SOCIALWATT

CONNECTING

OBLIGATED PARTIES

TO ADOPT INNOVATIVE SCHEMES TOWARDS

ENERGY POVERTYALLEVIATION

D1.5

SocialWatt Decision Support Tools

August 2022

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

WWW.SOCIALWATT.EU

PREFACE

SocialWatt aims to develop and provide utilities and energy suppliers with appropriate tools for effectively engaging with their customers and working together towards alleviating energy poverty.
SocialWatt also enables obligated parties under Article 7 of the Energy Efficiency Directive across Europe to develop, adopt, test and spread innovative energy poverty schemes.

SocialWatt contributes to the following three main pillars:

1. Supporting utilities and energy suppliers contribute to the fight against energy poverty through the use of decision support tools.

2. Bridging the gap between energy companies and social services by promoting collaboration and implementing knowledge transfer and capacity building activities that focus on the development of schemes that invest in Renewable Energy Sources / Energy Efficiency to alleviate energy poverty.

3. Implementing and replicating innovative schemes to alleviate energy poverty.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

CONSORTIUM

ICCS	INSTITUTE OF COMMUNICATION & COMPUTER SYSTEMS	EL
IEECP	INSTITUTE FOR EUROPEAN ENERGY AND CLIMATE POLICY STICHTING	NL
RAP	REGULATORY ASSISTANCE PROJECT	BE
E7	E7 ENERGIE MARKT ANALYSE	AT
ISPE DC	ISPE PROIECTARE SI CONSULTANTA SA	RO
NATURGY	NATURGY ENERGY GROUP SA	ES
PPC	PUBLIC POWER CORPORATION S.A.	EL
CEZ VANZARE	CEZ VANZARE SA	RO
GREN	SIA GREN JELGAVA	LV
HEP ESCO	HEP - ESCO DOO ZA VODENJE I FINANCIRANJE PROJEKATA ENERGETSKE UCINKOVITOSTI	HR
EVISO	EVISO SRL	IT
EDP NEW	CNET CENTRE FOR NEW ENERGY TECHNOLOGIES SA	PT
CARITAS AUSTRIA	OSTERREICHISCHE CARITASZENTRALE	AT

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

CONNECTING OBLIGATED PARTIES TO ADOPT INNOVATIVE SCHEMES TOWARDS ENERGY POVERTY ALLEVIATION

GA#:	845905	**Start Date:**	September 2019
Topic:	LC-SC3-EC-2-2018	**Duration:**	43 Months
Type of Action:	CSA	**Coordinator:**	ICCS

Deliverable Number	D1.5
Deliverable Title	SocialWatt Decision Support Tools
Work Package Number	WP1
Task Number	Task 1.3
Date of Delivery	August 2022
Dissemination Level	Public
Work Package Leader	ICCS
Lead Beneficiary	ICCS
Contributors	Apostolis Arsenopoulos, Andriana Stavrakaki, Konstantinos Koasidis & Simos Ntanopoulos (ICCS)
Reviewer	John Psarras (ICCS)

Disclaimer

Copyright Message

Table of Contents

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Figures

The SocialWatt project has received funding from the European Union's Horizon 2020
Research and Innovation Programme under grant agreement No 845905

Tables

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Executive Summary

Within the framework of SocialWatt, three decision support tools have been developed to facilitate utilities' efforts to alleviate energy poverty. In particular, these user-friendly tools aim to facilitate utilities identify energy poor households, select the most appropriate energy efficiency and renewable energy actions, design targeted schemes that can be included under their energy efficiency obligation, monitor their effectiveness and evaluate their actual impact.

The purpose of this report is to present the three SocialWatt tools developed, i.e. SocialWatt Analyser, SocialWatt Plan and SocialWatt Check. It includes information regarding the modelling methodology of each tool, data requirements and resources, the development process, the interconnections between the tools, the testing and validation process and the tools configuration.

A manual for running the tools is also available, which includes step by step instructions for their use, as well as information on inputs required by each tool and outputs produced.[1]

[1] Apostolis Arsenopoulos, Andriana Stavrakaki, Panagiotis Kapsalis & Konstantinos Koasidis, *D3.3. Guidebook for the use of the SocialWatt tools*, 2022

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

1 INTRODUCTION

SocialWatt, a project funded by the EU's Horizon 2020 Research and Innovation Programme, aims to enable energy suppliers and utilities develop, adopt, implement and spread innovative energy poverty schemes across Europe. More specifically, the project aims to enable energy suppliers and utilities to build their capacity and use tools developed within the framework of the project to effectively engage with their customers and implement schemes that aim to alleviate energy poverty.

Three different decision support tools have been developed to facilitate utilities/energy companies alleviate energy poverty:

- SocialWatt Analyser for identifying energy poor households among clients, based on utilities/energy companies' real energy consumption and cost data, as well as other readily available data;
- SocialWatt Plan for evaluating the performance of several energy poverty schemes and actions, and selecting the optimal ones to be implemented (in terms of cost minimisation on the utilities/energy companies' end and energy savings maximisation); and
- SocialWatt Check for monitoring and assessing the effectiveness of schemes (being) implemented.

This report outlines the development process of the SocialWatt tools, and describes in detail each tool, including data requirements, key technical information related to the development of the SocialWatt tools (in terms of protocols, libraries, programming tools and methods0, and the interfaces developed for the SocialWatt tools, in order to help the user better delve into their functionalities and more easily use them.

In an attempt to ensure clarity throughout this report, the following terms, frequently used in this report, are defined:

Terminology

Energy poor households: People having difficulty maintaining an adequate level of energy services (e.g., heating, cooling, etc.) at an affordable cost. The term "energy poor households" is specified accordingly, based on the context and the energy poverty indicator that is used in each case.

Action (or Measure): A specific action targeting energy poor households that aims to alleviate energy poverty, by either triggering behaviour change or facilitating the implementation of energy efficiency interventions and/or increasing the uptake of renewable energy sources (RES). For instance, some indicative actions can be: the thermal insulation of a household's roof; the replacement of windows with double-glazed ones; and the replacement of the heating system of a household with a new gas-fired one.

Energy poverty scheme: An energy poverty scheme comprises one or more actions that can be implemented by utilities and energy suppliers, including obligated parties under Article 7 of the Energy Efficiency Directive (EED)[2]. For example, 'Greening Home' includes

[2] Directive 2018/2002 amending Directive 2012/27/EU

three actions and aims at improving a household's shell (i.e., roof insulation, exterior walls insulation and installation of double-pane windows).

Portfolio: A set of different energy poverty schemes (or part of schemes). Each set comprises a unique combination of actions that belong to different schemes, extracted from the SocialWatt Plan (i.e., through the optimisation process), with the aim to help utilities/energy companies select the most appropriate schemes and actions to implement, that meet their needs and requirements.

Energy Poverty Action Plan: An Energy Poverty Action Plan constitutes the 'roadmap' for effectively designing and implementing schemes to alleviate energy poverty.

1.1 Aim and Objectives of the Tools

Overall, the SocialWatt tools are a set of user-friendly decision support tools, with intelligible features to ensure ease of use. The three tools are designed to be used jointly, to support utilities/energy companies' efforts to alleviate energy poverty in an integrated manner. Nevertheless, these tools can also be used independently, to meet specific needs of users.

The connecting bridge between the first two tools (SocialWatt Analyser and SocialWatt Plan) lies in the total number of energy poor citizens. This figure can be extracted from SocialWatt Analyser, and be used as a target value in SocialWatt Plan, along with other input parameters, in order to define the final number of energy poor households to be engaged, in terms of optimal number of interventions to be implemented (one intervention per household is assumed). On the other hand, SocialWatt Check may use the optimal number of interventions, the energy savings and the renewable energy production (determined by SocialWatt Plan when considering, among other, cost, and maximum available budget, energy savings target, renewable energy production target, etc.) and monitor progress in the implementation of schemes. Figure 1 illustrates the interconnections between the tools.

Figure 1: The SocialWatt Tools

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

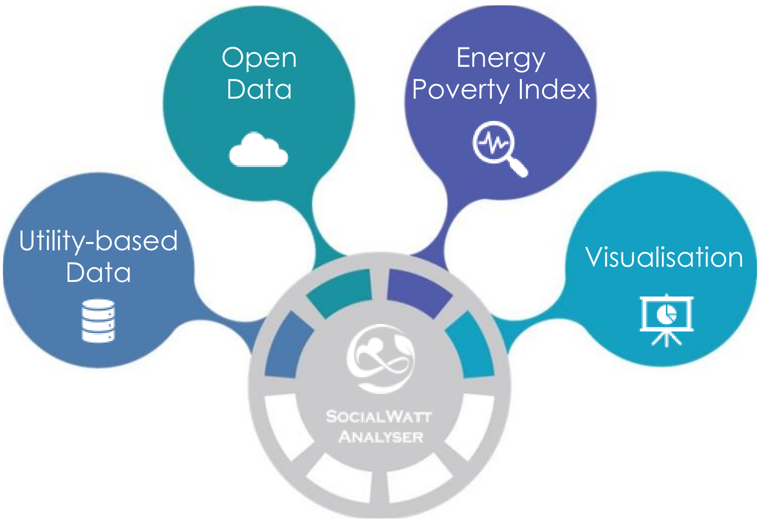
1.1.1 SOCIALWATT ANALYSER

The aim of SocialWatt Analyser is to help utilities/energy companies identify energy poor households among their clients in order to more effectively target and engage them.

The main driver behind the development of this tool lies in the lack of in-depth methodologies and numerical approaches for directly identifying energy poor households, so that they can benefit from targeted policies, rather than from indirect measures, focused on providing mainly financial incentives, which essentially do not deal effectively with the root of the problem.

Figure 2 presents an overview of the framework used for the development of the SocialWatt Analyser .

Figure 2: The SocialWatt Analyser concept



The development of the tool has considered three major implementation pillars:

- To provide in-depth information about energy poor households at national, regional and local level depending on input data;
- To enable utilities/energy companies identify energy poor households, using customer data collected and held internally, especially energy consumption and costs at household level, as well as diversified layers of information in terms of open data, such as climate data (e.g., climate zones) socioeconomic data (e.g., income), other customer data (e.g., arrears on utility bills), and comfort levels (energy needs); and
- To allow customisations, in terms of different input methods, data types and structures, and consequently facilitate utilities/energy companies (even those with limited expertise and technical skills on tools) to identify energy poor households. Functions for configuring the tool and appropriately adjusting its settings are built-in. For example the tool enables users to select different energy poverty indicators and to import income data at national, regional or local level, depending on available data.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

1.1.2 SocialWatt Plan

SocialWatt Plan aims to enable the evaluation of the performance and potential replicability of different actions considered to tackle energy poverty. This tool is intended to help utilities/users elaborate Energy Poverty Action Plans, by evaluating different actions and schemes that are being considered to alleviate energy poverty. As such, this advanced ICT tool has the following objectives:

- To help evaluate different energy poverty schemes (e.g., 'Greening Home' , 'Renovate your home', 'Smarter Home', etc.), which comprise behavioural measures, low and high-cost energy efficiency actions as well as renewable energy sources; and
- To provide utilities/energy companies with a set of conventional and innovative optimal portfolios, comprising different combinations of energy poverty schemes (or part of schemes) and actions, along with a budget allocation for each scheme and proposed number of energy poor households to be involved. The optimisation process is structured in a Multi-objective Programming framework which is designed to consider a set of targets and constraints, aiming to minimise the investment costs on the utilities' perspective and maximise the total energy savings triggered.

1.1.3 SocialWatt Check

SocialWatt Check aims to assist utilities and other stakeholders effectively monitor and verify schemes being implemented. In particular, SocialWatt Check aims to:

- Monitor the effectiveness of schemes and evaluate their actual impact, in terms of energy savings, households engaged, CO_2 emissions reduction, energy cost reduction, total investment, investment by the final user and increase in renewable energy production;
- Enable users track progress, identify in a timely manner risks/threats, exploit opportunities and safely meet targets in a sustainable way; and

1.2 Energy Poverty Indicators

Energy poverty is broadly understood as the inability of a household to maintain adequate levels of energy services at an affordable cost. Energy poverty is perceived to be mainly caused by the interplay of three main factors: low income, high energy needs (due to inefficient housing) and high energy prices. Although these three factors are distinct, there is a clear overlap and interplay amongst them. Therefore, energy poverty is a complex concept that sits between economic, social and energy policy.

Although the number of countries that recognise energy poverty formally in legislation or policy is rising, the majority of Member States do not have a formal definition. Where definitions of energy poverty have been established at Member State level, they are usually accompanied by a narrative description that either points directly to or is supported by one or more indicators and thresholds.

Four distinct approaches have been identified for measuring energy poverty[3]:

[3] F. Vondung, J. Thema, *Energy poverty in the EU-indicators as a base for policy action*, ECEEE Summer

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

- expenditure-based metrics;
- consensual-based metrics;
- direct measurement (of the level of energy services achieved); and
- outcome-based metrics (focused on relevant outcomes like cold or heat-related mortality, arrears on energy bills, disconnections, etc.).

Several indicators based on the first two categories, i.e., expenditure-based metrics and consensual-based metrics, have been established by the EU Energy Poverty Observatory (EPOV)[4] and are gaining more attention. Overall, the EPOV measures energy poverty using a suite of indicators (primary and secondary indicators), with each indicator capturing a slightly different aspect of energy poverty.

Each indicator identified, features strengths and weaknesses, with varying sensitivities and distortions. For example, expenditure-based indicators that use a fixed threshold (e.g., the 10% indicator) are particularly sensitive to country-specific energy expenditure distribution across income deciles[5].

Expenditure-based indicators are those most commonly used by Member States. In this context, EPOV has established two expenditure-based indicators under its primary indicator group , i.e.:

- High share of energy expenditure in income (2M): households whose share of energy expenditure in income is more than twice the national median share; and
- Low absolute energy expenditure (M/2): households whose absolute energy expenditure is below half of the national median.

In addition to these two, Member States also use the following expenditure-based metrics:

- 10% threshold: households whose energy expenditure is more than 10% of annual income;
- Low-Income-High-Cost (LIHC): households whose energy expenditure is above the median level, and their residual income (when subtracting energy expenditure) is below the nationally-defined poverty line.

Study proceedings, 2019

[4] The Energy Poverty Advisory Hub (EPAH) is the successor of the Energy Poverty Observatory (EPOV) https://energy-poverty.ec.europa.eu/index_en

[5] Rademaekers et al., *Selecting Indicators to measure energy poverty*, 2016 https://ec.europa.eu/energy/sites/ener/files/documents/Selecting%20Indicators%20to%20Measure%20Energy%20Poverty.pdf

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

1.3 ACTIONS AND SCHEMES TO TACKLE ENERGY POVERTY

Across Europe, energy poverty is often addressed by actions and measures that aim to reduce energy costs. Nevertheless, there are a number of policies at national level, as well as several actions and schemes, that aspire to increase home energy efficiency and also alleviate energy poverty.

Within the framework of SocialWatt, different policies to mitigate energy poverty were reviewed, as well as numerous schemes, initiatives and good practices focusing on alleviating energy poverty[6]. Emphasis was given on programmes and schemes delivered by or in partnership with an energy supplier, through the use of appropriate financial instruments and mechanisms. Good practices were categorised under four broad types of support provided to energy poor, low-income or vulnerable households, i.e.:

- Bill support and disconnection prevention;
- Energy saving and energy bill advice (with low-cost measures);
- Low-cost energy-saving measures; and
- Energy efficiency and renewable energy measures.

Overall, 42 schemes were selected and further analysed, with the aim to identify appropriate and innovative schemes to incorporate in the SocialWatt tools for tackling energy poverty.[7] Numerous stakeholders were also actively engaged to help shape new schemes that may have a considerable economic and social impact on energy poverty.

[6] Sunderland et al., *Report on the Status Quo of Energy Poverty and its Mitigation in the EU*, 2019 https://socialwatt.eu/sites/default/files/2020-01/D1.1%20Status%20Quo%20of%20Energy%20Poverty.pdf

[7] Osso et al., *Brief on actions and schemes to consider for tackling energy poverty*, 2020 https://socialwatt.eu/sites/default/files/2020-04/D1.2%20Brief%20on%20actions%20and%20schemes%20.pdf

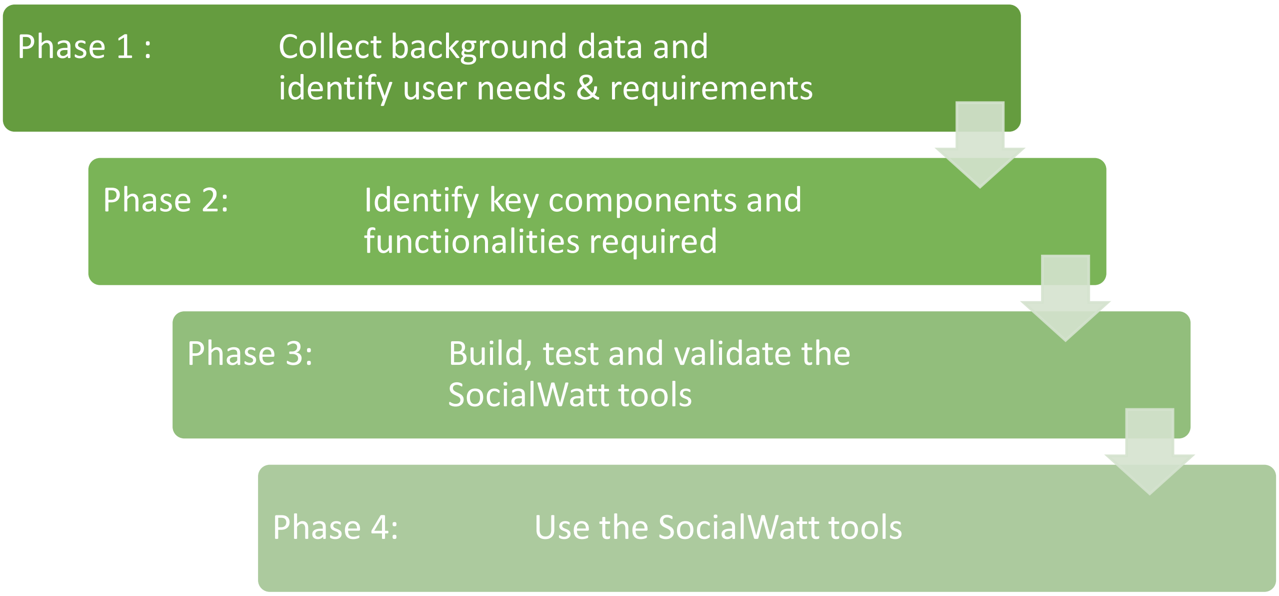
The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

2 DEVELOPMENT OF THE SOCIALWATT TOOLS

2.1 Overall Process

This section describes the process followed for the development of the SocialWatt tools. Overall, the four key phases outlined below (also depicted in the figure below) ensured the effective and efficient development of the tools.

Figure 3: SocialWatt tools development process



Phase 1: Collection of background data and identification of users' needs and requirements

During this phase, user's needs and requirements were identified for each tool, in particular through extensive consultation with SocialWatt utilities/energy companies. Emphasis was given on identifying appropriate outputs that the tools will need to produce, as well as data type and sources available that could be used by the tools. The interaction between the tools was also extensively considered, whilst data security/privacy was carefully studied, ensuring in parallel compliance with the General Data Protection Regulation 2016/679 (GDPR). As a result, the needs the tools must address and the overall scope and specific objectives of the tools were defined.

Phase 2: Identification of key components and functionalities

During this phase, the objectives of each tool were better defined, the different functionalities and components that are required for each tool were identified, along with their interaction, and the elements in each tool that should be kept customisable by the user were considered. As with the previous phase, the requirements and specifications of the SocialWatt tools were thoroughly discussed and analysed with SocialWatt utilities/energy companies during numerous (physical and virtual) meetings. This enabled the conceptual development of the SocialWatt tools. Furthermore, utilities/energy companies provided feedback on the specifications developed, through several bilateral calls, but also by providing input and comments on the specifications through questionnaires and other documents developed.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Phase 3: Development, testing and validation of the SocialWatt tools

During this phase, the SocialWatt tools were developed (both the backend and frontend of the tools), based on the conceptual models built in the previous phase. Furthermore, the tools were validated, to ensure that these meet the needs and requirements set in phase 1, but also that the results produced are correct. In addition to this, both tools were tested by the SocialWatt utilities/energy companies, and as a result of feedback provided, numerous adjustments and improvements were made, especially in the tools interface.

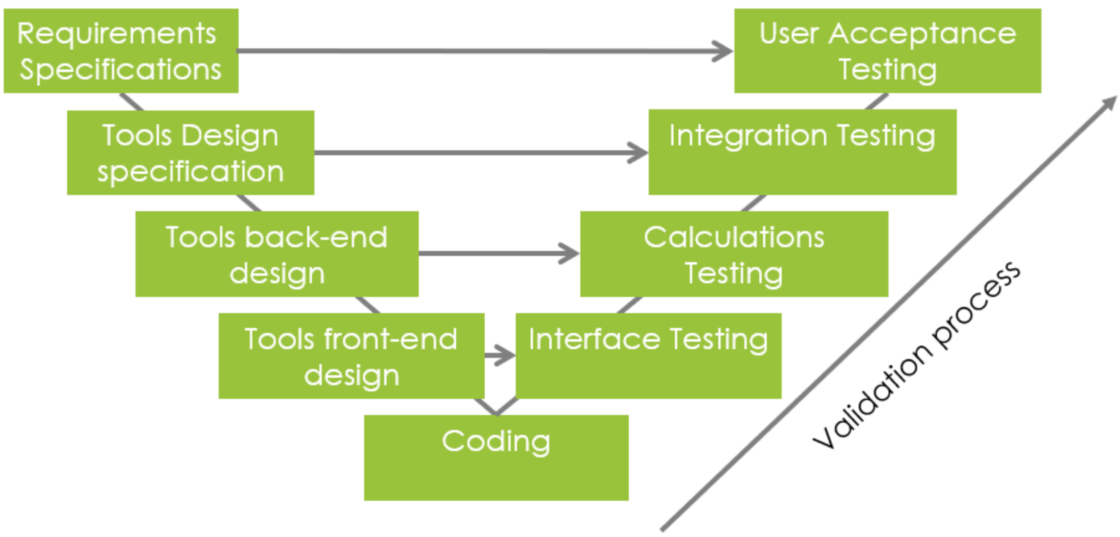
Phase 4: Use of the SocialWatt tools

During this phase, the SocialWatt tools were used by utilities/energy companies to identify energy poor households, evaluate different energy poverty schemes and evaluate the implementation process based on key monitoring indicators.

2.2 Testing and Validation

The validation and testing process, as shown in the figure below, was used to adapt and improve the design of the SocialWatt tools, in order to ensure that these meet users' requirements and needs. Validation and testing used real data provided by utilities/energy companies to also test the accuracy of the results.

Figure 4: SocialWatt tools validation and testing workflow



To date, the SocialWatt tools have been tested extensively both in terms of the back-end and front-end design, and all critical functionalities have been checked.

Initially, the tools' developers (ICCS) performed several internal tests. The tests included the validation of calculations and the assessment of the accuracy of the results. Moreover, the graphical interfaces were tested in order to ensure and validate the interaction with the backend of the tool, and improve the visual details like images, colours, and fonts. Every aspect related to the functionalities of the tools were also tested, including controls, navigation, error messages, data entry format and handling.

Subsequently, an online version of each SocialWatt tool was developed. These were tested by SocialWatt partners, in particular utilities/energy companies, in order to assess both the interface functionalities and the results' accuracy and relevance. Feedback was provided,

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

through numerous testing loops, and as a result the tools were adjusted and improved to better meet users' needs.

More specifically, the feedback received during the validation and testing phase of the SocialWatt tools has triggered the following improvements:

- SocialWatt Analyser:
  - Income-related data can be changed at municipal, regional or county level;
  - Income-related data can be imported;
  - Additional energy poverty indicators have been added;
  - Customised parameters have been included for each indicator (e.g., national poverty line);
  - A brief description of each indicator has been added;
  - Information has been added on the type and structure of data required for each data input method; and
  - Results present number of households in energy poverty disaggregated by buildings' floor area, year of construction, etc.
- SocialWatt Plan
  - Financial mechanisms have been incorporated in the analysis
  - The results include optimal financial mechanisms per scheme.
- SocialWatt Check
  - The tools' features have been optimised based on feedback by utilities/energy companies.
  - The user can set specific values for energy savings per intervention for each action, which is particularly important for countries that have defined specific calculation methods for energy savings (e.g., White Certificates in France and other Energy Efficiency Obligation schemes).

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

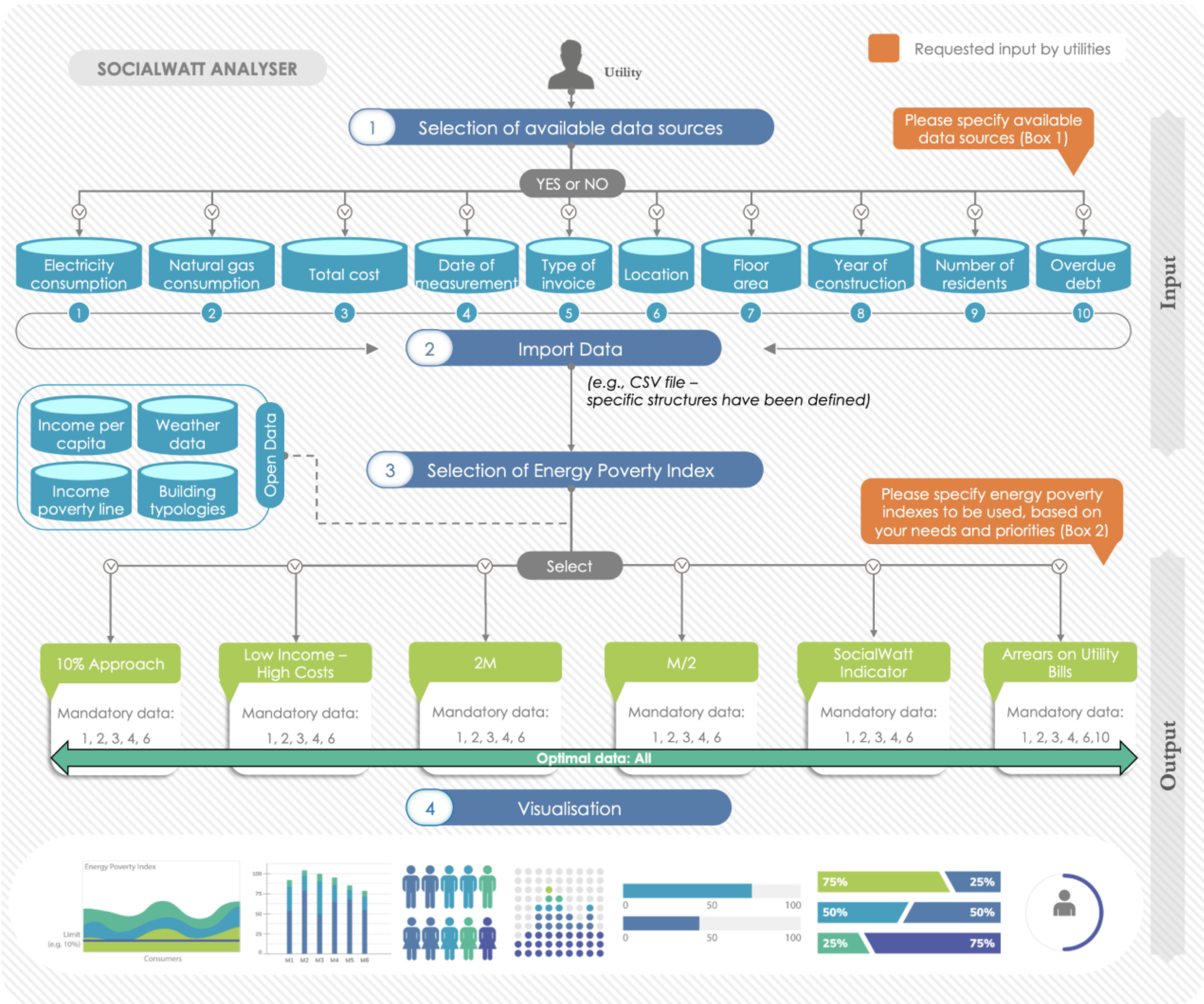
3 SOCIALWATT ANALYSER

3.1 Description

The SocialWatt Analyser helps utilities identify energy poor households amongst their customers, using multi-sourced data and diversified layers of information, such as customers' data, comfort levels (energy needs) as well as climate and socioeconomic data.

The figure below illustrates the four steps utilities need to follow in order to run the tool.

Figure 5: The SocialWatt Analyser steps



More specifically, utilities need to:

- Select their country of interest *(Step 1)*;

  There are 9 countries incorporated in the tool for the user to choose from, namely, Croatia, Greece, France, Ireland, Italy, Romania, Spain, Latvia and Portugal. For each selected country, there is a downloadable file that lists municipalities/regions/counties for further elaboration by the user (i.e. to be imported in the tool once this is filled with relevant income data).

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

- Select the data process method (Step 2);

  There are 10 data process methods incorporated in the tool. As indicated in the respective window that pops up upon selecting a process method, each method presupposes a different set of mandatory input data (i.e. data with a "check mark). and a different structure. The first 9 methods are tailored for SocialWatt utilities/energy companies, based on anonymized sample datasets of clients. Other users can select one of these tailored methods, if relevant, or select "Method 10", which is designed to handle all types of available data, and adjust the structure of the data to be imported, to be compatible with this method (in this case only, data with a "check mark" in the respective pop up window may be disregarded if the user does not intend to provide such information).

- Select an Energy Poverty Indicator *(Step 3)*;

  There is a drop-down list of 6 energy poverty indicators that are incorporated in the tool, which are the basis of the energy poverty analysis. These indicators are presented in more detail below.

- Import the energy and income data for the analysis *(Step 4);*

  There are two separate files of Comma-Separated Values (CSV) format that needs to be imported in the tool in order for the analysis to be continued; a) one containing the mandatory energy-related data for each household, i.e., energy consumption (kWh), date of measurement, annual energy cost (€) and location, as well as any extra data that the utility/energy company may retrieve such as: arrears on utility bills, building's year of construction, etc., in a structure that is indicated by the data process method selected above and b) one containing the optional income-related data such as the average income per capita for each municipality/region/county.

- Run the tool to produce results *(Step 5)*;

  The results include different visualisation options, stemming from the backend mathematical analysis of the available data. Once the tool runs, all data are analysed and results are presented, more specifically each household is categorised as 'energy poor', 'at risk of energy poverty' or 'not energy poor'. Users can download the results in a form of a .csv file. Apart from this, SocialWatt Analyser provides statistical results in the form of charts, which for example enable a comparison between regions/municipalities in terms of number of households in energy poverty.

3.1.1 Energy Poverty Indicators

SocialWatt Analyser incorporates five different energy poverty indicators, to ensure consistency with Member States' approaches to define energy poverty (i.e., 10% approach, LIHC) and the EPOV (i.e., 2M, M/2, arrears on utility bills). Another key driver behind the integration of several indicators was to provide utilities/energy companies with the opportunity to delve into the issue of identifying energy poverty, by testing different indicators and selecting the most appropriate one based on national requirements (e.g., official national energy poverty indicator) and business preferences to base their analysis upon, after considering the limitations associated with each indicator.

In addition, after carefully considering the numerous energy poverty indicators used across Europe[8] a new energy poverty indicator was developed within the framework of SocialWatt, that is to say the SocialWatt Energy Poverty Indicator, in an attempt to overcome the drawbacks from the use of some of the other indicators. This indicator presumes that energy poverty is linked to dwelling characteristics (e.g., the condition of a dwelling) and income. Therefore, the 'SocialWatt Energy Poverty Indicator' deconstructs energy poverty using two core factors (i.e., energy needs and income) and examines them jointly.

SocialWatt Energy Poverty Indicator

If the actual energy consumption (e.g., electricity, natural gas, etc.) of a household is lower than the theoretically required for maintaining thermal comfort (heating/cooling), the household is classified as energy poor. Otherwise, the ratio between energy cost and income is taken into consideration.

The last part of the definition is income-driven and quite similar to the 10% threshold. The main difference between them is that the latter strictly defines 10% as the decisive threshold, whilst SocialWatt Indicator allows for full customisation.

The novelty of the SocialWatt indicator lies in the integration of the two major factors that may instigate energy poverty, more specifically income and thermal comfort. This enables the identification of energy poor citizens within a city, region, or country, through the utilisation of multi-source, cross-domain data, such as weather and socioeconomic data, household characteristics and location, comfort levels elicited from the calculation of each household's energy needs, energy consumption, energy costs and demographic data.

In summary, the energy poverty indicators incorporated in SocialWatt Analyser include:

- **10% Approach:** A household is classified as energy poor if it needs to spend more than 10% of its income on energy, to maintain an adequate level of thermal comfort;
- **Low income high costs LIHC):** A household is classified as energy poor if its actual energy costs are above average (national median level) <u>and</u> its residual income (i.e., energy costs subtracted from income) is below the national poverty line;
- **High share of energy expenditure in income (2M):** A household is classified as energy poor if its share of energy expenditure in income is more than twice the national median share;
- **Low absolute energy expenditure (M/2):** A household is classified as energy poor if its absolute energy expenditure is below half the national median;
- **Arrears on utility bills:** A household is classified as energy poor if it has arrears on utility bills'; and
- **SocialWatt Indicator:** If the actual energy consumption (e.g., electricity, natural gas,

[8] Sunderland et al., Report on the Status Quo of Energy Poverty and its Mitigation in the EU, 2019 https://socialwatt.eu/sites/default/files/2020-01/D1.1%20Status%20Quo%20of%20Energy%20Poverty.pdf

etc.) of a household is lower than the theoretically required for maintaining thermal comfort (heating/cooling/ventilation), the household is classified as energy poor. Otherwise, the ratio between energy cost and income (in a monthly or annual basis) is taken into consideration.

To conclude, a diverse set of energy poverty indicators are incorporated in the SocialWatt Analyser tool, including among other, the most common ones that have remained on the spotlight throughout the years, such as the 10% approach, the ones presented as of primary significance by the EPOV, for instance 2M, and ultimately a custom-made SocialWatt indicator, which aspires to address the weaknesses of other indicators.

3.2 Input Requirements

The type of data required to determine the profile of a household in terms of energy poverty were examined, including data utilities hold for their customers and readily available data (demographic, location, property details, etc.). In summary, the following data were deemed important in order to better identify energy poor households, and as such are required by SocialWatt Analyser:

- Location / Weather data (data from utilities / data built in the tool)
- Data on buildings for creating a “reference household” (built in the tool)
- Energy consumption data (real measurements from utilities)
- Income data (readily available data)
- Energy cost data (real data from utilities)
- Date of measurement (real data from utilities)

3.2.1 Data from Utilities

Utilities and energy suppliers have at their disposal a plethora of data that can be used to identify energy poor customers (energy consumption, energy costs, payment frequency, payment arrangements, debt profile, location of the property etc.). As such, the SocialWatt Analyser makes use of this data, for example:

- Client ID
- Electricity and/or natural gas consumption;
- Date of measurement;
- Electricity and/or natural gas costs;
- Type of invoice;
- Residences’ year of construction;
- Floor area;
- Number of residents;
- Location (municipality, county, region etc);
- Age of Customer; and
- Overdue debt.

The SocialWatt project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under grant agreement No 845905

The table below presents an example of utility data imported in SocialWatt Analyser.

Table 1: Example "dummy" data held by utilities that can be imported in SocialWatt Analyser

Client ID	No. of measurement	Date of measurement		Consumption (kWh)	Cost (€)	Type of invoice	Location	Year of construction	Area (m^2)	Number of residents	Type of use
		From	To								
1	1	2/11/2017	2/2/2018	1484	40	Advance payment bill	Athens-centre	1965	30	1	Residential
1	2	2/3/2017	2/11/2017	2174	75	Clearing bill	Athens-centre	1965	30	1	Residential
2	1	19/7/2017	16/11/2017	593	80	Advance payment bill	Athens-centre	1961	100	-	Residential
2	2	16/3/2017	19/7/2017	1151	51	Clearing bill	Athens-centre	1961	100	-	Residential
2	3	18/11/2016	16/3/2017	4155	100	Advance payment bill	Athens-centre	1961	100	-	Residential

It should be noted that such data are strictly protected by regulations (in particular GDPR). Therefore, the use of such data was carefully considered. As a result, fully anonymised sample data were provided by partner utilities for the development of the tool, but also the validation of the tool. The data were also examined in terms of type and format, so that the SocialWatt tools developed are customised for SocialWatt utilities, but can also be used more broadly.

Although all of the aforementioned data are useful to better identify energy poor households, only a subset of them is mandatory, including the energy-related data for each household, i.e., energy consumption (kWh), date of measurement, annual energy cost (€) and location. SocialWatt Analyser is designed to make use of additional data as well, such as the arrears on utility bills, building's year of construction, etc., and provide respective visualised results. However the analysis to determine the energy poverty status of each household could be easily conducted without the additional data.

Additional/supplementary data lead to more accurate results, as depending on the energy poverty indicator selected, several assumptions are introduced when required data are not available. For example,

- When location data are missing, the analysis is conducted at national level, ignoring any potential regional or municipal specificities; and
- When data about the type of invoice for each customer are missing, the whole analysis is designed to take into consideration the invoices as if they refer to actual clearing bills, disregarding the fact that some of them may be estimated bills.

Last but not least, parameters such as the number of residents in each household, are used for statistical analysis only, helping utilities to draw useful insights on the relation between energy poverty and other factors.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Table 2. Mandatory and optional data for using SocialWatt Analyser

<table>
<tr><th>Energy Poverty Indicator</th><th>Configuration Parameters</th><th>Minimum Required Input Data (for each customer)</th><th>Optimal Input Data (for each customer - in addition to the minimum required)</th></tr>
<tr><td>10% approach</td><td>• National Income</td><td rowspan="5">1. Customer ID
• Anonymised identifier
2. Energy consumption
• Electricity or Natural Gas
3. Total cost
• Energy expenditure
4. Billing period
• Regular or annual basis
5. Location
• Region, county or municipality level</td><td rowspan="6">1. Energy consumption
• Electricity or Natural Gas (whichever is not included in the required input data)
2. Type of invoice
• Bi-monthly/clearing bills
3. Size of house
• Floor area
4. Age of building
• Year of construction
5. Household composition
• Number of residents
6. Age of customer</td></tr>
<tr><td>Low-Income-High-Cost (LIHC)</td><td>• National Income
• National Poverty Line
• National Average Energy Cost</td></tr>
<tr><td>High Share of Energy Expenditure (2M)</td><td>• National Income
• National Median Share</td></tr>
<tr><td>Low Absolute Energy Expenditure (M/2)</td><td>• National Median Absolute Energy Expenditure</td></tr>
<tr><td>SocialWatt Indicator</td><td>• National Income
• Floor Area of a typical Household
• Lowest Energy consumption threshold
• Building Evaluation Index (Min – Max)
• Household Evaluation Index (Min – Max)</td></tr>
<tr><td>Arrears on Utility Bills</td><td>-</td><td>(in addition to the above)
6. Overdue debt
• Arrears on utility bills</td></tr>
</table>

3.2.2 READILY AVAILABLE DATA

As mentioned above, user data in SocialWatt Analyser are considered along with other readily available information and data, in particular:

- Data that help determine household energy needs

  "Reference households" were modelled in order to define energy needs of a typical household per location and per time period of a building's constructions (i.e., built before/after 1980). Depending on the availability of data in each country, assumptions were introduced when needed.

- National, regional or local average income data

  Income-related data at national level, and the national income poverty line have been included in SocialWatt Analyser based on readily available data. Nevertheless, income data at regional or even local level can be also imported in the tool by the end user/utility.

The data required by SocialWatt Analyser to identify energy poor customers when selecting the most common energy poverty indicators (i.e., 10% approach, LIHC) and the ones used by the EPOV (i.e., 2M, M/2, arrears on utility bills) are dictated by their respective definitions (i.e., income data, energy costs and arrears on utility bills). Regarding the SocialWatt Energy

Poverty indicator, the following data are also used:

- EnergyPlus, Renewables.ninja, Tabula and other open data sources were extensively utilised to approximate the energy needs of a "reference household". National standards (e.g., wall, window, roof, and floor heat transfer coefficients) and typical types of dwelling per geographical area (e.g. apartments or single houses) were considered in order to make sure that the energy consumption computed both ensures thermal comfort, and is representative of the examined areas.
- The actual energy consumption of households, as provided by utilities, is compared to the abovementioned estimated energy needs, to identify energy poor customers at a first stage (i.e. when actual consumption is lower than the estimated energy needs).
- When households' actual energy consumption is greater than the estimated energy needs, then income (i.e., income per capita at municipal, regional or national level) is compared to energy costs, as determined by utilities. The comparison is conducted based on a pre-defined, and completely customised threshold by the user, resembling in a way the 10% approach.

3.3 Technical Details

Given the sensitive nature of the underlying data used and in order to ensure compliance with the GDPR, the SocialWatt Analyser tool is a 'desktop' application. This means that users can download and use the tool locally, so that personal data and information imported and analysed is not shared with any other organisation or stored in an open database or repository.

SocialWatt Analyser processes and analyses 10 different types of datasets based on 6 different energy poverty indicators. These datasets include real data held by utilities.

The development of the tool was based on the Django MVC (Model-View-Controller) Framework and consists of a frontend side (HTML5, CSS3, Javascript V1.8.5) and a backend side (Python V3.7). The Django Project Framework[9] and more specifically version 3.0.3[10] was selected due to its state-of-the-art implementation and documentation.

The tool is designed to accept input data files of both .csv and .xlsx format. Data are imported from the frontend of the tool, where they are handled, processed and analysed with Pandas[11] and NumPy[12] (Python Data Analysis Libraries).

Furthermore, for the frontend design the main software library used was Bootstrap 4.4.1[13], jQuery[14] and Javascript 1.8.5,[15] along with HTML5 and CSS3 modules.

[9] https://www.djangoproject.com/
[10] https://developer.ibm.com/docloud/blog/2019/12/09/cplex-optimization-studio-12-10-is-available/
[11] https://pandas.pydata.org/
[12] https://numpy.org/
[13] https://getbootstrap.com/
[14] https://jquery.com/
[15] https://www.javascript.com/

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Due to the variability in the structure of the imported data, the backend reprocesses them during the execution phase, so that the output complies with a global structure, allowing the frontend to handle and plot graphs of the results.

Its fundamental structure includes different classes (based on the chosen method of analysis) which guarantees efficiency, stability, speed and simultaneous use by different users.

Along with the imported data files, the user is able to tailor the tool to meet its needs through the frontend, for instance by selecting the process method and the energy poverty indicator to be used.

Regarding the results, these are presented in the form of plotted graphs, using a Javascript software library, Highcharts.js[16]. The user is also able to access the analytical data (i.e. per household) in .csv format.

Currently, the different **views** of the tool include:

- **Login page**, where the user logs in using global credentials to access the tool;
- **Home page**, where the user can upload input data (energy- and income- related data files) and choose the way that the analysis will be executed. This is the most fundamental part of the frontend of the tool;
- **Visualisation**, where the user can access the results of the analysis, including statistical graphs and/or data per household for further analysis; and
- **Logout**.

3.4 Tool Configuration

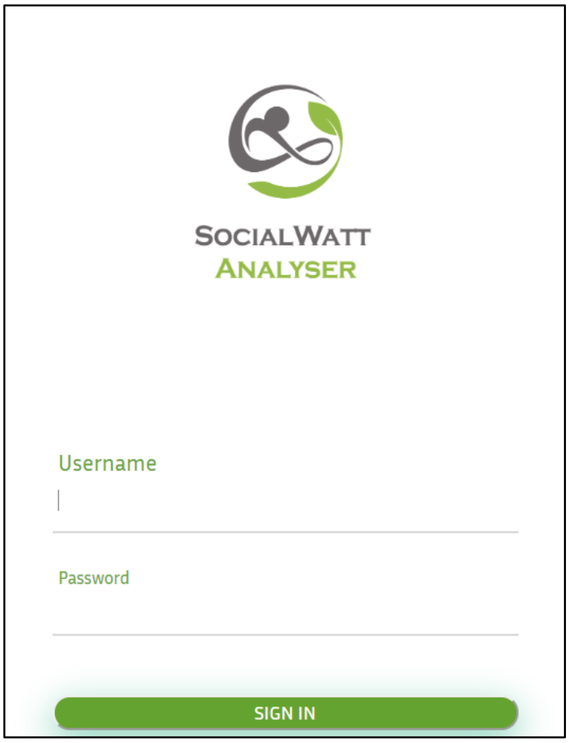
The key features of SocialWatt Analyser are presented below, in order to showcase the functionalities of the tool, its ease of use, and the way it interacts with the user.

Initially, the user needs to enter his/her credentials when attempting to access the tool. Currently, a common username ('admin') and password ('admin') is used for every user, but this can be customised by the developers of the tool if needed / upon request. Therefore, it is possible to set up different credentials for each user, although the locality of the installation method (the tool is designed to be installed locally at each utility/energy company's facilities) makes this redundant.

[16] https://www.highcharts.com/

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Figure 6: Accessing the SocialWatt Analyser



After accessing the tool, the user is asked to provide the following information (also shown in the figures that follow):

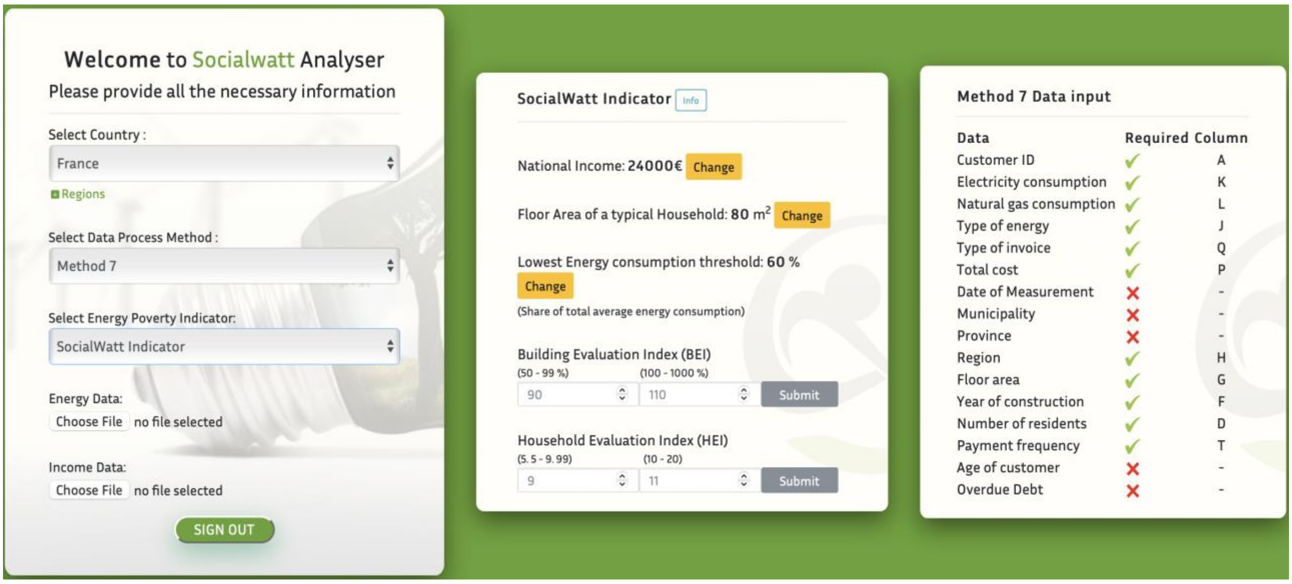
- Select country: The user selects the country to be considered in the analysis, using a drop-down menu. Nine countries have been incorporated in the tool (i.e., Greece, France, Spain, Romania, Latvia, Croatia, Italy and Ireland). When a specific country is selected, a pop up 'regions' and/or 'municipalities', and/or 'counties' icon appears with a download button. This funcionality intends to give the user the opportunity to enter income per capita data by downloading a .csv file of the selected country's regions/municpalities/counties and completing it with income data. This provides some flexibility to the user in terms of using the income per capita data and entering them at regional, municipal or county level, whatever is deemed more appropriate.
- Select Data Process Method: Once the country is selected, the user selects the data input method, by using the respective drop-down menu. Currently, ten methods have been incorporated, each one of which has been developed to accept a different set of input data from a pre-defined list, structured in set columns accordingly. The input data types of a specific method are indicated by a green mark while the ones that are not considered by the selected method are indicated by a red ban sign.
- Select Energy Poverty Indicator: A diverse set of energy poverty indicators has been integrated in the tool for the user to select, including among others the 10% approach, LIHC, 2M, M/2, arrears on utility bills, and the SocialWatt indicator. The user selects the indicator and enters the required data needed for this indicator (e.g. for M/2 the national median absolute energy expenditure). The user must ensure that the data entered are directly comparable to the energy data imported (e.g. entering national median absolute electricity consumption if only electricity

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

consumption per household is imported in the tool).

- Energy Data: The user then imports an external file of .csv format that includes the utility/energy company data. In order for the tool to run correctly it is imperative that the energy data imported are structured in a way that fully complies with the data structure of the input method selected (i.e. the right data included under the indicated column of the input method selected).
- Income Data: Finally, the user imports an external .csv file to upload income per capita data at a municpal, regional or county level. The imported .csv file should be the same one with that dowloaded at the beginning of the data input process (see "Select Country" step above), but with filled income data. If an income-related .csv file is not imported into the tool (e.g., the user does not have this type of information), national income per capita is considered in the analysis. In the same context, when the income .csv file contains the name of a region/county/municipality thas has not been assigned a value of income per capita, then the national income per capita is also used for this specific location.

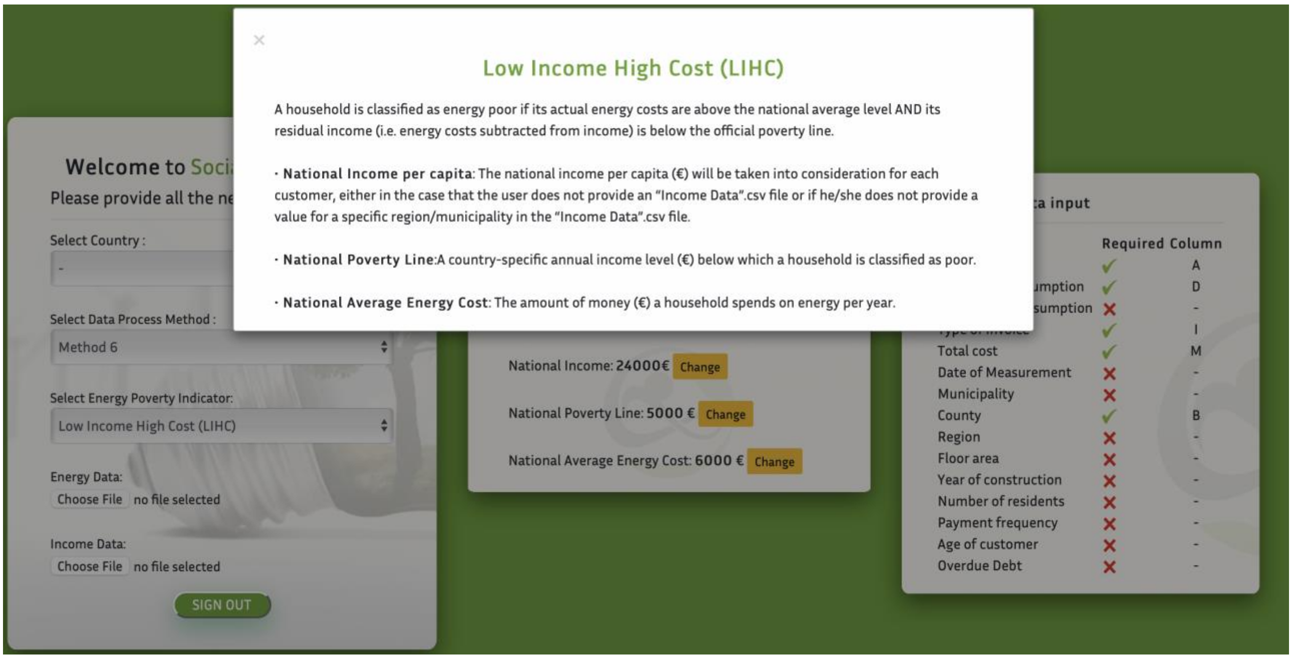
Figure 7: SocialWatt Analyser: user options and Input data requirements



For clarity and ease of use, when the user selects a specific energy poverty indicator for the analysis, an 'info' tab appears. By clicking this the user can read more about the selected indicator and related parameters.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Figure 8: SocialWatt Analyser: information on each energy poverty indicator

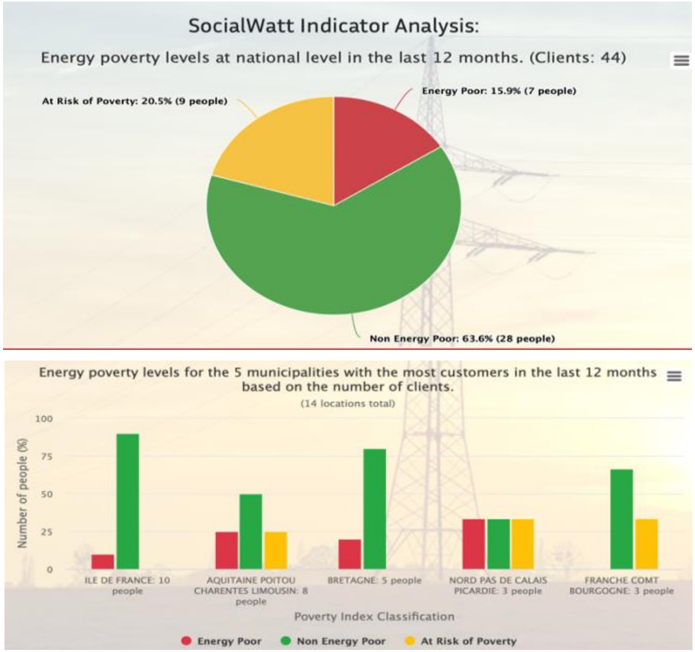


Once the user has provided all the required information, the Analyse button initiates the Energy Poverty Analysis. Results are then presented in a visual manner, in terms of the allocation of energy poor households across the examined country, as well as broken down by municipality, with gainful insights that can eventually contribute towards developing more targeted schemes to alleviate energy poverty.

Last but not least, the SocialWatt Analyser can provide a detailed report with information about each customer, as well as the energy poverty status of households across the years (in case a user imports data for more than one year). For example, as shown in the figure below, anonymised household 1 was considered energy poor in 2018 but escaped energy poverty in 2019.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Figure 9: SocialWatt Analyser "dummy" results



Customer	Year	Annual Energ	Annual Energ	Poverty Inde	Location
1	2013	1072	201	EP	Saluzzo
1	2014	1160	203	EP	Saluzzo
1	2015	1104	196	EP	Saluzzo
1	2016	1314	220	EP	Saluzzo
1	2017	1270	262	EP	Saluzzo
1	2018	1186	260	EP	Saluzzo
1	2019	862	207	NEP	Saluzzo
2	2014	3082	720	EP	CASALGRASSO
2	2015	448	181	NEP	CASALGRASSO
2	2016	297	157	NEP	CASALGRASSO
2	2017	356	208	NEP	CASALGRASSO
2	2018	104	55	NEP	CASALGRASSO
3	2015	348	82	NEP	VILLAFALLETTO
3	2016	3971	866	EP	VILLAFALLETTO
3	2017	4166	817	EP	VILLAFALLETTO
3	2018	4273	876	EP	VILLAFALLETTO
3	2019	3551	738	EP	VILLAFALLETTO
4	2015	5880	1735	EV	CAVALLERLEONE
4	2016	6620	1684	EP	CAVALLERLEONE
4	2017	6204	1262	EV	CAVALLERLEONE
4	2018	6657	1439	EP	CAVALLERLEONE
4	2019	5347	1180	EP	CAVALLERLEONE
5	2014	471	125	NEP	CARAMAGNA PIEMONTE
5	2015	4496	1087	EP	CARAMAGNA PIEMONTE
5	2016	5970	1449	EV	CARAMAGNA PIEMONTE
5	2017	6408	1283	EV	CARAMAGNA PIEMONTE
5	2018	6011	1285	EV	CARAMAGNA PIEMONTE
5	2019	6468	1401	EV	CARAMAGNA PIEMONTE

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

4 SOCIALWATT PLAN

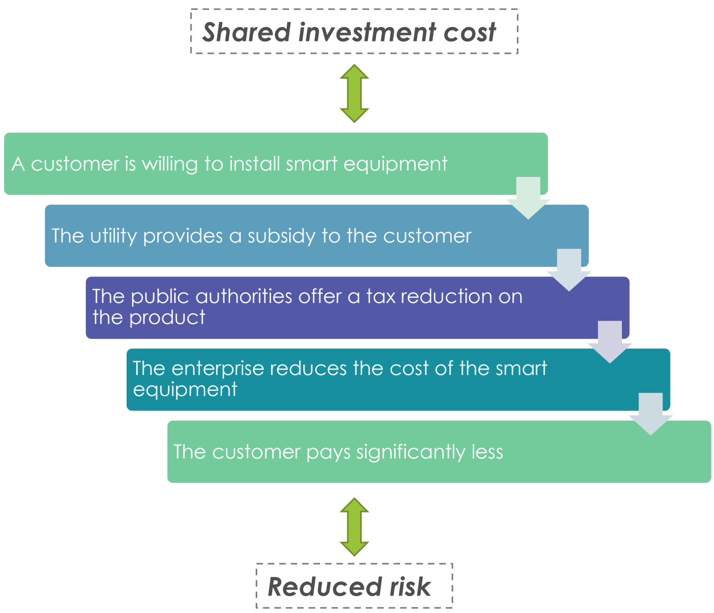
4.1 DESCRIPTION

SocialWatt Plan enables the evaluation of different energy poverty schemes**.** More specifically, the tool provides utilities with a set of optimal portfolios, comprising different combinations of conventional and innovative schemes (or part of schemes) to alleviate energy poverty, along with the optimal financial mechanism to support the implementation of each portfolio, a budget allocation for each included scheme and the expected number of energy poor households to be involved.

The optimisation includes a set of pre-defined targets and constraints, which can be customised by the user as to their thresholds, including the available budget of the utility/energy company, the number of total interventions in terms of households to be engaged (assuming one interventions per household), the share of interventions and energy savings in old/new buildings, the maximum risk allowed, energy savings and renewable energy production targets, and finally the number of portfolios to formulate the pareto front. The different portfolios are then evaluated against the objective of minimising the investment cost on the utility/energy company's perspective and maximising the energy savings triggered, by considering the cost and energy savings effectiveness per action.

The optimal portfolios extracted from SocialWatt Plan, both in terms of number and synthesis (selected schemes), can inform the development of Energy Poverty Action Plans. The figure below presents an indicative example of a scheme that could be included in an Energy Poverty Action Plan.

Figure 10: Example of an energy poverty scheme



4.1.1 Energy Poverty Schemes and Actions incorporated in the tool

The schemes comprise actions that aim to trigger low and high-cost interventions as well as behavioural change measures. The table below, presents the ten schemes, along with the actions these include.

Table 3: Schemes and actions to mitigate energy poverty included in SocialWatt Plan

Scheme	Actions
Greening home	Insulation - Exterior Walls Insulation - Roof Windows - Double Pane Windows
Renovate your home	Low-budget renovations (e.g., leaking roofs, plumbing insulation, air leakages, etc.) Efficient lighting
White Appliances	Washing machine Kitchen Fridge
Smarter Home	Smart meters
Information and Communication	Energy advice and leaflets
Fighting the Cold	Energy Efficient Air Conditioning Heat pumps Boilers - Gas
RES4ALL	Solar thermal panels Boilers - Biomass Photovoltaics (PVs)
Helping Hand	Customer charge
eVouchers	Bonus tickets Stand by Killers Installation
Protection hand	Prohibiting disconnection based on weather Prohibiting disconnection based on customers' needs Prepaid amount of energy

Behavioural change schemes (i.e., ‘Helping Hand’, ‘eVouchers’ and ‘Protection hand’) are excluded from the optimisation process (except for the ‘Information and Communication’ scheme) due to a lack of quantified data as to their cost-effectiveness. The budget allocation for the latter schemes is calculated as a whole, based on the residual budget between the originally available from the utility/energy company and the optimal one extracted from SocialWatt Plan for the low- and high-cost interventions. It is then up to each user to decide how to further break down this budget into the included behavioural schemes.

It should also be noted that renewable energy sources are not eligible under Article 7 of the EED, if they do not trigger energy savings among final customers, and thus they cannot benefit utilities/energy companies that are obligated parties meet their energy efficiency obligations. Despite this, there are a few such actions incorporated in SocialWatt Plan under the RES4ALL scheme, as these are actions that utilities may wish to consider.

The SocialWatt project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under grant agreement No 845905

4.2 Input Requirements

SocialWatt Plan requires a set of data and inputs in order to provide the portfolio analysis of different schemes to tackle energy poverty. These include user data (in the form of targets and constrains) and embedded data.

The actions included in each scheme are then evaluated in terms of their performance in meeting predefined targets, whilst in parallel minimising the total cost from the utility/energy company's perspective and maximising energy savings triggered.

4.2.1 Targets and Constrains

The pre-defined targets and constraints incorporated in SocialWatt Plan are fully customisable by the user, in terms of defining specific thresholds, in order to create optimal portfolios based on the users' specific needs and requirements. In particular, the following targets and constraints need to be set before running SocialWatt Plan:

- Number of energy poor households to be targeted (note: the outputs from the SocialWatt Analyser can be used to inform this target);
- Share of total interventions in old/new buildings;
- Share of total energy savings in old/new buildings;
- Maximum risk allowed;
- Maximum annual utility/energy company budget/investment;
- Renewable energy production target;
- Energy savings target; and
- Number of portfolios to be included in the pareto front.

4.2.2 Embedded Data for Actions and Schemes

The cost effectiveness of each action, and consequently of each scheme, was estimated using the DREEM software (Section 4.3.1). More specifically, each action incorporated in the SocialWatt Plan, was evaluated on the "reference households" used in the SocialWatt Analyser, to estimate energy savings. Costs were also estimated per action, climate zone and type of building (e.g. new and old). Subsequently, the cost effectiveness of each examined action, expressed in $€_{investment}$ / $kWh_{saving\ (or\ production)}$, was calculated.

The data considered by the DREEM software include:

- Weather and climate data

  Weather data were obtained from EnergyPlus[17] and Renewables.ninja[18] open source databases. The data were used to create the boundary conditions and determine heating/cooling requirements and thermal comfort conditions. The latter was based on national standards, appropriate thermal conditions and temperature ranges that result in thermal satisfaction of occupants.
- Activity levels and Heating, Ventilation and Air Conditioning (HVAC) control settings

[17] EnergyPlus. Available: https://energyplus.net/weather
[18] Renewable.ninja. Available: https://www.renewables.ninja/

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Control strategies and activity levels drive energy use, given the time-shifting events of demand and occupancy signals.

- Occupancy profiles

  Single-family household with three members, two economically active individuals and 1 dependant family member

- Building envelope typologies and construction materials

  Data were derived from the TABULA Webtool[19]. TABULA was a project funded by Horizon 2020, whose objective was to create a harmonised model for European building typologies, in particular residential buildings. The set of typologies represent different construction periods and building sizes. The TABULA webtool provides information for more than 20 countries. Data for three countries included in the SocialWatt consortium but not in the TABULA WebTool were extracted from national standards.

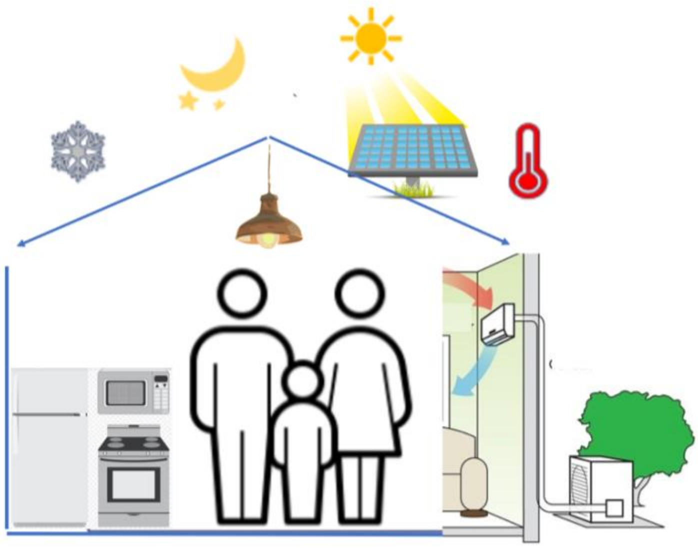
- Appliances

- RES system characteristics and energy efficiency interventions

  The installation of Photovoltaics (PV) in SocialWatt Plan refers to a small-scale system (i.e., 1-10 kWp of nominal power selected based on the electricity needs of each typical household) under a net-metering scheme.

The figure below presents the "reference household" in SocialWatt as a system with its subsystems. It also indicates the type of occupancy (single family with 3 members) and activity level taken into consideration in DREEM.

Figure 11: "Reference household" as a system with its subsystems



In order to make sure that users understand the underlying assumptions used on costs and impacts when running the tool, these are clearly presented in the tool itself. Thus, users can view investment costs, energy savings and other information per action, building type and

[19] TABULA WebTool, «TABULA WebTool» Typology Approach for Building Stock Energy Assessment, 2012. Available: http://webtool.building-typology.eu/#bm

climate zone through the tool's frontend.

4.2.3 Data related to Financial Mechanisms

In order to propose the optimal financial instrument per action selected in the final portfolio, the cost and risk values associated to each action per financial mechanism are considered, as defined by the user.

As such, the tool assumes varying financial contributions by utilities/energy companies per financial mechanism and also includes default risk values for each action per financial mechanism. The latter have been drawn as a result of the Multi-Criteria Analysis that was conducted on the assessment of each action against the following set of criteria, undertaken by SocialWatt utilities/energy companies. It should be noted that each financial mechanism is represented by a different weighting vector within the Multi-Criteria Analysis, based on which the default risk values of the actions are differentiated between the financial mechanisms.

- Repayment of investment (e.g. high payback period, partial or no re-payment of investment);
- Investment cost (e.g. high upfront cost, availability of budget for implementation);
- Bureaucracy (e.g. related to the administration of the scheme, the involvement of public authorities);
- Public acceptance (e.g. ease of engaging customers, credibility of the utility/funding mechanism);
- External factors (e.g. political inertia or instability, regulatory barriers, public health or economic crisis);
- Implementation complexity (e.g. technical or administrative complexity);
- Data Accuracy; and
- Scheme Duration

In addition to extracting the optimal financial mechanism per action, the overall optimal financial mechanism for each portfolio is also presented. This is derived by selecting the financial mechanism with the highest contribution in terms of cost among the ones extracted for each action, following the assumption that the remaining budget can be allocated by the utilities to behavioural actions. It should be noted that behavioural actions are excluded from the optimisation process (except for the "information and communication" scheme) due to the lack of quantified data.

The table below presents the financial mechanisms that are incorporated in the tool, along with the risks that carry the highest weight per mechanism (as assessed by SocialWatt partners) and the likely % contribution of utilities, in terms of investment.

Table 4: Financial mechanisms incorporated in SocialWatt Plan

Financial Mechanism	Description	% Contribution of Utilities	Risks with a higher weight
Utility/energy company	The utility/energy company covers the full amount of the necessary investment for the implementation of the scheme	100%	Repayment of investment – Investment cost

Financial Mechanism	Description	% Contribution of Utilities	Risks with a higher weight
Partial/ Scalable funding by a utility/energy company	The utility/energy company covers a percentage of the investment necessary for energy interventions (under scalable funding this varies for different groups of citizens, e.g. higher subsidy for energy poor households), while the customer is responsible for the residual amount	20-30%	Investment cost
On-bill financing	The utility/energy company incurs the cost of energy interventions, which is then repaid on the utility bill	5-30%	Repayment of investment – Investment cost – Public acceptance
Revolving loan fund	The utility/energy company sets up a pool of capital to provide loans to finance energy interventions / the purchase of energy efficient products, which is self-replenishing, utilizing interest and principal payments on old loans to issue financing for new interventions	20-100%	Repayment of investment – Investment cost – Implementation complexity
Financial Incentive	The utility/energy company provides incentives to customers to implement energy efficiency interventions, e.g. reduced energy prices / tariffs, rebates, monetary contributions	10-30%	Repayment of investment – Bureaucracy
Partnership with the public sector	The utility/energy company collaborates with national/regional/local authorities to offer financial incentives and support for the implementation of energy efficiency interventions	20-80%	Repayment of investment – Bureaucracy – External factors
Green Loans	The utility/energy company, in collaboration with financial institutions / banks, offers customers low / no interest loans to finance energy efficiency interventions / the purchase of energy efficient products (may also involve public authorities as loan guarantors)	20-50%	Repayment of investment – Implementation complexity
Collaboration with the private sector	The utility/energy company, in collaboration with enterprises from the private sector, offers discounts for purchasing energy efficient products / services or leasing energy efficient products	10-30%	Repayment of investment – Implementation complexity – External factors
Collaboration with third parties	A third party or an Energy Service Company (ESCO) finances energy efficiency interventions and uses cost savings to repay the costs of investment (Energy Performance Contracting (EPC) / Energy Service Agreements (ESA) / Metered Energy Efficiency Transaction Structures (MEETS)) or charges a fee equivalent to a part of the energy savings achieved (Third-Party Funding (TPF) / Managed Energy Services Agreements (MESA) / Chauffage Contracts)	5-30%	Repayment of investment

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Financial Mechanism	Description	% Contribution of Utilities	Risks with a higher weight
Crowdfunding	The customers of the utility/energy company are encouraged to donate an amount through their utility bill, in order to fund energy efficiency interventions or help reduce the tariffs of energy poor customers	5-30%	Repayment of investment – Public acceptance

Users can download a file that contains the detailed input data for risks in order to undertake their own assessment of risks, and upload again the revised file before running the tool. In this case the user is responsible for defining risk values for the included actions (e.g. the risk weighting vector per financial mechanism is not considered by the tool if the user does not consider this when defining risk values).

In conclusion, the final output of the SocialWatt Plan is a set of optimal portfolios (in terms of minimising costs and maximising energy savings), including different combinations of schemes (or part of schemes with their respective actions), which meet the aforementioned set of targets and constraints. For each portfolio, the optimal financial mechanism to support the implementation of the included schemes is provided, whilst for each scheme, the cost (based on the selected financial mechanism but also the total cost), the number of energy poor households to be involved in terms of number of interventions to be implemented, and the total energy savings are estimated.

4.3 Technical Details

SocialWatt Plan is also developed as a 'desktop' application. The development of SocialWatt Plan is based on MVC (Model-View-Controller). This is a software design pattern commonly used for developing user interfaces that divides the related program logic into three interconnected elements. This helps separate internal representations of information from the way information is presented and accepted by the user. Based on the need to model nine unique country situations, the MVC model was considered ideal.

The SocialWatt Plan, incorporates:

- Selected schemes-actions to be examined
- Financial mechanisms to support the implementation of the schemes
- Cities and their respective climate zones
- Building types, along with their thermal characteristics and energy consumption
- Users-countries to access the application.

The **views** include:

- **Login page**: **where** the user logs in using country specific credentials to access the tool;
- **Home page - Interventions index**: where an index of the schemes is presented (e.g., Greening Home, Renovate your Home, White Appliances, Smarter Home, Information & Communication, Fighting the Cold, RES4ALL).
- **Interventions' category index**: where the actions in each scheme are presented.
- **Scheme-action detailed page for every scheme**: where all the data related to

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

each action, categorised by climate zone and buildings' age, are presented.

- **Financial mechanisms' description:** where all commonly available financial mechanisms to support the implementation of the examined schemes are presented, along with the user's contribution for each of them.
- **Solver page**: this is the most important view/page of the application as the user can modify certain parameters (constraints and targets) of the algorithm used for the portfolio optimisation. The results include a customisable (by the user in the frontend) number of portfolios that meet the constrains and targets set, and are plotted as dots on a chart of cost (y-axis) and energy savings (x-axis). The chart allows users to click on each dot and view the detailed analysis of each portfolio in the form of pie charts and tables.
- **Admin site page**: only the administrator of the application has access to this page. It is used for modifying the data in the application without having to alter the database of the application with queries.
- **Logout page**.

The **controllers** are the part of the software which recognise the users' actions and directs them accordingly to their requested page or action. Specifically, in SocialWatt Plan the controllers receive the data from the URL requests and render the HTML Django templates accordingly.

The framework used for the application is based on the Django Framework[20] and more specifically on version 3.0.3. The Django Project Framework was chosen due to its state-of-the-art implementation and documentation.

The database used for storing the data mentioned above is Sqlite3[21] and is directly integrated within the Django framework.

The portfolio optimisation algorithm for SocialWatt Plan was established upon Mixed Integer Programming (MIP) and was developed on Python programming language. For the input data of the portfolio analysis on the Python-based analysis framework, a combination of data in excel form was used.

Finally, for the frontend design the main software library used was Bootstrap 4.4.1[22] and jQuery.[23] As for the plotted visualisation, the application uses a Javascript software library, Plotly.js[24].

4.3.1 Dynamic high-Resolution dEmand-sidE Management model (DREEM)

In order to create optimal portfolios of schemes for mitigating energy poverty, the cost effectiveness ($€_{investment}$ / $kWh_{saving\ (or\ production)}$) of each action incorporated in each scheme is needed. This was obtained by DREEM[25], a dynamic high-resolution demand-side

20 https://www.djangoproject.com/
21 https://www.sqlite.org/index.html)
22 https://getbootstrap.com/
23 https://jquery.com/
24 https://plotly.com/javascript/
25 V. Stavrakas, A. Flamos, «A modular high-resolution demand-side management model to quantify benefits of demand-flexibility in the residential sector» Energy Conversion and Management, volume 205, 2020

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

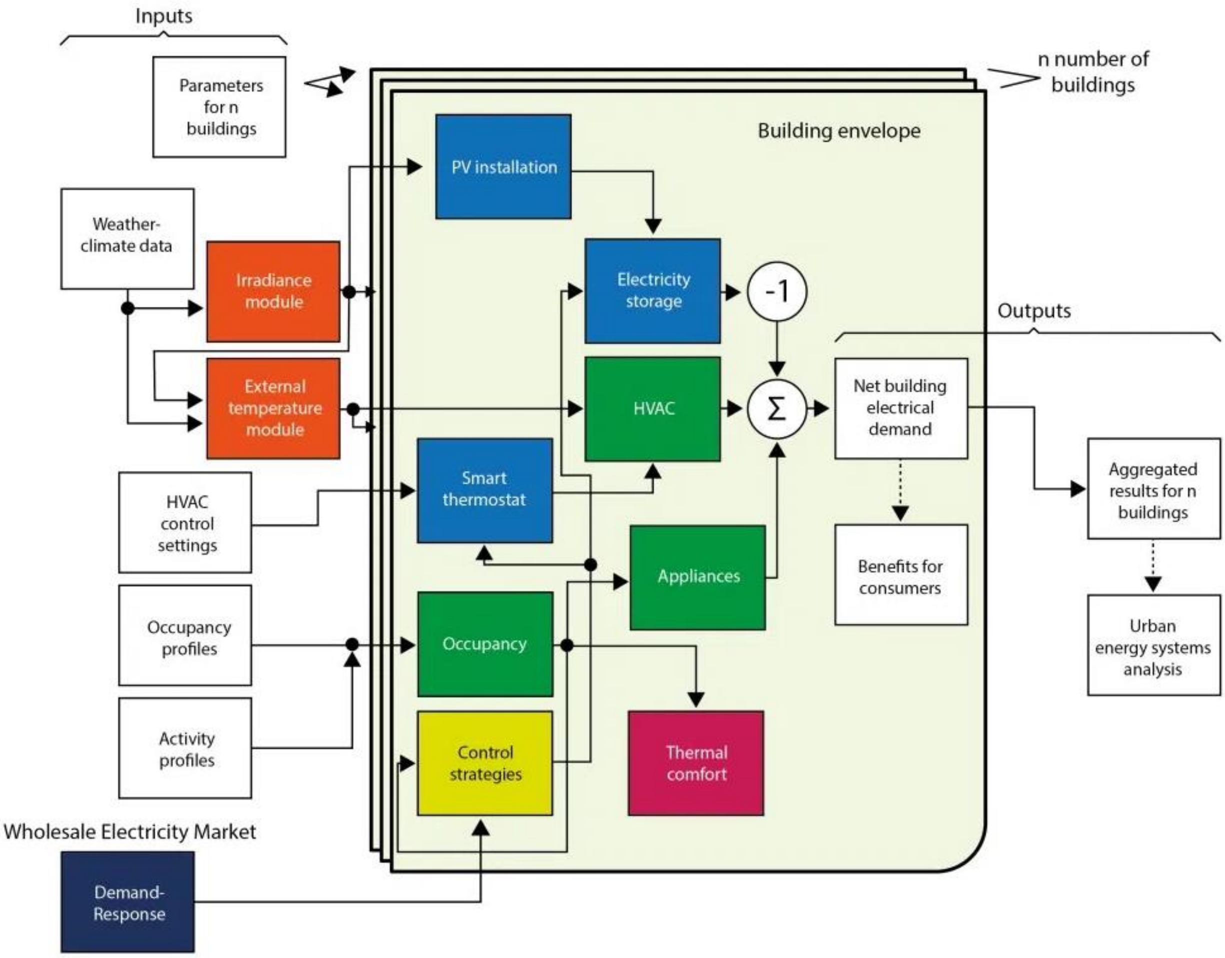
management model which brings together all the key features and guiding principles of demand-side management modeling. It is a hybrid bottom-up model that combines the modelling characteristics of both statistical and engineering models. It is flexible in terms of possible system configurations and control strategies and consists of multiple components, each one of which is composed of additional modules.

The novelty of DREEM lies mainly in its modularity, as its integrated structure allows for the model components' output variables to be appropriately correlated. A component-based system modeling approach refers to a system which is specified by a network of interconnected component models. This approach is more flexible in terms of possible system configurations and control strategies.

DREEM consists of multiple components, each one of which is composed of additional modules, a short description of which is presented in following graph and table. All the modules of the model were developed using the "Buildings" library, which is an open-source, freely available Modelica library for building energy and control systems. Modelica is an equation-based, object-oriented modeling language for the simulation of dynamic systems, and has been used in several studies and applications for the design and the simulation of various Building Energy System (BES) and control systems. Alongside to the Modelica models, Python scripts have been developed to model parts of the Deman-Response (DR) and control components, and to enable the interface with the Dymola simulation environment[25].

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Figure 12: Overall architecture of the DREEM model



The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Table 5: Short description of the main components and modules of the DREEM model

Components	Modules	Description
C1: Weather-climate	-	This one module component is responsible for generating climatic boundary conditions. It reads weather data from the respective files and then provides them to the other components, where and when necessary.
C2: Building envelope	-	This one module component models different building typologies with the corresponding characteristics, properties and heat conduction elements.
C3: Electricity demand	C3M1: Occupancy	This module defines and sets the parameters related to the behaviour and activities of occupants by generating and storing default patterns, such as for the case of a residential building: wake up times and arrival times from work, washing hours, cooking hours, etc. An uncertainty variable is available to make the person more stochastic. Also, active occupancy modelling is enabled to account for the 'sharing of appliances' effect.
	C3M2: Appliances	This module is responsible for generating energy demand profiles from appliances, using statistics describing their mean total daily energy demand and associated power use characteristics, including steady-state consumption or typical use cycles, as appropriate. The "Occupancy" module considers when specific appliances are likely to be used.
	C3M3: HVAC	This module is responsible for heating/cooling and ventilation (HVAC) inside the building studied, according to the "Smart thermostat" module's input data and signals.
C4: Thermal comfort	-	This one module component is responsible for determining, based on international standards, appropriate thermal conditions and temperature ranges that result in the thermal satisfaction of occupants.
C5: Flexibility management	C5M1: PV installation	This module contains information about the orientation of the roof to determine the PV generation based on the position of the sun and recorded irradiation data for the location of interest.
	C5M2: Electricity storage	This module contains models that represent different energy storages. It takes as an input the power that should be stored in/extracted from the battery. The "Control strategies" component is responsible so that only a reasonable amount of power is exchanged, and that the state of charge remains between the appropriate ranges.
	C5M3: Smart thermostat	This module is responsible for the HVAC control system. By receiving the indoor temperature as a measured signal and, based on the difference of set and measured temperature, it sends signals to the "HVAC" module to yield the heat and ventilation flows inside the building studied.
C6: Demand-Response	C6M1: Real-time price signals	This one module component simulates DR mechanisms that motivate the consumers to respond to real-time price signals.
C7: Control strategies	C7M1: Momentary Control Algorithm	This module is responsible for the energy management supervision strategy that, given the time-shifting events of demand and the occupancy signals, aims at achieving energy savings and cost-effectiveness.

The DREEM model addresses the climatic conditions thoroughly compared to other approaches through the inclusion of a single module component dedicated to generating accurate climatic boundary conditions based on historical weather data. To do so, the component uses Typical Meteorological Year (TMY) weather data format and in particular the TMY3 format. The module is then configured to provide a common set of irradiance and temperature data for the geography under study, with the respective irradiance and temperature profiles having appropriate time-diversity to enable higher resolution.

Regarding the building envelope, the DREEM model builds on the concept of 'reduced (low)-order' modules that represent adequately building thermal dynamics for the purposes at hand. Reduced-order thermal network modelling represents a thermal zone by thermal resistances and capacities (RC-network), using the electrical circuit analogy, in which voltage is analogous to temperature and current is analogous to convective and radiative heat transfer. The respective module represents all main thermal masses of the building under study as four elements, accompanied with supportive features for consideration of solar radiation. The parameters for heat transfer coefficients, and thermal resistances and capacities, are determined using historical data and standards for the geographical context of interest.

Recognising that it is not possible to predict the exact behaviour of individual occupants or appliances, the aim of stochastic demand modelling is to provide simulated data, with the right statistics, suitable for the task at hand. The 'human dimension' is not to be neglected, as there is an increasing recognition of the value of integrating social and behavioural insights into models. The DREEM uses a bottom-up approach with the spikiness of the load created by simulating the switching on/off of individual appliances. The individual modules use many simplified assumptions to simulate various aspects of electricity demand (i.e., occupancy and occupants' behaviour, sharing of appliances, etc.) and focuses on a minimal set of easily obtainable parameters and statistics (such as from surveys or census data). The household composition and occupancy patterns derived from historical and statistical data, based on the concept of a fixed, priori schedule. In particular, occupancy states are described in terms of a combined state variable which consists of a first state which describes the presence (home, not at home) and a second describes the activity state (active, not active). Activity states need to be connected with appliances as well. In DREEM each person that changes its state to active can trigger a device to be turned on, and in that event a random value between 0.7 and 1.3 is selected as weight for its power consumption. Finally, the module distinguishes between weekdays and weekends and holidays (i.e., no occupancy), and ensures that no appliances are left on when nobody is at home, except from individual freezers/refrigerators and routers.

HVAC systems plays a vital role, however, detailed system modelling of final consumption is not required, and a simpler modelling approach can be used. As a result, a conceptual system representation becomes sufficient when only load predictions are considered and energy savings are investigated, as in the case of the SocialWatt tools. For that reason, in DREEM, the HVAC system is a split AC unit for electric space heating/cooling, along with an electric pump for indoor ventilation and infiltration. This module is controlled by the "Smart thermostat" module that allows the HVAC system to operate properly and to provide adequate services, adjusting the control variables to meet the required setpoint in spite of disturbances and considering the system dynamic characteristics. Thermal comfort conditions in DREEM, are based on international standards, using the characteristic numbers Predicted Mean Vote (PMV) and Percentage of Dissatisfies (PPD) to compute thermal comfort of occupants.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

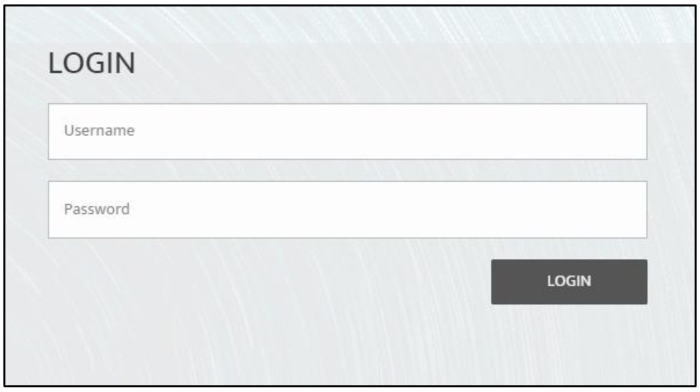
Regarding renewable energy systems and especially PV installations, DREEM models a simple small-scale PV installation (up to 10kWp) with orientation. However, the electricity produced by PV installations, is used only to meet exactly the electricity consumption of households and not to be fed into the grid. The reason for the latter lies in the fact that in a number of countries (e.g., Greece), this surplus is not compensated.

4.4 TOOL CONFIGURATION

The key features of SocialWatt Plan are presented below, in order to showcase the functionalities of the tool, its ease of use, and the way it interacts with the user.

Initially, the user needs to enter his/her credentials when attempting to access the tool. Currently, a country specific username (name of the country – with capital first letter) and password ('demosite') is used for every user. This tailors the application's data and features, based on the user's location, for example in terms of climate zones, building types, and costs of interventions. The figure below shows the login interface for users.

Figure 13: Accessing SocialWatt Plan



An overview of the intervention schemes included in the SocialWatt Plan tool are presented in the figure below. These schemes are evaluated in terms of their performance in meeting a set of predefined targets and constrains, whilst in parallel minimising the total cost from the user's perspective and maximising the energy savings triggered. Each scheme (e.g., 'Greening Home') is focused on a specific area (e.g. thermal renovation of private housing), and includes a set of actions.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Figure 14: Intervention schemes included in SocialWatt Plan

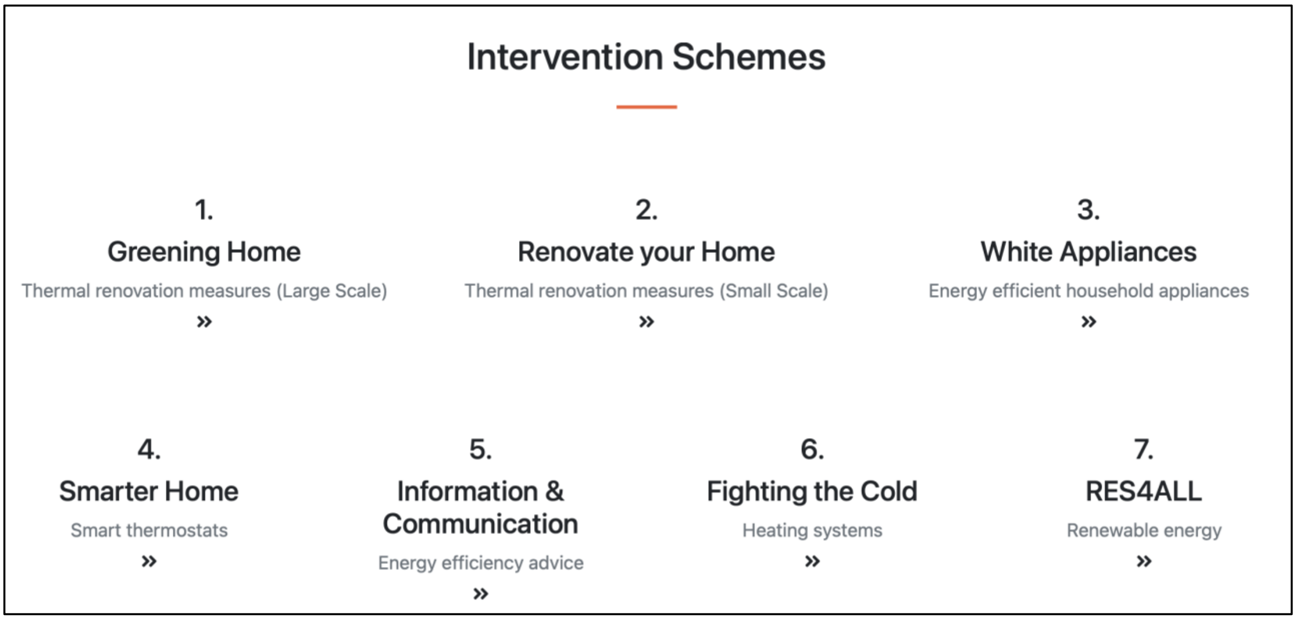


Figure 17: Actions included in the ‘Greening Home’ scheme in SocialWatt Plan

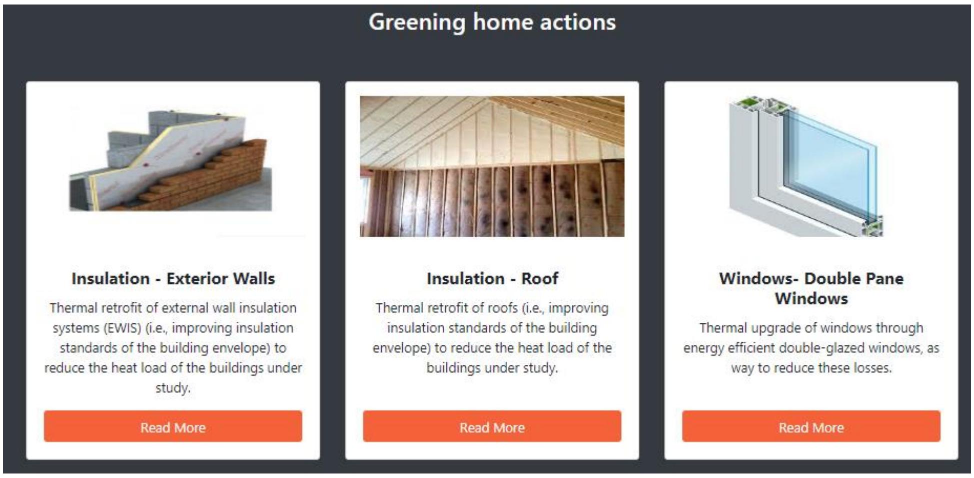


Figure 17: Example of the information embedded in the tool for each action

B climatic zone | Athens   C climatic zone | Thessaloniki

Type of Building: OLD

Total Energy Consumption (kWh/m2): 161.0

Thermal Energy Consumption (kWh/m2): 145.4

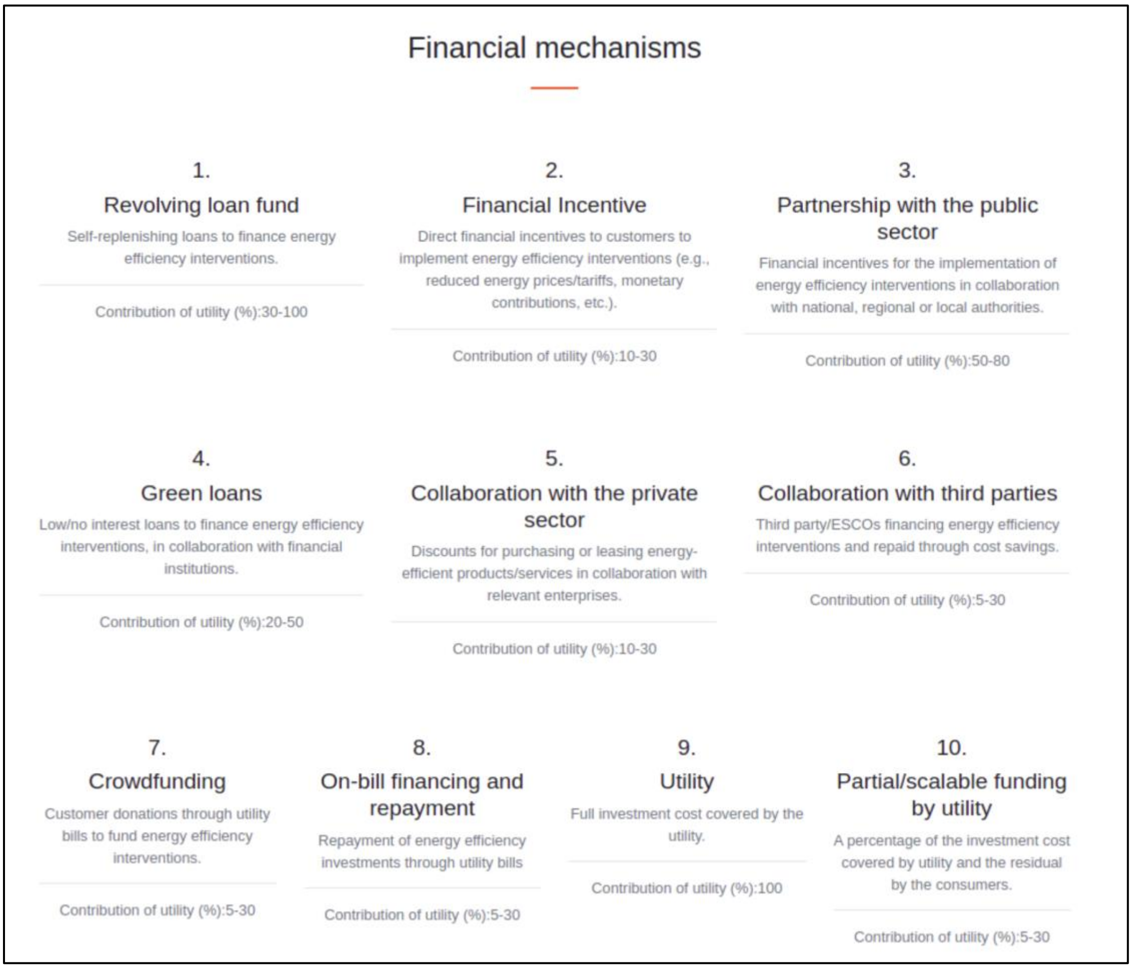
Electrical Energy Consumption (kWh/m2): 15.6

Investment costs (€)	Energy saved (kWh/year)	Lifetime of measure (years)	Capital recovery factor	Levelised cost (€/kWh)
5146.24	3586.9	30	0.051	0.073

An overview of the financial mechanisms that are considered to support the implementation of the examined schemes is also included in the SocialWatt Plan tool. Each mechanism is assigned a different range of participation in terms of the utility/energy company's contribution.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

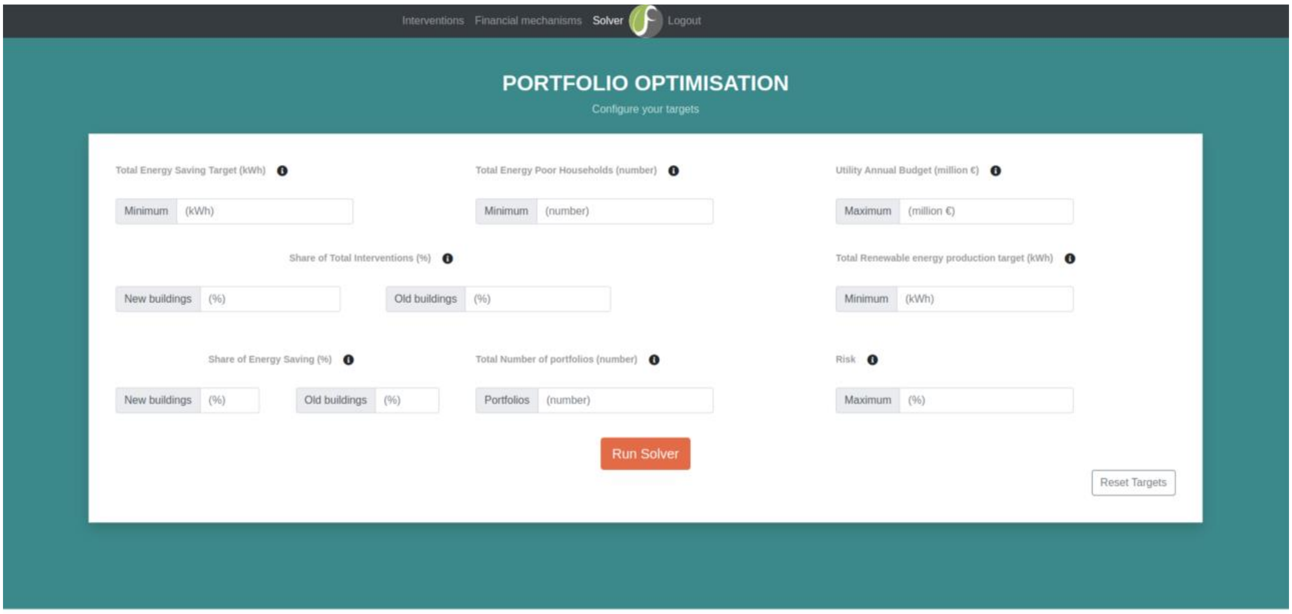
Figure 15: Financial mechanisms included in SocialWatt Plan



The figure below presents the targets and constraints the user needs to define when using SocialWatt Plan. The values are customisable; thus it is entirely up to the user to decide the respective thresholds for each target and constraint. The tool is designed in a way so that the provided thresholds are dynamically dealt with, within the optimisation process, in order for the latter to run smoothly. However, it should be noted that there is always a possibility that a specific combination of thresholds leads to an unfeasible solution, urging the user to modify the targets and constraints set.

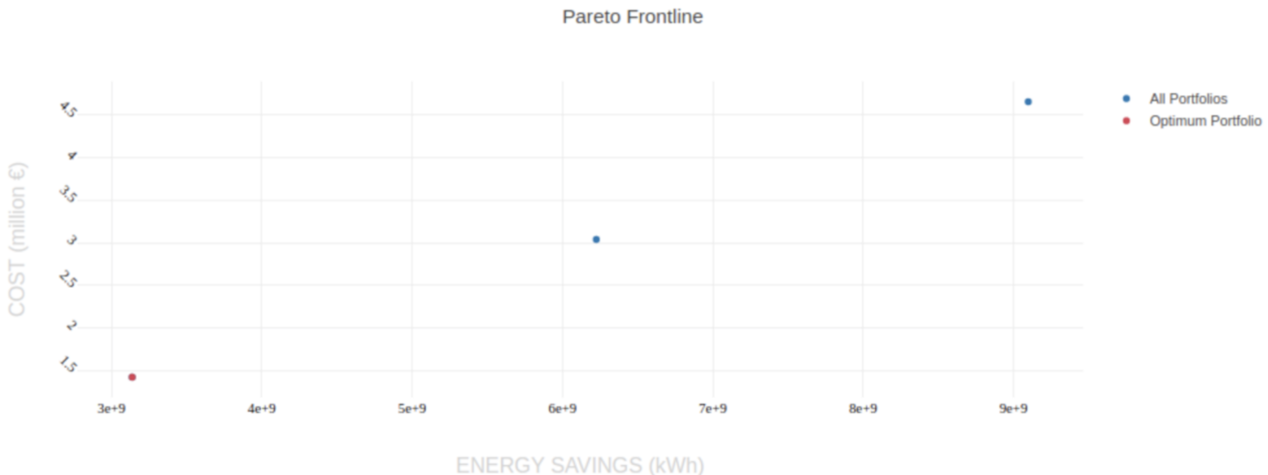
The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Figure 16: User customisable targets and constraints in SocialWatt Plan



As shown in the figure below, the results are presented using a Pareto front, which includes the optimal solutions that meet the pre-defined thresholds, in terms of targets and constraints. The Pareto front consists of multiple dots, each one of which features a specific combination of schemes, and a unique pair of cost-energy savings. In order to facilitate the process of selecting a portfolio that best suits the user's needs and priorities, a portfolio considered optimal is clearly marked.

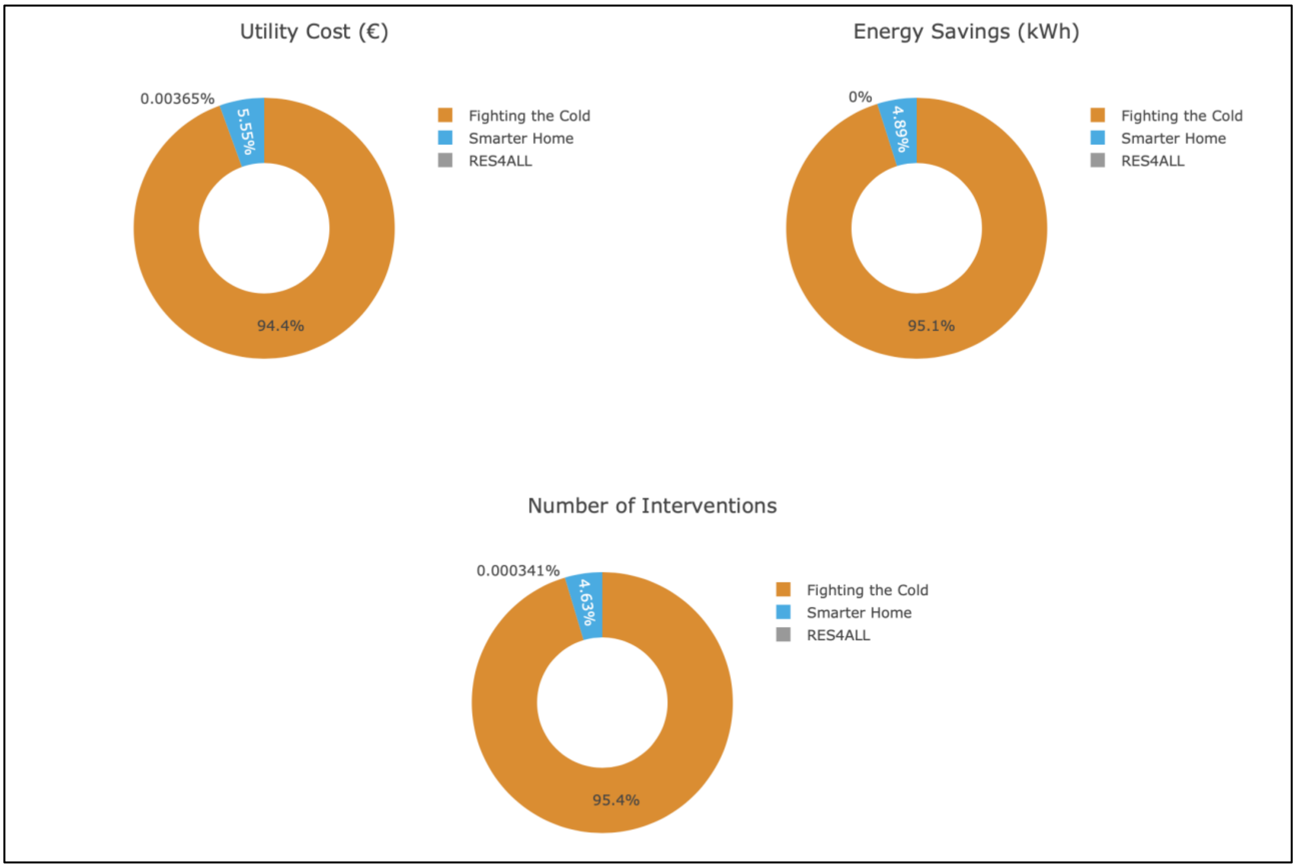
Figure 17: Set of optimal portfolios produced by SocialWatt Plan



In addition to this, SocialWatt Plan presents the results of each portfolio in tables and graphs, considering cost, energy savings, and number of interventions per scheme, whilst detailed results are also downloadable as a .csv file.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Figure 18: SocialWatt Plan results



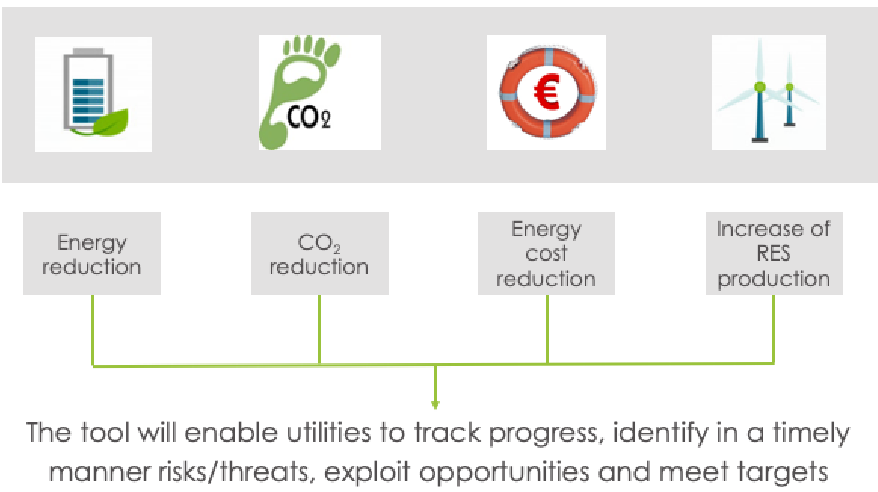
5 SOCIALWATT CHECK

5.1 DESCRIPTION

SocialWatt Check aims to assist utilities effectively monitor and verify schemes that are being implemented. In order to do this, a number of Key Performance Indicators (KPIs) have been defined. More specifically, the impact of each scheme is assessed, in terms of:

- Households engaged;
- Energy savings;
- CO_2 emissions reduction;
- Energy cost reduction;
- RES production;
- Total investment; and
- Total investment by the user.

Figure 19: Key Performance Indicators included in SocialWatt Check



The approach selected for estimating energy savings triggered by the schemes implemented within the framework of SocialWatt is the 'deemed savings' method as described in Annex V of the Energy Efficiency Directive. This enables the assessment of the impact of each scheme beforehand and the calculation of energy at a scheme level. This way, utilities also have the ability to test the actions they intend to implement during the design stage and gain insights on the expected outcomes of each scheme. Although, this "ex-ante" approach is based on estimations from the literature and similar actions implemented in the past, for schemes with a large number of participants, as is the case for utility-based actions, energy savings tend to be around average values, thus providing adequate accuracy to SocialWatt Check. Alternative calculations as part of a 'metered savings' approach would have required a much larger amount of data, time and cost without necessarily leading to huge improvements in terms of accuracy.

The main limitation from the use of the above-mentioned KPIs and the chosen calculation method is that it does not allow utilities to directly assess the total number of citizens that have escaped energy poverty as a result of the implemented scheme. SocialWatt Check

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

addresses this issue by interlinking with SocialWatt Analyser. This feedback process between the tools enables the user to monitor changes in the number of customers identified as energy poor, as a result of the implementation of the scheme.

Overall, SocialWatt Check is designed to allow for multiple actions to be evaluated simultaneously. Once the user has provided all the required information, SocialWatt Check proceeds with the calculations of the key monitoring indicators.

5.2 Input Requirements

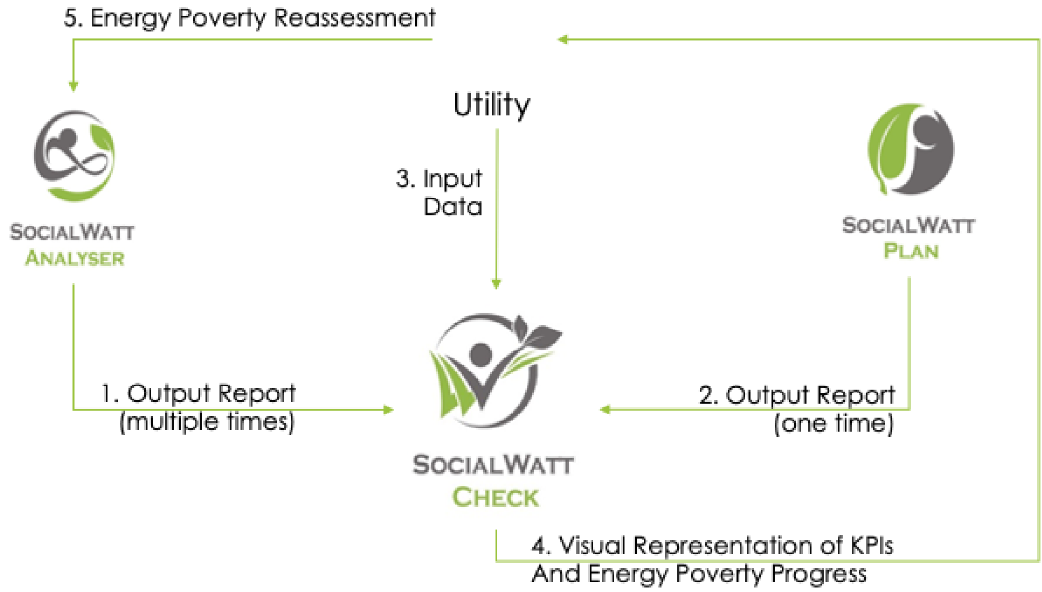
In order for SocialWatt Check to monitor and evaluate the impact of schemes/actions implemented, the following input data and information are needed:

- **Country / location,** where the user selects from a drop down list the country where the schemes are being implemented;
- **Number of households targeted,** where the user determines the total number of households targeted (derived from SocialWatt Plan or set by the user based on the design of the actions/schemes to be implemented);
- **Price of electricity,** allowing the user to set the price of energy for electricity in (€/MWh) or use the pre-defined value;
- **Price of thermal energy,** allowing the user to set the price of energy for thermal energy in (€/MWh) or use the pre-defined value;
- **CO_2 for electricity,** allowing the user to set the CO_2 conversion factor for electricity in tn/MWh or use the pre-defined value;
- **CO_2 for thermal,** allowing the user to set the CO_2 conversion factor for thermal in tn/MWh or use the pre-defined value;
- **User targets:**
    - **Investment target,** enabling the user to set the total amount to be invested in Euro (€);
    - **Energy savings target,** where the user enters an energy savings target in MWh;
    - **CO_2 reduction target,** where the user enters a CO_2 emission savings target in tn;
    - **Renewable energy production target,** where the user enters a Renewable energy production target in MWh;
- **Information on the actual implementation of schemes/actions**, and as a minimum number of households that each action has impemented. Energy savings and the cost per action is estimated by the tool (in line with the methodology used by SocialWatt Plan) or set by the user.

As seen above, the pre-defined parameters incorporated in SocialWatt Check are fully customisable by the user based on the users' specific needs and requirements.

The figure below presents the input requirements of SocialWatt Check, as well as its interactions with the other two SocialWatt tools.

Figure 20: SocialWatt Check interaction with other SocialWatt tools



5.3 Technical Details

SocialWatt Check tool utilises user input data to monitor and verify schemes that are being implemented. It is developed as a 'desktop' application, so that users can download and use the tool locally. As such, personal data and information imported and analysed are not shared with any other organisation or stored in an open database or repository.

The SocialWatt Check, incorporates:

- Schemes-actions that have been selected to be examined
- Cities and their respective climate zones
- Building types, along with their thermal characteristics and energy consumption

The **views** include:

- **Home page – data input form**: where the user is able to input the required background data for the analysis (e.g. targets and conversion factors).
- **Scheme select page**: where the user can select the actions to be evaluated and enter the required data per scheme (e.g. climate zone, number of interventions and relevant data).
- **Evaluation results plotter page**: where all the results are presented in a graphical form (linear) through a plotter plug in and are availiable to download in .csv format.
- **Overview page**: where the results are presented in graphical form (Pie) allowing for detailed analysis.

Django

The framework used for the application is based on the Framework and more specifically on version 3.0.3. The Django Project Framework was chosen due to its state-of-the-art implementation and documentation. The JavaScript libraries include jQuery 3.5.1 and the programming language used is Python. The UI framework is Bootstrap 4.0.0.

The database used for storing the data mentioned above is Sqlite3 and is directly integrated within the Django framework.

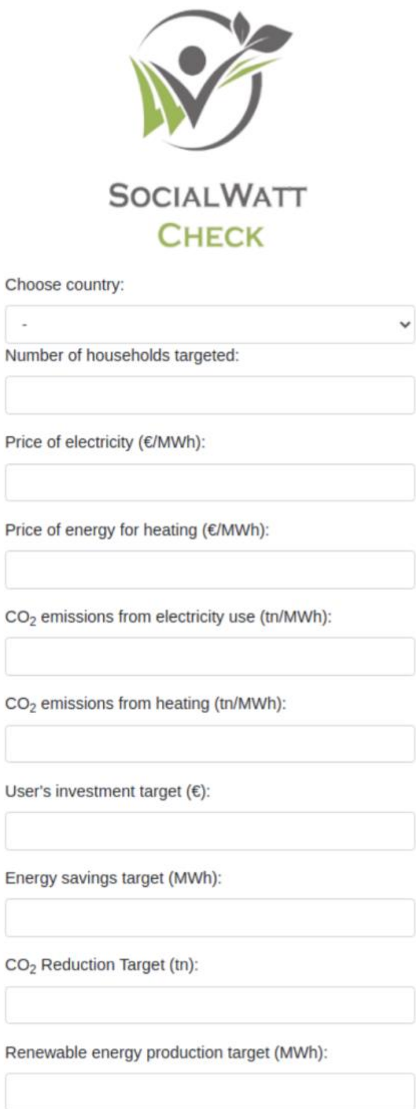
The tool used for the plotting features of SocialWatt Check is Plotly and for the dynamic, interactive data visualisation D3 was used.

5.4 Tool Configuration

The key features of SocialWatt Check are presented below, in order to showcase the functionalities of the tool, its ease of use, and the way it interacts with the user.

Initially, the user is requested to input the key data required that will allow the monitoring and evaluation of schemes/actions being implemented, such as targets set and conversion factors.

Figure 21: SocialWatt Check: initial data input form



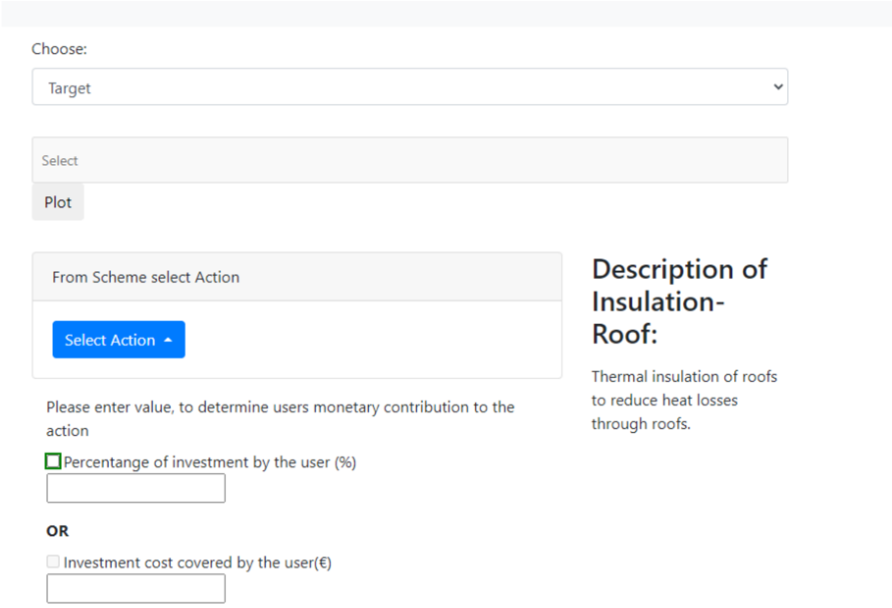
After accessing the tool, the user is requested to select the evaluated scheme from an indexed drop-down list.

Upon selecting the scheme, the user determines its' monetary contribution to each action by either setting the users percentage contribution to the investment or the user's fixed

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

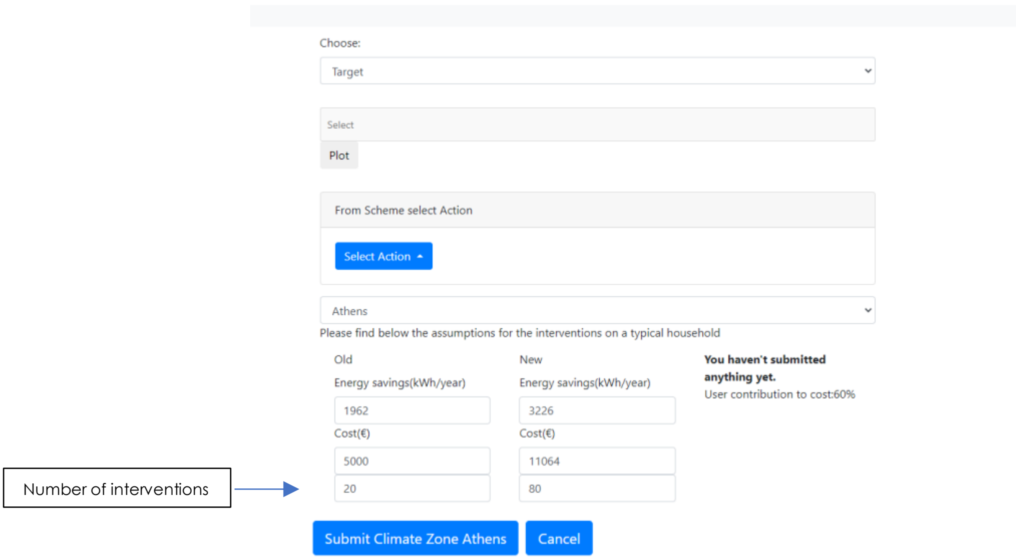
investment value.

Figure 22: SocialWatt Check: selection of actions and user contribution



The user can then proceed in choosing the appropriate climate zone and providing input on the corresponding amount of interventions implemented, along with the energy savings in kWh/year and the cost of the interventions (if better data are available to the values automatically calculated) in old and new buildings respectively.

Figure 23: SocialWatt Check: data input for actions



The user may then proceed with the submission and return in the main page to see the results or to enter data for another climate zone.

SocialWatt Check is designed to allow for multiple schemes/actions to be evaluated simultaneously, so the user can repeat the above process to add more actions/schemes and respective data on their implementation.

Once the user has provided all the required information, SocialWatt Check calculates each

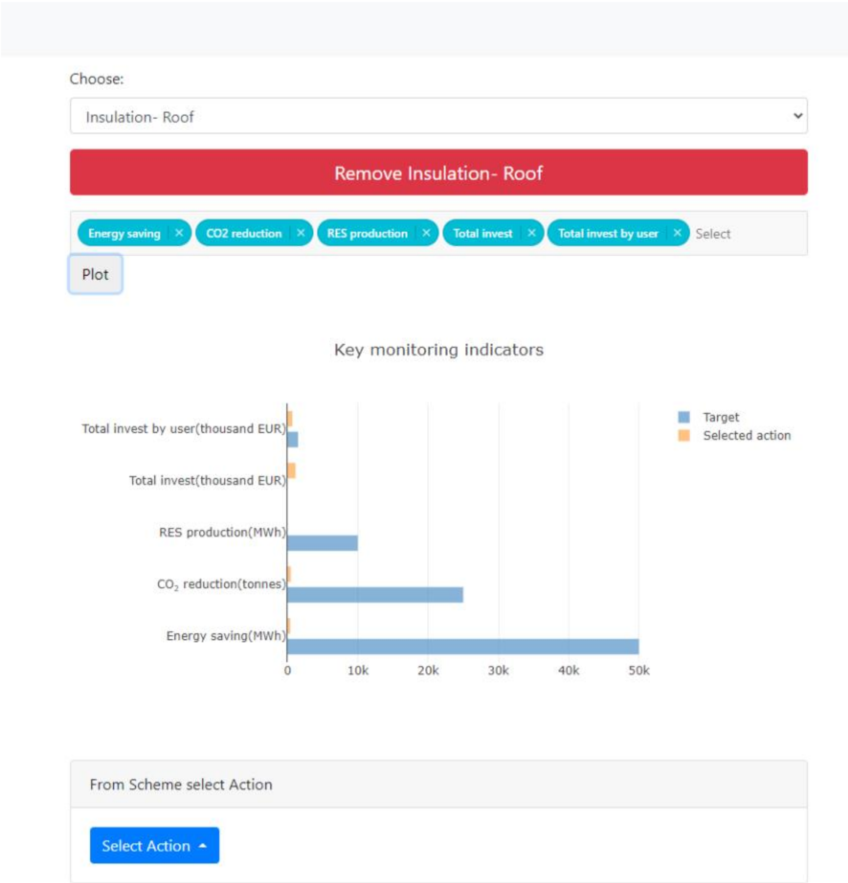
The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

action/scheme's impact, using the following key performance indicators:

- Households engaged;
- Energy savings;
- CO_2 emissions reduction;
- Energy cost reduction;
- RES production;
- Total investment; and
- Total investment by the user.

A plotter tool then presents the above-mentioned calculated data, which are also available to download in a .csv format.

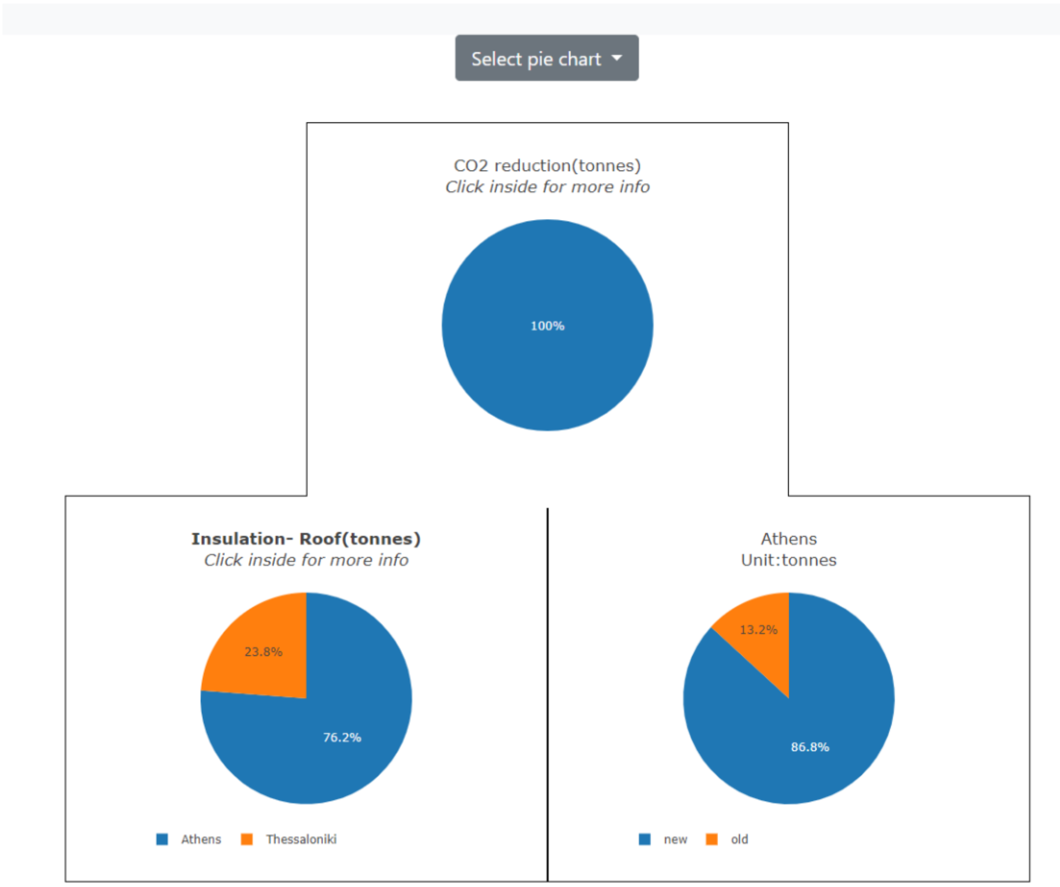
Figure 24: Example of SocialWatt Check results of actions performance over targets



Finally, the tool provides a pie chart graphical visualisation that the user can use to delve into the results on the performance of the actions/schemes for each key performance indicator per climate zone and household type.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

Figure 25: Example of SocialWatt Check pie chart graphical representation of the results



6 LIMITATIONS AND UNCERTAINTIES

As with any tool, the SocialWatt tools also have limitations. Although, these have been developed to be as inclusive and customisable as possible, there are a number of assumptions used, as well as inherent uncertainties associated with the tools. For example, a tool can be as good and accurate as the input data used, thus the use of some of the energy poverty indicators in SocialWatt (e.g., 10% approach and LIHC) introduce a number of uncertainties, as income data are not available at a household level.

Furthermore, given that energy poverty is closely connected to building standards in each country, the parameters used for estimating the energy needs of the "reference households" (e.g., building transmission coefficient, efficiency of equipment, and base temperatures that ensure comfort to the user) may change over time. On top of that, it is assumed that the "reference households" used for conducting the analysis represent average type of households, thus leading to different results if other representative types of "reference households" were to be considered. In this respect, results are expected to be more accurate in areas where households display similar characteristics in terms of floor area, efficiency of heating/cooling systems, wall and window surface and construction materials etc.

The same applies with the occupancy of a "typical household", since one typical occupancy profile has been tested (a single-family house with three members, one of which is a dependant member). Especially for occupancy schedules, due to their deterministic nature, they typically represent environments where the occupants' behaviour is foreseeable and repeatable. Although the DREEM model builds on the simplicity of this approach, using a heuristic approach to address the limitation of repeatability, inaccuracies might arise.

In addition to this, a specific number of climate zones has been considered per country. As such, assumptions have been made regarding the aggregation of areas in order to depict populated cities in the different climate zones considered. These assumptions may result in approximated values and consequently results would be more accurate if more climate zones were introduced or areas with similar geographical characteristics were only considered.

In terms of SocialWatt Check, which has been designed based on a 'deemed savings' approach, the tool enables the user to keep track of the total interventions implemented, and the resulting energy savings, CO_2 emission reductions, cost savings, etc. and compares this to the user-defined targets. This approach based on aggregated calculations does not allow the user to directly monitor progress and assess impact at a household level. As such, it is not easy to identify citizens that have escaped energy poverty due the schemes implemented. Nevertheless, as this is an important consideration, the SocialWatt Check deals with this issue in combination with SocialWatt Analyser, as the user can re-run the latter with the most recent energy data that the utility/energy company holds (i.e. after the implementation of the action/scheme) and compare the status of each customer, in terms of energy poverty, with that before the implementation of the action/scheme (i.e. results produced by SocialWatt Analyser when planning the scheme or for a year preceding the interventions). This clearly identifies changes at household level in terms of escaping energy poverty.

Finally, another limitation relates to the availability of data required to check the accuracy

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905

of the outputs from the SocialWatt tools. To address this, SocialWatt tools are being extensively stress-tested and continuously improved to more accurately interpret and depict reality.

The SocialWatt project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 845905