DEDICATION

I dedicate this work to the pursuit of knowledge and the relentless curiosity that drives scientific discovery.

To the experiences we never expected and the paths that were redirected.

Bharat Terang

DECLARATION BY THE CANDIDATE

I hereby declare that the thesis entitled **"A COMPREHENSIVE GIS-BASED FRAMEWORK FOR PHOTOVOLTAIC ENERGY PLANNING AND MANAGEMENT IN RURAL ASSAM"** has been submitted to the Department of Energy, Tezpur University, Assam, India, under the School of Engineering for partial fulfilment for the award of the degree of Doctor of Philosophy in Energy. This is an original work carried out by me under the supervision of Prof. Debendra Chandra Baruah. The research was conducted at the Energy Conservation Laboratory, Department of Energy, Tezpur University.

Additionally, I declare that no part of this work has been reproduced elsewhere for the award of any other degree from another university or institute.

All the assistance and support received from various sources have been duly acknowledged.

Bharat Terang

Date: 24/06/2025

(Bharat Terang)

Place: Tezpur

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The committee recommends the award of the degree of Doctor of Philosophy.

Supervisor **External Examiner**

Date: **Date:**

ACKNOWLEDGEMENT

"From patience comes wisdom, from humility comes honour, from absence of envy comes knowledge, and from knowledge comes liberation." - Bhagavad Gita 13.8

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With heartfelt appreciation,
Bharat Terang

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LIST OF ABBREVIATIONS

Abbreviation	Full form
AC	Alternating current
AI	Artificial intelligence
BESS	Battery energy storage systems
BOS	Balance of system
CEA	Central electricity authority
CFA	Central financial assistance
CR	Crop rotation
DC	Direct current
DI	Duration of irrigation
DISCOMs	Distribution companies
DOI	Days of irrigation
DWP	Diesel water pump
EMS	Energy management system
EOL	End-of-life
EV	Electric vehicle
EWP	Electrical water pump
FiTs	Feed-in-tariffs
FL	Frictional lift
FPO	Farmer producer organizations
GHG	Greenhouse Gas
GMS	Ground mounted solar
GW	Gigawatt
INDC	Intended nationally determined contributions
kWh	Kilowatt-hour
LCA	Lifecycle analysis
LULC	Land use land cover
MFI	Microfinance institutions
MNRE	Ministry of new and renewable energy
MPPT	Maximum power point tracking

Abbreviation	Full form
MSP	Minimum support prices
MW	Megawatt
NGO	Non-governmental organization
O&M	Operation and maintenance
PAYG	Pay as you go
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan
PPA	Power purchase agreement
PPP	Public-private partnerships
PR	Performance ratio
PV	Photovoltaic
REPP	Renewable energy-based power plants
ROI	Return on Investment
RTS	Rooftop solar
SHG	Self-help groups
STC	Standard test conditions
SWP	Solar photovoltaic water pump

LIST OF SYMBOLS

Symbol	Meaning
A_{SWP}	Area of solar PV
$B_{capacity}$	Battery capacity
$C_{O\&M}$	Operation & maintenance cost
CO_2	Carbon Emission reduction
C_{cap}	Capital cost
C_{net}	Net consumer cost
C_t	Capital cost at time t
C_{total}	Total system cost
$D_{transport}$	Transportation distance
E_h	Hydraulic energy
E_{EV}	EV energy demand
$EF_{battery}$	Emission factor of the battery
EF_{diesel}	Emission factor for diesel
$EF_{disposed}$	Emission factor for disposal process
$EF_{install}$	Installation emission factor
$EF_{inverter}$	Emission factor of the inverter
$EF_{maintenance}$	Emissions factor from maintenance activities
EF_{pv}	Emission factor of PV module
$EF_{recycle}$	Emission factor during recycling process
$EF_{transport}$	Transportation emission factor
E_{SWP}	Energy generated by solar photovoltaic water pumping system
$E_{charged}$	Energy stored in the battery
E_e	Electrical energy
E_{grid}	Grid energy
$E_{irrigation}$	Energy requirement for irrigation
E_{pump}	Energy required for water pumping
E_{req}	Energy requirement of the battery

Symbol	Meaning
E_{sol}	Solar insolation
E_{sol}	Solar insolation
E_{solar}	Solar energy generation
$E_{supplied}$	Energy supplied to the battery
$E_{surplus}$	Excess energy available from SWP
E_t	Energy generated at time t
F_{tilt}	Panel tilt angle
$GHG_{O\&M}$	GHG emissions during operation and maintenance phase
GHG_{end}	End of life GHG emissions
$GHG_{install}$	GHG emissions during installation phase
$GHG_{manufacture}$	GHG emissions during manufacturing phase
$GHG_{reduction}$	Reduction in GHG emission
GHG_{total}	Total lifecycle GHG emissions
$GHG_{transport}$	GHG emission during transportation
I_0	Leakage current
I_L	Light generated current
I_{batt}	Current of battery
$I_{capacity}$	Inverter capacity
L_n	Diffusion length of electrons
L_p	Diffusion length of holes
$L_{shading}$	Energy loss due to shading
M_t	Maintenance cost at time t
O_t	Operating cost at time t
P_{annual}	Annual profit
P_{inv}	Inverter capacity
P_{margin}	Profit margin
$P_{monthly}$	Monthly profit
P_{pv}	PV system capacity
P_{solar_max}	Maximum power generated by the solar panels
R_t	Annual net cash flow at in year t
$T_{charging}$	EV charging time

Symbol	Meaning
T_{life}	Total lifespan of PV system
T_{module}	Module temperature
V_{batt}	Voltage of battery
$W_{disposed}$	Weight of disposed components
W_{labor}	Total labour hours for installation
$W_{recycled}$	Total weight of recycled PV system components
W_{weight}	Total weight of all PV system
t_c	Battery charging duration
η_{PV}	Efficiency of PV module
$\eta_{charging}$	EV charging efficiency
η_{inv}	Inverter efficiency
$\eta_{storage}$	Efficiency of the battery storage system
η_{surf}	Surface efficiency
$\omega_{\circ}$	Solar hour angle
₹	Rupees
°C	Degree Celsius
A	Area
CUF	Capacity utilization factor
$E_{storage}$	Battery energy storage requirements
I	Current
k	Boltzmann constant
L	Project lifetime
$LCOE$	Levelized cost of energy
n	Number of days
NPV	Net present value
PBP	Payback period
q	Charge on an electron
T	Temperature of the solar cell
V	Voltage
W	Width of depletion layer
ϕ	Latitude angle

Symbol	**Meaning**
CoI	Cost of irrigation
$G(\tau)$	Carrier generation rate
H	Hydraulic head of pump
$L(i, j)$	Load requirement for EV charging at location i and time j
Q	Rate of flow of water
S	Government subsidy
g	Acceleration due to gravity
n	System lifetime
r	Discount rate
δ	Solar declination angle
ρ	Density of water