Water Footprint Calculator: Tracking Daily Water Usage with Digital Tech

Dr G Prabhakar Raju[1], Sama Vikyath Reddy[2], Shubhranshu Ranjan Dash[3], Bijnapally Megnadh[4]

[1]*Associate Professor, Department of Computer Science and Engineering, Anurag University, Telangana, India*
[2,3,4]*Student, Department of Computer Science and Engineering, Anurag University, Telangana, India*

Abstract. As per the recent statistics the population is increasing rapidly and the need of food and water is increasing as well but the amount of freshwater is rapidly decreasing leading to major water scarcity. Water scarcity is increasingly recognized as a global challenge, necessitating a deeper understanding of water consumption across different products. Hence, the need for water footprint increases so as to monitor the water usage of an individual and thereby implement measures to decrease the unnecessary usage of water.

In the recent decade there have been studies that have calculated the water footprint based on different measures like the amount of water required to assimilate the pollutants in the freshwater reserves, based on the direct and indirect usage of water in the different day to day activities.

We focus on Using a web-based questionnaire that collects detailed information about their appliance usage. This data is then compared against a comprehensive database containing average usage metrics for various appliances, such as refrigerators, air conditioners, and televisions. The platform provides a personalized water footprint analysis, highlighting whether a user's consumption is higher or lower than the average. Additionally, it offers tailored recommendations for reducing water usage based on individual habits and appliance efficiencies. The findings from this study are aimed at educating consumers and influencing policy decisions to foster water conservation in residential environments. By leveraging digital tools, this research contributes to the broader goal of promoting sustainable water use practices. Which can be improvised further by integrating a machine learning model in order to process the information and thereby predict and analyze the usage in order to advise users to incorporate practices that lead to a smaller water footprint.

1. INTRODUCTION

A "water footprint" refers to the total volume of freshwater used to produce goods and services, or in the case of individuals, the amount of water they consume directly and indirectly. It's an important metric for understanding the impact of human activities on global water resources and helps in assessing sustainability. The concept can be applied to individuals, businesses, industries, countries, or entire supply chains. The need for understanding water footprints is driven by several key factors:

A "water footprint" is the total volume of freshwater used in producing goods and services or, for people, the amount of water they consume directly and indirectly. This is an important metric in understanding human activity impact on global water resources and also helps in assessing sustainability. It applies to individuals, businesses, industries, countries, or entire supply chains. There is a driving motivation to understand water footprints form the following key reasons:

1.1 Scarcity of Water

Several regions of the world from parts of Africa, Asia, and parts of the southwestern U.S. are dealing with water scarcity. The understanding of the amount of water required for producing a good would reveal a great deal regarding areas where consumption is too excessive and can pave the way for more sustainable consumption patterns. Impacts of Climate Change: Changes in climatic patterns modify the availability of water, as with some regions on earth facing more serious cases of flood and drought. Knowledge of water footprints can lead decisions toward water conservation and fairer distribution.

1.2 Environmental Sustainability

Ecosystem Conservation: Overexploitation of fresh water by either agricultural, industrial, or household use can lead to inadequate freshwater ecosystems like rivers, lakes, and underground reserves. Having knowledge about water footprints reduces the negative environmental impacts and starts practicing responsible use of

water. Avoidance of Overuse: In industries and agriculture, overuse is most commonly inefficient. Analysis on water footprint will point out areas for better practice to reduce exploitation on natural resources.

1.3 Agriculture and Food Production

High-water usage is primarily related to agriculture, mainly in water-guzzling crops Such as rice, cotton, and meat. The where and how much of the water used for food production could hold the key to resource use improvement and reducing water loss in agriculture.

Consumers can opt for water-friendly foods -Water footprint: consumers can minimize their water footprint by opting for the right kind of food. For instance, plant-based foods normally have a much smaller water footprint than food derived from animals.

1.4 Corporate Responsibility and Supply Chains

Water footprint analyses help businesses to evaluate their supply chains, identify the water- related hot spots in the chain and then improve steps towards increasing their water efficiency. Committed firms reduce water footprint enhance their brand reputation and attract green customers. Regulatory Compliance: Some governments in regions are enforcing stricter regulations on water usage. With water footprint knowledge, companies will be able to obey such measures and avoid penalties.

2. LITERATURE SURVEY

In recent years, the concept of the water footprint has gained prominence as a metric to assess the use of freshwater resources across various sectors. This literature survey reviews key contributions to the field, highlighting both the methodologies used and the limitations identified.

Hoekstra's 2017 study published by Springer, titled **"Water Footprint Assessment: Evolvement of a New Research Field,"** explores the development of water footprint assessment methodologies. The study emphasizes the complexity of integrating various footprinting approaches (e.g., **green**, **blue**, and **grey water footprints**) into a unified framework. A key limitation noted is the difficulty in standardizing the calculation and estimation due to diverse methodological approaches. The general formula used for water footprint assessment WFWFWF can be expressed as:

$$\mathbf{WF = WF_{green} + WF_{blue} + WF_{grey}}$$

where:

- WF_{green} is the volume of rainwater consumed,
- WF_{blue} is the volume of surface and groundwater consumed,
- WF_{grey} is the volume of water required to assimilate pollutants.

In a 2016 article published in Elsevier titled **"A Critique on the Water-Scarcity Weighted Water Footprint in LCA,"** Hoekstra addresses the temporal aspects of water footprint assessments. The study critiques the use of water-scarcity weighted indicators within life cycle assessments (LCA), suggesting that water usage must be considered over time, given seasonal variations and temporal water availability. The formula for calculating the water-

scarcity weighted footprint. WF_{WS} includes a scarcity weighting factor SSS:

$$\mathbf{WF_{WS} = WF \times S(t)}$$

where S(t) is the time-based scarcity factor reflecting seasonal changes.

Finally, the 2012 study by Mekonnen and Hoekstra, **"A Global Assessment of the Water Footprint of Farm Animal Products,"** published in Ecosystems, examines the water footprint associated with farm animal products. The assessment utilizes the consumption patterns of various farm animals, including feed, drinking water, and service water. The study's main limitation is that it focuses on animal consumption and does not directly relate to human consumption or industrial water use. The formula for animal product water

footprint WF_{animal} can be represented as:

$$\mathbf{WF_{animal}=WF_{feed}+WF_{drinking}+WF_{service}}$$

where:

- WF_{feed} is the water footprint of the feed,
- $WF_{drinking}$ is the drinking water footprint,
- $WF_{service}$ is the service water footprint used for cleaning and maintenance.

Overall, these studies highlight the evolving methodologies in water footprint assessment and underscore the challenges of standardization, the temporal dynamics of water use, and the specific focus on agricultural practices.

The reviewed literature offers valuable insights into the assessment and management of water footprints. By addressing critical factors such as water usage efficiency, sustainability, resource conservation, and environmental impact, effective strategies can be developed to reduce the overall water footprint. The research emphasizes the importance of implementing sustainable practices, enhancing resource management, and ensuring the responsible use of water to meet the growing demands of both industry and agriculture while maintaining ecological balance and promoting water conservation.

3. SYSTEM DESIGN AND ARCHITECTURE

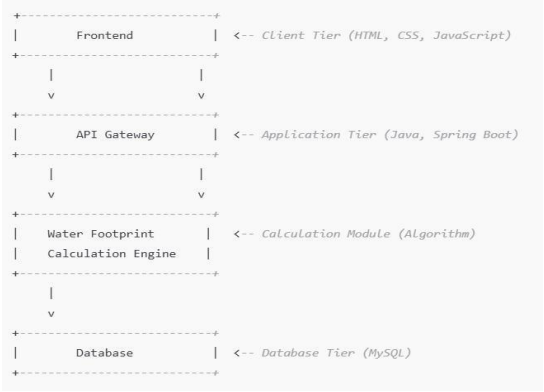
The Water Footprint Calculation System for electronic devices aims to help users assess the water footprint of their daily use electronics (e.g., smartphones, laptops, TVs) using a web- based application. The system design incorporates both the front-end user interface and the back-end processing, as well as an efficient database schema to manage user data, device profiles, and water usage statistics. Below is a comprehensive design of the system architecture, technology stack, and key components.

3.1. System Architecture Overview

The architecture of the Water Footprint Calculation System follows a **three-tier architecture**

pattern:

1. **Client Tier (Front-end)**: User interface for interaction and data input.
2. **Application Tier (Back-end)**: Business logic, calculation algorithms, and API services.
3. **Database Tier**: Data storage and retrieval, managing device profiles, user data, and water footprint statistics.



3.2. Database Design

The database schema consists of several key tables:

- Users Table: Stores user information and access roles (e.g., admin, student, guest).
- Devices Table: Contains a list of electronic devices, including details like power consumption and water footprint data.
- Water_Footprint Table: Stores calculation results for each device, including timestamps and user IDs.

3.3. Technology Stack

The technology stack selection is tailored to the platform's needs for scalability, responsiveness, and efficient data processing:

- **Frontend**:
  - HTML, CSS for basic structure and styling.
  - JavaScript and frameworks like React or Vue.js for dynamic content and interactive UI.
- **Backend**:
  - Java with Spring Boot for REST API development and business logic.
  - Water footprint calculation engine implemented in Java.
- **Database**:
  - MySQL for structured data storage and efficient querying.

3.4 User Interface (UI) Design

The UI will include:

- **Home Page**: Introduction to the water footprint concept and system overview.
- **User Dashboard**: Personalized space for users to input data and view their water footprint results.

- **Admin Panel**: Allows admins to manage device data, view usage statistics, and generate reports

4. RESEARCH METHODOLOGY

The Water Footprint Calculator website is designed to provide an accessible, user-friendly platform for individuals and organizations to estimate their daily water usage and understand its environmental impact. The research methodology integrates user-centered design, data analysis, and digital development techniques, following a structured approach. This methodology involves several phases to ensure effective design, development, and evaluation of the platform.

4.1 Goal Setting and Scope Definition

The first step in the development of the Water Footprint Calculator involves clearly defining the objectives and scope of the project. The goal is to create a tool that:

- Measures the water usage of daily activities and consumer products.
- Provides a comprehensive view of direct and indirect water usage.
- Offers insights into the environmental impact of water consumption at the individual, household, or organizational level.

4.2 Conceptual Framework and Water Footprint Breakdown

To ensure the calculator covers all aspects of water use, it follows the Water Footprint Network methodology, dividing water consumption into three main categories:

- Blue Water Footprint: Water drawn from natural sources like rivers, lakes, or groundwater for human use (e.g., drinking, manufacturing, irrigation).
- Green Water Footprint: Rainwater stored in the soil and utilized by plants and crops (e.g., agriculture, forestry).
- Grey Water Footprint: The volume of freshwater required to assimilate pollutants to meet water quality standards (e.g., water pollution from domestic or industrial discharge).

4.3 Data Collection

Data collection involves gathering both primary and secondary data to accurately estimate water usage:

Primary Data Collection

- User surveys and feedback forms to gather data on individual consumption habits, including household water usage and specific daily activities.
- Collaborating with local industries, farms, and utility companies to collect real-world water usage data for specific products or services.

Secondary Data Collection

- Utilizing established databases like the Water Footprint Network, FAO Statistics, and government reports to obtain water usage metrics for various products and activities.

- Reviewing academic research, industry reports, and environmental studies to gather estimates of water usage across different sectors.

4.4 Digital Technology Integration

The Water Footprint Calculator leverages digital tools and technologies to enhance user experience and streamline data processing:

- Web Development: The calculator is built using modern web technologies (HTML, CSS, JavaScript) to provide a responsive and interactive user interface.

- Data Analytics: Backend systems integrate data processing tools (Python, R, or SQL databases) to handle large datasets and perform complex calculations.

4.5 Water Footprint Calculation

- The core of the methodology involves calculating the water footprint based on collected data and established formulas:

- Life Cycle Analysis (LCA): This approach evaluates the water used at every stage of a product's life cycle, from raw material extraction to disposal.

- Formula Application: Mathematical formulas are employed to estimate water usage, adjusted for regional factors and user input. Simple calculations might use:

- Total Water Use = Blue Water + Green Water + Grey Water

- Tools like Excel spreadsheets, R, or Python scripts automate the calculations.

4.6 Analysis and Interpretation

The results of the calculations are analyzed to provide meaningful insights:

- Comparison with Benchmarks: The results are compared against regional and global benchmarks to evaluate sustainability. For example, individual water usage can be compared to national averages.

- Impact Assessment: The analysis includes evaluating the environmental impact of water use, such as potential water scarcity issues or the effects on local ecosystems.

4.7 User-Centered Design and Testing

The website follows a user-centered design process, ensuring it is easy to use and provides valuable feedback:

- Prototyping: Initial versions of the calculator are tested with a sample user base to gather feedback on usability and accuracy.

- User Testing: Feedback is collected through surveys, user interviews, and usability testing sessions to refine the interface and improve user engagement.

4.8 Reporting and Visualization

The final output of the Water Footprint Calculator is presented to users through clear, visually appealing formats:

- Graphs and Charts: The tool uses visualizations to show the breakdown of water usage (e.g., pie charts for blue, green, and grey water).

- Interactive Maps: Regional data and comparisons are displayed using interactive maps, allowing users to see the impact of water usage in different areas.

4.9 Evaluation and Continuous Improvement

Post-launch, the tool's performance is evaluated based on user feedback and ongoing data analysis:

- User Feedback Analysis: Surveys and analytics tools (e.g., Google Analytics) are used to monitor user engagement and identify areas for improvement.

- Data Updates: The calculator's database is updated regularly with the latest water usage data and research findings to maintain accuracy.

5. RESULTS

5.1 Landing Page

The landing page is the first place users visit on the website. It includes Login and Sign Up buttons. The page also gives a quick overview of the site's features, such as browsing research papers, exploring information about the water footprint, and an introduction to tools for calculating water footprints for different devices.

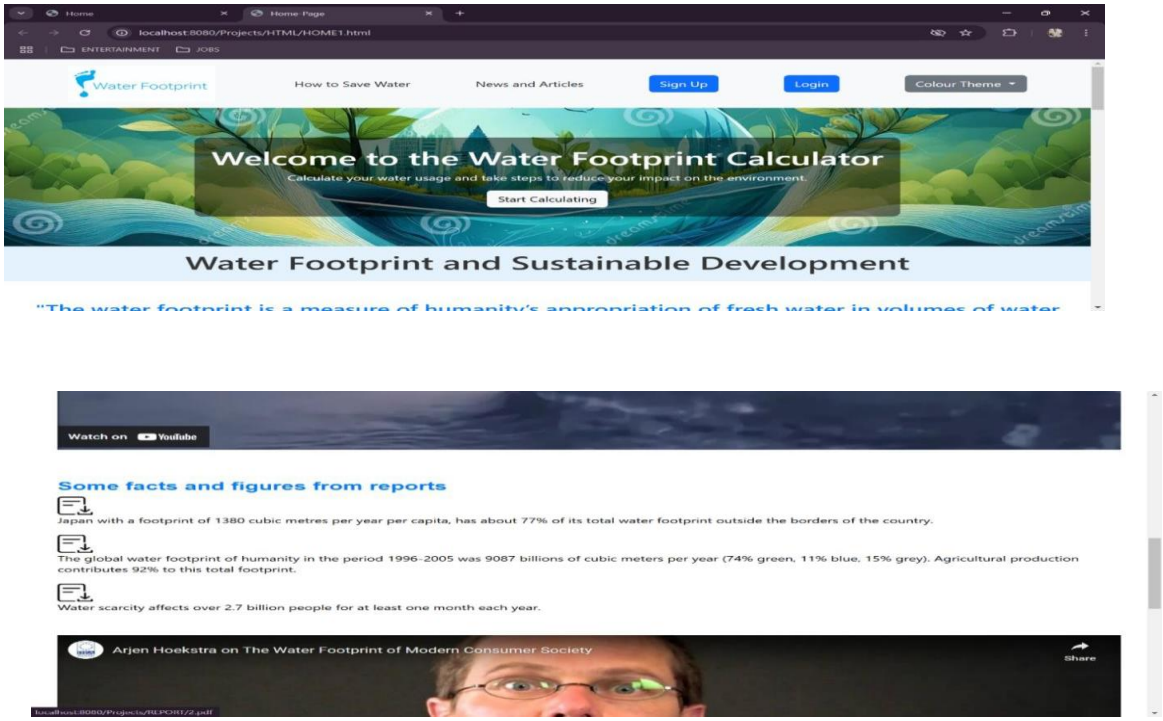


FIGURE 1. Landing Page

5.2 Registration and Login Page

User should register to get the login credentials. After registering the data is stored in the database and

while logging in the page It checks for the details in the database and if details match then only it redirects to the home page.

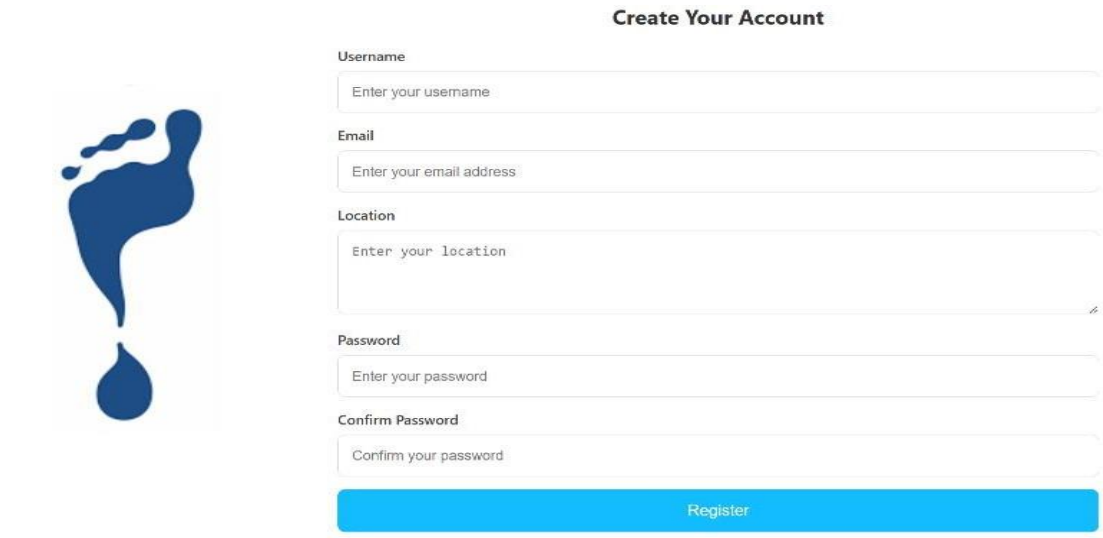


FIGURE 2. Registration Page

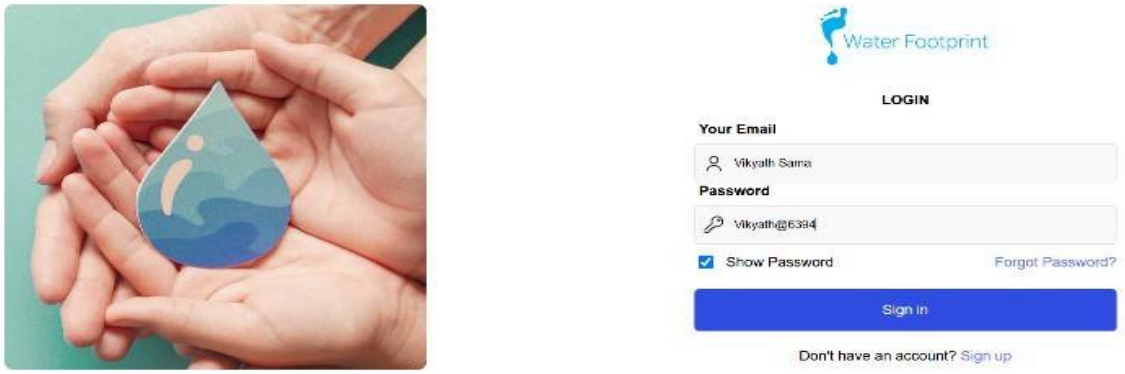


FIGURE 3. Login Page

5.3 User Home page

After login into the portal with their respective credentials, the login page redirects to the home page where they can explore tips for saving water, learn about water footprint, and start calculating the water footprint for different devices.

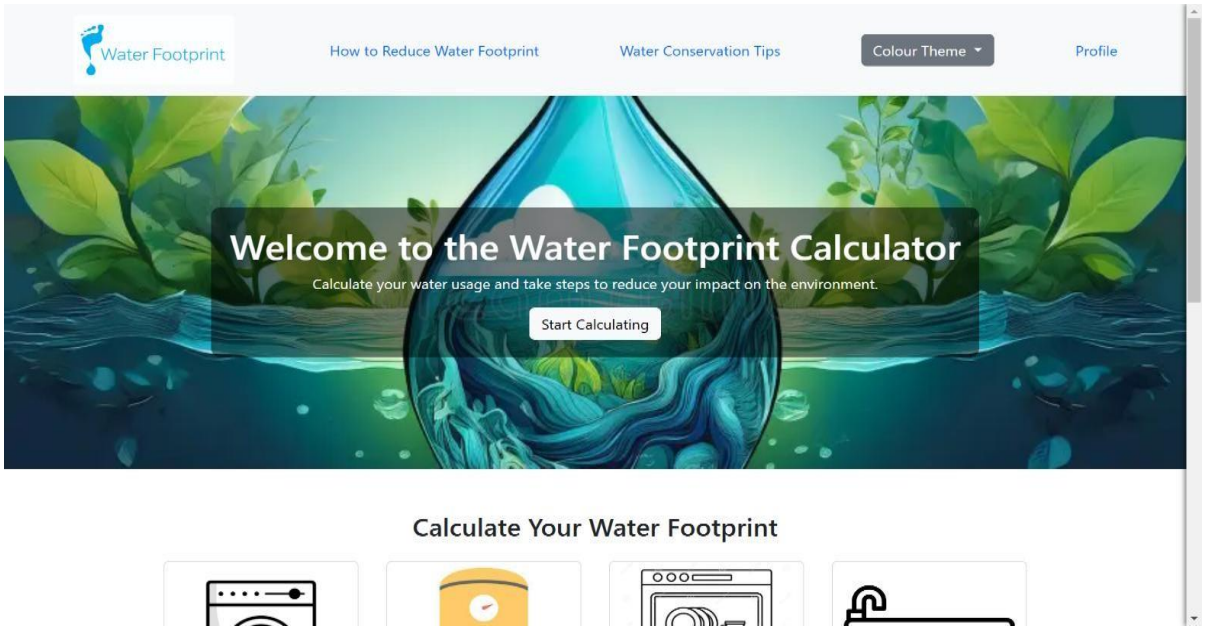
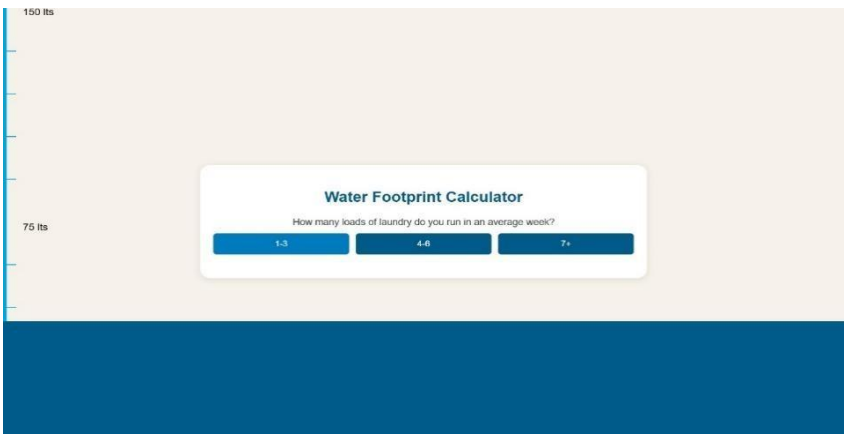
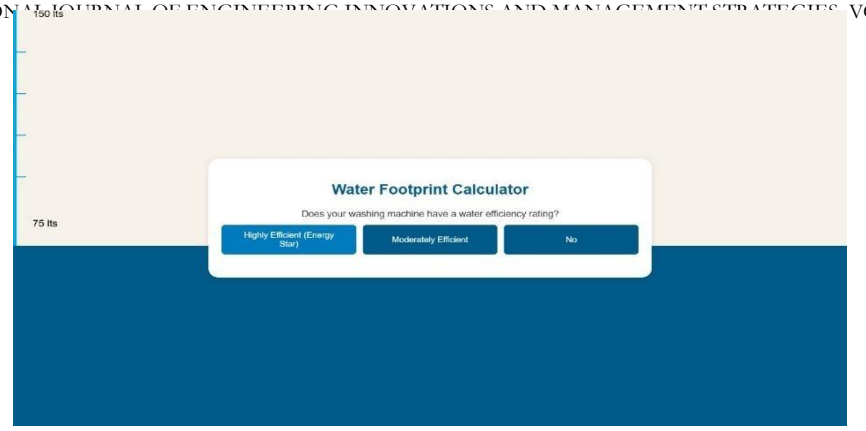


FIGURE 4. User Homepage

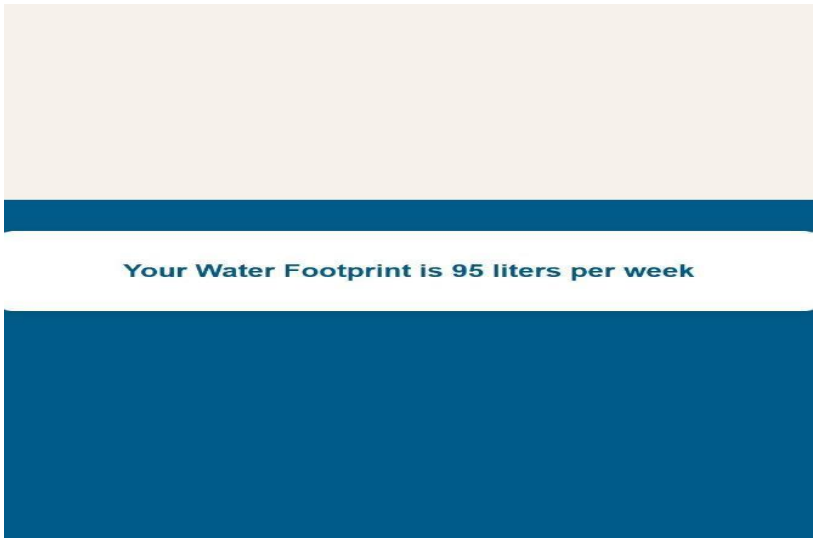
5.4 Calculation Page

After logging in, the page redirects to the calculation page where you can add or delete water usage categories. Each category should include all necessary details, such as appliance name, usage type, water consumption per use, and any relevant notes.





Average usage has to be calculated:



5.5 Data Visualization

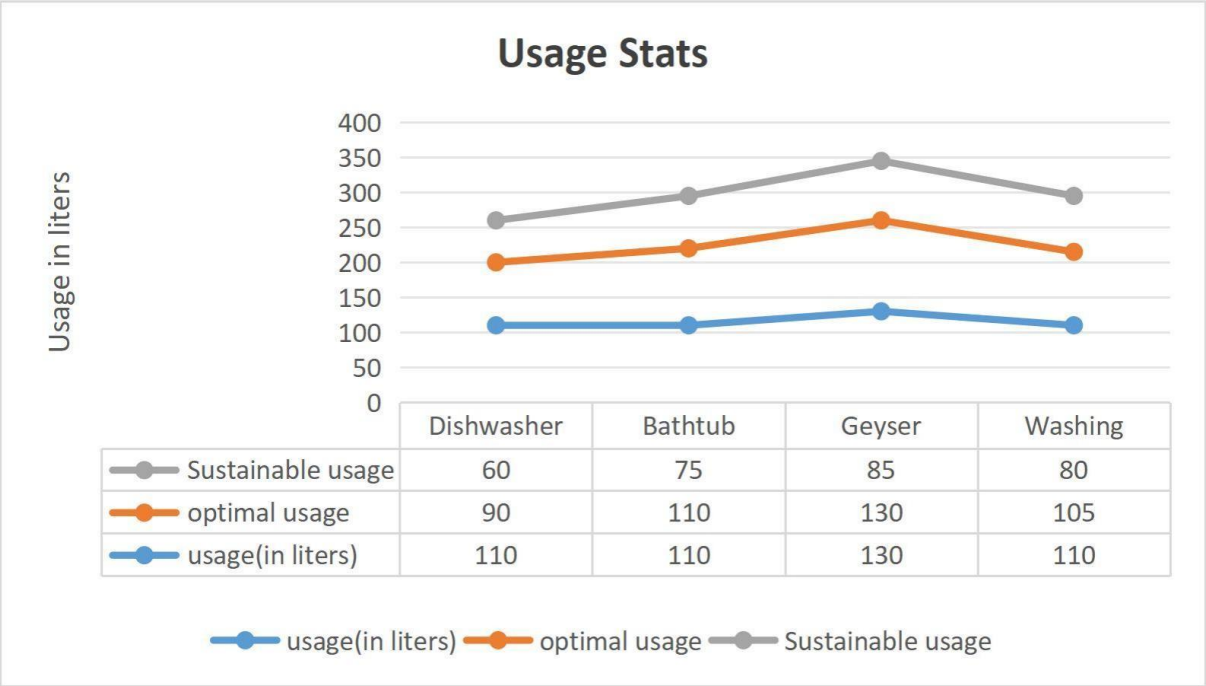
We Will take four household equipment as the base to calculate the results that is the water footprint (direct usage), the equipment are Dishwasher, Bathtub , Geyser and Washing machine.

Appliance	**usage(in liters)**	**optimal usage**	**Sustainable usage**
Dishwasher	110	90	60
Bathtub	110	110	75
Geyser	130	130	85
Washing	110	105	80

This is the average usage for the equipment based on the questionnaire provided to the users. For dishwasher it is the average of 48 different cases/ different mappings.

For Bathtub it is the average of 48 different cases/ different mappings. For the Geyser it is the average of 48

different cases/ different mappings.



	Dishwasher	Bathtub	Geyser	Washing
Sustainable usage	60	75	85	80
optimal usage	90	110	130	105
usage(in liters)	110	110	130	110

For the Washing machine it is the average of 108 different cases/ different mappings.

6. FUTURE SCOPE AND IMPROVEMENT

The Water Footprint Calculator website establishes a solid foundation for providing users with personalized insights into their water usage. However, there are several potential areas for further development and enhancements to increase the platform's utility, scalability, and user engagement.

6.1 Advanced Data Management Features

To improve the organization and accuracy of water usage data, the following features could be introduced:

Data Version Control: Implementing version control for user-submitted data, allowing users to update their water usage records without losing previous data entries. This would be beneficial for tracking usage trends over time.

Data Tagging and Filtering: Adding sophisticated tagging, categorization, and filtering mechanisms would enable users to review their water usage across different appliances more efficiently.

6.2 Mobile Application Development

Offline Access: Enabling users to download data or calculators for offline use would be especially useful in areas with intermittent internet connectivity.

Push Notifications: Providing notifications for users on tips for reducing water usage, updates on new features, or reminders to update their water usage data.

6.3 AI-Powered Analytics and Reporting

Personalized Insights: Using AI to analyze water usage patterns and provide personalized recommendations for

reducing water consumption.

Predictive Analysis: Leveraging AI to forecast a user's future water footprint based on their historical data and suggest actionable steps to minimize it.

6.4 Gamification for User Engagement

To make water conservation engaging, gamification features could be introduced:

Badges and Achievements: Rewarding users with badges for reducing their water usage or reaching water-saving milestones could increase motivation and commitment.

Leader boards and Challenges: Adding leaderboards or regional challenges to encourage users to compare their water-saving efforts could foster a sense of community and friendly competition.

6.5 Globalization and Localization

Multilingual Support: Implementing support for multiple languages would make the platform accessible to a broader, global audience.

Cultural and Regional Customization: Adapting the platform to account for local water usage norms and conservation methods could enhance its relevance in different regions.

7. CONCLUSION

Here's a refined conclusion for your project with a focus on providing a strong closing statement:

The Water Footprint Calculator website successfully achieves its primary goal of providing users with an intuitive platform to measure and understand their water usage. With a user- friendly interface, the platform allows individuals to input data across various water- consuming appliances and receive a personalized water footprint calculation. This empowers users to make informed choices about their water usage and adopt more sustainable habits.

Looking ahead, there is significant potential for further development, including mobile application integration, AI-driven insights for personalized water-saving recommendations, gamification to encourage engagement, and multilingual support for broader accessibility. These enhancements would amplify the platform's functionality, user engagement, and adaptability, making it an invaluable tool for promoting global water conservation.

In summary, the Water Footprint Calculator website serves as a robust solution for those seeking to understand and reduce their water footprint. The project lays a strong foundation for future growth and innovation, with the potential to become a vital resource in global water sustainability efforts.

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