HEAT PUMPS SKILLS FOR NZEB CONSTRUCTION (HP4ALL)

Introduction to HP Benchmarking Tool for Pilot

Lead Contractor: International Energy Research Centre (IERC)

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This report describes initial ideas of heat pump benchmarking tool for HP4All pilot countries.

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Project details			
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Acronyms and abbreviations

HP	Heat Pump
BER	Building Energy Rating
COP	Coefficient of Performance
SEAI	Sustainable Energy Authority of Ireland
ESV	OÖ Energiesparverband
SPF	Seasonal Performance Factor
WF	Weight Factor
CF	Corrective Factor

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1 Executive summary

HP4All brings together leading experts across Europe to enable capacity and skills development within the heat pump (HP) sector and to ensure that the energy efficiency gains afforded by HPs are realised. HP4All will work both with the supply side (manufacturers, SMEs, installers etc.) and demand side (building owners, public sector etc.) to enhance, develop, and promote the skills required for high quality, optimised HP installations within residential/non-residential buildings.

As part of T4.3 of the HP4All project, a heat pump benchmarking tool has been developed to help raise awareness and understanding of end users regarding expected annual energy consumption and running cost for space heating and water heating delivered by heat pump within their building. The tool will also act as decision-making instrument for heat pump installation and encourage end users to install heat pump within their buildings.

Since all the pilot countries of HP4All project i.e. Ireland, Spain and Austria have different target audience and have different pilot activities, three different tools have been developed to satisfy the needs of each pilot country and their respective pilot activities. Section 2 provides overview of the benchmarking tool and Section **Error! Reference source not found.** of the document describes the design approach and methodology for each of the tools.

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2 Overview

a. Project background

HP4ALL aims to facilitate the massive rollout of heat pumps (HPs) in residential and non-residential buildings by working with the entire HP value chain including both the supply side (manufacturers, engineers, designers, installers) and the demand side (building owners and end users). The project focused on holistically and systemically reducing the energy performance gap in Nearly Zero Energy Buildings (NZEBs) through increasing the level of skills in the HP value chain. HP4ALL has developed a set of tools and resources for use by the different stakeholders to test and validate in different markets through regional implementation in Austria, Spain and Ireland. The intention is that these resources, which are tailored to the needs of each market, will drive market change, influence end-user decisions and accelerate uptake of innovations and emerging technologies in the HP market.

b. Purpose of the HP Benchmarking Tool

The aim of HP benchmarking tool is to encourage end users to install heat pumps in their building by providing them an estimated running cost and energy usage figure that will help by providing them an estimated running cost and energy usage figure that will help with decision-making regarding heat pump installation.

The HP Benchmarking tool acts as a decision tree for end-users during the evaluation of a HP installation in their building. The tool will also encourage end-users to develop a basic awareness regarding the energy tariff applicable to their home, annual energy consumption and costs for heating and building energy rating of their home.

The tool has been integrated within the HP4All Knowledge Hub, which will further provide end-users with knowledge of heat pumps. The tool will predict average annual energy consumption and cost for space heating and water heating delivered by a heat pump within their building. It will help end-users to understand the running cost of a heat pump providing space and water heating.

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3 Design approach of tool

The target audience and pilot activities for all three pilot countries (Ireland, Spain and Austria) are completely different from each other, therefore, in order to fulfil the requirements of each pilot country three different tools for three pilot countries have been designed and developed. Each tool has been tailored in terms of design approach, methodology and output to cater the needs of each pilot. Below is the initial design approach being adopted for each of the pilot countries.

a. Ireland

The heat pump benchmarking tool designed for Ireland is capable of predicting the average annual energy consumption and annual running cost of running a heat pump for space heating and water heating in a residential setting. The target audience for the tool in Ireland is homeowners. Foe either, users who have already installed a heat pump or plan to install one during renovation of an old house or building a new house. This tool will help the homeowners in decision making, when considering the installation of a heat pump by providing them estimated annual energy and annual running cost for a heat pump in their home. Keeping the target audience in mind, who have little or no knowledge about heat pumps and related parameters, the tool has been designed to be easy to understand and very simple to use, requiring users to provide bare minimum information about their building.

The backbone of the HP Benchmarking tool for Ireland is the SEAI Building Energy Rating (BER) database, which is made available by SEAI for the purpose of research. The tool predicts the average annual energy consumption and annual running cost of HP using this database. SEAI BER database offers a wide range of data on various aspects of building construction that will have an affect on the energy performance of a heat pump. It provides information on the annual energy consumption of Irish houses, which are registered with the National BER register. Energy consumption data of the buildings is further categorised into energy consumption for space heating, water heating, ventilation, lighting etc.

An Irish Benchmarking Database was created using the SEAI BER database purely with the purpose to be used by the tool. The Irish benchmarking database includes the average annual electricity consumption for space heating and water heating for all types of building ranging from A1 energy rating to C3 energy rating with a heat pump installed. Annual electricity consumption in this database is average electricity consumption (for space heating and water heating) of all the buildings in Ireland registered in the SEAI BER register, presenting all the possible combination of house based on users' input parameter i.e., type of building, energy rating and area range of house.

Below is the list of information required from the users as input parameters for the tool. All the User input data in the dropdown list is in line with the database.

Input parameters:

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- Type of Building: Type of their residential building, for example, apartment, Basement dwelling, detached house, end of terrace house, ground floor apartment, House, Maisonette, Mid-floor apartment, Mid-terrace apartment, semidetached house, and top-floor house. . Users are provided with a dropdown menu, with all the possible options to choose the most suitable option for them.
- Building Energy Rating (BER): Building energy rating, as defined in Ireland, of their house or which the users estimate they will achieve either after renovation or for a new house, for example A1, A2, A3, B1 etc. The users are provided with a dropdown menu to select appropriate option. The minimum available building energy rating in the dropdown menu is C1, because for a heat pump to operate efficiently, buildings need to be tightly insulated and meet minimum energy performance requirements. This will ensure users are either having or planning to upgrade their home to achieve minimum C1 building energy rating before considering the heat pump installation.
- Area range of house (m^2): Range of the area of the user's house, for example, 0-49m^2, 50-74m^2, 75-99m^2, 100-124 m^2, 125-149 m^2, 150-174 m^2, 175-199 m^2, 200-249 m^2, and more than 250 m^2 . Again, users are provided with a dropdown menu for them to select best suitable option for their house.
- Electricity tariff: Next question user is asked is if they know the average unit electricity rate for 24 hours applicable to their house. The user can select either yes or no for this question. If the user selects yes, then the tool will provide user with an option to enter the average unit electricity rate for 24 hours applicable to their house expressed in cents/kWh. If user selects 'no', then tool will be fed with standard electricity tariff as published by Sustainable Energy Authority of Ireland (SEAI). Providing this information will encourage users to check and get aware about the applicable electricity tariff for their house.

Output:

- The output of the tool is the average annual energy consumption (kWh/year) and annual running cost (€/year) for a heat pump to deliver space heating and water heating.

Methodology:

- Based on input parameters provided by user about their building (Type of Building, Building Energy Rating and Area of the house), the tool will compare the user's building with similar house(s) in the Irish benchmarking database.
- After comparison, the tool will predict the average annual energy consumption of the hypothetical heat pump (for space heating and water heating) based on the energy consumption of similar houses.
- Once the tool predicts the average annual energy consumption for the hypothetical heat pump, then based on input provided for electricity tariff, the tool will finally predict the average annual running cost for a heat pump.

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- Annual electricity consumption data is not available for some buildings in the SEAI BER Database, in such case tool displays the closest match building to predict the annual electricity consumption and annual electricity cost. In such cases the tool's output page displays the message – "There is no data for your building. The data displayed is the closest match."

The link to the Heat Pump Benchmarking Tool for Ireland is: http://hp4all.ierc.info/development/index.php

The tool is in English language. Below **Error! Reference source not found.** is a screenshot of user input page of the Irish tool, where the user needs to provide information about their building.

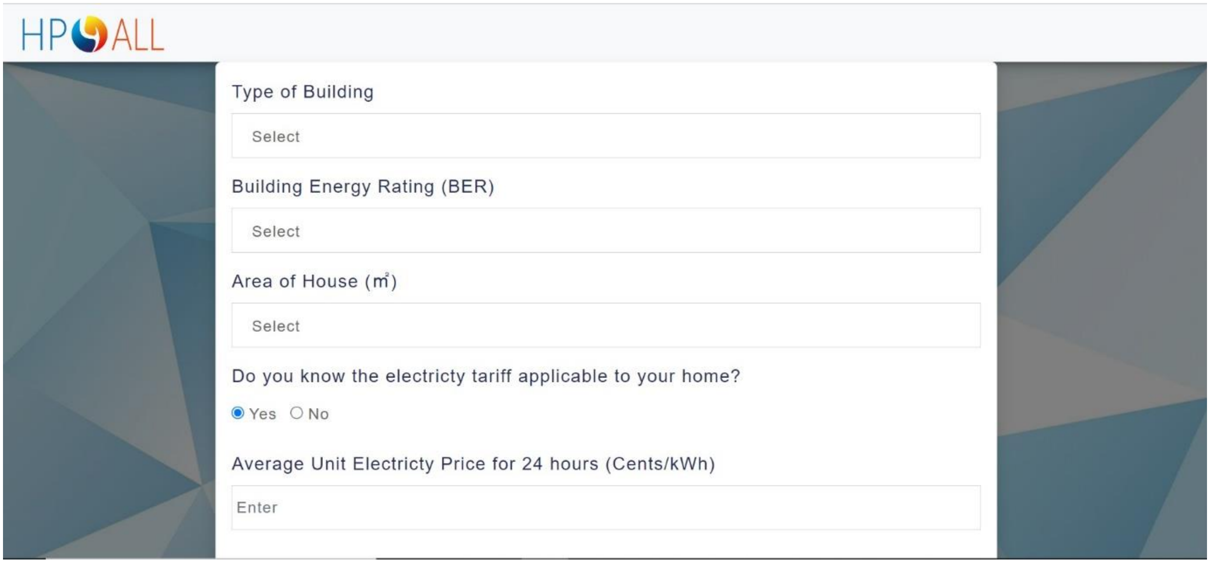

Figure 1: User input page of HP Benchmarking Tool for Ireland

Error! Reference source not found. is the screenshot of tool's output, where tool provides summary of user inputs and then predicts annual electricity consumption (kWh/year) and annual electrical cost (€/year) for running a heat pump to provide both space heating and water heating.

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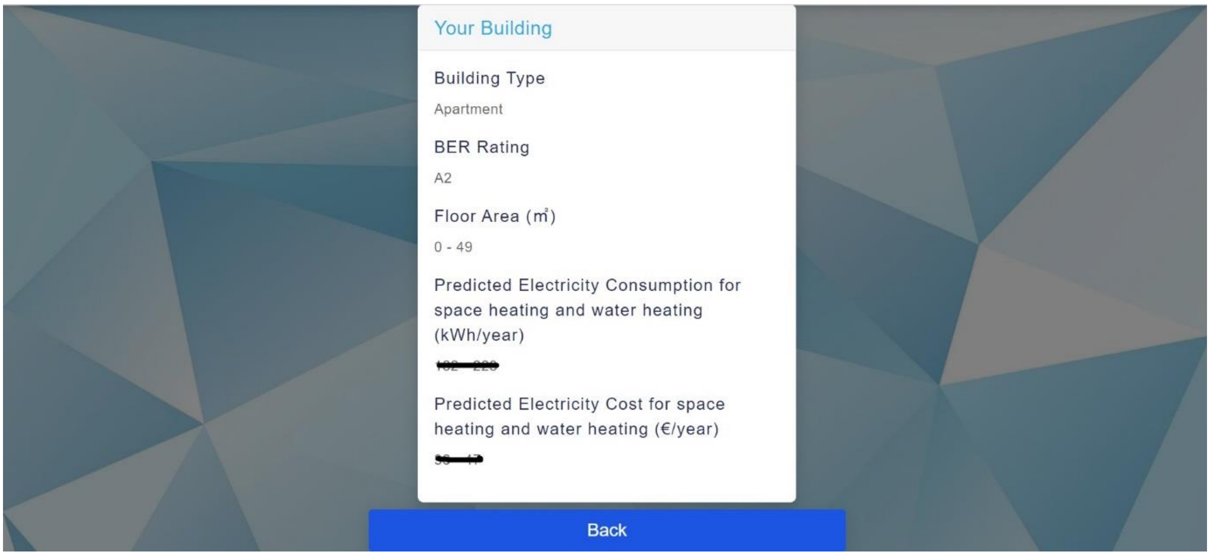

Figure 2: User output page of HP Benchmarking Tool for Ireland

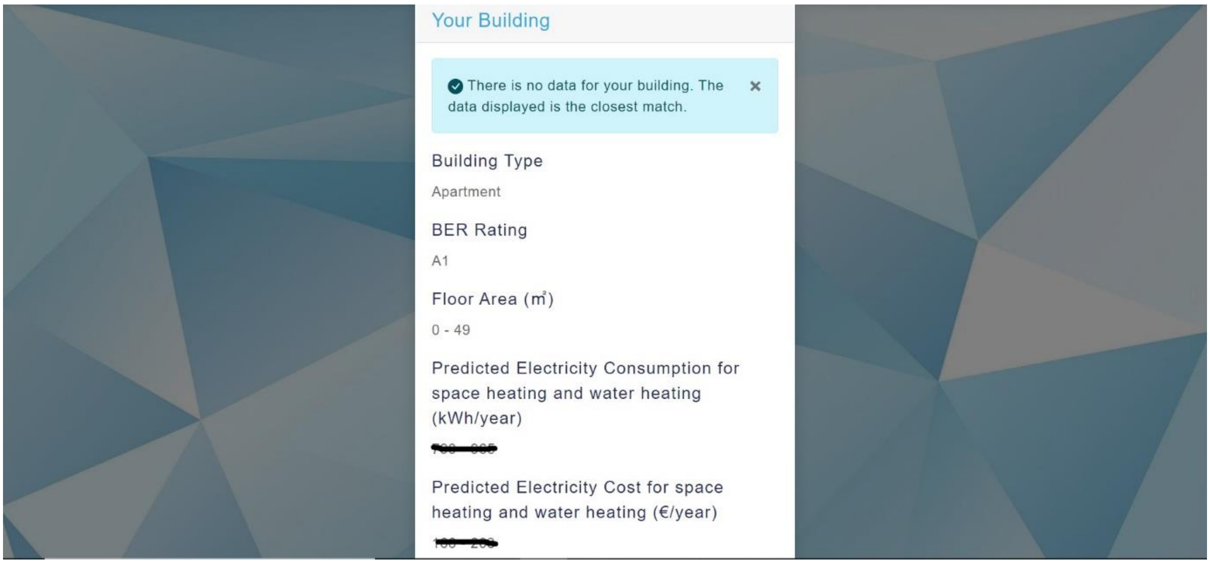

Figure 3: User output page of HP Benchmarking Tool for Ireland when no data is available for user's building

b. Austria

The Heat Pump Benchmarking tool designed for Austria assesses the real-life Annual Performance Factor of residential heat pump installations. It determines the "in situ COP" (Coefficient of Performance) of a system and offers a general indication on the performance level compared to other systems of the same type (air source heat pumps, ground source heat pumps). The tool is primarily targeted to end-users of residential heat pump installations who would like to assess the efficiency and real-life or in-situ performance of their systems.

Input data:

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* Annual heat output of the system: Typically, this information can be assessed by either reading the heat meter or is available directly in the control system on modern heat pump systems. In Upper Austria, a heat meter is required for accessing the heat pump funding programme. In modern heat pumps, a heat meter is integrated in the control system.
* Annual electricity consumption of the heat pump: This information can be assessed by reading the meter (in Austria, heat pumps usually have their own electricity meter) or via the smart meter tool of the electricity provider.
* Type of heat pump: air source heat pump or ground source heat pump.

Output:

* The tool calculates the real-life performance factor of the heat pump system (as a number). The result is presented on a coloured scale (green to red), indicating the level of performance compared to other systems of the same type.

Methodology:

The Austrian Regional Energy Agency of Upper Austria, OÖ Energiesparverband (ESV) developed and offered the tool on its website. ESV is a recognised source of information in Upper Austria for new build, building refurbishment, energy efficiency and renewable energy.

Example of calculation:

Input data:

* Annual heat output of the system: 8000 kWh
* Annual electricity consumption of the heat pump: 2000 kWh

Calculation:

8000 kWh ÷ 2000 kWh = 4

Result:

Annual Performance Factor = 4.

For an air source heat pump, this result would be depicted in the "green" section of the colour scale. For a ground source heat pump, in the "yellow" section. Because the average COP value for the air source heat pump is 3-4 and for ground source heat pump is 4.5-6.

The link to the Heat Pump Benchmarking Tool for Spain is -
https://www.energiesparverband.at/energiespartipps/heizen-warmwasser

The tool is in German language. Below are the screenshot of user input and output page of the tool –

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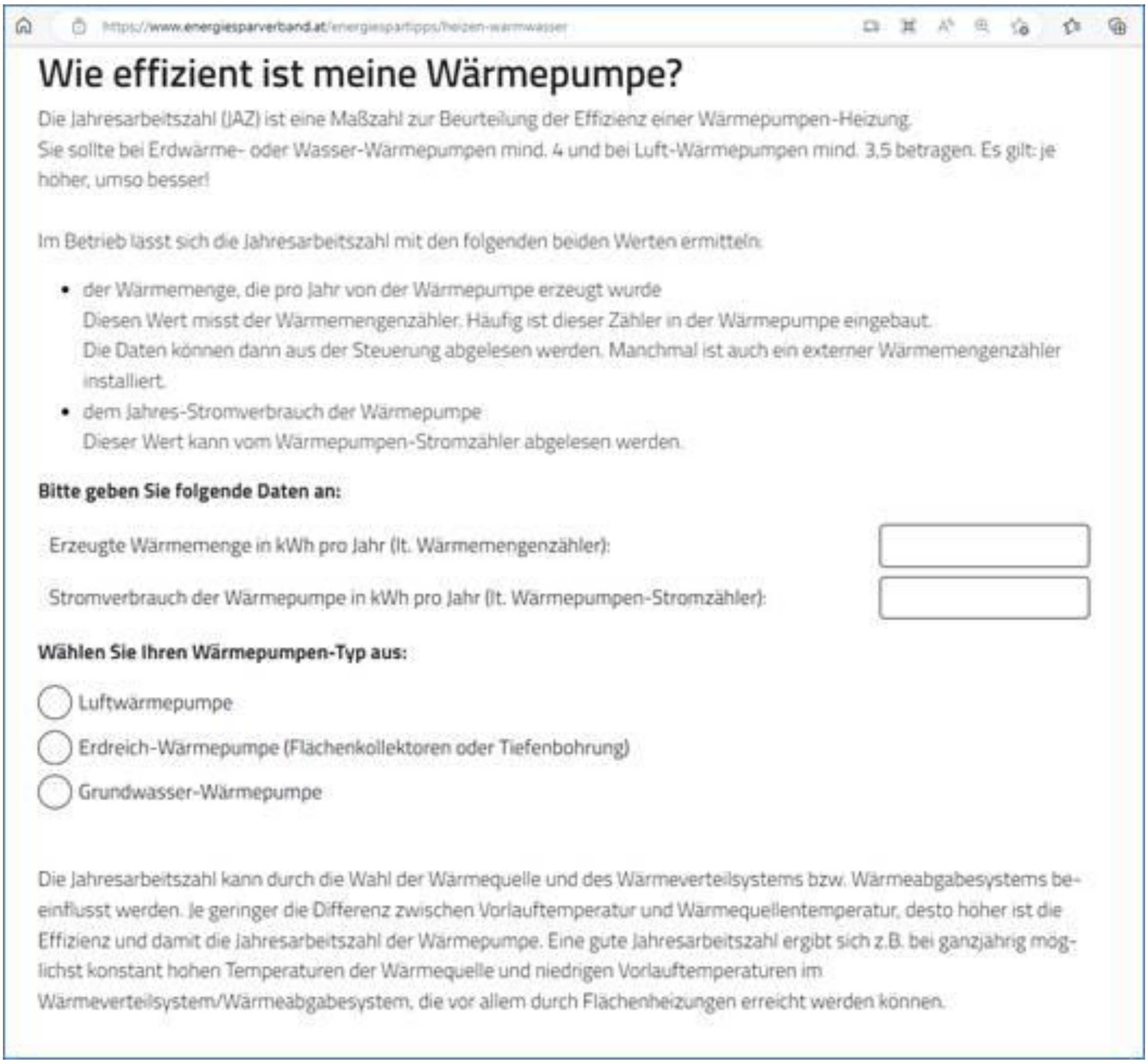

https://www.energiesparverband.at/energiespartipps/heizen-warmwasser

Wie effizient ist meine Wärmepumpe?

Die Jahresarbeitszahl (JAZ) ist eine Maßzahl zur Beurteilung der Effizienz einer Wärmepumpen-Heizung.
Sie sollte bei Erdwärme- oder Wasser-Wärmepumpen mind. 4 und bei Luft-Wärmepumpen mind. 3,5 betragen. Es gilt: je höher, umso besser!

Im Betrieb lässt sich die Jahresarbeitszahl mit den folgenden beiden Werten ermitteln:

- der Wärmemenge, die pro Jahr von der Wärmepumpe erzeugt wurde
  Diesen Wert misst der Wärmemengenzähler. Häufig ist dieser Zähler in der Wärmepumpe eingebaut.
  Die Daten können dann aus der Steuerung abgelesen werden. Manchmal ist auch ein externer Wärmemengenzähler installiert.
- dem Jahres-Stromverbrauch der Wärmepumpe
  Dieser Wert kann vom Wärmepumpen-Stromzähler abgelesen werden.

Bitte geben Sie folgende Daten an:

Erzeugte Wärmemenge in kWh pro Jahr (lt. Wärmemengenzähler):

Stromverbrauch der Wärmepumpe in kWh pro Jahr (lt. Wärmepumpen-Stromzähler):

Wählen Sie Ihren Wärmepumpen-Typ aus:

- Luftwärmepumpe
- Erdreich-Wärmepumpe (Flächenkollektoren oder Tiefenbohrung)
- Grundwasser-Wärmepumpe

Die Jahresarbeitszahl kann durch die Wahl der Wärmequelle und des Wärmeverteilsystems bzw. Wärmeabgabesystems beeinflusst werden. Je geringer die Differenz zwischen Vorlauftemperatur und Wärmequellentemperatur, desto höher ist die Effizienz und damit die Jahresarbeitszahl der Wärmepumpe. Eine gute Jahresarbeitszahl ergibt sich z.B. bei ganzjährig möglichst konstant hohen Temperaturen der Wärmequelle und niedrigen Vorlauftemperaturen im Wärmeverteilsystem/Wärmeabgabesystem, die vor allem durch Flächenheizungen erreicht werden können.

Figure 4: Input page of HP Benchmarking tool for Austria

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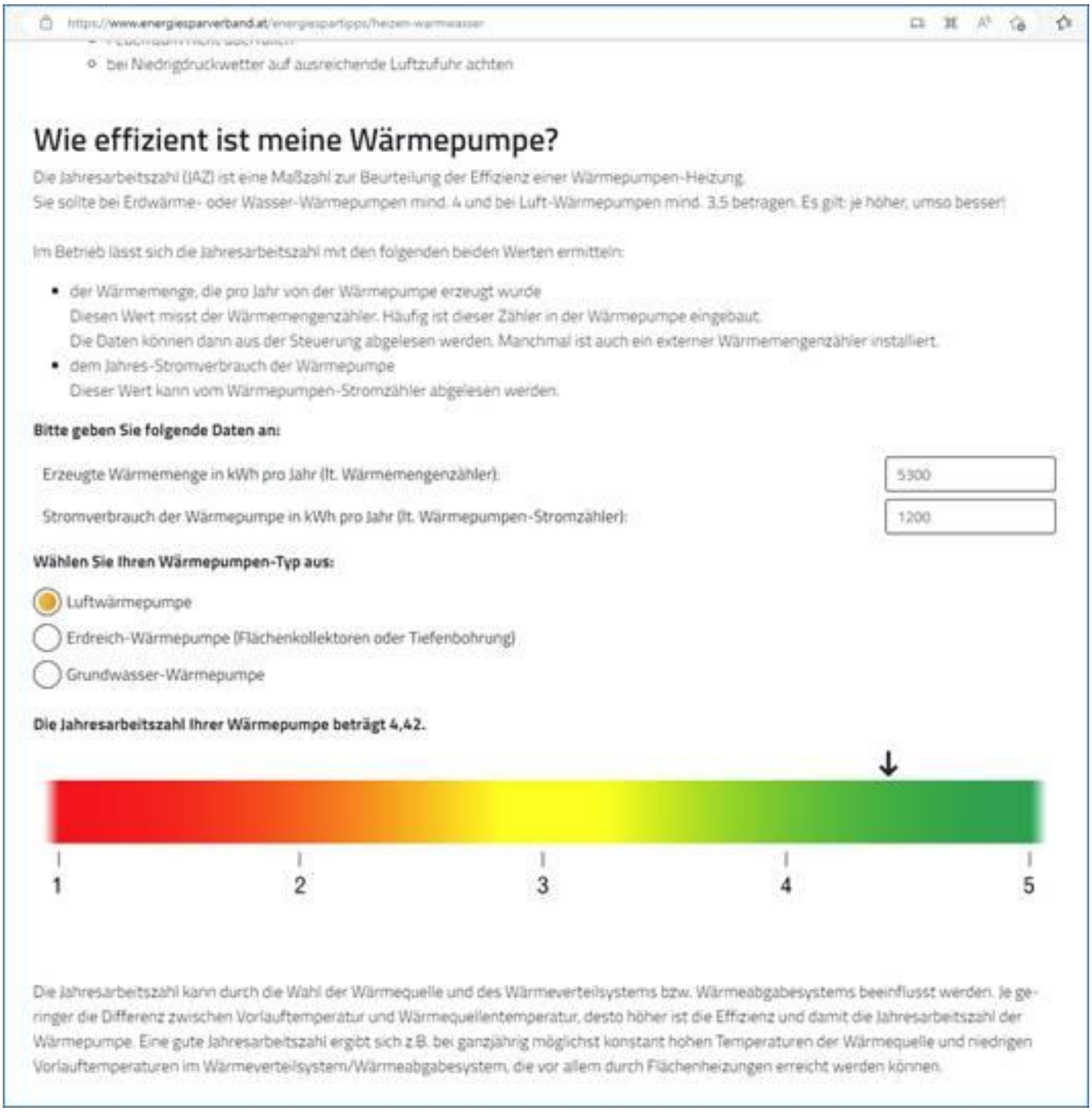

Figure 5: Result page for Air source heat pump in HP Benchmarking tool for Austria

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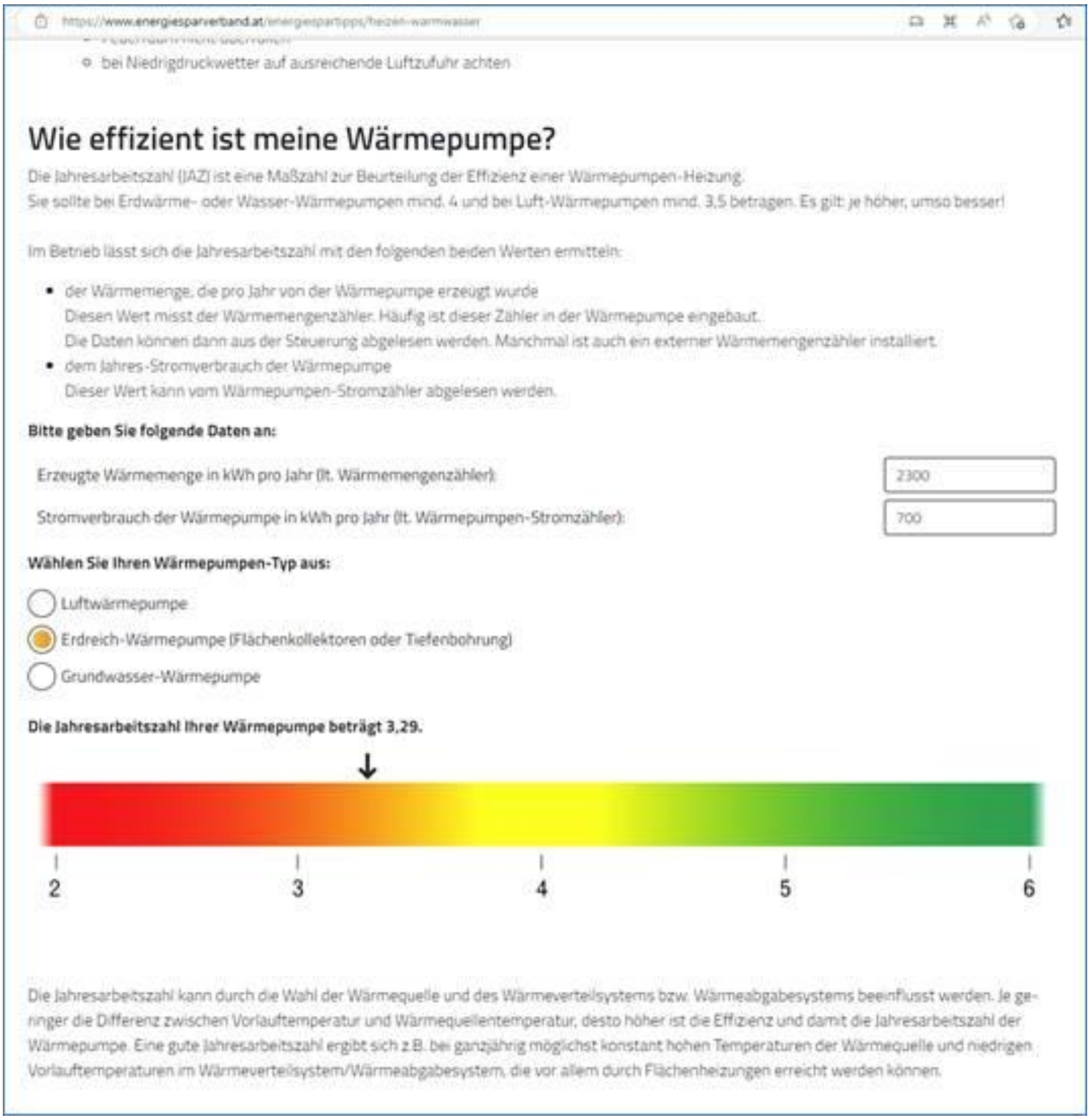

Figure 6: Result page for Ground source heat pump in HP Benchmarking tool for Austria

c. Spain

The heat pump benchmarking tool for Spain follows a similar approach as Ireland. The target audience for the Spanish tool includes public buildings owners / tenants, who are planning to install heat pumps within their building. Since heat pump operation (energy demand and COP) largely depends on climatic conditions and Spain has three different climatic zones, the impact of climate on the heat pump operation needs to be considered in the calculations performed by the tool. To take into account the impact of climate change/ seasonal variation the tool

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needs to calculate the 'Seasonal Performance Factor' (SPF) for the heat pump. SPF is calculated using following Equation 1 -

$$SPF = \text{Nominal COP} \times WF \times CF$$

Equation 1: SPF of Heat Pump in Spain

Where COP (Coefficient of Performance) is the measure of heat pump operational efficiency and Nominal COP is the COP calculated in the standard lab condition. COP nominal value stems from official lab tests outcomes according to the applicable regulation for every technology (UNE-EN 14511: 2012, UNE-EN 15316: 2010, UNE-EN 16147, etc.), temperature conditions corresponding to the climate zone and HP application (heating, SHW etc.). WF (Weight Factor) and CF (Corrective Factor) are the multiplying factors accounting for the impact of climate.

WF takes into account the climate zone (A, B, C, D and E) in which the heat pump has been installed. This value is defined by the Spanish Technical Building Code - CTE and has been calculated by a purely technical methodology and documentation[1]. WF value also differs for different technology of heat pump. CF outweighs differences between actual, operational, and testing temperature at which COP is calculated for different technology of the heat pump in lab scale.
The table presents standard values for WF and CF.

	Weight Factor (WF)				
Heat Pump Power Supply	**A**	**B**	**C**	**D**	**E**
Aerotechnical Energy. Centralaised Equipments.	0,87	0,8	0,8	0,75	0,75
Aerotechnical Energy. Individual Equipments (split)	0,66	0,68	0,68	0,64	0,64
Hydrothermal Energy.	0,99	0,96	0,92	0,86	0,8
Closed-loop Geothermal Energy. Horizontal exchangers.	1,05	1,01	0,97	0,9	0,85
Closed-loop Geothermal Energy. Vertical exchangers.	1,24	1,23	1,18	1,11	1,03
Open-loop Geothermal Energy	1,31	1,3	1,23	1,17	1,09

Table 1. Weighting factor (WF) for heating and/or DHW systems with heat pumps as a function of energy sources, depending on the climate zone.

	Corrective Factor (CF)					
Condensation temperature (ºC)	CF (COP at 35ºC)	CF (COP at 40ºC)	CF (COP at 45ºC)	CF (COP at 35ºC)	CF (COP at 35ºC)	CF (COP at 35ºC)
35	1,00	-	-	-	-	-
40	0,87	1,00	-	-	-	-
45	0,77	0,89	1,00	-	-	-
50	0,68	0,78	0,88	1,00	-	-
55	0,61	0,70	0,79	0,90	1,00	-
60	0,55	0,63	0,71	0,81	0,90	1,00

Table 2. Correction factors (CF) as a function of condensing temperatures, depending on the COP test temperature.

[1] https://www.caloryfrio.com/calefaccion/zonas-climaticas-espana-segun-cte.html

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Spanish Technical Building Code have categorised the Spanish provinces into five different climate zones as A, B, C, D and E. Users are asked to provide information about their respective province and based on the climate categorization user's location will be allocated one of the five zone. This categorisation is important to take into consideration to determine the value of the Weight Factor (WF) as defined in Table 1.

Asking users about the condensation temperature and temperature at which COP is calculated for user's heat pump might discourage the users to use the tool. Hence, after discussing with heat pump experts a default value for CF was agreed: 0.88; reflecting a condensation temperature of 50°C and a COP temperature of 45°C.

Spanish Energy Agency IDAE provided a Building Energy Efficiency database for old buildings (built before 2007)[2] and for new buildings (built on or after 2007)[3]. This database provides average annual thermal heating demand (space heating and domestic hot water) for individual household and block of buildings for each province of Spain. Thermal heating demand is presented as kWh/m^2.

Input Parameter:

- Type of Building: Type of the building – either individual building or block of buildings. User is provided with a dropdown menu, with these two options because the database provided by the Spanish Energy Agency IDEA categorises the building as individual building or block of building.
- Location: Next information user needs to enter is the location of their building. A list of Spanish provinces is provided to the user via a dropdown list. The users can choose the most suitable location for themselves. These locations are in correspondence to the climate zone as defined by Technical Building Code – CTE.
- Year of building construction: The user then needs to enter the year of building construction, which needs to be chosen from a dropdown list. To make it simple and easy for user only two options are provided as 'Before 2007' and 'On and after 2007'. The user can choose the most appropriate option for themselves. Buildings constructed before 2007 are regarded as old buildings whereas buildings constructed on and after 2007 are regarded as new buildings. This assumption is in line with the information and database provided by Spanish Energy Agency IDEA.
- Area range of the building (m²): The user needs to enter the area of the building in m^2. This is a free text field, where the user is allowed to enter numeric value for the area of their building/house.

2 https://www.idae.es/uploads/documentos/documentos_11261_EscalaCalifEnerg_EdifExistentes_2011_accesible_c762988d.pdf

3 https://www.idae.es/sites/default/files/documentos/publicaciones_idae/documentos_calener_07_escala_calif_energetica_a2009_a_5c0316ea.pdf

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- Type of HP installed/planning to install: User needs to enter the technology of the heat pump installed or that the user is planning to install. User is again provided with a dropdown list to select the most appropriate option for their building.
- Nominal COP of HP installed/planning to install: The user is asked if they know the nominal COP of the heat pump already installed or planning to install in their building with an option of 'yes' and 'no'. If user selects 'yes' then to the tool asks to enter the nominal COP value for the heat pump. If user selects 'no' then tool will consider a default COP value (Air source heat pump- 3.2, Water source heat pump – 3.6 and Geothermal heat pump – 3.8) based on the heat pump technology selected by user. This default value was collected by consulting HP experts.
- Average unit electricity price for 24 hours (cents/kWh): The user is asked to enter the average unit price of electricity for 24 hours applicable to them. This value should be in cents for each unit of electricity (i.e. cents/kWh). This is a free text field where user can enter the numeric value. This information can be retrieved in the user's electricity bill. Providing this information will help user to raise their awareness about unit price of electricity applicable to them.

Output:

- The tool provides information about SPF of the heat pump installed in users building.
- The tool also provides information about average annual energy consumption (kWh/year) and annual running cost (€/year) for a heat pump delivering space and water heating.

Methodology:

- Based on type of building, location of building and year of construction the tool will fetch the average thermal heating demand (space heating + domestic hot water) for the users building in kWh/m^2/Year using the database provided by Spanish Energy Agency.
- The unit of annual average thermal heating demand fetched from the database is kWh/m^2/Year; hence, by using the building area provided by the user, the tool will calculate the total annual average thermal heating demand for the building. The tool will do so by using following Equation 2:

Annual Average Thermal Heating Demand (KWh/Year) = Thermal heating demand (kWh/m^2/Year)*area of building (m^2).

Equation 2: Annual Average Thermal Heating Demand

- Based on information about location and type of heat pump provided by user the tool fetches a weight factor (WF) to calculate the SPF value.
- The tool checks if the user has provided the nominal COP value for the heat pump installed or planned to be installed. If user has provided the nominal COP value, then the tool uses user's value to calculate SPF, otherwise it uses the default nominal COP for the heat pump technology selected by the user .

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- The tool calculates the SPF for the user's heat pump using the Equation 3 :

SPF = Nominal COP* WF*CF

Equation 3: SPF of Heat Pump in Spain

- In the above formula, the default value (0.88) for Corrective Factor is used as mentioned in the previous section.
- The tool calculates the electrical heating demand for the user's building using Equation 4 –

Annual Average Electrical Heating Demand (kWh/Year) = Annual Average Thermal Heating Demand (KWh/Year)/SPF

Equation 4: Annual Average Electrical Heating Demand

- Finally the tool will calculate electricity cost for space heating and domestic hot water heating using average unit electricity price for 24 hours with following Equation 5 –

Annual Average Electricity cost (Euro/year) = Annual Average Electrical Heating Demand (kWh/Year)*Average unit electricity price (Cents/kWh)/100

Equation 5: Annual Average Electricity Cost

The link to the Heat Pump Benchmarking Tool for Spain is: http://hp4all.ierc.info/development_spn/index.php

The tool is in Spanish language. The screenshot of user input and output page of the tool are shown in Figure 7 and Figure 8.

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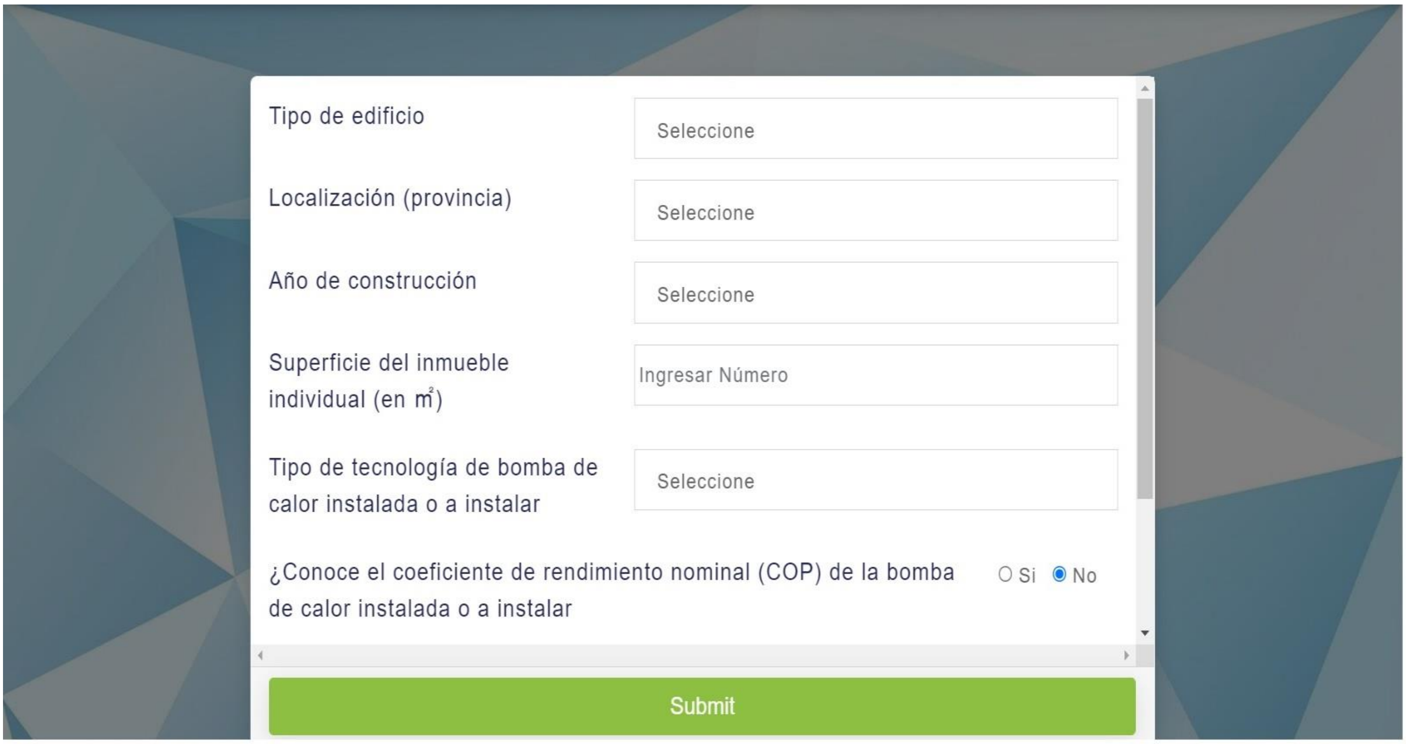

Figure 7: Input page of HP Benchmarking Tool for Spain

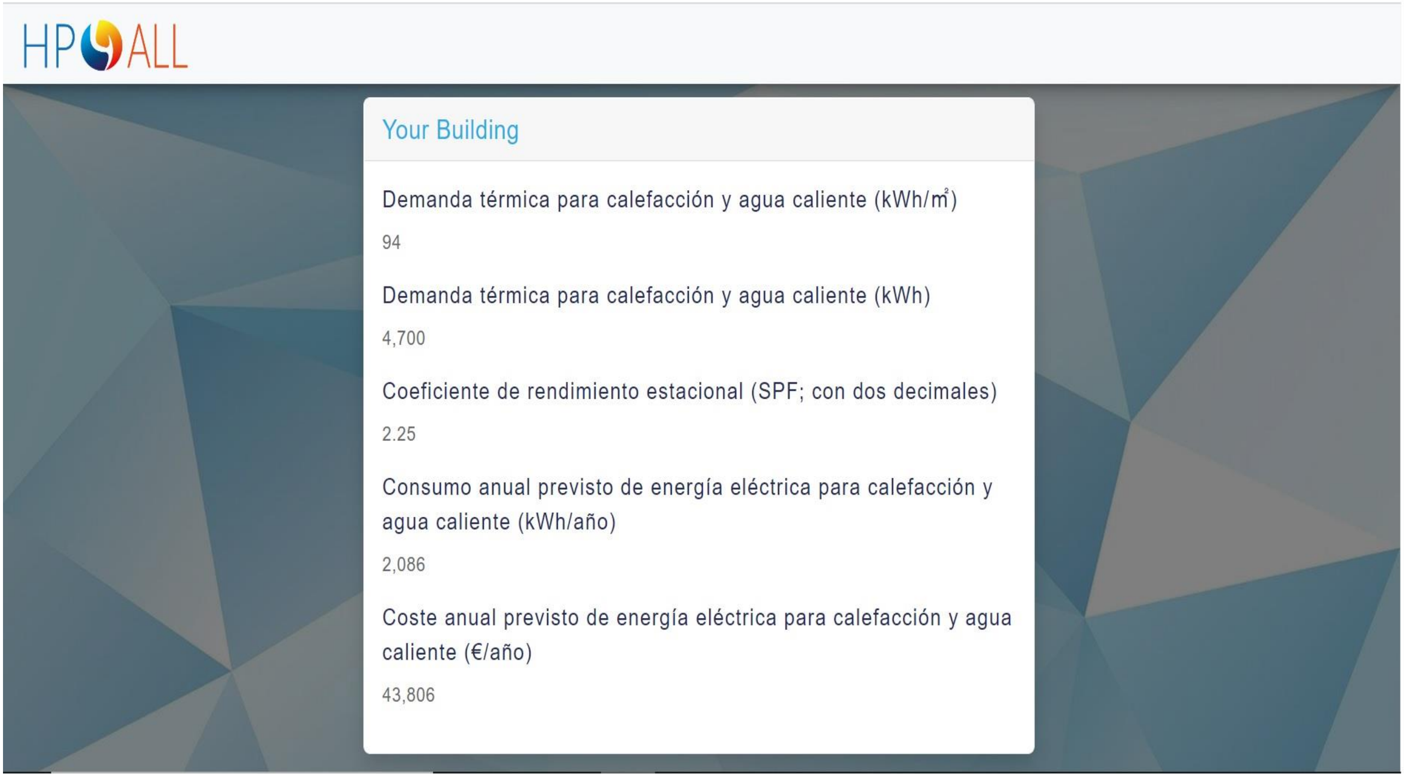

Figure 8: Output page of HP Benchmarking Tool for Spain

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4 Conclusion

This deliverable presents the overview and calculation methodology of the Heat Pump Benchmarking tools developed for the HP4All pilot countries (Ireland, Spain, and Austria). It also describes the reason for developing three different benchmarking tools for three pilot countries. Links to websites where the Benchmarking tools are hosted, and screenshots of each tool have been provided.

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