Optimizing Virtual Power Purchase Agreements (PPAs) Using Optimistic Ethereum Blockchain Network

Design, development, and implementation of smart contracts specifically tailored for closing Power Purchase Agreements (PPA)

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Overview

01

Motivation

Although most countries have the right conditions for renewable energy generation, businesses have had limited opportunities to benefit from clean energy. Central to this shift is the utilization of Power Purchase Agreements (PPAs), which have historically played an important role in promoting renewable energy and managing the transition from regulated to competitive electricity markets.

02

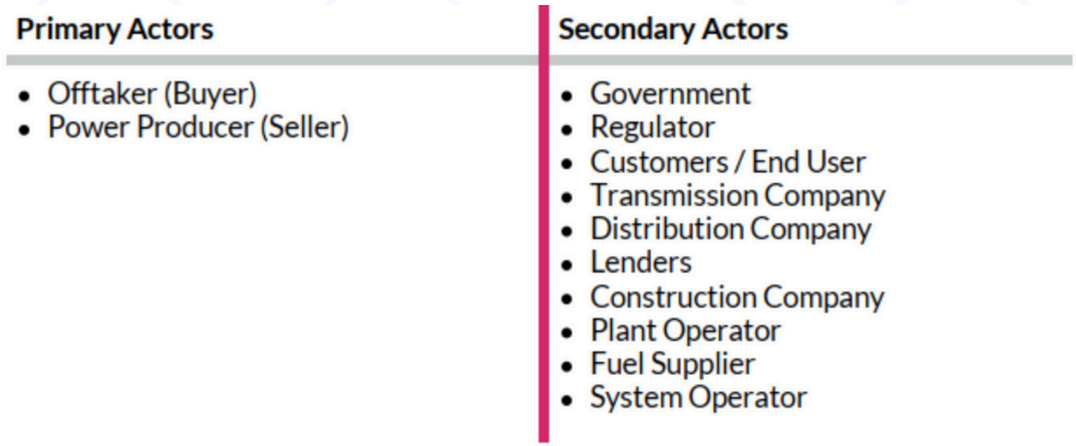
PPAs

A PPA is a contract between two parties:

- Seller: The party that generates electricity.
- Buyer: The party looking to purchase electricity.

The PPA specifies all commercial terms for the electricity sale, which can include:

- Pricing structure: Fixed, indexed, or “shaped” rates.
- Start date: When the project will begin commercial operation.
- Delivery schedule: The timeline for electricity delivery.
- Penalties: Consequences for under-delivery of electricity.
- Payment terms: Conditions for financial transactions.
- Termination terms: Conditions under which the contract may end.



02

Limitations

High legal and fnancial transaction fees. Average PPA process costs add up to $1 million for each client and the process can take 12-18 months to close.

Usually a few large buyers. No point of entry for smaller buyers.

01

To re-sell or decrease the quantity of purchased energy, the whole agreement must be renegotiated which adds even more time and costs.

02

03

Few large counterparties are expected to be solvent over the duration of the contract.

04

02

Virtual PPAs

A Virtual PPA is a type of contract, such as:

- Hedge or Contract for Difference (CfD).

In a Virtual PPA:

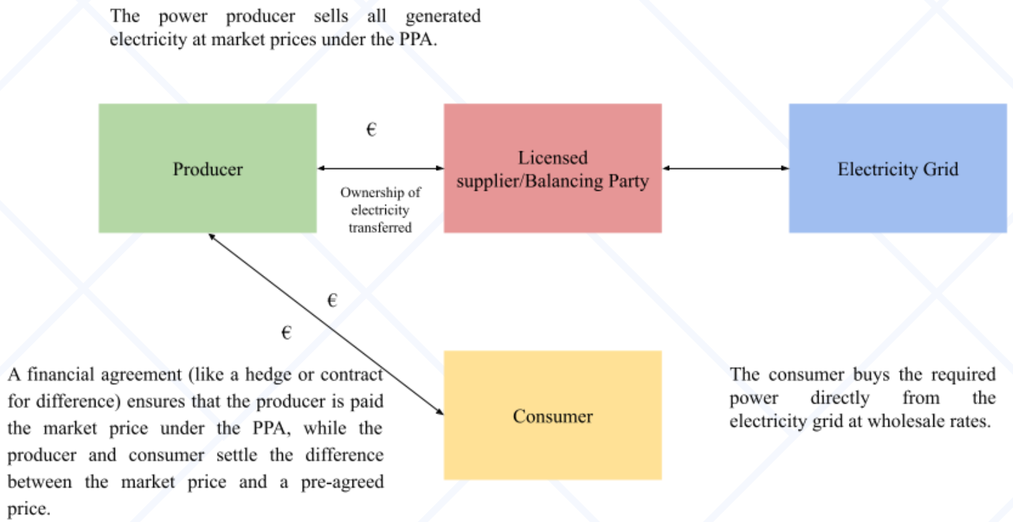
- The Generator receives the market price for electricity under the PPA.
- The Generator and Consumer settle the difference between the market price and the agreed fixed price.

It is considered "virtual" because:

- There is no physical purchase of electricity involved.
- Similar to most Contracts for Difference, it relies on financial settlement rather than physical delivery.

In commodities trading, this is common:

- Most trades involve financial settlement rather than physical settlement.



02

Energy Attributes Certificates

Renewable energy is essential for achieving a net zero transition by:

- Reducing scope 2 emissions as defined by the Greenhouse Gas (GHG) protocol.
- Meeting both statutory regulation and voluntary reporting criteria.

Energy Attribute Certificates (EACs):

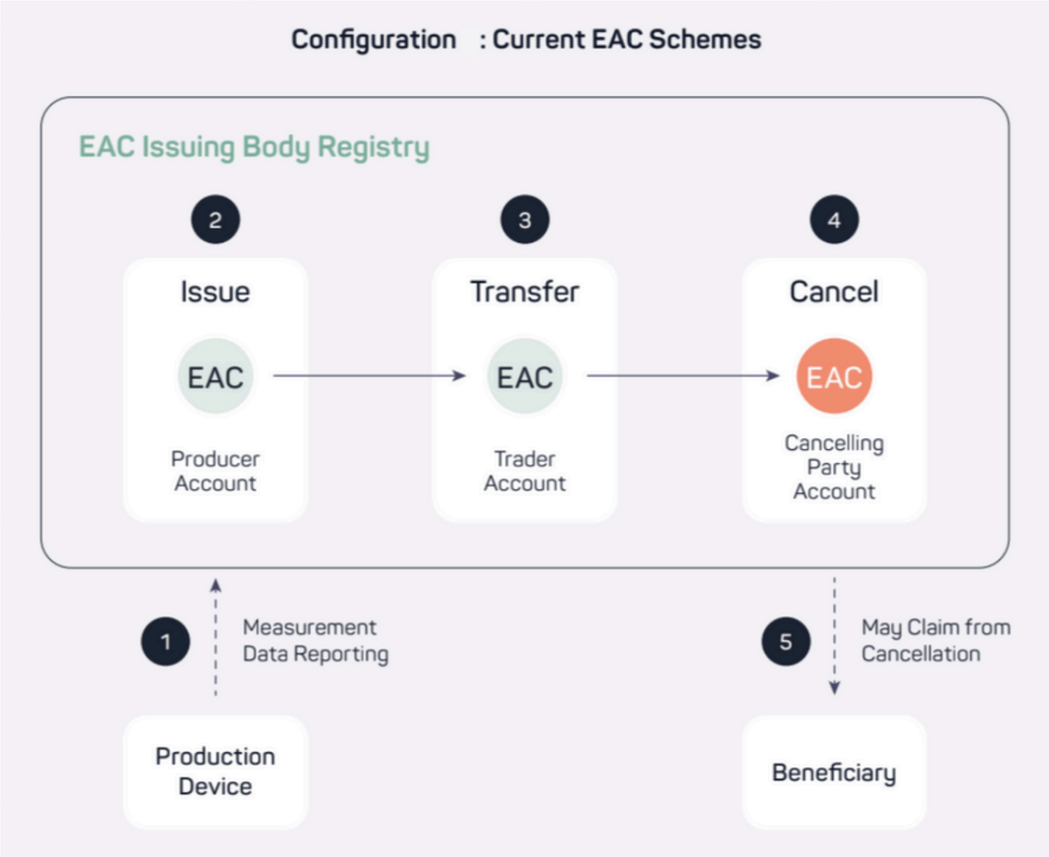
- Are official documents that verify the environmental attributes linked to renewable energy production.
- Were created to monitor electricity flow from the source to the end user.

Electricity characteristics:

- It is intangible and requires continuous grid maintenance.
- When purchased, the buyer acquires the right to withdraw a specific amount from the power grid.

Tracking system:

- The only method to connect the production and usage of a specific MWh of electricity.



02

Problem

High legal and fnancial transaction fees, and the process can take 12-18 months to close.

Usually a few large buyers. No point of entry for smaller buyers.

Duplication Issuance or during transfer: This can occur due to miscommunication between certifying bodies, inadequate controls in verifying existing certificates, technical errors in electronic processes, or fraud.

01

02

Renegotiates which adds even more time and fees.

03

04

Few large counterparties are expected to be solvent over the duration of the contract.

05

06

Double registration: in relation to IT system security and IT operational risks, the same Certificate could erroneously get registered more than once.

02

Blockchain Technology

Blockchain technology can greatly optimize VPPAs by:

- Enhancing transparency, security, and efficiency.

Benefits of blockchain in VPPAs:

- Utilizes a decentralized ledger to ensure all transactions and contract details are immutable and tamper-proof.
- Builds trust between energy producers and corporate consumers.

Additional capabilities:

- Avoids duplication of assets, as each asset is unique on the blockchain.
- Ensures that renewable energy claims are both credible and transparent.
- Ensures information cannot be changed in the ledger.

02

Optimistic Ethereum Blockchain

Optimism (OP) is a Layer 2 (L2) scaling solution developed to address Ethereum's scalability challenges.

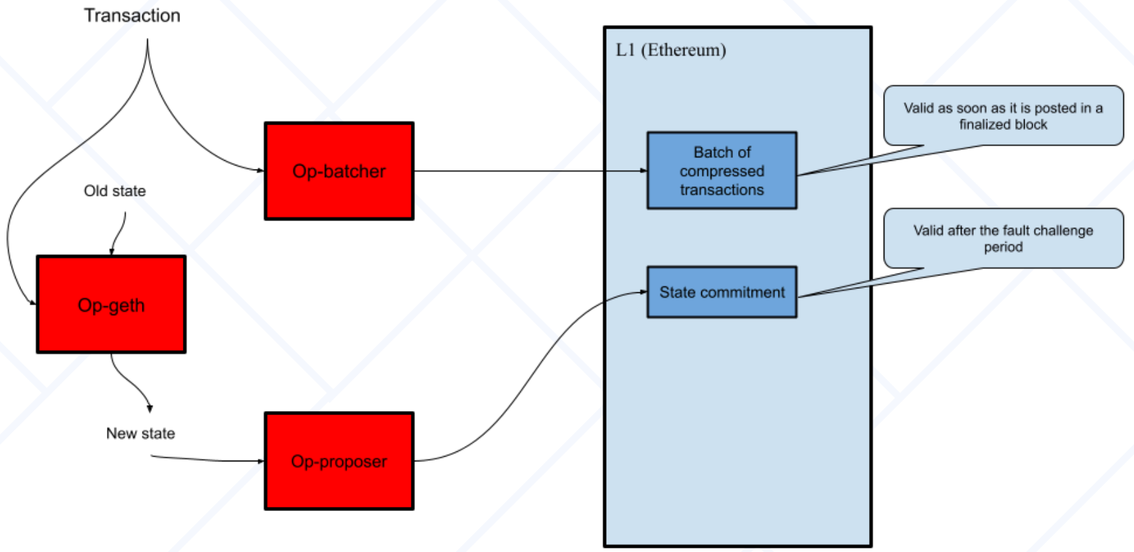
- Optimism is responsible for developing and operating the OP mainnet, an L2 solution based on optimistic-rollup technology.
- The current version of Optimism is known as Optimism Bedrock.

In blockchain architecture:

- A roll-up is a blockchain that derives its security from a higher-level chain.
- Ethereum serves as the parent chain for Optimism.

Optimism leverages Ethereum to:

- Store and archive block data in a compressed format, reducing costs.
- Utilize Ethereum's robust security for enhanced protection of data and transactions.



02

Optimistic Virtual Machine

State transitions represent the changes within the EVM that occur with every transaction. To prevent off-chain invalid state transitions, which could cause incorrect transactions when returning to Layer 1, Optimism introduced the OVM. This ensures that Layer 2 inherits the security protocols of the EVM and maintains the integrity of Layer 1.

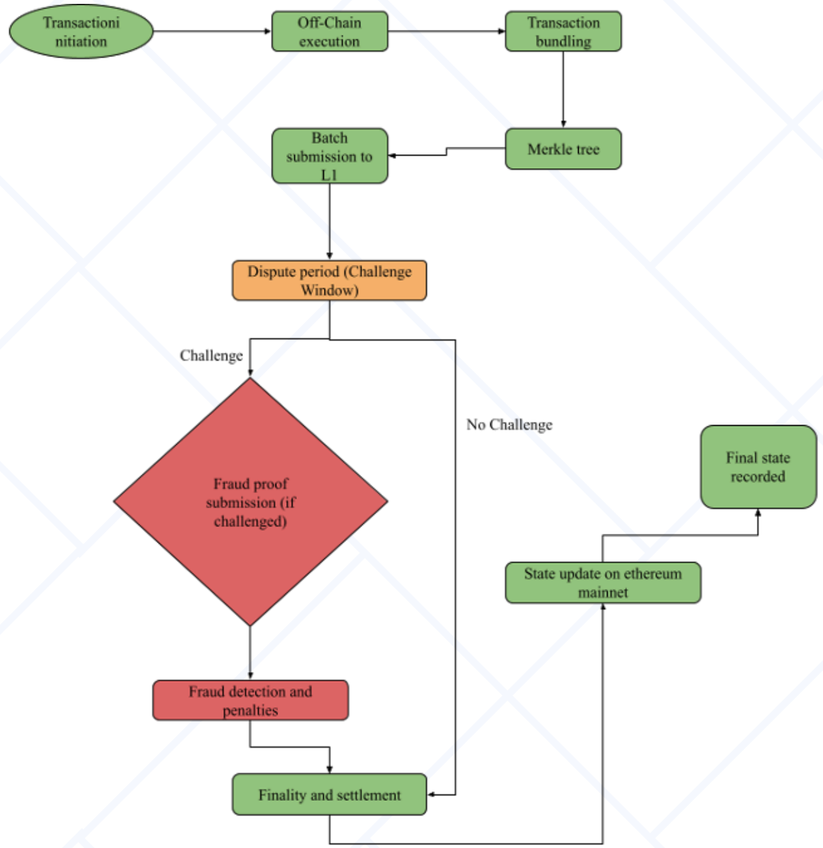
The OVM handles smart contract execution on the layer-2 chain, running them "optimistically" (assuming they are correct without immediate verification).

02

Fraud Proofs and Dispute Resolution

Because the OVM operates optimistically, it assumes transactions are valid unless challenged.

- Fraud Proofs: If someone detects an invalid transaction, they can submit a fraud proof. This initiates a process where the questionable transaction is re-evaluated on layer-1 to determine its validity.
- Challenge Period (~ 7 days): There's a predefined challenge period where anyone can contest a transaction. If no one disputes it within this time, it's considered valid and finalized.



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Ethereum Standards (ERCs)

In Ethereum, standards refer to predefined rules and guidelines that ensure interoperability, security, and functionality within the Ethereum blockchain ecosystem. These standards are critical for creating and interacting with smart contracts, tokens, dApps, and other blockchain-based systems. The Ethereum Request for Comments (ERC) process defines these standards, with various ERC proposals addressing different use cases.

For our project, the following ERCs used:

- **ERC-1155**: This is a multi-token standard that allows a single smart contract to manage both fungible and non-fungible tokens. ERC-1155 reduces the transaction and gas costs by enabling batch transfers of different tokens.
- **ERC-1888**: A relatively newer standard designed for EACs, a specific type of token representing environmental commodities like renewable energy credits. ERC-1888 facilitates the management, trade, and redemption of green energy certificates on the blockchain, making it highly relevant for energy markets and green energy certification projects.

03

Related PPA, EACs, P2P Energy Trading Projects

FlexiDAO

FlexiDAO is a software company that provides digital solutions for tracking and verifying renewable energy usage and carbon emissions. They leverage blockchain technology to offer real-time, transparent, and reliable data on energy consumption and its origin.

Wepower

WePower is a green energy trading platform that uses blockchain technology to facilitate direct connections between renewable energy producers and consumers, such as businesses and large-scale buyers.

PowerLedger

Powerledger is an Australian technology company that uses blockchain technology to enable peer-to-peer (P2P) energy trading, renewable energy tracking, and carbon credit transactions.

04

Implementation

Phase 02

Development of a platform for PPA creation and auction management.

Phase 01

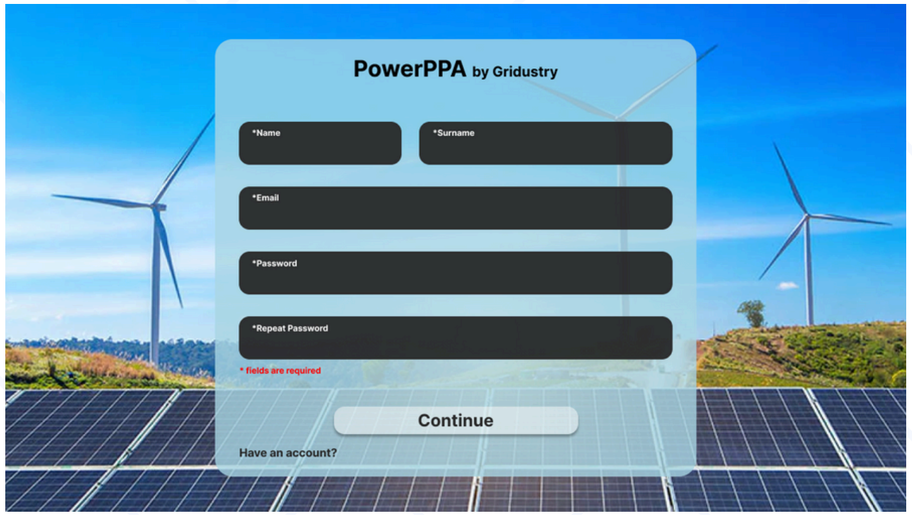
Smart Contracts for Auctions, PPAs, User Roles in the dApp, Energy Trading, and EAC Issuance.

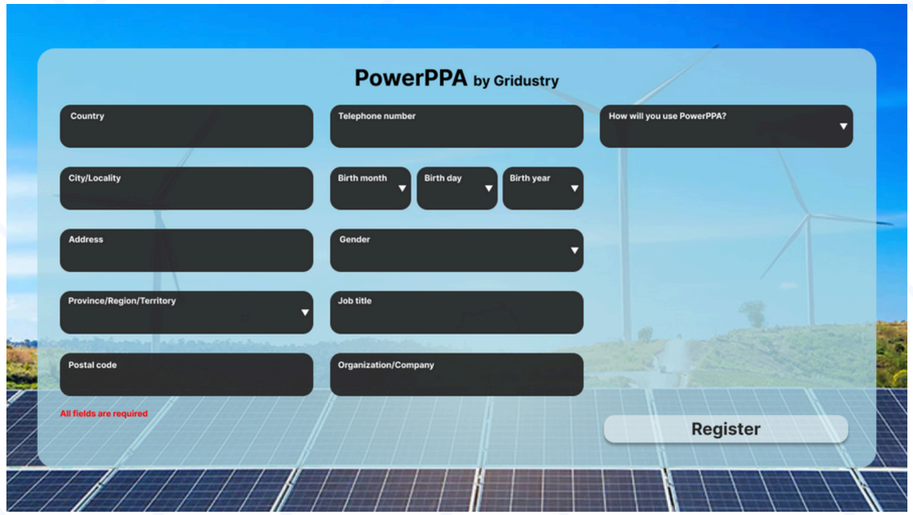
Phase 03

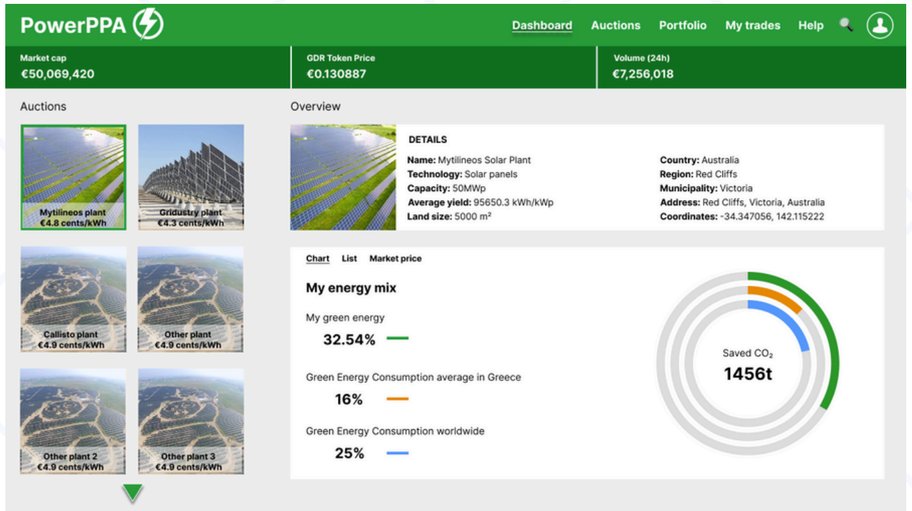
Smart Contracts deployment on OP SepoliaTestnet and integration.

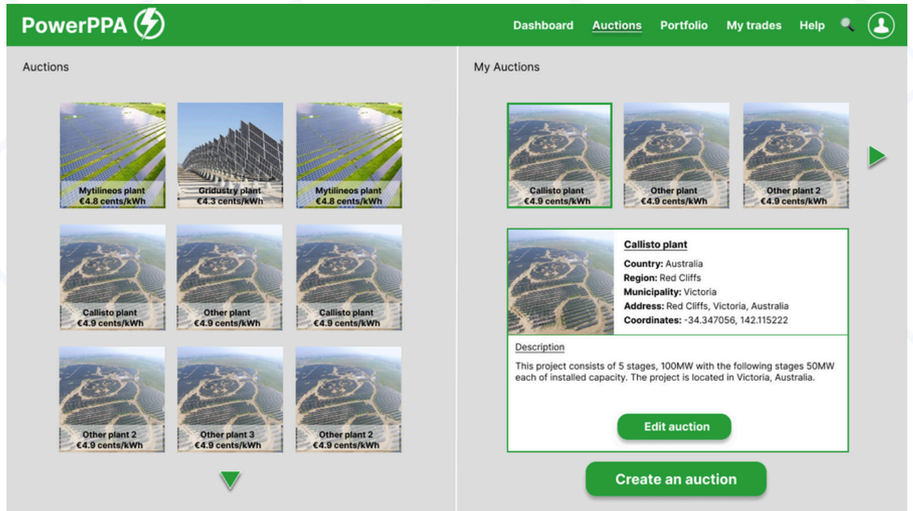
04

PowerPPA Platform









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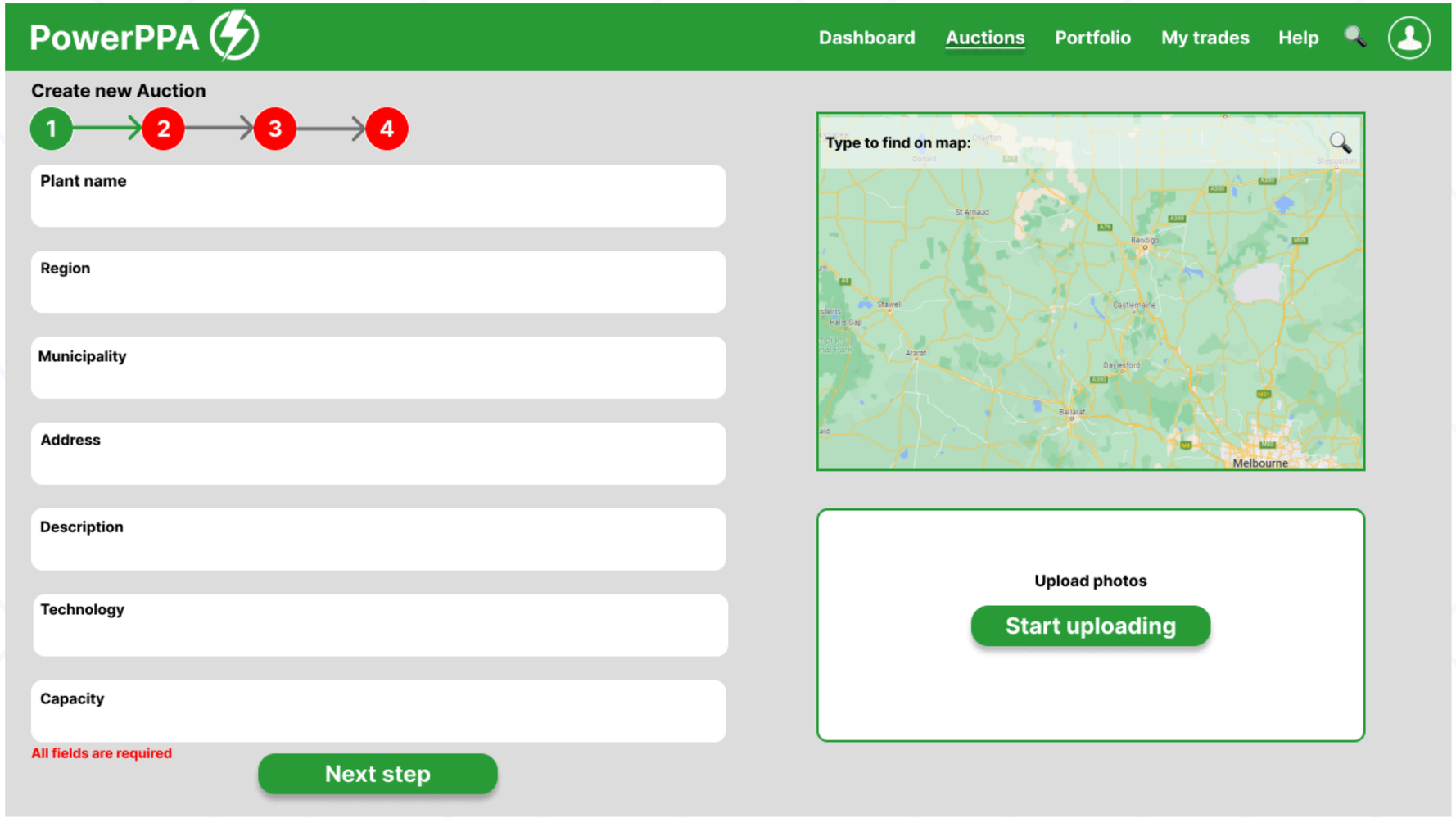

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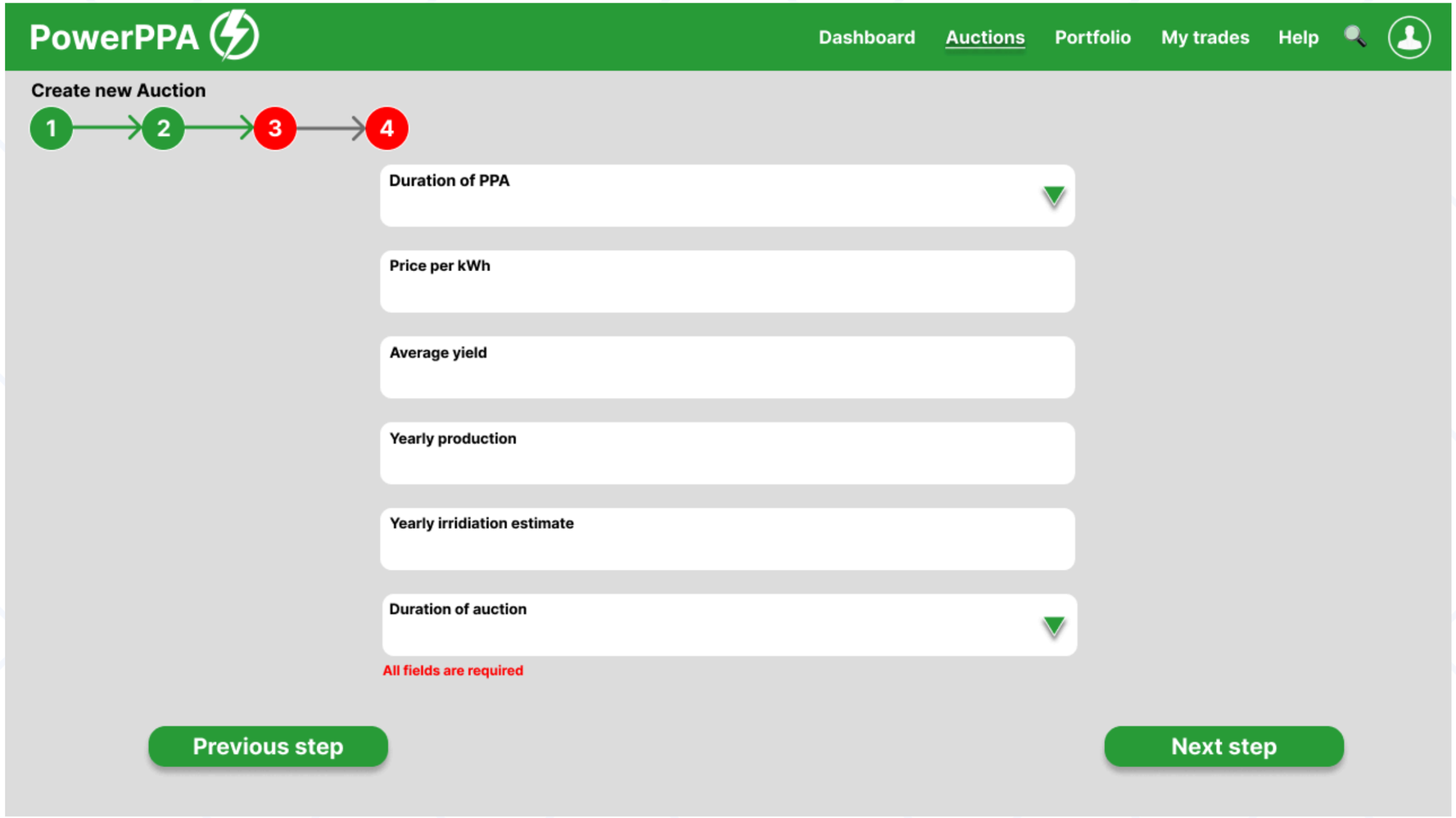

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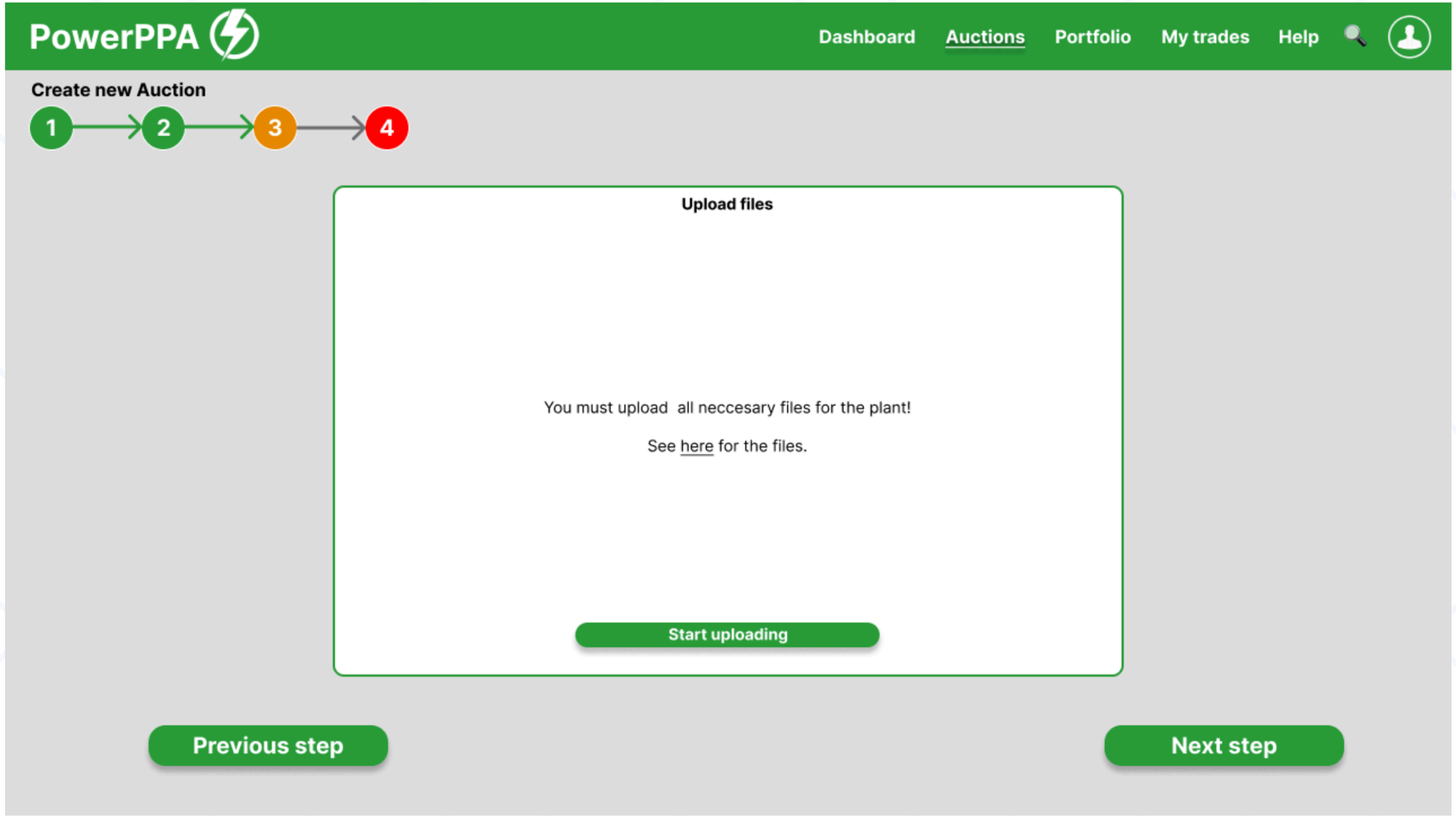

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PowerPPA Platform

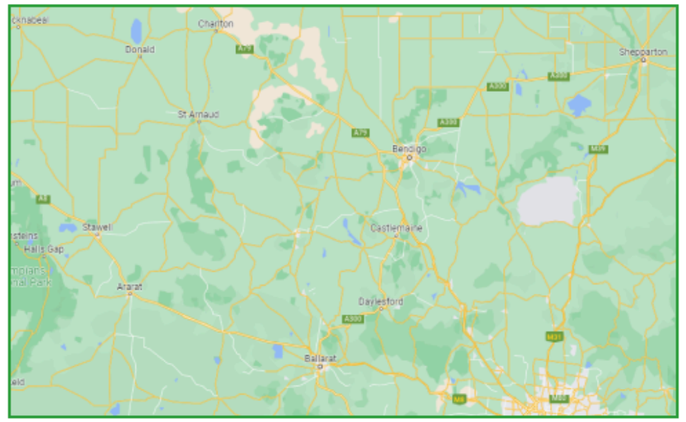
PowerPPA

Dashboard | Auctions | Portfolio | My trades | Help

Create new Auction

1 → 2 → 3 → 4

Plant name:
Region:
Municipality:
Address:
Duration of auction:
Technology:
Capacity:
Duration of PPA:
Price per kWh:
Average yield:
Yearly production:
Yearly irridiation estimate:



Description:



Auction **#3456**

Request new Auction

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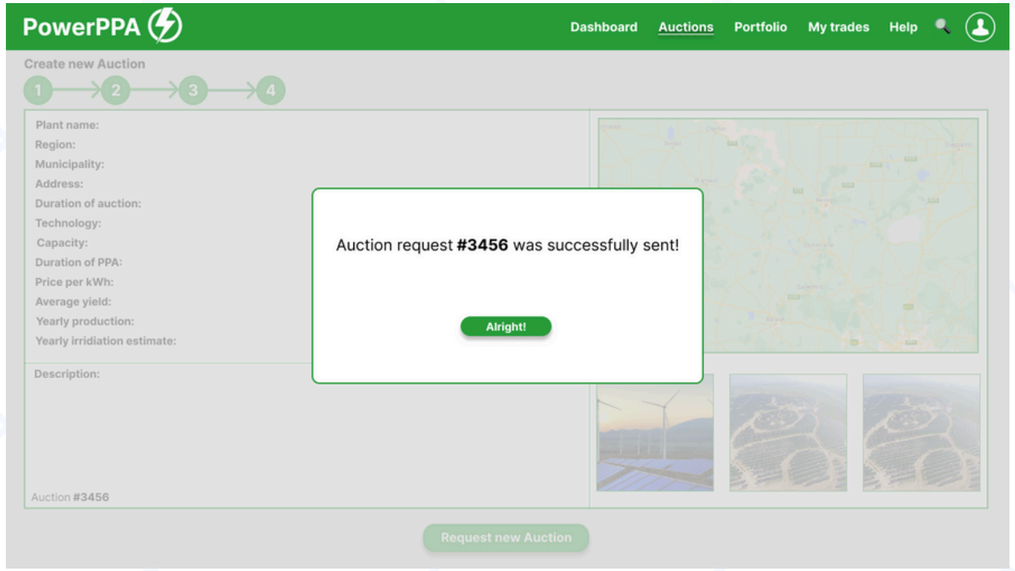
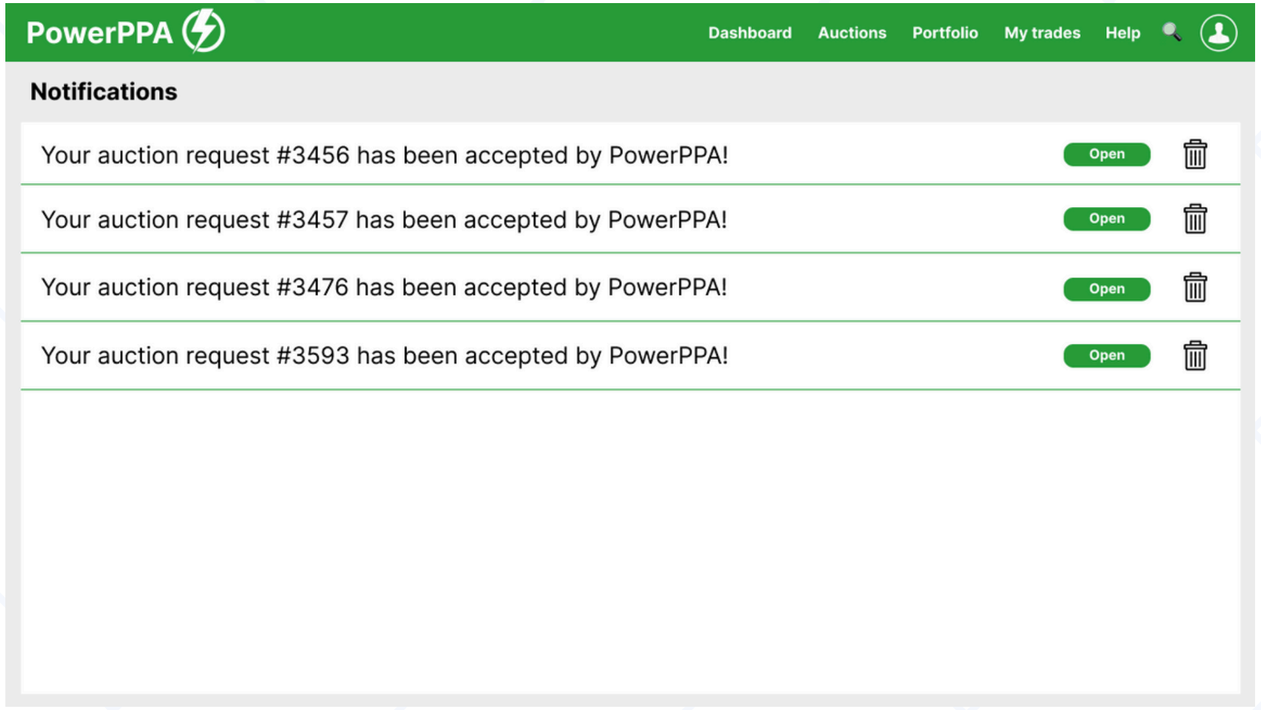
PowerPPA Platform





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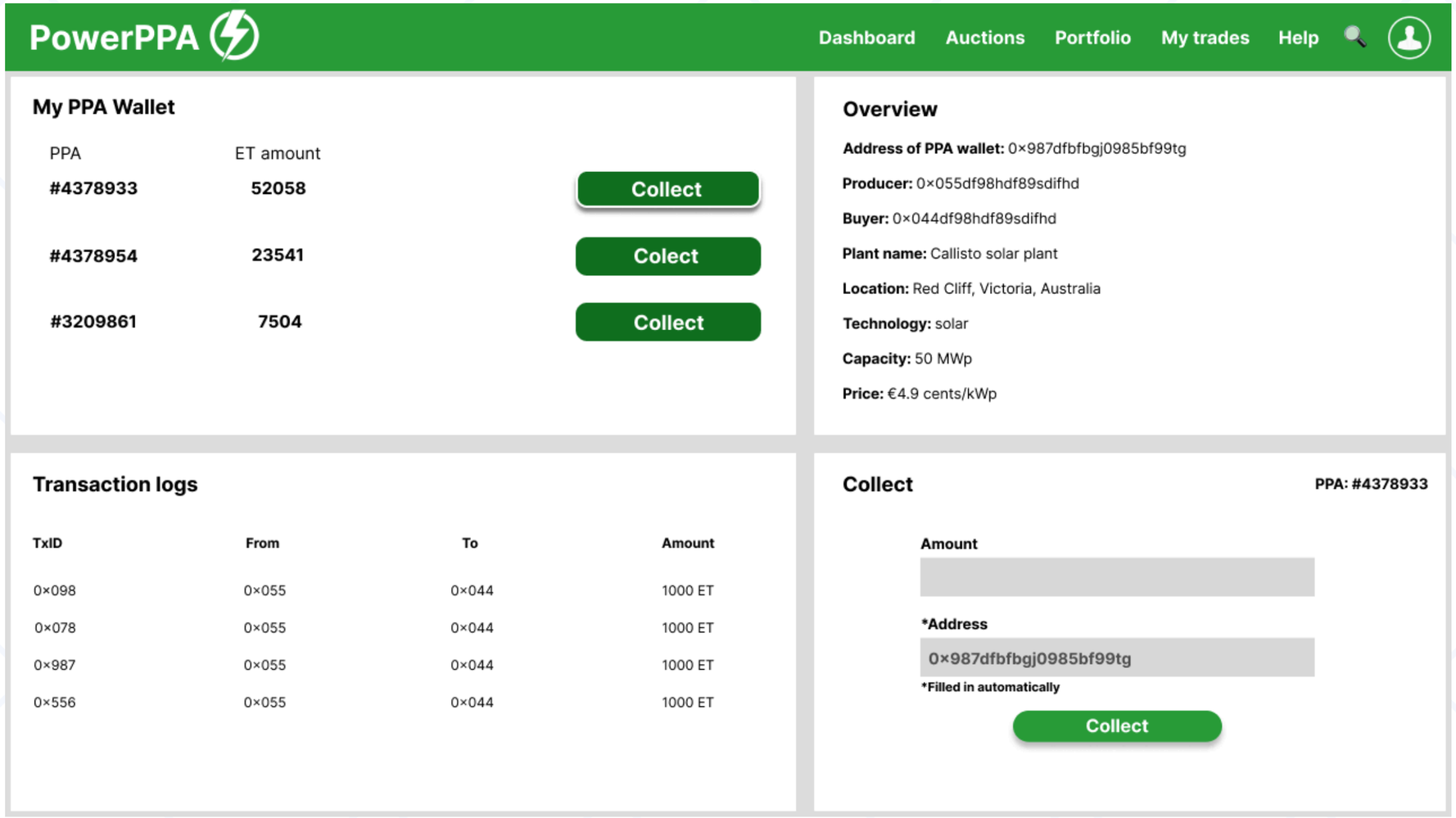

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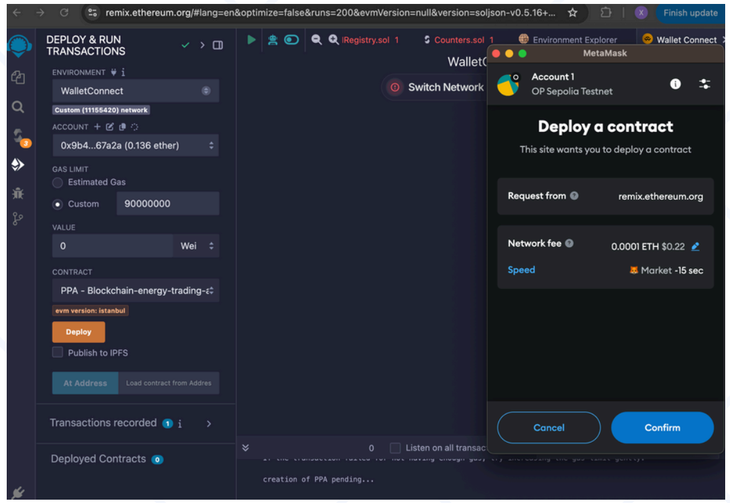
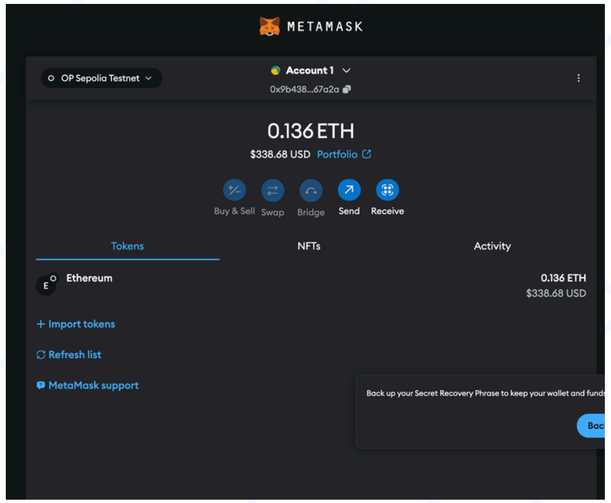
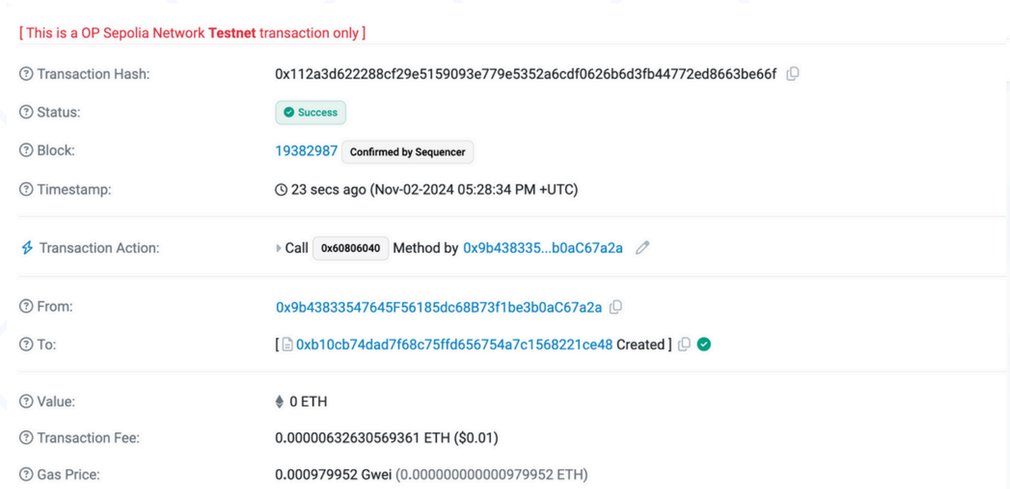
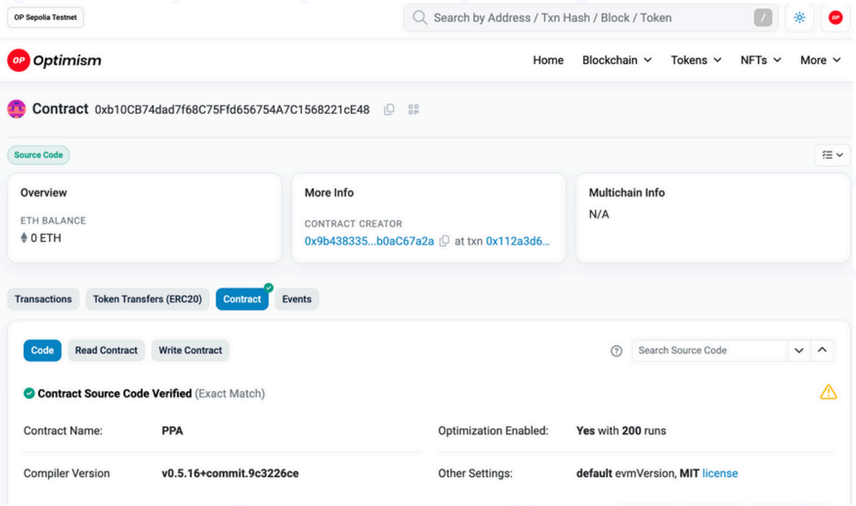
Smart Contracts





1. OP Sepolia Testnet
2. Metamask Wallet
3. Solidity compiler version 0.5.16
4. Remix IDE
5. OpenZeppelin SafeMath Libraries
6. OP Etherscan (Verify & Publish)
7. Free Faucets





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Smart Contracts

```
Step 1: Algorithm ManageEnergyAvailabilityAndPurchase
Step 2:    If producer wants to declare available energy then:
Step 3:        Call availableKwhs(buyer, energy, idOfMatchPPA)
Step 4:        Validate energy amount is >= 1 kWh
Step 5:        Add available energy to listOfkwhs
Step 6:        Emit availableEnergyNotification event
Step 7:    End_if
Step 8:    If buyer wants to purchase energy then:
Step 9:        If buyer wants to purchase based on PPA:
Step 10:           Call buyPPAKwhs(idOfPPA)
Step 11:           Search for matching energy in approved PPAs
Step 12:           If matching energy found then:
Step 13:               Transfer energy to buyer
Step 14:               Update energy records
Step 15:               Call iRegistry.issue() to issue EAC for the
buyer (to certify green energy)
Step 16:               Emit purchasedPPA event
Step 17:           End_if
Step 18:       End_if
Step 19:       If buyer wants to purchase a specific energy amount:
Step 20:           Call energyTradingPPA(idOfContract, buyEnergy)
Step 21:           Validate energy availability and contract terms
Step 22:           Transfer specified amount of energy to buyer
Step 23:          Call iRegistry.issue() to issue EAC for the buyer
(to certify green energy)
Step 24:           Emit purchasedPPA event
Step 25:       End_if
Step 26:   End_if
Step 27: End_ManageEnergyAvailabilityAndPurchase
```

Developed a smart contract for:

- Registering producers and registering buyers of green energy, integrating them into a trading network.

Created a smart contract for Energy Attribute Certificates (EACs):

- Based on the functionalities of ERC1155 and ERC1888 standards.
- Enables the management and tracking of energy certificates for green energy transactions based on VPPAs.

Developed a complex smart contract that integrates the above:

- Supports the creation of VPPAs.
- Includes an auction process for closing VPPAs.
- Facilitates the buying and selling of green energy based on activated (closed) VPPAs.

05

Results

01 Streamlined PPA Creation: Enabled the efficient setup of PPAs between energy producers and buyers.

02 Efficient Energy Trading: Provided a secure and efficient environment for buying and selling green energy directly through the platform.

03 Direct agreements between producers and buyers through the platform eliminate the need for third-party intermediaries who typically handle PPA negotiations, while RES Plant Developers can secure investors directly.

04 Reliable EAC Issuance: Implemented a system for issuing and managing EACs, ensuring accurate tracking and verification of renewable energy attributes.

06

Future Directions

This development requires further enhancements and additional security layers to be ready for production-level deployment.

In the future, this system could be applied to the flexibility energy market, enabling new use cases, such as:

- Ad-hoc PPAs for electric vehicle (EV) owners, activated each time they plug into a charging station.
- Allowing EV owners to receive a specified amount of green energy from Prosumers—individuals with surplus energy from sources like home solar panels (A new type of marketplace).

This approach would promote seamless and sustainable energy usage, leveraging on-demand agreements and expanding access to renewable energy sources.

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