

# Air Quality Sensor Deployment in Zenica Using Helium LoRaWAN

## Executive Summary

Zenica, one of the Balkan region's most industrialized cities, faces severe air pollution challenges, yet it currently relies on only a handful of traditional monitoring stations [1]. This project proposes a **decentralized, citywide air quality sensor network** leveraging Helium's LoRaWAN (Long Range Wide Area Network) infrastructure and blockchain-based incentive model. By deploying dozens of low-cost sensors across Zenica, connected via *The People's Network* (Helium), we aim to deliver real-time, hyper-local air quality data to citizens and authorities. This forward-looking initiative aligns with smart-city principles and **DePIN** (Decentralized Physical Infrastructure Network) values by empowering the community to build and maintain critical environmental monitoring infrastructure.

### Key Highlights:

- **Community-Driven Monitoring:** The network will involve local stakeholders in hosting sensors and Helium hotspots, incentivized by Helium's token rewards and a community engagement program.
- **Cutting-Edge Technology:** Utilizes Helium's global LoRaWAN coverage (over 2,300 cities globally [2]) to ensure wide, low-cost connectivity, and integrates a blockchain (Helium on Solana) for secure, transparent data credit usage and reward distribution.
- **Smart-City Data Platform:** Delivers an open-access, interactive online dashboard with real-time Air Quality Index (AQI) maps, trend analysis, and alerts, enabling evidence-based action to improve public health and urban planning.
- **Sustainability & Scale:** Combines a robust maintenance plan and innovative revenue strategies (token incentives, data services) to ensure the network's longevity. The model is designed to be replicable in other Balkan cities facing similar pollution issues, positioning Zenica as a pioneer in decentralized environmental monitoring.

## Introduction and Background

Zenica is historically known as a steel industry hub, and its air quality has been a source of concern for decades [3]. With limited official monitoring (only 3–4 stations in the city [1], which is questionable in itself - some sites that show air quality analysis show these 3-4 stations, while the Federal Hydrometeorological Institute lists only two stations for measuring air pollution at its meteorological stations), residents often lack timely information about the air they breathe. Bosnia and Herzegovina has ranked among the world's worst for air pollution-related mortality [4], highlighting the urgent need for better monitoring and community engagement. Traditional air quality stations (like the large stationary unit shown in Keene, NH) are expensive and sparse [5][6], leaving critical gaps in spatial coverage.

*Traditional fixed Air Quality Monitoring Station (Keene, NH) – such installations are costly and limited in number[5]. This project uses low-cost, decentralized sensors to achieve citywide coverage.*

**Opportunity:** Advances in IoT and wireless technology now allow a different approach. **LoRaWAN** is a long-range, low-power wireless protocol ideal for connecting distributed sensors in urban environments. Notably, a city-scale LoRaWAN network deployed in Southampton, UK demonstrated that LoRaWAN is a reliable solution for real-time urban air quality monitoring[7][8]. Helium’s global LoRaWAN network further offers a decentralized, incentive-driven connectivity layer. **Helium** is the world’s largest public LoRaWAN network, with over a million hotspots deployed by individuals globally[9], covering **1.2 million+ sq. miles** across thousands of cities[2]. By tapping into Helium, our sensors can send data through community-run hotspots, dramatically lowering infrastructure costs while *rewarding local participants* who provide coverage[10].

**Smart-City & DePIN Alignment:** This project exemplifies Decentralized Physical Infrastructure Networks (DePIN) in action[9]. Instead of top-down deployment, it empowers citizens to host sensors and network nodes, backed by blockchain tokens for coordination and incentives. This approach not only produces dense, high-resolution environmental data, but also fosters public trust and engagement. Every citizen can be a stakeholder in improving air quality – a critical aspect for Zenica where civil society has long fought for cleaner air amidst industrial pollution[3].

In summary, the **Air Quality Sensor Deployment in Zenica** will leverage Helium LoRaWAN technology, blockchain incentives, and community activism to create an innovative, scalable model for environmental monitoring. The sections below detail the project objectives, technical architecture, deployment plan, data platform, token integration, community model, sustainability strategy, timeline, and budget.

## Objectives

Our project’s objectives are both technical and social, reflecting a holistic approach to smart-city innovation:

- **High-Resolution Air Quality Mapping:** Deploy a network of sensors to continuously measure key pollutants (e.g. PM2.5, PM10, NO<sub>2</sub>, CO) across Zenica, providing street-level and real-time air quality data.
- **Real-Time Data Access & Awareness:** Develop a public web and mobile dashboard for citizens and officials to view current air quality indices, historical trends, and health advisories, thereby raising awareness and enabling data-driven decisions.
- **Community Empowerment:** Involve local residents, schools, and organizations in hosting sensors and Helium hotspots, turning the community into active contributors. Provide educational workshops on air pollution and sensor technology to foster citizen science.

- **Leverage Helium’s Decentralized Network:** Utilize Helium’s LoRaWAN coverage to avoid building a private network from scratch. By using **Helium Data Credits** (DC) for connectivity, minimize operating costs (on the order of ~\$1 per device per year for typical data rates[11]) while ensuring reliable data delivery.
- **Blockchain and Token Integration:** Integrate Helium’s token system (HNT on Solana, and IOT subtoken) to incentivize participation. Hotspot hosts in Zenica will earn IOT tokens for providing network coverage, which can be converted to HNT[12], creating a novel “**earn by contributing**” model for clean air efforts.
- **Sustainability & Expansion:** Establish a maintenance plan and revenue model (via token rewards, sponsorships, and potential data services) to sustain the network long-term. Use Zenica as a pilot blueprint to scale the solution to other polluted cities in the Balkans, multiplying the impact.
- **DePIN Awareness & Smart City Enablement:** Use the Zenica deployment as a *live, real-world* demonstration of **DePIN (Decentralized Physical Infrastructure Networks)**— showing citizens how community-owned connectivity and sensors work in practice. At the same time, advance Zenica toward the **Smart City** concept by combining **IoT sensors + data analytics + AI** to deliver clearer insights (hotspots, trends, anomaly detection), smarter health advisories, and better decision support for urban sustainability and infrastructure planning.

## System Architecture and Data Flow

The system architecture is designed to reliably collect sensor readings from the field and channel them to a cloud platform, using Helium’s decentralized infrastructure as the backbone. It consists of several layers:

- 1. Sensor Nodes (End Devices):** Each node is an IoT air quality sensor package measuring pollutants and atmospheric conditions. The node includes a LoRaWAN radio transceiver that periodically uplinks data packets over the air. Typical nodes will measure particulate matter (PM2.5/PM10) using laser scattering sensors and gases like NO<sub>2</sub>, CO using electrochemical sensors, along with temperature and humidity for calibration. The sensor data is encoded in a compact LoRaWAN payload (e.g. using CayenneLPP or similar formats).
- 2. Helium Hotspots (Gateways):** When a sensor transmits, the radio signal is received by any nearby Helium hotspots – community-operated LoRaWAN gateways that form **The People’s Network**. Unlike private networks, Helium’s gateways are run by individuals incentivized with crypto tokens, enabling a **permissionless, wide-area network**[13][14]. In Zenica, we will either utilize existing Helium coverage or deploy a few Helium-compatible hotspots at strategic locations (e.g. city center, near industrial zone) to ensure citywide LoRaWAN coverage. Hotspots forward encrypted sensor data to Helium’s cloud infrastructure.
- 3. Helium Network and Blockchain Layer:** Helium’s network server (Helium Packet Router) routes incoming LoRaWAN data to the appropriate application while also interfacing with Helium’s blockchain for accounting[15]. When a hotspot forwards a sensor’s packet, Helium’s system awards the hotspot operator **data transfer rewards** (in IOT tokens) and deducts a tiny

amount of Data Credits from our project's balance to pay for the delivery. All of this happens behind the scenes within seconds, leveraging Helium's *distributed ledger on Solana* for settlement and device addressing. **One Data Credit equals \$0.00001 USD**[16], fixed in value, which makes data costs predictable and insulated from crypto volatility[17]. For example, a 24-byte sensor reading costs 1 DC (i.e. 0.001¢); even sending data every few minutes amounts to only ~\$1 per year per device[18][11]. Helium's architecture thus provides *massive cost savings* and scalability over traditional cellular or Wi-Fi solutions.

**4. Data Routing and Backend:** Through Helium's Console or the Open LNS (LoRaWAN Network Server) Integration, we will configure all Zenica sensors to forward their data to our cloud application server. Helium allows flexible integrations (HTTPs endpoints, MQTT, etc.) once devices are provisioned. Each sensor's data payload, upon reaching Helium's router, is decrypted (using our credentials) and then relayed to our backend in real-time. The data flow is secure (LoRaWAN AES-128 encryption at device level) and reliable – if multiple hotspots pick up the same packet, Helium de-duplicates it[19] to avoid double counting.

**5. Cloud Database and Processing:** Our backend (hosted on a scalable cloud platform) receives incoming sensor data streams. It will validate and store readings in a time-series database. Basic calibration adjustments or QA checks (e.g. removing outliers, sensor drift correction) are applied here. We also integrate external data like official station readings (for calibration reference) and weather data (wind, etc. for context).

**6. Data Visualization & API Layer:** Processed data is made available to end-users through both a web UI and an open API. The architecture exposes endpoints for the front-end to fetch current conditions or historical data queries. Additionally, open data enthusiasts or researchers can pull data via a documented API, promoting transparency and further innovation (e.g. local apps or academic studies).

**6a. AI Analytics & Pollution Forecasting (Optional Enhancement):** If project resources allow, we will add an AI layer to turn raw measurements into more understandable insights and short-term forecasts. Using current sensor readings, local weather conditions (e.g., wind, temperature inversions, humidity), and historical trends, machine-learning models can provide **near real-time interpretation** (what's causing spikes, how unusual it is) and **predictions of future pollution levels** over the next hours or days—similar to how meteorologists forecast weather. These forecasts would be presented in simple citizen-friendly formats (e.g., “expected improvement after 14:00,” “high-risk evening window,” “likely smog accumulation overnight”), helping people plan daily activities and extending the project beyond monitoring into **actionable air-quality forecasting**.

**Data Flow Summary:** A pollutant sensor reading travels from a **Zenica rooftop or backyard**, via radio to a **Helium hotspot**, then through Helium's global LoRaWAN network to our **cloud server**, and finally to the **user dashboard** – all in near real-time (typically under a minute delay). This flow is illustrated below:

- **Sensor Node → Helium Hotspot:** LoRaWAN wireless transmission (10+ km range in urban area).

- **Hotspot → Helium Network Server (HPR):** Internet backhaul (the hotspot sends data to Helium’s cloud router)[15].
- **Helium Router → Application Server:** Encrypted payload is forwarded according to routing rules to our server (via HTTP/MQTT).
- **Application Server → Database:** Data stored and analyzed.
- **User Access:** Dashboard queries the database for visualization; alerts are generated if thresholds exceeded.

This serverless, distributed pipeline can scale easily as we add more sensors or as data frequency increases. Because Helium’s IoT network is **decentralized and massive**, adding a new sensor in Zenica does not require deploying a new gateway – any existing hotspot can carry its traffic. This is a key benefit: we essentially outsource connectivity to a *crowd-sourced telecom* that already covers extensive areas at a fraction of the cost[10][20].

## Technical Hardware Overview

**Sensor Hardware:** Each sensing unit will be built or procured to meet outdoor deployment needs (weather resistance, low power, and accurate measurements). We are considering robust LoRaWAN-compatible sensor modules such as the **Dragino LAQ4** or **SenseCAP** series, which integrate particulate sensors and gas sensors with LoRaWAN radios. Alternatively, a custom-built unit can be made using a microcontroller (e.g. Arduino or STM32 LoRaWAN board) plus discrete sensors. Key components of a typical node include:

- **MCU & LoRa Transceiver:** For example, an STM32-based LoRaWAN module (like ST B-L072Z-LRWAN1 Discovery kit[21]) or a Helium-compatible Arduino (such as a SeeedStudio LoRa-E5 module). This handles sensor readings and LoRaWAN communication (supporting EU868 MHz frequency plan used in Bosnia).
- **Particulate Matter Sensor:** A laser scatter sensor (Plantower PMS7003 or Nova SDS011, etc.) capable of measuring fine dust (PM2.5 and PM10). These provide concentrations of airborne particles – critical since Zenica’s pollution is often driven by particulate emissions from coal and steel operations.
- **Gas Sensors:** We will target NO<sub>2</sub> and CO as priority gases (by-product of traffic and industry). Electrochemical sensors (e.g. Alphasense or Spec sensors) can be integrated for these. Optionally O<sub>3</sub> or SO<sub>2</sub> sensors can be added if budget permits, given Zenica’s industrial profile. Many urban deployments use multi-gas modules; in fact, ~75% of city air sensor networks monitor a combination of PM2.5, PM10, NO<sub>2</sub>, CO, and O<sub>3</sub>[22][23], as these are the major health-relevant pollutants.
- **Environmental Sensors:** Temperature and humidity sensors (e.g. SHT31) are included for two reasons: (1) they help calibrate the gas sensor readings (many gas sensors have T/H sensitivity); (2) they provide useful ambient data to citizens. Pressure sensing is optional for altitude calibration.
- **Power Supply:** Most nodes will be installed at fixed locations (homes, schools, rooftops) with access to mains power or at least a steady power source (5V USB adapter). To handle any outages or remote spots, we’ll incorporate a battery backup (Li-ion battery

with a small solar panel for recharge in case of off-grid sites). The electronics are designed for low-power draw, and LoRaWAN itself allows devices to sleep between transmissions, making battery operation feasible (estimated battery life of 1-2 years on D-cell batteries if using a low transmit frequency, although mains powering is preferred for continuous data).

- **Enclosure:** Custom weatherproof enclosures (rated at least IP54) will house the electronics. Proper ventilation for the sensors is ensured (e.g. a Stevenson screen or mesh for air flow but with shielding from rain). We'll include filters to keep dust and insects out of the sensor chamber. A small blower or fan may be used to ensure consistent air sampling for the particulate sensor.

A typical assembled unit would be roughly the size of a wifi-router or smaller, and cost in the range of \$150–\$300 depending on sensor configuration. By focusing on **modularity**, we can tailor some units for specific needs (for instance, a few could include an H<sub>2</sub>S sensor near the steel plant if needed).

**Helium Hotspots:** To guarantee network reach, the project will deploy **Helium LoRaWAN Hotspots** in any areas of Zenica lacking coverage. Each hotspot is a LoRaWAN gateway (with an 8-channel LoRa concentrator and internet connection) that also runs Helium blockchain software. We plan an initial **2–3 Hotspots** to blanket Zenica (given its area ~150 km<sup>2</sup>, a few well-placed gateways can suffice thanks to LoRa's ~5-10 km urban range). These could be standard indoor Helium miners placed in volunteers' homes or on building rooftops for better range (we will provide outdoor enclosures and antennas as needed). Importantly, hotspot owners *earn Helium IOT tokens* for carrying our sensor data, aligning incentives – as Helium's model has shown, individuals are eager to host hotspots when there is potential to earn cryptocurrency by supporting network coverage[14][12].

Each Helium hotspot costs approximately \$400 and we will choose reputable models (e.g. Bobcat, RAK Hotspot Miner) that are known for reliability. They require minimal maintenance beyond power and internet; our budget includes a small stipend for host locations if needed (or they simply keep the tokens they earn as reward).

By leveraging Helium's existing device ecosystem, we skip the need for an expensive private gateway (~\$1000 each for typical LoRaWAN gateways[24]) and instead use consumer-deployed units – a cost revolution much like how Helium has achieved nationwide IoT coverage at *a fraction of telecom costs* by crowdsourcing[10].

**Backend and Dashboard Technology:** While not "hardware", it's worth noting the technical stack for data visualization. The server will run on a cloud VM (ensuring 24/7 uptime). The database could be InfluxDB or TimescaleDB (optimized for time-series sensor data). The dashboard will be a modern web app (likely built with React or Vue.js) with interactive maps (using libraries like Leaflet or Mapbox for plotting sensor locations and AQI color-coding). We will also incorporate a user-friendly mobile view. The UI will display indices like PM<sub>2.5</sub> in µg/m<sup>3</sup> and also convert to standardized AQI levels for easy interpretation (e.g. Green/Yellow/Red

indicators). If project resources allow, we will also generate automated alerts when pollution spikes (via email, SMS or a mobile app notification).

## Sensor Network Deployment Plan

A phased deployment approach will ensure systematic coverage and allow for learning and course correction:

- **Phase 1: Pilot Setup (Months 1–3).** We will install an initial **2-5 sensor nodes** in strategic locations: e.g. City Center, a residential area downwind of the steel plant, a school in an affected neighborhood, the city outskirts (as a control for background levels), and near the ArcelorMittal plant perimeter. These pilot sensors will test the hardware, network integration, and data pipeline. During this phase, we will work closely with local environmental groups and authorities for site selection permissions. The pilot helps validate sensor accuracy (we'll co-locate one sensor with an existing government monitor if possible to compare readings) and ensures Helium coverage is robust. Community members hosting these pilot sensors will be trained and will provide feedback on installation and usability.
- **Phase 2: Citywide Rollout (Months 4–9).** Based on pilot success, we will **scale up to ~12–25 sensors** (conditioned by the amount of funds raised) distributed across all key districts of Zenica. The density goal is about **1 sensor per 1–2 km<sup>2</sup>** in populated areas, aligning with recommendations that ~1 sensor per 0.5–1 km<sup>2</sup> provides good urban coverage[25]. We'll prioritize pollution "hotspots" – e.g. areas near heavy traffic or industry – and "sensitive receptors" – e.g. hospitals, schools – for denser sensor placement. The deployment will be mapped to ensure no large gaps; leveraging a rule of thumb that if population is dense or pollution sources are present, sensors are closer, and in cleaner or low-pop areas, spacing can be wider[26]. We will engage volunteer hosts through an open call, possibly providing the equipment for free in exchange for their willingness to power the device and perhaps periodically check on it. Each installation will be documented (GPS location, height above ground, etc.) for data context. By Month 9, Zenica should have a functioning **mesh of sensors** sending continuous data.
- **Phase 3: Optimization & Community Integration (Months 10–12).** After full deployment, we will fine-tune the network. This involves calibrating sensors using reference data (e.g. adjusting algorithms during different weather conditions), and ensuring data completeness. We anticipate >95% data delivery success based on LoRaWAN reliability in similar deployments[27][28]. Packet loss or interference will be analyzed; if any blind spots are found, we will add an extra hotspot or reposition sensors. We'll also implement preventative maintenance: e.g. cleaning PM sensor inlets every few months (community volunteers can be trained to do this). During this phase, **public workshops** will be held to introduce the dashboard to citizens, and gather their input. We aim to integrate the project with local schools' curriculum (students can

“adopt a sensor” and learn from the data) and to present findings to city officials to encourage policy action (such as traffic restrictions on high pollution days, etc.).

- **Beyond 1st Year:** Once steady-state is reached, the network will operate continuously. We plan periodic recalibration (perhaps annually, by collocating a few nodes with a reference instrument or via intra-network comparison). Additional sensors could be added in future (for example, expanding into nearby towns or adding *mobile sensors* on vehicles for greater coverage). The infrastructure also allows adding other types of sensors (noise, weather) to the LoRaWAN network with minimal effort, turning it into a multi-purpose smart city IoT network over time[29].

Throughout deployment, **safety and data quality** are paramount. We will follow guidelines for siting (placing sensors at roughly breathing height when measuring street-level exposure vs. on rooftops for general air quality – a mix of heights will be used to get a full picture[30]). Redundant measurements (overlapping coverage) are planned in critical areas to validate readings. A validation service can be employed to compare our sensor data against known standards – for instance, using algorithms to cross-check neighboring sensor readings for anomalies.

By the end of the deployment plan, Zenica will transform from having very limited air monitoring to one of the **best-mapped air quality landscapes** in the region. This data will empower citizens with knowledge (recalling the adage “you can’t manage what you don’t measure”), and thereby drive collective action for cleaner air.

## Data Visualization Platform and UI Strategy

An intuitive and engaging data visualization platform is crucial for reaching both technical and non-technical audiences. Our UI strategy focuses on clarity, accessibility, and actionable insight:

### Platform Features:

- **Real-Time City Map:** The landing page will be an interactive map of Zenica dotted with colored markers at each sensor location. Colors will indicate the current AQI (Air Quality Index) category – for instance, green (Good), yellow (Moderate), orange/red (Unhealthy) – updated in near real-time (refreshing every few minutes). Users can click on a marker to see detailed current readings (e.g. “PM<sub>2.5</sub> = 80 µg/m<sup>3</sup> (Unhealthy), PM<sub>10</sub> = 120 µg/m<sup>3</sup>, NO<sub>2</sub> = 55 ppb”) and a small trend sparkline for that site.
- **Sensor Detail Pages:** Each sensor will have a dedicated page or popup showing graphs of pollutant levels over time (hourly, daily, weekly trends). This caters to power users who want granular data. The platform will support overlays (e.g. temperature vs. pollution, or multiple sensors compared).
- **Aggregated Insights:** We will also present citywide summaries: for example, *the worst air quality areas in the past 24h*, or an animation of how pollution spread during the day. A timeline slider on the map could allow users to rewind and see a heatmap of

pollution over time. There will be a “Key Metrics” section highlighting stats like “Zenica’s average PM2.5 today” compared to WHO guidelines.

- **Alerts and Forecasts:** The UI will incorporate health recommendations. If certain stations detect hazardous levels (e.g. AQI above 150), the site will display an alert (“Unhealthy air detected – sensitive groups should reduce outdoor activities”). We will integrate basic forecasting (possibly using IQAir or OpenWeatherMap data for air quality forecasting) so users can see if tomorrow is expected to be better or worse. Also if project resources allow, we will add an AI layer to turn raw measurements into more understandable insights and short-term forecasts. Using current sensor readings, local weather conditions and historical trends, machine-learning models can provide **near real-time interpretation** (what’s causing spikes, how unusual it is) and **predictions of future pollution levels** over the next hours or days—similar to how meteorologists forecast weather. Citizens can also sign up for notifications: e.g. an email or text alert when pollution exceeds a threshold in their area.
- **Multilingual Support:** To maximize local impact, the interface will be provided in Bosnian/Croatian/Serbian (BCS) as well as English. This ensures older residents or those less comfortable in English can fully engage with the information.
- **Mobile-Friendly Design:** Many users will access the data on smartphones. The UI will be responsive, with a simplified mobile view. We may also develop a native mobile app if resources allow, to send push notifications for alerts and allow location-based queries (“what’s my current AQI based on nearest sensor”).
- **Community and Education Integration:** The platform will feature an **open data portal** where raw data can be downloaded (CSV or via API) by researchers, students, or curious citizens. We plan to publish periodic analysis blog posts on the site – e.g. monthly air quality reports, highlight improvements or severe episodes. A community forum or feedback section might be integrated for users to discuss and ask questions, further driving engagement and collective awareness.
- **UI/UX Clarity:** Given the diverse audience (investors, local government, general public), the style will remain professional and explanatory. Key indices will be explained with tooltips (e.g. “PM2.5: fine particulate matter <2.5µm, can affect lungs...”). We’ll avoid overly technical jargon or, where necessary, provide quick info definitions.
- **Map and Data Integration:** We intend to join global networks such as **OpenAQ** or others so that Zenica’s data contributes to global datasets. An API will allow services like aqicn.org or IQAir to pick up our data if desired, increasing its visibility and utility. Internally, 85% of modern urban sensor deployments integrate with broader smart city platforms[31] – in our case, we aim to share data with city officials’ dashboards or emergency response systems. For example, if extremely high pollution is detected, an automatic alert could be sent to city environmental inspectors or even trigger traffic policy (long-term vision).

**Security and Privacy:** All data published is environmental and not personal, so privacy concerns are minimal. We will ensure the network and platform are secure from tampering – using HTTPS, secure device credentials, and blockchain-verifiable data integrity where applicable. Since Helium provides a tamper-resistant record of data transfer, there is inherent trust in the readings’ provenance (each sensor has a unique cryptographic identifier on the network).

In summary, the visualization platform will transform raw sensor readings into *understandable, relevant information*. It acts as the public face of the project – demonstrating the value of the deployed sensors and fostering a sense of urgency and community around air quality. By making the invisible visible, we hope to catalyze citizen engagement and policy change.

## Token and Blockchain Integration Plan (Helium/Solana)

A distinguishing aspect of this project is the integration of blockchain technology not just for data transport, but also for incentivization and transparency. Helium’s migration to the Solana blockchain in 2023 enables more robust token features and smart contract integration for our use case[32][33]. Our plan leverages Helium’s native tokens and explores new possibilities on Solana:

- **Helium Data Credits (DC) for Connectivity:** As described, every sensor’s data usage is accounted via DC, which are created by burning Helium’s utility token HNT[12]. We will acquire a pool of HNT tokens to convert into Data Credits sufficient for at least 2–3 years of network traffic for all sensors. Given the low cost (\$1 gets 100,000 DC[34], and ~1 DC per sensor message[35]), an allocation of say \$100 (10 million DC) would more than cover our initial deployment’s data needs for years. This small cost, effectively “locked in” as DC, guarantees the network’s operation regardless of HNT price volatility[17]. We will manage DC top-ups via Helium’s on-chain governance tools or the DC portal, which even allows using a credit card to buy DC if needed[36][37] (abstracting the crypto aspect for ease of operations).
- **Helium HNT Token Rewards for Incentives (Simplified Model):** Helium has moved back to a **single reward token (HNT)** for hotspot rewards across the network, phasing out **IOT/MOBILE as reward emission tokens** under **HIP 138**. This simplifies the ecosystem and makes incentives easier for everyday participants to understand. In our plan, any Helium hotspot in Zenica that relays our sensor data will **earn HNT directly**, giving hotspot hosts a clear “earn by contributing” incentive for providing coverage and data delivery. We will encourage community members hosting hotspots to track their earnings (via the Helium Wallet app) and explain the practical options for using rewards (e.g., holding, swapping, or reinvesting into equipment/support costs). Our team may also operate one or two hotspots and reinvest earned HNT into network maintenance and expansion—helping create a sustainable loop where infrastructure contributions directly support clean-air monitoring.
- **Transparency and Data Integrity:** All Helium network transactions (DC burns, hotspot rewards) are recorded on the Solana blockchain. We will integrate this transparency by

perhaps creating a public dashboard of network usage – e.g. showing how many DC were spent each day for sensor data (which correlates with how much data was transmitted). This provides an auditable trail of project activity. We could also issue a periodic report to stakeholders with on-chain metrics (like how much HNT was burned for Zenica’s data – demonstrating real utility usage of the Helium network[39]).

- **Exploring Smart Contracts on Solana:** With Helium now part of Solana’s ecosystem, we have the option to develop custom smart contracts or tokens if needed for the community incentive model. One idea is a “**Zenica Clean Air Token**” or NFT badges for contributors: for instance, each sensor host or donor could receive a unique NFT acknowledging their contribution to cleaner air. These could be purely commemorative or tied to certain privileges (like governance in a community DAO for the project). While not essential, this could bolster community buy-in and potentially unlock new funding (imagine selling a limited set of sponsorship NFTs whose proceeds fund more sensors).
- **Governance and DAO:** We will structure community decision-making possibly through a DAO (Decentralized Autonomous Organization) using Solana’s governance tools (like Realms). This DAO could oversee the project’s token treasury (HNT funds, etc.) and allow local stakeholders to vote on expansions or expenditures. By locking some HNT or IOT tokens in the DAO, members could even earn yield or additional rewards, aligning long-term interest. This approach ensures **local ownership** – the project isn’t just run *for* the people of Zenica, but *by* the people, with blockchain providing the trust framework.
- **Funding Opportunities:** Tapping into the Helium/Solana ecosystem opens doors for grants and collaborations. The Helium Foundation offers grants for IoT use-cases; a well-publicized deployment in Zenica could attract Helium’s attention (since it showcases a positive real-world IoT-for-good story). Similarly, Solana’s community might support this as a flagship example of DePIN on Solana. We plan to apply for such grants, which if received, would come in tokens (HNT or SOL) to our project’s wallet.

In implementing this plan, we will keep user experience in mind. The average citizen checking air quality need not to worry about tokens or blockchain. Those aspects run in the background to reduce our costs and reward participants. However, for those interested (like tech enthusiasts or the hosts earning tokens), we will provide educational material on how Helium’s token economics work – e.g. explaining that **HNT is burned to create Data Credits[12], effectively converting cryptocurrency value into sensor data bandwidth**, and that this model ensures data costs remain low and fixed in USD[17]. By demystifying the technology, we hope to inspire others in the region to consider DePIN approaches for infrastructure challenges.

Overall, the blockchain integration is a backbone of our sustainability strategy: it turns the network into not just a consumer of funds (as traditional projects) but a generator of value and engagement, aligning incentives of all players (citizens, operators, backers) toward the common goal of cleaner air.

## Community Engagement and Incentive Model

Community engagement is the cornerstone of this decentralized project. Our model actively involves Zenica's residents at every stage, ensuring the project is rooted in local empowerment and not just technological deployment:

- **Local Partnerships:** We will collaborate with existing local entities like the Zenica Eco-Forum, university environmental departments, and health NGOs. These groups have trust and reach in the community. By partnering, we gain volunteer networks for sensor hosting and events. For example, Eco-Forum activists might help identify ideal sensor locations based on their knowledge of pollution complaints, or a local university could host a Helium hotspot on its rooftop and integrate the data into student research.
- **Citizen Sensor Hosts:** Rather than mounting all sensors on government property, we choose a citizen-centric approach. Residents can sign up to host a sensor at their home or business. The incentive for them is multi-fold: they get a personal air monitor (with access to detailed data about their immediate surroundings), recognition on the project's website (a "Thank You to our hosts" section), and potentially **token rewards**. While sensor hosts do not earn Helium tokens directly (those go to hotspot owners), we will allocate a small **community token fund** (in HNT or local currency) to reward sensor hosts periodically – for example, a monthly reward of a few HNT or a gift card for those who maintain high uptime. This is not a strict transaction but a gesture to value their contribution. Additionally, if a host also sets up a Helium hotspot (some tech-savvy individuals may volunteer to do both), they *will* earn IOT tokens via Helium's mining, as described earlier, which is a strong financial incentive[12].
- **Workshops and Education:** We plan to hold interactive workshops at different stages:
  - *Before deployment:* "Intro to Air Sensors & Helium" – explaining what we plan to do, how LoRaWAN and tokens work, and the benefits. This both recruits volunteers and demystifies the tech for the public.
  - *During deployment:* Training sessions for sensor hosts on installation and basic troubleshooting. Perhaps a hands-on session assembling a DIY sensor kit to spark interest (some citizens might build their own additional sensors, which we can integrate into the network).
  - *After launch:* Data literacy workshops on reading the air quality maps, understanding health implications, and ways to reduce exposure. We may engage local healthcare professionals to speak on pollution's impacts, making the issue tangible and personal.
- For younger audiences, we'll coordinate with schools to incorporate the sensor network into science projects – e.g. students can analyze data from the sensor on their school roof, learning about science and IoT. This fosters the next generation of environment-conscious technologists.
- **Community Dashboard & Gamification:** The public dashboard will have a community section. We might include a leader-board of sorts, for example:

- “Top contributing hotspots this month” (which hotspot relayed the most data – giving bragging rights to the operator, possibly correlating to token earnings as well).
- “Clean Air Hero of the Month” – featuring a profile of a community member (like a particularly active sensor host or volunteer who organized a local awareness drive). These human stories keep the community motivated and personalize the initiative.
- An interactive feature could allow citizens to **request a sensor** in their neighborhood if they feel it’s needed – a form of participatory planning.
- **Incentive Alignment through Tokens:** As described, Helium’s incentive model is a big plus. We will ensure hosts understand how to monitor their hotspot’s performance and token earnings. For those not technically inclined, the project team can manage a few hotspots and commit to using the generated tokens for community benefits (like buying replacement sensors or organizing events). This creates a transparent economy: pollution monitoring yields tokens, which feed back into improving pollution awareness – a self-reinforcing loop.
- **Open Data and Crowdsourcing:** By making all data open, we invite the community to derive value. Hackers and developers in Zenica (or the broader region) might create their own visualizations or analyses – e.g. a smartphone widget for Zenica AQI, or correlation studies between factory activity and pollution peaks. We’ll encourage such initiatives, possibly through a hackathon or challenge with small prizes for best community-built app or insight using the data. This crowdsourced analysis can uncover issues that lead to public pressure on polluters or authorities (for instance, identifying that on certain days/time the steel plant is likely causing spikes, adding proof to citizen complaints).
- **Feedback Mechanisms:** We treat the community as co-creators. A feedback form or forum will be provided for suggestions and reporting issues. We expect to iterate on the project based on community input – e.g. if many request a sensor in a certain suburb, we try to accommodate. This responsiveness will build trust. Over time, we envision forming a local steering committee of citizen volunteers that can help guide expansion priorities and act as liaisons with local government.
- **Recognition and Social Impact:** The narrative of the project will emphasize how Zenica’s citizens are taking charge of their environment using cutting-edge tools. We will highlight this in local media, and possibly international media (positioning Zenica as a model for other polluted cities). Such positive coverage can boost civic pride and strengthen the community’s resolve to push for clean air policies. In essence, the network becomes not just a data source but a *social instrument* – rallying community activism. Indeed, data from citizen networks often fuels environmental justice campaigns<sup>[40][41]</sup>, giving hard evidence to demands. Zenica’s citizens suing for better air can use our high-resolution data to support their case, for example.
- **Inclusion:** We aim to include diverse segments – ensuring women, youth, and marginalized communities are represented among sensor hosts and participants.

Pollution often disproportionately affects lower-income neighborhoods; by placing sensors there and involving those residents, we amplify their voice. The incentive model (free hardware, possibly improved health outcomes, and small token rewards) is structured to not exclude anyone due to cost or expertise.

In summary, the project's success will be measured not only in data collected but in **community cohesion and empowerment**. If in a year's time, Zenica's people regularly check the air quality app, discuss it on local radio, or demand action on days with alarming data, then we have succeeded in decentralizing not just the network, but the very ownership of the air quality issue. This community-first approach will ensure the network's long-term survival and impact, since it will be protected and valued by the very people it serves.

## Sustainability and Revenue Strategies

A critical component of this proposal is ensuring that the sensor network remains financially and operationally sustainable beyond initial deployment. We outline a multi-pronged sustainability plan, combining cost control, revenue generation, and partnership development:

**1. Low Operating Costs by Design:** By leveraging Helium's network, we avoid recurring connectivity fees that typical cellular-based sensors would incur. As noted, the data transfer cost is extremely low (~\$1 per device/year for frequent uploads)[11]. Additionally, LoRaWAN sensors are low-power and, when mains powered, have negligible electricity costs (a few cents per month). The major ongoing costs are sensor maintenance (calibration, cleaning, part replacement) and cloud service hosting for the platform. We will keep the platform on cost-efficient cloud infrastructure (initially ~\$50/month server costs). Helium hotspot internet bandwidth use is minimal (and hosts are volunteers). So baseline OPEX is small.

However, **small doesn't mean zero** – studies show annual maintenance can be ~20–30% of initial deployment cost for urban sensor networks[42][43] due to recalibration, parts, and labor. We embrace this statistic in our budget planning (see Budget Summary), ensuring that maintenance needs are funded and not deferred. Each year, sensors might need new calibration or sensor replacement (e.g. electrochemical gas sensors have a life of ~2 years, laser PM sensors might need fan replacements, etc.). We budget for spare parts and even full unit replacements (assuming maybe 10% of sensors might fail per year and need refurbishing).

**2. Token Value and Crypto-Economics:** The Helium IOT tokens earned by hotspots (including any we operate) provide an **ongoing revenue stream**. While current token values fluctuate, any earned HNT or IOT can be converted to stable funding. For example, if our network's data usage burns, say, 100,000 DC per month (for all sensors)[39], Helium's network would reward hotspots accordingly – the exact token amount depends on Helium's token emission schedule and overall network usage, but it could be in the range of a few HNT per month per active hotspot. If Zenica eventually had 5-10 hotspots actively carrying not just our project's traffic but others (e.g. people might start using Helium for other IoT applications too), the tokens earned could be more substantial. We plan to **recycle a portion of these tokens**: tokens earned by any project-owned hotspots will be put into a project wallet and periodically sold or utilized for: - Buying more Data Credits (ensuring perpetual operation). - Funding sensor maintenance or new

sensor purchases. - Building a reserve for hardware upgrades (e.g. in 3-5 years, we might refresh the technology).

Helium is essentially *bootstrapping our network* by rewarding it for usage – a novel mechanism turning what is normally a cost (running a network) into a potential revenue. This is a foundational DePIN advantage.

**3. Data Services and Partnerships:** The high-resolution environmental data collected has value beyond public information. Potential revenue avenues include: - **Government Contracts:** Over time, the city or canton government may choose to officially support or integrate our network. Instead of investing hundreds of thousands in new fixed stations, they could subscribe to our data or sponsor the network at a far lower cost. We will demonstrate our data's quality and reliability to environmental agencies; if we can get our measurements recognized (perhaps even certified via comparative studies with reference equipment), the government might pay an annual fee for access to the dataset for regulatory and planning purposes. Even a modest contract could cover maintenance expenses fully. - **Industry Sponsorship:** Local industries (including ex. ArcelorMittal Zenica/now **Nova Željezara Zenica**) could be approached to sponsor parts of the network as a Corporate Social Responsibility (CSR) initiative. For instance, the steel mill could fund sensors in certain communities as a goodwill measure (especially if pressure mounts from citizens). While there is a balance to maintain independence (we wouldn't want a polluter to have control over the data), a transparent sponsorship (with no data influence) where a company funds expansion to more sensors or provides logistical support could be mutually beneficial. We will craft agreements ensuring data integrity regardless of sponsorship. - **Research Collaborations:** International researchers (e.g. climate scientists, public health experts) might be interested in our data for studies. We could partner on grants (EU Horizon projects or similar) that bring funding to maintain/expand the network in exchange for data sharing and co-design of experiments (e.g. adding specialized sensors temporarily for research campaigns). - **Value-Added Services:** Building on the data, we might develop premium services. One idea is a **SMS/app alert subscription** targeted at sensitive groups (elderly, asthmatics): for a symbolic fee, they get personalized alerts about air quality and health advice. The fee could be paid by sponsors/project funds or, better, by healthcare providers or insurers who want to reduce health incidents. If data shows certain neighborhoods suffer extreme pollution, local government might fund air purifiers or masks distribution – our network could become part of a *holistic health intervention program*, possibly unlocking public health funds. - **Advertising and Sponsorship on the Dashboard:** The web dashboard could host local environmental ads or sponsorship banners (e.g. a local solar panel company, or eco products), generating modest ad revenue which we funnel back into upkeep.

**4. Grants and Donations:** We will actively seek grants in the domains of environmental tech, civic tech, and DePIN. Possible sources: Helium Foundation grants (as noted), European Union environmental funds (Western Balkans have access to EU instruments for air quality improvement), UNDP or World Bank funds for air quality (Sarajevo has had World Bank projects for air management[4] – Zenica could too). Additionally, a donation campaign for citizens and the Bosnian diaspora can be run – people who care about Zenica's air might donate to a transparent fund (possibly in crypto or fiat) that goes to maintaining the sensors. Using

blockchain for donations (e.g. a multi-sig wallet where funds and spending are visible) can increase trust that every contribution is used effectively.

We will also approach regional smart-city accelerators for any incubation support (this also provides small funding and mentorship to make the project more sustainable business-wise).

**5. Cost-Sharing and Volunteerism:** Not all support is monetary. By cultivating volunteers (for sensor maintenance, hotspot hosting), we reduce the need for paid staff for routine tasks. If, for instance, a network of volunteers each “adopts” a sensor to clean and check bi-monthly, that’s labor we don’t have to hire. Community science projects often thrive on volunteer maintenance especially when people feel ownership. To coordinate this, we could create a simple task management (even a WhatsApp group or a Trello board for maintenance tasks) and give volunteers recognition and small rewards (as discussed in community engagement). The sense of civic duty and pride can be a powerful currency.

**6. Scalability to Other Cities:** In the long term, revenue can come from replicating the model in nearby municipalities. Once proven in Zenica, we could offer a **deployment service to other polluted Balkan cities** (Tuzla, Sarajevo, etc.). They could contract our team as consultants to set up similar Helium-powered sensor grids. The economies of scale would reduce unit costs, and part of the contract revenue flows back to sustaining the Zenica network (for example, we retain some central infrastructure that serves all deployments). Effectively, Zenica’s project could spin off into a social enterprise that helps many cities while keeping Zenica’s network robust via shared resources. The *knowledge capital* gained becomes an asset.

**7. Longevity of Helium Network:** One risk to sustainability is reliance on Helium. We mitigate this by the fact that LoRaWAN is an open standard – if Helium’s network faced issues, we could migrate sensors to another LoRaWAN network (like The Things Network) or deploy our own gateways. However, Helium’s recent growth and investments[44] indicate it’s here to stay, and our use of it is netting positive value (not cost). Helium’s token model even has governance mechanisms to adapt (e.g. the community can adjust HNT burn or reward rates). We will keep active in Helium’s community to stay ahead of any changes. As per Helium’s Q1 2024 report, municipal and IoT solution providers’ use of Helium is scaling[45][46] – this gives confidence that being part of this ecosystem is future-proof.

In summary, sustainability comes from **minimized recurring costs** and **maximized diverse income**. By year 2, we expect the project to reach an equilibrium where ongoing expenses (parts, replacements, cloud services, occasional new hardware) are fully covered by a combination of: a small municipal contribution or grant, Helium token proceeds, and possibly community fundraising. Any surplus will be reinvested to upgrade sensors (for instance, adding **edge computing** capabilities on some nodes to analyze data locally – a trend as 55% of urban IoT systems now use edge processing for faster alerts[47][48]). We treat the network as critical civic infrastructure, and will advocate for its inclusion in city budgets (it is far cheaper than hospital costs due to pollution; a smart city that reduces pollution by even a few percent via our data could save significantly in healthcare, as evidenced by IoT air sensors helping cut pollution-related ER visits by up to 20% in proactive cities[49][50]).

Finally, our revenue strategy isn't purely commercial – it is about **value for the community**. Cleaner air, informed citizens, and influence on policy are the ultimate “ROI”. The financial plan simply ensures we can keep delivering that value year after year, making Zenica’s air quality network a permanent fixture and a beacon of what decentralized tech can achieve for society.

## Timeline and Key Deliverables

The project will be executed over approximately 12–15 months, with clear milestones to track progress. The following table outlines the timeline and key deliverables for each phase:

Phase & Timeframe	Key Activities and Deliverables
<b>Phase 1: Planning &amp; Pilot</b> (Month 1–3)	<ul style="list-style-type: none"> <li>– <b>Project kickoff:</b> finalize team roles, partnerships (city/Eco-Forum MOUs).</li> <li>– <b>Hardware R&amp;D:</b> Select sensor models, order equipment; assemble 2-5 pilot sensor nodes.</li> <li>– <b>Helium setup:</b> Purchase/configure 2 Helium hotspots; ensure Zenica coverage map completed.</li> <li>– <b>Pilot deployment:</b> Install 5 sensors at chosen sites; Deliverable: <i>Pilot sensors operational</i>, initial data streaming to test dashboard.<sup>[51]</sup></li> <li>– <b>Pilot data report:</b> After 1 month, produce a Pilot Data Summary (comparisons with reference, any calibration adjustments).</li> </ul>
<b>Phase 2: Full Deployment</b> (Month 4–9)	<ul style="list-style-type: none"> <li>– <b>Scale hardware:</b> Procure remaining ~10-20 sensors; assemble and bench-test all units.</li> <li>– <b>Community onboarding:</b> Host volunteer training session; Deliverable: <i>20+ community members engaged</i>, sites confirmed, hosting agreements signed.</li> <li>– <b>Deployment rollout:</b> Week-by-week installation of sensors (about 5 per one month or two months - sensors are difficult or impossible to source locally - all will probably have to be ordered from China, adding extra shipping and delivery time); by Month 9 all ~12-25 sensors deployed and logging data.</li> <li>– <b>Dashboard launch:</b> Develop full web dashboard; beta release by Month 6, public launch by Month 9. <i>Deliverable: Live Zenica Air Quality Portal</i> with real-time map and graphs.</li> <li>– <b>Mid-point review:</b> By Month 9, prepare a report on network coverage and reliability (target &gt;90% data yield). If any gaps, deploy additional hotspot or sensor relocations as needed.</li> </ul>
<b>Phase 3: Engagement &amp; Optimization</b> (Month 10–12)	<ul style="list-style-type: none"> <li>– <b>Community events:</b> Organize at least 2 workshops (one for general public on using the dashboard, one at a local school or university). <i>Deliverable: Workshop materials</i> (presentations, brochures) and attendance of key stakeholders.</li> <li>– <b>Data analytics:</b> Implement alert system and generate first insights report (e.g. “Winter Air Quality Analysis for Zenica”).</li> <li>– <b>Maintenance protocols:</b> Establish routine (e.g. cleaning schedule), and document it. Train a small team for sensor</li> </ul>

Phase & Timeframe	Key Activities and Deliverables
Phase 4: Ongoing Operations (Beyond 1 Year)	<p>upkeep. – <b>Project evaluation:</b> In Month 12, compile a comprehensive Project Report for investors and city officials, including data impact (e.g. # of high pollution alerts issued), community feedback, and recommendations.</p> <p>– <b>Sustainability transition:</b> If grant or city funding is secured, integrate it. Possibly form the DAO for community governance by Month 15. – <b>Expansion planning:</b> Based on interest, plan Phase 4 which could be adding 10 more sensors in suburbs or in nearby mountains or starting replication in another city (Tuzla/Sarajevo). – <b>Final investor presentation:</b> Demonstrate ROI and social impact, setting stage for either closure or next round funding if scaling.</p>

We will use agile project management throughout – meaning regular progress checkpoints (weekly team meetings, monthly summary to stakeholders). The timeline is aggressive but achievable given the relatively short setup time for off-the-shelf sensors and Helium integration. Key deliverables like the dashboard and project report ensure transparency of outcomes.

If any delays occur (e.g. shipping lead times for hardware), the schedule will adapt, but the logical order of pilot → scale → optimize remains.

## Budget Summary (Estimated Costs)

The following table provides a breakdown of the projected costs for the project. Ranges are given where applicable to account for uncertainties (different hardware options, shipping, etc.). All costs are in USD:

Budget Item	Details	Estimated Cost (USD)
<b>Sensor Nodes (Hardware)</b>	~25 LoRaWAN sensor units (PM2.5, PM10, NO <sub>2</sub> , CO, T/H per node). Includes MCU, sensors, enclosure, mounting hardware. <i>Unit cost estimate:</i> \$150–\$250 each depending on sensor quality.	\$4,000 – \$6,000 [52]
<b>Helium Hotspots (Gateways)</b>	3 Helium-compatible LoRaWAN Hotspots for coverage. <i>Unit cost:</i> ~\$400 (inclusive of antenna, accessories).	\$1,200 – \$1,500
<b>Server &amp; Platform Development</b>	Cloud server hosting (1 year) – ~\$600. Dashboard development – assuming mostly in-house development effort, or minimal external cost (could value at ~\$3,000 if contracting). Also include domain and project webpage	\$3,000 – \$4,000

<b>Budget Item</b>	<b>Details</b>	<b>Estimated Cost (USD)</b>
	hosting.	
<b>Installation &amp; Misc. Equipment</b>	Poles, brackets, extension cords, router for hotspots, etc. Also includes initial calibration tools or rental of reference monitor for calibration check.	\$1,000 (approx.)
<b>Batteries, power converters and solar panels</b>	If the sensor is located in a remote location without access to electricity, it will need a battery, a voltage converter and a solar panel to operate the sensor. IPX7 or higher waterproof housings for remote sensors are also included here.	\$1000- \$1500
<b>Maintenance &amp; Calibration (Year 1)</b>	Spare parts (sensor replacements, calibration gas kits for NO <sub>2</sub> /CO), cleaning supplies. Also covers minor repairs.	\$500 – \$800
<b>Community Engagement &amp; Outreach</b>	Workshop materials, venues, marketing (posters, web ads). Many will be low-cost leveraging partners, but budget for community incentives (t-shirts, small host stipends).	\$500 – \$1,000
<b>Contingency (10%)</b>	Buffer for unexpected expenses (extra sensors if some fail, import duties, price fluctuations).	<b>\$1,000</b> (approx.)
<b>Total Initial Budget</b>	<i>(Excluding any volunteer in-kind contributions)</i>	<b>\$11,000 – \$15,500</b>
<b>Annual Recurring (Year 2+)</b>	Data Credits (covered by HNT burn, ~\$50/year for all sensors at most). Server hosting: \$600/yr. Sensor calibration/replacement reserve: ~\$1,000/yr (assuming 2-3 sensor replacements). Community events: \$300/yr.	<b>\$2,000/yr (est.)</b>

**Notes:**

- The project is highly scalable, one or two sensors and a dashboard can be launched for little as \$3000 and have visible and measurable results. The budget presented in the table above is minimally optimal to cover the wider areas of the city where most activities are carried out and where most of the population lives. On the other hand, if the project raises \$50,000, it can be scaled to have redundant sensors at all critical

locations and to cover high mountain peaks and forest areas in the Zenica region that are traditionally assumed (but never confirmed by measurement) to have clean air.

- All prices are in dollars and not in convertible marks because the prices of equipment, maintenance, and related services required to make the project work are natively expressed in dollars.
- The budget is highly cost-efficient compared to conventional air monitoring setups. For context, a single reference-grade monitoring station can cost \$100,000+ upfront. Here, for around \$15k, we are covering an entire city with continuous monitoring.
- We anticipate some **in-kind support** will reduce costs: e.g. volunteers helping with installation (reducing labor cost), city providing venues for workshops free, possibly an NGO lending a high-end calibration instrument to avoid purchasing one.
- **Revenue offset:** As described in sustainability, after deployment we expect some costs to be offset by token earnings or sponsorships. For budgeting, we conservatively did not subtract those, but effectively the net cost may decrease if, say, hotspots earn a few dozens of dollars in tokens per year which are reinvested as data credits for transfer of data from sensors to dashboard.
- If additional fundraising is successful, we would allocate extra funds to *extend project impact* rather than significantly increase cost. For example, an extra \$5k grant could add 10 more sensors to neighboring areas, or upgrade some sensors to measure additional pollutants (like adding SO<sub>2</sub> sensors around the steel plant for greater insight).
- We include contingency because electronics projects often have minor overruns (perhaps needing to redesign enclosures, or express shipping for replacements). The contingency also covers any currency fluctuations (since some hardware might be priced in EUR/BAM).

The budget will be managed transparently, with accounts for each category. Should actual costs come in lower (e.g. if we secure a bulk discount on sensors or if we opt for a cheaper sensor model without compromising quality), we will reallocate savings to either additional sensors or to the maintenance reserve, ensuring longevity.

## Conclusion

The "Air Quality Sensor Deployment in Zenica Using Helium LoRaWAN" project is a pioneering venture at the intersection of environmental science, community engagement, and decentralized technology. By implementing a dense network of IoT air quality sensors connected through Helium's **people-powered network**, we will create an up-to-the-minute pollution map of Zenica – empowering citizens with knowledge to safeguard their health and compelling authorities to act on a problem that can no longer be ignored. The proposal has detailed how the project will be executed: from the technical architecture that ensures reliable data flow, to the community-driven approach that ensures the data leads to real-world impact, and the financial mechanisms that make it sustainable.

This project exemplifies the ideals of a modern **smart city**: not a top-down deployment of gadgets, but a collaborative, *citizen-centric infrastructure* that addresses a pressing urban challenge. It aligns perfectly with **DePIN values** – demonstrating how a decentralized network (Helium) and token economics can bootstrap physical infrastructure (an air monitoring network) far more efficiently than traditional methods[10][20]. In doing so, it gives the people of Zenica ownership of the solution, not just the problem, flipping the script on how environmental monitoring is done.

**Impact and Future Vision:** Within a year of deployment, we anticipate visible outcomes: residents checking air quality daily similar to weather, schools incorporating air health into curricula, city officials referencing our data in policy debates, and even industrial players showing more transparency due to public scrutiny. Over a longer term, the project can be expanded regionally – Zenica can lead a Balkan-wide network of decentralized air monitors, sharing data on a common platform (imagine comparing Sarajevo, Tuzla, Zenica in real-time, fostering a united call for cleaner air across the country). The model can inspire other sectors as well: if we can do air quality with this approach, others can do noise monitoring, water quality, even traffic monitoring as DePIN projects, gradually building a **decentralized smart-city ecosystem**.

The proposal also stands as an **investment in innovation**. For potential investors or sponsors, supporting this project is not only a goodwill initiative for environmental and public health – it's a validation of new technology (blockchain-enabled IoT) applied to solve real urban problems. The relatively small funding required belies the potentially outsized impact and replicability. Success in Zenica will be a proof-of-concept that could unlock further funding or commercial interest to scale similar solutions globally.

In conclusion, this project will **make the invisible visible** – turning air pollution data into a common good, galvanizing community action, and using cutting-edge Helium blockchain technology to do so in a sustainable way. It will transform Zenica into a model city that took charge of its environment through innovation and collective effort. We invite investors, community members, and stakeholders to join us in breathing life into this decentralized environmental network – for the health of Zenica's citizens and as a beacon of what's possible when people are empowered with information and technology. Together, we can ensure that every breath in Zenica and beyond becomes a bit cleaner, guided by the data and unity this project will deliver.

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