**3. PROBLEM STATEMENT**

**3.1 Objectives:**

The primary objectives of the IoT-Based Energy Optimization project are as follows:

* To design an intelligent system that automates the control of classroom appliances such as lights, fans, and projectors based on real-time human presence.
* To implement a human detection model using an ESP32-CAM module with integrated machine learning capabilities, ensuring the exclusion of non-human entities.
* To accurately detect human location within the classroom using laser sensors, enabling the system to control only the appliances directly above the identified location.
* To reduce electricity consumption and promote energy efficiency by ensuring that unused electrical appliances remain off.
* To develop a user-independent system that functions autonomously without manual intervention, suitable for smart classrooms in academic institutions.
* To build a scalable and cost-effective solution that can be deployed across multiple classrooms or buildings in an educational campus.
* To promote green technology practices by integrating smart automation with IoT and ML technologies for energy conservation.

**3.2 Feasibility Study:**

**3.2.1 Technical Feasibility**

* The project leverages widely available hardware such as ESP32, ESP32-CAM, and laser sensors, all of which are compatible and programmable using Arduino IDE and Python.
* The ML model for human detection can be trained using lightweight architectures compatible with the ESP32-CAM, ensuring real-time image inference capabilities.
* The integration of relay modules for switching appliances is technically straightforward and reliable for AC-powered classroom devices.
* Communication between sensors, controllers, and appliances is achievable using standard GPIO, I2C, or UART interfaces, proving the system to be technically viable.

**3.2.2 Economic Feasibility**

* The hardware components used in the project are affordable and readily available, making it a low-cost solution suitable for academic institutions with limited budgets.
* Once deployed, the system helps reduce electricity bills, leading to long-term cost savings.
* Since it is an open-source and scalable solution, the development and maintenance cost remains minimal compared to proprietary commercial energy management systems.

**3.2.3 Operational Feasibility**

* The system is fully automated and does not require user interaction, making it simple to operate by non-technical users such as teachers or staff.
* It ensures high operational efficiency by making decisions in real-time, based on actual classroom usage.
* The system can be installed in any classroom environment with minimal structural modifications.

**3.2.4 Schedule Feasibility**

* The development timeline is feasible for completion within an academic year.
* Each module—hardware setup, ML model training, sensor integration, and appliance control—can be developed and tested in parallel, reducing development time.
* Availability of project members and institutional resources ensures timely implementation and testing.

**4. PROJECT REQUIREMENTS**

**4.1 Software Requirements:**

* **Arduino IDE** – For programming and flashing the ESP32 microcontroller.
* **Python** – For preprocessing image datasets, training ML models, and deployment of the classification algorithm.
* **TensorFlow/Keras** – To train and deploy human detection models for the ESP32-CAM.
* **ESP32-CAM ML Model Deployment Tools** – For integrating the trained model into the ESP32-CAM module.
* **Serial Monitor/Putty** – For real-time logging and debugging.
* **Firebase/ThingSpeak (Optional)** – For storing or viewing system activity logs remotely.
* **Operating System** – Windows 10/11 or Linux (Ubuntu recommended for ML tasks).

**4.2 Hardware Requirements:**

* **ESP32 Microcontroller** – Central unit to collect data and control devices.
* **ESP32-CAM** – To capture images and run the ML model for detecting humans.
* **Laser Distance Sensor** (e.g., VL53L0X) – To detect the position of humans in the classroom.
* **Relay Module** (4/8-channel) – To switch lights, fans, and projectors ON/OFF.
* **Power Supply Units** – 5V/12V DC supply for microcontrollers and relays.
* **Classroom Appliances** – Lights, ceiling fans, projectors (to be controlled).
* **Cables, Breadboards, Connectors** – For circuit connections and prototyping.
* **Mounting hardware** – For securing sensors and microcontrollers in the classroom.