Machine Learning Based Automated Construction Planning System for Sri Lanka

Project ID 24-25J-201

Project Proposal Report

Linganathan. J - IT21223808

Bachelor of Science (Hons) Degree in Information Technology Specializing in Information Technology

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DECLARATION

I declare that this is my own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously publish or written by another person expect where the acknowledgement is made in the text.

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The supervisor/s should certify the proposal report with the following declaration.
The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

Ravi
……………………………… 23/08/2024

Signature of the Supervisor Date
(Mr. N.H.P. Ravi Supunya Swarnakantha)

……………………………… …………………

Signature of the Co-Supervisor Date
(Dr. Dharshana Kasthurirathna)

ABSTRACT

This research is motivated by the increasing need for sustainable energy sources and the demand for affordable and practical solar energy solutions. This study's overarching goal is to create a thorough system that precisely suggests solar panel specs and costs depending on predicted energy use, available land area, and financial concerns. The goal of the research is to overcome the difficulties in forecasting energy usage, choosing optimal solar panel layouts, and striking a balance between cost, efficiency, and available space.

The paper suggests a system that combines sophisticated algorithms for cost estimation, land area computation, and energy consumption prediction in order to meet these goals. In order to optimize solar panel choices and pricing, the system will collect user input, evaluate data (such as bills and geographic information), and use machine learning techniques (particularly, Linear Regression and Clustering Algorithms). The process entails creating a model that can determine the right kind and quantity of solar panels in relation to the amount of land available and the anticipated amount of energy required.

The suggested technique, which offers a comprehensive method that smoothly incorporates all pertinent elements into a single, user-friendly platform, closes a significant research gap. The results of this study should help the solar energy industry by offering a tool that improves installation efficiency and results in significant cost savings. In conclusion, by lowering the cost, increasing the accessibility, and improving the efficiency of solar energy systems for a variety of users, this research has the potential to significantly impact the global shift towards sustainable energy.

Key words:

1. Solar Energy - radiation from the Sun that is capable of producing heat, causing chemical reactions, or generating electricity [1].
2. Linear Regression - a supervised learning algorithm that simulates a mathematical relationship between variables and makes predictions for continuous or numeric variables such as sales, salary, age, product price, etc [2].
3. Clustering algorithms - procedures for partitioning data into groups or clusters such that the clusters are distinct, and members of each cluster belong together [3].

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LIST OF ABBREVIATIONS

Key Words	Meaning
GCP	Google Cloud Platform
PV	Photovoltaic
KW	Kilowatt
API	Application Programming Interface
UI	User Interface

Table 1: List of Abbreviations

1. INTRODUCTION

1.1 Background and Literature survey

Global Solar Energy Adoption

The desire to mitigate climate change and rely less on fossil fuels is driving an unparalleled increase in the use of solar energy worldwide. Because solar energy is plentiful, sustainable, and produces no greenhouse gas emissions, it is an essential part of the renewable energy portfolio. The International Renewable Energy Agency (IRENA) reports that in 2021, the capacity of solar photovoltaic (PV) systems worldwide reached 942 GW, indicating a notable rise in solar installations across the globe. Technological developments in solar panels, government subsidies, and the falling price of solar modules all contribute to this expansion. However, precise recommendations regarding the features and pricing of solar panels that are suited to certain requirements and situations are essential to guaranteeing the financial sustainability and efficacy of solar energy systems [4] [5].

Advances in Solar Panel Technology and Efficiency

Recent years have witnessed tremendous breakthroughs in solar panel technology, with an emphasis on lowering production costs and improving energy conversion efficiency. High-efficiency solar cells, like monocrystalline and polycrystalline silicon cells, have been developed as a result of research and give higher energy yields per unit area. Material innovations, like perovskite solar cells, also hold the potential to completely transform the market by offering more affordable and effective substitutes. Research has indicated that placing solar panels optimally according to their orientation and geographic location can result in notable increases in energy capture. The difficulty, though, is incorporating these developments into systems that can provide tailored recommendations for particular installations [6].

Cost Estimation and Financial Viability

Financial modeling and cost analysis are crucial parts of solar energy projects. Precise cost estimation necessitates taking into account a number of elements, such as the initial cost of installing solar panels, inverters, and installation as well as continuing maintenance expenses. Furthermore, feed-in rates, the availability of government incentives, and the anticipated savings on electricity bills are all important components of financial feasibility. Through the analysis of past data and market patterns, recent research has investigated the application of machine learning models to estimate the prices of solar systems. Nevertheless, these models frequently concentrate on a particular facet of cost analysis, like energy savings or equipment expenses, failing to offer a thorough perspective that incorporates all pertinent elements [7] [8] [9].

Energy Consumption Prediction and Optimization

For solar energy systems to be designed and installed successfully, energy consumption prediction is essential. Studies have demonstrated the accuracy with which machine learning algorithms, like time series analysis and regression models, can forecast future energy use using past usage trends, meteorological data, and other variables. In order to satisfy anticipated demand, solar installation size and configuration are determined in large part by energy prediction models. Despite these developments, a lot of current models fail to take into consideration dynamic changes in patterns of energy usage, such as those brought on by modifications in user behavior or financial considerations. In order to offer a comprehensive solution, technologies that can integrate energy forecast, cost analysis, and panel optimization are also required.

Challenges in Integrated Solar Energy Planning

Although there has been substantial advancement in each of the separate solar energy planning components panel efficiency, cost estimation, and energy forecast, for example - it is still difficult to combine these components into a functional whole. These elements are frequently studied separately in current research, which results in solutions that are not entirely comprehensive enough to satisfy end users' expectations. For instance, a system that precisely forecasts energy usage might not offer the best panel arrangements, or a tool for cost estimation might not take the influence of regional factors on solar energy generation. A platform that unifies these disparate components is obviously needed in order to provide users with a complete solution for organizing and maximizing solar energy systems.

Emerging Trends and Technologies

There are now more options to create integrated solar energy planning systems because to developments in machine learning and data analytics. For example, object detection algorithms have made it possible to analyze satellite photos and find areas that are ideal for solar panel installations, accounting for things like shade, terrain, and closeness to infrastructure. With the use of enormous datasets, energy prediction models have grown increasingly complex and accurate in their predictions of consumption. Simultaneously, a greater variety of variables, including shifts in material pricing and market conditions, can now be included in cost estimation algorithms. Combining these technologies could result in an effective tool that can help users plan their solar energy projects from the very beginning through the very end, from assessment to execution.

Because solar energy has the ability to produce clean, renewable power, it has becoming widely used. Enhancing solar panel efficiency, establishing tools for cost analysis, and creating algorithms for predicting energy usage have been the main areas of research in this subject. Nevertheless, the majority of current systems do not combine these elements into a single, cohesive platform. There are now more opportunities to close these gaps because to recent developments in machine learning, particularly in the areas of object detection, energy prediction, and cost estimation. Few research has effectively integrated these components to produce a comprehensive recommendation system, despite the fact that important studies have examined specific parts of solar energy systems, such as forecasting energy output and optimizing panel positioning [10] [11] [12] [13].

1.2 Research Gap

There is a noticeable gap in the integration of essential components needed for thorough solar energy planning, even with the significant improvements in solar energy research. The research currently in publication frequently concentrates on discrete elements of the solar energy system, such as cost analysis, panel placement optimization, or energy projection, without offering a cohesive strategy that unifies these elements into a single platform. Because users must piece together information from multiple sources to make educated judgments, the fragmentation of the problem limits the efficacy of present solutions.

In addition, a lot of the models and tools that are currently in use lack the accuracy required to provide customized suggestions based on unique user data and geographical considerations. While some systems, for example, can forecast energy use based on past data, they might not take user preferences or particular site features into account. In a similar vein, cost estimating models could offer broad insights but overlook the unique economic circumstances of a particular region.

By creating a complete system that combines cost estimation, solar panel configuration optimization, and energy consumption prediction into a unified platform, our research seeks to close these gaps. The suggested method will provide customized suggestions that optimize the return on investment for solar energy projects by utilizing cutting-edge machine learning algorithms and data analytics, taking into account variables like land acreage, energy needs, and budgetary restrictions [14].

1.3 Research Problem

The lack of an integrated system that can precisely prescribe solar panel specs and price based on a variety of parameters, including predicted energy use, available land area, and cost considerations, is the main research topic this study attempts to address. The difficulty is in creating a system that can successfully combine these disparate elements into an approachable interface that provides accurate, customized recommendations.

While current research has achieved great progress in many domains, like energy forecasting, optimizing panel installation, and cost analysis, these components are rarely integrated into a unified system. By utilizing innovative machine learning algorithms to forecast energy use, optimize solar panel designs, and estimate installation costs, the suggested system aims to close this gap. In the end, this integrated strategy will increase the effectiveness and financial sustainability of solar installations by giving users a complete tool for organizing and carrying out solar energy projects [15].

2. OBJECTIVES

2.1 Main Objectives

The main objective of this research is to create a precise and comprehensive recommendation system that can efficiently identify the best solar panel features and costs. Users will receive customized, reasonably priced solar energy solutions from the system, which will be based on the available land area, projected energy use, and associated expenses. The need for a holistic approach to solar energy planning that improves efficiency, lowers costs, and fosters wider adoption is driving this study, as is the rising need for sustainable energy sources.

1. Develop an Integrated System
    - ✓ The initial goal is to create and put into action an approachable platform that combines several important components of solar energy planning. The platform will incorporate cutting-edge models and algorithms for energy consumption prediction, land area computation, cost estimation, and solar panel layout optimization. Through the integration of these components into a unified instrument, the system will enable users to make knowledgeable decisions on solar panel installations. Because it solves the existing dearth of comprehensive market solutions that take into account the interdependencies between various components, this integration is essential. The ultimate objective is to provide a platform that makes investing in and designing solar energy systems easier for a wider range of users, from major corporations to individual households.
2. Enhance Solar Energy Adoption
    - ✓ This is to encourage the use of solar energy by offering accurate and trustworthy suggestions that maximize financial returns and energy efficiency. Carbon emissions might be drastically decreased by solar energy, helping to pave the way for sustainable energy in the future. However, potential users are frequently discouraged by the difficulty of choosing the best solar panel arrangement and the related expenses. The suggested approach seeks to reduce entrance barriers for solar energy investments by providing personalized suggestions that take

into account the demands of each individual user as well as regional circumstances. This goal supports international initiatives to utilize more renewable energy and less fossil fuels, which will ultimately help combat climate change.

3. Advance Research in Solar Energy Systems
    - ✓ By filling up the gaps found in the literature, the third goal is to advance the state of the art in solar energy system research. Even though there has been a lot of advancement in fields like panel optimization, cost analysis, and energy prediction, these elements are frequently researched separately. The purpose of the proposed study is to close this gap by combining these components into a coherent whole that is capable of offering thorough suggestions. In doing so, our research will provide a fresh perspective to the industry and provide insights into how data-driven models and machine learning may be used to increase the cost and efficiency of solar energy systems. Future research and technological advancements in renewable energy may build on the conclusions and techniques this study produced.

2.2 Specific Objectives

1. Train a Model for Energy Consumption Prediction
    - ✓ The creation and training of a machine learning model that can precisely estimate energy usage is a crucial part of the integrated system. To predict future energy demands, this model will include geographic data, historical data, and other pertinent variables. Since it directly affects the choice of suitable solar panel designs and cost estimations, the recommendation system's total efficacy depends on the accuracy of its projections of energy usage. To guarantee robustness and generalizability across numerous situations, the model will be trained using a varied dataset that covers a range of weather conditions, energy use patterns, and land features [16].

2. Integrate Cost Estimation Methods
    - ✓ The combination of clustering and linear regression algorithm-based cost estimating techniques is the subject of the second particular purpose. Using these techniques, the whole cost of installing solar panels which includes the cost of the panels, inverters, mounting systems, and other required parts will be estimated. The algorithms will also determine which configurations are the most economical for certain user profiles, accounting for variables like available land area, energy consumption objectives, and budgetary restrictions. The system will be able to give customers comprehensive financial estimates and ROI evaluations by merging these cost estimating methods with energy consumption forecasts, facilitating the process of helping users make well-informed investment decisions.[14].
3. Validate and Test the System
    - ✓ The comprehensive testing and validation of the integrated system using real-world data is the ultimate goal. In order to guarantee that the system provides accurate, dependable, and easy-to-use suggestions, this phase is essential. The system will be tested in a variety of circumstances, and its suggestions and predictions will be compared with the actual results as part of the validation process. In order to evaluate the overall performance and usefulness of the system, user input will also be gathered. The project intends to show the system's usefulness in assisting solar energy planning and its potential influence for quickening the uptake of renewable energy technology through extensive testing.

3. METHODOLOGY

3.1 Complete System Architecture

The user interface, backend processing, and data storage make up the three primary layers of the entire system design. Users can enter data and view recommendations using the React-built user interface. The backend, which is written in Python, manages prediction, model training, and data processing. It uses RESTful APIs to interface with the frontend. The system stores user data, energy usage records, and model outputs in MongoDB, which is accessible via pymongo [17] [18] [19].

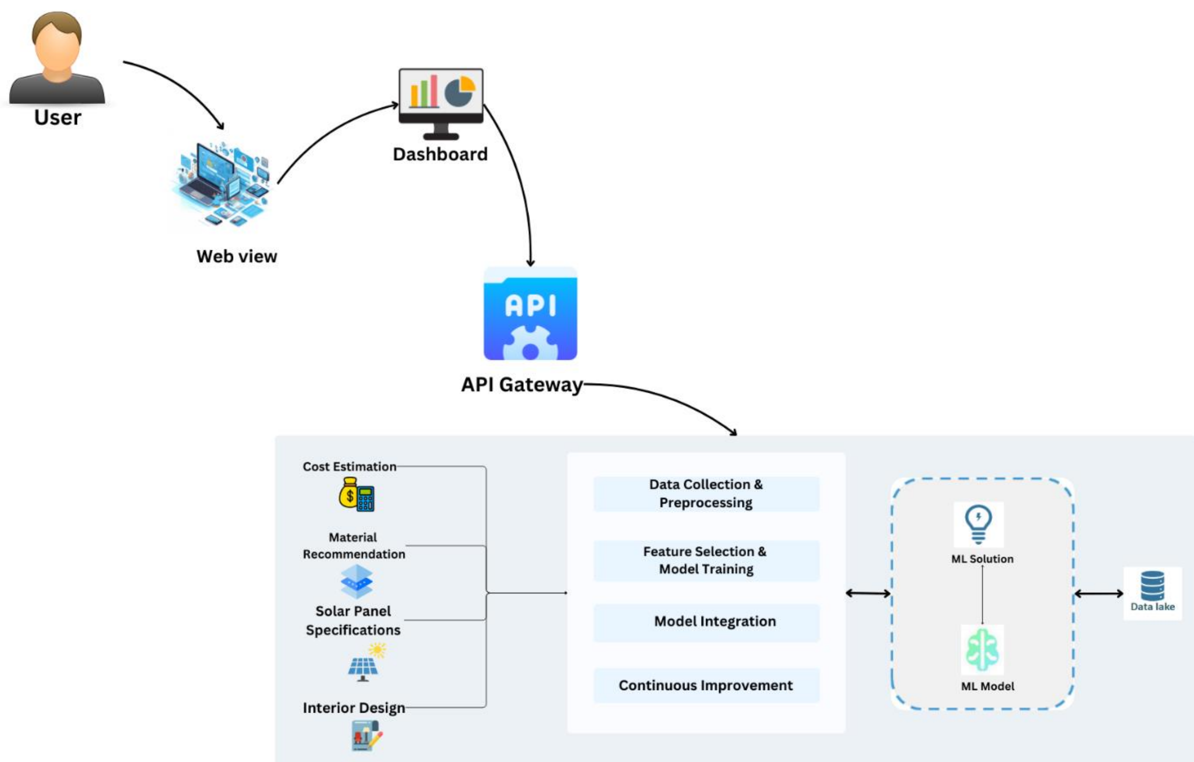

Figure 1 : Complete System Architecture

3.2 Component Architecture

1. User Interface (Frontend)
   - ✓ The frontend, which was created with React, offers customers a user-friendly and responsive interface via which they can enter data, browse suggested solar panels, and view information about their area [18].
2. Backend Processing
   - ✓ The backend, which manages user data, responds to queries, and develops machine learning models for solar panel design and energy usage forecasting, is built in Python. Algorithms for cost estimation and land area computation are also included in the backend [19].
3. Data Storage
   - ✓ All pertinent data, such as user profiles, historical energy usage statistics, and model outputs, are stored in MongoDB, which is interfaced using Pymongo. Both read and write operations in the database are intended to be scalable and effective [20] [17].

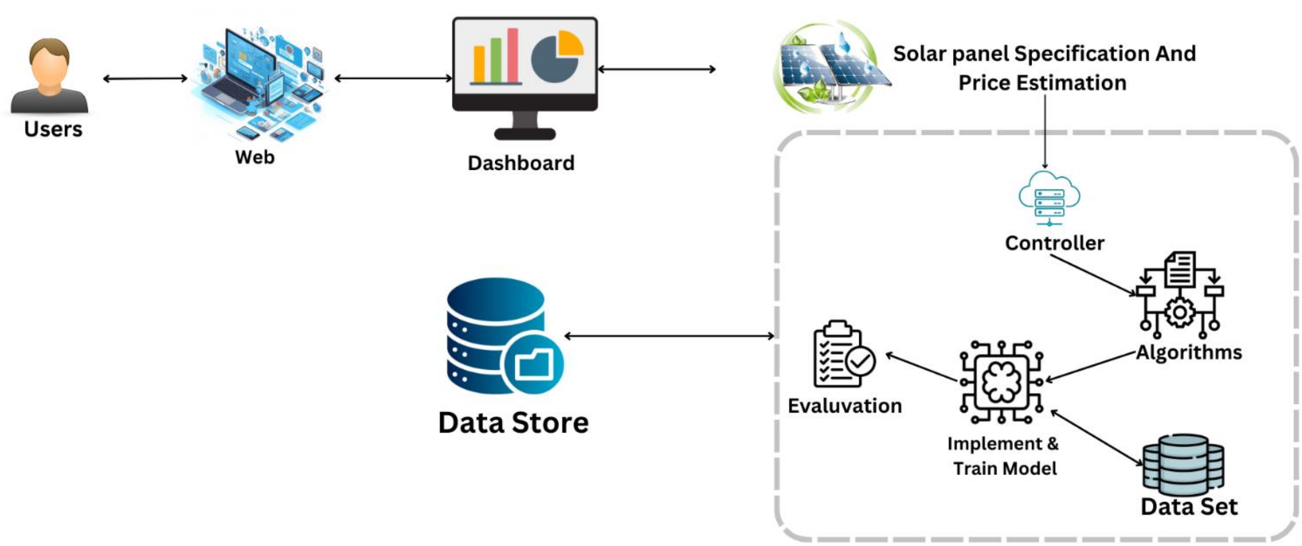

Figure 2 : Component Architecture

3.3 Functional Requirements

1. User Registration and Authentication
   - ✓ It must be possible for users to register, log in, and access their data safely.
2. Data Input and Processing
   - ✓ Users should be able to enter data into the system, such as location and land size, and have this data processed for analysis.
3. Energy Consumption Prediction
   - ✓ Utilize a machine learning model to forecast energy usage in the future by using user input.
4. Solar Panel Recommendation
   - ✓ Determine the optimal solar panel layout by optimizing it and recommending it based on available land and energy needs.
5. Cost Estimation
   - ✓ Provide comprehensive cost estimates using the Linear Regression and Clustering methods for various solar panel setups.

3.4 Non-Functional Requirements

1. Scalability
   - ✓ Large datasets and several users must be supported by the system without experiencing performance deterioration.
2. Security
   - ✓ Make sure that appropriate authentication and encryption procedures are in place for the safe storage and transmission of all user data.
3. Usability
   - ✓ It should be simple and intuitive for users with different levels of technical expertise to use the user interface.
4. Performance
   - ✓ Real-time or almost real-time recommendation processing should be the goal of the system.
5. Reliability
   - ✓ Make sure there is little downtime in the system and that data integrity is preserved.

3.5 Technology Selection

Performance, scalability, and ease of development had a role in the selection of the technological stack [21].

1. React (Frontend)
   - ✓ React was chosen because it can produce dynamic and responsive web interfaces. Because of its component-based architecture, creating UIs and reusable code are made possible [18].
2. Python (Backend & Model Training)
   - ✓ Python is favored because of its adaptability and abundance of data processing, machine learning, and API development libraries. It makes it easier to train intricate models and put cost- and energy-estimating algorithms into practice [19].
3. MongoDB with pymongo (Database)
   - ✓ NoSQL database MongoDB provides scalability for expanding datasets and flexibility in managing unstructured data. Pymongo is a stable interface that enables effective data operations between Python and MongoDB [17].

3.6 Gant Chart

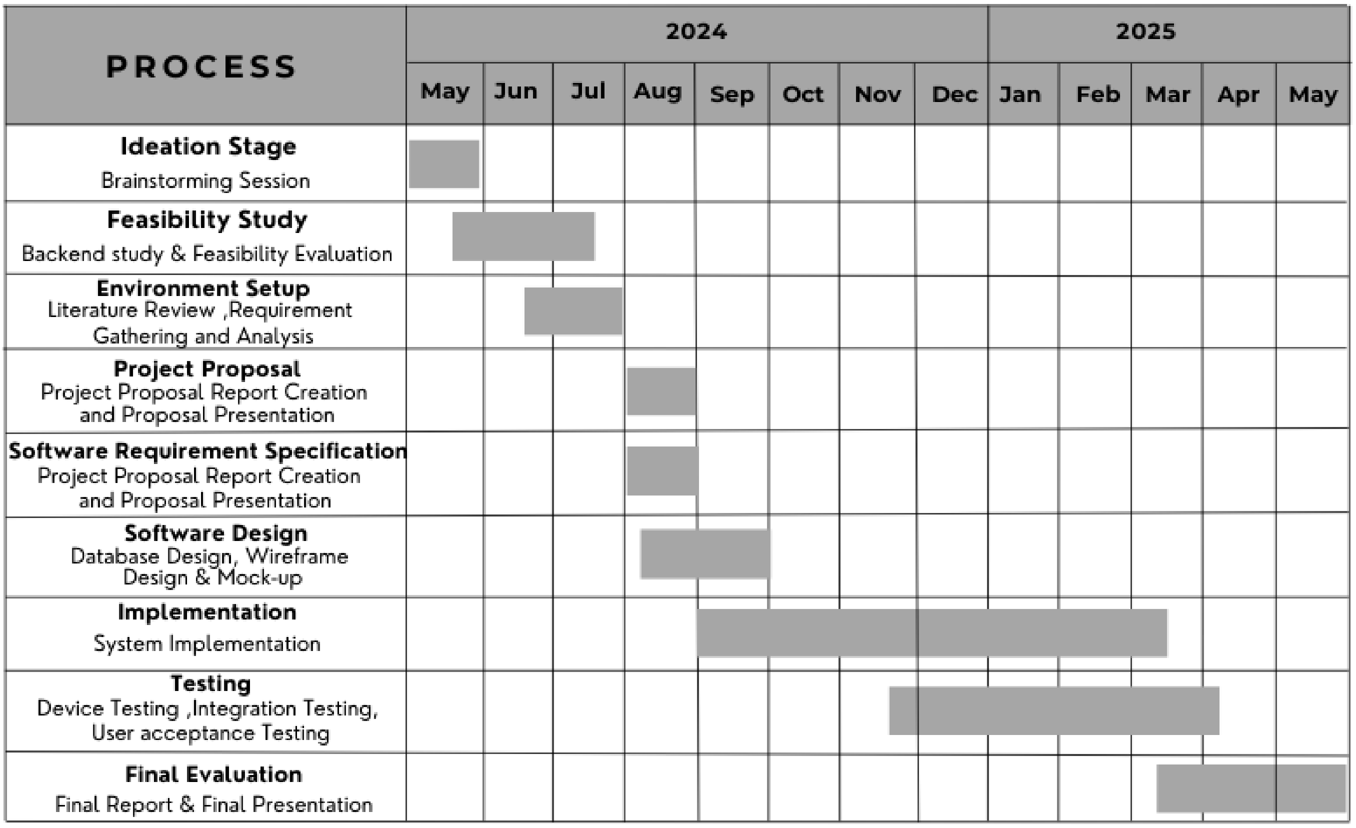

Figure 3 : Gantt Chart

3.7 Work Breakdown Structure

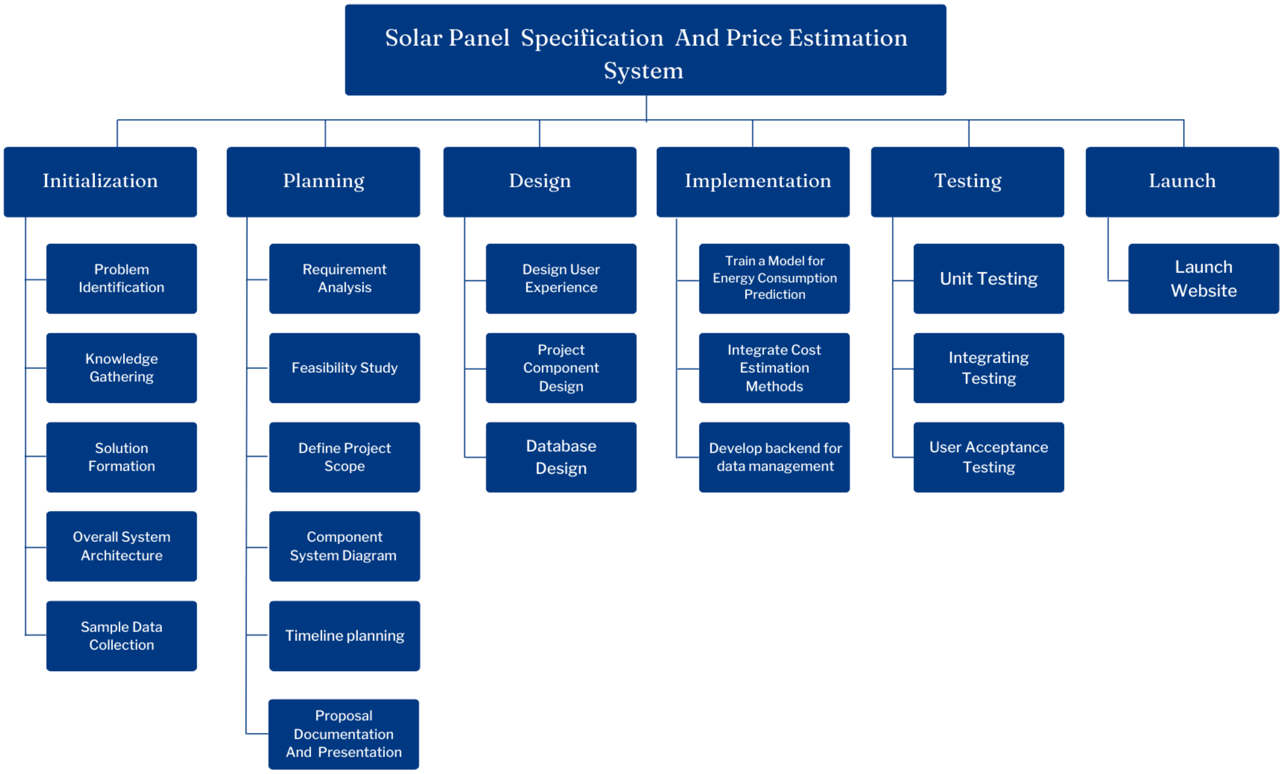

Figure 4 : Work Breakdown Structure

4. BUDGET AND BUDGET JUSTIFICATION

Item	Description	Cost Estimation
Google Cloud Platform (GCP)	Compute, storage, and database services for deployment and model training.	$300/month
Data Storage	Costs for storing datasets, user data, and model outputs on Google Cloud Storage (MongoDB).	$100/month

Table 2 : Budget and Justification

1. Google Cloud Platform (GCP)

    ✓ GCP is chosen as the deployment platform due to its scalability, reliability, and comprehensive suite of tools for machine learning and data storage. The estimated cost of $300/month covers compute instances, databases, and other services essential for the deployment and operation of the system [22].

2. Data Storage

    ✓ Storing large datasets, including historical energy consumption data, user data, and model outputs, is critical for the project. The $100/month allocation for Google Cloud Storage and MongoDB covers the necessary storage space with room for growth as the project scales.

5. COMMERCIALIZATION

The ultimate objective of this project's commercialization approach is to make the solar panel recommendation system a viable product that can be embraced by a range of stakeholders in the renewable energy industry. Residential and commercial property owners, solar installation businesses, and energy consultants in need of accurate, data-driven advice for solar energy solutions are among the target customers.

1. Market Potential
    - ✓ The transition to renewable energy on a worldwide scale offers a substantial opportunity for the suggested system. The demand for sustainable energy is rising, and this is driving a rapid expansion of the solar energy systems industry. The solution stands out in a crowded industry thanks to its capacity to offer tailored, reasonably priced recommendations based on precise data analysis.
2. Business Model
    - ✓ The proposed business model is based on a subscription-based service for end-users and a licensing model for businesses. The platform could offer tiered subscription plans based on the level of service.
3. Commercialization Strategy
    - ✓ Market Analysis and Segmentation - To determine important the client segments, pricing tactics, and possible partners, do a thorough market analysis.
    - ✓ Product Development - Improve the system in response to pilot users' comments to make sure it satisfies usability and market requirements.
4. Scaling
    - ✓ Continue to scale the system as the user base increases, adding features and reaching new international markets.

The commercialization plan makes that the research project is a useful solution that has an influence on the actual world and produces financial and environmental benefits, rather than just an academic exercise.

6. CONCLUSION

In summary, this project intends to construct an integrated system that precisely suggests solar panel specs and price based on predicted energy consumption, available land area, and cost factors, thereby addressing a key demand in the renewable energy market. This system will offer users tailored and optimal solar energy solutions by utilizing sophisticated algorithms for cost estimation, land area computation, and energy projection.

The suggested approach combines state-of-the-art models and technologies to produce a tool that increases the effectiveness of solar panel installations while simultaneously lowering costs and promoting the use of solar energy more widely. This study closes a big gap in the literature by providing a comprehensive method that unifies all important components of solar energy system design onto a single platform.

It is anticipated that the project's successful completion would progress the solar energy industry by offering insightful analysis and workable solutions that are suitable for both residential and business settings. In the end, our research helps advance a cleaner, more energy-efficient future by lowering carbon emissions and supporting the global push to switch to sustainable energy sources.

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APPENDICES

- Data Sources
  - ✓ Solar Power Generation Data [23] - https://www.kaggle.com/datasets/anikannal/solar-power-generation-data/data
  - ✓ Solar Energy Power Generation Dataset [9] - https://www.kaggle.com/datasets/stucom/solar-energy-power-generation-dataset
  - ✓ Daily Power Generated by 5kW Panel [8] - https://www.kaggle.com/datasets/fvcoppen/solarpanelspower
  - ✓ Photovoltaic (PV) Solar Panel Energy Generation Data [24] - https://data.london.gov.uk/dataset/photovoltaic--pv--solar-panel-energy-generation-data
  - ✓ PV-Live Real-Time Solar Energy Data [25] - https://www.solar.sheffield.ac.uk/pvlive/
- Technology Stack
  - ✓ Frontend - React
  - ✓ Backend - Phyton
  - ✓ Database [17] - MongoDB, using pymongo for data interaction