool and Spa systems</td><td>114, 150(p)</td><td>N.A.</td><td>N.A.</td><td>N.A.</td></tr>
</table>

Table 21: Application of Standards[32]

[31] California Building Standards Commission: 2010 California Green Building Standards Code – California Code of Regulations, Title 24, Part 11, Sacramento: 2010

[32] California Building Standards Commission: 2010 Building Energy Efficiency Standards, Title 24, Part 6, Sacramento: 2010

The key to Table 21 reads as follows:

Section	Description	Section	Description
100	Scope	118	Mandatory Requirements for Insulations and Roofing Products
101	Definitions and Rules of Construction	140	Choice of Performance and Prescriptive Approaches
102	Calculation of Time Dependent Valuation (TDV) Energy	141	Performance Approach: Energy Budgets
110	Systems and Equipment – General	142	Prescriptive Approach
111	Mandatory Requirements for Appliances Regulated by the Appliance Efficiency Regulations	143	Prescriptive Requirements for Building Envelopes
116	Mandatory Requirements for Fenestration Products and Exterior Doors	150	Mandatory Features and Devices
117	Mandatory Requirements for Joints and Other Openings	151	Performance and Prescriptive Compliance Approaches

Table 22: Key for Table 18

6.6.1 Low-rise residential buildings

"Low-rise residential building is a building, other than a hotel/motel that is of Occupancy Group R*, Division 1, and is multifamily with three stories or less, or a single family residence of Occupancy R, division 3 or an Occupancy Group U building located on a residential site" [33]

6.6.1.1 Mandatory Requirements for Fenestration Products and Exterior Doors (Section 116)

The mandatory measures for low-rise residential buildings of the above mentioned occupancy groups for the topic Mandatory Requirements for Fenestration Products and Exterior Doors (Section 116) are:

- **Air leakage:** Manufactured fenestration products and exterior doors shall have air infiltration rates not exceeding 0.3 cfm/ft² of window area, door area for residential doors and nonresidential single doors and 1.0 cfm/ft² for nonresidential double doors.
- **U-factor:** A fenestration product's U-factor shall be rated in accordance with NFRC 100**, or the applicable default U-factor […].
- **Solar Heat Gain Coefficient (SHGC):** A fenestration product's SHGC shall be rated in accordance with NFRC 200 for site-built fenestration, or use the applicable default SHGC […].
- **Labeling:** Fenestration product shall have a temporary label (or label certificate for site-built fenestration) […] listing the certified U-factor and SHGC, and

[33] Cf. California Building Standards Commission (2010)
* Definition of Occupancy Groups see Appendix A
** Abbreviation for a uniform rating system issued by the National Fenestration Rating Council (NFRC)

certifying that the air leakage requirements […] are met for each product line; and have a permanent label (or label certificate for site-built fenestration) […].

- **Fenestration acceptance requirements:** Not necessary for low-rise residential buildings. [34]

6.6.1.2 Mandatory Requirements for Joints and Other Openings (Section 117)

For the chapter of Mandatory Requirements for Joints and Other Openings (Section 117) the major criteria to fulfill are:

> *"Joints and other openings in the building envelope that are potential sources of air leakage shall be caulked, gasketed, weather-stripped or otherwise sealed to limit infiltration and exfiltration."*[35]

6.6.1.3 Mandatory Requirements for Insulations and Roofing Products (Section 118)

Buildings of this occupancy category also have to comply with the regulations of Mandatory Requirements for Insulations and Roofing Products (Section 118), which are: (only for the energy efficiency relevant paragraphs were chosen)

- Demising walls in nonresidential building shall be insulation with an installed R-value of no less than R-13 between framing members.
- Insulation requirements for heated slab floors shall be insulated according to the requirements […] in table 32 of Appendix B in chapter 9.2.2.

6.6.1.4 Mandatory Features and Devices (Section 150)

- **Ceiling insulation:** Ceilings shall be insulated between wood-framing members with insulation resulting in an installed thermal resistance of R-19 or greater for the insulation alone or with a weighted average U-factor of ceilings that shall not exceed the U-factor that would result from installing R-19 insulation between wood-framing members in the entire ceiling and accounting the effects of framing members.

- **Loose-fill insulation:** When loose-filled insulation is installed, the minimum installed weight per square foot shall conform with the insulation manufacturer's installed design weight per square foot at the manufacturer's labeled U-factor.

[34] Cf. California Building Standards Commission (2010)
[35] Cf. California Building Standards Commission (2010)

- **Wall insulation:** Wood framed walls shall be insulated between framing members with insulation having an installed thermal resistance of R-13 or greater, or have an average weighted U-factor of an installed R-13 insulation between framing members and accounting for the thermal effects of the holistic wall-system.

- **Raised-floor insulation:** Same R-value as for wall insulation.

- **Air retarding wrap:** Has to be labeled and tested by the manufacturer to comply with ASTM E1677-95, Standard Specification for an Air Retarder (AR) Material or system for Low-rise framed building walls, and have a minimum perm rating of 10.

- **Vapor barrier:** If a building has a control ventilation crawl space, a vapor barrier shall be placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation […].[36]

6.6.1.5 Performance and Prescriptive Compliance Approaches (Section 151)

A building complies with the performance standard if the combined depletable TDV* energy use for water heating […] and space conditioning […] is less than or equal to the combined maximum allowable TDV energy use for both water heating and space conditioning.

> *“The water heating budget for each climate zone shall be the calculated consumption of energy from depletable sources required for water heating in building in which the requirements […] for systems serving individual dwelling units or […] for systems serving multiple dwelling units are met […]. The space-conditioning budgets for each climate zone shall be the calculated consumption of energy from depletable sources required for space conditioning in buildings in which the basic requirements […] are met.”*[37]

> *“To demonstrate compliance, the applicant’s documentation shall […] calculate the TDV energy consumption total of the proposed building, using the proposed building’s actual glazing area, orientation and distribution, and its actual energy conservation and other features, including the actual water-heating, space-conditioning equipment and duct conditions and locations.”*[38]

A calculation of the required energy for cooling of the building is required even if the building plans do not indicate the installation of air conditioning.

[36] Cf. California Building Standards Commission (2010)
[37] Cf. California Building Standards Commission (2010)
[38] Cf. California Building Standards Commission (2010)

The required calculation assumptions in determining the water-heating and space-conditioning budgets and calculating the energy use of the proposed building design, the applicant shall use only these assumptions and calculation methods:

- The operating conditions regarding indoor temperature; occupancy loads and schedules; including lighting, HVAC and miscellaneous electrical; and outdoor weather conditions.
- The physical characteristics of building pressurization, interior heat transfer, film coefficients, solar heat gain coefficient and operation of installed shading devices, ground temperatures and the method of determining slab heat loss.
- The applicable modeling procedures for the assumptions, design conditions and physical characteristics.
- Water heating use schedules, cold water inlet temperatures and average outdoor temperatures for calculating water heating loads and losses.

Furthermore, the calculation of the total annual energy consumption has to include all energy used for comfort heating, comfort cooling, ventilation for the health and comfort of occupants, and service water heating. The solar heat gain coefficients for fenestration products shall be 0.68 for vertical and 1.00 for nonvertical.[39]

6.6.2 High-rise residential buildings

High-rise residential building is a building, other than a hotel/motel, of occupancy Group R, Division 1 with four or more habitable stories. [40]
While low-rise residential buildings comply with the applicable Sections 150 and 151, which are responsible for achieving energy efficiency, those sections do apply for high-rise residential buildings. The applicable Sections for high-rise residential buildings are 140, 141 and 142 of the 2010 Building Efficiency Standards. The approach can be chosen by the applicant and can either be accomplished by using the performance approach, which gives limits for the performance of the building envelope or the prescriptive approach. While the performance approach focuses on and states the ultimate result of a building's energy efficiency the prescriptive approach describes the way the ultimate result can be reached. For comparative reasons, the prescriptive approach was chosen for the comparison with the Austrian Energy certificate.

[39] Cf. California Building Standards Commission (2010)
[40] Cf. California Building Standards Commission (2010)

6.7 OIB Guideline 6 – Energy saving and thermal insulation

On April 25th 2007 the OIB Guideline 6 – Energy saving and thermal insulation was agreed on being the prevailing document for energy saving and thermal insulation during the general meeting of the Austrian Institute for Building Technology where all of the nine liable province representatives were present. With this step also the harmonization of legislation, which at this point is very goal-oriented, was realized. The OIB-Guideline 6 defines the requirements concerning thermal-energy quality of buildings and puts the EU building regulation 2002/91/EG into legislation.[41]

6.7.1 Terminology

At this point only the Energy Pass for Residential buildings is taken into consideration. This includes the heat requirement, hot water heat requirement, energy demand of the heating facility, final energy demand and further recommendations where appropriate. Possible cooling- and lighting energy demands are not included in these criteria, since they are only determined for commercial buildings.

To simplify matters, the abbreviations of the original version of the OIB Guideline 6 are adopted in this paper and therefore do not match with the initials of the English denotations.

Specific heating requirement (HWB)

The specific heating requirement represents the actual energy index and therefore is the most common comparative value to describe the thermal quality of a building envelope. This energy index is expressed in kWh/m²a and states how much energy a building would consume per square meter in one year if it would be located at the reference location. It is therefore not a reference of the actual climate zone but refers to the reference climate instead. Consequently this value is applicable for a comparison of the thermal quality of a building.[42]

The heating requirement states the calculated heat quantity that has to be added to a building over a long-term average during a heating season to meet a predefined indoor temperature.[43]

[41] Landgraf, Adolf: Leitfaden für die Umsetzung der EU-Gebäuderichtlinie bei Bestandsobjekten. [Master Thesis, Graz 2007]: 2007
* TDV: Time-Dependent Valuation
[42] URL: http://www.energiesparhaus.at/energieausweis/energieausweis.htm [05.10.2010]
[43] OIB Richtlinie 6. Energieeinsparung und Wärmeschutz. Österreichisches Institut für Bautechnik, 2007

Hot water heating demand (WWWB)

The hot water heating demand states the amount of energy needed for heating a certain quantity of potable water.[44]

Specific energy demand of a heating facility (HTEB)

The HTEB value states the amount of energy used for generation, storage, distribution and delivery as well as the energy losses within the system.

Value of Heating degree days (HGT)

The value of heating degree days is the sum of the daily determined difference between the indoor air temperature (T_i) and the average daily outside temperature (T_a).[45]

Final energy demand (EEB)

Is the externally added amount of energy for space heating and hot water in buildings, for instance the electricity used to operate the heat pump or the energy content of wood pellets.[46] Hence, this value does not only indicate the demand of energy, but also all of the energy losses within the holistic system.

Coefficient of heat transmission (U-Factor)

The U-Factor is the measurement of heat transmission through a building material and is indicated in W/(m²K). The U-Factor is the reciprocal of the thermal resistant coefficient and states the amount of heat quantity [Wh] that passes through one square meter of a material or component within one hour.[47]

Characteristic length (l_c)

In Austria a reference to the geometric ratios of a building has been common for over a decade. The associated value, the characteristic length is determined by the heated gross volume (V_B) over the heated gross surface area (A_B). Alternatively, also the reciprocal value which states the compactness is a usable indicator.[48]

$l_c = V_B / A_B$

[44] URL: http://www.gequo-home.de/glossar/char/W/id/1035.html [05.10.2010]
[45] URL: http://www.energiesparhaus.at/fachbegriffe/hgt.htm [05.10.2010]
[46] URL: http://www.energiesparhaus.at/energieausweis/energieausweis.htm [06.10.2010]
[47] Cf. Landgraf, Adolf (2007)
[48] Pech, Anton a.o.: Bauphysik – Energieeinsparung und Wärmeschutz, Energieausweis – Gesamtenergie-effizienz. Vienna: Springer, 1st extension, 2007

LEK – Value

The LEK – Value characterizes the protection against heat loss of the building envelope under consideration of the geometry of the building and is determined as follows:

LEK = 300 * (U_m / (2 + l_c))

Where: Um … average U-Factor of the building envelope
lc …… characteristic length

Gross plot area (BGF)

The gross plot area is the sum of plot areas of all floors of a building and comprises the net plot area and the construction plot area.[49]

6.7.2 Objective and composition

The guideline contains the following chapters:

- Terminology
- Requirements for heating- and cooling demand
- Requirements for the thermal quality of the building envelope
- Requirements for the final energy demand
- Requirements for heat-transferring components
- Requirements for parts of the power engineering system
- Other Requirements
- Energy Pass
- Exceptions
- Annex A: Sample Energy Passes

6.7.3 Residential Classification

The allocation of a building to the category of residential buildings takes place by means of the utilization, provided that other uses do not feature more than 50m² net surface area or a proportion not larger than 10% of the gross plot area. In case of exceedance of these factors, the building area has to be split and the proportions are assigned to the appropriate category of residential and commercial buildings. The examinations of the requirements are subsequently done for each category.

[49] Österreichisches Normungsinstitut: ÖNorm B 1800 – Determination of areas and volumes of buildings. Vienna: ON, Edition: 2002-01-01

6.7.3.1 Requirements for the heating demand

The following maximum permissible annual heating demand ($HWB_{BGF,WG,max,Ref}$) per m² gross plot area in reliance to the geometry (characteristic length l_c) and the reference climate according to the OIB – Guideline:

$HWB_{BGF,WG,max,Ref}$ = 19 * (1+2,5/lc) [kWh/m²a]	Maximum of 66,5 [kWh/m²a]

6.7.3.2 Controlled ventilation with heat recovery

In buildings with controlled ventilation and heat recovery the value of the heating demand $HWB_{BGF,WG,max,Ref}$ according to item 6.7.3.1 is reduced by 8 kWh/m²a.[50]

6.7.3.3 Requirements for the thermal quality of the building envelope

For residential buildings additional requirements apply for the heating energy demand:
New buildings have to be in compliance with the maximum allowable LEK-Value:

LEK_{max} = 27 [-]	$L_{c,min}$ = 1 [m]

Where: $l_{c,min}$ is the smallest possible characteristic length l_c

New buildings with a controlled ventilation and heat recovery have to be in compliance with the maximum allowable LEK-Value:

LEK_{max} = 31 [-]	$L_{c,min}$ = 1 [m]

Depending on the heating degree days (HGT) of the building location the maximum allowable LEK-Value is:

$$LEK_{Standort} = LEK_{max} * 3400 / HGT_{Standort}$$

Where:

$LEK_{Standort}$ maximum allowable LEK – Value at the building location [-]

LEK_{max} maximum allowable LEK – Value with a value of heating degree days of 3400 Kd […]

$HGT_{Standort}$ value of heating degree days (HGT12/20) at the building location [Kd], with a maximum of 4000 Kd.

6.7.3.4 Requirements for the final energy demand of new residential buildings

New buildings within the residential sector have to be in compliance with the following requirements:

$$EEB_{BGF,WG} \leq HWB_{BGF,WG,max,Standort} + WWWB_{BGF} + f_{HT} * HTEB_{BGF,WG,Ref}$$

Where:

$EEB_{BGF,WG}$ specific final energy demand for new residential buildings

[50] Cf. OIB Richtlinie 6 (2007)

$HWB_{BGF,WG,max,Standort}$ maximum allowable annual heating demand per m² of gross plot area at the building location

$$HWB_{BGF,WG,max,Standort} = HWB_{BGF,WG,max,Ref} * HGT_{Standort} / 3400$$

$HWB_{BGF,WG,max,Ref}$ maximum allowable annual heating demand at the reference climate

$HGT_{Standort}$ value of heating degree days ($HGT_{12/20}$) at the actual building location

$WWWB_{BGF}$ hot water heating demand referring to the gross plot area

$HTEB_{BGF,WG,Ref}$ specific energy demand of the heating facility of a reference facility According to the OIB – Guideline referring to the gross plot area

f_{HT} Increase factor of the specific energy demand of the heating facility of a reference facility: f_{HT} = 1,05.

6.7.3.5 Requirements for heat transferring components

The following U-Factors must not be exceeded:

Component	**U-Factor [W/m²K]**
Exterior walls	0,35
Small-sized exterior walls, which do not exceed 2% of the total surface area of exterior walls. […]	0,70
Partition walls between residential and commercial units	0,90
Walls against unheated building parts that are frost free (exception: attics)	0,60
Walls against unheated or not developed attics	0,35
Walls against other buildings at property lines	0,50
Ground-contact walls and floors	0,40
Windows, French doors, glazed or unglazed doors and other vertical transparent components against unheated building parts	2,50
Windows and French doors in residential buildings against outside air	1,40
Other Windows, French doors and vertical transparent components against outside air, glazed or unglazed exterior doors	1,70
Roof windows against outside air	1,70
Ceilings against outside air, against attics (aerated or uninsulated) and over passageways as well as sloping roofs against outside air	0,20

Table 23: Required U-Factors[51]

6.7.3.6 Special requirements for heat transferring components

In presence of wall-, floor- and ceiling heating systems the maximum heat transfer resistance between the heated surface and the outside air must reach a minimum value of 4,0 m²K/W and between the heated surface and the soil or the unheated building part it must reach a minimum value of 3,5 m²K/W.

[51] Cf. OIB Richtlinie 6 (2007)

6.8 Energy certificate

The Energy certificate for residential building must include the following minimum content:

- heating requirement of the building and a comparison to reference values
- Energy demand of the heating technology
- Final energy demand
- Recommendation of measures to reduce the final energy demand of the building, excluding new buildings.[52]

In May 2006 the Austrian National Council issued the federal law stating the obligation to provide an Energy certificate in case of sale and handover of buildings, both residential and designed for business activity. The provincial laws govern the regulations for new buildings, renovations and additions as well as complete rules about calculation, content, form and issuance competences. On the 1st of January 2008 the Energy Certificate for new buildings became obligatory and one year later it was compulsory for renovations and additions.

As a result of the federalist legal situation in Austria where building- and energy laws are subject to the provincial legislation, the basic idea of a uniform legislation will not be implemented. However, eight of the nine provinces agreed on standardized calculations methods. The energy pass is being regulated in the ÖNORM H 5055 – Energy certificate for buildings. Competences of issuance are controlled by the provincial legislators.

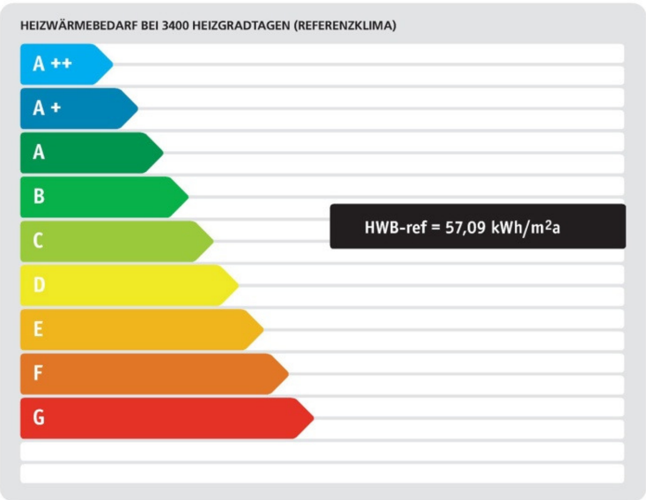


Figure 8: Energy Groups within the Energy Certificate

According to the implemented EU-Guideline all new buildings, extensive renovations, extensions and additions already require the issuance of an Energy Pass in the submission phase at the certification authorities. Since 2009 there is an obligation to provide an Energy Pass when residential buildings, apartments, offices or commercial buildings are for sale, lease or rent. The validity of an Energy Pass is ten years and the responsibility of submittal lies with the owner, landlord or seller of an object. [53] The classification is conducted by using Energy Groups (see Fig. 8)

[52] Cf. OIB Richtlinie 6 (2007)

7 DISCUSSION – ENERGY EFFICIENCY

7.1 Comparison with CEC – Title 24

In order to avoid confusion concerning the conversion of imperial and SI units, table 24 indicates the equivalent values for each system. Given R-Values stated by the California Energy Code or components of the reference project were converted according to this table and shown in SI units within all the following calculations.

1 Btu/h·ft²· °F	= 5,678 W/m²K
1 W/m²K	= 0,176 Btu/h·ft²· °F

Table 24: Conversion of units

Component	**U-factors [W/m²K] in OIB Guideline 6**	**U-factors [W/m²K] in 2010 Building Energy Efficiency Standards**
Exterior walls (wood framed)	0,35	0,34
Exterior walls (mass heavy)	0,35	1,04
Roofs/ ceilings	0,20	0,16
Windows (against outside air)	1,40	2,67
Doors (exterior – not swinging)	1,70	8,23
Doors (exterior – not swinging)	1,70	3,97
Skylights (no curb)	2,00	4,66 & 6,30 (curb)

Table 25: U-factor comparison

At this point a reference to table 33 in chapter 9.2.1 gives an exemplary statement about the quality of the building envelope of residential multi story buildings in California. The calculated total annual heating demands state as shown below:

HWB_{BGF} = 195,05 kWh/m²a for the actual location

$HWB_{BGF,Ref}$ = 147,19 kWh/m²a for the reference climate

This results in a classification of "Group F" which exceeds Austrian envelope criteria. The main responsibility of the poor outcome of this calculation obviously are the differing U-factors of fenestration products between the two used Codes OIB-6 and Title 24. A reduction to the maximum Austrian values would cause an improvement of the total annual heating value by 42%, resulting in a classification "Group D" by receiving the following values:

HWB_{BGF} = 107,16 kWh/m²a for the actual location

$HWB_{BGF,Ref}$ = 81,88 kWh/m²a for the reference climate

[53] URL: http://www.energieausweis.at/energieausweis-informationen.htm [30.9.2010]

According to chapter 6.5.3.1 the maximum $HWB_{BGF,Ref}$ for this building in Austria is calculated by the formula *19 * (1+2,5/lc) = 62,18 kWh/m²a* which is still not met after an improvement of the fenestration products. Further reduction could be achieved by revising the U-factors of fenestration products further downwards or focus on the wall framing structure.

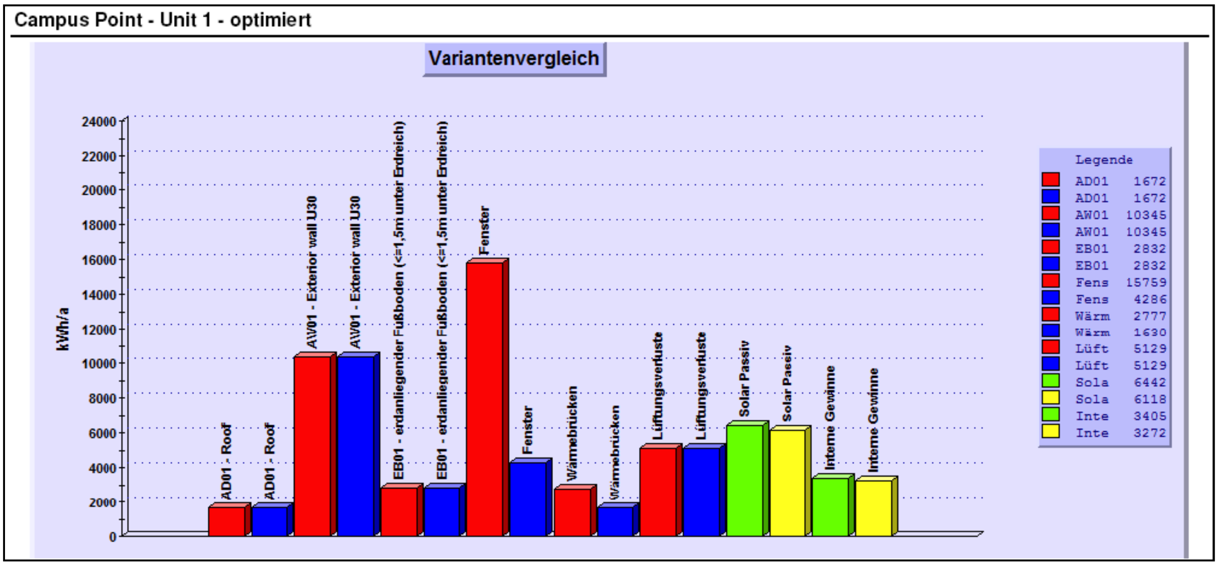


Figure 9: Unit 1 - optimized fenestration products

Maximum OIB-6 values can be reached by reducing the U-factors of windows to 1,2 W/m²K, exterior walls to 0,20 W/m²K and the floor of the lowest level to 0,30 W/m²K (see Fig. 10). This way, an improvement of 56% compared to the original version (see Appendix B, chapter 9.2.6) and a classification in “Group C” could be achieved.

$HWB_{BGF,Ref}$ = 62,10 kWh/m²a for the reference climate

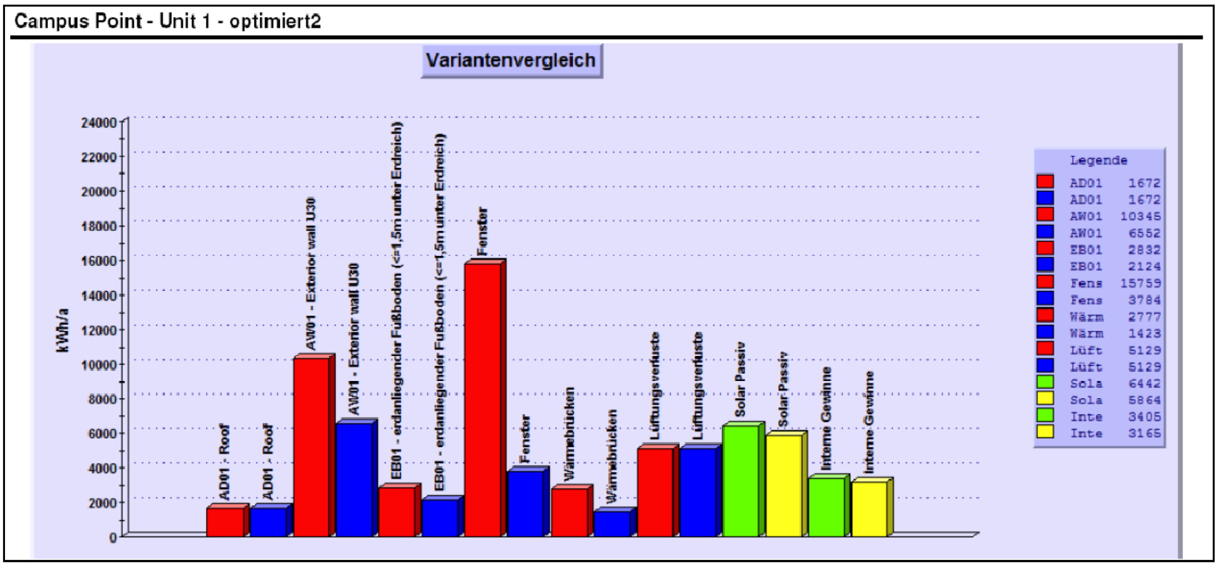
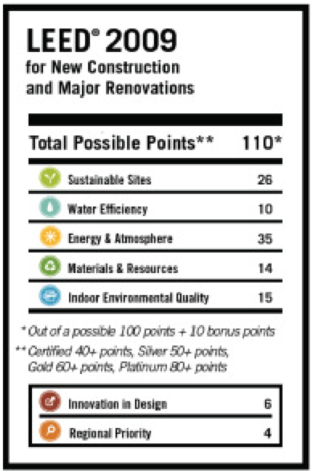
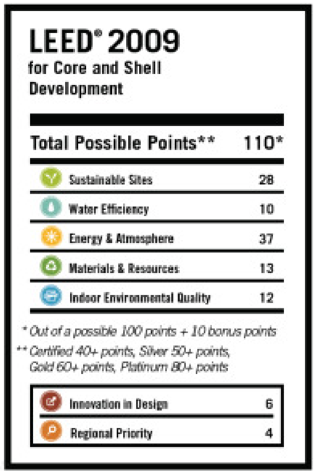


Figure 10: Unit 1 - optimized to reach OIB-6 goals

7.2 Comparison with LEED





category

Due to the major distinctions of the voluntary and holistic LEED system to the mandatory Austrian Energy certificate, which mainly focuses on energy efficiency, it is difficult to define significant comparative values. Further research about that topic involves solely the building physical calculation of the building envelope as well as annual heating and cooling demands of the LEED certification compared to the Austrian energy certificate. For the present Master's Thesis the comparison of the two mandatory certification models 'Energy certificate' and 'Title 24' has been carried out primarily but also the suitability of the Energy certificate as a prerequisite for a LEED certification was taken into consideration. While the Austrian Energy certificate focuses on the performance of the building envelope and energy demands, this section only accounts for 34 out of 110 total possible points (31%) of the LEED for Homes Rating System (see Fig. 11) and the rater can choose between two calculation methods as shown in Figure 12:

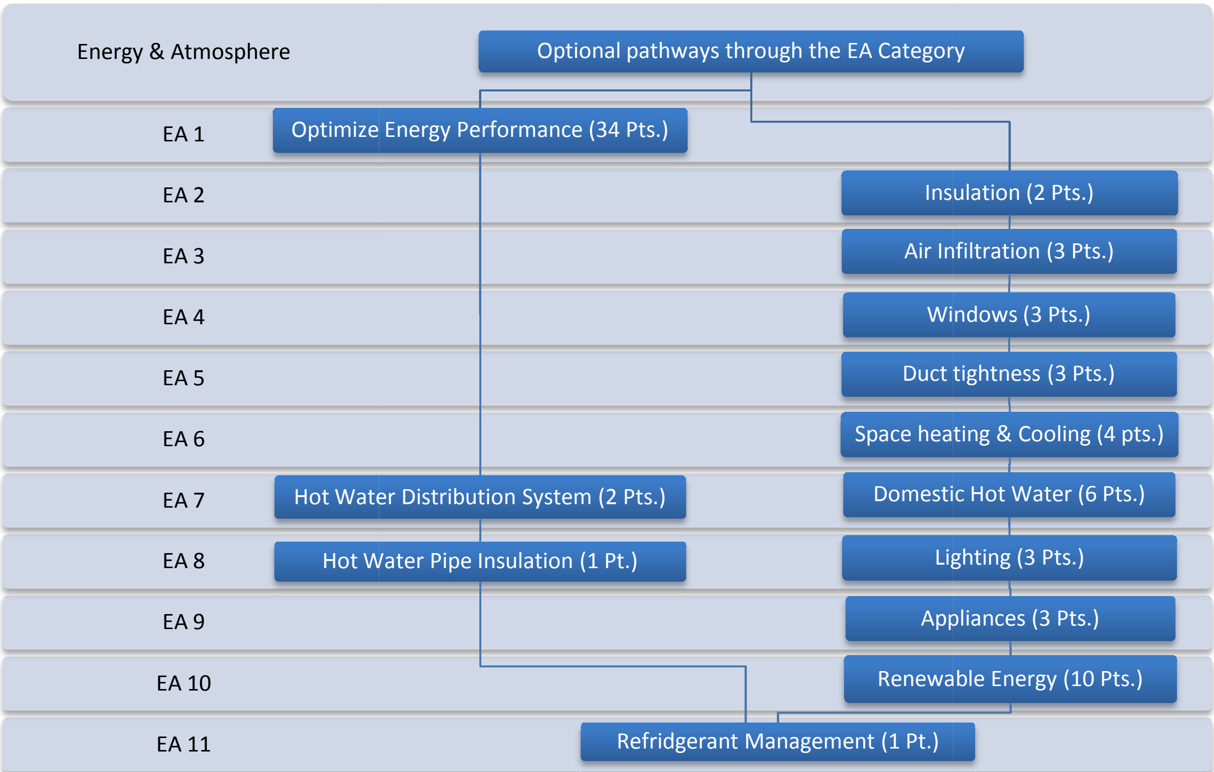


Figure 12: Pathways through the EA Category in the LEED for Homes Rating System

The LEED for Homes Rating System follows the energy efficiency rating of the Energy Star Home Energy Rating which yields a projected pre-construction HERS Index quite similar to the Austrian Energy Certificate. This rating also includes onsite inspections after completion of the project such as a blower door and duct test, to validate leakiness of the house and ducts, which together with the pre-construction HERS Index results in the generation of the HERS index score. Within this scoring system, a home which is built in accordance to the 2006 International Energy Conservation Code (IECC) scores a HERS Index of 100, while zero energy home score an Index of 0. That establishes a scale on which an improvement of percentage compared to a standard IECC home is shown. (See Fig. 13) [54]

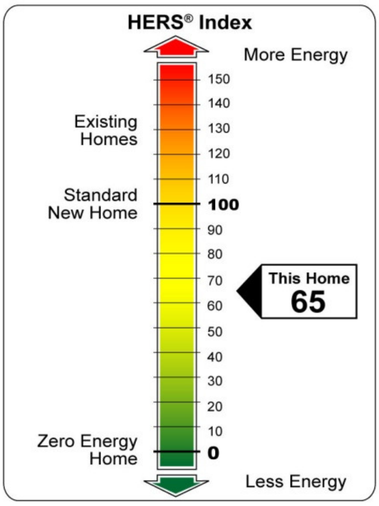


Figure 13: HERS Index

The obtained HERS Index is then indirectly transferred into the LEED for Homes Rating System by using the conversion graph[55] (Fig.14) based on the formula

$LEED\ Pts. = \left\{\frac{[Log(100-HERS\ Index)]}{0{,}024}\right\} - 48{,}3$; or the numerical Table 34, in chapter 9.2.4:

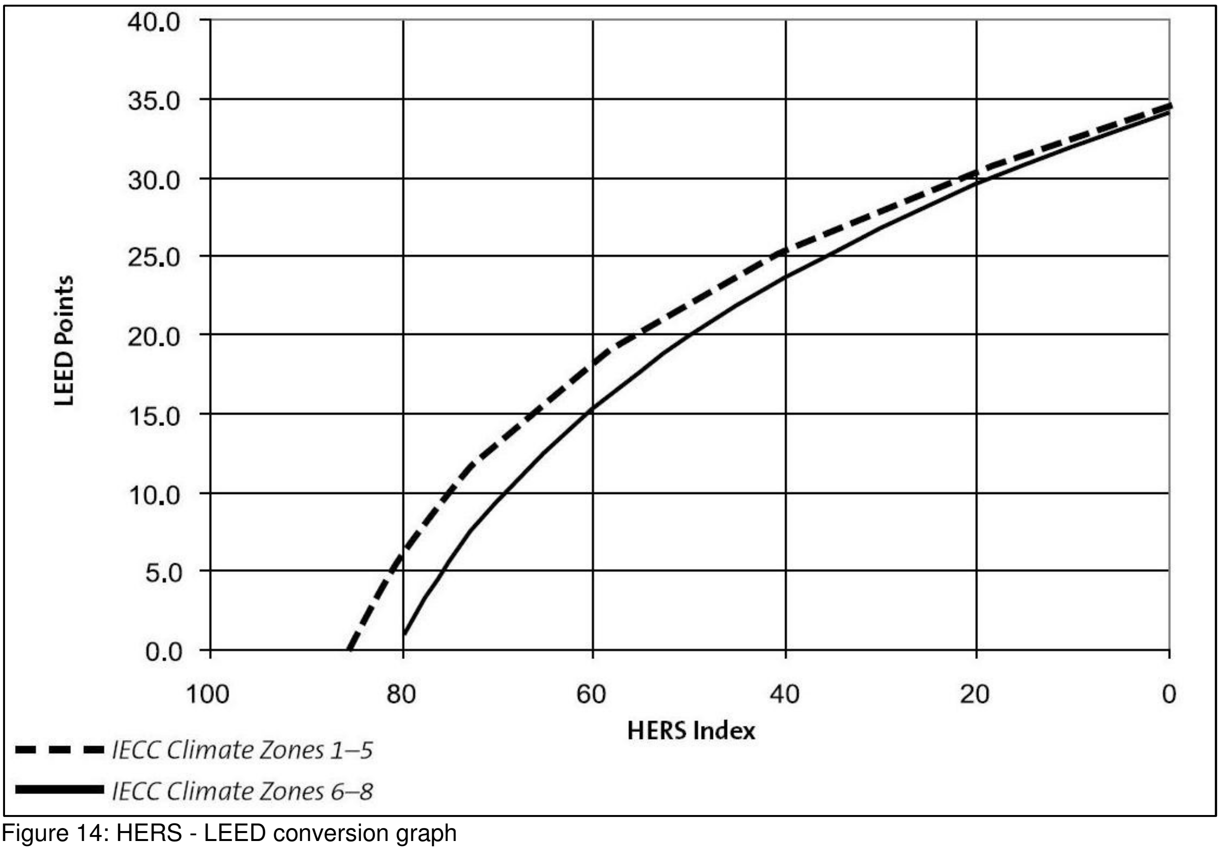


Figure 14: HERS - LEED conversion graph

[54] URL: http://www.resnet.us/home-energy-ratings [10.11.2010]
[55] U.S. Green Building Council: LEED for Homes Rating System, Version 2008. Washington, 2008

Choosing the performance option to receive an Energy Star for Homes certificate, the following mandatory requirements have to be met:

<table>
<tr><td>Envelope</td><td>Completed Thermal Bypass Inspection Checklist</td></tr>
<tr><td>Ductwork</td><td>Leakage ≤ 6 cfm to outdoors / 100 f²</td></tr>
<tr><td>Energy Star Products</td><td>At least one of the following Energy Star product category has to be included:
- Heating or cooling equipment
- Windows that meet the following eligibility requirements:
<table>
<tr><td>Energy Star window Zone</td><td>Southern</td><td>South Central</td><td>North/Central</td><td>Northern</td></tr>
<tr><td>Window U-factor [W/m²K]</td><td>≤ 3,70</td><td>≤ 2,27</td><td>≤ 2,27</td><td>≤ 1,99</td></tr>
<tr><td>Window SHGC:</td><td>≤ 0,40</td><td>≤ 0,40</td><td>≤ 0,55</td><td>Any</td></tr>
</table>
Table 26: Energy Star - window requirements
- Water heating equipment
- Five or more Energy Star qualified light fixtures, appliances, ceiling fans equipped with lighting fixtures, and/or ventilation fans</td></tr>
</table>

Table 27: Energy Star requirements

Fulfilling the windows section of the Energy Star product category of Table 26, applied to the reference project Campus Point, results in an improvement of 21% compared to the original version (see Fig. 15) by about cutting in half the window heat loss which goes hand in hand with a reduction by more than 50% of solar heat gains through the windows, since the solar heat gain coefficient is being improved. That definitely makes sense in the actual climate zone 3 (according to Fig. 18, chapter 9.2.5) in California, in which the main problem will certainly be overheating in summer and not heating during a cold winter season, such as prevalent in Austria.

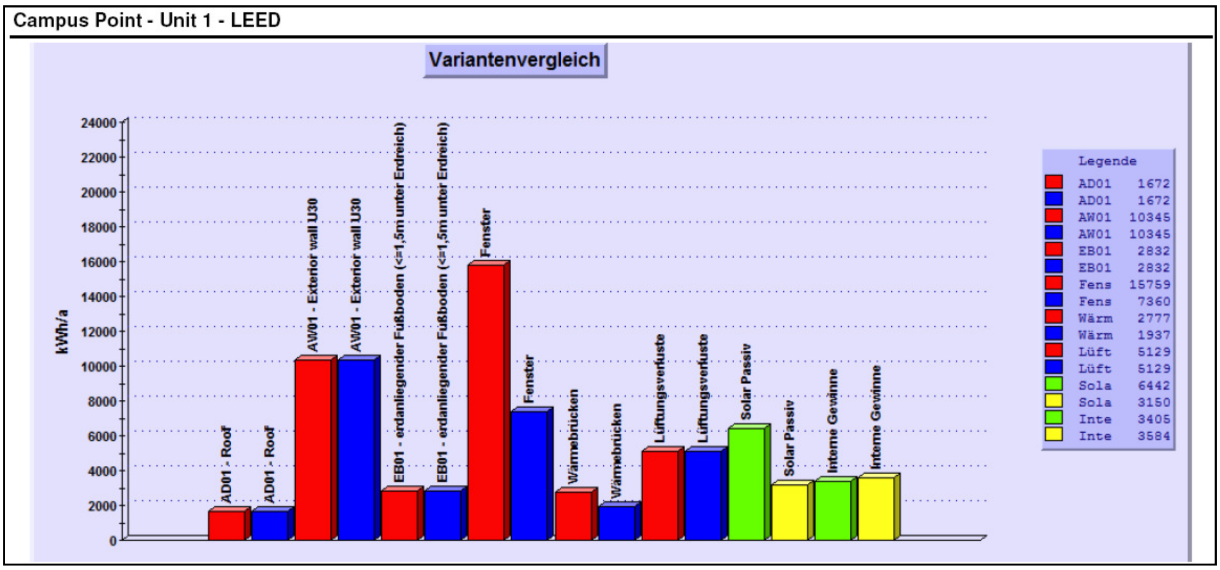


Figure 15: Windows providing Energy Star conformance

7.2.1 HERS calculation

While the submitted and approved plans of Campus Point in accordance with Title 24 of the California Building Code reach a HERS score of 91 and therefore do not qualify for LEED points according to table 34, a change of the building envelope criteria for this reference project in minimum accordance to OIB6 would result in 10,5 out of 34 possible points in the LEED for Homes Rating system by reaching a HERS Score of 74 in climate zone 3 - California. (Fig. 18 & 19, chapter 9.2.5)

For comparative reasons, the actual designated location of the building in San Luis Obispo in combination with the adequate Californian climate zone (zone 3) were used as the initial values for the HERS calculation of the building's efficiency. In order to obtain suitable values for an OIB6 compliant building, the calculations performed in chapter 9.2 were adjusted to reach the OIB conformance of 45 kWh/m²a within the reference climate. (See Fig. 16). This adjustment was carried out, by reducing the building envelope criteria in a step-by-step approach of applying lower U-Factors until conformance was obtained.

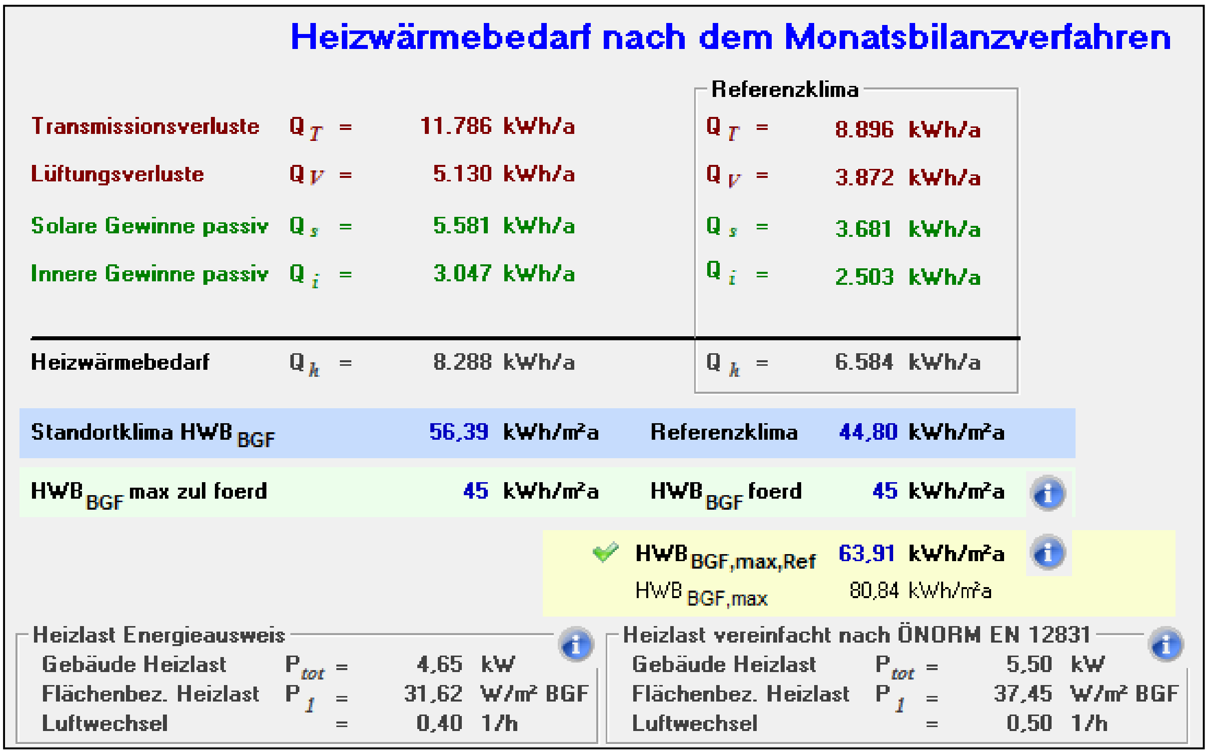


Figure 16: Heating demand – 45 kWh/m²a minimum compliance to OIB6

In order to obtain comparable values the calculation had to be performed for an equivalent US climate zone, which was found in the city Minneapolis in the state of Minnesota by comparing the data of heating degree days. (See Fig. 19) Due to this change, and the fact, that the HERS rating depends strongly on the actually used energy instead of using a reference climate, the exact same calculation lead to a HERS rating of only 87, which does not result in any LEED points at all. Even a further reduction of building envelope U-Factors, which lead to a 33% reduction of the energy demand and a total of 30 kWh/m²a in accordance to the OIB6 guideline, the improvement on the HERS scale was only by 6,9% to a total of 81 points. (see Fig. 17) Further reduction to an energy demand of 20 kWh/m²a lead to 78 points on the HERS scale.

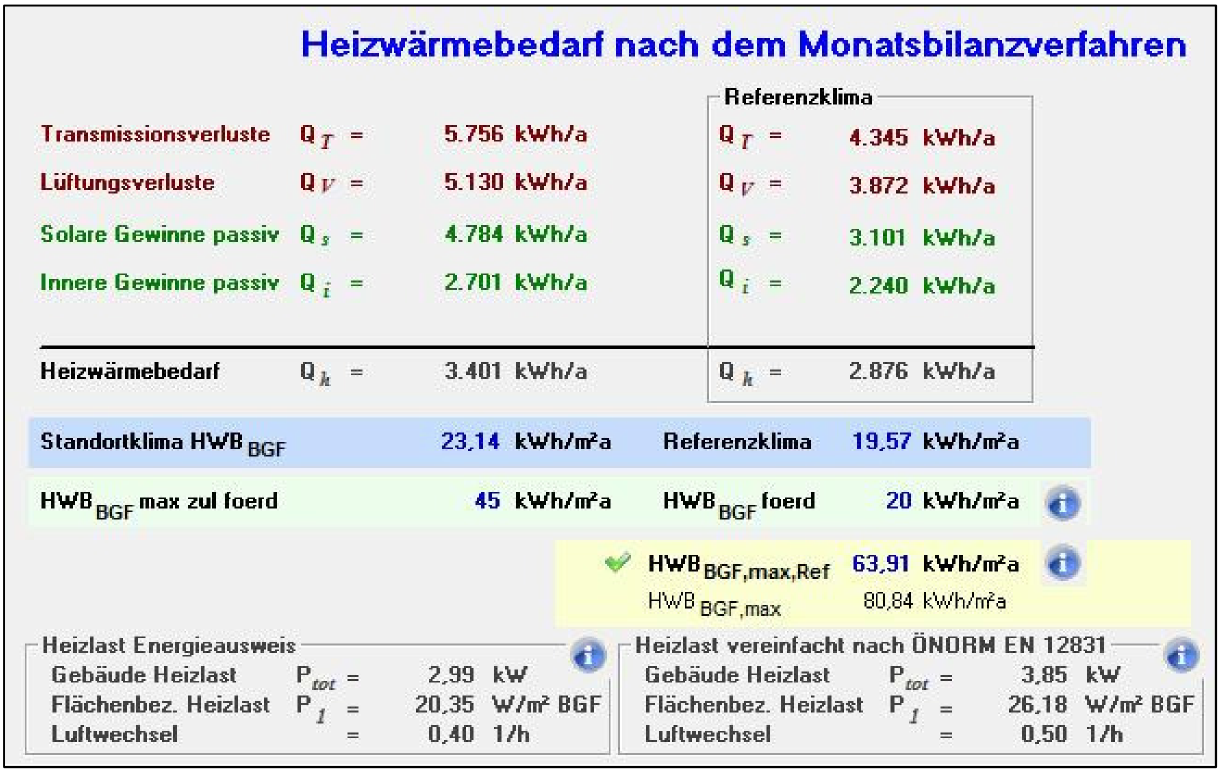


Figure 17: Heating demand - 30 kWh/m²a compliance to OIB6

While the responsible authorities do not publish data to calculate the HERS value, above performed calculations show, that the annual energy demand with regard to the building envelope does not influence the HERS value in the same ratio the Energy certificate Scale is affected. The HERS index obviously rather takes the building as a holistic system into consideration. Some input examples within the EnergyGauge Software are the heating and cooling system, duct location and insulation, hot water supply system, appliances and lights as well as photovoltaics. As an example, in addition to the latest version of the above performed calculations with a resulting HERS index of 78 and no credits for the LEED system, a 30m² photovoltaics system was applied without modifying any other data. This adjustment lead to a HERS index of 58 and thus a LEED credit of 16,5 points.

An incomprehensible measure of the EnergyGauge's approach of calculating the building envelope's energy efficiency is the absence of a matrix for fenestration products, in which cardinal points can be entered, which is a decisive factor for solar heat gain. The only way to do so is by adding an extra sunspace, which can only be one room.

Further research on this topic could provide a detailed analysis of prerequisites for a LEED rating by complying to the OIB-6 guideline, and therefore help to introduce and distribute the LEED System in Austria.

8 CONCLUSION

This thesis displays the current situation of building standards in California by providing a comparison to the in Austria prevalent codes. The main goal was to show major differences in the field of structural calculations such as wind and seismic as well as the field of energy efficiency by comparing different methods of certification.

The results clearly state a considerable vulnerability of the U.S. wind calculation which is about 6 times less stringent than the Austrian one within the case study of the chosen reference project in San Luis Obispo, California. However, this phenomenon is not effective for both of the mainly investigated topics concerning structural calculations. It should therefore be mentioned that the results of the seismic analyses were almost identical when using the same input values for calculations according to the different codes.

On the otherhand, a verification of the residential ceiling's vibration behavior is not even necessary at allwhen submitting the structural data for approval at the responsible authorities in California. The part of building physics was a tender subject, since scheme of comparability had to be found. The final outcome provides an initial outlook concerning the usability of the Energy certificate as a prerequisite for a "LEED for Homes" certification. So, complying with the anyhow mandatory regulations of the OIB-6 guideline in Austria would already provide 10,5 out of 34 reachable points in the category of Energy and Atmosphere.

Finally, the fictitious rearrangement of the reference project to climate zone 6 which is very similar to the Austrian climate, even provides a basis of comparison with regard to heating

9 APPENDIX

9.1 Appendix A

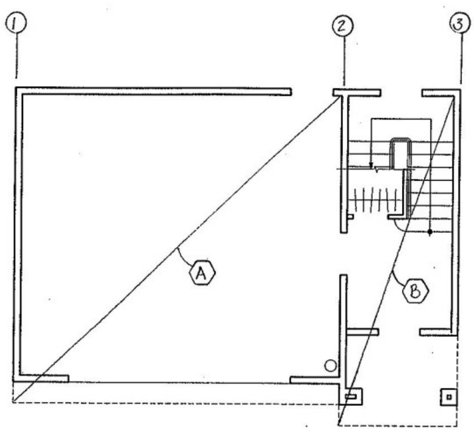
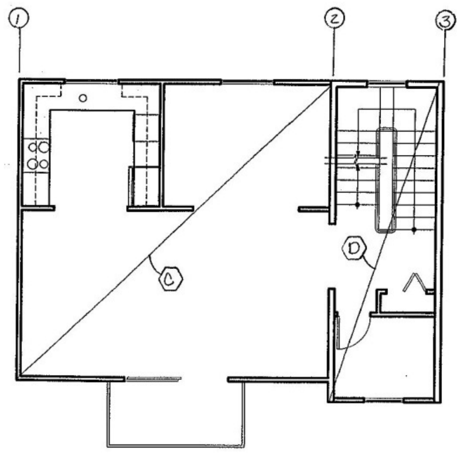
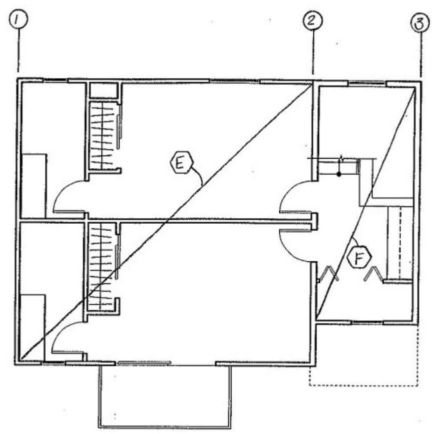
Floor weights A-B

Floor weights C-D

Floor weights E-F


Table 28: Floor weights - Areas A-F

9.1.1 Occupancy Groups

Occupancy Group R – Division 1
Residential occupancies containing sleeping units where the occupants are primarily transient in nature, including:

Boarding houses (transient)
Hotels (transient)
Motels (transient)

Occupancy Group R – Division 3
Residential occupancies where the occupants are primarily permanent in nature and not classified as Group R-1, R-2, R-2.1, R-3.1, R-4 or I, including:

Buildings that do not contain more than two dwelling units.
Adult care facilities that provide accommodations for six or fewer clients of any age for less than 24 hours. Licensing categories that may use this classification include, but are not limited to: Adult Day Programs.
Child care facilities that provide accommodations for six or fewer clients of any age for less than 24 hours. […]
Family Day-Care Homes that provide accommodations for 14 or fewer children, in the provider's own home for less than 24-hours.
Congregate living facilities or congregate residences with 16 or fewer persons.
Adult care and child care facilities that are within a single-family home are permitted to comply with the Californian Residential Code.

Occupancy Group U
Such buildings shall be classified as Group U and shall include the following uses:

1. Livestock shelters or buildings, including shade structures and milking barns.
2. Poultry buildings or shelters.
3. Barns.
4. Storage of equipment and machinery used exclusively in agriculture.
5. Horticultural structures, including detached production greenhouses and crop protection shelters.
6. Sheds.
7. Grain silos.
8. Stables.[56]

[56] California Building Standards Commission: 2010 California Building Code, Title 24, Part 2, Volume 2-2, p. 697, Sacramento: 2010

9.2 Appendix B

9.2.1 LEED rating system

CREDIT	TITLE	NC	SCHOOLS	CS
SS Prerequisite 1	Construction Activity Pollution Prevention	Required	Required	Required
SS Prerequisite 2	Environmental Site Assessment	NA	Required	NA
SS Credit 1	Site Selection	1 point	1 point	1 point
SS Credit 2	Development Density and Community Connectivity	5 points	4 points	5 points
SS Credit 3	Brownfield Redevelopment	1 point	1 point	1 point
SS Credit 4.1	Alternative Transportation—Public Transportation Access	6 points	4 points	6 points
SS Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1 point	1 point	2 points
SS Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3 points	2 points	3 points
SS Credit 4.4	Alternative Transportation—Parking Capacity	2 points	2 points	2 points
SS Credit 5.1	Site Development—Protect or Restore Habitat	1 point	1 point	1 point
SS Credit 5.2	Site Development—Maximize Open Space	1 point	1 point	1 point
SS Credit 6.1	Stormwater Design—Quantity Control	1 point	1 point	1 point
SS Credit 6.2	Stormwater Design—Quality Control	1 point	1 point	1 point
SS Credit 7.1	Heat Island Effect—Nonroof	1 point	1 point	1 point
SS Credit 7.2	Heat Island Effect—Roof	1 point	1 point	1 point
SS Credit 8	Light Pollution Reduction	1 point	1 point	1 point
SS Credit 9	Tenant Design and Construction Guidelines	NA	NA	1 point
SS Credit 9	Site Master Plan	NA	1 point	NA
SS Credit 10	Joint Use of Facilities	NA	1 point	NA

CREDIT	TITLE	NC	SCHOOLS	CS
WE Prerequisite 1	Water Use Reduction	Required	Required	Required
WE Credit 1	Water Efficient Landscaping	2-4 points	2-4 points	2-4 points
WE Credit 2	Innovative Wastewater Technologies	2 points	2 points	2 points
WE Credit 3	Water Use Reduction	2-4 points	2-4 points	2-4 points
WE Credit 4	Process Water Use Reduction	NA	1 point	NA

Table 29: LEED Rating No.1

CREDIT	TITLE	NC	SCHOOLS	CS
EA Prerequisite 1	Fundamental Commissioning of Building Energy Systems	Required	Required	Required
EA Prerequisite 2	Minimum Energy Performance	Required	Required	Required
EA Prerequisite 3	Fundamental Refrigerant Management	Required	Required	Required
EA Credit 1	Optimize Energy Performance	1-19 points	1-19 points	3-21 points
EA Credit 2	On-site Renewable Energy	1-7 points	1-7 points	4 points
EA Credit 3	Enhanced Commissioning	2 points	2 points	2 points
EA Credit 4	Enhanced Refrigerant Management	2 points	1 point	2 points
EA Credit 5	Measurement and Verification	3 points	2 points	NA
EA Credit 5.1	Measurement and Verification—Base Building	NA	NA	3 points
EA Credit 5.2	Measurement and Verification—Tenant Submetering	NA	NA	3 points
EA Credit 6	Green Power	2 points	2 points	2 points

CREDIT	TITLE	NC	SCHOOLS	CS
MR Prerequisite 1	Storage and Collection of Recyclables	Required	Required	Required
MR Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1-3 points	1-2 points	NA
MR Credit 1	Building Reuse—Maintain Existing Walls, Floors, and Roof	NA	NA	1-5 points
MR Credit 1.2	Building Reuse—Maintain Interior Nonstructural Elements	1 point	1 point	NA
MR Credit 2	Construction Waste Management	1-2 points	1-2 points	1-2 points
MR Credit 3	Materials Reuse	1-2 points	1-2 points	1 point
MR Credit 4	Recycled Content	1-2 points	1-2 points	1-2 points
MR Credit 5	Regional Materials	1-2 points	1-2 points	1-2 points
MR Credit 6	Rapidly Renewable Materials	1 point	1 point	NA
MR Credit 7	Certified Wood	1 point	1 point	NA
MR Credit 6	Certified Wood	NA	NA	1 point

Table 30: LEED Rating No.2

CREDIT	TITLE	NC	SCHOOLS	CS
IEQ Prerequisite 1	Minimum Indoor Air Quality Performance	Required	Required	Required
IEQ Prerequisite 2	Environmental Tobacco Smoke (ETS) Control	Required	Required	Required
IEQ Prerequisite 3	Minimum Acoustical Performance	NA	Required	NA
IEQ Credit 1	Outdoor Air Delivery Monitoring	1 point	1 point	1 point
IEQ Credit 2	Increased Ventilation	1 point	1 point	1 point
IEQ Credit 3.1	Construction Indoor Air Quality Management Plan During Construction	1 point	1 point	NA
IEQ Credit 3	Construction Indoor Air Quality Management Plan During Construction	NA	NA	1 point
IEQ Credit 3.2	Construction Indoor Air Quality Management Plan Before Occupancy	1 point	1 point	NA
IEQ Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1 point	1 point*	1 point
IEQ Credit 4.2	Low-Emitting Materials—Paints and Coatings	1 point	1 point*	1 point
IEQ Credit 4.3	Low-Emitting Materials—Flooring Systems	1 point	1 point*	1 point
IEQ Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1 point	1 point*	1 point
IEQ Credit 4.5	Low-Emitting Materials—Furniture and Furnishings	NA	1 point*	NA
IEQ Credit 4.6	Low-Emitting Materials—Ceiling and Wall Systems	NA	1 point*	NA
IEQ Credit 5	Indoor Chemical and Pollutant Source Control	1 point	1 point	1 point
IEQ Credit 6.1	Controllability of Systems—Lighting	1 point	1 point	NA
IEQ Credit 6.2	Controllability of Systems—Thermal Comfort	1 point	1 point	NA
IEQ Credit 6	Controllability of Systems—Thermal Comfort	NA	NA	1 point
IEQ Credit 7.1	Thermal Comfort—Design	1 point	1 point	NA
IEQ Credit 7	Thermal Comfort—Design	NA	NA	1 point
IEQ Credit 7.2	Thermal Comfort—Verification	1 point	1 point	NA
IEQ Credit 8.1	Daylight and Views—Daylight	1 point	1-3 points	1 point
IEQ Credit 8.2	Daylight and Views—Views	1 point	1-3 points	1 point
IEQ Credit 9	Enhanced Acoustical Performance	NA	1 point	NA
IEQ Credit 10	Mold Prevention	NA	1 point	NA

* note: Schools projects may choose from IEQ Credits 4.1-4.6 for a maximum of 4 points.

CREDIT	TITLE
ID Credit 1	Innovation in Design
ID Credit 2	LEED® Accredited Professional
ID Credit 3	The School as a Teaching Tool

CREDIT	TITLE
RP Credit 1	Regional Priority

Table 31: LEED Rating No.3

9.2.2 Slab insulation requirements for heated slab-on-grade

Insulation Location	Insulation Orientation	Installation Requirements	Climate Zone	Insulation R-Factor
Outside edge of heated slab, either inside or outside the foundation wall	Vertical	From the level of the top of the slab, down 16 inches or to the frost line, whichever is greater. Insulation may stop at the top of the footing where this is less than the required depth. For below grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.	1 – 15	5
			16	10
Between heated slab and outside foundation wall	Vertical and Horizontal	Vertical insulation from top of slab at inside edge of outside wall down to the top of the horizontal insulation. Horizontal insulation from the outside edge of the vertical insulation extending 4 feet toward the center of the slab in a direction normal to the outside of the building in plan view.	1 – 15	5
			16	10 vertical and 7 horizontal

Table 32: Slab-on-grade insulation R-Factors

9.2.3 Prescriptive envelope criteria for high-rise residential buildings

			Climate Zone															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roofs/Ceilings	Metal Building		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	Wood Framed and Other		0.034	0.028	0.039	0.028	0.039	0.039	0.039	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Roofing Products	Low-sloped	Aged Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.55	0.55	NR	0.55	0.55	0.55	NR
		Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.75	0.75	NR	0.75	0.75	0.75	NR
Walls	Metal Building		0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.057	0.057	0.057	0.057	0.057
	Metal-framed		0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
	Mass Light		0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227	0.196	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy		0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690	0.690	0.690	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-framed and Other		0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
Floors/Soffits	Mass		0.045	0.045	0.058	0.058	0.058	0.069	0.092	0.092	0.092	0.069	0.058	0.058	0.058	0.045	0.058	0.037
	Other		0.034	0.034	0.039	0.039	0.039	0.039	0.071	0.039	0.039	0.039	0.039	0.039	0.039	0.034	0.039	0.034
Windows	U-factor		0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
	RSHG North	0-10% WWR	0.68	0.49	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.49	0.49	0.49	0.49	0.47	0.47	0.68
		10-20% WWR	0.68	0.49	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.49	0.49	0.49	0.49	0.43	0.43	0.68
		20-30% WWR	0.47	0.40	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.40	0.40	0.40	0.40	0.43	0.43	0.47
		30-40% WWR	0.47	0.40	0.55	0.55	0.55	0.61	0.61	0.61	0.61	0.40	0.40	0.40	0.40	0.41	0.41	0.47
	RSHG Non-North	0-10% WWR	0.46	0.36	0.41	0.41	0.41	0.47	0.47	0.47	0.47	0.36	0.36	0.36	0.36	0.36	0.36	0.46
		10-20% WWR	0.46	0.36	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.36	0.36	0.36	0.36	0.31	0.31	0.46
		20-30% WWR	0.36	0.31	0.31	0.31	0.31	0.36	0.36	0.36	0.36	0.31	0.31	0.31	0.31	0.26	0.26	0.36
		30-40% WWR	0.30	0.26	0.26	0.26	0.26	0.31	0.31	0.31	0.31	0.26	0.26	0.26	0.26	0.26	0.26	0.30
Doors, U-factor	Non-Swinging		0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
	Swinging		0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Skylight	U-factor	Glass, curb	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
		Glass, no curb	0.68	0.68	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.68	0.68	0.68	0.68	0.68	0.68	0.68
		Plastic	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
	SHGC	Glass, 0-2%	0.46	0.46	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.46	0.46	0.46	0.46	0.46	0.46	0.46
		Glass, 2.1-5%	0.36	0.32	0.32	0.32	0.32	0.40	0.40	0.40	0.40	0.32	0.32	0.32	0.32	0.31	0.31	0.36
		Plastic, 0-2%	0.69	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
		Plastic, 2.1-5%	0.55	0.34	0.39	0.39	0.39	0.57	0.57	0.57	0.57	0.34	0.34	0.34	0.34	0.27	0.27	0.55

Notes:
1. Mass, Light walls are defined as having a heat capacity greater than or equal to 7.0 Btu/h-ft2 and less than 15.0 Btu/h-ft2. Heavy mass walls are defined as having a heat capacity greater than or equal to 15.0 Btu/h-ft2.

Table 33: Prescriptive envelope criteria

9.2.4 Numerical HERS – LEED conversion table

	IECC Climate Zones 1–5	
HERS Index	Percent Above IECC 2004	LEED for Homes Points
100	0	
95	5	
90	10	
85	15	
84	16	2.0
83	17	3.0
82	18	4.0
81	19	5.0
80	20	6.0
79	21	7.0
78	22	7.5
77	23	8.5
76	24	9.0
75	25	10.0
74	26	10.5
73	27	11.6
72	28	12.0
71	29	12.5
70	30	13.0
69	31	14.0
68	32	14.5
67	33	15.0
66	34	15.5
65	35	16.0
64	36	16.5
63	37	17.0
62	38	17.5
61	39	18.0
60	40	18.5
55	45	20.5
50	50	22.5
45	55	24.2
40	60	26.0
35	65	27.0
30	70	28.5
25	75	30.0
20	80	31.0
15	85	32.0
10	90	33.0
5	95	33.5
0	100	34.0

	IECC Climate Zones 6–8	
HERS Index	Percent Above IECC 2004	LEED for Homes Points
100	0	
95	5	
90	10	
85	15	
84	16	
83	17	
82	18	
81	19	
80	20	
79	21	2.0
78	22	3.0
77	23	4.0
76	24	5.0
75	25	6.0
74	26	6.5
73	27	7.5
72	28	8.0
71	29	9.0
70	30	9.5
69	31	10.0
68	32	11.0
67	33	11.5
66	34	12.0
65	35	12.5
64	36	13.5
63	37	14.0
62	38	14.5
61	39	15.0
60	40	15.5
55	45	18.0
50	50	20.0
45	55	22.0
40	60	24.0
35	65	25.5
30	70	27.0
25	75	28.5
20	80	30.0
15	85	31.0
10	90	32.0
5	95	33.0
0	100	34.0

Table 34: Numerical HERS - LEED conversion table

9.2.5 U.S. Climate zones

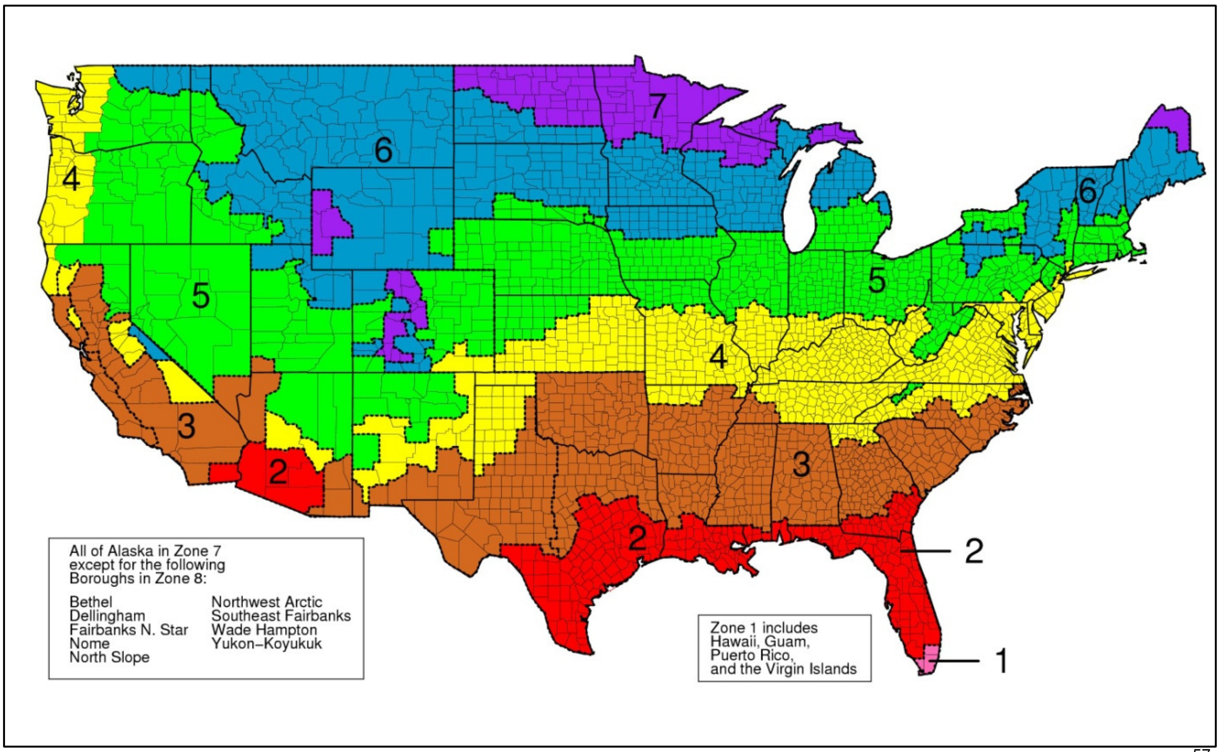


Figure 18: IECC Climate Zones[57]

ZONE NUMBER	THERMAL CRITERIA	
	IP Units	SI Units
1	9000 < CDD50°F	5000 < CDD10°C
2	6300 < CDD50°F ≤ 9000	3500 < CDD10°C ≤ 5000
3A and 3B	4500 < CDD50°F ≤ 6300 AND HDD65°F ≤ 5400	2500 < CDD10°C ≤ 3500 AND HDD18°C ≤ 3000
4A and 4B	CDD50°F ≤ 4500 AND HDD65°F ≤ 5400	CDD10°C ≤ 2500 AND HDD18°C ≤ 3000
3C	HDD65°F ≤ 3600	HDD18°C ≤ 2000
4C	3600 < HDD65°F ≤ 5400	2000 < HDD18°C ≤ 3000
5	5400 < HDD65°F ≤ 7200	3000 < HDD18°C ≤ 4000
6	7200 < HDD65°F ≤ 9000	4000 < HDD18°C ≤ 5000
7	9000 < HDD65°F ≤ 12600	5000 < HDD18°C ≤ 7000
8	12600 < HDD65°F	7000 < HDD18°C

Figure 19: Heating Degree Days (HDD) in US climate zones[58]

57 URL: http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/graphic/973 [10.11.2010]
58 URL: http://blog.mapawatt.com/2010/11/19/climate-zones-and-degree-days/ [29.11.2010]

9.2.6 Energy Certificate (Reference object: Campus Point)

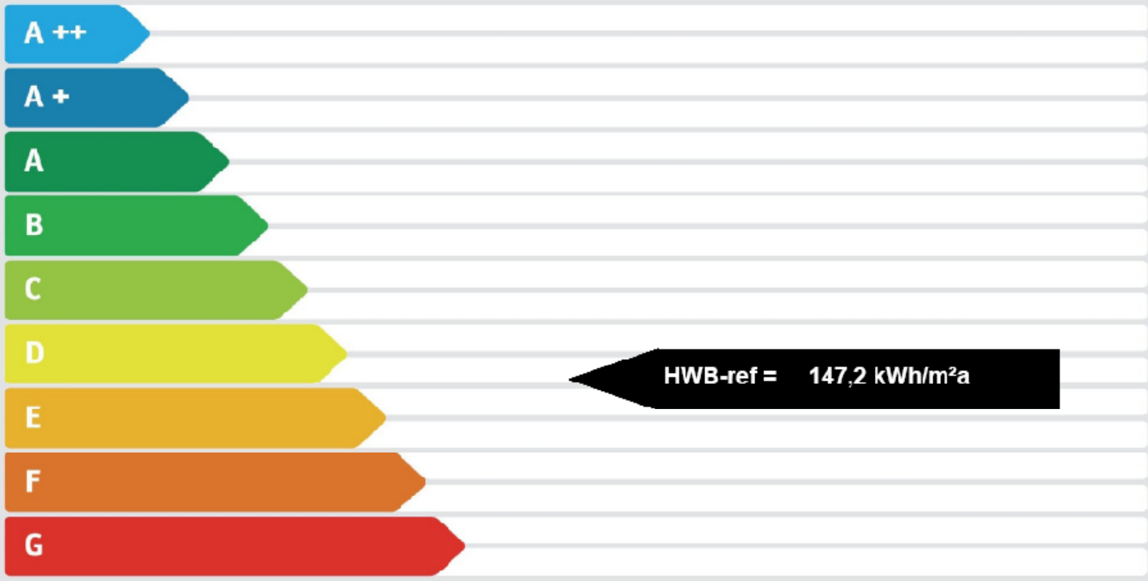
Energieausweis für Wohngebäude - Planung

gemäß ÖNORM H5055
und Richtlinie 2002/91/EG

OIB
Österreichisches Institut für Bautechnik

Gebäude	Campus Point - Unit 1		
Gebäudeart	Einfamilienhaus	**Erbaut im Jahr**	2010
Gebäudezone		**Katastralgemeinde**	Friedberg
Straße		**KG - Nummer**	64007
PLZ/Ort	8240 Friedberg	**Einlagezahl**	
		Grundstücksnr.	
EigentümerIn	Campus Point - Unit 1		
	8240 Friedberg		

SPEZIFISCHER HEIZWÄRMEBEDARF BEI 3400 HEIZGRADTAGEN (REFERENZKLIMA)



ERSTELLT

ErstellerIn	Christian Kasper	**Organisation**	Diplomarbeit
ErstellerIn-Nr.		**Ausstellungsdatum**	30.12.1899
GWR-Zahl		**Gültigkeitsdatum**	Planung
Geschäftszahl			

Unterschrift ____________________

Dieser Energieausweis entspricht den Vorgaben der Richtlinie 6 "Energieeinsparung und Wärmeschutz" des Österreichischen Instituts für Bautechnik in Umsetzung der Richtlinie 2002/91/EG über die Gesamtenergieeffizienz von Gebäuden und des Energieausweis-Vorlage-Gesetzes (EAVG).

EA-01-2007-SW-a
EA-WG
25.04.2007

Figure 20: GEQ Sheet 1

Energieausweis für Wohngebäude - Planung

gemäß ÖNORM H5055
und Richtlinie 2002/91/EG

OIB
Österreichisches Institut für Bautechnik

GEBÄUDEDATEN

Brutto-Grundfläche	147 m²
beheiztes Brutto-Volumen	492 m³
charakteristische Länge (lc)	1,06 m
Kompaktheit (A/V)	0,95 1/m
mittlerer U-Wert (Um)	0,58 W/m²K
LEK - Wert	57

KLIMADATEN

Klimaregion	NSO
Seehöhe	980 m
Heizgradtage	4601 Kd
Heiztage	365 d
Norm - Außentemperatur	-13,9 °C
Soll - Innentemperatur	20 °C

	Referenzklima zonenbezogen [kWh/a]	Referenzklima spezifisch [kWh/m²a]	Standortklima zonenbezogen [kWh/a]	Standortklima spezifisch [kWh/m²a]	Anforderungen ab 01.01.2010 [kWh/m²a]	
HWB	21.633	147,19	28.668	195,05	63,9	nicht erfüllt
WWWB			k.A.	k.A.		
HTEB-RH			40.934	278,51		
HTEB-WW			85	0,58		
HTEB			41.978	285,61		
HEB			72.523	493,44	227,6	nicht erfüllt
EEB			72.523	493,44		
PEB						
CO2						

* k.A. = keine Angabe, die Teile für die HEB Berechnung wurden nicht ausgeführt

ERLÄUTERUNGEN

Heizwärmebedarf (HWB): Vom Heizsystem in die Räume abgegebene Wärmemenge die benötigt wird, um während der Heizsaison bei einer standardisierten Nutzung eine Temperatur von 20°C zu halten.

Heiztechnikenergiebedarf (HTEB): Energiemenge die bei der Wärmeerzeugung und -verteilung verloren geht.

Endenergiebedarf (EEB): Energiemenge die dem Energiesystem des Gebäudes für Heizung und Warmwasserversorgung inklusive notwendiger Energiemengen für die Hilfsbetriebe bei einer typischen Standardnutzung zugeführt werden muss.

Die Energiekennzahlen dieses Energieausweises dienen ausschließlich der Information. Aufgrund der idealisierten Eingangsparameter können bei tatsächlicher Nutzung erhebliche Abweichungen auftreten. Insbesondere Nutzungseinheiten in besonderer Lage können aus Gründen der Geometrie und der Lage hinsichtlich ihrer Energiekennzahlen von den hier angegebenen abweichen.

EA-01-2007-SW-a
EA-WG
25.04.2007

Figure 21: GEQ Sheet 2

Datenblatt GEQ
Campus Point - Unit 1

Energiekennzahl Förderung Steiermark

$HWB_{BGF, Förderung}$	147	kWh/m²a	$HWB_{BGF, Förderung\ max}$	45	kWh/m²a

Gebäudedaten

Brutto-Grundfläche BGF	147	m²	charakteristische Länge l_C	1,06	m
Konditioniertes Brutto-Volumen	492	m³	Kompaktheit A_B / V_B	0,95	m^{-1}
Gebäudehüllfläche A_B	465	m²			

Ermittlung der Eingabedaten

Geometrische Daten: Christian Kasper, 07.11.2010

Bauphysikalische Daten: Christian Kasper, 07.11.2010

Haustechnik Daten:

Ergebnisse am tatsächlichen Standort: Friedberg

Leitwert L_T		270,6	W/K
Mittlerer U-Wert (Wärmedurchgangskoeffizient) U_m		0,58	W/m²K
Heizlast P_{tot}		10,6	kW
Transmissionswärmeverluste Q_T		33.386	kWh/a
Lüftungswärmeverluste Q_V	Luftwechselzahl: 0,4	5.130	kWh/a
Solare Wärmegewinne passiv $\eta \times Q_s$		6.442	kWh/a
Innere Wärmegewinne passiv $\eta \times Q_i$	leichte Bauweise	3.406	kWh/a
Heizwärmebedarf Q_h		28.668	kWh/a
Flächenbezogener Heizwärmebedarf HWB_{BGF}		**195,05**	**kWh/m²a**

Ergebnisse Referenzklima

Transmissionswärmeverluste Q_T	25.201	kWh/a
Lüftungswärmeverluste Q_V	3.872	kWh/a
Solare Wärmegewinne passiv $\eta \times Q_s$	4.572	kWh/a
Innere Wärmegewinne passiv $\eta \times Q_i$	2.868	kWh/a
Heizwärmebedarf Q_h	21.633	kWh/a
Flächenbezogener Heizwärmebedarf $HWB_{BGF\ ref}$	**147,19**	**kWh/m²a**

Haustechniksystem

Raumheizung: Kein Wärmebereitstellungssystem erfasst

Warmwasser: Kein Wärmebereitstellungssystem erfasst

RLT Anlage: natürliche Konditionierung; hygienisch erforderlicher Luftwechsel = 0,4

Berechnungsgrundlagen

Der Energieausweis wurde mit folgenden ÖNORMen und Hilfsmitteln erstellt: GEQ von Zehentmayer Software GmbH www.geq.at
Bauteile nach ON EN ISO 6946 / Fenster nach ON EN ISO 10077-1 / Erdberührte Bauteile vereinfacht nach ON B 8110-6 / Unkonditionierte Gebäudeteile vereinfacht nach ON B 8110-6 / Wärmebrücken pauschal nach ON B 8110-6 / Verschattung vereinfacht nach ON B 8110-6

Verwendete Normen und Richtlinien:
B 8110-1 / ON B 8110-2 / ON B 8110-3 / ON B 8110-5 / ON B 8110-6 / ON H 5055 / ON H 5056 / ON EN ISO 13790 / ON EN ISO 13370 / ON EN ISO 6946 / ON EN ISO 10077-1 / ON EN 12831 / OIB Richtlinie 6

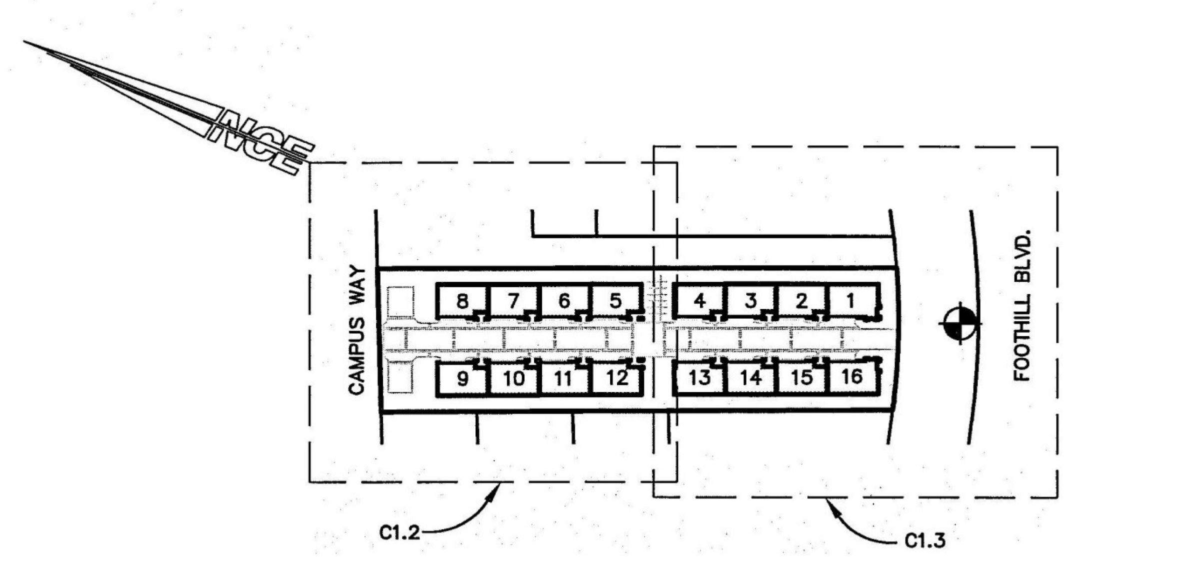
Anmerkung:
Der Energieausweis dient zur Information über den energetischen Standard des Gebäudes. Der Berechnung liegen durchschnittliche Klimadaten, standardisierte interne Wärmegewinne sowie ein standardisiertes Nutzerverhalten zugrunde. Die errechneten Bedarfswerte können daher von den tatsächlichen Verbrauchswerten abweichen. Bei Mehrfamilienwohnhäusern ergeben sich je nach Lage der Wohnung im Gebäude unterschiedliche Energiekennzahlen. Für die exakte Auslegung der Heizungsanlage muss eine Berechnung der Heizlast gemäß ÖNORM H 7500 erstellt werden

Figure 22: GEQ Sheet 3

9.2.7 Project Documentation – "CAMPUS POINT"

Due to the most advantageous orientation of Unit 1, it was chosen for the calculation of the Energy Certificate.

Index map



Front elevation (WSW)

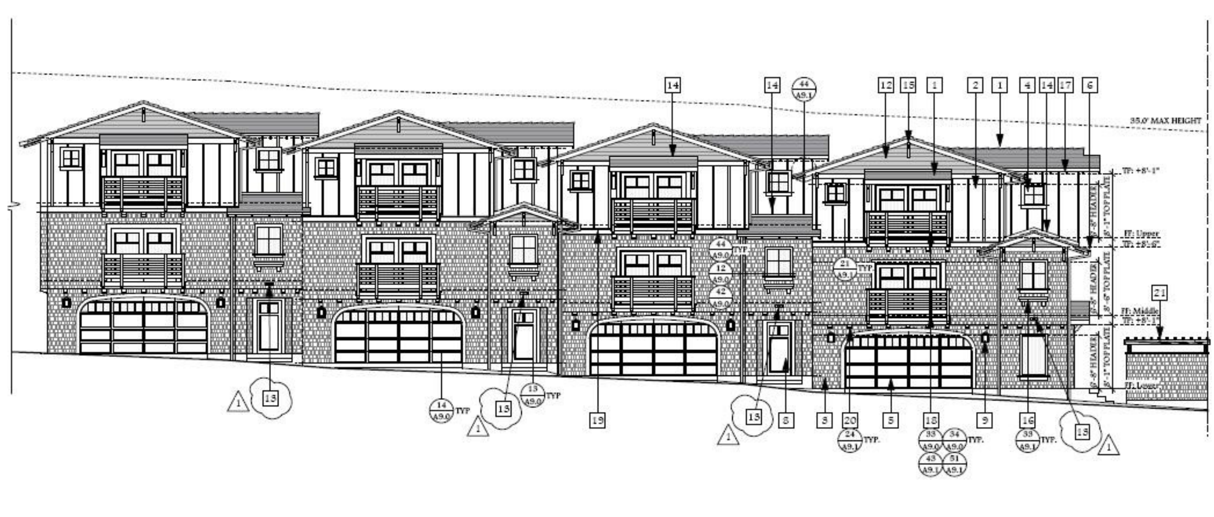


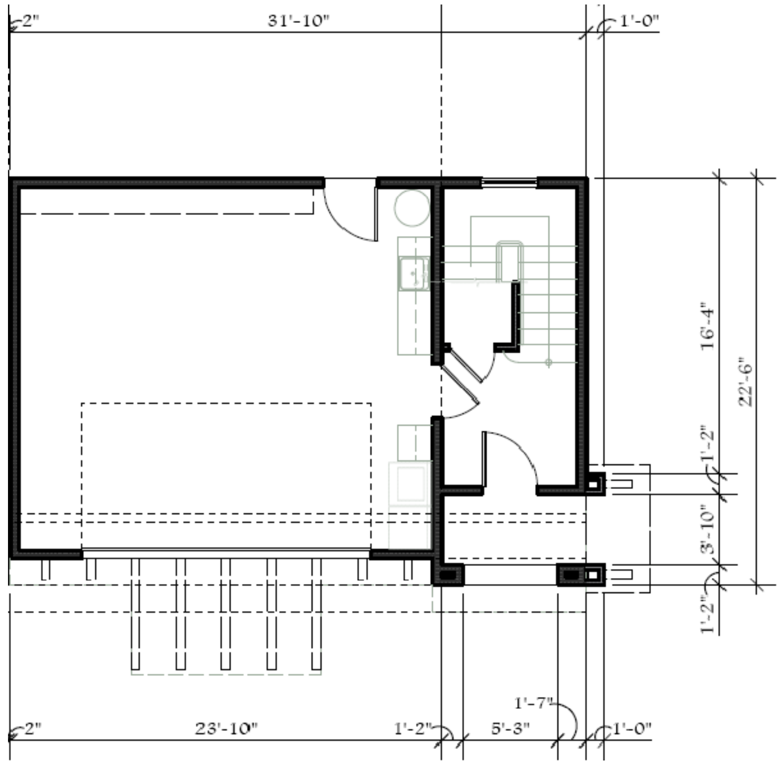
Table 35: Index and elevation

Reference Project relocated to: Friedberg / Steiermark
Elevation: 980m
Climate zone: N/SE
Reference elevation: 247,13m
Orientation: Front – West-South-West

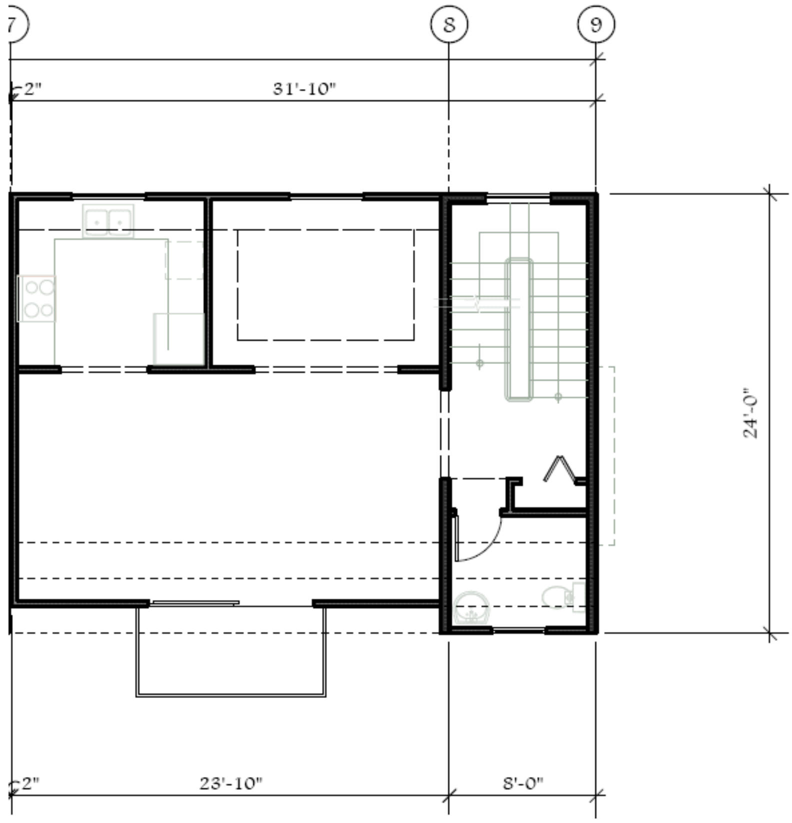
Layout: in accordance to project documentation

Note: Due to the precise calculation procedure performed manually by using the program Microsoft Excel 2007 opposed to a calculation of the program GEQ using only the first two digits after the decimal point, final results may differ among the value of the digit or decimal places.

Lower Floor



Middle Floor



Upper Floor

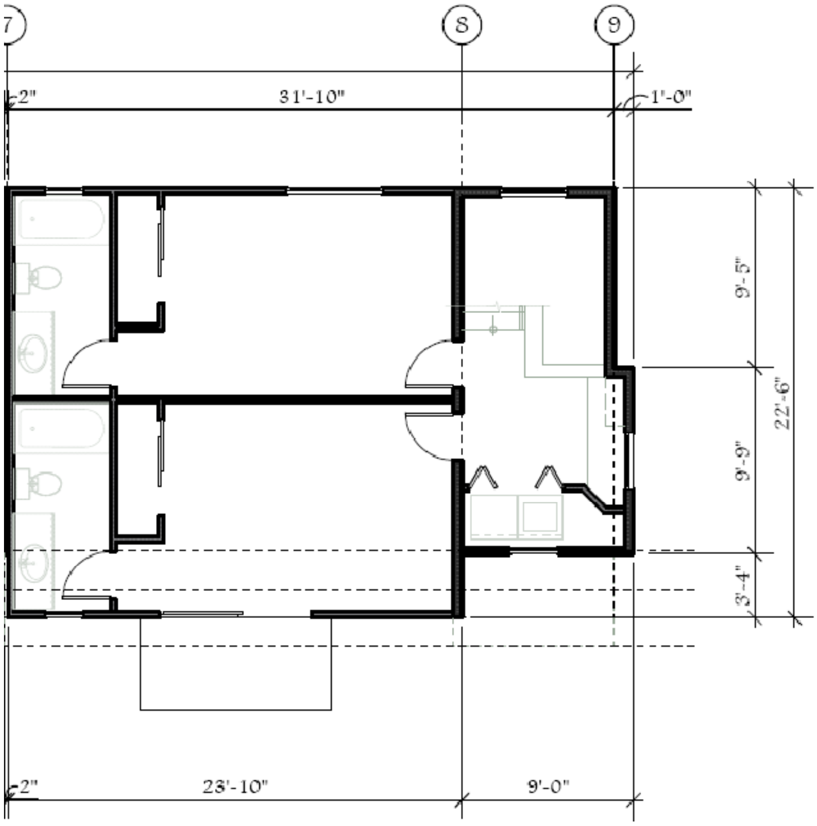


Table 36: Floor plans

9.2.8 Determination of the building's geometry (Units 1-4)

9.2.8.1 Gross plot area (BGF)

Floor	Area 1		Area 2		Area 3		Gross plot Area (BGF_{total}) [m²]
	length [m]	width [m]	length [m]	width [m]	length [m]	width [m]	
lower	2,44	5,33					13,01
middle	7,26	6,86	2,44	7,32			67,66
upper	7,26	6,86	2,87	2,44	2,97	2,74	64,94
						Σ =	145,61

Table 37: Gross plot area

9.2.8.2 Gross Volume (V_i)

Floor	Gross plot area (BGFtotal) [m²]	Floor height (h_i) [m]	Gross volume (V_i)
lower	13,01	2,84	36,93
middle	67,66	2,97	200,96
upper	64,94	2,84	184,44
basement floor	13,01	0,30	3,90
		Σ =	426,24

Table 38: Gross volume

9.2.9 Window types

Orientation	Floor	Type	Width [m]	Height [m]	Quantity	Area [m²]
North-North-West	lower	-				
	middle	window (type 1 - 3040)	0,91	1,22		0,00
	upper	window (type 1 -3040)	0,91	1,22		0,00
East-North-East (rear)	lower	door (type 3 - 3068)	0,91	2,03	1	1,85
	middle	window (Type C - 3040)	0,91	1,22	1	1,11
		window (Type D - 4050)	1,22	1,52	1	1,85
		window (Type E - 4030)	1,22	0,91	1	1,11
	upper	window (Type G - 4050)	1,22	1,52	1	1,85
		window (Type H - 2020)	0,61	0,61	1	0,37
South-South-East	lower	door (type 1 - 3068)	0,91	2,03	1	1,85
	middle	window (Type K - 2030)	0,61	0,91	1	0,56
		window (Type M - 3040)	0,91	1,22	1	1,11
	upper	window (Type N - 3040)	0,91	1,22	1	1,11
West-South-West (front)	lower	door (type 1 - 3068)	0,91	2,03	1	1,85
	middle	window (Type B - 3036)	0,91	1,07	1	0,97
		door (Type 8 - 8068)	2,44	2,03	1	4,95
	upper	window (Type I - 2020)	0,61	0,61	1	0,37
		door (Type 8 - 8068)	2,44	2,03	1	4,95
					Σ =	25,87

Table 39: Fenestration products

Sum NNW:

Windows [m²]	Doors [m²]
0,00	0

Sum ENE:

Windows [m²]	Doors [m²]
6,30	1,85

Sum SSE:

Windows [m²]	Doors [m²]
2,78	1,85

Sum WSW:

Windows [m²]	Doors [m²]	Doors (non winging) [m²]
11,25	1,85	9,91

9.2.10 Facade area

Facade (NNW)			
Floor	Length [m]	Height [m]	A_{gross} [m²]
lower	6,4	2,84	18,18
middle	7,32	2,97	21,74
upper	6,86	2,84	19,48
		ΣA_{gross}:	41,22
		- $\Sigma_{fenestration}$:	0,00
		= A_{net}:	41,22

Facade (EAST)			
Floor	Length [m]	Height [m]	A_{gross} [m²]
lower	2,44	2,84	6,93
middle	9,7	2,97	28,81
upper	10	2,84	28,40
		ΣA_{gross}:	64,14
		- $\Sigma_{fenestration}$:	8,15
		= A_{net}:	55,99

Facade (SOUTH)			
Floor	Length [m]	Height [m]	A_{gross} [m²]
lower	6,86	2,84	19,48
middle	7,32	2,97	21,74
upper	6,86	2,84	19,48
		ΣA_{gross}:	60,71
		- $\Sigma_{fenestration}$:	4,62
		= A_{net}:	56,08

Facade (WEST)			
Floor	Length [m]	Height [m]	A_{gross} [m²]
lower	2,44	2,84	6,93
middle	9,7	2,97	28,81
upper	10	2,84	28,40
		ΣA_{gross}:	64,14
		- $\Sigma_{fenestration}$:	13,10
		= A_{net}:	51,04

Table 40: Facade dimensions

9.2.11 Determination of building physics

U-Factors of the Reference project were either given, or minimum values in accordance to Title 24 were inserted:

Component	U-Factor [W/m²K]
Exterior wall (2/4)	0,30
Basement ceiling	0,19
Floor lowest level	0,30
Roof	0,19
Windows	2,67
Exterior doors (swinging)	3,97
Exterior doors (not swinging)	8,23

Table 41: Components

9.2.12 Transmission conductance (L_T)

$$L_T = L_e + L_u + L_g + L_\psi + L_\kappa \text{ [W/K]}$$ Formula (2); ÖN B 8110-6

9.2.12.1 Simplified calculation: transmission conductance (L_T) for heating ($\Sigma f_{i,h} * A_i * U_i$)

$$L_T = \Sigma f_i * A_i * U_i + L_\psi + L_\kappa \text{ [W/K]}$$ Formula (19); ÖN B 8110-6

Component	$f_{i,h}$	Area [m²]	U-Factor [W/m²K]	L_i ($f_{i,h}$*A*U_i) [W/K]
Roof	1	64,94	0,19	12,27
Overhang (2nd Floor)	1	4,46	0,19	0,84
Overhang (Entrance)	1	3,71	0,19	0,70
Basement floor	0,7	67,66	0,30	14,21
Exterior wall NNW	1	41,22	0,30	12,37
Exterior wall SSE	1	56,08	0,30	16,82
Exterior wall ENE	1	55,99	0,30	16,80
Exterior wall WSW	1	51,04	0,30	15,31
Windows NNW	1	0,00	2,67	0,00
Windows SSE	1	4,62	2,67	12,34
Windows ENE	1	8,15	2,67	21,76
Windows WSW	1	13,10	2,67	34,98
Doors - NNW	1	0,00	3,97	0,00
Doors - SSE	1	1,85	3,97	7,33
Doors - ENE	1	1,85	3,97	7,33
Doors - WSW	1	1,85	3,97	7,33
Doors - WSW (non swinging)	1	9,91	8,23	81,53
	ΣA =	386,43	$\Sigma f_{i,h} * A_i * U_i$ =	261,93

Table 42: Component areas

9.2.13 Conductance addition due to 2-dimensional thermal bridges (L_ψ)

9.2.13.1 Total transmission conductance for heating ($L_{T,h}$)

Total transmission conductance for heating ($L_{T,h}$)			
$\Sigma f_{i,h} * A_i * U_i$	L_ψ	L_k	$L_{T,h}$ [W/K]
261,93	0 (neglected)	0 (neglected	261,93

Table 43: Transmission conductance

9.2.14 Calculation of the ventilation conductance (L_v)

$L_v = \rho_a * c_a * v_v$ [W/K] Formula (24); ÖN B 8110-6

wherein:
ρ_a air density; approx. 1,2 kg/m³
c_a specific heat of air; approx. 1000 J/kgK (= 0,277 Wh/kgK)
v_v air flow volume [m³/h]

$v_v = n_{L,FL} * V_V$ [m³/h] Formula (25); ÖN B 8110-6

wherein:
$n_{L,FL}$ energetically effective air exchange rate [h^{-1}]; $n_{L,FL}$=0,4 Table (2); ÖN B 8110-5
V_V energetically effective air volume (V_{net}); [m³]

Ventilation conductance	
$Lv = \rho a * ca * vv$	
ρa (air density)	1,20 kg/m³
ca	0,277 Wh/kgK
vv	=nL,FL *Vv
	=0,4*Vv
Vv	=0,8*BGF*h
	337,87 m³
vv	135,15 m³/h
Lv =	44,92 m²

Table 44: Ventilation conductance

9.2.15 Calculation of the total heat loss Table A.1; ÖN B 8110-5

$\Theta_e = a + b * H$ [W/K] Formula (1); ÖN B 8110-5

wherein:
Θ_e average outside temperature in given month [°C]
a,b regression coefficient depending on climate zone Table B.1-B.7; ÖN B 8110-5
H elevation in 100m

Calculation of the average monthly outside air temperature (Θ_e)								
Region N/SO - Table B.7 B8110-5					average reference outside temperature	average interior temperature		
M	a	b	H	Θ_e	$\Theta_{e,Ref}$	Θ_i	$\Theta_i - \Theta_{e,Ref}$	$\Theta_i - \Theta_e$
1	-3,471	-0,010	9,8	-3,569	-1,53	20	21,53	23,569
2	-0,049	-0,229	9,8	-2,293	0,73	20	19,27	22,293
3	5,136	-0,412	9,8	1,098	4,81	20	15,19	18,902
4	10,483	-0,545	9,8	5,142	9,62	20	10,38	14,858
5	15,076	-0,545	9,8	9,735	14,2	20	5,8	10,265
6	18,013	-0,522	9,8	12,897	17,33	20	2,67	7,103
7	19,546	-0,468	9,8	14,960	19,12	20	0,88	5,040
8	18,653	-0,425	9,8	14,488	18,56	20	1,44	5,512
9	15,086	-0,342	9,8	11,734	15,03	20	4,97	8,266
10	8,876	-0,172	9,8	7,190	9,64	20	10,36	12,810
11	2,796	-0,139	9,8	1,434	4,16	20	15,84	18,566
12	-2,380	-0,010	9,8	-2,478	0,19	20	19,81	22,478

Table 45: Outside air temperature

9.2.16 Calculation of the monthly total heat loss (Q_l):

$Q_l = Q_T + Q_V$ [kWh/M] Formula (38); ÖN B 8110-6

$Q_T = L_T * (\Theta_i - \Theta_e) * t * {}^1/_{1000}$ [kWh/M] Formula (38); ÖN B 8110-6

$Q_T = L_V * (\Theta_i - \Theta_e) * t * {}^1/_{1000}$ [kWh/M] Formula (38); ÖN B 8110-6

wherein:

L_T total transmission conductance [W/K]

L_V Ventilation conductance [W/K]

Θ_i average interior temperature (=20°C)

Θ_e average outside temperature

t monthly hours [h/M]

Calculation (actual location climate)				
Month	t (h/M)	Q_T [kWh/M]	Q_V [kWh/M]	Q_I [kWh/M]
1	744	4593,12	787,75	5380,86
2	672	3924,05	673,00	4597,05
3	744	3683,54	631,75	4315,28
4	720	2802,12	480,58	3282,70
5	744	2000,44	343,09	2343,53
6	720	1339,50	229,73	1569,23
7	744	982,27	168,47	1150,74
8	744	1074,18	184,23	1258,40
9	720	1558,84	267,35	1826,18
10	744	2496,33	428,14	2924,46
11	720	3501,46	600,52	4101,98
12	744	4380,50	751,28	5131,78
Calculation (reference climate)				
Month	t (h/M)	$Q_{T,Ref}$ [kWh/M]	$Q_{V,Ref}$ [kWh/M]	$Q_{I,Ref}$ [kWh/M]
1	744	4195,76	719,60	4915,35
2	672	3391,91	581,73	3973,64
3	744	2960,22	507,70	3467,92
4	720	1957,60	335,74	2293,34
5	744	1130,30	193,85	1324,15
6	720	503,54	86,36	589,90
7	744	171,49	29,41	200,91
8	744	280,63	48,13	328,76
9	720	937,31	160,75	1098,06
10	744	2018,95	346,26	2365,21
11	720	2987,31	512,34	3499,66
12	744	3860,56	662,11	4522,67

Table 46: Climate calculations

9.2.17 Calculation of interior heat gain (Q_i)

$Q_i = q_{i,h,n} * BGF * 0,8 * t * {}^{1}/_{1000}$ [kWh/M] Formula (39); ÖN B 8110-6

wherein:
$q_{i,h,n}$ interior net heat gain [W/m²] Table (2); ÖN B 8110-6
BGF gross plot area [m²]
t monthly hours [h/M]

Month	t [h/M]	Q_i [kWh/M]
1	744	325,01
2	672	293,56
3	744	325,01
4	720	314,53
5	744	325,01
6	720	314,53
7	744	325,01
8	744	325,01
9	720	314,53
10	744	325,01
11	720	314,53
12	744	325,01

Table 47: Interior heat gain

9.2.18 Calculation of solar heat gain (Q_s)

$A_{trans,h} = A_g * F_s * g_w$ [m²] Formula (54); ÖN B 8110-6

$A_g = 0,7 * A_w$ [m²] Formula (50); ÖN B 8110-6

$F_s = \min(F_h, F_o, F_f)$ Formula (51); ÖN B 8110-6

$g_w = 0,9 * 0,98 * g$ Formula (52); ÖN B 8110-6

wherein:
A_g glazed area [m²]
A_w total area of window
F_s shading factor (=0,85) Table 17-19; ÖN B 8110-6
g solar energy transmittance Table 20; ÖN B 8110-6
g_w effective solar energy transmittance

9.2.18.1 Determination of solar effective window area ($A_{trans,h}$):

Orientation North						
Window type	A_w [m²]	A_g [m²]	F_s	g	g_w	$A_{trans,h}$
Glazing	0,00	0,00	0,85	0,87	0,77	0,00
Orientation South						
Window type	A_w [m²]	A_g [m²]	F_s	g	g_w	$A_{trans,h}$
Glazing	2,78	1,94	0,85	0,87	0,77	1,27
Orientation East						
Window type	A_w [m²]	A_g [m²]	F_s	g	g_w	$A_{trans,h}$
Glazing	6,30	4,41	0,85	0,87	0,77	2,88
Orientation West						
Window type	A_w [m²]	A_g [m²]	F_s	g	g_w	$A_{trans,h}$
Glazing	11,25	7,88	0,85	0,87	0,77	5,14

Table 48: Solar effective window area

9.2.18.2 Determination of the monthly average reference radiation values ($I_{S,Ref}$):

Table A.1; ÖN B 8110-5

Orientation	SSE	NNW	ENE	WSW
Month	$I_{S,Ref}$ [kWh/m²M]	$I_{S,Ref}$ [kWh/m²M]	$I_{S,Ref}$ [kWh/m²M]	$I_{S,Ref}$ [kWh/m²M]
1	37,06	13,11	15,72	25,66
2	56,49	21,08	26,16	40,81
3	74,95	30,23	42,43	60,88
4	78,96	43,71	59,22	73,61
5	89,71	61,53	79,55	91,63
6	81,69	65,39	82,66	89,06
7	87,32	66,64	85,31	94,34
8	89,33	50,03	71,33	87,43
9	79,92	37,86	51,09	68,16
10	66,04	23,81	32,66	50,27
11	38,90	13,21	16,01	26,63
12	31,97	9,60	11,36	20,66

Table 49: Reference radiation values

9.2.18.3 Determination of the monthly average location radiation values (I_S) for horizontal areas

$I_S = a_2 * h^2 * a_1 *h + a_0$ [kWh/m²M] Formula (2); ÖN B 8110-5

wherein:

I_S average monthly sum of global radiation per month on horizontal areas [kWh/m²M]
a_i Coefficients of climate zones per month Table D.1 – D.14; ÖN B 8110-5
h elevation

Month	a_2	a_1	a_0	I_S [kWh/m²M]
1	-1,7582E-06	1,4255E-02	2,6423E+01	38,70
2	1,4429E-06	8,4006E-03	4,9796E+01	59,41
3	7,3326E-06	-1,2605E-03	8,4435E+01	90,24
4	1,3960E-05	-2,1482E-02	1,2313E+02	115,48
5	2,3025E-05	-5,6133E-02	1,7128E+02	138,38
6	2,7337E-05	-6,8771E-02	1,7704E+02	135,90
7	1,9636E-05	-5,0399E-02	1,7678E+02	146,25
8	1,5634E-05	-3,4042E-02	1,5037E+02	132,02
9	1,0394E-05	-9,7880E-03	1,0432E+02	104,71
10	4,8585E-06	-2,4663E-03	6,7617E+01	69,87
11	-8,1460E-07	1,4348E-02	2,9541E+01	42,82
12	1,1435E-06	8,3307E-03	1,9925E+01	29,19

Table 50: Actual radiation values

9.2.18.4 Determination of the monthly average location depending radiation values (I_{SOL})

$I_{SOL} = I_S * T_F$ [kWh/m²M] Formula (2); B8110-5

wherein:

I_{SOL} monthly average location depending radiation values for any slope and azimuth
I_S average monthly sum of global radiation per month on horizontal areas
T_F transposition factor Table E.1-E.7; ÖN B 8110-5

SSE (Azimut +/- 22.5°)	Region: N/SE, 980m, (750-1250m)		
Month	I_S [kWh/m²M]	T_F	I_{SOL} [kWh/m²M]
1	38,70	1,72	66,57
2	59,41	1,31	77,83
3	90,24	0,94	84,83
4	115,48	0,70	80,84
5	138,38	0,55	76,11
6	135,90	0,52	70,67
7	146,25	0,53	77,51
8	132,02	0,63	83,17
9	104,71	0,80	83,77
10	69,87	1,16	81,04
11	42,82	1,59	68,08
12	29,19	1,81	52,83

NNW (Azimut +/- 157,5°)			
Month	I_S [kWh/m²M]	T_F	I_{SOL} [kWh/m²M]
1	38,70	0,32	12,39
2	59,41	0,29	17,23
3	90,24	0,33	29,78
4	115,48	0,38	43,88
5	138,38	0,41	56,74
6	135,90	0,42	57,08
7	146,25	0,41	59,96
8	132,02	0,40	52,81
9	104,71	0,38	39,79
10	69,87	0,31	21,66
11	42,82	0,33	14,13
12	29,19	0,36	10,51

Table 51: Location depending radiation values

ENE (Azimut +/- 112,5°)			
Month	I_S [kWh/m²M]	T_F	I_{SOL} [kWh/m²M]
1	38,70	0,45	17,42
2	59,41	0,46	27,33
3	90,24	0,50	45,12
4	115,48	0,53	61,21
5	138,38	0,54	74,73
6	135,90	0,54	73,39
7	146,25	0,53	77,51
8	132,02	0,55	72,61
9	104,71	0,53	55,50
10	69,87	0,48	33,54
11	42,82	0,47	20,13
12	29,19	0,47	13,72

WSW (Azimut +/- 67,5°)			
Month	I_S [kWh/m²M]	T_F	I_{SOL} [kWh/m²M]
1	38,70	1,04	40,25
2	59,41	0,88	52,28
3	90,24	0,76	68,58
4	115,48	0,66	76,22
5	138,38	0,60	83,03
6	135,90	0,58	78,82
7	146,25	0,58	84,82
8	132,02	0,64	84,50
9	104,71	0,70	73,30
10	69,87	0,84	58,69
11	42,82	1,00	42,82
12	29,19	1,08	31,52

Table 52: Location depending radiation values 2

9.2.18.5 Calculation of the monthly solar heat gains ($Q_{s,h}$) for the actual location

$$Qs,h = \sum j\,(ISOL,j * \Sigma\, Atrans,h,k,j)\ \left[\frac{kWh}{M}\right]$$

wherein:
s radiation
h situation of heating
j orientation
k type of transparent surface

MONTH	Orientation												Σ (Qs,h)j
	SSE			NNW			ENE			WSW			
	ISOL	Atrans,h	Qs,h	ISOL	Atrans,h	Qs,h	ISOL	Atrans,h	Qs,h	ISOL	Atrans,h	Qs,h	
1	66,57	1,27	84,36	12,39	0,00	0,00	17,42	2,88	50,11	40,25	5,14	206,79	341,26
2	77,83	1,27	98,63	17,23	0,00	0,00	27,33	2,88	78,63	52,28	5,14	268,61	445,87
3	84,83	1,27	107,49	29,78	0,00	0,00	45,12	2,88	129,81	68,58	5,14	352,34	589,65
4	80,84	1,27	102,44	43,88	0,00	0,00	61,21	2,88	176,09	76,22	5,14	391,57	670,10
5	76,11	1,27	96,45	56,74	0,00	0,00	74,73	2,88	214,99	83,03	5,14	426,56	737,99
6	70,67	1,27	89,55	57,08	0,00	0,00	73,39	2,88	211,13	78,82	5,14	404,94	705,61
7	77,51	1,27	98,22	59,96	0,00	0,00	77,51	2,88	223,00	84,82	5,14	435,77	756,99
8	83,17	1,27	105,40	52,81	0,00	0,00	72,61	2,88	208,91	84,50	5,14	434,08	748,39
9	83,77	1,27	106,15	39,79	0,00	0,00	55,50	2,88	159,66	73,30	5,14	376,56	642,37
10	81,04	1,27	102,70	21,66	0,00	0,00	33,54	2,88	96,48	58,69	5,14	301,50	500,68
11	68,08	1,27	86,28	14,13	0,00	0,00	20,13	2,88	57,90	42,82	5,14	219,98	364,16
12	52,83	1,27	66,95	10,51	0,00	0,00	13,72	2,88	39,47	31,52	5,14	161,94	268,35

Table 53: Actual solar heat gains

9.2.18.6 Calculation of the monthly solar heat gains ($Q_{s,h}$) for the reference climate

MONTH	Orientation												Σ (Qs,h)j
	SSE			NNW			ENE			WSW			
	ISOL	Atrans,h	Qs,h	ISOL	Atrans,h	Qs,h	ISOL	Atrans,h	Qs,h	ISOL	Atrans,h	Qs,h	
1	37,06	1,27	46,96	13,11	0,00	0,00	15,72	2,88	45,23	25,66	5,14	131,83	224,01
2	56,49	1,27	71,58	21,08	0,00	0,00	26,16	2,88	75,26	40,81	5,14	209,66	356,50
3	74,95	1,27	94,98	30,23	0,00	0,00	42,43	2,88	122,07	60,88	5,14	312,76	529,81
4	78,96	1,27	100,06	43,71	0,00	0,00	59,22	2,88	170,37	73,61	5,14	378,16	648,60
5	89,71	1,27	113,68	61,53	0,00	0,00	79,55	2,88	228,86	91,63	5,14	470,74	813,28
6	81,69	1,27	103,52	65,39	0,00	0,00	82,66	2,88	237,81	89,06	5,14	457,54	798,86
7	87,32	1,27	110,65	66,64	0,00	0,00	85,31	2,88	245,43	94,34	5,14	484,66	840,75
8	89,33	1,27	113,20	50,03	0,00	0,00	71,33	2,88	205,21	87,43	5,14	449,16	767,58
9	79,92	1,27	101,27	37,86	0,00	0,00	51,09	2,88	146,98	68,16	5,14	350,16	598,42
10	66,04	1,27	83,69	23,81	0,00	0,00	32,66	2,88	93,96	50,27	5,14	258,26	435,90
11	38,90	1,27	49,29	13,21	0,00	0,00	16,01	2,88	46,06	26,63	5,14	136,81	232,16
12	31,97	1,27	40,51	9,60	0,00	0,00	11,36	2,88	32,68	20,66	5,14	106,14	179,33

Table 54: Reference solar heat gains

9.2.19 Determination of monthly total heat gain ($Q_{g,h}$)

$Q_{g,h} = Q_i + Q_{s,h}$ [kWh/M] Formula (46); ÖN B 8110-6

Climate of actual location			
Month	Q_i [kWh/M]	$Q_{s,h}$	$Q_{g,h}$ [kWh[M]
1	325,01	341,26	666,27
2	293,56	445,87	739,42
3	325,01	589,65	914,66
4	314,53	670,10	984,63
5	325,01	737,99	1063,00
6	314,53	705,61	1020,14
7	325,01	756,99	1082,00
8	325,01	748,39	1073,40
9	314,53	642,37	956,89
10	325,01	500,68	825,69
11	314,53	364,16	678,68
12	325,01	268,35	593,36

Reference climate			
Month	Q_i [kWh/M]	$Q_{s,h}$	$Q_{g,h}$ [kWh[M]
1	325,01	224,01	549,02
2	293,56	356,50	650,06
3	325,01	529,81	854,82
4	314,53	648,60	963,12
5	325,01	813,28	1138,29
6	314,53	798,86	1113,39
7	325,01	840,75	1165,76
8	325,01	767,58	1092,59
9	314,53	598,42	912,95
10	325,01	435,90	760,91
11	314,53	232,16	546,69
12	325,01	179,33	504,34

Table 55: Monthly total heat gain

9.2.20 Balancing and Calculation of the heating requirement

Building constant (τ):		
V =	426,24	
LT =	261,93	
LV=	44,92341474	
fBW=	10	Wh/m³K

Table 56: Building constants

Unit	Formula	Calculation	Result
wirksame Speicherfähigkeit C [Wh/K]	$C = f_{BW} * V$ [Wh/K]	10*1734,45	4262,41
Gebäudekonstante τ [h]	$\tau = C / (L_T + L_V)$ [h]	17344,49/(925,57+45,59)	13,89

Table 57: Results

Wherein:
C effective heat storage capacity of the building
L_T transmission conductance [W/K]
L_V ventilation conductance [W/K]
f_{BW} coefficient for construction method.
Lightweight construction: f_{BW} = 10 Wh/m³K
τ building constant

9.2.20.1 Calculation of monthly utilisation of heat gains when heating (n_h)

If: $\gamma \neq 1$ → $n_h = (1 - \gamma_h^{a}) / (1 - \gamma_h^{a+1})$
If: $\gamma = 1$ → $n_h = a / (1 + a)$

Climate of actual location				
Month	$Q_{g,h}$	Q_l	γ_h	n_h
1	666,27	5380,86	0,12	0,98
2	739,42	4597,05	0,16	0,97
3	914,66	4315,28	0,21	0,96
4	984,63	3282,70	0,30	0,92
5	1063,00	2343,53	0,45	0,86
6	1020,14	1569,23	0,65	0,78
7	1082,00	1150,74	0,94	0,67
8	1073,40	1258,40	0,85	0,70
9	956,89	1826,18	0,52	0,83
10	825,69	2924,46	0,28	0,93
11	678,68	4101,98	0,17	0,97
12	593,36	5131,78	0,12	0,98

Reference climate				
Month	$Q_{g,h}$	Q_l	γ_h	n_h
1	549,02	4915,35	0,11	0,99
2	650,06	3973,64	0,16	0,97
3	854,82	3467,92	0,25	0,94
4	963,12	2293,34	0,42	0,87
5	1138,29	1324,15	0,86	0,70
6	1113,39	589,90	1,89	0,44
7	1165,76	200,91	5,80	0,17
8	1092,59	328,76	3,32	0,28
9	912,95	1098,06	0,83	0,71
10	760,91	2365,21	0,32	0,92
11	546,69	3499,66	0,16	0,97
12	504,34	4522,67	0,11	0,99

Table 58: Utilisation of heat gains

9.2.21 Balancing: Calculation of the monthly (Q_h) and annual heating requirement ($Q_{h,a}$):

Climate of actual location				
Month	Q_l	$Q_{g,h}$	n_h	$Q_{h,a}$
1	5380,86	666,27	0,98	4726,41
2	4597,05	739,42	0,97	3878,17
3	4315,28	914,66	0,96	3440,83
4	3282,70	984,63	0,92	2373,13
5	2343,53	1063,00	0,86	1428,48
6	1569,23	1020,14	0,78	774,23
7	1150,74	1082,00	0,67	424,48
8	1258,40	1073,40	0,70	505,15
9	1826,18	956,89	0,83	1030,77
10	2924,46	825,69	0,93	2156,10
11	4101,98	678,68	0,97	3443,06
12	5131,78	593,36	0,98	4547,76
			Σ =	28728,59

Reference climate				
Month	Ql	Qg,h	nü h	Qh,a
1	4915,35	549,02	0,99	4374,47
2	3973,64	650,06	0,97	3342,16
3	3467,92	854,82	0,94	2661,03
4	2293,34	963,12	0,87	1450,69
5	1324,15	1138,29	0,70	528,09
6	589,90	1113,39	0,44	100,99
7	200,91	1165,76	0,17	6,27
8	328,76	1092,59	0,28	25,18
9	1098,06	912,95	0,71	450,27
10	2365,21	760,91	0,92	1668,83
11	3499,66	546,69	0,97	2967,42
12	4522,67	504,34	0,99	4025,79
			Σ =	21601,18

Table 59: Monthly and annual heating requirements

9.2.22 Determination of building-physical energy indexes

9.2.22.1 Energy indexes independent of location

Kennzahl	Berechnung - Gebäudeteil	Ergebnis:
kond. Brutto-Grundfl. (BGF)		145,61 m²
kond. Brutto-Volumen (V)		426,24 m³
Gebäudehülle (A)		386,43 m²
Mittl. U-Wert (Um)	Um = Lt / A	0,68 W/m²K
char. Länge (lc)	lc = V / A	1,10 m
Kompaktheit (k0)	k0 = A / V	0,907 m^{-1}
LEK-Wert	LEK = 300 * [Um / (2 + lc)]	65,53

Table 60: Energy index

9.2.22.2 Energy indexes dependent of location

HWB_{BGF} = $Q_{h,a}$ / BGF =	197,29 kWh/m²a
$HWB_{BGF,Ref}$	148,35 kWh/m²a

Table 61: Energy index dependent of location

9.3 Modification of fenestration products according to OIB-6

Component	U-Factor [W/m²K]
Exterior wall (2/4)	0,30
Basement ceiling	0,19
Floor lowest level	0,30
Roof	0,19
Windows	1,40
Exterior doors (swinging)	1,70
Exterior doors (not swinging)	1,70

Table 62: Modification 1

Kennzahl	Berechnung - Gebäudeteil	Ergebnis:
kond. Brutto-Grundfl. (BGF)		145,61 m²
kond. Brutto-Volumen (V)		426,24 m³
Gebäudehülle (A)		386,43 m²
Mittl. U-Wert (Um)	Um = Lt / A	0,39 W/m²K
char. Länge (lc)	lc = V / A	1,10 m
Kompaktheit (k0)	k0 = A / V	0,907 m^{-1}
LEK-Wert	LEK = 300 * [Um / (2 + lc)]	37,98

Table 63: Modification 2

HWB_{BGF} = $Q_{h,a}$ / BGF =	107,16 kWh/m²a
$HWB_{BGF,Ref}$	81,88 kWh/m²a

Table 64: Modification 3

9.4 HERS calculation (performed with EnergyGauge Software)

Building Input Summary Report

PROJECT

Title:	Campus Point	Bedrooms:	4	Adress Type:	Street Address
Building Type:	User	Bathrooms:	2	Lot #	
Owner:		Conditioned Area:	1567	Block/SubDivision:	
# of Units:	1	Total Stories:	3	PlatBook:	
Builder Name:	Campus Point	Worst Case:	No	Street:	
Permit Office:		Rotate Angle:	0	County:	
Jurisdiction:		Cross Ventilation:		City, State, Zip:	San Luis Obispo ,
Family Type:	Single-family	Whole House Fan:			CA , 93401-
New/Existing:	New (From Plans)				
Comment:					

CLIMATE

Design Location	Tmy Site	Design Temp 97.5 %	Design Temp 2.5 %	Int Design Temp Winter	Int Design Temp Summer	Heating Degree Days	Design Moisture	Daily Temp Range
CA, Santa Maria	CA_SANTAMARIA	33	76	70	75	3053	2	Medium

UTILITY RATES

Fuel	Unit	Utility Name	Monthly Fixed Cost	$/Unit
Electricity	kWh	California Average	0	0.1381
Natural Gas	Therm	California Average	0	1.275
Fuel Oil	Gallon	California Default	0	2.33
Propane	Gallon	California Default	0	2.56

SURROUNDINGS

Ornt	Type	Shade Trees Height	Width	Distance	Exist	Adjacent Buildings Height	Width	Distance
N	None	0 ft	0 ft	0 ft		0 ft	0 ft	0 ft
NE	None	0 ft	0 ft	0 ft		0 ft	0 ft	0 ft
E	None	0 ft	0 ft	0 ft		0 ft	0 ft	0 ft
SE	None	0 ft	0 ft	0 ft		0 ft	0 ft	0 ft
S	None	0 ft	0 ft	0 ft		0 ft	0 ft	0 ft
SW	None	0 ft	0 ft	0 ft		0 ft	0 ft	0 ft
W	None	0 ft	0 ft	0 ft		0 ft	0 ft	0 ft
NW	None	0 ft	0 ft	0 ft		0 ft	0 ft	0 ft

FLOORS

#	Floor Type	Perimeter	Perimeter R-Value	Area	Joist R-Value	Tile	Wood	Carpet
1	Slab-On-Grade Edge Insulatio	1 ft	10	140.04 ft²		0	0	1
2	Raised Floor		30	728.29 ft²		0	0	1
3	Raised Floor		19	699 ft²		0	0	1

ROOF

#	Type	Materials	Roof Area	Gable Area	Roof Color	Solar Absor.	Tested	Deck Insul.	Pitch
1	Flat	Composition shingles	728 ft²	0 ft²	Medium	0.96	No	19	0 deg

ATTIC

#	Type	Ventilation	Vent Ratio (1 in)	Area	RBS	IRCC
1	No attic	Vented	300	728.29 ft²	N	N

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Figure 23: HERS input 1

Building Input Summary Report

CEILING

#	Ceiling Type	R Value	Area	Framing Fraction	Truss Type
1	Under Attic (Vented)	30	728.29 ft²	0.11	Wood

WALLS

Wall orientation below is as entered. Actual orientation is modified by rotate angle shown in "Project" section above.

#	Ornt	Adjacent To	Wall Type	Cavity R-Value	Width Ft	Width In	Height Ft	Height In	Area	Sheathing R-Value	Framing Fraction	Solar Absor.
1	E	Exterior	Frame - Wood	43.68	60.27		10		602.7 ft²	43.68	0.23	0.75
2	S	Exterior	Frame - Wood	43.68	60.36		10		603.6 ft²	43.68	0.23	0.75
3	N	Exterior	Frame - Wood	43.68	44.36		10		443.7 ft²	43.68	0.23	0.75
4	W	Exterior	Frame - Wood	43.68	54.94		10		549.4 ft²	43.68	0.23	0.75

DOORS

#	Ornt	Door Type	Storms	U-Value	Width Ft	Width In	Height Ft	Height In	Area
1	E	Wood	None	0.26	6	8	3		20 ft²
2	E	Wood	None	0.26	6	8	3		20 ft²
3	E	Wood	None	0.26	6	8	3		20 ft²

WINDOWS

#	Ornt	Frame	Panes	NFRC	U-Factor	SHGC	Storm	Area	Overhang Depth	Overhang Separation	Interior Shade	Screening
1	E	Metal	Double (Tinted)	Yes	0.18	0.6	N	49 ft²	0 ft 0 in	0 ft 0 in	Drapes/blinds	None
2	E	Metal	Double (Tinted)	Yes	0.18	0.6	N	87.7 ft²	0 ft 0 in	0 ft 0 in	Drapes/blinds	None
3	N	Metal	Double (Tinted)	Yes	0.18	0.6	N	141 ft²	0 ft 0 in	0 ft 0 in	Drapes/blinds	None

INFILTRATION & VENTING

Method	SLA	CFM 50	ELA	EqLA	ACH	ACH 50	Forced Ventilation Supply	Forced Ventilation Exhaust	Run Time	Terrain/Wind Shielding
Best Guess	0.00030	1233	67.7	127.3	0.292	4.92	0	0	0	Suburban / Suburban

MASS

Mass Type	Area	Thickness	Furniture Fraction
No Added Mass	0 ft²	0 ft	0.3

HEATING SYSTEM

#	System Type	Subtype	Efficiency	Capacity	Ductless
1	Fuel Oil Furnace	None	AFUE: 0.78	100 kBtu/hr	False

HOT WATER SYSTEM

#	System Type	EF	Cap	Use	SetPnt	Credits
1	Fuel Oil	0.52	40 gal	70 gal	120 deg	None

Figure 24: HERS input 2

Building Input Summary Report

SOLAR HOT WATER

Collector Type	Collector Tilt	Azimuth	Surface Area	Loss Coef.	Absorp. Prod.	Trans Corr.	Tank Volume	Tank U-Value	Tank Surf Area	Heat Exch Eff	PV Pumped	Pump Energy

DUCTS

#	---- Supply ---- Location	R-Value	Area	---- Return ---- Location	Area	Number	Leakage Type	Air Handler	CFM 25	Percent Leakage	QN	RLF
1	Attic	6	313.4 ft^2	Attic	78.35 ft^2	(invalid)	Default Leakage	Interior	(Default)	(Default)		

TEMPERATURES

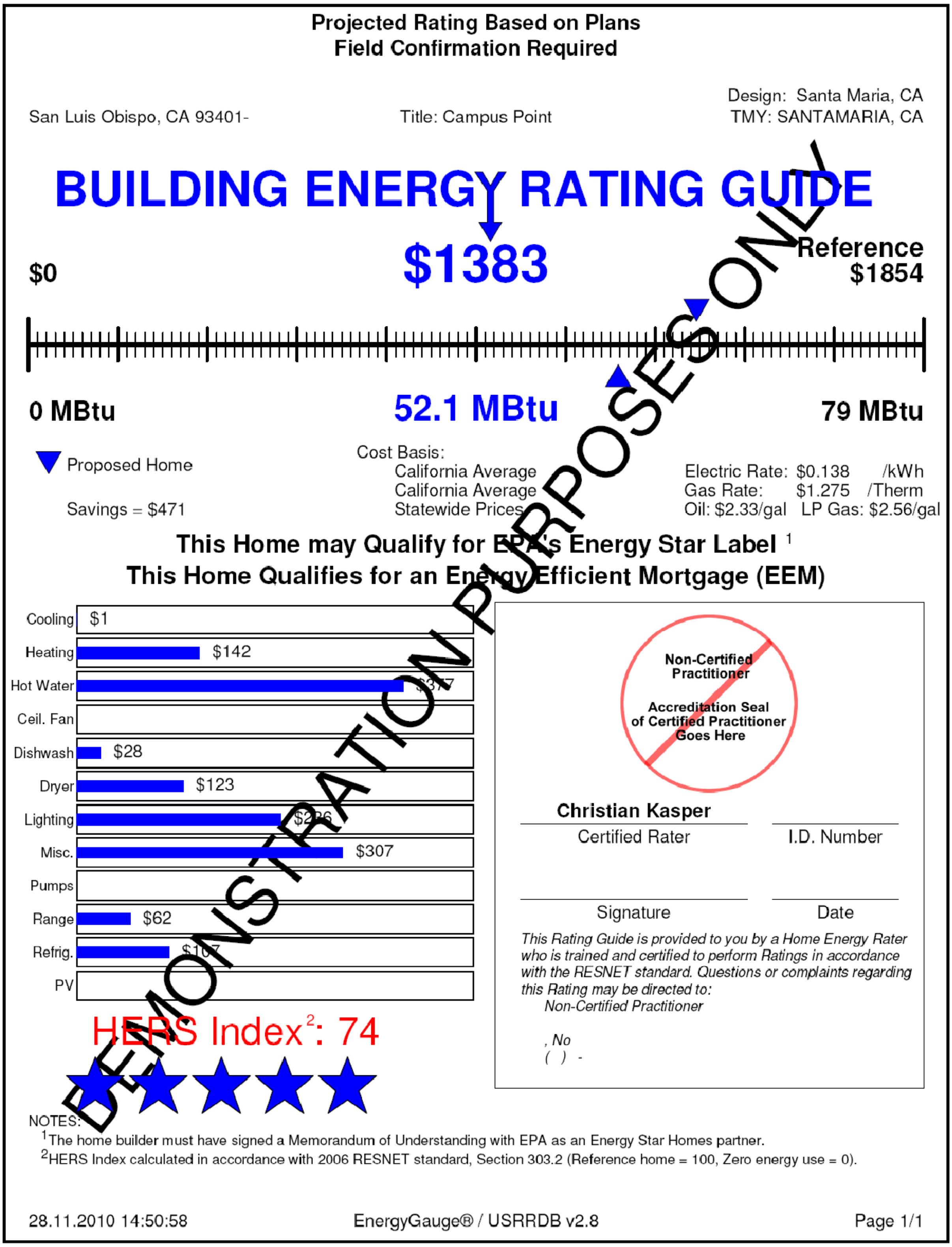
Programable Thermostat: None Ceiling Fans: N

Cooling	[X] Jan	[X] Feb	[X] Mar	[X] Apr	[X] May	[X] Jun	[X] Jul	[X] Aug	[X] Sep	[X] Oct	[X] Nov	[X] Dec
Heating	[X] Jan	[X] Feb	[X] Mar	[X] Apr	[X] May	[X] Jun	[X] Jul	[X] Aug	[X] Sep	[X] Oct	[X] Nov	[X] Dec
Venting	[X] Jan	[X] Feb	[X] Mar	[X] Apr	[X] May	[X] Jun	[X] Jul	[X] Aug	[X] Sep	[X] Oct	[X] Nov	[X] Dec

Thermostat Schedule: HERS 2006 Reference

Schedule Type		Hours 1	2	3	4	5	6	7	8	9	10	11	12
Cooling (WD)	AM	78	78	78	78	78	78	78	78	78	78	78	78
	PM	78	78	78	78	78	78	78	78	78	78	78	78
Cooling (WEH)	AM	78	78	78	78	78	78	78	78	78	78	78	78
	PM	78	78	78	78	78	78	78	78	78	78	78	78
Heating (WD)	AM	68	68	68	68	68	68	68	68	68	68	68	68
	PM	68	68	68	68	68	68	68	68	68	68	68	68
Heating (WEH)	AM	68	68	68	68	68	68	68	68	68	68	68	68
	PM	68	68	68	68	68	68	68	68	68	68	68	68

Figure 25: HERS input 3



Projected Rating Based on Plans
Field Confirmation Required

San Luis Obispo, CA 93401-

Title: Campus Point

Design: Santa Maria, CA
TMY: SANTAMARIA, CA

BUILDING ENERGY RATING GUIDE

$0 **$1383** **Reference $1854**

0 MBtu **52.1 MBtu** **79 MBtu**

Proposed Home

Savings = $471

Cost Basis:
California Average
California Average
Statewide Prices

Electric Rate: $0.138 /kWh
Gas Rate: $1.275 /Therm
Oil: $2.33/gal LP Gas: $2.56/gal

This Home may Qualify for EPA's Energy Star Label [1]
This Home Qualifies for an Energy Efficient Mortgage (EEM)

Cooling	$1
Heating	$142
Hot Water	$377
Ceil. Fan	
Dishwash	$28
Dryer	$123
Lighting	$236
Misc.	$307
Pumps	
Range	$62
Refrig.	$107
PV	

HERS Index[2]: 74

Non-Certified Practitioner

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Christian Kasper
Certified Rater I.D. Number

Signature Date

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Non-Certified Practitioner

, No
( ) -

DEMONSTRATION PURPOSES ONLY

NOTES:
[1] The home builder must have signed a Memorandum of Understanding with EPA as an Energy Star Homes partner.
[2] HERS Index calculated in accordance with 2006 RESNET standard, Section 303.2 (Reference home = 100, Zero energy use = 0).

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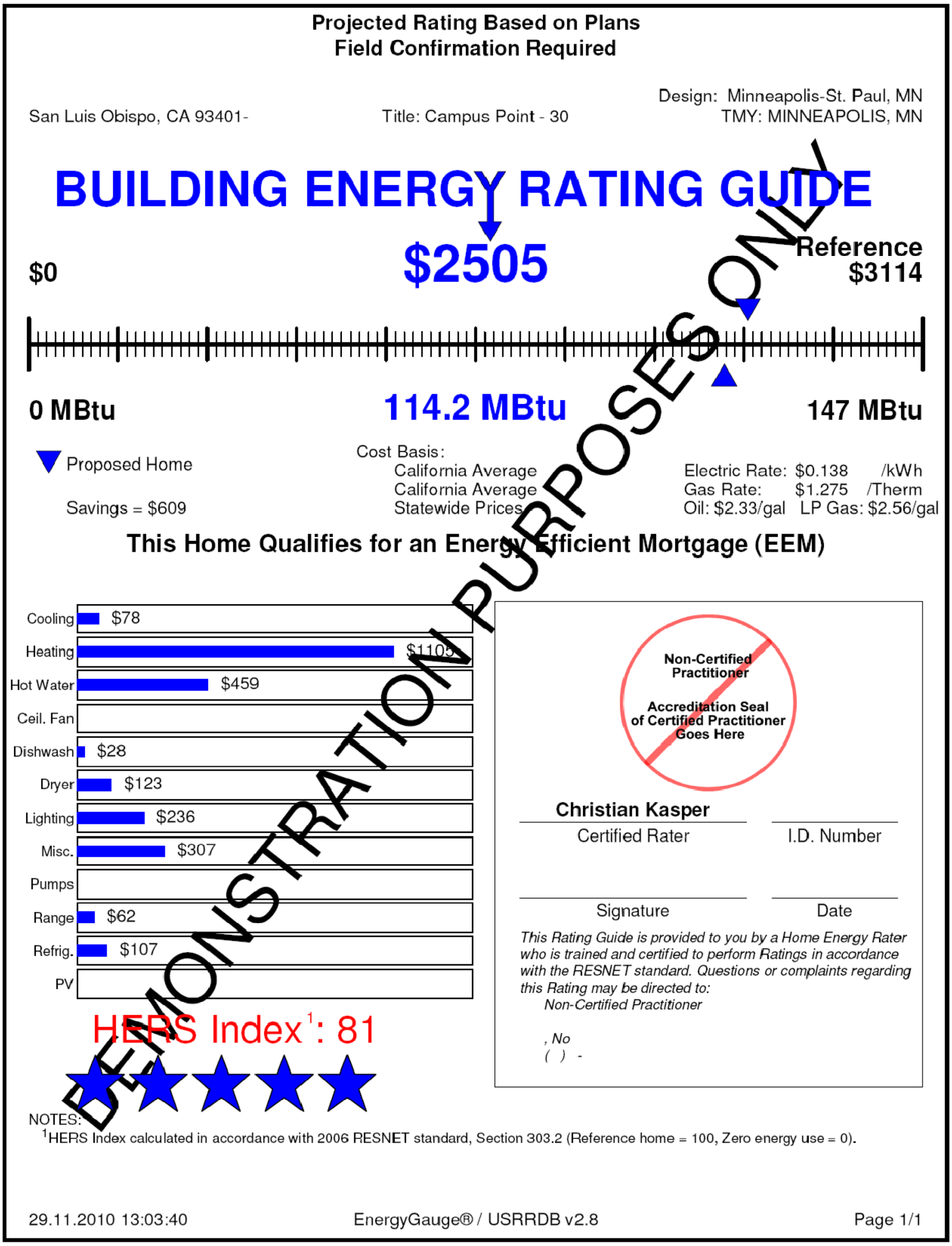
Figure 26: HERS output 1


Projected Rating Based on Plans
Field Confirmation Required

San Luis Obispo, CA 93401-
Title: Campus Point - 30
Design: Minneapolis-St. Paul, MN
TMY: MINNEAPOLIS, MN

BUILDING ENERGY RATING GUIDE

$0
$2505
Reference $3114

0 MBtu
114.2 MBtu
147 MBtu

Proposed Home
Savings = $609

Cost Basis:
California Average
California Average
Statewide Prices

Electric Rate: $0.138 /kWh
Gas Rate: $1.275 /Therm
Oil: $2.33/gal LP Gas: $2.56/gal

This Home Qualifies for an Energy Efficient Mortgage (EEM)

Cooling	$78
Heating	$1105
Hot Water	$459
Ceil. Fan	
Dishwash	$28
Dryer	$123
Lighting	$236
Misc.	$307
Pumps	
Range	$62
Refrig.	$107
PV	

HERS Index[1]: 81

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Signature
Date

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, No
( ) -

NOTES:
[1]HERS Index calculated in accordance with 2006 RESNET standard, Section 303.2 (Reference home = 100, Zero energy use = 0).

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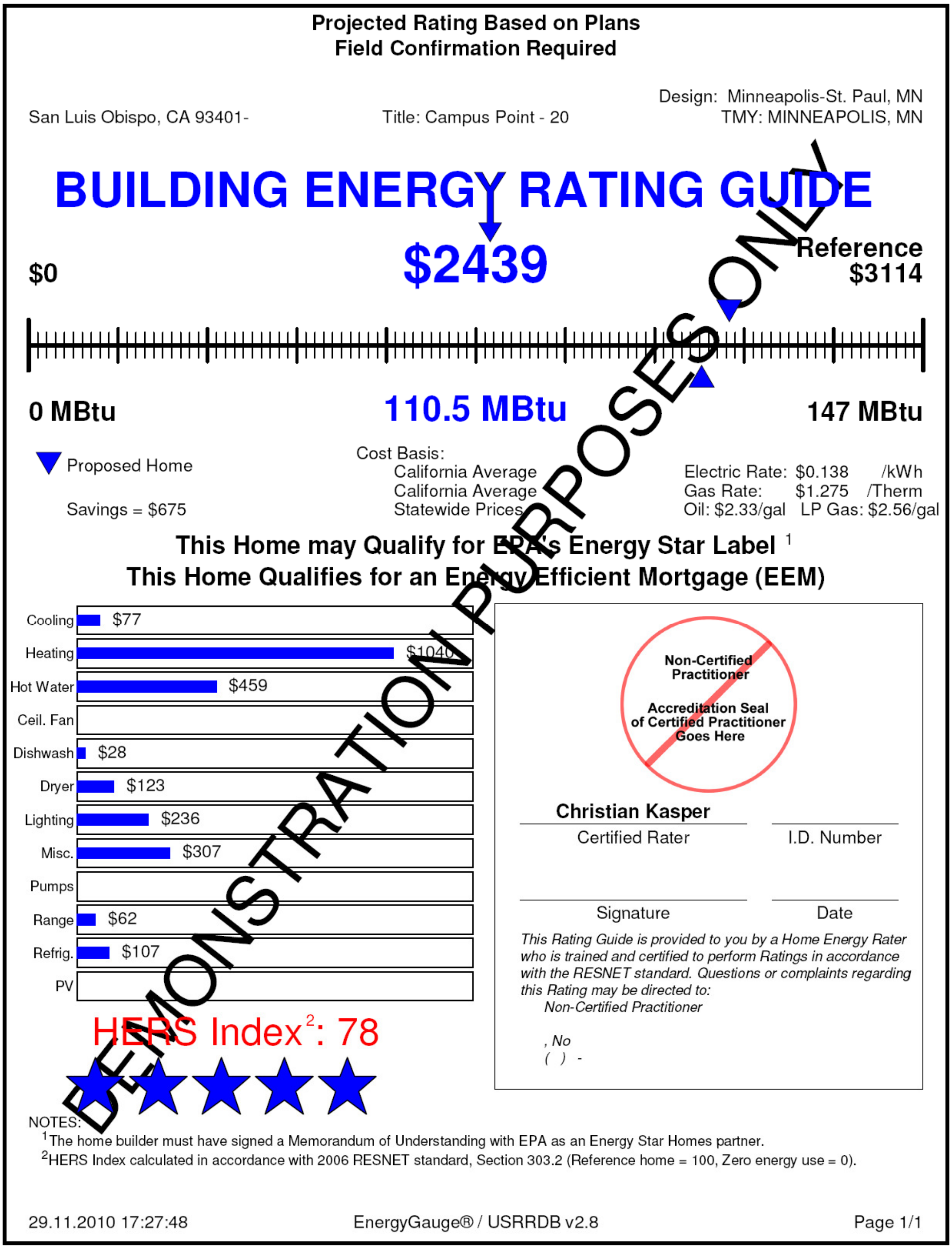
DEMONSTRATION PURPOSES ONLY

Figure 27: HERS output 2



Projected Rating Based on Plans
Field Confirmation Required

San Luis Obispo, CA 93401- Title: Campus Point - 20 Design: Minneapolis-St. Paul, MN
TMY: MINNEAPOLIS, MN

BUILDING ENERGY RATING GUIDE

$0 **$2439** Reference $3114

0 MBtu **110.5 MBtu** 147 MBtu

▼ Proposed Home

Savings = $675

Cost Basis:
California Average
California Average
Statewide Prices

Electric Rate: $0.138 /kWh
Gas Rate: $1.275 /Therm
Oil: $2.33/gal LP Gas: $2.56/gal

This Home may Qualify for EPA's Energy Star Label [1]
This Home Qualifies for an Energy Efficient Mortgage (EEM)

Cooling	$77
Heating	$1040
Hot Water	$459
Ceil. Fan	
Dishwash	$28
Dryer	$123
Lighting	$236
Misc.	$307
Pumps	
Range	$62
Refrig.	$107
PV	

HERS Index[2]: 78

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Signature Date

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( ) -

NOTES:
[1] The home builder must have signed a Memorandum of Understanding with EPA as an Energy Star Homes partner.
[2] HERS Index calculated in accordance with 2006 RESNET standard, Section 303.2 (Reference home = 100, Zero energy use = 0).

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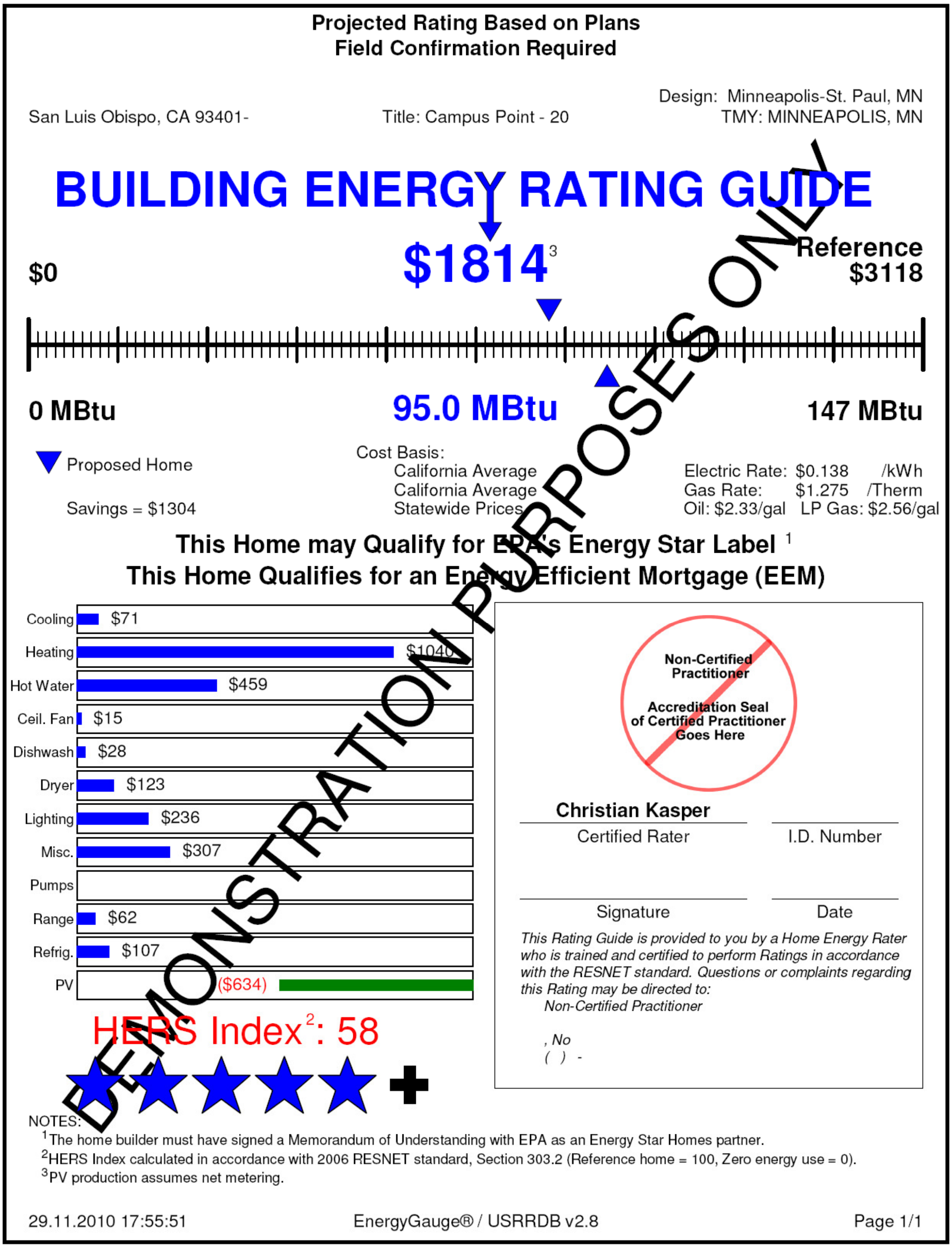
DEMONSTRATION PURPOSES ONLY

Figure 28: HERS output 3


Projected Rating Based on Plans
Field Confirmation Required

San Luis Obispo, CA 93401-
Title: Campus Point - 20
Design: Minneapolis-St. Paul, MN
TMY: MINNEAPOLIS, MN

BUILDING ENERGY RATING GUIDE

$0
$1814[3]
Reference $3118

0 MBtu
95.0 MBtu
147 MBtu

Proposed Home

Savings = $1304

Cost Basis:
California Average
California Average
Statewide Prices

Electric Rate: $0.138 /kWh
Gas Rate: $1.275 /Therm
Oil: $2.33/gal LP Gas: $2.56/gal

This Home may Qualify for EPA's Energy Star Label [1]
This Home Qualifies for an Energy Efficient Mortgage (EEM)

Cooling	$71
Heating	$1040
Hot Water	$459
Ceil. Fan	$15
Dishwash	$28
Dryer	$123
Lighting	$236
Misc.	$307
Pumps	
Range	$62
Refrig.	$107
PV	($634)

HERS Index[2]: 58

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Certified Rater
I.D. Number
Signature
Date

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Non-Certified Practitioner

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( ) -

DEMONSTRATION PURPOSES ONLY

NOTES:
[1]The home builder must have signed a Memorandum of Understanding with EPA as an Energy Star Homes partner.
[2]HERS Index calculated in accordance with 2006 RESNET standard, Section 303.2 (Reference home = 100, Zero energy use = 0).
[3]PV production assumes net metering.

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Figure 29: HERS output 4

10 DIRECTORIES

10.1 List of figures

10.2 List of tables

10.3 Abbreviations

To avoid misunderstandings when referring to the referenced standards, the list of abbreviations is in alphabetical order, but only after being summarized into the subchapters they appear in the text.

Seismic Analysis according to ASCE 7-05

b .... Width

C_d .... Deflection amplification factor

C_S .... Seismic response coefficient

C_t .... Value of approximate period parameter

F_a .... Site coefficient

h .... Height

I .... Importance factor

l .... Length

S_D .... Stiff soil profile

SDC .... Seismic design category

S_{DS} .... Design spectral response acceleration for short period (0,2 sec.)

S_{D1} .... Design spectral response acceleration for 1 sec. period

S_S .... Short period (0,2 sec.) spectral response acceleration

S_1 .... 1 sec. Period spectral response acceleration

T_a .... Approximate fundamental period

V .... Seismic Base Shear

x .... Value of approximate period parameter

ωd .... Design value of effective seismic weight

$ωd_{DL}$ .... Effective seismic weight of Dead Load

$ωd_{tot}$ .... Total effective seismic weight

$Ω_o$ .... System overstrength factor

ρ .... Redundancy factor

Seismic Analysis according to EC-8

A_c ....Total effective cross section of shear walls
A_i ....Effective cross section of the shear wall *i* in considered direction
a_g................................Design value of soil acceleration
a_{gR} ....Reference peak value of soil acceleration
C_t................................Structure coefficient
E_d ....Design value of endurance
F_b ....Total seismic force
l_{wi} ....Length of effective shear wall
m ....Effective mass
q ....Behavior coefficient
R ....Response modification coefficient
$S_{d(T)}$ ....Design spectrum for linear Calculations
s ....Displacement of the mass *m*
T_c.................................Parameter for elastic response spectrum
T_1 ....Fundamental oscillation period of a building
λ ....Slenderness ration
γ_i..................................Parameter of Significance

Wind Analysis according to ASCE 7-05

C_p ....External pressure coefficient
F.................................Building wind load
G ....Gust effect factor
GC_{pi} ....Internal pressure coefficient
I..................................Importance factor
K_d ....Wind directionality factor
K_h ....Velocity pressure coefficient
K_z ....Exposure category
K_{zt} ....Topographic factor
$p_{(z,h)}$ ....Design wind load
q_z ....Velocity pressure coefficient
q_h ....Velocity pressur coefficient
V ....Basic wind speed

Wind Analysis according to EC1

A_{ref} ....Reference work surface
c_d ....Dynamic coefficient
c_f ....Aerodynamic force coefficient
c_s ....Size coefficient
F_{w_lat} ....Wind force (lateral)
$F_{w\_long,1}$ ....Wind force (longitudinal)
$F_{w\_long,2}$ ....Wind force (longitudinal)
h..................................Reference height
$q_{p(h)}$ ....Top speed pressure
$q_{b,0}$ ....Basic windspeed pressure
$v_{b,0}$ ....Basic windspeed
z_{e1} ....Reference height for exterior and interior pressure coefficients (long.)
z_{e2} ....Reference height for exterior and interior pressure coefficients (lat.)

Vibration behavior of residential ceiling (ÖNORM EN 1995-1-1)

b..................................Width of ceiling [m]
EI_b ....Equivalent bending stiffness of the ceiling in longitudinal direction of
EI_l ....Equivalent ceiling bending stiffness perpendicular to the trusses
F..................................Initial force
f_1 ....Eigenfrequency
l..................................Ceiling span [m]

m .... Mass per unit of area [kg/m²]

n_{40} .... Number of vibrations of 1st order with a maximum resonance frequency of 40 Hz.

v .... Unit impuls velocity reaction

$w_{\_inst}$ .... Initial deflection

ω .... Maximum initial vertical deflection

v .... Characteristic impulse response

ζ .... Modal damping ratio

OIB Guideline 6 – Energy saving and thermal insulation

BGF .... Gross plot area ()

EEB .... Final energy demand ()

$EEB_{BGF,WG}$ .... Specific final energy demand for new residential buildings

f_{HT} .... Increase factor of the specific energy demand of the heating facility

HGT .... Heating degree days

$HGT_{Standort}$ .... Heating degree days ($HGT_{12/20}$) at the actual building location

HTEB .... Specific energy demand of a heating facility ()

$HTEB_{BGF,WG,Ref}$ .... Specific energy demand of the heating facility of a reference facility reference climate

HWB .... Specific heating requirement

$HWB_{BGF,WG,max,Ref}$ .... Maximum allowable annual heating demand per m² of gross plot area in the reference climate

$HWB_{BGF,WG,max,Standort}$ .... maximum allowable annual heating demand per m² of gross plot area at the building location

LEK .... LEK Value

LEK_{max} .... Maximum allowable LEK Value

$LEK_{Standort}$ .... LEK Value dependent on actual building location

l_c .... Characteristic length

$l_{c,min}$ .... Characteristic length (required minimum)

SHGC .... Solar heat gain coefficient

U .... Coefficient of heat transmission

U_m .... Average U-Factor of the building envelope

WWWB .... Hot water heating demand

$WWWB_{BGF}$ .... Hot water heating demand referring to the gross plot area of a reference facility: f_{HT} = 1,05

10.4 References

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10.5 Online resources

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URL: http://www.statistik.at/web_de/statistiken/energie_und_umwelt/energie/nutzenergieanalyse/022719.html [10.02.2011]

URL: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1750 [30.9.2010]

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URL: http://www.grist.org/article/leed1/ [26.11.2010]

URL: http://blog.mapawatt.com/2010/11/19/climate-zones-and-degree-days/ [29.11.2010]

10.6 Used software

GEQ
Gebäude Energy Qualität, Version: 2010,060343, © 1994-2010. Provider: Zehentmayer Software GmbH, Minnesheimerstraße 8b, 5023 Salzburg, Austria.
URL: http://www.geq.at

EnergyGauge
Energy and Economic Analysis Software, Version: USA2804. Provider: EnergyGauge, Florida Solar Energy Center, 1679 Clearlake Road, Cocoa, FL 32922-5703.
URL: http://www.energygauge.com