Hydrogen and Electric Power Application

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Abstract

The goal of this capstone project is to give the broad public the information and tools to learn about green energy solutions that are currently available in the US market. As people in the modern era produce more and more carbon emissions, the demand for a tool that can help make informed decisions about green energy usage is greater than ever.

The application that we developed is a mobile and desktop-friendly website that has several tools for the users. For the development of the front-end of our application, we used HTML, CSS, and JavaScript. For the backend and data representation, we used PHP, Google Maps, and Tableau.

The purpose of this report is to show the breakdown of what was achieved during the development of the project as well as the project analysis. During the project features development phase, we encountered a number of challenges that we discuss in this report. Some of these challenges are related to the costs of using a large amount of data. Handling a big amount of data requires ample data storage and processing power so that the handling can be smooth. In addition to that, we needed to have a user-friendly and familiar interface for the navigation map, which also comes with a cost challenge of its own. We discuss these and other considerations in the current report.

1. Introduction

Against the ever-pressing backdrop of climate change, green energy has never been more vital. With the announcement by the Biden administration that the US will endeavor to cut greenhouse gas emissions in half by 2030, realistic solutions to improve consumers' understanding of green energy are essential. There are many solutions already available on the market, nevertheless, many of them are not marketed properly or have controversial information about them.

As people in the modern era produce more and more carbon emissions, the demand for a tool to help us understand green energy is greater than ever. Because our group believes that it is essential to educate the general public about available green energy solutions, we decided to partner with the Hydrogen and Electric Power Foundation (The Foundation or HEPF) for this project. HEPF is a non-profit company whose goal is to educate its consumers about green energy and make the information about green energy solutions easy to understand by the broad public. Our hope is to provide the necessary technology to educate consumers about CO2 emissions and ways to reduce them. In addition to that, we want to promote the not popular but efficient solutions, for example, electric vs hydrogen vehicles. We also hope to help the user with a decision regarding energy consumption and the ways to deal with it. During this semester, we created a technological solution for the Foundation. The main goal that the Foundation seeks is to establish an online presence and reach out to consumers through an application that can showcase zero emotions technologies & climate change solutions.

Therefore, the objective of this capstone project is to give the broad public the information and tools to help make an informed decision about green energy consumption. Our users can also perform analysis of green energy near them as well as draw conclusions about what type of green energy to use in order to reduce carbon emissions.

The application that we developed is a mobile and desktop-friendly website that has several tools for the users. For the development of the front-end of our application, we used HTML, CSS, and JavaScript. For the backend and data representation, we used PHP, Google Maps, and Tableau. We apply and support our data with evident analysis that displays the best understanding of the available data. The data used was obtained from DOE (The US Department of Energy) and was collected from EIA (The US Energy Information Administration). According to the consent of data, both U.S. government sources provide the complete dataset regarding the information we wanted within the US territories. It is also available for any developer to use in their projects, and therefore meeting the demand of our project, giving us the permission to use the data.

The data is converted into CSV formats so it can be used in a PHP database for the purpose of our visualizations in Google Maps and Tableau. In this project, we use two different kinds of visualization methods - the charging station map and the green energy farm heatmap. We use Google Maps API for the charging station map because it must be user-friendly, must have a familiar interface, and have a navigation option. Our website displays visualizations that include

maps, data point markers, descriptions, and addresses of the location of the charging station as well as a direction button that will direct the user to a new Google Map page for the navigation.

The map that represents green energy farms, however, serves a different purpose. The main purpose is to visualize thousands of data points in one concise way. Therefore, we chose Tableau, where we created heatmaps using different grading of color. The heatmap showcases each state of the US and the number of the particular type of green energy farms in the state. Whereas the bigger the number of energy farms is within the state, the darker the color is. When the user clicks on the state, information about the data points is reflected. This way the user can see information regarding green energy farms such as solar, wind, hydroelectric, and others.

Besides the features that we just discussed, the application also has a news section, event calendar, and contact us page. Below you can find a general description of the website with mobile and web interfaces and its features:

A. Content Page
    1. About the Foundation
    2. About the issue
    3. General information holders
    4. News page
    5. FAQ
B. Tools
    1. Maps of charging stations and power plants
        a) Charging stations: hydrogen and electric
        b) Green energy farms: solar, wind, hydroelectric, etc.
    2. Calendar of events
    3. Contact form / newsletter subscription

In order to reflect on the work that was done, we discuss the following sections in this report. First, we review previous projects that are already available and why this project is different. Then, we outline the design requirements and project details as well as the costs that follow them. Next follows the feasibility of the project. Here we talk about the literature and justification for the design of the project. After the feasibility discussion, we show a use-case diagram (UML) and a Data-flow diagram (DFD) that outline the expected user experience of the website. Lastly, we discuss the results of the project and showcase the screenshots of the completed application.

2. Review, Design Requirements, and Project Details

The U.S. Department of Energy (DOE) provides a similar solution to some degree. Before the start of the project, we familiarized ourselves with the DOE website and the information that it provides. At a first glance, it may seem that the DOE website has many similar tools and information that we planned to bring into our project. A closer look into the available solution, however, revealed that the DOE uses an out-of-date and non-interactive website. We believe that it lacks user-friendliness which is the major goal of our project. In addition to that, we noticed that the available website was intended for the specific audience of researchers and people working in the energy sector.

With that being said, we believe that our project can help the general public to learn about current green energy solutions with ease. It can also help them make informed decisions about using clean energy. We made sure that our dynamic application is cross-platform and available in mobile and desktop formats. One of the tools of the application is an interactive map, we will talk about it in detail later in the report. Unlike the maps from the DOE website, our map allows the user to navigate to the desired destination. In our project, we wanted to make sure that all features that we implement are not only presented in a user-friendly manner but are also interactive if possible. Our users can select from a variety of options that will help them view and understand the data in different ways.

As we previously stated, the design of our project is built upon the need for an interactive tool as mentioned above. Our customer's (HEPF) objective is to support and power any user that is seeking comprehensible information about green energy and available zero-emission solutions in the current US market. We also provide consumers with tools to make informed decisions regarding green energy vs fossil fuel consumption and a medium to interact with the users that are interested in this cause.

From the discussions with the customer, we devised the end-user of the application. Users of our application are the general public without deep knowledge and understanding of technology and energy sectors. However, our users are people who are interested either to learn more about green energy resources or to get answers to the controversial questions about the technology currently available in the market.

After some considerations, we decided that it is essential to begin our work by establishing an internet presence for the Foundation. We started by designing and deploying an application that has web and mobile interfaces. It holds tools and features such as and not limited to pages with general and educational information, maps with green energy location data points, a subscription form, and other features. We used as many open-source tools as possible due to the nature of the organization. Our end-users have easy access to the various green energy charging stations available nearby. Moreover, they can access information about different green energy farms around them.

HEPF helps us to collect appropriate data concerning US solar and wind farms, as well as hydrogen and electric car charging stations. With that data, we built an application with a web and mobile interface that reflects comprehensive educational information about zero-emission solutions. The integral features of the application are the maps that display existing zero-emission power plants and hydrogen and electric charging stations. The map includes an option to filter based on various categories. The ability of the user to contact the Foundation and give feedback can help to collect new data to enhance the application.

As mentioned above, the website has two types of map applications: the charging station map and the green energy farm heatmap. The charging station map is used to display all available near to the user electric and hydrogen charging stations. Whereas, green energy farm heatmap showcases the distribution of different types of green energy farms in each state of the US. Examples of the farms are solar, wind, hydroelectric, and geothermal. Two map applications are created with different software. For the charging station map, we used a WordPress plugin and the Google Maps API key. This allows developers to easily embed the Google Map application with different aspects of usage in WordPress websites. For the green energy heatmap, we decided to use Tableau as the visualization tool. It provides a very professional heatmap visualization technique, and it is free.

All the data we need is collected from the US government organization websites, such as DOE and EIA. Yet, the data collected from different sources has an inconsistent structure and needs to be reorganized before implementation. Therefore, we mainly use Python for data cleaning and merging within a consistent data structure in order to implement it into those two types of map applications. The major attributes of the data for the map applications include descriptions of the data points, address, longitude, longitude, and energy type.

2.1. Costs

There are a number of costs that come with the requirements of the project. One of the main costs is the performance of the application. Due to the size of the data used, it is recommended for the client to have premium packages of all the tools used in hand. Specifically, API calls that can handle the application. Another cost of the application is privacy. Upon a worry that the third party can use or be involved in collecting personal information. This application is not intended for any harmful usage. In addition, it should be noted that the data is static, not dynamic, meaning that it requires manual updating.

Moreover, one of our critical considerations is the non-existent budget of the Foundation. While developing the website we had to consider this financial issue. Therefore, we had to choose free tools or technology with a minimal cost. We calculated that the minimal cost of maintaining the website is $120 per year, including the tools that we used. The HEPF can obtain a free Google API key as a non-profit organization going forward. In order to do that, they need additional documentation that they are currently obtaining and working on approval.

2.2. Data

For this project, we collected from the DOE website over 50k data points of electric and hydrogen charging stations. We also collected over 5k solar, wind, geothermal, and hydroelectric farms from the EIA website. However, large amounts of data can limit the performance of data processing. This, in addition, can have side effects including longer map response time; crashing of the browser; most notably, loss of track of information from the current session. Hence, we decided to only implement 10k data points for the charging station map and all data points for the green energy heatmap.

2.3. Security

As will be discussed in the Project Evaluation section, our core application is WordPress. By itself, WP is considered to be secure, as long as the developer of the website upholds security seriously and follows its best practices. Best practices include but are not limited to using safely recognized plugins and themes, keeping the website on regular updates from the publishers, and patching any holes that might give vulnerability to the website.

2.4. Privacy

The data that is integrated into the application was retrieved from the following resources: Alternative Fuels Data Center and The U.S. Energy Atlas websites. According to the privacy agreement, the data is categorized as public information and available for public usage. Therefore, this meets the demand of our client project, giving us permission to use the data as needed. The only concern is privacy because third-party applications can use the data to their advantage.

This is raised due to the fact that the data and information being retrieved and processed come from third parties and terms of usage might differ at any time. We strongly advise and recommend the client and his team to review the usage of data of the maps and read the terms of agreement every time before uploading/updating any data from third parties and to make sure that it serves the purpose it was created for legally and minimize any reference to any third party that is not needed.

2.5. Feasibility Discussion

At the start of this project, the team had difficulties identifying the resources needed for the purposes of the application. We were informed by our client, Joseph Alfred, that he needed a tool to serve his customers with a map interface. The challenges were mostly based on the idea

that there was no single source of data. Most of the required data were not consistent in one category and few of the required data were not clear. For example, in order to achieve the charging station map application, we collected two types of data from DOE which contained different formats. This required data cleaning and merging before applying the dataset to our WordPress plugin. Another example is the green energy heat map application. We needed to pre-process the datasets obtained from the EIA because they came from different categories.

Another limitation was that we lack professional knowledge about green energy or related domains. For example, while we were collecting the data, we realized that we don't have enough information about what kind of sources are considered green or not. In order to overcome this issue, we talked to our guiding compass - the client. Joseph helped us to better understand the differences between different energy sources.

For the green energy heatmap application, our client expected to have hydrogen farms that apply particular hydrogen generating technologies that are considered as zero-emission. However, after we did some study, we found out that hydrogen actually could be generated using various technologies. These technologies are coal, gas, wind, and geothermal, as long as the place is able to provide stable energy. Therefore, it is hard for us to determine if the resource we found fulfills the zero-emission requirement or not. Given this, we need to consider two aspects of the data collection and representation. First is the hydrogen power itself, and second how was the hydrogen obtained, by using zero-emission sources or not? As mentioned above, there was no budget for the data collection. We put our best effort into searching the data we wanted, yet we couldn't find anything online that meets our expectations. Therefore, we advised the client that this can be potentially a separate research study.

The team had to meet and conduct many brainstorming sessions to decide how the line of our project would work for the client. It was later decided that the best approach is to go with a website with a free plug-in and an easy dashboard to publish content to reach the client's goal. With that, we observed that there was an opportunity of generating more information from the data collected. We got this idea based on the model that we saw on the DOE website. They have many different static maps and we saw the chance to enhance them in a user-friendly way.

As was mentioned above, one of the ethical questions that were encountered is the use of data; will third parties be able to take advantage of it? and will energy firms leverage this to their favor into the dark path? The answer is not clear yet as more testing needed to be done and forecasted.

2.6. Project Evaluation and Performance

Efficiency

In order to give an evaluation of the website performance, we first want to understand the interaction between the front-end and back-end. We can view the available resources and give three different scenarios, best, worst and realistic. First, the best-desired scenario is that the user travels through the website seeking information about green energy. This happens in an easy and interactive manner due to the easy flow of data and hardware availability from the client that is trying to reflect that experience.

Second is the worst-case scenario, where the user is not able to go anywhere when they view the website due to heavy data and low processing time with every session they are opening.

Finally, we consider the realistic scenario. In this scenario, we tested the website and found out the general content loads very fast, around 3 to 5 seconds. This is considered to be an industry standard. However, when users access the map tools, it takes longer due to the amount of data involved. We recommend that the client upgrades the hardware and use premium tools such as Google API. Thus it will make it work faster and enhance the peak performance we are seeking.

Scalability

With the right combination of resources and services, WordPress is considered very scalable. Some of the biggest websites nowadays are powered by WordPress. It can uphold the service of thousands of users at the same time and still deliver the requirements. It can process requests with no downtime and can give the developer all the support to maintain the website upon scalability. However, we are using various plugins and APIs that come with financial costs and the client needs to take into consideration these things in order for them to scale up to the proper level they are targeting.

Reliability

WordPress is considered very reliable as it powers approximately 40% of all websites that you find on the Internet today. However, during our development, we encountered a couple of bugs that we had to deal with. These bugs are mostly related to paging; for example how the page is viewed and cut into different browsers; how images are being displayed in the different browsers. Some browsers cannot deal with the size of the images being introduced into the website and therefore require a dynamic code to understand what is going on and act upon it accordingly.

Expandability

WordPress has a variety of different plugins that can enhance the website with ease if extra features are needed. In addition, we can code our own features and plugins if the available features don't satisfy our requirements. For example, this way we added Tableau maps for the data visualization.

Usability

We believe that the website has a very good UI since professional themes were used during website development. The work that has been done currently consists of the website skeleton and working tools. However, the client did not have the content ready by the end of the project. We made sure that the client received instructions and documentation on how to add the content to the website later.

Reusability

The maps that we implemented on the website only cover either the Los Angeles area (for the navigation tool) or the US (for the data visualization tool). The client can easily add additional data in order to reproduce the same result for the different US states or even other countries if needed.

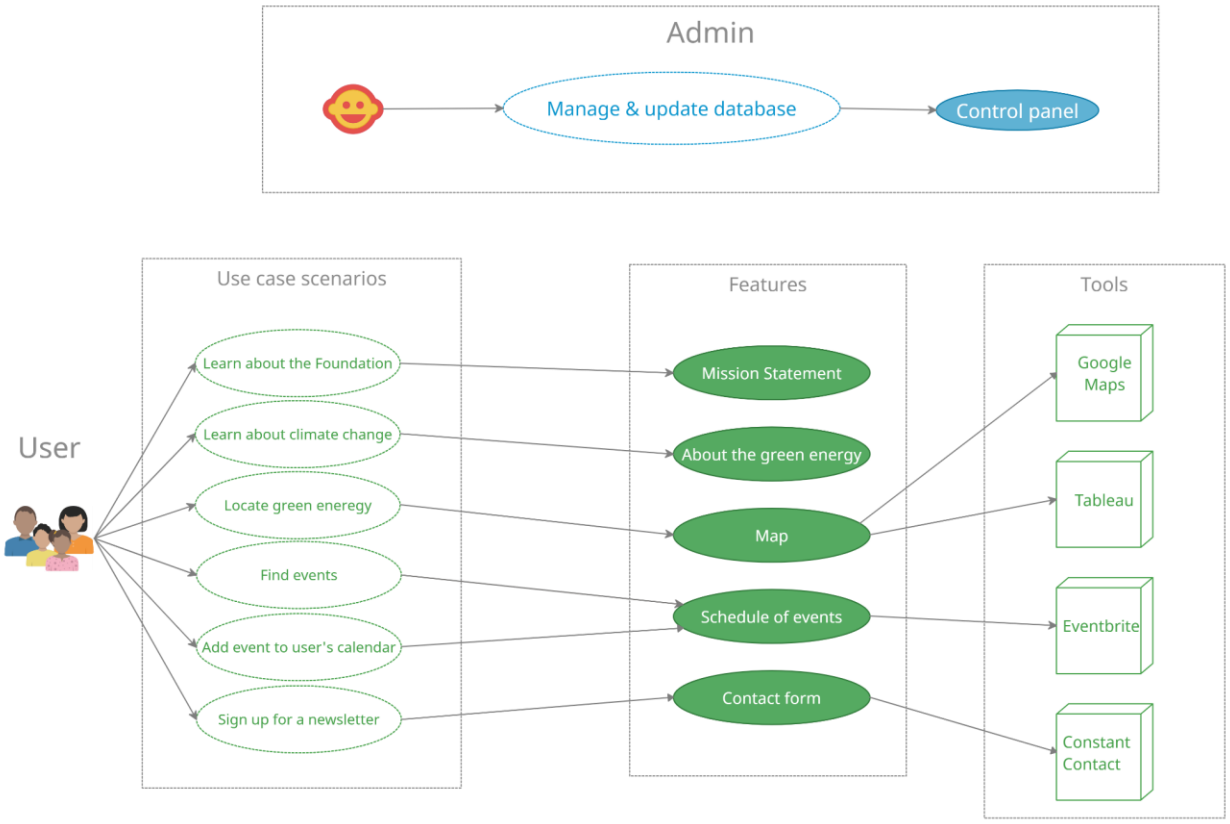
Maintainability

The website can be easily maintained by engineers due to the fact that it has many tools and plugins available for development. We also decided to use WordPress for the development, because it has a user-friendly interface for people without any technical knowledge. This way, if our client doesn't have a tech person to maintain the website content, this can be easily done by anybody else with the help of comprehensive documentation.

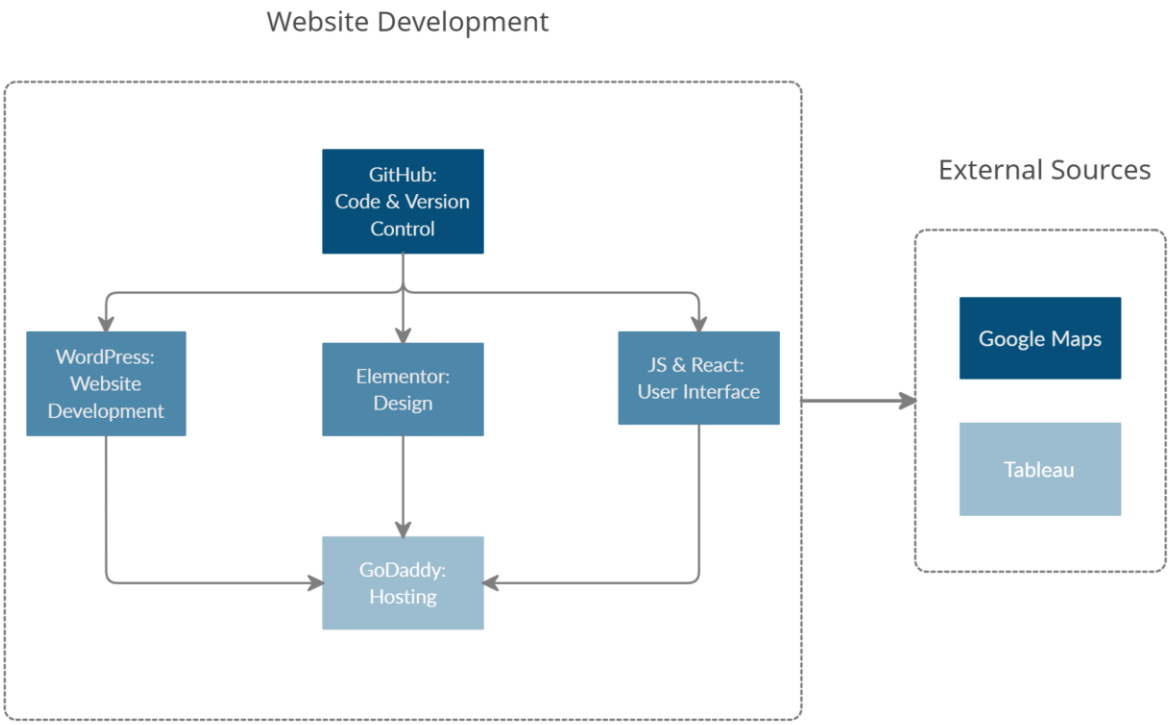
3. Final Implementation

Our application supports different environments such as Windows, Mac, Android, and iPhone. We decided that this can be achieved by using Javascript and other frameworks such as PHP and Google Technologies for web browser development. In the end, we decided to use WordPress and Elementor for the website design. Therefore we can use any Windows OS, Macintosh, or Linux machines for this purpose. We can test the application on a desktop browser, an Apple or Android device, or any available mobile simulator.

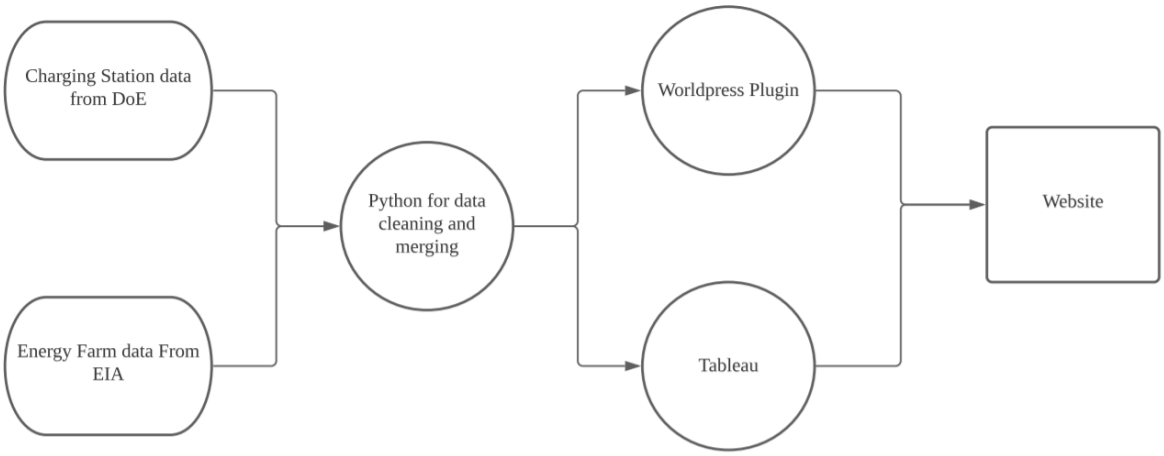
Before the beginning of the website development, we created a **Use Case Diagram (UCD)** that demonstrates the way the user can interact with the website. The UCD is shown below. According to the diagram, the user can browse all nine pages and sections of the website. The user can interact with the main page, which includes the Mission section, About the Organization section, Services section, Events, FAQ, News pages, Map pages, and Contact us. The user can also explore the other features embedded in the Google Map and the statistical analysis of Tableau in the Map sections. Our client will have the permission as an Admin to read and write to all these mentioned pages and their related content.



We also created an **Architecture Diagram** that can be seen below. As a main tool for the website development, we used WordPress and Elementor for the design. In addition to that, we used external sources such as Google Maps and Tableau to develop some map features.



Lastly, there is a **Data-Flow Diagram** (DFD) to depict the data that we used in our project. In this diagram we show where the data was obtained from, how is was processed and the data output.



4. Results

The screenshots in this section are to show the outputs of the project.

Image 1 displays the top of the home page with a description bar as well as the navigation bar with several options that will direct the user to the location of the website from the left. It also has a subscribe button located at the right for the newsletter subscription.

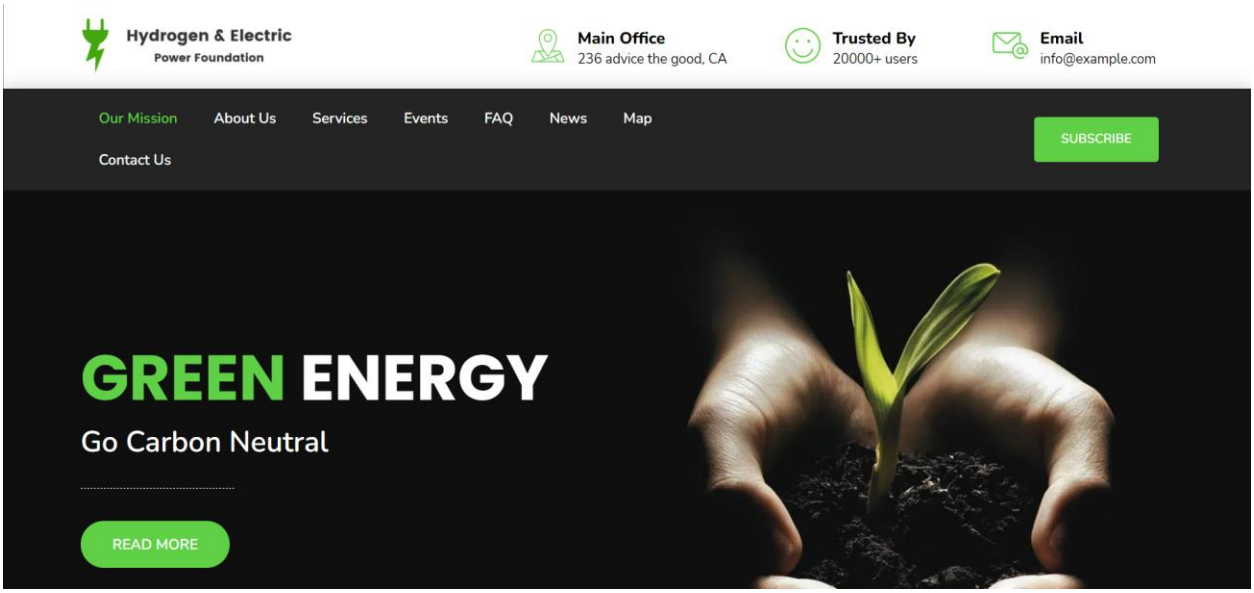
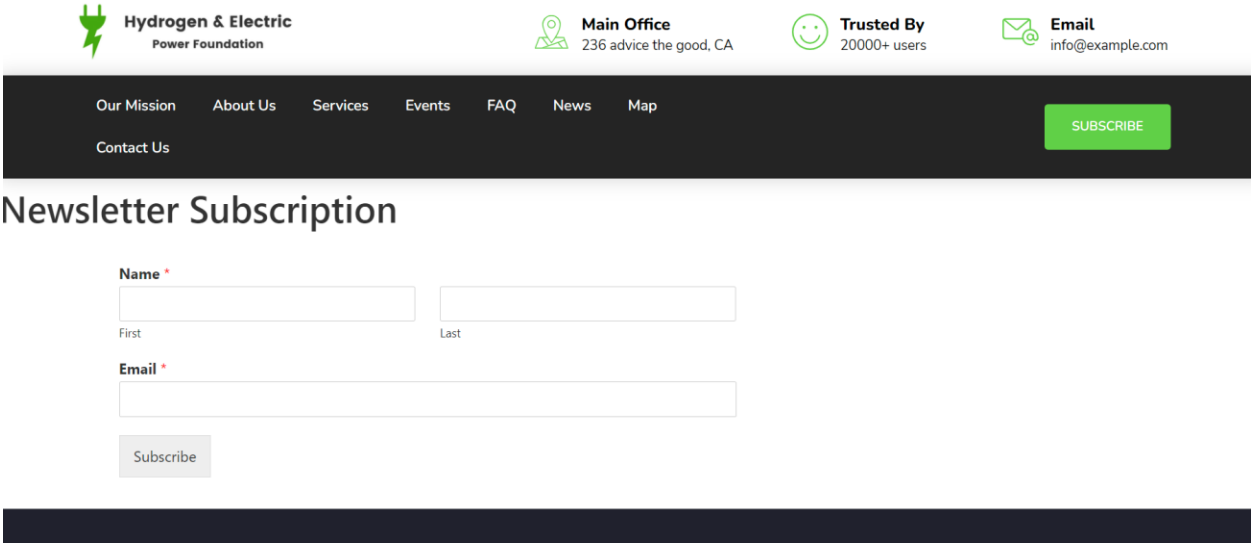


Image 2 displays the subscription form for the subscription features. After the user files the form and submit it, the data will be stored into the backend.



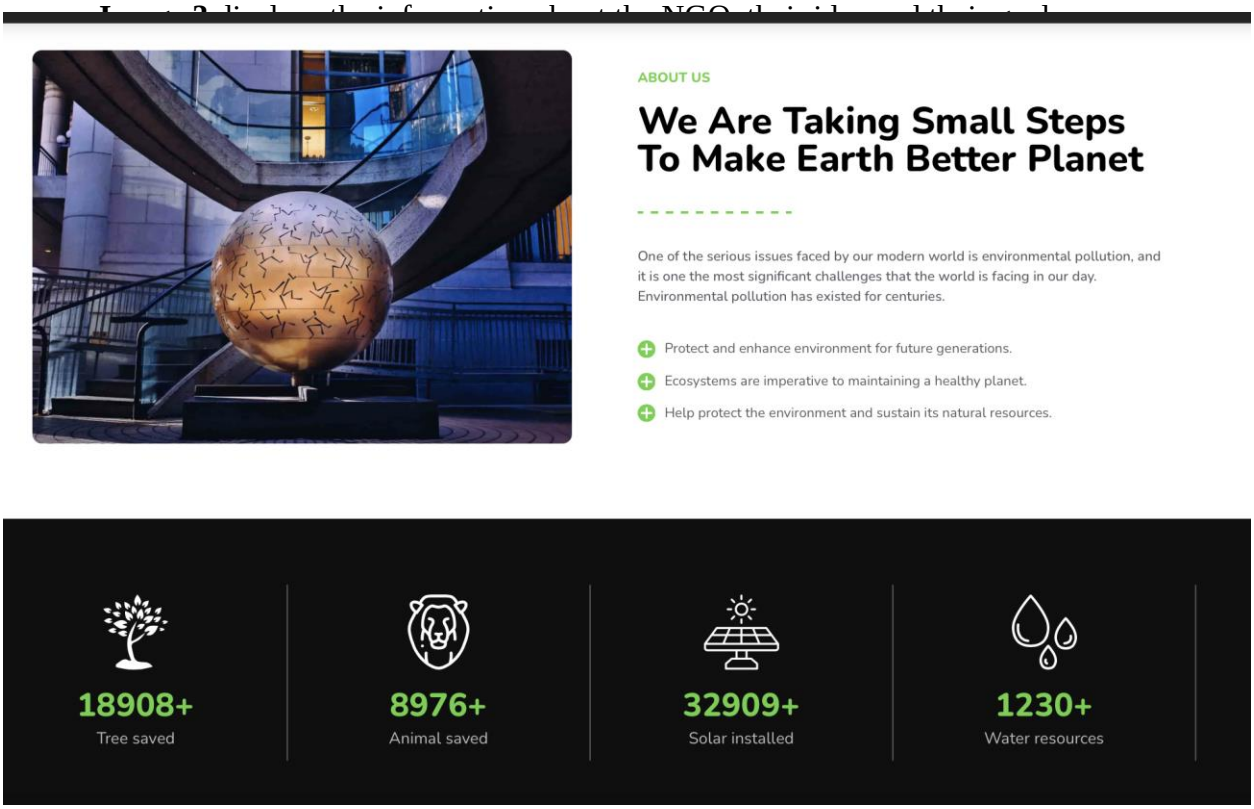


Image 4 displays the services that our client offers.

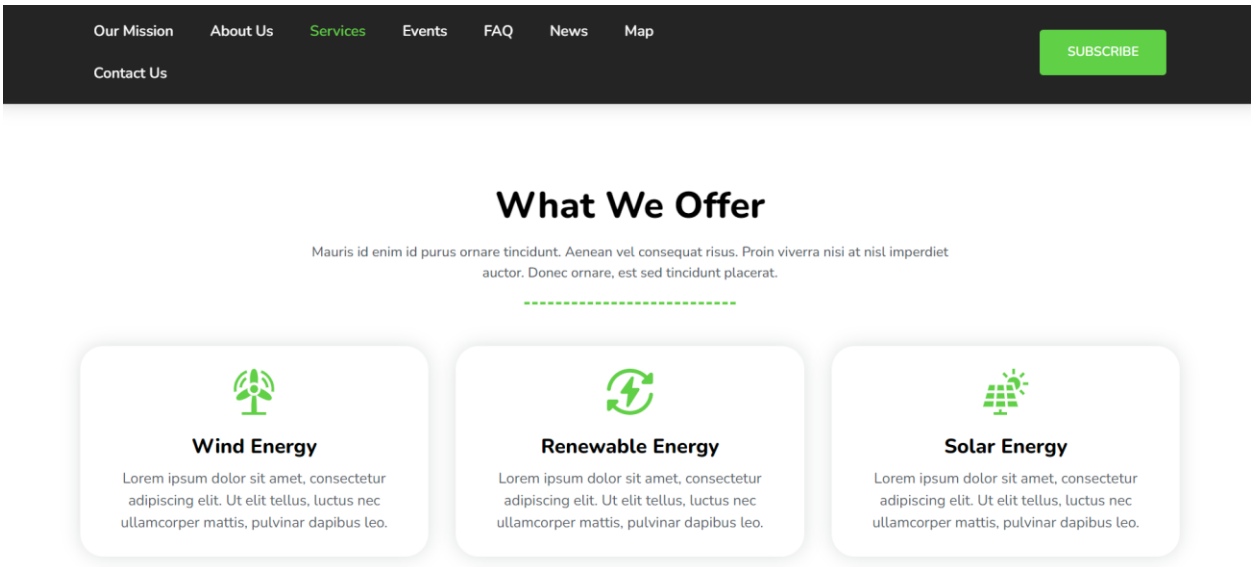
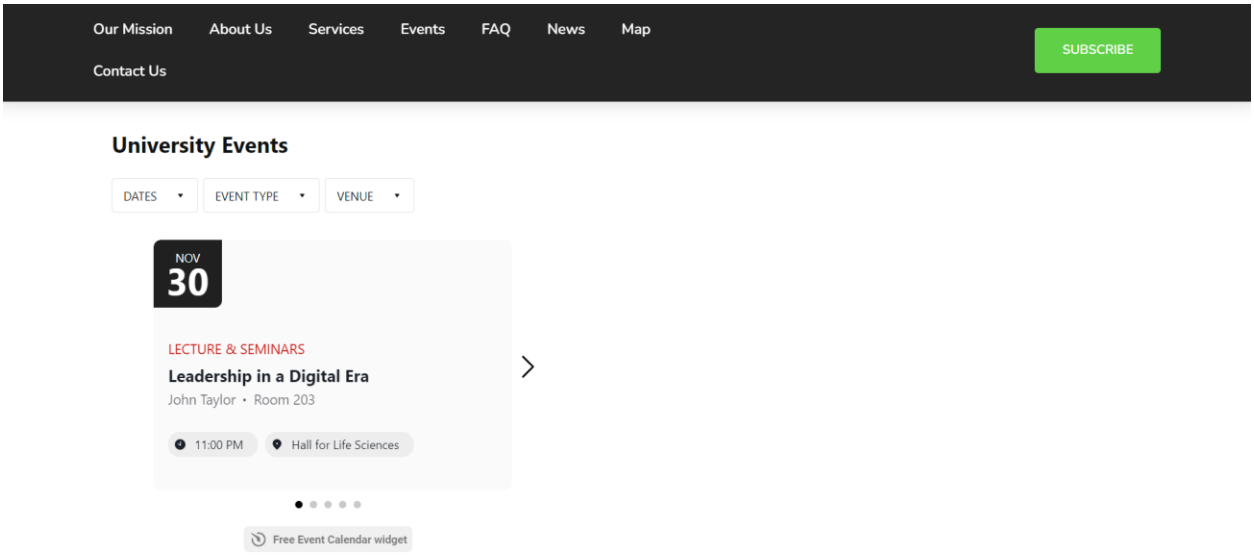


Image 5 and Image 6 display the event feature. This feature showcases all the time schedule and the location of events and allows users to add the event they are interested in into

their Google calendar.



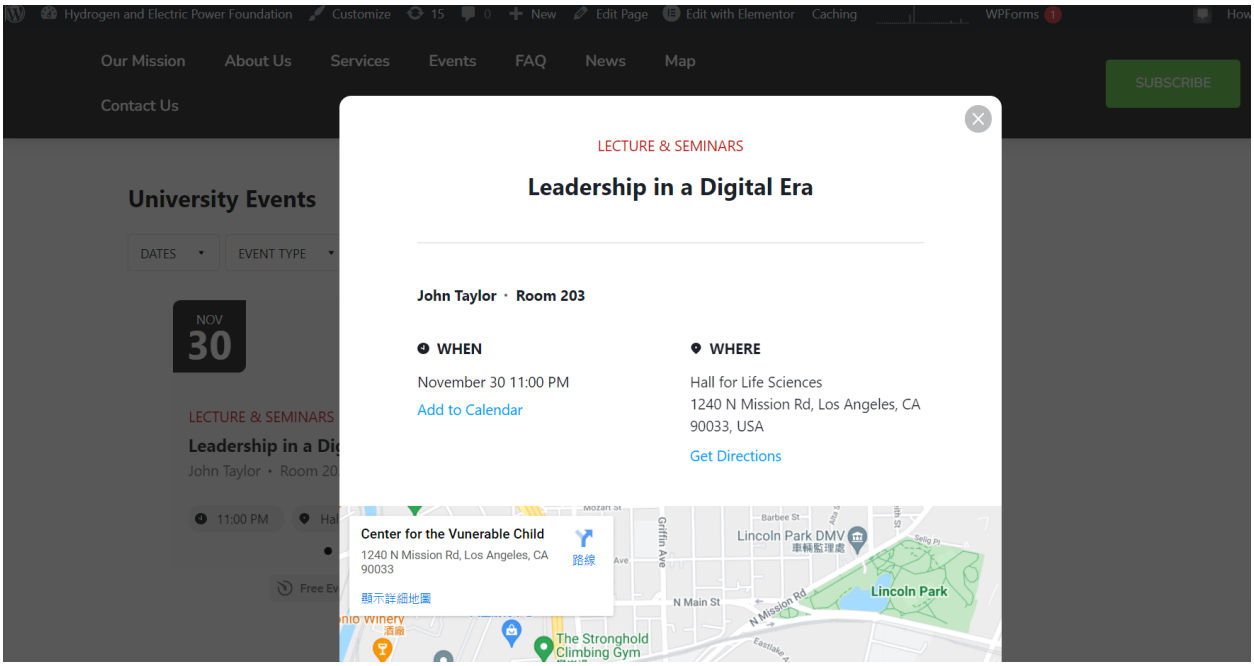


Image 7 displays latest news posts.

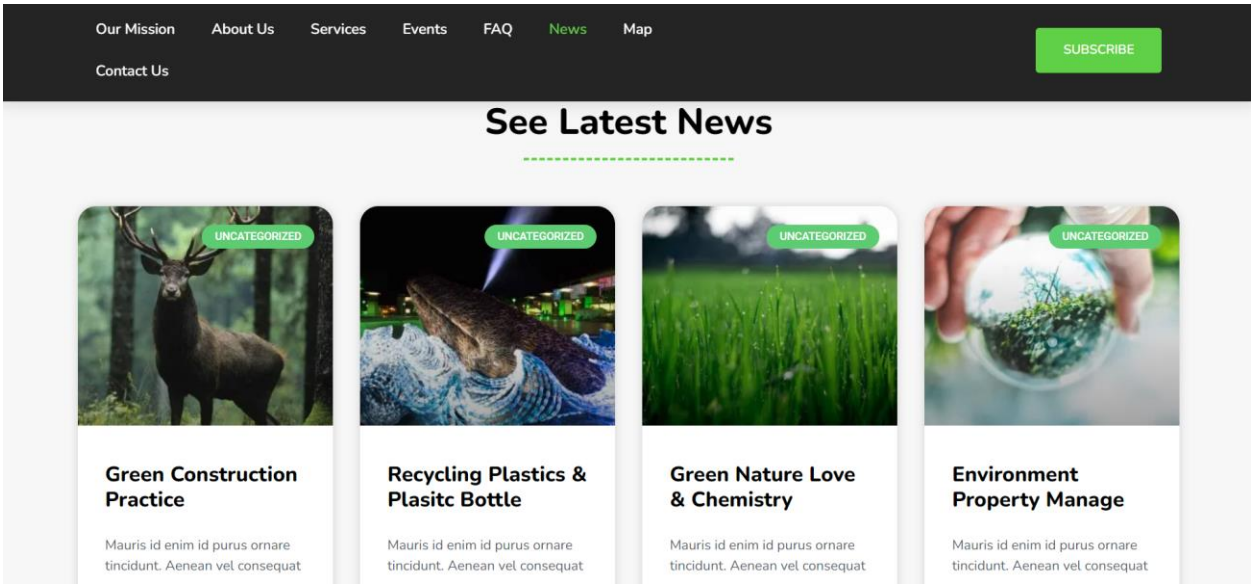


Image 8 shows the buttons for the map features.

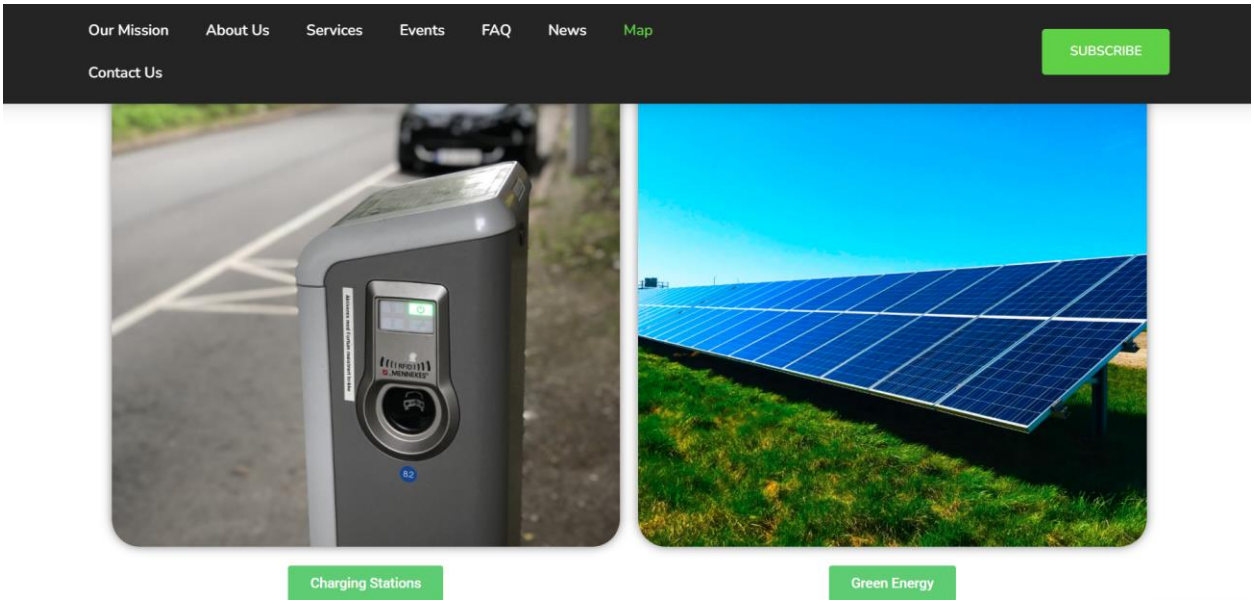


Image 9 is the navigation map with the charging stations.

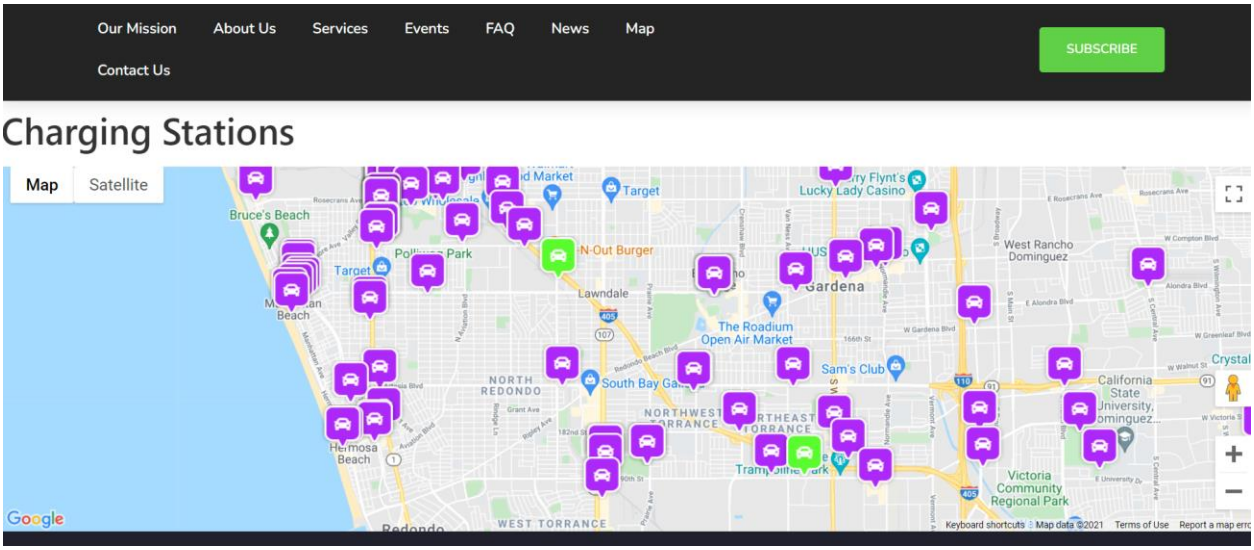
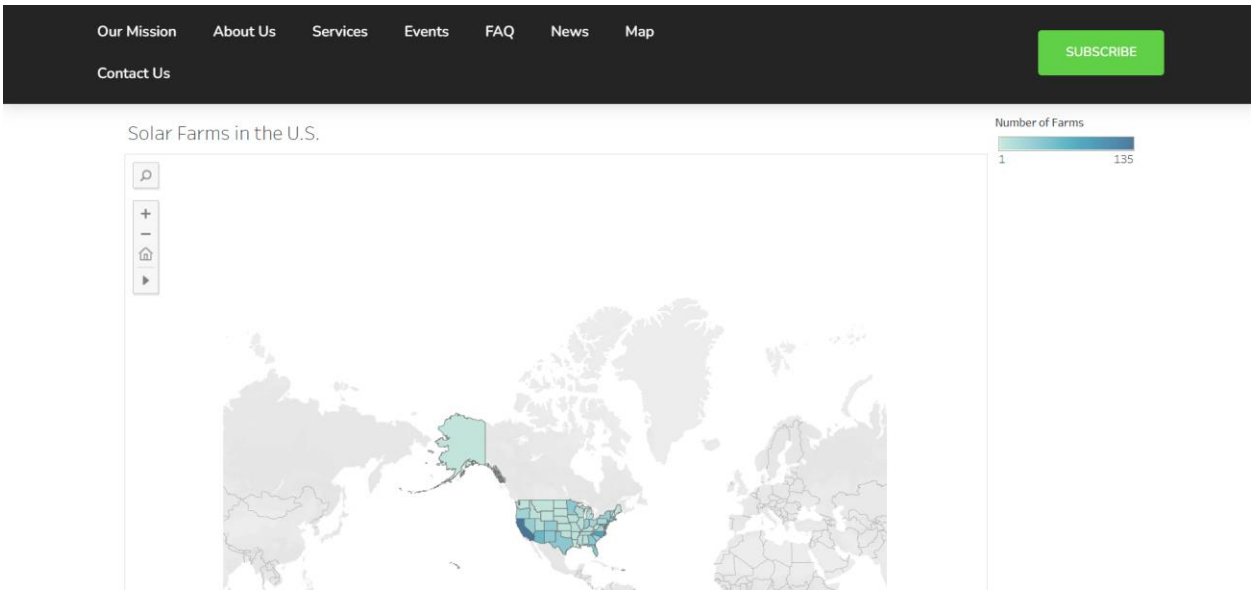
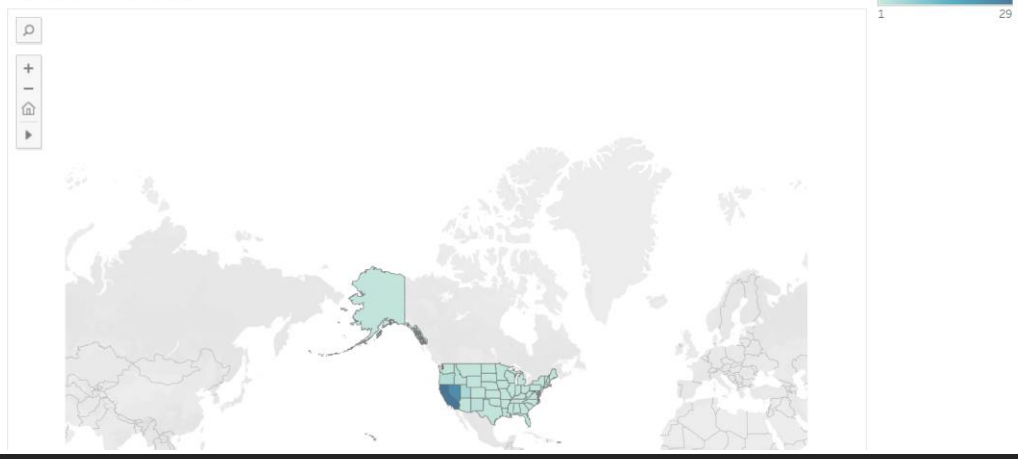


Image 10 and further display heatmap and data visualization.



Our Mission About Us Services Events FAQ News Map Contact Us SUBSCRIBE

Geothermal Farms in the U.S.

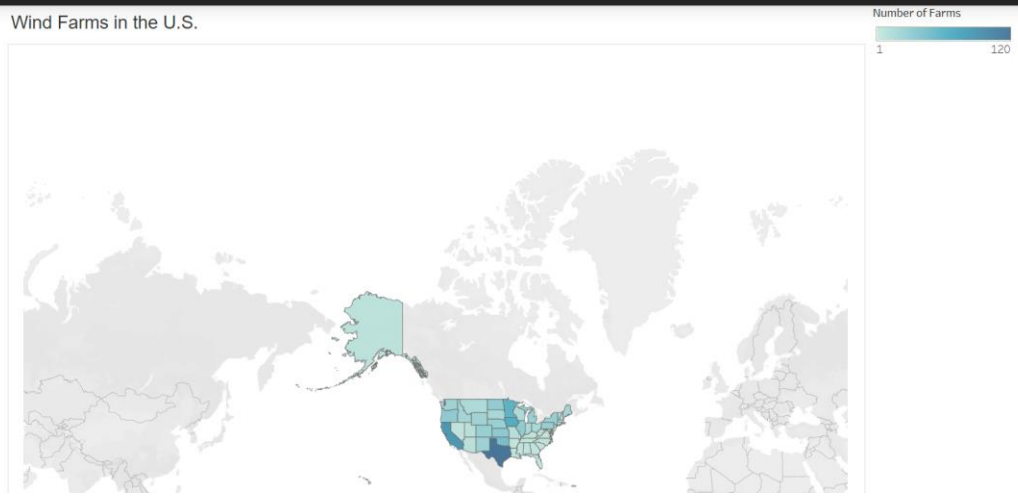


Our Mission About Us Services Events FAQ News Map Contact Us SUBSCRIBE

Hydroelectric Farms in the U.S.

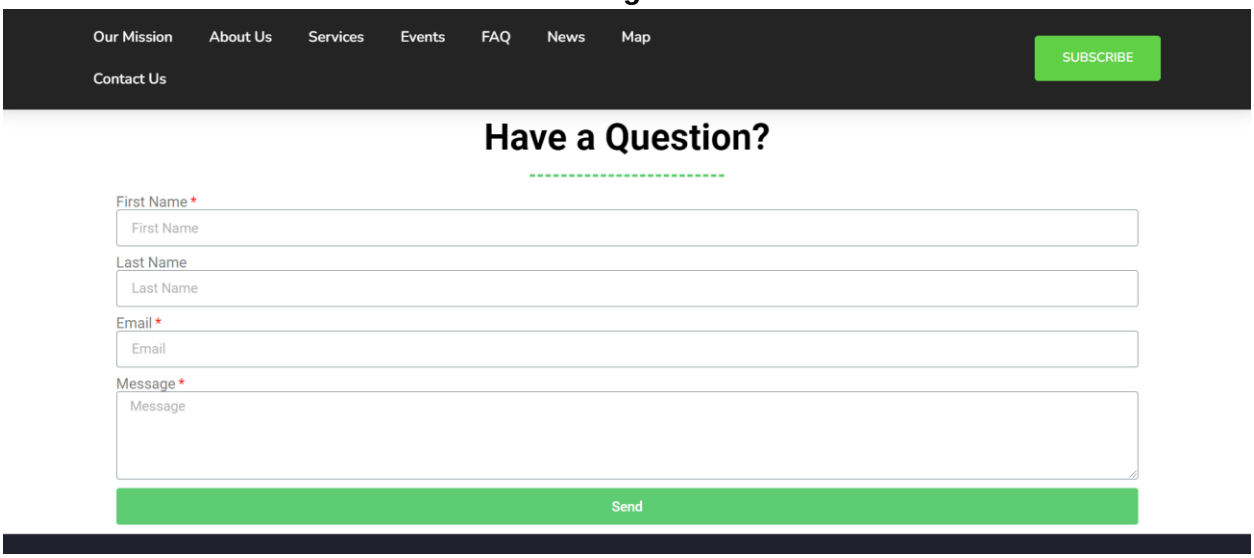
Our Mission About Us Services Events FAQ News Map Contact Us SUBSCRIBE

Wind Farms in the U.S.



Last image shows the contact form.

Image 8



5. Conclusion

Throughout the project our main goal was to create a technical solution for the client. After meetings with the client and some brain-storm sessions, we came up with the solution for the client's needs. We designed a user-friendly website that has working features such as navigation map, data visualization maps, event calendar, newsletter subscription, feedback form, and an information sharing tool (news pages).

For the purposes of the map tools, we had to collect the data available for public use. We had to learn the differences between green and non-green energy sources in order to produce data as well as to perform an appropriate data cleansing preprocessing to make sure that its integrity is up to the standard we are targeting.

We also had to consider that we were working with a non-profit organization and we didn't have any fundings for this project. Therefore, we had to research and find free tools or tools with the lower cost to use in the development phase.

As a team we saw potential and possibility to do more. The client didn't have a specific idea about how they wanted to use the data. Therefore, we decided to process the data in such a way that we split it into two datasets. This way we could reflect these datasets on different maps that enhanced the user's experience with the data. Visualization has been also used to carry heat map information about each respective energy farm type with the relation of location to guide weather experts to explore the trends in that field.

The platform that we used for the development of the website was chosen with such consideration that the client could easily maintain it after our group delivered the project. If the client decides to hire a tech professional to enhance the website, they can also choose to do so.

Even though we encountered a couple of challenges during the development process, we are happy to say that the project delivered is high quality and the client is highly satisfied with it.

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