The most suitable renovation package selected for each Pilot Site

D2.3

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Executive summary

This report contains the selection of the most suitable renovation package for the DREEAM Project, in order to come up with the most appropriate technical option, according to the following indicators:

- Energy consumption: Primary energy savings.
- Economic: Investment, economic savings and return of the investment.
- Environmental: reduction of carbon dioxide emissions.

The renovation concepts developed in the task 2.2 have been presented to each building owner, who has decided, with the help of internal technical experts, which one of all the packages is the most suitable.

The reasons why a renovation package has been selected between all the concepts proposed have been clearly explained.

The selected option for each Pilot Site is:

- **Treviso**: the selected **Concept 1** reaches energy savings of **85 %**.
- **Padiham**: for the electric dwellings, the selected **Concept 5** reaches energy savings of **72 %** and for the electric & gas dwellings, the **Concept 6** reaches a **70 %**.
- **Berlin**: the selected **Concept 1** reaches energy savings of **42 %**.

Once the preferred renovation package has been selected, it will be developed in the next task: T2.4 Elaborated renovation packages

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Padiham (UK)

Pilot site

1 Summary of the renovation concepts for Padiham

The following table represents the results obtained in the definition of renovation packages for Padiham according to the energy, economic and environmental indicators, that have been presented to the building owners.

The table contains the results from the two scenarios calculated in the Task 2.2: analysis 1 focusing in the envelope renovation and analysis 2 considering the maximal PV system possible.

Renovation package	Description	Energy savings	Economic savings (€)	Investment (€)	Payback (years)	CO2 reduction (tCO2eq)
Concept 1 elec/elec&gas*	Envelope: Wall insufflated + int. aerogel, roof , floor (when possible). 3-glz window Air-water heat pump + storage tank Mechanical extract ventilation Solar photovoltaic	90/88 % >100/>100 %	905,6/994 1.435/1.292	18.948/23.482 16.382/14.514	20,9/26,2 11,4/11,2	4,42/4,00 4,84/4,20
Concept 2 elec/elec&gas*	Envelope: Wall insufflated + int. aerogel, roof , floor (when possible). 3-glz window Condensing boiler + storage tank Mechanical extract ventilation Solar photovoltaic	75/75 % 85/87 %	923/995 1.210/1.320	19.494/25.121 14.745/21.907	21,1/25,3 12,2/16,6	3,39/2,88 3,12/3,22
Concept 3 Elec*	Envelope: Wall insufflated + int. aerogel, roof , floor (when possible). 3-glz window Night storage units Electric boiler for DHW Mechanical extract ventilation Solar photovoltaic	75 % 79 %	979 1.083	19.750 18.560	20,2 17,1	2,85 2,82
Concept 4 Elec*	Envelope: Wall insufflated + int. aerogel, roof , floor (when possible). 3-glz window Air-air heat pumps Electric boiler for DHW Mechanical extract ventilation Solar photovoltaic	75 % 81 %	975 860	18.787 11.698	19,3 13,1	3,40 2,96
Concept 5 elec	Envelope: External wall insulation, roof up to 300 mm insulation Night storage units Electric boiler for DHW Individual ventilation + heat recovery Solar photovoltaic: 3kWp	72 %	1.087	26.191	24,1	3,81
Concept 6 elec&gas	Envelope: External wall insulation, roof up to 300 mm insulation Condensing gas boiler Individual ventilation + heat recovery Solar photovoltaic: 3kWp	70 %	936	23.000	24,6	2,41

**Analysis 1 results*
Analysis 2 results

2 The most suitable renovation package for Padiham

After a deep analysis of the renovation packages proposed in the WP2, the building owner has decided to go through the **Concept 5** for the 100 % electric dwellings and **Concept 6** for the electric & gas dwellings.

Below, a clarification of why this concept have been selected:

- By insufflating the air cavity of the wall is a limited solution due to the existing thickness of the air camera. Therefore in this case, adding external insulation to the wall is the most effective action to reach the desired U-Value.
- Instead of the good properties of the aerogel as an insulation, the solution of internal aerogel is rejected because this solution reduces room area and increases the investment.
- The addiction of a thickness layer of insulation in the roof will reduce significantly the heating loses.
- For the case of 100 % electric dwellings, the solutions of air-water heat pump or condensing boiler require the installation of a pipe system which makes it more complicated in comparison with the substitution of the night storage units with more efficiency. Apart from this, it has the advantage of the lowest tariff during the night for the electricity.
- For the case of electric & gas dwellings, the current gas boiler has a low efficiency. The substitution of it for a condensing boiler makes it a very simple renovation measure, due to the advance of keeping the current pipes system. The good efficiency of the condensing boiler decreases the consumption of the heating system.
- The individual ventilation system is an ideal option in renovation when the available space is not to much. Therefore is not necessary to install a false ceiling. The consumption of the fan is lower than in a centralized system.
- The addiction of a solar photovoltaic system is a good combination with the night storage unit for the case of 100 % electric dwellings, which can storage the production of photovoltaic during the day. Due to the regulations in UK of the energy production by renewables, the export of energy to the grid is very cost-effective.
- The energy savings obtained despite of being lower than in the other concepts, are very close to the goal of 75 % from the current situation.
- Despite of the high payback of the concepts 5 and 6 compared with the others, the economic savings are very similar to them and in some cases even higher.
- The reduction of carbon dioxide emissions of the concept 5 is one of the highest.

Treviso (IT)

Pilot site

3 Summary of the renovation concepts for Treviso

The following table represents the results obtained in the definition of renovation packages for Treviso according to the energy, economic and environmental indicators, that have been presented to the building owners:

Renovation package	Description	Energy savings	Economic savings (€)	Investment (€)	Payback (years)	CO2 reduction (tCO2eq)
Concept 1	Envelope: EWI, aerogel, roof and floor. 3-glz window Condensing boiler + storage tank Mechanical ventilation + heat recovery Solar thermal (preheat water for the boiler) Photovoltaic	85 %	10.238	614.174	59,99	25,76
Concept 2a	Envelope: High envelope performance. Ventilated façade, roof and floor. 2-glz window Condensing boiler + storage tank Mechanical ventilation + heat recovery PV system in façade	88 %	10.965	605.799	55,25	26,39
Concept 2b	Envelope: Medium-high envelope performance. Ventilated façade, roof and floor. 2-glz window Condensing boiler + storage tank Mechanical ventilation + heat recovery PV system in façade	75 %	9.446	434.388	45,99	22,60
Concept 3	Envelope: EWI, aerogel, roof and floor. 3-glz window Mechanical ventilation + heat recovery Air-water heat pump	84 %	9.983	681.922	68,30	25,88

4 The most suitable renovation package for Treviso

After a deep analysis of the renovation packages proposed in the WP2, the building owner has decided to go through the **Concept 1**.

Below, a clarification of why this concept have been selected:

- The performance of the envelope is the highest of all the concept proposed. The addiction of aerogel to break the thermal bridges makes it very interesting for the building owners. Due to the high percentage of windows in the envelope, the solution of 3-glazed window reduces significantly the heating demand because windows are the element of the envelope with worst thermal resistivity.
- The current gas boiler has a low efficiency. The substitution of it for a condensing boiler makes it a very simple renovation measure, due to the advance of keeping the current pipes system. The good efficiency of the condensing boiler decreases the consumption of the heating system.
- All the concepts have the same ventilation system. Thanks to the heat recovery system the ventilation energy demand decreases significantly.
- The addiction of a solar thermal system is a good combination with the condensing boiler. The thermal installation preheats the water before it is conducted to the boiler. Therefore, the energy necessary to heat the water for the consumption will be less than take it directly from the cold water supply. The concept with photovoltaic in the façade (concept 2) is less effective due to the small wall surface of the building oriented to the south.
- The energy savings obtained fulfil the DREEAM approach reaching more than a 75 % of energy savings from the current situation.
- In spite of the bad payback period obtained due to the high prices from the Italian database, the economic energy savings are one of the highest from all the concepts proposed. With the concept 1, each dwelling will save around 570 € per year.
- The reduction of carbon dioxide emissions of the concept 1 is very similar to other concepts which similar energy savings (concept 2a and concept 3).

Berlin (GE)

Pilot site

5 Summary of the renovation concepts for Berlin

The following table represents the results obtained in the definition of renovation packages for Berlin according to the energy, economic and environmental indicators, that have been presented to the Berlin 1892:

Renovation package	Description	Energy savings	Economic savings (€)	Investment (€)	Payback (years)	CO2 reduction (tCO2eq)
Concept 1	Envelope: roof and floor. 3-glz window (intermediate) No actions in the heating and DHW system Photovoltaic	42 %	38.843	2.426.633	> 25	72,1
Concept 2	Envelope: roof and floor. 3-glz window (Low) No actions in the heating and DHW system Photovoltaic	28 %	25.385	2.109.771	> 25	46,9
Concept 3	Envelope: roof and floor. 3-glz window External walls (high) No actions in the heating and DHW system Photovoltaic	61 %	57.977	4.136.654	> 25	103,9

6 The most suitable renovation package for Berlin

The deep analysis of the renovation packages proposed in the WP2, the building owner is confirmed to go through the **Concept 1**.

Below, a clarification of why this concept have been selected:

- The performance of the envelope is the adequate to reach savings in the heating demand. The current values of the external walls are very good that is not necessary to add insulation to them The low price of the energy for the district heating makes not necessary to improve the envelope in a deeper way.
- In all of the concepts is not considered the substitution of the district heating, which has high efficiency.
- The high price of the electricity compared with the district heating rewards the concepts with a higher photovoltaic system. This rules out Concept 2, which has the smallest PV installation.
- Instead of the higher energy savings for Concept 3, the investment necessary is two times higher than Concept 1.
- Concept 1 has bigger battery size. That means better performance of the system in case of high specific demands in short time.

7 Conclusions

The renovation packages presented to the Building Owners fulfil the DREEAM aim. These options of renovation achieves a high reduction of the primary energy of the building in a cost-efficient way, taking into account the implementation of renewable energy systems and the increment of the renovation scope to multiple buildings.

The criteria to select which of the proposed renovation options suits better for the Pilot Site is very subjective. There are many target parameters that can be considered while taking a decision of that type:

- To reach the maximum energy savings
- To reach the maximum economic savings
- To find the most economical solution
- To reduce the maximum emissions
- To benefit from Renewables
- To find the easiest and less tenant disturbing solution
- To solve indoor air quality issues
- Etc.

It is for this reason, that depending on the parameters that each Building Owner has set, their election will be the most appropriate for their interests even though some of the other options could be more attractive considering other indicators.

8 Annexes

1. T2.1 Berlin Pilot Site
2. T2.2 Berlin Pilot Site

8.1 T.2.1 Berlin Pilot Site

D2.1 Baseline description

Berlin (Germany) Pilot site

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Executive summary

This report summarizes the results obtained by Exeleria on 15th of January (2018) during the visit in the Pilot Site inBerlin (Germany), which are property of Berliner Bau- und Wohnungsgenossenschaft von 1892 eG, where a process of refurbishment will take place under the DREEAM project approach.

The study focuses on the data gathering of the current situation of the components of the building for a later analysis. The elements subjected to be analysed can be classified in:

- Passive components:
  - Thermographic analysis
  - U-Value analysis
  - Windows
- Active components
  - Heating and DHW production
  - Terminal units
  - Lighting

Some conclusions have been taken after the analysis of all the data obtained during the visit. Of this conclusions is extracted an overview of the most critical situations, from an energetic point of view.

The parameters gathered have been used in the DREEAM tool which calculates the energy consumption of the current situation and the energy savings obtained from the combination of the different renovation solutions from the SOTA list.

An analysis of sensitivity has been done using the parameters room temperature, U-Value and infiltration showing how a variation of them affects the energy consumption.

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1 Pilot Site overview

1.1 General Description

The purpose of the visit is to evaluate the baseline situation of the building providing the starting point for the renovation DREEAM approach.

This technical baseline will be focus on the gathering of information about:

- **Passive technologies:** The thermal properties of the walls, roof, etc. analysing in which conditions are they currently and the features of the windows.
- **Active technologies:** Identifying every component of the installation of the buildings including electrical parts, heating systems, storage and lighting among other things.

1.2 Buildings Description

The visit took place in the city of Berlin (Germany) in the buildings located between the streets Adolfstrasse and Pasewalker Str.

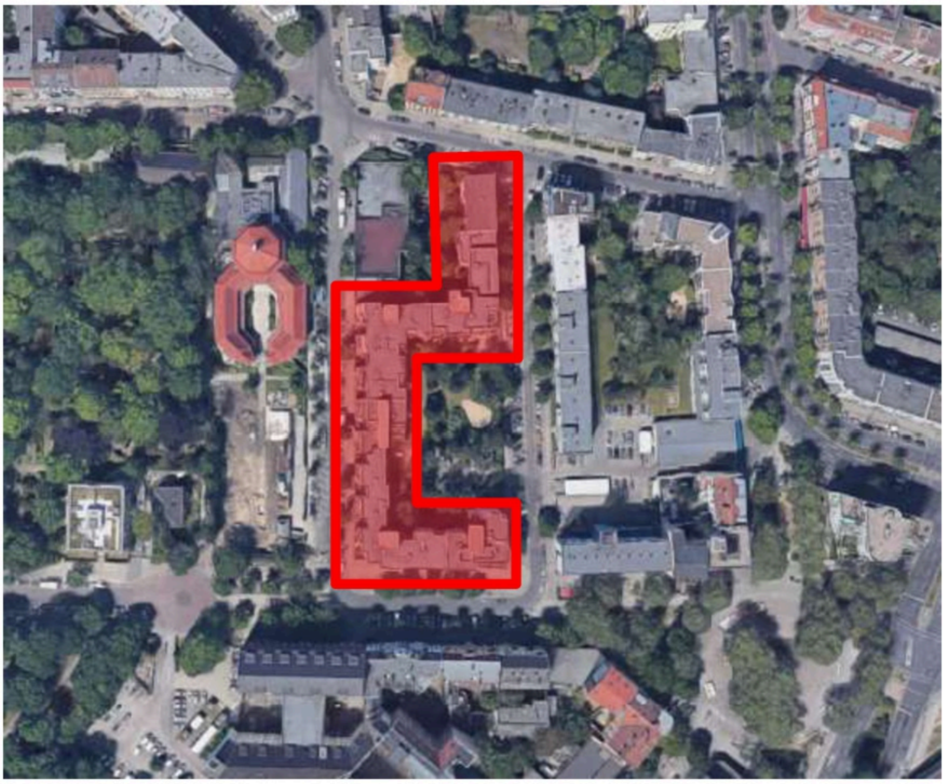


Figure 1 Aerial view of the pilot site

The pilot site is composed by the following buildings:

- Pasewalker Str.6
- Pasewalker Str.7
- Pasewalker Str.8
- Adolfstrasse 1
- Adolfstrasse 2
- Adolfstrasse 3

Figure 2 Adolfstrasse 1

Each building has ground floor, 5 or 6 floors of living spaces and a cellar in the basement. Most of the dwellings has a terrace.

Building	Living area m²
Pasewalker Str.6	854
Pasewalker Str.7	2.983
Pasewalker Str.8	2.106
Adolfstrasse 1	2.291
Adolfstrasse 2	2.069
Adolfstrasse 3	3.548
TOTAL	**13.851**

Figure 3 Building addresses

All the set of dwellings have different sizes with one or two rooms, a living room, a kitchen, a bathroom and in some cases also toilet. In the next figure it can be shown an example of one of the flats:

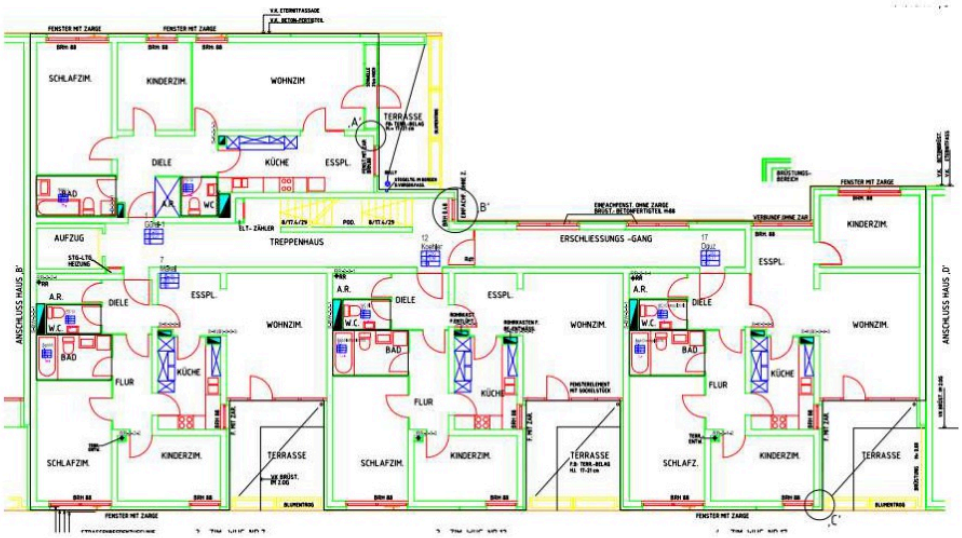


Figure 4 Floor plan of first floor of Adolfstr.2

The total amount of dwellings in all building is 160.

Building	Nº dwellings
Pasewalker Str.6	15
Pasewalker Str.7	29
Pasewalker Str.8	28
Adolfstrasse 1	25
Adolfstrasse 2	22
Adolfstrasse 3	41

1.3 BO requirements and objectives

To carry out the pilot visit, the collaboration of the building owners is required to facilitate to gather as much information as possible that can be used to make a deep analysis about the current situation of the building. For it, 1892 has made available the entry to different flats and technical rooms allowing to make a thermography analysis, to measure the thermal transmission of the passive components and to analyse the active components.

The main objective of the building owner about this visit is to have an understanding of the current situation of their properties. This information must cover the components of the building and the energy consumption of the social housing. It will consist be the first step of the renovation process.

1.4 Information needed

To perform the analysis of the building and compare the data obtained from the measurements it is necessary to have the construction plans which include every information about the typology, orientation, dimensions, components and details of the building.

1892 has provided all the construction drawings that allow Exeleria to get a deep study of the building.

This information includes:

- Building spaces Lay-out
- Energy Performance Certificates of the group of buildings
- Envelope components detailed description
- Dwelling - social statistics
- Energy consumptions of the central heating & DHW systems for the whole building

2 On site data gathering

2.1 Pasive components

2.1.1 Thermographic analysis

The detailed information related to the thermographic analysis could be found in the methodology document included in the annexes.

To carry out the thermographic analysis, a minimum thermal conditions for the difference of temperature between indoor-outdoor were necessary.

The temperature inside the building during the thermographic work ranged between 13 (non-heated rooms) and 18 °C (heated rooms). The temperature outside was between -1 and 1 ºC, which means a difference between 14 and 17 ºC.

After the thermographic analysis in the different parts of the building we can obtain the following conclusions:

There are generally no important thermal bridges in the dwellings. The joint between the window and the wall shows that there is a small thermal bridge. This is something very typical in windows due to the contact between the inside and the outside part of the frame and its properties.

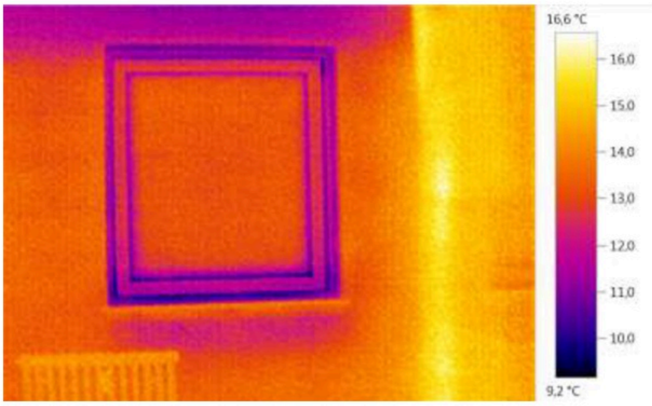


Figure 5 Thermal image of the window

In the following photo, it is observed that this difference between the sealing (10 ºC) and the wall (12 ºC) is around 2 ºC:

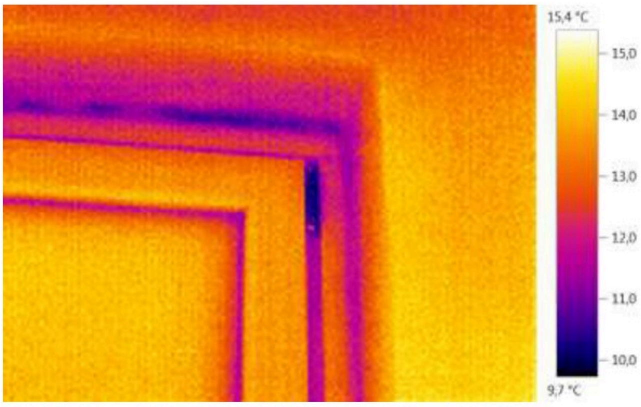


Figure 6 Thermal image of the sealing

However, in this case under the window we observe a discontinuity in the thermal properties of the wall. We can analyse the horizontal line in more detail:

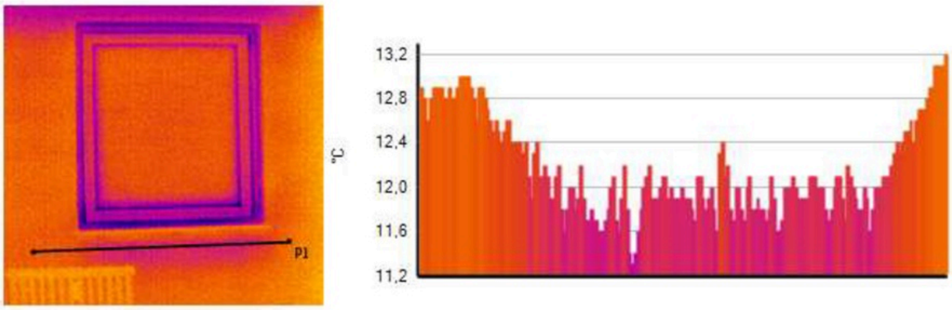


Figure 7 Thermal bridge of the wall under the window

The part of the wall under the window represent around one degree less than the rest of the wall. That could be produced by a loss of thermal properties of the insulation due to age of construction.

Another example of this situation can be observed in the following wall, where there is a discontinuity in the diagram of temperatures of the horizontal line represented:

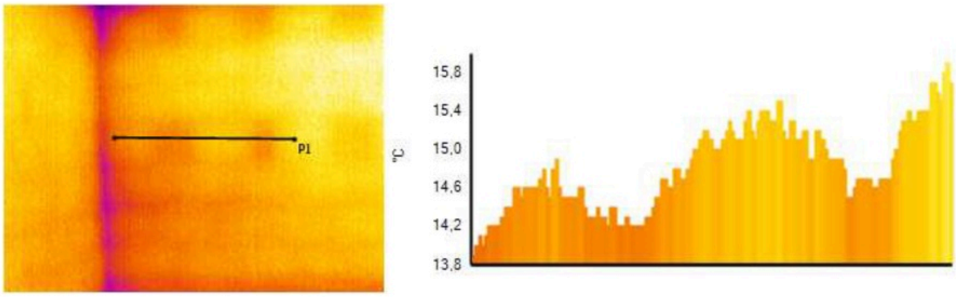


Figure 8 Thermal image of a wall

Other typical thermal bridges in construction have been found, as for example in corners between walls and roof:

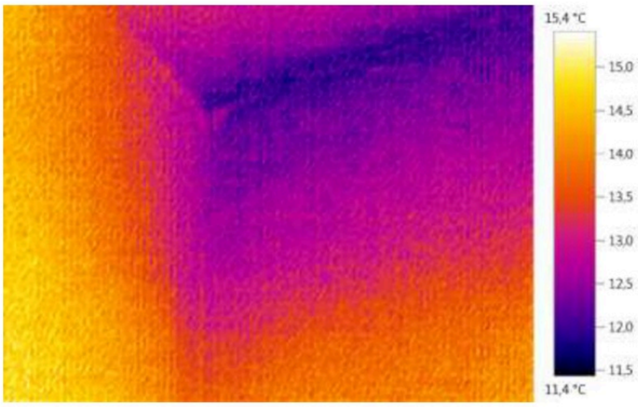


Figure 9 Thermal between walls and roof

As it can be seen in the photo below, the joint between the wall and the roof is at 12 ºC while the contour is one degree more and the rest of the wall is at 14,5 ºC.

In the dwelling where the themographic anlaysis has been made there is no presence of moistures or other similar problems.

Apart from the components of the envelope, the components of the heating system have been also analysed. There are no significant pipe loses in the heating distribution through the radiators and the hot water is correctly circulated though the device:

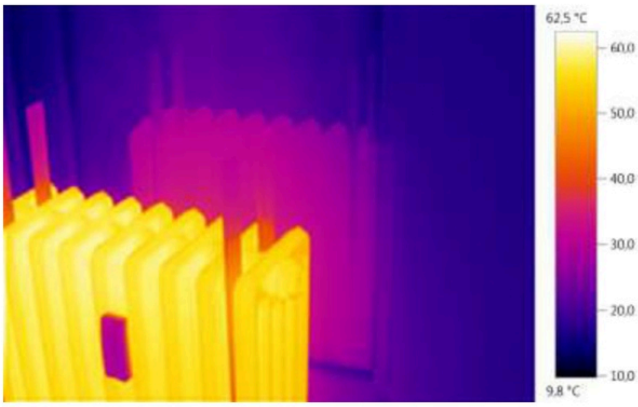


Figure 10 Thermal image of a radiator

In the photo can be observed that the radiator has a constant temperature in all the points of 55 ºC approximately.

Generally, there is no presence of leaks of energy in the heating or significant differences in the envelope components. In the dwellings there are also no problems of moistures.

2.1.2 U-Value analysis

The detailed information related to the U-values analysis could be found in the methodology document included in the annexes.

To ensure the accuracy of the measurements the ideal conditions required are:

- Temperature difference (outdoor - indoor) of at least 15 ªC
- External surfaces un exposed to solar radiation

A representative batch within each pilot case based on construction features (num. of bedroom, orientation, m2...) is selected. The equipment for measuring U-values include heat flux meters, thermistor temperature probes and data-loggers.

For the analysis of the building envelope four components of it have been analysed and obtained the currently U-value of them.

The results obtained are:

Number	Component	U-Value obtained [W/m²K]	U-Value calculated [W/m²K]
1	Wall against exterior air (concrete)	0,503	0,55
2	Wall against exterior air (ventilated façade)	0,709	0,51
3	Roof over basement	1,106	1,18
4	Flat roof	0,464	0,50
5	Window	2,322	2,50

1. Wall against exterior air (concrete). This is the external wall composed with concrete in the external face. The results obtained are:

- Temperature difference: 19,42 ºC
- Solar radiation: Not influenced

Date	Time	U-Value [W/m²K]	Tw [ºC]	Ti [ºC]	Hr [%]	To [ºC]
15.01.2018	08:41:11	0,503	16,95	18,22	74,60	-1,20

The high U-Value obtained is very similar to the calculated.

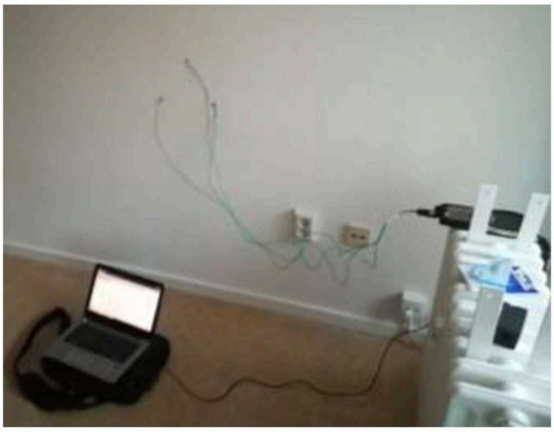


Figure 11 U-Value analysis of the wall

2. Wall against exterior air (ventilated facade). This is the external wall composed with air camera and fibre panel in the external face. The results obtained are:

- Temperature difference: 17,42 ºC
- Solar radiation: Not influenced

Date	Time	U-Value [W/m²K]	Tw [ºC]	Ti [ºC]	Hr [%]	To [ºC]
15.01.2018	09:39:24	0,709	15,82	17,42	69,50	0,20

The value obtained is a little bit higher than the calculated.

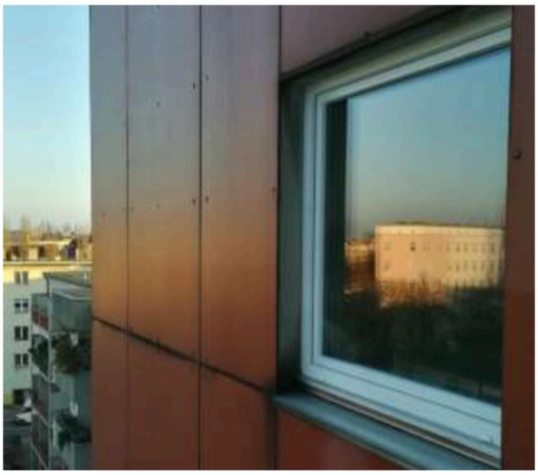


Figure 12 Ventilated facade

3. Roof over basement. This is the component between the cellar and the basement floor. The results obtained are:

- Temperature difference: 7,35 ºC
- Solar radiation: Not influenced

Date	Time	U-Value [W/m²K]	Tw [ºC]	Ti [ºC]	Hr [%]	To [ºC]
15.01.2018	11:30:35	1,106	21,49	20,45	32,10	13,10

The high U-Value obtained is very similar to the calculated.

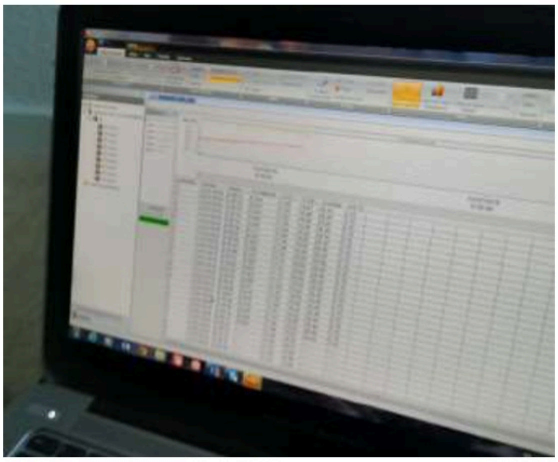


Figure 13 Software U-Value measurement

4. Flat roof. This is the roof of the building. The results obtained are:

- Temperature difference: 20,81 ºC
- Solar radiation: Not influenced

Date	Time	U-Value [W/m²K]	Tw [ºC]	Ti [ºC]	Hr [%]	To [ºC]
15.01.2018	09:01:02	0,464	18,24	19,51	75,60	-1,30

The high U-Value obtained is very similar to the calculated estimating 60 mm of insulation.

5. Window. This has been measured in one of the windows of the flat. The results obtained are:

- Temperature difference: 14,01 ºC
- Solar radiation: Not influenced

Date	Time	U-Value [W/m²K]	Tw [ºC]	Ti [ºC]	Hr [%]	To [ºC]
15.01.2018	10:12:01	2,322	9,61	13,61	66,60	0,40

The high U-Value obtained is very similar to the calculated.

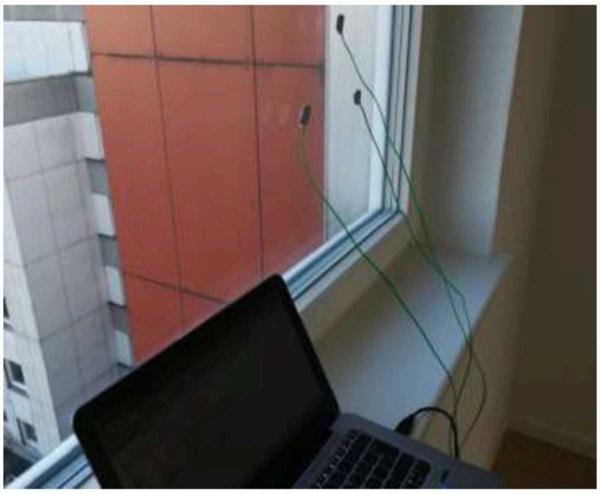


Figure 14 U-Value measurement of the window

dreeam

2.2 Active components

2.2.1 Heating & DHW production

For the heating and DHW production in the building a district heating system is used. This is a system for distributing heat generated in a centralized location for residential and commercial heating requirements such as space heating and water heating.

Vattenfall Europe Wärme AG Berlin is the provider of the district heating in the buildings, which is based in a 84,6 % of cogeneration.

A heat exchanger is required to provide in the building the heat from the system. In the following photos we can see the connections for the DHW:

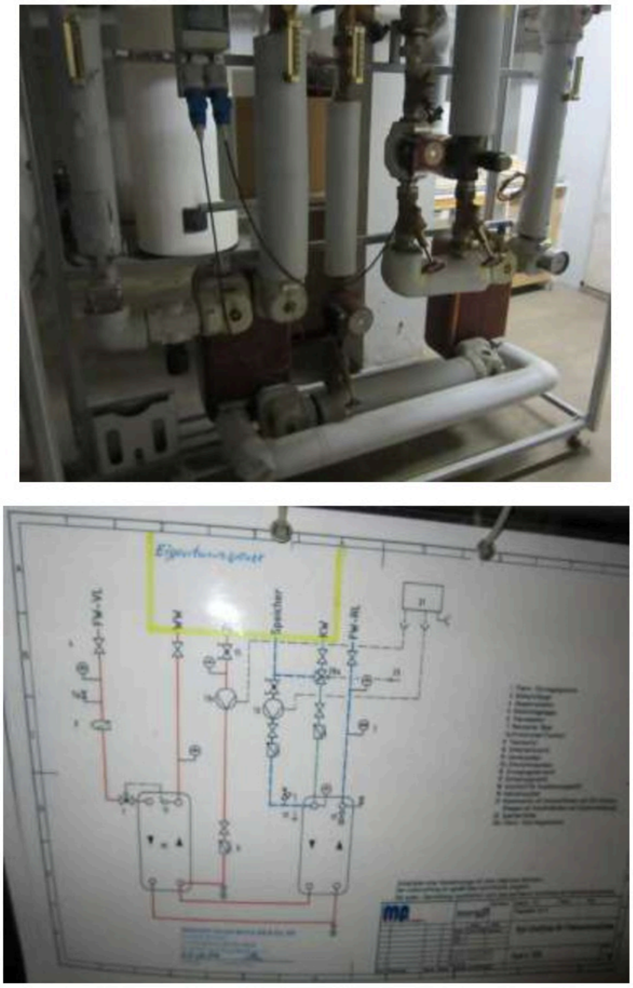


Figure 15 DHW installation

2.2.2 Terminal units

A terminal unit is the part of an installation which receives air or water from a centralized system acting on the conditions of a conditioned area.

The terminal units found in the building are:

- Radiators: Are the elements used in the building to transfer the heat generated by the district heating system There are one radiator per room and the dimensions of it depends on the area to be heated.

The radiator are made by molten steel:

Figure 16 Radiator

All radiators have a shut-off valve that can interrupt or allow the flow of water flowing through the radiator and also an individual meter, as we can see in the following photo:

Figure 17 Meter

2.2.3 Lighting

Room lighting can be general, punctual, ambient or decorative.

Depending on the lamp:

- Incandescent: a wire filament is heated to a high temperature, by passing an electric current through it. They have a very low efficiency (5%)
- Halogen: is an incandescent lamp that has a small amount of a halogen such as iodine or bromine added. They have a lifetime around 1.500 hours of use.
- Fluorescent: is a low pressure mercury-vapor gas-discharge lamp that uses fluorescence to produce visible light. They are more expensive than incandescent but they have more efficiency and life.
- Low consumption: are also fluorescent lamps adapted to the size, shape and stands of conventional bulbs. They are more expensive but easily to be depreciated with a lifetime between 6.000 and 9.000 hours.
- LED: it is a p–n junction diode, which emits light when activated. LED lamps have a very high efficiency (around 90%) Despite of its high price, they are the best option at long term.

The kind of lamps used in the building and it powers depends on the decision of the tenants. Generally the most used are:

- Incandescent: This kind of lamp is very common for the bedrooms and living-room with power range between 40 and 60 W.
- Halogen: There are some bedrooms with halogen lamps
- Fluorescent: This kind of lamp is used for the kitchen and toilets.

- Low consumption lamp: This kind of lamp is barely used in the building.

The consumption of lighting and appliances will be taken into consideration for the baseline analysis but not for the next steps due to the difficulty to establish energy savings measurements because of the variety and number of devices, the behaviour of the user, etc.

3 Simulation analysis

3.1 DREEAM tool

For the analysis of the current situation of the building, the DREEAM tool have been used. The main goals of this simulation are:

- To help to verify that the measured U-values and gathered building information are able to explain the current energy consumption.
- Sensitivity analysis of the different parameters, seeking for those parameters that have influence on energy consumption.
- Feasibility check: This model will be the starting point for the feasibility check to be developed later on.

3.1.1 Introduction

DREEAM tool is a software developed by Chalmers for the DREEAM Project which evaluates and provides decision support for building renovation strategies based on (Pareto-) balancing of energy supply and energy efficiency measures and addressing a building as part of a district rather than an individual stand-alone object

As part of the Task 2.1, the tool have been used to determine the current energy consumption of the buildings that make up the Pilot Site.

3.1.2 Input data

The introduction of the data in the tool can be divided in 3 steps:

- General information
- Passive components
- Active components

The multi-building scale approach of the DREEAM tool, allows the user to calculate the baseline analysis of the whole stock of buildings:

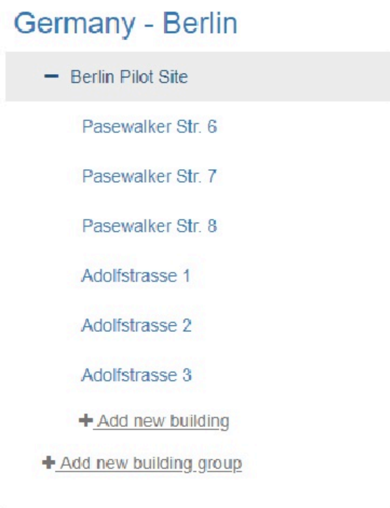
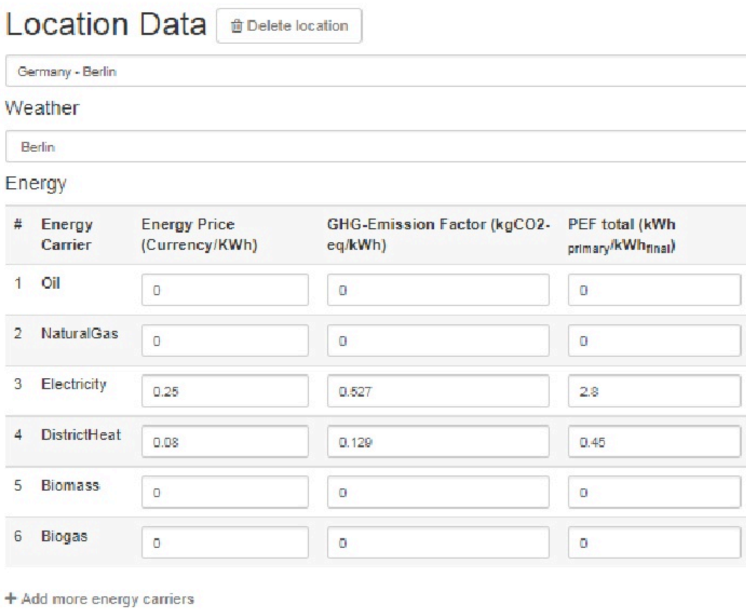


Figure 18 Building stock

For the building group can be selected at the beginning of the simulation the climatology and the energy data that will be used for the calculation:


Location Data Delete location

Germany - Berlin

Weather

Berlin

Energy

#	Energy Carrier	Energy Price (Currency/KWh)	GHG-Emission Factor (kgCO2-eq/kWh)	PEF total (kWh primary/kWh final)
1	Oil	0	0	0
2	NaturalGas	0	0	0
3	Electricity	0.25	0.527	2.8
4	DistrictHeat	0.08	0.129	0.45
5	Biomass	0	0	0
6	Biogas	0	0	0

+ Add more energy carriers

Figure 19 Weather and energy data

- General information –

The data includes the initial information of the building that are: indoor and water temperatures, electricity loads, schedules, dimensions of the building (sizes, area, volume) and occupancy.

Overview

Name	Pasewalker Str. 7
Street	Pasewalker Str. 7
Postcode/City	13347
Country	Germany
Year Of Construction	0

Indoor set temperatures

Heating (°C)	21
Cooling (°C)	0

Water

Cold water temperature (°C)	10
Hot water temperature (°C)	60
Hot water consumption (l / person / day)	28

Electricity

Electricity use from appliances (W / m^2)	5
Auxilary electricity use (W / m^2)	0

Thermal Mass

Building class	Medium
Effective mass area (m^2)	7837.5
Internal heat capacity (J / K)	517275000

Scheduled Data

Appliance use	Appliances Usage
Occupancy	Occupancy
Circulation schedule	100% Circulation
Ventilation	100% Ventilation
Hot water generation	100% HotWaterGeneration
Hotwater tapping	Hotwater Tapping - single person
Auxiliary electricity	100% Auxiliary Electricity
Lighting use	100% Lighting

Dimensions

Average room height (m)	2.8
Average height between stories (m)	0.5
Average building length (m)	39
Average building width (m)	25.6
Height of floor (m)	2.8
Number of floors above ground	6
Number of floors below ground	0
Heated floor area (m^2)	3135
Building volume (m^3)	9718.5

Occupancy

No. of dwelling units	29
No. of occupants	60
Average heat flow (W / person)	67

Figure 20 General data example Pasewalker Str. 7

- Passive components –

  They collect the information about the envelope of the building, which components have influence in the heating loses or gains during the whole year. These are floors, walls, roofs, windows and infiltrations:

Floors

#	Name	Area (m^2)	Orientation (°)	Angle (°)	U-value ($W/(m^2K)$)	b-Factor	Against
1	against cellar	480.1	0	0	1.1	0.8	Unheated
2	against air	145.6	0	0	0.6	1	OutsideAir

Walls

#	Name	Area (m^2)	Orientation (°)	Angle (°)	U-value ($W/(m^2K)$)	b-Factor	Against
1	Wall N	24.7	0	90	0.5	1	OutsideAir
2	Wall N	34	0	90	0.5	1	OutsideAir
3	Wall N (windows)	125.1	0	90	0.5	1	OutsideAir
4	Wall W (windows)	486.9	270	90	0.5	1	OutsideAir
5	Wall W	110.4	270	90	0.5	1	OutsideAir
6	Wall S	567.4	180	90	0.5	1	OutsideAir
7	Wall E	822.7	90	90	0.5	1	OutsideAir

Roofs

#	Name	Area (m^2)	Orientation (°)	Angle (°)	U-value ($W/(m^2K)$)	b-Factor	Against
1	Flat roof	588.7	0	0	0.5	1	OutsideAir
2	Roof terrace	37	0	0	0.5	1	OutsideAir

Windows

#	Name	Installed in	Area (m^2)	U-Value ($W/(m^2K)$)	G-Value	Frame Ratio	Shade Factor	Width (m)	Height (m)	Quantity
1	WN250/150	Wall N (windows)	45	2.3	0.8	0.2	0.9	2.5	1.5	12
2	WN125/150	Wall N (windows)	11.25	2.3	0.8	0.2	0.9	1.25	1.5	6
3	WW350/250	Wall W (windows)	43.75	2.3	0.8	0.2	0.9	3.5	2.5	5
4	WW125/150	Wall W (windows)	33.75	2.3	0.8	0.2	0.9	1.25	1.5	18
5	WW100/150	Wall W (windows)	9	2.3	0.8	0.2	0.9	1	1.5	6
6	WW250/150	Wall W (windows)	78.75	2.3	0.8	0.2	0.9	2.5	1.5	21
7	WS350/250	Wall S	253.75	2.3	0.8	0.2	0.9	3.5	2.5	29
8	WS130/150	Wall S	13.65	2.3	0.8	0.2	0.9	1.3	1.5	7
9	WS250/150	Wall S	15	2.3	0.8	0.2	0.9	2.5	1.5	4
10	WS150/250	Wall S	3.75	2.3	0.8	0.2	0.9	1.5	2.5	1
11	WS200/250	Wall S	5	2.3	0.8	0.2	0.9	2	2.5	1
12	WE125/150	Wall E	30	2.3	0.8	0.2	0.9	1.25	1.5	16
13	WE250/150	Wall E	37.5	2.3	0.8	0.2	0.9	2.5	1.5	10
14	WE350/250	Wall E	45	2.3	0.8	0.2	0.9	2.5	1.5	12

Ventilation

#	Name	Design Air Flow Rate (m^3/h)	Efficiency Heat Recovery (%)	Efficiency Sub-Soil Heat exchanger (%)	Specific Fan Power (Wh/m^3)	Maintenance Costs (Currency/year)	Additional Air Change Rate Infiltration (1/h)	Type
1	Ventilation	2400	0	0	0	0	0.5	Naturalventilation

Figure 21 Example of passive components

- Active components –

  These components are responsible of the energy production in the building. Is for that reason that are directly connected with the consumption. In this part we can find the heating systems, distribution of heating and domestic hot water, another sources of energy generation (photovoltaic or solar thermal) and mechanical ventilation:

Heating system

Heating system 1

Use for domestic hotwater distribution ☑

Use for space heating distribution ☑

Type	DistrictHeating
Description	
Selected energy carrier	DistrictHeat
Nominal power (kW)	275
Efficiency (%)	100
Maintenance costs (Currency/year)	0

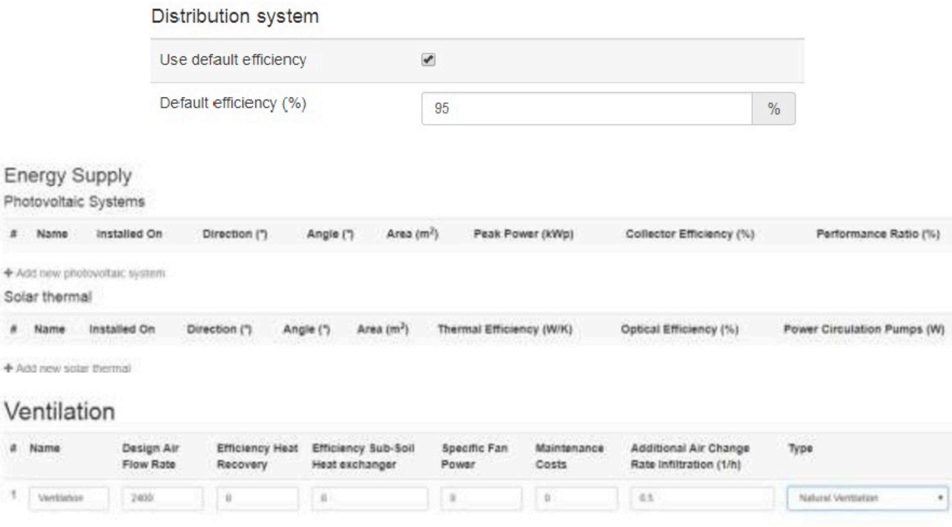


Figure 22 Example of active components

3.1.3 Simulation results

The following table represents the results obtained of the simulation of the Pilot Site in the DREEAM Tool for each building.

Building	[kWh/year]		
	Heating	DHW	Electricity
Pasewalker Str.6	86.301	16.936	8.321
Pasewalker Str.7	208.930	35.655	29.065
Pasewalker Str.8	163.641	31.198	20.524
Adolfstrasse 1	182.782	28.969	22.326
Adolfstrasse 2	190.884	29.415	20.157
Adolfstrasse 3	298.074	35.655	34.567
TOTAL	**1.130.612**	**177.828**	**134.960**

3.2 Analysis of sensitivity

After the simulation analysis with the DREEAM tool, the following parameters have been modified to see how they affect to the result of the consumption:

3.2.1 Room temperature

For the current analysis calculated before, it has been considered a room temperature of 21 ºC while heated. An increment and a decrease of 1 ºC on this temperature has been modified and checked the variation on the heating energy demand.

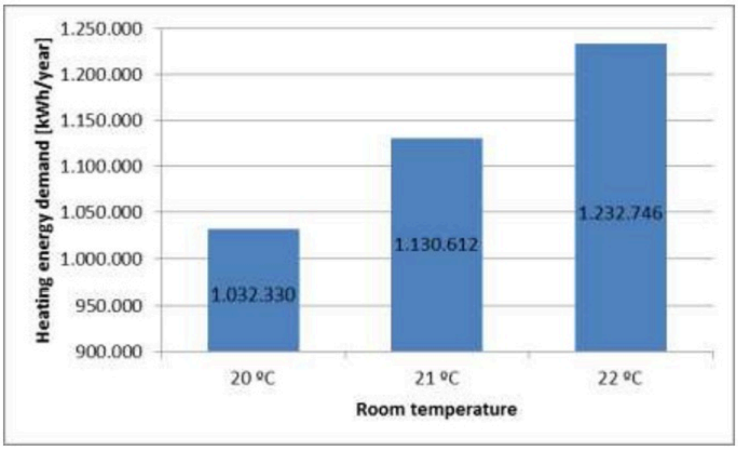


Figure 23 Heat energy demand in relation to room temperature

The variation in percentage produced is:

Temperature	Heating energy demand [kWh]
-1 ºC	-8,69 %
21 ºC	1.130.612
+1 ºC	+9,03 %

3.2.2 U-Value

In the following analysis the U-Values used in the simulation are compared with a deviation of 10% of them:

Component	Current values	Better values	Worse values
Floor	1,1	1,21	0,99
Wall	0,5	0,55	0,45
Roof	0,5	0,55	0,45
Window	2,3	2,53	2,07

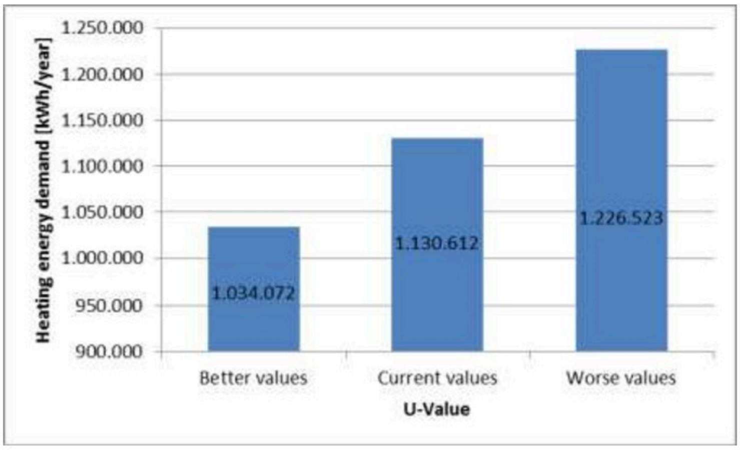


Figure 24 Heat energy demand in relation to the U-Value

The variation in percentage produced is:

U-Value	Heating energy demand [kWh]
Better values	-8,54 %
Current values	1.130.612
Worse values	+8,48 %

3.2.3 Ventilation

In the following analysis the ventilation rates used in the simulation are compared with a deviation of 10% of them:

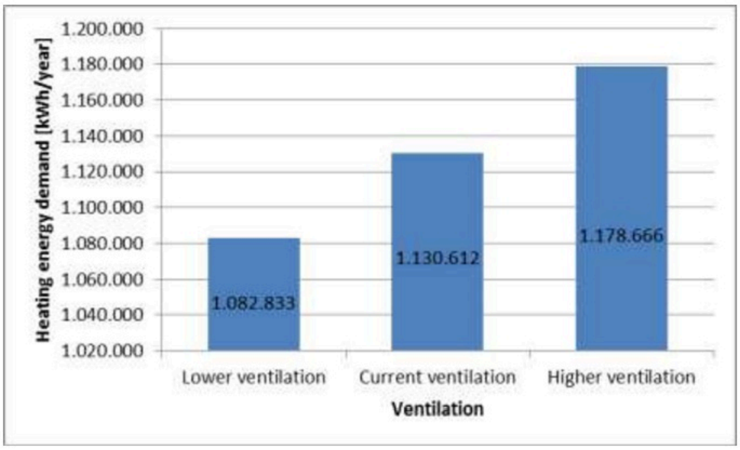


Figure 25 Heating energy demand in relation to the infiltration

The variation in percentage produced is:

U-Value	Heating energy demand [kWh]
Lower ventilation	-4,23 %
Current ventilation	1.130.612
Better ventilation	+4,25 %

3.2.4 Overview

Parameter	Heating energy demand [kWh]	Percentage
Temperature -1 ºC	1.032.330	-8,69 %
Temperature +1 ºC	1.232.746	+9,03 %
Better U-Values	1.034.072	-8,54 %
Worse U-Values	1.226.523	+8,48 %
Lower ventilation	1.082.833	-4,23 %
Higher ventilation	1.178.666	+4,25 %

4 Summary and conclusions

4.1 Passive Components

4.1.1 Thermographic analysis

From the thermographic analysis we can get the conclusion that generally, there is no presence of leaks of energy systems or significant differences in the envelope components. In addition, there is no presence of humidity in some dwellings.

In the thermography analysis made in the terminal units of the heating system can be seen that the distribution of hot water through the radiators is working properly.

Despite of this, there are areas where exist thermal bridges as for example in the joint between wall and ceiling (Figure 5) and in the joints between the window and the wall can be found small thermal bridges.

4.1.2 U-Value analysis

The detailed information about the composition of the envelope provided by Berlin 1892 was very useful to calculate in a theoretical method the values of the thermal properties, which can be compared with the results obtained in the U-value analysis measurement.

The results obtained in the measurement are in line with the values obtained by the calculation with the thermal properties and thickness of the components of the envelope, which implies the reliability of these values.

4.2 Active Components

4.2.1 Heating & DHW production

The district heating provides heating and DHW to the dwellings. This system provides high efficiency energy and low carbon footprints.

In addition to the ecological benefits, the great economic advantages of the efficient supply of energy through district heating projects also stand out. District heating installations are amortized in less than 10 years.

4.2.2 Terminal units

In the case of the radiators, the control of the heating depends on the user which can switch on or switch off it depending on their thermal comfort (not on the room temperature or the outside temperature). This system is not very efficient from an efficiency point of view.

As it can be seen in the thermographic analysis, the distribution of how water in the radiators is working correctly.

4.2.3 Lighting

There are installed a significant number of lamps that suppose a waste of energy comparing with the newest kind of lamps as LED or low consumption lamps. The use of lamps with a high nominal power in a dwelling increase significantly the power consumption considering the total amount and the number of hours they are working.

4.3 Simulation analysis

4.3.1 Results obtained

A comparison between the consumption obtained in the simulation and the real consumption obtained from the bills of the last 8 years have been made.

With this comparison can be determined the reliability of the values obtained in the DREEAM tool:

Energy system	Simulation [kWh/year]	Av .consumption [kWh/year]	Deviation
Heating	1.130.612	1.165.289	3,1 %
DHW	177.828	161.348	9,3 %
Lighting	134.960	115.801	14,2 %
TOTAL	**1.443.400**	**1.442.438**	**0,1 %**

The energy consumption obtained in the simulation is very similar to the energy bills of the last 8 years. All of the energy systems have a deviation less than 15 %, which implies that the simulation have been calibrated and represents the real consumption of the building.

4.3.2 Analysis of sensitivity

A sensitivity analysis has been done showing the influence of changes in the most relevant parameters.

- Room temperature

An increment or a decrease of 1 ºC on the room temperature produces a variation around 9 % in the heating energy demand. A temperature of 21 - 22 ºC during the day ensures a minimum of habitability conditions.

It can be considered that the temperature vary from one room to another. For example, in the bathroom can exceed this temperature to 23 °C and the rooms that are not usually used up to 18 °C.

To heat the building with a room temperature above 21 ºC implies a significant waste of energy.

- U-Value

The variation produced in the energy consumption having better U-Values shows the importance of having a good insulation system.

In this case, the variation of de properties of the envelope in a 10 % implies a reduction or increment of the heating demand in approximately 8,5 %.

- Ventilation

Through the analysis of the ventilation in the building, it can be shown that they have an important impact not only in the comfort of its users but also in the level of energy efficiency of the building. It is obvious that when the outside temperature is low, have an income of cold air inside the building increases the heating energy demand.

An increment in the ventilation rate produces a higher heating energy demand. For example the heating energy demand is increased a 4 % with an increment of 10 % in the ventilation.

8.2 T.2.2 Berlin Pilot Site

D2.2 Three renovation packages

Berlin (Germany) Pilot Site

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement no 680511. This document does not represent the opinion of the European Union, and the European Union is not responsible for any use that might be made of its content.

Executive summary

This report contains the methodology and steps used to design at least three renovation packages for the pilot site, that has been described previously in the baseline definition.

To carry out them, all the following elements have been taken into account:

- Baseline descriptions from Task 2.1
- Library of SOTA renovation options from WP1
- Innovative scan from WP1
- Requirements of building owner
- Knowledge and previous experiences of Exeleria, Chalmers and 3C-Pre

The three renovation packages proposed, following the DREEAM aim, should achieve a reduction of 75% of the primary energy of the building in a cost-efficient way, taking into account the implementation of renewable energy systems and the increment of the renovation scope to multiple buildings. The nZEB (nearly Zero-Energy Building) state of art boundaries have been applied in this task to reach the energy savings goals.

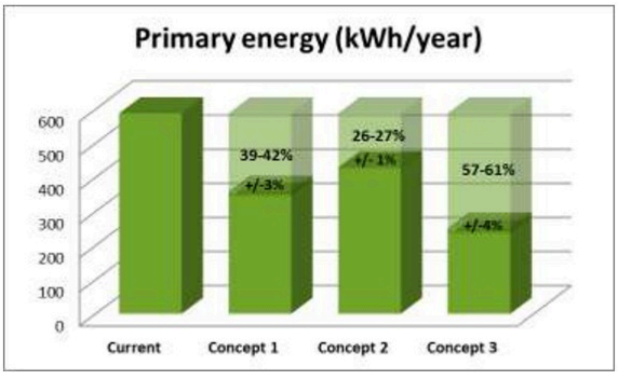
The results will be presented to the building owner, who will decide one concept between all the proposed.

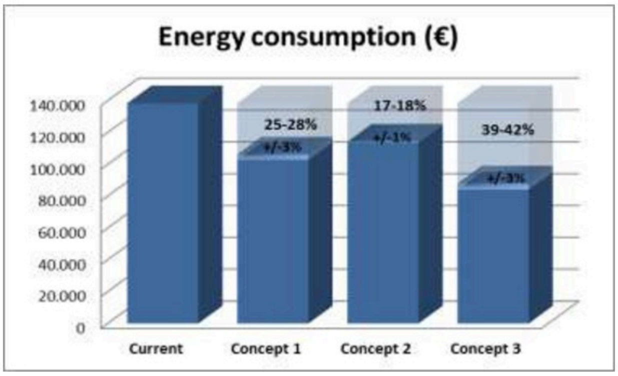
The results obtained are:

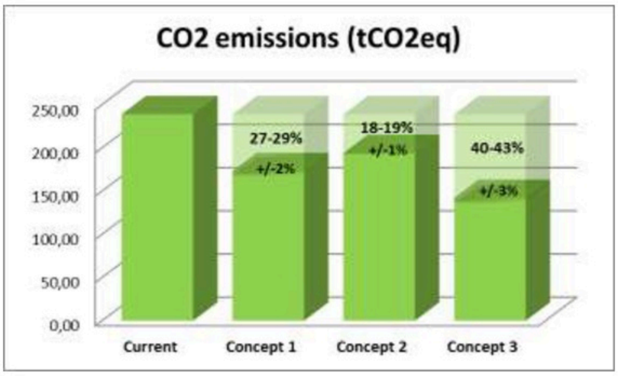
Berlin:

The renovation concepts proposed are focused in the improvement of the envelope and the implementation of a photovoltaic system as a source of renewable energy. The production of heating and DHW is made by a district heating system, which is not improved due to the high efficiency of it.

The three concepts are very similar in the solutions but varying the strength in the energy demand reduction. More detailed information of each concept can be found in section "renovation concepts".







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Berlin (GE)

Pilot site

1 Qualitative concept ideas (Berlin)

1.1 Introduction

During the Pilot Site visit in January, a meeting between Exeleria, Chalmers, RISE, SinCO2 and Berlin 1892 has taken place. On it, Berlin 1892 presented the idea of renovation measures that they want to implement in the pilot site.

The different solutions involve the following elements:

- Envelope:
  - Roof
  - Floor
  - Window
- Renewable energy

An analysis of the advantages, disadvantages and possible innovations has been made. To have an idea of the impact of every solution proposed exeleria has calculated how affect them to the primary energy in the pilot site using the same energy simulation tool as in the baseline analysis.

1.2 Design of the renovation concepts

Once the renovation package proposed by Berlin 1892 is analysed, the next step is to elaborate other two packages based in different scenarios: once scenario represent a lighter renovation than the proposed and other scenario with a dipper

The proposed renovation concepts have been designed based in the combination of the elements that Berlin 1892 are planning to renovate.

The 3 renovation concepts selected will be simulated in the DREEAM tool calculate the optimal solution and verify the energy savings. An extra analysis for the PV system has been made by Chalmers (see annex)

2 Assumptions (Berlin)

There are some factors to take into consideration when deciding to make an analysis of the renovation. These factors are: price of energy, primary energy factors and the emissions of carbon dioxide.

These factors vary in each pilot site due to many reasons like the market prices of the energy suppliers, government policies, the energy mix of the country which affects to the primary energy factor and the emission of carbon dioxide.

2.1 Price of energy

The dwellings are supplied by two different energy sources: electricity and district heating.

The prices of them have been obtained from the bills provided by the tenants, taking the most recently one:

- Electricity (day): 0,25 €/kWh
- District heating: 0,08 €/kWh

The tariffs for generation and export of the electricity generated by a renewable energy system is not considered in the proposed options due to the low profitability in the tariffs to export electricity to the grid in Germany.

2.2 Primary energy factors

The final energy only reflects the consumption. Therefore, it is necessary to convert it to primary energy which encompass the energy in its different steps that are: production, storage, transport and consumption.

These values, obtained by the providers, are:

- Electricity: 1,8
- District heating: 0,45

2.3 Carbon dioxide emission

The environmental aspect of the renovation it is focused in de carbon dioxide. Apart from the energy savings in a renovation is also important the reduction in the carbon dioxide emissions due to the reduction of the primary energy of the building.

These values, obtained by the providers, are:

- Electricity: 0,527 kgC02/kWh
- District heating: 0,129 kgC02/kWh

3 Renovation concepts (Berlin)

The renovation concepts proposed are focused in the improvement of the envelope both of the heating and domestic hot water efficiency. All of the concepts have mechanical ventilation system with heating recovery.

In the next section we can see a brief description of each concept:

3.1 Concept 1

- Envelope: For the roof over the basement 120 mm of mineral fibre. For the flat roof 240 mm of polystyrol. Triple-glazed windows. No actions are considered for the external wall.

  The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls	0,50	-
Ground floor	1,10	0,23
Roof	0,50	0,14
Windows	2,30	1,00

- Heating and DHW: No actions are considered due to the high efficiency of the district heating system.
- Ventilation: No mechanical ventilation systems with heating recovery are considered. Only the bathrooms are provided by a extraction ventilation system.
- Renewable energy: Solar photovoltaic system in the roof for the production of electricity. The installation it is composed by a total amount of 231 solar panels (378,84 m^2) and a storage system of batteries of 92 kWh. The annual production of the system is 74.676 kWh.

Figure 1 Solar panel

3.2 Concept 2

Concept 2, based in Concept 1, develops a lighter renovation acting in the same components but reducing the properties. Consequently this concept reaches less energy savings but with a lower investment.

- Envelope: For the roof over the basement 80 mm of mineral fibre. For the flat roof 180 mm of polystyrol. Triple-glazed windows. No actions are considered for the external wall.

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls	0,50	-
Ground floor	1,10	0,30
Roof	0,50	0,18
Windows	2,30	1,20

- Heating and DHW: No actions are considered due to the high efficiency of the district heating system.
- Ventilation: No mechanical ventilation systems with heating recovery are considered. Only the bathrooms are provided by a extraction ventilation system.

Figure 2 Extractor fan for bathrooms

- Renewable energy: Solar photovoltaic system in the roof for the production of electricity. The installation it is composed by a total amount of 148 solar panels (242,72 m^2) and a no storage system of batteries. The annual production of the system is 48.340 kWh.

3.3 Concept 3

Concept 3, based in Concept 1, develops a lighter renovation acting in the same components but reducing the properties. Consequently this concept reaches less energy savings but with a lower investment.

- Envelope: For the roof over the basement 160 mm of mineral fibre. For the flat roof 280 mm of polystyrol. Triple-glazed windows. External wall is improved with 100 mm of mineral fibre.

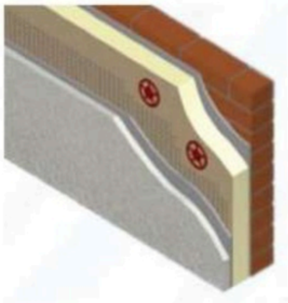

Figure 3 External wall insulation

The new U-Values obtained are:

Element	Current U-Value (W/m2K)	Proposed U-Value) (W/m2K)
External walls	0,50	0,21
Ground floor	1,10	0,19
Roof	0,50	0,12
Windows	2,30	1,20

- Heating and DHW: No actions are considered due to the high efficiency of the district heating system.

- Ventilation: No mechanical ventilation systems with heating recovery are considered. Only the bathrooms are provided by a extraction ventilation system.
- Renewable energy: Solar photovoltaic system in the roof for the production of electricity. The installation it is composed by a total amount of 301 solar panels (493,64 m^2) and a storage system of batteries of 39 kWh. The annual production of the system is 84.064 kWh.

4 Results (Berlin)

With the help of the simulation tool used in the baseline to analyse the energy consumption of the pilot site, all the renovation concepts proposed have been simulated in order to study the energy savings of each solution. An analysis of sensitivity has been made using the same procedure as in the baseline description with the parameters that can differ, resulting in different ranges.

4.1 Energy savings

The following tables reflect briefly the energy saving obtained:

Concept	Primary energy (kWh/year)		Primary energy savings
	Before	After	
Concept 1	588.775	339.944 - 358.721	39,1 - 42,3 %
Concept 2	588.775	426.972 - 430.852	26,8 - 27,5 %
Concept 3	588.775	229.580 – 250.756	57,4 – 61,0 %

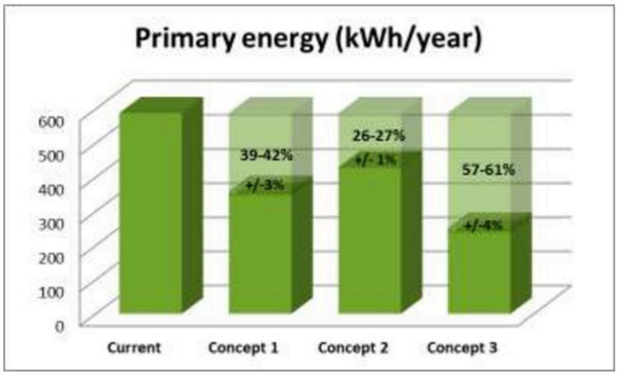

Figure 4 Primary energy overview

For the energy savings calculation, the consumption related to lighting and appliances have not been taken into account. To establish energy saving measures in this consumption is a tricky issue due to a factors like the high amount of devices, the variety of efficiency of the devices, the user's behaviour of them, etc. Therefore, it cannot be taken into account for the DREEAM Project.

4.1.1 Concept 1

Concept 1	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	1.130.612	884.306 - 926.034	508.775	397.938 - 416.715	18,1 - 21,8 %
DHW	177.828	177.828	80.023	80.023	0 %
PV	-	-76.676	-	-138.017	-
Total	1.308.440	985.458 - 1.027.168	588.798	339.944 - 358.721	39,1 - 42,3 %

4.1.2 Concept 2

Concept 2	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	1.130.612	964.358 - 972.981	508.775	433.961 - 437.841	13,9 – 14,7 %
DHW	177.828	177.828	80.023	80.023	0 %
PV	-	-48.340	-	-87.012	-
Total	1.308.440	1.1093.846 - 1.102.469	588.798	426.972 - 430.852	26,8 – 27,5 %

4.1.3 Concept 3

Concept 3	Final energy (kWh/year)		Primary energy (kWh/year)		Primary energy savings
	Before	After	Before	After	
Heating	1.130.612	668.605 – 715.664	508.775	300.872 – 322.049	36,7 – 40,9 %
DHW	177.828	177.828	80.023	80.023	0 %
PV	-	-84.064	-	-151.315	-
Total	1.308.440	762.369 – 809.428	588.798	229.580 – 250.756	57,4 – 61,0 %

4.2 Economic study

Another important aspect in a renovation is the economical one. The following tables reflect the amount of money saved and the investment necessary to implement each concept. With these two values, the payback period can be calculated to check the profitability of the investment.

Concept	Saved (€)	Investment (€)	Payback (years)
Concept 1	35.535 - 38.873	2.426.633	> 25
Concept 2	24.695 - 25.385	2.109.771	> 25
Concept 3	54.212 - 57.977	4.136.654	> 25

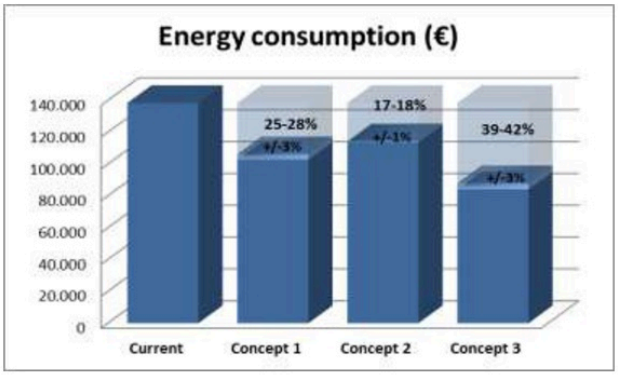

Figure 5 Economic savings overview

4.2.1 Concept 1

Item	Description	Cost/measure unit	Units	Total cost (€)
Roof	240 mm polystyrol	244,6 €/m2	3.033 m2	741.830
Floor	120 mm mineral fibre	92,0 €/m2	2.903 m2	267.073
Windows	1,0 W/m2K	438,8 €/m2	2.808 m2	1.231.821
PV	231 panels+bat	185.909 €	1	185.909
Total				**2.426.633**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
138.415	102.880 – 99.542	35.535 - 38.873	2.426.633	> 25

4.2.2 Concept 2

Item	Description	Cost/measure unit	Units	Total cost (€)
Roof	180 mm polystyrol	234,9 €/m2	3.033 m2	712.468
Floor	80 mm mineral fibre	72,7 €/m2	2.903 m2	211.046
Windows	1,2 W/m2K	394,8 €/m2	2.808 m2	1.108.429
PV	148 panels	77.828 €	1	77.828
Total				**2.109.771**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
138.415	113.030 – 113.720	24.695 - 25.385	2.109.771	> 25

4.2.3 Concept 3

Item	Description	Cost/measure unit	Units	Total cost (€)
Roof	280 mm polystyrol	248,7 €/m2	3.033 m2	754.266
Floor	160 mm mineral fibre	105,4 €/m2	2.903 m2	305.973
Windows	0,9 W/m2K	526,5 €/m2	2.808 m2	1.478.186
Ext. wall		131,8	10.720 m2	1.412.320
PV	301 panels+bat	185.909 €	1	185.909
Total				**4.136.654**

Before (€)	After (€)	Saved (€)	Investment (€)	Payback (years)
138.415	80.439 – 84.203	54.212 - 57.977	4.136.654	> 25

4.3 Environmental study

The purpose of this assessment is to identify the impact produced in the Environment by each renovation concept. For it, the equivalent carbon dioxide saved due to the application of each concept has been calculated:

Concept	Electricity	District heating	Total
	(tCO2eq)	(tCO2eq)	(tCO2eq)
Concept 1	40,4	26,3 – 31,7	66,8 – 72,1
Concept 2	25,4	20,3 – 21,4	45,8 – 46,9
Concept 3	44,3	53,5 – 59,6	97,8 – 103,9

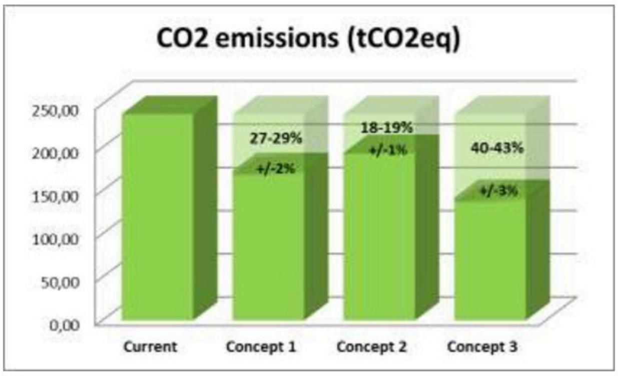

Figure 6 C02 emissions overview

5 Conclusions (Berlin)

In the results obtained we can see the impact in the energy consumption of the different measures in the envelope and in the production of electricity though the solar photovoltaic system.

An improvement in the envelope reduces the primary energy in small quantity, due to the high efficiency of the district heating system, which has a Primary Energy Factor of 0,45. Therefore, Concept 3, which compared with Concept 1 and 2 includes the renovation of the external walls, results less interesting in an economic point of view.

Apart of this, the price of the district heating is much cheaper than the electricity. That makes the implementation of a photovoltaic system necessary to reach important economic savings. The tariffs in Germany about exporting energy to the grid are not profitable compared with the storage of this energy. A deeper analysis of the PV system has been made by Chalmers (see annex).

All the concepts imply a good economic savings, between 150-350 €/year per dwelling and consequently a reduction of carbon dioxide emissions. Concept 3 obtains the highest reduction thanks to the production of the photovoltaic system. The reason of that is because the carbon dioxide emissions of the electricity is much higher than the district heating.

From an economic point of view, all the concepts present a payback higher than the standard. Therefore it should not only be considered the economic savings, but also the environmental and comfort of the tenants.

6 Annexes

1. PV analysis by Chalmers

INVESTIGATE THE ECONOMIC VIABILITY OF PV SYSTEM IN BERLIN: DIFFERENT SCENARIOS

Mohamad Karhseh
CHALMERS

Contents

List of Figures

Investigate the Economic Viability of PV System in Berlin: Different Scenarios

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Exclusive Summary

The current work reports the economic feasibility of utilizing PV system for electricity generation at the working conditions of Berlin. As can be seen in Figure 1, the report investigates mainly two different scenarios including:

1) The main scenario that was carried out based on the assumptions given by our partner (i.e., 1892) as follows: the size of the PV array and the battery were assumed 231 panels and 92 kWh, respectively. Based on the price was given by 1892, the total cost of such system is 186 k€. Consequently, the simulations aim, in addition to the determination the optimal direction of the panel, to calculate the figures of merit, which can be used to characterize the performance of the system.
2) The optimized scenario which was carried out to optimize the design of the PV system. The ambition of the optimized scenario is to define the optimal number of the panel, the size of the battery, and direction of the panels in which the economic viability of the system is maximized. To achieve this objective, the calculations were performed in two different settings. Firstly, the budget was assumed to be equal to the main scenario, i.e., 186 k€, and the objective of the optimization is to define the best distribution of the budget between the panels and the battery. Secondly, the budget was not specified, and the simulations aim to identify the optimal size of the system and the corresponding budget.

It is worth mention that because the lack of hourly electricity consumption data, annual electricity consumption of 2016, which was 140009 kWh, was assumed to be spread over the year in two different patterns. According to the first pattern, the consumption rate was considered constant over the years. This means the hourly electricity consumption rate is 15.98 kW. While in the second consumptions profile, the daytime consumption rate (8 Am to 8 PM) was assumed three times bigger than the nighttime consumption rate (from 8 PM to 8 AM). While from shading point of view, the simulations were performed for two different shading effect including 65% (as an

average of what was given by 1892), and 95% as I can safely assume based on the location and the hight of the building as compared to its surroundings.

To carry out the simulations, some assumptions were made, see Table 1.

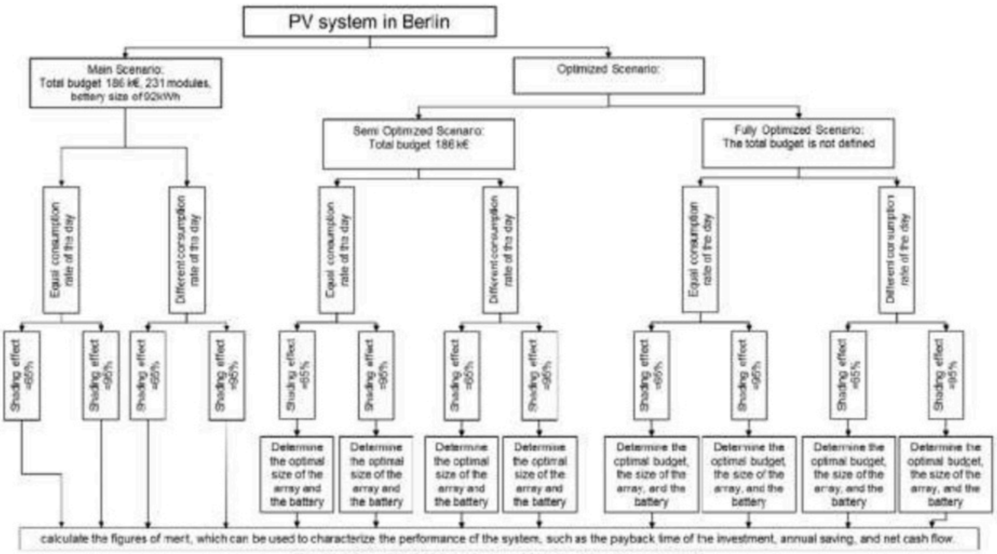

Figure 1. The flowchart of the current report

Table 1. Main assumption made in current work by our partner 1892.

Annual consumption	Electricity price	Panel brand	Battery brand
140 MWh	0.25 €/kWh	VITOVOL M300PA	Tesla PowerWall

Table 2. The summary of investigating the potential of PV in Berlin in for different scenarios.

		Budget [€]	Consumption pattern	Shading effect	array size [module]	battery size [kWh]	saving [%]	saving [€]	Payback time [year]	Dirction tilt	Dirction azimus
Main scenario	Fixed size of the array and battery	185909	constant	65%	231	92	37.6	13165	36,6	44	177
				95%			51	17904	19	53	180
			Varying	65%			38.2	13358	35,8	44	177
				95%			53	18669	17,9	44	177
Optimized Scenario	Fixed total budget		constant	65%	307	35	42	14798	22,1	49	179
				95%	257	73	51	17901	17,3	50	177
			Varying	65%	340	10	50	17571	16	47	178
				95%	301	39	60	21016	13,3	49	179
	Optimized budget	59343	constant	65%	113	0	19	6521	11,8	44	177
		51824		95%	98	0	23	8047	7,7	44	177
		107757	Varying	65%	205	0	34	11842	11,8	44	177
		77828		95%	148	0	35	12085	7,8	44	177

Detailed Results

The simulations were performed form two main scenario including main scenario and optimized scenario. The latter was split into two sub-scenarios. The semi optimized case, where the total budget was kept 186k€, and fully optimized case, where the budget was optimized as well.

1. **Main scenario:**

According to this scenario, the size of the array and the battery was assumed to be specified and equal to 231 modules and 92 kWh of battery size. As mentioned above, the main scenario was performed for different shading effects and different consumption profiles setting as follows.

1.1. Equal electricity consumption rate

The electricity consumption is assumed 15.98 kW and equals over the day. While the shading effect was considered to have two values.

1.1.1. The shading effect equals 65% of the effective area

The assumed shading value represents the average value of the shading effect that was given by our partner 1892. The simulation in this scenario was performed to optimize the direction and to calculate the figures of merit, which can be used to characterize the performance of the system, such as the payback time of the investment, annual saving, and net cash flow. Recall that this scenario was assumed based on the data were supplied by 1892 as follows. The total number of the module is 231 spread equally on seven buildings. Seven batteries are used for total size equals 92 kWh. The hourly electricity consumption rate is 15.98 kW. The calculations show that the first year net energy generation of the system is 52659 kWh, which corresponds to 38% of the annual electricity demand of the building and 13165 € as money saving of the electricity bill. The PBT of the investment is found to be <37 years. The optimal tilt and azimuth of the module are respectively 44 and 177 degrees.

It is worth mentioning that from the Figure 2, one can observe that the battery will never be full charger. In another word, the battery is oversized.

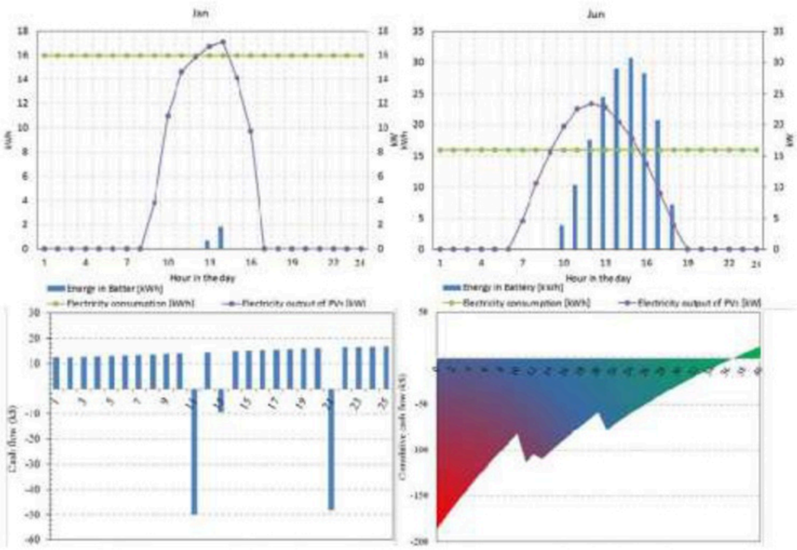

Figure 2. Energy and economic results of the PV system for the main scenario: Equal consumption rate and shading effect=65% of the effective area.

1.1.2. The shading effect equals 95% of the effective area

This value of shading effect was assumed based on the location of the building and its height as compared with its surroundings. The simulation in this scenario was performed to optimize the direction and to calculate the figures of merit, which can be used to characterize the performance of the system, such as the payback time of the investment, annual saving, and net cash flow. Recall that the total number of the module is 231 spread equally on seven buildings and seven batteries are used for total size equals 92 kWh. Similar to the previous case, the hourly electricity consumption rate is assumed to be constant and equals15.98 kW. The simulation shows that the first year net energy generation of the system is 71616 kWh, which corresponds to 51% of the annual electricity demand of the building and 17904 € money saving of the electricity bill. The PBT of the investment is found to be 19 years. The optimal tilt and azimuth angle of the modules are respectively 53 and 180 degrees.

Also, from the results, one can conclude that the battery is oversized, which can reduce the economic feasibility of the system.

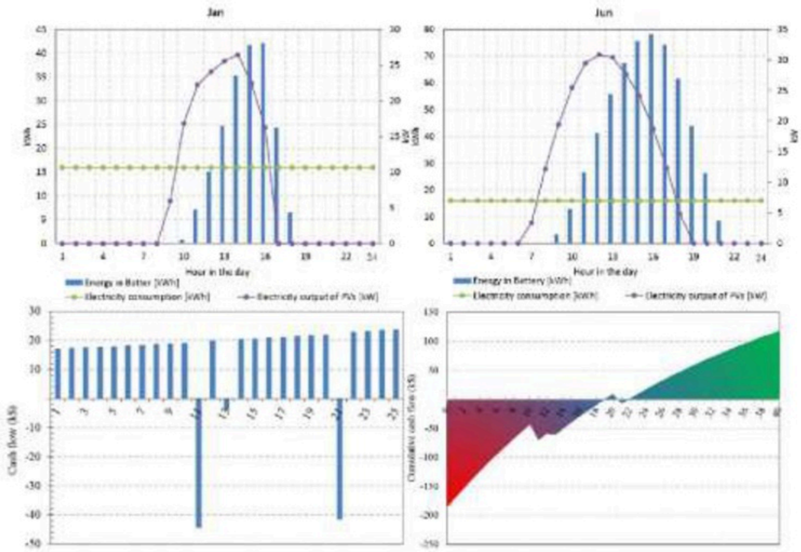

Figure 3. Energy and economic results of the PV system for the main scenario: Equal consumption rate and shading effect=95% of the effective area.

1.2. Different electricity consumption rate

In this scenario, the electricity consumption rate during daytime (from 8 AM to 8 PM) was assumed to be three times greater than the consumption rate during the night time. It is worth to mention that this assumption maintains the annual electricity consumption equals to the annual consumption of 2016. Also, the shading effect was assumed to have two values ass follows.

1.2.1. The shading effect equals 65% of the effective area

In this proposed scenario the shading effect assumed to be 65% of the active area of the module. The simulation shows that investing 185909 € in installing 231 modules, with a total size of the battery equals 92 kWh, results in the annual saving is 53433 kWh, namely 38% saving in electricity consumption that corresponds to 13358 € saving in electricity bill. The payback time of the investment is 35.8 years. The optimal tilt and azimuth angle of the modules are respectively 44 and 177 degrees. As an important conclusion from the results is that the battery is not required at all.

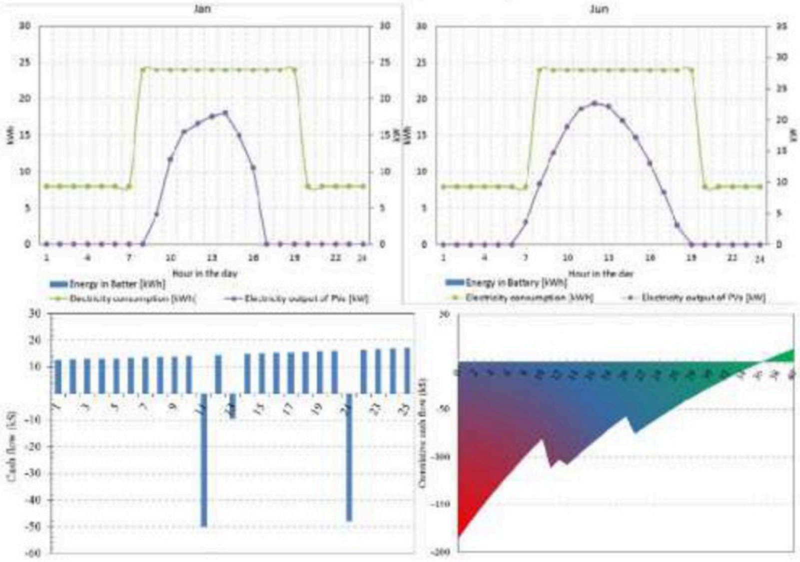

Figure 4. Energy and economic results of the PV system for the main scenario: Different consumption rate and shading effect=65% of the effective area.

1.2.2. The shading effect equals 95% of the effective area

In this case the simulation shows that installing 231 modules, with a total size of the battery equals 92 kWh, leads to 74675 kWh annual energy generation, which corresponds 53% of the electricity consumptions of the building as compared to the use of 2016. Assuming the electricity price 0.25 €/kWh, the achieved saving in this scenario equals 18669 € annual money. The payback time of the investment is 17.9 years, while the optimal tilt and azimuth angle of the modules are respectively 44 and 177 degrees. Again, it is evident from Figure 5 that the battery is oversized

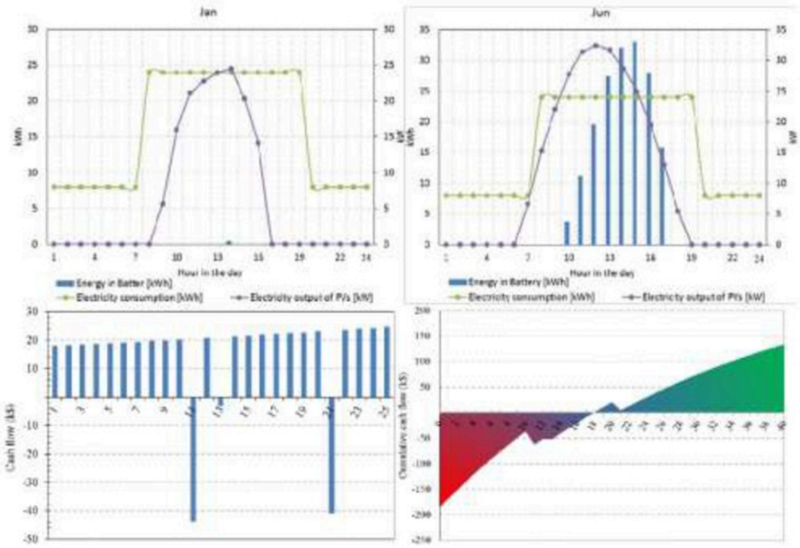

Figure 5. Energy and economic results of the PV system for the main scenario: Different consumption rate and shading effect=95% of the effective area.

2. Semi optimized scenario: Using the whole budget

As can be seen from above that the battery cannot be fully charged in some cases, which means that the battery is oversized. Therefore, the semi optimized scenario aims to determine the optimal design of the system in which the payback of the system is maximized. The front cost of the investment was assumed to be equal the main scenario, namely 185910 €. This means that the optimization process is aiming at defining the best distribution of the given budget among the PV panels and battery. This scenario was carried out for two different consumptions pattern and shading effect as follows.

2.1. Constant electricity consumption rate

The consumption rate was assumed to be constant over the year and equal 15.98 kW, while the shading effect has two levels as follows.

2.1.1. The shading effect equals 65% of the effective area

As mentioned, the total cost of the system is kept 185909 €. The optimization simulation results in 307 modules and the battery size is 35 kWh that corresponds to 3 connected batteries. The payback time of the investment is 22.1 years while the annual saving is 59191 kWh which corresponds to 42% of the electricity consumptions of the building as compared to the use of 2016. Assuming the electricity price 0.25 €/kWh, the achieved annual money saving in this scenario equals 4798 €. The optimal tilt and azimuth angle of the modules are respectively 49 and 179 degrees.

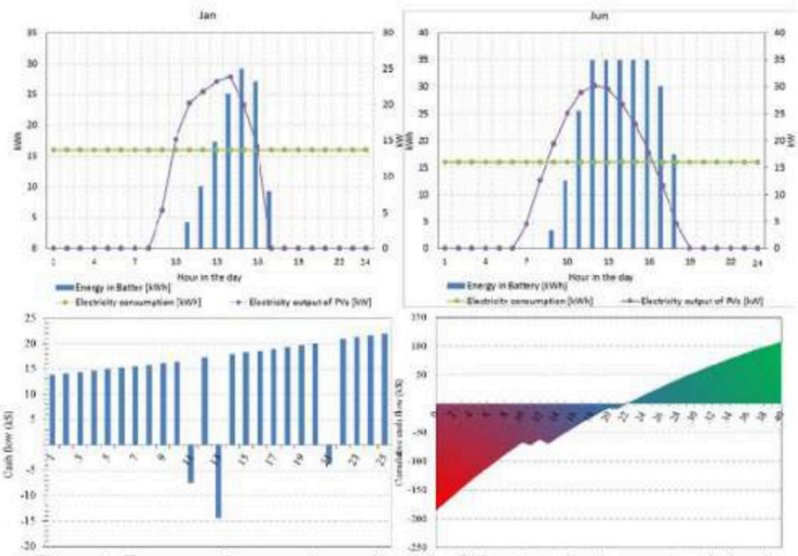

Figure 6. Energy and economic results of the PV system for the semi optimized scenario: constant consumption rate and shading effect=65% of the effective area.

2.1.2. The shading effect equals 95% of the effective area

In this proposed scenario the consumption load assumed to be constant over the year and equals 15.98 kW, while the shading effect thought to be 95% of the active area of the modules. Keeping the total budget equals 186 k€, the optimization simulation shows that installing 257 modules with a total size of the battery equals 73 kWh, namely about five batteries of the suggested model, are resulting in a maximum economic potential of the investment. The payback time of the investment is 17.3 years while the annual saving is 71602 kWh which corresponds 51% of the electricity consumptions of the building as compared to the consumption of 2016. Assuming the electricity price 0.25 €/kWh, the achieved saving in this scenario equals 17901 € annual money. The optimal tilt and azimuth angle of the modules are respectively 50 and 177 degrees.

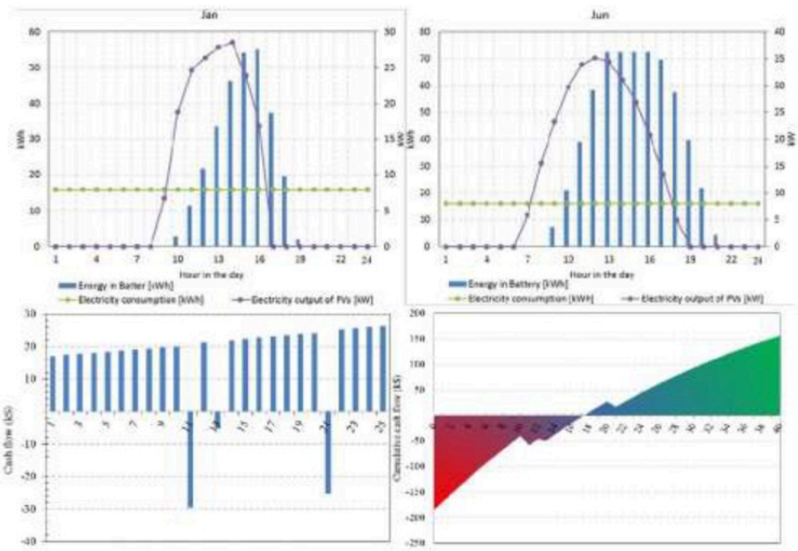

Figure 7. Energy and economic results of the PV system for the semi optimized scenario: constant consumption rate and shading effect=95% of the effective area.

2.2. Different electricity consumption rate

The current scenario optimizes the size of the modules and the battery keeping the total budget equals 86k€ and assuming the daytime consumption rate is three times greater ta the nighttime one. Also, the calculations were performed for two level of shading effect.

2.2.1. The shading effect equals 65% of the effective area

In this proposed scenario the shading effect assumed to be 65% of the effective area of the modules. The optimization simulation shows that installing 340 modules with a total size of the battery equals 10 kWh, namely about one battery of the suggested model, can result in a maximum economic potential of the investment. Such system results in 70282 kWh annual electricity generation, which corresponds to 17571€ money saving (assuming electricity price equals0.25 €/kWh) and 50% of electricity consumption of the building. The payback time of the investment is 16 years. The optimal tilt and azimuth angle of the modules are respectively 47 and 178 degrees.

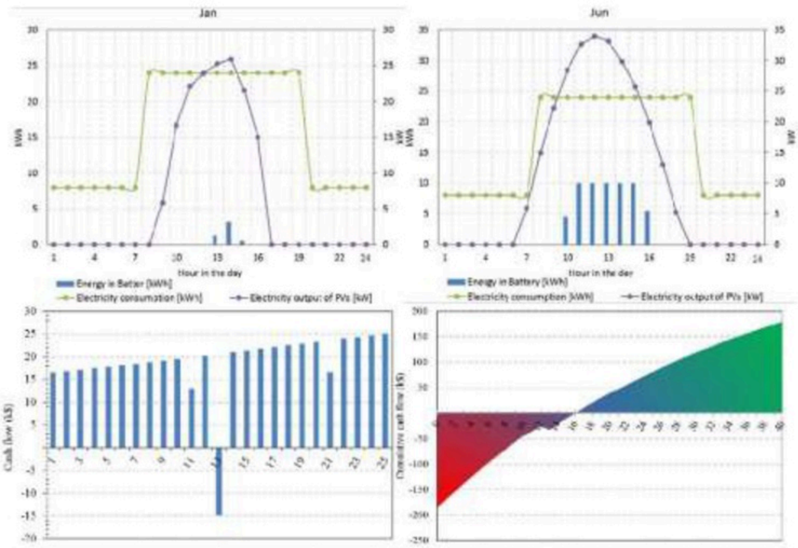

Figure 8. Energy and economic results of the PV system for the semi optimized scenario: different consumption rate and shading effect=65% of the effective area.

2.2.2. The shading effect equals 95% of the effective area

In this case, the optimization simulation shows that installing 301 modules with a total size of the battery equals 39 kWh, namely three batteries of the suggested model, are resulting in a maximum economic potential of the investment. The payback time of the investment is 13.3 years while the annual saving is 84064 kWh which corresponds 60% of the electricity consumptions of the building as compared to the consumption of 2016. Assuming the electricity price 0.25 €/kWh, the achieved saving in this scenario equals 21071 € annual money. The optimal tilt and azimuth angle of the modules are respectively 49 and 179 degrees.

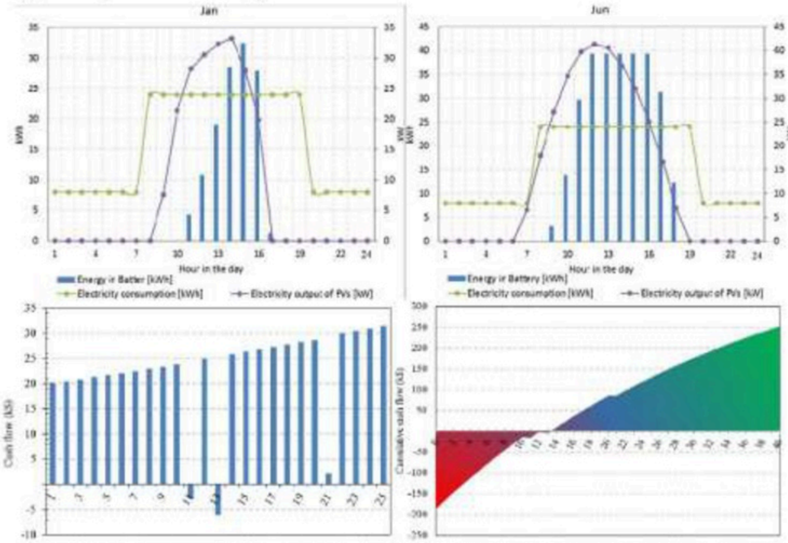

Figure 9. Energy and economic results of the PV system for the semi optimized scenario: different consumption rate and shading effect=95% of the effective area.

3. Fully Optimized scenario: Optimized budget

In this scenario, the optimization process aims to define the optimal amount of the money to be investigated in PV system at the working conditions of Berlin. Also, optimization seeks to determine the optimal size of the array and the battery in which the payback time of the investment is minimized. The simulations were performed for two different patterns of electricity load of the building as follows:

3.1. Equal electricity consumption rate

According to this setting, the hourly electricity consumption rate was assumed to be similar over the year and equals 15.98 kW. The calculations were repeated for two different shading effects levels were considered too.

3.1.1. The shading effect equals 65% of the effective area

The optimization simulation results in 113 modules and no battery are required. The total cost of the system is 59343 €. The payback time of the investment is 11.8 years while the annual saving is 26086 kWh which corresponds 19% of the electricity consumptions of the building as compared to the consumption of 2016. Assuming the electricity price 0.25 €/kWh, the achieved annual money saving in this scenario is 6521€. The optimal tilt and azimuth angle of the modules are respectively 44 and 177 degrees.

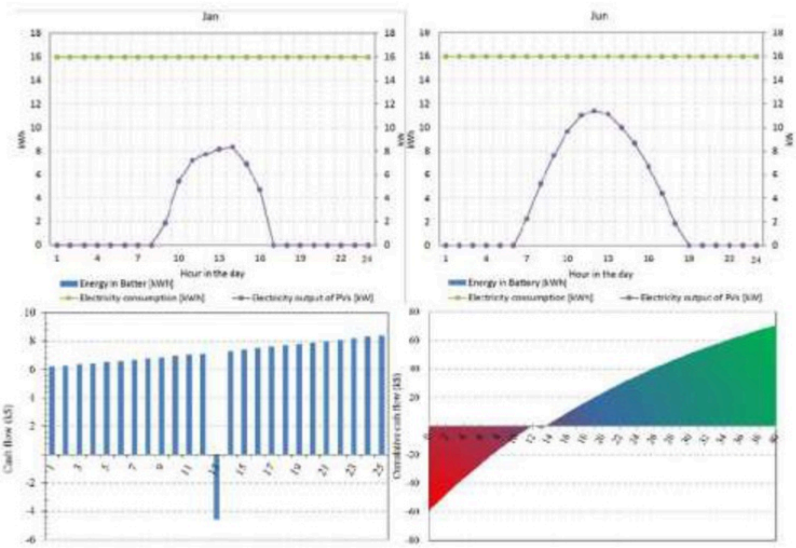

Figure 10. Energy and economic results of the PV system for the fully optimized scenario: constant consumption rate and shading effect=65% of the effective area.

3.1.2. The shading effect equals 95% of the effective area

The optimization simulation results in 98 modules, namely 160 m2 of the roof area, and no battery are required. The total cost of the system is 51824 €. The payback time of the investment is 7.7 years while the annual saving is 32189 kWh which corresponds 23% of the electricity consumptions of the building as compared to the consumption of 2016. Assuming the electricity price 0.25 €/kWh, the achieved saving in this scenario equals EUR 8047 annual money. The optimal tilt and azimuth angle of the modules are respectively 44 and 177 degrees.

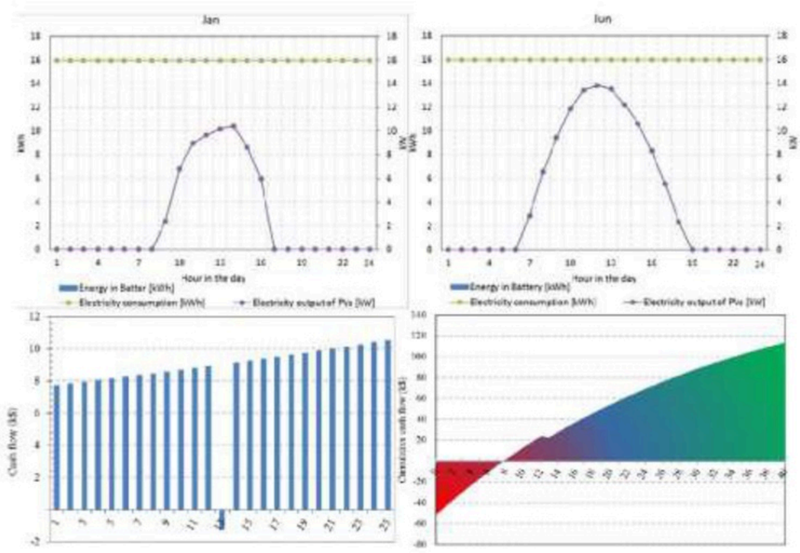

Figure 11. Energy and economic results of the PV system for the fully optimized scenario: constant consumption rate and shading effect=95% of the effective area.

3.2. Different electricity consumption rate

Also in this scenario, we have two different shading effect: 65% and 95% as follows.

3.2.1. The shading effect equals 65% of the effective area

The optimization simulation results in 205 modules and no battery are required. The total cost of the system is 107757 €. The payback time of the investment is 11.8 years while the annual saving is 47367 kWh which corresponds 34% of the electricity consumptions of the building as compared to the consumption of 2016. Assuming the electricity price 0.25 €/kWh, the achieved saving in this scenario equals 11842 € annual money. The optimal tilt and azimuth angle of the modules are respectively 44 and 177 degrees.

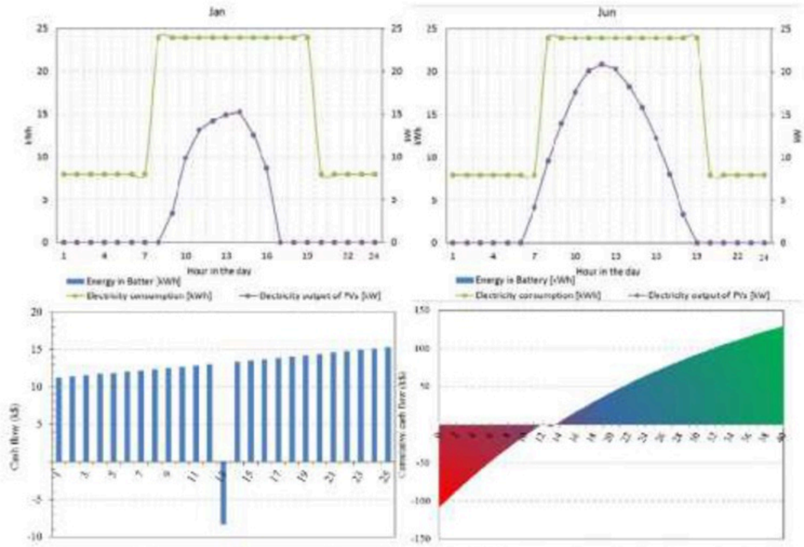

Figure 12. Energy and economic results of the PV system for the fully optimized scenario: different consumption rate and shading effect=65% of the effective area.

3.2.2. The shading effect equals 95% of the effective area

The optimization simulation results in 148 modules and no battery are required. The total cost of the system is 77828 €. The payback time of the investment is 7.8 years while the annual saving is 48340 kWh which corresponds 35% of the electricity consumptions of the building as compared to the consumption of 2016. Assuming the electricity price 0.25 €/kWh, the achieved saving in this scenario equals EUR 12085 annual money. The optimal tilt and azimuth angle of the module are 44 and 177 degrees, respectively.

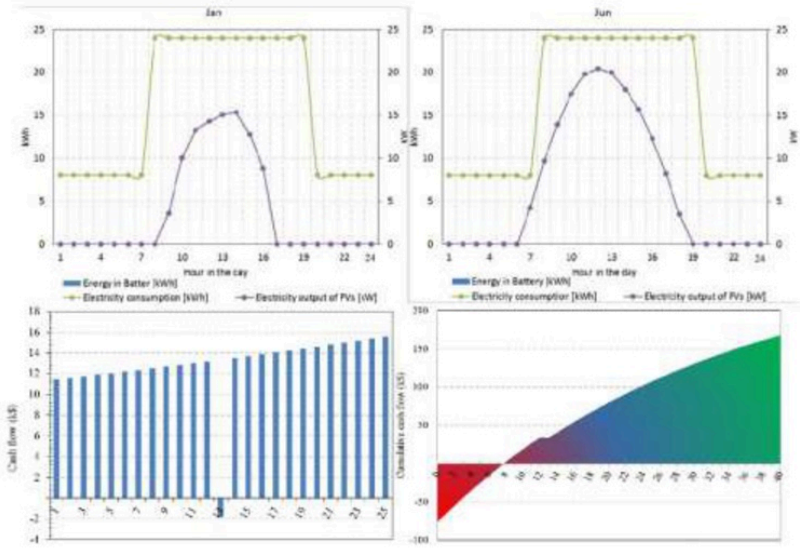

Figure 13. Energy and economic results of the PV system for the fully optimized scenario: different consumption rate and shading effect=95% of the effective area.

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