UKRENERGY

Innovative Master Courses Supporting the Improvement of the Energy and Carbon Footprint of the Ukrainian Building Stock

Energy Retrofit of Buildings

Michal Krajčík, PhD.
Slovak University of Technology in Bratislava
Faculty of Civil Engineering

1. Why reduce consumption of fossil fuels?

Environmental impacts & Dependence on import

Burning of fossil fuels

Source: https://pixels.com/featured/industrial-smoke-from-the-factories-mary-evans-picture-library.html

Import routes for natural gas

Source: http://corporate.vattenfall.com

What can we do?

Buildings are responsible for 40% of energy consumption

and 36% of CO_2 emissions in the EU

European Commission, 2016

2. Tools to reduce energy consumption

EU Directives related to energy efficiency

- Diective (EU) 2024/1275 on the energy performance of buildings
- Directive (EU) 2023/1791 o energy efficiency
- Directive 2018/2001 on the promotion of the use of energy from renewable sources (recast)
- Directive 2019/944 on common rules for the internal market for electricity
- 80 – 95% reduction of greenhouse gasses compared to 1990 level by 2050
- 55% reduction of greenhouse gasses compared to 1990 level by 2030
- etc.

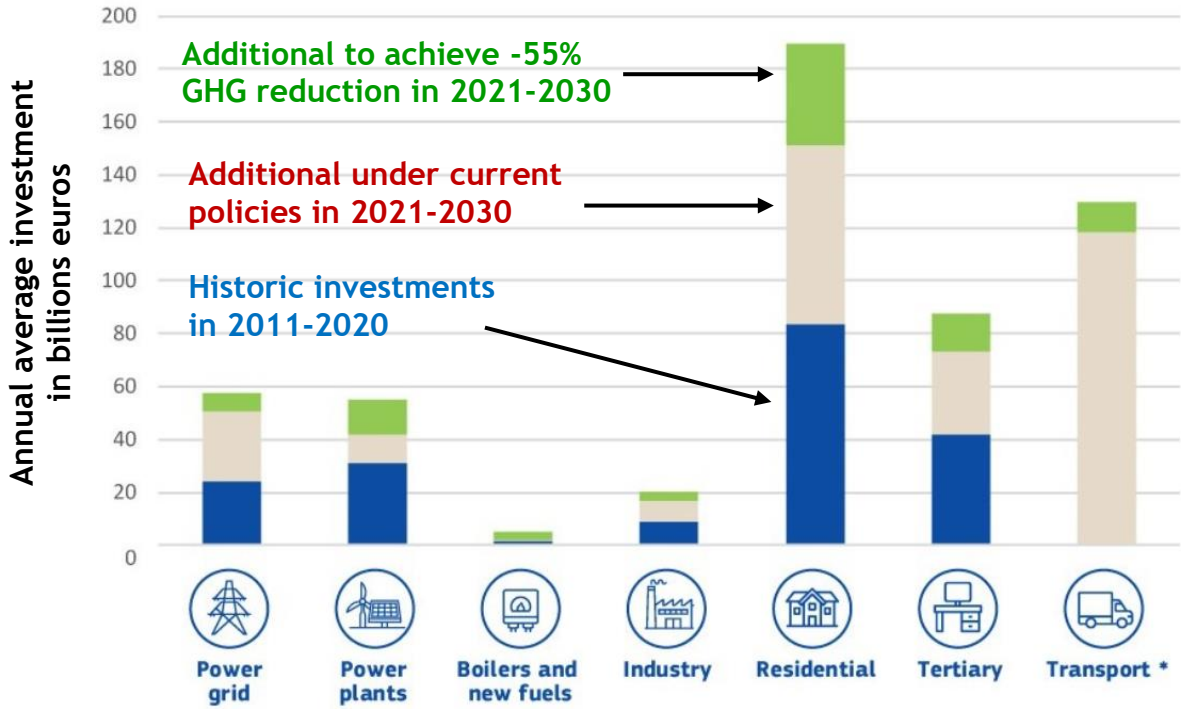
2. Tools to reduce energy consumption

Recent update

In September 2020 the EU Commission set out its blueprint:

- ~~40%~~ 55% reduction of greenhouse gasses compared to 1990 level by 2030
- The 40%-target would mean we only achieve a 60% reduction by 2050

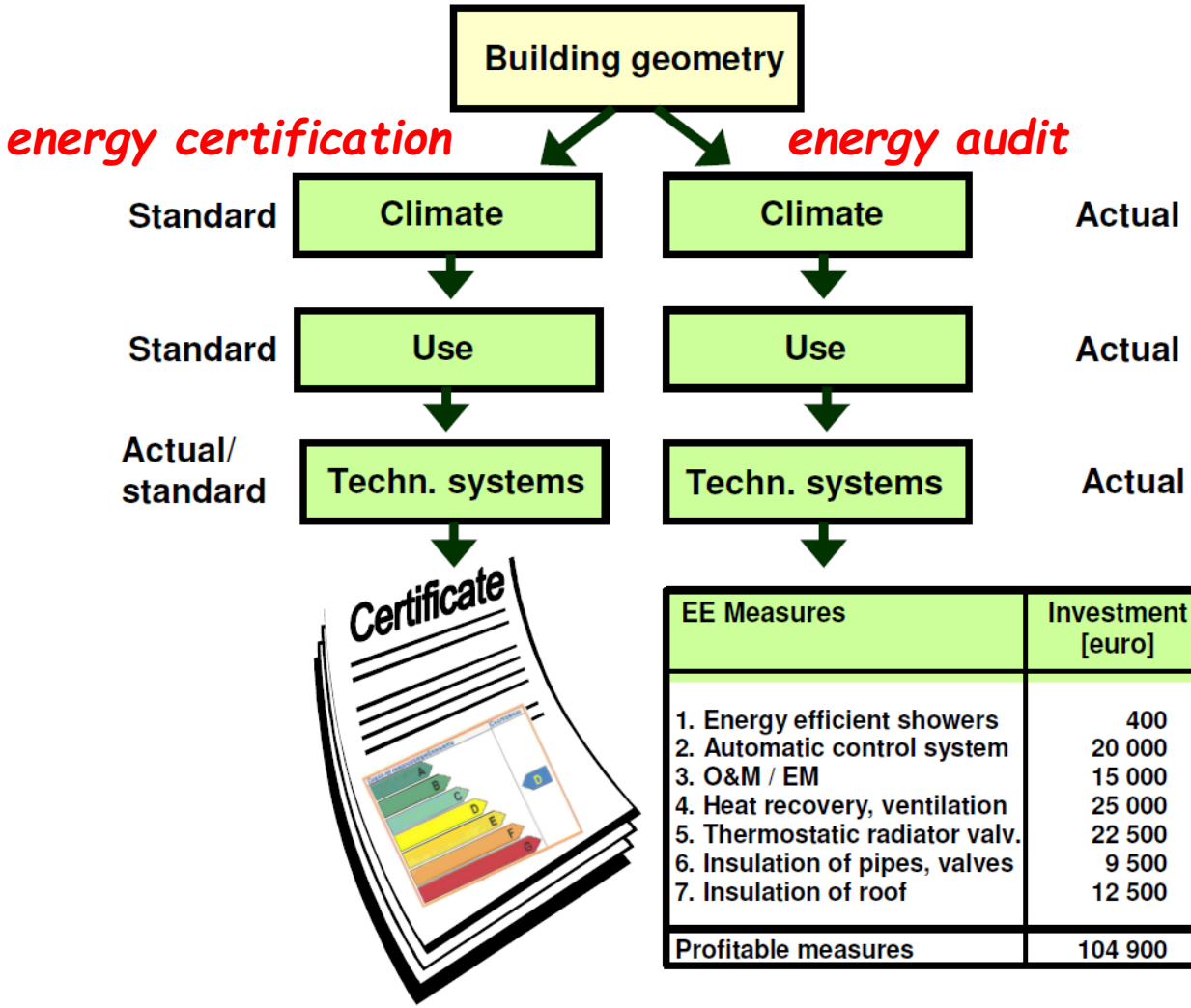
Annual investment in the energy system will need to be about €350 billion higher in 2021-2030 than in 2011-2020



Source: https://www.bbc.com/news/world-europe-55273004 (accessed 15.4.2021)
Source: https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_1598 (accessed 15.4.2021)

2. Tools to reduce energy consumption

Energy certification and Energy audit of buildings



EE Measures	Investment [euro]	Net savings [euro/yr]	PB [year]
1. Energy efficient showers	400	450	0.9
2. Automatic control system	20 000	12 270	1.6
3. O&M / EM	15 000	2 140	7.0
4. Heat recovery, ventilation	25 000	4 510	5.5
5. Thermostatic radiator valv.	22 500	3 050	7.4
6. Insulation of pipes, valves	9 500	1 640	5.8
7. Insulation of roof	12 500	1 970	6.4
Profitable measures	104 900	26 030	4.0

Source: Dahlsveen, T. – Mišči, J. – Tchervilov, L – Holubová, I. – Grytsenko, N. – Teigen, Ø. Energy auditing and certification of buildings. ENSI: Oslo. 2009.

2. Tools to reduce energy consumption

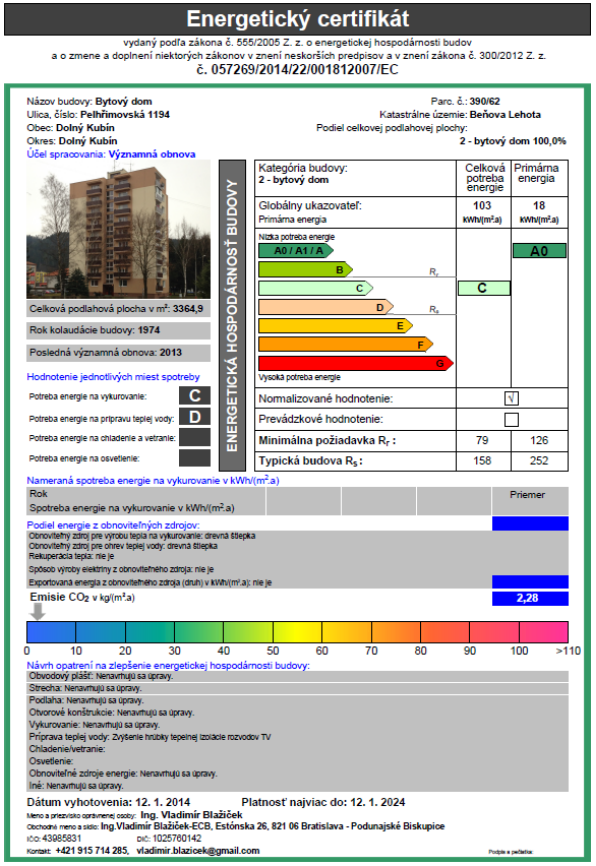
Energy certification vs. Energy audit: What´s the difference?

Difference	Energy certification	Energy audit
EU legislation	Directive 2010/31/EU	Directive 2012/27/EU
Purpose	- Compliance with requirements - Classification into energy class	- Information about potential of energy savings - Profitability of the energy saving measures
Outcome	- Energy certificate	- Report and summary
Who?	- Authorized person(s) for EC	- Energy auditor(s)
What?	- Energy need for heating (envelope), Space heating, Domestic hot water, Ventilation and cooling, Lighting	- Any energy-using equipment including HVAC, industrial technology, transport, outdoor lighting
When?	- New building, major renovation - Selling or renting - Public buildings, area ≥250 m^2	- Big companies - Energy performance contracting - Anytime to find saving potential
Validity	- Max. 10 years	- Big companies every 4 years
Calc. method	- Strictly given	- Not strictly given

3. Energy certification of buildings

Energy certificate

- Compliance with the energy standard
- Market tool to reflect energy performance in prices of buildings



Energetický certifikát

vydaný podľa zákona č. 555/2005 Z. z. o energetickej hospodárnosti budov a o zmene a doplnení niektorých zákonov v znení neskorších predpisov a v znení zákona č. 300/2012 Z. z.

č. 057269/2014/22/001812007/EC

Názov budovy: **Bytový dom**
Ulica, číslo: **Pelhřimovská 1194**
Obec: **Dolný Kubín**
Okres: **Dolný Kubín**
Účel spracovania: **Významná obnova**

Parc. č.: **390/62**
Katastrálne územie: **Beňova Lehota**
Podiel celkovej podlahovej plochy: **2 - bytový dom 100,0%**

Celková podlahová plocha v m²: **3364,9**
Rok kolaudácie budovy: **1974**
Posledná významná obnova: **2013**

ENERGETICKÁ HOSPODÁRNOSŤ BUDOVY

Kategória budovy: 2 - bytový dom	Celková potreba energie	Primárna energia
Globálny ukazovateľ: Primárna energia	103 kWh/(m².a)	18 kWh/(m².a)
Nízka potreba energie		
A0 / A1 / A		A0
B		
C	C	
D		
E		
F		
G		
Vysoká potreba energie		
Normalizované hodnotenie:	☑	
Prevádzkové hodnotenie:	☐	
Minimálna požiadavka R_T :	79	126
Typická budova R_S :	158	252

Hodnotenie jednotlivých miest spotreby

Potreba energie na vykurovanie:	C
Potreba energie na prípravu teplej vody:	D
Potreba energie na chladenie a vetranie:	
Potreba energie na osvetlenie:	

Nameraná spotreba energie na vykurovanie v kWh/(m².a)

Rok					Priemer
Spotreba energie na vykurovanie v kWh/(m².a)					

Podiel energie z obnoviteľných zdrojov:
Obnoviteľný zdroj pre výrobu tepla na vykurovanie: drevná štiepka
Obnoviteľný zdroj pre ohrev teplej vody: drevná štiepka
Rekuperácia tepla: nie je
Spôsob výroby elektriny z obnoviteľného zdroja: nie je
Exportovaná energia z obnoviteľného zdroja (druh) v kWh/(m².a): nie je

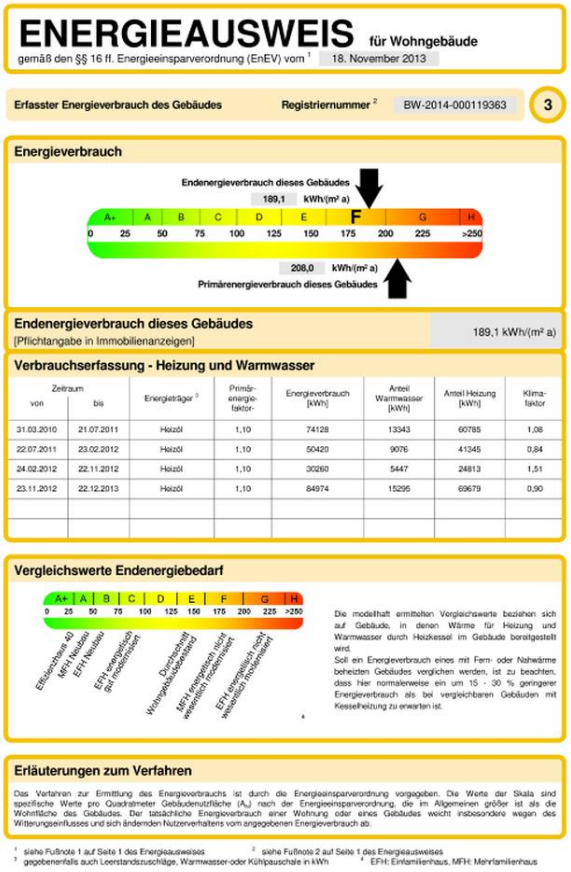
Emisie CO_2 v kg/(m².a): **2,28**

0 10 20 30 40 50 60 70 80 90 100 >110

Návrh opatrení na zlepšenie energetickej hospodárnosti budovy:
Obvodový plášť: Nenavrhujú sa úpravy.
Strecha: Nenavrhujú sa úpravy.
Podlaha: Nenavrhujú sa úpravy.
Otvorové konštrukcie: Nenavrhujú sa úpravy.
Vykurovanie: Nenavrhujú sa úpravy.
Príprava teplej vody: Zvýšenie hrúbky tepelnej izolácie rozvodov TV
Chladenie/vetranie:
Osvetlenie:
Obnoviteľné zdroje energie: Nenavrhujú sa úpravy.
Iné: Nenavrhujú sa úpravy.

Dátum vyhotovenia: 12. 1. 2014 **Platnosť najviac do: 12. 1. 2024**

Meno a priezvisko oprávnenej osoby: **Ing. Vladimír Blažiček**
Obchodné meno a sídlo: **Ing.Vladimír Blažiček-ECB, Estónska 26, 821 06 Bratislava - Podunajské Biskupice**
IČO: 43985831 DIČ: 1025760142
Kontakt: **+421 915 714 285, vladimir.blaziicek@gmail.com**



ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. Energieeinsparverordnung (EnEV) vom [1] 18. November 2013

Erfasster Energieverbrauch des Gebäudes — Registriernummer [2] BW-2014-000119363 — 3

Energieverbrauch

Endenergieverbrauch dieses Gebäudes: 189,1 kWh/(m² a)

A+ A B C D E F G H
0 25 50 75 100 125 150 175 200 225 >250

Primärenergieverbrauch dieses Gebäudes: 208,0 kWh/(m² a)

Endenergieverbrauch dieses Gebäudes [Pflichtangabe in Immobilienanzeigen] 189,1 kWh/(m² a)

Verbrauchserfassung - Heizung und Warmwasser

Zeitraum von	Zeitraum bis	Energieträger [3]	Primär-energie-faktor-	Energieverbrauch [kWh]	Anteil Warmwasser [kWh]	Anteil Heizung [kWh]	Klima-faktor
31.03.2010	21.07.2011	Heizöl	1,10	74128	13343	60785	1,08
22.07.2011	23.02.2012	Heizöl	1,10	50420	9076	41345	0,84
24.02.2012	22.11.2012	Heizöl	1,10	30260	5447	24813	1,51
23.11.2012	22.12.2013	Heizöl	1,10	84974	15295	69679	0,90

Vergleichswerte Endenergiebedarf

A+ A B C D E F G H
0 25 50 75 100 125 150 175 200 225 >250

Einfamilienhaus 4[4] — MFH Neubau — EFH Neubau — EFH energetisch gut modernisiert — Durchschnitt Wohngebäudebestand — MFH energetisch nicht wesentlich modernisiert — EFH energetisch nicht wesentlich modernisiert

Die modellhaft ermittelten Vergleichswerte beziehen sich auf Gebäude, in denen Wärme für Heizung und Warmwasser durch Heizkessel im Gebäude bereitgestellt wird.
Soll ein Energieverbrauch eines mit Fern- oder Nahwärme beheizten Gebäudes verglichen werden, ist zu beachten, dass hier normalerweise ein um 15 - 30 % geringerer Energieverbrauch als bei vergleichbaren Gebäuden mit Kesselheizung zu erwarten ist.

Erläuterungen zum Verfahren

Das Verfahren zur Ermittlung des Energieverbrauchs ist durch die Energieeinsparverordnung vorgegeben. Die Werte der Skala sind spezifische Werte pro Quadratmeter Gebäudenutzfläche (A_N) nach der Energieeinsparverordnung, die im Allgemeinen größer ist als die Wohnfläche des Gebäudes. Der tatsächliche Energieverbrauch einer Wohnung oder eines Gebäudes weicht insbesondere wegen des Witterungseinflusses und sich ändernden Nutzerverhaltens vom angegebenen Energieverbrauch ab.

[1] siehe Fußnote 1 auf Seite 1 des Energieausweises
[2] siehe Fußnote 2 auf Seite 1 des Energieausweises
[3] gegebenenfalls auch Leerstandszuschläge, Warmwasser-oder Kühlpauschale in kWh
[4] EFH: Einfamilienhaus, MFH: Mehrfamilienhaus

Hottgenroth Software, HGI Verbrauchspass 3.0.3

3. Energy certification of buildings

Brief history of energy certification of buildings

- **1985:** Document of the EC stating that 40% of all energy use in the EU is related to buildings
- **1989:** The EC proposed the SAVE Directive with 13 specific actions, 10 of which directly related to the building sector
- **1993:** SAVE Directive was introduced into practice
- **2001:** The EC proposed to adapt the SAVE Directive from 1993, which became the EBPD 2002/91/EC on 16th December 2002
- **2009:** Energy certification mandatory in Austria
- **2010:** EPBD recast – nearly zero-energy buildings (nZEB)

3. Energy certification of buildings

What was before Nearly-Zero Energy Buildings (2010)?

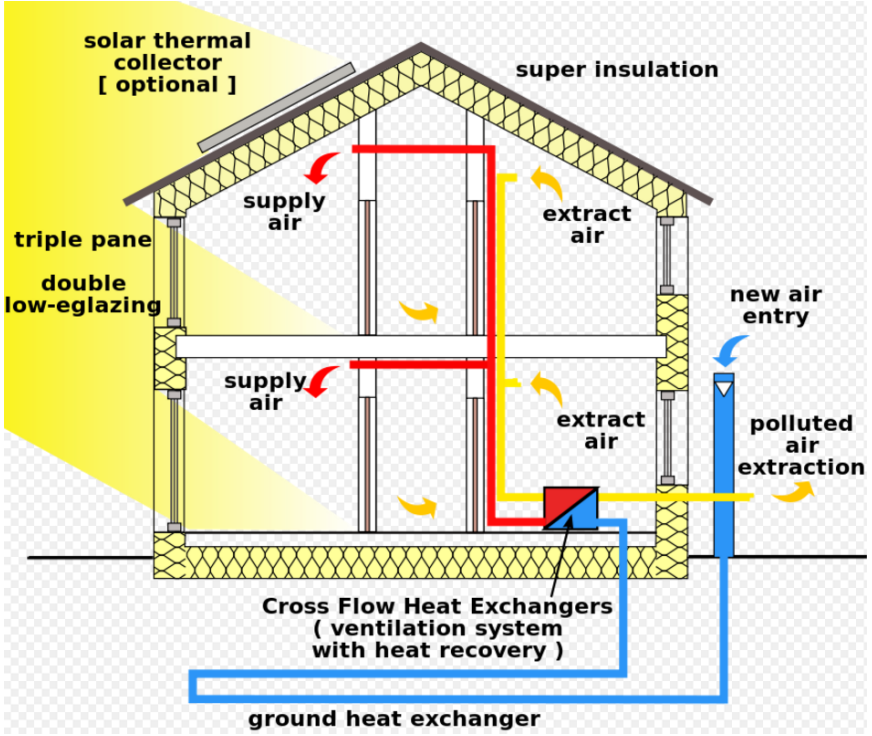
Low-energy building types and state of definition per 1st January 2010

Location	Issuer	St	Ce	Location	Issuer	St	Ce
EU				RAL Passive house	RAL	SO	yes
Low-energy building	EU Green Building	SO	yes	Passive house	PHI Darmstadt	SO	yes
SWEDEN				3-litre-house	Fraunhofer Institut	UO	no
Low-energy "Minienergi"	FEBY	SO	yes	Effizienzhaus 70	KfW	SO	no
Passive house	FEBY	SO	yes	Effizienzhaus 85	KfW	SO	no
Zero-energy house	FEBY	SO	yes	AUSTRIA			
NORWAY				Low-energy (state-aided)	MA 25	Of	no
Low-energy house class 1	Standard Norge	Of	no	Passive house (state-aided)	MA 26	Of	no
Low-energy house class 2	Standard Norge	Of	no	3-litre-house	3-Liter-Haus	SO	yes
Passive house	Standard Norge	Of	no	Klima aktiv Passive house	Klima: aktiv	SO	yes
Passive house	PHI Darmstadt	SO	yes	Klima aktiv house	Klima: aktiv	SO	yes
DENMARK				SWITZERLAND			
Low-energy house class 1	Bygningsreglement	Of	no	Low-energy (Minergie)	MINERGIE	SO	yes
Low-energy house class 2	Bygningsreglement	Of	no	Passive house (Minergie-P)	MINERGIE	SO	yes
Passive house	PHI Darmstadt	SO	yes	Minergie-ECO / P-ECO	MINERGIE	SO	yes
FINLAND				GREAT BRITAIN			
Low-energy house	RIL	SO	no	Passive house	PHI Darmstadt	SO	yes
Passive house	RIL	SO	no	POLAND			
GERMANY				Passive house	PHI Darmstadt	UO	no
RAL Low-energy house	RAL	SO	yes				

Source: Thullner et al. (2011) Low-energy buildings in Europe–Standards and their consequences on indoor climate. Proceedings of Indoor Air, Austin, TX.

3. Energy certification of buildings

Passive house

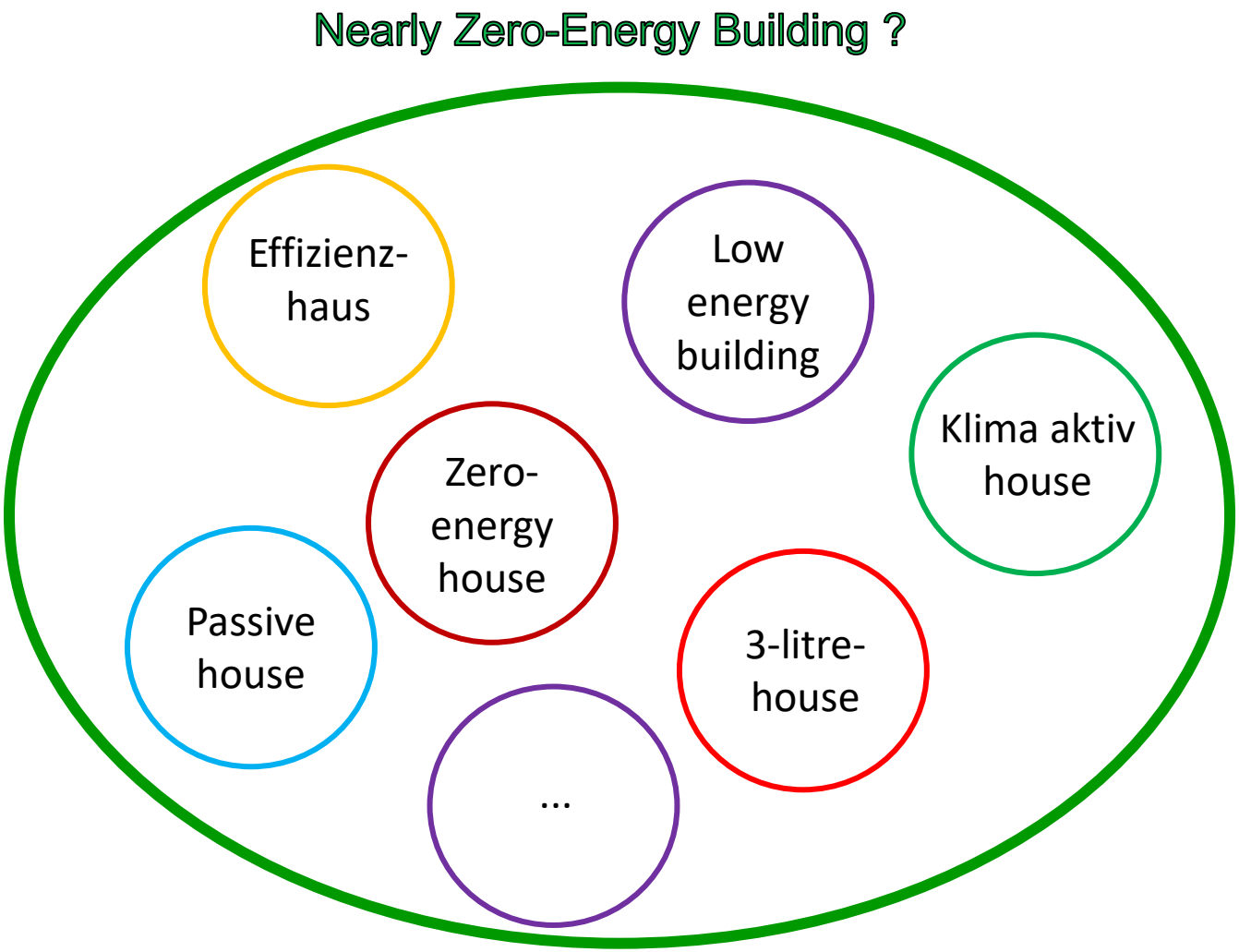


Source: Passivhaus_section_en.jpg: Passivhaus Institutderivative work: Michka B (talk) - Passivhaus_section_en.jpg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=9586761

- Overall U of opaque envelope ≤ 0.15 W/(m^2.K)
- Uwindow ≤ 0.8 W/(m^2.K)
- Solar transmittance τ ≥ 50%
- Efficiency of heat recovery ≥ 75%
- Electric demand for ventilation ≤ 45 W/(m^3.h)
- Heating and cooling demand ≤ 15 kWh/m^2
- Primary energy ≤ 120 kWh/m^2
- ....

3. Energy certification of buildings

Nearly Zero-Energy Buildings



4. Energy audit of buildings

Energy audit in brief

Main objective:

Find the profitability for the project and/or measure/subproject, and rank them correctly.

What is documented:

- energy saving potential
- environmental benefits (CO_2, particles, SO_2, NO_x, CO)
- profitability

Main objects of energy audit:

Big companies = companies from 250 emplyoees **alebo/a** > 50 Mio. € turnover

4. Energy audit of buildings

Outcome

EE Potential - Energy Audit					
Measures	**Investment**	**Net savings**		**Payback**	**NPVQ**
	[€]	**[kWh/year]**	**[€/year]**	**[year]**	r = 7%
1. Energy efficient showers	400	3 500	350	0,9	6,90
2. Automatic control system	20 000	148 250	14 300	1,4	4,02
3. Operation and maintenance manuals/ Energy monitoring system	20 000	45 200	3 530	5,7	0,61
4. Heat recovery, ventilation system	25 000	47 240	4 220	5,5	0,27
5. Balancing of heating system and thermostatic valves	53 000	73 340	7 330	7,1	0,26
6. Insulation of pipes, valves etc.	9 500	17 170	1 720	5,5	0,26
7. Insulation of attic floor	12 500	20 270	2 030	6,2	0,14
8. New windows	260 000	246 090	24 610	10,6	- 0,14
9. Insulation of external walls	185 000	106 310	10 630	17,4	- 0,29
Total all measures	**584 400**	**707 470**	**68 750**	**8,5**	

Source: Dahlsveen, T. – Mišči, J. – Tchervilov, L – Holubová, I. – Grytsenko, N. – Teigen, Ø. Energy auditing and certification of buildings. ENSI: Oslo. 2009.

4. Energy audit of buildings

ŐNORM EN 16247

EN 16247-1: General requirements

EN 16247-2: Buildings

EN 16247-3: Processes

EN 16247-4: Transport

EN-16247-5: Competence of energy auditors

4. Energy audit of buildings

ŐNORM EN 16247-2

4 Quality requirements ... 8
4.1 Energy auditor ... 8
4.1.1 Competency ... 8
4.1.2 Confidentiality ... 8
4.1.3 Objectivity ... 8
4.1.4 Transparency ... 8
4.2 Energy audit process ... 8

5 Elements of the energy audit process ... 9
5.1 Preliminary contact ... 9
5.2 Start-up meeting ... 10
5.3 Collecting data ... 10
5.3.1 General ... 10
5.3.2 Information request ... 10
5.3.3 Review of the available data ... 12
5.3.4 Preliminary data analysis ... 12
5.4 Measurement plan ... 12
5.5 Sampling methods ... 12
5.6 Field work ... 13
5.6.1 Aim of field work ... 13
5.6.2 Conduct ... 13
5.6.3 Site visits ... 13
5.7 Analysis ... 13
5.7.1 General ... 13
5.7.2 Energy breakdown ... 14
5.7.3 Energy performance indicators ... 14
5.7.4 Energy Performance Improvement Actions (EPIA) ... 15
5.8 Report ... 15
5.8.1 General ... 15
5.8.2 Content of report ... 15
5.9 Final meeting ... 15

Annex A (informative) Examples of parties of an energy audit in buildings ... 16

Annex B (informative) Examples of checklists for energy audit field work in buildings ... 17

B.1 General ... 17

B.2 Checklist ... 17

B.3 Building visit checklist ... 18

B.4 The building envelope ... 19

4. Energy audit of buildings

ŐNORM EN 16247-2

B.5 Useful documents 20

Annex C (informative) Examples of the analysis of energy use in buildings 22

C.1 Overview of the energy use in a building 22

C.2 Analysis of the energy use in a building 23

C.3 Energy breakdown examples 23

Annex D (informative) Examples of analysis checklists for energy audits in buildings 26

D.1 General 26

D.2 Checklist 26

Annex E (informative) Examples of energy performance indicators in buildings 30

E.1 General 30

E.2 Global indicators 30

E.3 Detailed indicators 30

Annex F (informative) Examples of EPIA opportunities in buildings 31

Annex G (informative) Examples of analysis and savings calculations in energy audits in buildings 32

G.1 Roof insulation 32

G.2 Ventilation system 35

Annex H (informative) Examples of the reporting of an energy audit in buildings 39

H.1 General 39

H.2 Table of contents 39

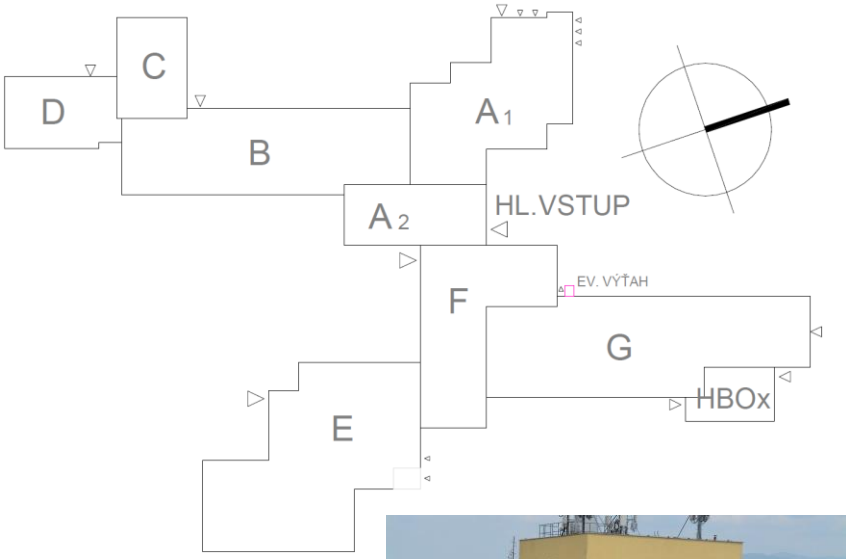
Annex I (informative) Example of energy performance verification method in buildings 41

I.1 General 41

I.2 Energy signature 41

4. Energy audit of buildings

What building size?



4. Energy audit of buildings

Energy efficiency measures

Where is energy conservation potential ?

Always do this after renovation of envelope

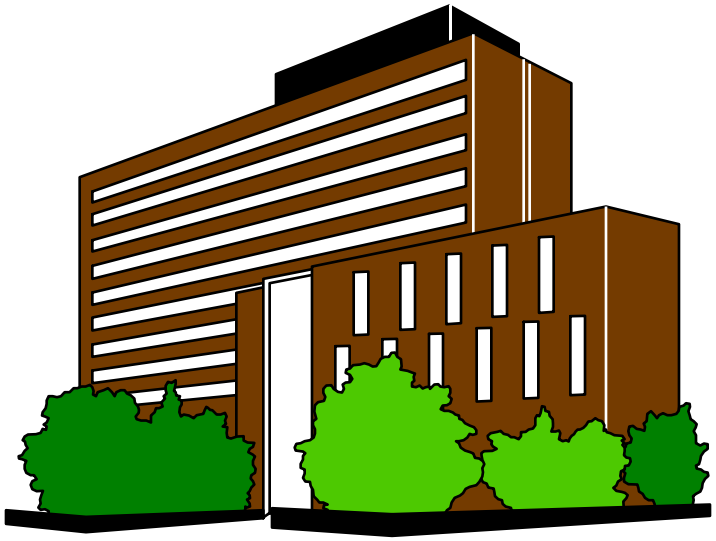
HVAC systems

Most common

Building envelope

Lighting is usually very profitable

Electrical systems

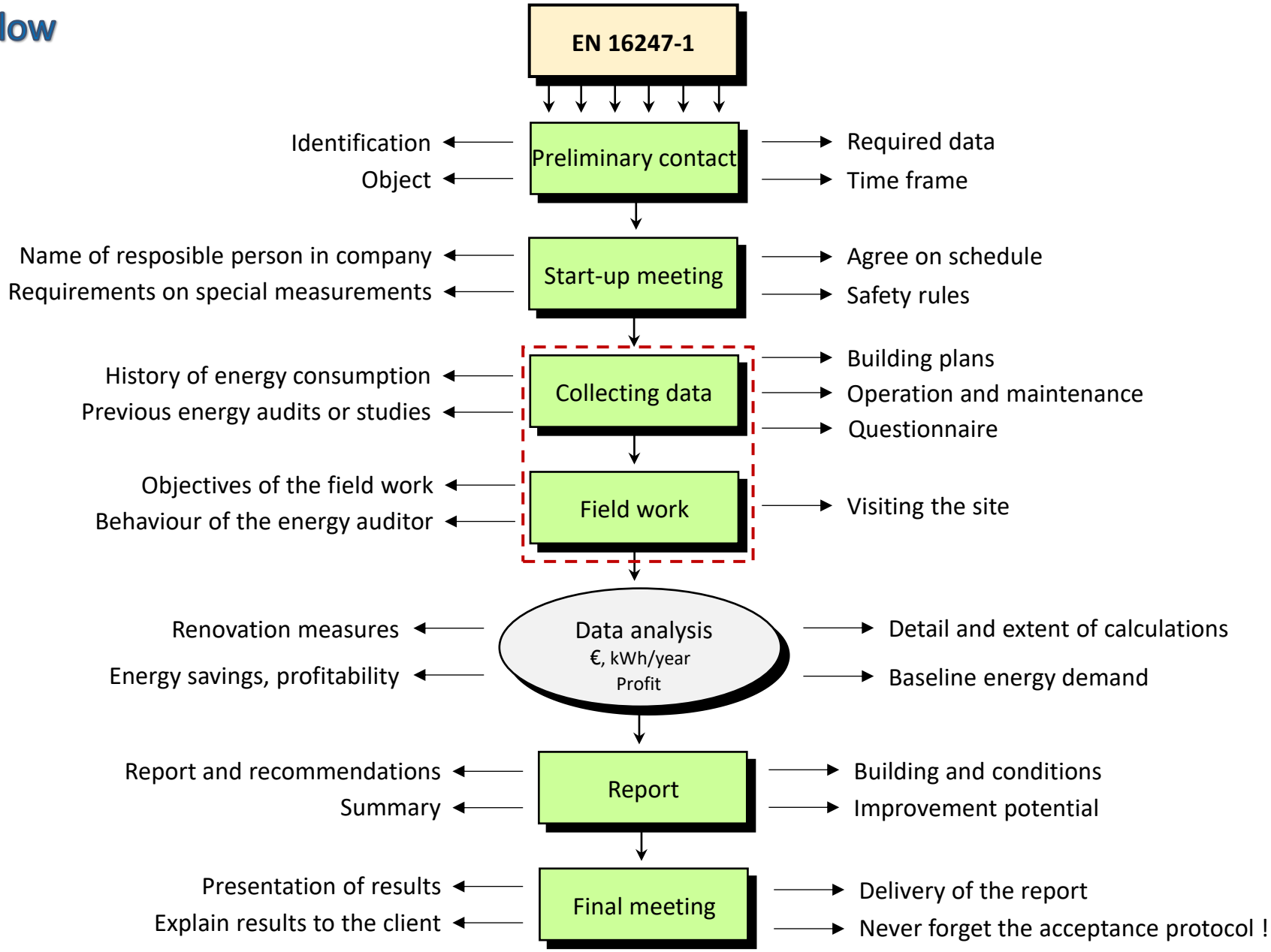


Operation / user pattern

Can be very profitable

5. Process of energy audit

Workflow



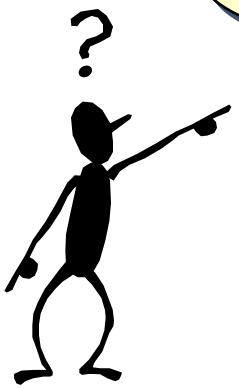
5. Process of energy audit

Preliminary contact – Project identification

- Dialogue with the building owner
- Identify problems, consider the renovation in context
- Profitability is not the only criterion

Large energy bills ?

High illness frequency ?



Renovation necessary ?

Bad indoor environment ?

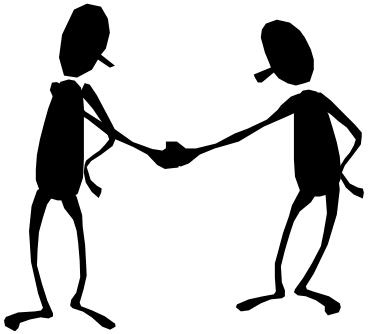
Technical or operational problems ?

5. Process of energy audit

Preliminary contact – Project identification

- Dialogue with the building owner
- Collection of main building and technical information
- Collection of energy consumption statistics from previous years
- Evaluation of the owner's interest in accomplishing a total project implementation
- Evaluation of the owner's business possibilities

Who is the real decision maker ?



Financing possibilities ?

Is the ENCON Potential big enough ?

5. Process of energy audit

Collecting data

- Collect documentation, questionnaire, interview, invoices ...
- Common challenge: lack of documentation
- Possibly prepare checklists

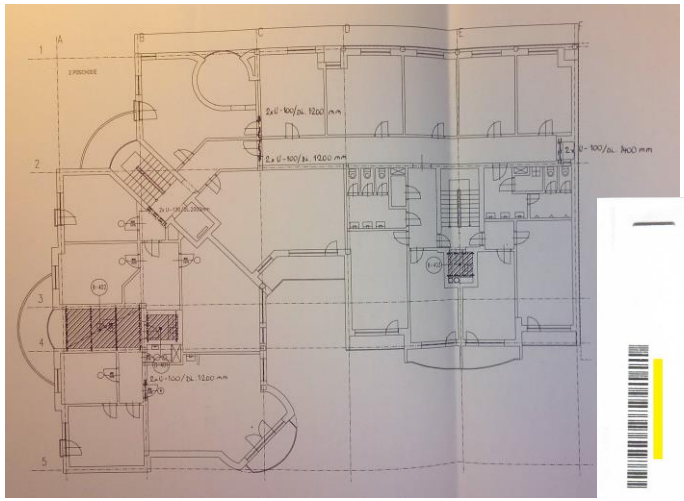
2. Building Envelope

Yes	No					Yes	No		
		Wall	☒ Brick	☐ Concrete	☐ Wood			Floor above unheated area	
			Insulation thickness		.....0..... mm			☒ Ground	☐ Unheated basement
			External wall area		...1.560... m²			Insulation thickness	.....0..... mm
		Windows	☐ Single	☒ Double	☐ Triple	☐	☒	Visible thermal bridges in	.....
		Window frames:	☒ Wood	☐ Metal	☐ Plastic			Visible damages in:	☐ Joints ☐ Windows
			Window area		.....360...m²				☐ Doors
☐	☒	Connected window glasses							
☐	☒	Window glass with energy coating						Floor area (heat losses)	.....396... m²
		Roof	☒ Angled w/attic		☐ Flat			Net room height	.....3,2... m
			☒ Concrete		☐ Wood				
			Insulation thickness		.....0..... mm				
			Roof area (heat losses)		.....396... m²				

Comments

Wall: Expanded clay granulate, 250 mm

Inspection checklist



Floor plan

SPP

Zákaznícke číslo:

Faktúra za opakovanú dodávku zemného plynu č.:

Vaše prípadné otázky zodpovie:

Biznis linka 0850 111 565
v pracovných dňoch od 7:00 do 20:00 hod.

V Bratislave dňa 08.01.2016

Vážený zákazník,

na základe harmonogramu budúcich platieb za opakované dodávky Vám zasielame faktúru za odber zemného plynu za obdobie **01.01.2016 - 31.01.2016**.
Uvedenú čiastku prosíme uhradiť v lehote splatnosti na náš bankový účet SK9002000000001001018151/SUBASKBX s variabilným symbolom

Dodaný tovar	Základ dane (EUR)	sadzba DPH	DPH (EUR)	Celkom (EUR)
Zemný plyn	2 074,17	20%	414,83	2 489,00
Na úhradu				2 489,00

V prípade nejasností súvisiacich s dodávkou zemného plynu, nás môžete kontaktovať na telefónnom čísle **Biznis linky 0850 111 565 v pracovné dni od 7:00 do 20:00 hod.**

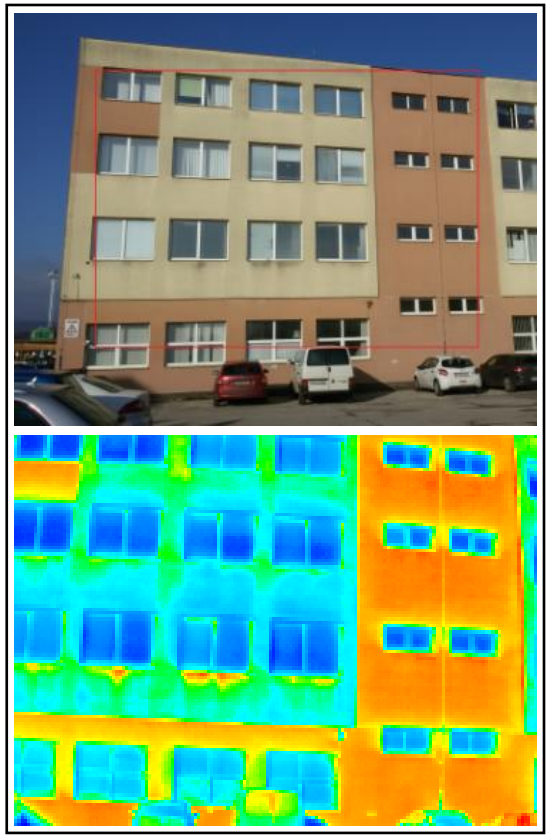
S pozdravom

Gas invoice

5. Process of energy audit

Field work

- Document physical condition and highlight problems
- Verify what they tell you, believe only half of what you see
- Make lots of photos
- Use measurements, for example:
  - distance meter
  - thermal imager
  - smoke analyser



Problem: High thermal losses

Problem: Inefficient boilers

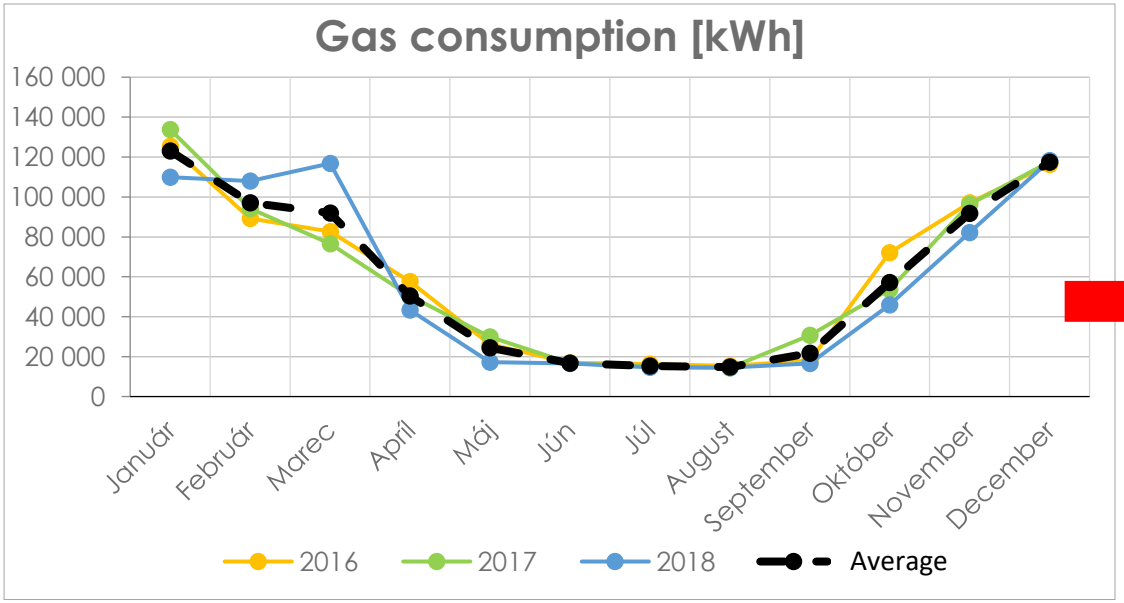
Problem: Mould on the ceiling

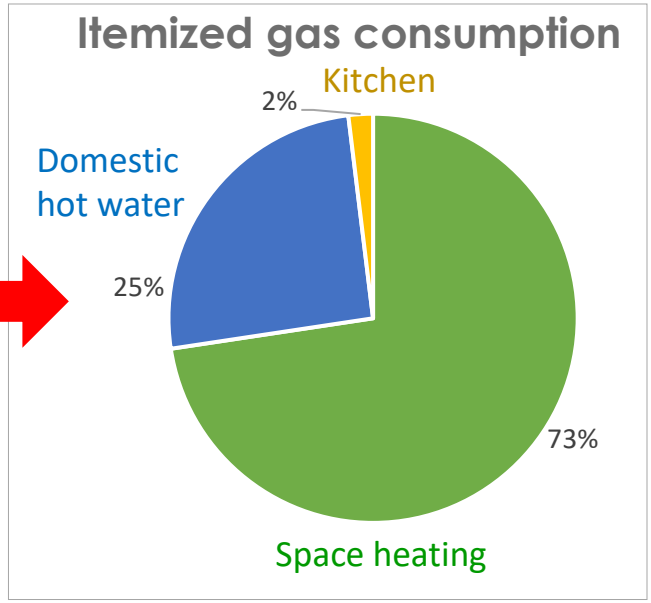
Problem: Additional heater & water leaks

5. Process of energy audit

Data analysis: Energy inputs and outputs

Calendar year :			2014	2015	2016	Average
Electricity	Amount [kWh]		53 730	59 606	58 172	57 169
	Costs [EUR]		7 692	6 685	6 283	6 887
	of which:	Heating [kWh]	-	-	-	-
		DHW [kWh]	-	-	-	-
		Lighting [kWh]	34 709	38 505	37 580	36 931
		Others [kWh]	19 020	21 100	20 591	20 237
Natural gas	Amount [kWh]		143 568	182 580	175 472	167 206
	Costs [EUR]		6 642	6 824	5 225	6 230
	of which:	Heating [kWh]	115 285	146 611	140 904	134 267
		DHW [kWh]	28 282	35 968	34 568	32 939
		Others [kWh]	-	-	-	-





5. Process of energy audit

Data analysis: Energy inputs and outputs

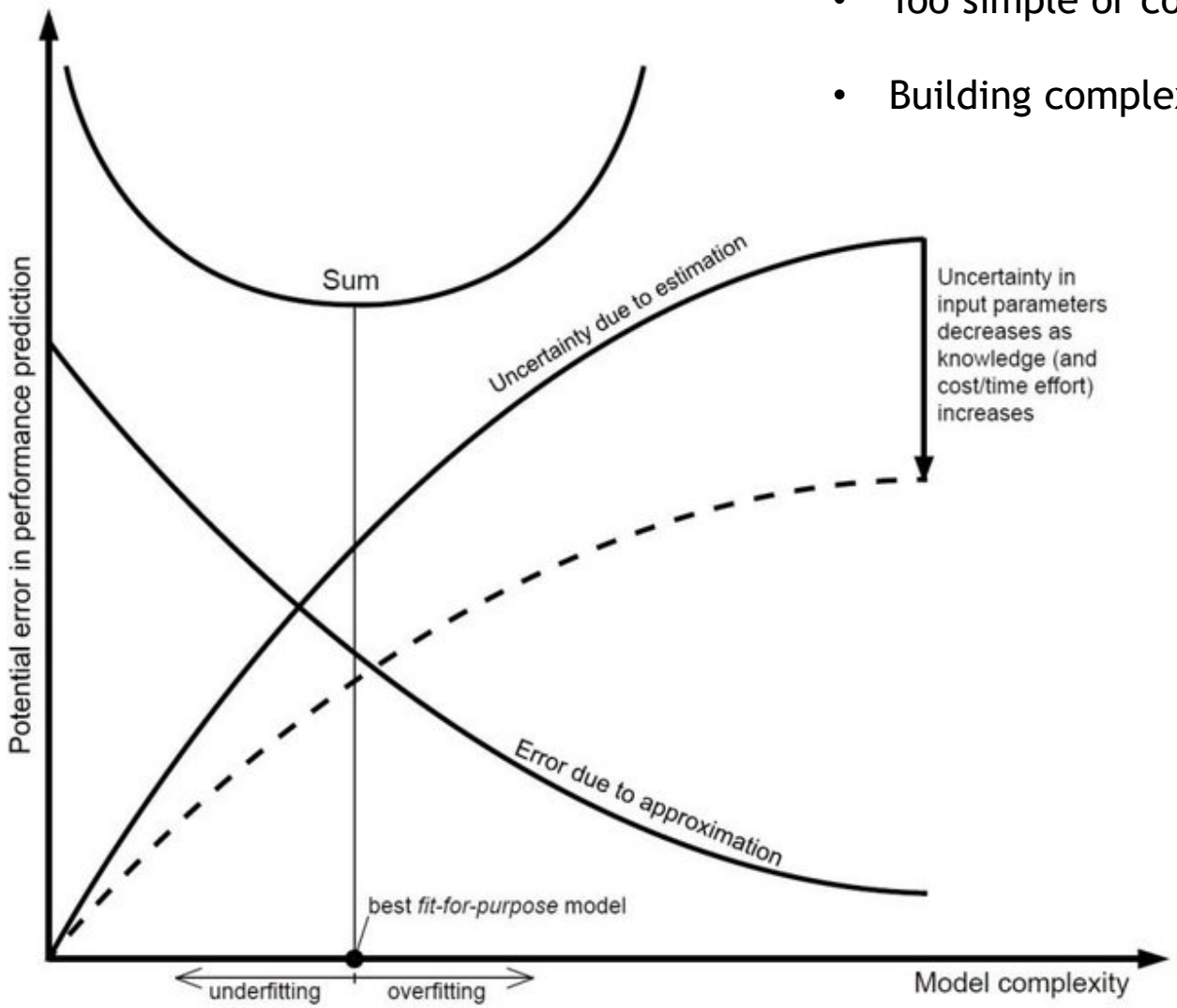
Calendar year :			2014	2015	2016	Average
Electricity	Amount [kWh]		53 730	59 606	58 172	57 169
	Costs [EUR]		7 692	6 685	6 283	6 887
	of which:	Heating [kWh]	-	-	-	-
		DHW [kWh]	-	-	-	-
		Lighting [kWh]	34 709	38 505	37 580	36 931
		Others [kWh]	19 020	21 100	20 591	20 237
Natural gas	Amount [kWh]		143 568	182 580	175 472	167 206
	Costs [EUR]		6 642	6 824	5 225	6 230
	of which:	Heating [kWh]	115 285	146 611	140 904	134 267
		DHW [kWh]	28 282	35 968	34 568	32 939
		Others [kWh]	-	-	-	-

Common challenge: lack of data on energy consumption

5. Process of energy audit

Data analysis: Energy calculations

- Too simple or complex model leads to errors
- Building complex models takes time



Source: Gaetani et al. (2016) Occupant behavior in building energy simulation: Towards a fit-for-purpose modeling strategy. In Energy and Buildings, 121, 188-204

5. Process of energy audit

Data analysis: Energy calculations

Level A:

- Losses or efficiencies based on the typology of the whole building / technical system

Frequently used for energy audit

Level B:

- Values taken from tables, based on the whole building / technical system

Level C:

- Calculations based on physical principles or corelations

Level D:

- Calculations based on dynamic computer simulations

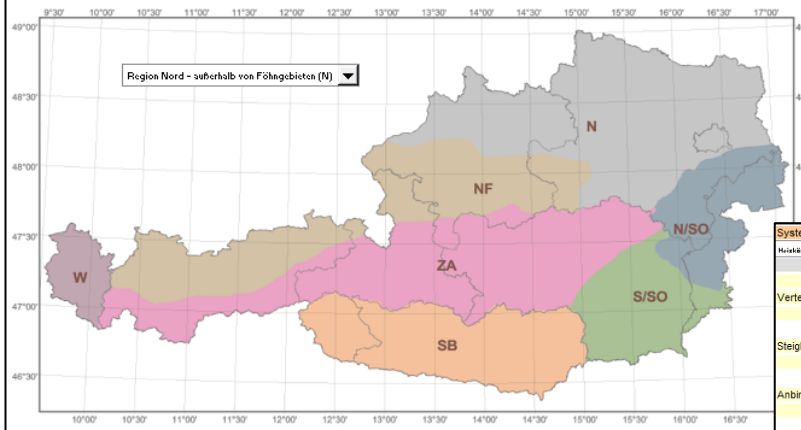
5. Process of energy audit

Data analysis: Energy calculation tools

Standortklima

Standort

Seehöhe 172.0 m ☐ Validierung — θ_{ne} -13.00 °C



	1	2	3	4	5	6
Temperatur	-1.65 °C	0.33 °C	4.29 °C	9.17 °C	13.85 °C	
S	34.64 kWh/m²	55.65 kWh/m²	76.26 kWh/m²	80.90 kWh/m²	90.21 kWh/m²	80.
SW + SO	27.87 kWh/m²	45.66 kWh/m²	67.34 kWh/m²	79.75 kWh/m²	94.96 kWh/m²	90
W + O	17.19 kWh/m²	29.97 kWh/m²	51.11 kWh/m²	69.34 kWh/m²	91.80 kWh/m²	91.
NW + NO	11.98 kWh/m²	20.93 kWh/m²	34.08 kWh/m²	52.01 kWh/m²	72.80 kWh/m²	77.
N	11.46 kWh/m²	19.50 kWh/m²	27.59 kWh/m²	40.45 kWh/m²	56.98 kWh/m²	61.
S 45	38.02 kWh/m²	64.69 kWh/m²	93.79 kWh/m²	121.35 kWh/m²	151.94 kWh/m²	144.
SW + SO 45	33.08 kWh/m²	57.08 kWh/m²	90.06 kWh/m²	115.57 kWh/m²	147.19 kWh/m²	143.
W + O 45	23.70 kWh/m²	42.33 kWh/m²	72.21 kWh/m²	101.71 kWh/m²	136.11 kWh/m²	138.
NW + NO 45	17.19 kWh/m²	29.97 kWh/m²	51.11 kWh/m²	79.75 kWh/m²	115.54 kWh/m²	122.
N 45	16.15 kWh/m²	26.64 kWh/m²	38.13 kWh/m²	64.72 kWh/m²	104.46 kWh/m²	115.
H	26.04 kWh/m²	47.57 kWh/m²	81.13 kWh/m²	115.57 kWh/m²	158.27 kWh/m²	160.
	7	8	9	10	11	1

Systemtemperaturen — $\theta_{VL,Ne}$ 55 °C — $\theta_{RL,Ne}$ 45.0 °C — n_{HK} 1.3 — 61.90 W — 100.00 W

Heizkörper (55 °C / 45 °C)

Raumheizung - Wärmeverteilung

		Lage	Dämmung	Dämmung der Armaturen		
Verteilleitungen	$\ell_{Verteil.}$ = 14.87 m	nicht konditioniert	3/3 gedämmt	Armaturen gedämmt		
	$d_{Verteil.}$ = 20.00 mm		$q_{Verteil.}$ = 0.24 W/mK		$f_{arm.1}$ = 1.50	
Steigleitungen	$\ell_{Steig.k}$ = 15.36 m	konditioniert	3/3 gedämmt	Armaturen gedämmt		
	$d_{Steig.}$ = 20.00 mm		$q_{Steig.}$ = 0.24 W/mK		$f_{arm.2}$ = 1.25	
Anbindeleitungen	$\ell_{Anbindel.k}$ = 107.52 m		Dämmung	Dämmung der Armaturen		
			1/3 gedämmt	Armaturen gedämmt		
	$d_{Anbindel.}$ = 20.00 mm		$q_{Anbindel.}$ = 0.45 W/mK		$f_{arm.2}$ = 1.04	

Raumheizung - Wärmebereitstellung

PH,KN = 11 kW — BGF_{RH} = 192.0 m² — RH-WB zentral

Raumheizungwärmebereitstellungssystem — $q_{b,WT}$ = 0.00 W/kW

Standardkessel, gasbefeuert (1994-....) — ET 1

Aufstellungsort	Betriebweise	Betriebsweise	
nicht konditioniert	modulierend	gleitende Betriebsweise	o.k.

Volllast	A = 84	B = 2	k_0 =	0.000
	$\eta_{100\%}$ = 86.1%	$\eta_{bo,100\%}$ = 85.08%	k_1 =	0.0100
Teillast	C = 80	D = 3	f_{ab} =	0.250
	$\eta_{30\%}$ = 83.1%	$\eta_{bo,30\%}$ = 82.1%	f_{sh} =	0.000
Bereitschaft	E = 2.5	F = 0.8	f_{sw} =	0.500
	$q_{bo,Pb}$ = 1.67%	θ_{UPb} = 20.00 °C	t_{SD} =	24.143
	$\Delta\theta_{SD}$ = 7.00 K		θ_{Pb} =	70.00 °C

Raumheizung-Wärmespeicherung

Art des Wärmespeichers — $V_{H,WS}$ = 275 ℓ — $q_{b,WS}$ = 2.86 kWh/d

Luftungsgleichspeicher (Bimsschüttung) (1994-....) — $\Sigma q_{bt,WS,Basis}$ 0.66 W/K

Anschlussteile gedämmt — $\theta_{H,WS}$ 38.00 °C — $\Sigma q_{bt,WS,kombiniert}$ 0.00 W/K

ohne E-Patrone — 10 — $\Sigma q_{bt,WS,E-Patrone}$ 0.00 W/K

nicht konditioniert — $\Delta\theta_{H,WS,Pb}$ 45.00 K

Raumheizung-Hilfsenergie

Hilfsenergie

	5	heizöl extraleicht	$P_{H,Vert}$ = 0.0
RH-Speicher	ja		$P_{H,WV,p}$ = 61.9 W
modulierend	ja		$P_{H,WS,o}$ = 55.7 W
ET	1		
Gebläse	1	gebläse	$P_{H,K,Op}$ = 0.0 W ☑ Ölpumpe nach 2004
			$P_{H,K,Geb}$ = 0.0 W ☐ Gebläse nach 2004
			$P_{H,BE}$ = 0.0 W

☐ Heizöl extraleicht / Heizöl leicht

☐ mit / ohne Gebläseunterstützung

☐ Förderschnecke / Fördergebläse

BF = 153.6 m² η_{Ib} = 0.8260

WW+RH-Wärmebereitstellung

zentral

dezentral

zentral

Wenn dezentral, dann Eingabe der Einheitengröße erforderlich!

Eingabe (obligatorisch)	Wohnungszahl	
Vorschlagswerte	BGF_{RH} =	192.0 m²
Eingabe (optional)	$BGF_{RH,n}$ =	
	BGF_{RH} =	192.0 m²
	BF_{RH} =	153.6 m²

Hier müssen Sie die Leistung des RH-Kessels eingeben!

L =	192 W/K	$\Delta\theta_{i,ol}$ =	33.00 K
Vorschlagswerte		PH,KN =	7 kW
Eingabe (optional)		PH,KN =	
		PH,KN =	11 kW

Achten Sie jedenfalls auf die richtige Eingabe im kombinierten Betrieb!

Ergebnis-Vorschau

$Q_{W,V}$ =	2,453 kWh/a	2,453 kWh/a	12.78 kWh/m²a
	3,134 kWh/a	3,134 kWh/a	16.32 kWh/m²a
Q_{HW} =	5,587 kWh/a	5,587 kWh/a	29.1 kWh/m²a
	31 kWh/a	31 kWh/a	0.2 kWh/m²a

Ergebnis-Vorschau

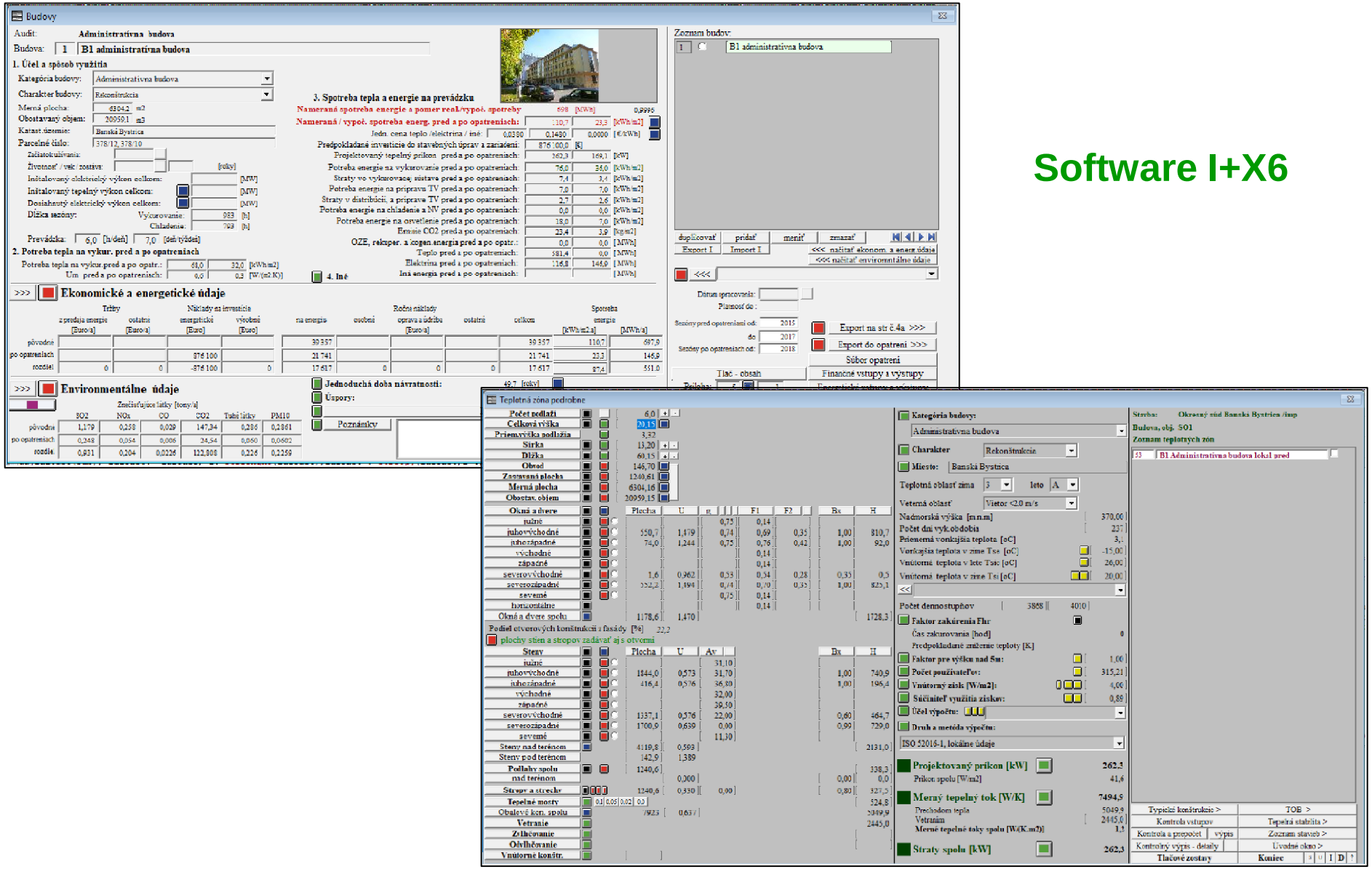
Q_{H} =	10,788 kWh/a	10,788 kWh/a	56.19 kWh/m²a
	3,857 kWh/a	3,857 kWh/a	20.09 kWh/m²a
Q_{H} =	14,645 kWh/a	14,645 kWh/a	76.3 kWh/m²a
	173 kWh/a	173 kWh/a	0.9 kWh/m²a

Ergebnis-Vorschau

Q_{h+hw} =	13,241 kWh/a		69.0 kWh/m²a
	6,991 kWh/a		36.41 kWh/m²a
Q_{HEB} =	20,436 kWh/a		106.44 kWh/m²a
			65%
		0.00 kWh/m²a	0.16 kWh/m²a
		0.00 kWh/m²a	0.90 kWh/m²a
			1.06 kWh/m²a

5. Process of energy audit

Data analysis: Energy calculation tools



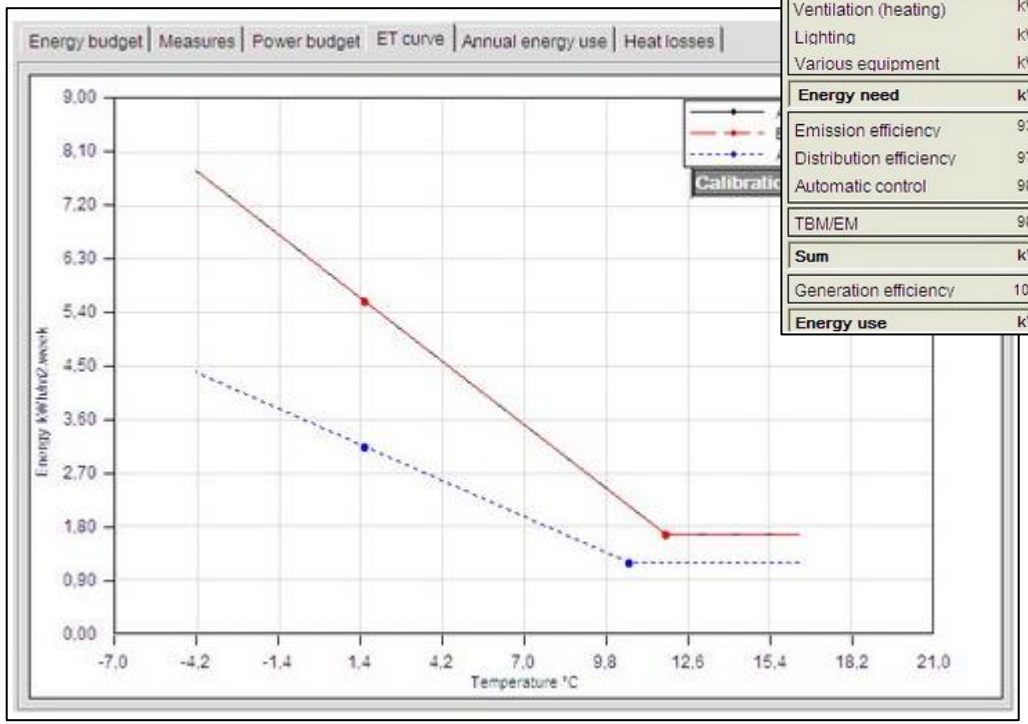
Software I+X6

5. Process of energy audit

Data analysis: Energy calculation tools

ENSI® Energy Saving International AS

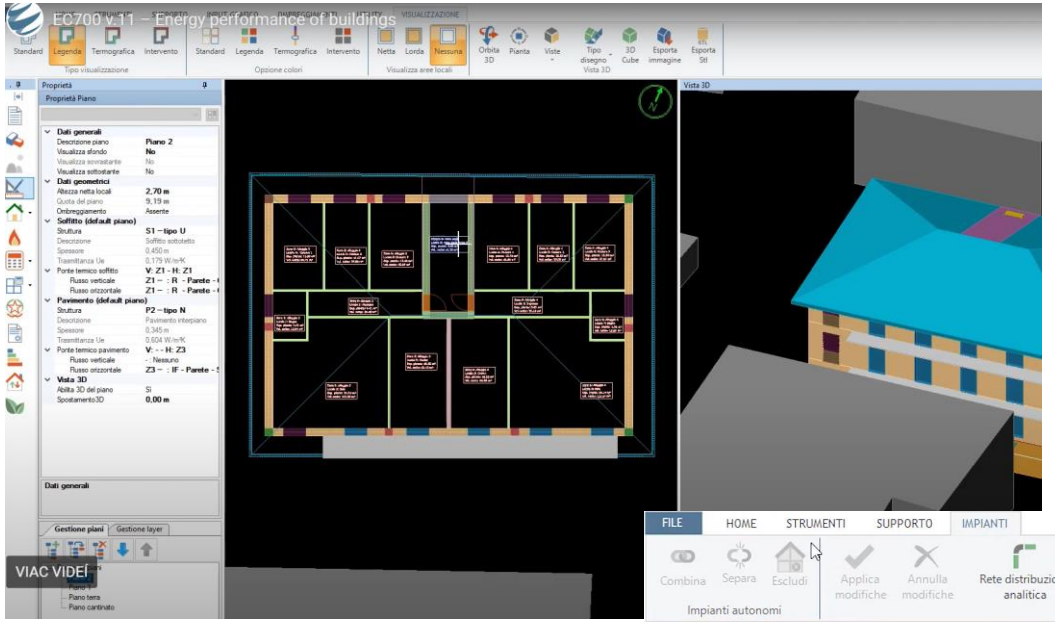
Parameter	Standard		Actual	Baseline	Sensitivity	kWh/m²a	Measure	Savings
1. Heating	**56,0**	kWh/m²a						
U - wall	0,30	W/m²K	0,45	0,45	+ 0,1 W/m²K	= 5.37	0,30	-7,53
U - window	2,40	W/m²K	3,00	3,00	+ 0,1 W/m²K	= 2.96	1,30	-45,67
U - roof	0,20	W/m²K	0,20	0,20	+ 0,1 W/m²K	= 1.35	0,20	
U - floor	0,30	W/m²K	0,30	0,30	+ 0,1 W/m²K	= 1.35	0,30	
Compactness ratio	0,33	-	0,33	0,33			0,33	
Window factor	27,1	%	27,1	27,1			27,1	
Total solar gain	0,55	-	0,55	0,55			0,55	
Infiltration	0,25	1/h	0,40	0,40	+ 0,1 1/h	= 10.13	0,25	-14,04
Indoor temperature	21,0	°C	21,0	21,0	+ 1 °C	= 8.18	21,0	
Setback temperature	18,0	°C	18,0	18,0	+ 1 °C	= 5.65	18,0	
Contribution from								
Ventilation (heating)		kWh/m²a	0,00	0,00			0,00	
Lighting		kWh/m²a	18,16	18,16			16,04	
Various equipment		kWh/m²a	10,92	10,92			9,65	
Energy need		kWh/m²a	81,8	81,8			23,7	
Emission efficiency	93,0	%	93,0	93,0			93,0	
Distribution efficiency	97,0	%	97,0	97,0			97,0	
Automatic control	98,0	%	98,0	98,0			98,0	
TBM/EM	98,0	%	95,0	95,0			98,0	-2,81
Sum		kWh/m²a	97,4	97,4			27,4	
Generation efficiency	100,0	%	100,0	100,0			100,0	
Energy use		kWh/m²a	97,4	97,4			27,4	



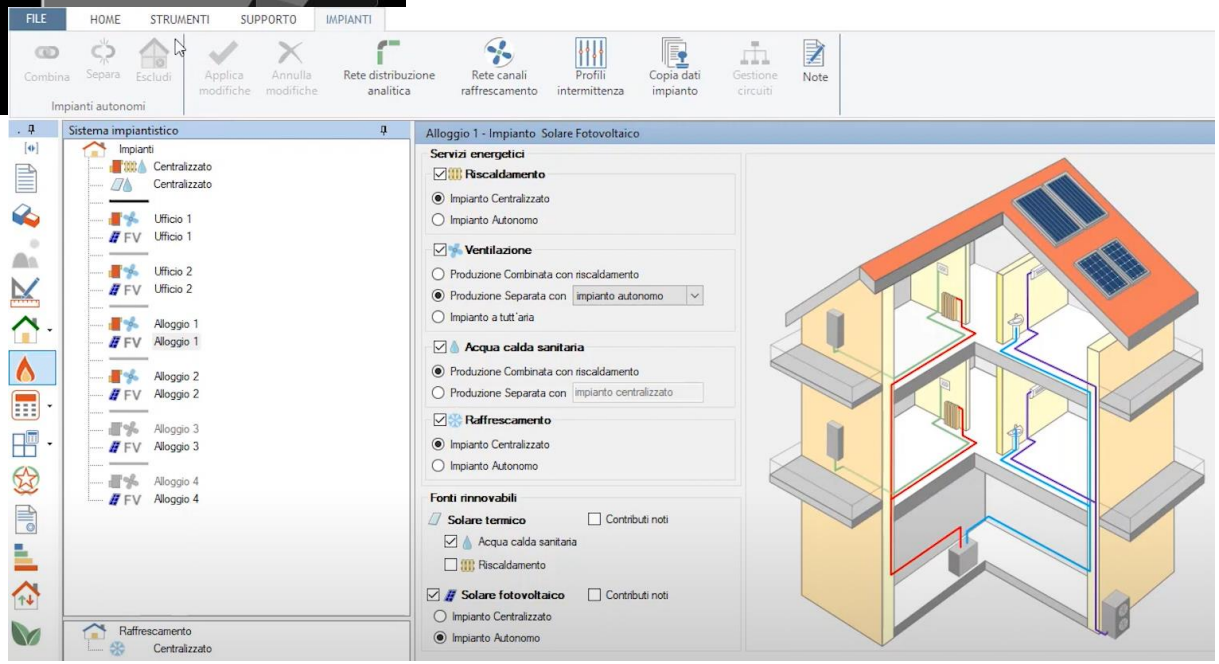
Source: http://kunde.123onweb.no/ensi/index.php?ledd2ID=140&sideID=277

5. Process of energy audit

Data analysis: Energy calculation tools



Edilclima EC

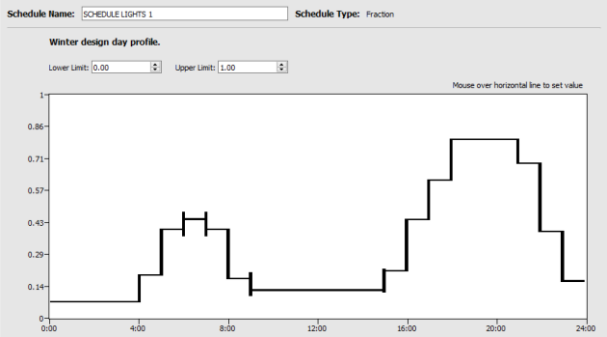


5. Process of energy audit

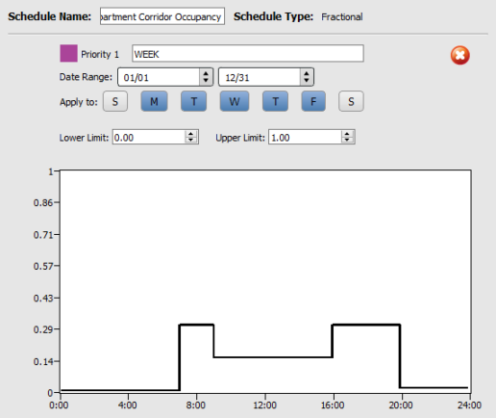
Data analysis: Energy calculation tools

Are computer simulations feasible?

Lighting schedule

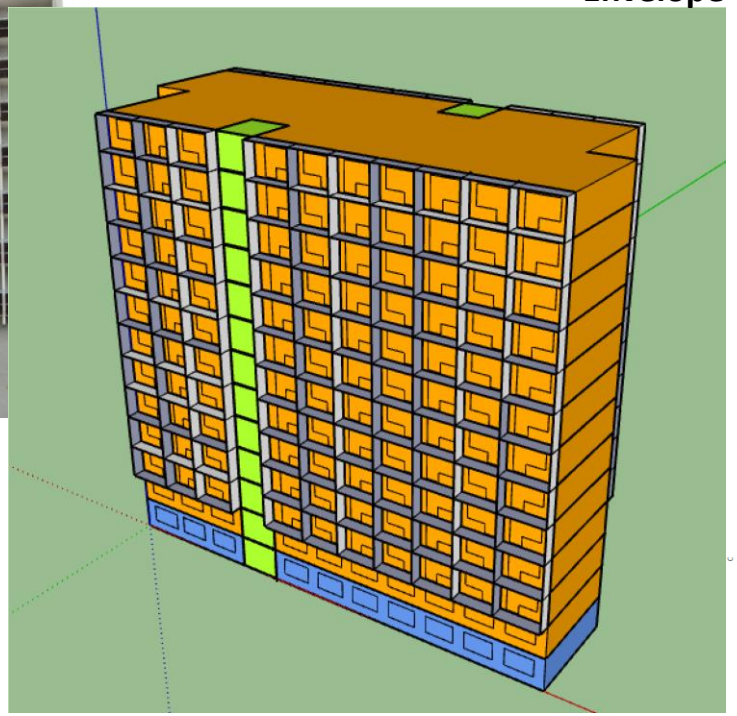


Occupancy schedule

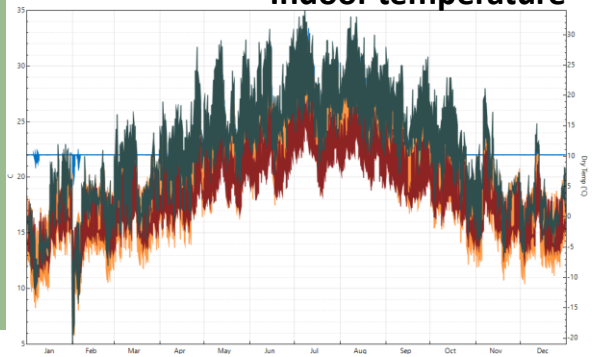


Photo

Envelope



Indoor temperature



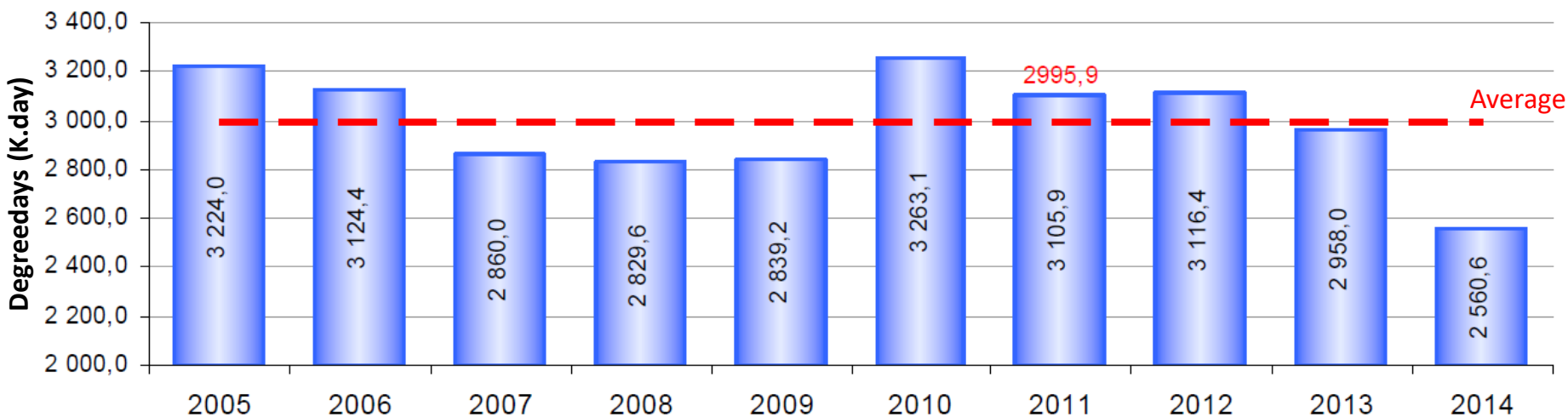
5. Process of energy audit

Climatic data

- What are real indoor temperatures, solar gains, internal gains, ventilation rates ?

Calendar year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	...
Number of heating days	208	214	220	216	182	219	203	212	204	217	...
Average external temp. (°C)	3.3	4.2	5.8	5.7	3.2	3.9	3.5	4.1	4.3	7.0	...
Degreedays (K.day)	3224	3124	2860	2830	2839	3263	3106	3116	2958	2561	...

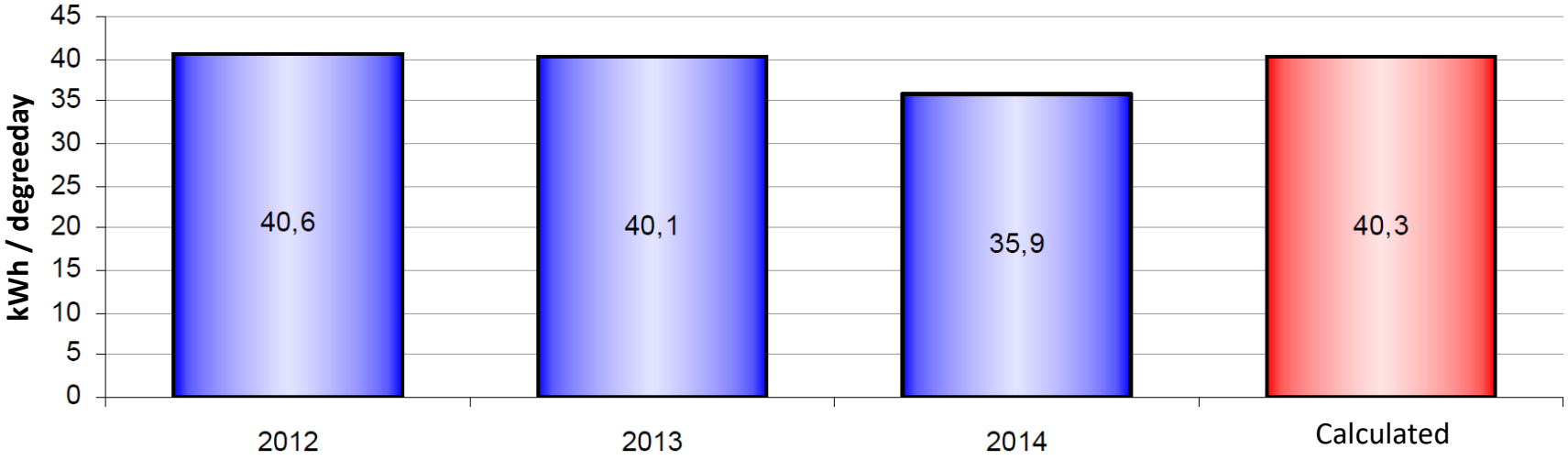
* Degreedays refer to indoor temperature = 18.8°C



5. Process of energy audit

Calculation vs. Measurement

- Use measured climatic data in energy calculations
- Compare calculation (baseline) with measurement



5. Process of energy audit

Energy efficiency measures

EE Measure in the heating system	Influenced software parameters
Hydraulic balancing of the heating system	Indoor temperature (*)
Installation of thermostatic valves	Indoor temperature (*)
Replace broken thermostatic valves	Indoor temperature (*)
New type of heaters	Emission efficiency
Reduction of heating media temperatures	Emission efficiency
Change location of existing heaters	Emission efficiency
Installation of closed expansion vessel	Distribution efficiency
Repairing of leakage	Distribution efficiency
Insulation of pipes, valves, etc.	Distribution efficiency
Repairing of automatic control system	Automatic control
New automatic control system	Automatic control
Temperature set back (nights and weekends)	Setback temperature
Adjustment of burner/boiler	Generation efficiency
Sweeping of boiler	Generation efficiency
New burner/boiler	Generation efficiency
Sequence control of burner	Generation efficiency
Stop circulation in non-operating boilers	Generation efficiency
Installation of flue gas damper	Generation efficiency
Operation and maintenance manual	TBM/EM
Energy monitoring	TBM/EM

(*) According to EU standards, it is possible to include this parameter into the emission efficiency.

Source: Dahlsveen, T. – Mišči, J. – Tchervilov, L – Holubová, I. – Grytsenko, N. – Teigen, Ø. Energy auditing and certification of buildings. ENSI: Oslo. 2009.

5. Process of energy audit

Data analysis: Profitability indicators

Methods to calculate the profitability for investments:

- Payback
- Net Present Value
- Net Present Value Quotient
- Discounted Payback (Pay-Off)
- Internal Rate of Return

The discounted value and Net Present Value concept
is the basis for several methods

5. Process of energy audit

Data analysis: Inputs for profitability calculations

•	Investment	I_0	€
•	Annual net saving	B	€ /year
•	Technical / Economic lifetime	n	year
•	Nominal interest rate	$n_r \cdot 100$	%
•	Real interest rate	$r \cdot 100$	%
•	Inflation rate	$b \cdot 100$	%

$$r = \frac{n_r - b}{1 + b}$$

To define accurate economic input parameters is very important to calculate the correct profitability

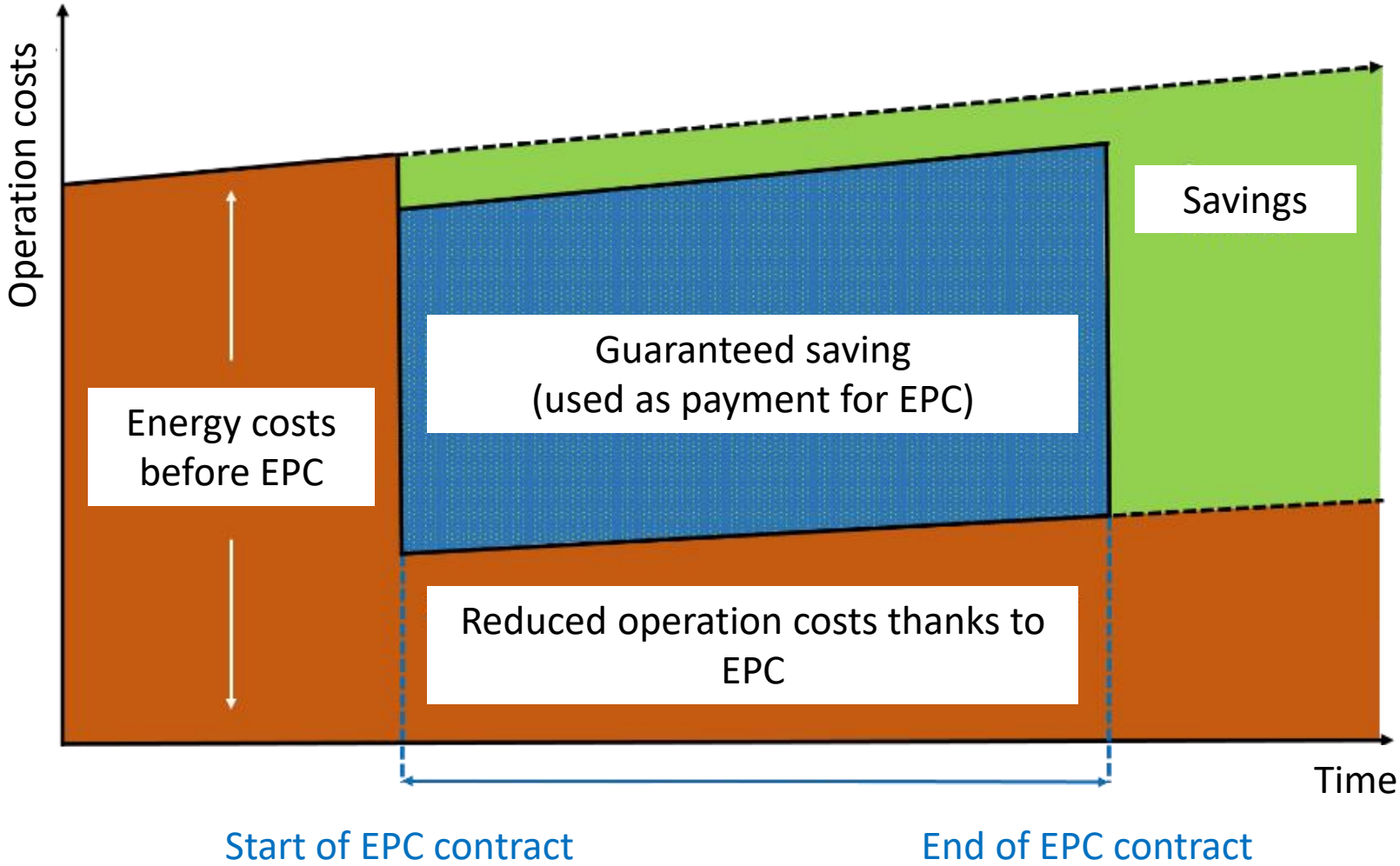
Data analysis: Funding

Where can you get the money?

- Own capital
- Loan (e.g. state, bank)
- Grants and subsidies (e.g. EU, state, municipality)
- Energy Performance Contracting (EPC)
  - EPC involves an Energy Service Company (ESCO)
  - ESCO provides finances and guarantees energy savings
  - The profit of the ESCO depends on the energy savings

5. Process of energy audit

Data analysis: Energy Performance Contracting (EPC)

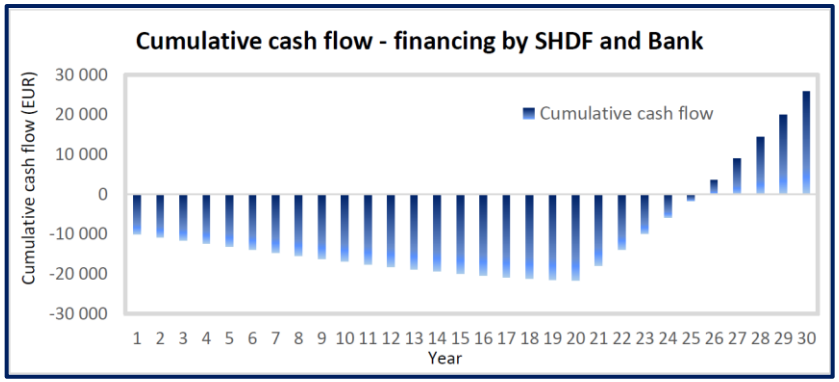


Source: http://www.apes-sk.eu/co-je-epc/definicia-epc/

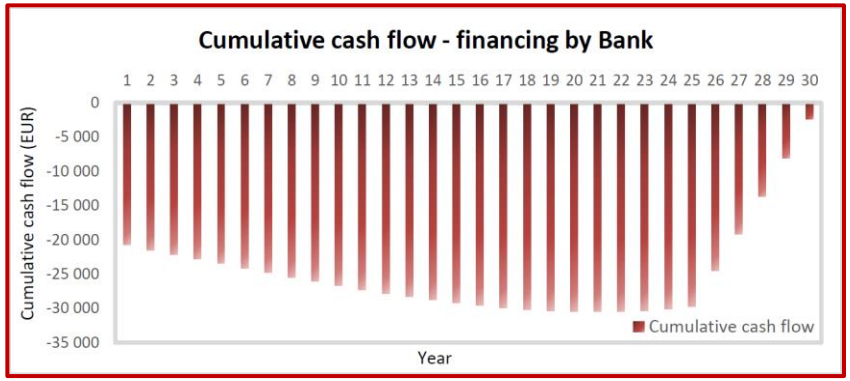
5. Process of energy audit

Data analysis: Effect of funding on cashflow

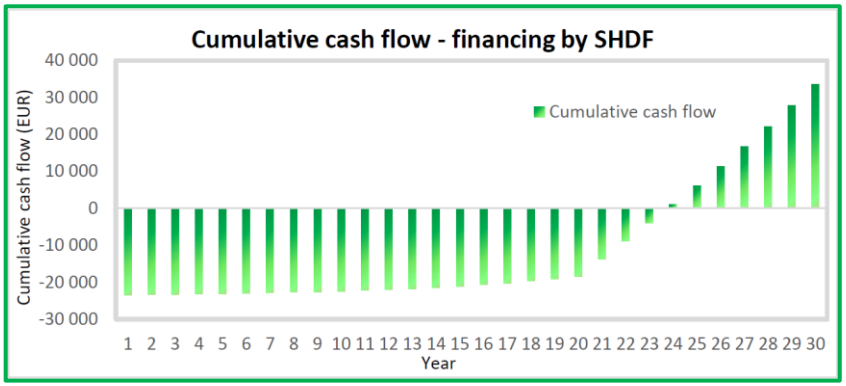
75% SHDF* + 15% Bank + 10% Own capital



80% Bank loan + 20% Own capital



75% SHDF* + 25% Own capital



*SHDF = State House Development Fund

Source: Bartošová, J. Technical and economic assessment of complex renovation of apartment buildings in life cycle. Doctoral thesis. 2018.

5. Process of energy audit

Energy audit report

- Indentification of building owner and energy auditor
- Object of energy audit – purpose of audit, building info, documents
- Building description – characteristics, systems, problems
- Data on energy inputs and outputs
- Evaluation of building structures – climatic data, insulation level ...
- Proposal of energy efficiency measures and their evaluation
    - building structures
    - space heating
    - domestic hot water
    - indoor lighting
    - ventilation and air conditioning
    - automated control ...
- Recommendations on renovation measures
- Energy evaluation after renovation
- Conclusion / summary

5. Process of energy audit

Energy audit report – example of summary list

Recommended measures

Object of the EA	**Building.....**
Description of the building	.....

Energy efficient measures

Recommended measures	**Energy saving [kWh]**	**Investments [EUR]**
Insulation of walls		
Insulation of roof		
Insulation of floor		
Reconstruction of the energy source		
Measurement and control		
Solar panels for domestic hot water		
Change of illuminators		
Total:		

Energy

Energy evaluation of the project

	Current condition	**After measures**	**Reduction**	**Reduction**
Specific heat loss by transmission [W.K^{-1}]				%
Specific heat loss by ventilation [W.K^{-1}]				%
Total heat gains [kWh]				%
Energy need for heating [kWh]				%
Primary energy demand for heating [kWh]				%
Energy demand for lighting [kWh]				%
Energy demand for heating and lighting [kWh]				%
Energy demand for domestic hot water [kWh]				%

Environment

Environmental evaluation of the project

	Current condition	**After measures**	**Reduction**	**Reduction**
Annual emissions of CO_2 [ton/year]				%
Annual emissions of TZL [ton/year]				%
Annual emissions of SO_2 [ton/year]				%
Annual emissions of ;NO_x [ton/year]				%
Annual emissions of CO [ton/year]				%
Annual emissions of PM_{10} [ton/year]				%

Profit

Economic evaluation of the project

Investments [€]	
Annual savings [€]	
Net present value [€]	
Evaluation period [year]	
Simple payback [year]	
Discounted payback [year]	
Internal rate of return [%]	

6. Case study

Building description

- **Office building**
- About 20 years in use

Total built area [m²]	A	652
Heated area [m²]	A_b	3 070
Built volume – total [m³]	V	8 989
Built volume – heated [m³]	V_b	8 989
Area of heated envelope [m²]	$\sum A_i$	1 727
Form factor [m⁻¹]	$\sum A_i/V_b$	0,38
Number of storeys	n	5

6. Case study

Building description

- Walls non-insulated, U = 1.05 W/(m^2.K)
- Plastic windows with double glazing
- Leakages and moulds on structures
- Gas boilers for space heating 2 x 160 kW
- Locally undersized radiators
- Gas boiler tank for domestic hot water
- Fluorescent lamps in whole building

Fluorescent lamps

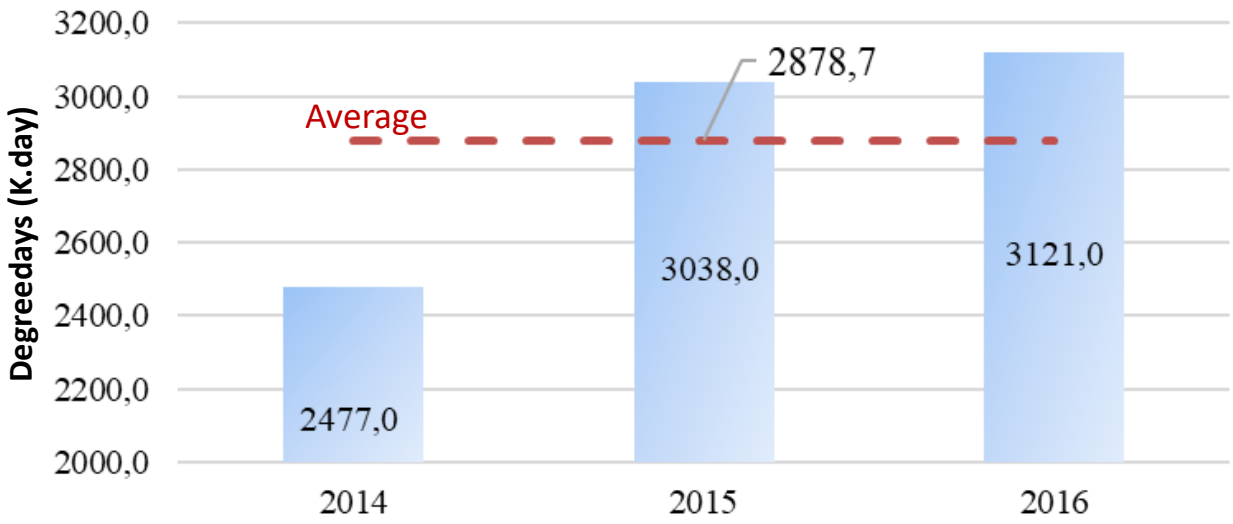
Boilers for space heating

Radiator with thermostatic head

Boiler tank for hot water

6. Case study

Degreedays

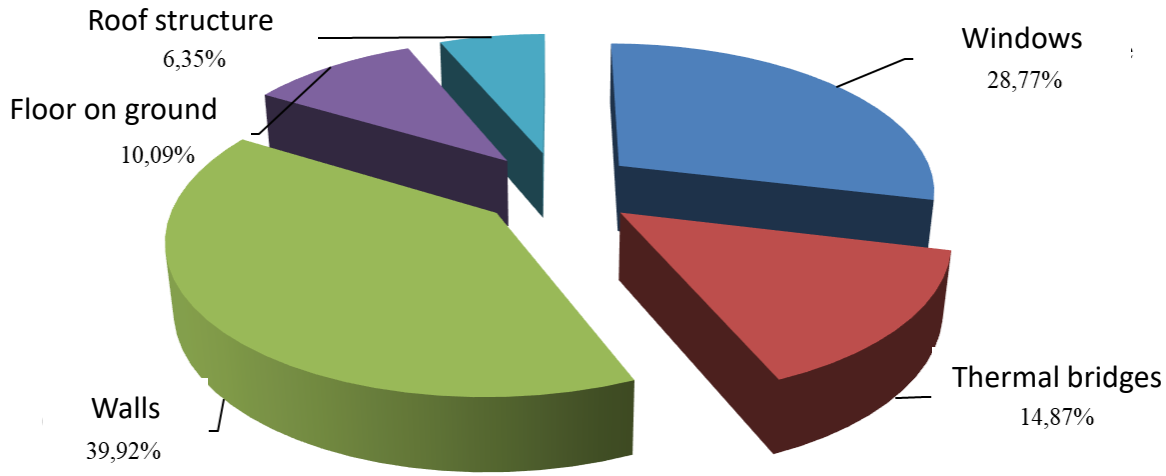


Calendar year	2014	2015	2016
Number of heating days	186	197	215
Average external temperature [°C]	6.7	5.7	5.5
Degreedays (K.day)	2 477	3 038	3 121

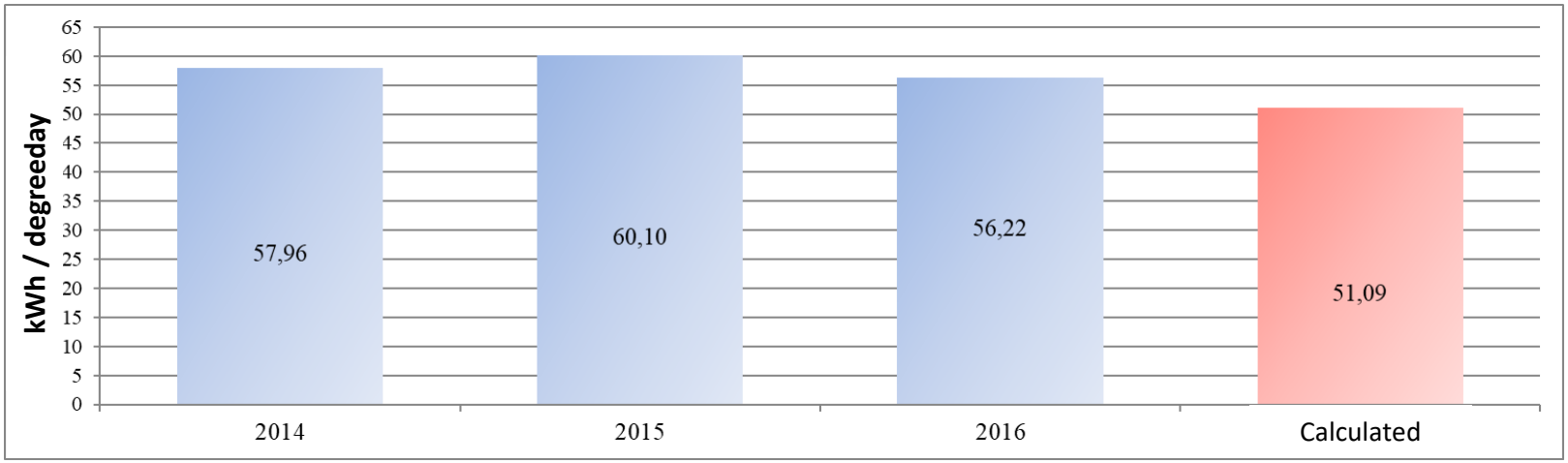
6. Case study

Thermal losses and energy for space heating

Thermal losses through the envelope



Calculated vs. Measured energy for space heating



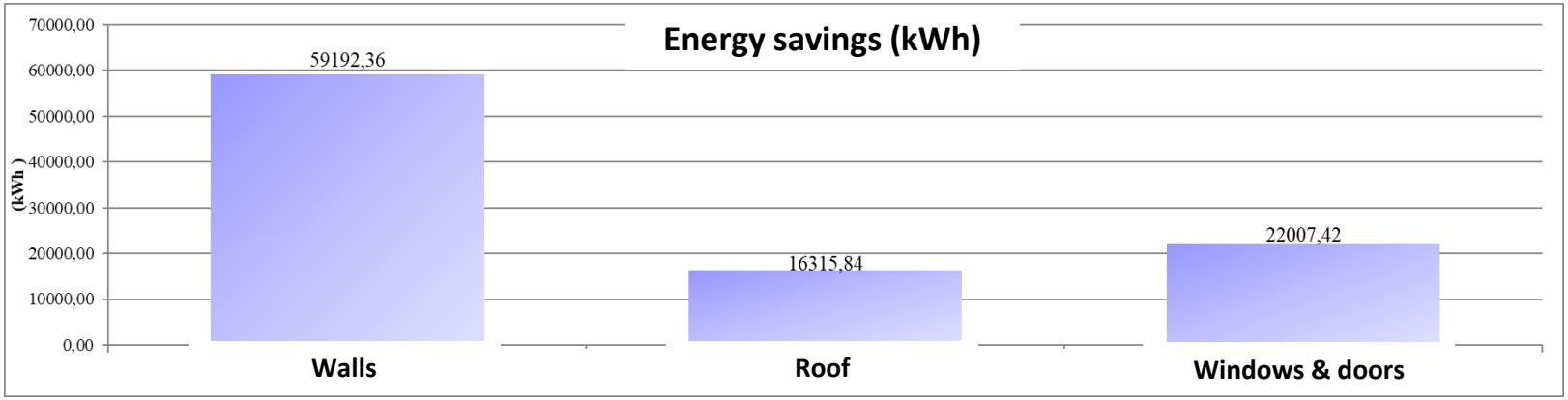
6. Case study

Energy savings for building structures

Energy need for space heating = 35.4 kWh/m^2
Current requirement = 26.8 kWh/m^2

Building structures:

- Insulation of external walls
- Insulation of roof
- Replacement of windows and doors

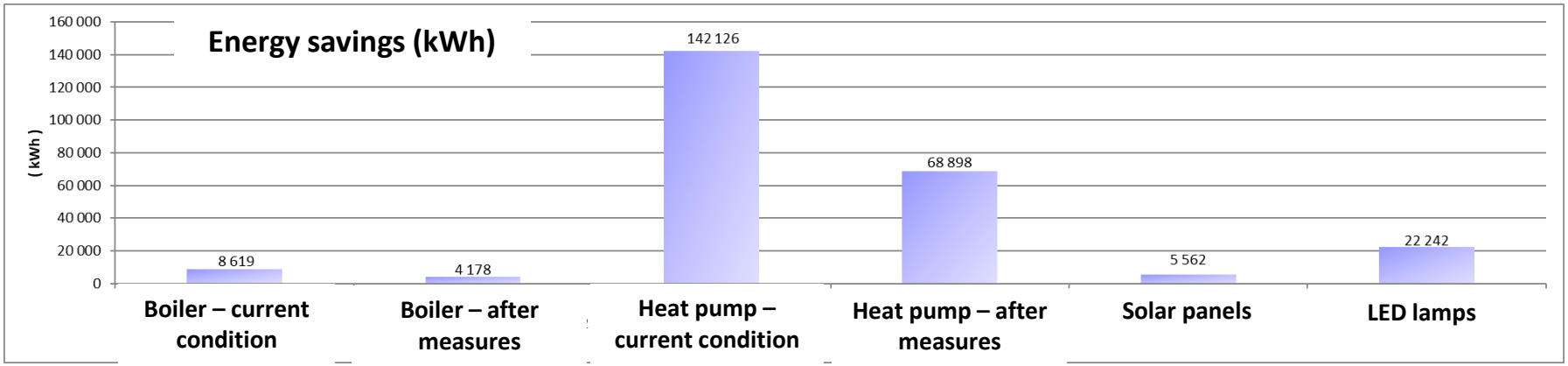


6. Case study

Energy savings for building structures

Technical systems:

- Replacement of energy source:
  - boiler at current conditions
  - boiler after implementation of measures
  - heat pump at current conditions
  - heat pump after implementation of measures
- Solar thermal panels for domestic hot water
- Replacement of fluorescent lamps with LED lamps

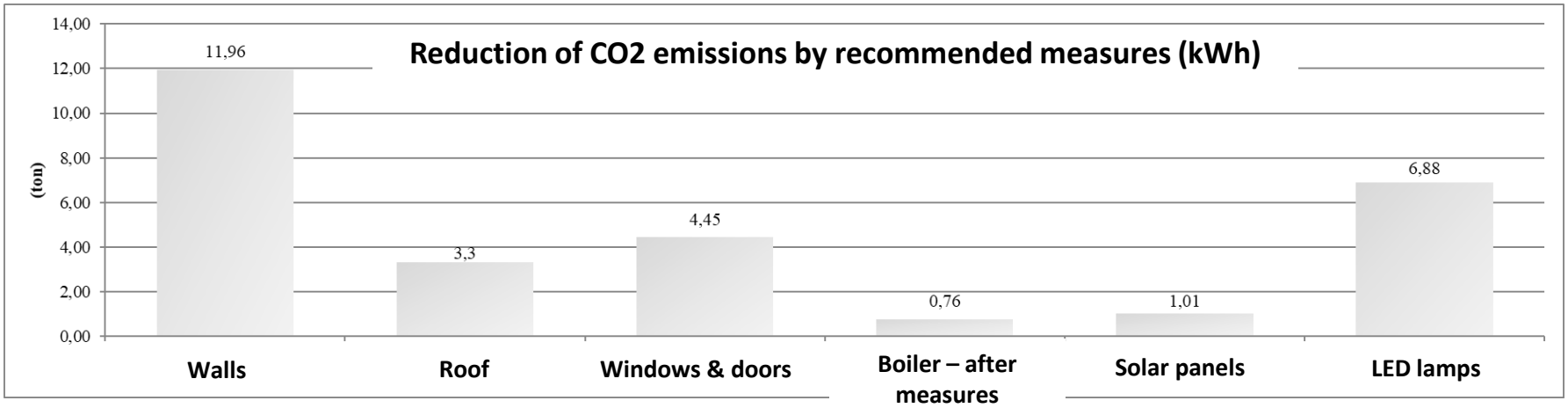


6. Case study

Selected measures and summary after renovation

Energy need for space heating = 18.4 kWh/m^2
Current requirement = 26.8 kWh/m^2

Indicator	kWh/(m^2.a)	Energy class
Space heating	23,3	A
Domestic hot water	7,4	B
Lighting	11,1	A
Total energy use	41,8	A
Primary energy	55,0	A1



6. Case study

Summary

Energy assessment				
	Initial condition	After renovation	Reduction	Reduction rate
Specific heat loss - transmission [$W.K^{-1}$]	2 267	949	1 318	58 %
Specific heat loss - ventilation [$W.K^{-1}$]	1 273	1 273	0	0 %
Total heat gains [kWh]	49 901	49 072	828	1.7 %
Energy need for space heating [kWh]	120 958	58 637	62 321	52 %
Primary energy for space heating [kWh]	158 227	62 812	95 415	60 %
Energy use for lighting [kWh]	37 580	15 338	22 241	59 %
Energy use for space heating and lighting [kWh]	195 808	78 151	117 657	60 %

Environmental assessment				
	Initial condition	After renovation	Reduction	Reduction rate
Annual production of CO_2 [ton/rok]	37.9	8,8	29,1	77 %
Annual production of PM [kg/rok]	1.8	0,5	1,3	73 %
Annual production of SO_2 [kg/rok]	21.5	11,0	10,5	49 %
Annual production of NO_x [kg/rok]	30.5	7,1	23,4	77 %
Annual production of CO [kg/rok]	13.6	3,5	10,1	74 %
Annual production of PM_{10} [kg/rok]	1.7	0,5	1,2	73 %

Economic assessment	
Investment costs [€]	345 043
Annual cost savings [€]	7 014
Net Present Value [€]	-208 068
Assessment period [years]	25
Simple Payback [roky]	>25
Discounted Payback [roky]	>25
Internal Rate of Return [%]	-

Not profitable 😔

Thank you for attention!