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Sun coupled innovative Heat pumps

D7.4 – Pre-Feasibility Replication studies

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Abbreviations

Acronym	Definition
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BMs	Business Models
CAPEX	Capital Expenditure
CPI	Consumer Price Index
DER	Distributed Energy Resource
DHW	Domestic Hot Water
DSO	Distribution System Operator
DUU	Design Under Uncertainty
ESCo	Energy Service Company
GHG	Greenhouse gas
H&C	Heating & Cooling
HICP	Harmonised Index of Consumer Prices
HP	Heat Pump
IRR	Internal Rate of Return
NPV	Net Present Value
O&M	Operation & Maintenance
OPEX	Operational Expenditure
PBP	Pay-Back Period
PDA	Personal Digital Assistant
PV	Photovoltaic
PV-T	Hybrid Photovoltaic – Thermal Panels
RES	Renewable Energy Source
SH	SunHorizon
ST	Solar Thermal
TPs	Technology Packages
TSO	Transmission System Operator
WP7	Work Package 7

Executive summary

The main objective of SunHorizon project is to demonstrate innovative and reliable heat pump solutions properly coupled with advanced solar panels and thermal energy storage that can provide heating and cooling to residential and tertiary buildings.

Six different kinds of technologies are designed and developed during the project, specifically:

- BH Thermal Compression Heat Pump;
- FAHR Adsorption Heat Pump;
- BDR Reversible Heat Pump;
- RATIO Enhanced Stratified Thermal Storage Tank
- DS Hybrid PV-T
- TVP LT-POWER High Vacuum solar thermal panels

The innovative heat pump technologies are combined with solar appliances in technology packages (TPs) with the aim of unlocking the potential for a mass-customized, user-friendly and cost-effective solution for heating and cooling. TPs are demonstrated in real buildings in four geographically spread locations in the European Union (Germany, Spain, Belgium and Latvia).

This deliverable is part of Work Package 7 (WP7) aimed at outlining innovative pathways for the rapid market replication of the novel solar panels coupled heat pumps demonstrated in SunHorizon. It is also related to the activities performed in Task 7.3" Pre-feasibility studies in six virtual demonstrators all around Europe via SunHorizon Design Optimized Tool". The goal of this task is to achieve optimized design and building integration of SunHorizon Heating & Cooling (H&C) technologies.

Six Pre-feasibility studies on SunHorizon Technology Packages (TPs) were performed for **virtual demonstrators**, i.e.: buildings of different typologies and located in different climate zones. The six Pre-feasibility studies are focused on **technical aspects**, **economic aspects**, as well as **legal aspects**

As regards the technical aspects the analysis was carried out with the support of the Tool developed by RINA-C in the WP4, specifically in Task 4.3 "Formulation and methods for optimal design under uncertainty of H&C components".

It is worth mentioning that this Tool can be used by a potential user (e.g.: energy systems designer, engineers, energy managers, etc.) for the predesign and preliminary assessment of the SunHorizon TPs.

The economic aspects were studied by partner Veolia which has a high expertise in this field; Veolia prepared Business Models for each of the six virtual demonstrator buildings. As regards the legal aspects, support was provided by partner Sant Cugat that has a high skill and experience in this sector. Sant Cugat and RINA-C prepared an EU legal on-line survey aimed at investigating the legal building requirements in the European countries.

1 Introduction

This deliverable represents the work carried out in Task 7.3 – "Pre-feasibility studies in six virtual demonstrators all around Europe via SunHorizon Design Optimized Tool" included in the WP7.
The aim of this task is to achieve optimized design and building integration of SunHorizon H&C technologies respecting the aesthetical restrictions of the buildings, maximizing the usage of RES and, therefore, ensuring proper satisfaction of local H&C demand.
The purpose of this deliverable is to present six Pre-feasibility studies of SunHorizon TPs focused on virtual demonstrators, i.e.: buildings of different typologies and located in different climate zones identified according to the methodological approach described in Section 2 of this deliverable.
It is worth mentioning that the analysis involves "pre-feasibility" studies, i.e.: preliminary studies undertaken to determine, analyze, and select the best business scenarios. In fact, the present study considers a predesign and preliminary assessment of the SunHorizon TPs, in order to evaluate the optimal configuration of SunHorizon innovative technology in six virtual demonstrators for a possible replicability of them in other buildings than the pilot sites of the project (where the SunHorizon TPs will be/were/are installed).

The application of SunHorizon TPs has been assessed considering technical aspects, legal aspects as well as economic aspects (i.e.: feasibility of the installations). Partners of Task 7.3 were involved for the assessment of the three above-mentioned aspects, specifically CNR/ITAE, CARTIF and BDR for the technical aspects, VEOLIA for the economic aspects and SANT CUGAT for the legal aspects.

In particular, the technical activities have been performed starting from the excel based Tool developed by RINA-C in the Work Package 4, Task 4.3 "Formulation and methods for optimal design under uncertainty of H&C components". This tool was prepared and tested for both residential and non-residential buildings (for more details about excel Tool refer to Section 3 of this deliverable). This tool has been applied in this deliverable to four technology packages (TPs), the ones tested in the real SunHorizon demonstrators.

The four technology packages considered are:

- TP1 (Boost Heat HP;Ratiotherm Tank; TVP Solar Panels) and TP2 (Boost Heat HP; Ratiotherm Tank; Dual Sun PV-T panels) are meant for DHW and heating supply, while
- TP3 (Fahrenheit Sorption Chiller; Compression Chiller; Ratiotherm Tank; TVP Solar Panels) and TP4 (BDR AWHP; Heating/Cooling Tank; DHW/RATIO tank; BAXI PV panels; BAXI Solar Panels) are meant for cooling, heating and DHW supply.

Within this Deliverable, besides Section 1 that constitutes the present Introduction, the following sections are included:

- Section 2 describes the methodological approach;
- Section 3 describes the DUU optimization Tool used for the simulations of the six demonstrator buildings;
- Section 4 is focused on the pre-feasibility studies and specifically on technical (input data, simulations outcomes from DUU Tool and an example of "design applying a safety factor"), economic (Business Models) and legal (results from the EU legal on-line survey) aspects related to the six virtual demonstrator buildings;
- Section 5 draws the conclusions of the present deliverable.

Deliverable 7.4 is supported by Part A (two Annexes: Annex 1-Business Models and Annex 2-Building Legal Requirements-EU Survey) and by Part B (Bibliography).

2 Methodological approach

In this section the approach/methodology used to carry out the six pre-feasibility studies under the technical, economic and legal point of view is shown, according to the following main steps:

1. Investigation of interconnection with other SunHorizon activities and examination of already submitted deliverables. Particularly useful have been the following deliverables:
   - T2.2 – D2.2 "*Mapping solar resource and building demand for SunHorizon implementation*" for the TPs replicability in EU MS according to the availability of support schemes or to energy demand,
   - T2.2 – D2.3 "*Macro-market analysis, value chain and conceptual business model definition*" for the TPs development in demo sites PESTLE (Political, Economic, Social, Technological, Environmental and Legal),
   - T7.1 - D7.1 "*SunHorizon Technologies social and market acceptance*" for the literature review and survey for market and social acceptance of TPs,
   - T7.1 - D7.2 "*SunHorizon Technologies benefit impact in terms of emissions*" for the Life Cycle Assessment (LCA) per technology and technology package;

2. Study of Design Under Uncertainties (DUU) tool, developed in **WP4**, in particular in T4.3 "*Formulation and methods for design «under uncertainty» to optimize H/C systems and the components in different climates (thermal comfort), energy habits/demand, energy prices etc"* which aim to find the optimal configuration (in term of in terms of equipment size, capital-machinery cost and operating-energy cost of the components of the 4 TPs.
   The study has involved the investigation of data input required (on climate data, building characteristics, and energy/gas cost), as well as the study of the 4 TPs and the output of the tool, examination of the submitted deliverable of T4.3 and meeting with responsible partner and in deep examination of excel working version of the tool.
   For more details see the submitted D4.3 *"Implementation of design under uncertainty optimization tools".*

3. Engagement of T7.3 partners and definition of roles within periodic monthly meetings (from June 2021 to April 2022) to brainstorm on the approach and update all partners on progresses and next steps.
   In particular, based on what suggested in the GA, RINA-C proposed the roles for each T7.3 partner involved in each of the 6 studies and partners agreed on the following list:
   - Technical aspects: BDR, CARTIF, ITAE/CNR, RINA;
   - Economic aspects: VEOLIA, RINA;
   - Legal aspects: SANT CUGAT, RINA.

4. Identification of demonstrator buildings: location
   In order to perform the 6 Pre-Feasibility Replication studies for buildings of different typologies and located in different climate zones, RINA, proposed different possibilities in term of EU climate areas mapping systems (e.g.: EcoDesign Directive, Köppen-Geiger system, download data from PVGIS on a national level, classification used in SunHorizon D2.2).
   T7.3 partners agreed on mapping EU using **ecodesign** system mainly because is the one used to classify the seven Sunhorizon demo-sites and is the European Reference for climate conditions which divides Europe into 3 "Climate Zones for Heating Mode" with the aim of calculating the energy efficiency taking into consideration the actual regional ambient temperatures: cold (Northern Europe- annual temperature of Helsinki), average (Central Europe- annual temperature of Strasbourg) and warm (Southern Europe- annual temperature of Athens).

EU Climate Area	City and Country
Cold	Nurnberg (Germany), Berlin (Germany), Riga (Latvia)
Average	Madrid (Spain), Verviers (Belgium)
Warm	Sant Cugat (Spain), S. Lorenzo (Spain)

According to this clusterization system, RINA selected the countries (and then cities), according to the possible presence of local partners within T7.3 or the whole project Consortium partners:

EU Climate Area	City and Country
Cold	Goteborg (Sweden)
Average	Rotterdam (Netherlands)
Warm	Rome (Italy)

5. Identification of demonstrator buildings: typology

Together with T7.3 partners, RINA decided to split the 6 pre-feasibility studies into 3 residential (multi-family house) and 3 tertiary (offices) typology of virtual buildings.

In the following figures an example of typical residential and tertiary buildings in Italy, The Netherlands and Sweden is shown. The pictures of these buildings have to be considered simply indicative.

		
Multi Family House - Italy	Multi Family House – The Netherlands	Multi Family House - Sweden

Figure 2.1:Example of Residential buildings in the three countries[1]

		
Tertiary building - Italy[2]	Tertiary building – The Netherlands[3]	Tertiary building - Sweden[4]

Figure 2.2:Example of Tertiary buildings in the three countries

So, the studies will be carried out on 2 buildings for Sweden cold zone (1 Res, 1Ter), 2 for Netherlands average zone (1 Res, 1Ter) and 2 for Italy warm zone (1 Res, 1Ter).

[1] Episcope/Tabula: Italy: https://episcope.eu/building-typology/country/it/; The Netherlands: https://episcope.eu/building-typology/country/nl/; Sweden: https://episcope.eu/building-typology/country/se/

[2] https://commons.wikimedia.org/wiki/File:POSTEEUR30082021.jpg

[3] https://commons.wikimedia.org/wiki/File:Claus_en_Kaan_Architecten_Office_in_Amsterdam.jpg

[4] https://commons.wikimedia.org/wiki/File:Lindholmspiren_i_G%C3%B6teborg_02.JPG

6. Technical data collection

RINA-C updated on Teams repository an excel file with T4.3 tool technical building data input and ask support to technical partners (BDR, ITAE/CNR, CARTIF) to fill it in.

Then RINA double-checked the input data and sources indicated by partners to uniformize them, especially in term of reference sources.

In term of reference sources, RINA underlined the need for building values to be comparable in term, for example, of aesthetical similarities, building typology or age of the building.

7. Legal data collection

RINA proposed the following few legal aspects to be investigated both at EU and at the above-selected countries level:

- analysis of self-consumption,
- % of RES mandatory,
- architectural/aesthetical restrictions,
- thermal comfort requirements,
- presence of support incentives schemes;

Sant Cugat then drafted a short survey to discover which legal building requirements would have been useful to investigate and uploaded the questionnaire online through EC platform EUSurvey[5]. So, RINA distributed the online link to all the Consortium partners by e-mail (https://ec.europa.eu/eusurvey/runner/SUNHORIZON-WP7-BLR-SURVEY2021-)

8. Economic data collection

RINA proposed to include the following financial parameters in the economic analysis for the six virtual demonstrator buildings.

- Savings;
- Cash Flow;
- IRR (Internal Rate of Return);
- NPV (Net Present Value);
- Pay-back period.

Therefore, VEOLIA which deals with economic aspects, carried out 24 Business Models (BMs) related to the six buildings and four Technology Packages (TP1÷TP4) to calculate the financial parameters. BMs were prepared starting from technical data (heating/cooling demand and electricity/natural gas consumptions) provided by RINA that filled-in an excel data collection template of Veolia.

[5] https://ec.europa.eu/eusurvey/home/welcome

3 Design Under Uncertainty (DUU) optimization Tool

Technology packages (TPs) defined in WP3 provide different configurations to integrate multiple technologies for energy production and saving to both residential and non-residential buildings.

Through the Design Under Uncertainty (DUU) Tool in the predesign phase of the TPs, an optimal design 'under uncertainty' in terms of size and costs of a combination of technology for heating and cooling supply is obtained, taking into account the uncertainties of the building input parameters used to calculate the building energy loads and demands.

DUU has been carried out applying **Monte Carlo method** and following three main steps:

- define the peak loads, the energy demands and generate the loads distribution involving uncertainties;
- determine different design capacities of the energy system based on the loads probability distribution;
- define the optimal system configuration thanks to a multicriteria analysis, by assigning a score depending on cost and thermal comfort of different configurations.

In more details, the input data provided by the user, are used to calculate the peak loads for both heating and cooling, according to the Residential Load Factor (RTF) and the Radiant Time Series (RTS) methods as proposed by ASHRAE (ASHRAE, 2017).

The accuracy of the estimation of the peak load can vary as physical building parameters are affected by uncertainty and weather conditions that might be different from real conditions. Therefore, a peak load distribution accounting for the uncertainties of the input parameters has been calculated using the Monte Carlo method.

Seven different peak loads are selected from the peak load distribution, considering 7 different thresholds based on the standard deviation of the distribution (λ) and the average peak load. The chosen thresholds correspond to seven peak loads with an associated risk to be overcome varying from 50 % for λ1 to less than 1 % for λ7.

There are also two values of threshold, λ_{min} and λ_{max} that represents the maximum and minimum number of discomfort hours respectively.

For each technology package **four different configurations** are considered in the Tool based on the percentage of solar thermal/PV technology used, with configuration 1 accounting for 100 % of the possible solar installed capacity, while configuration 4 accounting for 25 %.

Finally, a scoring system considering thermal comfort ($\Gamma_{comfort}$) score, based on peak load distributions, and cost score (Γ_{cost}) based on configuration is adopted to rank the **best combination** and, therefore, the **optimised technical configuration**. In particular, tool calculates the performance score (J), weighted according to the user preference about cost and/or comfort. The final performance score J will identify the best combination of the selected TP, providing for each technology an estimation of size, capital cost and operative (energy related) costs.

The aim is to calculate, for each of the selected peak load and for each configuration, the **capital costs** depending on the size (calculated according to the Peak Loads and DHW demand) and the **operative costs** (depending on the energy consumptions). A **cost score** is then assigned to each combination (e.g.: λ7-configuration 1).

The **Monte Carlo** method has been implemented in an **excel based Tool** developed by RINA-C to preliminarly test the methodology and all the functionalities and equations. This tool can be used by a potential user (e.g.: energy systems designer, engineers, energy managers) for the predesign and preliminary assessment of the SunHorizon Technology Packages. The excel based tool has been used in this deliverable for the identification of the optimal configuration for each technology package.

The uncertainties in the energy field can be divided into two main groups: design uncertainties and operation uncertainties. Only design uncertainties are considered in this model (mostly related to the heating and cooling loads uncertainties since the selection and sizing of the HVAC components depend on the annual profile of the energy loads). Heating and cooling loads uncertainties, for examples, are related to the heat transfer performance of building envelopes and efficiency of air conditioning equipment, and to variability (e.g.: number of occupants and weather).

For more detailed information about the Tool, refer to deliverable D4.3 "*Implementation of design under uncertainty optimization tools*".

It is worth mentioning that the excel based Tool will be included in the SUNHORIZON integrated Tool of WP4 prepared by IES. The integrated Tool is a web application and integrates the code developed in Pyton to do calculations (calculations are the same done with the excel based Tool). Therefore, in the future any replications for building demonstrators including the technology packages can be done using the on-line web Tool. Currently, at the time this document is drawn up, the on-line web Tool is under development and testing.

3.1 Technologies implemented in the Tool

The excel based Tool was applied in this study to four technology packages (TPs), the ones tested in the SunHorizon demonstrators. Among the technology packages considered:

- **TP1** (Boost Heat HP;Ratiotherm Tank; TVP Solar Panels) and **TP2** (Boost Heat HP; Ratiotherm Tank; Dual Sun PV-T panels) are meant for DHW and heating supply, while
- **TP3** (Fahrenheit Sorption Chiller; Compression Chiller; Ratiotherm Tank; TVP Solar Panels) and **TP4** (BDR AWHP; Heating/Cooling Tank; DHW/RATIO tank; BAXI PV panels; BAXI Solar Panels) are meant for cooling, heating and DHW supply.

The aim of this section is to provide a description of the Technology Packages (TPs) implemented in the Tool. These TPs were used in the simulation carried out for the six virtual demonstrator buildings. The following table shows the TPs implemented in the Tool with a brief description of how the innovative technology works.

Table 3.1:Technology Packages implemented in the Tool

Technology Packages	Supply	Technology	Description
TP1	Heating + DHW	Boost Heat Heat Pump (HP) Ratiotherm Tank TVP Solar Thermal Panels	Solar thermal for space heating based on High Vacuum Flat Panel (HVFP) technology provided by TVP + Domestic Hot Water (DHW) + Heat Pump (provided by BH) to cover non solar periods
TP2	Heating + DHW	Boost Heat HP Ratiotherm Tank Dual Sun hybrid Photovoltaics-Termal (PV-T) panels	Hybrid PV-T panels (provided by DS) thermal output to cover as much heat demand as possible + excess electricity production for appliances + Heat Pump (provided by BH) for space heating + DHW support
TP3	Cooling + Heating/DHW contribution thanks to solar panels	Fahrenheit Adsorption Chiller Compression Chiller Ratiotherm Tank TVP Solar Thermal Panels	Solar thermal for space heating based on High Vacuum Flat Panel (HVFP) technology, provided by TVP + DHW in winter + activation of the thermal compressor of the adsorption chiller Heat Pump for cooling, provided by FAHR
TP4	Heating/Cooling + DHW	BDR AWHP Heating/Cooling Tank DHW tank BAXI FOTON PV panels BAXI SOL Solar Panels	Hybrid PV-T panels (provided by DS) thermal output to cover part of space heating and DHW heat demand + electricity production to cover reversible HP (provided by BDR) electricity consumption

4 Pre-feasibility studies on six virtual demonstrator buildings

In this section six pre-feasibility studies, focused on the six virtual buildings in the three countries that were selected in the previous sections, are presented. The first three pre-feasibility studies are focused on virtual residential (RES) buildings in Italy, The Netherlands and Sweden, whereas the other three studies are focused on the virtual tertiary (TER) buildings always in the same countries.

Pre-feasibility studies cover three different aspects: technical and economic aspects focused on the identification of the TPs optimized configuration in terms of size and costs respectively, and legal aspects regarding the building requirements in place in the European countries.

Technical, economic and legal aspect are described in the following sections as follow:

- Technical aspects which are divided in two parts:
  - ✓ a first part including technical data and assumptions used as input data in the DDU Tool for the simulation of the six virtual demonstrators, three residential and three tertiary buildings. Input data include in particular: building design parameter and building envelope characterization, energy costs (electricity and natural gas), the climate data; and
  - ✓ a second part including the outcomes coming from the Tool simulations;
- Economic aspects including the Business Models carried out for each of the six demonstrator buildings and for each of the four TPs (TP1÷TP4);
- Legal aspects focused on the results coming from the EU legal on-line survey.

4.1 Technical aspects: Input data - Building Definition and Assumptions

In this section input data provided by SunHorizon partners and related to the six virtual demonstrator buildings located in three different European countries Italy, The Netherlands and Sweden, are shown. Data refers to both residential and non-residential buildings built during the period 90s/00s.

The DUU optimization tool has been applied to run the simulations of the six demonstrator buildings shown in Table 2:

Table 4.1:Six Buildings: Three Residential and Three Non-Residential (Tertiary) Buildings

LOCATION	90s/00s RESIDENTIAL BUILDING	90s/00s TERTIARY BUILDING
Italy	Demonstrator building # 1: Design parameters for an average building with about 10 apartments, 90 m^2 each in Rome[6]	Demonstrator building # 4: Average tertiary building (office as destination) in Rome
The Netherlands	Demonstrator building # 2: Design parameters for an average building with about 18 apartments 100 m^2 each in Rotterdam[6]	Demonstrator building # 5: Average tertiary building (office as destination) in Rotterdam
Sweden	Demonstrator building # 3: Design parameters for an average building with about 12 apartments 100 m^2 each in Goteborg[6]	Demonstrator building # 6: Average tertiary building (office as destination) in Goteborg

[6] International Journal of Environmental Research and Public Health-MDPI: Housing spaces in nine European countries-A comparison of dimensional requirements: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8073340/

4.1.1 Energy cost (gas and electricity)

This section is focused on the energy cost used in the simulation Tool. In particular, the electricity cost and natural gas cost shown in the following table were used:

Table 4.2:Electricity and gas costs

	Parameter	Units	Ref value
Electricity	Electricity cost	€/kWh	0.22
Gas	Gas cost	€/kWh	0.08

These costs are the average European costs provided by Eurostat.[7]

4.1.2 Building input parameters

In this section data regarding Building design parameter and Building envelope characterization related to the three countries, Italy, The Netherlands and Sweden are shown in the following tables. Support for input data collection was provided by CNR, BDR and CARTIF respectively for Italy, The Netherlands and Sweden.

4.1.2.1 Italy

Table 4.3:Input data-Rome (Italy)

ITALY (ROME)					
				RES	**TER**
Building design parameter			**Units**	**Value**	**Value**
Ambient data	Tset,h	Heating set point	°C	20	20
	Tset,c	Cooling set point	°C	26	26
	n	Infiltration Rate	1/h	0.2	0.4
Building	Ac	Ac - Conditioned Building area	m^2	952	3,584
	Vc	Heated/Conditioned Building Volume	m^3	2,380	10,752
	Nap	N° of apartment (only for residential)	N°	10	-
	Ac,ap	Average Conditioned area per apartment (only for residential)	m^2	90	-
	Nbath	N° of Bathroom Sink (only for non residential)	N°	-	26
	Noc	N° of occupants	N°	23	251
	Amax,sp	Max m^2 of PV or ST Panels to be considered	m^2	150	358
Building envelope characterization				**1991-2005**	**1990-2000**
Walls	Uwall	External wall(s) Transmittance (U_{value})	W/m^2K	0.59	0.8
	Awall	External wall(s) Area	m^2	868	648
	Uwall	External wall(s) Transmittance (U_{value})	W/m^2K	0.51	
	Awall	External wall(s) Area	m^3	144	

[7] https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

https://ec.europa.eu/eurostat/statistics-explained/index.php/Natural_gas_price_statistics

ITALY (ROME)					
Floor	Ufloor	Ground floor slab(s) Transmittance (U_{value})	W/m²K	0.77	0.5
	Afloor	Ground floor slab(s) Area	m²	179	896
	Ufloor	Ground floor slab(s) Transmittance (U_{value})	W/m²K	0.63	
	Afloor	Ground floor slab(s) Area	m³	194	
Roof	Uroof	Roof(s) Transmittance (U_{value})	W/m²K	0.57	0.83
	Aroof	Roof(s) Area	m²	374	896
Windows	Uw,N/S	Window(s) N/S oriented Transmittance (U_{value})	W/m²K	2.2	3.6
	Aw,N/S	Window N/S oriented Area	m²	96.6	52.5
	Uw,W	Window(s) West oriented Transmittance (U_{value})	W/m²K	2.2	3.6
	Aw,W	Window West oriented Area	m²	101.5	140

4.1.2.2 The Netherlands

Table 4.4:Input data-Rotterdam (The Netherlands)

THE NETHERLANDS (ROTTERDAM)					
				RES	**TER**
Building design parameter			**Units**	**Value**	**Value**
Ambient data	Tset,h	Heating set point	°C	18	18
	Tset,c	Cooling set point	°C	26	26
	n	Infiltration Rate	1/h	0.4	0.4
Building	Ac	Ac - Conditioned Building area	m²	1,804	764
	Vc	Heated/Conditioned Building Volume	m³	4,510	2,292
	Nap	N° of apartment (only for residential)	N°	18	-
	Ac,ap	Average Conditioned area per apartment (only for residential)	m²	100	-
	Nbath	N° of Bathroom Sink (only for tertiary)	N°	-	6
	Noc	N° of occupants	N°	38	53
	Amax,sp	Max m² of PV or ST Panels to be considered	m²	141	76
Building envelope characterization				**1992-2005**	**1990-2000**
Walls	Uwall	External wall(s) Transmittance (U_{value})	W/m²K	0.36	0.5
	Awall	External wall(s) Area	m²	928	299
Floor	Ufloor	Ground floor slab(s) Transmittance (U_{value})	W/m²K	0.36	0.9
	Afloor	Ground floor slab(s) Area	m²	328	191
Roof	Uroof	Roof(s) Transmittance (U_{value})	W/m²K	0.36	0.5
	Aroof	Roof(s) Area	m²	353	191
Windows	Uw,N	Window(s) North oriented Transmittance (U_{value})	W/m²K	1.8	2.9
	Aw,N	Window North oriented Area	m²	346	48
	Uw,S	Window(s) South oriented Transmittance (U_{value})	W/m²K	2.9	2.9
	Aw,S	Window(s) South oriented Area	m²	6	48
	Uw,E	Window(s) East oriented Transmittance (U_{value})	W/m²K		2.9

THE NETHERLANDS (ROTTERDAM)					
	Aw,E	Window East oriented Area	m^2		0.1
	Uw,W	Window(s) West oriented Transmittance (U_{value})	W/m^2K		2.9
	Aw,W	Window(s) West oriented Area	m^2		64
	Ud	Door	W/m^2K	3.5	
	Ad	Door Area	m^2	48	

4.1.2.3 Sweden

Table 4.5:Input data-Goteborg (Sweden)

SWEDEN (GOTEBORG)					
				RES	**TER**
Building design parameter			**Units**	**Value**	**Value**
Ambient data	Tset,h	Heating set point	°C	21	21
	Tset,c	Cooling set point	°C	24	25
	n	Infiltration Rate	1/h	0.2	0.4
Building	Ac	Ac - Conditioned Building area	m^2	1,207	1,801
	Vc	Heated/Conditioned Building Volume	m^3	3,018	5,403
	Nap	N° of apartment (only for residential)	N°	12	-
	Ac,ap	Average Conditioned area per apartment (only for residential)	m^2	100	-
	Nbath	N° of Bathroom Sink (only for non residential)	N°	-	13
	Noc	N° of occupants	N°	24	126
	Amax,sp	Max m^2 of PV or ST Panels to be considered	m^2	188	180
Building envelope characterization			**1996-2005**		**1990-2000**
Walls	Uwall	External wall(s) Transmittance (U_{value})	W/m^2K	0.2	0.2
	Awall	External wall(s) Area	m^2	560	459
	Uwall	External wall(s) Transmittance (U_{value})	W/m^2K	0.70	
	Awall	External wall(s) Area	m^3	240	
Floor	Ufloor	Ground floor slab(s) Transmittance (U_{value})	W/m^2K	0.21	0.2
	Afloor	Ground floor slab(s) Area	m^2	470	450
Roof	Uroof	Roof(s) Transmittance (U_{value})	W/m^2K	0.13	0.1
	Aroof	Roof(s) Area	m^2	470	450
Windows	Uw,N/S	Window(s) N/S oriented Transmittance (U_{value})	W/m^2K	1.97	0.25
	Aw,N/S	Window N/S oriented Area	m^2	180	74
	Uw,W	Window(s) West oriented Transmittance (U_{value})	W/m^2K	1.5	0.25
	Aw,W	Window West oriented Area	m^2	10	99
	Ud	Door	W/m^2K	1.5	
	Ad	Door Area	m^2	10	

The presented input data for the six virtual demonstrators have been obtained from different sources and have required some assumptions shown below:

Residential building:

- The data for all the three virtual demonstrators has been taken from the building webtool TABULA[8];
- Vc = Ac x 2,5 m (average room high 2,5 m) taken from the building webtool TABULA[9];
- Noc for each country taken from the "International Journal of Environmental Research and Public Health-MDPI: Housing spaces in nine European countries-A comparison of dimensional requirements"[10] and "Eurostat – Size of housing".[11]
- Amax,sp has been considered as 40% of the available roof area (reference to: IEA International Energy Agency-Potential for Building Integrated Photovoltaics- Photovoltaic Power Systems Programme [12]).

Tertiary Building:

- Ambient data (summer and winter set point temperatures) for the Netherland and Sweden have been taken from a REHVA document "Thermal and acoustic comfort requirements in European Standard and National Regulations[13], while in Italy the UNI10339 provides guidelines also for thermal comfort.
- U-values for the envelopes have been provided by INSPIRE document "D2.1A Survey on the energy needs and architectural features of the EU building stock".[14]
- Average Areas for the different parts of the envelopes are taken from Ecofys document "Panorama of the European non-residential construction sector, Final report"[15], where Sweden is included in the document, Germany is used as reference for Western European countries (the Netherlands) and Spain for the Southern ones (Italy);
- Values provided for Italy in the "Testo Unico della Sicurezza" for what concern the number of persons and sinks per office have been adopted for all the three virtual demonstrators. Specifically, around 7 persons every 100 m^2 and 1 bathroom every 10 persons has been assumed.

4.1.3 Input - Weather/Climate data

PVGIS web site by JRC was used for the meteorological data https://re.jrc.ec.europa.eu/pvg_tools/it/#TMY.
In the spreadsheet Input - Weather the meteorological data from the website must be inserted for the specific location of the virtual demonstrator. The file has 8,760 rows which corresponds to the yearly hours.

Solar Radiation Database PVGIS-CMSAF provides data for the following solar angles (Azimuth) and tilt angle (slope):

- "G(h) *Horizontal Solar irradiation"*: slope 0°, Azimuth 0°
- "*Gv,s [W/m2] South Vertical irradiation*" slope 90°, Azimuth 0° (Ideal panel orientation)
- "*Gv,e [W/m2] Est Vertical irradiation*" slope 90°, Azimuth -90°
- "*Gv,w [W/m2] West Vertical irradiation"* slope 90°, Azimuth +90°
- *"Gv,n [W/m2] North Vertical irradiation"* slope 90°, Azimuth +180°

In the following figures the annual global radiation and the annual average temperature for The Netherlands, Italy and Sweden are shown.

8 https://webtool.building-typology.eu/#bm

9 https://webtool.building-typology.eu/#bm

10 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8073340/

11 https://ec.europa.eu/eurostat/cache/digpub/housing/bloc-1b.html?lang=en-

12 https://iea-pvps.org/wp-content/uploads/2020/01/rep7_04.pdf

13 https://www.rehva.eu/rehva-journal/chapter/thermal-and-acoustic-comfort-requirements-in-european-standard-and-national-regulations

14 https://inspire-fp7.eu/wp-content/uploads/2016/08/WP2_D2.1a_20140523_P18_Survey-on-the-energy-needs-and-architectural-features.pdf

15 http://leonardo-energy.pl/wp-content/uploads/2018/03/Europejski-sektor-budownictwa-niemieszkalnego.pdf

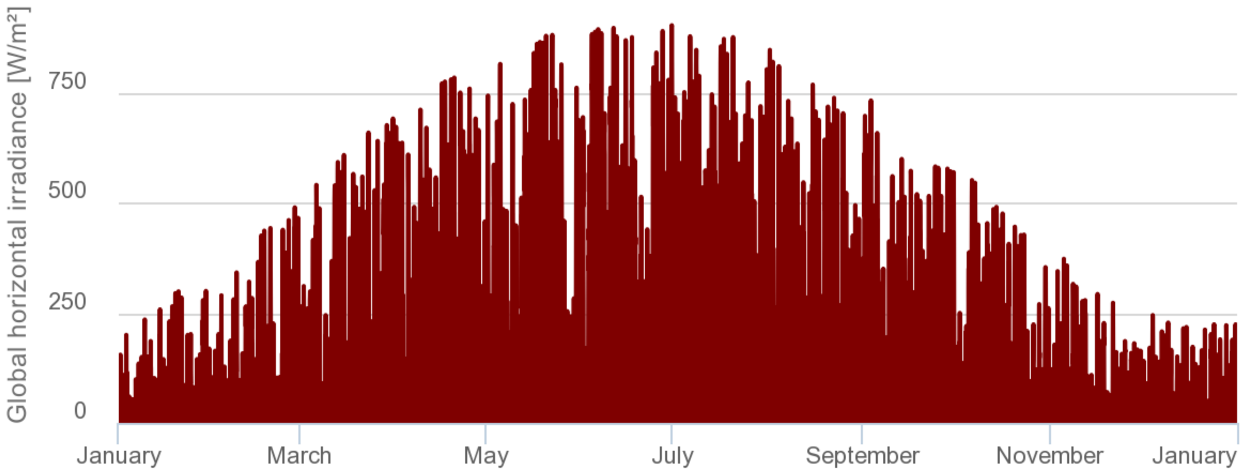

Figure 4.1:Annual global radiation - The Netherlands

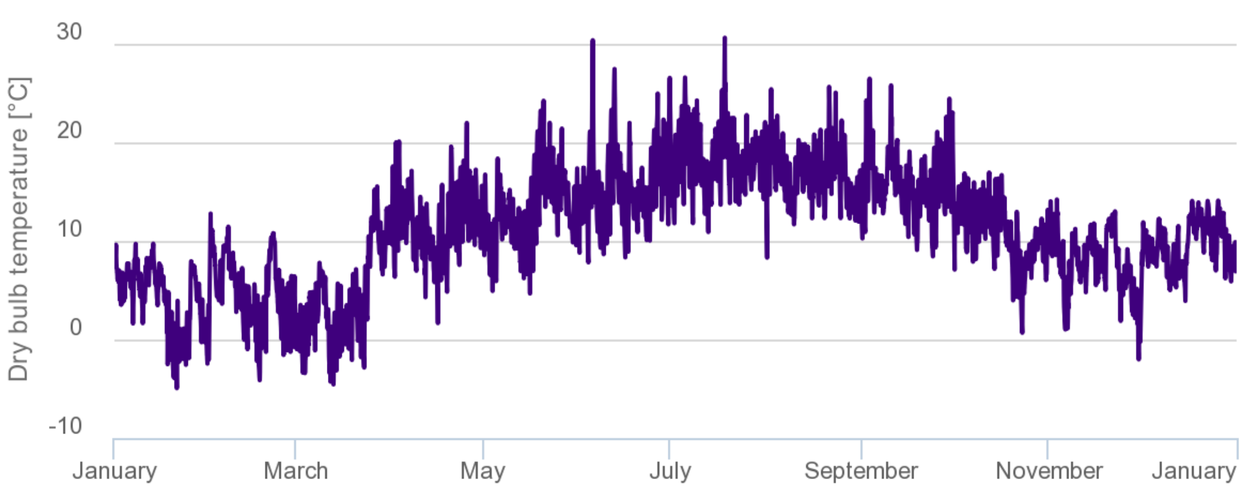

Figure 4.2:Annual average temperature - The Netherlands

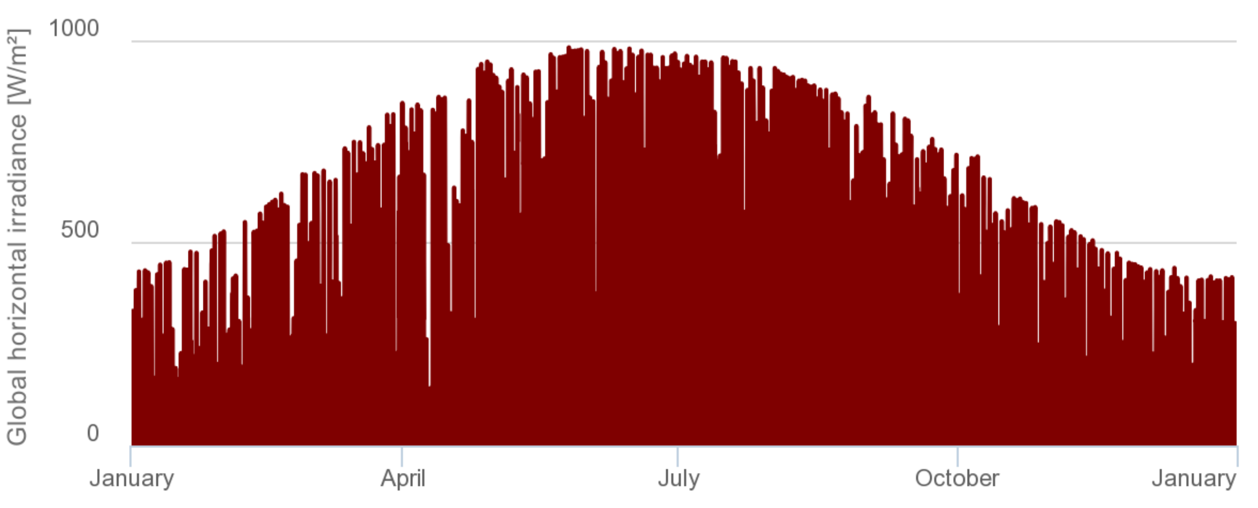

Figure 4.3:Annual global radiation - Italy

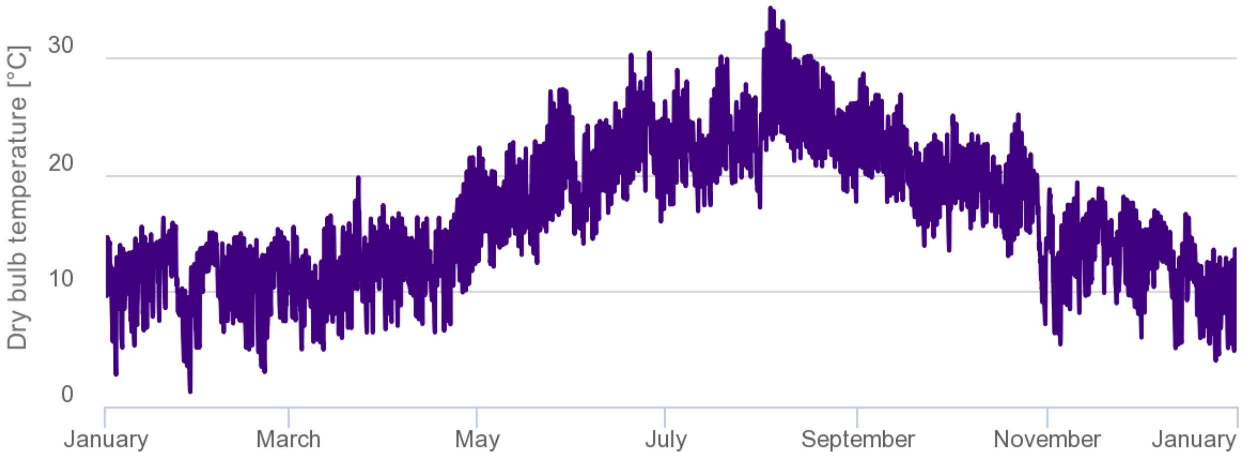

Figure 4.4:Annual average temperature - Italy

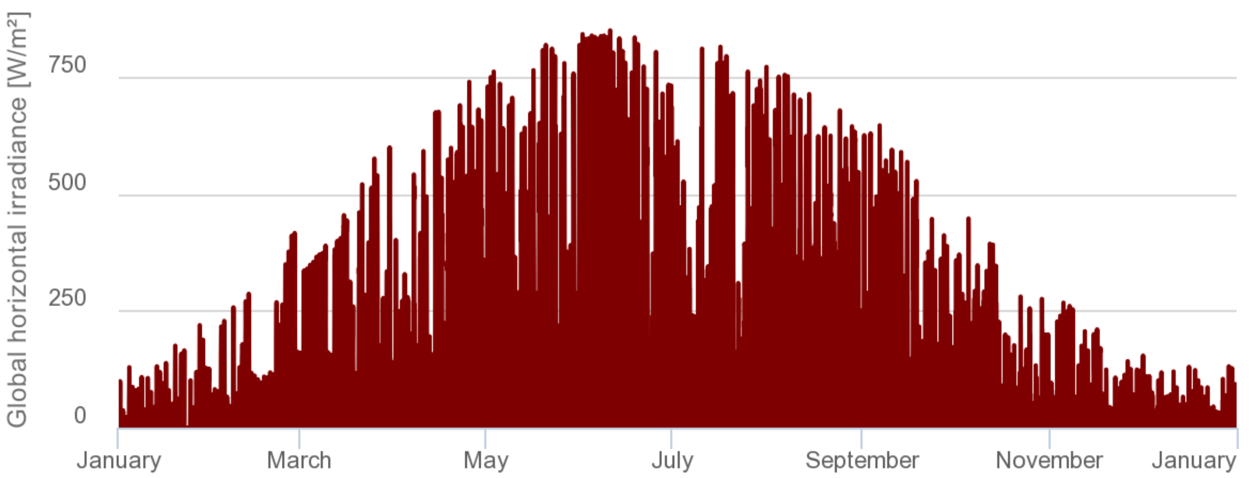

Figure 4.5:Annual global radiation - Sweden

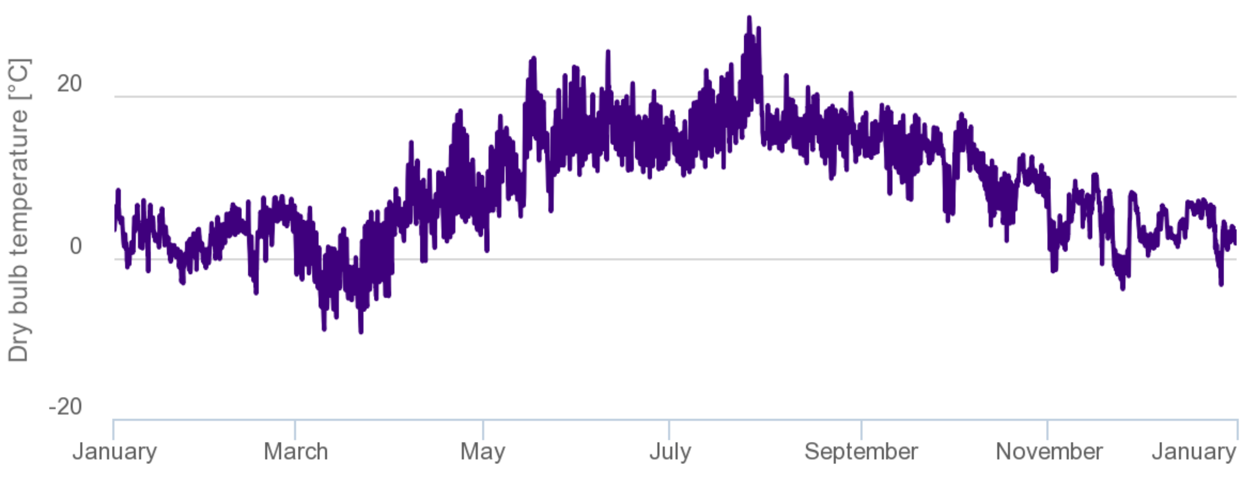

Figure 4.6:Annual average temperature - Sweden

4.1.4 Technology Packages description

Within the SunHorizon project, four technology packages have been chosen to optimize the combination of different technologies and sustainable energy sources. The four TPs are listed below (information taken from deliverables D2.1 and D6.2):

Table 4.6:Description of the chosen technology packages

TP #	Solar – HP integration concept	Description
TP1	TVP + BH +RATIO	Vacuum solar thermal panels TVP for space heating and DHW + BH and RATIO stratified thermal storage tank to cover the non-solar periods
TP2	DS + BH + RATIO	BH and RATIO stratified thermal storage tank for space heating and DHW + Hybrid PV-T panels from DualSun to cover as much heat demand as possible plus electricity to reduce electrical consumption
TP3	Solar driven HP for cooling (TVP + FAHR) + RATIO	TVP for space heating and DHW in winter and activation of the hybrid sorption/compression chiller from Fahrenheit (FAHR) and RATIO stratified thermal storage tank for space cooling
TP4	DS + BDR +RATIO	DS PVT thermal output to cover part of space heating and DHW demand and electricity production to cover reversible heat pump electricity consumption

4.2 Technical aspects: Simulation outcomes from DUU Tool

The tool has been used to simulate the thermal load and peak demand of the six virtual demonstrators. Based on the simulation output, the best combination between the TP configuration and thermal comfort has been identified for each virtual demonstrator. In the following sections the outcomes from excel Tool concerning the three residential and the three tertiary buildings located in the three selected countries are shown.

4.2.1 Demonstrator building # 1 (Residential – Italy/Rome)

As described in Section 3, in the DUU tool the input data provided by the user are used to calculate the peak loads and the energy demands for both heating and cooling and generate the loads distribution involving uncertainties.

Heating

As regards heating for the present demonstrator building the following data were calculated by DUU Tool:

- heating energy demand: 82,956.36 kWh. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- heating peak load: 36.81 $kW_{th.}$ It is the maximum peak value of the annual heating energy profile (refer to the vertical axis - kW).

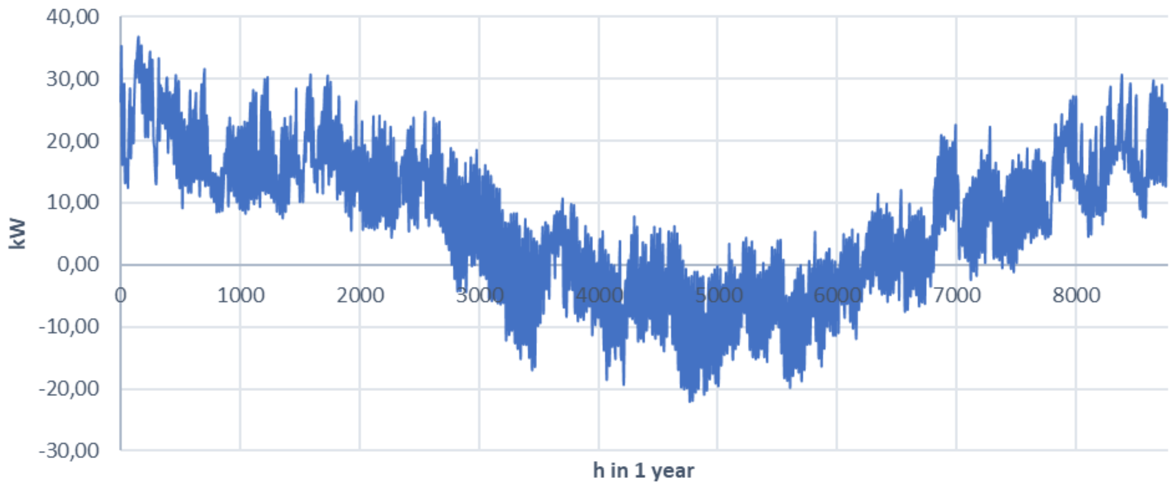

Figure 4.7:Demonstrator building #1: Residential Italy - Annual heating energy profile

Figure above shows the hourly heating power request for heating over the year for the reference building; therefore, the annual heating demand is obtained by adding together all the positive values (e.g.: kWh/y)

The Montecarlo analysis calculates the uncertainties related to the calculated heating peak load (36.81 kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below. λ7 corresponds to the lower discomfort hours and lower discomfort rate over the year.

Table 4.7:Demonstrator building #1: Residential Italy - Seven different heating peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Heating PL [kW]	33.704	**36.935**	**37.337**	**37.739**	**38.141**	**38.543**	**38.945**	**39.347**	**40.283**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	96	34	29	22	19	10	8	7	0
Discomfort rate over the year [%]	1.1%	0.4%	0.3%	0.3%	0.2%	0.1%	0.1%	0.1%	0.0%

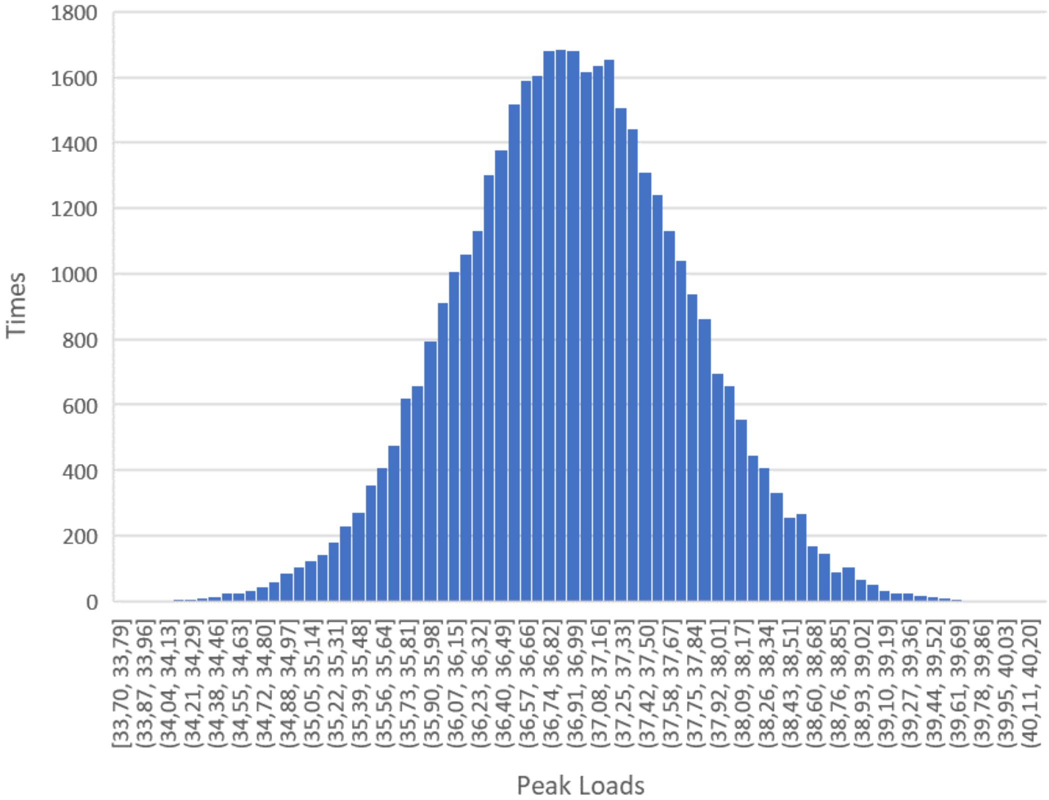

Figure 4.8:Demonstrator building # 1: Residential Italy - Annual heating peak loads

The Monte Carlo method is applied and a total of 40,000 peak load values are calculated.

In the above figure, the probability distribution of the so obtained heating peak load is reported; the ordinate shows the number of times the peak range value indicated in the abscissa is repeated (e.g.: the peak range 36.91÷36.99 is repeated approximately 1,650 times during the run of the excel Tool). The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economical configuration.

Cooling

As regards cooling for the present demonstrator building, the following data were calculated by DUU Tool for the cooling peak load and the cooling energy demand.

- cooling energy demand:18,567.76 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- cooling peak load: 36.65 kW. It is the maximum peak value of the annual cooling energy profile (refer to the vertical axis - kW).

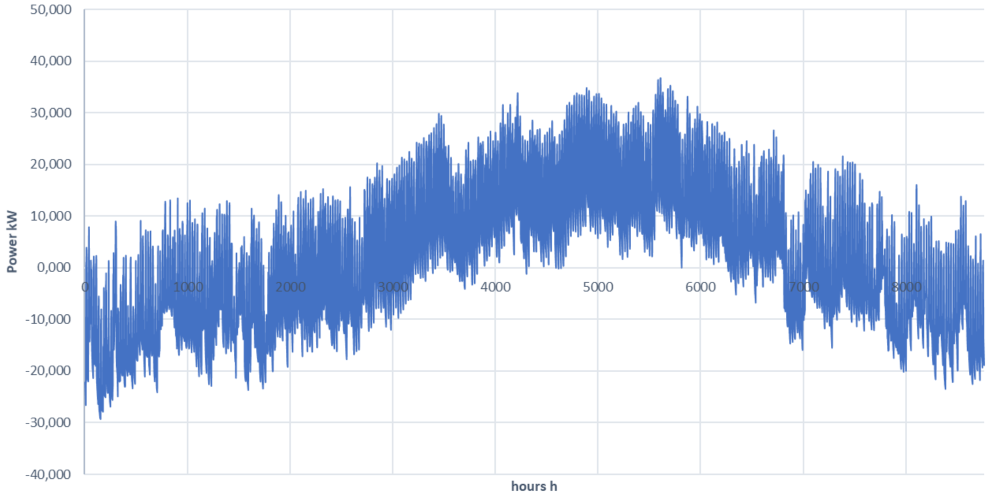

Figure 4.9:Demonstrator building #1: Residential Italy - Annual cooling energy profile

The Monte Carlo analysis is also applied to the cooling demand and calculates the uncertainties related to the calculated cooling peak load (36.65kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below.

In particular, λ7 corresponds to the lower discomfort hours and lower discomfort rate over the year.

Table 4.8:*Demonstrator building #1: Residential Italy* -Seven different cooling peak loads and thresholds based on the standard deviation of the distribution (*λ)*

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Cooling PL [kW]	**22.713**	**36.663**	**38.264**	**39.865**	**41.465**	**43.066**	**44.667**	**46.268**	**50.559**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	1,500	405	315	223	147	101	60	24	0
Discomfort rate over the year [%]	17.1%	4.6%	3.6%	2.5%	1.7%	1.2%	0.7%	0.3%	0.0%

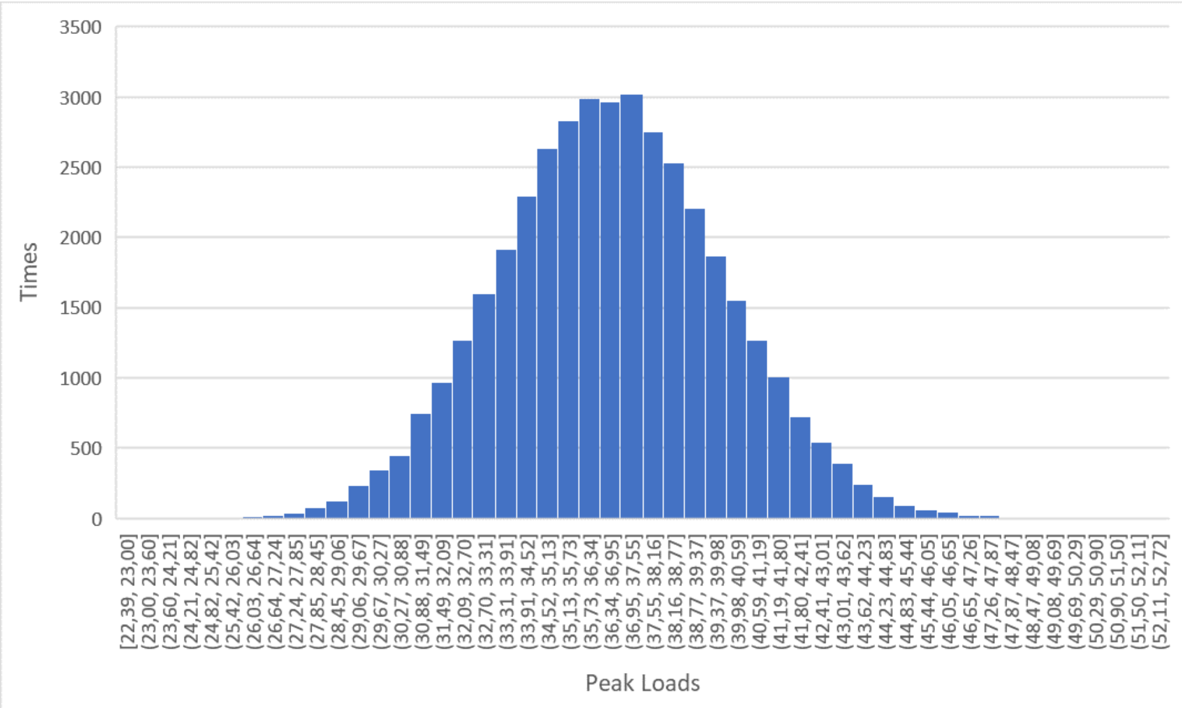

Figure 4.10:Demonstrator building #1: Residential Italy - Annual cooling peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained cooling peak load is reported; the ordinate shows the number of times the peak range value indicated in the abscissa is repeated (e.g.: the peak range 36.34÷36.95 is repeated approximately 3,000 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economical configuration

Domestic Heat Water (DHW)

For calculation of DHW, UNI EN 11300 has been used. Based on this Standard an annual DHW demand can be calculated (not the hourly DHW demand).

- DHW annual energy demand: 13,754.29 kWh/y

Otucomes from Tool

Finally, based on the optimal combination of discomfort rate and costs, the tool selected the proper configuration for each TP and for each equipment as shown below.

TP1	TP1 Best Ranking						
	λ7 Conf2	BH HP		RATIO TANK		TVP SP	
	SIZE	40	kW	5,290	liters	113	m²
	Energy produced	0	kWh/y	\	\	127,242	kWh/y
	YEOH	0	YEOH	\	\	\	\
	Capital Cost	40,000	€	10,097	€	56,250	€
	Operative Cost	0	€/y	\	\	\	\

In this configuration 113 m^2 of thermal solar module can fulfil the entire demand. Approximately 5,300 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW, required to overcome 39.34 kW peak load (λ7), in this building results to be redundant due to the abundant capacity of solar technology.

In fact, the annual heating energy demand required by building is equal to 88,673.84 kWh/y. This is the energy demand affected by uncertainties. It has been calculated dividing the heating energy demand without uncertainties (e.g.: 82,956 kWh) by the heating peak load (e.g.: 36.81 kW_{th}), thus obtaining the yearly operating hours (e.g.: 2,254 h/y). Multiplying the operating hours by the peak load λ7 (39.34 kW), the annual heating energy demand value of 88,673.84 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (13,754.29 kWh/y): 102,428 kWh/y. Therefore, **the energy produced by TVP solar (127,242 kWh/y) cover the total heating demand (102,428 kWh/y).**

TP2

TP2 Best Ranking						
λ7 Conf1	BH HP		RATIO TANK		DUAL SUN PVT	
SIZE	40	kW	7,041	liters	150	m2
Energy produced	50,278	kWh/y	\	\	52,157	kWh/y Th
					46,944	kWh/y El
YEOH	1,257	YEOH	\	\	\	\
Capital Cost	40,000	€	12717	€	112,800	€
Operative Cost	3,511	€/y	\	\	-10,328	€/y

In this configuration 150 m^2 of both photovoltaic and thermal solar modules are installed. Approximately 7,000 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW, required to overcome 39.34 kW peak load (λ7), in this building is needed to fulfil the gap between the required heating demand (88,673.84 kWh/y) plus the DHW demand (13,754.29 kWh/y) and the energy produced by solar technology (52,157kWh/y). In this building the electric energy produced by the PV technology can be used by the system or sold to the grid resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (e.g.: 88,673.84 kWh/y) is the annual heating energy demand required by building affected by uncertainties (e.g.: λ7, including 7 discomfort hours and 0.1% discomfort rate over the year). It has been calculated dividing the heating energy demand without uncertainties (e.g.: 82,956 kWh) by the heating peak load (e.g.: 36.81 kW_{th}), thus obtaining the yearly operating hours (e.g.: 2,254 h/y). Multiplying the operating hours by the peak load λ7 (39.34 kW), the annual heating energy demand value of 88,673.84 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (13,754.29 kWh/y): 102,428 kWh/y. Therefore, **the energy produced by BH HP and Dual Sun PVT (102,435 kWh/y) cover the total heating demand (102,428 kWh/y).**

TP3

TP3 Best Ranking								
λ2 Conf1	FARH SORP CHILLER		COMPR. CHILLER		RATIO TANK		TVP SP	
SIZE	39	kW	38	kW	7,041	liters	150	m2
Energy produced	13,611	kWh/y	5,776	kWh/y	\	\	28,678	kWh/y Th
YEOH	349	YEOH	151	YEOH	\	\	\	\
Capital Cost	73,200	€	30,640	€	12,717	€	75,000	€
Operative Cost	172	€/y	374	€/y	\	\	0	€/y

This technology package mainly provides space cooling during summer. The sorption chiller must be coupled with the solar thermal source, for which the summer production is considered. All the heating produced during winter is considered as a saving. In particular, this configuration consists of 150 m^2 of thermal solar module. Approximately 7,000 l storage tank must be coupled with solar technology.

The annual cooling energy demand required by building affected by uncertainties (λ2, including 315 discomfort hours and 3.6% discomfort rate over the year) has been calculated dividing the cooling energy demand without uncertainties (e.g.: 18,567.76 kWh/y) by the cooling peak load (e.g.: 36.65 kW$_{th}$), thus obtaining the yearly operating hours (e.g.: 507 h/y). Multiplying the operating hours by the cooling peak load λ2 with uncertainties (38.264 kW), the annual cooling energy demand value of 19,385.3 kWh/y is obtained. This **cooling demand is covered by the energy produced by Farhenehit sorption and compressor chillers which is equal to 19,387 kWh/y**.

TP4	TP4 Best Ranking										
	λ5 Conf1	BDR ASHP		TANK DHW		TANK H/C		Baxi TH		Baxi EL	
	SIZE	43	kW	817	liters	1,875	liters	37.5	m^2	112.5	m^2
	Energy produced	90,170	kWh/y	\	kWh/y	\	\	10,453	kWh/y Th	31,360	kWh/y El
	YEOH	2094	YEOH	\	\	\	\	\	\	\	\
	Capital Cost	26,270	€	3276	€	5,653	€	15,000	€	33,750	€
	Operative Cost	6,066	€/y	\	€/y	\	\	\	€/y	-6,899	€/y

This configuration, similarly to the TP2, consists of 150 m^2 of solar panels (37.5 m^2 thermal and 112.5 m^2 photovoltaic) which provide hot water and electricity, this second one as a saving. Two separates tank are considered for DHW and SH.

The annual heating energy demand required by building affected by uncertainties (λ5, including 10 discomfort hours and 0.1 discomfort rate over the year) has been calculated dividing the heating energy demand without uncertainties (e.g.: 82,956 kWh/y) by the heating peak load (e.g.: 36.81 kW$_{th}$), thus obtaining the yearly operating hours (e.g.: 2,254 h/y). Multiplying the operating hours by the heating peak load λ5 with uncertainties (38.543 kW), the annual heating energy demand value of 86,861.54 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (13,754.29 kWh/y): 100,615.83 kWh/y. Therefore, **the energy produced by BDR AHSP and Baxi TH (100,623.00 kWh/y) cover the heating demand.**

BDR full electric Air-Water heat pump is considered to fulfil the gap between the thermal energy demand and that produced by solar thermal collectors.

4.2.2 Demonstrator building #2 (Residential – The Netherlands/Rotterdam)

As described in Section 3, in the DUU tool the input data provided by the user are used to calculate the peak loads and the energy demands for both heating and cooling and generate the loads distribution involving uncertainties.

Heating

As regards heating for the present demonstrator building the following data were calculated by DUU Tool:

- heating energy demand: 116,214.91 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- heating peak load: 42.12 kW$_{th}$. It is the maximum peak value of the annual heating energy profile (refer to the vertical axis - kW).

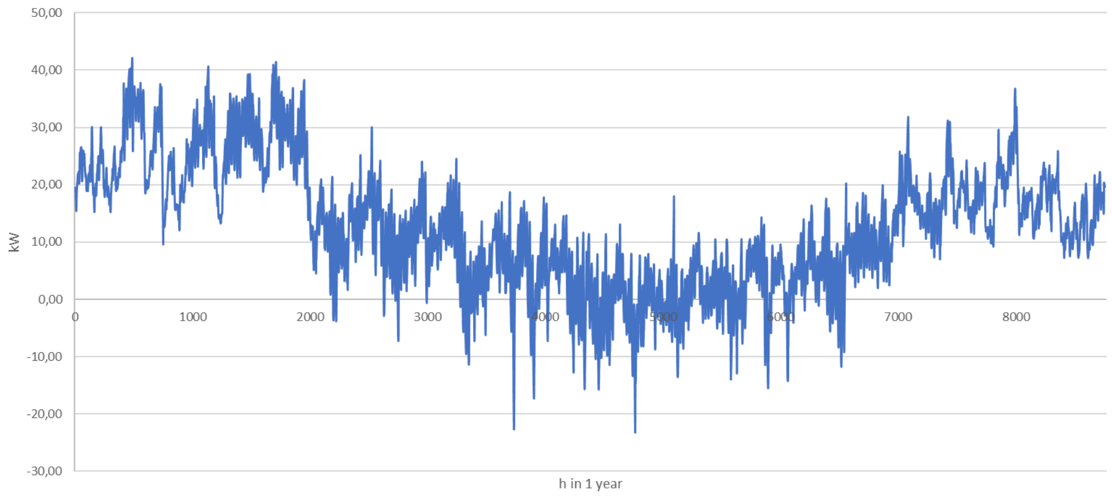

Figure 4.11:Demonstrator building #2: Residential Netherlands - Annual heating energy profile

The Montecarlo analysis calculates the uncertainties related to the calculated heating peak load (42.12kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below. λ7 corresponds to the lower discomfort hours and lower discomfort rate over the year.

Table 4.9: Demonstrator building #2: Residential Netherlands - Seven different heating peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Heating PL [kW]	**37.634**	**41.258**	**41.722**	**42.186**	**42.650**	**43.114**	**43.578**	**44.043**	**45.604**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	288	81	67	55	41	34	24	20	4
Discomfort rate over the year [%]	3.3%	0.9%	0.8%	0.6%	0.5%	0.4%	0.3%	0.2%	0.0%

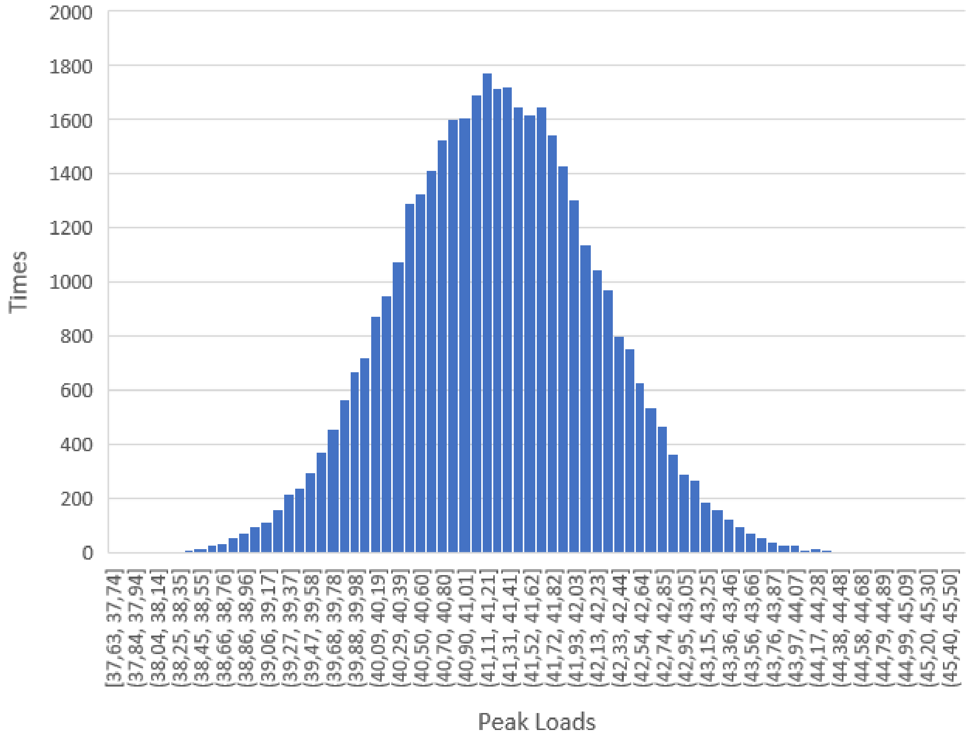

Figure 4.12:Demonstrator building #2: Residential Netherlands - Annual heating peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained heating peak load is reported; the ordinate shows the number of times the peak range value indicated in the abscissa is repeated (e.g.: the peak range 41.31÷41.41 is repeated approximately 1,750 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economic configuration.

Cooling

As regards cooling for the present building, the following data were calculated by DUU Tool for the cooling energy demand and the cooling peak load.

- cooling energy demand: 355.82 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- cooling peak load: 22.49 kW. It is the maximum peak value of the annual cooling energy profile (refer to the vertical axis - kW).

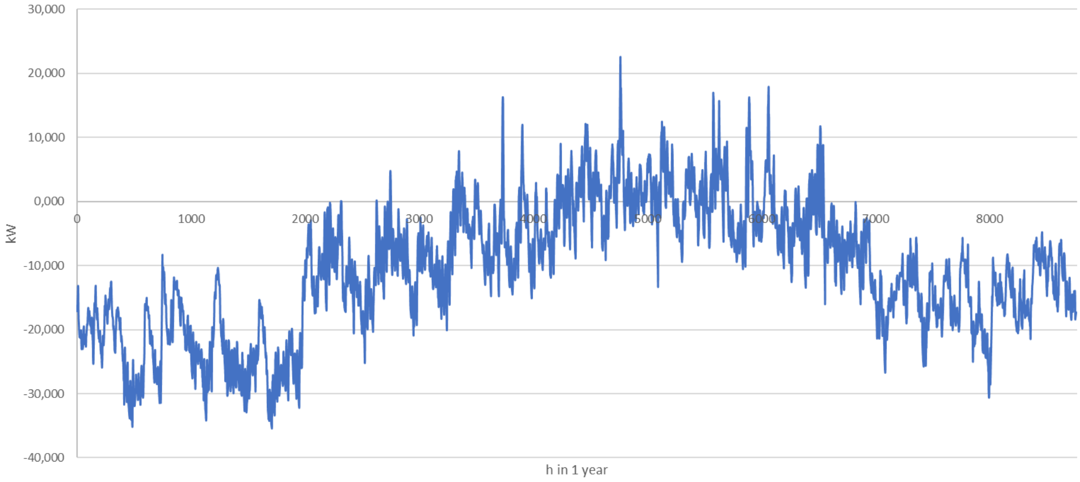

Figure 4.13:Demonstrator building #2: Residential Netherlands - Annual cooling energy profile

The Montecarlo analysis is also applied to the cooling demand and calculates the uncertainties related to the calculated cooling peak load (22.49 kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below.

In particular, λ7 corresponds to the lower discomfort hours and lower discomfort rate over the year.

Table 4.10:Demonstrator building #2: Residential Netherlands - Seven different cooling peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Cooling PL [kW]	**10,225**	**22,532**	**24,637**	**26,742**	**28,847**	**30,952**	**33,057**	**35,162**	**49,41**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	0,00	79,51	84,99	89,66	90,47	92,29	93,31	95,94	100,00
Discomfort rate over the year [%]	5,6%	1,2%	0,8%	0,6%	0,5%	0,4%	0,4%	0,2%	0,0%

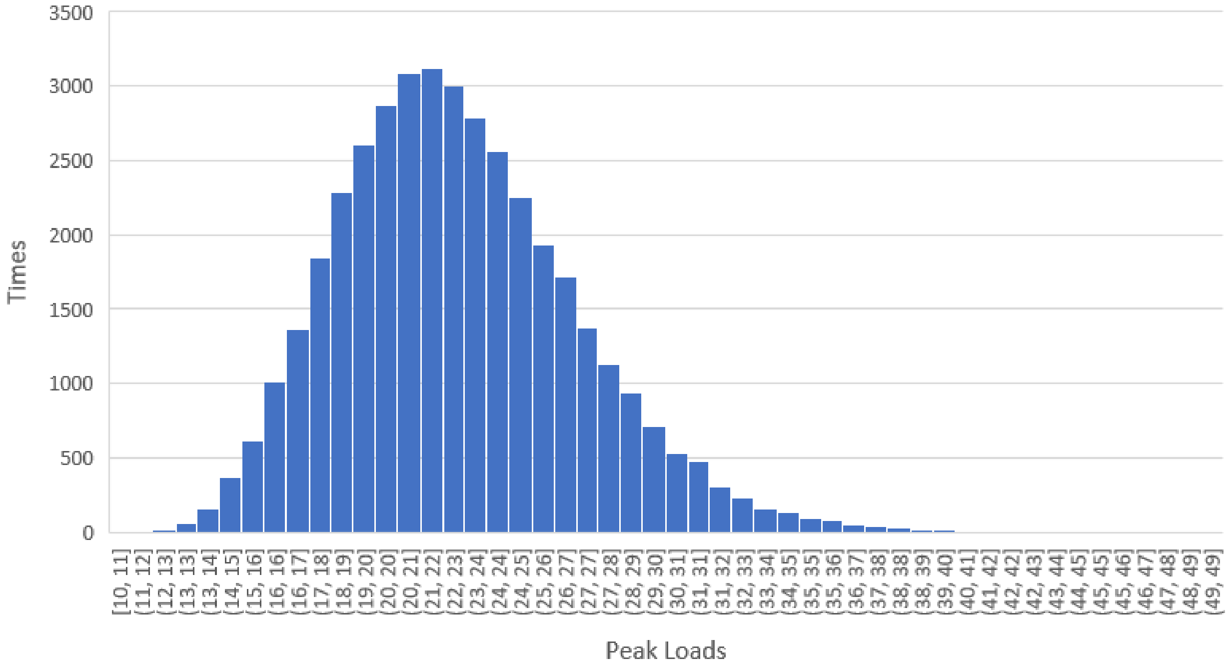

Figure 4.14:Demonstrator building #2: Residential Netherlands - Annual cooling peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained cooling peak load is reported; the ordinate shows the number of times the peak range value indicated in the abscissa is repeated (e.g.: the peak range 22÷23 is repeated approximately 3,000 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economic configuration

Domestic Heat Water (DHW)

For calculation of DHW, UNI EN 11300 has been used. Based on this Standard an annual DHW demand can be calculated (not the hourly DHW demand).

- DHW energy demand: 31,650.34 kWh/y.

Outcomes of the Tool

Based on the optimal combination of discomfort rate and costs, the tool selects the proper configuration for each TP and for each equipment as shown below:

TP1	TP1 Best Ranking						
TP1	λ4 Conf1	BH HP		RATIO TANK		TVP SP	
TP1	SIZE	60	kW	6,620	litres	141	m²
TP1	Energy produced	48,390	kWh/y	\	\	100,932	kWh/y
TP1	YEOH	806	YEOH	\	\	\	\
TP1	Capital Cost	60,000	€	12,088	€	70,500	€
TP1	Operative Cost	3,379	€/y	\	\	\	\

In this configuration 141 m^2 of thermal solar module cannot fulfill the entire heating demand (117,671.35 kWh/y). Approximately 6,600 l storage tank must be coupled with the solar technology. The heat pump capacity of 60 kW is suitable to overcome 42.12 kW peak load and to fulfil the entire heating demand.

The annual heating energy demand required by building is equal to 117,671.35 kWh/y. This is the energy demand affected by uncertainties. It has been calculated dividing the heating energy demand without uncertainties (e.g.: 116,214.91 kWh) by the heating peak load (e.g.: 42.12 kW$_{th}$), thus obtaining the yearly operating hours (e.g.: 2,759 h/y). Multiplying the operating hours by the peak load λ4 (42.65 kW), the annual heating energy demand value of 117,671.35 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand and the DHW demand (31,650.34 kWh/y): 149,321.69 kWh/y. Therefore, **the energy produced by BH HP and TVP solar (149,322 kWh/y) cover the total heating demand (149,321.69 kWh/y).**

TP2

TP2 Best Ranking						
λ4 Conf1	BH HP		RATIO TANK		DUAL SUN PVT	
SIZE	60	kW	6,618	litres	141	m^2
Energy produced	130,455	kWh/y	\	\	18,867	kWh/y Th
					29,983	kWh/y El
YEOH	2174	YEOH	\	\	\	\
Capital Cost	60,000	€	12,088	€	106,032	€
Operative Cost	9,109	€/y	\	\	-6,596	€/y

In this configuration 141 m^2 of both photovoltaic and thermal solar modules are installed. Approximately 6,620 l storage tank must be coupled with the solar technology. The heat pump capacity of 60 kW, required to overcome 42.12 kW peak (λ4) load, in this building is needed to fulfil the gap between the required heating demand (117,671.35 kWh/y) plus the DHW demand (31,650.34 kWh/y) and the energy produced by solar technology (18,867 kWh/y). In this building the electric energy produced by the PV technology can be used by the system or sold to the grid resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (e.g.: 117,671.35 kWh/y) is the annual heating energy demand required by building affected by uncertainties (e.g.: λ4, including 42 discomfort hours and 0.1% discomfort rate over the year). It has been calculated dividing the heating energy demand without uncertainties (e.g.: 116,214.91kWh) by the heating peak load (e.g.: 42.12 kW$_{th}$), thus obtaining the yearly operating hours (e.g.: 2,759 h/y). Multiplying the operating hours by the peak load λ4 (42.65 kW), the annual heating energy demand value of 117,671.35 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (13,754.29 kWh/y): 149,321.69 kWh/y. Therefore, **the energy produced by BH HP and Dual Sun PVT (149,322 kWh/y) cover the total heating demand (149,321 kWh/y).**

TP3

TP3 Best Ranking								
λ2 Conf1	FARH SORP CHILLER		COMPR. CHILLER		RATIO TANK		TVP SP	
SIZE	26	kW	25	kW	6,618	litres	141	m^2
Energy produced	136	kWh/y	232	kWh/y	\	\	286	kWh/y Th
YEOH	5	YEOH	9	YEOH	\	\	\	\
Capital Cost	48,800	€	19,760	€	12,088	€	70,500	€
Operative Cost	2	€/y	15	€/y	\	\	0	€/y

This technology package mainly provides space cooling during summer. The sorption chiller must be coupled with the solar thermal source, for which the summer production is considered. All the heating produced during winter is considered as a saving. In particular, this configuration consists of 141 m^2 of thermal solar module. Approximately 6,620 l storage tank must be coupled with solar technology.

Farhenehit sorption chiller and compressor chiller are able to cover the cooling energy demand (e.g.:367.83 kWh/y)

The annual cooling energy demand required by building affected by uncertainties (λ2, including 85 discomfort hours and 0.8% discomfort rate over the year) has been calculated dividing the cooling energy demand without uncertainties (e.g.: 355.82 kWh/y) by the cooling peak load (e.g.: 22.49 kW_{th}), thus obtaining the yearly operating hours (e.g.: 15 h/y). Multiplying the operating hours by the cooling peak load λ2 with uncertainties (24.637 kW), the annual cooling energy demand value of 367.83 kWh/y is obtained. This **cooling demand is covered by the energy produced by Farhenehit sorption and compressor chillers which is equal to 368 kWh/y**.

TP4	TP4 Best Ranking										
	λ3 Conf1	BDR ASHP		TANK DHW		TANK H/C		Baxi TH		Baxi EL	
	SIZE	45	kW	1581	litres	1762,5	litres	35,25	m^2	105,75	m^2
	Energy produced	141365	kWh/y	\	kWh/y	\	\	6677	kWh/y Th	20030	kWh/y El
	YEOH	3146	YEOH	\	\	\	\	\	\	\	\
	Capital Cost	27407	€	4992	€	5400	€	14100	€	31725	€
	Operative Cost	9511	€/y	\	€/y	\	\	\	€/y	-4406	€/y

This configuration, similarly to the TP2, consists of 141 m^2 of solar panels (35.25 m^2 thermal and 105.75 m^2 photovoltaic) which provide hot water and electricity, this second one as a saving. Two separates tank are considered for DHW and SH.

The annual heating energy demand required by building affected by uncertainties (λ3, including 55 discomfort hours and 0.6% discomfort rate over the year) has been calculated dividing the heating energy demand without uncertainties (e.g.: 116,214.91 kWh/y) by the heating peak load (e.g.: 42.12 kW_{th}), thus obtaining the yearly operating hours (e.g.: 2,759 h/y). Multiplying the operating hours by the heating peak load λ3 with uncertainties (42.186 kW), the annual heating energy demand value of 116,391.17 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (31,650.34 kWh/y): 148,041.51 kWh/y. Therefore, **the energy produced by BDR AHSP and Baxi TH (148,042 kWh/y) cover the heating demand.**

BDR full electric Air-Water heat pump is considered to fulfil the gap between the thermal energy demand and that produced by solar thermal collectors.

4.2.3 Demonstrator building #3 (Residential – Sweden/Goteborg)

As described in Section 3, in the DUU tool the input data provided by the user are used to calculate the peak loads and the energy demands for both heating and cooling and generate the loads distribution involving uncertainties.

Heating

As regards heating for the present demonstrator building the following data were calculated by DUU Tool:

- Heating energy demand: 148,833.74 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- Peak load: 42.36 kW. It is the maximum peak value of the annual heating energy profile (refer to the vertical axis - kW).

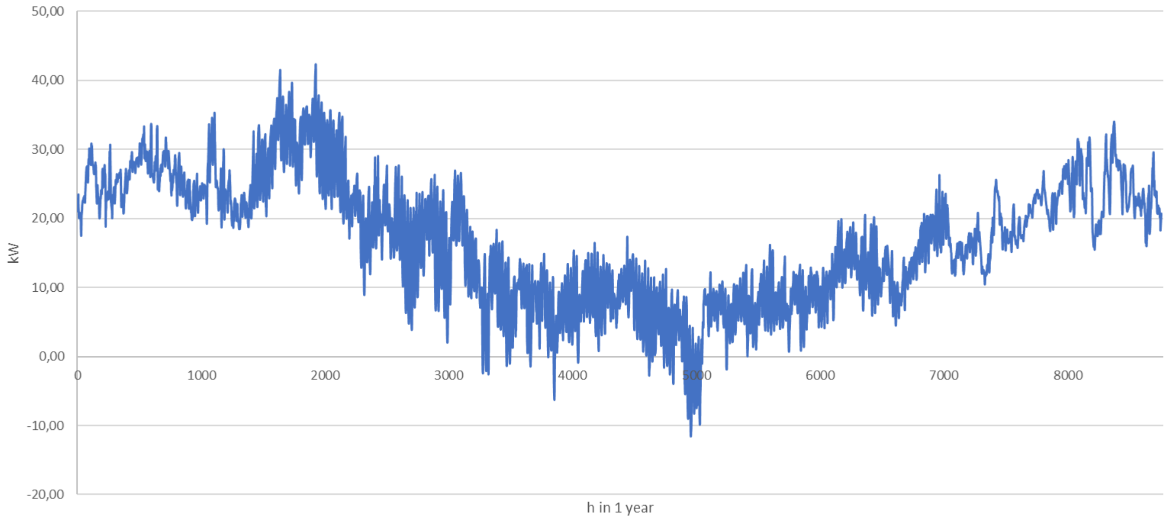

Figure 4.15:Demonstrator building #3: Residential Sweden - Annual heating energy profile

The Montecarlo analysis calculates the uncertainties related to the calculated heating peak load (42.36kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below. λ7 corresponds to the lower discomfort hours and lower discomfort rate over the year.

Table 4.11:Demonstrator building #3: Residential Sweden - Seven different heating peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Heating PL [kW]	37.976	**42.241**	**42.788**	**43.335**	**43.882**	**44.429**	**44.977**	**45.524**	**46.606**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	172	23	20	16	13	10	8	5	1
Discomfort rate over the year [%]	2.0%	0.3%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%

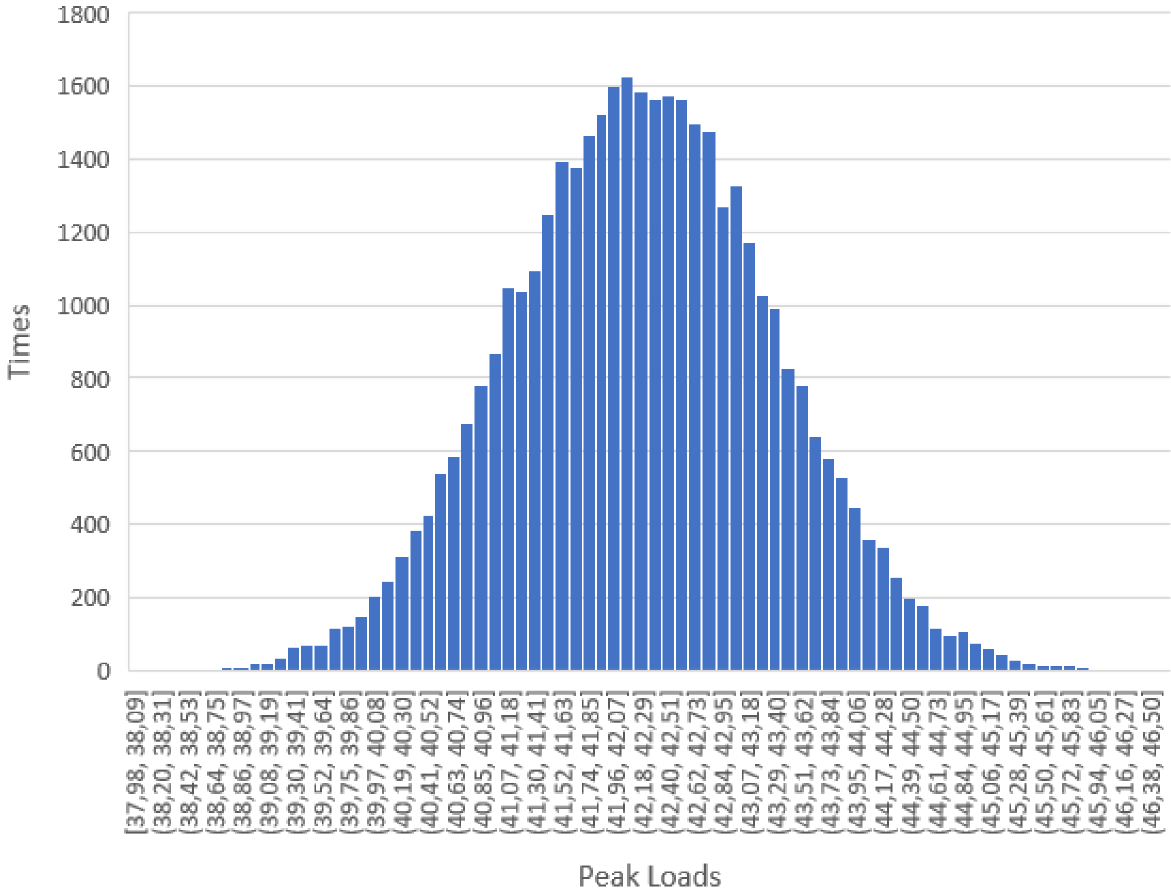

Figure 4.16:Demonstrator building #3: Residential Sweden -Annual heating peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained heating peak load is reported; the ordinate shows the number of times the peak value indicated in the abscissa is repeated (e.g.: the peak range 41.96÷42.07 is repeated approximately 1,620 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economic configuration.

Cooling

As regards cooling for the present building, the following data were calculated by DUU Tool for the cooling peak load and the cooling energy demand.

- cooling energy demand: 1,356.07 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- cooling peak load: 47.03 kW. It is the maximum peak value of the annual cooling energy profile (refer to the vertical axis - kW).

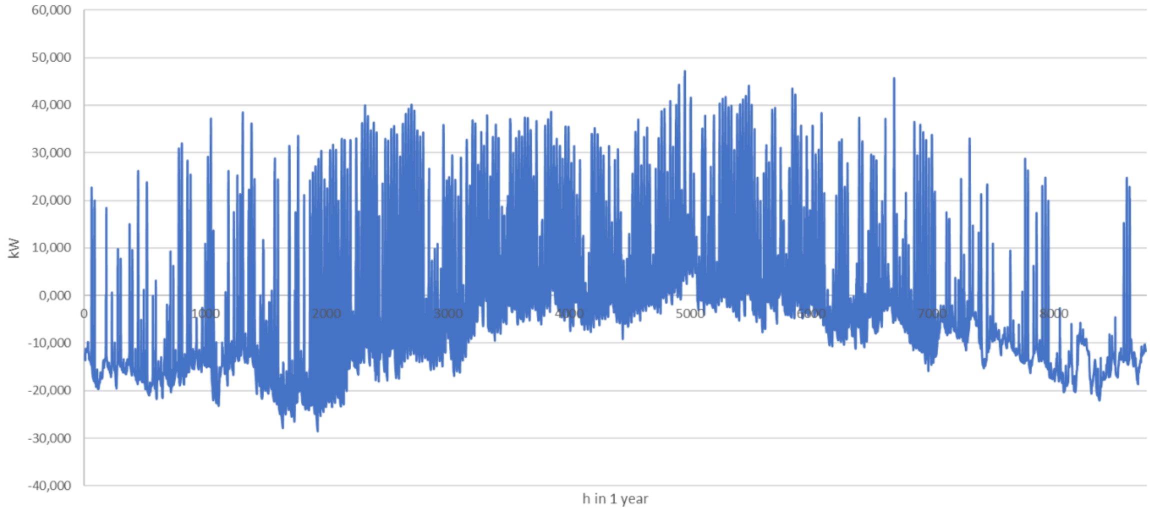

Figure 4.17:Demonstrator building #3: Residential Sweden - Annual cooling energy profile

The Montecarlo analysis is also applied to the cooling demand and calculates the uncertainties related to the calculated cooling peak load (47.03kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below.

Table 4.12:Demonstrator building #3: Residential Sweden - Seven different cooling peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Cooling PL [kW]	**20.294**	**47.042**	**50.720**	**54.398**	**58.076**	**61.754**	**65.432**	**69.110**	**81.590**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	1,308	492	403	296	203	123	64	31	0
Discomfort rate over the year [%]	14.9%	5.6%	4.6%	3.4%	2.3%	1.4%	0.7%	0.4%	0.0%

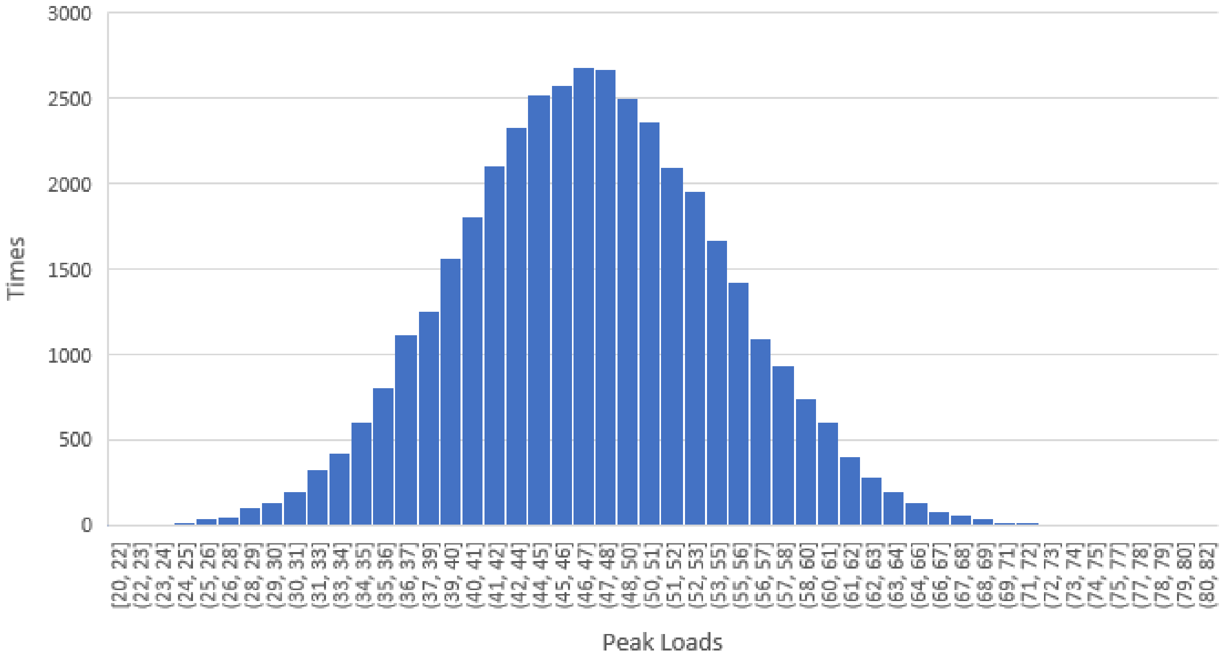

Figure 4.18:Demonstrator building #3: Residential Sweden - Annual cooling peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained cooling peak load is reported; the ordinate shows the number of times the peak value indicated in the abscissa is repeated (e.g.: the peak range 47÷48 is repeated approximately 2,600 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economical configuration.

Domestic Heat Water (DHW)

For calculation of DHW, UNI EN 11300 has been used. Based on this Standard an annual DHW demand can be calculated (not the hourly DHW demand).

- DHW energy demand: 22,871.32 kWh/y.

Outcomes of the Tool

Based on the optimal combination of discomfort rate and costs, the tool selects the proper configuration for each TP and for each equipment as follow:

TP1	TP1 Best Ranking						
	λ1 Conf1	BH HP		RATIO TANK		TVP SP	
	SIZE	60	kW	8,830	litres	188	m^2
	Energy produced	53,383	kWh/y	\	\	117,911	kWh/y
	YEOH	890	YEOH	\	\	\	\
	Capital Cost	60,000	€	15,373	€	94,000	€
	Operative Cost	3,727	€/y	\	\	\	\

In this configuration 188 m² of thermal solar module cannot fulfill the entire heating demand (148,415.63 kWh/y). Approximately 8,830 l storage tank must be coupled with the solar technology. The heat pump capacity of 60 kW is suitable to overcome 42.36 kW peak load and to fulfil the entire heating demand

The annual heating energy demand required by building is equal to 148,415.63 kWh/y. This is the energy demand affected by uncertainties. It has been calculated dividing the heating energy demand without uncertainties (e.g.: 148,833.74 kWh) by the heating peak load (e.g.: 42.36 kW_{th}), thus obtaining the yearly operating hours (e.g.: 3,514 h/y). Multiplying the operating hours by the peak load λ1 (42.241 kW), the annual heating energy demand value of 148,415.63 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (22,871.32 kWh/y): 171,286.95 kWh/y. Therefore, **the energy produced by BH HP and TVP solar (149,322 kWh/y) cover the total heating demand (171,294 kWh/y).**

TP2

TP2 Best Ranking						
λ1 Conf1	BH HP		RATIO TANK		DUAL SUN PVT	
SIZE	60	kW	8,824	litres	188	m2
Energy produced	152,605	kWh/y	\	\	18,689	kWh/y Th
					35,617	kWh/y El
YEOH	2,543	YEOH	\	\	\	\
Capital Cost	60,000	€	15,373	€	141,376	€
Operative Cost	10,655	€/y	\	\	-7,836	€/y

In this configuration 188 m² of both photovoltaic and thermal solar modules are installed. Approximately 8,820 l storage tank must be coupled with the solar technology. The heat pump capacity of 60 kW, required to overcome 42.24 kW peak (λ1) load, in this building is needed to fulfil the gap between the required heating demand (148,415.63 kWh/y) plus the DHW demand (22,871.32 kWh/y) and the energy produced by solar technology (18,689 kWh/y). In this building the electric energy produced by the PV technology can be used by the system or sold to the grid resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (e.g.: (148,415.63 kWh/y) is the annual heating energy demand required by building affected by uncertainties (e.g.: λ1, including 23 discomfort hours and 0.3% discomfort rate over the year). It has been calculated dividing the heating energy demand without uncertainties (e.g.: 148,833.74 kWh) by the heating peak load (e.g.: 42.36 kW_{th}), thus obtaining the yearly operating hours (e.g.: 3,514 h/y). Multiplying the operating hours by the peak load λ1 (42.24 kW), the annual heating energy demand value of 148,415.63 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (22,871.32 kWh/y): 171,286.95 kWh/y. Therefore, **the energy produced by BH HP and Dual Sun PVT (171,294 kWh/y) cover the total heating demand (171,286.95 kWh/y).**

TP3

TP3 Best Ranking								
λ2 Conf1	FARH SORP CHILLER		COMPR. CHILLER		RATIO TANK		TVP SP	
SIZE	52	kW	51	kW	8824,5	liters	188	m2
Energy produced	697	kWh/y	766	kWh/y	\	\	1468	kWh/y Th
YEOH	13	YEOH	15	YEOH	\	\	\	\
Capital Cost	97600	€	40640	€	15373	€	94000	€
Operative Cost	9	€/y	50	€/y	\	\	0	€/y

This technology package mainly provides space cooling during summer. The sorption chiller must be coupled with the solar thermal source, for which the summer production is considered. All the heating produced during winter is considered as a saving. In particular, this configuration consists of 188 m^2 of thermal solar module. Approximately 8,820 l storage tank must be coupled with solar technology.

Farhenehit sorption chiller and compressor chiller are able to cover the cooling energy demand (e.g.:1,462.47 kWh/y)

The annual cooling energy demand required by building affected by uncertainties (λ2, including 403 discomfort hours and 4.6% discomfort rate over the year) has been calculated dividing the cooling energy demand without uncertainties (e.g.: 1,356.07 kWh/y) by the cooling peak load (e.g.: 47.03 kW_{th}), thus obtaining the yearly operating hours (e.g.: 29 h/y). Multiplying the operating hours by the cooling peak load λ2 with uncertainties (50.72 kW), the annual cooling energy demand value of 1,462.47 kWh/y is obtained. This **cooling demand is covered by the energy produced by Farhenehit sorption and compressor chillers which is equal to 1,463 kWh/y**.

TP4	TP4 Best Ranking										
	λ1 Conf1	BDR ASHP		TANK DHW		TANK H/C		Baxi TH		Baxi EL	
	SIZE	47	kW	1,088	liters	2,350	liters	47	m2	141	m2
	Energy produced	163,363	kWh/y	\	kWh/y	\	\	7,931	kWh/y Th	23,793	kWh/y El
	YEOH	3473	YEOH	\	\	\	\	\	\	\	\
	Capital Cost	28,696	€	3,886	€	6,720	€	18,800	€	42,300	€
	Operative Cost	10,991	€/y	\	€/y	\	\	\	€/y	-5,235	€/y

This configuration, similarly to the TP2, consists of 188 m^2 of solar panels (47 m^2 thermal and 141 m^2 photovoltaic) which provide hot water and electricity. Two separates tank are considered for DHW and SH.

The heat pump capacity of 47 kW, required to overcome 42.24 kW peak (λ1) load, in this demonstrator building is needed to fulfil the gap between the required heating demand (148,415.63 kWh/y) plus the DHW demand (22,871.32 kWh/y) and the energy produced by solar technology (7,931 kWh/y). In this demonstrator building the electric energy produced by the PV technology can be used by the system or sold to the grid resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (e.g.: (148,415.63 kWh/y) is the annual heating energy demand required by building affected by uncertainties (e.g.: λ1, including 23 discomfort hours and 0.3% discomfort rate over the year). It has been calculated dividing the heating energy demand without uncertainties (e.g.: 148,833.74 kWh) by the heating peak load (42.36 kW_{th}), thus obtaining the yearly operating hours (3,514 h/y). Multiplying the operating hours by the peak load λ1 (42.24 kW), the annual heating energy demand value of 148,415.63 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (22,871.32 kWh/y): 171,286.95 kWh/y. Therefore, **the energy produced by BDR ASHP plus Baxi thermal solar panels (171,294 kWh/y) cover the total heating demand (171,286.95 kWh/y).**

4.2.4 Demonstrator building #4 (Tertiary – Italy/Rome)

As described in Section 3, in the DUU tool the input data provided by the user are used to calculate the peak loads and the energy demands for both heating and cooling and generate the loads distribution involving uncertainties.

Heating

As regards heating for the present demonstrator building the following data were calculated by DUU Tool:

- Heating Energy Demand: 203,324.77 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- Heating Peak load: 90.21 kW. It is the maximum peak value of the annual heating energy profile (refer to the vertical axis - kW).

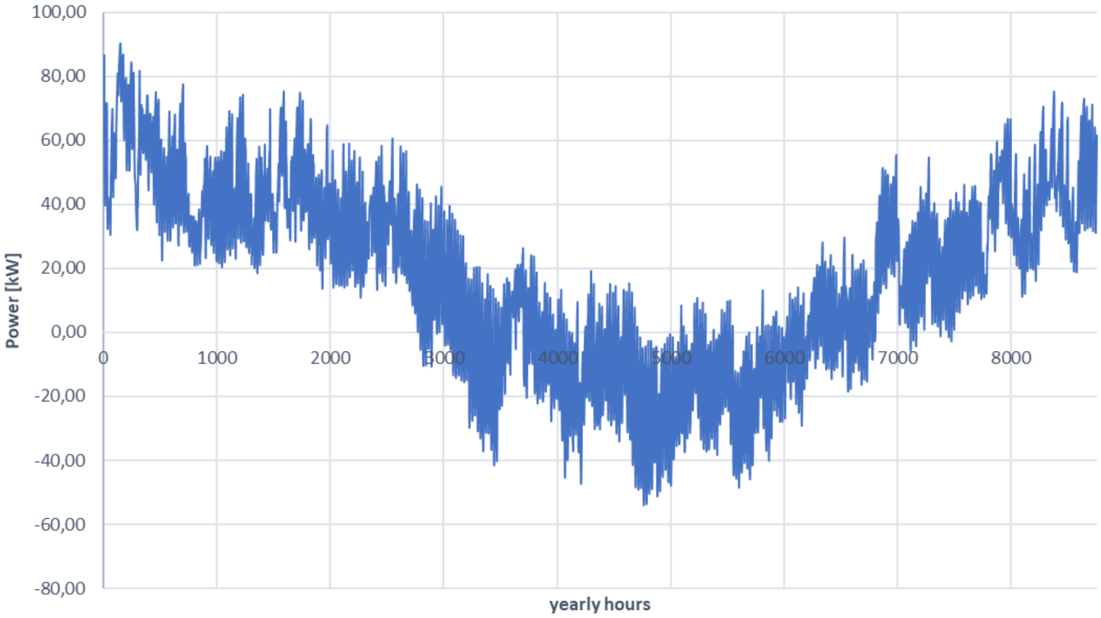

Figure 4.19:Demonstrator building #4: Tertiary Italy - Annual heating energy profile

The Montecarlo analysis calculates the uncertainties related to the calculated heating peak load (90.21 kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below. λ7 corresponds to the lower discomfort hours and lower discomfort rate over the year.

Table 4.13:Demonstrator building #4: Tertiary Italy - Seven different heating peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Heating PL [kW]	**83.139**	**88.617**	**89.290**	**89.964**	**90.637**	**91.310**	**91.983**	**92.657**	**94.862**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	73	34	31	27	23	21	18	12	7
Discomfort rate over the year [%]	0.8%	0.4%	0.4%	0.3%	0.3%	0.2%	0.2%	0.1%	0.1%

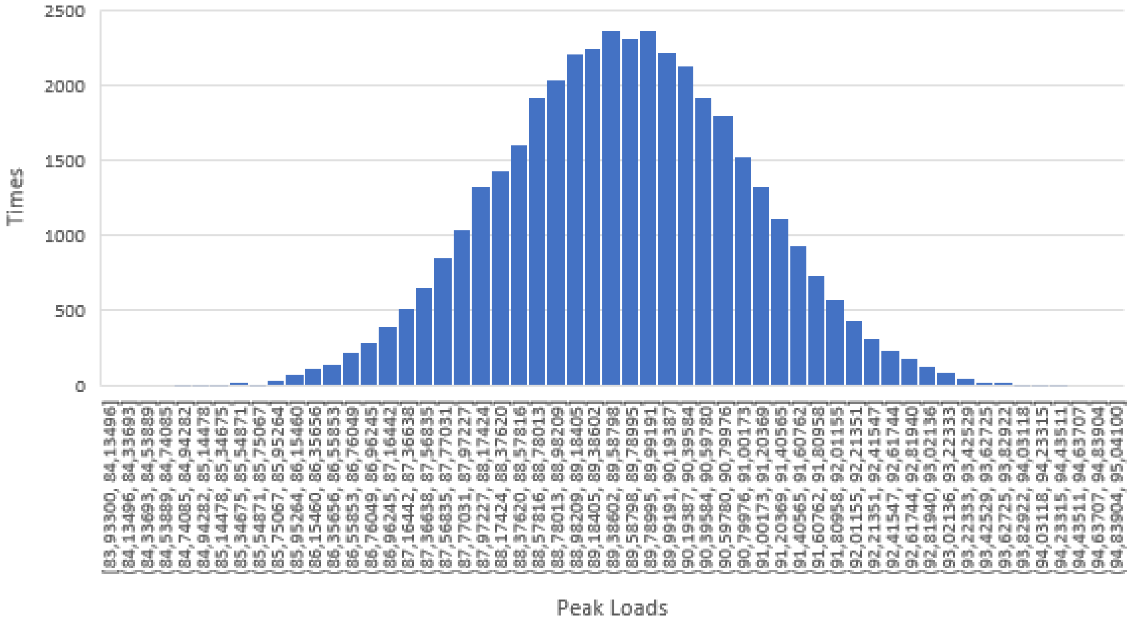

Figure 4.20: Demonstrator building #4: Tertiary Italy - Annual heating peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained heating peak load is reported; the ordinate shows the number of times the peak value indicated in the abscissa is repeated (e.g.: the peak range 88.57÷88.78 is repeated approximately 1,900 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economical configuration.

Cooling

As regards cooling for the present demonstrator building, the following data were calculated by DUU Tool for the cooling peak load and the cooling energy demand.

- Cooling Energy Demand: 95,932.04 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- Cooling Peak Load: 196.33 kW. It is the maximum peak value of the annual cooling energy profile (refer to the vertical axis - kW).

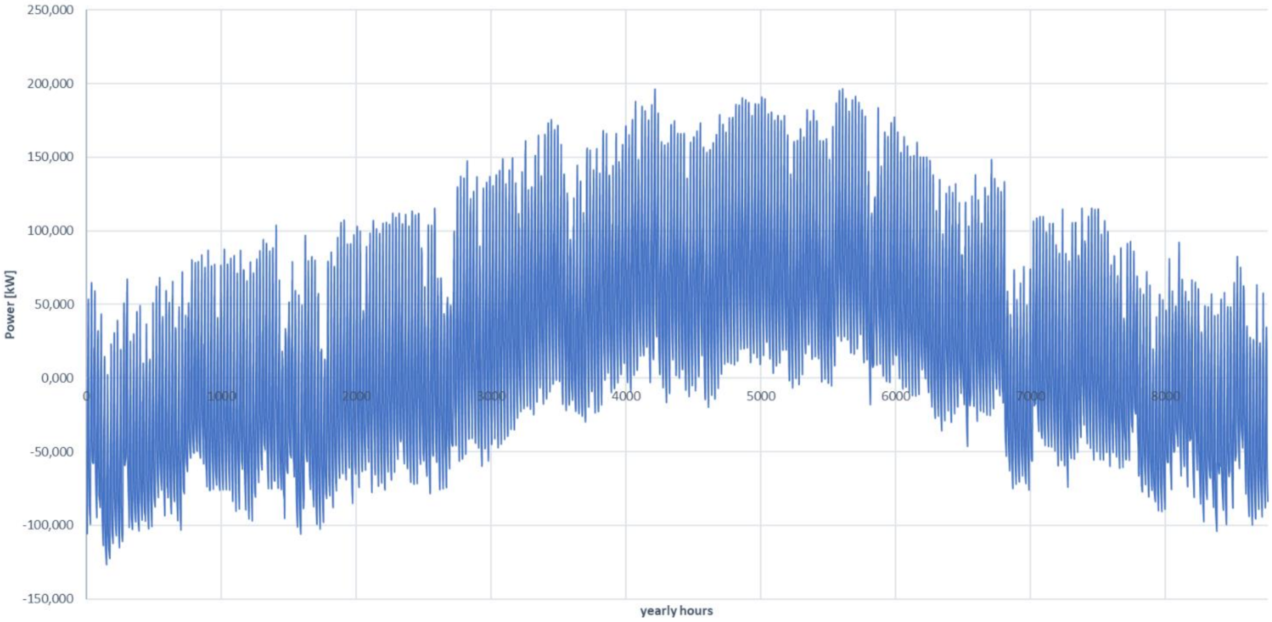

Figure 4.21:Demonstrator building #4: Tertiary Italy - Annual cooling energy profile

The Montecarlo analysis is also applied to the cooling demand and calculates the uncertainties related to the calculated cooling peak load (196.33 kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below.

Table 4.14:Demonstrator building #4: Tertiary Italy - Seven different cooling peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Cooling PL [kW]	**128.173**	**198.859**	**207.241**	**215.623**	**224.006**	**232.388**	**240.770**	**249.152**	**267.397**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	1371	372	310	239	171	126	70	33	0
Discomfort rate over the year [%]	15.7%	4.2%	3.5%	2.7%	2.0%	1.4%	0.8%	0.4%	0.0%

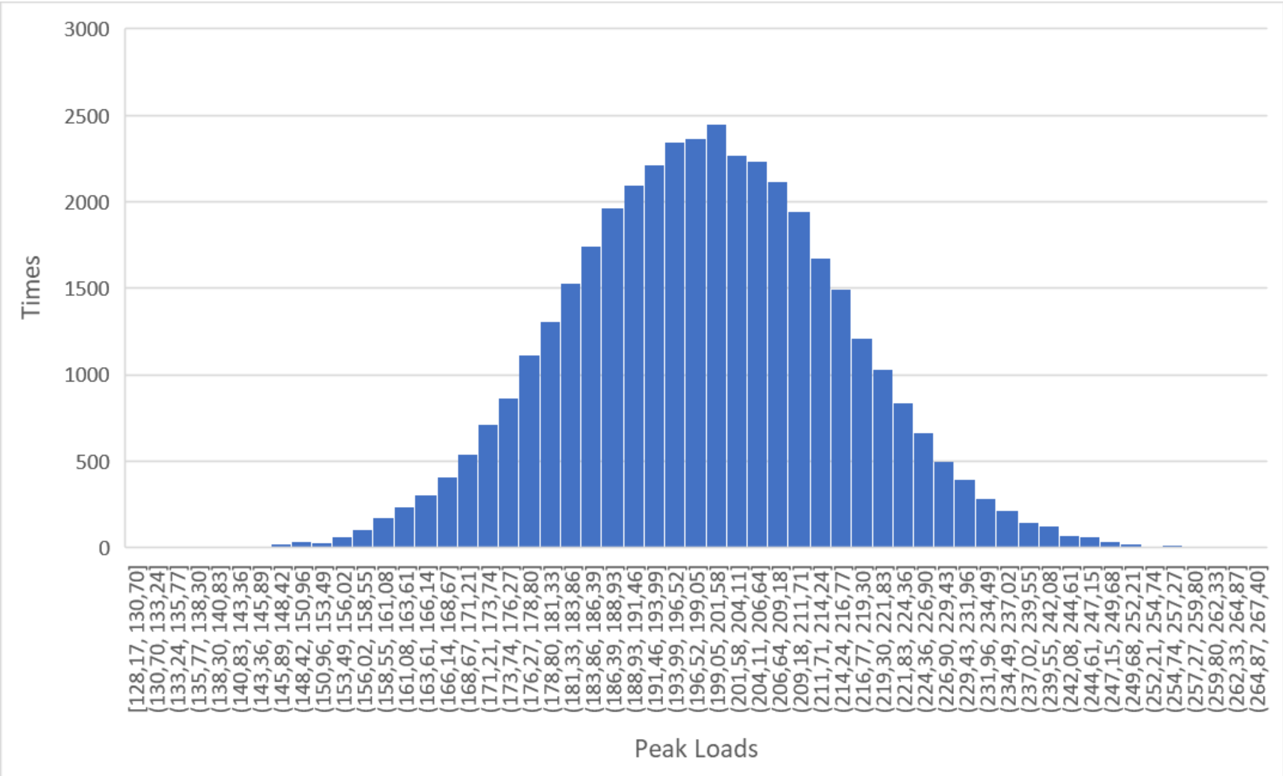

Figure 4.22:Demonstrator building #4: Tertiary Italy - Annual cooling peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained cooling peak load is reported; the ordinate shows the number of times the peak value indicated in the abscissa is repeated (e.g.: the peak range 196.52÷199.05 is repeated approximately 2,300 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economical configuration.

Domestic Heat Water (DHW)

For calculation of DHW, UNI EN 11300 has been used. Based on this Standard an annual DHW demand can be calculated (not the hourly DHW demand).

- DHW demand: 7,427.35 kWh/y

Outcomes of the Tool

Based on the optimal combination of discomfort rate and costs, the tool selects the proper configuration for each TP and for each equipment as follow:

TP1	TP1 Best Ranking						
	λ7 Conf3	BH HP		RATIO TANK		TVP SP	
	SIZE	100	kW	8,410	liters	179	m^2
	Energy produced	13,801	kWh/y	\	\	202,457	kWh/y
	YEOH	138	YEOH	\	\	\	\
	Capital Cost	100,000	€	14,744	€	89,500	€
	Operative Cost	964	€/y	\	\	\	\

In this configuration 179 m^2 of thermal solar module can fulfill the entire heating demand (208,830.81 kWh/y). Approximately 8,400 l storage tank must be coupled with the solar technology. The heat pump capacity of 100 kW is suitable to overcome 92.65 kW peak load and to fulfil the entire heating demand.

The annual heating energy demand required by building is equal to 208,830.81 kWh/y. This is the energy demand affected by uncertainties. It has been calculated dividing the heating energy demand without uncertainties (203,324.77 kWh) by the heating peak load (90.214 kW_{th}), thus obtaining the yearly operating hours (2,254 h/y). Multiplying the operating hours by the peak load λ7 (92.65 kW), the annual heating energy demand value of 208,830.81 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (7,427.35 kWh/y): 216,258.16 kWh/y. Therefore, **the energy produced by BH HP plus the energy produced by TVP solar panels (218,580 kWh/y) cover the total heating demand (216,258.16 kWh/y).**

TP2	TP2 Best Ranking						
	λ7 Conf1	BH HP		RATIO TANK		DUAL SUN PVT	
	SIZE	100	kW	16,804	liters	358	m^2
	Energy produced	110,081	kWh/y	\	\	106,177	kWh/y Th
						112,040	kWh/y El
	YEOH	1,101	YEOH	\	\	\	\
	Capital Cost	100,000	€	27,254	€	89,500	€
	Operative Cost	7,686	€/y	\	\	-24,649	€/y

In this configuration 358 m^2 of both photovoltaic and thermal solar modules are installed. Approximately 16,800 l storage tank must be coupled with the solar technology. The heat pump capacity of 100 kW, required to overcome 92.65 kW peak load (λ7), in this case is needed to fulfil the gap between the required heating demand (208,829.42 kWh/y) plus the DHW demand (7,427.35 kWh/y) and the energy produced by solar technology (106,177 kWh/y). In this case the electric energy produced by the PV technology can be used by the system or sold to the grid resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (208,829.42 kWh/y) is the annual heating energy demand required by building affected by uncertainties (e.g.: λ7, including 12 discomfort hours and 0.1% discomfort rate over the year). It has been calculated dividing the heating energy demand without uncertainties (e.g.: 203,324.77 kWh) by the heating peak load (90.21 kW_{th}), thus obtaining the yearly operating hours (e.g.: 2,254 h/y). Multiplying the operating hours by the peak load λ7 (92.65 kW), the annual heating energy demand value of 208,829.42 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (7,427.35 kWh/y): 216,256.77 kWh/y. Therefore, **the energy produced by BH HP and Dual Sun PVT (218,579 kWh/y) cover the total heating demand (216,256.77 kWh/y).**

TP3	TP3 Best Ranking								
	λ2 Conf1	FARH SORP CHILLER		COMPR. CHILLER		RATIO TANK		TVP SP	
	SIZE	208	kW	199	kW	16,804	liters	358	m^2
	Energy produced	101,264	kWh/y	0	kWh/y	\	\	214,034	kWh/y Th
	YEOH	487	YEOH	0	YEOH	\	\	\	\
	Capital Cost	390,400	€	159,120	€	27,253	€	179,000	€
	Operative Cost	1,413	€/y	0	€/y	\	\	0	€/y

This technology package mainly provides space cooling during summer. The sorption chiller must be coupled with the solar thermal source, for which the summer production is considered. All the heating produced during winter is considered as a saving. In particular, this configuration consists of 358 m^2 of thermal solar module. Approximately 16,800 l storage tank must be coupled with solar technology.

The annual cooling energy demand required by building affected by uncertainties (λ2, including 310 discomfort hours and 3.5% discomfort rate over the year) has been calculated dividing the cooling energy demand without uncertainties (e.g.: 95,932.04 kWh/y) by the cooling peak load (196.33 kW), thus obtaining the yearly operating hours (e.g.: 489 h/y). Multiplying the operating hours by the cooling peak load λ2 with uncertainties (207.241kW) the annual cooling energy demand value of 101,262.96 kWh/y is obtained. This **cooling demand is covered by the energy produced by Farhenehit sorption which is equal to 101,264 kWh/y**.

The energy produced by the compressor chiller is equal to zero because the cooling energy demand is covered by the sorption chiller.

TP4	TP4 Best Ranking										
	λ7 Conf1	BDR ASHP		TANK DHW		TANK H/C		Baxi TH		Baxi EL	
	SIZE	199	kW	327	kW	4,475	liters	89,5	m2	268,5	m^2
	Energy produced	191,309	kWh/y	\	kWh/y	\	\	24,949	kWh/y Th	74,846	kWh/y Th
	YEOH	962	YEOH	\	\	\	\	\	\	\	\
	Capital Cost	121,304	€	2175	€	11,493	€	35,800	€	80,550	€
	Operative Cost	12,871	€/y	\	€/y	\	\	\	€/y	-16,466	€/y

This configuration, similarly to the TP2, consists of 358 m^2 of solar panels (89.5 m^2 thermal and 268.5 m^2 photovoltaic) which provide hot water and electricity, this second one as a saving. Two separates tank are considered for DHW and SH.

The heat pump capacity of 199 kW, required to overcome 92.65 kW peak load (λ7), in this building is needed to fulfil the gap between the required heating demand (208,830.35 kWh/y) plus the DHW demand (7,427.35 kWh/y) and the energy produced by solar technology (24,949 kWh/y). In this demonstrator building the electric energy produced by the PV technology can be used by the system or sold to the grid resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (208,830.35 kWh/y) is the annual heating energy demand required by building affected by uncertainties (λ7, including 12 discomfort hours and 0.1% discomfort rate over the year). It has been calculated dividing the heating energy demand without uncertainties (e.g.: 203,324.77 kWh) by the heating peak load (90.21 kW_{th}), thus obtaining the yearly operating hours (2,254 h/y). Multiplying the operating hours by the peak load λ7 (92.65 kW), the annual heating energy demand value of 208,830.35 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (7,427.35 kWh/y): 216,257.70 kWh/y. Therefore, **the energy produced by BDR ASHP plus Baxi thermal solar panels (216,258 kWh/y) cover the total heating demand (216,257.70 kWh/y).**

4.2.5 Demonstrator building #5 (Tertiary – The Netherlands/Rotterdam)

As described in Section 3, in the DUU tool the input data provided by the user are used to calculate the peak loads and the energy demands for both heating and cooling and generate the loads distribution involving uncertainties.

Heating

As regards heating for the present demonstrator building the following data were calculated by DUU Tool:

- Heating Energy Demand: 75,598.09 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- Heating Peak load: 27.40 kW. It is the maximum peak value of the annual heating energy profile (refer to the vertical axis - kW).

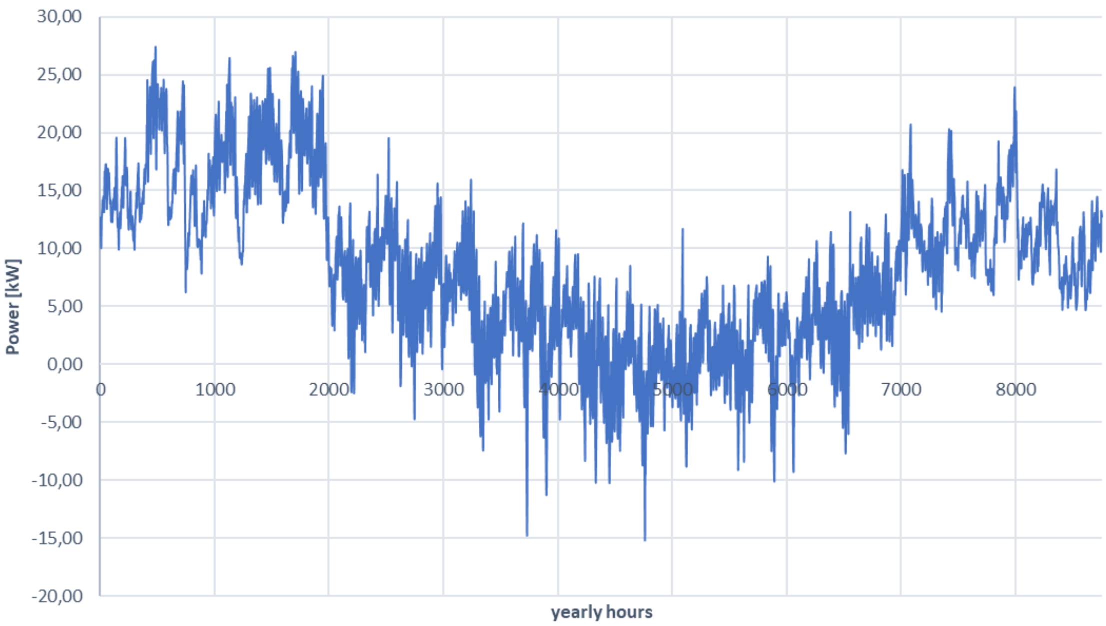

Figure 4.23:Demonstrator building #5: Tertiary Netherlands - Annual heating energy profile

The Montecarlo analysis calculates the uncertainties related to the calculated heating peak load (27.40 kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below. λ7 corresponds to the lower discomfort hours and lower discomfort rate over the year.

Table 4.15:Demonstrator building #5: Tertiary Netherlands - Seven different heating peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Heating PL [kW]	**25.364**	**27.334**	**27.582**	**27.830**	**28.078**	**28.326**	**28.574**	**28.822**	**29.566**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	144	36	30	23	20	16	10	6	1
Discomfort rate over the year [%]	1,6%	0,4%	0,3%	0,3%	0,2%	0,2%	0,1%	0,1%	0,0%

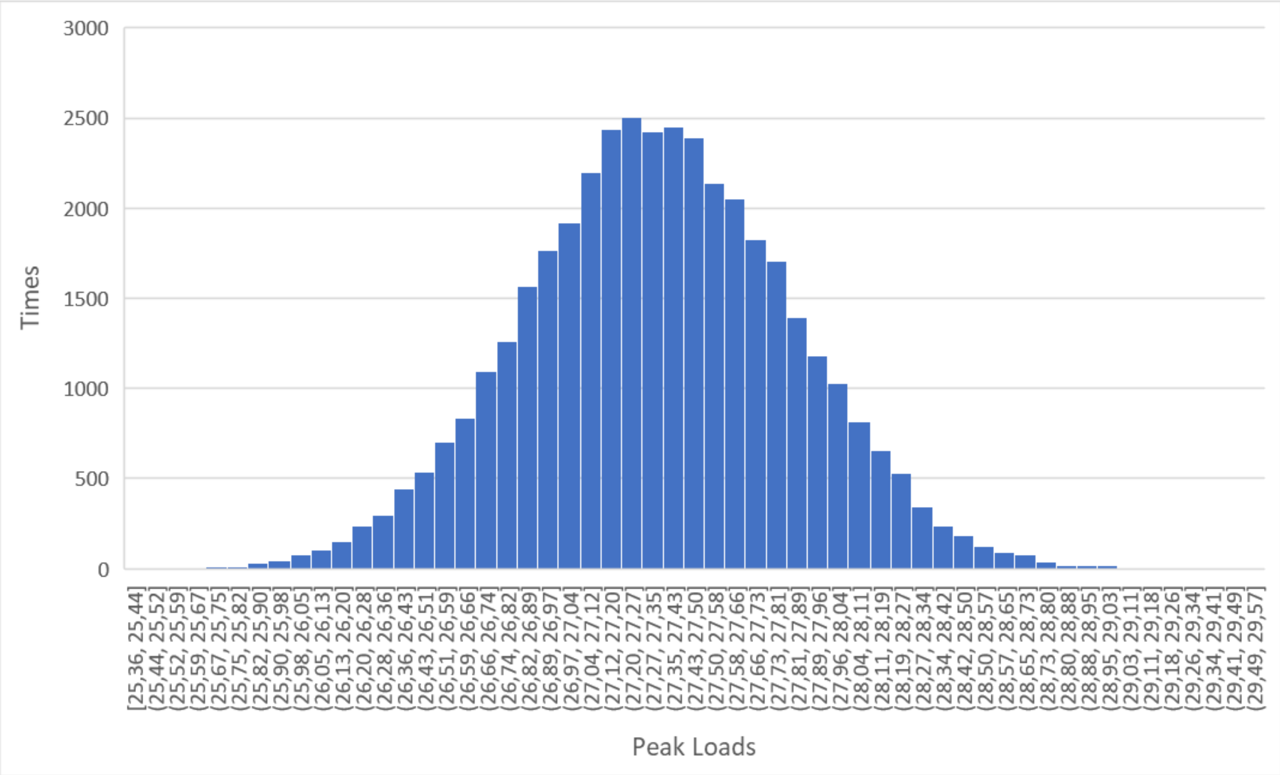

Figure 4.24:Demonstrator building #5: Tertiary Netherlands - Annual heating peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained heating peak load is reported; the ordinate shows the number of times the peak value indicated in the abscissa is repeated (e.g.: the peak range 27.27÷27.35 is repeated approximately 2,500 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economical configuration.

Cooling

As regards cooling for the present demonstrator building, the following data were calculated by DUU Tool for the cooling peak load and the cooling energy demand.

- Cooling Energy Demand: 817.68 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- Cooling Peak Load: 54.26 kW. It is the maximum peak value of the annual cooling energy profile (refer to the vertical axis - kW).

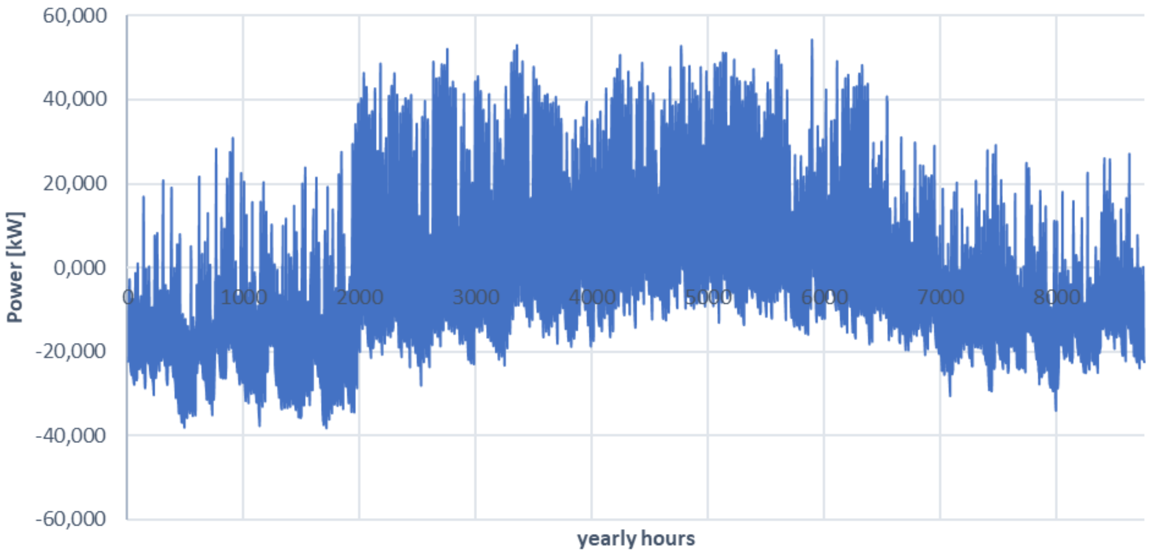

Figure 4.25:Demonstrator Building #5: Tertiary Netherlands - Annual cooling energy profile

The Montecarlo analysis is also applied to the cooling demand and calculates the uncertainties related to the calculated cooling peak load (54.26 kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below.

Table 4.16:Demonstrator building #5: Tertiary Netherlands - Seven different cooling peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Cooling PL [kW]	**33.651**	**55.323**	**57.945**	**60.568**	**63.190**	**65.812**	**68.435**	**71.057**	**76.065**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	994	251	186	124	81	40	21	7	0
Discomfort rate over the year [%]	11,3%	2,9%	2,1%	1,4%	0,9%	0,5%	0,2%	0,1%	0,0%

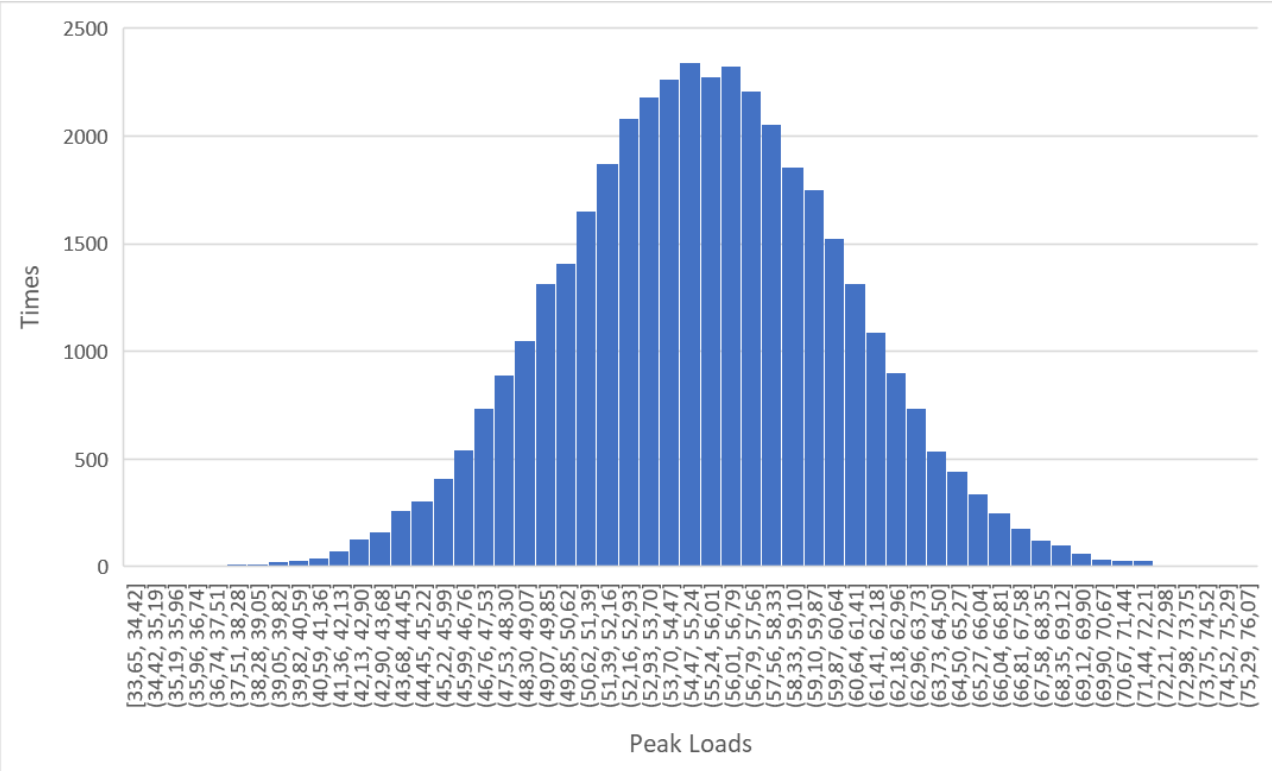

Figure 4.26:Demonstrator building #5: Tertiary Netherlands - Annual cooling peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained cooling peak load is reported; the ordinate shows the number of times the peak value indicated in the abscissa is repeated (e.g.: the peak range 55.24÷56.01 is repeated approximately 2,300 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economical configuration.

Domestic Heat Water (DHW)

For calculation of DHW, UNI EN 11300 has been used. Based on this Standard an annual DHW demand can be calculated (not the hourly DHW demand).

- DHW demand: 1,873.87 kWh/y

Outcomes of the Tool

Based on the optimal combination of discomfort rate and costs, the tool selects the proper configuration for each TP and for each equipment as shown below.

TP1	TP1 Best Ranking						
	λ7 Conf1	BH HP		RATIO TANK		TVP SP	
	SIZE	40	kW	3,570	liters	76	m^2
	Energy produced	26,992	kWh/y	\	\	54,403	kWh/y
	YEOH	675	YEOH	\	\	\	\
	Capital Cost	40,000	€	7,546	€	38,000	€
	Operative Cost	1,885	€/y	\	\	\	\

In this configuration 76 m^2 of thermal solar module cannot fulfil the entire demand (79,519.90 kWh/y). Approximately 3,600 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW, suitable to overcome 28.822 kW peak load (λ7) and to fulfil the entire heating demand.

The annual heating energy demand required by building is equal to 79,519.90 kWh/y. This is the energy demand affected by uncertainties. It has been calculated dividing the heating energy demand without uncertainties (75,598.09 kWh) by the heating peak load (27.4 kW), thus obtaining the yearly operating hours (2,759 h/y). Multiplying the operating hours by the peak load λ7 (28.822 kW), the annual heating energy demand value of 79,519.90 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (1,873.87 kWh/y): 81,393.77 kWh/y. Therefore, **the energy produced by BH HP plus the energy produced by TVP solar panels (81,395 kWh/y) cover the total heating demand (81,393.77 kWh/y).**

	TP2 Best Ranking						
TP2	λ3 Conf1	BH HP		RATIO TANK		DUAL SUN PVT	
	SIZE	40	kW	3,567	liters	76	m^2
	Energy produced	72,209	kWh/y	\	\	6,449	kWh/y Th
						16,161	kWh/y El
	YEOH	1,805	YEOH	\	\	\	\
	Capital Cost	40,000	€	7,546	€	38,000	€
	Operative Cost	4,993	€/y	\	\	-3,555	€/y

In this configuration 76 m^2 of both photovoltaic and thermal solar modules are installed. Approximately 3,600 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW, required to overcome 27.83 kW peak load (λ3), in this case is needed to fulfil the gap between the required heating demand (76,782.97 kWh/y) plus the DHW demand (1,873.87 kWh/y) and the energy produced by solar technology (6,449 kWh/y). In this case the electric energy produced by the PV technology can be used by the system or sold to the grid resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (76,782.97 kWh/y) is the annual heating energy demand required by building affected by uncertainties (λ3, including 23 discomfort hours and 0.3% discomfort rate over the year). It has been calculated dividing the heating energy demand without uncertainties (e.g.: 75,598.09 kWh) by the heating peak load (27.4 kW), thus obtaining the yearly operating hours (2,759 h/y). Multiplying the operating hours by the peak load λ3 (27.83 kW), the annual heating energy demand value of 76,782.97 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (1,873.87 kWh/y): 78,656.84 kWh/y. Therefore, **the energy produced by BH HP and Dual Sun PVT (78,658 kWh/y) cover the total heating demand (78,656.84 kWh/y).**

TP3	TP3 Best Ranking								
	λ4 Conf1	FARH SORP CHILLER		COMPR. CHILLER		RATIO TANK		TVP SP	
	SIZE	65	kW	55	kW	3,568	liters	76	m^2
	Energy produced	952	kWh/y	0	kWh/y	\	\	25,028	kWh/y Th
	YEOH	15	YEOH	0	YEOH	\	\	\	\
	Capital Cost	122,000	€	44,320	€	7,545	€	38,000	€
	Operative Cost	165	€/y	0	€/y	\	\	0	€/y

This technology package mainly provides space cooling during summer. The sorption chiller must be coupled with the solar thermal source, for which the summer production is considered. All the heating produced during winter is considered as a saving. In particular, this configuration consists of 76 m^2 of thermal solar module. Approximately 3,600 l storage tank must be coupled with solar technology.

The annual cooling energy demand required by building affected by uncertainties (λ4, including 81 discomfort hours and 0.9% discomfort rate over the year) has been calculated dividing the cooling energy demand without uncertainties (817.68 kWh/y) by the cooling peak load (54.26 kW), thus obtaining the yearly operating hours (15 h/y). Multiplying the operating hours by the cooling peak load λ4 with uncertainties (63.19 kW) the annual cooling energy demand value of 952 kWh/y is obtained. This **cooling demand is covered by the energy produced by Farhenehit sorption chiller which is equal to 952 kWh/y**.

The energy produced by the compressor chiller is equal to zero because the cooling demand is already covered by the sorption chiller.

TP4	TP4 Best Ranking										
	λ5 Conf1	BDR ASHP		TANK DHW		TANK H/C		Baxi TH		Baxi EL	
	SIZE	55	kW	81	kW	950	liters	19	m2	57	m2
	Energy produced	76,428	kWh/y	\	kWh/y	\	\	3,599	kWh/y Th	10,796	kWh/y Th
	YEOH	1,381	YEOH	\	\	\	\	\	\	\	\
	Capital Cost	33,747	€	1,623	€	3,575	€	7,600	€	17,100	€
	Operative Cost	5,142	€/y	\	€/y	\	\	\	€/y	-2,375	€/y

This configuration, similarly to the TP2, consists of 76 m^2 of solar panels (19 m^2 thermal and 57 m^2 photovoltaic) which provide hot water and electricity, this second one as a saving. Two separates tank are considered for DHW and SH.

The heat pump capacity of 55 kW, required to overcome 28.33 kW peak (λ5) load, in this demonstrator building is needed to fulfil the gap between the required heating demand (78,151.43 kWh/y) plus the DHW demand (1,873.87 kWh/y) and the energy produced by solar technology (3,599 kWh/y). In this building the electric energy produced by the PV technology can be used by the system or sold to the grid resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (78,151.43 kWh/y) is the annual heating energy demand required by building affected by uncertainties (λ5, including 16 discomfort hours and 0.2% discomfort rate over the year). It has been calculated dividing the heating energy demand without uncertainties (75,598.09 kWh) by the heating peak load (27.4 kW), thus obtaining the yearly operating hours (2,759 h/y). Multiplying the operating hours by the peak load λ5 (28.326 kW), the annual heating energy demand value of 78,151.43 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (1,873.87 kWh/y): 80,025.30 kWh/y. Therefore, **the energy produced by BDR ASHP plus Baxi thermal solar panels (80,027 kWh/y) cover the total heating demand (80,025.30 kWh/y).**

4.2.6 Demonstrator building #6 (Tertiary – Sweden/Goteborg)

As described in Section 3, in the DUU tool the input data provided by the user are used to calculate the peak loads and the energy demands for both heating and cooling and generate the loads distribution involving uncertainties.

Heating

As regards heating for the present demonstrator building the following data were calculated by DUU Tool:

- Heating Energy Demand: 111,538.36 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;
- Heating Peak load: 31.74 kW. It is the maximum peak value of the annual heating energy profile (refer to the vertical axis - kW).

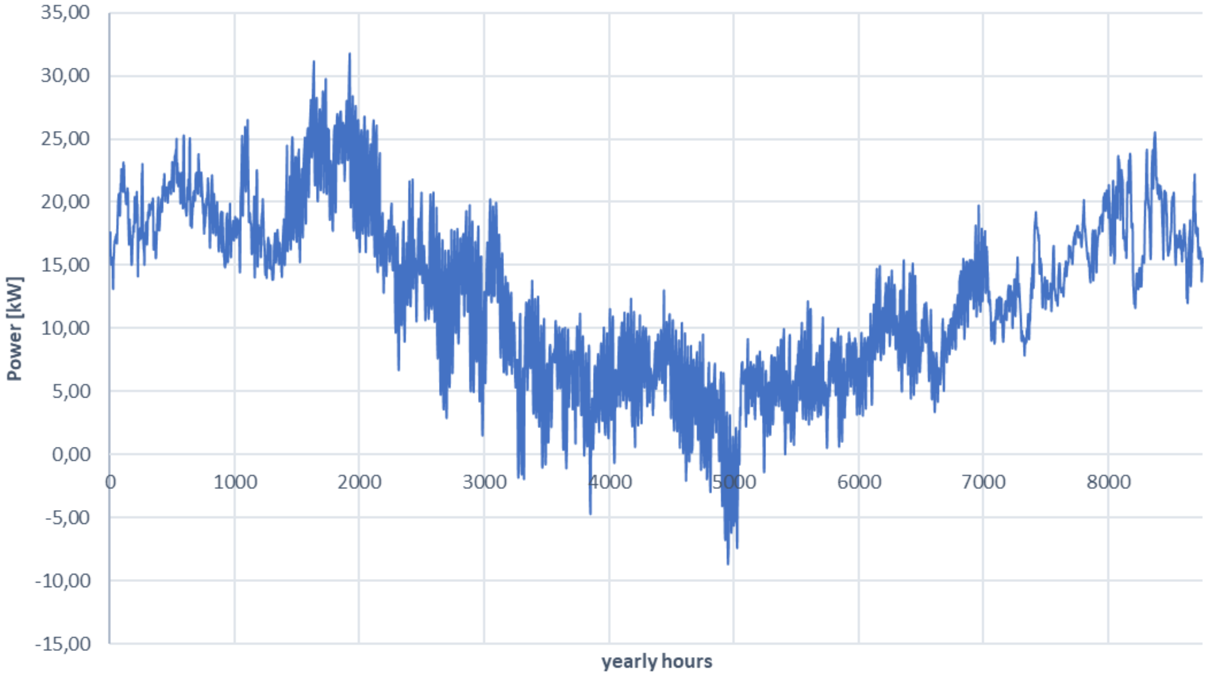

Figure 4.27:Demonstrator building #6: Tertiary Sweden - Annual heating energy profile

The Montecarlo analysis calculates the uncertainties related to the calculated heating peak load (31.74 kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below. λ7 corresponds to the lower discomfort hours and lower discomfort rate over the year.

Table 4.17:Demonstrator building #6: Tertiary Sweden - Seven different heating peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Heating PL [kW]	29.267	**31.513**	**31.765**	**32.017**	**32.270**	**32.522**	**32.774**	**33.026**	**33.525**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	52	16	13	11	9	8	6	4	1
Discomfort rate over the year [%]	0.6%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%

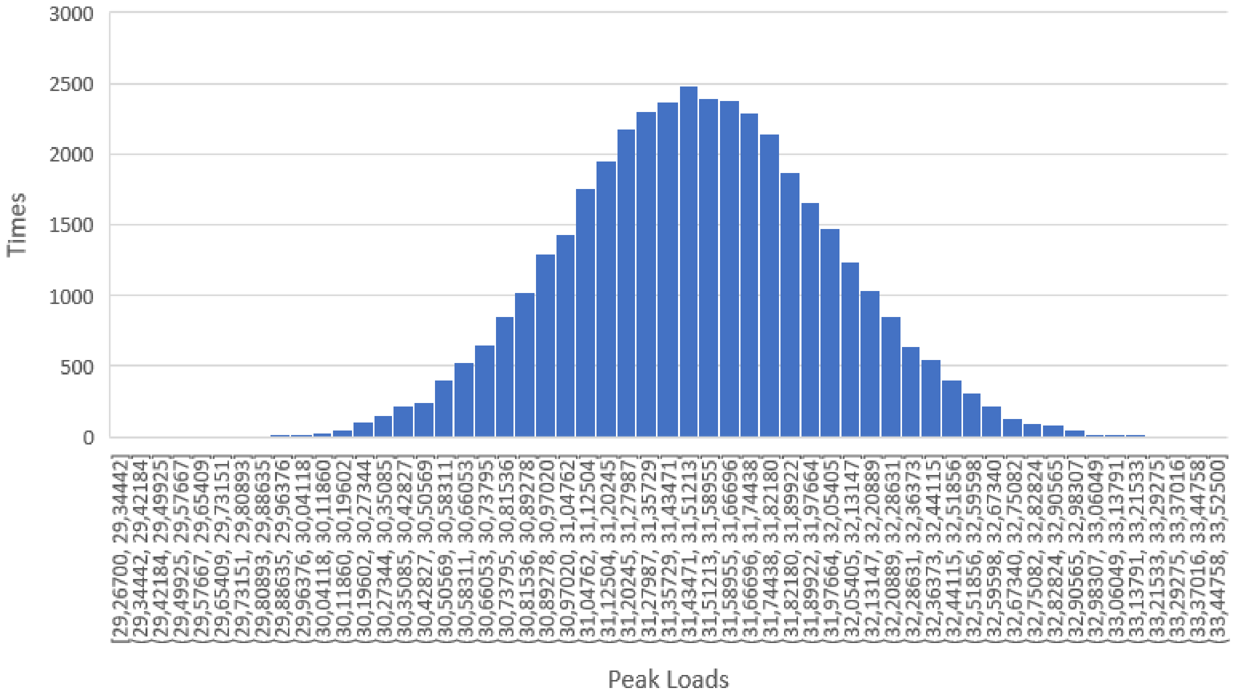

Figure 4.28:Demonstrator building #6: Tertiary Sweden - Annual heating peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained heating peak load is reported; the ordinate shows the number of times the peak value indicated in the abscissa is repeated (e.g.: the peak range 31.43÷31.51 is repeated approximately 2,500 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economical configuration.

Cooling

As regards cooling for the present demonstrator building, the following data were calculated by DUU Tool for the cooling peak load and the cooling energy demand.

- Cooling Energy Demand: 3,150.40 kWh/y. This is the sum of all the positive terms of the hourly power profile calculated for one entire year;

- Cooling Peak Load: 104.61 kW. It is the maximum peak value of the annual cooling energy profile (refer to the vertical axis - kW).

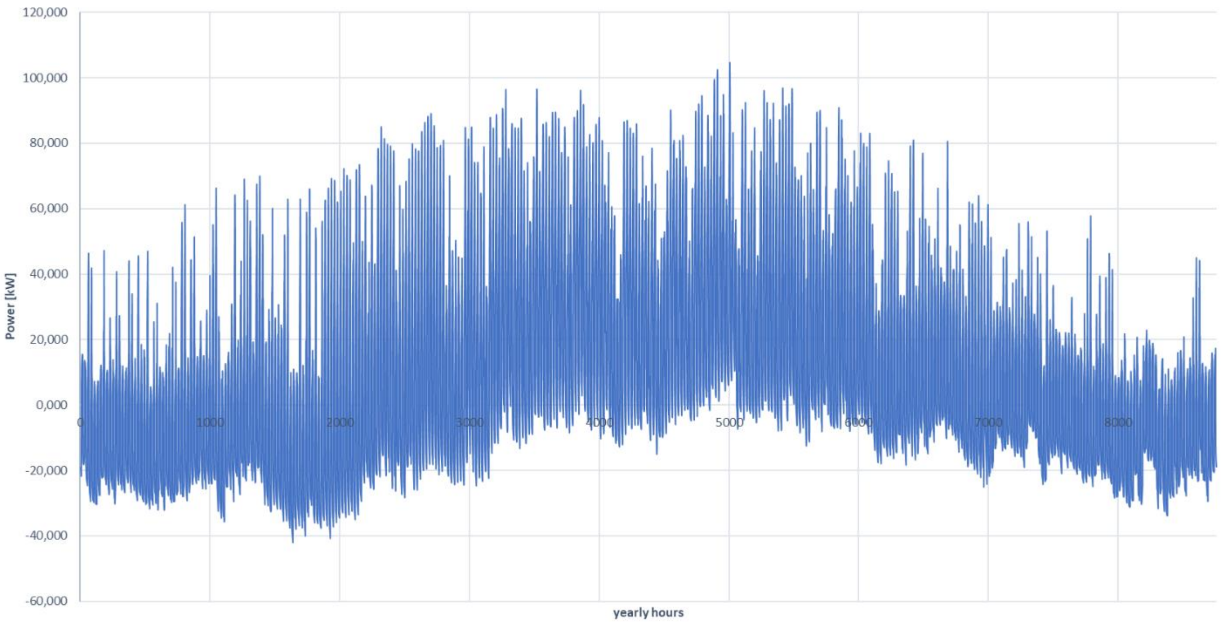

Figure 4.29:Demonstrator building #6: Tertiary Sweden - Annual cooling energy profile

The Montecarlo analysis is also applied to the cooling demand and calculates the uncertainties related to the calculated cooling peak load (104.61 kW) and provides seven alternative peak loads with a gradually higher standard deviation threshold (**λ**), which corresponds to a different probability of matching the demand (discomfort rate over the year) as shown in table below.

Table 4.18:Demonstrator building #6: Tertiary Sweden - Seven different cooling peak loads and thresholds based on the standard deviation of the distribution (λ)

	λmin	λ1	λ2	λ3	λ4	λ5	λ6	λ7	λmax
Cooling PL [kW]	**70.66**	**107.614**	**112.364**	**117.115**	**121.865**	**126.615**	**131.366**	**136.116**	**148.296**
Standard deviation threshold		**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	
Discomfort hours[h]	1213	292	203	131	73	33	17	7	0
Discomfort rate over the year [%]	13.8%	3.3%	2.3%	1.5%	0.8%	0.4%	0.2%	0.1%	0.0%

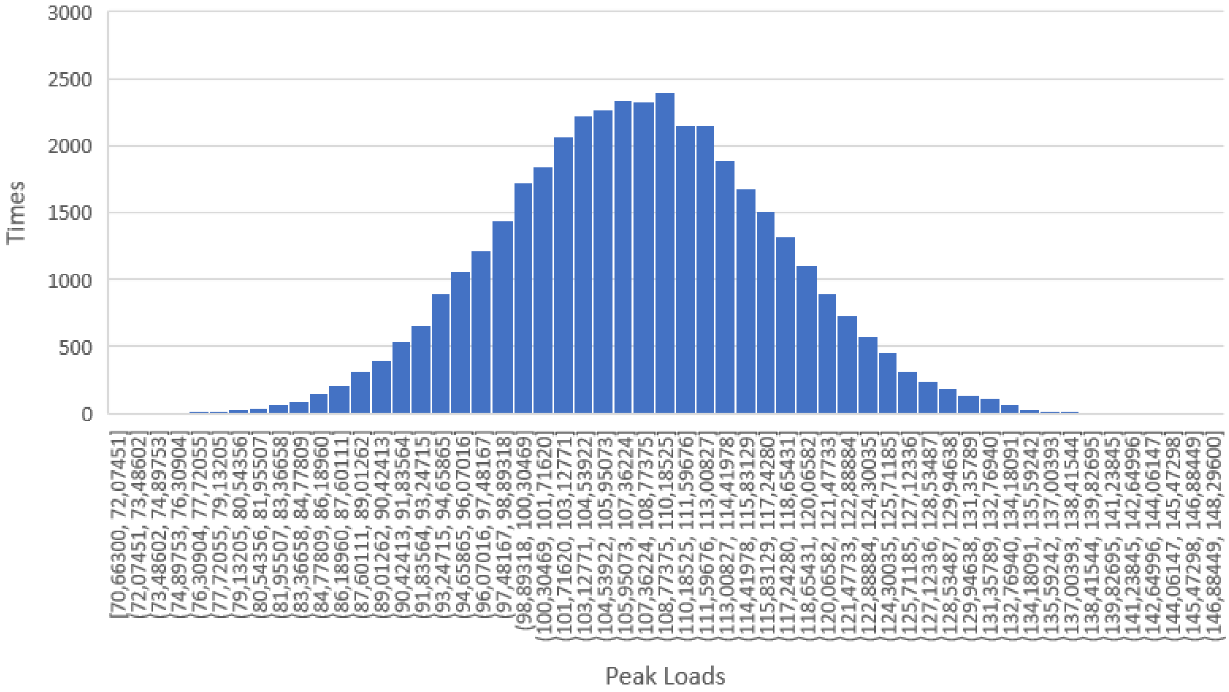

Figure 4.30:Demonstrator building #6: Tertiary Sweden - Annual cooling peak loads

The Monte Carlo method is applied and a total of 40,000 peak load samples are calculated.

In the above figure, the probability distribution of the so obtained cooling peak load is reported; the ordinate shows the number of times the peak value indicated in the abscissa is repeated (e.g.: the peak range 107.36÷108.77 is repeated approximately 2,400 times during the run of the excel Tool).

The aim of Montecarlo method is to identify the peak that occurs more frequently. The following step consists in applying the uncertainties and to calculate the other six peak loads which are compared each other to identify the best technical and economical configuration.

Domestic Heat Water (DHW)

For calculation of DHW, UNI EN 11300 has been used. Based on this Standard an annual DHW demand can be calculated (not the hourly DHW demand).

- DHW demand: 4,788.15 kWh/y

Outcomes of the Tool

Based on the optimal combination of discomfort rate and costs, the tool selects the proper configuration for each TP and for each equipment as shown below.

TP1	TP1 Best Ranking						
	λ7 Conf1	BH HP		RATIO TANK		TVP SP	
	SIZE	40	kW	8,450	liters	180	m^2
	Energy produced	7,938	kWh/y	N.A.	N.A	112,893	kWh/y
	YEOH	198	YEOH	N.A	N.A	N.A	N.A
	Capital Cost	40,000	€	14,814	€	90,000	€
	Operative Cost	554	€/y	N.A	N.A	N.A	N.A

In this configuration 180 m² of thermal solar module cannot fulfil the entire heating demand (116,042.80 kWh/y). Approximately 8,450 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW is suitable to overcome 33.026 kW peak load (λ7) and to fulfil the entire heating demand.

The annual heating energy demand required by building is equal to 116,042.80 kWh/y. This is the energy demand affected by uncertainties. It has been calculated dividing the heating energy demand without uncertainties (111,538.36 kWh) by the heating peak load (31.74 kW), thus obtaining the yearly operating hours (3,514 h/y). Multiplying the operating hours by the peak load λ7 (33.026 kW), the annual heating energy demand value of 116,042.80 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (4,788.15 kWh/y): 120,830.95 kWh/y. Therefore, **the energy produced by BH HP plus the energy produced by TVP solar panels (120,831 kWh/y) cover the total heating demand (120,830.95 kWh/y).**

TP2	TP2 Best Ranking						
	λ2 Conf1	BH HP		RATIO TANK		DUAL SUN PVT	
	SIZE	40	kW	8,449	liters	180	m²
	Energy produced	104,560	kWh/y	N.A		11,856	kWh/y Th
						34,102	kWh/y El
	YEOH	2,614	YEOH	N.A	N.A	N.A	N.A
	Capital Cost	40,000	€	14,814	€	90,000	€
	Operative Cost	7,300	€/y	\	\	-7,502	€/y

In this configuration 180 m² of both photovoltaic and thermal solar modules are installed. Approximately 8,450 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW, required to overcome 31.765 kW peak load (λ2), in this case is needed to fulfil the gap between the required heating demand (111,612.05 kWh/y), plus the DHW demand (4,788.15 kWh/y), and the energy produced by solar technology (11,856 kWh/y). In this case the electric energy produced by the PV technology can be used by the system or sold to the grid, resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (111,612.05 kWh/y) is the annual heating energy demand required by building affected by uncertainties (λ2, including 13 discomfort hours and 0.1% discomfort rate over the year). It has been calculated dividing the heating energy demand without uncertainties (111,538.36 kWh) by the heating peak load (31.74 kW), thus obtaining the yearly operating hours (3,514 h/y). Multiplying the operating hours by the peak load λ2 (31.765 kW), the annual heating energy demand value of 111,612.05 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (4,788.15 kWh/y): 116,400.20 kWh/y. Therefore, **the energy produced by BH HP and Dual Sun PVT (116,416.43 kWh/y) cover the total heating demand (116,400.20 kWh/y).**

TP3	TP3 Best Ranking								
	λ2 Conf1	FARH SORP CHILLER		COMPR. CHILLER		RATIO TANK		TVP SP	
	SIZE	117	kW	108	kW	8,449	liters	180	m²
	Energy produced	3,384	kWh/y	0	kWh/y	\	\	50,370	kWh/y Th
	YEOH	29	YEOH	0	YEOH	\	\	\	\
	Capital Cost	219,600	€	86,160	€	14,814	€	90,000	€
	Operative Cost	332	€/y	0	€/y	\	\	N.A	€/y

This technology package mainly provides space cooling during summer. The sorption chiller must be coupled with the solar thermal source, for which the summer production from TVP panels is considered. All the heating produced by TVP panels during winter is considered as a saving. In particular, this configuration consists of 180 m² of thermal solar module. Approximately 8,450 l storage tank must be coupled with solar technology.

The annual cooling energy demand required by building affected by uncertainties (λ2, including 203 discomfort hours and 2.3% discomfort rate over the year) has been calculated dividing the cooling energy demand without uncertainties (3,150.40 kWh/y) by the cooling peak load (104.61 kW), thus obtaining the yearly operating hours (30.12 h/y). Multiplying the operating hours by the cooling peak load λ2 with uncertainties (112.364 kW) the annual cooling energy demand value of 3,383.92 kWh/y is obtained. **This cooling energy demand is covered by the energy produced by Farhenehit sorption chiller which is equal to 3,384 kWh/y**.

The energy produced by the compressor chiller is equal to zero because the cooling energy demand is covered by the sorption chiller.

TP4

TP4 Best Ranking										
λ6 Conf1	BDR ASHP		TANK DHW		TANK H/C		Baxi TH		Baxi EL	
SIZE	108	kW	181	kW	2,250	liters	45	m2	135	m²
Energy produced	112,352	kWh/y	\	kWh/y	\	\	7594	kWh/y Th	2,2781	kWh/y Th
YEOH	1,044	YEOH	\	\	\	\	\	\	\	\
Capital Cost	65,645	€	1,848	€	6,495	€	18000	€	40,500	€
Operative Cost	7,559	€/y	\	€/y	\	\	\	€/y	-5,012	€/y

This configuration, similarly to the TP2, consists of 180 m² of solar panels (45 m² thermal and 135 m² photovoltaic) which provide hot water and electricity, this second one as a saving. Two separates tank are considered for DHW and SH.

The heat pump capacity of 108 kW, required to overcome 32.774 kW peak (λ6) load, in this case is needed to fulfil the gap between the required heating demand (115,157.35 kWh/y) plus the DHW demand (4,788.15 kWh/y) and the energy produced by solar technology (7,594 kWh/y). In this building the electric energy produced by the PV technology can be used by the system or sold to the grid resulting in a negative operative cost (it is a cost saving for this configuration).

The required heating demand value shown above (115,157.35 kWh/y) is the annual heating energy demand required by building affected by uncertainties (λ6, including 6 discomfort hours and 0.1% discomfort rate over the year).

It has been calculated dividing the heating energy demand without uncertainties (111,538.36 kWh) by the heating peak load (31.74 kW), thus obtaining the yearly operating hours (3,514 h/y). Multiplying the operating hours by the peak load λ6 (32.774 kW), the annual heating energy demand value of 115,157.35 kWh/y is obtained.

The total heating demand is the sum of annual heating energy demand plus the DHW demand (4,788.15 kWh/y): 119,945.50 kWh/y. Therefore, **the energy produced by BDR ASHP plus Baxi thermal solar panels (119,946.00 kWh/y) cover the total heating demand (119,945.50 kWh/y).**

4.3 Design with safety factor

In order to be conservative in the design and sizing phase, a safety factor of 10% has been applied to the calculated peak load. This can greatly vary from company to company and even from engineer-to-engineer within the same company, and is affected by many factors, including distribution losses, regional construction quality, space operation and start-up capacity[16].

In the following table it is shown a comparison between the heating and cooling peak load, and the annual heating demand and the annual cooling demand obtained with the DUU Tool without uncertainties and the ones obtained applying a safety factor of 1.1 (e.g.: 10%) to the peak loads and the energy demand. This comparison has been applied to the virtual residential building demonstrator in Italy and includes the four TPs. The aim is to show how the design of technology packages and the related equipment is affected by the application of a safety factor.

[16] https://www.iesve.com/discoveries/article/10017/ashrae-heating-and-cooling-load-calculations

Comparison has been carried out, as an example to provide an overview on the impact of safety factor on TPs design, only for residential building in Italy, because the outcomes are still the same applying a safety factor of 1.1 to the other virtual demonstrator buildings (residential and tertiary).

Table 4.19:Comparison between peak load and annual energy demand obtained with DUU Tool and peak load and annual energy demand obtained with a safety factor

	DUU Tool (without uncertainties)	1.1 Safety factor	U.M.
Heating Peak Load	36.81	40.49	kW
Annual Heating Energy	82,956.36	91,251.99	kWh/y
YEOH	2,254		h
DHW demand	13,754.3	15,129.7	kWh/y
Total Heating Demand	96,710.65	106,381.71	kWh/y
Cooling Peak Load	36.65	40.32	kW
Annual Cooling Energy	18,567.76	20,424.54	kWh/y
YEOH	507		h

The technology packages design is affected by the application of the safety factor mainly in the sizing of the heat pumps and chillers as shown in tables below.

<u>Heating</u>

Table 4.20:TP1/TP2 design affected by safety factor application

TP Equipment		Size- DUU	1.1 Safety factor	
TP1	BH HP	40	60	kW
TP2	BH HP	40	60	kW
YEOH (TP2)		1,257	904	h

It is worth mentioning that, as regards TP1, the energy produced by solar panel is able to cover all the heating annual demand and, therefore, the heat pump is not needed for supplying heating (for TP1: YEOH= 0)

In TP2 the increased energy demand, which is not completely fulfilled by the solar panels technology, implies the increment of the requested energy from the heat pump. However, the higher installed capacity results in the reduction of the equivalent operating hours (YEOH) from 1,257 h to 904 h.

Heat pump is affected by the application of the safety factor, resulting in an increment in sizing and therefore in an increase of both capital and operative costs. Size of Boost Heat HP with safety factor is equal to 60 kW (instead of 44kW, 10% of 40 kW) because the Boost Heat HP size after 40 kW is 60 kW.

For what concern TP4, the increased energy demand, which is not completely fulfilled by the solar panel technology, implies the increase of the requested energy from the BDR heat pump.

In this case BDR heat pump is not affected by the application of the safety factor; in fact, as shown in table below, size of BDR ASHP remains the same also for scenario with safety factor because the heating peak is 40.49 kW (36.81 kW x 1.1) and this peak is covered by the size of the BDR heat pump (43 kW).

Table 4.21:TP4 design affected by safety factor application

	TP Equipment	Size -DUU	1.1 Safety factor	
TP4	BDR ASHP	43	43	kW
	Tank DHW	2,692	2,961	l
YEOH		2,097	2,231	h

<u>Cooling</u>

Finally, TP3 has a similar behaviour when applying the safety factor even though the technology package works mainly in cooling mode and, therefore, the safety factor is applied to the cooling demand instead of heating demand.

Sorption chiller and electric chiller are affected by the application of safety factor, resulting in an increase in sizing and therefore in both capital and operative costs.

For the sorption chiller the higher installed capacity results in the reduction of the equivalent operating hours (YEOH) from 349 to 262 because this chiller produces cooling energy exploiting the heating energy provided by solar panels which is always the same and is not affected by safety factor (it depends only by the surface available for solar panels on the roof). Moreover, the sorption chiller is composed by modules of 13 kW each and, therefore, to cover the peak of 40.32 kW (including the safety factor), four modules for a total of 52 kW are needed. Therefore, dividing the energy produced by sorption chiller (13,611 kWh/y) by peak with safety factor (52 kW), 262 hours are obtained.

For what concern the compression chiller, it is used to provide the remaining energy resulting from the difference between the cooling energy demand and the energy provided by the sorption chiller. Thus, the energy that the compression chiller must provide is 6,814 kWh/y with an installed capacity of 41 kW (to overcome the 40.32 kW of cooling peak calculated with the SF). Therefore, 166 hours (6,814 kWh/y/41 kW) slightly higher compared to hours in DUU scenario are obtained.

Table 4.22:TP3 design affected by safety factor application

	TP Equipment	Size -DUU	1.1 Safety factor	
TP3	FAHR Sorption Chiller	39	52	kW
	FAHR Electric Chiller	38	41	kW
YEOH FAHR Sorption Chiller		349	262	h
YEOH FAHR Electric Chiller		152	166	h

Conclusion

The main aspect derived from this analysis is that the application of a safety factor mainly affects the sizing of the heat pumps and sorption / electric chillers, whereas the solar installed capacity and the heating energy provided by solar panels depend on only by the available surface on the roof. Therefore, the amount of energy produced with solar panels does not vary with the demand but, what is affected, is the contribution given by the heat pump technologies to reach the increased energy demand.

It is worth mentioning that scenario with safety factor can be considered as an alternative scenario of the Design Under Uncertainties (DUU). Applying the safety factor, in case the heating or cooling peak load highly increases, it may become mandatory to consider larger equipment with the risk of having oversized equipment and, consequently, higher costs (e.g.: for TP1, TP2 and TP3 shown in tables above).

On the contrary, the DUU scenario, through the uncertainties, allows a better control on the equipment sizing.

4.4 Economic aspects: Business Models for the six demonstrator buildings

The aim of this section, which is focused on the economic aspects, is to present the outcomes of the 24 Business Models (BMs) carried out by partner Veolia (VEO) related to the six virtual demonstrator buildings and each of the four Technology Packages (TP1 ÷ TP4). Specifically, the outcomes from the BMs for each demonstrator building concern the following financial parameters:

- Savings;
- Cash Flow;
- IRR (Internal Rate of Return);
- NPV (Net Present Value);
- Pay-back period

4.4.1 Methodological approach and assumptions

Business Models were prepared starting from technical data provided by RINA that filled-in an excel data collection template of VEO. This excel includes data regarding heating, cooling and domestic hot water (DHW) demand, and natural gas and electricity consumptions. These data were provided both for a "Baseline" configuration (without SUNHORIZON TPs installation) and for a "Project" configuration that includes the installation of the TPs (after SUNHORIZON installation)

Moreover, cost of the equipment (CAPEX) calculated by the DUU Tool and cost of Operation and Maintenance (O&M), mainly related to spare parts and working days of specialized technicians, were included in the data collection template.

For the development of the Business Models, a methodological approach and assumptions, valid for all the BMs, is done. A first assumption is made to define the project duration: it will be considered to be of 25 years as practically all of the small equipment, accessories and/or components of the installations do have high lifespans such as valves (25 years), pipelines and traps (35 years), expansion vessels (25 years), electrical wiring and accessories (20 to 25 years), boilers and chillers (between 15 and 20 years), etc., while some other equipment lifespan is significantly lower (as it is the case of photovoltaic system inverters, whose maximum lifespan is usually no more than 10 years). For that reason, the following section will provide a private partnership BM simulation of 25 years for each virtual demonstrator building-considering that the client relies on its own financial strength or a third-party financing to assume the initial investment costs. In the same path, the O&M will be undertaken either by an ESCO or another small maintenance operator. The baseline proposal on many of the buildings will be done under the estimation of actual technology providers' technical specifications of heating/cooling generation units (pressurized/atmospheric/condensing/electrical boilers, chillers, AHU/fan-coil/split units, etc.) considering that their lifespans stand between 10 and 25 years. In the same path, a lifespan of the overall PV installation is considered to be of 25 years, approximately the same lifespan in terms of overall solar thermal plus thermal energy storage systems (which in some cases can even last more as different literature and case studies have shown).

That being said, the following section will provide a private partnership BM approach so that the scope of the most feasible scenarios under the actual SunHorizon's TP's deployment parameters is identified. In general terms, and as general remarks on the parameter definition of the simulations:

- VEO's experience concludes that investment costs can be curtailed up to 10 – 15% through a public or private tender and procurement process for the selection of the contractor/tenderer that will be responsible for the installation. That's one of the main issues that the SunHorizon project has faced during the deployment phase, mainly due to construction and/or civil works that were required in order to adapt the system to each pilot buildings' typologies;
- Also through VEO and other ESCOs'/technology suppliers'/research technology organisations' experience, the degradation of PV panels and therefore the reduction of the PV panels' electricity generation is about 0,5 – 1% per year; the upcoming simulations will consider an annual decay of the PV production of 0,8%;
- In order to maximize the financial viability/profitability of the SunHorizon's TP's deployment from the client's perspective, in the following simulations have been only considered normative O&M costs, that is, maintenance provision with the minimum cost to comply with local regulations in terms of O&M. Neither full warranty nor improvement and renewal of installations provision have been considered for the BM simulations;
- With regards to the maintenance provision, it is meant to consider abovementioned aspects but, more specifically:

- ✓ Personnel costs, including operational staff, operator/workman, etc.;
- ✓ Tools, clothing and other material costs including uniforms, protective and safety equipment, etc.;
- ✓ Vehicle and transportation costs;
- ✓ Communication and management systems (Personal Digital Assistant/handheld devices-PDA, monitoring devices, etc.);
- ✓ Subcontracting costs for specific works;
- ✓ Additional specific contracting works not included before (such as legionella prevention tasks, sanitation, etc.).

For this reason, different O&M costs are accounted according to the different scenarios and their TP's. For standard assets such as natural gas boilers for satisfying the heating & DHW demand plus fan coils/splits for satisfying the cooling demand, approx. 3% of the CAPEX should be considered as a feasible annual O&M quota. For the new TP's deployment, between 0.25 – 0.50% of the CAPEX is considered as O&M annual cost (OPEX) according to each TP's small equipment, accessories and/or components. Note that PV-T panels require more complex maintenance and repair than regular PV panels, therefore TP2 are considered to have similar features (both deal with PV-T RES generation and HPs) and share an OPEX of 0,35% of the CAPEX. By contrast, TP1 deals with ST panels and BH's gas-driven HP therefore their OPEX has been considered the lowest among all TP's with 0,25% of the CAPEX. Since TP3 deals with both PV-T RES generation as well as FAHR's adsorption chiller and a compression chiller, these kinds of equipment require more conductive maintenance therefore the OPEX has been considered the highest among all TP's with 0,50% of the CAPEX;

- Several scenarios will be simulated under different conditions regarding the actual equipment that might be already deployed in the pilot sites and could be part of the SunHorizon's TP's deployment through adaptation/adjustment procedures coming from the DUU tool. This will enhance the identification of the most suitable scenarios according to the insights of WP4;
- The profitability of the 24 BM simulations will be mainly assessed through 3 financial indicators: the net present value (NPV), the internal rate of return (IRR) and the payback period. As a brief summary:
  - ✓ The net present value (NPV) represents one of the best financial profitability indicators; it is a useful tool to determine whether a project or investment will result in a net profit or a loss. Whenever the NPV is positive, the project is profitable;
  - ✓ The internal rate of return (IRR) is another of the best financial profitability indicators; it is defined as the rate of return that sets the NPV of all cash flows for the investment equal to zero, meaning that it is the discount rate at which the NPV of the future cash flows is equal to the initial investment. Whenever the IRR is positive, the project is profitable. The IRR is a relative profitability indicator of the project, but not an absolute profitability indicator. When comparing different internal rates of return of two projects, the possible difference over their size is not considered (neither do other external factors as inflation, cost of capital or various financial risks). A project with a huge investment and a low IRR can have a bigger NPV than a lower investment project with a higher IRR; in conclusion, IRR cannot be considered as an alternative to NPV but as complementary information while comparing different project's profitability.
  - ✓ The payback period refers to the amount of time it takes to recover the cost of an investment. It can be seen as the length of time reaches a breakeven point; it is calculated by dividing the amount of the investment by the annual cash flow. A shorter payback means more attractive investment but one of its main downsides is that it disregards the time value of money.

Although the actual economic scenario is completely uncertain due to many different reasons, i.e. the COVID-19 pandemic or the Ukraine war which highly impacted the worldwide economic scenario, for all 24 BM simulations it has been considered that the consumer price index (CPI) increases a 1.45% every year. Note that on June 2022 the harmonised index of consumer prices (HICP) was of 8.6% while on June 2021 it was of 1.9%. In any case, in order to be realistic and consider scenarios in which the inflation rate will still raise over the next 20-25 years but at a more conservative rate, both the energy savings and the OPEX will be considered to be increasing 1.45% each year.

4.4.2 Results from Business Models

The results from the 24 Business Models, related to each virtual demonstrator building and for each Technology Package, are summarized in the following sections.

For each of the six buildings, both the four Technology Packages (TP1÷TP4) and the baseline scenario (e.g.: before Sun Horizon TPs installation) were simulated, and savings, cash flow, IRR and NPV and pay-back period were calculated (for more details refer to the following sections). Moreover, a graph related to the financial feasibility analysis within 25 years was done for each building. This graph represents the accumulated cash flow between the baseline scenario and each TP scenario; it allows to visually checking the project's payback for each TP scenario.

Note that Deliverable D7.3 "SunHorizon Business and ESCO Model" provides an in-depth review of the several BMs that are applicable for the use cases of SunHorizon project and its TP's but in this report, as stated before, focus is on private partnerships considering a simplification of the ESCO BM that is presented in D7.3. Of course, this can be further improved and/or extended according to each country's legal framework with regards to several of the following possible revenue streams:

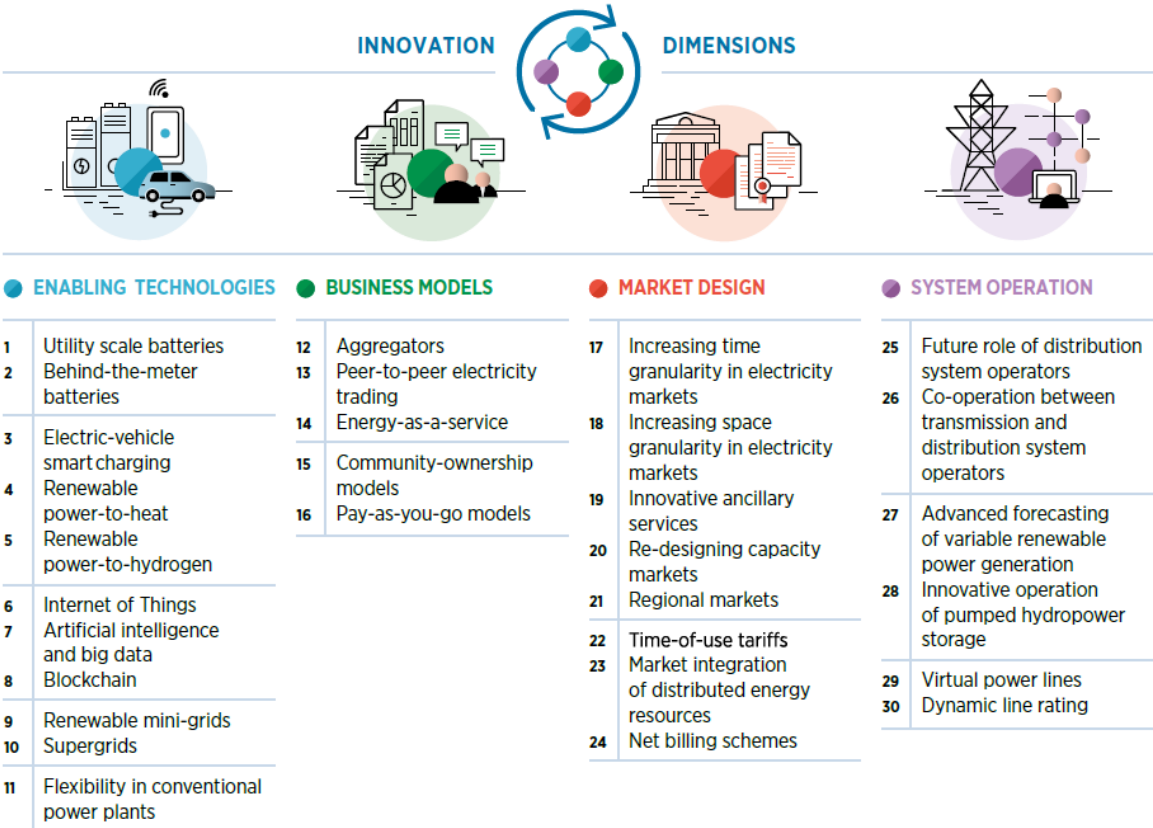

Figure 4.31:Innovation dimensions to assess new business model proposals[17]

As seen in the previous figure one of the key enabling technologies is the energy storage. The main objective of deploying residential energy storage systems, according to Scott P. Burger and Max Luke (2016) has been to" *increase the profitability of solar PV systems through increasing "self-consumption" (i.e. minimizing the export of energy produced onsite). (…) As technology costs have fallen, providing backup power to residential customers and critical commercial and industrial loads has also emerged as a driver"* (P. Burger & Luke, 2016). These BMs are usually performed by EPC contracts (shared or guaranteed savings arrangements) or through the sale and financing of the storage assets.

[17] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jul/IRENA_Business_Models_Collection_2020.pdf

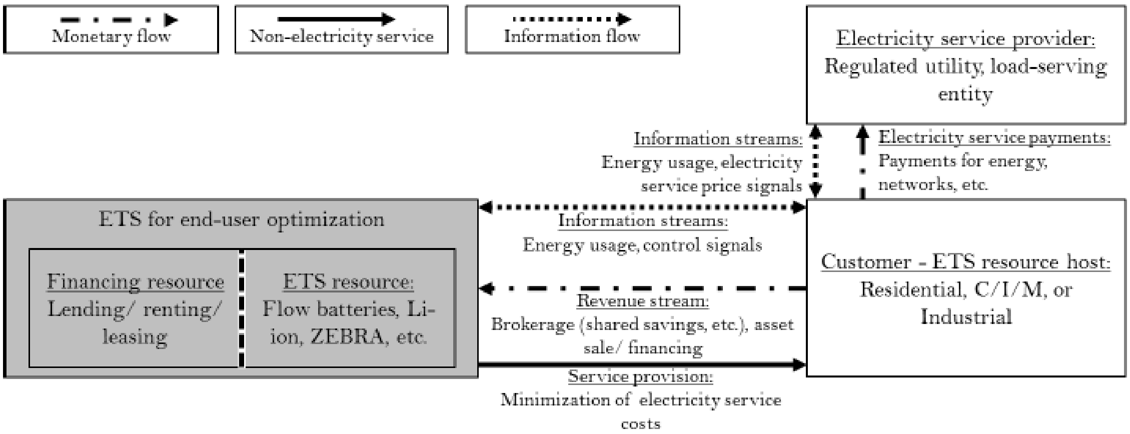

Figure 4.32:Generic energy storage for end-user Business Model structure[18]

The actual BM structure considered for SunHorizon focuses on taking into account a PV or PV-T generation and energy storage coupling (as several major PV producers and electricity/thermal storage business have joined forces over the last years). Since SunHorizon's thermal energy solution is not meant to connect distributed generation and storage assets with bulk power system markets or operators, this model is applicable in terms of maximizing end-users' financial returns without integrating with the market or Transmission System Operator (TSO)/Distribution System Operator (DSO)- at least yet and until these mechanisms are properly regulated and economically compensated, therefore its main interest is to create an efficient, profitable and scalable solution to maximize the use of energy storage and reduce end-users' energy demand as much as possible. The main scheme of this BM could be the one that follows:

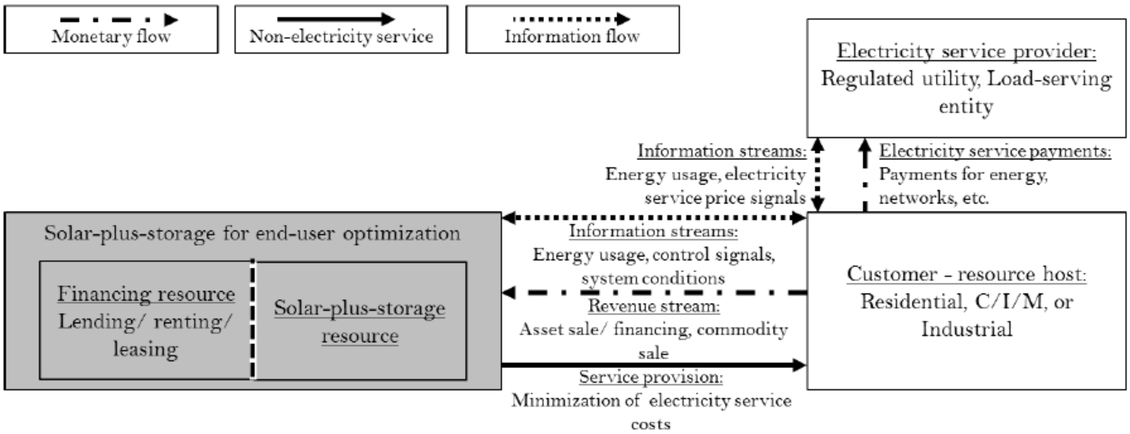

Figure 4.33:Business Model structure for generic energy storage and PV production for end-user[19]

As it is well known, integrating any form of RES generation with any form of storage provides a decrease on conventional grid systems' dependency, therefore it contributes to deploying economic attractive solutions and enhance system-wide economic implications of integrating PV or ST and storage systems in terms of network services. As stated on Burger and Luke's deep analysis on BMs for Distributed Energy Resource (DER), "*Of particular interest is the ability for these systems to enable the system host to significantly reduce or eliminate their total consumption of energy from the bulk power system, thereby reducing network congestion and deferring investments in network reinforcements (but also commonly resulting in a shift of sunk network costs from the system hosts to other network users)*".

[18] P. Burger & Luke, 2016

[19] P. Burger & Luke, 2016

It is not casual that, over the last years, different partnerships have been performed between solar PV companies and energy storage companies; many solar thermal or PV plants have matched their plant design and operation with different ESS so that overall system performance can increase the partnership's revenue streams by diversifying the services provided and cover the needs of either TSOs/DSOs (for example, explicit/incentive-based DR programs such as Direct Load Control (DLC), Interruptible/curtailable service market, emergency DR programs, demand bidding, capacity market or ancillary service market) or end users.

As stated again on Burger and Luke's deep analysis on BMs for DER, "*A number of business models have emerged attempting to bring "firm" solar PV resources to market by pairing solar PV and storage technologies. The aggregations of PV and storage (and, in some cases, other technologies, such as demand response and distributed generators) are often termed "virtual power plants," or "VPPs." Revenue streams are structured around the sales and financing of the assets and fees for brokering market interactions on behalf of the system hosts. In certain cases, businesses will own the projects and earn revenues on the sales of energy (most often under long term power purchase agreements), operating reserve, and capacity services (i.e. commodity sales revenues)*".

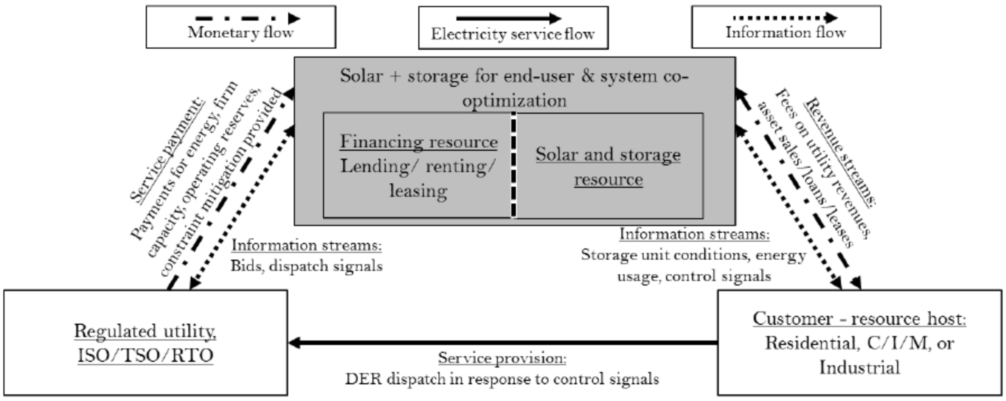

Figure 4.34:Business Model structure for generic energy storage and PV production for end-user and system co-optimization[20]

Anyways, and as noted previously, solar-plus-storage systems as SunHorizon's TP's are meant to be deployed at customer site in order to increase energy self-consumption and pairing on-site RES generation curve with client's demand curve, trying to match them as much as possible in order to reduce energy consumption and lower energy costs as much as possible, as well as increasing self-sufficiency and decreasing grid dependency. While offering solar PV/thermal generation with energy storage solutions, those businesses tend to sell products directly to commercial, industrial or residential customers and structure revenue streams around the sales and financing of all equipment and services involved.

Solar-plus-storage for end-user and system co-optimization business models		
Solar-plus-storage for end-user and system co-optimization Typical customers: • Residential, C/I/M, Industrial <-> Regulated utility, ISO/TSO/RTO Typical Services: • Energy, firm capacity, operating reserves	Solar-plus-storage developers	Sunverge (United States)
		Solar Grid Storage/ SunEdison (United States)
	Virtual power plant developers	Lichtblick (Europe)
		DONG Powerhub (Europe)

Figure 4.35:Energy storage and PV production for end-user and system co-optimization Business Model examples[21]

[20] P. Burger & Luke, 2016

[21] P. Burger & Luke, 2016

After this small literature review, it is worth mentioning that the simulations have been done according to the following:

- Current and future installation elements/equipment;
- Current energy demand and consumption profile as a baseline/reference;
- Current energy costs, referenced both to final thermal energy consumption [€/kWh$_t$] and electricity consumption [€/kWh$_e$];
- Estimated energy savings generated with the new equipment/solution:
  - ✓ Final thermal energy consumption savings [kWh$_t$], as energy saved by replacing fuel-based energy assets with RES/storage assets such as PV/PV-T/ST panels, thermal storage, electrically-driven and gas-driven heat pumps, adsorption and conventional chillers, etc.;
  - ✓ Final electrical energy consumption savings [kWh$_e$], as energy saved by installing RES generation assets such as PV/PV-T panels;
- Estimated economical savings generated with the new equipment/TP:
  - ✓ Final thermal energy economical savings [€$_t$], by multiplying final thermal energy consumption savings [kWh$_t$] and current energy thermal energy costs [€/kWh$_t$];
  - ✓ Final electrical energy economical savings [€$_e$], by multiplying final electrical energy consumption savings [kWh$_e$] and current electricity energy costs [€/kWh$_e$];
- Total investment costs (CAPEX);
- Total O&M costs (OPEX);
- Current economic indicators (mainly CPI).

For more details regarding the Business Models outcomes refer to Annex 1.

4.4.2.1 Demonstrator building # 1 (Residential – Italy/Rome) - Business Model

The simulation results for this demonstrator building are summarized below:

Table 4.23: Demonstrator building #1: Residential Italy - Summary of profitability assessment results

Scenario	Equipment cost (€)	Annual energy costs 1st year (€)	Annual energy savings 1st year (€)	IRR (%)	NPV (€)	Payback period (years)
Baseline scenario	40,000.00	10,959.00	-	-	-	-
Scenario 1: TP1	107,331.28	272.20	10,686.79	10.17	67,090.48	6.07
Scenario 2: TP2	167,216.45	4,674.22	6,284.78	0.90	-64,636.29	17.90
Scenario 3: TP3	193,016.45	1,348.40	9,610.60	3.16	-36,151.77	14.39
Scenario 4: TP4	59,941.87	212.83	10,746.17	19.09	115,450.67	1.84

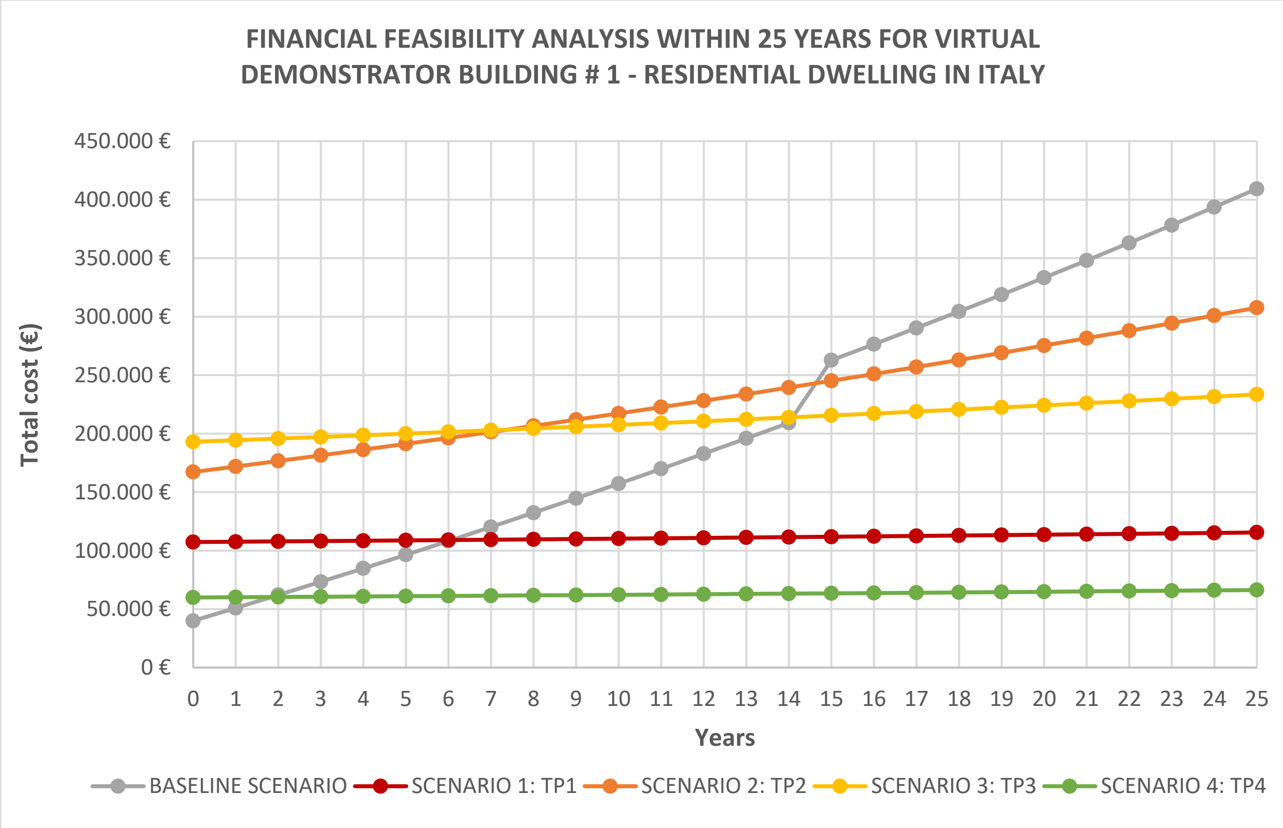

Figure 4.36:Demonstrator building #1: Residential Italy – Financial feasibility analysis among different scenarios

Note that the baseline scenario has been drafted considering the initial status of the HVAC system. In that case, the baseline scenario considered a wall-hung condensing boiler to satisfy both the heating and the DHW demand. For example, a BAXI Platinum Plus/Max Plus/ Duo Plus/Combi Plus brand would fit, considering a 3-bedroom flat with floor indoor area of 80-100m^2. In that case, the nominal heating power rounds above 24 and 34 kW with an approximate cost between 1,500 and 2,500€; we will consider a 2,000€ overall installation cost. In the same path, fan coils/splits from manufacturers DAIKIN or MUNDOCLIMA range between 450 and 600€: we will consider a cost per unit of 500€. Considering that the system must be designed and sized for up to 10 apartments, the total initial investment cost for the baseline scenario will be considered of 40,000€.

According to the simulation results, the most profitable and efficient technology deployments for Scenario #1 are both TP1 and TP4, whose IRR are 10.17% and 19.09% respectively. Note that the paybacks are of 6.07 and 1.84 years respectively, which are very competitive options within the current energy sector market. Both NPVs are positive in those cases, so the options are both technically and financially positive.

By contrast, for Scenario #1 it is noticed that the payback for TP2 is 17.90 years with a slightly positive IRR (0.90%) but a negative NPV (-65 k€). For TP3, we have a payback of 14.39 years and again a very low IRR (3.16%), and a negative NPV too (-36 k€). Therefore, these options are not suitable for a Mediterranean climate as we have in Rome, Italy. The considerable cost of BH heat pump or FAHR chiller seems to be the main reason behind such a considerable initial investment cost (167 k€ for TP2 and 193 k€ for TP3). Therefore, both PV or PV-T generation assets combined with thermal storage and a reasonable cost €/kW for the energy conversion assets (heat pumps and chillers) are very suitable for Mediterranean climates where the RES generation is high and there is neither need of a significant thermal storage nor a significant amount of operating hours of the energy conversion assets.

4.4.2.2 Demonstrator building #2 (Residential – The Netherlands/Rotterdam) - Business Model

The simulation results for this demonstrator building are summarized below:

Table 4.24:Demonstrator building #2: Residential Netherlands - Summary of profitability assessment results

Scenario	Equipment cost (€)	Annual energy costs 1st year (€)	Annual energy savings 1st year (€)	IRR (%)	NPV (€)	Payback period (years)
Baseline scenario	81,000.00	15,125.14	-	-	-	-
Scenario 1: TP1	144,054.45	4,613.81	10,511.33	6.70	27,503.50	5.79
Scenario 2: TP2	179,582.36	11,223.55	3,901.59	-2.89	-115,898.60	21.98
Scenario 3: TP3	152,850.36	790.50	14,334.64	9.45	81,114.86	4.87
Scenario 4: TP4	60,842.44	216.02	14,909.11	24.48	147,786.23	0.00

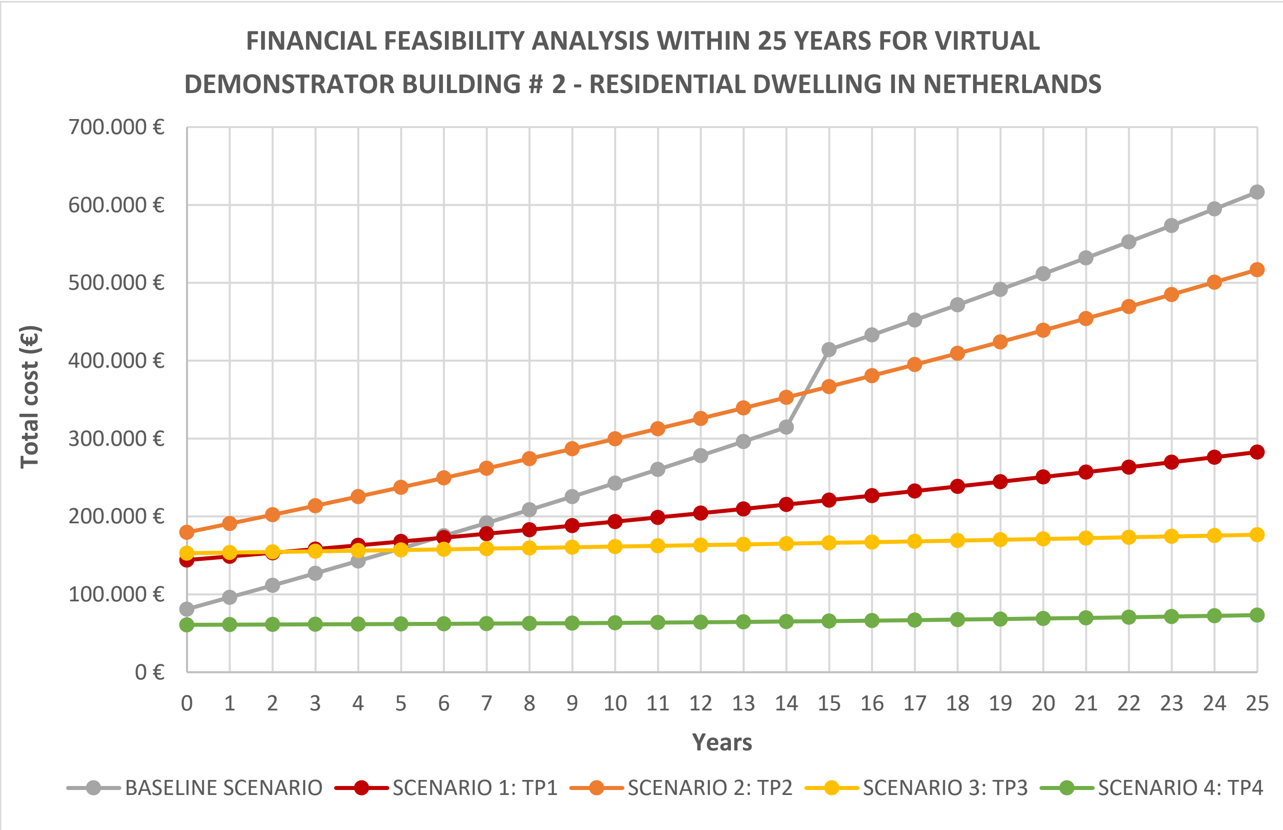

Figure 4.37:Demonstrator building #2: Residential Netherlands – Financial feasibility analysis among different scenarios

Again note that the baseline scenario has been drafted considering the initial status of the HVAC system. In that case, the baseline scenario considered a wall-hung condensing boiler to satisfy both the heating and the DHW demand. For example, a BAXI Platinum Plus/Max Plus/ Duo Plus/Combi Plus brand would fit, considering a 3-bedroom flat of 100-150 m^2 of floor indoor area. In that case, the nominal heating power rounds above 24 and 34 kW with an approximate cost between 1,500 and 2,500€; we will consider a 2,000€ overall installation cost. In the same path, fan coils/splits from manufacturers DAIKIN or MUNDOCLIMA range between 450 and 600€: we will consider a cost per unit of 500€. Considering that the system must be designed and sized for up to 18 apartments, the total initial investment cost for the baseline scenario will be considered of 81,000€.

According to the simulation results, the most profitable and efficient technology deployments for Scenario #2 are both TP3 and TP4, whose IRR are 9.45% and 25.83% respectively. Note that the paybacks are of 4.87 and 0 years respectively, which are extremely competitive options within the current energy sector market. Both NPVs are positive in those cases, so the options are both technically and financially positive.

That makes sense as TP3 is now sized with FAHR HP of 26kW and a chiller capacity of 25kW, way lower than Scenario #1 which considered FAHR HP of 39 kW and chiller capacity of 38 kW. As we are in a slight northern climate, the electrical consumption to run both the HP and the chiller in summer is way lower and we can still rely on a significant solar thermal generation in winter (67.7 MWh of thermal energy), therefore the RES generation share is higher and the operating hours of both the HP and the chiller are very low.

By contrast, for Scenario #1 it is noticed that the payback for TP2 is 21.98 years with a negative IRR (-2.89%) and a negative NPV (-115 k€). For TP1, we have a payback of 5.79 years, a positive IRR (6.70%), and a positive NPV too (27 k€). Again, BP's significant CAPEX hinders the profitability of a ST/PV-T coupling option, and the results of the DUU tool show that in that case BP HP capacity was increased from 40kW (Scenario #1) to 60 kW with a similar thermal capacity (102 MWh for Scenario #1 TP2 vs 149 MWh for Scenario #2 TP2).

Of special relevance is TP4: when optimizing the solar thermal BAXI panel surface (35 m^2) and the photovoltaic BAXI panel surface (105.7 m^2) we can compensate the significant amount of yearly operating hours of BDR AWHP with RES electric generation and rely on less thermal storage capacity installed. This leaves a scenario where CAPEX is roughly 61k€ with annual savings of 14.9k€; considering that the baseline scenario implied a CAPEX of 81k€, therefore even a first savings of already 20k€, that option provides a financial surplus from day 1 therefore its implementation already represents a gain from the beginning. This is understood in the context that CAPEX + energy costs from the baseline scenario on year 1 is 96 k€ while with TP4 is of 61 k€. Note that, by just comparing the savings, the payback would be of approximately 3 years but all simulations are made also considering baseline scenario CAPEX; otherwise we will be just comparing the savings to each new scenario's TP implementation but, of course, the actual HVAC system of each baseline scenario had its cost back in the day it was installed and it must be considered while comparing financial feasibility of each TP implementation.

4.4.2.3 Demonstrator building #3 (Residential – Sweden/Goteborg) - Business Model

The simulation results for this demonstrator building are summarized below:

Table 4.25:Demonstrator building #3: Residential Sweden - Summary of profitability assessment results

Scenario	Equipment cost (€)	Annual energy costs 1st year (€)	Annual energy savings 1st year (€)	IRR (%)	NPV (€)	Payback period (years)
Baseline scenario	60,000.00	16,602.33	-	-	-	-
Scenario 1: TP1	172,079.43	5,092.98	11,509.34	5.84	15,767.36	9.16
Scenario 2: TP2	219,443.14	13,161.87	3,440.46	-4.88	-163,290.55	24.20
Scenario 3: TP3	250,467.14	1,297.79	15,304.54	4.97	-678.01	11.50
Scenario 4: TP4	71,053.31	252.28	16,350.05	24.35	195,079.58	0.00

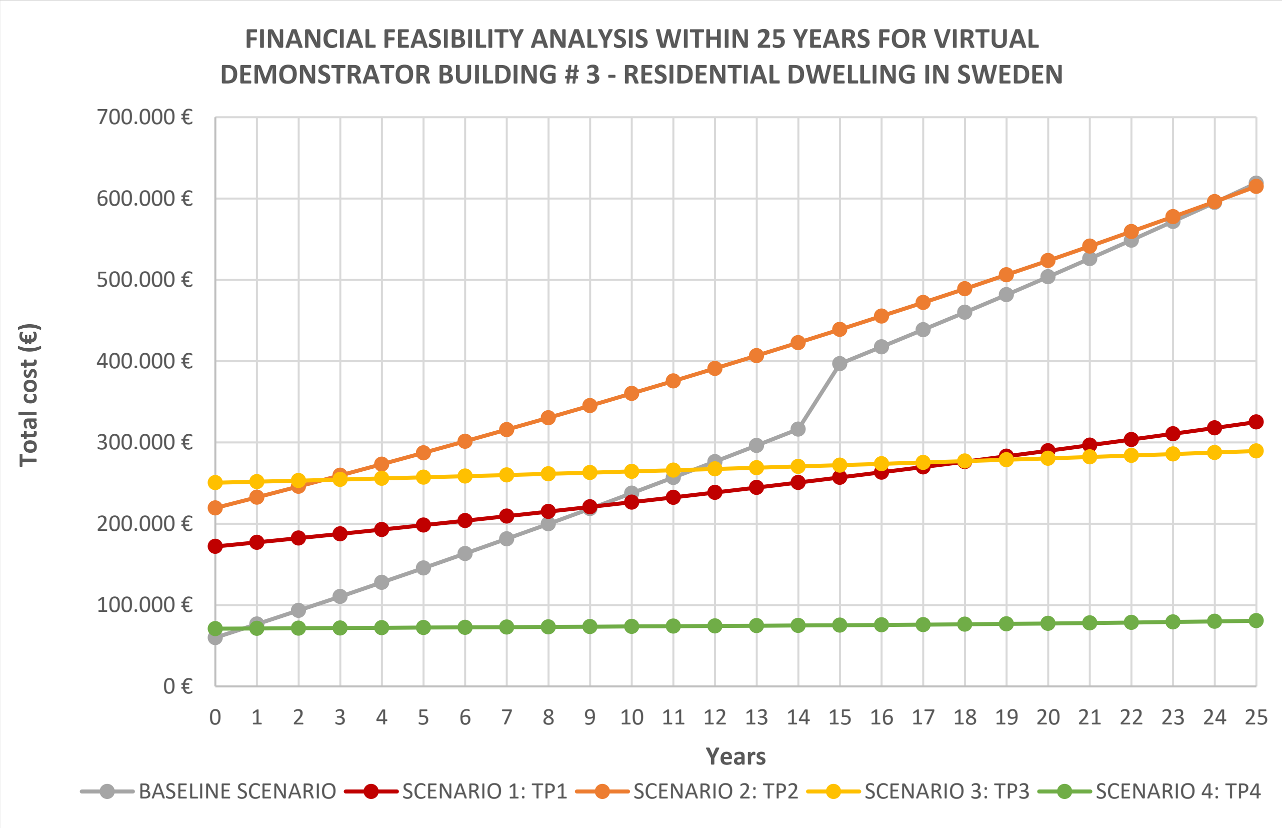

Figure 4.38:Demonstrator building #3: Residential Sweden – Financial feasibility analysis among different scenarios

Again note that the baseline scenario has been drafted considering the initial status of the HVAC system. In that case, the baseline scenario considered a wall-hung condensing boiler to satisfy both the heating and the DHW demand. For example, a BAXI Platinum Plus/Max Plus/ Duo Plus/Combi Plus brand would fit, considering a 3-bedroom flat of 100-150 m² of floor indoor area. In that case, the nominal heating power rounds above 24 and 34 kW with an approximate cost between 1,500 and 2,500€; we will consider a 2,000€ overall installation cost. In the same path, fan coils/splits from manufacturers DAIKIN or MUNDOCLIMA range between 450 and 600€: we will consider a cost per unit of 500€. Considering that the system must be designed and sized for up to 12 apartments, the total initial investment cost for the baseline scenario will be considered of 60,000€.

According to the simulation results, the most profitable and efficient TP deployments for Scenario #3 are both TP4 and TP1, whose IRR are 24.35% and 5.84% respectively. Note that the paybacks are of 0 and 9.16 years respectively, which are extremely competitive options within the current energy sector market. Both NPVs are positive in those cases, so the options are both technically and financially positive.

This makes sense as, similar to Scenario #2, the cooling demand is minimal and both the heating and the DHW demand are the most significant ones. Since TP4 has been optimized in a way that the PV panel surface is of 141 m², this compensates the significant BDR HP years of annual operation (3,438) and its related electric energy consumption (20.8 MWh), which is fully compensated by the RES electric generation (23.8 MWh). We even have an optimized contribution of solar thermal generation according to the northern location of this scenario, therefore the tank capacity is also lowered and the HP (whose CAPEX is very competitive) can take over the role to supply the heating + DHW demand.

Again, note that TP3's FAHR HP and chiller are quite oversized (52KW and 51 kW respectively) while the cooling demand is extremely low. Considering that the CAPEX of FAHR HP is of 20,000€ per 13kW of cooling capacity, the DUU tool has not succeeded in considering that the energy conversion assets' capacity needed for such a cold climate should be minimal. Although the peak load has been estimated at approximately 40kW, which is quite high for such a cold climate, this should stick to very few moments of summer, therefore the actual design and sizing could be improved in order to obtain an IRR>10% and paybacks lower than 10 years.

4.4.2.4 Demonstrator building #4 (Tertiary – Italy/Rome) - Business Model

The simulation results for this demonstrator building are summarized below:

Table 4.26:Demonstrator building #4: Tertiary Italy - Summary of profitability assessment results

Scenario	Equipment cost (€)	Annual energy costs 1st year (€)	Annual energy savings 1st year (€)	IRR (%)	NPV (€)	Payback period (years)
Baseline scenario	32,500.00	40,607.19	-	-	-	-
Scenario 1: TP1	206,719.48	1,727.65	38,879.54	20.01	427,842.86	4.37
Scenario 2: TP2	403,622.19	10,368.32	30,238.87	6.97	89,913.72	11.35
Scenario 3: TP3	811,006.19	4,323.37	36,283.81	2.27	-218,809.32	18.06
Scenario 4: TP4	212,556.10	754.69	39,852.49	19.95	437,892.04	4.40

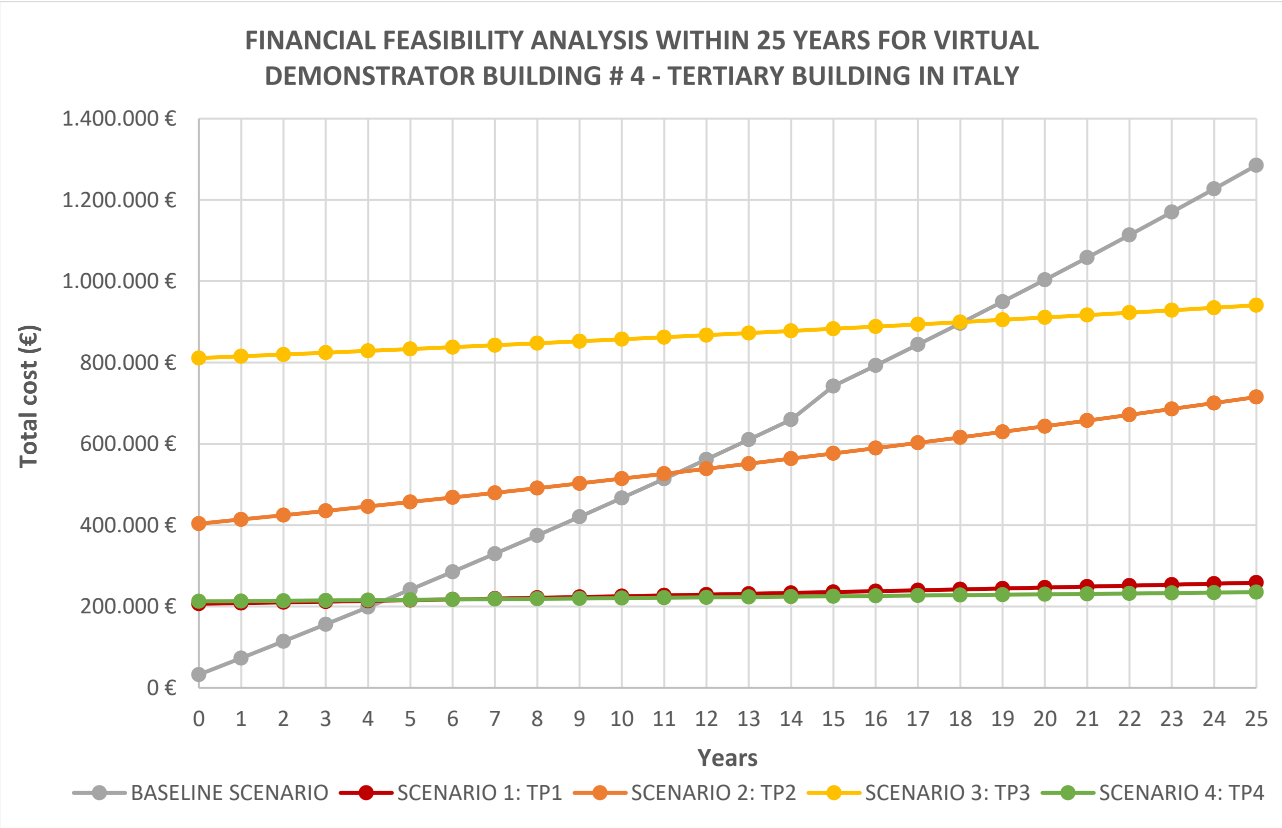

Figure 4.39:Demonstrator building #4: Tertiary Italy – Financial feasibility analysis among different scenarios

In that case, the baseline scenario has been drafted considering the initial status of the HVAC system. In that case, the total conditioned building area is of 3,584 m² (10,752 m³) with maximum available area for either PV or ST panels of 358 m². In that case, we will consider a standing condensing boiler to satisfy both the heating and the DHW demand. For example, a BAXI EuroCondens SGB 125 or Power HT Plus 130 F to overcome a 92.65 kW peak load and to fulfil the entire heating demand, with a cost ranging between approx. 6,700 and 8,700€: we will consider a 7,500€ overall installation cost. In the same path, fan coils/splits of up to 7kW of cooling capacity from manufacturers DAIKIN or MUNDOCLIMA range between 450 and 600€ and outdoor units between 4.1 and 12.3 kW of output power range between 1,250 and 3,200 €. Considering that the system must be designed and sized for a peak cooling load of 198 kW, the total initial investment cost for the baseline scenario will be considered of 32,500€.

According to the simulation results, both TP1 - IRR of 20.01%; NPV of 427 k€ and a payback period of 4.37 years, and TP 4 – IRR of 19.95%, NPV of 438 k€ and payback period of 4.40 years, are the most suitable options for this Scenario #4. The total heating demand is the sum of annual heating energy demand plus the DHW demand (7,427.35 kWh/y): 216,258.16 kWh/y. For TP1, the energy produced by BH HP plus the energy produced by TVP solar panels (218,580 kWh/y) cover the total heating demand (216,258.16 kWh/y); for TP4, the total heating demand is the sum of annual heating energy demand plus the DHW demand (7,427.35 kWh/y): 216,257.70 kWh/y. Therefore, the energy produced by BDR ASHP plus Baxi thermal solar panels (216,258.00 kWh/y) cover the total heating demand (216,257.70 kWh/y). Therefore it looks clear that, in Mediterranean climates, and considering a significant heating demand, these options are highly competitive and they are both technically and financially positive.

With regards to TP2, the energy produced by BH HP and Dual Sun PVT (218,579 kWh/y) cover the total heating demand (216,256.77 kWh/y) but once again we deal with a significant CAPEX that hinders the financial profitability of the TP proposal. The BH HP capacity is set to 100 kW to meet the 92.65 kW peak load but, most important, the 358 m^2 of hybrid PV-T panels allow his configuration to produce a significant amount of electrical energy (112 MWh), way more than its annual demand (3.3 MWh); with a proper feed-in tariff and compensation mechanism, the profitability of this TP (right now with IRR of 6.97%, NPV of 90 k€ and payback period of 11.35 years) could be significantly improved and achieve similar results as TP1 and TP4.

With regards to TP3, as a kind reminder it mainly serves for space cooling during summer. The sorption chiller must be coupled with the solar thermal source, for which the summer production is considered. All the heating produced during winter is considered as a saving. In particular, this configuration consists of 358 m^2 of thermal solar module. The annual cooling energy demand required by building affected by uncertainties has been calculated dividing the cooling energy demand without uncertainties (e.g.: 95,932.04 kWh/y) by the cooling peak load (196.33 kW), thus obtaining the yearly operating hours (e.g.: 489 h/y). Multiplying the operating hours by the cooling peak load λ2 with uncertainties (207.241kW) the annual cooling energy demand value of 101,262.96 kWh/y is obtained. This cooling demand is covered by the energy produced by FARH sorption which is equal to 101,264 kWh/y. Once again, the significant FARH HP CAPEX (24.400 € per 13kW) hinders the overall system cost and, although it provides 36,283.81 € of annual energy cost savings, we are dealing with an investment cost over 800 k€, which led to an IRR of 2.21%, a negative NPV (-219 k€) and a payback period of 18.06 years. The energy produced by the compressor chiller is equal to zero because the cooling energy demand is covered by the sorption chiller; therefore this cost should also be removed if we wanted to optimize the overall TP final deployment (approximately 160k€). Without it, the IRR will be increased to 4.31%, the NPV will still be negative but improved (49 k€) and the payback period will be lowered to 15.04 years.

4.4.2.5 Demonstrator building #5 (Tertiary – The Netherlands/Rotterdam) - Business Model

The simulation results for this demonstrator building are summarized below:

Table 4.27:Demonstrator building #5: Tertiary Netherlands - Summary of profitability assessment results

Scenario	Equipment cost (€)	Annual energy costs 1st year (€)	Annual energy savings 1st year (€)	IRR (%)	NPV (€)	Payback period (years)
Baseline scenario	13,000.00	7,079.00	-	-	-	-
Scenario 1: TP1	85,309.58	2,508.02	4,570.99	3.79	-10,705.41	14.31
Scenario 2: TP2	104,455.43	6,175.12	903.88	0.81	-49,986.04	20.17
Scenario 3: TP3	211,303.43	1,078.24	6,000.76	-1.12	-113,363.56	>25
Scenario 4: TP4	49,783.13	176.76	6,902.24	14.71	62,871.45	5.17

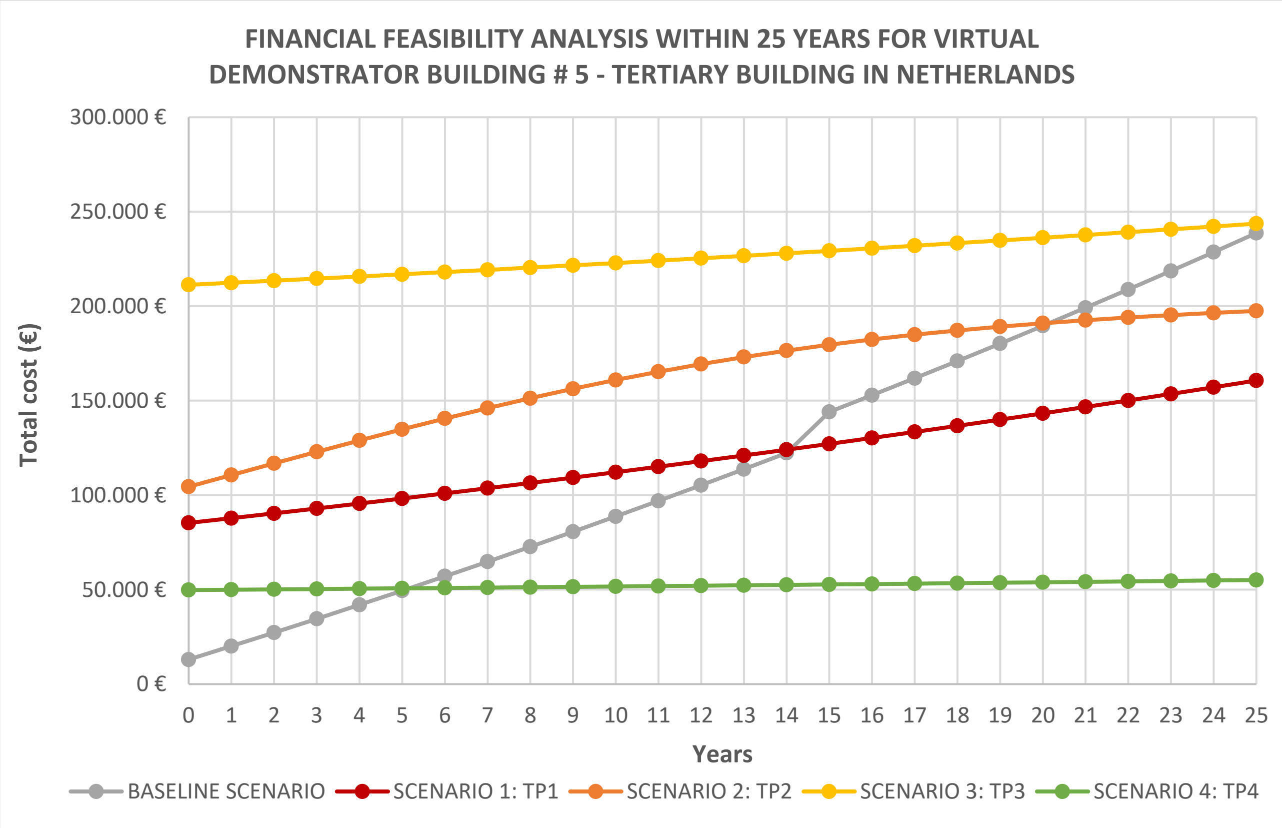

Figure 4.40:Demonstrator building #5: Tertiary Netherlands – Financial feasibility analysis among different scenarios

In that case, the baseline scenario has been drafted considering the initial status of the HVAC system. In that case, the total conditioned building area is of 764 m² (2,292 m³) with maximum available area for either PV or ST panels of 76 m². In that case, we will consider a standing condensing boiler to satisfy both the heating and the DHW demand. For example, a BAXI EcoTherm Plus WGB 38, Vaillant EcoTec Plus YMW 306/5-5 GN or Daikin D2CND35SET to overcome a 27.40 kW peak load and to fulfil the entire heating demand, with a cost ranging between approx. 2,700 and 3,400€: we will consider a 3.000€ overall installation cost. In the same path, fan coils/splits of up to 7kW of cooling capacity from manufacturers DAIKIN or MUNDOCLIMA range between 450 and 600€ and outdoor units between 4.1 and 12.3 kW of output power range between 1,250 and 3,200 €. Considering that the system must be designed and sized for a peak cooling load of 54.26 kW, the total initial investment cost for the baseline scenario will be considered of 13,000€.

According to the simulation results, TP4 with an IRR of 14.71%, a NPV of 63k€ and a payback period of 5.17 years is the most suitable option for Scenario #5. The rest of the options are quite far from this one, with IRRs between -1.12 and 3,79% and negative NPV's, one of them with a payback >25 years (TP3). In the following the assessment of the reasons behind this is shown.

Regarding TP1, in this configuration 76 m² of thermal solar module cannot fulfil the entire demand (79,519.90 kWh/y). Approximately 3,600 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW is suitable to overcome 28.822 kW peak load (λ7) and to fulfil the entire heating demand. The total heating demand is the sum of annual heating energy demand plus the DHW demand (1,873.87 kWh/y): 81,393.77 kWh/y. Therefore, the energy produced by BH HP plus the energy produced by TVP solar panels (81,395 kWh/y) cover the total heating demand (81,393.77 kWh/y). As in previous cases, the BH HP capacity is set to 40 kW and its total CAPEX is of 40,000 € which is more than 10 times the cost of the existing boiler. Although the overall NG consumption is lowered to 1/3 of the baseline scenario, the ST panel installation is not able to fulfill the peak load times; therefore, we still need to rely on BH HP acting for 657 hours a year. This implies 4,570 € of cost savings but with an investment of 85k€, therefore leading us to a scenario with an IRR of 3.79%, a negative NPV (-11k€) and 14.31 years of payback. This configuration could be further improved if the BH HP size could be lowered, leading to less (but way more efficient) NG consumption with lower CAPEX and bigger savings, thus offering a scenario with IRR≥10% and payback periods ≤10 years, which will be more competitive and sustainable than the actual baseline scenario.

With regards to TP2, in this configuration 76 m^2 of both photovoltaic and thermal solar modules are installed. Approximately 3,600 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW is required to overcome the peak load. In this scenario it is needed to fulfil the gap between the required heating demand (79,521.57 kWh/y) plus the DHW demand (1,873.87 kWh/y) and the energy produced by solar technology (6,449 kWh/y). The energy produced by BH HP and Dual Sun PVT (78,658 kWh/y) cover the total heating demand (78,656.84 kWh/y). As in previous cases, the BH HP capacity is set to 40 kW and its total CAPEX is of 40,000 € which is more than 10 times the cost of the existing boiler. Since BH HP is gas-driven and thanks to the PV-T support, the actual natural gas cost is slightly lowered and the electricity cost is now 0 but previously it was already very low since the electric demand was only of 292 kWh/y. Therefore considering the energy demand of that building, the BM simulation results are not profitable (IRR of 0.81%; NPV of -50k€ and payback period of 20.17 years) so in that case it would be way better to go for a TP4 configuration where an electrically driven HP can replace previous NG consumption thanks to the electricity produced by the PV-T panels.

For TP3 we have quite a similar issue. In particular, this configuration consists of 76 m^2 of thermal solar module. Approximately 3,600 l storage tank must be coupled with solar technology. The annual cooling energy demand required by building affected by uncertainties (λ4, including 81 discomfort hours and 0.9% discomfort rate over the year) has been calculated dividing the cooling energy demand without uncertainties (817.68 kWh/y) by the cooling peak load (54.26 kW), thus obtaining the yearly operating hours (15 h/y). Multiplying the operating hours by the cooling peak load λ4 with uncertainties (63.19 kW) the annual cooling energy demand value of 952 kWh/y is obtained. This cooling demand is covered by the energy produced by Farhenehit sorption chiller which is equal to 952 kWh/y. The problem is that FAHR sorption chiller has been sized up to 65 kW, with a total CAPEX of 122,000 € for operating just 15 hours. On top of that, the compression chiller has been sized up to 55 kW with 0 hours of operation throughout the year and a total CAPEX of 44,320 €. Although we need to fulfil the cooling peak demand, it seems clear that this technology configuration is way too oversized and expensive considering the actual demand profile of Scenario #5. Again, the BM simulation results are not profitable (IRR of -1.12%; NPV of -113 k€ and payback period of >25 years) so this is not a feasible option. Just by erasing the compression chiller we would have a positive IRR (0.82%) and we will cut up the NPV to -66k€, with a payback of 19.69 years. With such a small cooling demand, the use of such an exceptional technology like FAHR's HP is wasted so in this scenario it would be better to stick to TP4.

4.4.2.6 Demonstrator building #6 (Tertiary – Sweden/Goteborg) - Business Model

The simulation results for this demonstrator building are summarized below:

Table 4.28:Demonstrator building #6: Tertiary Sweden - Summary of profitability assessment results

Scenario	Equipment cost (€)	Annual energy costs 1st year (€)	Annual energy savings 1st year (€)	IRR (%)	NPV (€)	Payback period (years)
Baseline scenario	19,000.00	10,766.76	-	-	-	-
Scenario 1: TP1	147,301.38	710.92	10,055.84	6.04	16,822.39	11.77
Scenario 2: TP2	192,659.33	8,776.88	1,989.87	-7.22	-160,182.10	>25 years
Scenario 3: TP3	414,099.33	2,112.90	8,653.86	-3.14	-272,857.54	>25 years
Scenario 4: TP4	105,307.47	373.90	10,392.86	10.06	64,319.84	7.89

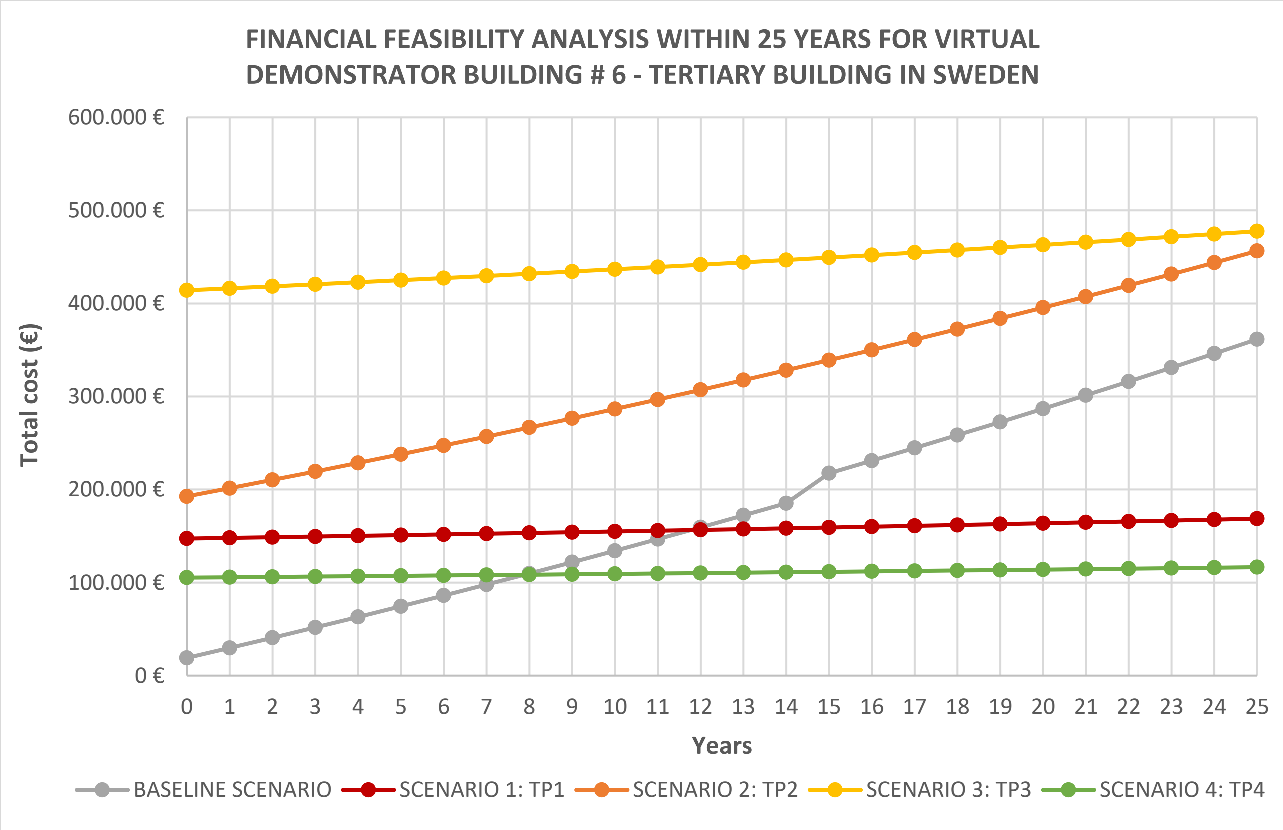

Figure 4.41:Demonstrator Building #6: Tertiary Sweden – Financial feasibility analysis among different scenarios

As seen before, the baseline scenario has been drafted considering the initial status of the HVAC system. In that case, the total conditioned building area is of 1.801 m^2 (5.403 m^3) with maximum available area for either PV or ST panels of 180 m^2. In that case, we will also consider a standing condensing boiler to satisfy both the heating and the DHW demand. For example, a BAXI Neodens Plus 33/33 F ECO or Platinum GTAF Combi 32 or Bios Plus 50 F, Vaillant EcoTec Plus YMW 306/5-5 GN or Daikin D2CND35SET to overcome a 31.74 kW peak load and to fulfil the entire heating demand, with a cost ranging between approx. 2.700 and 4.000€: we will consider a 3,500€ overall installation cost. In the same path, fan coils/splits of up to 7kW of cooling capacity from manufacturers DAIKIN or MUNDOCLIMA range between 450 and 600€ and outdoor units between 4.1 and 12.3 kW of output power range between 1,250 and 3,200 €. Considering that the system must be designed and sized for a peak cooling load of 104.61 kW, the total initial investment cost for the baseline scenario will be considered of 19,000€.

According to the simulation results, TP4 with an IRR of 10.06%, a NPV of 64 k€ and a payback period of 7.89 years is the most suitable option for Scenario #6. The rest of the options are quite far from this one, with IRRs between -7.22 and 6.04%, NPV's between -273 and 17 k€ and paybacks between 11.77 and >25 years (TP2 and TP3). In the following the assessment of the reasons behind this is shown.

Regarding TP1, in this configuration 180 m^2 of thermal solar module cannot fulfil the entire heating demand (116,042.80 kWh/y). The total heating demand is the sum of annual heating energy demand plus the DHW demand (4,788.15 kWh/y): 120,830.95 kWh/y. Approximately 8,450 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW is suitable to overcome 33.026 kW peak load (λ7) and to fulfil the entire heating demand. The energy produced by BH HP plus the energy produced by TVP solar panels (120,831 kWh/y) cover the total heating demand. As in previous cases, the BH HP capacity is set to 40 kW and its total CAPEX is of 40,000 € which is close to 10 times the cost of the existing boiler. Although TP1 almost reaches 94% of energy self-sufficiency quota, the high CAPEX hinders the profitability of the solution therefore leading us to a scenario with an IRR of 6.04%, a NPV of 17 k€ and a payback period of 11.77 years. This is still competitive and comparable to actual ST installations and it could hardly be improved as we have almost reached the 100% self-sufficiency thanks to the BH HP increase of NG conversion to useful thermal energy (40% increased efficiency according to the manufacturer's datasheet).

In TP2 we have 180 m^2 of both photovoltaic and thermal solar modules are installed. Approximately 8,450 l storage tank must be coupled with the solar technology. The heat pump capacity of 40 kW, required to overcome 31.765 kW peak load (λ2), in this scenario is needed to fulfil the gap between the required heating demand (111,612.05 kWh/y), plus the DHW demand (4,788.15 kWh/y), and the energy produced by solar technology (11,856 kWh/y). In this scenario the electric energy produced by the PV technology can be used by the system or sold to the grid, resulting in a negative operative cost (it is a cost saving for this configuration). The total heating demand is the sum of annual heating energy demand plus the DHW demand (4,788.15 kWh/y): 116,400.20 kWh/y. Therefore, the energy produced by BH HP and Dual Sun PVT (116,416.43 kWh/y) cover the total heating demand (116,400.20 kWh/y). The main issues with this configuration are both the low solar thermal production, which leads to the BH HP operating 2.493 hours a year, therefore a low decrease of NG consumption (almost 20%), and the low electric energy consumption (2,991.60 kWh/y) while the PV-T panels produce up to 34.102 kWh/y. With a proper feed-in tariff and compensation mechanism, the profitability of this TP (right now with IRR of -7.22%, NPV of -160 k€ and payback period >25 years) could be significantly improved and achieve similar results as TP1 and TP4. As in Scenario # 5, in that case it would be way better to go for a TP4 configuration where an electrically driven HP can replace previous NG consumption thanks to the electricity produced by the PV-T panels.

For TP3 we have quite a similar issue. In particular, this configuration consists of 180 m^2 of both photovoltaic and thermal solar modules. Approximately 8,450 l storage tank must be coupled with the solar technology. The annual cooling energy demand required by building affected by uncertainties (λ2, including 203 discomfort hours and 2.3% discomfort rate over the year) has been calculated dividing the cooling energy demand without uncertainties (3,150.40 kWh/y) by the cooling peak load (104.61 kW), thus obtaining the yearly operating hours (30.12 h/y). Multiplying the operating hours by the cooling peak load λ2 with uncertainties (112.364 kW) the annual cooling energy demand value of 3,383.92 kWh/y is obtained. This cooling energy demand is covered by the energy produced by Fahrenheit sorption chiller which is equal to 3,384 kWh/y. As in Scenario #5, the main issue is that FAHR sorption chiller has been sized up to 117 kW, with a total CAPEX of 219,600 € for operating just 29 hours a year. On top of that, the compression chiller has been sized up to 109 kW with 0 hours of operation throughout the year and a total CAPEX of 86,160 €. Although we need to fulfil the cooling peak demand, it seems clear that this technology configuration is way too oversized and expensive considering the actual demand profile of Scenario #6. Again, the BM simulation results are not profitable (IRR of -3.14%; NPV of -273 k€ and payback period of >25 years) so this is not a feasible option. By suppressing the compression chiller and shaping the demand curve so that FAHR chiller could be downsized to a reasonable peak power, we would be able to have a profitable scenario but we must bear in mind that Sweden is way up North; therefore, although having significant cooling peak loads according to the DUU tool, the actual cooling demand is just 3,150.40 kWh/y so it seems pretty clear that this TP is not suitable for cold climates.

4.5 Legal aspects: EU on-line legal survey

4.5.1 Brief Introduction

The aim of this section is to present the outcomes of the EU legal on-line survey aimed at investigating the legal building requirements in the European countries, with a focus on the three countries with different climatic conditions identified as location of the six virtual demonstrator buildings (Italy, The Netherlands and Sweden).

RINA proposed the following few legal aspects to be investigated both at EU and at the above-selected countries level:

- analysis of self-consumption,
- % of RES mandatory,
- architectural/aesthetical restrictions,
- thermal comfort requirements,
- presence of support incentives schemes;

Sant Cugat then drafted a short survey to discover which legal building requirements would have been useful to investigate and uploaded the questionnaire online through EC platform EUSurvey[22]. So, RINA on February 2022 distributed the online link to all the Consortium partners by e-mail pointing out partners to feel free to forward the e-mail

[22] https://ec.europa.eu/eusurvey/home/welcome

and/or the survey link to their contacts/external stakeholders of SunHorizon project. The first deadline to fill-in the Eu legal survey was March 2022 but, due to the few answers received, it was extended many times till to the mid of July.

4.5.2 Results of the EU Survey

In this section the results obtained from the survey are displayed.

A total of 11 answers, included the one by Sant Cugat, from five countries (Sweden, Netherlands, Italy, France and Spain) were obtained; specifically, two answers both from Italy and Sweden, one answer from Netherlands (countries selected for demonstrator buildings), four answers from France and two from Spain.

It is pointed out that, among the 11 answers, one answer from France cannot be considered valid since it stated that "it did not have sufficient knowledge to complete the survey". Therefore, the total number of valid answers is 10 included Sant Cugat. It is pointed out that 10 answers are few to have a representative sample, but, in any case, some interesting outcomes were obtained. It is worth mentioning also that, in few cases, answers contradict in the same country (e.g.: minimum % of other RES required, in France)

50% of the 10 answers were provided by people not involved with the Sun Horizon project and the other 50% from people working on SunHorizon. Of the 10 responses received, only 2 were from female participants, 7 were from male participants and 1 participant prefers not answer.

Moreover, four out of ten answers were provided by employee for a company that works on similar SunHorizon technology (heat pumps, solar panels, thermal energy storages), two from Small Medium Enterprises (SME), two from research bodies, one from a University and one from a Municipality. The average age of people who answered is about 35-40 years old.

The survey is relatively short and it assesses the existing country, regional, and local regulations in the different countries. It consists of 10 questions organized into three sectors:

- **Analysis of photovoltaic self-consumption:** four questions related to the regulations governing self-consumption in cities of respondents and which connection and energy compensation methods are possible;
- **Energy efficiency requirements for buildings**: three questions regarding the Regulations that establish the requirements in energy efficiency and renewable energies and the minimum percentage of RES mandatory;
- **Architectural/aesthetical restrictions, thermal comfort requirements and presence of support incentives schemes for energy self-consumption:** one question for each of the three aspects including: mechanism to control restrictions, regulation that establishes comfort requirements and the existence of specific incentives for self-consumption and RES.

For an overview about the questions included in the EU legal survey refer to the Annex 2.

In the following the main conclusions, related to the three above mentioned sectors and coming from the analysis of the answers provided, are shown.

1. Analysis of photovoltaic self-consumption

The main outcomes emerged by the answers provided by respondents are the following:

- All countries have support mechanisms to promote the use of RES. Some with specific rules and regulations and others apply aid and financial support for the installation of solar panels;
- In Italy exists three main mechanisms that support electricity conversion and self-consumption through PV. Users can choose only one among them:
  - ✓ electricty self-consumption ("Scambio sul posto"). This service let to balance the electricity produced and fed into the grid at a certain time with that got from the grid at a different time. The excess of energy production is rewarded with a variable rate calculated by considering the market price of energy,
  - ✓ rewarding of produced electricity ("Ritiro dedicato"). The Government Energy Service Manager corresponds an economic reward for each produced kWh,
  - ✓ Renewable Energy Communities: citizens, enterprises and public bodies are encouraged to form "prosumers" net through dedicated incentives for the electricity production and self-consumption. The self-consumption is not considered at the level of the single user but for all the prosumers association.

- All countries have the possibility to compensate for the excess electricity produced with the "Net Billing" mode. Italy includes as well as the "Net Metering" mode as a possible mode. Netherlands uses the Net Metering mode, energetic compensation (credit in kWh). The law on net metering states that the power companies are obligated to deduct all the power that a household feeds back into the grid, from the amount of power that it consumes from the grid. This means people only end up paying for the resulting balance between the two. For the consumer therefore is no need to store the energy in batteries
- In Sweden there is no regulation directly aimed at supporting self-consumption of electricity. There are however regulations related to it. There is a green benefit of 15% of the total investment cost of solar PV systems for private home-owner and a tax deduction of about 0.06 €/kWh of electricity feed into the Grid. Some municipalities have lower fee for building permit if solar PV is included in construction, and there is not any regulation for collective self-consumption yet.
- In France, self-consumption support mechanism is a subsidy to PV installation owner. There is a grant for self-consumption (up to 100 kWp) on buildings;
- In Spain the Country Royal Decree 244/2019 regulates the administrative, technical and economic conditions for self-consumption of electricity. The main objectives of the Royal Degree are:
  - ✓ Promote self-consumption, especially in installations which produce electricity out of RES;
  - ✓ Define and regulate collective self-consumption;
  - ✓ Define simplified compensation mechanisms between surpluses and deficits;
  - ✓ Simplify technical and administrative requirements;
  - ✓ Establish a follow-up of the implementation.

At regional level (e.g.: Catalonia) there is the Decree-Law 24/2021 on the acceleration of the deployment of distributed renewable energies including modification of Decree Law 16/2009 on urgent measures for the climate emergency and the promotion of renewable energies;

- There can be self-consumption with surplus and without surplus. With surplus means that it is possible to send the surplus into the network. Self-consumption is divided into:
  - ✓ *self-consumption with surpluses* receiving compensation when both the consumer and producer agree on receiving compensation for surplus (e.g.: Italy, Netherlands, Sweden, Spain and France)
  - ✓ *self-consumption with surpluses without compensation* when voluntarily they do not want to accept the scheme (e.g.: Sweden and Spain)
  - ✓ *self-consumption without surplus*: it is not possible to send the surplus into the network (e.g.: Italy and France)
- Regarding access and connections permits to the Grid the following aspects emerged:
  - ✓ *self-consumption with surpluses* with power installed ≤15 kW located in urban areas (Italy, Netherlands, France and Spain).
  - ✓ *self-consumption without surpluses* (Italy, France and Spain).
    In Spain the generation facilities of consumers under the modality of self-consumption without surplus and with surpluses, with power installed ≤15 kW located in urban area, will be exempt from obtaining access and connection permits. Moreover, for self-consumption facilities with surpluses which are excluded in the conditions of the points above, the producers must have their corresponding access and connection permits for each of the production facilities nearby and associated consumption points of which they are owners.
- As regards the mechanism of surpluses compensation with the energy supplier the following aspects emerged:
  - ✓ The net billing- monetary compensation (credit in monetary unit) is used in Italy, Sweden, Spain and France;
  - ✓ The net metering- energetic compensation (credit in kWh) is used in Italy and Netherlands;
  - ✓ The self-consumption- real time (e.g.: 15 minutes) in Italy and France. It gives how much power is used in real time, and where that power is coming from: panels, battery or grid. It also tells how much power the solar panels are generating and whether people used, stored or sent it to the grid.

2. Energy efficiency requirements for buildings

The main outcomes emerged by the answers provided by respondents are the following:

- All information received is at the country level but there is a lack of regulation at the regional and local level. Two national strategies can be observed: one in the production of renewable energies and the other in the reduction of energy consumption in the building and the limitation of fossil fuel consumption.
- In Italy all the minimum energy performance requirements for refurbishment and new building, differentiated for refurbishment typology (large or small, according to the ratio of building surface object of refurbishment) and for Italian climatic zone are presented in the Interministerial Decree - 26/06/2015.[23]

- In Netherlands there is the NTA8800 regulations which is used for calculating the energy efficiency of buildings. It contains the determination method for the energy performance of buildings.[24]

- As regards Sweden respondents highlighted the Act on energy declaration on buildings.[25] The purpose of the Act is to promote efficient energy use and a good indoor environment in buildings. The Act will be applied to buildings for which energy is used with the aim of influencing the buildings' indoor climate.
- In France there are the following legislations:
  - ✓ RE2020 which is a new regulation entered into force in 2020 regarding new buildings.[26] It is based on a gradual transformation of construction techniques, industrial sectors and energy solutions. Its objective is to continue improving the energy performance and comfort of buildings, while reducing their carbon impact. It revolves around three main axes:
    - continue to improve energy performance and reduce consumption in new buildings,
    - reduce the impact of new buildings on the climate by taking into account all of the building's emissions over its life cycle, from the construction phase to the end of its life via a life cycle analysis,
    - enable occupants to live in a living and working environment adapted to future climatic conditions by pursuing the objective of comfort in summer.
  - ✓ Tertiary decree relating to obligations for actions to reduce final energy consumptions in buildings for tertiary use[27]. Any building with an area > 1,000 m² devoted to a tertiary activity has the obligation to reduce its energy consumption by 40% by 2030 (then 50% in 2040, 60% in 2050);
  - ✓ Climate law on the fight against the climate change and strengthening resilience to its effects[28] related to new constructions and major renovations:
    (i) for commercial, logistics and artisanal buildings of more than 500 m², (ii) for office buildings over 1000m², that have the obligation on 30% of the surface of their roof (or parking shades created) : to grow vegetables or equip with renewable energy production devices
  - ✓ In Spain, at county level, there is the Technical Building Code (CTE) which is the regulatory framework that establishes the basic quality requirements that buildings must meet in relation to the basic safety and habitability requirements[29]. At regional level there is the Decree 21/2006 which regulates the adoption of environmental and eco-efficiency criteria in buildings[30]. At local level respondents pointed out that there is the Municipal Ordinance regulating the implementation of systems of solar energy captures for thermal uses in buildings in Sant Cugat del Vallès[31].

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23 https://www.mise.gov.it/images/stories/normativa/DM_requisiti_minimi.pdf

24 https://www.nen.nl/nta-8800-2022-nl-290717

25 https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-2006985-om-energideklaration-for_sfs-2006-985

26 https://www.ecologie.gouv.fr/reglementation-environnementale-re2020

27 https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000038812251/

28 https://www.legifrance.gouv.fr/jorf/article_jo/JORFARTI000043957078

29 https://www.codigotecnico.org/DocumentosCTE/AhorroEnergia.html

30 https://dogc.gencat.cat/ca/document-del-dogc/?documentId=406954

31 https://santcugat.cat/files/651-11533-fitxer/EnergiaSolarEdificacions_20101019BOPB_101220.pdf

- ✓ As regards the minimum % of solar thermal energy required in new or rehabilitated buildings, it emerged that only Spain has minimum solar thermal production requirements in the building. In particular, at country level, the main regulations on domestic thermal installations include CTE: buildings will satisfy their needs for DHW and indoor pool heating by employing in largely energy from renewable sources or renewable cogeneration processes. At regional level the Decree 21/2006: minimum contribution of solar energy in the production of domestic hot water according to climatic zones from 40% to 70% of total DHW consumption needs in the building. At local level: solar local ordinance requires a minimum contribution of solar energy from 65% up to 70% of total DHW needs in the building.
- Concerning Sweden, Swedish legislation and building regulations do not require mandatory installation of PV in buildings. Sweden is a special case because most of the energy consumption is provided by district heating and no facilities are built in buildings.
- As regards the minimum % of other RES required in new buildings, in Italy for new buildings or large refurbishments the minimum requirement, in terms of energy covered by RES is 60% for private building and 65% for public ones[32]. Respondents also pointed out the existence of the Decree 28 of 3 March 2011 that foresees a minimum rate of renewable energy production to supply heating, cooling and domestic hot water demand[33].
- The Netherlands regulation requires the most contribution of renewables for all the energy consumption of the building, with a minimum coverage of renewable energy of 50% and a maximum fossil energy use of 30 kWh/m^2.
- In Spain, at country level, the Regulation for Thermal installation in buildings (RITE) includes the use of available renewable energies, especially solar energy and biomass, the incorporation of energy recovery subsystems and the use of residual energy. Moreover, respondent pointed out the Technical Building Code (CTE) which states that the use of other renewable energy is promoted by:
  - ✓ reducing the value existing non-renewable Primary Energy Consumption limit previously,
  - ✓ increasing the use of renewables generated in the building,
  - ✓ improving energy contribution mandatory minimum renewable to produce hot sanitary water, allowing, in addition, the use of any technology without giving priority to any one in particular.
- In France one respondent stated that the minimum percentage of other RES required is 25%, whereas another respondent wrote that there is not a minimum % of other RES required (this is an inconsistency).

3. Architectural/aesthetical restrictions, thermal comfort requirements and presence of support incentives schemes for energy self-consumption

The main outcomes emerged by the answers provided by respondents are the following:

- Generally, regarding mechanisms to control **architectural or aesthetical restrictions** in existing or new buildings, local regulations are strong enough to forbid the use of panels on the roofs of buildings.
- In Italy each region locates areas subjected to safeguard due to the presence of historical, artistic or naturalistic heritage. Within these areas there are special requirements for each project related to the buildings or RES outdoor installation. At country level it is worth mentioning the Decree 22/01/2004 n. 42[34] - requirement for the cultural heritage safeguard- and the Decree of the President of the Republic n. 31 of 13 February 2017[35].
- In Netherlands the mechanisms to control architectural and aesthetical restrictions in existing or new buildings is regulated by permissions on local level (townhall).

32 https://www.gazzettaufficiale.it/eli/id/2021/11/30/21G00214/sg

33 https://www.gazzettaufficiale.it/eli/id/2011/03/28/011G0067/sg

34 https://www.bosettiegatti.eu/info/norme/statali/2004_0042.htm

35 https://www.gazzettaufficiale.it/eli/id/2017/03/22/17G00042/sg

- As regards Sweden, respondents highlighted that for the protection of historic buildings and urban areas, the local government/municipal often has local guidance/requirements. Moreover, there is an office in each municipality responsible for the architectural or aesthetical dimensions of all new construction or major refurbishments.
- In France respondents wrote that the monument protection law is still very strong and enables to stay at 0% RES. The municipal building and neighbourhood design guideline are very strong and give RES a very low priority. It is still possible to forbid solar installation near historical sites (numerous in France.).
  Building permit request to local authorities, mentioning solar panels installation on roof required, can be rejected by "Architecte des bâtiments de France" during request evaluation.
- As regards Spain respondents highlighted the Solar Thermal Ordinance in buildings, landscape protection related to the solar energy installations regulated in this Ordinance, the urban planning regulations intended to prevent the disfigurement of the landscape perspective or damage to landscape or architectural harmony. The preservation and protection of buildings, complexes, environments and landscapes must also be guaranteed included in the corresponding catalogues or urban plans for the protection of heritage. The municipal body competent authority shall verify the adequacy of the facilities to the urban planning regulations and will value architectural integration as well as potential benefits and harms environmental. It will also take into account that these facilities do not produce reflections frequent which may disturb persons residing in adjoining buildings.
- As regards Regulation that establishes **thermal comfort requirements** in temperature and humidity in existing and new buildings, the responses received do not provide enough information to differentiate the criteria of thermal comfort for each of the countries, but all have regulations governing it.
- Concerning Italy, respondents highlighted the Decree of the President of the Republic 16/04/2013 n.74[36] which establishes the following comfort requirements:
  - ✓ Heating:
    - 18°C + 2°C of tolerance for industrial and manufacturing buildings,
    - 20°C + 2° C of tolerance for all other building typology
  - ✓ Cooling:
    - 26°C -2°C of tolerance for all buildings

    The fulfilment of the air temperature in the rooms within the limits set above are obtained with measures that do not involve a waste of energy.

- For Netherlands comfort requirements are layed down in the Bouwbesluit[37].

- As regards Sweden comfort requirements, respondents pointed out that there are building regulations - mandatory provisions and general recommendations to be followed (Boverkets Byggregler (BBR)[38].

- As regards France, respondents pointed out the role of RE2020 as regards the specific comfort temperature requirement for summer. Each new construction must meet standards, particularly in terms of thermal regulations. The building sector is today the largest consumer of energy in France. In 2022, the Thermal Regulation 2020 (RT2020), also called Environmental Regulation 2020 (RE2020), replaced RT2012. RT2020 (or RE2020) reduces the carbon impact of new buildings by improving their energy performance and comfort in summer.
  To make housing self-sufficient and reduce energy waste, the RT2020 goes further by requiring houses to be passive (therefore with very low energy loss) and buildings to be energy positive (therefore produce more energy than they consume).

[36] https://www.gazzettaufficiale.it/eli/id/2013/06/27/13G00114/sg

[37] https://rijksoverheid.bouwbesluit.com/Inhoud/docs/wet/bb2012/hfd7/afd7-3

[38] https://www.boverket.se/en/start/publications/publications/2019/boverkets-building-regulations--mandatory-provisions-and-general-recommendations-bbr/

- As regards Spain, at country level, respondents pointed out that Royal Decree 1826/2009 sets the air conditioning temperature in offices at a minimum of 26ºC and with a relative humidity between 30% and 70%. The specific rule includes that in:
  - ✓ summer the air conditioning temperature must be between 23 ºC to 25ºC with a humidity between 45% and 60%;
  - ✓ winter the air conditioning temperature must be between 21ºC and 23ºC and humidity between 40% and 50%.
- As regards the presence of **support incentives schemes** for energy self-consumption, from the responses provided in the survey it emerged that all countries, except Sweden, have subsidies and aids for the installation of renewable energy in buildings. This may be due to the large expansion of district heating in Sweden, which delegates responsibility for energy production to other entities.
- In Italy there are several incentives for RES installation and energy efficiency in building (e.g.: Ecobonus, Superbonus, Bonus casa). They are collected by the National Authority for Energy and Environment (ENEA)[39]. Moreover, respondent highlighted the Decree of Ministry of Economic Development 4 July 2019[40].
- As regards the Netherlands respondents said that there is the Sustainable Energy Investment Subsidy (ISDE). It is a Subsidy for the production of sustainable energy. It is used for the purchase of the following installations[41]:
  - ✓ heat pump space heater,
  - ✓ water heater,
  - ✓ an installation placed on or attached to a building consisting of an assembly of facilities for the production of renewable electricity from sunlight via photovoltaic solar panels.

  The parties eligible for the subsidy are private individuals, independent entrepreneurs, housing associations, companies, municipalities, provinces and other public bodies.
- As regards Sweden, respondents pointed out that in Sweden there are not regulations directly aimed at supporting self-consumption of electricity.
- In France, **self-consumption** support mechanism is a subsidy to **PV** installation owner[42]. Installations that allow self-consumption (surplus sales installations) are eligible for an investment premium. This premium is degressive and variable according to the power of the installation. It is spread over the first five years of operation. Self-consumptions premium based on the plant power, in euro per kWp, in effect for the 1st quarter of 2022 are the following:

Plant power	***Amount of the premium for an installation***
Less than or equal to 3 kWp	380 €/kWp
Between 3 and 9 kWp	290€/kWp
Between 9 and 36 kWp	160 €/kWp
Between 36 and 100 kWp	80€/kWp

As regards **RES** (solar thermal including PVT, geothermal, biomass) respondents highlighted that there are renewable energy support schemes. In particular, the development of renewable energies benefits from State support either upstream in the field of research and development, or in the industrialization phase in support of demand and commercial deployment (for example through electricity tariffs, purchasing, calls for tenders or tax measures)[43]. Moreover, there are also general incentives for energy renovation of residential sector[44]. People can claim aid to finance the energy renovation work of their home.

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39 https://www.efficienzaenergetica.enea.it/detrazioni-fiscali.html

40 https://www.gazzettaufficiale.it/eli/id/2019/08/09/19A05099/sg

41 https://wetten.overheid.nl/BWBR0035474/2022-07-20/#Hoofdstuk4

42 https://www.economie.gouv.fr/particuliers/aides-installation-photovoltaiques

43 https://www.ecologie.gouv.fr/dispositifs-soutien-aux-energies-renouvelables

44 https://www.economie.gouv.fr/particuliers/aides-renovation-energetique

- As regards Spain at Country level, Spanish Royal Decree 477/2021, of June 29, approved the direct concession to the autonomous communities and the cities of Ceuta and Melilla of aid for the execution of various incentive programs linked to self-consumption and storage, with sources of renewable energy, as well as the implementation of renewable thermal systems in the residential sector.
  At regional level, respondent pointed out an aid for renewables in self-consumption, storage, and thermal in all sectors (pending call) ICAEN, November 2021 to December 2023., including some incentive programs:
  - ✓ Incentive program 4: carrying out self-consumption installations, with renewable energy sources, in the residential sector, public administrations and the third sector, with or without storage.
  - ✓ Incentive program 5: incorporation of storage in self-consumption facilities, with renewable energy sources, already existing in the residential sector, public administrations and the third sector.
  - ✓ Incentive program 6: Realization of thermal renewable energy installations in the residential sector. Includes solar thermal, biomass, geothermal, hydrothermal or aerothermal technologies (excluding air-to-air technologies) for air conditioning and / or domestic hot water.

Conclusion

The outcomes deriving from the answers provided by respondents of the EU legal survey showed:

- all countries have support mechanisms to promote the use of RES. Some with specific rules and regulations and others apply aid and financial support for the installation of solar panels;
- all information received is at the country level but there is a lack of regulation at the regional and local level. Two national strategies can be observed: one in the production of renewable energies and the other in the reduction of energy consumption in the building and the limitation of fossil fuel consumption.
- regarding mechanisms to control *architectural or aesthetical restrictions* in existing or new buildings, local regulations are strong enough to forbid the use of panels on the roofs of buildings. As regards Regulation that establishes *thermal comfort requirements* in temperature and humidity in existing and new buildings, the responses received do not provide enough information to differentiate the criteria of thermal comfort for each of the countries, but all have regulations governing it. As regards the presence of *support incentives schemes* for energy self-consumption, from the responses provided in the survey it emerged that all countries, except Sweden, have subsidies and aids for the installation of renewable energy in buildings.

5 Conclusions

The main objective of SunHorizon project is to demonstrate innovative and reliable heat pump solutions properly coupled with advanced solar panels and thermal energy storage that can provide heating and cooling to residential and tertiary buildings.

This deliverable represents the work carried out in Task 7.3 – "Pre-feasibility studies in six virtual demonstrators all around Europe via SunHorizon Design Optimized Tool" included in the Work Package 7. The aim of this task is to achieve optimized design and building integration of SunHorizon H&C technologies respecting the aesthetical restrictions of the buildings, maximizing the usage of RES and, therefore, ensuring proper satisfaction of local H&C demand.

The purpose of this deliverable is to present six Pre-feasibility studies of SunHorizon Technology Packages focused on virtual demonstrators, i.e.: buildings of different typologies and located in different climate zones.

The approach/methodology used to carry out the six pre-feasibility studies under the technical, economic and legal point of view has foreseen the following main steps: a) Investigation of interconnection with other SunHorizon activities and examination of already submitted deliverables; b) study of the DUU Tool prepared in the WP4; c) Engagement of T7.3 partners and definition of roles within periodic monthly meetings to brainstorm on the approach and update all partners on progresses and next steps; d) identification of demonstrator buildings (location and typology); e) technical, economic and legal data collection.

The analysis involves preliminary studies undertaken to determine, analyze, and select the best business scenarios. In fact, the present study considers a predesign and preliminary assessment of the SunHorizon TPs, to evaluate the optimal configuration of SunHorizon innovative technology in six virtual demonstrators for a possible their replication in other buildings than the pilot sites of the project (where the SunHorizon TPs will be/were/are installed).

The application of SunHorizon TPs has been assessed considering technical, economic, as well as legal aspects. Partners of Task 7.3 were involved for the assessment of these three aspects, specifically CNR/ITAE, CARTIF and BDR for the technical aspects, VEOLIA for the economic aspects and SANT CUGAT for the legal aspects.

In particular, the **technical activities** have been performed starting from the excel based Tool developed by RINA-C in the Work Package 4, Task 4.3 "Formulation and methods for optimal design under uncertainty of H&C components". This tool was prepared and tested for both residential and non-residential buildings. This tool has been applied in this deliverable to four technology packages (TPs), the ones tested in the real SunHorizon demonstrators. The four technology packages are:

- TP1 (Boost Heat HP;Ratiotherm Tank; TVP Solar Panels) for heating and DHW supply;
- TP2 (Boost Heat HP; Ratiotherm Tank; Dual Sun PV-T panels) for heating and DHW supply;
- TP3 (Fahrenheit Sorption Chiller; Compression Chiller; Ratiotherm Tank; TVP Solar Panels) for cooling supply;
- TP4 (BDR AWHP; Heating/Cooling Tank; DHW/RATIO tank; BAXI PV panels; BAXI Solar Panels) for cooling, heating and DHW supply.

The excel based Tool has been applied to each of the six buildings; for each building, based on the optimal combination of discomfort rate and costs, Tool selected the proper configuration for each of the four TPs (TP1÷TP4) and for each equipment.

In particular, Tool estimated the equipment size, the energy produced by the equipment included in each TP (e.g.: heat pumps, solar panels), both capital and energy costs of each equipment taking into account the uncertainties related to the input parameters for the peak load and the energy demand calculation.

For all the six buildings and for each TP it has been verified that the energy produced by heat pumps and solar panels is able to cover the heating/cooling/DHW demand of each TP for each building (e.g.: residential and tertiary).

It is worth mentioning that the excel based Tool will be included in the SUNHORIZON integrated Tool of WP4 prepared by IES. The integrated Tool is a web application and integrates the code developed in Pyton to do calculations (calculations are the same done with the excel based Tool). Therefore, in the future, any replications for building demonstrators including the technology packages can be done using the on-line web Tool. Currently, at the time this document is drawn up, the on-line web Tool is under development and testing.

As regards the **economic aspect** Veolia calculated, by means of Business Models, the financial parameters (e.g.: IRR, NPV, Pay-back time, cash flows, savings) for each Technology Package of each building in order to assess the economic feasibility of each installation.

The outcomes showed that, in the case of moderate/Mediterranean climates, the most suitable options are both TP1 with IRRs between 10.17% and 20.21%, and TP4, ranging from IRRs between 19.09% and 19.95%. The coupling of either ST-only RES generation with BH gas-driven HP or PV-T RES generation with BDR electrically-driven HP are very profitable in locations with high solar irradiance (therefore, both thermal and electric energy harvesting potential). The returns of investment in the form of payback periods range between 4÷5 years which makes these options, in the case of both RES-IT and TER-IT technically feasible and financially profitable, with all related energy and cost savings plus the sustainability contribution to lower GHG emissions and contribute to the decarbonisation of the world's energy systems.

By contrast, TP2 seems to be not so profitable since it couples hybrid PV-T RES generation with BH gas-driven HP. The higher cost of energy generation and the need of relying on quite a significant amount of operating hours of BH HP provides more efficient gas consumption (up to 40% of thermal savings) but provides a surplus of electric energy that right now is not consumed in the building; therefore, it must be fed into the grid with a poor compensation in return in most of EU countries right now.

On top of that, and although moderate/Mediterranean climates do have significant cooling demands, the proposed TP3 option seems to be quite oversized as the DUU tool considers very significant peak loads for those scenarios. The FAHR adsorption chiller CAPEX is quite significant and in most of the cases the compressor chiller is accounted as an investment cost too but with no operating hours, therefore this CAPEX should be removed and the profitability of the solutions will significantly improve.

In the case of severe/Northern climates, TP4 still wins because although the irradiance is significantly lower, it matches with the needs of a reversible and electrically-driven heat pump like BDR's coupled to PV-only or PV-T generation. In the case of RES NL (Netherlands), TP4 CAPEX is roughly 61 k€ with annual savings of 14.9k€. Considering that the baseline scenario implied a CAPEX of 81k€, therefore even a first saving of already 20k€, that option provides a financial surplus from day 1, therefore its implementation already represents a gain from the beginning. This is understood in the context that CAPEX plus energy costs from the baseline scenario on year 1 is 96 k€ while with TP4 is of 61 k€. Note that, by just comparing the savings, the payback would be of approximately 3 years but all simulations are made also considering baseline scenario CAPEX; otherwise we will be just comparing the savings to each new scenario's TP implementation but, of course, the actual HVAC system of each baseline scenario had its cost back in the day it was installed and it must be considered while comparing financial feasibility of each TP implementation.

In an even more harsh cold climate like Sweden, TP4 offers an IRR of 10.06% and a payback period of 7.89 years, showing that these technology coupling is great even in further northern areas. Of course, TP3, which is thought basically for providing space cooling during summer, is not profitable there as sizing such chillers (FAHR's or regular compression ones) to fulfil very low cooling demands is not profitable.

Concerning the **legal aspects**, the aim was to investigate the legal building requirements in the European countries, with a focus on the three countries with different climatic conditions identified as location of the six virtual demonstrator buildings (Italy, The Netherlands and Sweden). A total of 11 answers from five countries (Sweden, Netherlands, Italy, France and Spain) were obtained.

The survey is relatively short and it assesses the existing country, regional, and local regulations in the different countries. It consists of 10 questions organized into three sectors: a) Analysis of photovoltaic self-consumption; b) Energy efficiency requirements for buildings; c) Architectural/aesthetical restrictions, thermal comfort requirements and presence of support incentives schemes for energy self-consumption.

The outcomes deriving from the answers provided by respondents of the EU legal survey showed:

- all countries have support mechanisms to promote the use of RES. Some with specific rules and regulations and others apply aid and financial support for the installation of solar panels;
- all information received is at the country level but there is a lack of regulation at the regional and local level. Two national strategies can be observed: one in the production of renewable energies and the other in the reduction of energy consumption in the building and the limitation of fossil fuel consumption.
- regarding mechanisms to control *architectural or aesthetical restrictions* in existing or new buildings, local regulations are strong enough to forbid the use of panels on the roofs of buildings. As regards Regulation that establishes *thermal*

comfort requirements in temperature and humidity in existing and new buildings, the responses received do not provide enough information to differentiate the criteria of thermal comfort for each of the countries, but all have regulations governing it. As regards the presence of *support incentives schemes* for energy self-consumption, from the responses provided in the survey it emerged that all countries, except Sweden, have subsidies and aids for the installation of renewable energy in buildings.

A. ANNEXES

1. Business Models

TECHNOLOGY

TVP	Aperture Area/tot Area	0,94	
	Cap Cost [€/m2]	500,00 €	
DS	Aperture Area/tot Area	1,00	
	Cost [€/m2]	752,00 €	
Baxi Sol200	Aperture Area/tot Area	0,95	
	Cost [€/m2]	400,00 €	
Baxi Foton	Cap Cost [€/m2]	300,00 €	
DE Dietrich BPB	vol	200	3000
DE Dietrich BC DHW	Cap Cost [€]	1.890,00 €	8.180,00 €
		9,45 €	2,73 €
RT Tank	vol [l]	400,00	4000,00
	Cap Cost [€]	2.830,00 €	8.190,00 €
		7,08 €	2,05 €

Note: Costs of technologies come from RINA-C. excel Tool - WP4

BH Heat pump	kW	20	
	Cap Cost [€/unit]	20.000,00 €	
	Efficency [SGUE]	1,36	average of Sunisi, Berlin and Numberg demo
	ElCons/GasCons	5%	estimated from sunisi simulation
FARH HP	Model	ZeoM10	
	kW (cooling)	13	*see tech calculation
	Cap Cost [€/unit]	24.400,00 €	
BDR AWHP ALEZIO 16	kW (heating)	12,9	
	Efficency COP (2/35)	3,27	
	kW (cooling)	14,46	
	Efficency EER	3,96	
	Cap Cost [€/kW]	610,00 €	calculated considering kW for heating
Copression Chiller	Cap Cost [€/kW]	800,00 €	
	COP Cooling	3,4	
Ref HP	COP	3	

INITIAL CONSUMPTIONS (BEFORE SUNHORIZON) - All data are "Annual data, referred to one year"

Hypothesis: natural gas boiler for DHW all the year and SH but only in winter.
Electric Fan Coil for refrigeration in summer

	Heating & Cooling			Total	Natural Gas	Electricity
	Heating demand (kWht)	Cooling demand (kWht)	DHW demand (kWht)	Heating&cooling demand (kWht)	consumption (Nm3)	consumption (kWhe)
RES - IT	82.956,36	18.567,76	13.754,29	115.278,41	10.611,98	6.631,34
RES - NL	116.214,91	355,82	31.650,34	148.221,07	16.225,13	127,08
RES - SE	148.833,74	1.356,07	22.871,32	173.061,13	18.841,05	484,31
TER - IT	203.324,77	282.134,00	7.427,35	492.886,12	23.125,65	100.762,14
TER - NL	75.598,09	817,68	1.873,87	78.289,64	8.500,93	292,03
TER - SE	111.538,36	3.150,40	4.788,15	119.476,91	12.764,41	1.125,14

Current energetic costs		
Thermal energy (€/kWh)	0,08	
Electricity (€/kWh)	0,22	Average European costs provided by Eurostat

NG-Boilers			
CHP efficiency	95%		
Calorific value	9,593	kWh/Nm3	Tab. 1 dell’allegato A della del. 103/03 dell’Autorità per l’energia elettrica e il gas - AEEG, ora ARERA
Emission factor	0,202	kgCO2e/kWh	SEAP Guidelines, European Commission (da IPCC)
Price	0,441	€/Nm3	global petrol prices
Electic Fan Coils			
EER	2,8	kWht/kWhe	Vaillant

CONSUMPTIONS (AFTER SUNHORIZON INSTALLATION) - All data are "Annual data, referred to one year"

YEOH= Yearly Operating Hours

			Heating & Cooling		Total	TP1						
		Heating demand 1 (kWht)	cooling demand 1 (kWht)	DHW demand (kWht)	heating&cooling demand (kWht)	BH HP Capacity (kW)	Tanks Capacity (litres)	HP YEOH	NG consumption (Nm^3)	Energy consumption (kWhe)	Solar Energy [kWh]	Solar [m^2]
RES - IT	**λ7 Conf2**	88.673,84	0,00	13.754,29	102.428,13	40,00	5.290	0	**0,00**	**0,00**	127.242,00	113
RES - NL	**λ4 Conf1**	117.677,25	0,00	31.650,34	149.327,59	60,00	6.620	806	**3.879,04**	**1.450,80**	100.932,00	141
RES - SE	**λ1 Conf1**	148.415,63	0,00	22.871,32	171.286,95	60,00	8.830	890	**4.283,31**	**1.602,00**	117.911,00	188
TER - IT	**λ7 Conf3**	208.840,08	0,00	7.427,35	216.267,43	100,00	8.410	138	**1.106,92**	**414,00**	202.457,00	179
TER - NL	**λ7 Conf1**	79.521,47	0,00	1.873,87	81.395,34	40,00	3.570	657	**2.107,97**	**788,40**	54.403,00	76
TER - SE	**λ7 Conf1**	111.626,21	0,00	4.788,15	116.414,36	40,00	8.450	96	**308,01**	**115,20**	112.893,00	180

			Heating & Cooling		Total	TP2							
		Heating demand 1 (kWht)	cooling demand 1 (kWht)	DHW demand (kWht)	heating&cooling demand (kWht)	BH HP Capacity (kW)	Tanks Capacity (litres)	HP YEOH	NG consumption (Nm^3)	Energy consumption (kWhe)	Solar Th Energy [kWh]	Solar El Energy [kWh]	Solar [m^2]
RES - IT	**λ7 Conf1**	88.673,84	0,00	13.754,29	102.428,13	40,00	7.041	1.257	**4.033,05**	**1.508,40**	52.157,00	46.944,00	150
RES - NL	**λ4 Conf1**	117.677,25	0,00	31.650,34	149.327,59	60,00	6.618	2.174	**10.462,82**	**3.913,20**	18.867,00	29.983,00	141
RES - SE	**λ1 Conf1**	148.415,63	0,00	22.871,32	171.286,95	60,00	8.824	2.543	**12.238,71**	**4.577,40**	18.689,00	35.617,00	188
TER - IT	**λ7 Conf1**	208.840,08	0,00	7.427,35	216.267,43	100,00	16.804	1.101	**8.831,31**	**3.303,00**	106.177,00	112.040,00	358
TER - NL	**λ3 Conf1**	79.521,47	0,00	1.873,87	81.395,34	40,00	3.567	1.788	**5.736,75**	**2.145,60**	6.449,00	16.161,00	76
TER - SE	**λ2 Conf1**	111.626,21	0,00	4.788,15	116.414,36	40,00	8.449	2.493	**7.998,72**	**2.991,60**	11.856,00	34.102,00	180

Solar production in winter is at 60° C
Solar production in summer is at 90° C

			Heating & Cooling		Total	TP3									
		Heating demand 1 (kWht)	cooling demand 1 (kWht)	DHW demand (kWht)	heating&cooling demand (kWht)	FARH SORP Capacity (kW)	Chiller Capacity (kW)	Tanks Capacity (litres)	FARH YEOH	Chiller YEOH	NG consumption (Nm^3)	Energy consumption (kWhe)	Solar Energy summer [kWh]	Solar Energy winter [kWh]	Solar [m^2]
RES - IT	**λ2 Conf1**	82.956,36	19.385,45	13.754,29	116.096,10	39,00	38,00	7.041	349	151	**0,00**	**1.655,07**	28.678,00	70.377,00	150
RES - NL	**λ2 Conf1**	116.214,91	389,79	31.650,34	148.255,04	26,00	25,00	6.618	5	9	**0,00**	**68,15**	286,00	67.734,00	141
RES - SE	**λ2 Conf1**	148.833,74	1.462,47	22.871,32	173.167,53	52,00	51,00	8.824	13	15	**0,00**	**122,59**	1.468,00	108.925,00	188
TER - IT	**λ2 Conf1**	203.324,77	101.263,47	7.427,35	312.015,59	208,00	198,00	16.804	487	0	**0,00**	**939,91**	214.034,00	167.967,00	358
TER - NL	**λ4 Conf1**	75.598,09	952,25	1.873,87	78.424,21	65,00	55,00	3.567	15	0	**0,00**	**28,95**	25.028,00	36.509,00	76
TER - SE	**λ2 Conf1**	111.538,36	3.956,08	4.788,15	120.282,59	117,00	109,00	8.449	29	0	**0,00**	**55,97**	50.370,00	104.290,00	180

			Heating & Cooling		Total	TP4								
		Heating demand 1 (kWht)	cooling demand 1 (kWht)	DHW demand (kWht)	heating&cooling demand (kWht)	BDR AWHP Capacity (kW)	Tanks Capacity (litres)	HP YEOH	NG consumption (Nm^3)	Energy consumption (kWhe)	Solar Th Energy [kWh]	Solar Th [m^2]	Solar El Energy [kWh]	Solar El [m^2]
RES - IT	**λ5 Conf1**	86.861,91	21.818,26	13.754,29	122.434,46	43,00	2.692	2.094	**0,00**	**12.564,00**	10.453,00	37,5	31.360,00	112,5
RES - NL	**λ3 Conf1**	116.397,01	423,09	31.650,34	148.470,45	45,00	3.344	3.146	**0,00**	**18.876,00**	6.677,00	35,3	20.030,00	105,7
RES - SE	**λ1 Conf1**	148.415,63	1.356,42	22.871,32	172.643,36	47,00	3.438	3.473	**0,00**	**20.838,00**	7.931,00	47	23.793,00	141
TER - IT	**λ7 Conf1**	208.840,08	121.742,89	7.427,35	338.010,31	199,00	4.802	962	**0,00**	**5.772,00**	24.949,00	89,5	74.846,00	268,5
TER - NL	**λ5 Conf1**	78.152,97	991,76	1.873,87	81.018,61	55,00	950	1.378	**0,00**	**8.268,00**	3.599,00	19	10.796,00	57
TER - SE	**λ6 Conf1**	116.057,53	4.099,22	4.788,15	124.944,90	109,00	2.431	968	**0,00**	**5.808,00**	7.594,00	45	22.781,00	135

Technology	Gas Consumption kWht/Nm3	Energy consumption kWhe/kWht		Current energetic costs
BH HP	12,467	0,03	gas	Thermal energy (€/kWh)
FARH SORPTION		1,93	*	Electricity (€/kWh)
Chiller		6,5		
BDR AWHP	0	6	full electric consumption of about 6 kW for each working hour (See Sheet1_BDR)	
Ratio Tank	0	0	10 Wh aux	
Tank H/C	0	0		
Baxi Solar	0	0		
TVP Solar	0	0		
Dual Sun	0	0		

*
There is no gas consumption for both units. The electrical consumption depends on the operation point. The maximum electrical consumption is:
Compression chiller: 6500 W
Fahrenheit ZeoM10: 1930 W

BDR - Data Sheet

■ PUHZ-SW120V/YHA(-BS)

Water outlet temperature[°C]		25		35		40		45		50		55		60	
Ambient temperature[°C]		Capacity	COP	Capacity	COP	Capacity	COP	Capacity	COP	Capacity	COP	Capacity	COP	Capacity	COP
Max	-20	-	-	8.0	1.74	7.9	1.60	7.8	1.46	-	-	-	-	-	-
	-15	-	-	9.6	2.10	9.5	1.88	9.4	1.66	9.3	1.50	9.2	1.32	-	-
	-10	11.2	2.92	11.1	2.43	11.1	2.19	11.1	1.94	10.8	1.73	10.6	1.51	-	-
	-7	12.6	3.21	12.4	2.65	12.3	2.38	12.2	2.10	11.9	1.89	11.5	1.66	-	-
	2	13.8	3.50	13.4	3.07	13.2	2.75	13.0	2.44	12.5	2.16	12.0	1.86	11.2	1.54
	7	18.0	4.40	17.3	4.03	16.9	3.60	16.6	3.18	15.9	2.86	15.2	2.52	14.5	2.13
	12	20.8	5.07	19.8	4.58	19.4	4.09	18.9	3.61	18.2	3.25	17.4	2.87	16.7	2.44
	15	22.0	5.34	21.0	4.83	20.5	4.32	20.0	3.80	19.2	3.43	18.4	3.02	17.7	2.58
	20	23.2	5.64	22.2	5.11	21.7	4.58	21.2	4.04	20.5	3.66	19.7	3.25	19.0	2.80
Nominal	-20	-	-	8.0	1.74	7.9	1.60	7.8	1.46	-	-	-	-	-	-
	-15	-	-	9.6	2.10	9.5	1.88	9.4	1.66	9.3	1.50	9.2	1.32	-	-
	-10	11.2	2.92	11.1	2.43	11.1	2.19	11.1	1.94	10.8	1.73	10.6	1.51	-	-
	-7	11.2	3.38	11.2	2.85	11.2	2.49	11.2	2.14	11.2	1.92	11.2	1.68	-	-
	2	12.0	3.76	12.0	3.24	12.0	2.88	12.0	2.52	12.0	2.20	12.0	1.86	11.2	1.54
	7	16.0	4.58	16.0	4.10	16.0	3.67	16.0	3.23	15.9	2.86	15.2	2.52	14.5	2.13
	12	18.4	5.38	18.4	4.74	18.4	4.19	18.4	3.64	18.2	3.25	17.4	2.87	16.7	2.44
	15	19.4	5.66	19.4	5.01	19.4	4.43	19.4	3.84	19.2	3.43	18.4	3.02	17.7	2.58
	20	20.6	5.95	20.6	5.31	20.6	4.71	20.6	4.10	20.5	3.66	19.7	3.25	19.0	2.80
Mid	-20	-	-	6.4	1.78	6.3	1.65	6.2	1.51	-	-	-	-	-	-
	-15	-	-	7.6	2.17	7.6	1.94	7.5	1.71	7.5	1.55	7.4	1.37	-	-
	-10	9.0	3.23	8.9	2.56	8.9	2.30	8.9	2.04	8.7	1.84	8.5	1.61	-	-
	-7	9.0	3.54	9.0	2.87	9.0	2.54	9.0	2.20	9.0	1.96	9.0	1.70	-	-
	2	9.6	4.17	9.6	3.57	9.6	3.16	9.6	2.75	9.6	2.37	9.6	1.95	8.9	1.70
	7	12.8	5.03	12.8	4.43	12.8	3.91	12.8	3.40	12.7	3.02	12.2	2.61	11.6	2.17
	12	14.7	5.83	14.7	5.11	14.7	4.50	14.7	3.89	14.5	3.47	14.0	3.02	13.3	2.53
	15	15.6	6.18	15.6	5.42	15.6	4.78	15.6	4.14	15.4	3.70	14.7	3.23	14.1	2.71
	20	16.5	6.62	16.5	5.89	16.5	5.21	16.5	4.52	16.4	4.04	15.8	3.53	15.2	2.96
Min	-20	-	-	6.4	1.78	6.3	1.65	6.2	1.51	-	-	-	-	-	-
	-15	-	-	7.6	2.17	7.6	1.94	7.5	1.71	7.5	1.55	7.4	1.37	-	-
	-10	9.0	3.23	8.9	2.56	8.9	2.30	8.9	2.04	8.7	1.84	8.5	1.61	-	-
	-7	5.9	3.49	4.2	2.68	4.1	2.36	3.9	2.04	3.7	1.77	3.4	1.49	-	-
	2	9.0	4.33	5.9	3.68	5.7	3.24	5.5	2.80	5.1	2.43	4.8	2.03	-	-
	7	10.8	5.24	5.8	4.39	5.4	3.77	5.0	3.14	4.4	2.59	3.9	2.00	-	-
	12	13.2	5.93	5.7	5.45	5.2	4.51	4.8	3.58	4.2	2.94	3.6	2.27	-	-
	15	14.1	6.42	6.2	6.02	5.7	4.98	5.2	3.94	4.6	3.25	3.9	2.52	-	-
	20	15.5	6.62	12.3	6.26	11.7	5.35	11.2	4.43	10.8	3.94	10.5	3.39	-	-

		55		
		capacity	COP	consumo
		kWt		kWe
nominal	-15	9,2	1,32	6,97
	-10	10,6	1,51	7,02
	-7	11,2	1,68	6,67
	2	12	1,86	6,45
	7	15,2	2,52	6,03
	12	17,4	2,87	6,06
	15	18,4	3,02	6,09
	20	19,7	3,25	6,06

CAPEX AND OPEX

CAPEX (SUNHORIZON INVESTMENT)						
REF.	CONCEPT (Equipment)	TYPE	LIFETIME (years)	CAPACITY	TOTAL COST	
	BH Heat Pump	HP	20	20 kW	20.000,00 €	
	FARH HP - ZeoM10	HP	20	13 kW	24.400,00 €	
	BDR AWHP ALEZIO 16	HP	20	13 kW	7.870,00 €	
	Compressor Chiller	HP	20	1 kW	800,00 €	
	RT Tank 400 l	Tank	20	400 l	2.830,00 €	
	RT Tank 4000 l	Tank	20	4000 l	8.190,00 €	
	DE Dietrich DHW 200 l	Tank	20	200 l	1.890,00 €	
	DE Dietrich DHW 3000 l	Tank	20	3000 l	8.180,00 €	
	TVP	solar	20	1 mq	500,00 €	
	DS	solar	20	1 mq	752,00 €	
	Baxi Solar	solar	20	1 mq	400,00 €	
	Baxi Foton	solar	20	1 mq	300,00 €	
	Interconnections costs (piping+ en. Meters+ insulation+ small pumps)				**20.000,00 €**	(see point 3 below)

OPEX (SUNHORIZON INVESTMENT)					
REF.	CONCEPT (Equipment)	TYPE	LIFETIME (years)	CAPACITY	TOTAL COST
	spare parts		1	3% of total cost	
	cost for routine maintenance		1		

CAPEX:

Note: during call with Veolia I had understood to consider the following costs:

1. equipment costs (from RINA tool, see column F above)

2. installation costs (support from VEOLIA based on VEOLIA experience and their work in SunHorizon on real demos)

3. interconnection costs including: piping + energy meters+ insulation + small pumps costs (for Sant Cugat this cost is 60,000€, VEOLIA said to consider, for a virtual demo, a 30% of this cost, that is: **20.000,00 €** but only for interconnections)

Total costs= (1) + (2) + (3)

OPEX:

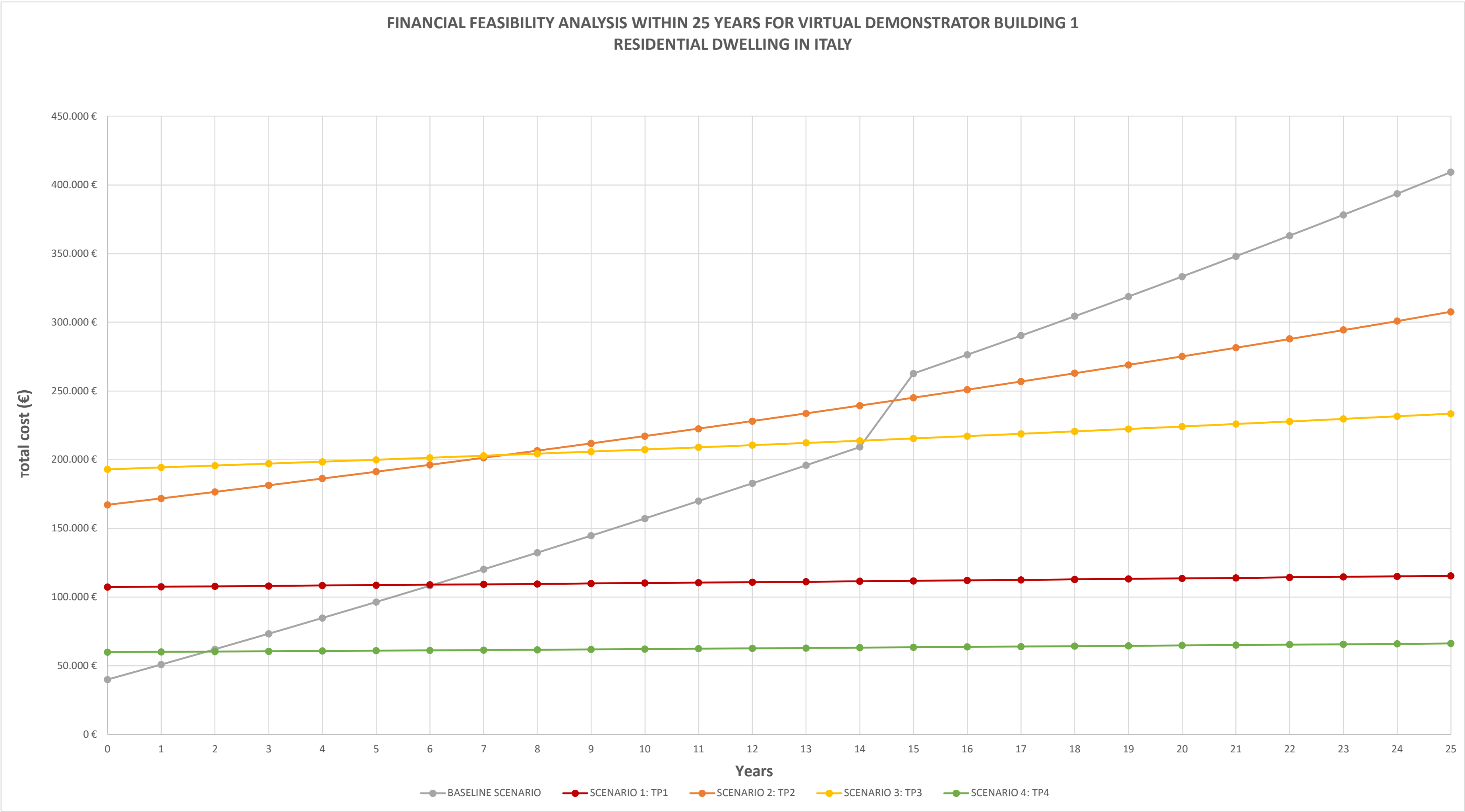
Spare parts costs= 3% of total costs. We believe that this percentage can be reasonable. What does Veolia think about it?

Cost of routine maintenance: based on days of technicians for maintenance (e.g.. 2 persons for 2 days every three/four months)

OPEX (BEFORE SUNHORIZON INVESTMENT)					
REF.	CONCEPT (Equipment)	TYPE	LIFETIME (years)	CAPACITY	TOTAL COST
	spare parts			3% of total cost	
	cost for routine maintenance				

BUSINESS MODEL RESIDENTIAL ITALY

IPC		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
IPC (Previsión GRUPO VEOLIA)		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
IPC Acumulado		1,4445%	2,9075%	4,3890%	5,8890%	7,3890%	8,8890%	10,3890%	11,8890%	13,3890%	14,8890%	16,3890%	17,8890%	19,3890%	20,8890%	22,3890%	23,8890%	25,3890%	26,8890%	28,3890%	29,8890%	31,3890%	32,8890%	34,3890%	35,8890%	37,3890%
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
BASELINE SCENARIO																										
Equipment (€)	19.000,00 €	1 x boiler + 6 x fan coils/splits														19.000,00 €										
Energy cost (electricity) (€)		251,11 €	254,78 €	258,56 €	262,43 €	266,37 €	270,37 €	274,42 €	278,54 €	282,72 €	286,96 €	291,26 €	295,63 €	300,06 €	304,56 €	309,13 €	313,77 €	318,48 €	323,25 €	328,10 €	333,02 €	338,02 €	343,09 €	348,24 €	353,46 €	358,76 €
Energy cost (natural gas) (€)		9.937,42 €	10.082,80 €	10.232,18 €	10.385,66 €	10.541,45 €	10.699,57 €	10.860,06 €	11.022,96 €	11.188,31 €	11.356,13 €	11.526,47 €	11.699,37 €	11.874,86 €	12.052,99 €	12.233,78 €	12.417,29 €	12.603,55 €	12.792,60 €	12.984,49 €	13.179,26 €	13.376,94 €	13.577,60 €	13.781,26 €	13.987,98 €	14.197,80 €
3,00% Operation & Maintenance cost (€)		578,23 €	586,69 €	595,39 €	604,32 €	613,38 €	622,58 €	631,92 €	641,40 €	651,02 €	660,79 €	670,70 €	680,76 €	690,97 €	701,33 €	711,85 €	722,53 €	733,37 €	744,37 €	755,54 €	766,87 €	778,37 €	790,05 €	801,90 €	813,93 €	826,13 €
TOTAL	**19.000,00 €**	**29.766,76 €**	**40.691,04 €**	**51.777,16 €**	**63.029,57 €**	**74.450,77 €**	**86.043,28 €**	**97.809,69 €**	**109.752,59 €**	**121.874,63 €**	**134.178,50 €**	**146.666,94 €**	**159.342,69 €**	**172.208,59 €**	**185.267,47 €**	**217.522,24 €**	**230.975,83 €**	**244.631,22 €**	**258.491,44 €**	**272.559,57 €**	**286.838,72 €**	**301.332,05 €**	**316.042,79 €**	**330.974,19 €**	**346.129,55 €**	**361.512,25 €**
		10.766,76 €																								
PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
SCENARIO 1: TP1																										
Equipment (€)	147.301,38 €																									
Energy cost (electricity) (€)		25,71 €	26,09 €	26,47 €	26,87 €	27,27 €	27,68 €	28,10 €	28,52 €	28,95 €	29,38 €	29,82 €	30,27 €	30,72 €	31,18 €	31,65 €	32,13 €	32,61 €	33,10 €	33,59 €	34,10 €	34,61 €	35,13 €	35,65 €	36,19 €	36,73 €
Energy cost (natural gas) (€)		311,64 €	316,20 €	320,88 €	325,69 €	330,58 €	335,54 €	340,57 €	345,68 €	350,87 €	356,13 €	361,47 €	366,89 €	372,40 €	377,98 €	383,65 €	389,41 €	395,25 €	401,18 €	407,19 €	413,30 €	419,50 €	425,79 €	432,18 €	438,66 €	445,24 €
0,25% Operation & Maintenance cost (€)		373,57 €	379,04 €	384,65 €	390,42 €	396,28 €	402,22 €	408,26 €	414,38 €	420,60 €	426,91 €	433,31 €	439,81 €	446,41 €	453,10 €	459,90 €	466,80 €	473,80 €	480,91 €	488,12 €	495,44 €	502,87 €	510,42 €	518,07 €	525,84 €	533,73 €
TOTAL	**147.301,38 €**	**148.012,30 €**	**148.733,62 €**	**149.465,62 €**	**150.208,61 €**	**150.962,74 €**	**151.728,19 €**	**152.505,12 €**	**153.293,70 €**	**154.094,10 €**	**154.906,52 €**	**155.731,12 €**	**156.568,09 €**	**157.417,61 €**	**158.279,88 €**	**159.155,08 €**	**160.043,41 €**	**160.945,07 €**	**161.860,25 €**	**162.789,15 €**	**163.732,00 €**	**164.688,98 €**	**165.660,32 €**	**166.646,22 €**	**167.646,92 €**	**168.662,63 €**
		710,92 €																								
		-	-	-	-	-	-	-	-	-	-	-	1	0	1	2	5	6	6	7	8	9	10	11	12	12
Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
SAVINGS		**-118.245,54 €**	**-108.042,58 €**	**-97.688,47 €**	**-87.179,04 €**	**-76.511,98 €**	**-65.684,91 €**	**-54.695,43 €**	**-43.541,11 €**	**-32.219,47 €**	**-20.728,01 €**	**-9.064,18 €**	**2.774,60 €**	**14.790,97 €**	**26.987,59 €**	**58.367,16 €**	**70.932,41 €**	**83.686,15 €**	**96.631,20 €**	**109.770,41 €**	**123.106,72 €**	**136.643,07 €**	**150.382,47 €**	**164.327,96 €**	**178.482,63 €**	**192.849,62 €**
CASH FLOW	**-147.301**	**10.055,84 €**	**10.202,96 €**	**10.354,11 €**	**10.509,42 €**	**10.667,07 €**	**10.827,07 €**	**10.989,48 €**	**11.154,32 €**	**11.321,63 €**	**11.491,46 €**	**11.663,83 €**	**11.838,79 €**	**12.016,37 €**	**12.196,62 €**	**12.379,57 €**	**12.565,26 €**	**12.753,74 €**	**12.945,04 €**	**13.139,22 €**	**13.336,31 €**	**13.536,35 €**	**13.739,40 €**	**13.945,49 €**	**14.154,67 €**	**14.366,99 €**
IRR	6,04%																									
NPV	16.822,39 €																									
PAYBACK	11,77 years	12,19 years																								
PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
SCENARIO 2: TP2																										
Equipment (€)	192.659,33 €																									
Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
Energy cost (natural gas) (€)		8.092,84 €	8.211,23 €	8.332,88 €	8.457,88 €	8.584,75 €	8.713,52 €	8.844,22 €	8.976,88 €	9.111,54 €	9.248,21 €	9.386,93 €	9.527,74 €	9.670,65 €	9.815,71 €	9.962,95 €	10.112,39 €	10.264,08 €	10.418,04 €	10.574,31 €	10.732,92 €	10.893,92 €	11.057,33 €	11.223,19 €	11.391,53 €	11.562,41 €
0,35% Operation & Maintenance cost (€)		684,05 €	694,06 €	704,34 €	714,90 €	725,63 €	736,51 €	747,56 €	758,77 €	770,15 €	781,71 €	793,43 €	805,33 €	817,41 €	829,67 €	842,12 €	854,75 €	867,57 €	880,59 €	893,79 €	907,20 €	920,81 €	934,62 €	948,64 €	962,87 €	977,31 €
TOTAL	**192.659,33 €**	**201.436,21 €**	**210.341,50 €**	**219.378,72 €**	**228.551,50 €**	**237.861,88 €**	**247.311,90 €**	**256.903,68 €**	**266.639,34 €**	**276.521,03 €**	**286.550,94 €**	**296.731,31 €**	**307.064,38 €**	**317.552,44 €**	**328.197,83 €**	**339.002,89 €**	**349.970,04 €**	**361.101,69 €**	**372.400,31 €**	**383.868,42 €**	**395.508,54 €**	**407.323,27 €**	**419.315,22 €**	**431.487,05 €**	**443.841,45 €**	**456.381,17 €**
		8.776,88 €																								
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
SAVINGS		**-171.669,45 €**	**-169.650,47 €**	**-167.601,57 €**	**-165.521,94 €**	**-163.411,11 €**	**-161.268,62 €**	**-159.094,00 €**	**-156.886,75 €**	**-154.646,40 €**	**-152.372,44 €**	**-150.064,37 €**	**-147.721,68 €**	**-145.343,85 €**	**-142.930,35 €**	**-121.480,65 €**	**-118.994,21 €**	**-116.470,47 €**	**-113.908,87 €**	**-111.308,85 €**	**-108.669,82 €**	**-105.991,22 €**	**-103.272,43 €**	**-100.512,86 €**	**-97.711,90 €**	**-94.868,92 €**
CASH FLOW	**-192.659**	**1.989,87 €**	**2.018,99 €**	**2.048,90 €**	**2.079,63 €**	**2.110,83 €**	**2.142,49 €**	**2.174,63 €**	**2.207,25 €**	**2.240,35 €**	**2.273,96 €**	**2.308,07 €**	**2.342,69 €**	**2.377,83 €**	**2.413,50 €**	**2.449,70 €**	**2.486,45 €**	**2.523,74 €**	**2.561,60 €**	**2.600,02 €**	**2.639,02 €**	**2.678,61 €**	**2.718,79 €**	**2.759,57 €**	**2.800,96 €**	**2.842,98 €**
IRR	-7,22%																									
NPV	-160.182,10 €																									
PAYBACK	#REF!	80,56 years																								
PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
SCENARIO 3: TP3																										
Equipment (€)	414.099,33 €																									
Energy cost (electricity) (€)		12,49 €	12,67 €	12,86 €	13,05 €	13,25 €	13,45 €	13,65 €	13,86 €	14,06 €	14,27 €	14,49 €	14,71 €	14,93 €	15,15 €	15,38 €	15,61 €	15,84 €	16,08 €	16,32 €	16,57 €	16,81 €	17,07 €	17,32 €	17,58 €	17,85 €
Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,50% Operation & Maintenance cost (€)		2.100,40 €	2.131,13 €	2.162,71 €	2.195,15 €	2.228,07 €	2.261,50 €	2.295,42 €	2.329,85 €	2.364,80 €	2.400,27 €	2.436,27 €	2.472,82 €	2.509,91 €	2.547,56 €	2.585,77 €	2.624,56 €	2.663,93 €	2.703,89 €	2.744,44 €	2.785,61 €	2.827,39 €	2.869,81 €	2.912,85 €	2.956,55 €	3.000,89 €
TOTAL	**414.099,33 €**	**416.212,22 €**	**418.356,03 €**	**420.531,60 €**	**422.739,80 €**	**424.981,13 €**	**427.256,07 €**	**429.565,14 €**	**431.908,85 €**	**434.287,71 €**	**436.702,25 €**	**439.153,01 €**	**441.640,53 €**	**444.165,37 €**	**446.728,08 €**	**449.329,23 €**	**451.969,39 €**	**454.649,16 €**	**457.369,13 €**	**460.129,89 €**	**462.932,07 €**	**465.776,28 €**	**468.663,15 €**	**471.593,33 €**	**474.567,45 €**	**477.586,19 €**
		2.112,90 €																								
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
SAVINGS		**-386.445,46 €**	**-377.665,00 €**	**-368.754,44 €**	**-359.710,23 €**	**-350.530,36 €**	**-341.212,79 €**	**-331.755,45 €**	**-322.156,26 €**	**-312.413,08 €**	**-302.523,75 €**	**-292.486,08 €**	**-282.297,84 €**	**-271.956,78 €**	**-261.460,61 €**	**-231.806,99 €**	**-220.993,57 €**	**-210.017,94 €**	**-198.877,69 €**	**-187.570,32 €**	**-176.093,35 €**	**-164.444,23 €**	**-152.620,36 €**	**-140.619,14 €**	**-128.437,90 €**	**-116.073,94 €**
CASH FLOW	**-414.099**	**8.653,86 €**	**8.780,47 €**	**8.910,55 €**	**9.044,21 €**	**9.179,87 €**	**9.317,57 €**	**9.457,33 €**	**9.599,19 €**	**9.743,18 €**	**9.889,33 €**	**10.037,67 €**	**10.188,24 €**	**10.341,06 €**	**10.496,17 €**	**10.653,62 €**	**10.813,42 €**	**10.975,62 €**	**11.140,26 €**	**11.307,36 €**	**11.476,97 €**	**11.649,13 €**	**11.823,86 €**	**12.001,22 €**	**12.181,24 €**	**12.363,96 €**
IRR	-3,14%																									
NPV	-272.857,54 €																									
PAYBACK	#REF!	39,81 years																								
PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
SCENARIO 4: TP4																										
Equipment (€)	105.307,47 €																									
Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,35% Operation & Maintenance cost (€)		373,90 €	379,30 €	384,85 €	390,55 €	396,41 €	402,36 €	408,39 €	414,52 €	420,74 €	427,05 €	433,45 €	439,95 €	446,55 €	453,25 €	460,05 €	466,95 €	473,96 €	481,06 €	488,28 €	495,60 €	503,04 €	510,58 €	518,24 €	526,02 €	533,91 €
TOTAL	**105.307,47 €**	**105.681,37 €**	**106.060,67 €**	**106.445,52 €**	**106.836,08 €**	**107.232,49 €**	**107.634,84 €**	**108.043,23 €**	**108.457,75 €**	**108.878,49 €**	**109.305,53 €**	**109.738,99 €**	**110.178,94 €**	**110.625,49 €**	**111.078,74 €**	**111.538,80 €**	**112.005,75 €**	**112.479,70 €**	**112.960,77 €**	**113.449,05 €**	**113.944,65 €**	**114.447,69 €**	**114.958,27 €**	**115.476,52 €**	**116.002,53 €**	**116.536,44 €**
		373,90 €																								
		-	-	-	-	-	-	-	1	0	1	2	3	4	5	6	8	9	10	11	12	12	13	14	15	15
Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
SAVINGS		**-75.914,61 €**	**-65.369,64 €**	**-54.668,37 €**	**-43.806,51 €**	**-32.781,72 €**	**-21.591,56 €**	**-10.233,55 €**	**1.294,83 €**	**12.996,14 €**	**24.872,97 €**	**36.927,95 €**	**49.163,75 €**	**61.583,10 €**	**74.188,73 €**	**105.983,45 €**	**118.970,08 €**	**132.151,52 €**	**145.530,68 €**	**159.110,52 €**	**172.894,07 €**	**186.884,36 €**	**201.084,51 €**	**215.497,67 €**	**230.127,02 €**	**244.975,81 €**
CASH FLOW	**-105.307**	**10.392,86 €**	**10.544,98 €**	**10.701,27 €**	**10.861,86 €**	**11.024,79 €**	**11.190,16 €**	**11.358,01 €**	**11.528,38 €**	**11.701,31 €**	**11.876,83 €**	**12.054,98 €**	**12.235,80 €**	**12.419,34 €**	**12.605,63 €**	**12.794,72 €**	**12.986,64 €**	**13.181,44 €**	**13.379,16 €**	**13.579,85 €**	**13.783,54 €**	**13.990,30 €**	**14.200,15 €**	**14.413,15 €**	**14.629,35 €**	**14.848,79 €**
IRR	10,06%																									
NPV	64.319,84 €																									
PAYBACK	7,89 years	8,43 years																								


FINANCIAL FEASIBILITY ANALYSIS WITHIN 25 YEARS FOR VIRTUAL DEMONSTRATOR BUILDING 1
RESIDENTIAL DWELLING IN ITALY
450.000 €
400.000 €
350.000 €
300.000 €
250.000 €
200.000 €
150.000 €
100.000 €
50.000 €
0 €
total cost (€)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Years
BASELINE SCENARIO
SCENARIO 1: TP1
SCENARIO 2: TP2
SCENARIO 3: TP3
SCENARIO 4: TP4

BUSINESS MODEL RESIDENTIAL NETHERLANDS

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	IPC		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
	IPC (Previsión GRUPO VEOLIA)		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
	IPC Acumulado		1,4445%	2,9075%	4,3890%	5,8890%	7,3890%	8,8890%	10,3890%	11,8890%	13,3890%	14,8890%	16,3890%	17,8890%	19,3890%	20,8890%	22,3890%	23,8890%	25,3890%	26,8890%	28,3890%	29,8890%	31,3890%	32,8890%	34,3890%	35,8890%	37,3890%

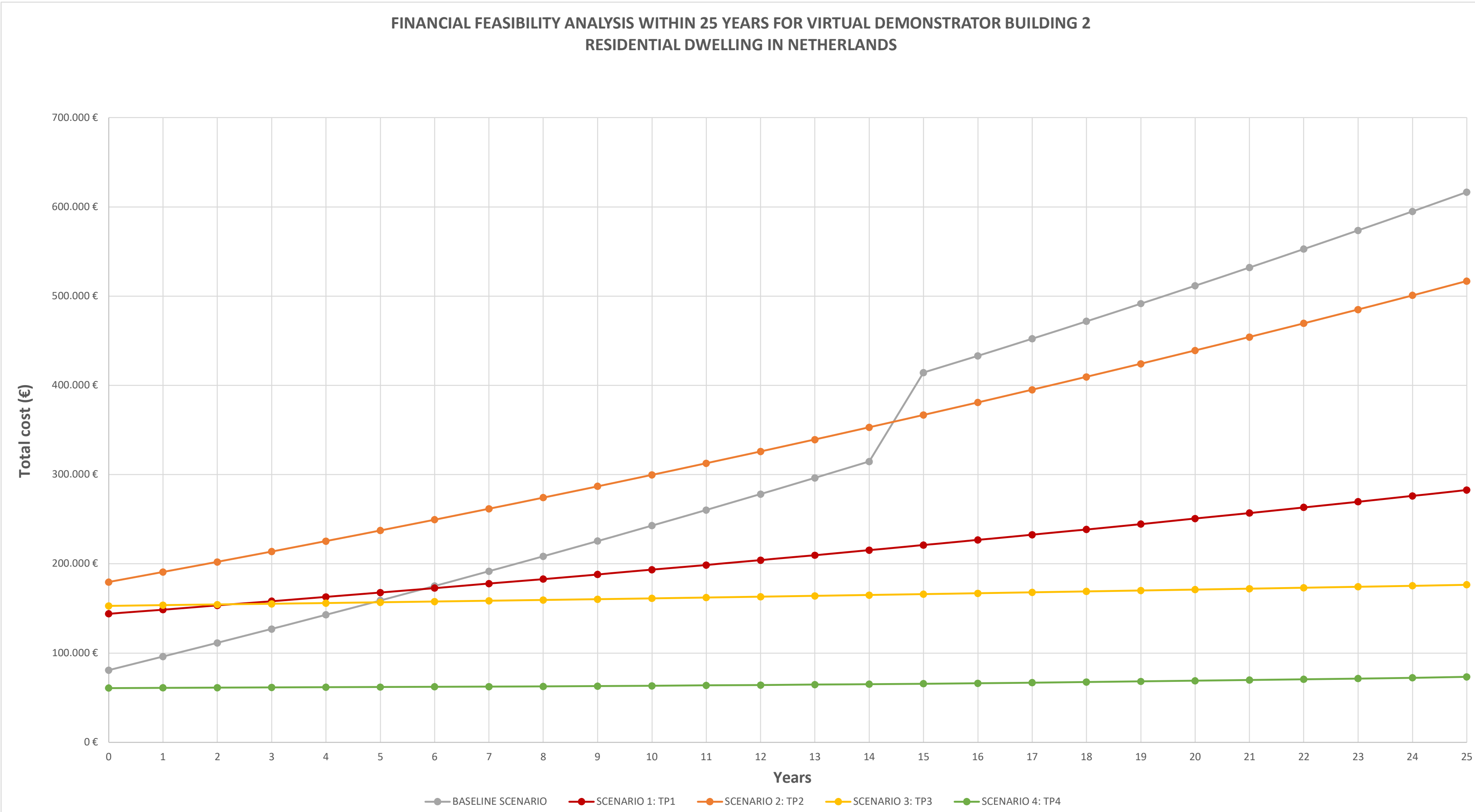
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	BASELINE SCENARIO																										
	Equipment (€)	81.000,00 € (1 x boiler + 4 x fan coils/splits) x 18 apartments															81.000,00 €										
	Energy cost (electricity) (€)		28,36 €	28,78 €	29,20 €	29,64 €	30,09 €	30,54 €	30,99 €	31,46 €	31,93 €	32,41 €	32,90 €	33,39 €	33,89 €	34,40 €	34,91 €	35,44 €	35,97 €	36,51 €	37,06 €	37,61 €	38,18 €	38,75 €	39,33 €	39,92 €	40,52 €
	Energy cost (natural gas) (€)		12.631,68 €	12.816,48 €	13.006,35 €	13.201,45 €	13.399,47 €	13.600,46 €	13.804,47 €	14.011,54 €	14.221,71 €	14.435,04 €	14.651,56 €	14.871,34 €	15.094,41 €	15.320,82 €	15.550,63 €	15.783,89 €	16.020,65 €	16.260,96 €	16.504,88 €	16.752,45 €	17.003,74 €	17.258,79 €	17.517,67 €	17.780,44 €	18.047,15 €
3,00%	Operation & Maintenance cost (€)		2.465,10 €	2.501,17 €	2.538,22 €	2.576,29 €	2.614,94 €	2.654,16 €	2.693,97 €	2.734,38 €	2.775,40 €	2.817,03 €	2.859,29 €	2.902,18 €	2.945,71 €	2.989,89 €	3.034,74 €	3.080,26 €	3.126,47 €	3.173,36 €	3.220,97 €	3.269,28 €	3.318,32 €	3.368,09 €	3.418,62 €	3.469,89 €	3.521,94 €
	TOTAL	**81.000,00 €**	**96.125,14 €**	**111.471,56 €**	**127.045,34 €**	**142.852,72 €**	**158.897,22 €**	**175.182,38 €**	**191.711,82 €**	**208.489,20 €**	**225.518,24 €**	**242.802,72 €**	**260.346,46 €**	**278.153,36 €**	**296.227,37 €**	**314.572,48 €**	**414.192,77 €**	**433.092,37 €**	**452.275,46 €**	**471.746,30 €**	**491.509,19 €**	**511.568,54 €**	**531.928,77 €**	**552.594,40 €**	**573.570,02 €**	**594.860,28 €**	**616.469,89 €**
			15.125,14 €																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 1: TP1																										
	Equipment (€)	144.054,45 €																									
	Energy cost (electricity) (€)		323,79 €	328,52 €	333,39 €	338,39 €	343,47 €	348,62 €	353,85 €	359,16 €	364,54 €	370,01 €	375,56 €	381,20 €	386,91 €	392,72 €	398,61 €	404,59 €	410,66 €	416,82 €	423,07 €	429,41 €	435,86 €	442,39 €	449,03 €	455,76 €	462,60 €
	Energy cost (natural gas) (€)		3.924,68 €	3.982,10 €	4.041,10 €	4.101,71 €	4.163,24 €	4.225,69 €	4.289,07 €	4.353,41 €	4.418,71 €	4.484,99 €	4.552,27 €	4.620,55 €	4.689,86 €	4.760,21 €	4.831,61 €	4.904,08 €	4.977,65 €	5.052,31 €	5.128,09 €	5.205,02 €	5.283,09 €	5.362,34 €	5.442,77 €	5.524,41 €	5.607,28 €
0,25%	Operation & Maintenance cost (€)		365,34 €	370,68 €	376,17 €	381,82 €	387,54 €	393,36 €	399,26 €	405,25 €	411,33 €	417,50 €	423,76 €	430,11 €	436,57 €	443,11 €	449,76 €	456,51 €	463,36 €	470,31 €	477,36 €	484,52 €	491,79 €	499,17 €	506,65 €	514,25 €	521,97 €
	TOTAL	**144.054,45 €**	**148.668,26 €**	**153.349,57 €**	**158.100,23 €**	**162.922,16 €**	**167.816,41 €**	**172.784,07 €**	**177.826,25 €**	**182.944,07 €**	**188.138,65 €**	**193.411,15 €**	**198.762,73 €**	**204.194,60 €**	**209.707,93 €**	**215.303,97 €**	**220.983,95 €**	**226.749,13 €**	**232.600,79 €**	**238.540,22 €**	**244.568,74 €**	**250.687,69 €**	**256.898,43 €**	**263.202,32 €**	**269.600,78 €**	**276.095,21 €**	**282.687,06 €**
			4.613,81 €																								
			-	-	-	-	-	1	0	1	2	3	4	5	6	7	8	15	15	16	17	18	18	19	20	21	21
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-52.543,12 €**	**-41.878,01 €**	**-31.054,90 €**	**-20.069,43 €**	**-8.919,19 €**	**2.398,30 €**	**13.885,56 €**	**25.545,13 €**	**37.379,59 €**	**49.391,57 €**	**61.583,73 €**	**73.958,77 €**	**86.519,43 €**	**99.268,51 €**	**193.208,82 €**	**206.343,24 €**	**219.674,67 €**	**233.206,08 €**	**246.940,45 €**	**260.880,84 €**	**275.030,34 €**	**289.392,08 €**	**303.969,24 €**	**318.765,07 €**	**333.782,83 €**
	CASH FLOW	**-144.054**	**10.511,33 €**	**10.665,11 €**	**10.823,11 €**	**10.985,46 €**	**11.150,24 €**	**11.317,50 €**	**11.487,26 €**	**11.659,57 €**	**11.834,46 €**	**12.011,98 €**	**12.192,16 €**	**12.375,04 €**	**12.560,67 €**	**12.749,08 €**	**12.940,31 €**	**13.134,42 €**	**13.331,43 €**	**13.531,40 €**	**13.734,38 €**	**13.940,39 €**	**14.149,50 €**	**14.361,74 €**	**14.577,17 €**	**14.795,82 €**	**15.017,76 €**
	IRR	6,70%																									
	NPV	27.503,50 €																									
	PAYBACK	5,79 years	11,40 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 2: TP2																										
	Equipment (€)	179.582,36 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
	Energy cost (natural gas) (€)		10.585,94 €	10.740,81 €	10.899,93 €	11.063,43 €	11.229,38 €	11.397,83 €	11.568,79 €	11.742,32 €	11.918,46 €	12.097,24 €	12.278,69 €	12.462,88 €	12.649,82 €	12.839,57 €	13.032,16 €	13.227,64 €	13.426,06 €	13.627,45 €	13.831,86 €	14.039,34 €	14.249,93 €	14.463,68 €	14.680,63 €	14.900,84 €	15.124,35 €
0,35%	Operation & Maintenance cost (€)		637,62 €	646,83 €	656,29 €	666,01 €	676,00 €	686,14 €	696,44 €	706,88 €	717,49 €	728,25 €	739,17 €	750,26 €	761,51 €	772,94 €	784,53 €	796,30 €	808,24 €	820,37 €	832,67 €	845,16 €	857,84 €	870,71 €	883,77 €	897,02 €	910,48 €
	TOTAL	**179.582,36 €**	**190.805,91 €**	**202.193,55 €**	**213.749,77 €**	**225.479,22 €**	**237.384,61 €**	**249.468,57 €**	**261.733,80 €**	**274.183,01 €**	**286.818,96 €**	**299.644,44 €**	**312.662,31 €**	**325.875,44 €**	**339.286,77 €**	**352.899,28 €**	**366.715,96 €**	**380.739,90 €**	**394.974,20 €**	**409.422,02 €**	**424.086,55 €**	**438.971,05 €**	**454.078,81 €**	**469.413,19 €**	**484.977,59 €**	**500.775,46 €**	**516.810,29 €**
			11.223,55 €																								
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	10	11	11	12	13	14	15	15	16	17
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-94.680,77 €**	**-90.721,99 €**	**-86.704,43 €**	**-82.626,50 €**	**-78.487,39 €**	**-74.286,20 €**	**-70.021,99 €**	**-65.693,81 €**	**-61.300,71 €**	**-56.841,72 €**	**-52.315,84 €**	**-47.722,08 €**	**-43.059,40 €**	**-38.326,79 €**	**47.476,81 €**	**52.352,47 €**	**57.301,26 €**	**62.324,28 €**	**67.422,65 €**	**72.597,49 €**	**77.849,96 €**	**83.181,21 €**	**88.592,43 €**	**94.084,82 €**	**99.659,60 €**
	CASH FLOW	**-179.582**	**3.901,59 €**	**3.958,78 €**	**4.017,55 €**	**4.077,94 €**	**4.139,11 €**	**4.201,19 €**	**4.264,21 €**	**4.328,17 €**	**4.393,10 €**	**4.458,99 €**	**4.525,88 €**	**4.593,77 €**	**4.662,67 €**	**4.732,61 €**	**4.803,60 €**	**4.875,66 €**	**4.948,79 €**	**5.023,02 €**	**5.098,37 €**	**5.174,84 €**	**5.252,47 €**	**5.331,25 €**	**5.411,22 €**	**5.492,39 €**	**5.574,78 €**
	IRR	-2,89%																									
	NPV	-115.898,60 €																									
	PAYBACK	21,98 years	38,29 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 3: TP3																										
	Equipment (€)	152.850,36 €																									
	Energy cost (electricity) (€)		15,21 €	15,43 €	15,66 €	15,90 €	16,13 €	16,38 €	16,62 €	16,87 €	17,12 €	17,38 €	17,64 €	17,91 €	18,17 €	18,45 €	18,72 €	19,01 €	19,29 €	19,58 €	19,87 €	20,17 €	20,47 €	20,78 €	21,09 €	21,41 €	21,73 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,50%	Operation & Maintenance cost (€)		775,29 €	786,49 €	798,00 €	809,82 €	821,97 €	834,30 €	846,81 €	859,51 €	872,41 €	885,49 €	898,77 €	912,26 €	925,94 €	939,83 €	953,93 €	968,23 €	982,76 €	997,50 €	1.012,46 €	1.027,65 €	1.043,06 €	1.058,71 €	1.074,59 €	1.090,71 €	1.107,07 €
	TOTAL	**152.850,36 €**	**153.640,86 €**	**154.442,78 €**	**155.256,44 €**	**156.082,15 €**	**156.920,25 €**	**157.770,92 €**	**158.634,36 €**	**159.510,74 €**	**160.400,27 €**	**161.303,14 €**	**162.219,56 €**	**163.149,72 €**	**164.093,83 €**	**165.052,11 €**	**166.024,76 €**	**167.012,00 €**	**168.014,04 €**	**169.031,12 €**	**170.063,46 €**	**171.111,28 €**	**172.174,82 €**	**173.254,31 €**	**174.349,99 €**	**175.462,11 €**	**176.590,91 €**
			790,50 €																								
			-	-	-	-	1	0	1	2	3	4	5	6	7	8	8	14	15	15	16	17	18	18	19	20	20
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-57.515,72 €**	**-42.971,22 €**	**-28.211,10 €**	**-13.229,43 €**	**1.976,96 €**	**17.411,45 €**	**33.077,46 €**	**48.978,46 €**	**65.117,97 €**	**81.499,58 €**	**98.126,91 €**	**115.003,65 €**	**132.133,54 €**	**149.520,38 €**	**248.168,02 €**	**266.080,37 €**	**284.261,42 €**	**302.715,17 €**	**321.445,74 €**	**340.457,26 €**	**359.753,95 €**	**379.340,10 €**	**399.220,03 €**	**419.398,17 €**	**439.878,98 €**
	CASH FLOW	**-152.850**	**14.334,64 €**	**14.544,50 €**	**14.760,12 €**	**14.981,67 €**	**15.206,39 €**	**15.434,49 €**	**15.666,01 €**	**15.901,00 €**	**16.139,51 €**	**16.381,61 €**	**16.627,33 €**	**16.876,74 €**	**17.129,89 €**	**17.386,84 €**	**17.647,64 €**	**17.912,36 €**	**18.181,04 €**	**18.453,76 €**	**18.730,56 €**	**19.011,52 €**	**19.296,69 €**	**19.586,15 €**	**19.879,94 €**	**20.178,14 €**	**20.480,81 €**
	IRR	9,45%																									
	NPV	81.114,86 €																									
	PAYBACK	4,87 years	8,87 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 4: TP4																										
	Equipment (€)	60.842,44 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	28,56 €	64,35 €	100,13 €	135,91 €	171,69 €	207,47 €	243,25 €	279,04 €	314,82 €	350,60 €	386,38 €	422,16 €	457,94 €	493,73 €	529,51 €	565,29 €	601,07 €	636,85 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,35%	Operation & Maintenance cost (€)		216,02 €	219,15 €	222,35 €	225,65 €	229,03 €	232,47 €	235,95 €	239,49 €	243,08 €	246,73 €	250,43 €	254,19 €	258,00 €	261,87 €	265,80 €	269,79 €	273,83 €	277,94 €	282,11 €	286,34 €	290,64 €	295,00 €	299,42 €	303,91 €	308,47 €
	TOTAL	**60.842,44 €**	**61.058,46 €**	**61.277,61 €**	**61.499,96 €**	**61.725,61 €**	**61.954,64 €**	**62.187,10 €**	**62.423,05 €**	**62.691,11 €**	**62.998,54 €**	**63.345,40 €**	**63.731,74 €**	**64.157,62 €**	**64.623,09 €**	**65.128,22 €**	**65.673,05 €**	**66.257,65 €**	**66.882,08 €**	**67.546,40 €**	**68.250,67 €**	**68.994,96 €**	**69.779,32 €**	**70.603,82 €**	**71.468,53 €**	**72.373,51 €**	**73.318,83 €**
			216,02 €																								
			0	2	3	4	5	6	7	8	9	10	10	11	12	13	14	19	20	20	21	22	23	23	24	25	25
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**35.066,67 €**	**50.193,95 €**	**65.545,38 €**	**81.127,12 €**	**96.942,58 €**	**112.995,28 €**	**129.288,76 €**	**145.798,09 €**	**162.519,70 €**	**179.457,32 €**	**196.614,72 €**	**213.995,75 €**	**231.604,28 €**	**249.444,27 €**	**348.519,73 €**	**366.834,72 €**	**385.393,38 €**	**404.199,89 €**	**423.258,52 €**	**442.573,58 €**	**462.149,45 €**	**481.990,58 €**	**502.101,49 €**	**522.486,77 €**	**543.151,05 €**
	CASH FLOW	**-60.842**	**14.909,11 €**	**15.127,28 €**	**15.351,43 €**	**15.581,74 €**	**15.815,46 €**	**16.052,70 €**	**16.293,49 €**	**16.509,33 €**	**16.721,61 €**	**16.937,62 €**	**17.157,40 €**	**17.381,02 €**	**17.608,53 €**	**17.839,99 €**	**18.075,46 €**	**18.314,99 €**	**18.558,66 €**	**18.806,52 €**	**19.058,63 €**	**19.315,06 €**	**19.575,87 €**	**19.841,13 €**	**20.110,91 €**	**20.385,27 €**	**20.664,29 €**
	IRR	25,83%																									
	NPV	180.115,97 €																									
	PAYBACK	0,00 years	3,44 years																								


FINANCIAL FEASIBILITY ANALYSIS WITHIN 25 YEARS FOR VIRTUAL DEMONSTRATOR BUILDING 2
RESIDENTIAL DWELLING IN NETHERLANDS
Total cost (€)
700.000 €
600.000 €
500.000 €
400.000 €
300.000 €
200.000 €
100.000 €
0 €
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Years
BASELINE SCENARIO
SCENARIO 1: TP1
SCENARIO 2: TP2
SCENARIO 3: TP3
SCENARIO 4: TP4

BUSINESS MODEL RESIDENTIAL SWEDEN

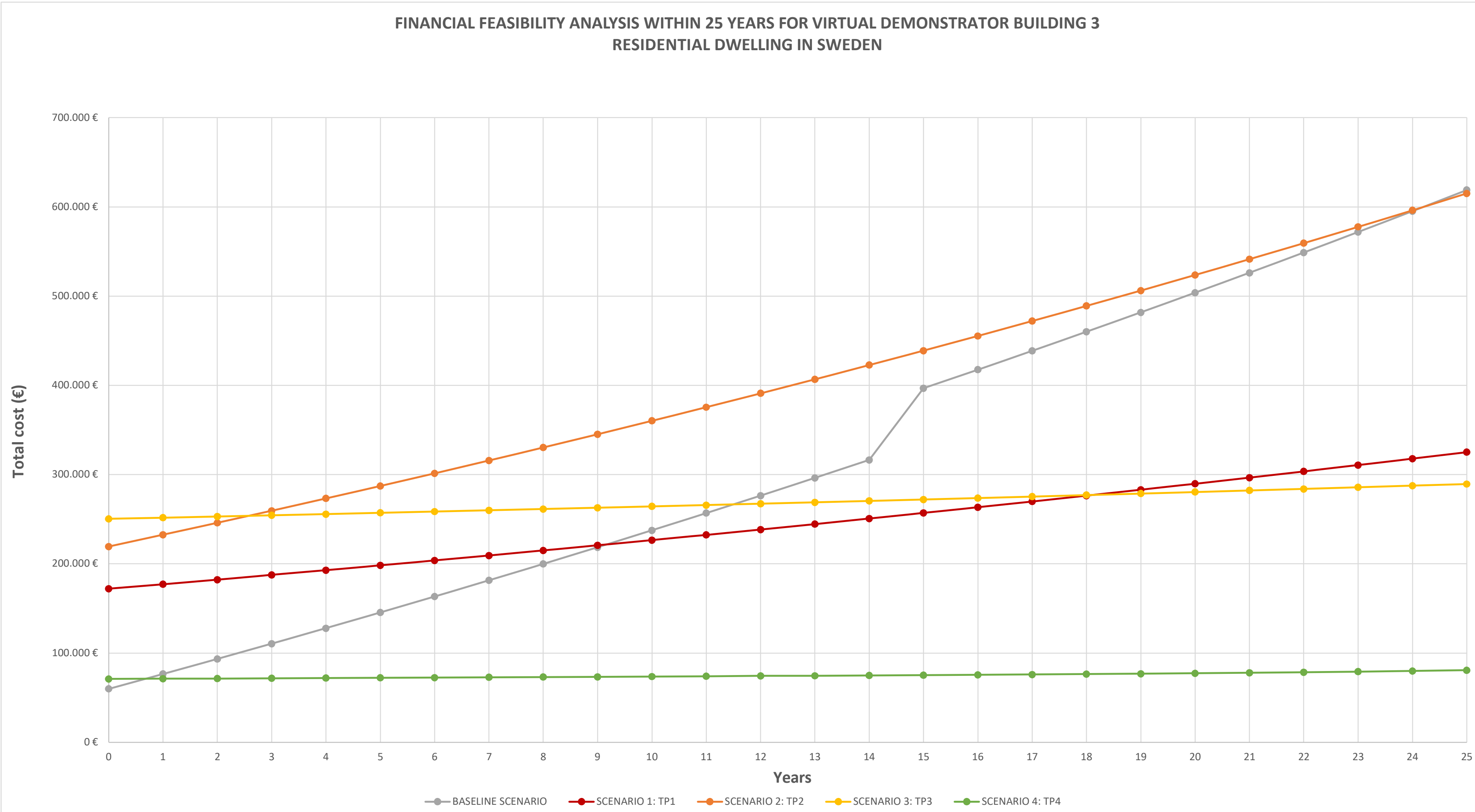
	IPC		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
	IPC (Previsión GRUPO VEOLIA)		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
	IPC Acumulado		1,4445%	2,9075%	4,3890%	5,8890%	7,3890%	8,8890%	10,3890%	11,8890%	13,3890%	14,8890%	16,3890%	17,8890%	19,3890%	20,8890%	22,3890%	23,8890%	25,3890%	26,8890%	28,3890%	29,8890%	31,3890%	32,8890%	34,3890%	35,8890%	37,3890%
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	BASELINE SCENARIO																										
	Equipment (€)	60.000,00 € (1 x boiler + 6 x fan coils/splits) x 12 apartments															60.000,00 €										
	Energy cost (electricity) (€)		108,09 €	109,67 €	111,29 €	112,96 €	114,66 €	116,38 €	118,12 €	119,89 €	121,69 €	123,52 €	125,37 €	127,25 €	129,16 €	131,10 €	133,06 €	135,06 €	137,09 €	139,14 €	141,23 €	143,35 €	145,50 €	147,68 €	149,90 €	152,14 €	154,43 €
	Energy cost (natural gas) (€)		14.668,24 €	14.882,84 €	15.103,32 €	15.329,87 €	15.559,82 €	15.793,22 €	16.030,12 €	16.270,57 €	16.514,63 €	16.762,35 €	17.013,78 €	17.268,99 €	17.528,02 €	17.790,95 €	18.057,81 €	18.328,68 €	18.603,61 €	18.882,66 €	19.165,90 €	19.453,39 €	19.745,19 €	20.041,37 €	20.341,99 €	20.647,12 €	20.956,83 €
3,00%	Operation & Maintenance cost (€)		1.826,00 €	1.852,72 €	1.880,16 €	1.908,37 €	1.936,99 €	1.966,05 €	1.995,54 €	2.025,47 €	2.055,85 €	2.086,69 €	2.117,99 €	2.149,76 €	2.182,01 €	2.214,74 €	2.247,96 €	2.281,68 €	2.315,90 €	2.350,64 €	2.385,90 €	2.421,69 €	2.458,01 €	2.494,88 €	2.532,31 €	2.570,29 €	2.608,85 €
	TOTAL	**60.000,00 €**	**76.602,33 €**	**93.447,55 €**	**110.542,33 €**	**127.893,53 €**	**145.505,00 €**	**163.380,65 €**	**181.524,42 €**	**199.940,36 €**	**218.632,53 €**	**237.605,09 €**	**256.862,23 €**	**276.408,24 €**	**296.247,43 €**	**316.384,21 €**	**396.823,04 €**	**417.568,45 €**	**438.625,05 €**	**459.997,49 €**	**481.690,52 €**	**503.708,95 €**	**526.057,65 €**	**548.741,59 €**	**571.765,78 €**	**595.135,33 €**	**618.855,43 €**
			16.602,33 €																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 1: TP1																										
	Equipment (€)	172.079,43 €																									
	Energy cost (electricity) (€)		357,53 €	362,76 €	368,14 €	373,66 €	379,26 €	384,95 €	390,73 €	396,59 €	402,54 €	408,57 €	414,70 €	420,92 €	427,24 €	433,65 €	440,15 €	446,75 €	453,45 €	460,26 €	467,16 €	474,17 €	481,28 €	488,50 €	495,83 €	503,26 €	510,81 €
	Energy cost (natural gas) (€)		4.299,04 €	4.361,93 €	4.426,56 €	4.492,95 €	4.560,35 €	4.628,75 €	4.698,19 €	4.768,66 €	4.840,19 €	4.912,79 €	4.986,48 €	5.061,28 €	5.137,20 €	5.214,26 €	5.292,47 €	5.371,86 €	5.452,44 €	5.534,22 €	5.617,24 €	5.701,49 €	5.787,02 €	5.873,82 €	5.961,93 €	6.051,36 €	6.142,13 €
0,25%	Operation & Maintenance cost (€)		436,41 €	442,80 €	449,36 €	456,10 €	462,94 €	469,88 €	476,93 €	484,09 €	491,35 €	498,72 €	506,20 €	513,79 €	521,50 €	529,32 €	537,26 €	545,32 €	553,50 €	561,80 €	570,23 €	578,78 €	587,46 €	596,28 €	605,22 €	614,30 €	623,51 €
	TOTAL	**172.079,43 €**	**177.172,41 €**	**182.339,90 €**	**187.583,95 €**	**192.906,66 €**	**198.309,21 €**	**203.792,80 €**	**209.358,65 €**	**215.007,98 €**	**220.742,05 €**	**226.562,13 €**	**232.469,51 €**	**238.465,51 €**	**244.551,44 €**	**250.728,67 €**	**256.998,55 €**	**263.362,48 €**	**269.821,86 €**	**276.378,14 €**	**283.032,77 €**	**289.787,21 €**	**296.642,97 €**	**303.601,57 €**	**310.664,54 €**	**317.833,46 €**	**325.109,91 €**
			5.092,98 €																								
			-	-	-	-	-	-	-	-	-	0	1	2	3	4	5	10	11	11	12	13	14	15	15	16	17
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-100.570,08 €**	**-88.892,35 €**	**-77.041,62 €**	**-65.013,13 €**	**-52.804,21 €**	**-40.412,16 €**	**-27.834,22 €**	**-15.067,62 €**	**-2.109,52 €**	**11.042,96 €**	**24.392,72 €**	**37.942,73 €**	**51.695,99 €**	**65.655,54 €**	**139.824,49 €**	**154.205,98 €**	**168.803,18 €**	**183.619,35 €**	**198.657,76 €**	**213.921,74 €**	**229.414,68 €**	**245.140,02 €**	**261.101,24 €**	**277.301,87 €**	**293.745,52 €**
	CASH FLOW	-172.079	**11.509,34 €**	**11.677,73 €**	**11.850,73 €**	**12.028,49 €**	**12.208,92 €**	**12.392,05 €**	**12.577,93 €**	**12.766,60 €**	**12.958,10 €**	**13.152,47 €**	**13.349,76 €**	**13.550,01 €**	**13.753,26 €**	**13.959,56 €**	**14.168,95 €**	**14.381,48 €**	**14.597,21 €**	**14.816,16 €**	**15.038,41 €**	**15.263,98 €**	**15.492,94 €**	**15.725,34 €**	**15.961,22 €**	**16.200,64 €**	**16.443,65 €**
	IRR	5,84%																									
	NPV	15.767,36 €																									
	PAYBACK	9,16 years	12,44 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 2: TP2																										
	Equipment (€)	219.443,14 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
	Energy cost (natural gas) (€)		12.382,72 €	12.563,88 €	12.750,01 €	12.941,26 €	13.135,38 €	13.332,41 €	13.532,40 €	13.735,39 €	13.941,42 €	14.150,54 €	14.362,80 €	14.578,24 €	14.796,91 €	15.018,87 €	15.244,15 €	15.472,81 €	15.704,90 €	15.940,48 €	16.179,58 €	16.422,28 €	16.668,61 €	16.918,64 €	17.172,42 €	17.430,01 €	17.691,46 €
0,35%	Operation & Maintenance cost (€)		779,15 €	790,54 €	802,26 €	814,29 €	826,50 €	838,90 €	851,49 €	864,26 €	877,22 €	890,38 €	903,74 €	917,29 €	931,05 €	945,02 €	959,19 €	973,58 €	988,18 €	1.003,01 €	1.018,05 €	1.033,32 €	1.048,82 €	1.064,55 €	1.080,52 €	1.096,73 €	1.113,18 €
	TOTAL	**219.443,14 €**	**232.605,01 €**	**245.959,43 €**	**259.511,70 €**	**273.267,26 €**	**287.229,15 €**	**301.400,46 €**	**315.784,35 €**	**330.383,99 €**	**345.202,63 €**	**360.243,55 €**	**375.510,08 €**	**391.005,61 €**	**406.733,58 €**	**422.697,46 €**	**438.900,80 €**	**455.347,19 €**	**472.040,28 €**	**488.983,77 €**	**506.181,40 €**	**523.637,00 €**	**541.354,44 €**	**559.337,63 €**	**577.590,58 €**	**596.117,31 €**	**614.921,95 €**
			13.161,87 €																								
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-156.002,68 €**	**-152.511,88 €**	**-148.969,37 €**	**-145.373,73 €**	**-141.724,14 €**	**-138.019,82 €**	**-134.259,92 €**	**-130.443,63 €**	**-126.570,10 €**	**-122.638,46 €**	**-118.647,85 €**	**-114.597,38 €**	**-110.486,15 €**	**-106.313,25 €**	**-42.077,76 €**	**-37.778,74 €**	**-33.415,23 €**	**-28.986,27 €**	**-24.490,88 €**	**-19.928,05 €**	**-15.296,78 €**	**-10.596,05 €**	**-5.824,80 €**	**-981,98 €**	**3.933,48 €**
	CASH FLOW	-219.443	**3.440,46 €**	**3.490,79 €**	**3.542,51 €**	**3.595,65 €**	**3.649,58 €**	**3.704,33 €**	**3.759,89 €**	**3.816,29 €**	**3.873,53 €**	**3.931,64 €**	**3.990,61 €**	**4.050,47 €**	**4.111,23 €**	**4.172,90 €**	**4.235,49 €**	**4.299,02 €**	**4.363,51 €**	**4.428,96 €**	**4.495,39 €**	**4.562,83 €**	**4.631,27 €**	**4.700,74 €**	**4.771,25 €**	**4.842,82 €**	**4.915,46 €**
	IRR	-4,88%																									
	NPV	-163.290,55 €																									
	PAYBACK	24,20 years	53,07 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 3: TP3																										
	Equipment (€)	250.467,14 €																									
	Energy cost (electricity) (€)		27,36 €	27,76 €	28,17 €	28,59 €	29,02 €	29,46 €	29,90 €	30,35 €	30,80 €	31,27 €	31,73 €	32,21 €	32,69 €	33,18 €	33,68 €	34,19 €	34,70 €	35,22 €	35,75 €	36,28 €	36,83 €	37,38 €	37,94 €	38,51 €	39,09 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,50%	Operation & Maintenance cost (€)		1.270,43 €	1.289,01 €	1.308,11 €	1.327,73 €	1.347,65 €	1.367,86 €	1.388,38 €	1.409,20 €	1.430,34 €	1.451,80 €	1.473,57 €	1.495,68 €	1.518,11 €	1.540,89 €	1.564,00 €	1.587,46 €	1.611,27 €	1.635,44 €	1.659,97 €	1.684,87 €	1.710,14 €	1.735,80 €	1.761,83 €	1.788,26 €	1.815,08 €
	TOTAL	**250.467,14 €**	**251.764,93 €**	**253.081,70 €**	**254.417,98 €**	**255.774,30 €**	**257.150,97 €**	**258.548,29 €**	**259.966,57 €**	**261.406,12 €**	**262.867,26 €**	**264.350,33 €**	**265.855,64 €**	**267.383,53 €**	**268.934,33 €**	**270.508,40 €**	**272.106,08 €**	**273.727,73 €**	**275.373,70 €**	**277.044,36 €**	**278.740,08 €**	**280.461,23 €**	**282.208,20 €**	**283.981,38 €**	**285.781,16 €**	**287.607,93 €**	**289.462,10 €**
			1.297,79 €																								
			-	-	-	-	-	-	-	-	-	-	-	0	0	1	2	7	7	8	9	10	11	12	12	13	14
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-175.162,60 €**	**-159.634,15 €**	**-143.875,65 €**	**-127.880,77 €**	**-111.645,97 €**	**-95.167,64 €**	**-78.442,14 €**	**-61.465,76 €**	**-44.234,73 €**	**-26.745,24 €**	**-8.993,40 €**	**9.024,71 €**	**27.313,10 €**	**45.875,81 €**	**124.716,96 €**	**143.840,73 €**	**163.251,35 €**	**182.953,14 €**	**202.950,45 €**	**223.247,72 €**	**243.849,45 €**	**264.760,20 €**	**285.984,62 €**	**307.527,40 €**	**329.393,33 €**
	CASH FLOW	-250.467	**15.304,54 €**	**15.528,45 €**	**15.758,50 €**	**15.994,88 €**	**16.234,80 €**	**16.478,32 €**	**16.725,50 €**	**16.976,38 €**	**17.231,03 €**	**17.489,49 €**	**17.751,84 €**	**18.018,11 €**	**18.288,38 €**	**18.562,71 €**	**18.841,15 €**	**19.123,77 €**	**19.410,63 €**	**19.701,78 €**	**19.997,31 €**	**20.297,27 €**	**20.601,73 €**	**20.910,76 €**	**21.224,42 €**	**21.542,78 €**	**21.865,93 €**
	IRR	4,97%																									
	NPV	-678,01 €																									
	PAYBACK	11,50 years	13,62 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 4: TP4																										
	Equipment (€)	71.053,31 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	20,21 €	62,71 €	105,22 €	147,72 €	190,22 €	232,73 €	275,23 €	317,74 €	360,24 €	402,74 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,35%	Operation & Maintenance cost (€)		252,28 €	255,92 €	259,67 €	263,51 €	267,47 €	271,48 €	275,55 €	279,68 €	283,88 €	288,14 €	292,46 €	296,85 €	301,30 €	305,82 €	310,41 €	315,06 €	319,79 €	324,59 €	329,45 €	334,40 €	339,41 €	344,50 €	349,67 €	354,92 €	360,24 €
	TOTAL	**71.053,31 €**	**71.305,58 €**	**71.561,51 €**	**71.821,17 €**	**72.084,69 €**	**72.352,16 €**	**72.623,63 €**	**72.899,18 €**	**73.178,87 €**	**73.462,75 €**	**73.750,89 €**	**74.043,35 €**	**74.340,19 €**	**74.641,49 €**	**74.947,31 €**	**75.257,72 €**	**75.592,99 €**	**75.975,49 €**	**76.405,29 €**	**76.882,47 €**	**77.407,09 €**	**77.979,23 €**	**78.598,96 €**	**79.266,37 €**	**79.981,53 €**	**80.744,51 €**
			252,28 €																								
			0	0	1	2	3	4	5	6	7	8	9	9	10	11	12	16	17	17	18	19	20	20	21	22	22
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**5.296,74 €**	**21.886,04 €**	**38.721,15 €**	**55.808,84 €**	**73.152,85 €**	**90.757,01 €**	**108.625,24 €**	**126.761,49 €**	**145.169,78 €**	**163.854,20 €**	**182.818,89 €**	**202.068,04 €**	**221.605,94 €**	**241.436,90 €**	**321.565,32 €**	**341.975,46 €**	**362.649,56 €**	**383.592,20 €**	**404.808,06 €**	**426.301,86 €**	**448.078,42 €**	**470.142,62 €**	**492.499,41 €**	**515.153,81 €**	**538.110,92 €**
	CASH FLOW	-71.053	**16.350,05 €**	**16.589,30 €**	**16.835,11 €**	**17.087,69 €**	**17.344,00 €**	**17.604,16 €**	**17.868,23 €**	**18.136,25 €**	**18.408,29 €**	**18.684,42 €**	**18.964,68 €**	**19.249,16 €**	**19.537,89 €**	**19.830,96 €**	**20.128,43 €**	**20.410,14 €**	**20.674,09 €**	**20.942,64 €**	**21.215,86 €**	**21.493,81 €**	**21.776,56 €**	**22.064,20 €**	**22.356,79 €**	**22.654,40 €**	**22.957,12 €**
	IRR	24,35%																									
	NPV	195.079,58 €																									
	PAYBACK	0,00 years	3,63 years																								


FINANCIAL FEASIBILITY ANALYSIS WITHIN 25 YEARS FOR VIRTUAL DEMONSTRATOR BUILDING 3
RESIDENTIAL DWELLING IN SWEDEN
700.000 €
600.000 €
500.000 €
400.000 €
300.000 €
200.000 €
100.000 €
0 €
Total cost (€)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Years
BASELINE SCENARIO
SCENARIO 1: TP1
SCENARIO 2: TP2
SCENARIO 3: TP3
SCENARIO 4: TP4

BUSINESS MODEL TERTIARY ITALY

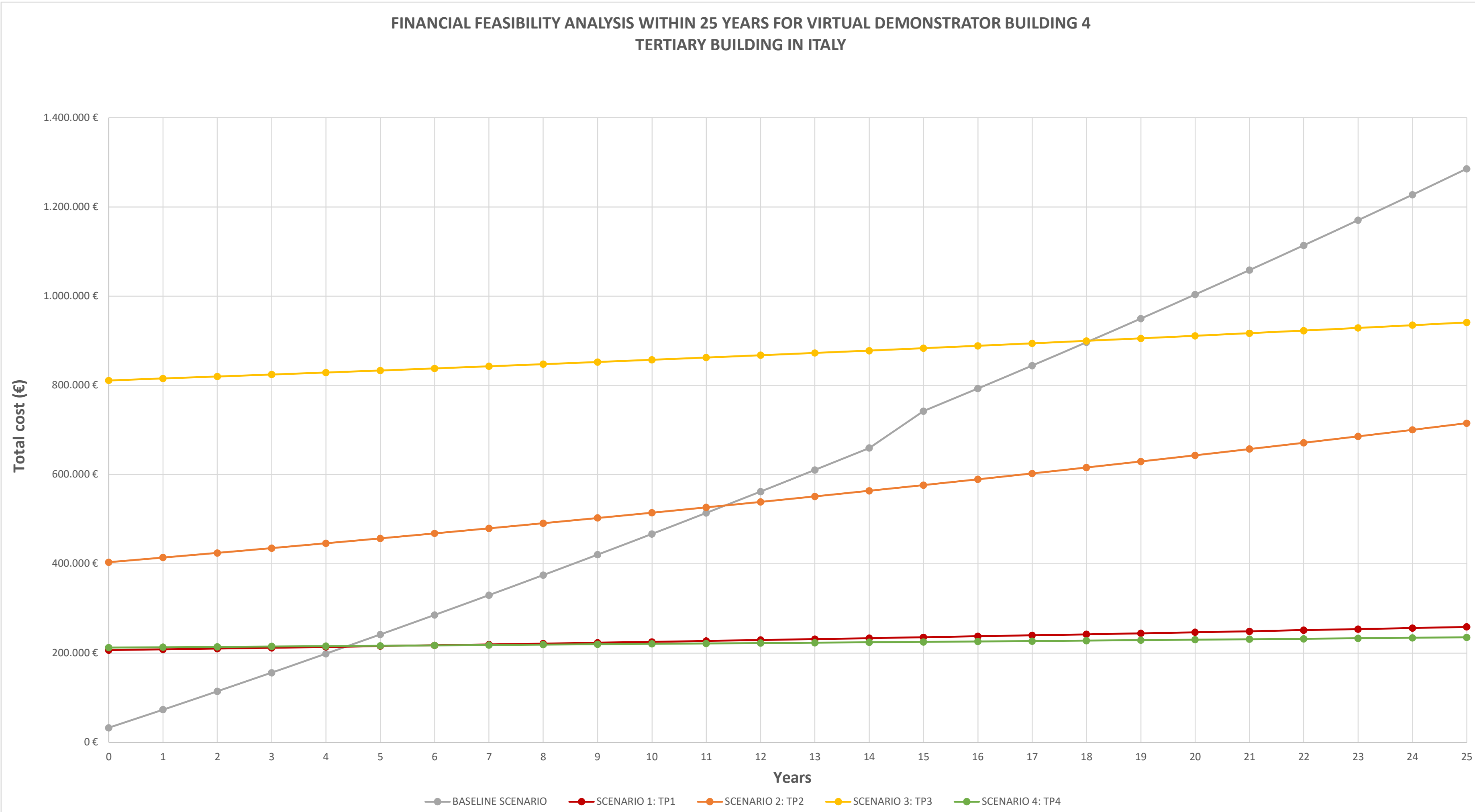
	IPC		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
	IPC (Previsión GRUPO VEOLIA)		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
	IPC Acumulado		1,4445%	2,9075%	4,3890%	5,8890%	7,3890%	8,8890%	10,3890%	11,8890%	13,3890%	14,8890%	16,3890%	17,8890%	19,3890%	20,8890%	22,3890%	23,8890%	25,3890%	26,8890%	28,3890%	29,8890%	31,3890%	32,8890%	34,3890%	35,8890%	37,3890%
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	BASELINE SCENARIO																										
	Equipment (€)	32.500,00 €	1 x boiler + 15 x fan coils/splits														32.500,00 €										
	Energy cost (electricity) (€)		22.487,88 €	22.816,88 €	23.154,91 €	23.502,24 €	23.854,77 €	24.212,59 €	24.575,78 €	24.944,42 €	25.318,58 €	25.698,36 €	26.083,84 €	26.475,10 €	26.872,22 €	27.275,31 €	27.684,44 €	28.099,70 €	28.521,20 €	28.949,02 €	29.383,25 €	29.824,00 €	30.271,36 €	30.725,43 €	31.186,31 €	31.654,11 €	32.128,92 €
	Energy cost (natural gas) (€)		18.003,91 €	18.267,31 €	18.537,94 €	18.816,01 €	19.098,25 €	19.384,72 €	19.675,49 €	19.970,62 €	20.270,18 €	20.574,24 €	20.882,85 €	21.196,09 €	21.514,03 €	21.836,74 €	22.164,30 €	22.496,76 €	22.834,21 €	23.176,72 €	23.524,37 €	23.877,24 €	24.235,40 €	24.598,93 €	24.967,91 €	25.342,43 €	25.722,57 €
3,00%	Operation & Maintenance cost (€)		115,39 €	117,08 €	118,82 €	120,60 €	122,41 €	124,24 €	126,11 €	128,00 €	129,92 €	131,87 €	133,85 €	135,85 €	137,89 €	139,96 €	142,06 €	144,19 €	146,35 €	148,55 €	150,78 €	153,04 €	155,33 €	157,66 €	160,03 €	162,43 €	164,86 €
	TOTAL	**32.500,00 €**	**73.107,19 €**	**114.308,46 €**	**156.120,12 €**	**198.558,97 €**	**241.634,39 €**	**285.355,95 €**	**329.733,32 €**	**374.776,36 €**	**420.495,05 €**	**466.899,52 €**	**514.000,05 €**	**561.807,09 €**	**610.331,24 €**	**659.583,24 €**	**742.074,03 €**	**792.814,68 €**	**844.316,44 €**	**896.590,73 €**	**949.649,13 €**	**1.003.503,41 €**	**1.058.165,50 €**	**1.113.647,52 €**	**1.169.961,77 €**	**1.227.120,74 €**	**1.285.137,09 €**
			40.607,19 €																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 1: TP1																										
	Equipment (€)	206.719,48 €																									
	Energy cost (electricity) (€)		92,40 €	93,75 €	95,14 €	96,56 €	98,01 €	99,48 €	100,97 €	102,49 €	104,03 €	105,59 €	107,17 €	108,78 €	110,41 €	112,07 €	113,75 €	115,45 €	117,18 €	118,94 €	120,73 €	122,54 €	124,38 €	126,24 €	128,13 €	130,06 €	132,01 €
	Energy cost (natural gas) (€)		1.110,99 €	1.127,24 €	1.143,94 €	1.161,10 €	1.178,52 €	1.196,19 €	1.214,14 €	1.232,35 €	1.250,84 €	1.269,60 €	1.288,64 €	1.307,97 €	1.327,59 €	1.347,50 €	1.367,72 €	1.388,23 €	1.409,06 €	1.430,19 €	1.451,65 €	1.473,42 €	1.495,52 €	1.517,95 €	1.540,72 €	1.563,83 €	1.587,29 €
0,25%	Operation & Maintenance cost (€)		524,26 €	531,93 €	539,81 €	547,91 €	556,13 €	564,47 €	572,94 €	581,53 €	590,26 €	599,11 €	608,10 €	617,22 €	626,48 €	635,87 €	645,41 €	655,09 €	664,92 €	674,89 €	685,02 €	695,29 €	705,72 €	716,31 €	727,05 €	737,96 €	749,03 €
	TOTAL	**206.719,48 €**	**208.447,12 €**	**210.200,04 €**	**211.978,94 €**	**213.784,51 €**	**215.617,17 €**	**217.477,32 €**	**219.365,37 €**	**221.281,74 €**	**223.226,86 €**	**225.201,16 €**	**227.205,07 €**	**229.239,03 €**	**231.303,51 €**	**233.398,95 €**	**235.525,83 €**	**237.684,61 €**	**239.875,77 €**	**242.099,80 €**	**244.357,19 €**	**246.648,44 €**	**248.974,05 €**	**251.334,56 €**	**253.730,47 €**	**256.162,31 €**	**258.630,64 €**
			1.727,65 €																								
			-	-	-	-	0	1	2	3	4	4	5	6	7	8	9	10	11	12	13	14	14	15	16	17	17
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-135.339,94 €**	**-95.891,59 €**	**-55.858,81 €**	**-15.225,55 €**	**26.017,22 €**	**67.878,62 €**	**110.367,95 €**	**153.494,62 €**	**197.268,19 €**	**241.698,36 €**	**286.794,98 €**	**332.568,06 €**	**379.027,72 €**	**426.184,29 €**	**506.548,20 €**	**555.130,07 €**	**604.440,67 €**	**654.490,93 €**	**705.291,94 €**	**756.854,97 €**	**809.191,44 €**	**862.312,96 €**	**916.231,31 €**	**970.958,42 €**	**1.026.506,45 €**
	CASH FLOW	**-206.719**	**38.879,54 €**	**39.448,35 €**	**40.032,77 €**	**40.633,27 €**	**41.242,77 €**	**41.861,41 €**	**42.489,33 €**	**43.126,67 €**	**43.773,57 €**	**44.430,17 €**	**45.096,62 €**	**45.773,07 €**	**46.459,67 €**	**47.156,56 €**	**47.863,91 €**	**48.581,87 €**	**49.310,60 €**	**50.050,26 €**	**50.801,01 €**	**51.563,03 €**	**52.336,47 €**	**53.121,52 €**	**53.918,34 €**	**54.727,12 €**	**55.548,02 €**
	IRR	20,01%																									
	NPV	427.842,86 €																									
	PAYBACK	4,37 years	4,42 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 2: TP2																										
	Equipment (€)	403.622,19 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
	Energy cost (natural gas) (€)		8.935,23 €	9.065,95 €	9.200,27 €	9.338,27 €	9.478,34 €	9.620,52 €	9.764,83 €	9.911,30 €	10.059,97 €	10.210,87 €	10.364,03 €	10.519,49 €	10.677,28 €	10.837,44 €	11.000,01 €	11.165,01 €	11.332,48 €	11.502,47 €	11.675,00 €	11.850,13 €	12.027,88 €	12.208,30 €	12.391,42 €	12.577,30 €	12.765,96 €
0,35%	Operation & Maintenance cost (€)		1.433,08 €	1.454,05 €	1.475,59 €	1.497,73 €	1.520,19 €	1.542,99 €	1.566,14 €	1.589,63 €	1.613,48 €	1.637,68 €	1.662,24 €	1.687,18 €	1.712,48 €	1.738,17 €	1.764,24 €	1.790,71 €	1.817,57 €	1.844,83 €	1.872,50 €	1.900,59 €	1.929,10 €	1.958,04 €	1.987,41 €	2.017,22 €	2.047,48 €
	TOTAL	**403.622,19 €**	**413.990,51 €**	**424.510,51 €**	**435.186,37 €**	**446.022,36 €**	**457.020,90 €**	**468.184,41 €**	**479.515,38 €**	**491.016,31 €**	**502.689,75 €**	**514.538,30 €**	**526.564,57 €**	**538.771,24 €**	**551.161,01 €**	**563.736,63 €**	**576.500,88 €**	**589.456,59 €**	**602.606,64 €**	**615.953,94 €**	**629.501,45 €**	**643.252,17 €**	**657.209,15 €**	**671.375,49 €**	**685.754,32 €**	**700.348,83 €**	**715.162,27 €**
			10.368,32 €																								
			-	-	-	-	-	-	-	-	-	-	-	0	1	2	3	4	5	6	7	8	9	10	11	11	12
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-340.883,32 €**	**-310.202,05 €**	**-279.066,24 €**	**-247.463,40 €**	**-215.386,51 €**	**-182.828,47 €**	**-149.782,05 €**	**-116.239,94 €**	**-82.194,70 €**	**-47.638,78 €**	**-12.564,53 €**	**23.035,85 €**	**59.170,22 €**	**95.846,62 €**	**165.573,16 €**	**203.358,09 €**	**241.709,81 €**	**280.636,79 €**	**320.147,68 €**	**360.251,24 €**	**400.956,35 €**	**442.272,03 €**	**484.207,45 €**	**526.771,90 €**	**569.974,82 €**
	CASH FLOW	**-403.622**	**30.238,87 €**	**30.681,27 €**	**31.135,81 €**	**31.602,85 €**	**32.076,89 €**	**32.558,04 €**	**33.046,41 €**	**33.542,11 €**	**34.045,24 €**	**34.555,92 €**	**35.074,26 €**	**35.600,37 €**	**36.134,38 €**	**36.676,39 €**	**37.226,54 €**	**37.784,94 €**	**38.351,71 €**	**38.926,99 €**	**39.510,89 €**	**40.103,56 €**	**40.705,11 €**	**41.315,69 €**	**41.935,42 €**	**42.564,45 €**	**43.202,92 €**
	IRR	6,97%																									
	NPV	89.913,72 €																									
	PAYBACK	11,35 years	11,11 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 3: TP3																										
	Equipment (€)	811.006,19 €																									
	Energy cost (electricity) (€)		209,77 €	212,84 €	215,99 €	219,23 €	222,52 €	225,86 €	229,24 €	232,68 €	236,17 €	239,71 €	243,31 €	246,96 €	250,66 €	254,42 €	258,24 €	262,11 €	266,05 €	270,04 €	274,09 €	278,20 €	282,37 €	286,61 €	290,91 €	295,27 €	299,70 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,50%	Operation & Maintenance cost (€)		4.113,61 €	4.173,79 €	4.235,62 €	4.299,16 €	4.363,64 €	4.429,10 €	4.495,54 €	4.562,97 €	4.631,41 €	4.700,88 €	4.771,40 €	4.842,97 €	4.915,61 €	4.989,35 €	5.064,19 €	5.140,15 €	5.217,25 €	5.295,51 €	5.374,94 €	5.455,57 €	5.537,40 €	5.620,46 €	5.704,77 €	5.790,34 €	5.877,20 €
	TOTAL	**811.006,19 €**	**815.329,56 €**	**819.716,19 €**	**824.167,80 €**	**828.686,18 €**	**833.272,35 €**	**837.927,30 €**	**842.652,08 €**	**847.447,73 €**	**852.315,31 €**	**857.255,91 €**	**862.270,62 €**	**867.360,55 €**	**872.526,83 €**	**877.770,60 €**	**883.093,03 €**	**888.495,29 €**	**893.978,59 €**	**899.544,14 €**	**905.193,17 €**	**910.926,93 €**	**916.746,71 €**	**922.653,78 €**	**928.649,45 €**	**934.735,06 €**	**940.911,96 €**
			4.323,37 €																								
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	2	3	4	5	6
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-742.222,38 €**	**-705.407,73 €**	**-668.047,68 €**	**-630.127,22 €**	**-591.637,96 €**	**-552.571,36 €**	**-512.918,75 €**	**-472.671,36 €**	**-431.820,26 €**	**-390.356,40 €**	**-348.270,57 €**	**-305.553,46 €**	**-262.195,59 €**	**-218.187,35 €**	**-141.018,99 €**	**-95.680,61 €**	**-49.662,15 €**	**-2.953,41 €**	**44.455,96 €**	**92.576,47 €**	**141.418,79 €**	**190.993,74 €**	**241.312,32 €**	**292.385,68 €**	**344.225,13 €**
	CASH FLOW	**-811.006**	**36.283,81 €**	**36.814,65 €**	**37.360,05 €**	**37.920,46 €**	**38.489,26 €**	**39.066,60 €**	**39.652,60 €**	**40.247,39 €**	**40.851,10 €**	**41.463,87 €**	**42.085,82 €**	**42.717,11 €**	**43.357,87 €**	**44.008,24 €**	**44.668,36 €**	**45.338,39 €**	**46.018,46 €**	**46.708,74 €**	**47.409,37 €**	**48.120,51 €**	**48.842,32 €**	**49.574,95 €**	**50.318,58 €**	**51.073,36 €**	**51.839,46 €**
	IRR	2,27%																									
	NPV	-218.809,32 €																									
	PAYBACK	18,06 years	18,60 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 4: TP4																										
	Equipment (€)	212.556,10 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,35%	Operation & Maintenance cost (€)		754,69 €	765,59 €	776,79 €	788,30 €	800,13 €	812,13 €	824,31 €	836,68 €	849,23 €	861,96 €	874,89 €	888,02 €	901,34 €	914,86 €	928,58 €	942,51 €	956,65 €	971,00 €	985,56 €	1.000,35 €	1.015,35 €	1.030,58 €	1.046,04 €	1.061,73 €	1.077,66 €
	TOTAL	**212.556,10 €**	**213.310,79 €**	**214.076,38 €**	**214.853,18 €**	**215.641,48 €**	**216.441,61 €**	**217.253,74 €**	**218.078,05 €**	**218.914,72 €**	**219.763,95 €**	**220.625,92 €**	**221.500,81 €**	**222.388,83 €**	**223.290,16 €**	**224.205,02 €**	**225.133,60 €**	**226.076,11 €**	**227.032,76 €**	**228.003,76 €**	**228.989,32 €**	**229.989,66 €**	**231.005,01 €**	**232.035,59 €**	**233.081,63 €**	**234.143,36 €**	**235.221,02 €**
			754,69 €																								
			-	-	-	-	0	1	2	3	3	4	5	6	7	8	9	10	11	12	13	14	14	15	16	17	17
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-140.203,60 €**	**-99.767,93 €**	**-58.733,05 €**	**-17.082,51 €**	**25.192,78 €**	**68.102,21 €**	**111.655,28 €**	**155.861,64 €**	**200.731,10 €**	**246.273,60 €**	**292.499,24 €**	**339.418,26 €**	**387.041,07 €**	**435.378,22 €**	**516.940,43 €**	**566.738,57 €**	**617.283,68 €**	**668.586,97 €**	**720.659,81 €**	**773.513,74 €**	**827.160,48 €**	**881.611,93 €**	**936.880,14 €**	**992.977,38 €**	**1.049.916,07 €**
	CASH FLOW	**-212.556**	**39.852,49 €**	**40.435,68 €**	**41.034,87 €**	**41.650,54 €**	**42.275,30 €**	**42.909,43 €**	**43.553,07 €**	**44.206,36 €**	**44.869,46 €**	**45.542,50 €**	**46.225,64 €**	**46.919,02 €**	**47.622,81 €**	**48.337,15 €**	**49.062,21 €**	**49.798,14 €**	**50.545,11 €**	**51.303,29 €**	**52.072,84 €**	**52.853,93 €**	**53.646,74 €**	**54.451,44 €**	**55.268,21 €**	**56.097,24 €**	**56.938,70 €**
	IRR	19,95%																									
	NPV	437.892,04 €																									
	PAYBACK	4,40 years	4,44 years																								



FINANCIAL FEASIBILITY ANALYSIS WITHIN 25 YEARS FOR VIRTUAL DEMONSTRATOR BUILDING 4
TERTIARY BUILDING IN ITALY
Total cost (€)
1.400.000 €
1.200.000 €
1.000.000 €
800.000 €
600.000 €
400.000 €
200.000 €
0 €
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Years
BASELINE SCENARIO
SCENARIO 1: TP1
SCENARIO 2: TP2
SCENARIO 3: TP3
SCENARIO 4: TP4

BUSINESS MODEL TERTIARY NETHERLANDS

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
IPC		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
IPC (Previsión GRUPO VEOLIA)		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
IPC Acumulado		1,4445%	2,9075%	4,3890%	5,8890%	7,3890%	8,8890%	10,3890%	11,8890%	13,3890%	14,8890%	16,3890%	17,8890%	19,3890%	20,8890%	22,3890%	23,8890%	25,3890%	26,8890%	28,3890%	29,8890%	31,3890%	32,8890%	34,3890%	35,8890%	37,3890%
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

BASELINE SCENARIO

	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Equipment (€)	13.000,00 €	1 x boiler + 6 x fan coils/splits														13.000,00 €										
	Energy cost (electricity) (€)		65,17 €	66,13 €	67,11 €	68,11 €	69,14 €	70,17 €	71,23 €	72,29 €	73,38 €	74,48 €	75,60 €	76,73 €	77,88 €	79,05 €	80,23 €	81,44 €	82,66 €	83,90 €	85,16 €	86,44 €	87,73 €	89,05 €	90,38 €	91,74 €	93,12 €
	Energy cost (natural gas) (€)		6.618,19 €	6.715,02 €	6.814,50 €	6.916,72 €	7.020,47 €	7.125,78 €	7.232,66 €	7.341,15 €	7.451,27 €	7.563,04 €	7.676,48 €	7.791,63 €	7.908,51 €	8.027,13 €	8.147,54 €	8.269,75 €	8.393,80 €	8.519,71 €	8.647,50 €	8.777,21 €	8.908,87 €	9.042,51 €	9.178,14 €	9.315,82 €	9.455,55 €
3,00%	Operation & Maintenance cost (€)		395,63 €	401,42 €	407,37 €	413,48 €	419,68 €	425,98 €	432,37 €	438,85 €	445,43 €	452,12 €	458,90 €	465,78 €	472,77 €	479,86 €	487,06 €	494,36 €	501,78 €	509,31 €	516,95 €	524,70 €	532,57 €	540,56 €	548,67 €	556,90 €	565,25 €
	TOTAL	**13.000,00 €**	**20.079,00 €**	**27.261,57 €**	**34.550,54 €**	**41.948,86 €**	**49.458,14 €**	**57.080,07 €**	**64.816,32 €**	**72.668,62 €**	**80.638,70 €**	**88.728,33 €**	**96.939,31 €**	**105.273,45 €**	**113.732,61 €**	**122.318,65 €**	**144.033,48 €**	**152.879,04 €**	**161.857,28 €**	**170.970,19 €**	**180.219,79 €**	**189.608,14 €**	**199.137,32 €**	**208.809,43 €**	**218.626,63 €**	**228.591,08 €**	**238.705,00 €**
			7.079,00 €																								

SCENARIO 1: TP1

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Equipment (€)	85.309,58 €																									
	Energy cost (electricity) (€)		175,95 €	178,53 €	181,17 €	183,89 €	186,65 €	189,45 €	192,29 €	195,17 €	198,10 €	201,07 €	204,09 €	207,15 €	210,26 €	213,41 €	216,61 €	219,86 €	223,16 €	226,51 €	229,91 €	233,35 €	236,85 €	240,41 €	244,01 €	247,67 €	251,39 €
	Energy cost (natural gas) (€)		2.115,71 €	2.146,66 €	2.178,46 €	2.211,14 €	2.244,31 €	2.277,97 €	2.312,14 €	2.346,82 €	2.382,03 €	2.417,76 €	2.454,02 €	2.490,83 €	2.528,19 €	2.566,12 €	2.604,61 €	2.643,68 €	2.683,33 €	2.723,58 €	2.764,44 €	2.805,90 €	2.847,99 €	2.890,71 €	2.934,07 €	2.978,08 €	3.022,76 €
0,25%	Operation & Maintenance cost (€)		216,35 €	219,52 €	222,77 €	226,11 €	229,51 €	232,95 €	236,44 €	239,99 €	243,59 €	247,24 €	250,95 €	254,72 €	258,54 €	262,41 €	266,35 €	270,35 €	274,40 €	278,52 €	282,69 €	286,94 €	291,24 €	295,61 €	300,04 €	304,54 €	309,11 €
	TOTAL	**85.309,58 €**	**87.817,59 €**	**90.362,30 €**	**92.944,70 €**	**95.565,85 €**	**98.226,31 €**	**100.926,68 €**	**103.667,55 €**	**106.449,54 €**	**109.273,25 €**	**112.139,32 €**	**115.048,39 €**	**118.001,08 €**	**120.998,07 €**	**124.040,02 €**	**127.127,59 €**	**130.261,48 €**	**133.442,37 €**	**136.670,98 €**	**139.948,02 €**	**143.274,21 €**	**146.650,30 €**	**150.077,02 €**	**153.555,15 €**	**157.085,45 €**	**160.668,71 €**
			2.508,02 €																								
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	3	4	5	6	7	8	8	9	10	11
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-67.738,59 €**	**-63.100,73 €**	**-58.394,16 €**	**-53.616,99 €**	**-48.768,17 €**	**-43.846,61 €**	**-38.851,23 €**	**-33.780,92 €**	**-28.634,55 €**	**-23.410,99 €**	**-18.109,07 €**	**-12.727,63 €**	**-7.265,46 €**	**-1.721,37 €**	**16.905,89 €**	**22.617,56 €**	**28.414,91 €**	**34.299,21 €**	**40.271,78 €**	**46.333,93 €**	**52.487,02 €**	**58.732,41 €**	**65.071,48 €**	**71.505,63 €**	**78.036,29 €**
	CASH FLOW	**-85.310**	**4.570,99 €**	**4.637,86 €**	**4.706,57 €**	**4.777,17 €**	**4.848,83 €**	**4.921,56 €**	**4.995,38 €**	**5.070,31 €**	**5.146,37 €**	**5.223,56 €**	**5.301,92 €**	**5.381,44 €**	**5.462,17 €**	**5.544,10 €**	**5.627,26 €**	**5.711,67 €**	**5.797,34 €**	**5.884,30 €**	**5.972,57 €**	**6.062,16 €**	**6.153,09 €**	**6.245,39 €**	**6.339,07 €**	**6.434,15 €**	**6.530,66 €**
	IRR	3,79%																									
	NPV	-10.705,41 €																									
	PAYBACK	14,31 years	15,53 years																								

SCENARIO 2: TP2

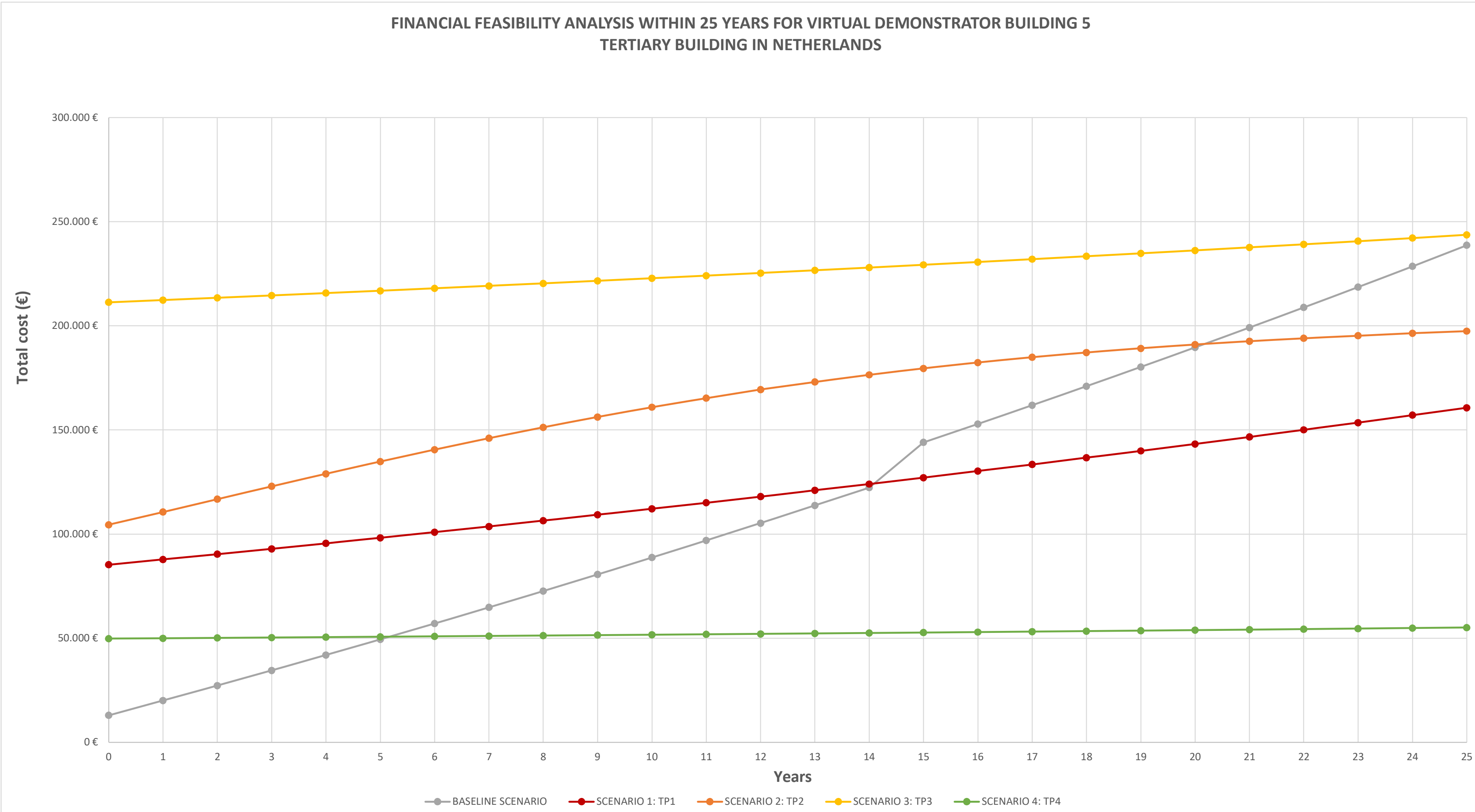
	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Equipment (€)	104.455,43 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
	Energy cost (natural gas) (€)		5.804,25 €	5.794,94 €	5.739,65 €	5.639,32 €	5.494,96 €	5.309,67 €	5.087,51 €	4.833,34 €	4.552,62 €	4.251,23 €	3.935,28 €	3.610,86 €	3.283,86 €	2.959,81 €	2.643,70 €	2.339,89 €	2.051,99 €	1.782,85 €	1.534,53 €	1.308,34 €	1.104,87 €	924,07 €	765,35 €	627,68 €	509,68 €
0,35%	Operation & Maintenance cost (€)		370,88 €	376,30 €	381,88 €	387,60 €	393,42 €	399,32 €	405,31 €	411,39 €	417,56 €	423,82 €	430,18 €	436,63 €	443,18 €	449,83 €	456,58 €	463,43 €	470,38 €	477,43 €	484,59 €	491,86 €	499,24 €	506,73 €	514,33 €	522,05 €	529,88 €
	TOTAL	**104.455,43 €**	**110.630,56 €**	**116.801,79 €**	**122.923,32 €**	**128.950,25 €**	**134.838,62 €**	**140.547,61 €**	**146.040,42 €**	**151.285,15 €**	**156.255,33 €**	**160.930,38 €**	**165.295,85 €**	**169.343,34 €**	**173.070,38 €**	**176.480,01 €**	**179.580,29 €**	**182.383,60 €**	**184.905,97 €**	**187.166,25 €**	**189.185,37 €**	**190.985,58 €**	**192.589,69 €**	**194.020,49 €**	**195.300,17 €**	**196.449,90 €**	**197.489,45 €**
			6.175,12 €																								
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1	2	3	4
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-90.551,56 €**	**-89.540,23 €**	**-88.372,78 €**	**-87.001,39 €**	**-85.380,48 €**	**-83.467,54 €**	**-81.224,10 €**	**-78.616,53 €**	**-75.616,63 €**	**-72.202,05 €**	**-68.356,53 €**	**-64.069,88 €**	**-59.337,77 €**	**-54.161,36 €**	**-35.546,81 €**	**-29.504,56 €**	**-23.048,69 €**	**-16.196,06 €**	**-8.965,58 €**	**-1.377,44 €**	**6.547,63 €**	**14.788,94 €**	**23.326,45 €**	**32.141,18 €**	**41.215,55 €**
	CASH FLOW	**-104.455**	**903,88 €**	**1.011,33 €**	**1.167,45 €**	**1.371,39 €**	**1.620,91 €**	**1.912,94 €**	**2.243,44 €**	**2.607,57 €**	**2.999,91 €**	**3.414,58 €**	**3.845,52 €**	**4.286,65 €**	**4.732,11 €**	**5.176,40 €**	**5.614,56 €**	**6.042,24 €**	**6.455,87 €**	**6.852,63 €**	**7.230,48 €**	**7.588,14 €**	**7.925,06 €**	**8.241,31 €**	**8.537,51 €**	**8.814,73 €**	**9.074,37 €**
	IRR	0,81%																									
	NPV	-49.986,04 €																									
	PAYBACK	20,17 years	21,82 years																								

SCENARIO 3: TP3

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Equipment (€)	211.303,43 €																									
	Energy cost (electricity) (€)		6,46 €	6,56 €	6,65 €	6,75 €	6,85 €	6,96 €	7,06 €	7,17 €	7,27 €	7,38 €	7,49 €	7,61 €	7,72 €	7,84 €	7,95 €	8,07 €	8,19 €	8,32 €	8,44 €	8,57 €	8,70 €	8,83 €	8,96 €	9,09 €	9,23 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,50%	Operation & Maintenance cost (€)		1.071,78 €	1.087,46 €	1.103,57 €	1.120,12 €	1.136,92 €	1.153,98 €	1.171,29 €	1.188,86 €	1.206,69 €	1.224,79 €	1.243,16 €	1.261,81 €	1.280,74 €	1.299,95 €	1.319,45 €	1.339,24 €	1.359,33 €	1.379,72 €	1.400,41 €	1.421,42 €	1.442,74 €	1.464,38 €	1.486,35 €	1.508,64 €	1.531,27 €
	TOTAL	**211.303,43 €**	**212.381,67 €**	**213.475,69 €**	**214.585,91 €**	**215.712,78 €**	**216.856,56 €**	**218.017,50 €**	**219.195,85 €**	**220.391,87 €**	**221.605,84 €**	**222.838,01 €**	**224.088,67 €**	**225.358,08 €**	**226.646,54 €**	**227.954,33 €**	**229.281,73 €**	**230.629,04 €**	**231.996,56 €**	**233.384,60 €**	**234.793,45 €**	**236.223,44 €**	**237.674,88 €**	**239.148,09 €**	**240.643,40 €**	**242.161,14 €**	**243.701,64 €**
			1.078,24 €																								
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-192.302,67 €**	**-186.214,12 €**	**-180.035,36 €**	**-173.763,93 €**	**-167.398,42 €**	**-160.937,43 €**	**-154.379,53 €**	**-147.723,25 €**	**-140.967,14 €**	**-134.109,68 €**	**-127.149,36 €**	**-120.084,63 €**	**-112.913,93 €**	**-105.635,68 €**	**-85.248,24 €**	**-77.750,00 €**	**-70.139,29 €**	**-62.414,41 €**	**-54.573,66 €**	**-46.615,30 €**	**-38.537,56 €**	**-30.338,66 €**	**-22.016,77 €**	**-13.570,06 €**	**-4.996,64 €**
	CASH FLOW	**-211.303**	**6.000,76 €**	**6.088,55 €**	**6.178,75 €**	**6.271,44 €**	**6.365,51 €**	**6.460,99 €**	**6.557,90 €**	**6.656,27 €**	**6.756,12 €**	**6.857,46 €**	**6.960,32 €**	**7.064,73 €**	**7.170,70 €**	**7.278,26 €**	**7.387,43 €**	**7.498,24 €**	**7.610,72 €**	**7.724,88 €**	**7.840,75 €**	**7.958,36 €**	**8.077,74 €**	**8.198,90 €**	**8.321,89 €**	**8.446,71 €**	**8.573,42 €**
	IRR	-1,12%																									
	NPV	-113.363,56 €																									
	PAYBACK	#REF!	29,30 years																								

SCENARIO 4: TP4

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Equipment (€)	49.783,13 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,35%	Operation & Maintenance cost (€)		176,76 €	179,31 €	181,93 €	184,63 €	187,40 €	190,21 €	193,06 €	195,96 €	198,90 €	201,88 €	204,91 €	207,98 €	211,10 €	214,27 €	217,48 €	220,75 €	224,06 €	227,42 €	230,83 €	234,29 €	237,81 €	241,37 €	244,99 €	248,67 €	252,40 €
	TOTAL	**49.783,13 €**	**49.959,88 €**	**50.139,19 €**	**50.321,13 €**	**50.505,76 €**	**50.693,16 €**	**50.883,37 €**	**51.076,43 €**	**51.272,39 €**	**51.471,29 €**	**51.673,17 €**	**51.878,08 €**	**52.086,07 €**	**52.297,17 €**	**52.511,44 €**	**52.728,92 €**	**52.949,67 €**	**53.173,73 €**	**53.401,15 €**	**53.631,98 €**	**53.866,27 €**	**54.104,08 €**	**54.345,45 €**	**54.590,45 €**	**54.839,12 €**	**55.091,52 €**
			176,76 €																								
			-	-	-	-	-	0	1	2	3	4	5	6	6	7	8	11	11	12	13	14	15	15	16	17	18
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-29.880,88 €**	**-22.877,63 €**	**-15.770,58 €**	**-8.556,90 €**	**-1.235,02 €**	**6.196,70 €**	**13.739,89 €**	**21.396,23 €**	**29.167,41 €**	**37.055,16 €**	**45.061,23 €**	**53.187,39 €**	**61.435,44 €**	**69.807,21 €**	**91.304,56 €**	**99.929,37 €**	**108.683,55 €**	**117.569,04 €**	**126.587,82 €**	**135.741,87 €**	**145.033,24 €**	**154.463,98 €**	**164.036,18 €**	**173.751,96 €**	**183.613,48 €**
	CASH FLOW	**-49.783**	**6.902,24 €**	**7.003,26 €**	**7.107,04 €**	**7.213,68 €**	**7.321,89 €**	**7.431,71 €**	**7.543,19 €**	**7.656,34 €**	**7.771,18 €**	**7.887,75 €**	**8.006,07 €**	**8.126,16 €**	**8.248,05 €**	**8.371,77 €**	**8.497,35 €**	**8.624,81 €**	**8.754,18 €**	**8.885,49 €**	**9.018,78 €**	**9.154,06 €**	**9.291,37 €**	**9.430,74 €**	**9.572,20 €**	**9.715,78 €**	**9.861,52 €**
	IRR	14,71%																									
	NPV	62.871,45 €																									
	PAYBACK	5,17 years	6,00 years																								


FINANCIAL FEASIBILITY ANALYSIS WITHIN 25 YEARS FOR VIRTUAL DEMONSTRATOR BUILDING 5
TERTIARY BUILDING IN NETHERLANDS
Total cost (€)
300.000 €
250.000 €
200.000 €
150.000 €
100.000 €
50.000 €
0 €
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Years
BASELINE SCENARIO
SCENARIO 1: TP1
SCENARIO 2: TP2
SCENARIO 3: TP3
SCENARIO 4: TP4

BUSINESS MODEL TERTIARY SWEDEN

	IPC		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
	IPC (Previsión GRUPO VEOLIA)		1,4445%	1,4630%	1,4815%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%	1,5000%
	IPC Acumulado		1,4445%	2,9075%	4,3890%	5,8890%	7,3890%	8,8890%	10,3890%	11,8890%	13,3890%	14,8890%	16,3890%	17,8890%	19,3890%	20,8890%	22,3890%	23,8890%	25,3890%	26,8890%	28,3890%	29,8890%	31,3890%	32,8890%	34,3890%	35,8890%	37,3890%
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

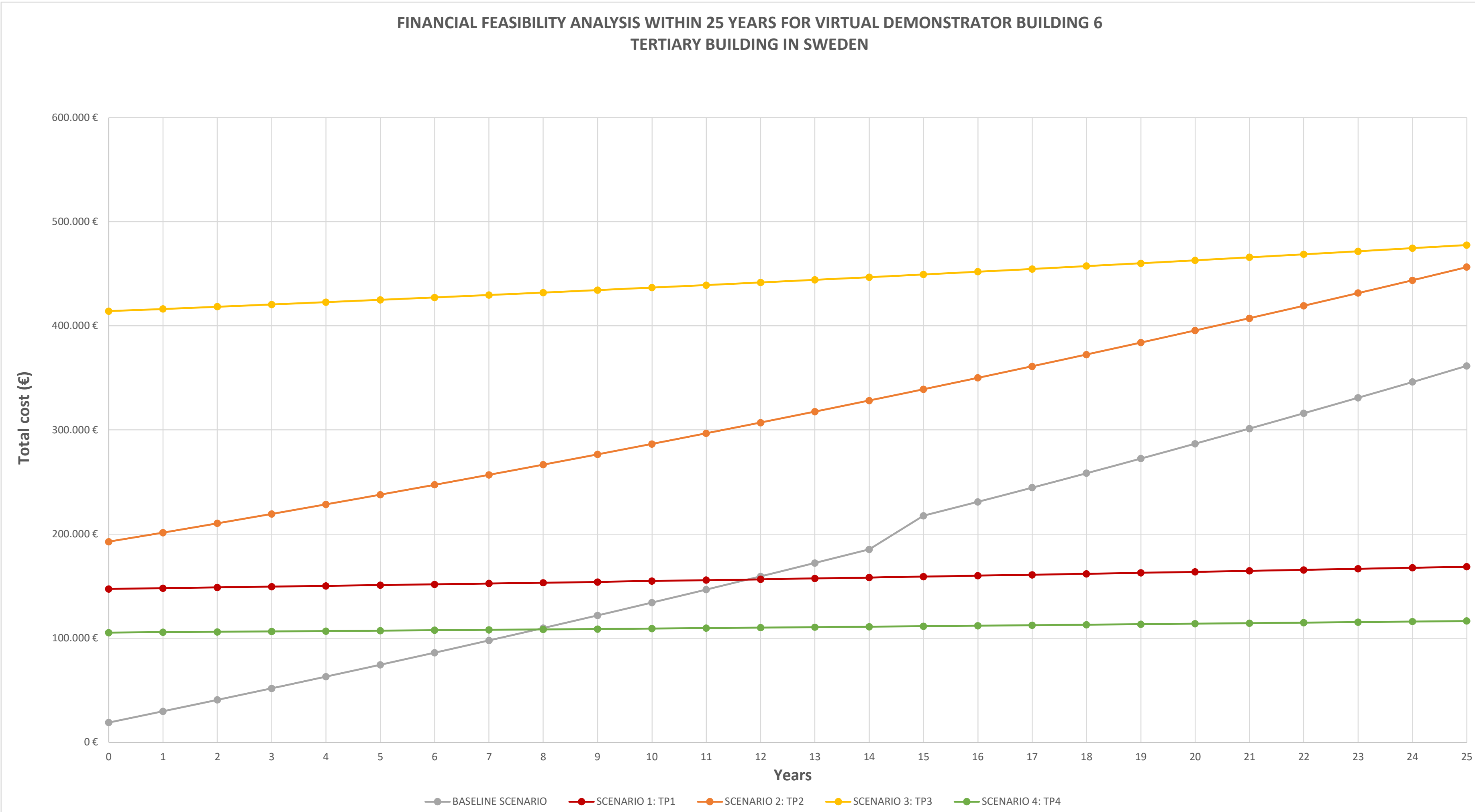
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	BASELINE SCENARIO																										
	Equipment (€)	19.000,00 €	1 x boiler + 6 x fan coils/splits														19.000,00 €										
	Energy cost (electricity) (€)		251,11 €	254,78 €	258,56 €	262,43 €	266,37 €	270,37 €	274,42 €	278,54 €	282,72 €	286,96 €	291,26 €	295,63 €	300,06 €	304,56 €	309,13 €	313,77 €	318,48 €	323,25 €	328,10 €	333,02 €	338,02 €	343,09 €	348,24 €	353,46 €	358,76 €
	Energy cost (natural gas) (€)		9.937,42 €	10.082,80 €	10.232,18 €	10.385,66 €	10.541,45 €	10.699,57 €	10.860,06 €	11.022,96 €	11.188,31 €	11.356,13 €	11.526,47 €	11.699,37 €	11.874,86 €	12.052,99 €	12.233,78 €	12.417,29 €	12.603,55 €	12.792,60 €	12.984,49 €	13.179,26 €	13.376,94 €	13.577,60 €	13.781,26 €	13.987,98 €	14.197,80 €
3,00%	Operation & Maintenance cost (€)		578,23 €	586,69 €	595,39 €	604,32 €	613,38 €	622,58 €	631,92 €	641,40 €	651,02 €	660,79 €	670,70 €	680,76 €	690,97 €	701,33 €	711,85 €	722,53 €	733,37 €	744,37 €	755,54 €	766,87 €	778,37 €	790,05 €	801,90 €	813,93 €	826,13 €
	TOTAL	**19.000,00 €**	**29.766,76 €**	**40.691,04 €**	**51.777,16 €**	**63.029,57 €**	**74.450,77 €**	**86.043,28 €**	**97.809,69 €**	**109.752,59 €**	**121.874,63 €**	**134.178,50 €**	**146.666,94 €**	**159.342,69 €**	**172.208,59 €**	**185.267,47 €**	**217.522,24 €**	**230.975,83 €**	**244.631,22 €**	**258.491,44 €**	**272.559,57 €**	**286.838,72 €**	**301.332,05 €**	**316.042,79 €**	**330.974,19 €**	**346.129,55 €**	**361.512,25 €**
			10.766,76 €																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 1: TP1																										
	Equipment (€)	147.301,38 €																									
	Energy cost (electricity) (€)		25,71 €	26,09 €	26,47 €	26,87 €	27,27 €	27,68 €	28,10 €	28,52 €	28,95 €	29,38 €	29,82 €	30,27 €	30,72 €	31,18 €	31,65 €	32,13 €	32,61 €	33,10 €	33,59 €	34,10 €	34,61 €	35,13 €	35,65 €	36,19 €	36,73 €
	Energy cost (natural gas) (€)		311,64 €	316,20 €	320,88 €	325,69 €	330,58 €	335,54 €	340,57 €	345,68 €	350,87 €	356,13 €	361,47 €	366,89 €	372,40 €	377,98 €	383,65 €	389,41 €	395,25 €	401,18 €	407,19 €	413,30 €	419,50 €	425,79 €	432,18 €	438,66 €	445,24 €
0,25%	Operation & Maintenance cost (€)		373,57 €	379,04 €	384,65 €	390,42 €	396,28 €	402,22 €	408,26 €	414,38 €	420,60 €	426,91 €	433,31 €	439,81 €	446,41 €	453,10 €	459,90 €	466,80 €	473,80 €	480,91 €	488,12 €	495,44 €	502,87 €	510,42 €	518,07 €	525,84 €	533,73 €
	TOTAL	**147.301,38 €**	**148.012,30 €**	**148.733,62 €**	**149.465,62 €**	**150.208,61 €**	**150.962,74 €**	**151.728,19 €**	**152.505,12 €**	**153.293,70 €**	**154.094,10 €**	**154.906,52 €**	**155.731,12 €**	**156.568,09 €**	**157.417,61 €**	**158.279,88 €**	**159.155,08 €**	**160.043,41 €**	**160.945,07 €**	**161.860,25 €**	**162.789,15 €**	**163.732,00 €**	**164.688,98 €**	**165.660,32 €**	**166.646,22 €**	**167.646,92 €**	**168.662,63 €**
			710,92 €																								
			-	-	-	-	-	-	-	-	-	-	-	1	0	1	2	5	6	6	7	8	9	10	11	12	12
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-118.245,54 €**	**-108.042,58 €**	**-97.688,47 €**	**-87.179,04 €**	**-76.511,98 €**	**-65.684,91 €**	**-54.695,43 €**	**-43.541,11 €**	**-32.219,47 €**	**-20.728,01 €**	**-9.064,18 €**	**2.774,60 €**	**14.790,97 €**	**26.987,59 €**	**58.367,16 €**	**70.932,41 €**	**83.686,15 €**	**96.631,20 €**	**109.770,41 €**	**123.106,72 €**	**136.643,07 €**	**150.382,47 €**	**164.327,96 €**	**178.482,63 €**	**192.849,62 €**
	CASH FLOW	-147.301	**10.055,84 €**	**10.202,96 €**	**10.354,11 €**	**10.509,42 €**	**10.667,07 €**	**10.827,07 €**	**10.989,48 €**	**11.154,32 €**	**11.321,63 €**	**11.491,46 €**	**11.663,83 €**	**11.838,79 €**	**12.016,37 €**	**12.196,62 €**	**12.379,57 €**	**12.565,26 €**	**12.753,74 €**	**12.945,04 €**	**13.139,22 €**	**13.336,31 €**	**13.536,35 €**	**13.739,40 €**	**13.945,49 €**	**14.154,67 €**	**14.366,99 €**
	IRR	6,04%																									
	NPV	16.822,39 €																									
	PAYBACK	11,77 years	12,19 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 2: TP2																										
	Equipment (€)	192.659,33 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
	Energy cost (natural gas) (€)		8.092,84 €	8.211,23 €	8.332,88 €	8.457,88 €	8.584,75 €	8.713,52 €	8.844,22 €	8.976,88 €	9.111,54 €	9.248,21 €	9.386,93 €	9.527,74 €	9.670,65 €	9.815,71 €	9.962,95 €	10.112,39 €	10.264,08 €	10.418,04 €	10.574,31 €	10.732,92 €	10.893,92 €	11.057,33 €	11.223,19 €	11.391,53 €	11.562,41 €
0,35%	Operation & Maintenance cost (€)		684,05 €	694,06 €	704,34 €	714,90 €	725,63 €	736,51 €	747,56 €	758,77 €	770,15 €	781,71 €	793,43 €	805,33 €	817,41 €	829,67 €	842,12 €	854,75 €	867,57 €	880,59 €	893,79 €	907,20 €	920,81 €	934,62 €	948,64 €	962,87 €	977,31 €
	TOTAL	**192.659,33 €**	**201.436,21 €**	**210.341,50 €**	**219.378,72 €**	**228.551,50 €**	**237.861,88 €**	**247.311,90 €**	**256.903,68 €**	**266.639,34 €**	**276.521,03 €**	**286.550,94 €**	**296.731,31 €**	**307.064,38 €**	**317.552,44 €**	**328.197,83 €**	**339.002,89 €**	**349.970,04 €**	**361.101,69 €**	**372.400,31 €**	**383.868,42 €**	**395.508,54 €**	**407.323,27 €**	**419.315,22 €**	**431.487,05 €**	**443.841,45 €**	**456.381,17 €**
			8.776,88 €																								
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-171.669,45 €**	**-169.650,47 €**	**-167.601,57 €**	**-165.521,94 €**	**-163.411,11 €**	**-161.268,62 €**	**-159.094,00 €**	**-156.886,75 €**	**-154.646,40 €**	**-152.372,44 €**	**-150.064,37 €**	**-147.721,68 €**	**-145.343,85 €**	**-142.930,35 €**	**-121.480,65 €**	**-118.994,21 €**	**-116.470,47 €**	**-113.908,87 €**	**-111.308,85 €**	**-108.669,82 €**	**-105.991,22 €**	**-103.272,43 €**	**-100.512,86 €**	**-97.711,90 €**	**-94.868,92 €**
	CASH FLOW	-192.659	**1.989,87 €**	**2.018,99 €**	**2.048,90 €**	**2.079,63 €**	**2.110,83 €**	**2.142,49 €**	**2.174,63 €**	**2.207,25 €**	**2.240,35 €**	**2.273,96 €**	**2.308,07 €**	**2.342,69 €**	**2.377,83 €**	**2.413,50 €**	**2.449,70 €**	**2.486,45 €**	**2.523,74 €**	**2.561,60 €**	**2.600,02 €**	**2.639,02 €**	**2.678,61 €**	**2.718,79 €**	**2.759,57 €**	**2.800,96 €**	**2.842,98 €**
	IRR	-7,22%																									
	NPV	-160.182,10 €																									
	PAYBACK	#REF!	80,56 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 3: TP3																										
	Equipment (€)	414.099,33 €																									
	Energy cost (electricity) (€)		12,49 €	12,67 €	12,86 €	13,05 €	13,25 €	13,45 €	13,65 €	13,86 €	14,06 €	14,27 €	14,49 €	14,71 €	14,93 €	15,15 €	15,38 €	15,61 €	15,84 €	16,08 €	16,32 €	16,57 €	16,81 €	17,07 €	17,32 €	17,58 €	17,85 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,50%	Operation & Maintenance cost (€)		2.100,40 €	2.131,13 €	2.162,71 €	2.195,15 €	2.228,07 €	2.261,50 €	2.295,42 €	2.329,85 €	2.364,80 €	2.400,27 €	2.436,27 €	2.472,82 €	2.509,91 €	2.547,56 €	2.585,77 €	2.624,56 €	2.663,93 €	2.703,89 €	2.744,44 €	2.785,61 €	2.827,39 €	2.869,81 €	2.912,85 €	2.956,55 €	3.000,89 €
	TOTAL	**414.099,33 €**	**416.212,22 €**	**418.356,03 €**	**420.531,60 €**	**422.739,80 €**	**424.981,13 €**	**427.256,07 €**	**429.565,14 €**	**431.908,85 €**	**434.287,71 €**	**436.702,25 €**	**439.153,01 €**	**441.640,53 €**	**444.165,37 €**	**446.728,08 €**	**449.329,23 €**	**451.969,39 €**	**454.649,16 €**	**457.369,13 €**	**460.129,89 €**	**462.932,07 €**	**465.776,28 €**	**468.663,15 €**	**471.593,33 €**	**474.567,45 €**	**477.586,19 €**
			2.112,90 €																								
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-386.445,46 €**	**-377.665,00 €**	**-368.754,44 €**	**-359.710,23 €**	**-350.530,36 €**	**-341.212,79 €**	**-331.755,45 €**	**-322.156,26 €**	**-312.413,08 €**	**-302.523,75 €**	**-292.486,08 €**	**-282.297,84 €**	**-271.956,78 €**	**-261.460,61 €**	**-231.806,99 €**	**-220.993,57 €**	**-210.017,94 €**	**-198.877,69 €**	**-187.570,32 €**	**-176.093,35 €**	**-164.444,23 €**	**-152.620,36 €**	**-140.619,14 €**	**-128.437,90 €**	**-116.073,94 €**
	CASH FLOW	-414.099	**8.653,86 €**	**8.780,47 €**	**8.910,55 €**	**9.044,21 €**	**9.179,87 €**	**9.317,57 €**	**9.457,33 €**	**9.599,19 €**	**9.743,18 €**	**9.889,33 €**	**10.037,67 €**	**10.188,24 €**	**10.341,06 €**	**10.496,17 €**	**10.653,62 €**	**10.813,42 €**	**10.975,62 €**	**11.140,26 €**	**11.307,36 €**	**11.476,97 €**	**11.649,13 €**	**11.823,86 €**	**12.001,22 €**	**12.181,24 €**	**12.363,96 €**
	IRR	-3,14%																									
	NPV	-272.857,54 €																									
	PAYBACK	#REF!	39,81 years																								

	PV degradation	0,00%	0,80%	1,60%	2,40%	3,20%	4,00%	4,80%	5,60%	6,40%	7,20%	8,00%	8,80%	9,60%	10,40%	11,20%	12,00%	12,80%	13,60%	14,40%	15,20%	16,00%	16,80%	17,60%	18,40%	19,20%	20,00%
	Year	0 (Initial Investment)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SCENARIO 4: TP4																										
	Equipment (€)	105.307,47 €																									
	Energy cost (electricity) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
	Energy cost (natural gas) (€)		0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €	0,00 €
0,35%	Operation & Maintenance cost (€)		373,90 €	379,30 €	384,85 €	390,55 €	396,41 €	402,36 €	408,39 €	414,52 €	420,74 €	427,05 €	433,45 €	439,95 €	446,55 €	453,25 €	460,05 €	466,95 €	473,96 €	481,06 €	488,28 €	495,60 €	503,04 €	510,58 €	518,24 €	526,02 €	533,91 €
	TOTAL	**105.307,47 €**	**105.681,37 €**	**106.060,67 €**	**106.445,52 €**	**106.836,08 €**	**107.232,49 €**	**107.634,84 €**	**108.043,23 €**	**108.457,75 €**	**108.878,49 €**	**109.305,53 €**	**109.738,99 €**	**110.178,94 €**	**110.625,49 €**	**111.078,74 €**	**111.538,80 €**	**112.005,75 €**	**112.479,70 €**	**112.960,77 €**	**113.449,05 €**	**113.944,65 €**	**114.447,69 €**	**114.958,27 €**	**115.476,52 €**	**116.002,53 €**	**116.536,44 €**
			373,90 €																								
			-	-	-	-	-	-	-	1	0	1	2	3	4	5	6	8	9	10	11	12	12	13	14	15	15
	Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SAVINGS		**-75.914,61 €**	**-65.369,64 €**	**-54.668,37 €**	**-43.806,51 €**	**-32.781,72 €**	**-21.591,56 €**	**-10.233,55 €**	**1.294,83 €**	**12.996,14 €**	**24.872,97 €**	**36.927,95 €**	**49.163,75 €**	**61.583,10 €**	**74.188,73 €**	**105.983,45 €**	**118.970,08 €**	**132.151,52 €**	**145.530,68 €**	**159.110,52 €**	**172.894,07 €**	**186.884,36 €**	**201.084,51 €**	**215.497,67 €**	**230.127,02 €**	**244.975,81 €**
	CASH FLOW	-105.307	**10.392,86 €**	**10.544,98 €**	**10.701,27 €**	**10.861,86 €**	**11.024,79 €**	**11.190,16 €**	**11.358,01 €**	**11.528,38 €**	**11.701,31 €**	**11.876,83 €**	**12.054,98 €**	**12.235,80 €**	**12.419,34 €**	**12.605,63 €**	**12.794,72 €**	**12.986,64 €**	**13.181,44 €**	**13.379,16 €**	**13.579,85 €**	**13.783,54 €**	**13.990,30 €**	**14.200,15 €**	**14.413,15 €**	**14.629,35 €**	**14.848,79 €**
	IRR	10,06%																									
	NPV	64.319,84 €																									
	PAYBACK	7,89 years	8,43 years																								


FINANCIAL FEASIBILITY ANALYSIS WITHIN 25 YEARS FOR VIRTUAL DEMONSTRATOR BUILDING 6
TERTIARY BUILDING IN SWEDEN
600.000 €
500.000 €
400.000 €
300.000 €
200.000 €
100.000 €
0 €
Total cost (€)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Years
BASELINE SCENARIO
SCENARIO 1: TP1
SCENARIO 2: TP2
SCENARIO 3: TP3
SCENARIO 4: TP4

Sunhorizon project/ Building legal requirements survey

Fields marked with * are mandatory.

Dear Respondent,

This survey is proposed in the context of the project " SunHorizon - Sun coupled innovative Heat Pumps (HP)" funded by European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement No 818329 to integrate solar and heat pumps technology with the following objectives:

- cover the whole Heating & Cooling (H&C) demand of the building
- maximize solar self-consumption
- guarantee adequate internal comfort

The questionnaire aims at investigating legal aspects for the replication of SunHorizon technologies (Heat Pumps and solar thermal integration).

The survey will not take you more than 20 minutes!

Thank you in advance for your time!

Privacy Policy:
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* I have read and agree to the SunHorizon Survey Privacy Policy.
- [ ] Yes
- [ ] No

* Where is your company/organization located? (please select the country and specify the city)

* Single Choice Question
- ○ AT - Austria
- ○ BE - Belgium
- ○ BG - Bulgaria
- ○ HR - Croatia
- ○ CY - Cyprus
- ○ CZ - Czechia
- ○ DK - Denmark
- ○ EE - Estonia
- ○ FI - Finland
- ○ FR - France
- ○ DE - Germany
- ○ EL - Greece
- ○ HU - Hungary
- ○ IE - Ireland
- ○ IT - Italy
- ○ LV - Latvia
- ○ LT - Lithuania
- ○ LU - Luxembourg
- ○ MT - Malta
- ○ NL - Netherlands
- ○ PL - Poland
- ○ PT - Portugal
- ○ RO - Romania
- ○ SK - Slovak Republic
- ○ SI - Slovenia
- ○ ES - Spain
- ○ SE - Sweden

* In which one of the following cities of the pilot sites of Sunhorizon project are you participating if any?
- [ ] 1-Berlin (Germany)
- [ ] 2-Nürnberg (Germany)

- [ ] 3- Verviers (Belgium)
- [ ] 4- Riga (Latvia)
- [ ] 5- Sant Cugat (Spain)
- [ ] 6- Madrid (Spain)
- [ ] 7- San Lorenzo (Spain)
- [ ] 8- None of them.

* What gender do you identify as?

- [ ] Male
- [ ] Female
- [ ] I indetify as other
- [ ] Prefer not to answer

* What is your age?

- [ ] 15-30
- [ ] 30-45
- [ ] 45+
- [ ] Prefer not to answer

* Which category are you indentify by?

- [ ] Employee for a company that works on similar SunHorizon technology (heat pumps, solar panels, thermal energy storages)
- [ ] University
- [ ] Owner of private building
- [ ] Small Medium Enterprise (SMEs)
- [ ] Owner of public building
- [ ] Building resident (end-user)
- [ ] Third party building user (end-user)
- [ ] Research body
- [ ] Other

* Can you explain the previows answer as "Other" if corresponds?

Analysis of self photovoltaic consumption (local use of PV electricty in order to reduce the buying of electricity from other producers)

By clicking the simbol **?** after each question you will find Sant Cugat partner answers to legal building requirements in Spain, Catalonia and Sant Cugat for a better comprehension of the questionaire.

* 1-Existing **COUNTRY/REGION** level mechanisms supporting the PV self-consumption of electricity in (please add the link of the regulation) ?

* 2- Which modalities of PV self-consumption are defined in your country ?

- ☐ - Self-consumption without surplus
- ☐ - Self-consumption with surpluses receiving compensation
- ☐ - Self-consumption with surpluses without compensation
- ☐ - Other.

* Can you explain the previows answer as "Other" if corresponds?

* 3-Which modalities are defined in your country for the access and connection permission to the grid?

- ☐ - Self-consumption without surplus
- ☐ - Self-consumption facilities with surpluses, with power installed ≤15 kW located in urban areas.
- ☐ - Self-consumption facilities with surpluses which are excluded in the conditions of the point above.
- ☐ - Other

* Can you explain the previows answer as "Other" if corresponds?

* 4- Which is the mechanism compensation of excess PV electricity with the energy supplier depending on the self consumption modality?

- ☐ Net metering: energetic compensation (credit in kWH)
- ☐ Net billing: monetary compensation (credit in monetry unit)
- ☐ Self-consumption: real time (e.g. 15 minutes)
- ☐ Net metering and net billing: time frame is typically one year althoguh there are some exceptions (from credits that can be rolled over the following billing cycle to quarterly compensation)
- ☐ Geographical compensation
- ☐ Other

* Can you explain the previows answer as "Other" if corresponds?

Related to legal requirements in Energy Efficiency and % of RES mandatory in buildings

EUROPE:

- EPBD (Energy Performance of Building Directive) Directive 2010/31/EU. Ongoing EPBD review.
- Energy Efficiency Directive 2018/2002/EU amending Directive 2012/27/ EU.

* 5-Which is the **COUNTRY/REGION/LOCAL** regulation that establishes the requirements in energy efficiency and renewable energies that must be pursue in new buildings and refurbishment of existing buildings (please add the link of the regulation)?

* 6-What is the minimum % of **SOLAR THERMAL** energy required in new or rehabilitated buildings in your **COUNTRY/REGION/LOCAL** regulations (please add the link of the regulation)?

* 7-What is the minimum % of **other RES** required in your **COUNTRY/REGION** in **new** buildings?

Architectural / Aesthetical building restrictions

* 8-Existing **COUNTRY/REGION/LOCAL** mechanisms to control architectural or aesthetical restrictions in existing or new buildings?

Thermal comfort building requirements

EUROPE- Directive (EU) 2018/2002 of the European Parliament and of the Council of December 11, 2018 amending Directive 2012/27 / EU on energy efficiency

* 9-Which is the **COUNTRY** regulation that establishes comfort requirements in **temperature and humidity i** n existing and new buildings?

Presence or support of incentives for energy self consumption and RES

EUROPE:
UE Recovery, Transformation and Resilience Plan- **Next Generation grants**

* 10- Do you have specific **economic incentives** for self consumption and RES in your country?

Conclusions

Do you think other legal aspects could be investigated? If yes, please indicated them in the box below and comment the actual status on this in your country.

Useful links

Sunhorizon website (https://sunhorizon-project.eu/)

Contact

martaoliver@santcugat.cat

B. Bibliography

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- Tabula buildings typology- country pages: https://episcope.eu/building-typology/country/
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- Sunhorizon project/ Building legal requirements survey: *https://ec.europa.eu/eusurvey/runner/SUNHORIZON-WP7-BLR-SURVEY2021-*
- International Journal of Environmental Research and Public Health-MDPI: Housing spaces in nine European countries-A comparison of dimensional requirements: *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8073340/*
- Eurostat Electricity Price statistics: *https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics*
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- INSPIRE report "D2.1A Survey on the energy needs and architectural features of the EU building stock": *https://inspire-fp7.eu/wp-content/uploads/2016/08/WP2_D2.1a_20140523_P18_Survey-on-the-energy-needs-and-architectural-features.pdf*
- Ecofys report "Panorama of the European non-residential construction sector, Final report": *http://leonardo-energy.pl/wp-content/uploads/2018/03/Europejski-sektor-budownictwa-niemieszkalnego.pdf*
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- International Renewable Energy Agency (IRENA), Business Models: Innovation Landscape: *https://www.irena.org/media/Files/IRENA/Agency/Publication/2020/Jul/IRENA_Business_Models_Collection_2020.pdf*
- S.P. Burger & M. Luke (2016). Business Models for Distributed Energy Resources: A Review and Empirical Analysis. Massachusetts Institute of Technology, MIT Energy Initiative and MIT Institute for Data, System and Society, Cambridge (Boston)