## Case Study 1 : Smart Electricity, Water and Air Quality Monitoring System

### Overview

As cities grow and urban living becomes the norm, the pressure on our natural resources is increasing. I noticed a lack of accessible tools that empower individuals to track their own environmental impact. With this in mind, I designed and built a system that monitors electricity usage and the quality of air and water in real time using affordable IoT hardware and interprets it using machine learning. It wasn't just about building a system—it was about helping people stay informed and make better daily decisions.

▭▭▭ *(Insert system dashboard or architecture image)*

### The Problem

In most Indian homes, we only become aware of our electricity usage when the monthly bill arrives. There is little visibility into how we consume vital resources like electricity, water, and clean air. Worse, there are no predictive systems in place for households to anticipate problems before they happen. Existing solutions are expensive, fragmented (focused on a single resource), and don't empower users with meaningful insights.

### My Motivation

I grew up watching my parents worry about high electricity bills and poor water quality, especially during the summer months. This project was my way of giving back—to design something that not only works but feels accessible and impactful for families like mine. I also wanted to explore how human-centered design and AI could come together in practical, grounded ways.

### Project Goals

- Monitor air, water, and electricity usage in real-time
- Predict air and water quality for the next 7 days
- Alert users when thresholds are exceeded (pollution, usage, etc.)
- Design a dashboard that's simple, clear, and meaningful
- Keep hardware and implementation affordable for everyday homes

### Design Process

### 1. Research & Discovery

I reviewed existing smart meters, IoT projects, and environmental monitoring apps. I realized most of them required expensive setups or only targeted a single resource. More importantly, they didn't involve users meaningfully. I talked to a few local families and asked: *"Would you use* *something that told you your air was unsafe or you were overusing water?"* The answer was unanimously yes.

□□□ *(Insert user persona or research process image)*

**2. Ideation & Early Sketches**

I brainstormed how to design a holistic system that could be built cheaply but provide powerful insights. I focused on these data points:

- Electricity: Amperes (via ACS712)
- Air: PPM of gases like $CO_2$, $NO_x$, ammonia (via MQ135)
- Water: Turbidity, pH, and temperature (using DHT11 and pH sensors)

□□□ *(Insert early sketches or whiteboard photo)*

**3. Building the System**

I connected sensors to an Arduino Uno and used a NodeMCU for WiFi connectivity. Real-time data was pushed to Google Sheets and Adafruit dashboards. Data cleaning and transformation were handled with Python. To forecast air and water quality, I trained multiple models: LSTM, ARIMA, and Random Forest Regressor.

□□□ *(Insert circuit diagram or photo of hardware setup)*

**4. Designing the Dashboard**

I created a web application where users could:

- Log in securely
- View live air/water/electricity data
- View a 7-day forecast for air and water
- Get alerts if electricity usage or pollution levels crossed thresholds

□□□ *(Insert screenshots or wireframes of dashboard)*

**5. User Journey**

A typical user experience looks like this:

- User logs in to the dashboard using their home ID
- System displays real-time air and water quality values
- Dashboard alerts the user if any reading exceeds safety limits
- Forecast section helps them prepare for changes in water or air quality
- User adjusts resource usage based on this feedback

□□□ *(Insert user journey diagram or storyboard)*

## 6. Testing & Feedback

I tested the dashboard with my family and a few neighbors. Some initial feedback included:

- "The numbers are useful, but what do they mean?"
- "I didn’t realize our water quality changed so much after rain."

Based on this, I added color-coded ranges and simple tooltips explaining what each reading meant. I also ensured that the dashboard was mobile-friendly so users could check updates anytime.

### Machine Learning Insights

Out of all the models tested, **Random Forest Regressor** performed best, especially considering the relatively small dataset (~400 entries). It gave me the lowest Root Mean Squared Error (RMSE) of 23.94.

□□□ *(Insert comparison graph or evaluation table)*

### System Architecture

- Sensors collect real-time environmental and usage data
- NodeMCU sends this data to Google Sheets using API integration
- Python scripts clean and transform the data, preparing it for modeling
- ML models predict future values and update the dashboard daily
- Adafruit handles electricity visualization; custom dashboard handles the rest

This setup keeps costs low and implementation easy, even for non-technical users.

### What Impacted Me Most

While testing the system at home, we noticed how poor the air quality was during cooking hours and how much electricity the refrigerator consumed overnight. My family began using the dashboard daily. My parents were proud of what I built, and more importantly, they changed how they used these resources. That shift in behavior was the most rewarding part of the project.

### What I Learned

- Designing for real users changes everything. Real impact comes from empathy, not features.
- Forecasting environmental data with small datasets is hard—but doable with the right ML model.
- Hardware debugging and circuit stability matter just as much as code or model performance.
- People don’t want data; they want meaning. The dashboard had to explain, not just display.

**If I Did It Again**

- I would design a mobile-first version of the dashboard with voice alerts for elderly users.
- I'd add noise and gas sensors to track more pollution metrics.
- I'd collaborate with more families across income brackets to improve inclusivity.
- I'd explore adding an assistant to give tips based on the forecasts.

**Tools & Stack**

- **Hardware**: Arduino Uno, NodeMCU, MQ135, ACS712, DHT11, pH and turbidity sensors
- **Software**: Python (Pandas, Scikit-learn), Google Sheets API, Adafruit IO
- **ML Models**: Random Forest Regressor, ARIMA, LSTM
- **Frontend**: HTML, CSS, JS (for dashboard)

**My Role**

- Full system design: hardware, data pipeline, ML modeling
- UX design: dashboard architecture, flow, alert logic
- Frontend development and sensor integration

**Final Thoughts**

This wasn't a flashy project, but it was deeply personal. It combined my love for engineering with a belief that technology should serve people in practical, immediate ways. I learned to build not just for performance, but for purpose.

**Vision**

I envision this system being adopted in housing colonies, schools, and rural communities where resource awareness is critical but access to smart technology is limited. With multilingual support and localized alerts, it can become a true community-level monitoring tool that empowers people to protect their health and reduce waste.

## Case Study 2: Survival of the Fittest

### Overview

This project began with a constraint — designing for a narrow domestic passageway. Instead of seeing this as a limitation, I saw it as an opportunity to reimagine fitness and presence in VR. The result was a physically interactive experience that transforms everyday movement into a game-like mission, motivating users to jump, squat, and push their way through a suspenseful, apocalyptic hallway — all from the comfort (and constraints) of their own home.

▭▭▭ *(Insert image of in-game hallway scene)*

### The Problem

Most VR fitness experiences assume a large play area, yet the average home doesn't offer that. My goal was to create an immersive VR experience that fits within a **3.2 ft wide × 10 ft long** hallway — a ubiquitous, often overlooked space in many homes. It needed to feel purposeful, cinematic, and physical — all within a tight physical footprint.

### Design Goals

- Use limited physical space to inspire movement and immersion
- Make players feel like they are progressing forward through action
- Create spatial tension that reinforces narrative urgency
- Keep the experience intuitive without needing visual explanations
- Motivate through embodiment rather than gamified scoring alone

### Setting & Spatial Constraints

- Width: ~1m (3.2 ft)
- Length: ~3m (10 ft)
- Ceiling: ~2.4m (8 ft)

Rationale:

- Found in most homes
- Safe to use for in-place movement
- Allows for seated, standing, or squat-based input

▭▭▭ *(Insert sketch or dimensions layout of hallway)*

### Movement as Input

The design mapped specific physical actions to movement in the virtual world:

- **Jumping Jacks → 0.8m forward**
- **Bodyweight Squats → 1.5m forward**

- **Shadow Boxing → breaks through virtual walls**

Each movement served as a mechanic, not just a fitness goal. The goal was to make actions feel like progression, not repetition.

▭▭▭ *(Insert image showing avatar actions or animation triggers)*

**Prototype Design**

The experience was broken into 3 distinct scenes:

**Scene 1: Warm-Up**

- Light jumping jacks and squats
- Orientation to space and controls

**Scene 2: Main Mission**

- Use squats and jumping jacks to escape a collapsing hallway
- Must shadow-box through debris and locked barriers

**Scene 3: Mission Accomplished**

- Breathing space, cool down visuals, and light feedback

▭▭▭ *(Insert story flow or scene diagram)*

**Tools Used**

- **Engine**: Unity 2021.3.45f1
- **VR Headset**: Meta Quest 2
- **Toolkit**: XR Interaction Toolkit
- **Animation**: Mixamo
- **Assets**: Unity Asset Store

**User Testing**

Two users tested the experience in similar hallway conditions. Both scored **87.5/100** on the System Usability Scale (SUS).

**Key Feedback:**

- "I felt exhausted — but in a good way."
- "I forgot I was working out."
- "Captions would help, especially in noisy homes."
- "The hallway felt suspenseful, not restrictive."

□□□ *(Insert quote cards or SUS bar chart)*

**Design Learnings**

- **Context-aware spatial mapping**: The real hallway shaped the virtual one.
- **Embodied interaction**: Users were more engaged when they forgot it was exercise.
- **Minimalist HUDs**: Audio worked well, but captions improved accessibility.

**Post-Test Improvements**

- Added **captions** to support noisy environments
- Improved **cue clarity** with timed animations
- Considered adding **leaderboards and timers** to support replayability
- Revised **punch interaction** for better responsiveness

**What I Learned**

Design thrives under constraints. By designing for tight spaces, I was forced to prioritize clarity, movement, and immersion. The hallway became more than a backdrop — it was a co-actor, shaping the pace, tension, and physicality of the story.

**Reflection**

- Design doesn't begin with a feature list; it begins with what the space allows.
- Motivation doesn't always come from scores — it can come from embodiment.
- Simple mechanics like squats and punches can be deeply immersive when framed within urgency and story.

□□□ *(Insert before/after improvements or user reaction photos)*

**Vision**

This prototype lays the groundwork for home-based mixed reality experiences that are compact, embodied, and emotionally engaging. With minor adjustments, it could be scaled for:

- Apartments or dorms
- Fitness routines disguised as missions
- Therapy or rehab gamification

I'd love to expand this into a multi-chapter fitness story designed entirely for overlooked corners of our homes — hallways, landings, bedrooms — transforming daily space into stages for presence and play.