Empowering Energy Transformation Through Distributed Residential Energy Assets

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Abstract

The world is undergoing a profound energy transition, moving from traditional centralised electricity generation reliant on fossil fuels towards a more sustainable model powered by renewable resources. This transition is characterised by the widespread adoption of solar energy and battery storage systems, spanning from small, individual residential installations to large-scale grid projects. As these renewable assets proliferate, they usher in a new era of decentralised energy generation and storage, presenting both opportunities and challenges.

Residential homes serve as prime examples of this fast growing, decentralised energy model, embodying the potential for individuals to become active participants in the energy landscape. However, this decentralisation introduces complexities for grid operators tasked with reliably integrating these diverse assets into the existing infrastructure, as well as for homeowners seeking to optimise the returns on their energy asset investment.

In this landscape, effective coordination of decentralised energy assets is paramount for seamless integration into the grid. Blockchain technologies emerge as powerful tools for fostering trust and coordination among a network of distributed nodes, making them well-suited for orchestrating the behaviour of decentralised energy assets.

Enter the Decentralised Physical Infrastructure Network (DePin), a solution designed to coordinate and manage these energy asset nodes. DePin serves as a nexus, facilitating the seamless interaction between disparate energy assets and providing a fertile ground for the development of innovative applications. From enhancing the energy efficiency of individual homes to enabling participation in broader energy markets, DePin empowers users to maximise both environmental and financial gains.

This whitepaper delves into the intricacies of a residential energy DePin, exploring the economic incentives that drive user behaviour and exploring potential use cases for decentralised application (dApp) development. By adopting such a DePin, stakeholders can unlock the potential of decentralised energy assets, for a financially and environmentally sustainable future.

The Problem.

The global energy landscape is undergoing a significant transformation, transitioning from a traditional centralised model, dominated by large-scale, fossil-fuel based, generators, to a decentralised paradigm where consumers also act as producers of energy. This shift is evident in the widespread adoption of rooftop solar panels, home batteries, and electric vehicles (EVs) equipped with substantial battery storage. However, while this decentralisation offers many opportunities, it also presents challenges for both grid operators and home users.

Grid infrastructure and energy markets, designed for centralised energy generation, face hurdles in accommodating the growing number of decentralised energy assets acting bidirectionally as both consumer and producer. Increasing home energy assets, operating independently from centralised control, exacerbate issues such as the mismatch between peak energy demand and solar generation times, illustrated by the infamous "duck curve". While battery storage holds potential for mitigating this imbalance, it has yet to keep pace with solar oversupply, resulting in renewable energy waste.

Moreover, the shift towards renewable energy to meet climate targets further strains existing grid infrastructure, necessitating costly upgrades and transmission line expansions. Grid-scale renewable energy projects often experience long regulatory approval times and community opposition at installation sites due to their social and environmental impact. Meanwhile, home energy assets, including rooftop solar and home batteries, continue to grow in capacity, surpassing grid-scale solar generation in some regions. Yet, these assets remain underutilised due to challenges in maximising their potential benefits.

Electric vehicle adoption adds another layer of complexity. While advancements in battery technology and government incentives drive adoption, latent benefits such as Vehicle-to-Home (V2H) and Vehicle-to-Grid (V2G) capabilities remain untapped. For homeowners, rising energy costs, despite the low production cost of renewable energy, coupled with significant capital outlays for home energy assets, pose financial challenges.

Efforts to integrate Distributed Energy Resources (DERs) into VPPs offer solutions to grid stability and participation in energy markets. However, centralised control limits the full utilisation of physical assets, hindering widespread adoption and stifling innovation.

This paper explores the potential of blockchain technologies as a solution platform for maximising the benefits of home energy assets, addressing the challenges faced by both grid operators and home users in the evolving energy landscape.

The Solution

DePin - a pioneering mode of blockchain coordination.

Decentralised Physical Infrastructure Network (DePin) represents a pioneering integration of blockchain technology into the realm of physical infrastructure across various industries such as energy, communications, transport, and manufacturing. It serves as a crucial link between the digital world of blockchain assets, including decentralised finance (DeFi), and the tangible assets of our physical infrastructure.

At its core, DePin establishes a dynamic network that unites diverse physical assets, seamlessly coordinated and managed through blockchain technology. This framework acts as a foundational layer, facilitating smooth interaction and interoperability among distributed assets within decentralised ecosystems.

DePin optimises the utilisation of a wide array of physical resources, spanning from machinery and equipment to sensors and infrastructure components. Leveraging cutting-edge technologies like blockchain, smart contracts, and Internet of Things (IoT) devices, it facilitates the efficient management and coordination of these assets in a transparent, secure, and decentralised manner.

By unlocking the potential of decentralised asset management, DePin drives efficiency, transparency, and collaboration across industries. It empowers stakeholders to streamline asset management processes, enhance resource utilisation, and foster innovation in decentralised environments.

In essence, DePin serves as a transformative force, revolutionising how organisations navigate and harness the potential of physical infrastructure in a decentralised world. Whether in energy, manufacturing, logistics, or beyond, DePin is poised to catalyse efficiency and resilience in decentralised physical infrastructure systems.

Our Solution - Lightcone

Our solution is to create a DePin named Lightcone to coordinate and optimise the operation of home energy assets within a decentralised energy ecosystem. Lightcone serves as a foundational layer that enables seamless interaction and interoperability among diverse energy resources, including rooftop solar panels, home batteries, and electric vehicles (EVs) equipped with battery storage.

At its core, Lightcone provides the infrastructure necessary to facilitate the efficient generation, storage, and distribution of energy at the local level, empowering individual homeowners and their communities to become active participants in the energy market. By leveraging blockchain technology and smart contracts, Lightcone ensures transparent, secure, and decentralised management of energy transactions, fostering trust and collaboration among network participants.

Through Lightcone, homeowners can maximise the value of their energy assets by optimising their usage patterns, participating in P2P energy trading, participating in energy markets and contributing to grid stability and resilience. Additionally, Lightcone

serves as a platform for innovation through third-party development of novel decentralised applications (dApps) and services aimed at enhancing energy efficiency, reducing costs, creating new revenue streams and promoting sustainability.

Essentially, Lightcone serves as the backbone of a decentralised energy infrastructure, providing the necessary infrastructure and protocols to facilitate the efficient utilisation of various home energy resources, such as rooftop solar panels, home batteries, and EVs. By leveraging advanced technologies like blockchain and smart contracts, Lightcone ensures transparent, secure, and automated interactions among participants while promoting interoperability and scalability.

Design Objectives

The overarching objective is to establish a cohesive network of decentralised home energy assets, capable of individual and collective action to redefine energy management. Lightcone forms the foundation for implementing innovative applications benefiting individual consumers, community entities, and grid operators.

1. **Integration with Hardware Manufacturer Systems**: Lightcone will seamlessly integrate with various manufacturer's energy management systems, by accessing hardware APIs and enabling Lightcone signals to control energy assets. Select hardware manufacturers in each region will be supported, giving homeowners flexibility in hardware choices. As a future development, the opportunities for running Lightcone code on manufacturer’s microcontrollers will be explored.

2. **Developer Support and Innovation**: Lightcone will provide an API layer, sandboxes, and development kits for dApp developers to create innovative applications. Developers can interact with smart contracts to manipulate energy assets and utilise Lightcone tokens for rewards, incentives, and payments. dApp development is a crucial component of the Lightcone ecosystem, providing end user functionality.

3. **On-chain Transaction Settlement**: Transaction settlement will be facilitated through digital tokens, enabling payments between customers and app developers, node operators, and for incentives and governance functions.

4. **Optimization Algorithms**: Implement advanced analytics and machine learning techniques to extract valuable insights from the data and optimise network operation and rewards.

5. **Scalable and Flexible Architecture**: Lightcone will possess a scalable and flexible architecture to accommodate the growth of home energy assets and adapt to evolving market dynamics, regulatory requirements, and technological advancements.

6. **User Empowerment**: All stakeholder, including homeowners, communities and dApp developers will be empowered to actively participate in the energy market through user-friendly interfaces, tools, incentives and governance structures

that promote participation and engagement in the development and prosperity of Lightcone.

7. **Security and Reliability**: Ensure a secure and reliable environment, maintaining high levels of confidentiality, integrity, and availability, and complying with privacy laws and regulations.

8. **Environmental Sustainability**: Promote environmental sustainability by encouraging the adoption of renewable energy sources, promoting energy efficiency measures, and facilitating the reduction of carbon emissions through optimal utilisation and financial return of home energy assets.

9. **Data Management and Insights**: Establish comprehensive data management protocols to securely collect, analyse, and utilise data generated by home energy assets. Enable data owners to monetize their data by providing mechanisms for fair compensation and rewards based on data usage. Ensure data integrity, privacy, and security while fostering data sharing among stakeholders to enable informed decision-making and enhance energy efficiency.

Key Technical Components

Homeowner energy assets

In the journey towards creating a sustainable and efficient energy ecosystem, the integration of various technical components assumes paramount importance. At the core of this integration lie the homeowner energy assets, encompassing rooftop solar panels, home batteries, and electric vehicles (EVs). These assets serve as the foundational pillars of the network, interconnected and orchestrated by the underlying blockchain platform.

Homeowners invest in energy assets that are managed by on-site hardware Energy Management Systems (EMS) provided by manufacturers. These systems, often accessible through Wi-Fi or Bluetooth, offer Application Programming Interfaces (APIs) for interaction and energy optimization software, empowering homeowners to take control of their energy consumption. However, prevailing market conditions tether homeowners to single energy retailers, limiting their access to services like VPPs and constraining their choices. Participation in Lightcone opens a realm of possibilities, enabling homeowners to leverage various decentralised applications (dApps) for innovative energy management solutions. As a token of appreciation for contributing their energy assets to the network, homeowners receive Lightcone tokens, whose value appreciates through the outlined cryptoeconomic mechanisms.

Blockchain Protocol

Blockchain protocols provide the decentralised, secure and transparent backbone for communication among network nodes. They facilitate decentralised governance, aligning with the distributed nature of energy assets. While initial development occurs on a public blockchain for expediency, the roadmap outlines a transition to a purpose-built blockchain optimised for home energy assets. Throughout this evolution,

Lightcone tokens maintain compatibility with the Ethereum Virtual Machine (EVM), ensuring a seamless transition.

Nodes

Hardware devices at homeowner sites will serve as Lightcone nodes optimising response times for energy asset control and with the potential of running multiple various programs, including blockchain validators, Lightcone controllers for interfacing with energy assets, and data collectors for secure data transmission. Utilising hardware virtualization platforms, such as Vistara Labs offering ensures efficient program segregation and execution on local hardware nodes.

Smart contracts

Smart contracts provide programmable blockchain functionality and execute actions related to energy asset controls, transactions, and settlement. They enable energy actions such as VPP signals for battery management, facilitate transactions in energy exchanges such as in a P2P exchange, and settle transactions using Lightcone native tokens, ensuring transparent and verifiable execution.

Integration layer

The Lightcone integration layer serves as the bridge between the platform and the energy hardware manufacturers. This layer ensures effortless interaction and compatibility across diverse energy assets, promoting interoperability, optimising their functionality and facilitating scale of Lightcone.

Integration with a wide array of hardware manufacturers is vital for the effective functioning of the DePin. Currently, the primary method of integration involves leveraging the exposed APIs provided by these manufacturers. This straightforward approach enables Lightcone to establish connections with home energy management systems, EV chargers, solar panels, battery inverters, and other relevant devices. It's a method already widely adopted by existing VPP developers and is expected to be readily available for most popular hardware manufacturers in the market.

Looking ahead, Lightcone also explores the possibility of running its software directly on hardware manufacturers' microcontrollers, offering even greater integration capabilities. However, in the present scenario, interaction via exposed APIs remains the preferred and most practical approach.

Smart contracts, deployed on Lightcone interface with the exposed APIs of hardware devices. These contracts facilitate the seamless exchange of data between Lightcone and the home management systems, enabling efficient monitoring and control of energy assets

API layer and developer tools

The API Layer is designed to facilitate integration and interaction with third-party application developers. This layer provides a comprehensive set of interfaces and protocols, enabling developers to connect to the Lightcone infrastructure and leverage its capabilities to build innovative applications such as VPPs, P2P energy trading platforms, and other energy management solutions.

Data Access and Management: The API layer provides secure access to a wide range of energy-related data collected from household energy assets. This data includes real-time and historical energy production, consumption metrics, battery status, and other relevant information. By exposing this data through well-defined APIs, Lightcone empowers developers to create applications that can analyse and optimise energy usage for consumers.

Communication Protocols: The API layer supports various communication protocols to ensure robust and efficient data exchange between Lightcone and third-party applications. This includes RESTful APIs for standard web communication, WebSockets for real-time data streaming, and other relevant protocols tailored to specific application needs. These protocols enable real-time monitoring, control, and automation of energy assets, enhancing the responsiveness and effectiveness of the applications.

Smart Contract Interaction: Developers can interact with Lightcone's smart contracts through the API layer, allowing applications to automate transactions, execute predefined actions based on specific conditions, and ensure transparency and security in energy trading and asset management. For example, smart contracts can be used to facilitate and verify energy trades, distribute rewards, and manage membership in VPPs.

Authentication and Authorization: To maintain security and privacy, the API layer incorporates robust authentication and authorization mechanisms. Developers and applications must authenticate to access Lightcone's services, ensuring that only authorised entities can interact with the system.

Settlement layer

The Settlement Layer within Lightcone is designed to facilitate efficient, transparent transactions using a native digital currency. Smart contracts ensure automatic execution of transactions and issuance of rewards, enhancing reliability and reducing the need for manual intervention. Leveraging a native digital token streamlines transactions, reduces costs, and offers greater efficiency compared to using external fiat currency gateways. Lightcone aims to provide real-time settlement rather than traditional batched processing, further increasing transactional efficiency. The native token will be listed on external crypto exchanges, enabling application developers to purchase tokens and allowing holders to convert tokens to fiat currency.

Data layer

Within Lightcone, a robust data layer is established to harness the wealth of energy data generated by individual homes, encompassing rooftop solar panels, home batteries, electric vehicles, and energy-consuming appliances. This data holds immense value, yet its true potential is unlocked through careful processing, analysis, and transformation into actionable insights for homeowners.

Lightcone assumes the responsibility of collecting, managing, and categorising this data in a privacy-sensitive manner, ensuring compliance with privacy regulations while enabling its utilisation for the development of intelligent dApps on the Lightcone platform. Zero-Knowledge-Proofs will be an essential element in achieving privacy by

proving transaction correctness without revealing data content. Leveraging predictive analysis and machine learning techniques, this data is refined to provide homeowners with valuable insights into their energy usage patterns, aiding in informed decision-making regarding both energy management and financial planning.

The processed data becomes a valuable resource for third-party dApp developers, who can harness it to create innovative solutions catering to homeowner needs, such as VPPs, P2P trading platforms, and various other energy-based applications.

In alignment with principles of fairness and equity, homeowners, as the producers of this data, should be duly compensated for its use. Additionally, homeowners retain the right to opt out of data utilisation if they so choose. To maintain privacy and confidentiality, data aggregation and normalisation techniques are employed, safeguarding individual privacy while still allowing for household-specific insights where necessary, such as in-home energy management systems tailored to individual consumption patterns.

Security, privacy and identity layer

The DePin blockchain has generic built-in security measures through the nature of blockchain design. These are:

- **Tamper-proof ledger** for recording transactions and data entries. Each transaction is cryptographically linked to previous transactions, ensuring transparency and immutability.
- **Distributed data and processing across multiple nodes** in the network, reducing the risk of single points of failure and enhancing resilience against cyber attacks. Decentralisation also mitigates the risk of unauthorised access or manipulation of data.
- **Cryptographic techniques** to protect sensitive data both in transit and at rest. Implements robust access control mechanisms to restrict access to sensitive data and functionalities based on user roles and permissions.
- **Consensus mechanisms** such as proof of stake (PoS) validate and authenticate transactions on the blockchain network. They ensure that only valid transactions are added to the blockchain, enhancing security and preventing double-spending attacks.
- **Privacy-Enhancing Technologies** such as zero-knowledge proofs, homomorphic encryption will be explored to enhance data privacy and confidentiality. These technologies allow for the verification of transactions without revealing sensitive information, preserving user privacy.
- **Blockchains provide transparency and auditability** by enabling stakeholders to trace and verify transactions on the blockchain network.

Furthermore, stringent security protocols govern the integration of the DePin with local energy hardware assets. Individual authentication credentials are maintained for each site, and encryption protocols are utilised to secure communication with the hardware, ensuring the integrity and confidentiality of data exchange.

Home Owner Participates in Lightcone for choices on which VPP or P2P provider to use, flexibility to form community VPP or energy cooperative, maximise their existing energy assets (financially, environmentally, socially).	
Application Development Layer	
VPP Controls batteries to switch from charging to discharging based on external signals such as broad market demand for energy or ancillary services, external market pricing, home energy planning apps that predict home usage and reserve energy for that, including predicted EV travel time when available	**P2P** Controls battery charging and discharging based on external signals such as local P2P market demand for energy only, home energy planning apps that predict home usage and reserve energy for that, including predicted EV travel time when available.
Battery Energy Certificate Recognises and certifies the amount of renewable energy stored in the battery. Uses the energy mix of the grid or rooftop solar at time of charge. Incentivises daytime charging. Can be applied to EV charging.	**Innovative Application Design** Encourages innovative application design by creating a development environment. For example, Power Purchase Agreements and benchmark based home energy reduction certificates that are similar in function to compliance carbon markets.
Incentives Layer Providing tokenomic incentives for desired behaviour such as early joining of the network, sharing energy assets, community driven initiatives.	
API Layer Providing an interface for application developers onto the Lightcone functionality	
Blockchain Layer Connects all nodes, provides security, validates transactions, manages all digital assets such as native token transactions. Provides smart contract execution and event driven interactions with the Integration Layer.	
Integration Layer Provides a communications channel between the home energy assets and Lightcone for energy data collection and command and control signals.	
Security and Privacy Layer User authentication, Identity, confidentiality and privacy provisions including zero-knowledge-proofs	
Data Layer Collects and stores data from energy devices, trading and other events. Stores either on-chain or off-chain. Provides analytics via machine learning for network and node optimisation.	
Energy Asset layer Home batteries, EV chargers, energy management systems any other energy assets	

Table 1 Lightcone Layers

Use Cases / Applications

Below are proposed dApps that could leverage the Lightcone infrastructure platform. These dApps, developed by third-party innovators, can be provided as services back to the homeowners that formed the DePin network. While the list outlines several potential development avenues, it's the creativity and ingenuity of the development community that will ultimately shape and bring to life practical applications for the energy ecosystem.

Virtual Power Plants (VPPs)

The DePin establishes a network of interconnected nodes, essentially comprising household energy assets. Third-party developers can leverage this network to create VPPs, which aggregate multiple home energy assets to function collectively as a unified entity. These VPPs can then participate in energy markets and offer ancillary services, such as grid stability. We envision several innovative applications for VPPs within the DePin ecosystem.

Homeowners participating in VPPs stand to gain rewards in Lightcone native tokens, while also having the option to engage with dApp developers on the DePin platform. dApp Developers seeking to deploy their applications on Lightcone are required to acquire Lightcone native tokens as gas fees, thereby contributing to the token's value appreciation.

Standard VPP

Standard VPPs adhere to the existing market model and consist of a collection of fixed home energy assets, like rooftop solar panels and stationary home batteries, operating in tandem to participate in broader energy markets. Currently, these VPPs are offered by energy retailers to their existing energy customers only, thereby creating lock-in. dApp VPPs created on Lightcone break the VPP - retailer lock-in and allow VPPs to form regardless of the homeowner’s retailer. dAPP VPP developers are able to innovate in their market offering, features, pricing, service levels, etc to satisfy individual customer needs.

Community VPPs

Community networks arise when residents within a localised area collaborate to establish an energy cooperative, pooling their energy assets within the immediate community. In contrast to VPPs initiated by energy retailers, which typically comprise customers dispersed across various locations, community VPPs are composed of energy assets located in close proximity to one another. This proximity aligns with electrical subnets, offering inherent electrical advantages and enabling grid operators to manage VPP loads and generation more effectively based on localised electrical needs. Community VPPs are characterised by their community-driven nature, with objectives extending beyond mere financial gains to encompass broader community and social goals. Lightcone serves as a facilitator for the creation and governance of community VPPs, providing robust mechanisms for overseeing operations, even at larger scales.

VPPs for EVs

Building upon the standard VPP model, an innovative approach involves integrating electric vehicle (EV) batteries into VPPs. However, the intermittent connection of EV batteries to the network and their varying connection points, such as home chargers or public stations, pose challenges. This form of VPP must address the intermittency while leveraging the significant energy storage capacity of EV batteries. Vehicle-to-Grid (V2G) technologies are essential for this model, necessitating V2G-compatible EVs, bidirectional chargers, and regulatory standards. Despite these challenges, the abundance of EVs and their sizable batteries present opportunities for energy and grid stability services.

Grid Integration and Frequency Markets

Frequency markets are an essential component of electricity grid management, where grid operators maintain the balance between electricity supply and demand in real-time. These markets allow for the trading of frequency control services. Participants, including power generators, aggregators, and demand-side resources, provide services to help stabilise the grid frequency and ensure its reliability.

Research conducted by governmental energy institutions suggests that the participation of home and EV batteries in frequency markets can be financially rewarding for energy asset owners. However, challenges related to market design, regulatory frameworks, and technical coordination currently hinder home energy asset participation in frequency markets. Despite debates surrounding the feasibility of forming VPPs suitable for frequency market participation, the growing number of distributed home energy assets presents opportunities to deliver grid ancillary services effectively.

P2P networks

In addition to VPP development, the Lightcone infrastructure provides a robust foundation for the creation of P2P energy trading platforms. Leveraging the interconnected nodes of home energy assets within the Lightcone network, developers can establish P2P networks that enable direct energy trading among participants.

These P2P networks could be monetized by developers, offering subscription-based access to participants seeking alternatives to traditional centralised energy retailers. By operating within a P2P framework, participants gain the flexibility to trade energy directly with one another, bypassing intermediaries.

Key benefits of P2P energy trading platforms include:

1. **Enhanced Tariff Rates**: Participants stand to benefit from potentially higher feed-in tariffs compared to those offered by conventional retail energy providers.
2. **Energy Gifting**: The platform could facilitate the exchange of energy as gifts, allowing participants to support local community entities such as schools and kindergartens.

3. **Establishment of Energy Cooperatives**: By fostering collaboration among like-minded households, the platform can facilitate the formation of energy cooperatives aimed at achieving common energy-related goals and fostering community resilience.

Through P2P energy trading platforms, Lightcone empowers participants to engage in decentralised energy transactions, promoting sustainability, community empowerment, and financial autonomy.

Tokenised certificate for battery energy

In Australia, small-scale renewable energy certificates are issued for sources like rooftop solar, but battery storage, critical to the renewable energy transition, lacks recognition as a renewable energy generation source. Yet, batteries play a pivotal role in absorbing excess solar energy during daylight hours and releasing it during evening or morning peak times when renewable energy is scarce. This renders battery energy inherently more desirable than instantaneously generated energy.

To address this disparity, we propose a tokenized certificate system for energy stored in batteries. This system aims to recognize the value of battery-stored renewable energy by issuing certificates proportionate to the amount of renewable energy on the grid at the time of charging. By leveraging data provided by the market operator on the grid's renewable energy mix, homeowners charging their batteries or electric vehicles (EVs) with rooftop solar can earn higher levels of credits.

Our envisioned system involves issuing tokenized certificates to batteries based on the prevailing energy mix of the grid. For instance, if solar energy dominates the grid during the day, more certificates are allocated to batteries absorbing this load. Subsequently, batteries discharging energy to the grid during peak times can trade these certificates along with their energy, certifying its renewable nature and enhancing its value. We plan to establish a marketplace to facilitate the trading of these certificates, with blockchain technology verifying and tracking them via smart contracts on-chain, thereby creating a Voluntary Battery Certificate market.

These energy tokens will possess various characteristics such as the time of day consumed or stored and the type of generation. These diverse attributes enable their trade on a new marketplace, offering flexibility and adaptability to users. Additionally, the certificates can signify the daytime charging of EVs, incentivising owners to charge when renewable energy is abundant. Furthermore, with the advent of Vehicle-to-Grid (V2G) technology, battery-stored energy can be sold back to the grid, with token purchase ensuring its daytime charging, a feature of considerable value to grid operators.

A CryptoEconomic framework for Lightcone

Lightcone's crypto-economic framework is designed to incentivise long term participation in the Lightcone Network and support the efficient transaction of energy services among participants. Central to this framework is a dual-token model with $Photon as a utility token, exclusively used for governance and rewards accompanied by $Graviton which facilitates stable, on-chain transactions and serves as the medium of exchange. This dual-token approach allows for the independent pursuit of economic activities and decentralised governance, ensuring a balanced and efficient network.

Primary Utility Token ($Photon)

- **Utility Purpose:** Governance and rewards.
    - **Governance:** The governance aspect allows $Photon token holders to actively participate in Lightcone's decentralised decision making process for future directions of the Lightcone Network. Holders of $Photons have voting (quadratic voting) rights on key proposals, such as protocol upgrades, governance changes, and fund allocations, fostering a community-driven approach to platform development. $Photon holders can submit proposals for new features, modifications, or other strategic decisions, ensuring diverse voices are heard. Governance rights can also be delegated to form collectives or cooperatives, enhancing community involvement. By separating governance from economic transactions, $Photon aligns its value with the network's long-term health.
    - Minting transaction tokens: To use the network, $Graviton tokens are required as gas fees. $Graviton are minted from staking $Photon and both tokens are used to create a stable transaction cost with sufficient liquidity to promote network use.
- **Distribution:** Distributed to Lightcone participants who create, support, and secure the network. Key recipients of $Photon include:
    - **Homeowners** who provide energy assets such as batteries to the network.
    - **dApp Developers** who build decentralised applications on Lightcone.
    - **Community Members** who suggest improvements to the network.
    - **Lightcone Network Development Team** who suggest and implement improvements to the network.

Transaction Token ($Graviton)

- **Utility Purpose:** $Graviton is used to pay for energy transactions executed on the Lightcone Network. Each $Graviton is the transaction fee for 1Kwh of energy traded on Lightcone.
- **Fixed Value:** Pegged to a stable value of USD $0.02 plus an inflation rate of 2% per annum will ensure predictable and stable transaction costs. $Graviton are burned after use.
- **Dynamic Minting Mechanism:** $Graviton tokens are minted by staking $Photons. The amount of $Graviton generated from staking $Photon is calculated with consideration to the number and staking duration of $Photon, network demand, transaction volumes, cost of $Photon as determined by a defined external Oracle, burn rate and demand of $Graviton. This measure will affect a stable network transaction cost plus inflation target. For example the number of $Graviton minted will increase as the cost of $PinSeeds,. Network activity and $Graviton demand increases.

Treasury

The treasury in Lightcone's crypto-economic framework acts as a central reserve to manage the supply and distribution of $Photon and $Graviton tokens and ensure the network's long-term sustainability. Here's a summary of its key functions:

- **Token Distribution:** The treasury holds a significant portion of the total $Photon supply (e.g., 70%) and releases them over time. It distributes these tokens to reward homeowners, developers, and other network participants based on predefined criteria, such as energy contributions or ecosystem development efforts.
- **Network Growth:** It funds ecosystem expansion by offering grants, rewards, and incentives to developers and participants, encouraging active involvement and network improvements.
- **Minting and Inflation Control:** The treasury dynamically mints new $Photons as needed, factoring in network demand and growth. It also manages deflationary pressure as $Photons are staked to minting $Graviton. Treasury ensures that there is enough $Photon to satisfy the demand for $Graviton as the network participation and usage grows
- **Stabilising the Economy:** By acting as a reserve, the treasury can intervene to stabilise the token economy, funding network operations, managing liquidity, and ensuring a stable supply of $Photons to meet network needs.

Rationale for a Two-Token Model

The rationale behind a two-token system, $Photon for governance and reward and $Graviton for transaction, is to separate different functions within the network to

optimise for stability, growth, and decentralised governance. This separation can help balance network incentives, ensure predictable transaction costs, and promote long-term participation.

The two-token system helps achieve a more balanced ecosystem by:

- **Separating Governance and Utility:** Preventing network transactions from being affected by market volatility.
- **Maintaining Predictable Costs:** Using a stable transaction token ensures consistent transaction fees.
- **Incentivizing Participation:** $Photon rewards encourage participants to contribute and remain engaged.
- **Managing Inflation:** Controlling $Graviton's issuance and burning maintains an equilibrium between supply and demand, aiding in long-term network sustainability.
- **Minimising Securities Risks:** By creating distinct roles for each token, the system aims to comply with regulatory guidelines, focusing on network use and participation rather than speculative investment.

Incentive Mechanisms

Homeowners

- **Participation Rewards:**
    - Onboarding Bonus: Homeowners receive an initial $Photon token bonus when they integrate their energy assets (solar panels, home batteries, EVs) into the Lightcone network.
    - Energy Contribution: $Photons are rewarded based on the amount of energy contributed to the grid or P2P trading. Higher contributions yield higher rewards.
- **Referral Program:** Homeowners are incentivized to invite others to join the network.
- **Longevity Rewards:** Additional $Photons can be earned for consistently contributing to the network over a long term.

Developers

- **Development Grants:**
    - Initial Grants: Early-stage developers receive $Photon tokens as grants / incentives to support the initial development and deployment of their dApps on the Lightcone platform. These Photons can be burned for $Graviton and use of the network.

    - Innovation Grants: $Photon tokens awarded to developers who create high-impact applications that enhance the Lightcone ecosystem.

- **Incentivized Innovation:**
    - Innovation Challenges: Regularly hosted challenges with significant token rewards for developing unique and impactful dApps that address specific energy management issues.
    - Hackathons: Tokens are awarded to winners of hackathons focused on creating innovative solutions for the Lightcone ecosystem.

Issuance

Total Supply

- **$Photons:** A fixed total supply of 1 billion $Photons. A fixed supply creates scarcity, potentially driving demand over time, especially as staking is required to mint $Graviton.
- **$Graviton:** Not capped, as it is minted dynamically based on the amount of staked $Photons and network activity. This is key to maintaining a stable cost of network transactions.

$Photons Allocation Breakdown

To ensure the network has a healthy distribution and to incentivise various participants, the $Photons allocation might look like this:

1. **Community & Ecosystem Development (40%)** – **400 million $Photons**
    - Used to reward homeowners, early adopters, and dApp developers for joining and supporting the Lightcone network.
    - Distribution over time, with monthly rewards based on network participation and energy asset contributions.
    - Can include grants to incentivize third-party developers to build on Lightcone.
    - Distribution Schedule:
        - Initial Issuance: 20% (80 million $Photons) released immediately to reward early adopters and incentivize participation.
        - Subsequent Issuance: Remaining 80% (320 million $Photons) distributed over 5 years with a monthly release schedule based on network participation and energy contributions.

        - Vesting Schedule for Grants: Developer grants follow a 2-year vesting schedule with a 6-month cliff to ensure commitment to the network.

2. **Network Treasury (20%)** – **200 million $Photons**
    - Managed by the Lightcone network's decentralised governance.
    - Used to fund future network upgrades, research, marketing, partnerships, and other ecosystem support activities.
    - Acts as a reserve to manage the token economy and stabilise the network.
    - **Distribution Schedule:**
        - Initial Allocation: 50% (100 million $Photons) allocated to the Treasury at launch to manage initial network costs and support early development.
        - Subsequent Allocation: The remaining 100 million $Photons vested over 5 years, released monthly to align with network growth and economic demands.
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3. **Founders & Team (15%)** – **150 million $Photons**
    - Allocated to founders, team members, and early contributors.
    - Vesting schedule: 4 years with a year cliff. This ensures long-term commitment and aligns with network growth.
    - Distribution Schedule and Vesting:
        - Vesting Schedule: 4-year vesting period with a 1-year cliff. After the first year, tokens are released monthly to the founders, team members, and early contributors.
        - Initial Allocation: 10% (15 million $Photons) available immediately after the cliff period to support team liquidity needs.
4. **Public Distribution (25%)** – **250 million $Photons**
    - Reserved for public sale events, airdrops, or community rewards.
    - A smaller public allocation helps create initial demand while avoiding excess supply that could negatively impact the market price.
    - Distribution Schedule:
        - Seed Round: 5% (50 million $Photons) allocated to early investors with a 1-year lockup followed by a 2-year linear vesting schedule.

        - Private Sale: 10% (100 million $Photons) allocated to strategic investors with a 6-month lockup and a 2-year linear vesting schedule.
        - Public Sale: 10% (100 million $Photons) offered to the public with no lockup but limited to prevent market dumping.

Initial Distribution Strategy

1. **Reward Homeowners:**
    - Upon joining Lightcone and registering energy assets, homeowners are allocated a certain amount of $Photons as an incentive. The amount depends on the capacity and characteristics of their assets.
    - Monthly rewards will be given in $Photons based on their energy contribution, capped to prevent over-inflation of circulating supply.
2. **Developer Incentives:**
    - $Photons will be granted to dApp developers who build applications on the network, distributed from the Community & Ecosystem Development allocation.
3. **Staking Rewards:**
    - Staking $Photons generates $Photon rewards. This encourages participation in governance activities for the long term health of the network.
4. **Initial Public Sale:**
    - A portion of the public distribution (e.g., 250 million $Photons) could be sold in a public offering to bootstrap the network and create liquidity. This public sale should emphasise the utility and governance aspects of $Photons.

$Graviton Initial Supply

- **Initial Minting:** To kickstart the network, mint an initial supply of 1 billion $Graviton, distributed as follows:
    - **Ecosystem Fund (50%)** – 500 million $Graviton for incentivizing early network participants, initial liquidity provision, and strategic partnerships.
        - Initial Allocation: 40% (200 million $Graviton) released immediately at network launch.
        - Subsequent Distribution: The remaining 60% (300 million $Graviton) released over 3 years on a monthly schedule, tied to

network usage and participation. Monthly release rates can be adjusted based on network burn rates to avoid oversupply.

- **Network Treasury (30%)** – 300 million $Graviton to be used for ongoing network operations, grants, and stabilising network economics.
    - Initial Allocation: 50% (150 million $Graviton) allocated to the Treasury at launch.
    - Subsequent Allocation: The remaining 50% (150 million $Graviton) released over 4 years with monthly vesting, allowing flexibility to respond to network demand and usage.
- **Liquidity Provision (20%)** – 200 million $Graviton allocated to exchanges (both decentralised and centralised) to ensure there is enough liquidity for users to buy and sell $Graviton, facilitating smooth network transactions.
    - Initial Allocation: 50% (100 million $Graviton) provided at launch to exchanges.
    - Subsequent Allocation: The remaining 50% (100 million $Graviton) allocated over 2 years with monthly releases to maintain market liquidity.

Our Team

The Lightcone core team comprises three co-founders, each bringing a diverse and accomplished background to the project. United by a strong interest in applying advanced technologies such as blockchain and AI to address sustainability issues, our team is uniquely positioned to lead the development of a Decentralised Physical Infrastructure Network (DePin) for home energy assets.

Dr. Sumeet Chougle – Chief Executive Officer (CEO)

Dr. Sumeet Chougle holds a Ph.D. in Astrophysics and has an extensive background in academic research, with several published papers to his name. His expertise in AI strategy and strategic thinking drives the vision and direction of Lightcone. Sumeet's ability to bridge complex scientific concepts with practical applications ensures that Lightcone is grounded in rigorous academic research and innovative thinking.

Mark Tsang – Chief Operations Officer (COO), Director

Mark Tsang has a Master's degree in Sustainable Development and a Bachelor's degree in Electrical Engineering. He brings vast experience in business and corporate management, particularly in the governance and management of large-scale IT projects within the financial markets. Mark's background in formal compliance and risk management, including audit and board reporting, ensures that Lightcone operates with the highest standards of integrity and efficiency.

Stefano Tempesta – Chief Technology Officer (CTO)

Stefano Tempesta is a University lecturer in blockchain and AI strategy and has authored a book on blockchain technology. He has vast experience in blockchain development, including Web3 fintech and blockchain-based carbon market platforms. Stefano's extensive startup experience in Web3 and social enterprises positions him perfectly to lead the technological development of Lightcone. His leadership ensures that Lightcone remains at the forefront of technological innovation.

Our team's unique blend of capabilities, experiences, and achievements makes us exceptionally qualified to lead the Lightcone project. We cover the essential cornerstones of a successful startup:

- Academic Excellence: Strong foundation in scientific research, providing a rigorous and methodical approach to problem-solving.
- Technical Expertise: Proven track record in Web3 and AI application development, specifically for the startup ecosystem.
- Business Management: Extensive experience in operations, compliance, risk management, startup foundation and governance of large-scale IT projects.
- Sustainability Focus: Deep interest and involvement in applying advanced technologies like blockchain and AI to address sustainability issues.

Lightcone aims to create a decentralised network of home energy assets, leveraging blockchain and AI to optimise the use of deployed assets for both financial and environmental benefits. By integrating our diverse expertise and commitment to innovation, we are poised to drive significant advancements in the decentralised energy market.

Conclusion

The Decentralised Physical Infrastructure Platform (DePin) introduces a groundbreaking approach to managing residential energy assets within a decentralised energy ecosystem. By harnessing the power of blockchain technology and smart contracts, DePin empowers homeowners to actively engage in the energy market, optimising the utilisation of renewable resources and bolstering grid stability. Built upon the DePin framework, the Lightcone solution offers a flexible and scalable architecture, empowering individuals and communities to realise both environmental and financial benefits from their energy investments. As we stride toward a sustainable future, the adoption of DePin and Lightcone holds the promise of seamlessly integrating the rapidly expanding segment of residential home energy assets.

Throughout this paper, we have delved into the DePin concept and its potential to unlock the benefits of underutilised infrastructure. Our implementation of this concept focuses on the energy industry, aiming to contribute to the ongoing transformation it is currently undergoing. Lightcone serves as an innovation hub within the energy

ecosystem, fostering a diverse community of creative minds dedicated to injecting innovation into an industry undergoing significant change.