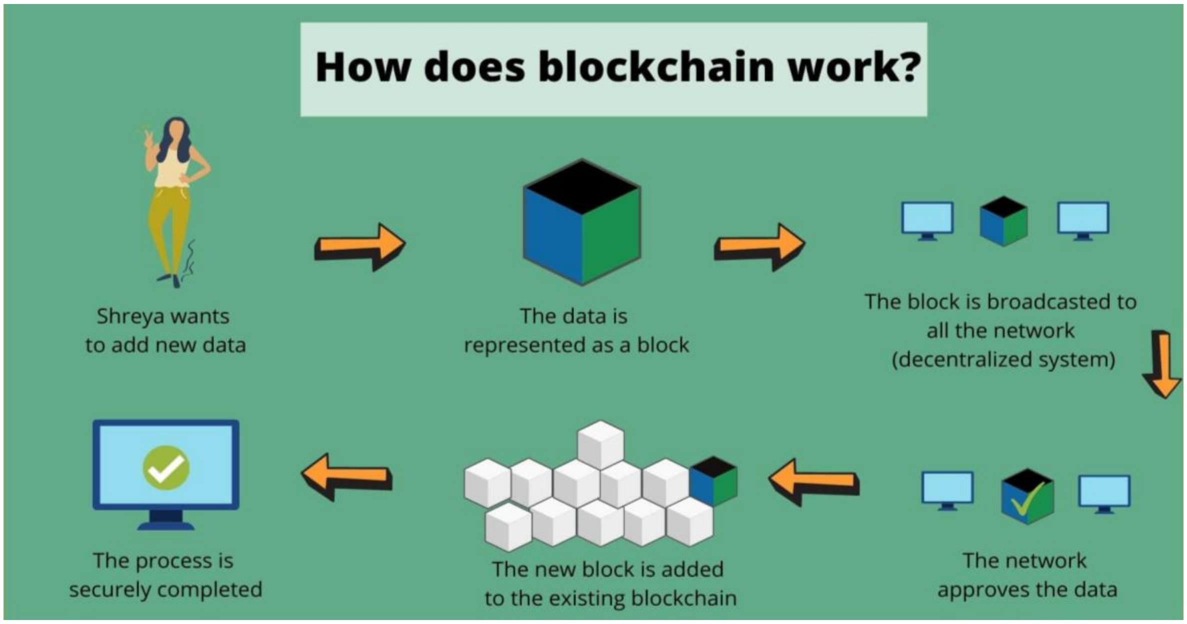
What is Blockchain?

The blockchain is a distributed database of records of all transactions or digital events that have been executed and shared among participating parties. Each transaction is verified by the majority of participants in the system.



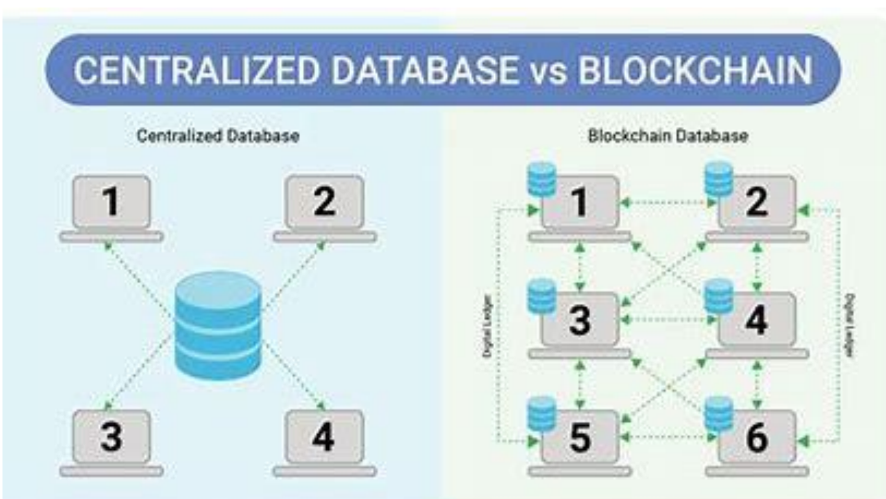
A blockchain is a **digital ledger** that records information (like transactions) in a **secure, tamper-proof way**.

1. **Blocks:** Data (e.g., a transaction) is stored in units called blocks. Each block has three key parts:
    a. The data or transaction information.
    b. A timestamp.
    c. A unique code called a **hash**.
2. **Chain:** Blocks are linked together, where each block points to the hash of the **previous block**, forming a continuous chain.
3. **Decentralization:** Instead of being controlled by one authority, the data is shared across a **network of participants** (nodes). Every node keeps a copy of the blockchain.
4. **Security:** Since changes require approval from the majority of the network, **tampering** with data is nearly impossible.

Blockchain is a technology that enables the secure sharing of information. Data, obviously, is stored in a database. Transactions are recorded in an account book called a **ledger**. A blockchain is a type of *distributed* database or ledger, which means the power to update a blockchain is distributed between the nodes, or participants, of a public or private computer network. This is known as **distributed ledger technology** (DLT). Nodes are rewarded with digital tokens or currency to make updates to blockchains.

1. Blockchain as a Database

- **Stores Data:** Blockchain **stores information** just like a database. The information could be transactions, smart contracts, or other types of data.
- **Structure:** Data is stored in **blocks** that are linked in a chain, rather than in rows and tables like a traditional relational database.
- **Decentralized Storage:** Unlike centralized databases, blockchain distributes data across many participants (nodes) in a network.



Key difference:

While databases allow for CRUD operations (Create, Read, Update, Delete), a blockchain database only supports **appending** new data—**no changes or deletions** are allowed once a block is added.

Key Attributes of Block chain

Cryptographic Security:

- Access and data additions require **two keys**:
  - **Public key:** Functions like an address on the blockchain.
  - **Private key:** A unique, secret key that must be authenticated to ensure secure access.

Digital Log of Transactions:

- Blockchain acts as a **fully online database** that records transactions in a tamper-proof, sequential way.

Shared Network:

- Blockchain data is **distributed across a network** (public or private).
- Example: The **Bitcoin blockchain** is a well-known public network.

PoW VS PoS

Blockchain networks use different methods to agree on which transactions are valid, called **consensus mechanisms**. Two common types are **Proof of Work (PoW)** and **Proof of Stake (PoS)**.

Proof of Work (PoW)

PoW is a consensus mechanism where miners solve complex mathematical puzzles to validate transactions and create new blocks.

- **How It Works**:
  - Miners compete to solve cryptographic challenges.
  - The first miner to solve the puzzle gets to add the block to the blockchain and is rewarded with cryptocurrency.

Proof of Stake (PoS)

PoS is a consensus mechanism where validators are chosen to create new blocks based on the number of coins they hold and are willing to "stake" as collateral.

  - Instead of mining, validators are selected to propose and validate new blocks based on their stake (the amount of cryptocurrency they hold).
  - Validators earn rewards for confirming transactions and can lose their stake if they act maliciously.

Setting up a blockchain system to track carbon emissions across a supply chain:

1. Data Collection

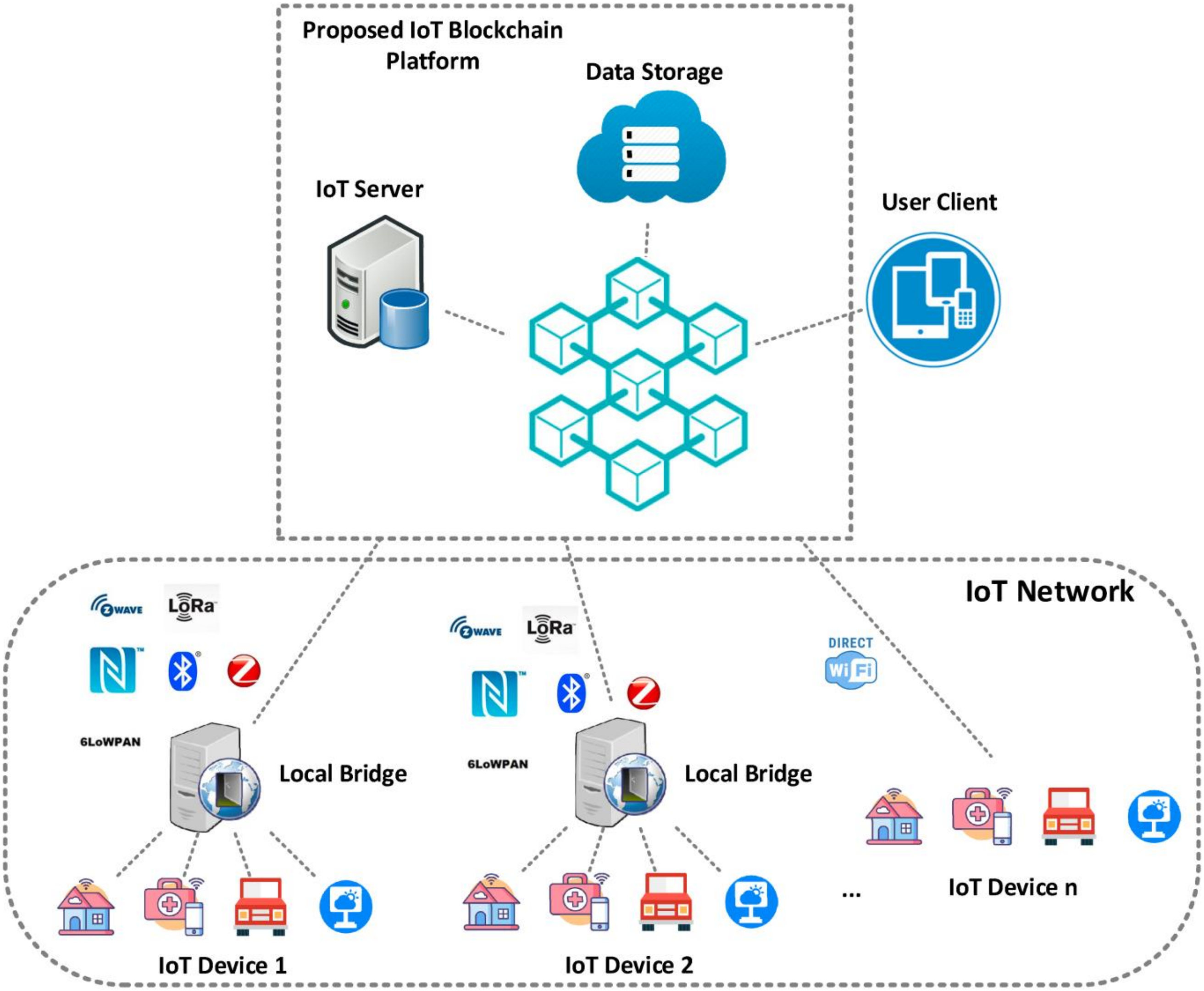
- **Sensors and IoT Devices**: Suppliers would install sensors or Internet of Things (IoT) devices to capture real-time data on carbon emissions. These could be placed in factories, transportation fleets, or power consumption systems. For example, sensors can measure fuel usage, electricity consumption, or emissions directly from manufacturing processes.

- **Manual Data Entry**: For processes where sensors aren't practical, suppliers might use a combination of manual data entry and auditing to track emissions.

2. Data Recording on Blockchain

- **Immutable Record**: The emission data captured by sensors or entered manually is recorded as a transaction on the blockchain. Once added, this data is immutable, meaning it cannot be tampered with or altered. This ensures the authenticity of emission records.

- **Smart Contracts**: Suppliers can use smart contracts (self-executing contracts with predefined rules) to automatically log emissions data on the blockchain whenever a certain event occurs. For example, when a shipment is dispatched, the associated emissions data is recorded automatically based on transport mode and distance.

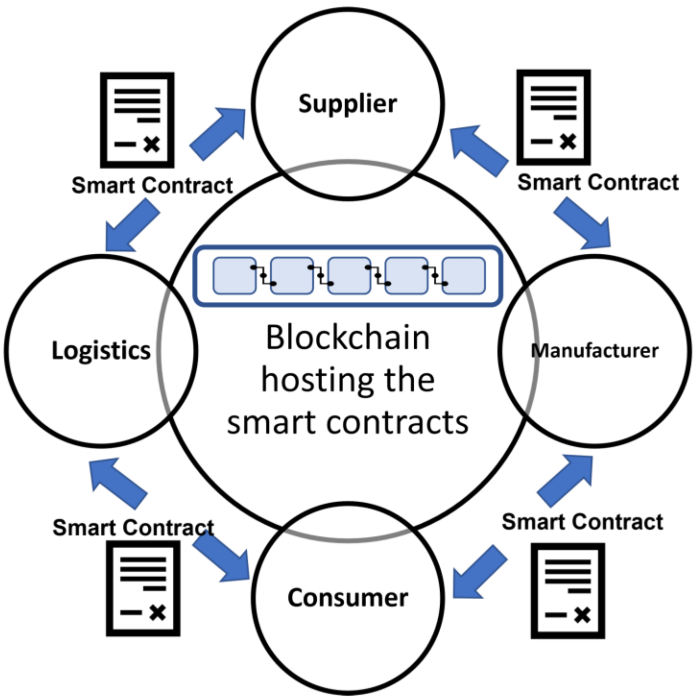


3. Verification and Validation

- **Third-Party Verification**: Auditors or environmental agencies can be part of the blockchain network to verify and validate the emission data before it's added to the blockchain. They ensure the accuracy of data submitted by suppliers.
- **Consensus Mechanism**: Suppliers' emissions data are validated by the network using a **consensus mechanism** like Proof of Stake (PoS) or another efficient method. This ensures that all network participants agree on the data's validity.

4. Tracking Emissions Across the Supply Chain

- **End-to-End Visibility**: As each supplier in the chain logs their emissions, the blockchain provides an end-to-end view of the entire carbon footprint across different stages of the supply chain. For instance, raw material extraction, transportation, manufacturing, and distribution stages are all captured on the ledger.
- **Tokenization**: In some setups, emissions can be represented as **tokens** (like carbon credits). Companies or suppliers with lower emissions can earn tokens, which can be traded or used to offset emissions elsewhere in the supply chain.



5. Real-Time Monitoring and Reporting

- **Dashboard and Analytics**: Suppliers can view real-time data through dashboards connected to the blockchain. These systems can analyze and display emissions at various stages, helping suppliers reduce their carbon footprint and identify inefficiencies.
- **Reporting and Compliance**: Blockchain helps suppliers and manufacturers comply with international standards by providing transparent, verifiable reports on carbon emissions, which can be shared with stakeholders, regulators, or customers.

6. Auditing and Accountability

- **Audit Trail**: Blockchain provides an immutable audit trail of all emissions data. This means that suppliers can be held accountable for their environmental impact, and fraudulent data manipulation is nearly impossible due to the blockchain's structure.
- **Environmental Goals**: Companies can set sustainability goals, such as reducing emissions by a certain percentage over time. The blockchain will track progress toward these goals in a transparent and verifiable way.

Sensor Data to Blockchain via Smart Contracts

Key Components and Process

1. **Sensor Data Collection:**
    a. Sensors gather real-time data from the physical environment.
    b. Data is preprocessed and formatted for compatibility with the blockchain.
2. **Smart Contract Deployment:**
    a. A smart contract is deployed on a suitable blockchain platform (e.g., Ethereum, Hyperledger Fabric).
    b. The contract defines the rules and conditions for data submission and verification.
3. **Data Submission:**

   a. Sensor data is transmitted to a designated node or oracle that interacts with the smart contract.
   b. The contract verifies the data's authenticity and integrity.
4. **Blockchain Recording:**
   a. Upon verification, the data is recorded as a transaction on the blockchain.
   b. The transaction becomes part of an immutable ledger, ensuring data security and traceability.

IBM Block Chain Solutions

Example:

IBM’s blockchain solution for tracking carbon emissions is part of their broader initiative to help businesses achieve sustainability goals. By leveraging blockchain, IoT data, and smart contracts, IBM creates a transparent and verifiable system that tracks carbon emissions across the entire supply chain. Here's a more detailed explanation of their process:

1. Integration of IoT and Data Capture

- **IoT Sensors**: IBM uses Internet of Things (IoT) devices to gather real-time data related to carbon emissions. These sensors are deployed at various points in the supply chain, such as manufacturing facilities, transportation vehicles, and warehouses. They collect data on energy consumption, fuel usage, waste production, and direct carbon emissions.
- **Automated Data Collection**: The sensors automatically collect and transmit data to the blockchain without human intervention. This removes the possibility of human error and ensures that the data is consistently accurate and reliable.
- **Types of Data Collected**:

    - Energy consumption (electricity, natural gas, etc.)
    - Emissions from transportation (e.g., fuel combustion, distance traveled)
    - Manufacturing process emissions (e.g., emissions from machinery, factories)
    - Recycling and waste management data

2. Blockchain as the Distributed Ledger

- **Immutable Ledger**: IBM uses its enterprise-grade blockchain platform (often built on **Hyperledger Fabric**) to create a distributed, immutable ledger. Once the IoT devices send the emissions data to the blockchain, it becomes permanently recorded. This ensures that no data can be altered or tampered with after it is entered, providing trust and transparency.
- **Distributed Network**: Suppliers, manufacturers, regulators, and other stakeholders involved in the supply chain can participate in the blockchain network. Each party can see the recorded emissions data, but the system ensures privacy and security through permissions (e.g., a supplier only sees their own data, but a manufacturer might see aggregated data).

3. Smart Contracts for Automation

- **Smart Contracts**: Smart contracts are self-executing contracts where the terms are written directly into code. IBM uses smart contracts to automate various processes, such as recording emissions data or triggering reports.
  For example:
    - When a shipment of goods is dispatched, the smart contract can automatically calculate and record the emissions generated by the transportation.
    - If a supplier reaches a certain emissions threshold, the smart contract might trigger an alert or initiate an audit to verify the data.
- **Automated Reporting**: Based on pre-defined conditions, smart contracts can generate reports and carbon footprints automatically. For example, if a manufacturing plant emits a certain amount of CO_2, the smart contract logs this data and makes it available to the network in real-time.

4. Tracking and Tracing Across the Supply Chain

- **End-to-End Visibility**: IBM's blockchain system tracks carbon emissions across each stage of the supply chain. From the extraction of raw materials to production, transportation, and delivery, the system captures emissions at every touchpoint.

- **Digital Twins**: A **digital twin** is a virtual representation of physical assets. IBM's blockchain solution often uses digital twins to represent products, machinery, or vehicles on the blockchain. This allows stakeholders to monitor the carbon emissions associated with each asset as it moves through the supply chain.
- **Supply Chain Mapping**: The system offers a detailed view of the entire supply chain, allowing companies to track not just their own emissions, but also the emissions of their suppliers, sub-suppliers, and transport partners. This full visibility helps companies identify the most carbon-intensive parts of the chain and make targeted improvements.

5. Carbon Emission Data Verification

- **Third-Party Verification**: To ensure data integrity, IBM allows for third-party verification of the carbon emissions data. Independent auditors or environmental agencies can join the blockchain network and verify that the data being recorded is accurate. They can cross-check the data coming from IoT devices and match it against other records or industry standards.
- **Consensus Mechanism**: IBM's blockchain uses a consensus mechanism to validate emissions data before it is added to the blockchain. In private or permissioned blockchains like those used by IBM, consensus mechanisms can be more efficient than traditional public systems, ensuring that only verified and trusted participants can add or validate data.

6. Data Analytics and Insights

- **Advanced Analytics**: IBM's solution integrates advanced data analytics to help companies understand their carbon footprint better. By analyzing the data collected across the supply chain, companies can:
    - Identify trends in carbon emissions.
    - Detect inefficiencies or areas with high carbon output.
    - Simulate different scenarios to reduce emissions, such as changing transportation methods or switching to renewable energy sources.
- **Custom Dashboards**: The blockchain system provides stakeholders with custom dashboards that offer real-time insights into their emissions. This allows companies to monitor their sustainability goals and make informed decisions about how to reduce their carbon footprint.

7. Carbon Credits and Offsetting

- **Tokenization of Emissions**: IBM's blockchain solution can tokenize emissions data into **carbon credits**. For example, a company that reduces its emissions below a certain level can earn carbon credits. These credits can be traded or sold on carbon markets or used to offset emissions in other parts of the supply chain.

- **Offsetting**: IBM's blockchain can also integrate with carbon offset programs. If a company's emissions exceed a certain threshold, it can purchase carbon offsets via the blockchain, ensuring that any excess emissions are balanced by environmental projects (e.g., reforestation, renewable energy projects).

8. Regulatory Compliance and Reporting

- **Real-Time Compliance**: By using blockchain to track and trace carbon emissions, companies can ensure compliance with local, national, and international regulations related to carbon reporting. Governments and regulatory bodies can access the blockchain to verify that companies are meeting their carbon reduction goals.
- **Auditable Reports**: IBM's blockchain solution can automatically generate auditable, verifiable reports for regulators, investors, or customers. These reports provide transparent evidence of the company's carbon footprint, making it easier to comply with environmental reporting requirements.

9. Collaboration Across Industries

- **Cross-Industry Platforms**: IBM's blockchain solutions are often part of larger, cross-industry platforms where multiple companies collaborate. This means that even if a company sources materials from various suppliers across different industries (e.g., raw materials, transport, retail), the emissions data from all these players can be recorded and managed within the same blockchain system.
- **Shared Goals**: By using blockchain, companies can set shared sustainability goals, monitor progress, and hold each other accountable. For example, all the players in a supply chain can agree on a collective carbon reduction target and use the blockchain to track each company's contribution.

Example: IBM Food Trust for Carbon Tracking

IBM has already applied blockchain solutions in sectors like food safety with the **IBM Food Trust**, which uses blockchain to track food from farm to table. The same principles are being applied to carbon emissions, allowing manufacturers, suppliers, and retailers to track emissions data at every step. For example, a company can see the emissions associated with producing a particular ingredient, transporting it, and processing it into a final product, enabling carbon-conscious decision-making.

[IBM Blockchain - Enterprise Blockchain Solutions and Services]

[IBM Supply Chain Intelligence Suite - Food Trust]

Building Blockchain-Powered IoT Solutions

Setting Up the Development Environment

Before you can embark on developing blockchain-based IoT solutions, it's crucial to establish your development environment. Here's a step-by-step guide to help you get started:

- **Choose a Blockchain Platform**: Begin by selecting the blockchain platform that best suits your project's specific requirements. Popular options include Ethereum, Hyperledger Fabric, and IOTA, each offering unique features tailored to different use cases.
- **Install Necessary Tools:** Depending on the chosen blockchain platform, install the essential development tools and Software Development Kits (SDKs). These tools are crucial for coding, testing, and deploying your IoT applications on the blockchain.
- **Hardware Setup:** Acquire the IoT devices and sensors that will be integrated into your solution. Ensure that these devices are compatible with the blockchain platform you've chosen. Compatibility is essential for seamless data integration and communication between your IoT devices and the blockchain network.

Developing Smart Contracts

Smart contracts serve as the backbone of blockchain-powered IoT applications, facilitating automated and trustless interactions among devices. Here's a step-by-step guide to creating smart contracts:

- **Choose a Programming Language:** Depending on your chosen blockchain platform, select an appropriate programming language for smart contract development. Solidity is a commonly used language for Ethereum-based contracts, but different platforms may have their preferred languages.
- **Code Your Smart Contract:** Begin by writing the code for your smart contract. Define its logic, functions, and how it will interact with IoT devices. Ensure that your contract's code is clear, secure, and aligns with your project's requirements.
- Testing: Before deployment, it's essential to thoroughly test your smart contract. Utilize a testnet (a blockchain environment for testing) to identify and rectify any bugs, vulnerabilities, or logical issues. Rigorous testing helps ensure that your contract functions correctly and securely.
- **Deployment**: Once your smart contract has passed all tests and is deemed ready, deploy it on the mainnet (the live blockchain network) or a private blockchain network, depending on your project's scope and requirements. This

step makes your smart contract accessible and operational for IoT devices and other participants on the network.

Integrating IoT Devices

Integrating IoT devices into your blockchain-powered application involves a series of essential steps:

- **Connectivity:** Establish a secure and reliable connection between your IoT devices and the blockchain network. This may require implementing Application Programming Interfaces (APIs), custom communication protocols, or IoT-specific middleware to enable seamless data exchange.
- **Data Encryption:** Implement robust encryption techniques to safeguard the integrity and confidentiality of data transmitted between IoT devices and the blockchain. Encryption ensures that sensitive information remains protected from unauthorized access or tampering during transmission.
- **Data Validation:** Ensure that data generated by IoT devices adheres to predefined rules and standards set by your smart contract. Data validation helps maintain data integrity on the blockchain and prevents erroneous or malicious data from compromising the network.
- **Oracles:** Bridge the gap between the off-chain world of IoT and the on-chain world of the blockchain by utilizing oracles or data feeds. Oracles act as intermediaries that fetch real-world data and feed it into the blockchain, enabling smart contracts to make informed decisions based on external information. This integration enhances the functionality and reliability of your IoT-enabled blockchain application.

Building the User Interface

The user interface serves as the primary channel for users to interact with your blockchain-powered IoT application. To ensure a seamless user experience, consider the following key considerations:

- **User-Friendly Design**: Design an intuitive and user-friendly interface that makes it easy for users to monitor and control their IoT devices. Prioritize simplicity and clarity in the layout and navigation to enhance user engagement.
- **Real-Time Data:** Display real-time data from IoT devices prominently on the interface. Providing users with up-to-the-minute information and insights about their connected devices enhances the utility of your application and helps users make informed decisions.
- **Transaction Management:** Implement transaction management features within the interface. Enable users to initiate transactions, execute commands, or

interact with IoT devices directly through the user interface. Make sure these interactions are secure, reliable, and presented to users.

A well-crafted user interface not only enhances the accessibility of your blockchain-powered IoT application but also contributes significantly to the overall user satisfaction and adoption of your technology.

Security and Privacy

When integrating IoT with blockchain, prioritizing security and privacy is of utmost importance. Here are essential security measures to consider:

- **Identity Management:** Implement robust identity management for both IoT devices and users interacting with the blockchain. Ensure that each device and user have a unique and secure identity within the system. Utilize cryptographic techniques such as digital certificates to verify identities and maintain trust.
- **Access Control:** Define granular access control policies to restrict unauthorized access to sensitive data and system functionalities. Assign appropriate permissions based on roles and responsibilities, and regularly review and update access privileges as needed.
- **Data Encryption:** Employ encryption mechanisms for data protection, both in transit and at rest. Use strong encryption algorithms to safeguard data from potential breaches and eavesdropping. Encryption ensures that even if unauthorized parties gain access to data, it remains unintelligible to them.
- **Regular Auditing:** Conduct routine security audits and assessments to proactively identify vulnerabilities and weaknesses in your blockchain IoT system. Regular audits help in the early detection of potential threats and allow for timely mitigation measures. Make necessary security updates and improvements based on audit findings.

By implementing these security measures, you can enhance the overall safety and privacy of your blockchain-powered IoT integration, mitigating risks and ensuring the trustworthiness of your system for both IoT devices and users.

Real-World Applications

Blockchain development for IoT integration has a wide range of real-world applications, revolutionizing various industries.

Supply Chain Management

Blockchain ensures transparency and traceability in the supply chain by recording every step of the production and distribution process. This is particularly beneficial for industries like:

- **Food and Beverage**: Blockchain enables the tracking of food products from their origin to the consumer's table. It enhances safety by quickly identifying the source of contamination in a food recall. Additionally, consumers can access information about the product's origin and quality, fostering trust in the supply chain.
- **Pharmaceuticals:** The pharmaceutical industry benefits from blockchain by verifying the authenticity of drugs. By recording the journey of medications from manufacturers to patients, blockchain helps combat counterfeit drugs, ensuring that patients receive safe and genuine medications.
- **Logistics:** Blockchain optimizes logistics operations by providing a transparent and immutable record of goods movement. It streamlines the supply chain by reducing delays, enhancing route optimization, and minimizing errors in shipping and delivery processes.

Reference:

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- What is blockchain technology? | McKinsey
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Readymade devices IoT/GPS/GPRS via 0G technology to capture carbon emissions from the supplier vehicles:

There are some IoT devices that utilize 0G technology (such as Sigfox) to capture data related to carbon emissions, including GPS or GPRS capabilities for tracking vehicles. These devices focus on low-power, long-range data transmission, making them ideal for tracking and monitoring emissions in supply chains.

What is sigfox?

Sigfox is a **long range cellular wireless communication** that offers custom solutions primarily for low-throughput Internet of Things (IoT) and **M2M applications** by availing its **end-to-end IoT connectivity services** using it's patented technologies. The Sigfox network protocol has patented base stations that are integrated with software defined radios. The end devices use **binary phase-shift keying (BPSK)** modulation to connect to the base stations.

The Sigfox network has been designed to facilitate **effective communication over low power consumption**. Low power consumption ensures that remote devices run for long with minimal battery charging or maintenance. Sigfox enables IoT communication over long distances making it possible to transmit with minimal base stations. The Sigfox network uses a cellular style approach to enable the remote nodes to use the internet to communicate with base stations. This facilitates remote control and data collection from the Sigfox nodes over a wide geographical area if there is internet connectivity.

Ready-made Sigfox-enabled sensors available for various applications, including monitoring carbon emissions:

Daviteq Sigfox-Ready Sensors

Wireless Sensors (daviteq.com)

Daviteq offers a range of IoT sensors designed to operate over the **Sigfox** network, which is based on **0G technology**. These sensors are engineered for various environmental monitoring applications, including air quality, temperature, humidity, and more. The combination of low power consumption, long-range communication, and easy integration makes Daviteq Sigfox-ready sensors suitable for many industries, including logistics, agriculture, and urban planning.

Here are some specific examples of Sigfox-enabled sensors that can be used to monitor carbon emissions:

1. **Daviteq Sigfox-Ready CO_2 Sensor**

Features:

- **Ultra-Low Power**: Designed to operate for up to 10 years on a single battery.

- **High Accuracy**: Measures CO_2 levels with high precision, suitable for both indoor and outdoor environments.
- **Durability**: IP67-rated housing ensures protection against dust and water.

Application:

- **Industrial Monitoring**: Used in factories and plants to monitor CO_2 emissions from various processes.
- **Environmental Monitoring**: Deployed in urban areas to track air quality and CO_2 levels.

2. **Sigfox-Ready Gas Sensor for General Industries**

Features:

- **Multi-Gas Detection**: Capable of detecting CO_2, NH_3, Cl_2, and H_2S.
- **Long Battery Life**: Operates for more than 5 years with a single size-D battery.
- **Robust Design**: IP66-rated polycarbonate housing for harsh industrial environments.

Application:

- **Air Quality Monitoring**: Used in facilities to ensure safe working conditions by monitoring harmful gas levels.
- **Emission Tracking**: Helps in tracking emissions from industrial processes to comply with environmental regulations.

3. **Sigfox-Ready AC Current Sensor (WSSFC-AC)**

Features:

- **Energy Monitoring**: Measures AC current to monitor energy consumption, indirectly helping to track carbon emissions.
- **High Precision**: Provides accurate readings of current flow, aiding in energy efficiency improvements.
- **Long Battery Life**: Designed to last up to 10 years.

How They Work

1. **Installation**: Sensors are installed at emission sources such as vehicles, machinery, or facilities.
2. **Data Transmission**: Sensors transmit data over the Sigfox network, ensuring low power consumption and wide coverage.
3. **Data Analysis**: Collected data is analyzed to provide insights into emission levels and identify areas for improvement.

4. **Actionable Insights**: Based on the analysis, companies can implement strategies to reduce emissions, such as optimizing routes for vehicles or improving energy efficiency in facilities.

These sensors provide a comprehensive solution for monitoring and managing carbon emissions, leveraging the benefits of Sigfox's 0G technology.

Here are some companies that use Daviteq Sigfox-ready sensors and methods for monitoring and managing carbon emissions:

1. **Shell**: Utilizes Daviteq sensors to monitor emissions from their oil and gas operations, ensuring compliance with environmental regulations and optimizing processes to reduce emissions.
2. **BASF**: This chemical company uses Daviteq sensors to track emissions from3 their production processes, helping to maintain safe working conditions and reduce environmental impact.
3. **Nestlé**: In the food and beverage industry, Nestlé employs Daviteq sensors to monitor air quality and CO_2 levels in their production and storage areas, ensuring product quality and worker safety.
4. **Siemens**: Uses Daviteq sensors in their smart city projects to monitor air quality and emissions, helping to develop strategies for improving urban air quality and reducing the overall carbon footprint.
5. **DHL**: In the logistics sector, DHL uses Daviteq sensors to monitor emissions from their fleet of vehicles, optimizing routes and improving fuel efficiency to reduce their carbon footprint.

These companies leverage the advanced capabilities of Daviteq Sigfox-ready sensors to enhance their environmental monitoring and sustainability efforts.

Sensors : [Wireless Sensors (daviteq.com)]

Collecting data on carbon emissions from suppliers Scope 2 and Scope 3 emissions tracking.

(Integration of Blockchain Technology & IoT Devices for Carbon Emission Tracking and Carbon Credits)

1. Blockchain & Smart Contract Integration

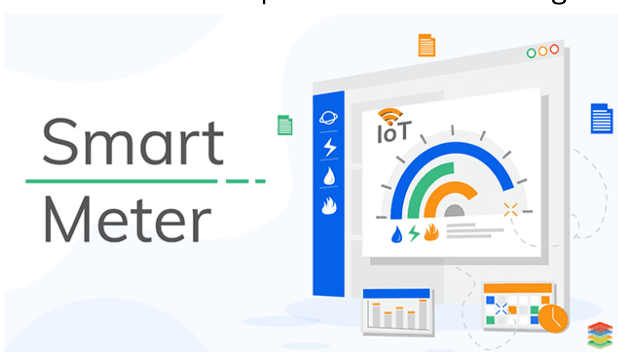
- Use **blockchain smart contracts** to automate emission data capture and validation:
    - Suppliers submit emission data to the blockchain ledger.
    - TVS verifies it against agreed benchmarks and **VERRA standards**.
    - If emissions stay within targets, TVS can reward suppliers with **carbon credits or incentives**.

2. IoT Devices & Smart Meters at Supplier Sites

- Deploy **IoT sensors or smart meters** at supplier facilities to monitor:
    - **Electricity and fuel consumption** in real-time.
    - Emissions from **specific processes** like welding, painting, and machining.

How it Works:

- IoT devices transmit real-time data to TVS's **blockchain** system for emissions tracking.
- **Dashboards and alerts** provide real-time insights into supplier emissions.

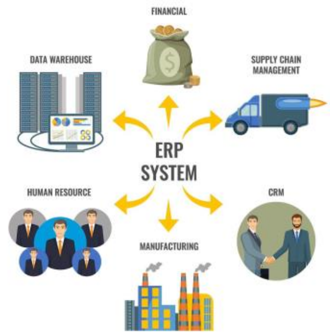


3. Integration with Supplier Systems (ERP Data Sync)

- Ask suppliers to share data from their **ERP (Enterprise Resource Planning) systems**.
    - **Electricity bills** and fuel consumption for operations.
    - **Logistics and transportation data** for shipments to TVS manufacturing units.

How to Implement:

    - Build **APIs** to sync data automatically with TVS's **blockchain-based carbon tracking system**.
    - Use **smart contracts** to validate and reward timely reporting from suppliers.



4. Emission Data from Transporters (Scope 3)

- Collaborate with transport companies to capture **fleet emissions** during delivery.
    - Use **GPRS trackers** and **fuel sensors** to monitor vehicles in real time.
    - Implement **telematics systems** to track routes, fuel usage, and emissions.

Traditional Methods for Carbon Emission Tracking

1. Supplier Data Collection via Surveys and Audits – Data collection forms – DCF's

- TVS can send **standardized questionnaires** or **self-assessment templates** to suppliers, asking for (**Emission Reporting Surveys)**:

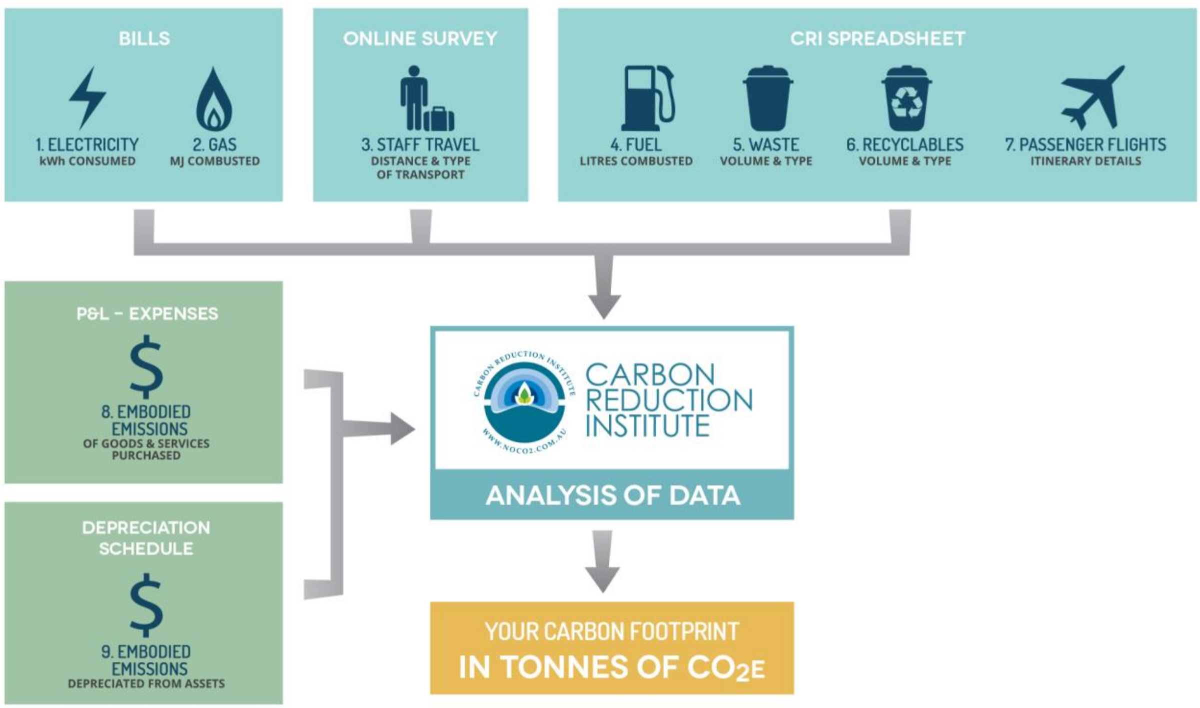
- Energy consumption (electricity, fuel usage)
- Emissions factors (kg CO_2 per kWh, etc.)
- Annual carbon footprint data (if available)

Tools:

- CDP (Carbon Disclosure Project) questionnaires
- GHG Protocol Supplier Engagement tools

- **Audits:**

  In cases where direct data isn't available, conduct **on-site audits** or **third-party audits** to verify energy use and emissions.



2. GHG Protocol & Emission Factor Databases

- If direct data isn't available, estimate supplier emissions using the **GHG Protocol's Scope 3 Calculation Guidelines**:
  - Multiply **input materials (e.g., steel, rubber)** with **industry-specific emission factors** from:
    - **EPA Emissions Factors Hub**
    - **Eco invent Database**

Example:
If a supplier uses 100 tons of steel with an emission factor of 1.85 kg CO_2 per kg, the emissions will be 185 tons of CO_2.

5. CDP Supply Chain Program Participation

- Encourage key suppliers to participate in **CDP's Supply Chain Program**.
  - CDP collects emissions and environmental data from companies worldwide.
  - TVS can use **supplier reports from CDP** to track emissions accurately.

6. Certifications and Reporting Standards

- Require suppliers to obtain **certifications** (e.g., ISO 14001 for environmental management).
  - Certified suppliers must maintain and report emissions data annually.
  - TVS can integrate this data into **internal sustainability reports**.

7. Supplier Agreements & Incentives

- TVS can include **emission reporting clauses** in supplier contracts, ensuring compliance.
  - Offer **incentives** (discounts, bonuses, or partnerships) to suppliers who share detailed emissions data or reduce their carbon footprint.

8. Benchmarking & Estimation Using Industry Averages

- For smaller suppliers without detailed reports, **estimate emissions** using industry benchmarks.
  - Example: Assume **X kg CO_2 per ton** of a specific material, based on average emission factors in the industry.

References

Using Blockchain for Scope 3 Carbon Emission Tracking | LinkedIn
With emissions reporting in disarray, blockchain provides a path forward from COP26 - Ledger Insights - blockchain for enterprise
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Digitalised Carbon Credits | LinkedIn

Automated Carbon Credit Platform | LinkedIn

How 0G Technology is Used to Capture Carbon Emissions from Suppliers

0G technology refers to a **low-power, wide-area network (LPWAN)** designed for IoT devices that transmit small amounts of data over long distances.

This network is ideal for **remote monitoring of carbon emissions** from suppliers.

Sigfox and **LoRaWAN** support 0G networks, enabling seamless, lightweight data communication.

1. Deployment of Sensors in Supplier Facilities

- **IoT sensors and smart meters** are installed at supplier locations to monitor:
  - **Energy consumption:** Electricity, gas, or fuel usage.
  - **Carbon emissions from industrial processes:** Such as welding, painting, or machining operations.
  - **Air quality and pollutants:** Tracking CO_2, NOx, SO_2, or particulate matter levels.

A. Key Locations for Sensor Deployment

1. **Manufacturing Floor & Production Units:**
   a. **Emission-heavy processes** like:
      i. Welding, painting, machining, casting.
      ii. Boilers, furnaces, and generators.
   b. Sensors to use:
      i. **CO_2, NOx, and SO_2 sensors**
      ii. **PM2.5/PM10 sensors**
      iii. **Flow meters:** Track fuel flow and consumption of diesel, natural gas, or other fuels.
   c. **Energy Generation Units:**
      i. **Smart meters** to monitor electricity consumption and energy generated from renewable sources.
      ii. **Fuel consumption meters** installed on boilers and power units for tracking fossil fuel usage.

2. **Storage and Warehouse Areas:**
    a. **Temperature and energy sensors** help monitor the carbon footprint
3. **Transportation and Loading Docks:**
    a. Monitor emissions from trucks and vehicles **entering/exiting supplier facilities.**
        i. **Telematics and GPS tracking systems** collect data on fuel consumption and emissions from fleets.
        ii. **GPRS-enabled sensors** installed on loading docks to track logistics emissions.

B. Sensor Types for Specific Use Cases

Sensor Type	**Purpose**
CO_2 Sensors	Measure carbon dioxide levels from combustion processes.
NOx and SO_2 Sensors	Monitor nitrogen and sulfur oxides emitted during operations.
Smart Meters	Track energy consumption (electricity, gas, etc.) in real-time.
Flow Meters	Monitor fuel or steam usage in industrial processes.
PM2.5/PM10 Sensors	Measure particulate matter levels (dust, smoke, etc.).
GPS & Telematics Devices	Track vehicle emissions and fuel usage during transportation.
Temperature & Humidity Sensors	Ensure optimal energy use in temperature-controlled spaces.

2. Integration with Blockchain for Carbon Tracking

- **Emission data from 0G devices** feeds directly into the **blockchain-based ledger** for:
    - **Verification** through smart contracts.
    - **Automated rewards** (carbon credits) if emissions meet targets.

A. Steps to Integrate Blockchain for Carbon Tracking

1. **Set up a Blockchain Ledger for Emission Data:**

    a. Create a **private blockchain** where all supplier emissions data will be stored.
    b. Suppliers and TVS become **nodes** in the network, meaning they have access to the shared ledger for transparent tracking.
2. **Use IoT Devices to Feed Data into the Blockchain:**
    a. IoT devices deployed at supplier facilities send **emission and energy consumption data** directly to the blockchain in **real-time**.
    b. This data is logged securely with **timestamps and digital signatures** to ensure authenticity.
3. **Smart Contracts for Emission Validation:**
    a. **Smart contracts** are deployed on the blockchain to automatically **validate and process the emissions data**.
    b. Example logic:
        i. If a supplier's emissions for the month stay below a predefined threshold, **carbon credits are issued** automatically.
        ii. If emissions exceed the threshold, the smart contract can **flag a non-compliance alert** and suggest corrective action.
4. **Emission Data Auditing and Verification:**
    a. TVS can **verify emissions** data against external standards (e.g., **VERRA Gold** or **GHG Protocol**).
    b. All transactions are immutable, meaning no data can be tampered with, ensuring **data integrity.**
5. **Carbon Credit Issuance and Management:**
    a. When suppliers maintain low emissions or use **renewable energy sources**, TVS can reward them with **carbon credits.**
    b. These carbon credits are tokenized as **NFTs (Non-Fungible Tokens)** on the blockchain.

3. Supply Chain Transport Monitoring via 0G

- **Telematics devices** with 0G modules are attached to **trucks and fleets** that transport parts to TVS manufacturing units.
    - These devices monitor fuel consumption, engine emissions, and vehicle routes.
    - Data is transmitted in real-time or at regular intervals to ensure the **carbon footprint of logistics** is accurately captured.
      Ex: GPS devices, Vehicle tracking systems, Fleet management systems

- **Why 0G Helps Here:**
    - 0G technology **does not require continuous internet connectivity**. It sends periodic updates reliably over long distances, even from locations with **poor cellular coverage.**
    - Since 0G focuses on **small, infrequent transmissions,** it minimizes communication costs.
    - Many suppliers may operate in **remote or rural areas** where traditional internet connectivity is poor.
    - 0G devices consume very little power, allowing them to run on small batteries for years, making them ideal for **remote, unmanned facilities.**
    - It ensures **cost-efficient tracking** across a fleet of vehicles, especially for **long-haul or rural routes** where conventional cellular networks may not work.

Architecture for Emission Monitoring

1. **Data Collection Layer**
    a. Sensors and IoT devices installed on vehicles (inbound, outbound, and post-delivery) collect emission, fuel, and route data.
2. **Transmission Layer**

   a. **0G Network** (Sigfox/LoRaWAN) for real-time data transmission, ensuring **reliable performance in remote areas**.
   b. GPS/GPRS used where available, with 0G as fallback.
3. **Data Aggregation Layer**
   a. Central **cloud platform** aggregates data from sensors for analytics and monitoring.
   b. Real-time **alerts** triggered for emission threshold breaches or route deviations.

Carbon Emission Benchmarks for Different Fleet Types

Fleet Type	Average CO_2 Emission (kg/km)	Average Carbon Credits per km	Use Case

Light-duty Trucks / Pickups	0.25 – 0.30	0.00025 – 0.00030	Short-distance delivery of small parts or materials.
Medium-duty Trucks	0.70 – 1.00	0.00070 – 0.00100	Moving medium-sized parts over mid-range distances.
Heavy-duty Trucks / Trailers	1.50 – 2.00	0.00150 – 0.00200	Transporting heavy machinery, engines, or bulk parts.
Reefer Trucks (Cold Chain)	1.80 – 2.20	0.00180 – 0.00220	Cold chain transportation for batteries or sensitive parts.
Cargo Trains (Rail Freight)	0.015 – 0.030 per ton-km	0.000015 – 0.000030	Long-distance movement of bulk materials or finished vehicles.
Air Freight (Cargo Planes)	500 – 600 per ton-km	0.50 – 0.60	High-value, time-sensitive parts transported internationally.
Car Carrier Trailers	2.20 – 2.50	0.00220 – 0.00250	Transporting vehicles to dealers and warehouses.
Last-Mile Delivery Vehicles	0.20 – 0.40	0.00020 – 0.00040	Delivering vehicles or parts in small batches to nearby dealerships.
Ro-Ro Ships (Maritime Freight)	15 – 20 per vehicle-km	0.015 – 0.020	Exporting vehicles to overseas markets.

Carbon Credit Conversion:

- **1 carbon credit** = 1 ton of CO_2 reduction = **1000 kg CO_2**.

  (1 ton = 1000 kg of CO_2.)

- Carbon Credits (CC)=Total CO_2 Emission (kg) / 1000

How can we determine the portion of carbon emissions accountable to TVS for fleet transportation carrying parts from multiple suppliers?

Logic for Allocating Percentage of Carbon Emissions:

1. Identify the Total CO_2 Emissions for the Trip
   Formula: OBJOBJOBJ
   a. Determine the Contribution of Each Supplier or TVS
      Weight/Volume-Based Allocation

Formula to Calculate TVS's Share of Emissions:

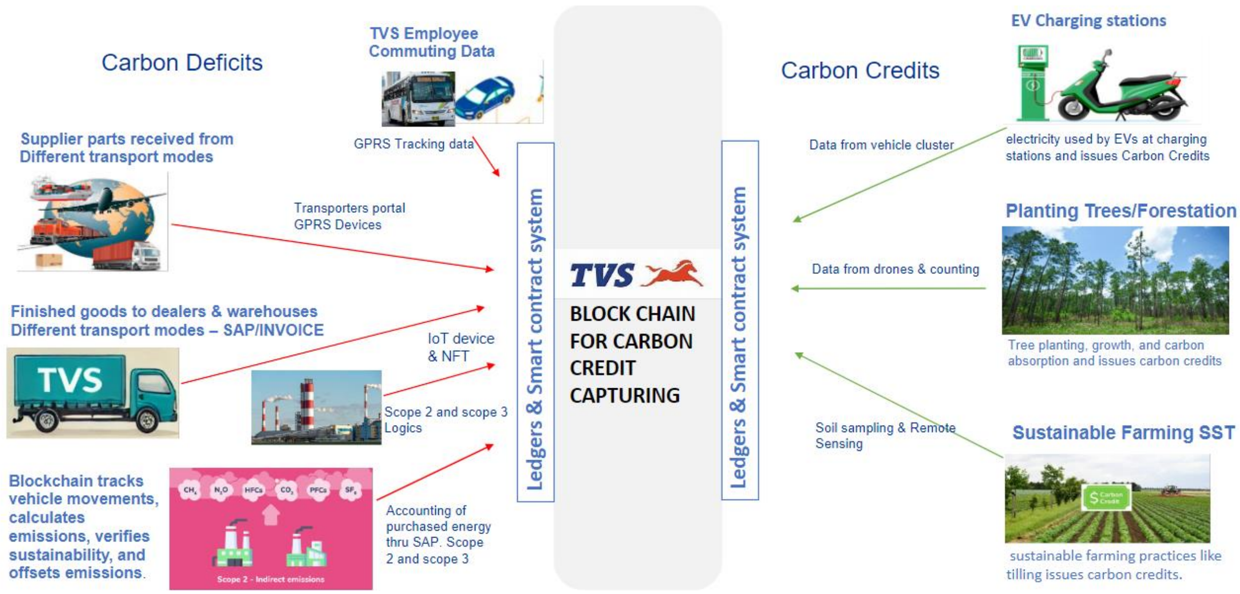
$$\text{TVS CO}_2\text{ Share (kg)} = \text{Total CO}_2\text{ Emissions} \times \left(\frac{\text{Weight/Volume of TVS Cargo}}{\text{Total Weight/Volume of Cargo}}\right)$$

SCOPE 1,2&3 CARBON EMISSION

	Scope 1	Scope 2	Scope 3

Definition	Direct emissions owned or controlled by the company.	Emissions from the energy purchased by the company.	Indirect emissions from other activities related to the company, such as supply chain, product lifecycle, and disposal.
Phase of Production Cycle	During Production	Upstream	Both upstream and downstream.
Activities	**1.Stationary combustion** Emissions from on-site fuel combustion for power. **2.Mobile combustion** Fuel consumption from TVSM-owned trucks and vehicles. **3.Process emissions** Emissions during metal forging or painting and other operations **4.Fugitive emissions** Refrigerant leaks from air conditioning units and other cooling systems in factories	**1.Purchased electricity** Energy used to run manufacturing lines, etc. **2.Purchased Steam** Steam used in heating and manufacturing processes.	**1.Employee Commuting** Emissions from business travel (flights, company-provided vehicles). **2.Upstream transportation** Transportation of raw materials from suppliers to TVSM plants. **3.Downstream transportation** Distribution of finished vehicles to dealerships. **4.Waste disposal** **5.Product use** Emissions from the use of TVSM vehicles by customers (fuel combustion in vehicles). **6.End-of-life treatment**: Emissions from disposal or recycling of vehicles.
Data Capturing methods	**1.Automated fuel tracking**: Using IoT sensors on fuel storage and consumption systems. **2.Emission monitoring systems**:	**1.Smart meters**: IoT-enabled meters measure energy consumption. **2.Utility invoices**: Automated capture of energy bills.	**1.Supply chain tracking**: Using blockchain to capture data on transportation methods **2.Usage tracking**: Data from telematics in vehicles.

	Continuous monitoring devices measuring emissions. **3.Refrigerant tracking**: Sensors that log refrigerant levels and detect leaks in real-time.		
Blockchain Role	**1.Secure fuel data**: Blockchain securely records data from fuel logs and production meters. **2.Emission compliance**: Real-time data on emissions enables transparent reporting and regulatory compliance.	**1.Energy consumption tracking**: Blockchain can log electricity consumption and for verification.	**1.Supply chain traceability**: Blockchain provides transparency by tracking emissions through the supply chain. **2.Lifecycle data tracking**: Blockchain records vehicle usage and emissions throughout the product's lifecycle, ensuring accurate end-to-end carbon footprint.
Reduction Measures	**1.Cleaner fuels**: Transition to natural gas or electric alternatives for on-site machinery and vehicles. **2.Efficiency upgrades**: Optimize manufacturing processes for lower emissions. **3.Carbon capture**: Install carbon capture technology for process emissions.	**1.Renewable energy**: Transition to solar or wind energy for manufacturing facilities. **2.Energy-efficient technology**: Install energy-saving devices and upgrade machinery.	**1.Logistics optimization**: Work with suppliers to use eco-friendly shipping methods. **2.Vehicle efficiency**: Design more fuel-efficient models and encourage eco-friendly driving among customers.



Carbon Deficits
TVS Employee Commuting Data
GPRS Tracking data
Supplier parts received from Different transport modes
Transporters portal GPRS Devices
Finished goods to dealers & warehouses Different transport modes – SAP/INVOICE
TVS
IoT device & NFT
Scope 2 and scope 3 Logics
Blockchain tracks vehicle movements, calculates emissions, verifies sustainability, and offsets emissions.
Scope 2 - Indirect emissions
Accounting of purchased energy thru SAP. Scope 2 and scope 3
Ledgers & Smart contract system
TVS
BLOCK CHAIN FOR CARBON CREDIT CAPTURING
Ledgers & Smart contract system
Carbon Credits
EV Charging stations
Data from vehicle cluster
electricity used by EVs at charging stations and issues Carbon Credits
Planting Trees/Forestation
Data from drones & counting
Tree planting, growth, and carbon absorption and issues carbon credits
Soil sampling & Remote Sensing
Sustainable Farming SST
Carbon Credit
sustainable farming practices like tilling issues carbon credits.

Supply Chain Carbon Emission Monitoring

via 0G Technology for TVS

Objective:

To fulfill the regulatory requirement of declaring carbon of sold vehicles TVSM is exploring different cost-effective solutions & 0G Technology is one of them.

2. Utilize 0G technology to monitor and track carbon emissions across TVS's supply chain, covering inbound and outbound logistics, as well as emissions tracking after delivery to customers.

Use Cases of 0G Technology in the TVS Supply Chain

1. **Inbound Logistics**

   Track suppliers' vehicles delivering parts to TVS and collecting raw materials from their suppliers.

2. **Outbound Logistics**

   Monitor TVS vehicles responsible for delivering manufactured vehicles to warehouses and dealers worldwide.

3. **Post-Delivery Monitoring**

   Track emissions from TVS vehicles after delivery to customers or dealers for lifecycle emission monitoring.

Possible Devices & Sensors Planned

1. **CO_2 Emission Sensors**: Track carbon emissions from vehicle exhaust.
2. **Fuel Consumption Meters**: Monitor fuel usage and calculate vehicle efficiency.
3. **GPS/GPRS Trackers**: Capture routes, idle times, and delivery milestones.

4. **Onboard IoT Devices**: Installed in post-delivery vehicles to monitor emissions and driving behavior.

0G Network Modules

- **Sigfox/LoRaWAN Transmitters**: Integrated into sensors for **low-power, long-range** data transmission.
- **Intermittent Transmission**: Emission and GPS data sent periodically (e.g., every hour or trip completion) to conserve battery.
- **0G Fallback**: Ensures data capture in **remote areas** or when cellular networks (GPS/GPRS) are unavailable.

Initial Survey of 0G Technology for Implementation

- **Network Suitability**: Ideal for **low-bandwidth, intermittent data** such as emissions and route tracking.
- **Coverage**: 0G networks like Sigfox offer **global coverage**, ensuring connectivity even in remote regions.
- **Power Efficiency**: Sensors with **0G modules have multi-year battery life**, reducing maintenance.
- **Cost-Effective**: Lower operational costs compared to cellular networks, making it viable for large-scale logistics.

Applications Achieved via 0G Technology

1. Continuous Emission Tracking across Supply Chain Phases
2. Reliable Data Transmission in Remote Areas
3. Energy-efficient Operations