

Conceptual design for an energy consumption meter simulator

Students:

- Andres Jeronimo Ramirez
- David Santiago Ibañez
- Johan Danilo Trujillo

Course: Object-Oriented Programming — Semester 2025-II

1. Requirements documentation

1.1. Functional requirements

The system must have:

- Display consumption data to the user.
- Notify the user about consumption.
- Allows you to set consumption limits.
- Show expected device consumption.
- View consumption over the course of the month, either numerically or graphically.
- View a list of each device, sorted from highest to lowest, based on consumption, including the cost in Colombian pesos (COP) for each device.
- View a breakdown of each device in the list.
- Change the device name.
- Remotely turn off the desired socket.
- Allows you to view information about concepts and functions.
- When a device in the list is selected, open a detailed interface with a daily consumption graph (kWh vs. time).
- Integrate an analysis module that identifies consumption patterns, anomalies (e.g. devices consuming more than expected), and provides recommendations for energy saving.

1.2. No functional requirements

Category	Requirement
Usability	The interface should be intuitive for new users or people with little experience.
Performance	Must support at least 20 devices stably
Reliability	It must maintain stable transitions even with rapid interaction.
Portability	The system should run on Windows, macOS, and Linux using Python.
Maintainability	Modular OOP design to ensure readable and modifiable classes.
Educational Value	The system must support clear visualization of signal flow for learning purposes.

2. User stories

US-01: Real-Time Energy Dashboard for Homeowners	Priority: High	Estimate: 10-12 hours
As a homeowner, I want to view my current and past energy usage in a dashboard, so that I can identify which appliances use the most power and receive alerts if usage is unexpectedly high.		
Acceptance criteria: <ul style="list-style-type: none">- The dashboard shows live voltage, current, and power values for each monitored appliance.- The homeowner can select a time range and see a historical graph of total energy consumption.- The web app sends a notification (email or on-screen) if an appliance's power exceeds a set threshold.		

- The interface displays an estimated cost of energy used in the current billing cycle.

US-02: Sensor Calibration and Diagnostics for Technicians	Priority: Medium-High	Estimate: 8-10 hours
As a technician, I want to calibrate and test the sensors and device, so that I can ensure accurate measurements and diagnose any issues.		
<p>Acceptance criteria:</p> <ul style="list-style-type: none"> - A “Calibration” section allows adjusting sensor calibration parameters (offset/gain) and saving them. - The technician can trigger a self-test or view raw sensor readings. - All calibration actions and measurements are logged with timestamps. - If any hardware error (e.g. sensor disconnected) is detected, an error alert is raised. 		

US-03: Modular Code and Simulator for Developers	Priority: High	Estimate: 12-16 hours
As a developer, I want clear, modular classes and a simulator, so that I can develop and maintain the system easily and test features without the hardware.		

Acceptance criteria:

- Code is organized into OOP classes (Sensor, NetworkManager, etc.) and fully documented.
- A virtual simulator can feed fake sensor data into the system for testing.
- The developer can deploy firmware updates (via OTA) and access debug logs.
- Unit or integration tests exist for each module (e.g. data logging, alerting).

US-04: Family Member Shared Access Dashboard	Priority: Medium	Estimate: 6-8 hours
As a family member, I want to view the household's energy usage and alerts so that I can help monitor and reduce our home's energy consumption.		
Acceptance criteria:		
<ul style="list-style-type: none">- The homeowner can invite family members with limited (read-only) access.- Shared accounts can view the dashboard and alerts but cannot modify system settings.- The system ensures proper permissions per role.- Family members can receive alert notifications if enabled by the homeowner.		

US-05: System Administration and OTA Management	Priority: High	Estimate: 10-12 hours
As a system administrator, I want to manage users, configurations, and firmware updates so that the network remains secure and up-to-date.		

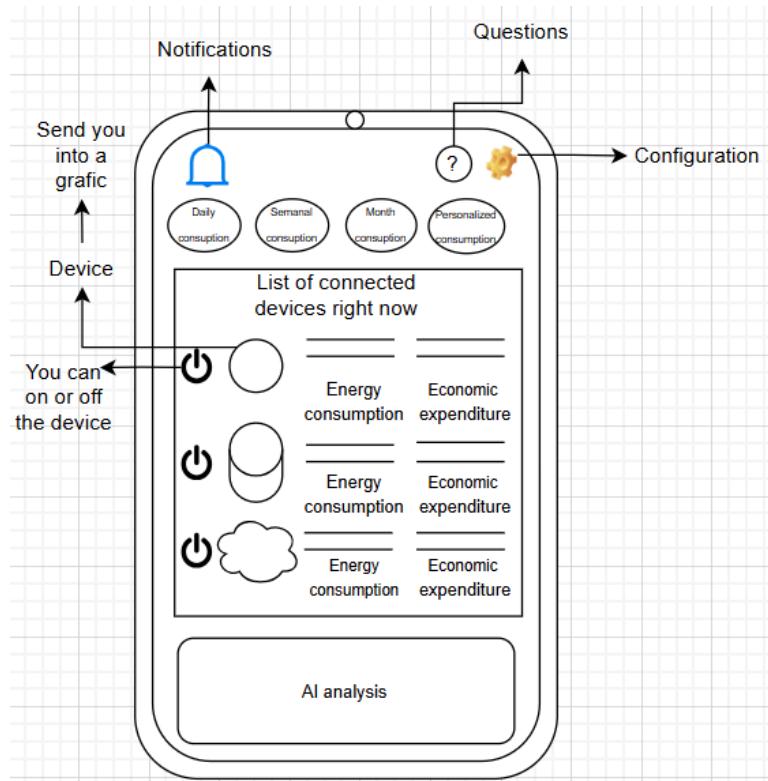
Acceptance criteria:

- Admin can add/remove users and assign roles (owner, family, technician).
- Admin can trigger and monitor OTA firmware updates.
- Admin can view system logs (connectivity, sensor errors, firmware status).
- Admin can edit global thresholds and alert rules.

US-06: Energy Ranking and Cost Analysis	Priority: High	Estimate: 12-14 hours
As a homeowner, I want to see an ordered list of devices by energy consumption and cost in Colombian pesos, so that I can identify which devices use the most power and take actions to reduce my bill.		
Acceptance criteria:		
<ul style="list-style-type: none">- The system displays a ranked list (high → low) of devices by daily energy usage (kWh).- Each device shows its consumption cost in COP using a configurable tariff.- When clicking a device, a detailed page opens showing a daily consumption graph.- A “Monthly Analysis” tab ranks devices by monthly usage and total cost.- The system highlights outliers or excessive consumption and suggests possible causes (e.g., standby losses, malfunction).		

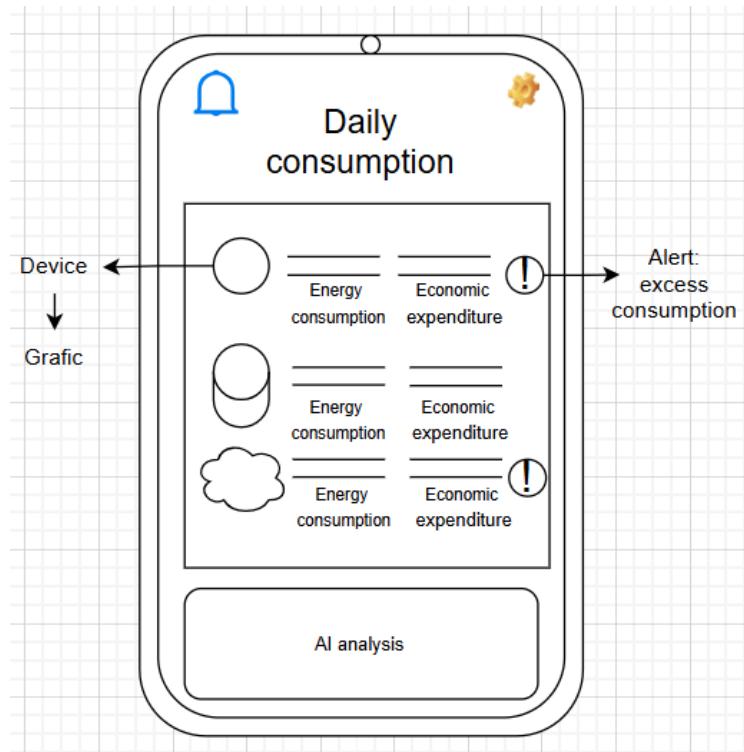
3. Mockups

3.1 Main dashboard



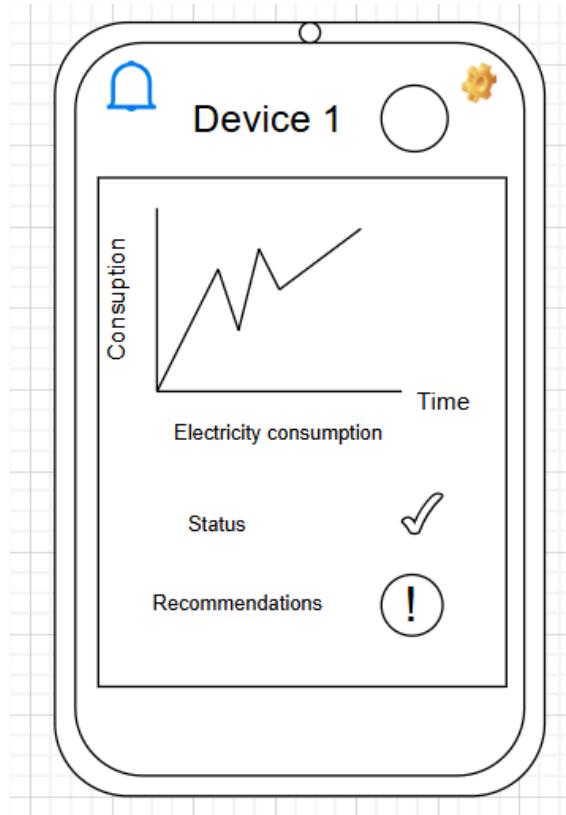
Provide simple navigation

3.2 Consumption



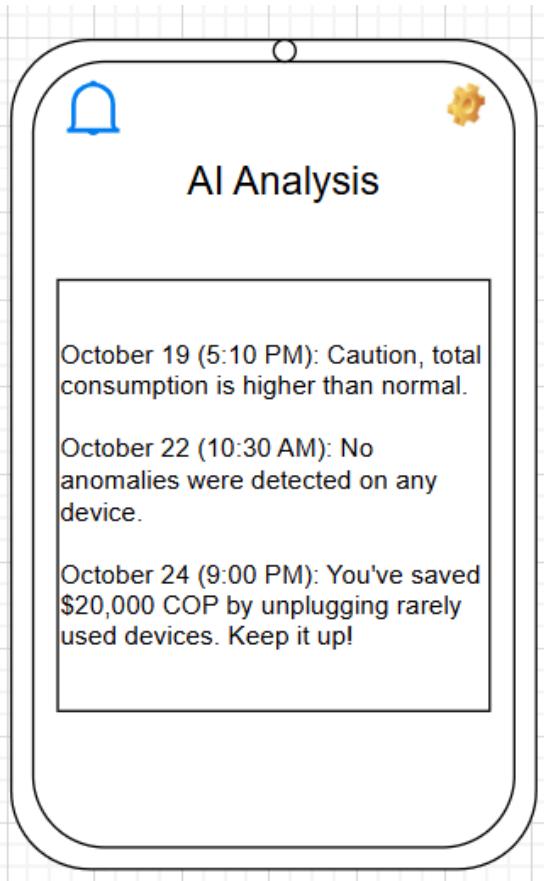
Total monthly, weekly or daily consumption

3.3 Device menu



All information and settings of the connected device

3.4 AI Analysis



Recommendation, warnings and messages from the AI

4. CRC Cards

4.1. Class: Device

Responsibilities:

- Store device data (name, power, usage time).
- Calculate individual energy consumption (kWh).
- Provide consumption history.
- Send data to the consumption manager.

Collaborators:

- Device manager
- Energy calculator
- UI

4.2. Class: Device manager

Responsibilities:

- Register devices.
- Delete and edit connected devices.
- Maintain a list of all devices.
- Request individual usage calculations.
- Detects devices with high usage.

Collaborators:

- Device
- Energy calculator
- UI

4.3. Class: Energy calculator

Responsibilities:

- Calculate consumption in kWh (energy = power × time).
- Convert kWh to Colombian pesos.
- Calculate total monthly consumption.
- Generate statistics (averages, peaks, trends).

Collaborators:

- Device
- Device manager

4.4. Class: Consumption history

Responsibilities:

- Save daily/weekly/monthly usage.
- Allow historical analysis.
- Export data for reporting.
- Notify of usage changes.

Collaborators:

- Device
- Device manager
- UI

4.5. Class: Concept info

Responsibilities:

- Store educational definitions (voltage, current, power, resistance).
- Show real-life examples.

- Provide optional diagrams or images.
- Act as a study guide.

Collaborators:

- UI
- Settings

4.6. Class: User settings

Responsibilities:

- Save user preferences.
- Configure notifications (consumption limits).
- Change currency and units (optional).
- Control language and interface.

Collaborators:

- UI

4.7. Class: Notification manager

Responsibilities:

- Send alerts when a device consumes too much.
- Notify of monthly increases.
- Show savings tips.

Collaborators:

- Device manager
- Consumption history
- UI

4.8. Class: UI (user interface)

Responsibilities:

- Display monthly usage.
- Display monthly cost in pesos.
- Render list of devices.
- Pressing a device → opens details.
- Display educational information (Concept Info).

Collaborators:

- Device manager
- Energy calculator
- Concept info
- Notification manager

5. References

Interface of popular applications such as Instagram or finance in the use of graphics
geeksforgeeks (2025), “*Object-Oriented Design (OOD) - System Design*”

<https://www.geeksforgeeks.org/system-design/oops-object-oriented-design/>

habado bado, “*Object Oriented Design*”

<https://es.scribd.com/presentation/562066603/Object-Oriented-Design>

Awasthi, M., & Kumar, R. (2023). *Energy monitoring and management using IoT: A review on smart metering systems*. *International Journal of Electrical and Electronics Research*, 11(2), 145–156. <https://doi.org/10.37391/IJEER.110208>

Espressif Systems. (2024). *ESP32 technical reference manual* (Version 4.4).
Retrieved from

<https://www.espressif.com/en/support/documents/technical-documents>

Ibrahim, F., & Shaaban, M. (2021). *Smart home energy management systems: Real-time monitoring and optimization techniques*. *IEEE Access*, 9, 112345–112358.
<https://doi.org/10.1109/ACCESS.2021.3101421>

ISO. (2018). *ISO 50001:2018 – Energy management systems — Requirements with guidance for use*. International Organization for Standardization.
<https://www.iso.org/standard/69426.html>

Microchip Technology Inc. (2023). *PZEM-004T V3.0 AC multifunction power meter – Datasheet*. Retrieved from <https://www.microchip.com>

National Institute of Standards and Technology (NIST). (2019). *Framework for cyber-physical systems (Release 1.0)*. NIST Special Publication 1500-201.

<https://doi.org/10.6028/NIST.SP.1500-201>

OpenAI Research. (2024). *AI-driven anomaly detection in IoT systems: Lightweight predictive models for embedded devices*. *Journal of Intelligent Systems and Applications*, 18(3), 201–214. <https://doi.org/10.1007/s10209-024-01325-9>

Patel, S., & Sharma, A. (2022). *Design of energy consumption dashboards for residential IoT systems*. *Sustainability*, 14(15), 9231–9245.

<https://doi.org/10.3390/su14159231>

Raza, M., Aslam, N., Le-Minh, H., & Hussain, S. (2019). *A security survey on smart home networks and applications*. *IEEE Communications Surveys & Tutorials*, 21(3), 2529–2554. <https://doi.org/10.1109/COMST.2019.2899740>

Sartori, M., & Ortega, A. (2020). *Comparative analysis of household appliance energy consumption and efficiency standards*. *Energy Policy Journal*, 45(2), 77–89.

<https://doi.org/10.1016/j.enpol.2020.112003>

World Energy Council. (2023). *Smart homes and sustainable energy: Global report on domestic IoT adoption*. Retrieved from <https://www.worldenergy.org/publications>