Report for detailed analysis

Project Title: **EmBuild** - *Empower public authorities to establish a long-term strategy for mobilizing investment in the energy efficient renovation of the building stock*

Grant Agreement N° 695169 - Deliverable N° 3.4
Work Package 3 Lead Partner: eza!

Date: 27.06.2018

Imprint

This document is issued by the consortium formed for the implementation of the EmBuild project under Grant Agreement N° 695169 by the following partners:

GIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (Germany)
KSSENA - Energy Agency of Savinjska, Šaleška and Koroška Region (Slovenia)
Eza - Energie- und Umweltzentrum Allgäu gemeinnützige GmbH (Germany)
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 695169.

About the project

EmBuild is a coordination and support project implemented by a consortium of ten institutions based in eight countries throughout Europe under the Horizon 2020 research and innovation Programme. Overall coordination rests with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

The main objectives of EmBuild are to increase the capacity of public authorities at regional/municipal level to collect the necessary data to prepare ambitious, sustainable and realistic renovation strategies for public buildings, analyse and identify cost-effective approaches to renovations, guide investment decisions and facilitate private sector involvement. EmBuild is supporting municipalities and towns in Bulgaria, Croatia, Germany, Romania, Serbia and Slovenia. In addition, the project will focus on analyzing policies and implemented measures that stimulate cost-effective deep renovation of buildings and identify best practices in 6 partner countries.

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CONTENT

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1. Introduction

In the course of the elaboration of a renovation strategy, or to prepare the renovation of a single building, a detailed analysis might be necessary. This includes the collection of data of the building, the energetic status of the building envelope and the technical infrastructure and the status of repair. With this detailed information, the energy balance of the building and saving measures can be calculated. A template for such a detailed analysis and a standardised report were generated by the EmBuild-project.

To carry out energy audits for municipal buildings, a certain amount of expertise is necessary. For this reason, this template for a detailed analysis is addressed to experts in the field of energy audits like energy consultants, engineers, skilled craftsmen.

But it can also be an aid to persons with less expertise, e.g. public officers or responsible persons in charge for the municipal building stock. The template can be used as a guideline for external experts. It can be used to clarify the requirements and the standard that has to be met by the external experts. This is essential, if more than one expert provides energy audits for a municipality. The content and the outcome of the energy audits should be comparable.

This template for a detailed analysis tries to be as generic as possible, so that it can be used and adopted by partners in the EU. Before applying it, the template should be adapted to the national context, legislation and requirements. Especially, the methodology for the calculation of the energy balance of a building may vary from country to country. Also, the climate correction or the adjustment of the consumption due to under-heating has be handled different. The calculation and description of single measures may be optional in some countries. They alternatively have defined a cost optimal standard (Passive-house standard, NZEB-standard) as the goal for a deep renovation.

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2. Description of the Workflow

For the elaboration of a long-term renovation strategy, a stepwise approach is recommended:

Step 1: preliminary analysis[1]

1. Gather Data about the municipal building stock
   Minimum data required: energy consumption for heat and electric energy, surface area and year of construction
2. Data analysis and portfolio analysis: create specific values for heat consumption and electric energy [kWh/m²/a] to be compared with reference values or existing benchmarks.
3. Portfolio-analysis:
   I. On-site visit of buildings for a rough overview of the building-stock
   (sequence of the on-site visits according to the priorities of the portfolio analysis)
   II. Identification of low-cost and no-cost measures
   III. overview over possible measures to increase the energy-efficiency of the buildings, and
   IV. time-frame for the measures, for the single building
4. Compilation of all measures to generate a draft for a long-term renovation strategy
   time-horizon until 2050 (EU-goal); breakdown into decades (2020-2030-2040-2050)

Outcome: The preliminary analysis will have identified the buildings that should be prioritized for renovation or retrofitting. For detailed measures and expected savings a more in-depth analysis is need (i.e. step 2).

Step 2: Detailed Analysis

After the overview of the building stock and the overview of possible measures and savings, the implementation of measures and the renovation of single buildings can be planned. Prior to this, a detailed analysis of the building is recommended. For this, the following steps and contents are necessary:

1. Gather more in-depth information of the building
2. Gather energy consumption data of the quantities of fuel and electric energy
3. Climate correction of the consumption data
4. On-site visit for data acquisition; additional information to preliminary analysis
5. Calculation of the energy balance of the building
6. Comparison of energy demand and climate-corrected energy consumption
7. Calculation of the energy performance characteristics of the building and determination of the energy class
8. Optional: Calculation of possible single measures for energy efficiency – energy savings, CO_2 reductions, monetary savings and estimated investment;
9. Calculation of packages of measures– energy savings, CO_2 reductions, monetary savings, estimated investment, expected energy performance characteristics and energy class – to meet a defined energetic standard (cost optimal, NZEB etc.)

[1] See report „Preliminary Analysis: quick review of the existing building stock“, published by EmBuild

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10. Calculation of financial indicators for different packages of measures – pay-pack period; internal rate of return; net present value;
11. Compilation of the results and comparison of alternatives

The elements and the modus operandi of the detailed analysis are described in the following sections.

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3. Elements of the Detailed Analysis

3.1 Gather relevant information of the building

Additionally to the information that was already taken into account for the preliminary analysis, more in-detail information of an individual building is required. At least the following information is necessary:

- engineering drawings like ground plots, cross sections, faces/facades
  (they are necessary for the calculation of the energy balance of the building);
- detail plans (if available), for information about the constructions and parts of the buildings that cannot be inspected, e.g. flat roof constructions under sealing;
- energy consumption of at least the last 3 years for heat and electric energy;
- the surface area, especially the conditioned area can be determined via the engineering drawings (in some municipalities, information about the surface area are available in databases);
- typical number of inhabitant and operation schedule – hours of use;
- typical heating and cooling schedule;
- previous energy audits;
- reports from pervious analysis of the efficiency of the boilers and of the air-conditioning installation, if applicable; and
- for the planning of measures, information about last renovation steps can be helpful. This information might be gathered from the caretaker or the responsible person in the municipality.

3.2 Gather energy consumption data

In the first step - the preliminary analysis – some information about the energy consumption of the building was already gathered. For the detailed analysis, more information is necessary to assess the energy performance of the building more in-depth:

- Knowledge about the development of the energy consumption over several years -
  are there reasons for changes in the energy consumption?
- Balance of Energy with Break-down of energy carriers (fuels, electric energy)
- Comparison of the used applications: heating, cooling, ventilation, lighting, appliances etc.
- Knowledge about the load profile over the year, if available with monthly energy consumption data (e.g. fuel consumption for heating in winter, electric energy-consumption for cooling in summer) can provide ideas for possible measures like e.g. CHP (combined heat and power generation) or photovoltaic systems for self-consumption
- Determination of irregularities in the energy consumption or the consumption-profile
- Calculation of CO_2-emissions

It is necessary to get information about the energy consumption of the building that is analyzed. The analysis can be done according to the knowledge and expertise of the energy auditor – in most cases Excel should be sufficient.

The information can be gathered from the building owner / building user. In the municipalities, this information should be available the finance depart (energy bills or budgets) and the energy management department (data from energy monitoring).

Energy bills / budgets provide information about:

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- annual energy consumption
- for building with higher consumption, a monthly bill / budget may be available
- energy prices, tariffs and costs
- specific CO_2-emissions of the energy carrier [kg CO_2/MWh]

Energy controlling / monitoring provides information about:

- information about the energy consumption in a higher resolution: annual, monthly, weekly, daily, real-time
- the load profile is measured or can be calculated
  calculation: amount of energy / time = power
  e.g. electric energy 20 kWh per 15 Minutes = average power of 80 KW
  (20 kWh / 0,25 h = 80 KW)

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3.3 Climate correction

Due to changes in the weather from year to year, the energy consumption – especially the heat consumption – varies. Thanks to a climate correction it is possible to compare the energy consumption of a single building over several years. With the climate correction, the annual energy consumption is referred to a local „standard year“. The standard year is the result of a calculation of the average temperature over 30 years. The daily temperature figures are put in relation and a climate factor is calculated (daily temperature figure $_{\text{standard year}}$ / daily temperature figure $_{\text{year}}$). The basic principle is that the amount of energy is calculated that would have been used from the building in the same period, at the same place with a long-term average weather / climate.

The methodology and the norms for climate correction may vary from country to country:

- Germany:
  - Norms: VDI 3807 and VDI 2067
  - Internal temperature: 20°C
  - Temperature for heating limit: 15°C
  - Source for factors: Deutscher Wetterdienst, IWU
- Slovenia:
  - Source for factors: official national and local climate data are provided by Environmental agency of the Republic of Slovenia founded by Ministry of the environment and spatial planning
  - Energy consumption in buildings is limited by Energy act (Official Gazette No. 17/14 and 81/15) and Rules on efficient use of energy in buildings with a technical guideline (Official Gazette No. 52/10)
- Croatia:
  - Norms: HRN EN ISO 13790 and ENSI (2012)
  - Internal temperature: 20°C
  - Temperature for heating limit: 12°C
  - Source for factors: Meteorological and Hydrological Service, Gric 3, Zagreb
- Bulgaria:
  - Guidebook: TU-Sofia, Calculation of annual energy consumption in buildings, Sofia, 2005;
  - Internal temperature: Depends by the activities of the building occupants (16-23°C) - Ordinance No.РД-07-3/18.07.2014;
  - Temperature for heating limit: 5°C less than inddor temperature;
  - Sources for factors: Ordinance No.15/28.06.2005 by MRDPW and ME (Design Degree-days and outdoor temperature).
- Romania: There are no norms for climate correction .According with SR 4839 Monthly Average Temperatures(Romanian Standard) , outdoor conventional computing temperatures are considered in accordance with climatic zoning map of Romania . There are five climatic zones
- Serbia still does not have officially developed standard meteorological year. In the Regulations on energy efficiency of buildings internal and external temperatures for calculation of heating energy demand are specified, internal is 20OC while external is defined for 20 towns in Serbia.

Definition of the daily temperature figure:
The daily temperature figure (G20/15) is the sum of the difference between a standardised indoor temperature of 20°C and the average outside air temperature. For the sum, all days in one year with a average air temperature below 15°C are taken into account.

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Example for climate factors in Germany. Source:www.iwu.de/…/Gradtagszahlen_Deutschland.xls

Klimadaten deutscher Stationen

Datenquelle: Klimadaten Deutscher Stationen, Deutscher Wetterdienst, Offenbach - www.dwd.de

IWU

Postleitzahl | **Wetterstation** Kempten | **Jahr** 2016 | **Start** Januar

PLZ ist nicht korrekt, Station: Kempten verwendet

Klimazone 15 nach DIN V 4108-6:2003

Innentemperatur 20,0 °C

Ausgabegröße Gradtagzahl

Heizgrenztemperatur 15 zur Berechnung der Gradtagzahl nach VDI 3807

	2016				langjähriges Mittel *			
	Gradtagzahl G20/15	Heiztage	Außen-temperatur	Außentemp. an Heiztagen	Gradtagzahl G20/15	Heiztage	Außen-temperatur	Außentemp. an Heiztagen
Monat	[Kd]	[d]	[°C]	[°C]	[Kd]	[d]	[°C]	[°C]
Januar 2016	585	31	1,1	1,1	658	31	-1,2	-1,2
Februar 2016	496	29	2,9	2,9	581	28	-0,6	-0,5
März 2016	524	31	3,1	3,1	524	31	3,1	3,1
April 2016	374	30	7,5	7,5	399	30	6,6	6,5
Mai 2016	249	26	11,6	10,4	246	25	11,5	10,3
Juni 2016	104	16	15,6	13,5	128	15	14,8	11,7
Juli 2016	33	4	18,1	11,8	66	9	16,8	12,6
August 2016	55	8	17,1	13,1	79	11	16,2	12,8
September 2016	117	16	15,0	12,7	202	23	12,4	11,1
Oktober 2016	384	31	7,6	7,6	367	31	8,1	8,0
November 2016	499	30	3,4	3,4	513	30	2,9	2,9
Dezember 2016	620	31	0,0	0,0	626	31	-0,2	-0,2
Jahr	4039	283	8,6	5,7	4389	294	7,6	5,1

* 46 Jahre bis 2016 (evtl. mit Lücken)

Verhältnis der Gradtagzahl G20/15 2016 zu langjährigem Mittel 0,92

Verhältnis der Heiztage Ht15 2016 zu langjährigem Mittel 0,96

Klimafaktor für Energieverbrauchskennwerte nach EnEV [1] 0,93 Potsdam (ab 2014)
0,96 Würzburg (alt)

The picture shows a German tool for climate correction. After the selection of a location [Kempten] and a year [2016] in the top-row, the indoor air temperature (standard = 20°C) in the second row and the temperature for heating limit (standard = 15°C) the data for the selected year and the long-term average data is provided in two tables. Below the climate factor G 20/15 (here: 0,92) and the proportion of the heating days compared to the long-term average are provided (here: 0,96).

To issue an energy passport, additionally to the climate correction the location of the building is taken into account. With this factor, the buildings in different climate zones can be compared. This factor is provided in the last row (here: 0,93). The table indicates the factors for Potsdam and Würzburg; (in 2014 the Energy act changed the reference climate from Würzburg to Potsdam).

3.4 On-site visit

For a detailed analysis of a building, further data about the building is necessary. This is information, additional to the information that was collected in the preliminary analysis. The main task of preliminary analysis was to get a rough overview of many buildings in a short time. The main task of the second on-site visit for the detailed analysis

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is to get information that is necessary to calculate the energy demand of the building. For this, the following information must be gathered:

- **area of building elements:**
  The area of every different element of the building envelope should be determined. The areas of the external walls, windows and doors should be calculated by types and by orientation (North, South, etc.). The areas of the roofs and floors should also be calculated by types. The total floor area, as well as the heated and cooled area should be evaluated and calculated, as well as the volumes. If the existing documentation is not sufficient or not update than all sizes should be measured on-site and the areas should be calculated.
- **construction layers and u-values**
  Additionally to the information from the engineering drawings, the inspection of the parts of the building is necessary. The energy consultant should examine the building as exactly as possible and detect the construction layers as accurate as possible. With this information- - the materials and thickness of the layers – the u-value [W/mK] can be calculated for every type of the different building elements and is the basis for the calculation of the thermal losses of the building envelope. The shading to the transparent building elements should be determined.
- **technical infrastructure**
  During the on-site visit, information about the technical infrastructure for heating, ventilation, cooling, heat distribution and hot water should be collected.
  - heat generation: (i) year of construction, type, power; (ii) measurement of the efficiency by gas analyzer if applicable; and (iii) operating regimes
  - heat distribution: heating circuits, heating pumps, length of the pipe system, insulation of the heating pipes
  - heat delivery: radiators, convector heaters, thermostat valves
  - control and regulation systems, set-ups
  - ventilation system: central or decentralised systems, heat recovery, ventilators, operating regimes
  - cooling systems, type of machines; efficiency characteristics; operating regimes
  - domestic hot water generation and consumers of hot water
  - lighting system – type and number of lamps; installed capacities; maintenance; operating regimes
  - appliances divided in groups influencing the heating balance of the building and influencing the heating balance - type and number of appliances; installed capacities; operating regimes

3.5 Calculation of the energy balance of the building

For the planning of measures and the assessment of the profitability of saving measures, it is necessary to calculate the energy demand of the building. The energy consumption of a building is determined by the energy losses and energy gains. The energy demand describes the amount of energy that is necessary to fill the gap between energy losses and energy gains.

energy losses:

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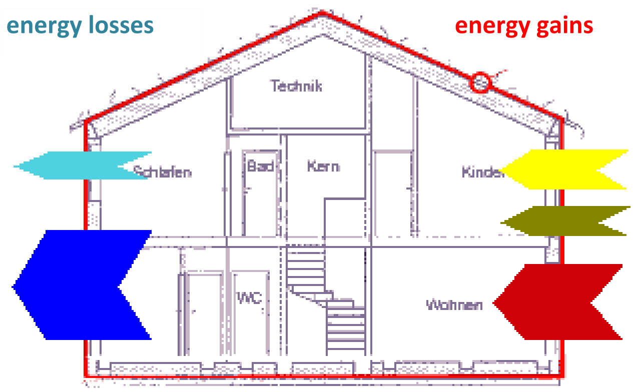
- transmission
- ventilation

energy gains:

- solar radiation
- ventilation (summer only)
- internal (persons)



The results of a calculation of the building should usually display the energy balance for the different uses of energy: the net energy, end energy and primary energy for heating, cooling, ventilation, electric lights and hot water generation.

For the calculation of the energy balance, software tools are used. The most common tools in the EmBuild-partner countries are:

- Germany: Energieberater Hottgenroth, Dämmwerk, BKI Energieplaner
- Slovenia: Building physics URSA 4.0 (calculation of energy consumption in building according to Rules on efficient use of energy in buildings with a technical guideline - Official Gazette No. 52/10)
- Croatia: EnCert-HR, KI Expert PLUS
- Bulgaria: EAB (Energy auditing of buildings); Shtrakov
- Romania: Doset-PEC(Energy Performance for Buildings software tools), AllEnergy, Matrix Energ
- Serbia: Knauftherm and Ursa.

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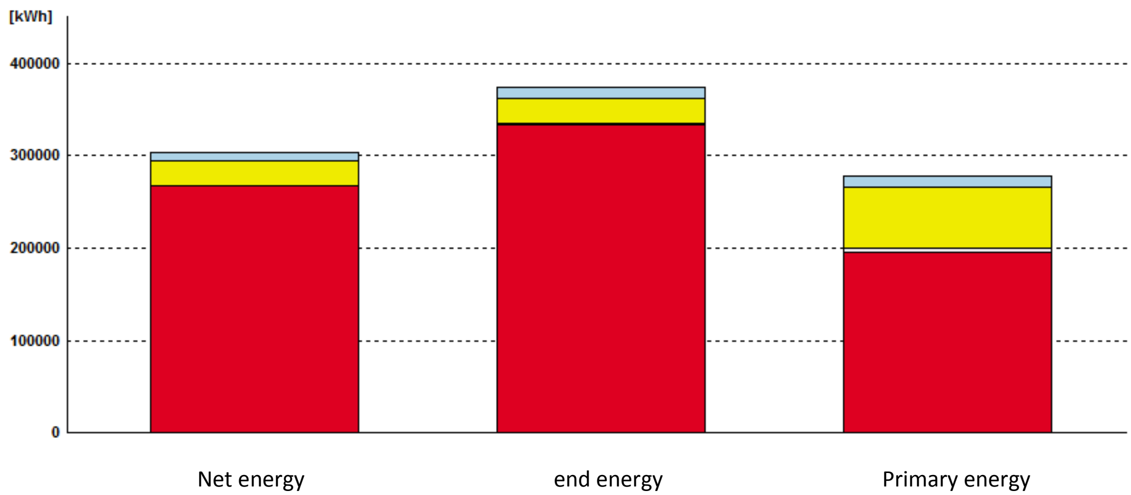
Energy balance

	Total kWh/a	heating kWh/a	cooling kWh/a	ventilation kWh/a	lighting kWh/a	Hot water kWh/a
Net energy	303405	266878	0	0	27527	9000
	156,72	137,85	0	0	14,22	4,65
end energy	374307	332814	0	1740	27527	12226
	193,34	171,91	0	0,90	14,22	6,32
Primary energy	278025	195524	0	4176	66065	12259
	143,61	100,99	0	2,16	34,12	6,33



3.6 Comparison of energy demand and energy consumption

The next step is the comparison of the calculated energy demand and the actual energy consumption. Some buildings are underheated or are used less intensely than the calculation methodology assumes. In case of underheating, calculation of an adjusted energy demand of the building by simulation of normal indoor temperatures. For this, the demand and the consumption should be compared and, if deemed necessary, the calculation parameters should be adjusted to get more realistic results. This is especially crucial for the calculation of the profitability.

Illustrative adjustment of calculation parameters:

- Internal temperature
- Hours of use (hours per day, days per year)
- Internal gains
- …

The modifications have to be documented in the detailed report.

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3.7 Calculation of the energy performance characteristics of the building and determination of the energy class

With the data about the energy consumption, specific values can be calculated and be compared with reference values from existing building benchmarks. The specific values of energy consumption indicate the energetic performance of a building independent from the size of the building. With the break-down to the consumption per square-meter of conditioned surface area, buildings of different sizes but of the same use or category can be compared.

Example for the calculation of energy performance indicators:

2013	consumption	climate correction factor	consumption with climate correction
heat consumption	367.093 kWh	0,98	359.751 kWh
electric energy	60.330 kWh	-	-
water consumption	997 m³	-	-
surface area conditioned	1.586 m²		

	specific value
heat consumption	231 kWh/m²a
electric energy	38 kWh/m²a
water consumption	629 Liter/m²a
surface area conditioned	1.586 m²

The specific values can be compared to reference values from benchmarks to assess the energy performance of the building according to the use of the building:

building category	reference value heat	reference value electricity
9100 convention halls	65 kWh/m²a	20 kWh/m²a
9140 festival hall	110 kWh/m²a	40 kWh/m²a
restaurant	205 kWh/m²a	95 kWh/m²a

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Reference values are generated from a monitoring of the energy consumption of existing buildings. There are different organisations that make surveys to generate benchmarks and reference values. Sources for benchmarks are:

- Germany:
    - AGES Gesellschaft für Energieplanung und Systemanalyse mbH
    - Bekanntmachung der Regeln für Energieverbrauchswerte und der Vergleichswerte im Nichtwohngebäudebestand; federal ministry of economics and energy
    - European energy award
- Slovenia:
    - National Register of Energy performance certificates
    - Statistical Office of the Republic of Slovenia
    - Building and Civil Engineering Institute
- Croatia:
    - Information system for energy management (ISGE), Agency for Transactions and Mediation in Immovable Properties (APN)
    - System for measuring, monitoring and verification of energy savings (SMIV), Center for Monitoring Business Activities in the Energy Sector and Investments (CEI)
- Bulgaria:
    - Ordinance No. 18/12.11.2004 by MRDPW and ME (Terminated) – benchmarks for heating (heat), ventilation (heat), domestic hot water (heat/electricty), fans and pumps (electricity) for different types of buildings in different climate zones;
- Romania:
    - BUILD UP Skills – România, average consumption 2008-2010
    - INCD URBAN-INCERC- Energy Performance Certificates Databases analysis
- Serbia has different regulations, benchmarks are defined but reference buildings are not used.

	Type of building	Max energy heating demand kWh/m2a **New buildings**	Max energy heating demand kWh/m2a **Existing buildings**
1	Single family houses	65	75
2	Multy family houses (more than 2 flats)	60	70
3	Administrative and office building	55	65
4	Educational and culture buildings	65	75
5	Health and social welfare	100	120
6	Tourism and restaurants	90	100
7	Sports and recreation facilities	80	90
8	Wholesale, retail and services	70	80

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Besides the comparison of the specific energy consumption, the detection of the energy class is possible or recommended e.g. by national norms and legislation. The rating to the energy class for a building is dependent on the end energy demand or the end energy consumption:

- Germany: Energy classes according to the Energy Savings Act (ENEV 2014):

energy class	**end energy** [kWh/(m² a)]
A+	< 30
A	< 50
B	< 75
C	< 100
D	< 130
E	< 160
F	< 200
G	< 250
H	> 250

- Slovenia:
  Energy classes according to the Slovenian Energy act (Official Gazette No. 17/14 and 81/15)and Rules on the methodology for the production and issuance of energy performance certificates for buildings (Official Gazette No. 92/14):

energy class	**end energy** [kWh/(m² a)]
A1	≤ 10
A2	≤ 15
B1	≤ 25
B2	≤ 35
C	≤ 60
D	≤ 105
E	≤ 150
F	≤ 210
G	> 210

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- Croatia: Energy classes according to *Ordinance on energy audits and energy certification of buildings* (Official Gazette 48/14, 150/14, 133/15, 22/16, 49/16, 87/16)

E_{del} (kWh/m^{2}a)	RESIDENTIAL		FAMILY		OFFICE		EDUCATIONAL		HOSPITAL		HOTEL AND RESTAURANT		SPORTS HALL		STORE		OTHER NONRESIDENTIAL	
Energy class	*K*	*P*	*K*	*P*	*K*	*P*	*K*	*P*	*K*	*P*	*K*	*P*	*K*	*P*	*K*	*P*	*K*	*P*
A+	≤ 45	≤ 35	≤40	≤30	≤20	≤15	≤45	≤25	≤145	≤190	≤65	≤40	≤145	≤95	≤105	≤90	≤45	≤35
A	>45 ≤ 65	>35 ≤50	>40 ≤60	>30 ≤40	>20 ≤30	>15 ≤30	>45 ≤55	>25 ≤45	>145 ≤185	>190 ≤205	>65 ≤80	>40 ≤45	>145 ≤215	>95 ≤100	>105 ≤200	>90 ≤130	>45 ≤65	>35 ≤50
B	>65 ≤80	>50 ≤ 60	>60 ≤80	>40 ≤50	>30 ≤40	>30 ≤40	>55 ≤60	>45 ≤60	>185 ≤220	>205 ≤220	>80 ≤90	>45 ≤50	>215 ≤290	>100 ≤110	>200 ≤290	>130 ≤170	>65 ≤80	>50 ≤60
C	>80 ≤165	>60 ≤120	>80 ≤175	>50 ≤120	>40 ≤120	>40 ≤125	>60 ≤120	>60 ≤100	>220 ≤320	>220 ≤235	>90 ≤155	>50 ≤105	>290 ≤410	>110 ≤165	>290 ≤330	>170 ≤180	>80 ≤170	>60 ≤115
D	>165 ≤250	>120 ≤170	>175 ≤270	>120 ≤190	>120 ≤195	>125 ≤205	>120 ≤180	>100 ≤140	>320 ≤420	>235 ≤250	>155 ≤220	>105 ≤155	>410 ≤525	>165 ≤220	>330 ≤370	>180 ≤200	>170 ≤255	>115 ≤170
E	>250 ≤310	>170 ≤210	>270 ≤340	>190 ≤240	>195 ≤245	>205 ≤255	>180 ≤225	>140 ≤175	>420 ≤525	>250 ≤315	>220 ≤275	>155 ≤195	>525 ≤655	>220 ≤275	>370 ≤465	>200 ≤220	>255 ≤320	>170 ≤215
F	>310 ≤370	>210 ≤250	>340 ≤400	>240 ≤280	>245 ≤290	>255 ≤300	>225 ≤270	>175 ≤210	>525 ≤630	>315 ≤370	>275 ≤330	>195 ≤230	>655 ≤790	>275 ≤330	>465 ≤555	>220 ≤265	>320 ≤385	>215 ≤255
G	>370	>250	>400	>280	>290	>300	>270	>210	>630	>370	>330	>230	> 790	> 330	> 555	>265	> 385	> 255

***E*del** – specific annual delivered energy (kWh/m²a)
K – continental Croatia
P – coastal Croatia

- Bulgaria

	Administrative buildings	Schools	Universities	Kindergartens	Health care buildings	Hotel and hostels	Retail buildings	Spots buildings	Buildings for art and culture
Energy class	**Primary energy** [kWh/(m² a)]								
A+	< 70	< 25	< 45	< 33	< 70	< 85	< 138	< 88	< 55
A	< 140	< 50	< 90	< 65	< 140	< 170	< 275	< 175	< 110
B	< 280	< 100	< 180	< 130	< 280	< 340	< 550	< 350	< 220
C	< 340	< 130	< 220	< 195	< 365	< 390	< 600	< 400	< 270
D	< 400	< 160	< 260	< 260	< 450	< 440	< 650	< 450	< 320
E	< 500	< 200	< 325	< 325	< 563	< 550	< 813	< 563	< 400

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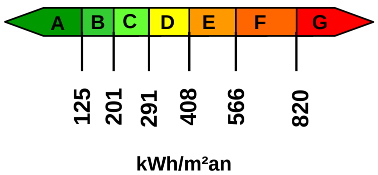
F	< 600	< 240	< 390	< 390	< 675	< 660	< 975	< 675	< 480
G	> 600	> 240	> 390	> 390	> 675	> 660	> 975	> 675	> 480

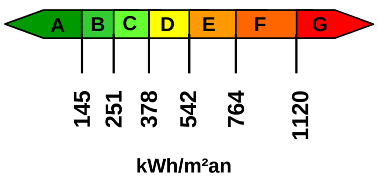
- Romania:

According to romanian methodology there are four energy classes for buildings with different utilities

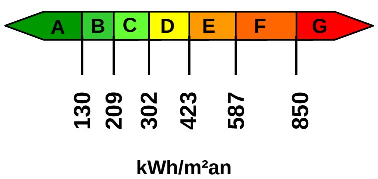
1. UTILITIES: heating, hot water, lighting



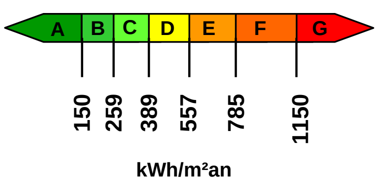
2. UTILITIES: heating, hot water, lighting, coling,



3. UTILITIES: heating, hot water, lighting, ventilation.



4. UTILITIES: heating, hot water, lighting, cooling, ventilation.



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- Serbia: Energy classes are defined for eight specified types of buildings

Single family houses		new	existing
Energy class	$Q_{H,nd,rel}$	$Q_{H,nd}$	$Q_{H,nd}$ [kWh/m²a)]
A+	< **15**	< 10	< 12
A	**<25**	**< 17**	<20
B	**< 50**	**<33**	**<38**
C	< **100**	**<65**	**<75**
D	< **150**	**<98**	**<113**
E	**<200**	< **130**	< **150**
F	**<250**	< **163**	< **188**
G	> **250**	> **163**	> **188**

Multi – family houses		new	existing
Energy class	$Q_{H,nd,rel}$	$Q_{H,nd}$	$Q_{H,nd}$ [kWh/m²a)]
A+	< 15	<9	< 10
A	<25	< 15	< 18
B	< 50	<30	<35
C	< 100	<60	<70
D	< 150	<90	< 105
E	<200	< 120	< 140
F	<250	< 150	< 175
G	>250	>150	> 175

Administrative and office building		new	existing
Energy class	$Q_{H,nd,rel}$	$Q_{H,nd}$	$Q_{H,nd}$ [kWh/m²a)]
A+	< 15	< 8	< 10
A	< 25	< 14	< 17
B	< 50	< 28	< 33
C	< 100	< 55	< 65
D	< 150	< 83	< 98
E	< 200	< 110	< 130
F	< 250	< 138	< 163
G	>250	>138	> 163

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Educational and culture buildings		new	existing
Energy class	$Q_{H,nd,rel}$	$Q_{H,nd}$	$Q_{H,nd}$ [kWh/m²a)]
A+	< 15	< 10	< 12
A	< 25	< 17	< 20
B	< 50	< 33	< 38
C	< 100	< 65	< 75
D	< 150	< 98	< 113
E	< 200	< 130	< 150
F	< 250	< 163	< 188
G	> 250	> 163	> 188

Health and social welfare		new	existing
Energy class	$Q_{H,nd,rel}$	$Q_{H,nd}$	$Q_{H,nd}$ [kWh/m²a)]
A+	< 15	< 15	< 18
A	< 25	< 25	< 30
B	< 50	< 50	< 60
C	< 100	< 100	< 120
D	< 150	< 150	< 180
E	< 200	< 200	< 240
F	< 250	< 250	< 300
G	> 250	> 250	> 300

Tourism and restaurants		new	existing
Energy class	$Q_{H,nd,rel}$	$Q_{H,nd}$	$Q_{H,nd}$ [kWh/m²a)]
A+	< 15	< 14	< 15
A	< 25	< 23	< 25
B	< 50	< 45	< 50
C	< 100	< 90	< 100
D	< 150	< 135	< 150
E	< 200	< 180	< 200
F	< 250	< 225	< 250
G	> 250	> 225	> 250

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Sports and recreation facilities		new	existing
Energy class	$Q_{H,nd,rel}$	$Q_{H,nd}$	$Q_{H,nd}$ [kWh/m^{2}a)]
A+	< 15	< 12	< 14
A	< 25	< 20	< 23
B	< 50	< 40	< 45
C	< 100	< 80	< 90
D	< 150	< 120	< 135
E	< 200	< 160	< 180
F	< 250	< 200	< 225
G	> 250	> 200	> 225

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3.8 Optional: Calculation of possible single measures

Depending on national legislation, the calculation of single measures can be an option. So this chapter has to be adapted to the national context. In some countries the passive-house-standard is defined as cost optimal and has to be achieved with a deep renovation of the building. In other countries, there may be no or a different definition of the cost optimal level. To provide decision makers at community level information about possible options, the calculation of single measures can be reasonable.

For the building envelope and the technical infrastructure, single measures to improve the energy efficiency can be proposed. The energy savings, savings of greenhouse-gas emissions and cost savings should be calculated. For the building envelope measures for the base plate, the walls, windows and the roof should be proposed. Typical measures are:

- Insulation of walls
- Installation of new windows
- Insulation of the roof, additional insulation for platform roofs

For the technical infrastructure, typical measures are:

- Installation of new boilers, connection to district heating
- Mechanical ventilation with heat recovery
- Refurbishment of the light-system

For the description of the single measure, the following structure is proposed:

- Description of the actual state and construction
- Review / appraisal: U-value, what is the problem, need for improvement
- Proposed measure
- Savings: energy and CO_2-emissions (net savings and %)

For the quality of the proposed measures, a target should be defined. Possible targets for U-values for the building envelope could be:

- minimal requirements defined by legislation
- new-building-standard
- passive house standard

Optionally, the results of the single measures can be aggregated and displayed graphically:

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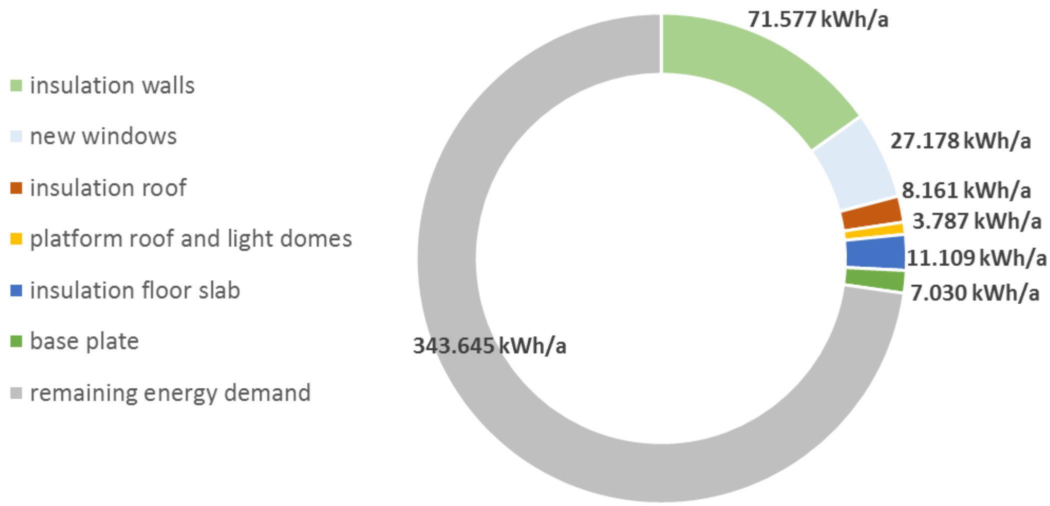

3.9 Calculation of packages of measures

Building upon the analysis of the single measures, packages of measures should be proposed in the next step. The goal is to reach a certain energetic level for the building. This target can be - equivalent to individual measures – defined by national strategies or legislation. Possible targets are minimal requirements defined by legislation, new-building-standard or passive house standard.

Stakeholder should be sensitized that for a renovation a sustainable standard should be chosen. The typical renovation cycle for a building is approx. 30 years. If a mediocre energetic standard is chosen now, the higher energy consumption, costs and CO_2-emissions will imply that the EU-goals will not be reached.

For the description of the packages of measures, the following structure is proposed:

- list of measures, which measures are combined an why
- results of the calculation with comparison of the target-values
    - primary energy demand
    - End energy demand
    - U-values
    - Specific energy consumption
- Estimation / calculation of the investment costs
  with differentiation of costs for energetic improvement and costs that are necessary anyway
- Advice what has to be taken into consideration if the measures are implemented e.g. disassembling of evacuation staircases, derogation of ledges or cornices and sills
- Calculation of profitability
- Indication of subsidies

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3.10 Calculation of financial indicators

For the decision, which measures or which pack of measures / energetic level should be applied to the building, a calculation of the financial indicators is necessary.

A possible workflow could be:

1. Calculation of cost savings: annual energy savings x energy price = annual cost savings
2. Estimation of the investment costs for the proposed measures; here it can be reasonable to differentiate the costs in energetic relevant costs (costs that save energy) and costs for measures that are anyway necessary; for the estimation of the costs, databases can be helpful
3. Calculation of the annuity factor $ANF_{n,i} = (1+i)^n \times i / (1+i)^n - 1$
   i = interest rate; n = retention period
   for i = 3,0% and n = 30 years the annuity factor ANF = $(1{,}03)^{30} \times 0{,}03 / (1{,}03)^{30} - 1 = 0{,}051$
4. Calculation of the annuity of the energetic relevant costs with the annuity factor:
   Investment costs x ANF
   Example:
   investment costs 9.705 € x ANF 0,051 = 495 € annual costs for the investments
5. The measure is economic profitable, if the annual cost savings are higher than the annuity of the investment costs
6. As another factor to assess the profitability, the price per kilowatt-hour can be calculated:
   annuity of the total costs / annual energy savings = price per kWh
   Example: 1.005 € / 31.975 kWh = 0,03 €/kWh
   This price per kWh indicates the costs that arise to save the respective kilowatt-hour. If the price per saved kWh is lower than the price for the purchase of the energy, the measure is economically wise.

interest rate	3,0%
retention period	30 years
annuity factor	0,051
annuity of energetic relevant costs	495 €
annuity of total costs	1.005 €
annual cost savings	865 €
annual energy savings	31.975 kWh
price per kWh (basis: annuity of the total costs)	0,03 € / kWh

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Cost databases can be helpful to estimate the costs for investments. The cost niveau depends on various factors like:

- Country, state
- Season and weather
- Economic growth or slowdown

Sources for costs are:

- Germany:
  - BKI, Baukosteninformationszentrum Deutscher Architektenkammern
  - BBSR-Online Publikatoin Nr 06/2014 Kosten energierelevanter Bau- und technischer Anlagenteile bei der energetischen Sanierung von Nichtwohngebäuden / Bundesliegenschaften
- Slovenia:
  - The Slovenian Chamber of Engineers
  - The Chamber of Craft and Small Business of Slovenia / Section of civil engineering
  - The Institute of Macroeconomic Analysis and Development of the Republic of Slovenia
- Croatia
  There is no official database and prices of works. Approximate cost of the works can be found on the website such as:

  http://cijene-gradjevinskih-radova.blogspot.hr/

  http://www.gradimo.hr/cijene-gradevinskih-radova-troskovnik and others.
- Bulgaria:
  - Sustainable Energy Development Agency – by request;
  - Energy Efficiency and Renewable Sources Fund – by request.
- Romania:
  - MDRAP (Ministry of Regional Development , Public Administration and Europeean Founds)- The methodological framework for calculating optimal energy performance requirements minimum cost for buildings and envelope elements-standard costs buildings
- Serbia: In Serbia, cost data bases are not developed yet. There are some investigations and some research project working on that issue, but not publicly available

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4. Compilation of results and comparison of alternatives

As a conclusion – that should be basis of the management summary at the beginning of the report – all the findings, especially the economic results should be visualised. For this, the costs of the different alternatives, including the actual situation, should be compared.

The cost elements that should be visualised over a period of 30 years are:

- Heating costs
- Costs for electric energy
- Costs of financing (investment costs plus accumulated interest)

For the comparison and the creation of the graph a spreadsheet programm (Excel) can be used.

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5. ANNEX: Template for detailed analysis

Note - different colors of the used text indicate how to use the template:

Italic blue text: information for the energy auditor about the purpose of the section (can be deleted).

Grey text: individual information and specific results of the single building

Energy-Audit report

Building name e.g. School #11

object:	Building name e.g. School # 11
address:	Street, Nr
municipality:	Zip Code, Municipality
energy auditor:	Felix Geyer – eza!
date:	16.11.2016

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Content

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1. Initial Situation

Max. 1 page
Addressed to stakeholders, mayor, city council etc. – non technical experts
Information about the purpose and the motivation of this report

This introduction to should describe why and how the detailed report for the Energy Audit was done.

Where does the municipality start, what is the goal of the municipality?

Please name:

- *Energy action plans*
- *Existing renovation strategies*
- *Previous actions in the context of the municipal buildings*

Who was contracted for the energy audits?

What is the timeframe for the investigation?

List of used databases, references, resources etc.

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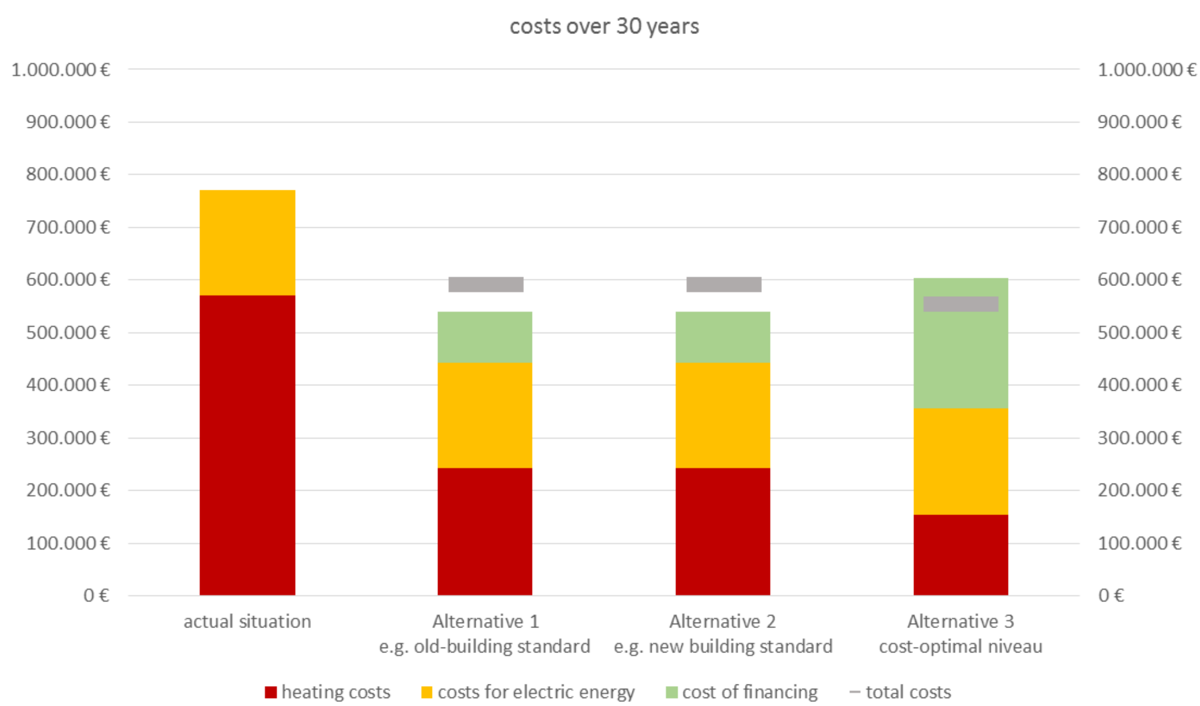
2. Summary

Max. 1 – 2 pages
Addressed to stakeholders, mayor, city council etc. – non-technical experts
Points out the most important results of the detailed building analysis and gives a clear recommendation and advice e.g. which measures or which set of measures should be implemented

This short and precise conclusion shall point out what are the main findings of the detailed analysis. What is the recommendation that the energy expert gives to the municipality? It should be clear for the non-expert what are the next steps? Why is this recommended? Please give reasons by naming benefits e.g. short payback-period, improved situation for the users of the building.



The graph shows the total costs over a period of 30 years. The costs for heat consumption (red) and consumption of electric energy (yellow), as well as the costs for financing the energy-saving measures (green). It compares the initial situation (left column) with the different renovation targets: minimum requirements (2^{nd}), new-building-standard (3^{rd}) and cost-optimal level (right) and also indicates the total costs (grey bar). In the total cost, the financing costs and other costs (cost that are necessary for the measure but are not related to energy savings).

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	actual situation	V1: min. requirements	V2: new-building standard	V3: cost effective
costs for heating	502.887 €	420.209 €	295.355 €	340.488 €
costs for electric energy	145.124 €	145.124 €	121.157 €	152.021 €
financing costs for energetic relevant costs	- €	14.850 €	202.320 €	135.600 €
Sum	**648.011 €**	**580.183 €**	**618.832 €**	**628.108 €**
annual costs (30a)	21.600 €	19.339 €	20.628 €	20.937 €
financing costs for the total costs		30.152 €	374.463 €	255.384 €
Sum (incl. Energy costs)	648.011 €	595.485 €	790.975 €	747.892 €
annual costs	21.600 €	19.850 €	26.366 €	24.930 €

At the end of this chapter, there should be an explanation which version is recommended by the energy auditor. There should be a clear explanatory statement – clear to understand for non-experts – why this particular alternative is prposed. This is the place to name the wider benefits, financial gains etc.

For the calculation of the profitability, the following parameters were used:

- energy price for heat XX €/kWh and for electric energy XX €/kWh
- annual price increase of energy prices X %
- interest rate X% retention period 30 years

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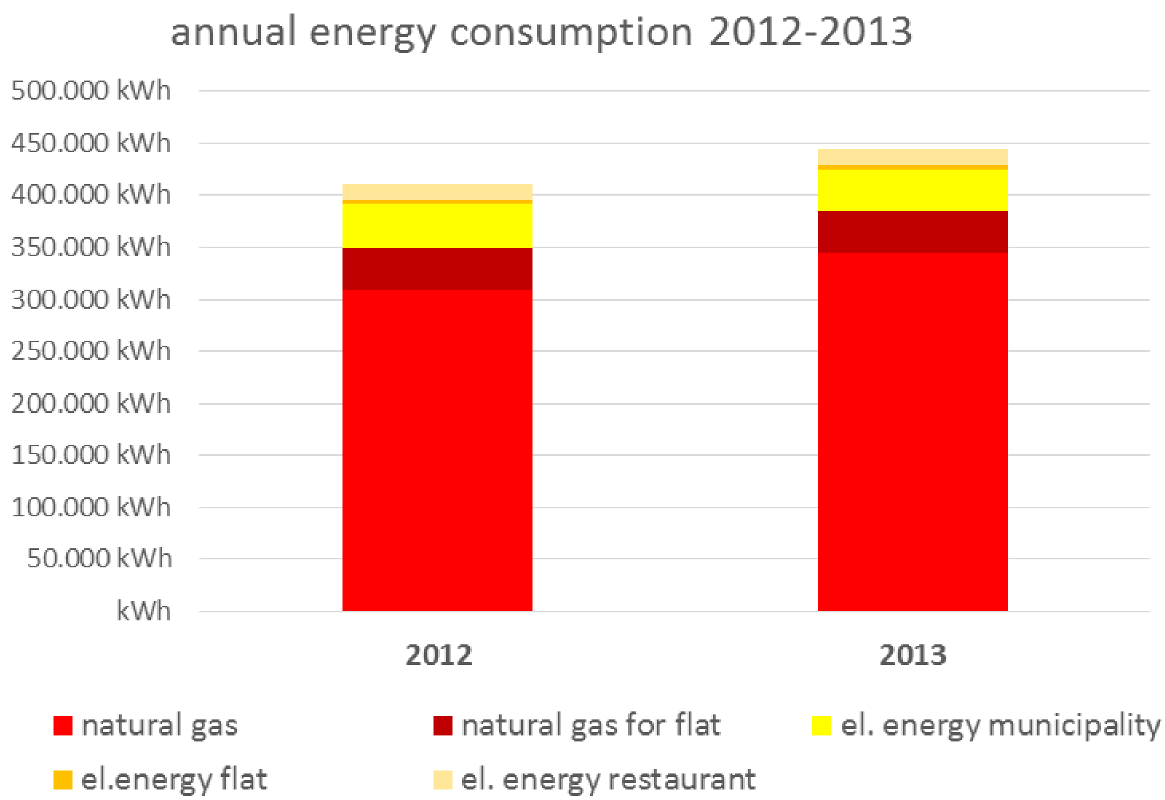
3. Energy consumption

Approx.. 1 page
for-technical experts
Analysis of the energy consumption; Based on Energy-Monitoring or on annual checks
Important in combination with the following chapter "5. Energy demand"



The annual consumption should be aggregated and displayed visually e.g. with a Excel-chart. The chart should be described and important points should be named e.g. as follows:

The annual end energy consumption of the building is around 420.000 kWh per year. The main share is natural gas – around 340.000 to 380.000 kWh per year are used for the heat generation of the building and the flat. Electric energy is used for the convention hall, the flat and in the restaurant. An amount of approx. 60.000 kWh is consumed per year.

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Specific energy consumption

2013	consumption	climate correction factor	consumption with climate correction
heat consumption	367.093 kWh	0,98	359.751 kWh
electric energy	60.330 kWh	-	-
water consumption	997 m^3	-	-
surface area conditioned	1.586 m^2		

Note:
Buildings may be underheated or may not be used according to their original purpose. The energy consumption should be normalized and adapted to the intended internal temperature of the building.

	specific value
heat consumption	231 kWh/m^2a
electric energy	38 kWh/m^2a
water consumption	629 $Liter/m^2a$
surface area conditioned	1.586 m^2

Benchmark

building category	reference value heat	reference value electricity
9100 convention halls	65 kWh/m^2a	20 kWh/m^2a
9140 festival hall	110 kWh/m^2a	40 kWh/m^2a
restaurant	205 kWh/m^2a	95 kWh/m^2a

The building is used for various and different purposes (festival hall and restaurant). The specific value for heat consumption of the existing building is significantly higher than existing buildings of the same category. The specific consumption of electric energy is within the range of the benchmark.

Source for the benchmark:
Bekanntmachung der Regeln für Energieverbrauchskennwerte und der Vergleichswerte im Nichtwohngebäudebestand; vom 30. Juli 2009

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4. Data collection

for-technical experts
Compilation and documentation of the building and the basis data that was used for the calculation of the energy demand of the building

component	description	U-value	energetic status	state of repair
base plate	concrete with floating screed	0,94 W/m²K	B	b
exterior walls	masonry with plaster	1,30 W/m²K	D	c
windows	wood frame 2-pane glazing	1,58–2,55 W/m²K	C-D	b
roof	roof with tiling	0,36 W/m²K	B	b-c
	platform roof	0,27 W/m²K	A	a-b
floor slab	wooden beams with packed bed	0,53 W/m²K	D	c

For explanation energetic status and repair status: see Annex

component	description
heating system	central heating system with 2 boilers
heat generation	2 x Viessmann Vitocrossal condensing boiler, build 2009 1x Viessmann Vitodens condensing boiler
energy carrier	natural gas
heat transfer	radiators
control and regulation system	central control unit for: Gaststätte, Duschen und Umkleiden, Vereinsräume, Gewichtheber, Saal/Foyer, RLT Gaststätte, RLT Dusche, Kegelbahn
hot water generation	decentrallised central with boiler
ventilation	windows and ventilation systems: - gym (inlet and exhaut air, heating register) - sanitary rooms (inlet and exhaust air, no heat recuperation) - restaurant (inlet and exhaust air, heat recuperation) - kitchen (inlet air with heating register, exhaust air for stove)
lighting system	luminescent screen tubes

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5. Energy demand

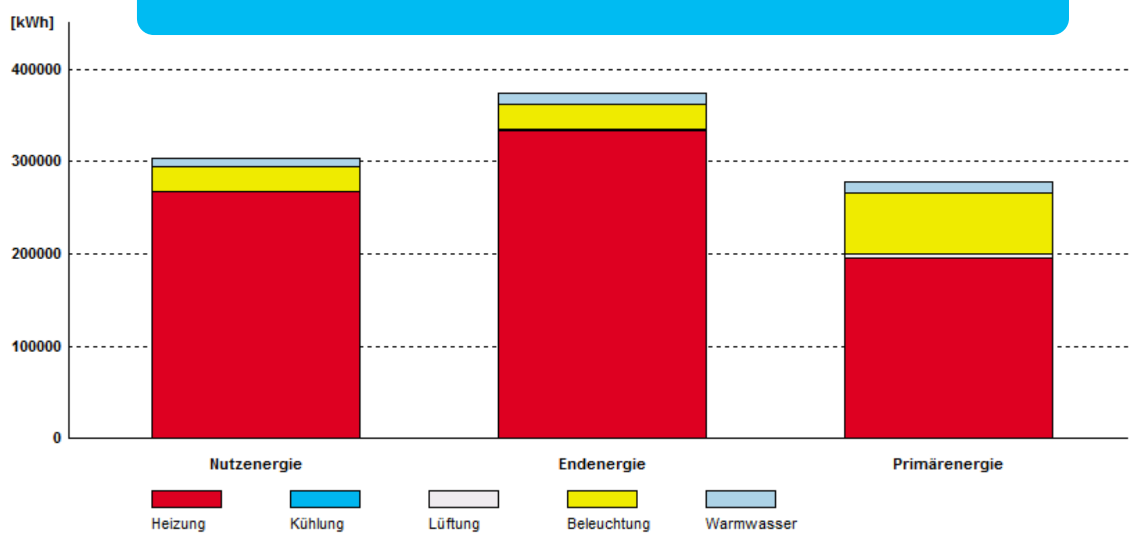
For technical experts
Displays the results of the calculation of the energy balance of the building. Indicates the relation between the different uses of energy (heating, ventilation, cooling, lighting) and gives an impression about the efficiency of the technical infrastructure (ration between net energy and end energy) and the environmental impact by the indication of the primary energy (related to CO2-emissions)-

The following graph shows the calculated energy balance of the building:

Energy balance

	Gesamt [kWh/a] [kWh/(m²a)]	Heizung [kWh/a] [kWh/(m²a)]	Kühlung [kWh/a] [kWh/(m²a)]	Lüftung [kWh/a] [kWh/(m²a)]	Beleuchtung [kWh/a] [kWh/(m²a)]	Warmwasser [kWh/a] [kWh/(m²a)]
Nutzenergie	303405	266878	0	0	27527	9000
	156,72	137,85	0	0	14,22	4,65
Endenergie	374307	332814	0	1740	27527	12226
	193,34	171,91	0	0,90	14,22	6,32
Primärenergie	278025	195524	0	4176	66065	12259
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6,33

Please replace by indidvual graphic



The calculated net energy demand is 303.405 kWh per year in total for heating ,lighting and hot water generation. The annual end energy demand is 374.307 kWh. The heat is generated with a condensing boiler with natural gas.

Note: Documentation and explanation of the changes in the calculation – if meanderings from the "official" norms and framework is necessary.

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6. Comparison of energy demand and consumption

In this section, the energy consumption and the calculated energy demand for heating are compared:

end energy	energy consumption	energy demand (calculated)	ratio
heat	384.955 kWh	332.814 kWh	115%

For the calculation of measures, deviating to norms and regulations, the parameters were adjusted to better match the energy consumption with the calculated energy demand. The changes in the calculation method are documented as follows:

	norm-parameters	applied parameters
area / zone: Technic	surface area [m²]	109 m²
days of use	250 days/a; 5 day per week	250 days/a; 5 days per week
daily hours of use	11 h/d	11 h/d
internal temperature	non-heated zone	non-heated zone
area / zone: gym	surface area [m²]	165 m²
days of use	250 days/a; 5 days per week	200 days/a; 4 days per week
daily hours of use	15 h/d	4 h/d
internal temperature	21°C	18°C
…		

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7. Measures

a. Exterior walls

For each measure, a description of the existing structure or technical facility should be provided. What are the layers of the part of the building envelope, U-value, problems, weaknesses, state of repair, need for improvement etc.

Actual status and construction:
The main building was erected in the year 1936, an annex was built 1985-87. The exterior walls of the town hall are of solid masonry with a gross density of 1.000 kg/m³. The walls of the annex are constructed with vertically perforated bricks with a gross density of 700 kg/m³. The thermal insulation is according to the year of construction, the plaster of the building needs maintenance. A new painting is suggested within the next 2 years. With the renovation measure, a thermal insulation could be put into place.

Review / appraisal
The energetic performance of the exterior walls is low. The actual minimal legal requirements (R=1,20 W/mK) is achieved. Structural damages are not visible.

U-values:

Exterior walls	U-value = 1,30 W/m²K
minimum requirement:	U-value $_{max}$ = 0,24 W/m²K
passive house:	U-value < 0,15 W/m²K

Proposed measure
To meet the minimum requirements of U=0,24 W/m²K, an insulation of the walls with a thickness of 12,0 cm (with a thermal conductivity of 0,035) is necessary. To reach passive house standard, an insulation of 22,0cm (with a thermal conductivity of 0,035) is necessary. With the insulation, a saving of 5% respectively 7% is achieved.

savings	%	end energy	CO_2-emissions
insulation of exterior walls minimum requirements 12,0cm WLG 035	5%	10.307 kWh/a	2,3 to/a
insulation of exterior walls passive house-standard 22,0cm WLG 035	7%	13.705 kWh/a	3,0 to/a

At the end of each section / measure, please add comments what has to be taken into consideration

The roof overhang is very small. When additional insulation is attached, the roof overhang has to be enlarged. The plaster of the walls is defective on the outside, there are cavities and stains. The reason for this might be humidity inside the walls. Before the walls are insulated, the source of the humidity should be eliminated.

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Description of further measures, analogue to the previous example

b. **Windows**.
c. **Roof**
d. **Base plate**
e. **Technical infrastructure**

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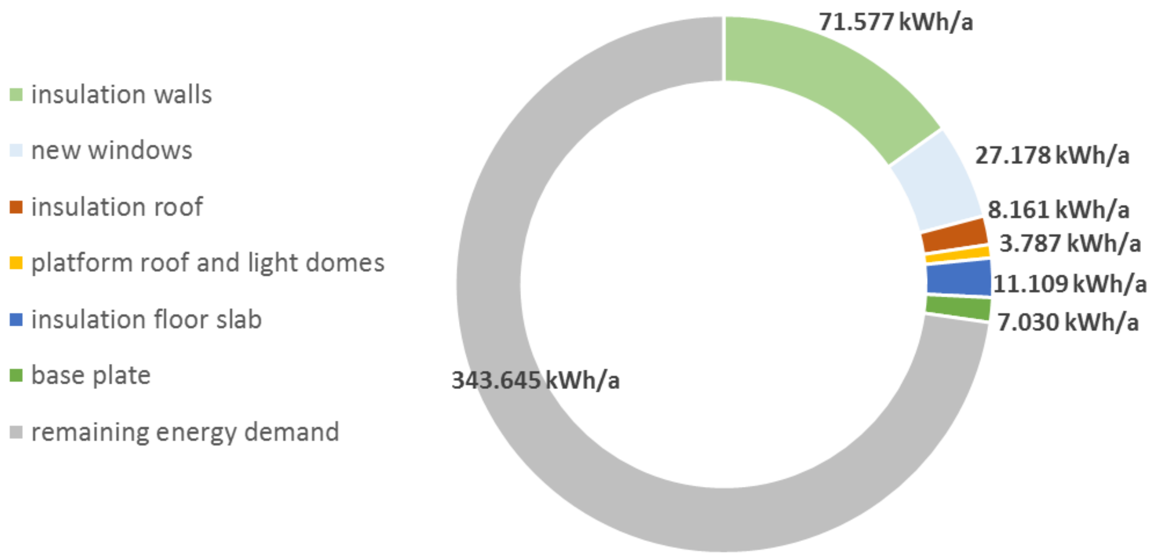
8. Overview measures

Visual compilation of the results of the measures for the building envelope and the technical infrastructure. This displays the savings per measure and the savings that can be achieved if all measures are implemented.



measure	savings end energy		CO_2
insulation of exterior walls	15%	71.577 kWh/a	15,9
new windows	6%	27.178 kWh/a	5,9
insulation roof	2%	8.161 kWh/a	1,8
platform roof and light domes	0%	3.787 kWh/a	0,5
insulation floor slab	2%	11.109 kWh/a	0,8
base plate	1%	7.030 kWh/a	1,6

With all analysed measures, the energy demand of the building could be reduced by 31%. With an renovation of the façade - insulation of the exterior walls and new windows – the energy demand can be reduced by 21%. With the insulation of the roof the floor slab and the base plate, the energy demand can be reduced by 5%. With all measures savings of 128.842 kWh per year can be achieved.

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9. Combination of measures

Alternative 1: minimum requirements
For a deep renovation, the following measures will be combined to reach a certain target of energetic status for the building:

- Installation of a new condensing boiler
- Hydraulic balancing of the heating system
- Installation of new heating circuit pumps

		max. value
primary energy demand	q_p = 379,73 kWh/m²a	426,49 kWh/m²a
max. u-value	0,35 W/m²K	0,49 W/m²K

		actual situation
end energy demand	156.918 kWh/a	188.882 kWh/a
savings	31.975 kWh/a	- 17%

primary energy demand	175.054 kWh/a	206.029 kWh/a
savings	30.975 kWh/a	-15%

		max. value
spec. end energy demand	273,0 kWh/m²a	328,7 kWh/m²a
spec. primary energy demand	304,4 kWh/m²a	358,5 kWh/m²a

Costs:

measure	amount	unit	price per unit	energet. relevant	total costs	total costs energet. relevant
installation of a new boiler	1	piece	13.700 €	9.042 €	13.700 €	9.042 €
hydraulic balancing	1	psch	5.000 €		5.000 €	
new pumps	2	piece	500 €/p	330 €/pc	1.000 €	660 €

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sum	19.700 €	9.702 €

The total costs for this set of measures are estimated at 19.700 €. The share of the total costs that are considered as energetic relevant are:

- 2/3 of the costs of the new boiler; the existing boiler is 15 years old and must be replaced in 5 to 10 years
- 2/3 of the costs of the new pumps; the existing pumps are 15 years old and must be replaced in 5 to 10 years

The hydraulic balancing is not considered as energetic relevant, for a hydraulic balancing of the heating system is required by existing laws and regulations and for this has to be done anyway.

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Economic parameters:

interest rate	3,0%
retention period	30 years
annuity factor	0,051
annuity of energetic relevant costs	495 €
annuity of total costs	1.005 €
annual cost savings	865 €
annual energy savings	31.975 kWh
price per kWh	0,03 € / kWh

Alternative 2: passive house standard

Description analogue to Alternative 1

Alternative 3: cost optimal level

Description analogue to Alternative 1

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10.Annex

Energetic status and state of repair

energetic status	description
A+	no need for renovation
A	low demand for renovation, actual energetic requirements are fulfilled
B	moderate need for renovation potential for improvement
C	high demand for renovation, inefficient systems and components, high potential for improvement
D	absolutely essential demand for renovation

state of repair	description
a+	good as new
a	good condition, no need for repairs in the next years
b	medium range, frequent repairs necessary
c	bad condition, components or technical infrastructure in need of renovation, immediate need for repairs
d	components or technical infrastructure defect, end of life-cycle

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