GRADO EN INGENIERÍA EN TECNOLOGÍAS DE TELECOMUNICACIÓN

TRABAJO FIN DE GRADO

TRANSITION FROM CONVENTIONAL ENERGY SOURCES TO RENEWABLE ENERGIES IN THE HOUSEHOLD SECTOR

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Madrid

Declaro, bajo mi responsabilidad, que el Proyecto presentado con el título

Transition from Conventional Energy Sources to Renewable Energies in the Household Sector

en la ETS de Ingeniería - ICAI de la Universidad Pontificia Comillas en el

curso académico 2019-2020 es de mi autoría, original e inédito y

no ha sido presentado con anterioridad a otros efectos.

El Proyecto no es plagio de otro, ni total ni parcialmente y la información que ha sido

tomada de otros documentos está debidamente referenciada.

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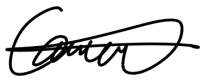

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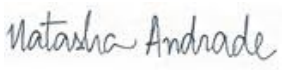

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My completion of this project could not have been accomplished without their support.

TRANSICIÓN DE FUENTES DE ENERGÍA CONVENCIONALES A FUENTES RENOVABLES EN LOS HOGARES

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RESUMEN DEL PROYECTO

El proyecto a desarrollar consiste en una aplicación web que permite al usuario a descubrir qué fuente de energía renovable puede ser instalada en su hogar para su autoconsumo basándose en las características de este. Además, la aplicación ofrece la oportunidad de calcular el ahorro económico anual que supone tener instalada una de estas fuentes renovables, así como las emisiones evitadas y una aproximación de lo que costaría su instalación.

Palabras clave: Aplicación web, Fuentes de Energía Renovables, Selector de Fuentes de Energía Renovables, Calculadora de ahorros

1. Introducción

El cambio climático es uno de los problemas más importantes a los que se enfrenta la sociedad hoy en día. Es un problema que debería preocupar a todos los individuos ya que es muy probable – 95% de probabilidad según la NASA – de que la principal causa del cambio climático sea la actividad humana. Los gases de efecto invernadero son necesarios para mantener la Tierra en su temperatura óptima, sin embargo, los niveles extremos que actualmente hay en la atmósfera pueden tener consecuencias devastadoras. Dichos efectos, no solo afectan al medio ambiente, sino que también condicionan la salud de las personas y la economía global. Si no se toman medidas con efecto inmediato, la adaptación y mitigación del cambio climático se va a volver cada vez más complicada y costosa. Mejoras en los sectores económico, social y tecnológico, así como en las decisiones políticas son la llave para una adaptación con éxito.

El sector energético es uno de los principales protagonistas para parar los efectos del cambio climático ya que es la mayor fuente de gases de efecto invernadero. Según la Agencia Internacional de la Energía (IEA) la producción de energía supone dos tercios del total de estos gases. A pesar de esto, el compromiso de todas las partes interesadas es necesario para superar las consecuencias que actualmente ha dejado el cambio climático y prevenir y adaptarse a aquellas que aún están por venir.

De acuerdo con una encuesta realizada por The Harris Poll para la Asociación Americana de Psicología, el 51% de los adultos estadounidenses no sabe por donde empezar para acabar con el cambio climático, mientras que el 72% están dispuestos a actuar. Esto supone que la falta de información disponible para llegar a todas las personas y motivarlas para tomar medidas es un problema real.

Hoy en día, la innovación y el uso de las nuevas tecnologías es indispensable para resolver cualquier problema. Por lo tanto, estas deben ser usadas para ayudar a las personas a tomar acción contra el cambio climático y promover el uso de fuentes de

energía renovables y así responder a la llamada urgente que las Naciones Unidas anunció en la Agenda para el Desarrollo Sostenible de 2030 para parar la pobreza y promover la prosperidad de las personas y del planeta.

2. Definición del Proyecto

Este proyecto intenta dar solución a este problema desarrollando una aplicación web que permite a los usuarios aprender sobre qué energías renovables son las más adecuadas para ser instaladas en sus respectivos hogares de acuerdo con las características de estos y también permitirles conocer una aproximación de los posibles beneficios económicos y medioambientales al tener una de estas fuentes instaladas.

El principal objetivo de la herramienta es guiar al usuario durante la transición a menos conocidas y más limpias fuentes de energía empezando por sus hogares y proporcionarles información útil para reducir el cambio climático.

La aplicación consiste, como ya se ha mencionado, en dos herramientas diferentes: un selector de fuentes de energía renovables y una calculadora de ahorros. Una vez que el usuario accede a cualquiera de las herramientas, tendrá que responder unas preguntas multi-respuesta necesarias para recoger la información necesaria para proporcionarle unos resultados óptimos. Una vez estos han proporcionado toda la información, los resultados son mostrados.

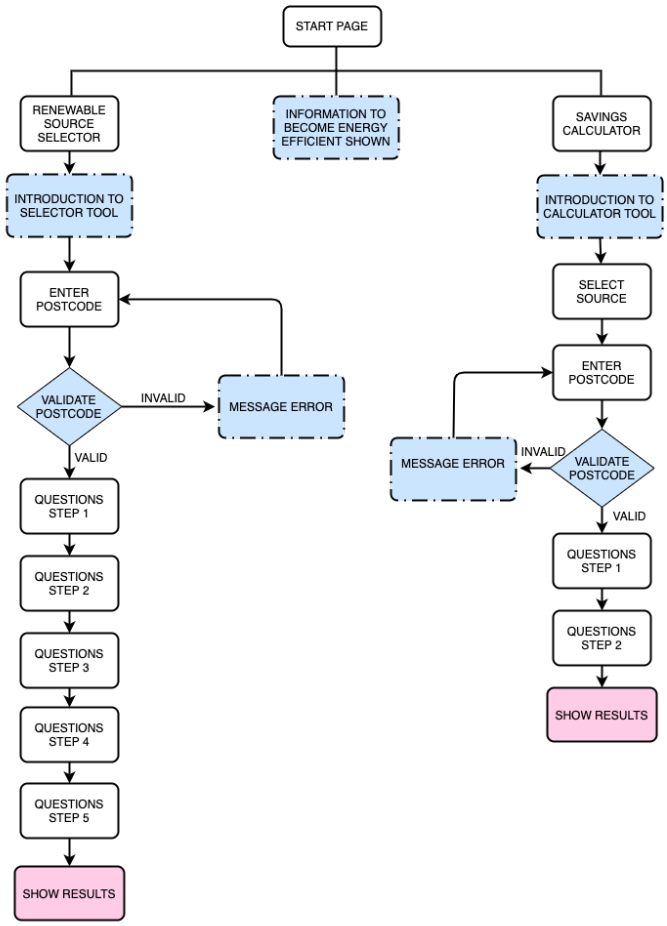

Ilustración 1. Diagrama de Navegabilidad de la aplicación.

3. Descripción de las herramientas desarrolladas

3.1. Selector de Fuentes de Energía Renovables

El Selector de Fuentes de Energía Renovables está solo disponible en España, por lo tanto, el primer paso de este es verificar que el código postal introducido por el usuario pertenece a alguna región española. A continuación, el resto de las preguntas son mostradas en unos pocos pasos. El usuario debe proporcionar la siguiente informacioón:

- Tipo de propiedad
- Localización
- Aislamiento
- Espacio para termo de agua
- Uso de energías renovables
- Espacio alrededor
- Espacio disponible para paneles solares
- Zona en la que se encuentra la propiedad
- Espacio para sistema de calefacción
- Espacio para guardar combustible

Por ultimo, se realiza un análisis de las fuentes de energía disponibles y estas son clasificadas como adecuadas o no adecuadas. Una pequeña explicación de cada fuente se muestra y en caso de que la propiedad no esté aislada correctamente, una pequeña descripción de su importancia se muestra.

3.2. Calculadora de Ahorros

Al igual que el selector, la calculadora de ahorros solo está disponible en el territorio español, lo que significa, que el código postal también debe ser validado. El procedimiento de esta herramienta es similar a la anterior pero las preguntas cambian ya que la información requerida es distinta. Las preguntas para llevar a cabo el cálculo son:

- Fuente de energía elegida
- Tipo de propiedad
- Localización
- Número de habitaciones
- Número de cuartos de estar
- Aislamiento
- Sistema de calefacción en uso
- Espacio disponible para termo de agua caliente

Una vez que los resultados han sido calculados según las respuestas del usuario, estos se muestran. Primero aparece el posible ahorro económico anual y luego el ahorro de emisiones de CO_2 y la aproximación del coste de instalación.

4. Resultados

Como el principal objetivo de la aplicación es ayudar a las personas en la toma de decisiones, la página web debe ser fácil de usar y eficiente. Usando técnicas comunes para el desarrollo de aplicaciones, se ha conseguido desarrollar una aplicación intuitiva. Los servicios proporcionados por la página web cumplen con los objetivos iniciales de experiencia de usuario y eficiencia, y la interfaz de ambas herramientas es atractiva y fácil de entender por el usuario.

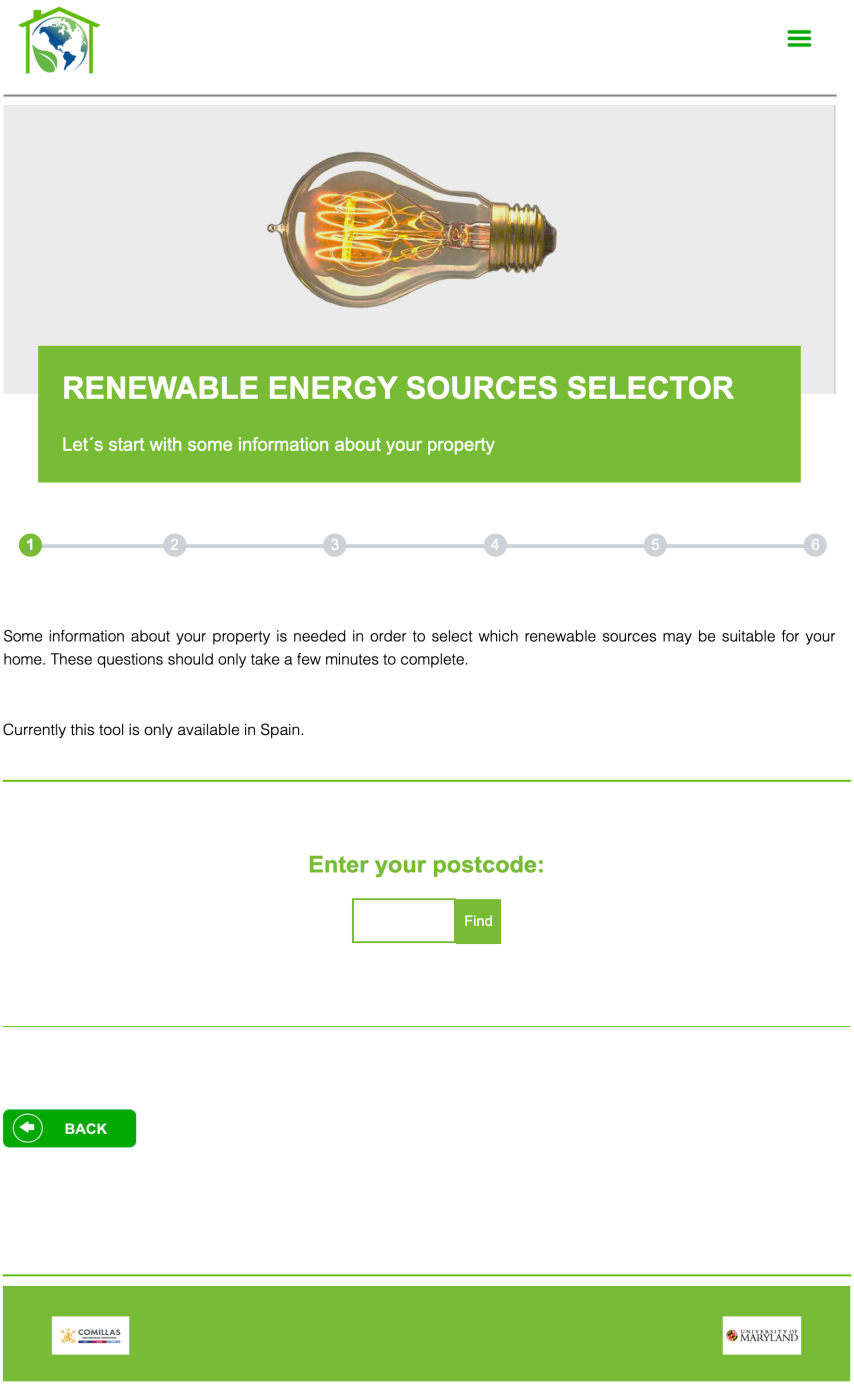

Ilustración 2. Página de inicio del Selector de Fuentes de Energía Renovables.

Ilustración 3. Ejemplo de la página de resultados del selector de fuentes de enrgías renovables.

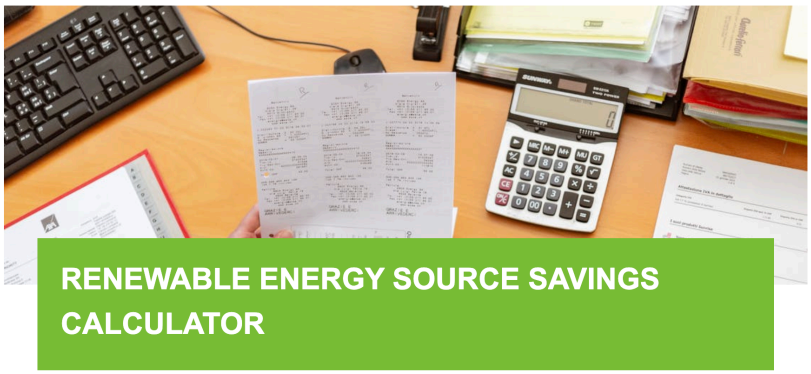

Ilustración 4. Página de inicio de la calculadora de ahorros.

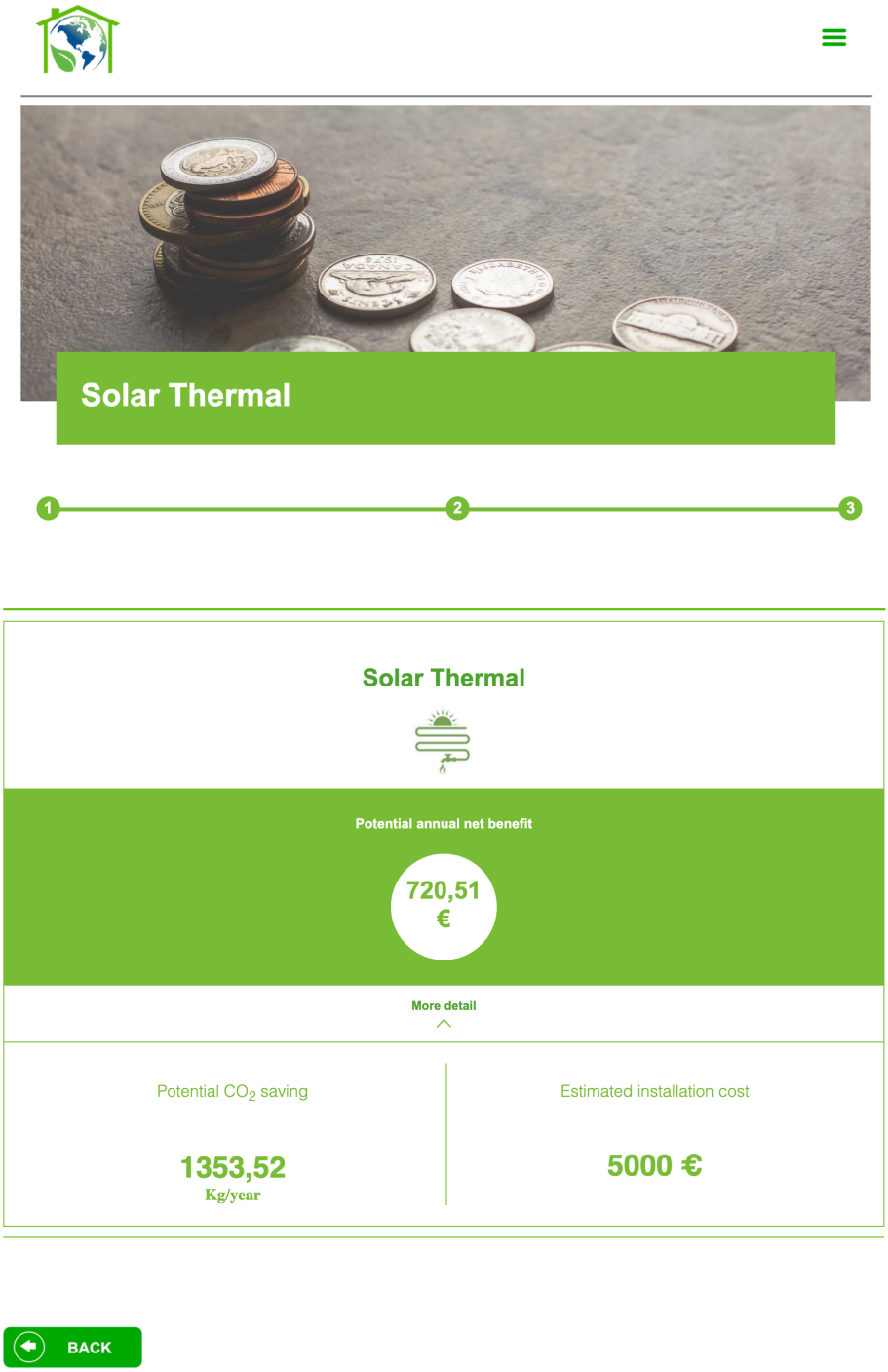

Ilustración 5. Ejemplo de la página de resultados de la calculadora de ahorros.

5. Conclusiones

Las funcionalidades proporcionadas por la aplicación son una forma interesante para motivar a los usuarios finales a cambiar sus hábitos actuales a unos nuevos que colaboren con las grandes instituciones y gobiernos que ponen gran esfuerzo en reducir su huella ambiental.

Tras una larga investigación, es indiscutible que los individuos aún requieren de ayuda y educación en cuanto al cambio climático y fuentes renovables se refiere. Si herramientas como las desarrolladas en este proyecto se popularizan realmente podrán suponer un cambio positivo en la economía, en la salud y en el medio ambiente.

La destinación de recursos a reeducar a la población es un buen punto de partida para generar cambios y volverse más conscientes de las acciones propias.

6. Referencias

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[2] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. https://www.ipcc.ch/report/ar5/syr/

[3] "Global Energy Review 2020". International Energy Agency (IEA). April 2020. https://www.iea.org/reports/global-energy-review-2020

[4] "Majority of US adults believe climate change is most important issue today". American Psychological Association. February 2020. https://www.sciencedaily.com/releases/2020/02/200207095418.htm

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TRANSITION FROM CONVENTIONAL ENERGY SOURCES TO RENEWABLE ENERGIES IN THE HOUSEHOLD SECTOR

Author: Ollero Merello, Carmen.
Supervisor: Andrade, Natasha.
Collaborating Entity: ICAI – Universidad Pontificia Comillas

ABSTRACT

This project consists on a dynamic web application that allows users to find out which renewable source could be suitable for their property based on certain characteristics of the house and it also provides a savings calculator that, giving a specific source and information about the house, it shows the potential annual economic savings as well as the CO_2 emissions savings and an estimation of the installation cost.

Keywords: Web Application, Renewable Energy Sources, Renewable Energy Source Selector, Savings Calculator

1. Introduction

Climate change is considered one of the most important issues that society is facing today. It is a problem that should concern individuals as it is extremely likely – more than 95% of probability according to NASA - that the main cause of climate change is human activity. Greenhouse gasses (GHG) are necessary to keep the earth at an optimal temperature; however, extreme levels have devastating effects. These effects affect the environment, but they also have serious consequences in human health and the global economy. If people do not act immediately, adaptation and mitigation will be more difficult and very costly. Improvements in economics, society, technology, and political decision are the key point for a successful adaptation.

The electricity sector plays the most important role in taking action as it is the main source of GHG emissions – according to the International Energy Agency (IEA) energy production implies two-thirds of total greenhouse gases. Despite this, a commitment from all stakeholders is necessary to be able to mitigate the current effects and to be ready to prevent and take action to the future effects.

According to a new survey carried out by the Harris Poll on behalf of the American Psychological Association, states that 51% of adults from the U.S. do not know where to start to combat climate change, although 72% are willing to act. This means that the lack of information available to influence people and to encourage them to take action is a real issue.

Nowadays innovation and the use of new technologies are essential in trying to solve any problem. Therefore, they are necessary to help people to take action against climate change and promote the use of renewable energy sources and respond to the urgent call from the United Nations made in the 2030 Agenda for Sustainable Development to stop poverty and enhance prosperity for people and the planet.

2. Project definition

This project aims to offer a solution to this problem by developing a web application that allows users to learn which renewable source is more suitable for their property, according to their house characteristics while also providing them with a report of potential environmental and economic savings to encourage its adoption.

The main objective of this tool is to guide people through the transition to less well known and cleaner energy sources starting in their homes and also providing other useful information that would help them to reduce climate change.

The application will provide two different tools as it was already mentioned, the renewable source selector and the savings calculator. Once the user accesses one of these tools they will have to answer some multi-choice questions needed to get enough data to provide an optimal result. Once they have filled in all the information, the results will be shown.

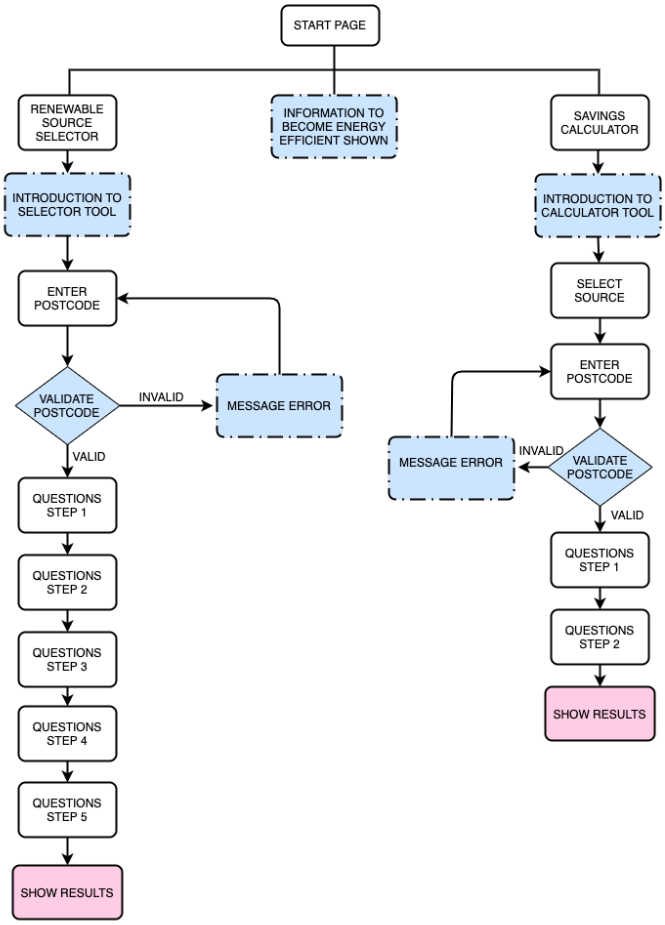

Illustration 1. Navigation Diagram of the application.

3. Tools description

3.1. Renewable Source Selector

The Renewable Source Selector is only available in Spain; therefore, the first step of this tool is to verify that the postcode entered by the user corresponds to a Spanish region. Then, once the input is validated the next questions are shown in a few steps. The user needs to provide the following information:

- Type of property
- Location
- Insulation
- Space availability for a hot water tank
- Use of renewable energies
- Outside space
- Space availability for solar panels
- Area
- Space availability for a heating system
- Space availability for fuel storage

Then the analysis of the different sources is carried out and these are classified as suitable or not suitable. A small explanation of each source is provided and in case of bad insulation, a small description of its importance is displayed.

3.2. Savings Calculator

As the Renewable Source Selector, the Savings Calculator is also only available in Spain, which means that once again the postcode validation is required. The procedure of this tool is similar to the previous one, but the questions are different as the data needed for savings calculation differs from the information needed to do the source classification. The questions of the calculator are:

- Chosen renewable source
- Type of property
- Location
- Number of bedrooms
- Number of living areas
- Insulation
- Current heating system used
- Space availability for a hot water tank

Based on the user´s answers to the previous questions, potential savings are calculated and displayed. The annual potential economic saving first and then the CO_2 emissions savings and an approximation of the installation cost.

4. Results

As the main objective of the application is to help people in the decision-making process, the website should be user-friendly, easy, and efficient. Using techniques commonly used in web application programming, an intuitive tool has been developed. The site features meet the initial requirements of user experience and efficiency, and the resulting interface is easy to navigate and understand by any user.

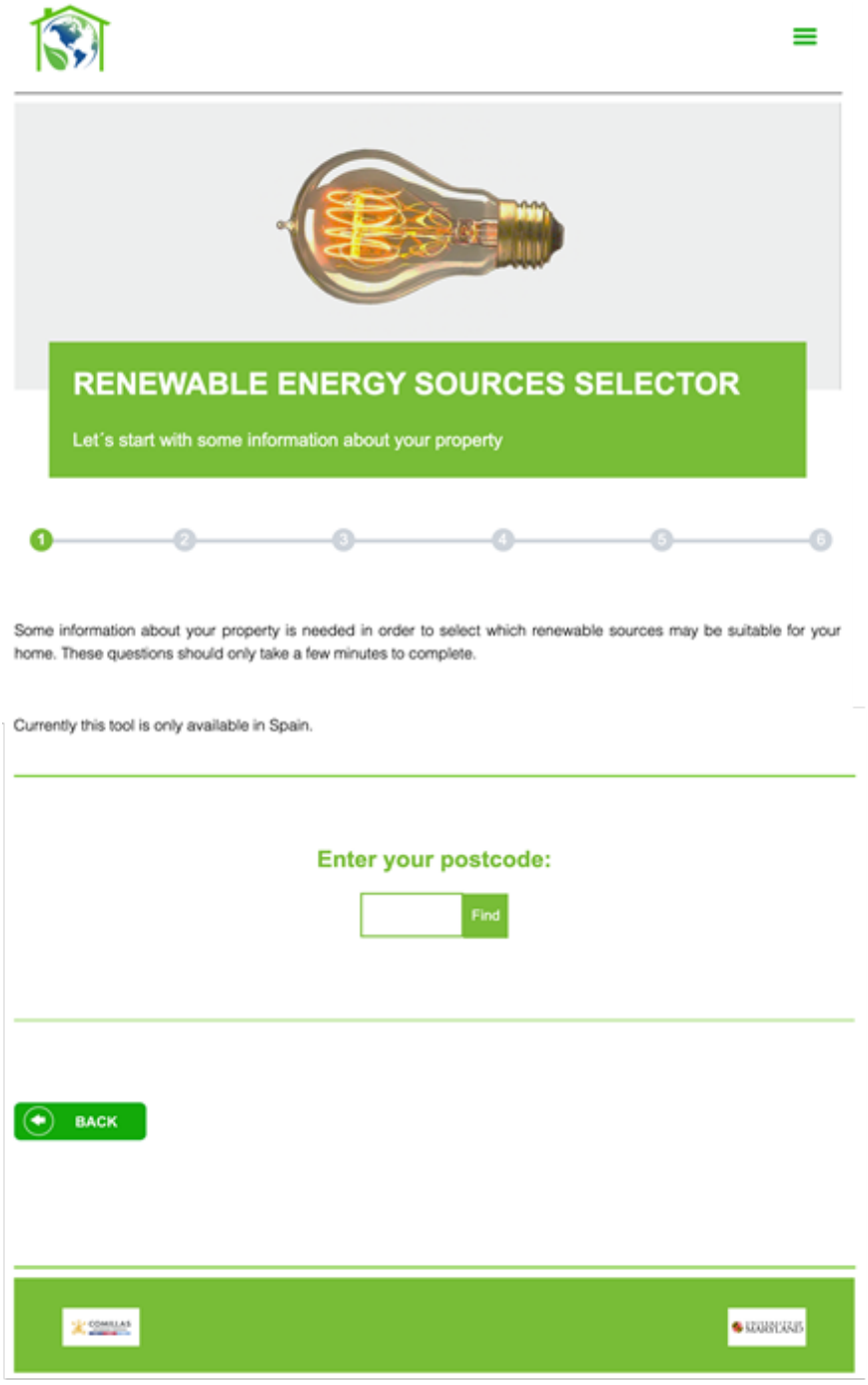

Illustration 2. Start page of the Renewable Source Selector

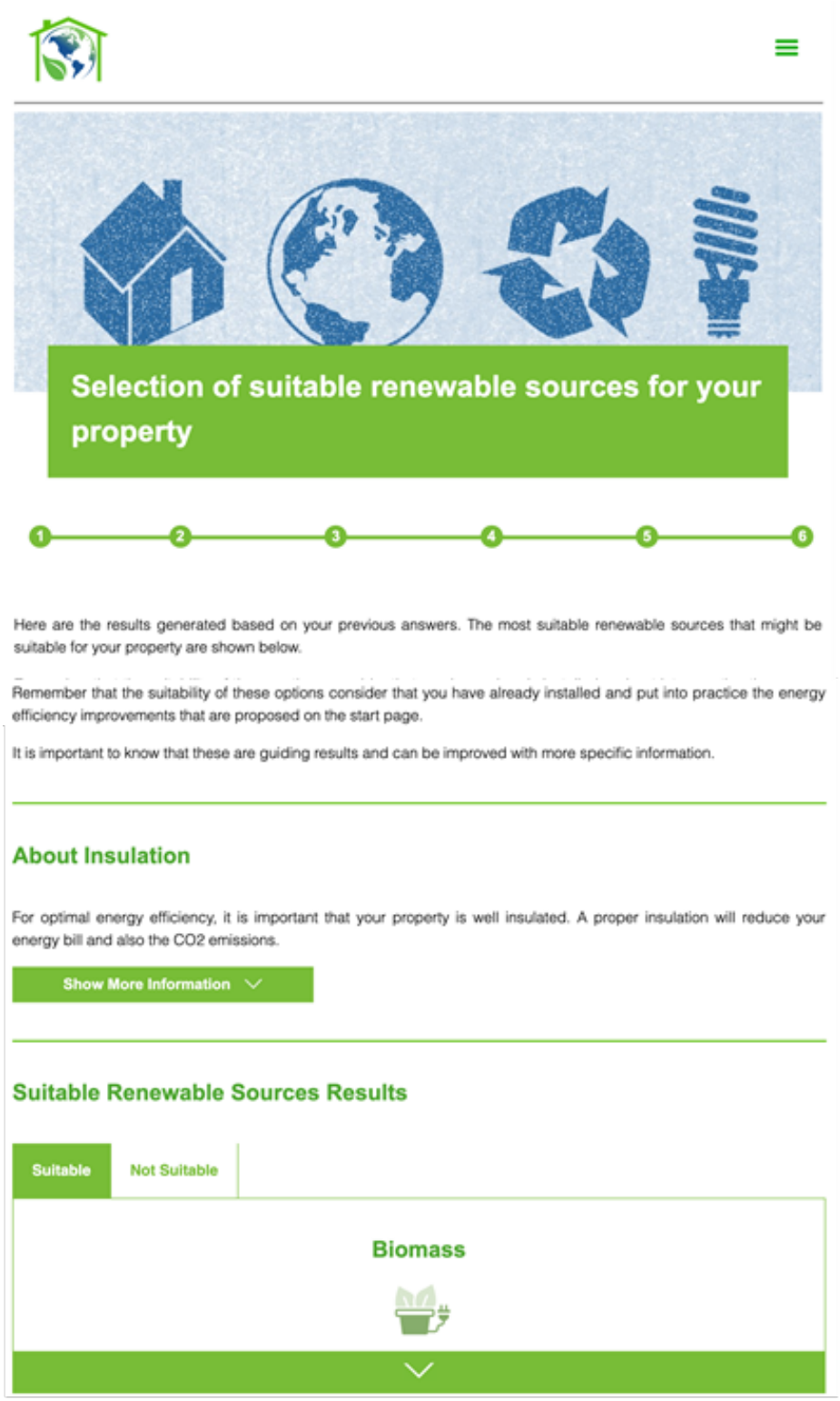

Illustration 3. Example of the result page of the Renewable Source Selector.

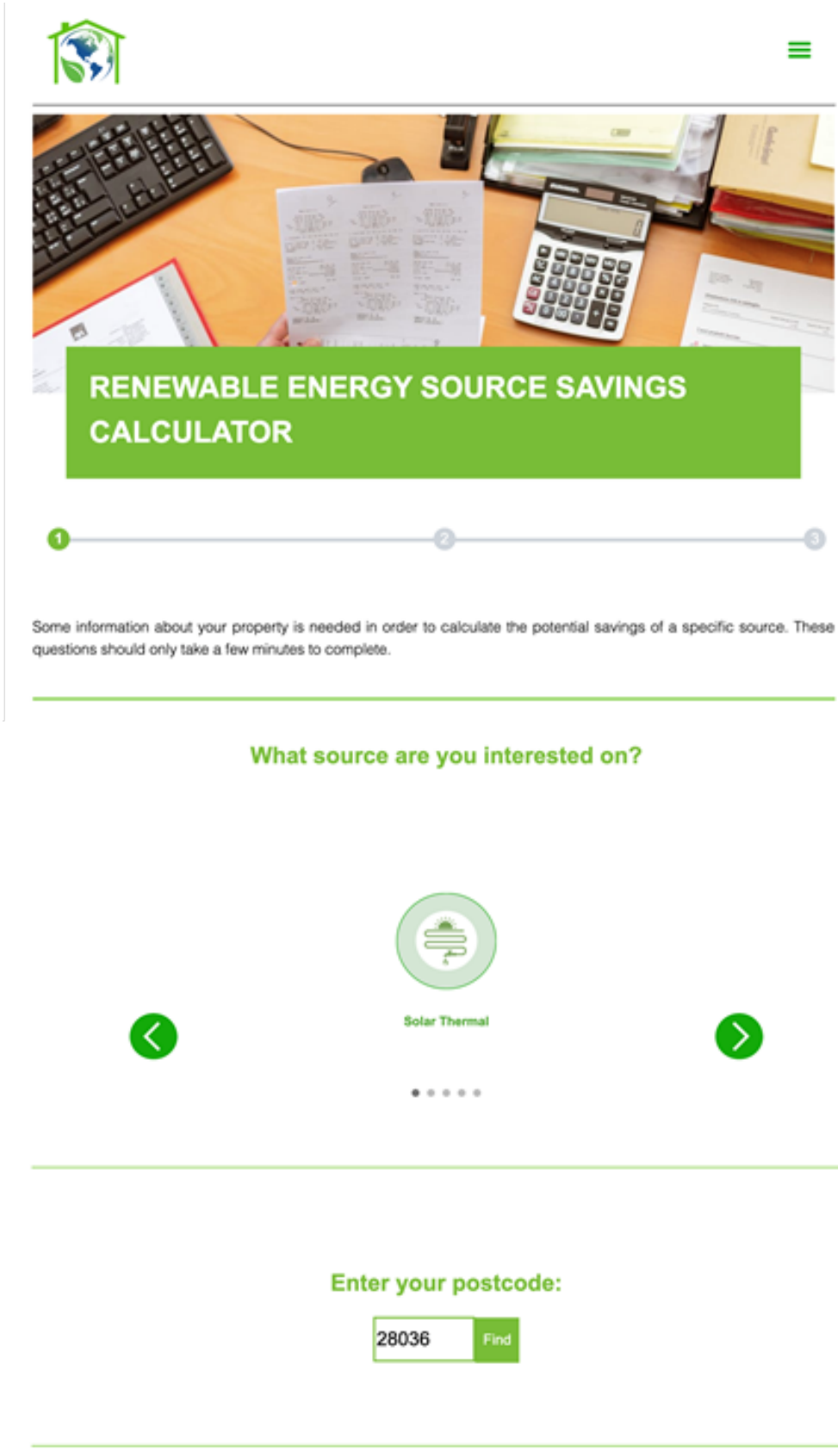

Illustration 4. Start page of the Savings Calculator.

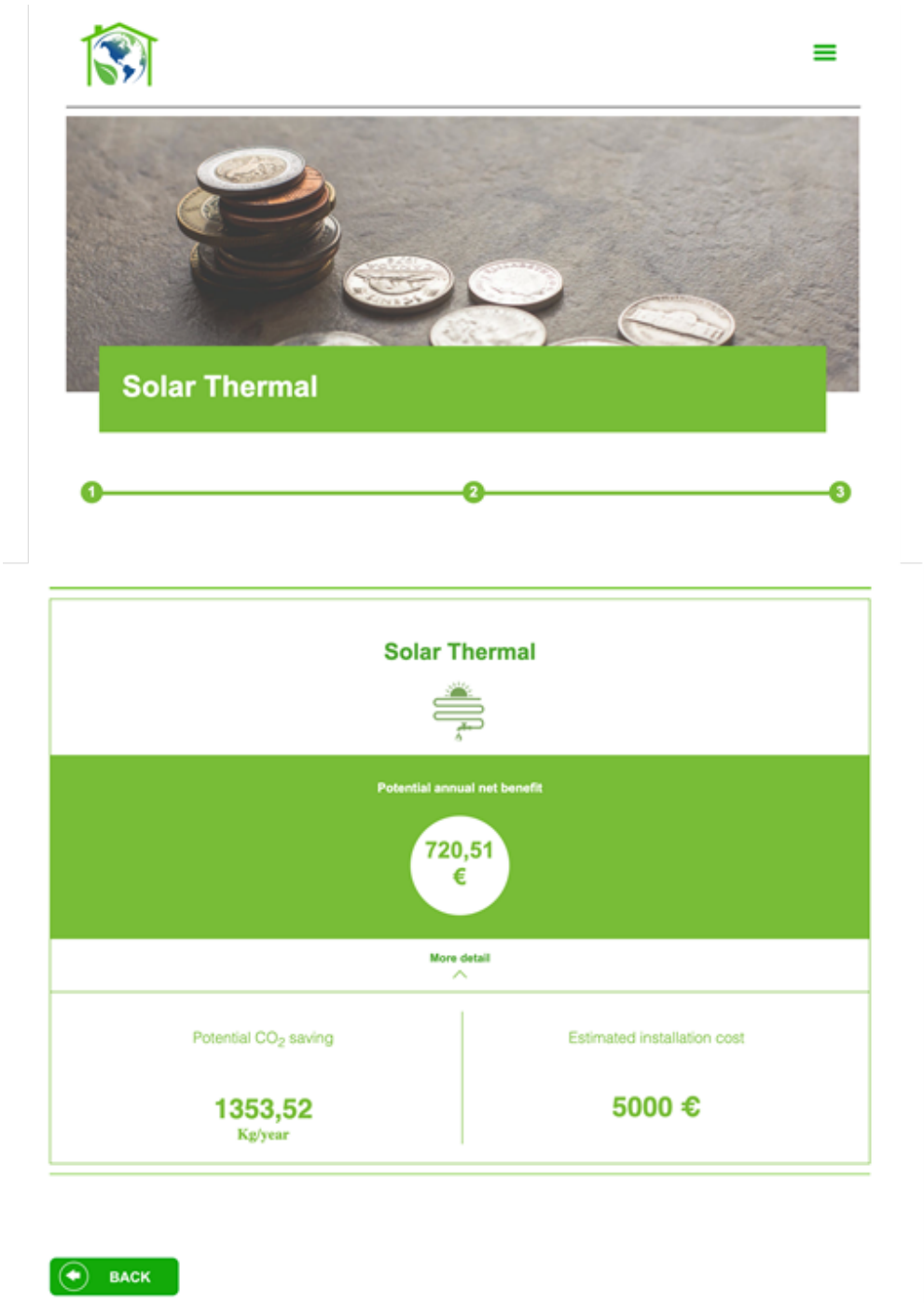

Illustration 5. Example of the result page of the Savings Calculator.

5. Conclusions

The tools provided by the application are an interesting way of motivating end-users to change their current habits into new ones that, together with the efforts of institutions and governments, could significantly reduce the environmental footprint.

After long research, it is undisputed that individuals still need a lot of help and awareness to be able to help and stop -or at least reduce - climate change consequences. If tools like

the one developed in this project become popular, they will have a positive impact on the economy, in human health, and on the planet.

The destination of resources to re-educate society is a good start to make useful changes and to become more conscious of our actions.

6. References

[1] "Climate Change: How do we Know?". Global Climate Change NASA. https://climate.nasa.gov/evidence/

[2] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri, and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. https://www.ipcc.ch/report/ar5/syr/

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Chapter 1. INTRODUCTION

1.1 BACKGROUND

Renewable energies are growing quickly, however, by the end of 2018 the estimated share of these sources in the global electricity was only about one third according to the International Renewable Energy Agency. While renewable capacity has expanded over the last years, also did the non-renewable as it is shown in the last report published by Ren21, besides, Carbon Dioxide emissions from the energy sector grew an estimated 1.7% in 2018 due to the increment (previously mentioned) of energy from fossil fuels. This information clearly shows that it is necessary not only to increase renewable energy capacity but also to stop or reduce the production of non-renewable energies.

The latest Global Energy and CO_2 status report shows that the worldwide energy demand grew from 2017 to 2018 and as the Fostering Effective Energy Transition Report claims, the reduction of CO_2 emissions is not enough to meet the Paris Agreement goals. Many nations, mostly developed countries, have already established many policies to help accelerate the process, but many scientists believe this is not enough and new strategies are needed. Dr. Faith Birol, the IEA´s executive director, for example, said *"The world cannot afford to press "pause" on the expansion of renewables and governments need to act quickly to correct this situation and enable a faster flow of new projects"*. Several jurisdictions have made renewable electricity the new target to accomplish their objectives, however, policy uncertainties and ensuring cost-effective systems still need to be addressed by governments.

1.2 MOTIVATION

It is undisputed that individuals, organizations, and other institutions' commitment to respond to the crisis of climate change is increasing every day. Social movements have been carried out to show public concerns over climate change, between September 20th and September 27th of 2019, around 6 million people around the world join the global climate strike, this supports the fact that people are willing to take action against climate change. A

new report from WWF, "Power Forward 3.0: How the largest US companies are capturing business value while addressing climate change" is a prove of how many important companies are taking action to reduce their greenhouse gasses (GHG) emissions. This report also shows that the companies that took part in this study have noticed an increase in their revenue which can be an incentive for other companies to also set targets to reduce their GHG emissions.

As many people are willing to take action to mitigate climate change and as it was previously mentioned most countries have set their target on the energy sector, this project tries to make more accessible ways of implementing renewable energies in the end-sector by helping consumers choosing the best option for their household.

Chapter 2. STATE OF THE ART

2.1 OVERVIEW

Social awareness about environmental sustainability has increased over the past years. Climate change is not a recent problem, however, as more and better information is available because of new technologies people are more conscious of how human activities have an impact on climate.

Renewable energies play a major role in the mitigation of climate change effects and they are expected to become even more important in the future. Renewable energy technologies have experienced substantial growth, particularly in the power sector. However, this growth has been considerably slower in the end-use sectors while residential and commercial energy use is the most rapidly growing after transport. According to some data published by the UN Environment Programme households consume 29% of global energy which means they contribute to 21% of global CO_2 emissions.

Renewable energies have outstanding economic, social, and environmental advantages. A lot of information about the innovation of renewable energy systems and studies and statistics about their benefits are available on the internet. Despite this, there is a lack of appropriate and verifiable information to assist in planning and implementation of renewable and also the general awareness on potential technical possibilities, economic, social, and environmental benefits of renewable energies is considerably poor on the end-sector. These issues should be solved by raising awareness as well as by promoting the use of these clean sources through information and advocacy. Consumers need to be provided with up-to-date data to be motivated to take part in the transition to clean energy, therefore, the development of tools that help users to have access to this information are crucial towards the goal of implementing renewable energies in the household sector. In the Climate Change and Renewable Energy report from the International Renewable Energy Agency (IRENA) it is supported the idea of programmes to raise awareness and understanding of the potential of renewable energies for direct users and society as a whole.

On the internet, lot of information can be found about the different renewable energy sources and also about the potential savings on energy bills but the only way to figure which source is the most suitable for a certain house or to calculate an estimate of the possible savings is by contacting a company from the energy sector.

2.2 RELATED WORK

Currently, in Spain, there is no tool that allows users to choose between different renewable energy sources. However, different tools for each renewable source are available to calculate their potential savings. A few available gears are "MySolar" to calculate solar energy savings, "Enair" provides users with a tool to calculate savings of eolic energy, "Click Renovables" permits the calculation of biomass and photovoltaics energy savings and they will provide soon the same tool for eolic, solar thermal and geothermal sources. The main problem is that there is one tool for each source which can make it harder and annoying to the user.

Energy Saving Trust, an independent organization, working to address the climate emergency, has made available to people from the UK several tools to provide information about energy saving to support householders, governments, and businesses. This institution has developed a tool only available in Scotland to help property owners to check their options and provide information about which energy technologies are best for their home and even calculate the potential savings based on the characteristics of the property. According to National Grid, the UK last year was generating for the first time more electricity from renewable sources than from fossil fuels. The Department for Business, Energy, and Industrial Strategy states that 82% of people in the UK support the use of renewable energy.

Chapter 3. PROJECT DEFINITION

3.1 JUSTIFICATION

As it is presented in the previous chapter the necessity of a transition to renewable energies is becoming indispensable every day. As most countries are promoting the use of renewable energies, it is time to make it easy for end-users and provide useful information about self-consumption in the household sector. As it has been already mentioned, consumers need a tool that provides them with up-to-date information about the different options as the information available is massive and in continuous change. Therefore, it seems that there is space in the market for a web page that supplies both a renewable source selector and also gives the opportunity to calculate the net benefit of a certain source.

This website would collaborate with the goal established by several countries of becoming greener to reduce climate change effects. Self-consumption in households will reduce the energy dependency of the country and therefore the country will reduce the importation of fuels from other countries meaning that it will not depend on their market prices, and at the same time the country could increase energy exportation even if it does not have many natural resources. The management of energy resources and the reduction of greenhouse gasses will help with economic growth, it will increase prosperity and also will reduce poverty.

Another benefit of installing renewable sources in houses is that the property value increases and also produce new jobs in several sectors (manufacturing, installation, engineering, sales, marketing…).

In Spain, renewable energies are consolidated as one of the main pillars to sustain economic regeneration because of their increasing contribution to the Gross Domestic Product (GDP).

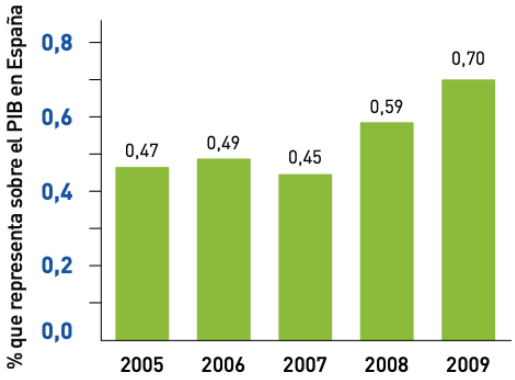

Figure 1. Contribution Percentage of Renewable Energy Sector to the Spanish Economy. (IDAE – "Impacto Económico de las Energías Renovables en el Sistema Productivo Español")

3.2 OBJECTIVES

The main issue about climate change is that it is not only a threat to the environment but also to human wellbeing and economy. A report published by the World Bank presents that the lack of action against climate change could push more than 100 million people into poverty. Renewable energies benefit both, the economy and human health, however, many people do not know all the possibilities they have. The World Bank, in its report "Shock waves. Managing the impacts of Climate Change on Poverty", states that renewable energies in low-income houses at reasonable prices could help meet their needs. Iberdrola, a Spanish electric utility company, exhibits that measures to mitigate climate change may serve to ensure sustainable development and promote economic growth.

Innovation expenditures and efforts have exponentially increased in the last few years. The Global Innovation Index 2019 puts forward that not only high-income economies have invested in R&D as these only represent the 64% of the total investments. This report also states that countries know the potential for innovation in many sectors including the energy sector. States usually align innovation and societal challenges this is a reason why investment in renewable technology went from $154 billion in 2007 to $305 billion in 2015. This large investment helps to produce big improvements in renewable energies' technology.

This constant improvement and publications of new policies around these sources make it really hard for people without any knowledge of the sector to keep up.

From all the information presented above, there is no doubt that a lot needs to be addressed in order to reduce climate change effects. As institutions and different organizations are already taking part in this, it is time to motivate people to do the same. However, a lot of individuals consider they do not know how to collaborate in a way different than recycling, but recycling is not enough, it is critical to maximize energy efficiency and to shift to cleaner energy sources.

The present thesis is aimed to motivate people to collaborate in the transition to renewable energy sources by making these more accessible. This will be accomplished by designing a web page that, based on the information given by a user about the characteristics of its house, will provide the most suitable renewable source for that specific household. It will also provide a tool that would calculate the saving of installing a specific source in the house based on the current consumption and other important information also provided by the user.

By providing easy access to a tool that would make easy for end-users to assess the use of cleaner sources the following issues will be indirectly assisted:

- Carbonization reduction. Becoming more energy-efficient and reducing the consumption of fossil fuels by using cleaner sources will help to reduce CO_2 emission as the main GHG emissions sources are energy production and consumption.

- Reinforce the use of renewable energies. Encourage people to use cleaner sources by making different options more visible.

- Augment knowledge of renewable energy sources in the household sector. Having people informed is the main way of changing their way of thinking and therefore the key to the intended transition. Consumers opinion is essential to improve environmentally and economically.

- Examine and make accessible the benefits of different renewable power sources in households. The necessity to develop new techniques to have people informed and up to date is required as renewable energies are in continuous change due to new improvements and creations.

3.3 METHODOLOGY

As it was mentioned above, this project consists of a web page to mainly help users. After realizing a knowledge gap about renewable energies in the household from the owner, the necessity of a transition to cleaner energies as well as the benefits users could have by producing their own energy are just a few reasons why the development of a website that could guide a person through the selection of a renewable source and also provide information about the advantages that could have to have a specific source installed in a house given certain information is a good idea that could easily be accomplished.

First, the website design was carried out. The interface of the website is essential in this project as it is supposed to assist a person which means it should be user-friendly. This tool should be simple, fast, and efficient. Several technologies, explained in the following sections, are used to meet this requirement. Another important part of the project is the performance of the available tools. The functioning of both the source selector and the savings calculator is carried out in the backend of the application and both are implemented based on the information collected by previous research also presented and explained in this same document as well as in the data provided about the property. During the research, a lot of information was collected and put it together, from this information a database was created with necessary data for the different activities and it is accessed according to the information provided by the user at the moment. The selection process and the calculations of the net savings, the CO_2 emissions savings, and the installation cost are also explained in the following sections.

The different information used in this project is gathered from existing data published by reliable sources. Data from different countries was considered and compared even though the website will only available for Spanish houses. A lot of information was found about this

topic however only the information published from 2015 in advance was used as it was considered as updated.

To obtain information about the property, several multi-choice questions are presented and answered by the user to get the results provided by the tools. The renewable selector source consists of a five steps questionnaire with a total of eleven questions. At the same time, the savings calculation consists also in a questionnaire of two steps this time formed by ten questions.

3.4 PLANIFICATION AND ECONOMIC ESTIMATION

Among all the different costs of this project, the following are worthy mentioned:

- Web page domain, which is the identification string that indicates ownership or control of a resource. The average cost of a domain is between 10 and 15€ annual.
- Hosting is an online service that allows developers to publish an application web on the internet and makes it accessible via the World Wide Web. The base price is around 120€ annually. Good web is important as it should provide technical support, security, frequent website backups, search engine rankings, and increases website load time. Some extra costs should be considered such as SSL Certificates which have an average price of 50€ per year but vary from free to 450€ or SiteLock that typically cost 25€/year.
- Software acquisition should be free as there are a lot of options available. More specifically, this time we have used the resources provided by both ICAI and UMD. However, a programming team of at least two workers should be in charge of the website which could cost around 3000€ per month.
- An investment in publicity and marketing to promote the web page to reach as many people as possible. This cost would depend on the method chosen but we could also include ads on the web page to generate income and reduce this cost.

In the first place, the benefits of this project are not economical, however, they could be in a future with small changes. As it has been mentioned several times, the main benefits of this web page are:

- Serve the user and provide useful information.
- Promote the use of renewable energies.
- Reduce GHG emissions.

Chapter 4. SYSTEM/MODEL DEVELOPED

4.1 SYSTEM ANALYSIS

Users are the key players in this project. The web application is geared towards the clients in order to guide them into becoming cleaner in their homes, therefore, when programming the website, it is necessary to focus on their interests and preferences for the purpose of helping people to easily find and understand the information provided. The web page should be clear and easy and should put in context the information shown and make sure it is trustworthy. To do so, it is essential to develop the project considering what users look for, including features that they feel are important, however, it is also important to focus on the business perspective and also include features that would make the web page popular. In other words, the project should incorporate the main characteristics of Business-to-Consumer (B2C) websites to achieve a better performance in both client and business viewpoints.

Three important characteristics that every website should have are accessibility, usability, and acceptability. Accessibility addresses the fact that every user should be able to use the web page without any major issue. At the same time, usability guarantees that the website is effective, efficient, and fulfilling. Last but not least, acceptability measures the user´s experience with the application from a functional and operational point of view.

Web site characteristics	Description
CONTENT	
1. Presence of Decision Aids	Does the firm's Web site provide help for decision-making?
2.Information on products and services	Does the firm's Web site provide information on the products and services?
3. Information on the firm	Basic information on the company, background, etc.
4. Frequent update of content	How often is the Web site updated? Is there a "what's new" section or a section introducing new products, catalogues features or news that helps in identifying updated content?
5. Frequently Asked Questions (FAQ)	Does the firm's Web site provide frequently asked questions section on product related questions or the company?
6. Company contact information	Does the firms' Web site offer any way to contact it via mail, e-mail, phone or fax?
DESIGN	
1. Complexity of navigation	What type of navigation structures is deployed in the Web site?
2. Presence of site index / help section	Does the Web site provide an index / help page?
3. Use of multimedia	What type of multimedia does the Web site use? Are there heavy graphics, animations, sound and video?
4. Search function	Does the firm's Web site have a search function?
PRIVACY	
1. Privacy statement	Does the firm's Web site provide a privacy statement with notice, choice, access, security, and enforcement?
2. Use of third party privacy seals	Does the firm's Web site provide third party seals that reinforce privacy?
SECURITY	
1. Provision of individual user accounts and password	Does the firm's Web site provide opportunities to create individual accounts with logon-id and password?
2. Presence of mechanisms for making online as well as offline financial transactions	Does the firm's Web site provide opportunities to make no online transactions?
3 Use of Secure modes of data transmission	Does the firm's Web site provide secure modes of data transmission such as SSL, HTTPS, etc.?

Table 1. B2C Website Characteristics

(Source: Gao, Yuan. "Web Systems Design and Online Consumer Behavior". November 2004.)

In the development process of the website, both Front-End development and Back-End development were important. The Front-End, also known as the client-side, deals with making the website attractive to the clients and also makes sure everything is correctly shown, on the other hand, the Back-End or server-side takes care of the tasks such as data processing and data storage and also communicates with the Front-End. In other words, the Front-End focuses on what makes the web page attractive whereas the Back-End is what makes the application work. In figure 2, the Front-End development is graphically explained.

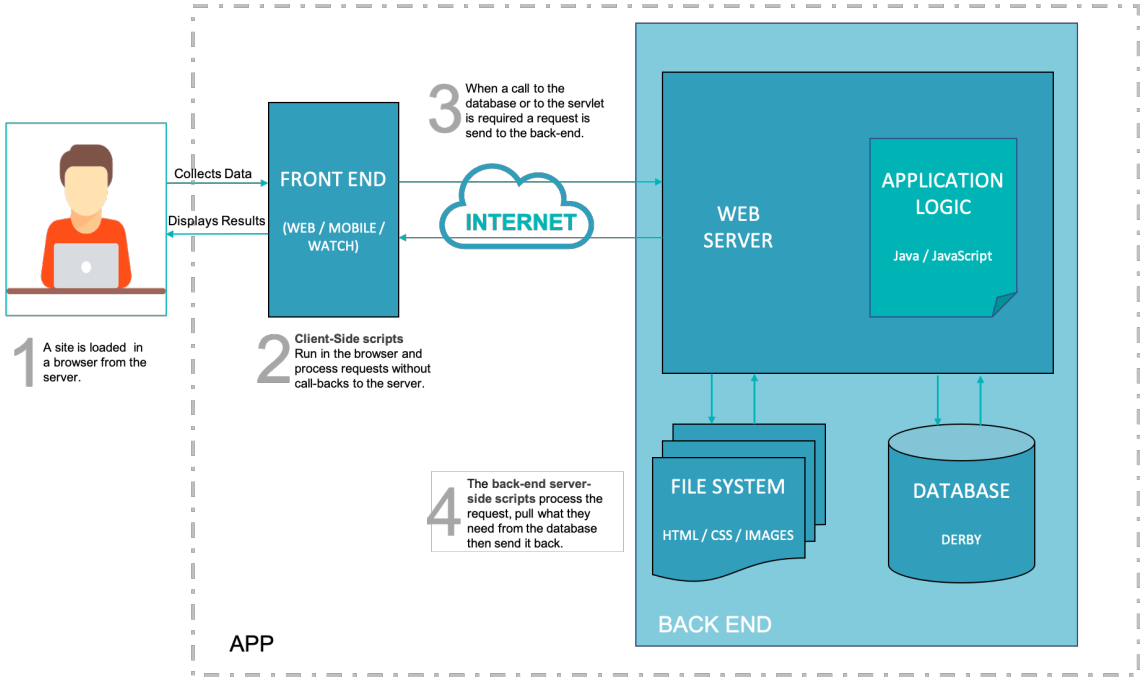

Figure 2. Front-End Development.

Representation of website design with the main steps of its functionality.

4.1.1 SYSTEM REQUIREMENTS

Requirement analysis is an essential part of any system development as it is supposed to improve the understandability of the project. This activity also helps to define the application scope in a more specific way and prioritize the most important requirements being able to meet quality standards. The definition of the project in detail allows the developers to identify any possible errors in the initial stage saving time and money.

Requirements are classified as functional or non-functional. Functional requirements define the services that the application offers to the user while non-functional requirements are the quality constraints and restrictions of the system.

4.1.1.1 Functional Requirements

The definition of functional requirements should be complete and consistent.

RF-RS	*Renewable Source Selection*
[Date]/[Version]	*2020/ v1.0*
[Dependencies]	*Postcode Validation* *User input*
Description	*The system will select the most suitable renewable source based on user input.*
Category	*Functional*
Related Requirements	*<Validate Postcode>*
[Importance]	*High*
[Priority]	*High*
[State]	*Completed*
Comments	

Table 2. Functional Requirement: Renewable Source Selection.

RF-SC	*Savings Calculation*
[Date]/[Version]	*2020/ v1.0*
[Dependencies]	*Postcode Validation* *User Input*
Description	*The system will calculate potential economic savings, CO_2 emissions savings, and an estimation of the installation cost based on the characteristics of the property provided by a user.*
Category	*Functional*
Related Requirements	*<Validate Postcode>*
[Importance]	*High*
[Priority]	*High*
[State]	*Completed*
Comments	*The system allows clients to calculate the potential savings even if the source is not suitable for the property in question.*

Table 3. Functional Requirement: Savings Calculation.

RF-IIS	*Insulation Improvements Suggestion*
[Date]/[Version]	*2020/ v1.0*
[Dependencies]	*Postcode Validation* *User Input* *Property insulation*
Description	*A section with suggested insulation improvements is shown if the user indicates that the property is not properly insulated.*
Category	*Functional*
Related Requirements	*<Validate Postcode>*
[Importance]	*High*
[Priority]	*High*
[State]	*Completed*
Comments	*The section is only shown if the house is not properly insulated.*

Table 4. Functional Requirement: Insulation Improvements Suggestion.

4.1.1.2 Non-functional Requirements

Non-functional requirements are not directly related to the services provided by the application. These requirements specify or restrict characteristics of the system and they usually affect the whole architecture.

RNF-VP	*Validate Postcode*
[Date]/[Version]	*2020/ v1.0*
[Dependencies]	*Renewable Source Selection* *Savings Calculation*
Description	*The system validates the postcode entered by the user. If it is valid it allows the user to continue but if it is not, a message is shown.*

Category	*Non-functional*
Related Requirements	
[Importance]	*High*
[Priority]	*High*
[State]	*Completed*
Comments	*The tools are only available in Spain, therefore, the validation of the postcode allows the system to verify that the property is in the Spanish region.*
RNF-VP	
[Date]/[Version]	

Table 5. Non-functional Requirement: Validate Postcode.

RNF-C	*Compatibility*
[Date]/[Version]	*2020/ v1.0*
[Dependencies]	
Description	*It is important that the application can be used in any device to provide better accessibility.*
Category	*Non-functional*
Related Requirements	
[Importance]	*Medium*
[Priority]	*Medium*
[State]	*Completed*
Comments	*The application should adapt to any browser and device screen.*

Table 6. Non-functional Requirement: Compatibility.

RNF-U	*Usability*
[Date]/[Version]	*2020/ v1.0*
[Dependencies]	*Renewable Source Selection* *Savings Calculation* *Insulation Improvements Suggestion*

Description	*The application should be efficient and easy to learn and should meet user expectations.*
Category	*Non-functional*
Related Requirements	*Renewable Source Selection* *Savings Calculation* *Insulation Improvements Suggestion*
[Importance]	*High*
[Priority]	*High*
[State]	*Completed*
Comments	

Table 7. Non-functional Requirement: Usability.

4.1.2 USE CASES

Use cases allow a better understanding of the web page functionality and options. Use cases also show the possible interactions between the different users and the application. Use cases identify actors and specify how they interact with the system. Use cases also show the system behavior from a user point of view.

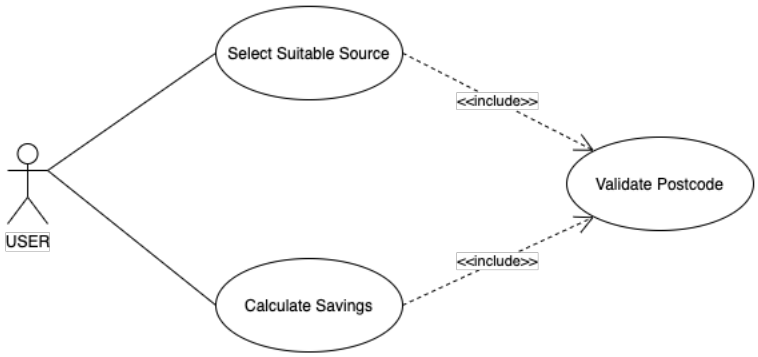

Figure 3. Use Cases Diagram.

The use cases diagram, shown in Figure 3, summarizes the relationships within the system and shows the functional requirements mentioned before. The specification of each use case can be found in Annex II.

4.1.3 SEQUENCE DIAGRAMS

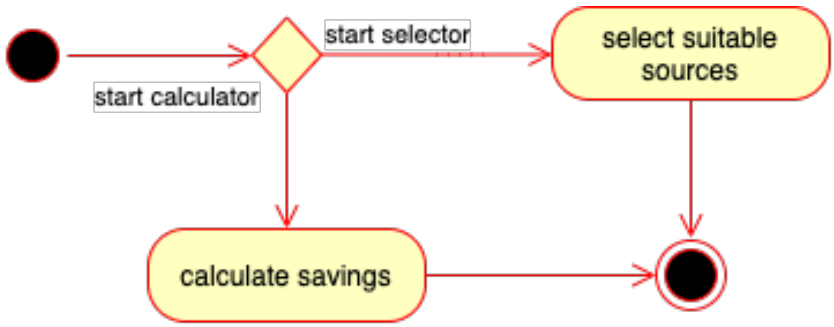

Figure 4. Activity diagram of the system.

Sequence diagrams show the interaction between the different system components in sequential order. More specifically, sequence diagrams capture the interaction in a system of a use case, therefore, in Figures 5 and 6, the sequence diagrams of the functional requirements are graphically represented. These diagrams provide an overview of how the different tasks are achieved. The sequence diagrams are based in a Model View Controller pattern that is explained in detail in the next section of this document.

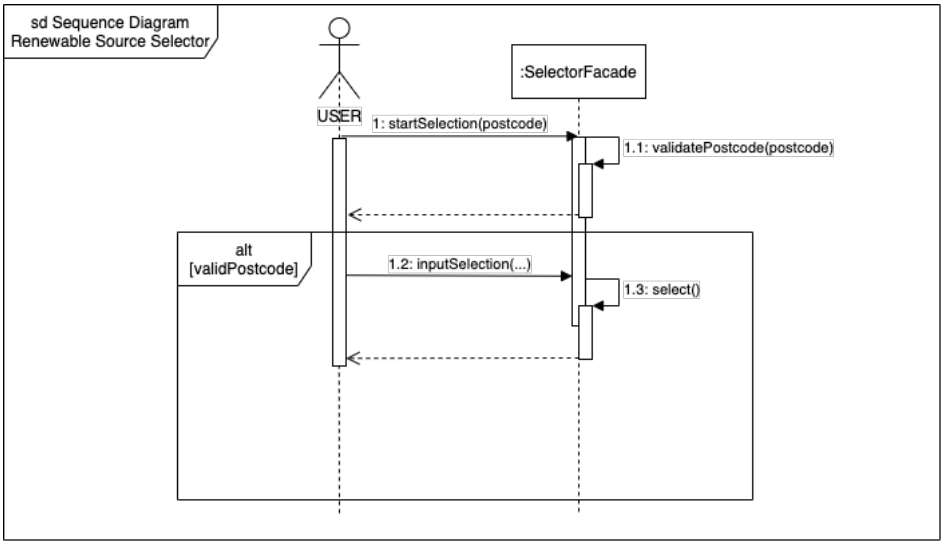

Figure 5. Sequence diagram of Renewable Source Selection.

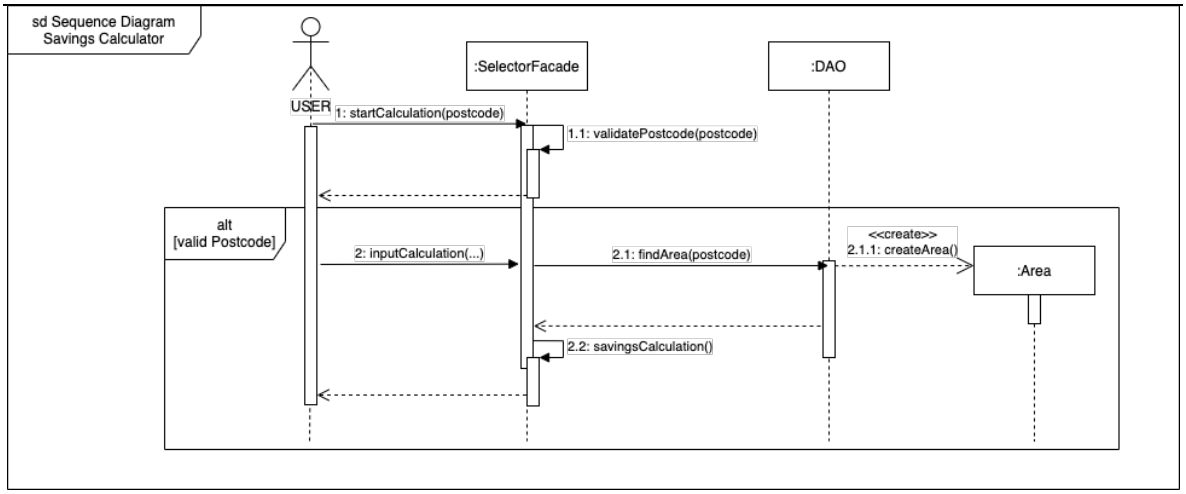

Figure 6. Sequence Diagram of Savings Calculator.

4.2 SOFTWARE DESIGN

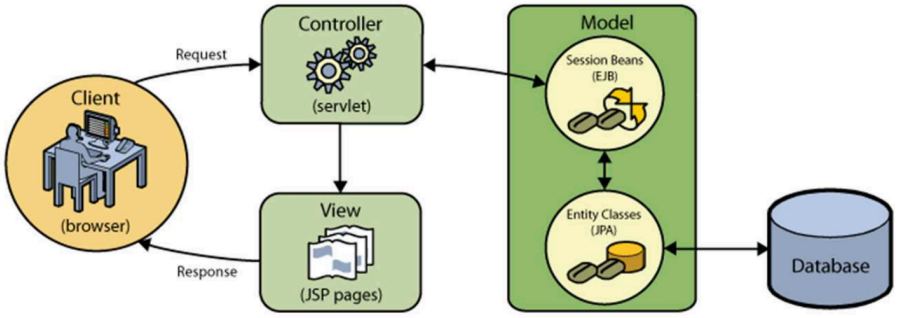

Figure 7. Model View Controller pattern components.
(Class notes for Programación de Aplicaciones Telemáticas 2019)

The web application is based on a model-view-controller design pattern. It is used to organize the different components of the application. The model is in charge of structuring and preparing data based on the controller´s instructions as it only contains pure data. The view displays data in an easy-to-understand format to the user based on its own actions. Finally, the controller is an intermediary between the user and the model, it collects user commands and events that serve as instructions and execute a proper reaction to respond to these events in most cases by passing them to the model. In connection to the Front-End and

Back-End development, the view corresponds to the client-side, the model to the server-side, and finally, the controller is in charge of the communication between the other two.

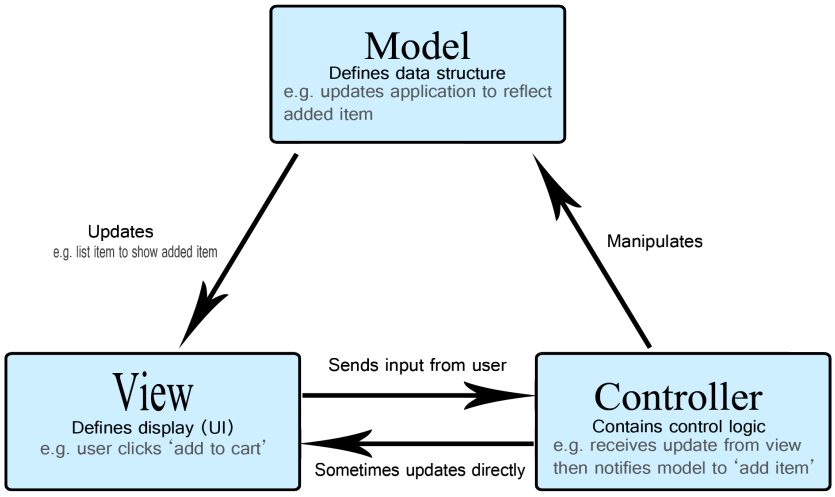

Figure 8. Model View Controller pattern.
(Source: "MVC". MDN web docs)

4.3 WEBSITE DESIGN

This section gathers the technologies used on the website design. These technologies put together make the web page work properly and they help to achieve its main goals.

4.3.1 HTML5

HTML is the standard markup language for Web pages. It helps the website to be compatible with most devices and it is supported in all kinds of browsers. This language is really easy to implement, and it defines the structure of the website. It allows the addition of features and functionality and it is easy to edit. One of the remarkable benefits of this language is that it is easy to integrate with other programming languages. It also helps to build websites that are friendly to the user.

4.3.2 JAVASCRIPT

JavaScript is an object-oriented programming language and it is one of the principal technologies of the World Wide Web (WWW). This language is usually used on client-side page behavior as it extends the functionality of the web page and makes them interactive. As it is executed on the client side it is considerably fast. It is accepted in most browsers as most of them have a specific engine to support it. It is a complement to HTML and CSS.

4.3.3 CSS

Cascading Style Sheets is a style sheet language used to separate the presentation of a website from its structure which corresponds to HTML markup language. CSS is supported in almost every browser and it is easy to use. It also produces cleaner and easier to read code. It allows for easier maintenance of the website. It provides a lot of formatting options and also provides great accessibility.

4.3.4 JSP

JavaServer Pages (JSP) is a technology for developing dynamic web pages. This software component defined by the Java EE platform is located on the web layer. It is used to implement dynamic content to the presentation of the application by allowing the use of Java code in HTML pages. This technology can be used to collect information provided by the user or to present data from a database or any other source while creating web pages dynamically. It is part of the View on a MVC design and its role is to present the request ´s results to the user.

4.3.5 JAVA SERVLETS

Software component defined by the Java EE platform which is located on the web layer or web container. They are used to implement dynamic content to the application. It is part of the controller as they are responsible to receive and validate requests, select the logic to be implemented, and select the view to present. Web modules are packaged in a WAR archive (Web ARchive), its structure can be seen in Figure 9. It contains the deployment descriptor

called web.xml in the \WEB-INF directory. This deployment descriptor is used to inform the application server of the existence of a Java Servlet.

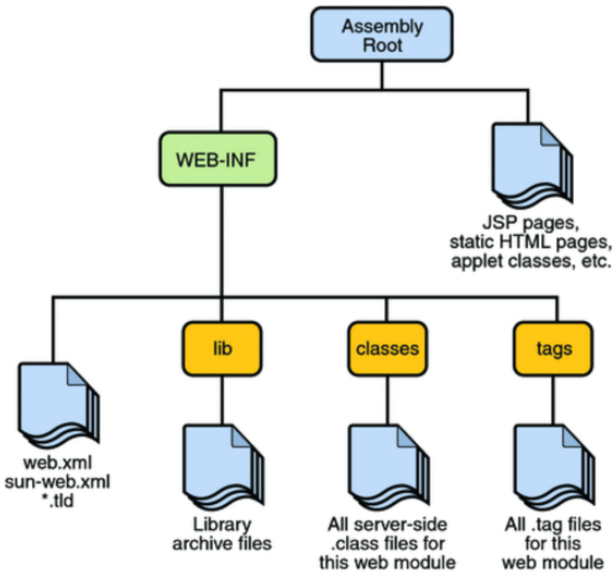

Figure 9. Web Module Structure.
(Class Notes for Programación de Aplicaciones Telemáticas 2019.)

The internet´s most basic architecture is based on HTTP (HyperText Transfer Protocol) and HTML (HiperText Markup Language). HTTP is a protocol implemented on the Application layer of a communication system based on the OSI model. The main components of this protocol are HTTP requests and HTTP responses which use certain methods. The most relevant methods are GET and POST and in the case of an application web, these are used to communicate with the Java Servlet.

4.3.6 APACHE DERBY

Apache Derby is an open source Relational Database Management System (RDBMS) which is fully written in Java programming language and it is developed by the Apache Software Foundation. Derby can be deployed in embedded mode, the database engine will run within the same Java Virtual Machine as the application, or server mode, the database manager runs in a Java Virtual Machine of an application server which handles the database requests.

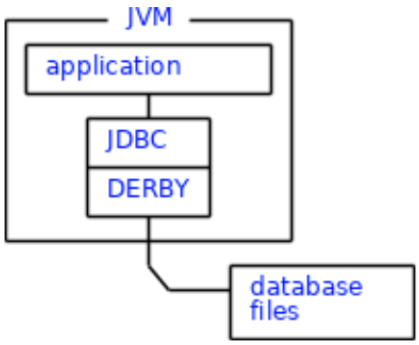

Figure 10. Derby Embedded Architecture.
(Source: "Embedded Derby". Apache Derby)

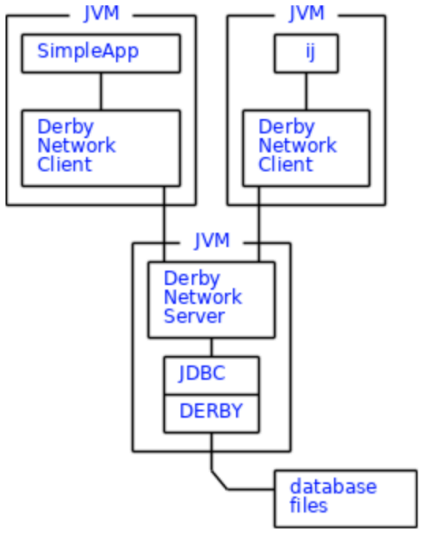

Figure 11. Derby Network Server Application.
(Source: "Derby Network Server". Apache Derby)

The web application developed uses the embedded mode so only this application can access the database. The chosen mode supports multiple connections to the same database, which means multiple users can execute the web application but only one JVM may boot the database. The driver used to implement the embedded mode is JDBC type 2 (also known as the Native-API) driver org.apache.derby.jdbc.EmbeddedDriver, which uses the client-side libraries of the database.

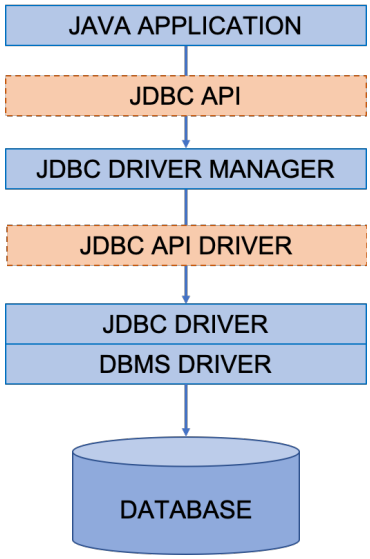

Figure 12. Driver JDBC type 2: "Native-API"

4.3.7 SQL

The database used by this application was created and accessed using Structured Query Language. SQL is the standard language for communicating and manipulating databases. The commands used are “create” and “insert”, to build the table with the information needed in the database, and “select”, to search and validate the information from the web application.

4.4 IMPLEMENTATION

4.4.1 OVERVIEW

As has been previously mentioned in this same document, the efficient use of energy is one of the key solutions to reduce carbon emissions. In households, there are several ways to become energy efficient. As the main goal of the website is to help people to contribute against climate change, the first step should be to provide information to the user to help them improve their energy efficiency. Therefore, the website includes a section where common and easy improvements are collected. Some possible changes suggested are:

- Use LED light bulbs.
- Turn off light when they are not being used.

- Unplugged devices and chargers when being unused.
- Sealing gaps, cracks and, leaks.
- Insulation.
- Double glazing windows.
- Use of efficient electrical appliances.

These improvements reduce the general energy consumption of the house and the possible implementation of renewable energies will be a more productive change since the energy produced will not be misused.

Research on which renewable energies are suitable for the household sector has been carried out. The conclusions drawn from this research were that only the following sources are suitable to be installed in houses due to their characteristics:

- Solar thermal energy: solar panels on a rooftop to heat water. The panels are not photovoltaic.
- Biomass for heating.
- Solar power: photovoltaic panels to produce electricity.
- Eolic energy: should be a complement to solar panels as it is produced by small wind turbines.
- Aerothermal: extracts energy contained in the air.

One of the services provided by the website is that, based on the information provided by the user about certain characteristics of the house, a source suitable for its property will be suggested. In order to be able to provide the most accurate option, the web page will guide the user to provide useful information. This task is accomplished by asking the user several questions:

- Postcode.
- Type of house: 1 storey house, 2 storey house, +2 storey house, flat.
- Property´s detachment: mid terraced, end terraced, semi-detached, detached, other.
- Flat location: Ground floor, mid floor, top floor.

To make it easier to the user these questions are multi-choice questions so the user will just have to select the more accurate response.

After these questions and based on the responses given, more specific questions will be asked such as house insulation, if the property has a water tank, outside space, or neighborhood area among others.

Once all the information is collected, the analysis of the most suitable source is carried out based on the answers given. In the results page, the renewable sources are classified as suitable and not suitable and some information about each source is provided.

The other service that is provided is the calculation of savings for a specific source. For a source given an average of the net savings, the CO_2 savings and an estimation of the installation cost will be shown. The multichoice questions asked to the user to carried out the calculations are:

- Source.
- Postcode.
- Type of house: 1 storey house, 2 storey house, +2 storey house, flat.
- Property´s detachment: mid terraced, end terraced, semi-detached, detached, other.
- Flat location: Ground floor, mid floor, top floor.
- Number of bedrooms.
- Number of living areas.
- Property insulation.
- Current heating system.
- Hot water tank.

With the information collected from the user choices, the calculations are carried out in the backend, and then the results are shown.

4.4.2 PHOTOVOLTAIC SYSTEMS

Photovoltaics converts sunlight into electricity by using semiconductors materials. This technology is easily adapted to small production sizes such as rooftops which makes this renewable source optimal for self-consumption. In addition to this, the cost of these systems is in decline (Figure 13).

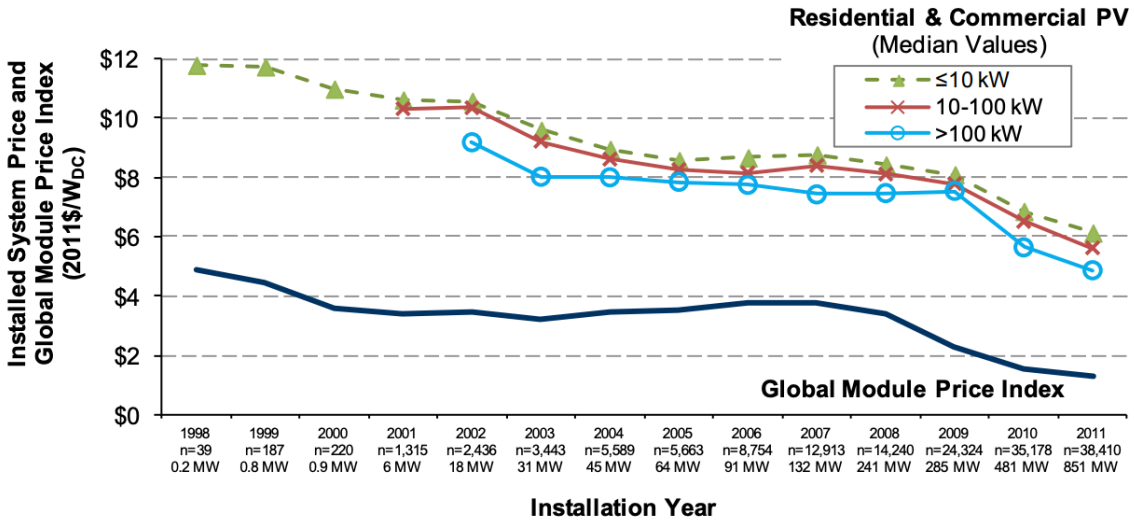

Figure 13. Installed price of residential and commercial PV systems.

(Source: Photovoltaic (PV) Pricing Trends: Historical, Recent and Near-Term Projections from SunShot, U.S. Department of Energy.)

Important parameters that related to the installation of PV systems are:

- What direction will panels face.
- Slope of the roof.
- Any potential obstacles.
- Size of the system to be installed (KWp).

The most ideal location for PV panels is south-facing rooftops without any obstacles around such as trees, chimneys, or antennas or south-west/south-east facing rooftops.

This source is considered suitable by the renewable source selector of the application if the property meets the following characteristics based on the answers provided by the client:

- The property is a house or a flat on the top floor.
- The property has a suitable area to install the panels.

The calculation of the potential energy produced by a PV system is calculated using the following formula:

$$EP = \frac{RS}{PS} * pp * SH * cc = np * pp * SH * cc$$

EP – Energy produced per year.

RS – Rooftop size [m^2].

PS – Average solar panel size (1.64 m^2).

pp – Average power produced by a panel (300W).

SH – Effective solar hours per year.

cc – correction coefficient.

np – number of solar panels.

However, to make it simple for the user, the application approximates the number of panels used based on the type of the property in question. In other words, if the type of property indicated by the user is a flat situated on the top floor, the number of panels will be 4, 7 in case of one-storey house, and 10 and 12 if the property is a two-storey house or bigger respectively.

Spain is divided into five different climate zones depending on the annual average global solar irradiation of an area. The effective solar hours depend on the region where the property is situated so this value is collected from the database given the postcode provided by the user.

The calculation of greenhouse gasses savings is computed using the next formula:

$$CO_2\ Savings = EF * PE$$

EF – Emission factor [Kg CO_2 /KWh]. The value used is 0.357 provided by the Spanish government.

PE – Energy Produced by year.

The installation cost of a PV system depends on its size therefore, the installation cost varies depending on the number of panels installed and therefore on the type of property.

TYPE OF PROPERTY	INSTALLATION COST
FLAT	1,500.00€
ONE-STOREY	3,600.00€
TWO-STOREY	5,000.00€
THREE-STOREY OR MORE	7,800.00€

Table 8. Installation cost of a PV system.

These calculations are used by the savings calculator to estimate the potential savings that a person could have by having this source installed, the benefits to the environment, and also to provide an approximation of the installation cost.

4.4.3 SOLAR THERMAL ENERGY SYSTEMS

Solar thermal systems collect energy from the sun and then this energy is used for heating purposes and in some that energy produces electricity. The panels are different from the pv panels as thermal systems collect sunlight to heat the fluid inside the panels that then transfers the energy to the heating system.

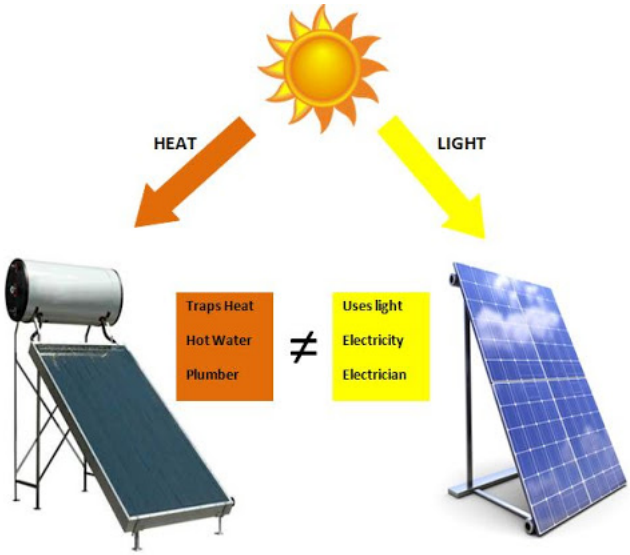

Figure 14. Solar thermal panel vs. PV panels.

(Source: "Solar PV vs Solar Thermal". Solar Thermal blog)

Solar thermal energy, as well as the solar PV panels, depends on geographical factors. As was mentioned before, the best direction for the panels to face is south and they should not have any obstacle to receive sunlight. To be able to store the heat a hot water cylinder needs to be installed so the house should have enough space for this requirement.

The same factors as with the PV panels should be asked to assess if this technology is suitable for a specific house as both have the same requirements but also the owner should specify if there is space for a hot water tank.

The calculations for the energy production and emission savings are the same as the one used for PV systems, however, as solar thermal is used for heating the emission factor changes and takes the value of the emission factor of the energy used for heating instead which depends on the heating system of the property.

HEATING SYSTEM	EMISSION FACTOR
NATURAL GAS	0.204 KgCO2/KWh
OIL	0.257 KgCO2/KWh
LPG	0.229 KgCO2/KWh
ELECTRIC	0.357 KgCO2/KWh
GAS	0.263 KgCO2/KWh
BUTANE	0.238 KgCO2/KWh
BIOMASS	0.018 KgCO2/KWh
COAL	0.256 KgCO2/KWh

Table 9. Emission factor for the different heating systems.

4.4.4 AEROTHERMAL SYSTEMS

Aerothermal systems consist of heat pumps that extract heat from the air and transfers it inside a building. The heat collected by these systems can be used for heating, to produce hot water, and for air conditioning. Therefore, aerothermal systems are usually used to improve home heating. However, for a house to be a good candidate for this technology should have energy efficiency standards. Some factors to consider before adding this heating system are.

- The local temperature. At extreme temperatures, the air pump does not work properly. In Spain, this is not a problem as extreme temperatures are not common.
- Insulation.
- Current HVAC systems (Heating, Ventilation, and Air Conditioning). If the current system is old but can be replaced the heating pump can be a good option.
- Space served. Depending on the size of the property to temperate the price of the air pump needed, and its efficiency can vary. Also, the temperature in certain areas in the property does not require to regulated.

Type of heating system	Average annual energy savings (kWh equivalent)	Average annual cost savings
Electric resistance heaters (i.e. furnaces, baseboard heating)	3,000	$459
Oil heating systems (i.e. furnaces, boilers)	6,200	$948
Displaced oil systems (oil system remains as back up, operates less frequently)	3,000	$300

Table 10. Example of potential savings after replacing a traditional heating system with air source heat pumps.

Heat pumps usually cost between $4,000-$7,000, and a single-family home usually needs between 3 and 5 units to heat the entire house.

TYPE OF PROPERTY	INSTALLATION COST
FLAT	4,000.00€
ONE-STOREY	4,200.00€
TWO-STOREY	5,300.00€
THREE-STOREY OR MORE	6,000.00€

Table 11. Installation cost of an aerothermal system.

The potential savings that can be obtained by having an aerothermal system installed depends on the price of the heating systems currently used, the size of the house and also on the heating and refrigeration demand:

$$Savings = size * demand * price = size * \left(\frac{HD}{SCOP} + \frac{RD}{SEER}\right) * price$$

Size – house size in m^2.

HD – heating demand.

SCOP – Seasonal Coefficient Of Performance.

RD – Refrigeration demand.

SEER – Seasonal Energy Efficiency Ratio.

Price – price of KWh of current source used.

The heating and refrigeration demand values are different depending on the region, these numbers are stored in the database and can be accessed using the postcode provided in the application. The size of the house is calculated based on the number of bedrooms and the number of living areas.

HEATING SYSTEM	PRICE

NATURAL GAS	0.068 €/KWh
OIL	0.08 €/KWh
LPG	0.119 €/KWh
ELECTRIC	0.11 €/KWh
GAS	0.14 €/KWh
BUTANE	0.09 €/KWh
BIOMASS	0.05 €/KWh
COAL	0.45 €/KWh

Table 12. Price of heating systems.

The emissions savings are calculated similarly:

$$CO_2\ Savings = size * demand * emissions = size * \left(\frac{HD}{SCOP} + \frac{RD}{SEER}\right) * EF$$

Size – house size in m^2.

HD – heating demand.

SCOP – Seasonal Coefficient Of Performance.

RD – Refrigeration demand.

SEER – Seasonal Energy Efficiency Ratio.

EF – Emission factor [$KgCO_2$ /KWh]. The value used corresponds to the emissions of the current source used.

The emission factors used are shown in Table 9.

4.4.5 BIOMASS SYSTEMS

Biomass systems consist of extracting energy from burning organic materials. Biomass boilers are likely to be suitable for most properties as they can be connected to already

existing radiators, water tanks, and under floor heating. However, if the property does not have already a wet heating system, this option can be very costly.

A factor to consider the suitability of one of these systems is:

- Space available for the boiler and fuel storage.
- Type of property as Spanish regulation (published in the Spanish Official Gazette) does not allow these systems in buildings except for the top floor as they require special ventilation.

The savings that could be obtained by a biomass system are calculated by the following equation:

$$savings = ED * size * (price - fp)$$

ED – Energy demand [KWh/m^2].
size – size of the house [m^2].
price –price of KWh of current source used.
fp – price of the fuel used by the biomass boiler

Once again, the size of the house is calculated based on the bedrooms and living areas.

$$CO_2\ savings = ED * size * EF$$

ED – Energy demand [KWh/m^2].
size – size of the house [m^2].
EF – Emission factor [$KgCO_2$ /KWh]. The value used is 0.018 which corresponds to the emission factor of biomass systems as it is shown in Table 9.

A log boiler costs around $5,500 and a wood pallet boiler around $15,000 so the calculator approximates the installation cost to 8000€.

4.4.6 EOLIC SYSTEMS

Domestic eolic systems use the kinetic energy obtained from the wind as an electricity generator through small turbines. This renewable source can be used at any time of the year day and night and its installation is simple and does not require many maintenances.

Usually, for a family unit, turbines rated between 5-15KW are needed to make a significant contribution to energy use. A 1.5KW wind turbine could be enough for a unit that requires 300KWh/month in a location with a 14mph annual average wind speed.
Eolic systems in Spain can only be installed in properties with space around the house which is the main condition for its suitability.
Information such as average annual wind speed at the location and the rotor diameter are required.
The energy produced can be calculated as:

$$EP = 0.01328 * D^2 * V^3$$

EP – Energy produced.
D – rotor diameter [ft^2]
V – annual average wind speed [mph]

By multiplying the energy produced by the price of the electricity, the potential savings are calculated, and by multiplying by the emission factor of the mixed energy the CO_2 emissions savings are obtained.

4.4.7 DATABASE

The web application needs access to a database that contains some data that is necessary to complete the processes offered. The database used has a single table that contains the effective solar hours, heating demand, refrigeration demand, and total energy demand by region. The information collected in that table comes from different sources.

The Spanish Photovoltaic Industry Association, ASIF for its initials in Spanish, has made public a map (Figure 15) containing the amount of power per year and meter squared of each province (number on top) and the annual effective solar hours (bottom number).

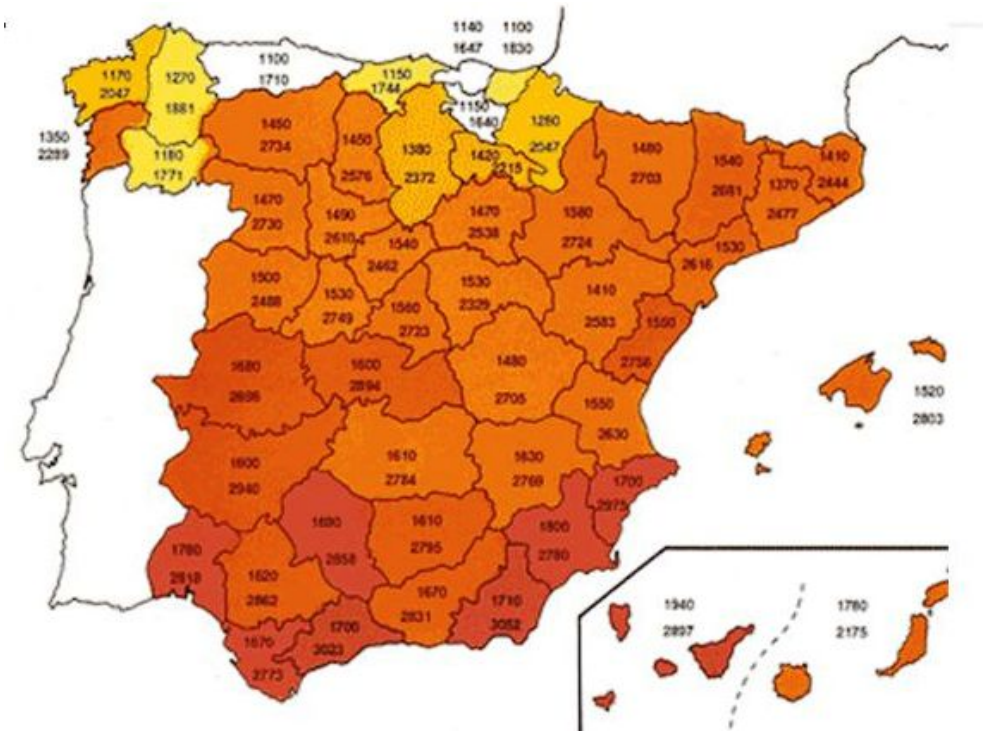

Figure 15. ASIF map of annual KW/m^2 and effective solar hours.

At the same time, an online platform called Certicalia, leaders in Energy Certification in Spain, has published individual studies about Spanish heating, refrigeration, and energy demand by region. The platform provides a map, a table, and a graph with the information.

Comunidad Autónoma	Demanda Refrigeración (kWh/m² año)
Aragón	12.19
Andalucia	22.17
Principado de Asturias	5.32
Islas Baleares	12.9
Islas Canarias	21.25
Cantabria	4.3
Castilla-La Mancha	14.53
Castilla y León	6.38
Cataluña	9.69
Comunidad Valenciana	20.66
Extremadura	20.63
Galicia	5.37
La Rioja	8.86
Madrid	15.47
Navarra	3.41
País Vasco	4.09
Murcia	15.56

Table 13. Refrigeration demand by Autonomous Community in Spain.
(Published by Certicalia.)

Comunidad Autónoma	Demanda Calefacción (kWh/m² año)
Aragón	120.85
Andalucia	53.19
Principado de Asturias	90.04
Islas Baleares	61.17
Islas Canarias	39.57
Cantabria	111.16
Castilla-La Mancha	113.5
Castilla y León	132
Cataluña	80.44
Comunidad Valenciana	61.6
Extremadura	126.5
Galicia	98.45
La Rioja	129.7
Madrid	102.76
Navarra	151.36
País Vasco	114.16
Murcia	66.54

Table 14. Heating demand by Autonomous Community in Spain.
(Published by Certicalia.)

Comunidad Autónoma	Demanda Global (kWh/m² año)
Aragón	133.03
Andalucia	75.36
Principado de Asturias	95.36
Islas Baleares	74.07
Islas Canarias	60.81
Cantabria	115.46
Castilla-La Mancha	128.03
Castilla y León	138.38
Cataluña	90.13
Comunidad Valenciana	82.26
Extremadura	147.13
Galicia	103.82
La Rioja	138.56
Madrid	118.23
Navarra	154.78
País Vasco	118.25
Murcia	82.1

Table 15. Global Energy Demand by Autonomous Community in Spain. (Published by Certicalia.)

All the information collected from the different sources then placed in a table of the database by using SQL statements.

Table		
PK	POSTCODE	VARCHAR(100)
	PROVINCE	VARCHAR(100)
	CCAA	VARCHAR(100)
	SOLAR HOURS	NUMERIC(6,2)
	HEATING	DECIMAL(5,2)
	REFRIGERATION	DECIMAL(5,2)
	ENERGY	DECIMAL(5,2)

Figure 16. Database entity relationship diagram.

Chapter 5. RESULTS ANALYSIS

In this chapter, the different interface designs of the applications are presented. An overview of the system organization is represented in Figure 16. The mentioned diagram models the interaction between the user and the application software.

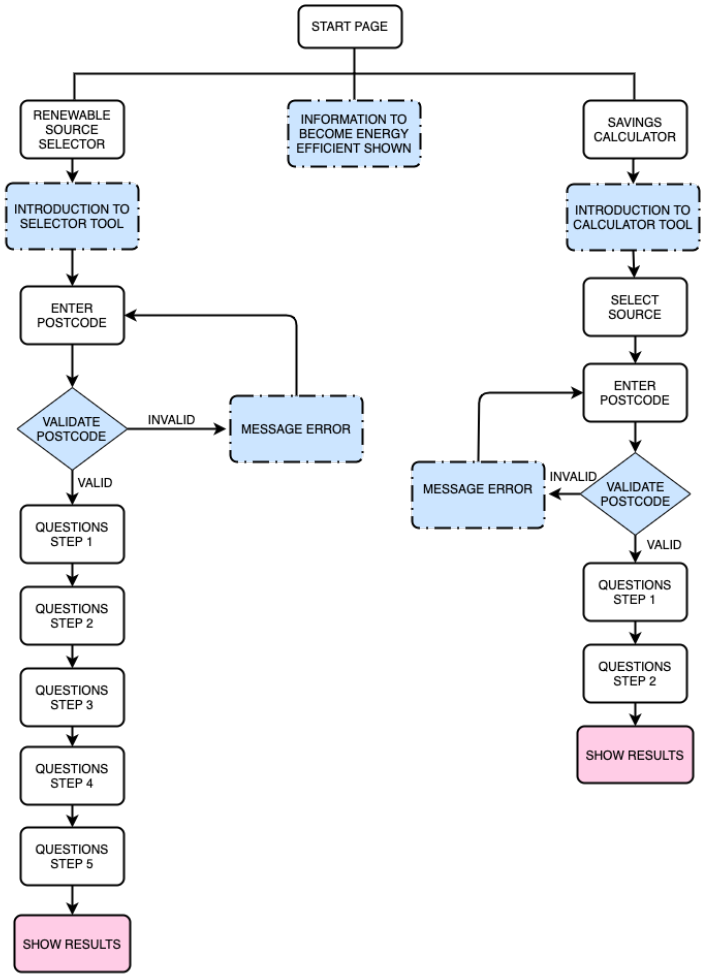

Figure 17. Navigability diagram.

5.1 START PAGE

In the start page, a small introduction to the application is shown and then a few pieces of advice for the user on how to become energy efficient. A drop-down menu on the top right

corner allows the user to navigate to the different tools directly. Then the two available tools are presented, and a start button allows the user to access.

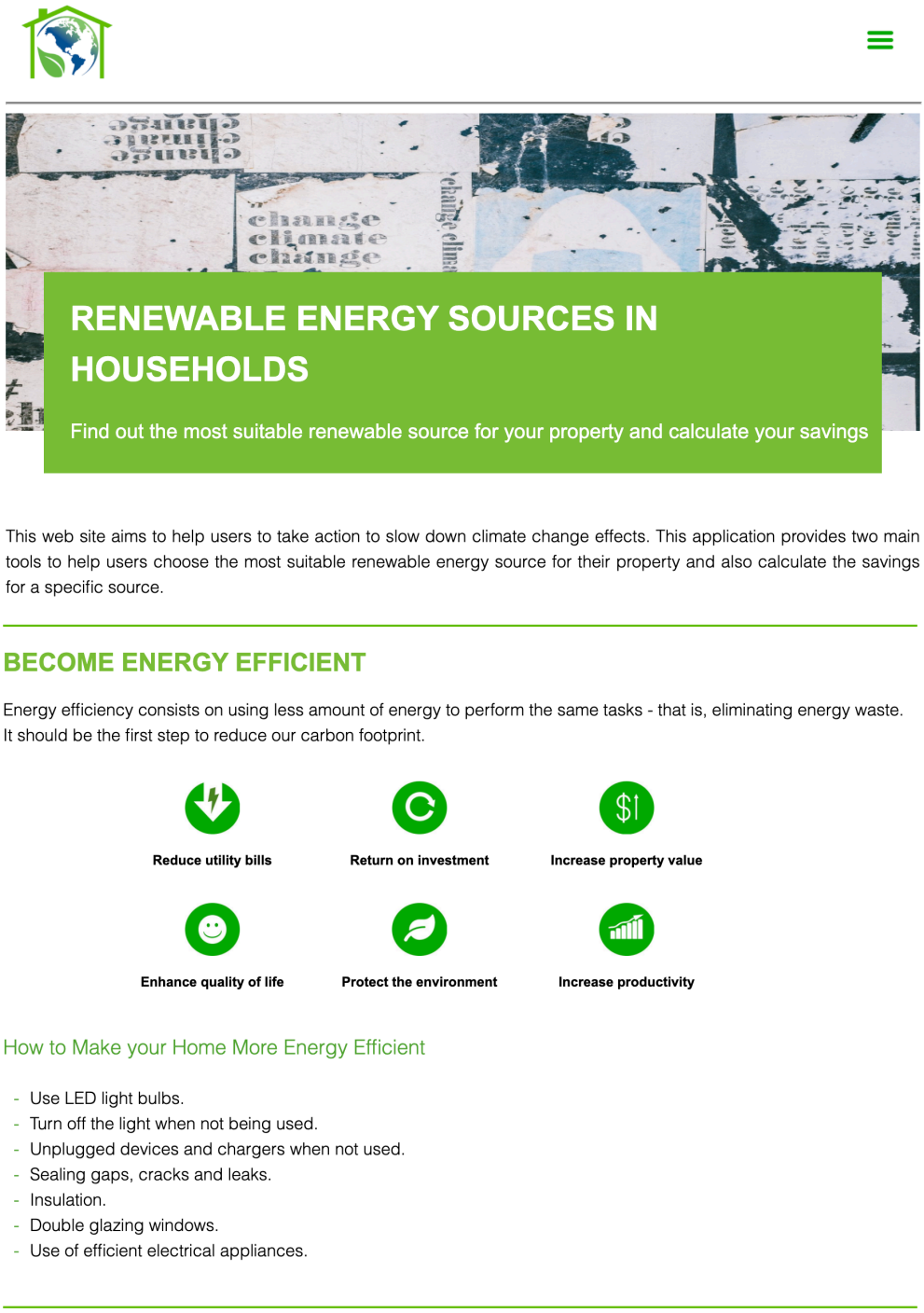

Figure 18. Start Page of the Renewable Energy Sources in Households application.

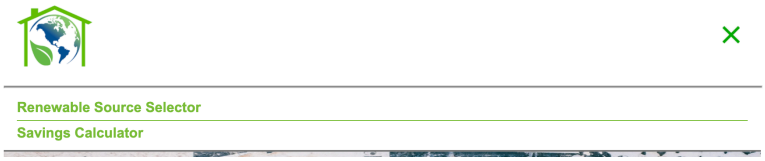

Figure 19. Drop-down menu.

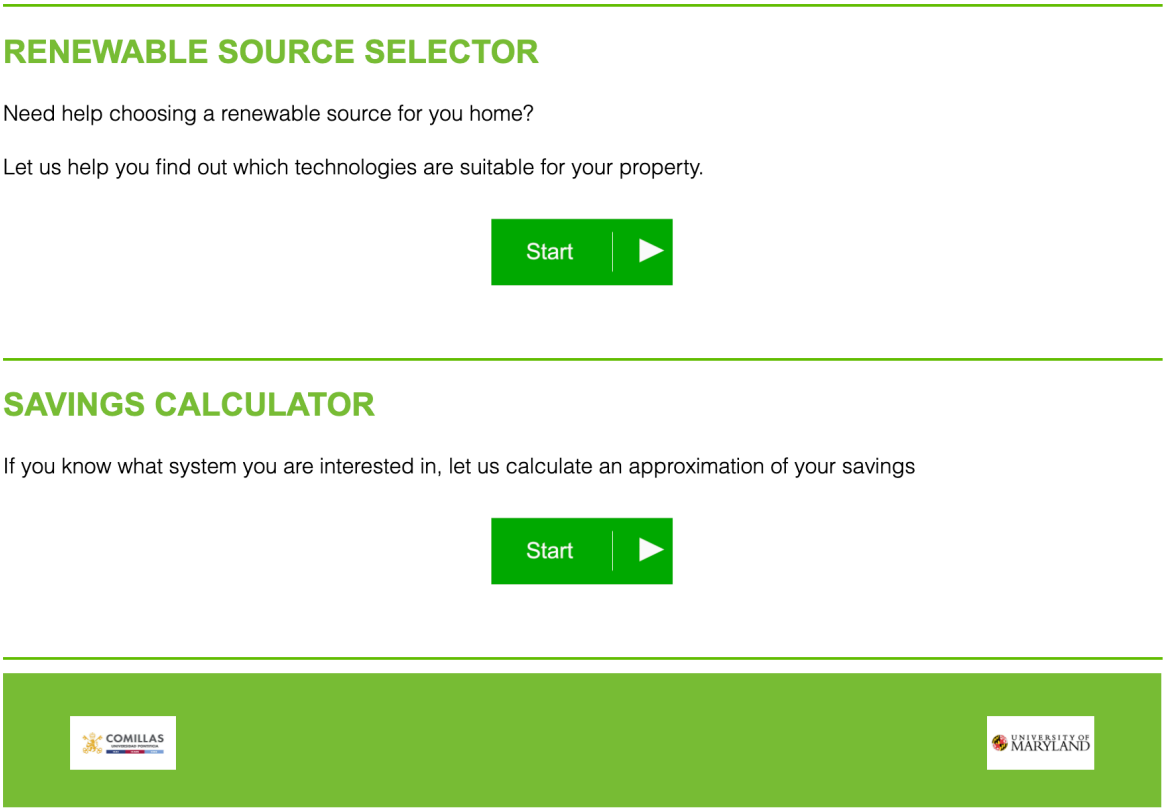

Figure 20. Tools section of the start page.

5.2 SOURCE SELECTOR

When the renewable selector is accessed by the user, an introduction to the tools is shown and the postcode of the property is required. If the postcode entered by the user is not a valid Spanish postcode an error message is shown as it can be seen in Figure 22.

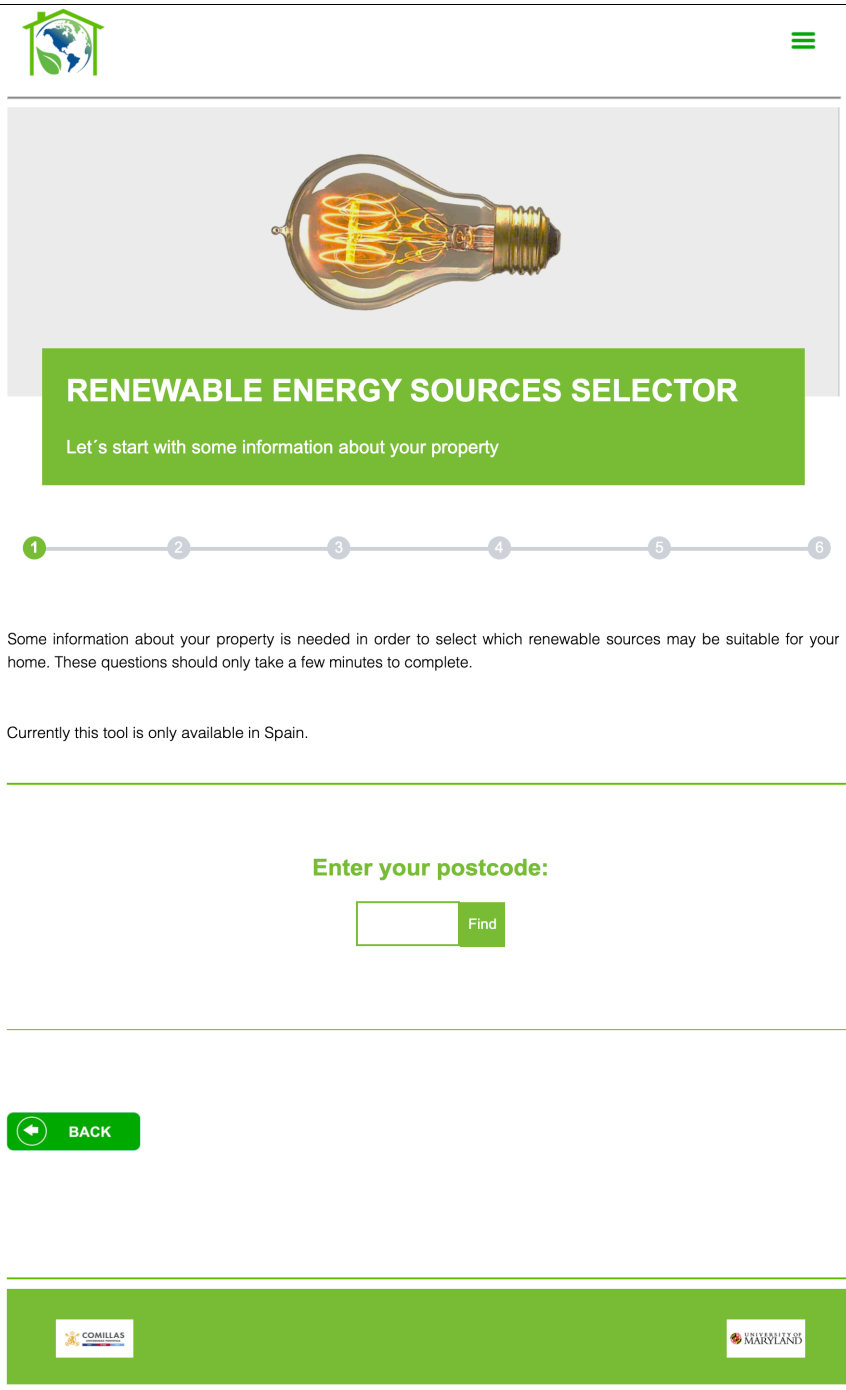

Figure 21. Renewable source selector start page.

Figure 22. Invalid postcode and error message.

If the postcode is valid, the multi-choice questions appear. First of all the type of property is asked and depending on the selected option the next question is one or another as it can be seen in Figures 23 and 24.

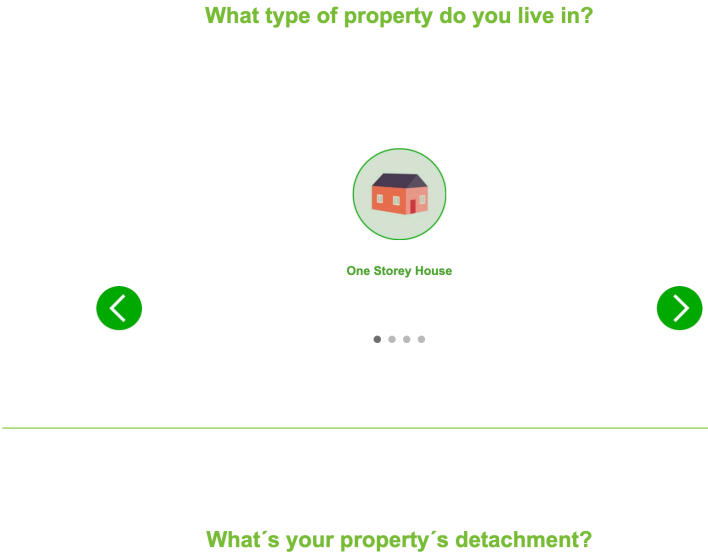

Figure 23. Type of property question and the next question when an option different than "flat" is selected.

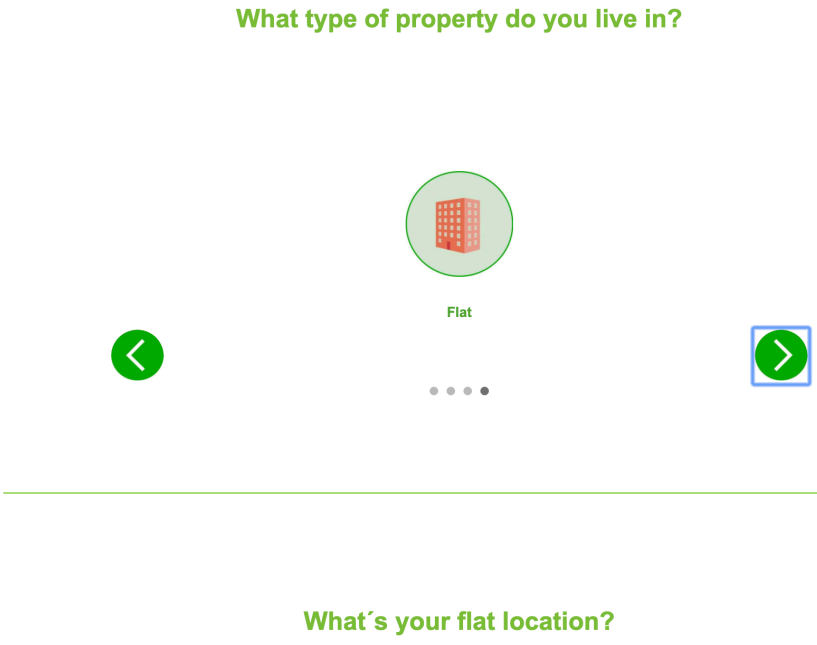

Figure 24. Type of property question and the next question when the "flat" option is chosen.

The following steps of the selector also have multi-choice questions to guide the user and provide an optimal result.

Figure 25. Renewable Source Selector Step 2.

Figure 26. Renewable Source Selector Step 3.

Figure 27. Renewable Source Selector Step 4.

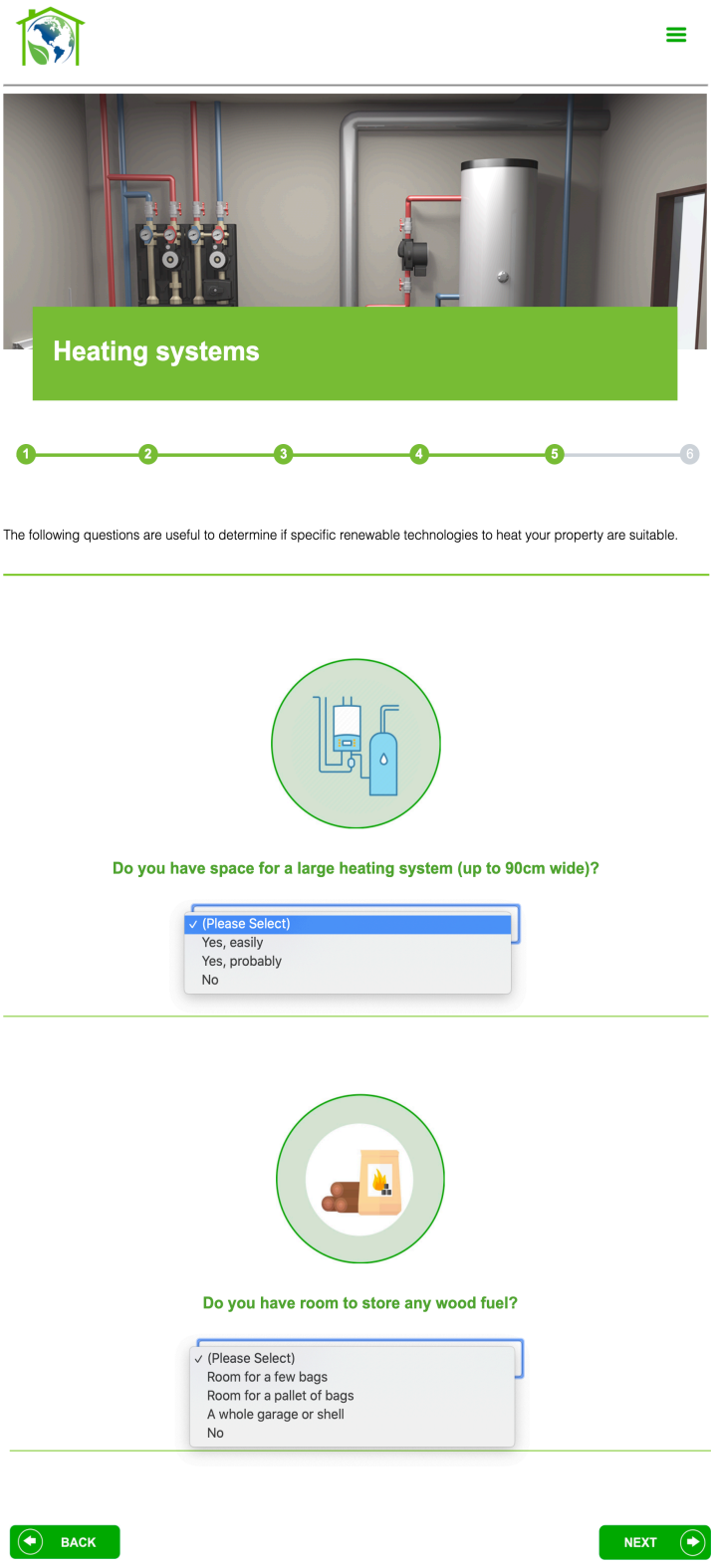

Figure 28. Renewable Source Selector Step 5.

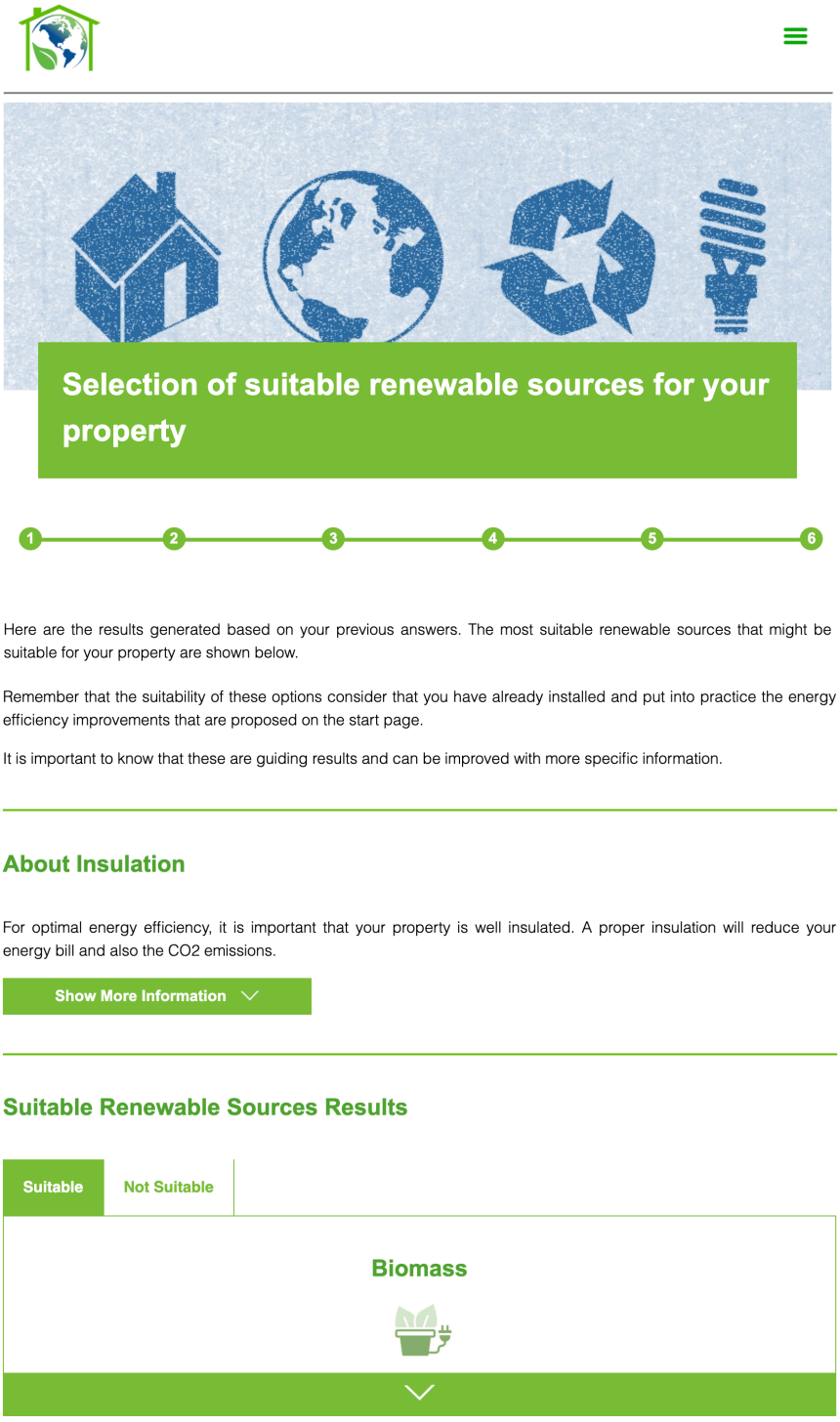

Figure 29. Renewable Source Selector Result Page.

In the result page of the renewable selector, if the user had indicated that the property was not correctly insulated, then some information about the importance of good insulation. An option to check the whole information is available as shown in Figures 29 and 30.

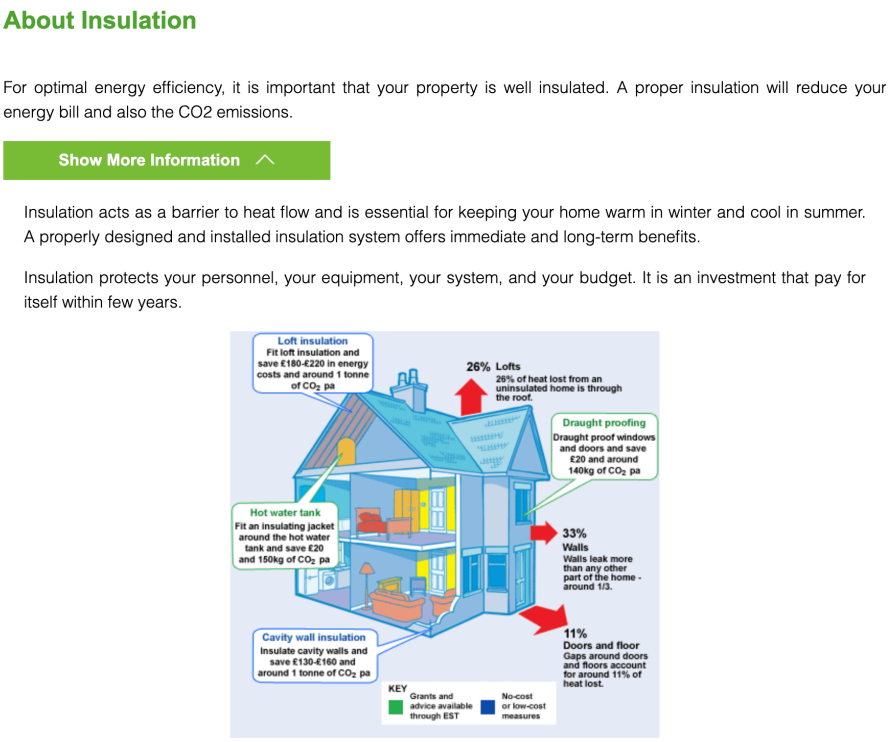

Figure 30. Complete information about the importance of insulation.

In the next section of the window, the results are shown. As can be seen in Figure 29, there are two different tags, one for those sources that are considered as suitable and another one that shows those that are not suitable. In both cases, an explanation of the source is given, and in case of the not suitable a small explanation of why those sources are not suitable is provided.

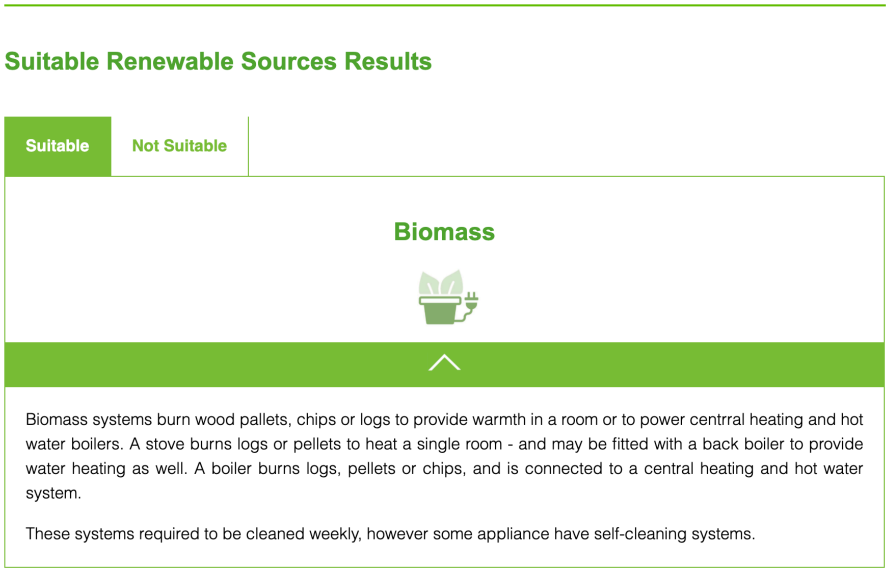

Figure 31. The suitable tag of the Renewable Source Selector Results page with the information expanded.

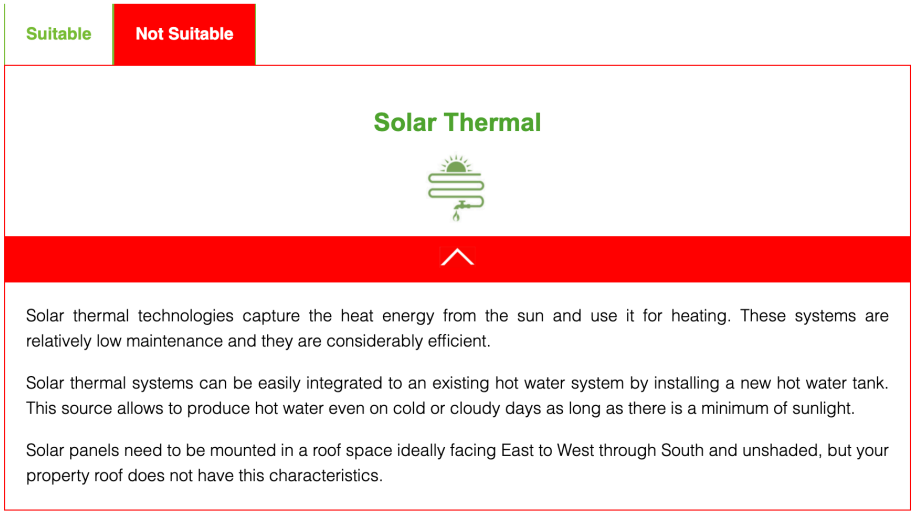

Figure 32. The not suitable tag of the Renewable Source Selector Results page with the information expanded.

5.3 SAVINGS CALCULATOR

The savings calculator interface is really similar to the renewable source selector, however, some of the questions differ as the information that is needed to calculate the different savings is different.

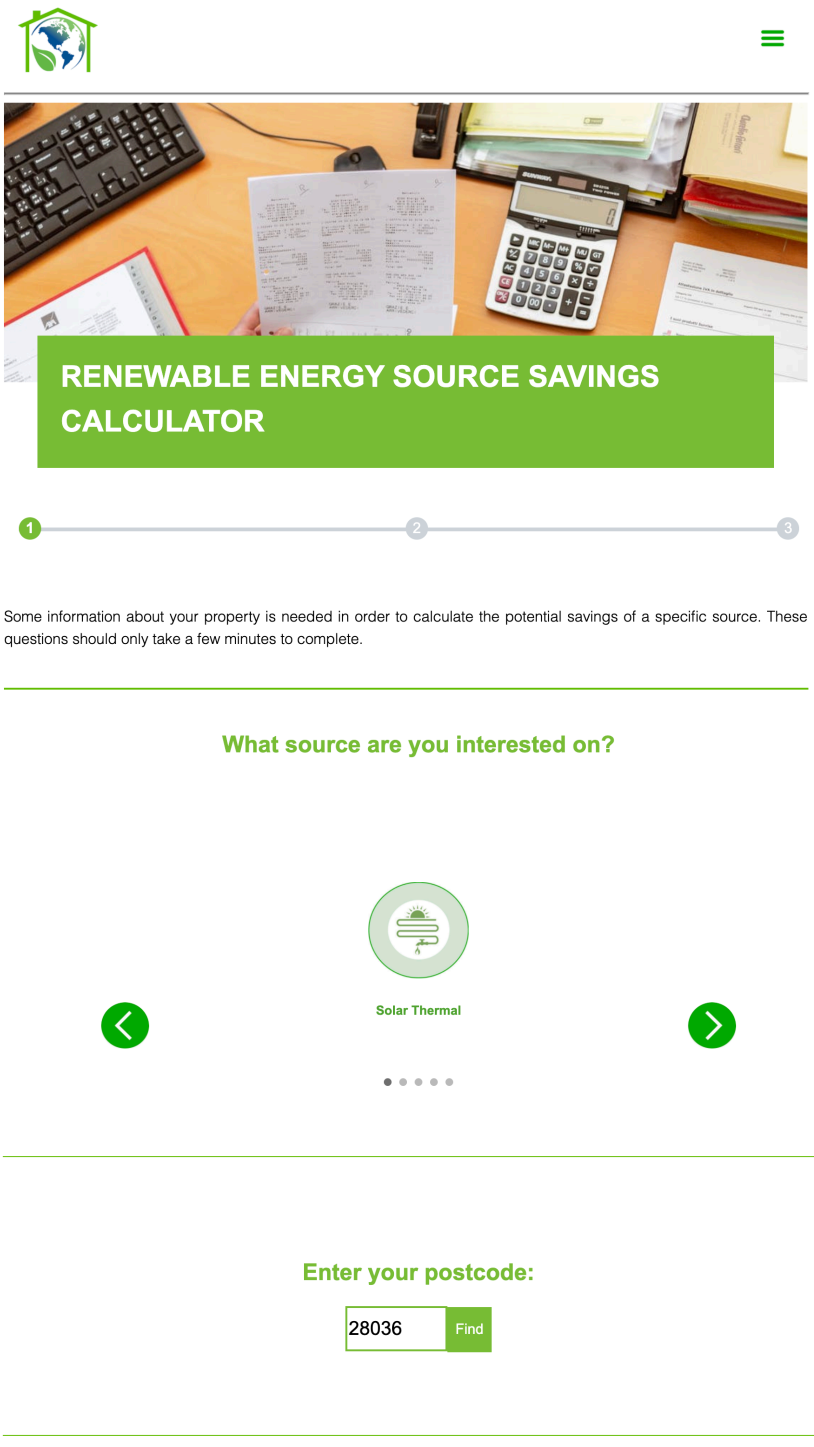

Figure 33. Renewable Energy Source Savings Calculator start page.

To start the calculator two important questions are asked to the user, first the source on which to calculate the savings and then the postcode. If the postcode given is valid, then

the next questions show. As in the selector, the type of property selected determines the next question.

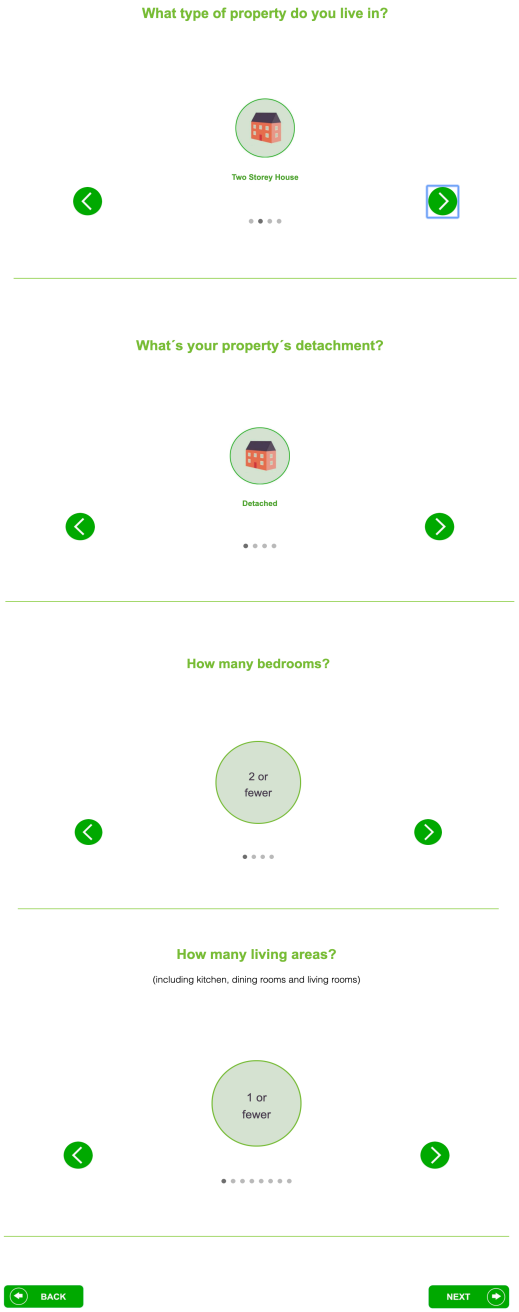

Figure 34. Renewable Energy Source Saving Calculator Step 1.

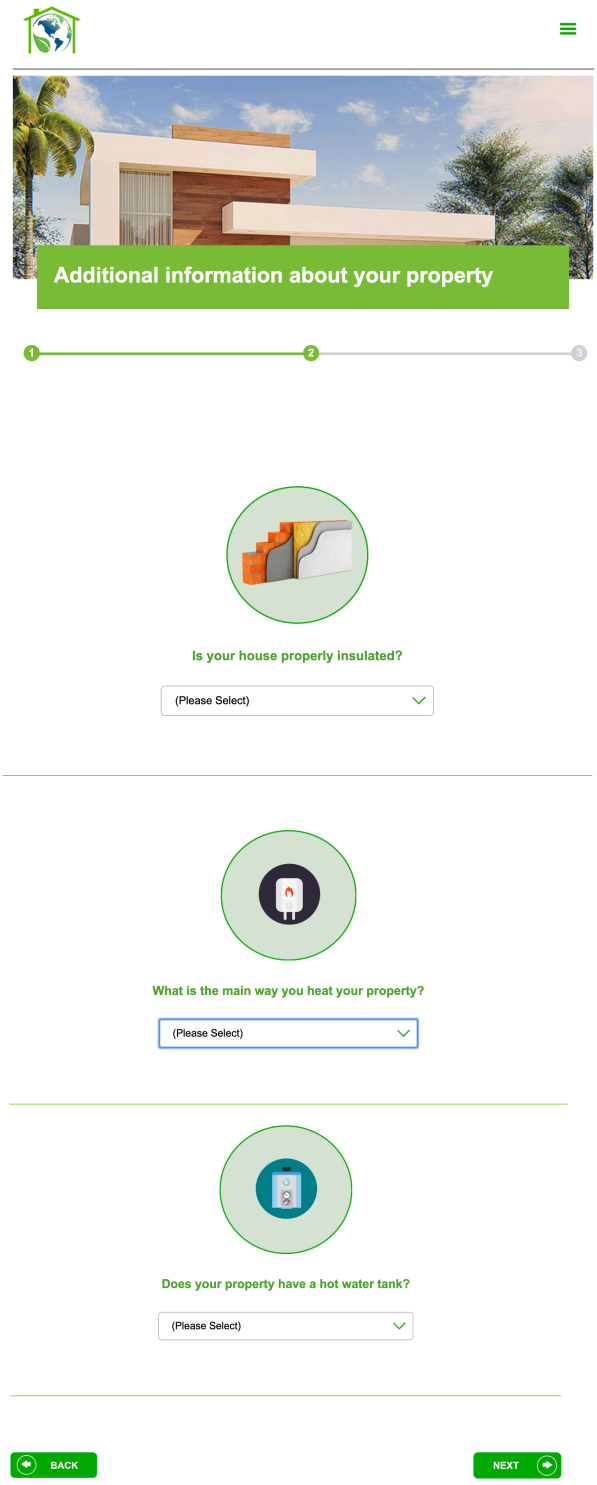

Figure 35. Renewable Energy Source Saving Calculator Step 2.

Finally, when the user has responded to all the questions the calculations are shown. The potential annual net benefit is first shown and then an option to check the CO_2 emissions savings and the installation cost is given.

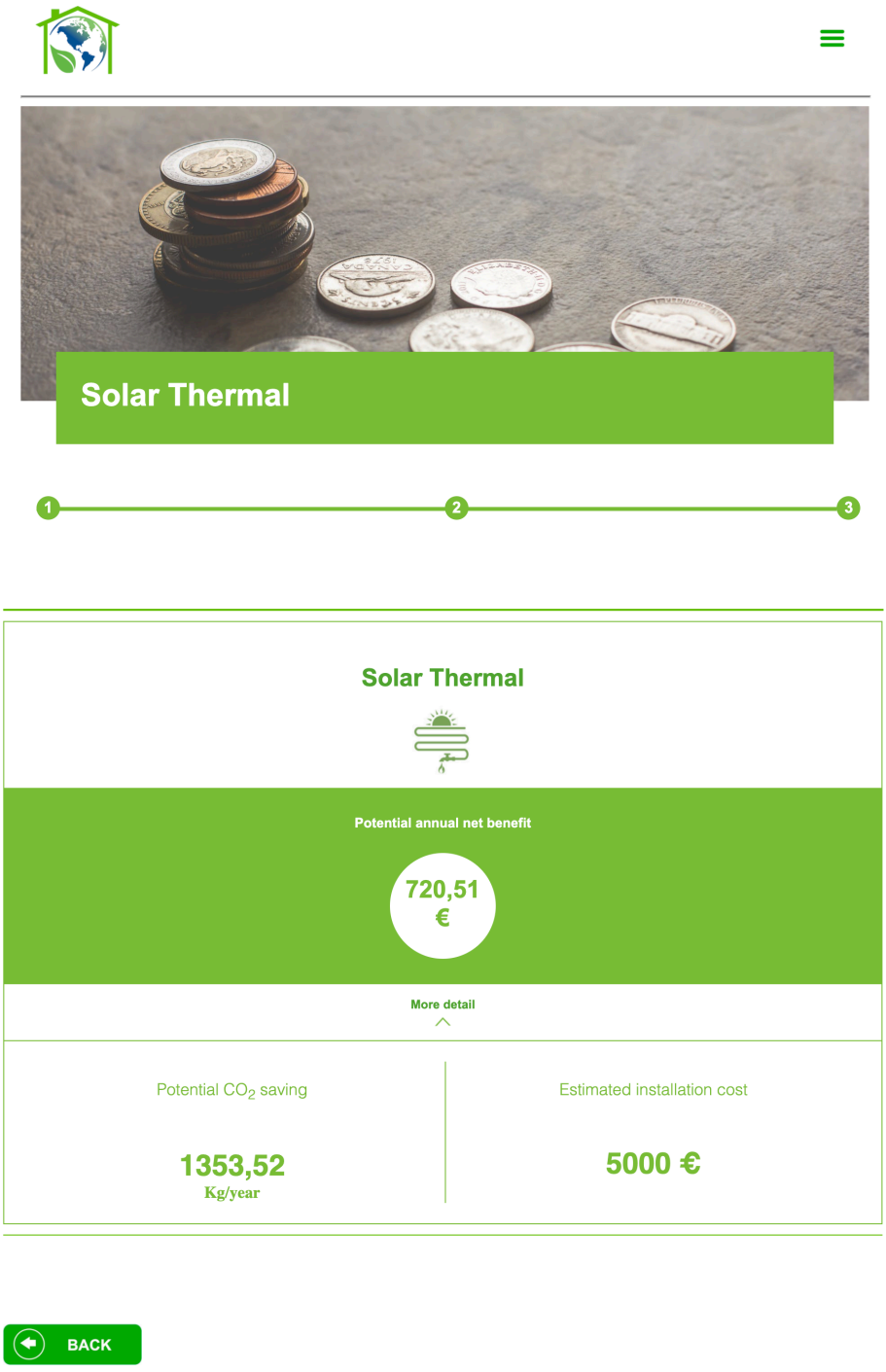

Figure 36. Renewable Energy Source Savings Calculator Results Page.

Chapter 6. CONCLUSIONS AND FUTURE WORK

6.1 CONCLUSION

Motivated by the need of action against climate change and the discovery of a gap of knowledge of renewable energy sources in the household sector, a dynamic web application to help end-users has been developed.

The web application consists of two main tools, a renewable source selector and a savings calculator both based on the information provided by a user about a specific property. Both tools are good options to achieve the proposed objectives as they are intended to help and motivate individuals to change into renewable sources which will produce less GHG emissions and will promote access to information and the acquisition of knowledge.

The testing phase shows how both services work correctly by collecting data with multi-choice questions. The selector shows suitable renewable sources with a small description and also those that are considered not suitable including a small explanation of why this decision. The savings calculator provides three different savings: annual economic saving, CO_2 emission savings, and an approximation of the installation cost.

6.2 FUTURE WORK

The information available on the internet about renewable sources in households is limited and not very specific. This has made hard the design of the offered tools as the selector needs access to installation and regulation restrictions and the calculator needs access to accurate national data. In Spain, the restrictions mentioned depend on each Autonomous Community and not all of them provide specific information. At the same time, the calculation of net savings depends on each source but also the energy consumption of each house, and this information is not of easy access. Energy consumption of each property is indicated in the monthly power bill, however, this web application is meant to be easy and simple so it uses

an approximation of this number by using the average demand of each region, however, a more specific value will result in a better approximation of the savings. In a future version of the application, an easy way of calculating a more accurate value will be a good improvement.

For the approximation of the installation cost, in the end, it all depends on the company in charge of the installation so for future versions, an arrangement with different companies could provide better information as they could make offers to the different users or different prices could be given.

Basically, this first version should be improved with more specific numbers to provide a better service. The different regional governments could be contacted to obtain more accurate data. It would also be a good idea to provide company names of those who have installation plans and maybe give the option to contact them.

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ANEXO I: PROJECT ALIGN TO THE SDGS

Figure 37. Sustainable Development Goals.

In 2015, the 2030 Agenda for Sustainable Development was adopted by the United Nations Sates. The Agenda is a plan of action for people, the planet, and prosperity that includes 17 Sustainable Development Goals (SDGs) which are a collection of goals designed to be a "blueprint to achieve a better and more sustainable future for all", and 169 targets. The five critical components of the 2030 Agenda are people, prosperity, peace, partnership, and the planet and all of them support the seventeen SDGs. Sustainability consists of three not mutually exclusive pillars: economy, society, and environment. Each of the SDGs can be linked to one of the three dimensions of sustainable development.

Figure 38. Figure 37. A new way of viewing the economic, social, and ecological aspects of the Sustainable Development Goals (SDGs) presented in the Stockholm EAT Food Forum in 2016.

Participation from all of society is crucial to realize the purpose of the Agenda by 2030. Therefore, this project contributes to sustainable development by integrating three of the SDGs. The design of a website that tries to make easy for users the transition into renewable energy sources and also promotes energy efficiency it is directly related to the following goals:

- Goal 7: Affordable and Clean Energy.
- Goal 11: Sustainable Cities and Communities.
- Goal 12: Responsible Consumption and Production.
- Goal 13: Climate action.

As it is shown in Figure 37, each of these goals covers one of the sustainability dimensions.

GOAL 7: AFFORDABLE AND CLEAN ENERGY

This goal focus on the target of providing access to affordable, sustainable, clean, and reliable energy while increasing the use of renewable energy. This involves improving energy efficiency and enhancing international cooperation. Targets of this goal are to

double the global rate of improvement in energy efficiency, by 2030 ensure universal access to affordable, reliable, and modern energy services and, also by that year, increase substantially the share of renewable energy in the global energy mix.

This goal can be identified as the primary SDG of this project as the main objective of the website is to provide property owners access to information to choose the most suitable renewable source for the property and also it promotes several practices to improve energy efficiency. Therefore, this tool contributes to the three targets of this SDG mentioned above.

GOAL 11: SUSTAINABLE CITIES AND COMMUNITIES

Human population has grown significantly and, since the eighteenth century with the Industrial Revolution, most people live in urban areas. As urbanization continuous to increase, it has become a threat to the environment and therefore, it is necessary to make cities available for everyone while respecting the environment. The eleventh goal mainly focuses in transforming cities into safer, more affordable and more sustainable areas.

Even though this goal is not primary in this project, it can be equally identified as the website tries to reduce the negative environmental impact per capita of cities by promoting and instilling the use of renewable sources in households.

GOAL 12: RESPONSIBLE CONSUMPTION AND PRODUCTION

This goal focuses on promoting social and economic progress combined with environmental protection. Among all the targets of this goal is ensuring that people have relevant information and awareness for sustainable development by 2030.

This goal is secondary on this project but can be identified as the tool design promotes the use of renewable energy sources that helps reduce CO_2 emissions and also the use of these sources can help users to save money on their energy bill promoting their economic progress by providing them with useful information. The target that was mentioned is accomplished by this project as the website objective is to provide information that can be used by the user.

GOAL 13: CLIMATE ACTION

As it has been mentioned several times in this same document, climate change is affecting the whole planet and is having negative effects on the economy and lives. To reduce these effects, it is crucial to reduce greenhouse gases emissions and to promote renewable energy. Target 13.3 plans to achieve an improvement in education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning and target 13.B consists of promoting mechanisms for raising capacity for effective climate change management.

This last goal is also secondary; however, it can be recognized as the app encourages and helps users to shift to renewable sources which reduces CO_2 emissions. The website can also be seen as a tool that improves education and awareness and human capacity as it provides useful information to reduce the adverse effects of climate change which can be related to the targets of this goal.

ANNEX II

II.I Use Cases

RF-RS	Renewable Source Selection	
Version	2020/v1.0	
Authors	Carmen Ollero	
Source	N/A	
Description	The system must allow the user to start the renewable source selector by answering the questions.	
Precondition	1. The property must be in Spain	
Sequence	**Step**	**Action**
	1	The user must select “start” in the selector section.
	2	The user must indicate a valid postcode.
	3	The user answers the questions about the property.
Postcondition		
Exceptions	**Step**	**Action**
	2	If the user indicates an invalid postcode, a message is shown.
	3	Every question must be answered.
Performance	**Step**	**Action**
Expected Frequency	10 selections/day	
Importance	Very important	
Urgency		
Comments		

RF-SC	Savings Calculation
Version	2020/v1.0
Authors	Carmen Ollero
Source	N/A
Description	The system must allow the user to start the savings calculator by answering the given questions.
Precondition	1. The property must be in Spain
Sequence	**Step** **Action**

	1	The user must select “start” in the calculator section.
	2	The user must indicate a source.
	3	The user must indicate a valid postcode.
	4	The user answers the questions about the property.
Postcondition		
Exceptions	**Step**	**Action**
	3	If the user indicates an invalid postcode, a message is shown.
	4	Every question must be answered.
Performance	**Step**	**Action**
Expected Frequency	15 calculations/day	
Importance	Very important	
Urgency		
Comments		