Web Application for Quantifying Carbon Footprint in Indian Coal Mines Using MERN Stack

Objectives:

- Quantify carbon emissions from coal mining activities.
- Estimate carbon sinks and calculate gaps.
- Provide pathways to achieve carbon neutrality.

Features:

- Emission Estimation Module
- Carbon Neutrality Pathways Module
- Data Visualization
- Scalability for different mine sizes and types.

Technologies:

Frontend Development

- **Technologies**: React.js, Redux (for state management), Chart.js/D3.js (for data visualization)
- **Components**:
  - **Dashboard**: Overview of carbon footprint, emission trends, and pathways to neutrality.
  - **Data Input Forms**: Forms for users to input mining activity data (e.g., equipment usage, excavation volumes).
  - **Results Visualization**: Charts/graphs to display emission estimates, carbon sinks, and potential reduction strategies.
  - **Pathway Simulator**: UI to simulate different carbon neutrality strategies (clean technologies, afforestation, etc.).

3. Backend Development

- **Technologies**: Node.js, Express.js
- **API Endpoints**:
  - **/api/emission-calculate**: Calculate carbon emissions based on input data.
  - **/api/carbon-sink**: Estimate current carbon sinks based on land area and tree density.
  - **/api/pathways**: Provide pathways for carbon neutrality based on user input and simulation data.
  - **/api/carbon-credits**: Estimate potential carbon credits based on emission reduction and market rates.

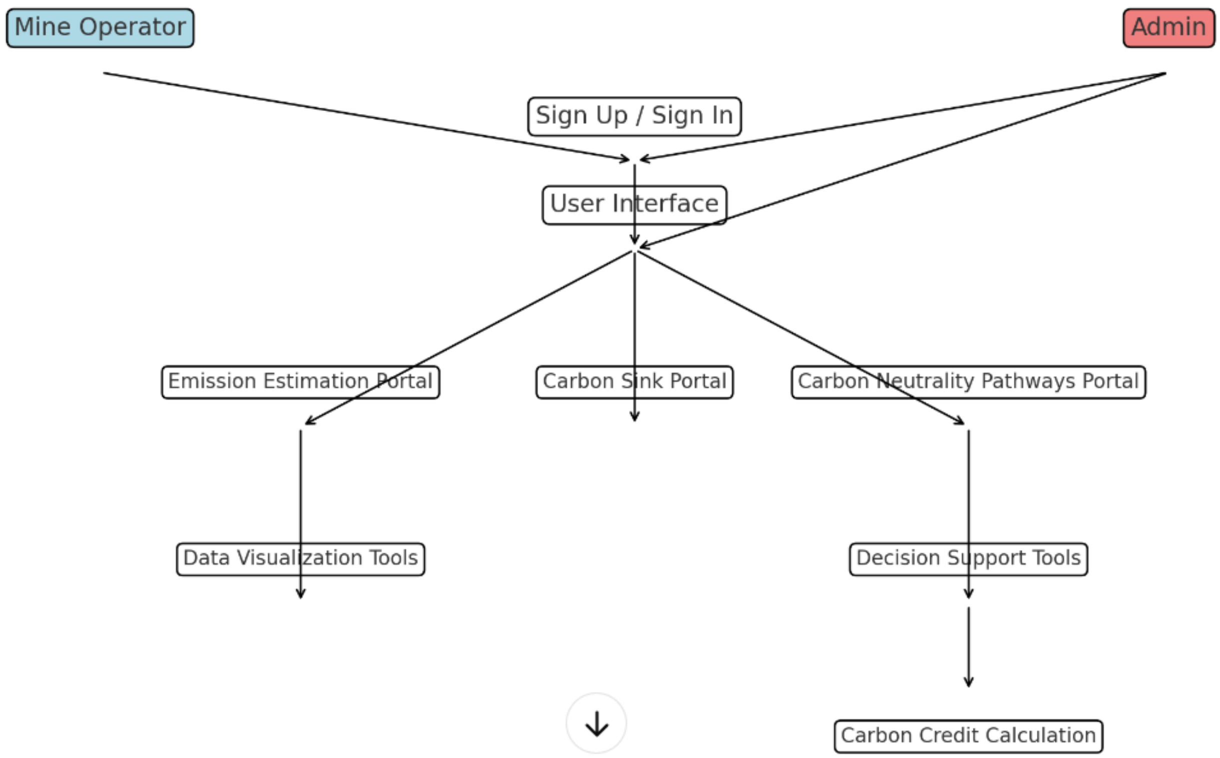
Algorithms:

- **Emission Estimation**:
  - Formula: `Total Emissions = ∑ (Activity Data × Emission Factor)`
  - **Activity Data**: Input from users about mining activities (e.g., diesel consumption, electricity usage).
  - **Emission Factors**: Pre-defined constants based on established guidelines for each activity.
- **Carbon Sink Estimation**:
  - Formula: `Carbon Sequestration = Area of Land × Tree Density × Sequestration Rate`
  - **Sequestration Rate**: Pre-defined values based on tree species and age.
- **Carbon Neutrality Pathways**:
  - **Clean Technologies**: Calculate emission reduction from electric vehicles, methane capture, etc.
  - **Afforestation**: Estimate land required for offsetting emissions through tree planting.
  - **Alternative Energy**: Assess the impact of using renewable energy (solar, wind) on emissions.

Database Structure

- **Technologies**: MongoDB
- **Schema Design**:
  - **Mines Collection**:
    - `mineId`: Unique identifier
    - `mineType`: Underground or Open-cast
    - `location`: Geographical data
    - `size`: Size of the mine (small, medium, large)
  - **Emissions Collection**:
    - `emissionId`: Unique identifier
    - `mineId`: Reference to Mines collection
    - `activityType`: Type of activity (excavation, transportation, etc.)
    - `activityData`: Data specific to the activity
    - `emissionValue`: Calculated emission
  - **CarbonSinks Collection**:
    - `sinkId`: Unique identifier
    - `mineId`: Reference to Mines collection
    - `landArea`: Area of land available for afforestation
    - `treeDensity`: Number of trees per unit area
    - `sequestrationRate`: Carbon absorption rate
  - **Pathways Collection**:
    - `pathwayId`: Unique identifier
    - `mineId`: Reference to Mines collection

- `strategy`: Type of strategy (clean tech, afforestation, etc.)
- `potentialReduction`: Estimated emission reduction



Real-Life Example: Coal Mine XYZ

Location: Eastern India

Size:5,000 hectares

Annual Coal Production:10 million tons

Employees:1,200

Step-by-Step Process

1. Data Collection

a. User Input

Fuel Consumption: The mine operator inputs that the machinery and vehicles used in the mining operations consume 500,000 liters of diesel annually.

Electricity Usage: The mine reports an annual electricity consumption of 10 million kWh.

Methane Emissions: The mine emits 2,000 tons of methane annually from coal seams.

Transportation Data:The transportation of coal and other materials consumes 200,000 liters of diesel annually.

Employee Travel: On average, each of the 1,200 employees travels 20 km daily using personal vehicles, with an average fuel efficiency of 15 km per liter.

- Waste Management:

b. Calculation:

Fuel Consumption (Mining Operations):

$$500,000 \text{ liters} \times 2.68 \text{ kg CO2e/liter} = 1,340,000 \text{ kg CO2e}$$

Electricity Usage:

$$10,000,000 \text{ kWh} \times 0.82 \text{ kg CO2e/kWh} = 8,200,000 \text{ kg CO2e}$$

Methane Emissions:

$$2,000 \text{ tons} \times 25 \text{ kg CO2e/kg} = 50,000,000 \text{ kg CO2e}$$

Transportation (Fuel Consumption):

$$200,000 \text{ liters} \times 2.68 \text{ kg CO2e/liter} = 536,000 \text{ kg CO2e}$$

Employee Travel:

$$\text{Total Annual Distance} = 1,200 \times 20 \text{ km/day} \times 300 \text{ days} = 7,200,000 \text{ km}$$

$$\text{Total Fuel Consumption} = \frac{7,200,000 \text{ km}}{15 \text{ km/liter}} = 480,000 \text{ liters}$$

$$480,000 \text{ liters} \times 2.68 \text{ kg CO2e/liter} = 1,286,400 \text{ kg CO2e}$$

Waste Management (Landfill):

- Assuming the emission factor for landfill is 0.2 kg CO2e per kg:

$$5,000,000 \text{ kg} \times 0.2 \text{ kg CO2e/kg} = 1,000,000 \text{ kg CO2e}$$

Waste Management (Incineration):

- Assuming the emission factor for incineration is 0.6 kg CO2e per kg:

$$5,000,000 \text{ kg} \times 0.6 \text{ kg CO2e/kg} = 3,000,000 \text{ kg CO2e}$$

3. Activity-Wise Carbon Footprint Quantification

a. Categorization: Scope 1 Emissions (Direct):

- Fuel consumption for mining operations and transportation.

- Methane emissions from coal seams.

Scope 2 Emissions (Indirect): Electricity usage.

Scope 3 Emissions (Value Chain): Employee travel.Waste management

4. Per Capita Emissions Calculation

Per Capita Emission:

$$\text{Per Capita Emission} = \frac{65,362,400 \text{ kg CO2e}}{1,200 \text{ employees}} = 54,468.67 \text{ kg CO2e/employee/year}$$

5. Estimation of Existing Carbon Sinks

Carbon Sink Data:

- **Green Cover:** 500 hectares sequestering 10 tons (10,000 kg) of CO2e per hectare per year.

Carbon Sequestration Calculation:

$$\text{Sequestration} = 500 \text{ hectares} \times 10,000 \text{ kg CO2e/hectare/year} = 5,000,000 \text{ kg CO2e/}$$

6. Gap Analysis and Pathway Suggestions

Carbon Neutrality Gap:

$$\text{Gap} = 65,362,400 \text{ kg CO2e/year} - 5,000,000 \text{ kg CO2e/year} = 60,362,400 \text{ kg CO2e/}$$

Pathway Simulation:

1. **Adopting Clean Technologies:**
   - **Reduction in Diesel Usage by 50%:**

b. Dashboard:

- The dashboard provides a breakdown:

  - Scope 1: 1,340,000 + 536,000 + 50,000,000 = 51,876,000 kg CO2e

  - Scope 2: 8,200,000 kg CO2e

  - Scope 3: 1,286,400 + 1,000,000 + 3,000,000 = 5,286,400 kg CO2e

Pathway Simulation:

1. **Adopting Clean Technologies:**
   - **Reduction in Diesel Usage by 50%:**

$$\text{Reduction} = (1,340,000 + 536,000) \times 0.5 = 938,000\,\text{kg CO2e/year}$$

2. **Afforestation:**
   - **Additional 1,000 Hectares:**

$$\text{Sequestration} = 1,000\,\text{hectares} \times 10,000\,\text{kg CO2e/hectare/year} = 10,000,000\,\text{kg}$$

3. **Carbon Credits:**
   - **Offset 50% of Remaining Emissions:**

$$\text{Carbon Credits} = 60,362,400 \times 0.5 = 30,181,200\,\text{kg CO2e/year}$$

Final Carbon Footprint After Implementing Pathways:

$$\text{Remaining Emissions} = 60,362,400 - (938,000 + 10,000,000 + 30,181,200) = 19,24$$

- Emissions Reduction (Clean Technologies):

  - 938,000 kg CO2e/year

-Additional Carbon Sequestration (Afforestation):

  - 10,000,000 kg CO2e/year

- Carbon Credits:

  - 30,181,200 kg CO2e/year

- Final Gap:

$$60,362,400 - (938,000 + 10,000,000 + 30,181,200) = 19,243,200 \text{ kg CO2e/year}$$