

SMART HOME ENERGY MANAGEMENT SYSTEM (SHEMS)

With AI Optimization



Smart Home Energy
Management System
(SHEMS)

Team Members



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AI/ML & Deployment
Developer

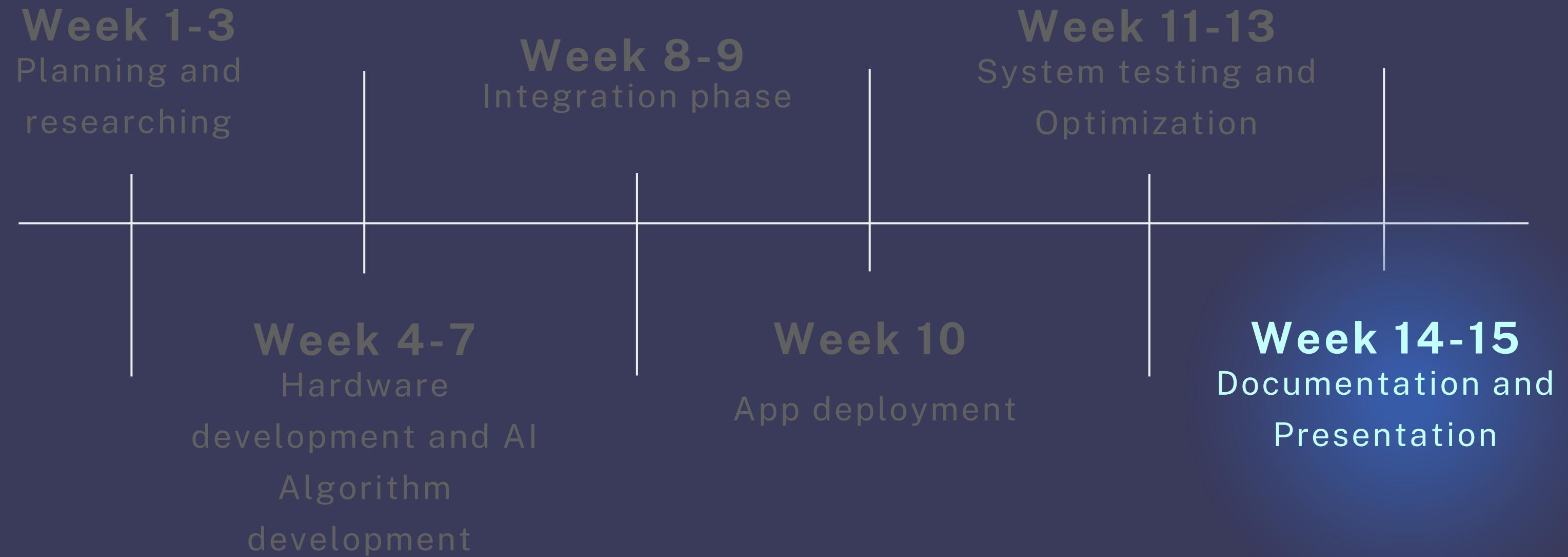


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Electrical & IoT
Engineer



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Full-Stack Developer

Timeline



Why SHEMS?

- SHEMS addresses energy waste with smart, sensor-driven automation
- Automates control of lights, heaters, and fans based on real-time data
- Uses AI to optimize usage patterns and schedules
- Remote control through a mobile app + real-time monitoring via Firestore
- Reduces energy bills and supports sustainability



Hardware and Cloud Integration

- Connected PIR and DHT11 sensors to Raspberry Pi
- Integrated Kasa smart plugs for controlling light and heater
- Implemented automation logic based on real-time sensor data
- Enabled real-time data upload to Firebase Firestore



Automation & Remote Control

- Light ON when motion detected; OFF after 1 hour of inactivity
- Heater ON if temperature $< 25^{\circ}\text{C}$; OFF if $\geq 25^{\circ}\text{C}$
- Mobile app sends ON/OFF commands via Firestore
- Raspberry Pi listens and triggers smart plug control instantly



Manual Hour Override & Dynamic Billing

- Manual commands pause automation for 1 hour
- Automation resumes based on sensor data after timeout
- Cost rate fetched from Firestore (user-editable)
- Real-time energy usage and cost logged every minute



Final Testing & System Validation

- Verified automation and override logic across devices
- Ensured auto-restart with systemd and Wi-Fi reconnect
- Minimized Firestore writes to once per minute
- Fully tested with mobile app for real-time sync



Demo Video

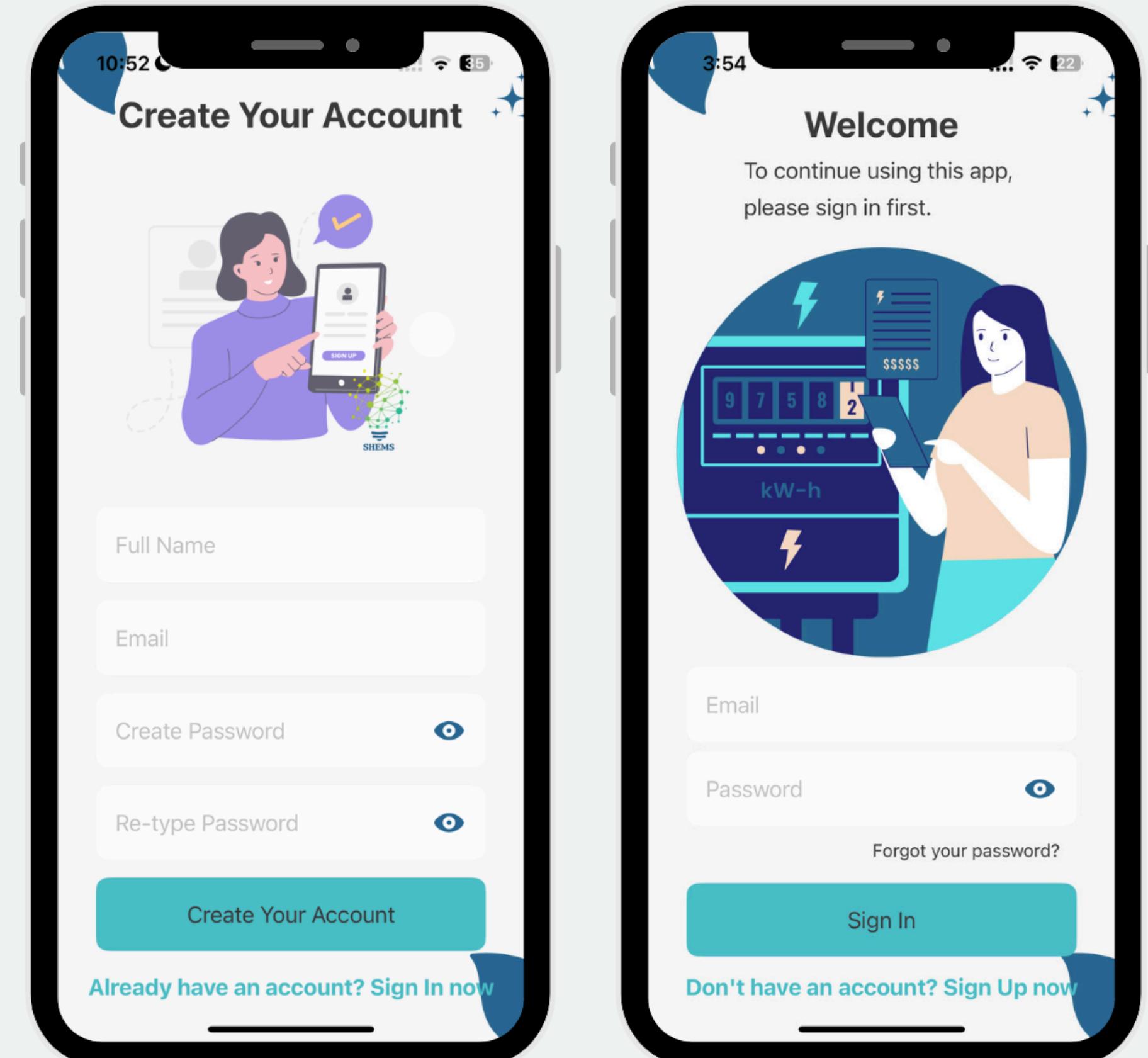




SHEMS Mobile App “Features”

Login & Authentication

- Register and login with Firebase email authentication
- Secure email/password login
- Password reset option

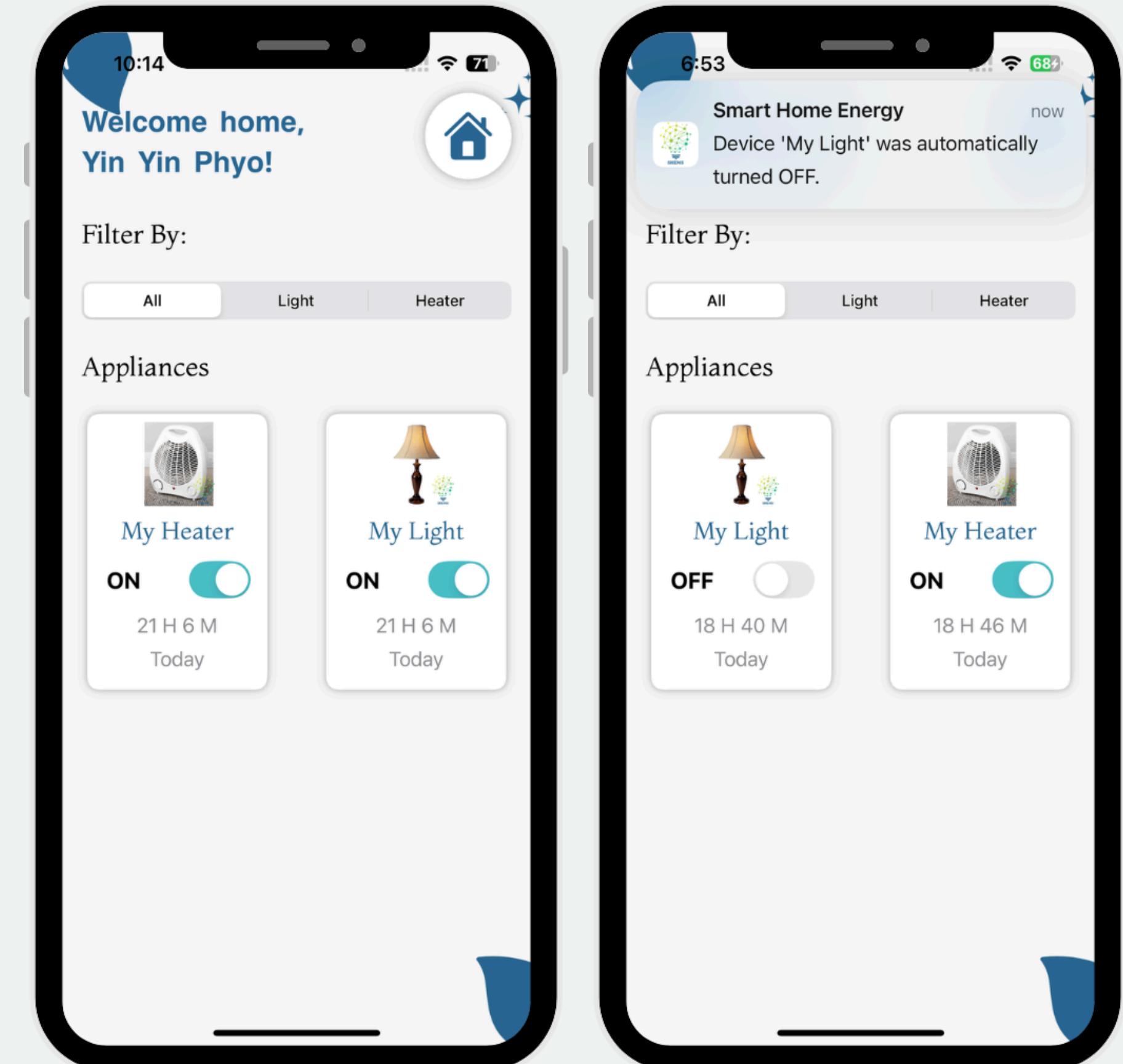




SHEMS Mobile App “Features”

Device Control

- Manual ON/OFF control
- Motion sensor-based automation for energy saving

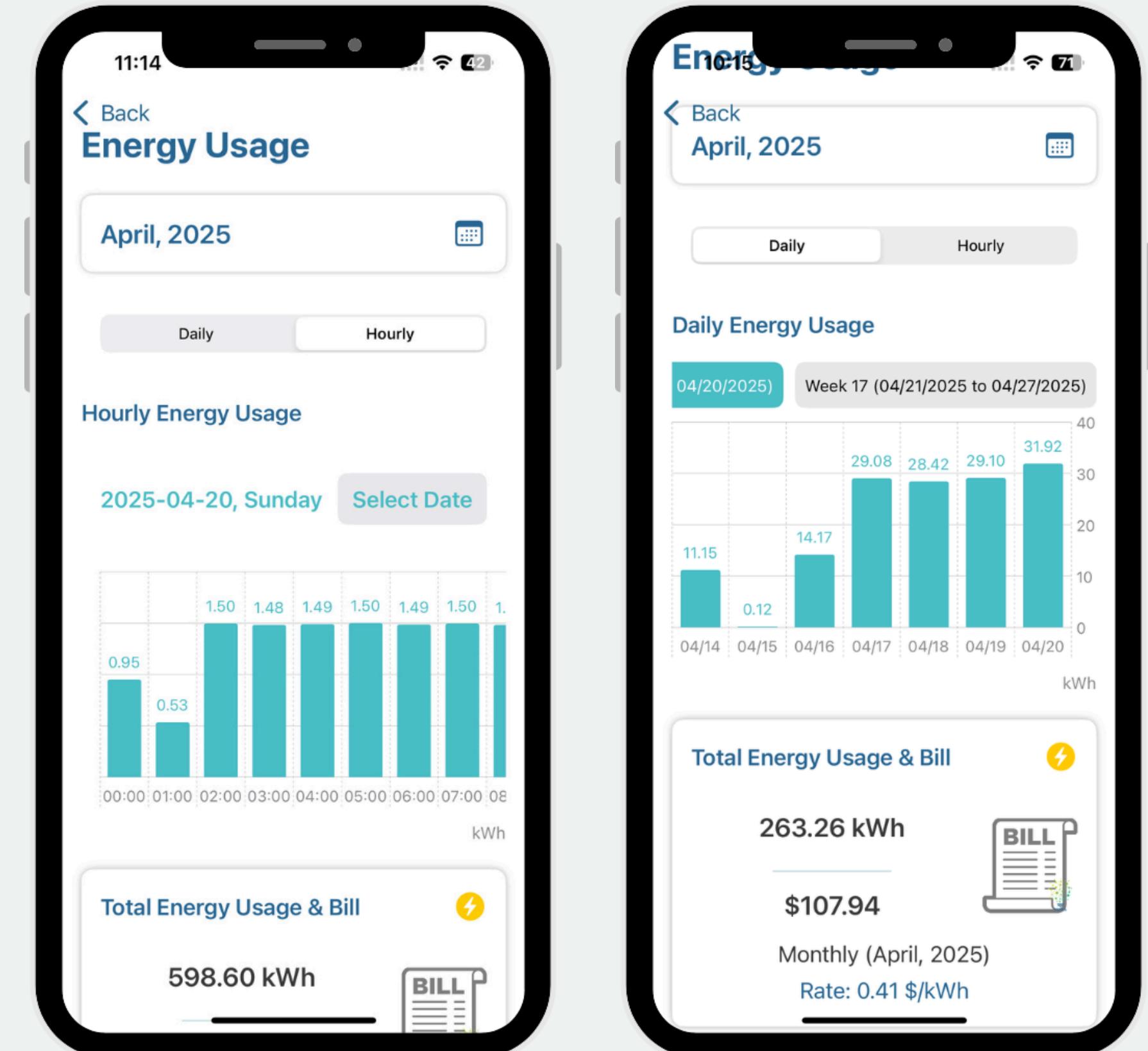




SHEMS Mobile App “Features”

Energy Monitoring

- Interactive graphs for real-time, daily, hourly & monthly energy usage
- Estimated monthly usage and bill cost





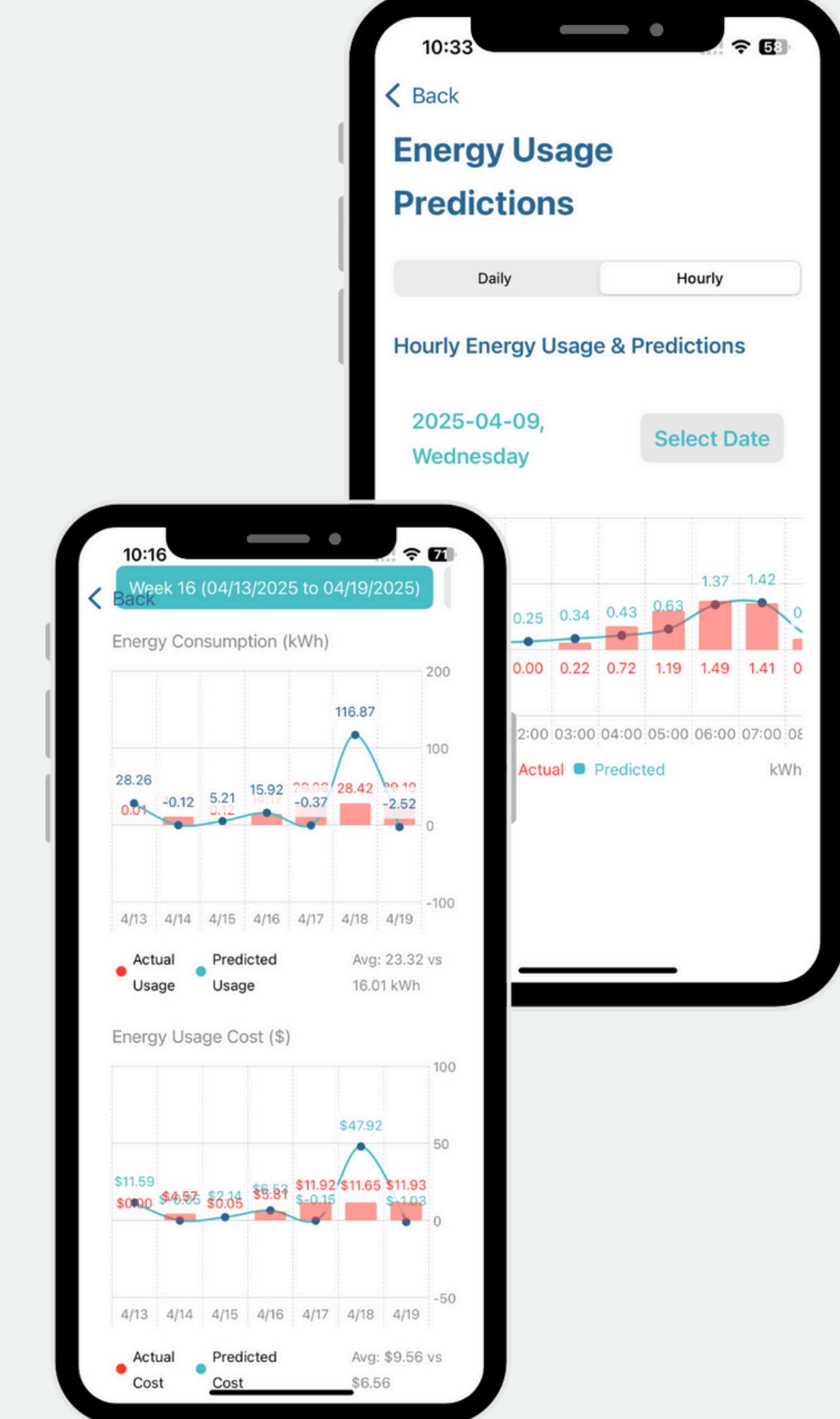
SHEMS Mobile App “Features”

Energy Usage Prediction & AI Suggestions

The screenshot shows the "AI Suggestions" screen. At the top, it says "Select Date: 2025-04-20". Below that, it shows "Source: AI Agent" and "Time: Apr 20, 2025 - 00:00". Under "Suggestions", there are two sections: "Utilize Natural Light" and "Adjust Thermostat Settings".

- Utilize Natural Light:** "With clear skies expected, take advantage of daylight by keeping blinds and curtains open during the day. This will reduce the need for artificial lighting in your home and help save energy."
- Adjust Thermostat Settings:** "Since the daytime temperature is predicted to be around 17.7°C, consider lowering your heating during the day if it's currently set higher, or setting it lower at night when it will cool down to about 11.36°C. This will help conserve energy without..."

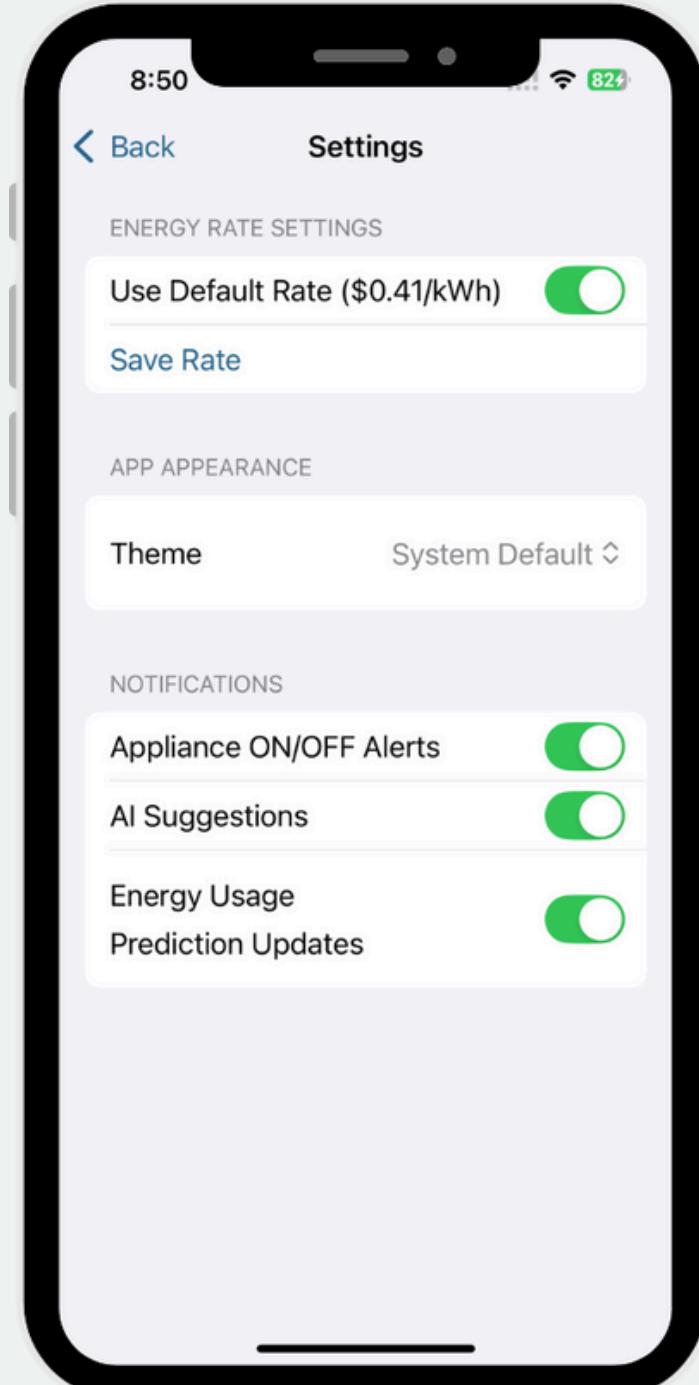
- Comparison with visualized charts for real-time and prediction of energy usage
- Estimated bill prediction
- Daily generated AI suggestions





SHEMS Mobile App “Features”

Settings



- Energy rate configuration (default/custom)
- App theme selection (System/Light/Dark)
- Manage notifications
 - Appliance ON/OFF, AI tips, and Energy Usage Prediction updates

The three screenshots show different types of notifications:

- Notification 1:** A system alert at 6:53 about a device being turned off. It includes a filter bar for "All", "Light", and "Heater".
- Notification 2:** A permission request from the app asking if it can send notifications. The user can choose "Don't Allow" or "Allow".
- Notification 3:** A personalized energy tip at 8:30, suggesting optimization based on weather and time.



Backend & ML/AI

Overview

- Developed energy usage **forecasting and optimization pipelines**
- Built and deployed **AI agent** for daily smart suggestions
- Designed **Firestore schema** for scalable, real-time data management
- Automated backend workflows using **GCP**
- Ensured production-grade **deployment** and system reliability



Backend & ML/AI

Forecasting Model - Prophet

- Fine-tuned Prophet model for hourly and daily energy predictions
- Custom seasonalities: weekly & monthly
- Trained on **real household data**, dynamically adjusts to behavior
- Read energy data from Firestore and write predictions into Firestore

	Model	MAE	MSE	RMSE
0	Hourly (Fine-Tuned)	0.107321	0.032279	0.179663
1	Daily (Aggregated Hourly)	1.171207	2.455835	1.567110

The screenshot shows a Google Cloud Firestore document structure. The root document contains fields for 'devices', 'energy_data', 'insights', 'model_params', 'predictions' (which is a subcollection), 'sensor_data', and 'weather_data'. The 'predictions' subcollection contains documents for dates from April 14 to April 29, 2025. Each prediction document includes fields for 'predicted_cost' (9.794) and 'total_prediction' (23.889). The document also contains user metadata like 'email' (yinyinphyo2021@gmail.com), 'latitude' (37.785834), 'longitude' (-122.406417), 'name' ("Yin Yin Phyo"), 'rate' (0.41), and 'uid' (HdCl0omyLWTep3SwuRA...).



Backend & ML/AI

Model Optimization

- Missing data handling (forward/backward fill)
- Clipping and filtering to prevent invalid predictions
- Support for user-customized electricity rates for cost estimates
- Automated monthly grid search to re-tune hyperparameters
- Minimized Firestore reads/writes to reduce latency and cost



Backend & ML/AI

AI Suggestions for Smarter Energy Usage

- Combines: forecast data + historical usage + weather data
- Uses OpenAI API (gpt-4o-mini) to generate human-readable tips
- Examples: reduce heater use because of warm weather; avoid heavy loads at peak hours
- Outputs written to Firestore, shown in mobile app

The screenshot shows a Google Firestore document view. The path is: users > HdCl0omyLWTeip3SwuRAf... > insights > 2025-05-06-07:00. The document contains the following fields:

- devices**: An array of documents for each device, with timestamps from 2025-04-21 to 2025-05-07.
- energy_data**: A timestamped document for energy data, with timestamps from 2025-04-22 to 2025-05-07.
- insights**: A timestamped document for AI-generated insights, with timestamps from 2025-04-23 to 2025-05-07.
- model_params**: A timestamped document for model parameters, with timestamps from 2025-04-24 to 2025-05-07.
- suggestions**: A list of tips:
 - 0 "Optimize Heating and Cooling: Use a programmable thermostat to adjust your heating and cooling based on the outdoor temperature. With tomorrow's forecast showing a mild day with a high around 20°C, consider turning down your heating and relying on natural ventilation during the day."
 - 1 "Utilize Daylight: Since the weather is partly cloudy with clear spells, take advantage of natural light. Keep blinds or curtains open during the day to reduce the need for artificial lighting. This reduces your electricity usage, especially during daylight hours."
 - 2 "Unplug Devices: Ensure that electronic devices and appliances not in use are unplugged or switched off. Even when devices are turned off, they can draw power if they are still plugged in. This "phantom energy" consumption can add up over time."

timestamp: May 6, 2025 at 12:00:19 AM UTC-7



Backend & ML/AI

Backend Deployment & Maintenance

- **3 RESTful API endpoints**
- **2 Dockerized microservices on Cloud Run**
- **3 Cron Jobs on Cloud Scheduler**
- Production server via **Gunicorn**
- API Keys managed with **GCP Secret Manager**
- Failure monitoring + email alert system

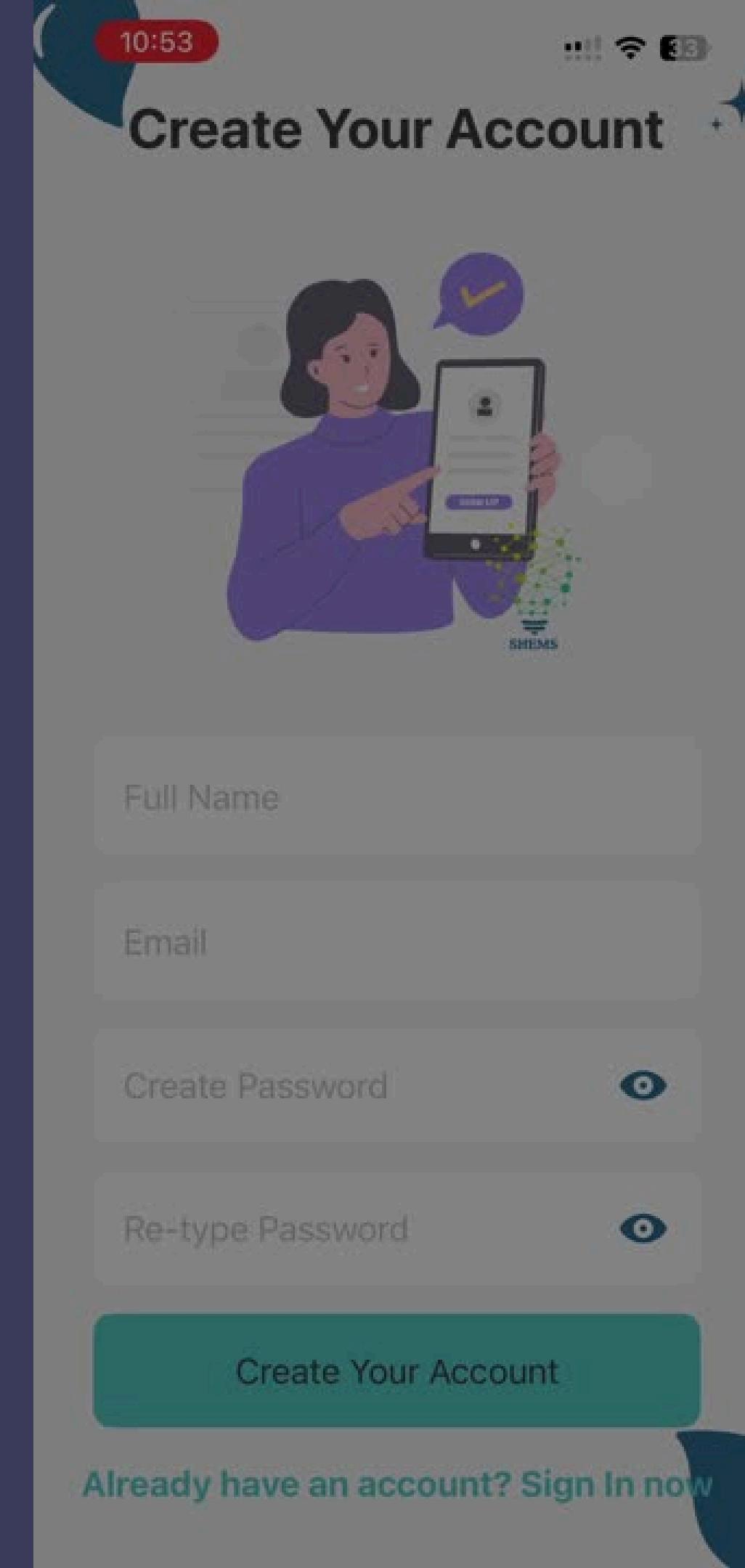
Services

Name	Deployment type	Req/sec	Region	Authentication	Ingress
ai-agent	Container	0	us-west1	Allow unauthenticated	All
predict-model	Container	0	us-west1	Allow unauthenticated	All

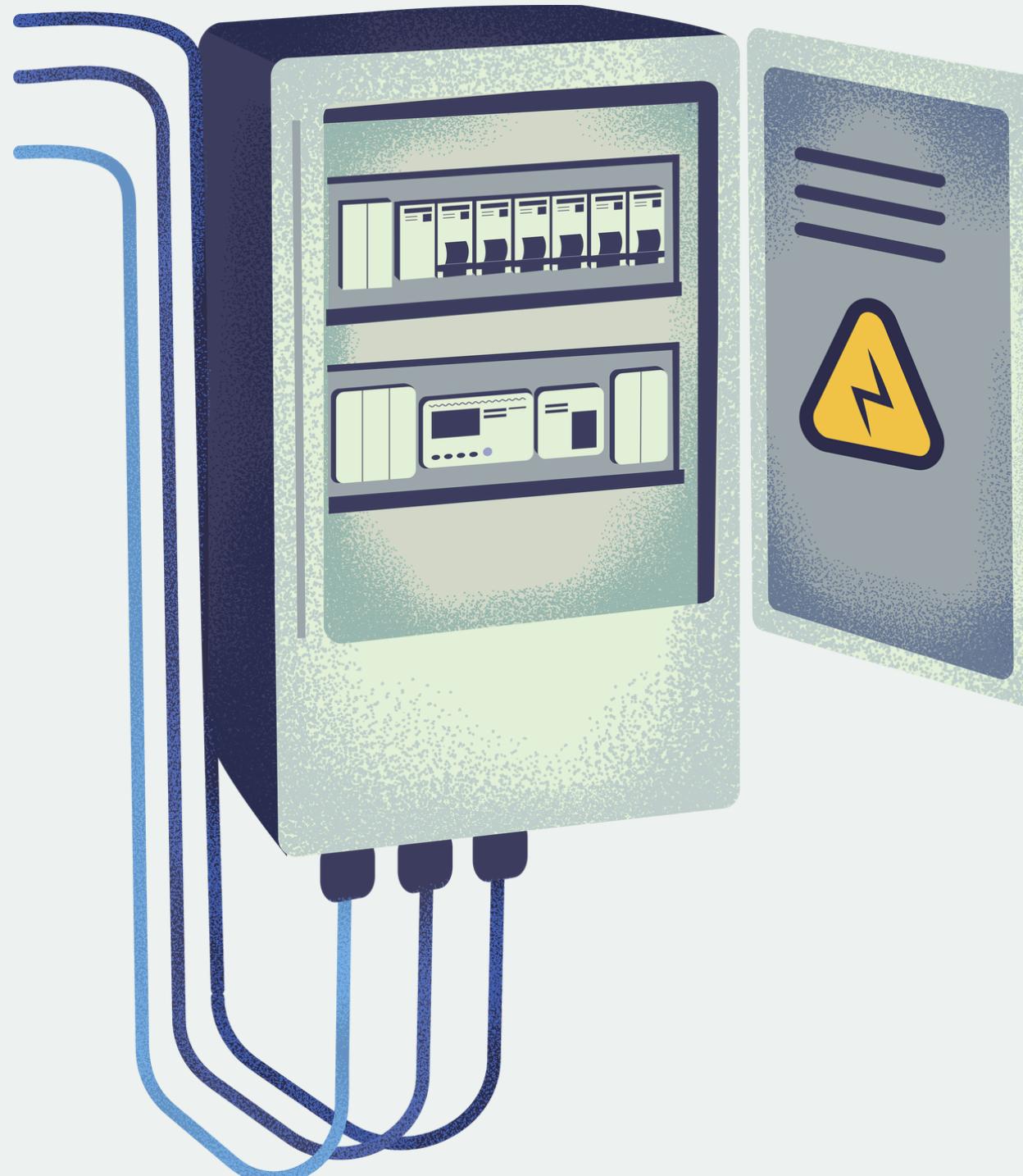
Cloud Scheduler / Jobs

Jobs	+ CREATE JOB	REFRESH	FORCE RUN	EDIT	COPY	PAUSE	RESUME	DELETE
SCHEDULER JOBS	APP ENGINE CRON JOBS							
Filter jobs								
Name	Status of last execution	Region	State	Description	Frequency	Target		
daily-ai-suggestion	Success	us-west1	Enabled		0 0 *** (America/Los_Angeles)	URL : https://ai-agent-399301927568.us-west1.run.app/trigger_all		
daily-prediction-job	Success	us-west1	Enabled		0 0 *** (America/Los_Angeles)	URL : https://predict-model-399301927568.us-west1.run.app/run_daily_pred		
monthly-grid-search-job	Success	us-west1	Enabled		0 0 1 ** (America/Los_Angeles)	URL : https://predict-model-399301927568.us-west1.run.app/run_grid_search		

Demo



References



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Kaur, H., Awasthi, A., & Lam, J. S. L. (2020). Smart home energy management systems: Recent advances and future trends. *Renewable and Sustainable Energy Reviews*, 121, 109637. <https://doi.org/10.1016/j.rser.2020.109637>

Hebrail, G., & Berard, A. (2006). Individual household electric power consumption [Dataset]. UCI Machine Learning Repository. <https://doi.org/10.24432/C58K54>

Khan, M. A., Rehmani, M. H., & Reisslein, M. (2020). Smart homes: Security challenges and solutions. *IEEE Communications Surveys & Tutorials*, 22(1), 426–458. <https://doi.org/10.1109/COMST.2019.2951814>



Thanks!

