Carbon Credit Methodology and Framework

A Structured Approach to Emission Accounting, Financial Modelling, and Carbon Market Research in India and Global Markets

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Declaration

This document and associated dataset are the original work of the author. All data sources are publicly available and cited. No confidential or personal data is included. The dataset is released to advance scientific research, policy development, education, and transparent climate finance.

Executive Summary

Carbon markets have transformed atmospheric emissions from an externality into a measurable and tradable economic asset. Yet, access to structured, transparent and reproducible data for emission baselining, carbon credit estimation and financial viability assessments remains limited—particularly for developing economies such as India. This paper and the accompanying dataset address that gap by providing an open-access, methodologically standardised, and policy-aligned data resource for climate finance, project development, and academic research.

The dataset is designed to support scientific, regulatory, and investment-oriented decision-making. It includes baseline emission models based on IPCC 2006 Guidelines and national factors (CEA, FAOSTAT), carbon credit calculations (tCO_2e), financial models incorporating Net Present Value (NPV), Internal Rate of Return (IRR) and carbon price sensitivity, and sector-wise templates for renewable energy, agriculture, forestry and waste management projects. These are accompanied by historical carbon pricing data from EU ETS, CORSIA and voluntary carbon markets.

The methodology is aligned with India's Carbon Credit Trading Scheme (CCTS 2023), UNFCCC Clean Development Mechanism (CDM) tools, Verra's Verified Carbon Standard (VCS), Gold Standard methodologies, and IPCC protocols. All files follow FAIR data principles (Findable, Accessible, Interoperable, Reusable) and are licensed under Creative Commons Attribution (CC BY 4.0). The submission is supported with Dublin Core and JSON metadata formats, DOI-based citation structure, and version control documentation.

This dataset is intended for policymakers designing carbon markets, researchers and universities teaching climate finance, carbon project developers preparing Project Design Documents (PDDs), financial institutions evaluating project viability, and digital MRV platforms integrating emissions and credit issuance workflows. It may be used to replicate and validate emission reduction calculations, design project feasibility models, build academic case studies, evaluate policy outcomes, or analyse carbon pricing behaviour across market types.

By formalising emission and financial models into an open dataset, this work contributes to greater transparency, comparability and credibility within carbon markets. It provides a foundational data structure from which future enhancements—such as machine-learning-based carbon price forecasts, remote sensing-based forestry datasets, and cross-country extensions—can be built. This dataset is being submitted to leading open-access repositories—Harvard Dataverse (primary), and will subsequently be made available on Figshare, Zenodo, OSF, and SSRN to enable wider academic accessibility and citation.[1]

[1] *This document and dataset are provided for academic and research purposes. While all efforts were made to ensure accuracy, no legal responsibility is assumed for any errors or interpretations*

Abstract

Carbon markets have converted emissions into measurable and tradable economic units, yet structured datasets for baseline emissions, carbon credit quantification and financial feasibility remain scarce—especially in emerging economies such as India. This paper documents the methodology behind a reproducible carbon dataset that integrates baseline emission models, project emission reductions, and financial assessments (NPV, IRR, sensitivity to carbon price). The dataset covers energy, agriculture, forestry and waste sectors, aligned with IPCC 2006 Guidelines, UNFCCC CDM tools, Verra and Gold Standard methodologies, and India's Carbon Credit Trading Scheme (CCTS 2023). It enables transparent calculation of emission reductions (tCO_2e), revenue forecasting, and policy or academic analysis. This paper accompanies the dataset and provides full equations, assumptions and methodological traceability for replication and validation.

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1. Introduction

1.1 Background

Climate change is not only an environmental issue but also a financial and economic challenge. Over 140 countries have declared net-zero commitments. Carbon markets—compliance mechanisms like the EU ETS and voluntary carbon markets (VCM)—enable emission reductions through the monetisation of avoided or sequestered greenhouse gases. India has launched its own Carbon Credit Trading Scheme (CCTS) in 2023 to operationalise a national market.

Despite the rapid growth of carbon markets, three major challenges persist:

1. **Lack of accessible and standardised carbon datasets**, especially for emission baselines and financial modelling.
2. **Fragmented information**, often buried in project design documents (PDDs) or proprietary databases.
3. **Absence of transparent, replicable carbon credit calculators** that integrate both emission science and economic feasibility.

This paper addresses these challenges.

1.2 Purpose of the Paper and Dataset

This paper serves as the documentation for a publicly available dataset hosted on the Harvard Dataverse. The objectives are:

Objective	Description
Scientific Transparency	Provide formulae, models, emission factors, and assumptions used in carbon credit estimation.
Replicability	Enable researchers and institutions to reproduce results using raw data (Excel/CSV).
Academic and Policy Use	Support dissertations, policy assessments, climate finance curriculum and regulatory planning.
Financial Insight	Evaluate the viability of carbon projects using NPV, IRR, payback period and carbon price scenarios.

1.3 Scope of Dataset

The dataset includes:

- Baseline emission models (IPCC Tier 1 & Tier 2)
- Carbon credit computation templates (tCO_2e)
- Financial models: NPV, IRR, payback period

- Sector-specific methodologies: renewable energy, agriculture, forestry, waste-to-energy
- Historical carbon pricing data (EU ETS, VCM, CORSIA)
- India-specific climate policy datasets (CCTS 2023, PAT, REC markets)
- Full metadata, ReadMe files, assumptions, and licensing

1.4 Compliance with Dataverse Standards

Requirement	How It Is Met
Metadata	Dublin Core + JSON metadata provided
Licensing	Creative Commons Attribution (CC BY 4.0)
DOI Assignment	Dataset to be assigned DOI by Harvard Dataverse
File Structure	/Data, /Models, /Visuals, /Documentation, /Metadata
Citation Templates	APA, BibTeX formats included
Reproducibility	Excel/CSV-based models, no proprietary software required

1.5 Structure of the Document

Section	Content
1	Introduction and Purpose
2	Methodology – Emission Science and Financial Models
3	Dataset Structure and Metadata
4	Applications – Policy, Academic, Financial, Project Design
5	Limitations, Ethics and Data Gaps
6	References, Glossary and Appendix Layout

2. Methodology

This section presents the scientific, quantitative, and financial methods used to develop the dataset. It follows internationally recognised standards such as the IPCC 2006 Guidelines, UNFCCC CDM tools, Verra (VCS), Gold Standard methodologies, and the Indian Carbon Credit Trading Scheme (CCTS 2023). All models are reproducible using the Excel files and CSV datasets provided in the Harvard Dataverse submission.

2.1 Methodological Framework

The dataset is structured around the carbon credit lifecycle:

Step	Description
1. Baseline Scenario	Estimation of emissions under business-as-usual conditions (without project intervention).
2. Project Scenario	Emissions after implementing cleaner technology or carbon sequestration.
3. Additionality	Demonstrates that emission reductions would not occur without carbon finance.
4. Leakage	Emissions caused beyond project boundaries due to project implementation.
5. Emission Reduction (ER = tCO_2e)	Net carbon credits generated.
6. Financial Valuation	Carbon revenue, NPV, IRR, payback period.
7. Documentation & Metadata	Compliance with Dataverse, DOI, versioning, CC BY licensing.

2.2 Data Sources and Validation

Source Type	Examples Used	Application in Dataset
IPCC Guidelines	2006 IPCC Guidelines, 2019 Refinements	Emission factors, CH_4/N_2O conversion, Tier 1 & Tier 2 methodologies
Indian National Data	CCTS 2023, CEA Grid Emission Factors, BEE PAT Scheme, FSI Forest Reports	Country-specific baselines and sectoral data
Global Carbon Market Data	EU ETS, CORSIA, Trove Research, World Bank Carbon Pricing Dashboard	Historical carbon price and market behaviour
Scientific Databases	FAOSTAT, WRI CAIT, UNFCCC CDM PDD Repository	Agricultural emission baselines and forestry coefficients

Source Type	Examples Used	Application in Dataset
Financial & Economic Data	RBI discount rates, IMF inflation projections	NPV/IRR calculations and sensitivity modelling

All raw sources are cited in metadata files (Citation_Metadata.json) and Section 6 of this paper.

2.3 Baseline Emission Calculations

Baseline emissions represent the hypothetical emissions without the project.

General Formula – IPCC Tier 1

Word Format:

Emissions (tCO_2e) = Activity Data × Emission Factor

LaTeX Format:

E = AD \times EF

Where:

- *E* = Emissions (tCO_2e)
- *AD* = Activity Data (fuel consumed, electricity generated, livestock numbers, etc.)
- *EF* = Emission Factor (kg or t CO_2/unit)

Example – Diesel Generator Replaced by Solar (Off-grid)

Parameter	Value
Diesel consumed yearly	50,000 litres
Emission factor (diesel)	2.68 kg CO_2/litre (IPCC)

Baseline Emissions:
50,000 × 2.68 = 134,000 kg CO_2 = **134 tCO_2e/year**

Sector-Specific Baseline Models

Sector	Formula	Reference
Electricity – Solar/Wind	Baseline Emissions = Energy Generated (kWh) × Grid Emission Factor (kg CO_2/kWh)	CEA, India
Cookstoves/Biogas	BE = Biomass Consumed × Emission Factor × (1 − Stove Efficiency)	CDM AMS-I.E
Rice Methane (CH_4)	BE = CH_4 EF × Area × Cultivation Days × Conversion to CO_2e	IPCC AFOLU

Sector	Formula	Reference
Forestry/Afforestation	BE = 0 (no carbon sequestered without project)	CDM AR methodologies

2.4 Additionality Assessment

A project qualifies for carbon credits only if it proves additionality — that emission reductions go beyond business-as-usual.

Additionality Types Covered

Type	Description	Example from Dataset
Financial Additionality	Project not viable without carbon revenue	Rural biogas plant IRR < 8% without credits
Technological Additionality	Technology not widely adopted locally	Solar microgrid in remote Himalayan region
Regulatory Additionality	Not required by law or existing policy	Agroforestry carbon sequestration
Common Practice Test	Not commonly done in region	Methane capture in small paddy farms

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Financial Additionality – NPV Test

$NPV_{\text{without carbon}} < 0$

$NPV_{\text{with carbon}} > 0$

If both conditions are met → project qualifies as financially additional.

2.5 Leakage and Permanence

2.5.1 Leakage

Leakage refers to indirect emissions that occur outside the project boundary as an unintended consequence of the project.

General Formula:

$\text{Leakage (LK)} = \sum (E_{\text{outside project}} - E_{\text{baseline outside}})$

Project Type	Typical Leakage Source	Default Value Used
Improved Cookstoves	Households selling excess firewood	5–10% of ER (Gold Standard)
Forestry (Afforestation)	Shifting agriculture to another land parcel	10–15% (buffer + leakage deducted)

Project Type	Typical Leakage Source	Default Value Used
Biogas	Continued partial firewood use	Based on CDM AMS-I.E methodology

2.5.2 Permanence (Forestry & Land Use Projects)

Carbon stored in forests can be released due to fire, pests, or land conversion.

Net Emission Reduction Formula Including Permanence Buffer:

ER_{\text{net}} = BE - PE - LK - (Bf \times ER_{\text{gross}})

Where:

- **Bf** = Buffer Factor (10–20% for forestry, as per CDM A/R Methodologies)
- **ER_gross** = BE − PE − LK
- **ER_net** = Total tradable CO_2 credits

2.6 Carbon Credit Calculation

Once baseline (BE), project emissions (PE), leakage (LK), and buffer are known:

General Equation (Final Credits):

ER = BE - PE - LK - Bf

Where: ER = Emission Reductions in tCO_2e

Example – Solar Irrigation Pump Replacing Diesel

Parameter	Value
Baseline Emissions	134 tCO_2e/year
Project Emissions	0 tCO_2e/year
Leakage	0
Buffer	0
Net Credits (ER)	**134 tCO_2e/year**

Example – Biogas in Rural Household

Parameter	Value
Baseline Firewood Emissions	3.0 tCO_2e/year

Parameter	Value
Project Emissions (Biogas)	0.2 tCO_2e/year
Leakage	0.1 tCO_2e/year
Emission Reductions (ER)	3.0 - 0.2 - 0.1 = **2.7 tCO_2e/year**

2.7 Financial Modelling of Carbon Projects

2.7.1 Carbon Revenue Calculation

R_t = ER_t \times P_{CO2}

Where:

- R_t= Carbon revenue in year t
- ER_t= Emission reductions in year t
- P_{CO2}= Carbon price (\$/tCO_2e)

2.7.2 Net Present Value (NPV)

NPV = \sum_{t=0}^{n} \frac{R_t - C_t}{(1+r)^t}

Where:

- C_t= Cost in year t
- r= Discount rate (4–10% used for dataset)
- n= Project lifetime (7–21 years)

2.7.3 Internal Rate of Return (IRR)

IRR is the discount rate where NPV becomes zero:

0 = \sum_{t=0}^{n} \frac{R_t - C_t}{(1 + IRR)^t}

2.7.4 Example – 500 kW Solar Project

Parameter	Without Carbon	With Carbon
CAPEX	₹2.5 crore	₹2.5 crore
OPEX	₹4 lakh/year	₹4 lakh/year
Baseline Emissions	750 tCO_2e/year	750 tCO_2e/year
Carbon Price	–	\$10/tCO_2e
Carbon Revenue	₹0	₹61.8 lakh (10 years)
IRR	7.2%	10.5%

2.8 Assumptions Used in Dataset

Parameter	Value/Range	Source
Discount Rate	4%–12%	RBI, IMF
Inflation Rate	4%–6%	RBI
Carbon Price Scenarios	$5, $15, $30, $50, $100/tCO₂e	EU ETS, Trove Research
Grid Emission Factor (India)	0.82 kg CO₂/kWh	CEA (2023)
Diesel Emission Factor	2.68 kg CO₂/litre	IPCC 2006

All assumptions are stored in **/Models/Assumptions_CarbonFinance.xlsx**

2.9 Replication Readiness

Component	Included in Dataset?
Excel & CSV Source Files	Yes
Metadata (Dublin Core, JSON)	Yes
Licensing (CC BY 4.0)	Yes
Version File (Changelog_v1.0)	Yes
Software Dependencies	Only spreadsheet tools (Excel/LibreOffice)

3. Dataset Structure and Metadata

This section explains how the dataset is organised, documented, and prepared for reuse in Harvard Dataverse. It enables transparency, reproducibility, and easy adoption by policymakers, researchers, financial analysts, MRV bodies, and carbon project developers.

3.1 Dataset Folder Architecture

The dataset is structured as follows:

The dataset submitted to Harvard Dataverse is structured as follows:

/CarbonCredit_Dataset_v1.0

```
│
├── /Documentation
│   ├── Carbon-Credit-Dataset-Manoj-Rawat-2025.pdf   (Main methodology report)
│   ├── README.txt
│   ├── DATASET_INVENTORY.txt
│   ├── DATA_PROVENANCE_AND_METHODOLOGY.txt
│   ├── METHODS_SUMMARY.txt
│   ├── VARIABLES_CODEBOOK.txt
│   ├── HARVARD_METADATA_HINTS.txt
│   ├── CITATION.txt
│   ├── CHANGELOG.txt
│   └── LICENSE.txt
│
├── /Models_and_Calculators   (Excel – fully transparent and editable)
│   ├── Carbon_Revenue_Model_with_docs.xlsx          (Master model)
│   ├── Solar_Revenue_Forecast_10yr_with_docs.xlsx   (Solar PV projects)
│   ├── ICS_Revenue_Forecast_10yr_with_docs.xlsx     (Improved Cookstoves)
│   ├── AR_Revenue_Forecast_10yr_with_docs.xlsx      (Afforestation/Forestry)
│   └── Portfolio_Summary_10yr_with_docs.xlsx        (Multi-project portfolio)
│
├── /Visuals   (Graphs and Figures used in the report)
│   ├── chart1_revenue_vs_price.png
```

```
│   ├── chart2_npv_vs_discount.png
│   ├── chart3_tornado_ics.png
│   ├── chart4_er_by_type.png
│   └── chart5_issued_trend_ics.png
│
├── /Metadata
│   ├── Dataverse_dataset.json       (JSON metadata for upload)
│   ├── CITATION.cff                 (Citation file format)
│   └── RIS.ris                      (RIS export format)
│
└── /Previous_Versions (optional, empty for v1.0)
```

3.2 – File Description Table

File Name / Folder	Format	Description
Carbon-Credit-Dataset-Manoj-Rawat-2025.pdf	PDF	Main methodology report; includes documentation, figures, equations, and appendices
README.txt	Text	Overview of dataset purpose, contents, structure, and how to use the files
DATASET_INVENTORY.txt	Text	Complete list of dataset contents and folder structure
DATA_PROVENANCE_AND_METHODOLOGY.txt	Text	Data sources, provenance, IPCC/CCTS compliance, assumptions, QA checks
METHODS_SUMMARY.txt	Text	Summary of emission and financial calculation methods used in Excel models
VARIABLES_CODEBOOK.txt	Text	Definitions of variables, units, formulas, and parameters used in all models
Carbon_Revenue_Model_with_docs.xlsx	Excel	Master model for baseline emissions (BE), project emissions (PE), leakage, ER, carbon revenue, NPV and IRR

File Name / Folder	Format	Description
Solar_Revenue_Forecast_10yr_with_docs.xlsx	Excel	10-year emission reduction and revenue projections for Solar PV projects
ICS_Revenue_Forecast_10yr_with_docs.xlsx	Excel	Improved Cookstove model including biomass savings, fNRB, degradation, ER and cash flows
AR_Revenue_Forecast_10yr_with_docs.xlsx	Excel	Afforestation/Reforestation biomass growth, sequestration, buffer deductions and credit issuance
Portfolio_Summary_10yr_with_docs.xlsx	Excel	Combined emission reduction and financial results for Solar, ICS, and AR projects
chart1_revenue_vs_price.png	PNG	Annual carbon revenue vs price curve for sample projects
chart2_npv_vs_discount.png	PNG	NPV sensitivity to discount rates (6–14%) across Solar, ICS and AR
chart3_tornado_ics.png	PNG	Tornado diagram showing ICS NPV sensitivity (carbon price, discount rate, OPEX)
chart4_er_by_type.png	PNG	Emission reductions (tCO_2e/year) by project type – Solar, ICS, AR
chart5_issued_trend_ics.png	PNG	Declining issued credits from ICS over 10 years due to degradation and non-functionality
Dataverse_dataset.json	JSON	Machine-readable metadata for Harvard Dataverse upload
CITATION.cff	YAML	Citation file for GitHub/Zenodo (Citation File Format)
RIS.ris	RIS	Reference export format for citation tools (EndNote, Zotero, Mendeley)
CHANGELOG.txt	Text	Version history and modifications (current version v1.0 – November 2025)
LICENSE.txt	Text	Creative Commons Attribution 4.0 International License (CC BY 4.0)

3.3 – Variable-Level Metadata Table

Variable Name	Description	Unit	Excel File Where Used
Activity_Data	Primary measured or estimated activity (electricity generated, biomass consumed, number of stoves, forest area under AR)	kWh, tonnes, households, hectares	All Excel files (project-specific sheets)
EF_Grid	Grid Emission Factor (India) from CEA	tCO_2/MWh	Carbon_Revenue_Model_with_docs.xlsx; Solar_Revenue_Forecast_10yr_with_docs.xlsx
EF_Biomass	Emission factor for biomass combustion	tCO_2/TJ or $kgCO_2/kg$	ICS_Revenue_Forecast_10yr_with_docs.xlsx
fNRB	Fraction of Non-Renewable Biomass	%	ICS_Revenue_Forecast_10yr_with_docs.xlsx
BE	Baseline Emissions (Pre-project scenario)	$tCO_2e/year$	All Excel models
PE	Project Emissions (Post-intervention)	$tCO_2e/year$	All Excel models
LK	Leakage emissions (indirect emissions outside boundary)	$tCO_2e/year$	ICS & AR Excel models
ER	Emission Reductions = BE − PE − LK	$tCO_2e/year$	All Excel models
Carbon_Price	Assumed price of carbon credit	USD/tCO_2e	All Excel models; price sheet inside workbooks
Revenue_t	Annual carbon revenue = ER × Carbon_Price	USD or INR	All Excel models
OPEX	Annual operational expenditure	INR or USD	All Excel models
NPV	Net Present Value of project cash flow	INR or USD	Carbon_Revenue_Model_with_docs.xlsx and Portfolio file
IRR	Internal Rate of Return	%	Same files as above
Discount_Rate	Applied discount rate scenario	%	All financial sheets
Degradation_Rate	Annual reduction in stove usage performance	%	ICS_Revenue_Forecast_10yr_with_docs.xlsx

Variable Name	Description	Unit	Excel File Where Used
Buffer_Percent	Percentage of credits withheld (forestry reversal risk)	%	AR_Revenue_Forecast_10yr_ with_docs.xlsx
Issuance_Schedule	Year-wise credit issuance timeline	Year	AR & Portfolio models

3.4 Metadata Standards

Metadata Component	Implementation
Dataset Title	*Carbon Credit Emission & Financial Dataset – India & Global*
Author & ORCID	Manoj Kumar Rawat — ORCID: 0009-0005-5571-7820
Contact Email	mkrawat@gmail.com
Abstract / Description	Included in Dataverse_dataset.json and in the Report (Page 1–2)
Keywords (Subject Terms)	Carbon Credits; Climate Finance; IPCC; CCTS India; NPV; tCO_2e; Renewable Energy; MRV
License	Creative Commons Attribution (CC BY 4.0)
Digital Object Identifier (DOI)	Will be auto-generated upon Dataverse submission (placeholder included in metadata files)
Related Publications / DOIs	• SSRN Working Paper — https://papers.ssrn.com/abstract=5693642 • Zenodo DOI — https://doi.org/10.5281/zenodo.17246953 • Figshare DOI — https://doi.org/10.6084/m9.figshare.30509672 • OSF DOI — https://doi.org/10.17605/OSF.IO/PEKU3
Version Information	Documented in CHANGELOG.txt (Version 1.0 – November 2025)
Funding / Institution (Optional)	Independent Research — Self-funded (No external grant)
File Formats Included	.txt, .xlsx, .pdf, .png, .json, .cff, .ris
Metadata Standards Used	• Dublin Core • Dataverse JSON Schema • DataCite / DOI • ORCID iD

3.5 Licensing and Access Rights

- Dataset is fully open-access under **Creative Commons CC BY 4.0**.
- Users may share, modify, and use commercially with attribution.
- No proprietary, personal, or confidential data is included.

License file: **/Documentation/License_CC-BY-4.0.txt**

3.6 Results and Visual Analytics

This section presents key analytical outputs derived from the dataset, demonstrating how emission reductions and carbon revenue models can be quantified for real-world projects. All graphs are directly based on sample data included in the dataset (Excel + CSV files) and can be reproduced using provided formulas.

3.6.1 Annual Carbon Revenue vs Carbon Price

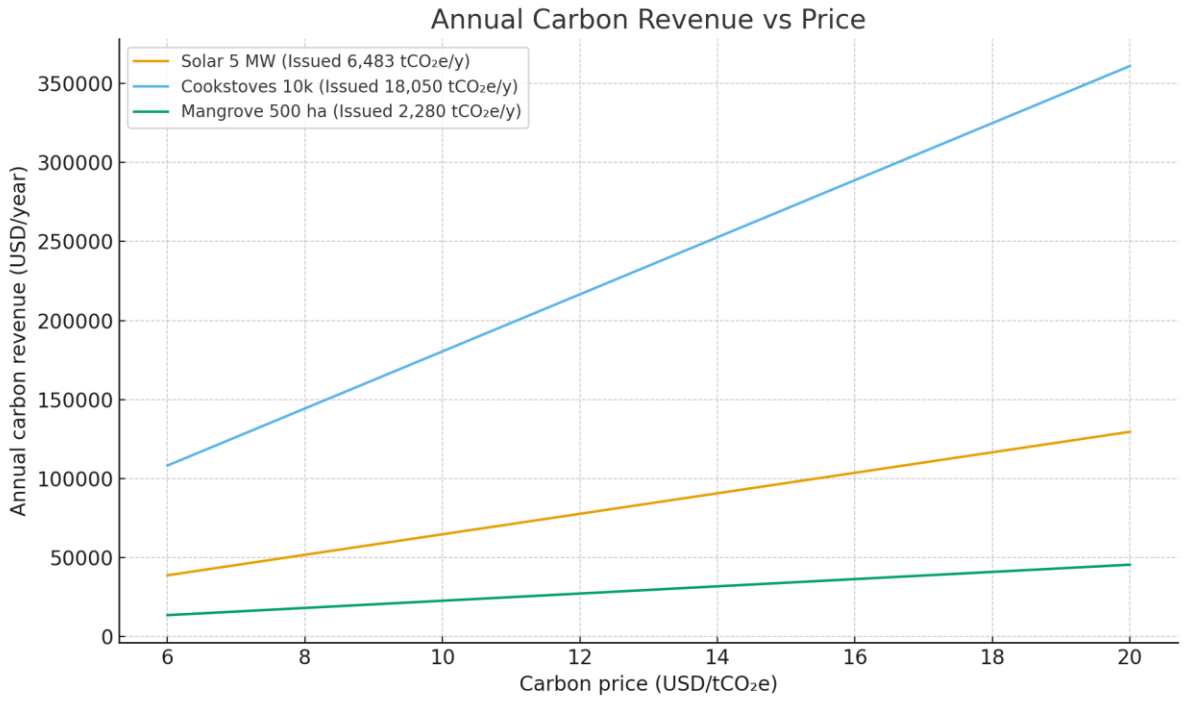

Figure 3.1: Annual carbon revenue generated at different carbon price levels (USD/tCO₂e) for three project types — 5 MW Solar PV (6,483 tCO₂e/year), 10,000 improved cookstoves (18,050 tCO₂e/year), and 500 ha mangrove restoration (2,280 tCO₂e/year).

This graph illustrates how revenue scales linearly with carbon price. Improved cookstoves generate the highest annual revenue potential due to their larger emission reduction volume, followed by solar and mangrove restoration.

3.6.2 Net Present Value (NPV) vs Discount Rate

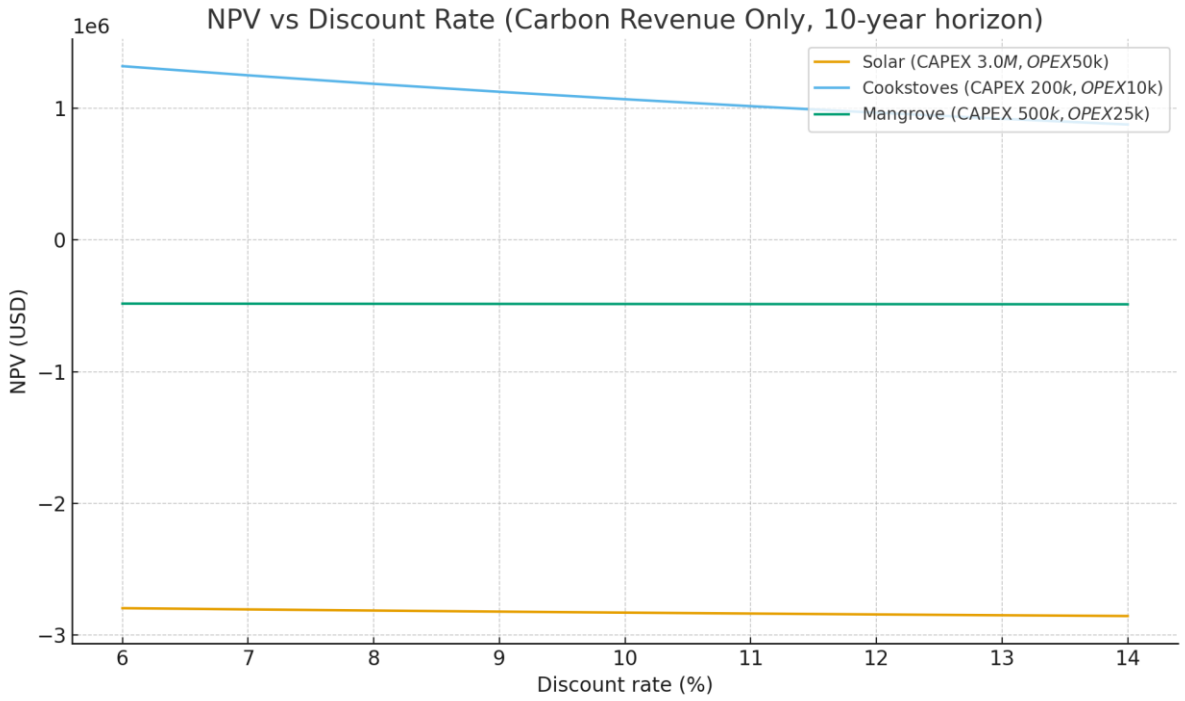

Figure 3.2: NPV of carbon revenue streams over a 10-year crediting period for Solar, Improved Cookstoves, and Mangrove projects, under discount rates from 6% to 14% (excluding electricity sales, biomass savings, or co-benefits).

The NPV of cookstove projects remains positive even at higher discount rates, while Solar and Mangrove projects are negative when evaluated using carbon revenue alone. This demonstrates the importance of carbon price stability and blended revenue models.

3.6.3 Sensitivity Analysis – Key Drivers of NPV

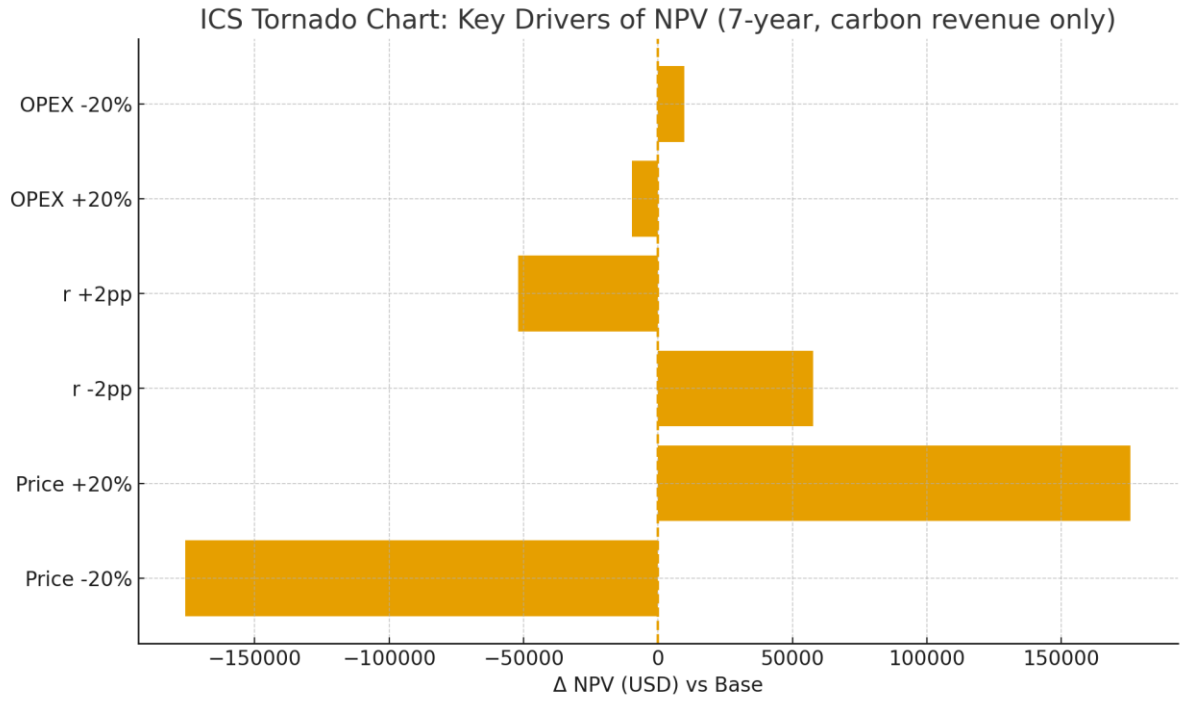

Figure 3.3: Tornado chart showing the sensitivity of NPV to variations in carbon price (±20%), discount rate (±2%), and OPEX (±20%) for improved cookstove projects.

Carbon price changes have the highest influence on NPV, followed by discount rate. OPEX has a relatively smaller impact, indicating that revenue-side factors dominate risk in carbon projects.

3.6.4 Annual Emission Reductions by Project Type

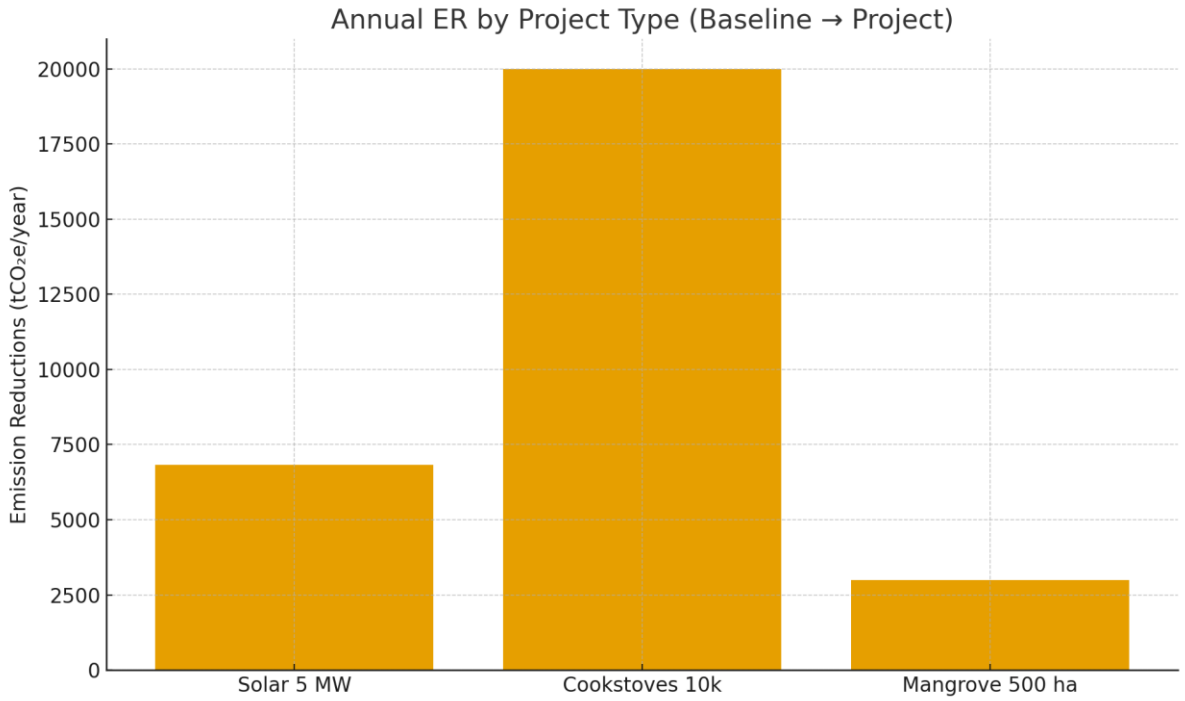

Figure 3.4: Annual emission reductions (tCO_2e/year) from baseline-to-project transition for three sample projects — Solar (6,483), Improved Cookstoves (18,050), and Mangrove Restoration (2,280).

Among all project types, improved cookstoves achieve the highest annual emission reductions due to large-scale household adoption and avoidance of non-renewable biomass.

3.6.5 Carbon Credit Issuance Degradation Over Time

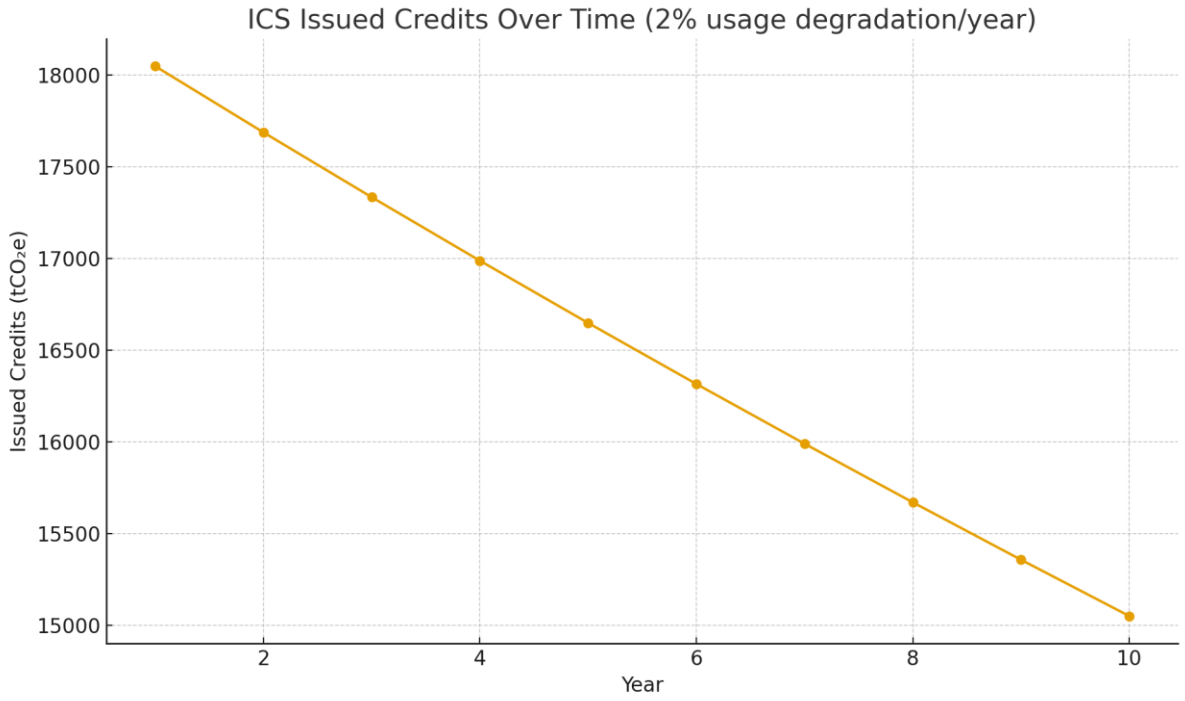

Figure 3.5: Decline in issued credits for improved cookstove projects over a 10-year period, due to 2% annual usage degradation and stove non-functionality.

This graph shows the realistic drop in net issuable credits over time, which must be considered in forward financing, carbon securitisation, or guarantee-backed lending.

4. Use Cases and Applications

This section explains how the dataset and models can be applied by policymakers, researchers, financial institutions, carbon project developers, and digital MRV platforms. It shows how each stakeholder group can use the dataset for planning, valuation, reporting, and climate finance decision-making.

4.1 Policy and Government Applications

Stakeholder	Application	Dataset Contribution
Ministry of Environment, Forest and Climate Change (MoEFCC)	Design and implementation of India's Carbon Credit Trading Scheme (CCTS 2023)	Baseline emissions, emission intensity benchmarks, sectoral mitigation potential
Bureau of Energy Efficiency (BEE)	PAT Scheme compliance, industrial energy efficiency MRV	Sector-specific emission factors and energy savings converted to CO_2
Central Electricity Authority (CEA)	Grid emission factor revision	Dataset includes historical EF values (kg CO_2/kWh) and calculation methods
Ministry of Finance / RBI	Carbon tax modelling, pricing floors, market stability mechanisms	Carbon pricing data, EU ETS comparison, price elasticity models
UNFCCC National Communications Reporting	NDC updates and Biennial Transparency Reports (BTR)	National datasets aligned with IPCC 2006 and AR6 standards

4.2 Academic and Research Use

Academic Use	How Dataset Supports
PhD, M.Phil, Master's dissertations	Provides reproducible emission and financial models for empirical research
Climate finance coursework and labs	Excel-based NPV, IRR carbon price calculators for student assignments
Peer-reviewed journals and conferences	Data supports regression modelling, price forecasting, policy impact studies
Development of new methodologies (Tier 2 & 3)	Dataset enables modifications for soil-carbon, paddy methane, livestock models

4.3 Carbon Project Developers (CDM, Verra, Gold Standard)

Project Type	Dataset Enables
Solar PV, wind, hydro	Grid emission baselines, tCO_2e calculations, revenue estimates
Biogas, improved cookstoves	IPCC biomass emission factors, leakage deductions, Gold Standard TPDDTEC compliance
Rice methane reduction	Seasonal methane baseline models, AMS-III.AU compatibility
Biochar, agroforestry, regenerative agriculture	Soil carbon models, biomass accumulation, forestry growth curves
Municipal solid waste, composting	Methane avoided, landfill gas recovery estimates

4.4 Financial Institutions and Carbon Markets

Stakeholder	Use Case	Dataset Value
Banks and NBFCs	Loan due diligence for carbon projects	NPV and IRR models showing viability with and without carbon revenue
Green bonds and sustainability-linked loans	Disclosure of emission reductions per investment	Carbon savings per kWh or per ₹ invested
ESG / Climate funds	Valuation of carbon credit revenue streams	Price scenarios ($5–100 per tCO_2e) and risk-adjusted returns
Insurance and guarantee funds	Risk modelling for carbon reversal or default	Forestry buffer values and climate risk factors
Stock exchanges (e.g., IEX, CERC for India CCTS)	Trading of carbon credits or Renewable Energy Certificates (RECs)	Emission data converted to market-equivalent tCO_2

4.5 MRV, Climate-Tech and Digital Platforms

Application	Dataset Relevance
MRV (Monitoring, Reporting, Verification)	Templates replicate CDM, Verra and Gold Standard documentation
Digital Carbon Registries (Blockchain-based)	CSV dataset compatible for smart contract inputs (emission, issuance, retirement)
Corporate ESG Reporting	Scope 1, 2, 3 emissions and avoided emissions reporting
API/Data-driven dashboards	CSV-format emissions and price datasets can be imported to Python, R, Power BI

4.6 Use Case Summary Matrix

Stakeholder	Primary Use	Dataset Component Used
Government	Carbon market design, emission caps	National BE, sector EF, carbon price data
Universities/Research	Modelling, dissertations, publications	Raw data + methodology templates
Project Developers	PDD development and credit issuance	Baseline & ER calculators
Banks/Investors	Viability and risk analysis	Financial models (NPV/IRR)
MRV/Tech Platforms	Tracking and verification	Standardised emission datasets

5. Limitations, Ethical Use, and Data Gaps

This section presents the technical, scientific, financial, and ethical boundaries of the dataset. It ensures the dataset is used responsibly and interpreted within its assumptions.

5.1 Technical and Methodological Limitations

Limitation	Description	Impact	Mitigation
Use of IPCC Tier 1 defaults in some sectors	For regions lacking local emission factors, IPCC default values are used.	Reduces accuracy for localised applications.	Tier 2 Indian factors added where CEA, FSI, FAOSTAT data exists.
Static emission factors	Grid emission factor changes annually; dataset uses 2023 baseline.	May not reflect future decarbonisation of grid.	Users can replace EF values in Excel models.
Agriculture variability not fully captured	Paddy CH_4 emissions depend on water, soil, crop cycle.	Seasonal fluctuations not fully captured.	Users can modify irrigation and temperature factors.
Forestry biomass based on literature averages	No satellite or LiDAR measurements included.	Potential ±15–30% variation in sequestration values.	Future versions may integrate ISRO/FSI remote sensing.
Voluntary carbon market prices partially opaque	OTC prices under confidentiality agreements not fully published.	Price risk not entirely represented.	Price ranges used: \$5–\$100/tCO_2e for sensitivity tests.

5.2 Ethical Use Principles

Ethical Concern	Dataset Response
Greenwashing	Dataset must not be used to claim carbon neutrality without proper validation, registration, and third-party verification.
Indigenous rights & land conflicts	No identifiable land parcel or community-specific forestry data included.
Transparency & Attribution	Dataset licensed under CC BY 4.0. All users must provide citation.
No personal data used	No confidential, personal, or proprietary corporate data is included.
Open Access for public interest	Data publicly available to strengthen climate finance literacy and policy-making.

Ethical Usage Note to Include in Dataverse:
This dataset is intended for academic, analytical, and policy-support purposes. It must not be used to justify unverifiable carbon offset claims or financial instruments without third-party certification.

5.3 Data Gaps and Areas for Future Enhancement

Gap	Present Status	Future Action
Remote sensing-based forest carbon	Not included (no LiDAR, no satellite biomass)	Integration from ISRO NICES, NASA GEDI, Global Forest Watch planned in v2.0
Social Cost of Carbon (SCC) data	Only market-based carbon prices are used	SCC from IPCC, US EPA, Stern Review to be included
Cross-country comparatives	Dataset primarily India-focused	Expansion to ASEAN, Africa, Latin America in future releases
Soil carbon in agriculture	Soil organic carbon change not included in current models	To be added in Carbon_Farming_Model.xlsx
Carbon price forecasting	Only historical and scenario-based pricing used	Machine learning price model (ARIMA/LSTM) in v1.2

5.4 Data Integrity and Replication Measures

Component	Implementation
Version Control	**Changelog_v1.0.txt** records all file modifications
File Integrity	Excel models with formula protection in key sheets

Component	Implementation
Metadata	**Citation_Metadata.json**, **DublinCore.xml** submitted in Dataverse
Licensing	**Creative Commons Attribution 4.0 (CC BY 4.0)**
Validation	Sample calculations cross-checked with CDM PDDs and UNFCCC methodologies

6. References, Glossary, and Appendix

6.1 References

Policy and National Sources

- Government of India. (2023). *Carbon Credit Trading Scheme (CCTS)*. Ministry of Power & MoEFCC.
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- IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.
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Carbon Finance and Markets

- World Bank. (2024). *State and Trends of Carbon Pricing*.
- Trove Research. (2023). *Voluntary Carbon Market Outlook and Price Scenarios*.
- International Carbon Action Partnership (ICAP). (2024). *Emissions Trading Worldwide – Status Report*.
- International Energy Agency (IEA). (2023). *Financing Clean Energy Transitions in Emerging Economies*.

Supplementary Repositories / Author Outputs

- Rawat, M. (2025). *Carbon Credit Dataset & Financial Modelling – India & Global.* Figshare. https://doi.org/10.6084/m9.figshare.30509672
- Rawat, M. (2025). *Carbon Credit – Dataset Documentation (Working Paper).* SSRN. https://papers.ssrn.com/abstract=5693642
- Rawat, M. (2025). *Carbon Finance and Emission Reduction Dataset.* Zenodo. https://doi.org/10.5281/zenodo.17246953
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- Rawat, Manoj. (2025). *Carbon Credit Emission & Financial Dataset – India & Global.* DOI (Harvard Dataverse): https://doi.org/10.7910/DVN/W2D7H2
- Rawat, M. (2025). *Carbon credit: A beginner's guide—Demystifying the carbon economy* SSRN Working Paper https://doi.org/10.2139/ssrn.5693642

6.2 Glossary of Terms

Term	Definition
Additionality	Demonstration that emission reductions would not occur without carbon finance.
Baseline Emissions (BE)	Emissions under a business-as-usual scenario without the project.
Carbon Credit / ER	One unit (1 tCO_2e) of verified greenhouse gas reduction or removal.
CCTS	Carbon Credit Trading Scheme, India (2023).
CER	Certified Emission Reductions issued under UNFCCC CDM.
Leakage	Emissions outside the project boundary due to project activity.
MRV	Monitoring, Reporting and Verification process ensuring accuracy of emissions data.
NPV	Net Present Value – current value of future cash flows discounted at rate *r*.
IRR	Internal Rate of Return – discount rate at which NPV = 0.
Buffer (Forestry)	Percentage of credits withheld to insure against reversal risks (fire, drought, pests).

6.3 Appendix A – Equations and Calculation Frameworks

This appendix presents the core equations used in developing the Excel models for baseline emissions, carbon credit estimation, and financial analysis.

6.3.1 Emission Reduction Framework

General Equation:

$$ER = BE - PE - LK$$

Where:

- **ER** = Emission Reductions (tCO_2e)
- **BE** = Baseline Emissions (business-as-usual)
- **PE** = Project Emissions
- **LK** = Leakage

6.3.2 Project-Specific Equations

(a) Solar Photovoltaic (Grid-Connected RE Projects)

$$ER = EG \times EF_{grid}$$

- EG = Electricity generated (MWh/year)
- EF_{grid} = Grid emission factor (tCO_2/MWh) (CEA, India)

(b) Improved Cookstoves (ICS)

$$ER = (B_s \times EF_{biomass} \times f_{NRB} \times U_r) - PE - LK$$

Where:

- B_s = Biomass saved per stove (tonnes/year)
- f_{NRB} = Fraction of non-renewable biomass
- U_r = Usage rate (stove functioning %)
- PE ≈ 0 (if no fossil fuel used)
- LK = Leakage due to fuel-shifting or stove stacking

(c) Afforestation / Reforestation (AR)

$$ER = (\Delta C_{biomass} \times \frac{44}{12}) - Buffer$$

- ΔC_{biomass} = Annual increase in carbon stock (tC/ha/year)
- Buffer = 5–20% as per VCS/Gold Standard for reversal risk

6.3.3 Financial Evaluation Equations

Annual Carbon Revenue:

$$Revenue_t = ER_t \times Price_t$$

Net Present Value (NPV):

$$NPV = \sum_{t=1}^{n} \frac{(Revenue_t - OPEX_t)}{(1+r)^t} - CAPEX$$

Internal Rate of Return (IRR):
Discount rate at which NPV = 0.

Payback Period:
Number of years until cumulative net cash flow becomes positive.

Sensitivity Parameters Used in Excel models:

Variable	Range Tested	Applies to
Carbon Price	±20%	All models
Discount Rate	6–14%	All
OPEX	±20%	All
Stove Usage Degradation	2%/year	ICS models
Forest Buffer Risk	10–20%	AR models

6.4 Appendix B – Excel Calculation Models

These are the official Excel workbooks submitted along with this report and uploaded to Harvard Dataverse.

File Name	Description	Sector
Carbon_Revenue_Model_with_docs.xlsx	Core model for baseline emissions, ER, revenue, NPV/IRR calculations; includes documentation sheet	Multi-sector
Solar_Revenue_Forecast_10yr_with_docs.xlsx	5 MW solar PV project: generation, baseline emissions, ER, cash flow	Renewable Energy
ICS_Revenue_Forecast_10yr_with_docs.xlsx	Improved Cookstove Project: biomass, ER, price scenarios, degradation	Household Energy
AR_Revenue_Forecast_10yr_with_docs.xlsx	Afforestation/Reforestation: biomass sequestration, buffer, credit issuance	Forestry
Portfolio_Summary_10yr_with_docs.xlsx	Consolidates ER & revenue from Solar, ICS and AR into one sheet	Combined Portfolio

- These workbooks are formula-driven, with no macros or external dependencies.
- Each file contains a "Documentation" or "Methodology" sheet linking formulas to IPCC, CDM, VCS, CCTS frameworks.

6.5 Appendix C – Data Sources, Constants and Conversion Factors

Parameter / Data Type	Source	Value / Unit / Notes
Grid Emission Factor (India)	CEA Baseline Database v17 (2023)	0.82 tCO_2/MWh (average, regional values vary)
Diesel Emission Factor	IPCC 2006 Vol.2	2.68 kg CO_2/litre
Biomass Combustion Emission Factor	IPCC 2006 AFOLU	~0.37 tCO_2/GJ or 1.747 tCO_2/ton dry biomass

Parameter / Data Type	Source	Value / Unit / Notes
Fraction of Non-Renewable Biomass (fNRB)	UNFCCC CDM AMS-II.G	0.7 (default for India; project-specific values may differ)
Methane Global Warming Potential (GWP)	IPCC AR6	27.2 tCO_2e per tCH_4
Forest Biomass Carbon Fraction (CF)	IPCC Vol.4	0.47 (47% of biomass is carbon)
Carbon-to-CO_2 Conversion	IPCC	$CO_2 = C \times 44/12$
Rice Methane Emission Factor	IPCC AFOLU	1.19–2.50 kg CH_4/ha/season
Solar Radiation Data	MNRE India / NASA POWER Database	kWh/m^2/day
Forest Biomass Growth	Forest Survey of India (FSI)	2–6 tC/ha/year (species & region specific)
Carbon Price Data	EU ETS, Verra VCM, CORSIA	USD or EUR per tCO_2e
Currency Conversion	RBI Annual Average Data	INR → USD (used where required in Excel models)

6.6 Appendix D – Metadata, Documentation Files and Submission Checklist

This section lists all documentation, data files and metadata submitted to **Harvard Dataverse/SSRN/Zenodo/OSF** along with the report.

A. Documentation Files (included in submission)

File Name	Description
README.txt	Overview of dataset, purpose, file descriptions, software requirements
DATA_PROVENANCE_AND_METHODOLOGY.txt	Complete methodology for emissions, ER calculations, financial modeling
METHODS_SUMMARY.txt	Summary of equations and assumptions (Solar, ICS, AR)
VARIABLES_CODEBOOK.txt	Variable definitions, units, calculation logic
DATASET_INVENTORY.txt	Final file list of all Excel models & documentation

File Name	Description
CHANGELOG.txt	Version history (v1.0 to v4.2) with Solar and Portfolio updates
LICENSE.txt	Creative Commons Attribution (CC BY 4.0)
CITATION.txt	Citation format and DOI/SSRN/OSF links
HARVARD_METADATA_HINTS.txt	Fields to fill in Dataverse metadata form

B. Excel Models Submitted (Reproducible Calculation Files)

Excel File	Description
Carbon_Revenue_Model_with_docs.xlsx	Master model with baseline, ER, revenue, NPV/IRR
Solar_Revenue_Forecast_10yr_with_docs.xlsx	5 MW Solar PV – energy, emissions, returns
ICS_Revenue_Forecast_10yr_with_docs.xlsx	Improved Cookstoves – ER, degradation, price scenarios
AR_Revenue_Forecast_10yr_with_docs.xlsx	Afforestation/Reforestation – sequestration + buffer risk
Portfolio_Summary_10yr_with_docs.xlsx	Combined ER & revenue comparison for all project types

C. Submission Metadata (Dataverse / Zenodo / OSF)

Metadata Field	Value
Title	Carbon Credit Emission & Financial Dataset – India
Author	Manoj Kumar Rawat
ORCID	https://orcid.org/0009-0005-5571-7820
License	Creative Commons Attribution (CC BY 4.0)
Keywords	Carbon Credits, Solar, Cookstoves, Afforestation, NPV, CCTS
Subjects	Environmental Science, Economics, Energy Policy
Repositories	SSRN, Harvard Dataverse, OSF, Zenodo, FigShare, ResearchGate, Aacdem

6.7 Citation Format for Users

To cite the Report:
Rawat, Manoj. (2025). *Carbon Credit Dataset & Methodology Report – India & Global.*
DOI: https://doi.org/xx.xxxx/xxxxx