dMRV and Carbon Tokenization System Report

Carbon sequestration project in rubber plantations, Buriram Province

(Group 01/BR01S1)

Using Cryptocurrency, Blockchain and Satellite Technology

Summary of project objectives (*Refer to PDD BR.001/ BR01S1 2025*)

Total project area 1,936.15 rai (157 plots, 131 members)

Credit period: 7 years (2016 - 2022)

Net credit volume expected to reduce/storage 8,578.98 tons CO2 e / year

1. Digital Architecture dMRV (Digital Architecture)

dMRV system is designed to be an end -to-end platform that uses digital technology as the core to create credibility for carbon credits (Carbon Tokens).

component	Core technology	Role in the project
Measurement (M)	Satellites (Gistda , Sentinel-2), AI/ML, GPS, IOT Sensors	Data collection Track biomass changes (AGB), risk (fire/cutting) , and activity data (fertilizer/fuel use).
Reporting (R)	Cloud Computing, Allometric Models (ML), Smart Contracts	Calculation Process raw data into accurate CO2e and generate audit-ready reports .
Verification (V)	Blockchain (DLT), Cryptocurrency (Carbon Token)	Auditing/Transparency Permanently record the calculation results and credit status (Immutable) and create tokens for trading.

2. Measurement using digital technology (Digital Measurement: M)

The measurement will use a combination of remote sensing and digital ground truthing.

2.1 Satellite Monitoring

- objective Monitor plant health (NDVI, EVI), range changes , biomass growth , and burn risk.

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- Inputs use high-resolution satellite spatial data (*e.g., images from Gistda*). as specified in the PDD appendix) and the UTM coordinates of all 157 planting plots (e.g. BRLS0001−BRLS0157).
- AI/ML processing

1. Image Segmentation Machine Learning model is used to classify and identify the boundaries of rubber plantations from other crops and open areas.
2. The Biomass Proxy Model creates a statistical relationship (Regression) between satellite vegetation indices (NDVI, EVI) and measured DBH and Height data in sample plots (Ground Truthing) to estimate AGB across the project area.

2.2 Digital Activity Data Collection

- objective Collects garden management data used in Project Emission and Additionality calculations.
- mechanism Farmers (131 cases) used a mobile application connected to the dMRV system to record activity data.

1. Fertilizer/chemical use Quantity , type , date of use (These data were used to calculate Emission 161.09 tCO2 e / year. In PDD)
2. Fuel consumption The amount of diesel fuel used in the preparation/transportation of the area (these data were used to calculate the Emissions of 40.34 tCO2 e and 50.42 tCO2 e in the PDD).
3. Evidence of non-burning Photography/videography (Geo-tagged/Time-stamped) confirms sustainable waste management.

3. Reporting and Calculation (Digital Reporting: R)

All results are calculated and collected in the cloud before being sent to the blockchain for permanent record.

3.1 Calculation of greenhouse gas sequestration/reduction volume

Net Carbon Sequestration calculation is based on the PDD principle, which is the difference in sequestration increment above the baseline minus the actual emissions from project activities.

Net CO2 e Sequestration = Project CO2 e SequestrationTotal −Baseline CO2e SequestrationTotal −Project Emission−Leakage

A. Baseline GHG Balance calculation

Net greenhouse gas emissions expected to occur in the absence of the project (BAU)

Annual Net Baseline GHG Balance (A)=Project Duration (Years)Total Baseline CO2 e A = 7 years 31,650 tons CO2e (7 years) = 4,521.42 tons of CO2e / year

B. Calculation of carbon sequestration from project implementation (Project Sequestration)

Calculated from the net increase in aboveground biomass (AGB) from project implementation (Based on PDD Data Total AGB = 18,414 tons)

1. Convert AGB to Carbon (C)

Total Carbon (C) = Total AGB×0.50Total C = 18,414 tons × 0.50=9,207 tons C

2. Convert Carbon (C) to CO2e

Total Project Sequestration CO2e = Total C × 1244 Total Project Sequestration CO2 e = 9,207 tons C × 3.6667 ≈ 33,759.31 tons of CO2e

3. Annual Average (Annual Project Sequestration - B)

Annual Project Sequestration (B) = 7 years 33,759.31 tons of CO2e ≈ 4,822.76 tons of CO2e / year

C. Calculation of greenhouse gas emissions from project operations (Project Emission)

Calculated from the use of fuel, fertilizer and chemicals (refer to PDD Section 3: 765,201.52 kgCO2e)

Annual Project Emission (C) = 765,201.52 kgCO2 e /1,000 = 765.20 tons of CO2e / year

D. Net Carbon Sequestration

It is calculated using the Net Sequestration formula , which includes a comparison between the project scenario and the base case.

Net CO2 e Sequestration = (A)−(C−B) − Leakage (0) Net CO2 e Sequestration = 4,521.42 − (765.20 − 4,822.76) – 0 Net CO2 e Sequestration = 4,521.42 − (−4,057.56) Net CO2 e Sequestration = 8,578.98 tons of CO2e / year

3.2 Digital Dashboard

The reporting system displays all of the above information in an easy-to-understand graphical format for project developers, verifiers and farmers, showing:

1. Area overview GIS map showing 1,936.15 rai With 157 plot coordinates and current AGB values (Source: Satellite/AI)
2. Credit status Net CO2e emissions (8,578.98 tons CO2e / year)
3. Audit Trail Link to the Hash of the data on the Blockchain (see section 4)

4. Verification, Blockchain and Cryptocurrency (Verification & Tokenization: V)

The use of Blockchain and Cryptocurrency solves the transparency and liquidity issues in trading carbon credits calculated by dMRV.

4.1 Recording data on the Blockchain (Immutable Ledger)

dMRV system uses Blockchain (Distributed Ledger Technology - DLT) to record the key information that cannot be altered (Immutable Audit Trail).

Recorded data	Recording format on Blockchain	objective
Raw Data Hashes	Hash of satellite image files, field DBH/Height data, and fertilizer/fuel use evidence.	Confirm that the original data has not been altered.
ML Model Parameters	Allometric equations and coefficients used in calculating AGB (so that auditors can check the formulas used)	Algorithmic Transparency
Verified CO2e Units	calculated CO2e volume is 8,578.98 tons CO2e / year.	input data for Minting Carbon Token.
Risk Flags	Record risk events such as fire alerts (satellite fire alerts) or premature felling of rubber trees.	Project Permanence Monitoring

4.2 Digital Verification Mechanism

The verifier (VVB) can access the dMRV Dashboard (Read-Only) and verify the accuracy of all data without having to access the entire 1,936.15 rai rubber plantation. Directly every time

1. Cross-Check compares the Net CO2e calculation results displayed on the Dashboard with the values recorded on the Blockchain.
2. Data Integrity Verifies the integrity of raw data by checking the hash of externally stored files.
3. The Additionality Review confirmed that all activities (8,578.98 tonnes of CO2e / year) were caused by the additionality operations described in the PDD.

4.3 Carbon Tokenization and Cryptocurrency

Once the carbon credit quantity has been verified and certified by an external verifier, the credit is tokenized .

1. Token Design
   - Token Standard: ERC-20 (Fungible Token) on a suitable Blockchain (e.g.Polygon or other high-speed, low-fee networks).
   - Token Value: 19.5 USDC = 1 ton of CO2e
2. Minting Process
   - The external auditor (VVB) approves the annual credit quantity (i.e. 8,578.98 Carbon Units).
   - The Smart Contract will be triggered to Mint (create) an amount of Carbon Tokens equal to the certified credits.
3. Benefit Distribution (Cryptocurrency)
   - Minted tokens will be sent directly to the digital wallet of the project developer/farmer (e.g.1,936.15 rai). In the area of Samrong Mai Subdistrict, Lahan Sai District, Buriram Province)

- Smart Contract system can be programmed to share benefits (Benefit Sharing) between the project developer and 131 farmers. Transparently and automatically, according to the agreed ratio.

4. Retirement When the credit buyer uses the token to offset carbon emissions, the token must be burned by a smart contract to prevent double counting, a key feature of blockchain.

4.4 Smart Contract Mockup (Solidity)

The sample code below demonstrates the Minting and Retirement /Burning mechanisms at the heart of Carbon Tokenization , based on the ERC-20 standard and limited to only Verifiers who can Mint new tokens.

Smart Contract Code (Mockup)

```solidity
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

// โค้ดนี้ใช้สำหรับการอ้างอิงเท่านั้น และแสดงฟังก์ชันหลักสำหรับการ Mint และ Burn โทเคน
// ในการใช้งานจริงจะต้องนำเข้าสัญญา ERC-20 มาตรฐาน เช่น OpenZeppelin

contract BuriramCarbonToken {
    // กำหนดชื่อโทเคนและสัญลักษณ์
    string public name = "Buriram Carbon Token";
    string public symbol = "BRC";
    uint8 public decimals = 18; // 1 BRC = 1 ตัน CO2e

    // การเก็บยอดโทเคนของแต่ละบัญชี
    mapping(address => uint256) private balances;
    uint256 private _totalSupply;

    // ที่อยู่ของผู้ทวนสอบ (Verifier) และเจ้าของโครงการ (Project Owner)
    address public verifierAddress;
    address public projectOwnerAddress;

    // Events สำหรับติดตามกิจกรรมบน Blockchain
    event Transfer(address indexed from, address indexed to, uint256 value);
    event CarbonMinted(address indexed to, uint256 amount, string verificationReportHash);
    event CarbonRetired(address indexed burner, uint256 amount);

    // Modifier เพื่อจำกัดให้เฉพาะ Verifier เท่านั้นที่เรียกใช้ฟังก์ชันได้
    modifier onlyVerifier() {
        require(msg.sender == verifierAddress, "Only Verifier can call this function.");
        _;
    }
```

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```
31
32      // Constructor: กำหนดผู้ทวนสอบและเจ้าของโครงการเมื่อเริ่มต้นสัญญา
33      constructor(address _verifier, address _owner) {
34          verifierAddress = _verifier;
35          projectOwnerAddress = _owner;
36      }
37
38      // ฟังก์ชันสำหรับ Mint (สร้าง) โทเคนคาร์บอนใหม่
39      // ฟังก์ชันนี้จะถูกเรียกใช้โดย Verifier หลังจากที่ dMRV ยืนยันปริมาณ CO2e แล้ว
40      function mintVerifiedCredits(uint256 _amount, address _recipient, string memory _reportHash) public onl
41          // 1. ตรวจสอบว่าปริมาณการ Mint มีค่ามากกว่าศูนย์
42          require(_amount > 0, "Mint amount must be greater than zero.");
43
44          // 2. เพิ่ม Total Supply และยอดคงเหลือของ Recipient
45          _totalSupply += _amount;
46          balances[_recipient] += _amount;
47
48          // 3. ปล่อย Event เพื่อบันทึกการ Mint และ Hash ของรายงานการทวนสอบ (Audit Trail)
49          emit CarbonMinted(_recipient, _amount, _reportHash);
50
51          // 4. ส่งมอบโทเคน (Token Distribution)
52          emit Transfer(address(0), _recipient, _amount);
53
54          // หมายเหตุ: ในทางปฏิบัติ ควรมีการกระจายโทเคนไปยังกระเป๋าเงินของเกษตรกร (Benefit Sharing)
55          // ผ่านฟังก์ชันแยกต่างหาก หรือระบบออฟเชนที่ถูกกำกับดูแล
56      }
```

```
57
58      // ฟังก์ชันสำหรับ Retirement (การปลดระวาง/ทำลาย) โทเคน
59      // ผู้ซื้อคาร์บอนเครดิตจะเรียกใช้ฟังก์ชันนี้เพื่อใช้เครดิตชดเชยการปล่อยก๊าซ
60      function retireCarbonCredits(uint256 _amount) public {
61          // 1. ตรวจสอบยอดคงเหลือ
62          require(balances[msg.sender] >= _amount, "Insufficient balance to retire.");
63
64          // 2. ลด Total Supply และยอดคงเหลือของผู้ทำลาย (Burner)
65          _totalSupply -= _amount;
66          balances[msg.sender] -= _amount;
67
68          // 3. ปล่อย Event เพื่อบันทึกการปลดระวาง
69          emit CarbonRetired(msg.sender, _amount);
70
71          // 4. ปล่อย Event Transfer ไปยัง address(0) เพื่อแสดงว่าถูก Burn
72          emit Transfer(msg.sender, address(0), _amount);
73      }
74
75      // ฟังก์ชันมาตรฐาน ERC-20
76      function totalSupply() public view returns (uint256) {
77          return _totalSupply;
78      }
79
80      function balanceOf(address account) public view returns (uint256) {
81          return balances[account];
82      }
83
84      // ฟังก์ชันอื่น ๆ ของ ERC-20 เช่น transfer, approve, allowance จะถูกละไว้
85  }
```

Note : This sample code shows that

1. **Minting** Restricted to **Verifier** only to ensure that new tokens are generated once they have gone through the dMRV process.

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2. function mintVerifiedCredits Will receive the fee **Hash** The verification report from dMRV is recorded in the Blockchain Event (Log) to create **Audit Trail** Perfect

3. function **Retirement** (use the name in the code as retireCarbonCredits) allows token holders to permanently destroy their credits to prevent **No Double Counting**

Carbonmark Market Link Summary

Carbon credit verification and tokenization system for digital assets (Verification & Tokenization) under technology **Blockchain and Cryptocurrency** It has laid the foundations of transparency and trust in modern carbon markets, especially when linked to **Carbonmark Platform** It is a global carbon credit trading marketplace that uses Web3 and DeFi standards to provide direct access to everyone.

1. Transparency from dMRV to Carbonmark

Measurement data recording, reporting and verification (dMRV) on **Blockchain (Immutable Ledger)** This enables carbon sequestration data such as satellite imagery , field data (DBH/Height), and allometric equations to be validated in real time when these data are referenced in **Carbonmark Smart Contract** Buyers worldwide can verify the source of their carbon credits (Carbon Provenance) directly on the project page, such as: https://app.carbonmark.com/projects/CMARK-4 which is a project under the standard **ECT – ETM Carbon Trade** This system was also used to confirm the fully verified net CO_2 e (8,578.98 tonnes/year).

2. Linking Smart Contracts with Tokenization Systems

the verifier verifies the data in the dMRV system, the smart contract is triggered to mint the certified amount of Carbon Tokens using the standard. **ERC-20** On the network **Polygon** This is in line with Carbonmark 's working structure that also supports ERC-20 tokens, so the ETM Group 's token issuance under the standard **EAT24MALL TOKEN** or “ETM Carbon Token” can **Instantly display and trade on the Carbonmark Marketplace.** To increase liquidity and access to foreign investors

3. Retire (Burn) mechanism and reliability of Carbonmark

When a buyer “Offsets ” their Carbonmark, the system will order **Burn Token (Retire)** This is automatically done through a Smart Contract, making the credits non-reusable (preventing double counting), which aligns with the Retirement mechanism in this project's Smart Contract Mockup. As a result, Carbonmark can transparently display the "credit retirement status" on the project page, along with the hash data confirming the transaction on the blockchain.

4. Distribution of benefits and connections with farmers

Tokens minted from carbon credits are sent directly to the wallets of farmers and project developers in proportion to the amount set in the Smart Contract (Benefit Sharing). Carbonmark can connect this data to provide buyers with transparency into the project's benefit distribution structure (Transparency to Farmers) — a key strength of the project. **ETM Carbon Trade Standard (ECT)** That truly creates co-benefits

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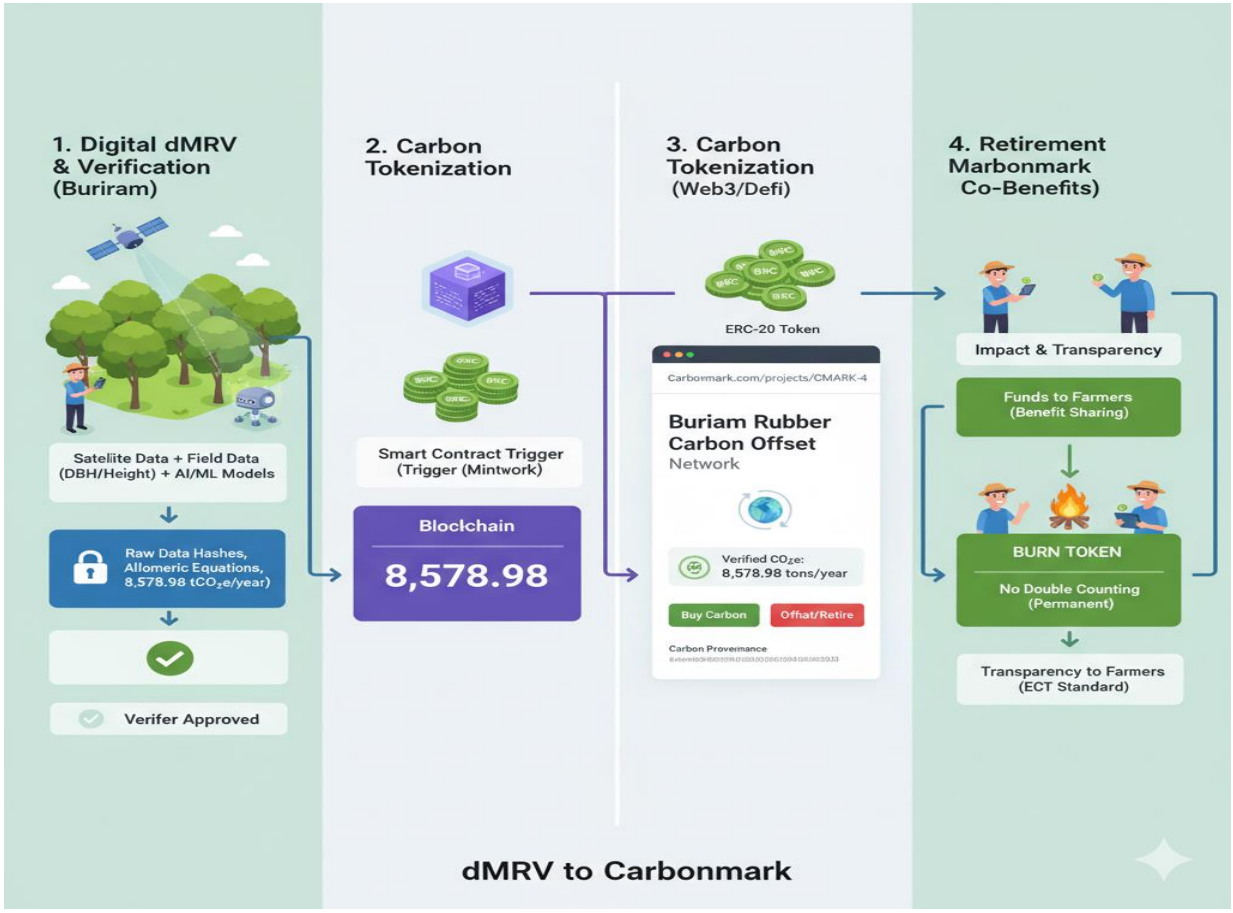

Strategic Summary: System Integration **dMRV + Blockchain + Tokenization** of projects under standards **ECT – ETM Carbon Trade** Therefore, it is a mechanism that is directly consistent with the architecture of **Carbonmark Marketplace** in both areas **Verification , Tokenization , and Retirement enable projects to enter the global carbon market efficiently , transparently, and with** 100% traceability **.**

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