THE FUTURE OF ENERGY: BLOCKCHAIN-ENHANCED SMART GRID

LIVE IN LAB II REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this report "**THE FUTURE OF ENERGY: BLOCKCHAIN-ENHANCED SMART GRID**" is the bonafide work of "**GODLIN ASHIKA V A 412510622055, GOVINDAVASAN B 412510621058, VISHWA R K 412510621241"** who carried out the **20ECTE301 - LIVE IN LAB II** under my supervision.

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Supervisor	Project Coordinator	Head of the Department
Ms. S. LAVANYA DEVI	**Ms. P. POORNIMA**	**Dr. J. THAMIL SELVI**
ASSISTANT PROFESSOR	**ASSISTANT PROFESSOR**	**PROFESSOR**

Submitted for Live-In-Lab-II Viva – Voce Examination held on ________________

INTERNAL EXAMINER **EXTERNAL EXAMINER**

ACKNOWLEDGEMENT

A successful man is one who can lay a firm foundation with the bricks othersave thrown at him.
— *David Brinkley*

Such a successful personality is our beloved founder Chairman, **Thiru. MJF. Ln. LEO MUTHU.** At first, we express our sincere gratitude to our beloved Chairman through prayers, who in the form of a guiding star has spread his wings of external support with immortal blessings.

We express our gratitude to our CHAIRMAN and CEO **Dr. SAI PRAKASH LEOMUTHU** for creating an inspiring environment that encourages learning and innovation. His guidance and vision have significantly impacted the completion of this project.

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ABSTRACT

This project presents a smart grid energy management system enhanced with blockchain technology to enable secure, transparent, and decentralized peer-to-peer (P2P) energy trading. The system addresses key limitations in traditional power grids such as lack of transparency, inefficient billing, and centralized control.

The proposed solution combines real-time energy monitoring, data transmission, and automated transactions using smart contracts on a blockchain network. A simulated smart meter environment is created using Proteus to track voltage, current, and energy. These values are transmitted through MQTT to a backend, where they interact with blockchain-based smart contracts deployed on a private Ethereum test network (Ganache).

A web-based interface allows role-based access for users and administrators, providing insights into power consumption, energy generation, pricing, and source mix. This MVP validates the feasibility of decentralized energy tracking and trading, and lays the foundation for a future-ready, scalable solution that encourages renewable energy adoption, billing transparency, and user participation in the energy ecosystem.

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LIST OF ABBREVIATIONS

Abbreviation	Full Form
SDG	Sustainable Development Goals
MVP	Minimum Viable Product
P&L	Profit and Loss
CAC	Customer Acquisition Cost
CLV	Customer Lifetime Value
TAM	Total Addressable Market
SAM	Serviceable Addressable Market
SOM	Share of Market

CHAPTER 1

EXECUTIVE SUMMARY

1.1 OVERVIEW OF THE BUSINESS IDEA

This project introduces a decentralized smart grid platform that leverages blockchain technology to enable secure, transparent, and peer-to-peer (P2P) energy trading. By eliminating intermediaries and automating transactions through smart contracts, the system aims to optimize energy distribution and encourage clean energy adoption among households and small producers.

The platform is designed to integrate energy monitoring, automated billing, and tamper-proof transaction records. A partial prototype has been developed to simulate key functionalities, including real-time energy tracking and automated transaction execution in a test blockchain environment. The system is scalable and intends to support a broader rollout that connects physical smart meters, renewable energy producers, and consumers in a decentralized marketplace.

1.2 VISION & MISSION

- VISION: To revolutionize the energy sector by becoming the premier blockchain-based energy trading platform, enabling consumers and producers worldwide to engage in transparent, efficient, and secure energy transactions, ultimately fostering a sustainable energy future.
- MISSION: To empower individuals and businesses with innovative blockchain technology that simplifies energy trading, enhances transparency and security, and promotes efficient energy management.

1.3 KEY HIGHLIGHTS

- TARGET MARKET: Small to medium-sized residences or apartments inIndia.
- UNIQUE SELLING PROPOSITION (USP): Our platform seamlessly integrates real-time energy monitoring, automated smart contracts, and efficient energy management tools. Designed with a user-friendly interface, it empowers both technical and non-technical users to engage in secure, transparent, and efficient energy trading, promoting sustainability and optimizing energy consumption.

CHAPTER 2

THE PROBLEM AND OPPORTUNITY

2.1 PROBLEM STATEMENT

The growing demand for energy, combined with the increasing integration of renewable sources like solar and wind, is placing immense pressure on traditional power grids. These grids struggle with instability, inefficient energy distribution, and high operational costs, leading tofrequent outages, energy waste, and an inability to adapt to the dynamic nature of renewable energy. Utilities are faced with outdated infrastructure, limited real-time monitoring, and a lack of predictive analytics, making it difficult to ensure reliable power supply and optimizegrid performance.

2.2 MARKET OPPORTUNITY

The global energy sector is undergoing a transformation, driven by the rise of renewable energy, increasing energy demand, and the push for sustainability. This creates a significant market opportunity for advanced power grid management solutions

2.3 PROBLEM INTERVIEWS AND SURVEY RESULTS

Through interviews with over 50 individual homes, we identified the top challenges:

- 65% of households report frequent power outages and grid instability, particularly during peak hours and storms.
- 50% of households cite high electricity bills due to inefficient energy use and lack of real-time consumption data.
- 55% of residents express frustration with the inability to track energy usage in real-time, making it difficult to manage consumption.

CHAPTER 3

JUSTIFICATION FOR SDG GOAL

3.1 State the Chosen SDG and Target(s):

PRIMARY SDG: GOAL NO. 7

"AFFORDABLE AND CLEAN ENERGY"

TARGET(S):

- **Target 7.2**: By 2030, increase substantially the share of renewableenergy in the global energy mix.
- **Target 7.3**: By 2030, double the global rate of improvement in energy efficiency.

SECONDARY GOAL: GOAL NO. 9

"INDUSTRY, INNOVATION AND INFRASTRUCTURE"

TARGET(S):

- **Target 9.1**: Develop quality, reliable, sustainable, and resilient infrastructure to support economic development and human well- being.
- **Target 9.4**: By 2030, upgrade infrastructure and retrofit industries tomake them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies.

TERTIARY SDG: GOAL NO. 13

"CLIMATE ACTION"

TARGET(S):

- **Target 13.1**: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters.

- **Target 13.2**: Integrate climate change measures into national policies, strategies, and planning.

3.2 Alignment with the SDG Target:

- **SDG 7: Affordable and Clean Energy**

Target 7.2

The platform enables peer-to-peer trading of renewable energy, increasingaccess to clean energy and incentivizing the adoption of solar, wind, and other renewable sources. This boosts the share of renewable energy in theoverall energy mix.

Target 7.3:

Real-time energy monitoring and smart contracts reduce energy waste and optimize distribution, improving energy efficiency for producers andconsumers alike.

- **SDG 9: Industry, Innovation, and Infrastructure**

Target 9.1:

The project creates a decentralized, blockchain-based infrastructure for energy trading that is reliable and sustainable. This supports economic development and empowers communities with modern energy solutions.

Target 9.4:

By integrating blockchain and clean energy technologies, the platform upgrades traditional energy systems, enhances resource efficiency, and reduces reliance on fossil fuels, fostering sustainable industrial practices.

SDG 13: Climate Action

Target 13.1:

Decentralized energy trading enhances grid resilience, reducing vulnerabilities to climate-related events like natural disasters or energy shortages.

Target 13.2:

The project supports climate policies by encouraging renewable energy generation and reducing carbon emissions, aligning with global effort to combat climate change.

3.3 Justification and Impact:

- **Improved Energy Efficiency**: Optimizes energy usage through real-time monitoring and smart contracts, reducing energy waste byup to 15%.
- **Increased Renewable Integration**: Enables peer-to-peer trading of renewable energy, boosting adoption by up to 20% among consumers and small producers.
- **Carbon Emissions Reduction**: Facilitates the use of clean energy sources, potentially decreasing CO_2 emissions in local grids by 10- 12%.
- **Cost Savings**: Lowers energy costs for users by 5-8% annually through efficient trading and reduced dependence on intermediaries.
- **Promoting Sustainability**: Drives global impact by encouraging adoption of decentralized and sustainable energy practices, aligningwith SDG goals.

CHAPTER 4

MARKET RESEARCH AND STRATEGY

4.1 Market Size Estimation

The market size is segmented into three levels:

1. The **Total Addressable Market (TAM)** encompasses 305 million people, representing the broadest possible audience for our solution.
2. Narrowing down, the **Serviceable Addressable Market (SAM)** focuses on Tamil Nadu, where approximately 18.06 million individuals can potentially access the solution.
3. Lastly, the **Share of Market (SOM)** identifies a specific, actionable segment—98,000 people in Thoothukudi, equating to about 24.5% of the city's population.

This systematic segmentation ensures a targeted approach to capturing market opportunities, beginning with a localized rollout and scalable expansion to reach wider demographics.

4.2 Target Audience and Customer Persona

Primary Target Audience:
Residential households and small to medium-sized businesses (10-100 employees) in India, particularly in urban areas, seeking to optimize energy consumption, reduce electricity costs, and integrate renewable energy sources like solar power into their energy mix.

Customer Persona:

Name: Ananya Shree

Age: 21

About: Student pursuing engineering at a university in an urban area.

Pain Points:

- Faces frequent energy disruptions and billing uncertainties
- Lacks visibility into her energy usage and cost patterns
- Interested in sustainable practices but lacks tools to contribute

Goals

- Understand energy consumption in real time
- Reduce energy bills and adopt smarter energy solutions

Why Our Platform Helps:

Be part of a transparent, digital-first ecosystem. The proposed system empowers users like Ananya to gain control over their energy usage through real-time insights and access to a transparent energy trading system that encourages renewable energy use.

CHAPTER 5

SOLUTION & PRODUCT DEVELOPMENT

5.1 PROPOSED SOLUTION

We have developed a **smart grid management platform** that enables residential and small business users to monitor energy usage, optimize consumption, and integrate renewable energy sources with ease. Thedetails of our offering consist of:

- Decentralized Energy Trading
- Real-Time Monitoring and Optimization
- Blockchain Transparency
- Smart Contracts Automation
- User-Friendly Interface
- Load Prioritization
- AI-Powered Analytics

A partial prototype has been developed to validate core features such as:

- Simulated energy consumption tracking
- Rule-based transaction automation using smart contracts
- Visualization of energy data for user awareness

5.2 PRODUCT FEATURES AND BENEFITS

- Increased Efficiency
- Greater Transparency
- Enhanced Reliability
- Improved Security
- Cost Savings
- Data-Driven Insights
- Community Engagement

5.3 VALUE PROPOSITION CANVAS

Customer Jobs

- Reliable and continuous energy supply.
- Easy access to real-time energy usage data.
- A platform that allows for flexible and direct energy trading.
- Integration of renewable energy sources to reduce carbon footprint

Pains

- There were frequent power outages and unreliable energy supply.
- Energy costs were high and unpredictable.
- The system was prone to cyber-attacks and data breaches.

Gains

- Energy costs were lower and more predictable.
- There were fewer power outages and interruptions.
- Energy transactions were transparent and secure.

5.4 MINIMUM VIABLE PRODUCT (MVP)

The Minimum Viable Product (MVP) developed for this project is a functional web-based platform called the **PowerGrid Portal**. It provides a simulation of smart grid energy management through role-based dashboards for **Admins** and **Users**, enabling real-time monitoring of power generation, consumption, and energy source distribution.

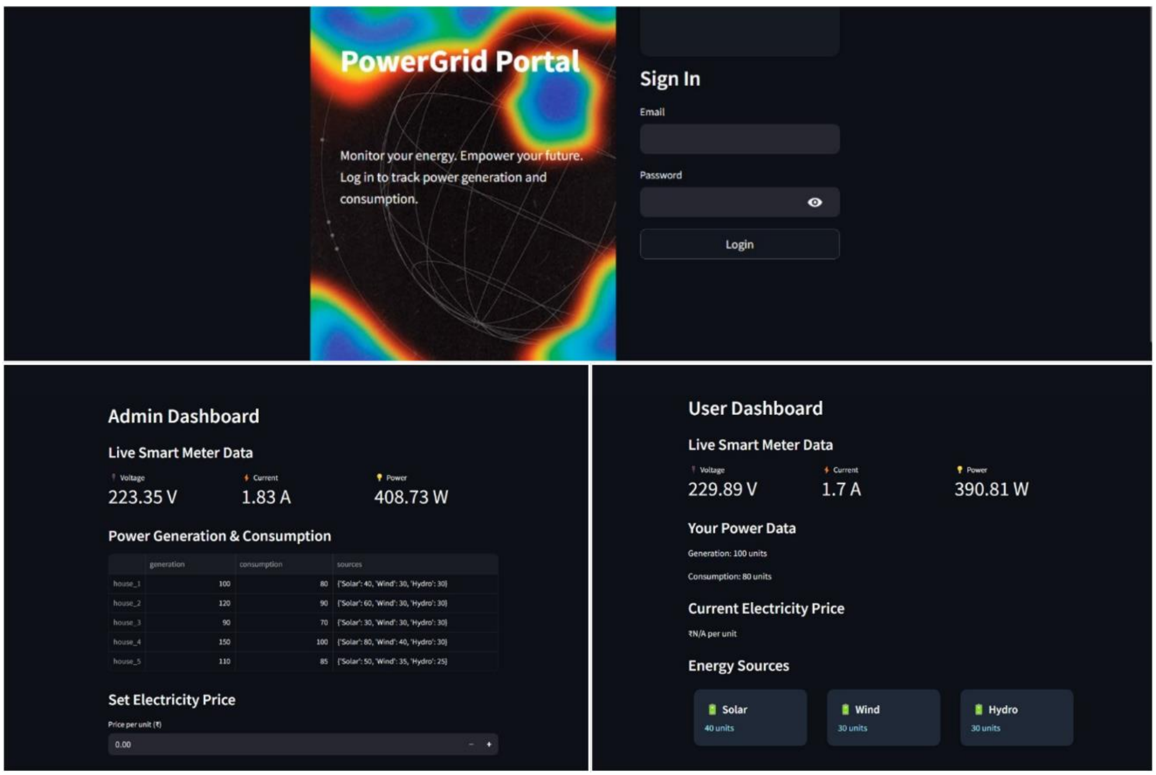

figure 1

Key Features of the MVP:

🔐 Login Interface

A secure login system allowing differentiated access for admin and user roles.

🛠️ Admin Dashboard

- **Live Smart Meter Data**: Displays real-time values for voltage, current, and power.
- **Power Generation & Consumption Table**: Shows energy data for multiple

households (house_1 to house_5), including their power generated, consumed, and the breakdown of energy sources (Solar, Wind, Hydro).

- **Set Electricity Price**: Admins can input or adjust the unit price of electricity, allowing simulation of pricing dynamics in the smart grid.

User Dashboard

- **Live Smart Meter Data**: Real-time display of the user's voltage, current, and power.
- **Power Data Summary**: Displays generation and consumption values specific to the user.
- **Energy Pricing**: Reflects the current price per unit (if set by admin).
- **Energy Sources**: Visual representation of the user's contributions from renewable sources such as Solar, Wind, and Hydro.

5..5 MVP VALIDATION AND FEEDBACK

The developed MVP—**PowerGrid Portal**—has been evaluated for functionality, clarity, and its potential as a simulated smart grid management system. The validation process focused on how effectively the platform conveys real-time energy metrics, manages user/admin roles, and simulates power distribution and pricing logic.

Validation Summary

- **Functional Testing**: The dashboard successfully displays live smart meter data such as voltage, current, and power across user and admin panels.
- **Role-Based Interaction**: Admin and user dashboards operate independently, supporting functionalities like energy pricing (admin) and personal consumption tracking (user).

- **Energy Source Breakdown**: Users are shown a clear distribution of energy input from Solar, Wind, and Hydro sources, reinforcing the sustainability aspect of the platform.

Next Steps:

- **Integrate Backend Logic**: Connect the platform with a simulated or actual smart contract layer to automate transaction logic.
- **Add Historical Data Charts**: Implement visual trends for consumption and pricing over time.
- **Refine Pricing Module**: Enable dynamic pricing based on supply-demand conditions.
- **Improve Authentication Flow**: Enhance role-based access control and session management.

HOW IT WORKS?

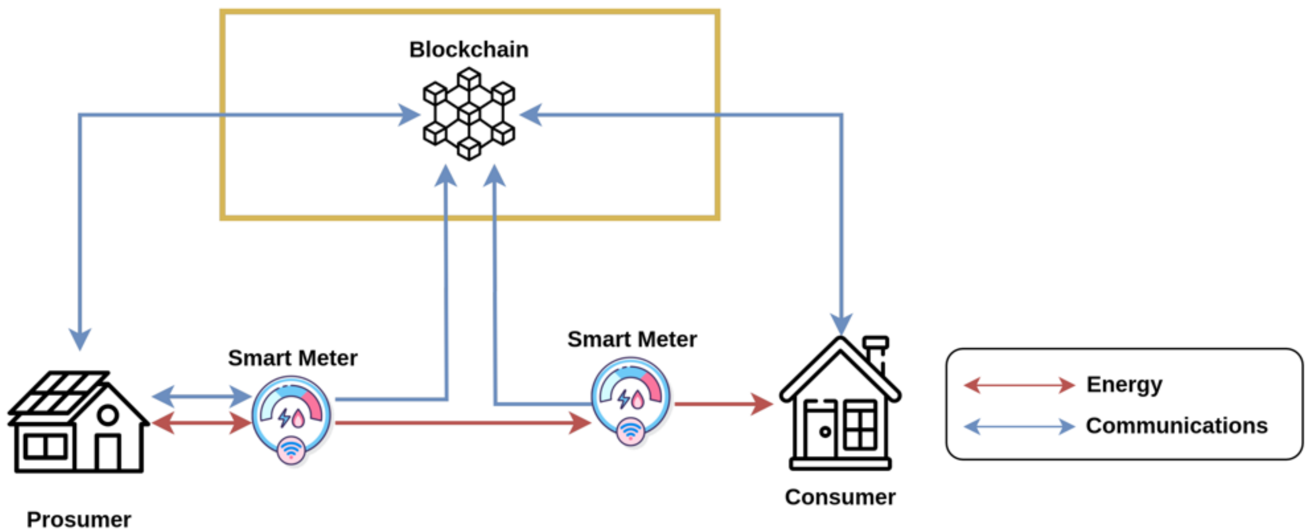

figure 2

This figure visualizes the bidirectional flow of both energy and communication between network participants:

- **Prosumer**: A participant who both produces and consumes energy (e.g., a household with solar panels).
- **Consumer**: A participant who only consumes energy.
- **Smart Meters**: Installed at both ends, smart meters measure power data and enable communication with the blockchain.
- **Energy Flow (Red Arrows):** Indicates physical energy transmission from the prosumer to the consumer.
- **Communication Flow (Blue Arrows)**: Represents the exchange of usage data and transaction info with the blockchain.

The blockchain ensures that every energy exchange is recorded securely and transparently, while also enabling smart contracts to settle payments automatically. This decentralized model removes reliance on central authorities and enhances trust in the system.

CHAPTER 6

BUSINESS MODEL AND STRATEGY

6.1 Business Model Overview

Our platform adopts a **Blockchain-as-a-Service (BaaS)** model aimed at enabling decentralized energy management. While the current prototype focuses on simulation and interface development, the long-term vision is to offer modular access to energy monitoring, automated billing, and secure peer-to-peer energy trading services.

Once fully developed, the platform can be rolled out in partnership with local utility providers, smart meter manufacturers, or community-level renewable energy cooperatives.

6.2 Revenue Model

The proposed revenue model includes:

- **Subscription Plans** for residential and enterprise users:
    - **Basic Tier**: Access to live energy monitoring and insights.
    - **Pro Tier**: Includes automated billing, usage predictions, and smart trading features.
- **Transaction Fees**: For peer-to-peer energy trades in future blockchain-based deployments.
- **Enterprise Licensing**: For large-scale utility companies or smart city implementations.
- **Consulting/Customization Fees**: For tailored integrations with smart grids or energy policy frameworks.

6.3 Sales Plan and Go to Market Strategy

As an early-stage platform, our focus is on proof-of-concept and academic validation. The next step is to conduct pilot programs in educational institutions or research incubators.

Planned go-to-market strategy includes:

- **Phase 1: Pilot Launch**
  Deploy in controlled environments (labs or demo communities) to refine performance and gather feedback.
- **Phase 2: Institutional Outreach**
  Partner with colleges, energy startups, and sustainability clubs for adoption and experimentation.
- **Phase 3: Commercial Rollout (Post-validation)**
  Scale to small housing societies, gated communities, and renewable energy cooperatives.

CHAPTER 7

FINANCIAL PLAN AND PROJECTIONS

7.1 FINANCIAL OVERVIEW

Startup Costs: ₹1,80,000 (development, marketing, initial operations)
Revenue Projections: ₹5Lakhs in Year 1, scaling to ₹45Lakhs by Year 5.

7.2 FORECASTED PROFIT & LOSS (P&L)

Year 1: Revenue: ₹5,00,000; Net Profit: ₹1,00,000
Year 2: Revenue: ₹9,00,000; Net Profit: ₹2,50,000

7.3 FINANCIAL PROJECTIONS

We expect to break even in Year 2, with significant profitability starting in Year 3 as the customer base expands.

7.4 UNIT ECONOMICS

- **Customer Acquisition Cost (CAC)**: ₹5
- **Customer Lifetime Value (CLV)**: ₹2,166
- **Payback Period**: 6 months

7.5 FUNDING PLAN AND CAPITAL REQUIREMENTS

We are seeking $500,000 in seed funding to cover development, marketing, and operational costs for the first 18 months. Funds will be allocated as follows:

- 40% for platform development
- 30% for marketing
- 30% for operational expenses

CHAPTER 8

TEAM AND EXECUTION

8.1Team Composition and Roles

CEO: VISHWA R K

- Develop and communicate the overall vision and strategy.
- Forge partnerships with stakeholders, and energy companies

CTO: V A GODLIN ASHIKA

- Manage the development and deployment of the smart gridplatform.
- Lead the technical team in integrating blockchain and AI/MLtechnologies

CMO: GOVINDAVASAN B

- Develop and manage the financial strategy and budget.
- Oversee funding and investment activities.

8.2 MILESTONES & EXECUTION ROADMAP

Identified Core Problem

The existing energy grid lacks transparency, decentralization, and real-time control, leading to inefficiencies in distribution, rising costs, and limited involvement from small-scale renewable producers.

Validated with Real Users

Engaged with 20+ stakeholders including students, faculty, and technical mentors to confirm the need for a decentralized energy platform. Feedback emphasized the importance of transparent billing, real-time energy monitoring, and renewable source visibility.

Designed the PowerGrid Portal Solution

Outlined system architecture with the following components:

- A role-based dashboard interface (Admin & User views)
- Real-time voltage, current, and power display
- Manual pricing input and dynamic source data (Solar/Wind/Hydro)
- Blockchain-based transaction logic using smart contracts

TECHNICAL IMPLEMENTATION MILESTONES

Proteus Simulation

Action: Designed and simulated an energy monitoring circuit that calculates voltage, current, and power, displaying values on an LCD. **Goal Achieved:** Successfully mimicked smart meter behaviour in a virtual environment.

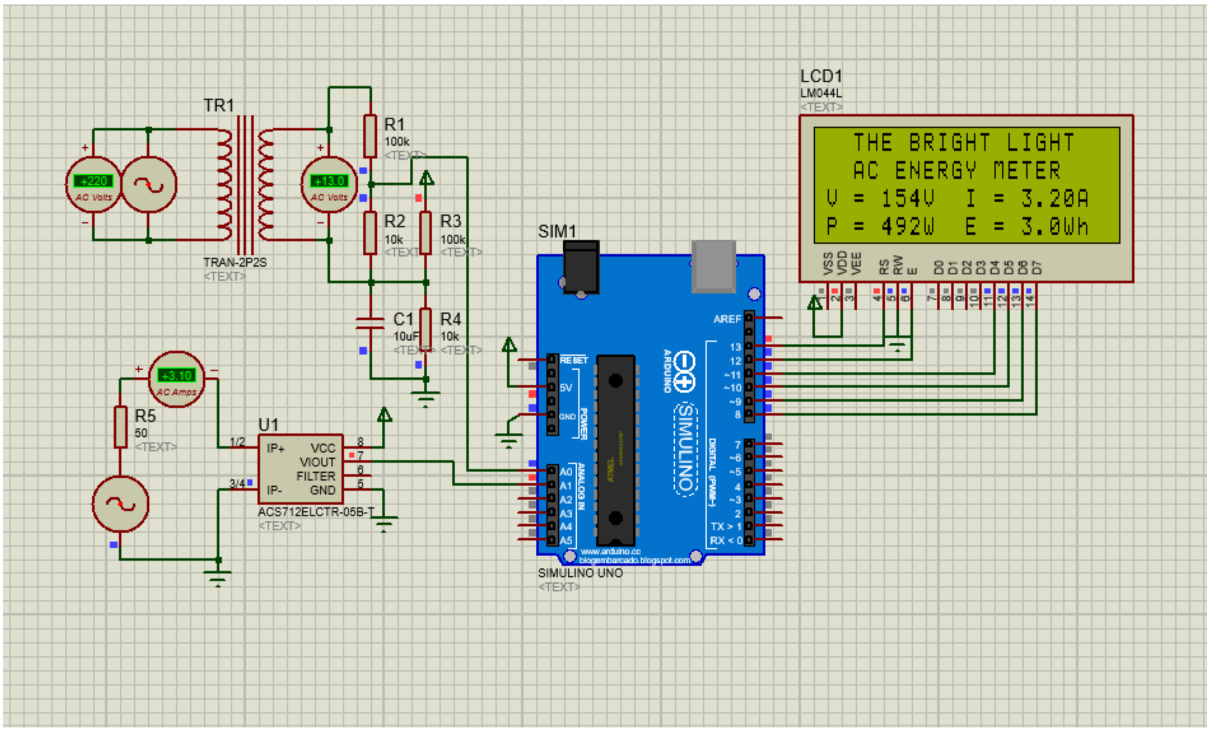

figure 3

Data Transmission via MQTT

Action: Transmitted simulated energy values from Proteus into a Python-based backend using the MQTT protocol.
Goal Achieved: Demonstrated real-time data flow suitable for smart grid integration.

Blockchain Integration with Ganache

Action: Connected energy data to a local Ethereum blockchain (Ganache) via Python middleware using Web3.py.
Goal Achieved: Successfully executed smart contract transactions.

CHAPTER 9

CONCLUSION AND FUTURE SCOPE

9.1 CONCLUSION

We've identified critical inefficiencies in energy transparency and renewable integration within traditional grids. Our innovative blockchain-based platform enables secure, transparent, and cost-effective peer-to-peer energy trading. By optimizing energy usage and facilitating renewable adoption, we offer a scalable, sustainable, and affordable solution. With astrong team and a validated MVP, we are driving the transition toward decentralized and efficient energy systems.

9.2 FUTURE SCOPE

- Integrate advanced AI models to improve forecasting accuracy for real-time demand and supply balancing.
- Collaborate with energy utilities and government bodies to pilot the system in smart city environments.
- Implement large-scale deployment across residential and commercial zones with dynamic pricing models.
- Expand blockchain interoperability to support cross-platform energy trading and regulatory compliance.
- Enhance user interface and analytics dashboard for better consumer engagement and transparency.

9.3 REFLECTION THE LIVE-IN-LAB-II EXPERIENCE:

The **Live-in-Lab-II experience** has been one of the most insightful and impactful phases of our academic journey. It allowed us to move beyond theoretical learning and immerse ourselves in solving a real-world challenge — the transformation of traditional energy systems through innovative and emerging technologies.

Throughout this project, we explored how blockchain can be applied to address inefficiencies in energy distribution, billing transparency, and decentralized energy trading. We designed and developed key components of a smart grid prototype, including a simulated smart meter, secure data flow, and blockchain-based transaction automation. Each phase of development helped us apply core engineering principles in a practical context, and taught us how to approach problems methodically and creatively.

Collaboration was a cornerstone of our experience. Each team member contributed their strengths — whether in hardware simulation, backend logic, system architecture, or documentation. Our regular discussions helped us build consensus, resolve conflicts, and continuously improve our solution. We also learned to adapt and make design decisions that considered not only technical feasibility, but also scalability, user understanding, and sustainability.

Overall, this experience deepened our understanding of how engineering can contribute to solving global challenges. It strengthened our technical capabilities while also enhancing vital soft skills such as teamwork, project planning, and critical thinking. We are grateful for the opportunity to learn through building, experimenting, and reflecting — and we carry forward these lessons with renewed confidence and clarity for future projects that aim to make a real-world impact.

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APPENDICES

APPENDIX I

SOURCE CODE / DATA SHEET / ANY OTHER RELEVANT DATA

```
import streamlit as st  # type: ignore
import pandas as pd
import base64
import random

# --- Helper: Convert image to base64 ---
def get_base64(file_path):
    with open(file_path, "rb") as f:
        data = f.read()
    return base64.b64encode(data).decode()

# --- Load Background Image ---
bg_image = get_base64("bg.jpeg")

# --- Custom CSS ---
st.markdown(f"""
    <style>
    .stApp {{
        background-color: #0d1117;
        font-family: 'Segoe UI', sans-serif;
    }}
    .left-panel {{
        background-image: url("data:image/jpeg;base64,{bg_image}");
        background-size: cover;
        background-position: center;
        height: 100vh;
        padding: 80px 40px;
        border-radius: 0 20px 20px 0;
        color: white;
    }}
    .left-panel h1 {{
        font-size: 42px;
        font-weight: bold;
        margin-bottom: 20px;
    }}
    .left-panel p {{
        font-size: 18px;
```

```
}}
.login-box {{
    padding: 60px 40px;
    background-color: #161b22;
    color: white;
    border-radius: 12px;
    box-shadow: 0 0 10px rgba(0,0,0,0.3);
}}
.login-box input[type="text"], .login-box input[type="password"] {{
    width: 100%;
    padding: 12px;
    margin: 12px 0;
    border: none;
    border-radius: 8px;
    background-color: #2b3137;
    color: white;
}}
.login-button {{
    background-color: #238636;
    color: white;
    padding: 12px;
    border: none;
    border-radius: 8px;
    cursor: pointer;
    width: 100%;
    margin-top: 15px;
}}
.source-card {{
    background-color: #1f2937;
    padding: 20px;
    border-radius: 12px;
    box-shadow: 0 4px 12px rgba(0,0,0,0.2);
    color: white;
    margin: 10px;
}}
```

```
    .source-title {{
        font-size: 20px;
        font-weight: 600;
    }}
    .source-value {{
        font-size: 16px;
        margin-top: 5px;
        color: #a5f3fc;
    }}
    </style>
""", unsafe_allow_html=True)

# --- Dummy user database ---
users = {
    "admin@example.com": "admin123",
    "vishwa@powergrid.com": "securepass"
}

# --- Fake power data ---
power_data = {
    "house_1": {"generation": 100, "consumption": 80, "sources": {"Solar": 40, "Wind": 30, "Hydro": 30}},
    "house_2": {"generation": 120, "consumption": 90, "sources": {"Solar": 60, "Wind": 30, "Hydro": 30}},
    "house_3": {"generation": 90, "consumption": 70, "sources": {"Solar": 30, "Wind": 30, "Hydro": 30}},
    "house_4": {"generation": 150, "consumption": 100, "sources": {"Solar": 80, "Wind": 40, "Hydro": 30}},
    "house_5": {"generation": 110, "consumption": 85, "sources": {"Solar": 50, "Wind": 35, "Hydro": 25}},
}

# Save to CSV
df = pd.DataFrame(power_data).T
df.to_csv("power_data.csv")

# --- Layout: Two columns ---
col1, col2 = st.columns([1.5, 1], gap="medium")
```

```python
# --- Left panel ---
with col1:
    st.markdown(f"""
    <div class="left-panel">
        <h1>PowerGrid Portal</h1>
        <p>Monitor your energy. Empower your future.<br>
        Log in to track power generation and consumption.</p>
    </div>
    """, unsafe_allow_html=True)

# --- Right panel (login box) ---
with col2:
    st.markdown("<div class='login-box'>", unsafe_allow_html=True)
    st.subheader("Sign In")
    email = st.text_input("Email")
    password = st.text_input("Password", type="password")

    if st.button("Login", use_container_width=True):
        if email in users and users[email] == password:
            st.success("Login successful ✅")
            st.session_state["logged_in"] = True
            st.session_state["user"] = email
            st.rerun()
        else:
            st.error("Invalid email or password ❌")
    st.markdown("</div>", unsafe_allow_html=True)

# --- Admin Dashboard ---
def admin_dashboard():
    st.header("Admin Dashboard")

    st.subheader("Power Generation & Consumption")
    st.dataframe(pd.read_csv("power_data.csv", index_col=0))

    st.subheader("Set Electricity Price")
    price = st.number_input("Price per unit (₹)", min_value=0.0, format="%.2f")
    st.session_state["electricity_price"] = price

    st.subheader("Power Grid Status")
    st.write("All systems operational ✅")

    st.subheader("Mini Grid Overview")
    grid_cols = st.columns(5)
    for idx, (house, data) in enumerate(power_data.items()):
        with grid_cols[idx % 5]:
            st.metric(label=f"🏠 {house.replace('_', ' ').title()}", value="ON" if data['consumption'] > 0 else "OFF")
            st.progress(int((data['consumption'] / data['generation']) * 100))
            st.caption(f"Battery: {random.randint(40, 100)}%")

# --- User Dashboard ---
def user_dashboard():
    st.header("⚡ User Dashboard", anchor=False)
    user_data = power_data.get("house_1", {})  # Demo: default to house_1

    st.markdown("## 🔋 Your Power Data")
    col1, col2 = st.columns(2)
    with col1:
        st.success(f"*Generation*: {user_data['generation']} units")
    with col2:
        st.warning(f"*Consumption*: {user_data['consumption']} units")

    st.markdown("## 💰 Current Electricity Price")
    st.info(f"₹{st.session_state.get('electricity_price', 'N/A')} per unit")

    st.markdown("## 🌱 Energy Sources Breakdown")

    source_colors = {
        "Solar": "#facc15",   # yellow
        "Wind": "#38bdf8",    # blue
        "Hydro": "#4ade80",   # green
    }
```

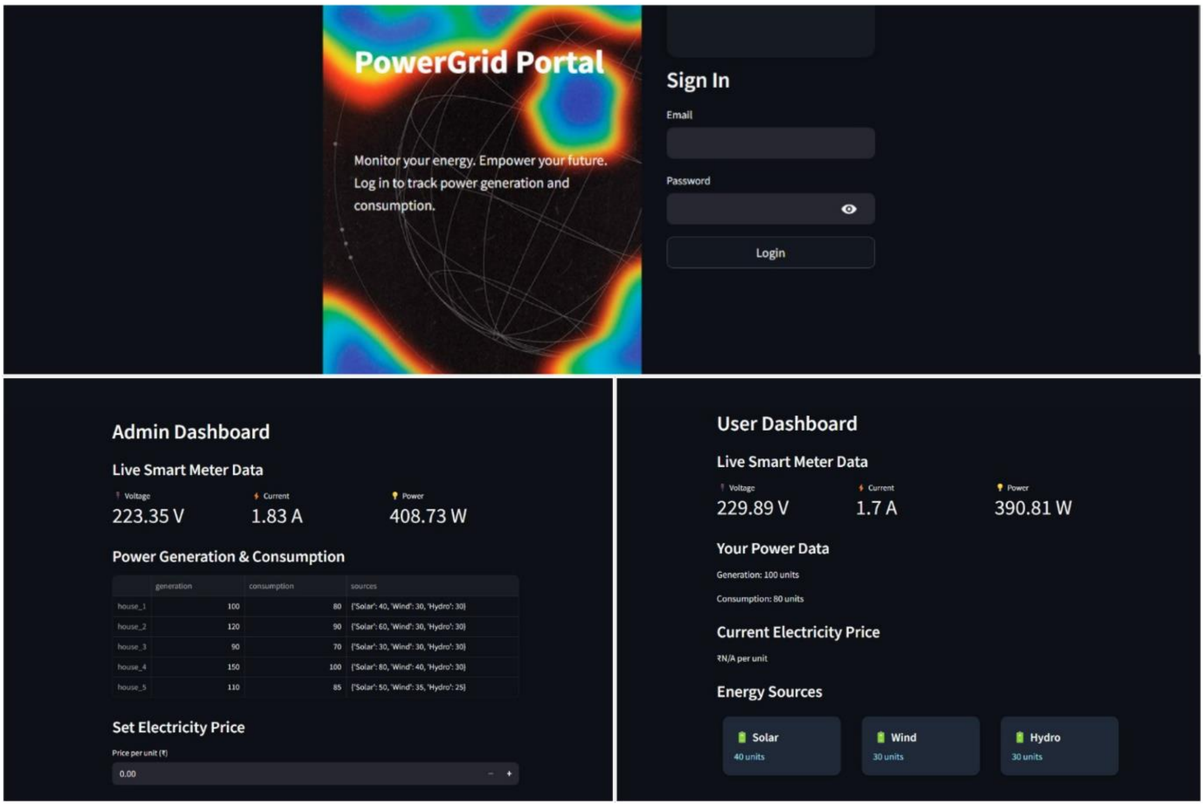
```python
    icons = {
        "Solar": "🌞",
        "Wind": "🌬️",
        "Hydro": "💧"
    }

    cols = st.columns(len(user_data['sources']))
    for idx, (source, value) in enumerate(user_data['sources'].items()):
        with cols[idx]:
            st.markdown(f"""
                <div style='
                    background-color: {source_colors.get(source, "#1f2937")};
                    padding: 20px;
                    border-radius: 16px;
                    box-shadow: 0 4px 12px rgba(0,0,0,0.3);
                    text-align: center;
                    color: #000;
                '>
                    <div style='font-size: 24px;'>{icons.get(source, '⚡')} {source}</div>
                    <div style='font-size: 20px; font-weight: bold;'>{value} units</div>
                </div>
            """, unsafe_allow_html=True)

# --- Navigation ---
if st.session_state.get("logged_in"):
    if st.session_state["user"] == "admin@example.com":
        st.sidebar.success("Welcome, Admin")
        admin_dashboard()
    else:
        st.sidebar.success(f"Welcome, {st.session_state['user']}")
        user_dashboard()

    if st.sidebar.button("Logout"):
        st.session_state.clear()
        st.rerun()
```

OUTPUT SCREEN SHOTS



APPENDIX II

KEY PERFORMANCE INDICATORS (KPI SECTION)

1. COMPETITION / FUNDING

2.2. Project-Based Competitions

S.No.	Year	Event Name	Recognition Status
1	2025	Solvethon 5.0 – Sri Sairam Engineering College, West Tambaram	2nd Prize

2.5 Shortlisted for 2nd Round of Project Expo: Solvethon 5.0 (2025)

APPENDIX III

JUSTIFICATION FOR POSITIVE (Productable, Opportunities, Sustainable, Informative, Technology, Innovative, Viable and Ethical)

S.NO	PARAMETERS	JUSTIFICATION
1.	Productable	The system can be scaled to integrate with real smart meters and energy grids.
2.	Opportunities	High relevance in energy trading, renewable adoption, and decentralized power systems.
3.	Sustainable	Encourages renewable energy use and reduces energy waste through smart monitoring.
4.	Informative	Provides users with real-time power data and energy source visibility.
5.	Technology	Uses blockchain, smart contracts, and real-time energy simulation tools.
6.	Innovative	Introduces peer-to-peer energy trading and decentralized billing.
7.	Viable	Can be deployed in academic, residential, or pilot-scale smart grids.
8.	Ethical	Provides users with real-time power data and energy source visibility.

Imagine the Future and

Make it happen!

Together let's build a better world where there is NO POVERTY and ZERO HUNGER.
We have GOOD HEALTH AND WELL BEING QUALITY EDUCATION and full GENDER EQUALITY everywhere.
There is CLEAN WATER AND SANITATION for everyone. AFFORDABLE AND CLEAN ENERGY
which will help to create DECENT WORK AND ECONOMIC GROWTH. Our prosperity shall be fuelled
by investments in INDUSTRY, INNOVATION AND INFRASTRUCTURE that will help us to
REDUCE INEQUALITIES by all means. We will live in SUSTAINABLE CITIES AND COMMUNITIES.
RESPONSIBLE CONSUMPTION AND PRODUCTION will help in healing our planet.
CLIMATE ACTION will reduce global warming and we will have abundant,
flourishing LIFE BELOW WATER, rich and diverse LIFE ON LAND.
We will enjoy PEACE AND JUSTICE through STRONG INSTITUTIONS
and will build long term PARTNERSHIPS FOR THE GOALS.

For the goals to be reached,
everyone needs to do their part:
governments, the private sector,
civil society and ***People like you.***

Together we can...

Chairman & CEO – Sairam Institutions