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Green and Sustainable Payment Systems for Advancing U.S. Climate Goals

Prakash Raju Kantheti[1], **Prof. Stella Bvuma**[2]
[1]Independent Researcher, USA
[2] School of Consumer Intelligence and Information Systems, University of Johannesburg, Johannesburg, South Africa
https://orcid.org/0000-0001-8351-5269

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ABSTRACT

In every industry, including finance, new solutions are required due to the rapid rate of climate change. Sustainable and eco-friendly payment methods have become vital tools for tying economic activity to green objectives. The potential of sustainable financial infrastructures to reduce carbon footprints, incentivise environmentally conscious consumer behaviour, and ease the shift to a low-carbon economy is highlighted in this article's investigation of their role in advancing US climate objectives. Green infrastructure's ability to mitigate the anticipated rise in excessive precipitation or warmth is usually linked to its benefits for climate adaptation. Benefits include reducing the incidence of combined storm and sewer overflows (CSOs), improving storm-water runoff management, conserving water, preventing flooding, accommodating natural hazards (such as moving out of floodplains), lowering ambient temperatures and the effects of urban heat islands (UHIs), and protecting against sea level rise (with the possibility of storm-surge protection measures). Additionally, according to the U.S. Environmental Protection Agency (EPA), green infrastructure can improve air quality and human health, reduce energy consumption, save capital costs, increase carbon storage, increase recreational space and wildlife habitat, and even raise land values by as much as 30%. Important developments include energy-efficient digital currencies, more effective blockchain technology, and carbon offset systems that emphasise accountability and transparency. These systems may operate as catalysts for environmental advancement by incorporating sustainability measures into financial transactions, increasing the efficiency of payment processing, and integrating renewable energy sources. In order to ensure that payment systems become a key component in attaining a sustainable future, the report ends with policy proposals to encourage adoption, including as regulatory frameworks, public-private collaborations, and consumer awareness campaigns.

Keywords :- Green and Sustainable Payment Systems, Public-Private Partnerships, Driving Force, Sustainable Future, U.S. Climate, Energy Sources, Energy Consumption, Consumer Behaviours.

I. INTRODUCTION

Two of the most important international initiatives for resolving the conflict between environmental stewardship and economic growth are the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) and the Sustainable Development Goals (SDGs) in the 2030 Agenda for Sustainable Development of the United Nations Development Programme (UNDP). While the latter calls for limiting the rise in global temperatures in the twenty-first century to 2° C (above pre-industrial levels) and funding low-carbon, [2] climate-resilient global development, the former seeks to end poverty and hunger, advance peace, justice, and human rights, and achieve environmentally friendly, [1] sustainable economic growth and universal prosperity (United Nations Framework Convention on Climate Change UNFCCC (2015a)). The climate-focused pledges in the Nationally Determined Contributions (NDCs) to the Paris Agreement are in line with the Sustainable Development Goals (SDGs) pertaining to infrastructure and industrialisation (SDG 9), access to next-generation energy (SDG 7), clean water and sanitisation (SDG 6), and other objectives [1, 3]. However, both models need significant financial outlays. For example, the U.N. The International Energy Agency projects that $53 trillion in energy-related investments will be needed by 2035 to maintain the 2°C temperature threshold of the Paris Agreement, while the Commission on Trade and Development estimates that $5 to $7 trillion in annual investments will be needed to meet the SDGs through 2030 (United Nations Conference on Trade and Development UNCTAD 2014) [4, 5]. As a result, the global society is under pressure to raise significant sums of money from both public and private sources in order to advance ambitious environmental goals.

Another significant environmental funding tool is the Green Climate Fund (GCF). Similar to the UNFCCC, it was created in 2010 as a more direct way to provide funding—mostly in the form of grants and loans—to poor nations' efforts to reduce greenhouse gas emissions and adapt to climate change. 40 participating nations have contributed $4.6 billion to 93 green projects since the initiative's founding [2, 4], with an additional $1.8 billion available for execution and an additional $10.3 billion in financial commitments to follow. According to the Green Climate Fund GCF (2018), the GCF is already funding green projects that are predicted to cut global CO2 emissions by 1.4 billion tonnes [2, 3]. The GCF is also expected to play a significant role in funding the Paris Agreement and other green policy outcomes in the developing world.

II. HIGH COMPUTE USAGE IN THE CURRENT PAYMENT SYSTEMS AND THE DIFFERENT STACKS ACROSS THE CURRENT SYSTEM

Concern about high computational utilisation in payment systems is developing both domestically and internationally as a result of the rise in digital transactions, security demands, and the complexity of financial technology stacks [2, 3]. An examination of the current stacks impacting the U.S. payment ecosystem and the variables causing excessive compute utilisation can be seen below:

1. **High Compute Usage in Payment Systems**

- **Transaction Volume and Real-Time Processing:** Low-latency processing is necessary for the growing usage of real-time payment systems (such as RTP by The Clearing House) [2, 3], which raises computational demands. Computational overhead is further increased by real-time fraud detection and reconciliation during transactions.

- **Fraud Prevention and Security:** Computational resources are used by advanced encryption protocols (such as TLS 1.3 and end-to-end encryption) and tokenisation. Continuous real-time data processing is necessary for AI/ML models for risk assessment and fraud detection [3, 4].
- **Data Analytics and Personalization:** Systems employ compute-intensive big data frameworks to assess user behaviour and provide tailored offers and recommendations.
- **Compliance and Regulations:** Maintaining extensive audit logs, encryption, and secure data storage are all necessary to comply with standards such as PCI DSS, GDPR, and AML rules [5]. Extensive data aggregation and processing are necessary for regulatory reporting.
- **Blockchain and Distributed Ledger Technology (DLT):** The proof-of-work (PoW) or proof-of-stake (PoS) protocols used by cryptocurrencies and decentralised finance (DeFi) systems are computationally demanding.

2. Technology Stacks Across U.S. Payment Systems

Front-End Layers:

Mobile and Web Applications:

- **Frameworks:** Swift, Flutter, Angular, and React on iOS [2, 3]. Connected to payment gateway APIs such as Square, PayPal, and Stripe.

Middleware and APIs:

- **Integration Layers:** Front-end interfaces and backend services can be connected using GraphQL, gRPC, and RESTful APIs [3, 4]. Mulesoft and Apache Camel are two examples of middleware technologies that facilitate system interconnection.

Back-End Systems:

- **Processing Engines:** Core financial systems such as Jack Henry, Fiserv, and FIS. platforms for real-time payments (like FedNow and Zelle) [5]. Event-based systems driven by RabbitMQ or Kafka.

Database Management:

- **Relational Databases:** Oracle, MySQL, and PostgreSQL.
- **NoSQL Databases:** Cassandra, DynamoDB, and MongoDB for high-volume, low-latency requirements.
- **AI/ML and Data Analytics:** AI frameworks: Torch, Py [5, 6], and TensorFlow. Big Data Ecosystems: Spark and Hadoop.
- **Fraud Detection:** cloud-native products from Google Cloud, Azure, or AWS (like Amazon Fraud Detector).

Security:

- **Encryption Libraries:** Bouncy Castle, OpenSSL [5, 6]. OpenID Connect and OAuth 2.0 are used for identity verification. WAFs and firewalls: Cloudflare, Palo Alto.
- **Blockchain Systems:** For decentralised payments, Ethereum, [5], Bitcoin; for enterprise-grade use cases, Hyperledger and R3 Corda.

3. Climate of Payment Systems in the U.S.

- **Dominance of Digital Wallets:** The widespread use of services like PayPal, Google Pay, and Apple Pay has increased the demand for powerful computing power in cloud environments.
- **Shift to Real-Time Payments (RTP):** The goal of the U.S. Federal Reserve's Fed Now initiative is to enhance and modernise instant payment capabilities [5, 6].
- **Fintech and Embedded Finance:** Financial services are directly integrated into non-financial platforms by start-ups and established players, creating diversified but dispersed stacks.
- **Cloud-First Architecture:** Significant dependence on cloud service providers for processing and scalability, such as AWS, Azure, and GCP [5].
- **Decentralized Finance Growth:** Growing interest in blockchain-based solutions and cryptocurrencies for cost-effectiveness and transparency [3].
- **Energy Concerns:** Concerns about carbon emissions from high-processor systems force

businesses to embrace green computing techniques.

III. COMPUTE INTENSIVE APPLICATIONS CAUSE NEGATIVE IMPACT ON THE ENVIRONMENT

Particularly when implemented at scale, compute-intensive applications can have a significant negative influence on the environment [3, 4]. These programs frequently use a lot of computing power, which raises energy consumption. This is how it relates to environmental and climate issues in the United States:

3.1 Environmental Impacts of Compute-Intensive Applications

- **Energy Consumption:** Large data centres need a lot of electricity to do compute-intensive operations like data processing, simulations, and machine learning. In some parts of the United States, this demand frequently originates from non-renewable sources [3, 6], which raises carbon emissions.
- **Carbon Emissions:** The production of power from fossil fuels adds to greenhouse gas emissions. Many compute-intensive applications still rely on carbon-intensive electricity infrastructures despite the move towards renewable energy.
- **E-Waste:** Rapid improvements cause the technology utilised for these applications, such as servers and GPUs, to become outdated very quickly [6, 7]. This leads to problems with e-waste because electronic component recycling rates are still low.
- **Water Usage:** Data centres need cooling systems, and a lot of them use water-based techniques [5, 8]. Water resources may be strained by this, particularly in regions of the United States that are prone to drought [6, 7].
- **Land Use and Ecosystem Disruption:** Local ecosystems may be disturbed by changes in land use brought about by the installation of data centres and related infrastructure [3, 4].

3.2 Addressing the Issue in the U.S. Context

As part of larger climate aims, the United States has been working to lessen these effects:

- **Renewable Energy Integration:** States like Texas and California are becoming more dependent on solar and wind energy. Data centres may lessen their carbon impact by being encouraged to run on green energy.
- **Efficiency Standards:** Energy efficiency guidelines for IT infrastructure, including the ENERGY STAR program, are promoted by agencies like the EPA and DOE [3, 6].
- **Carbon Offsetting Initiatives:** Energy efficiency guidelines for IT infrastructure, including the ENERGY STAR program, are promoted by agencies like the EPA and DOE [3, 6].
- **Policy and Regulation:** To assist integrate compute-related operations with climate objectives, the U.S. government funds sustainable technology innovation and supports programs like the Clean Energy Standard [3, 6].
- **Public-Private Partnerships:** Governments and tech businesses work together to develop greener technologies like AI optimisation for energy efficiency and low-energy computing [6, 5].

3.3 Sustainable Practices for Compute-Intensive Applications

- **AI and Algorithm Optimization:** Without compromising performance, increasing computational efficiency lowers resource use [6, 7].
- **Edge Computing:** Central servers use less energy when data is processed closer to the source.
- **Recycling and Circular Economy:** Advocating the usage of reconditioned equipment and supporting hardware recycling initiatives to reduce e-waste [3, 6].
- **Advancing Cooling Technologies:** Developing cutting-edge liquid and immersion cooling technologies to save water and energy.
- **Policy Advocacy:** Endorsing laws that encourage data centres to adopt renewable energy sources and disclose their carbon emissions [1, 6].

These initiatives seek to lessen the environmental impact of compute-intensive applications while promoting technical advancement, in tandem with a national emphasis on the clean energy transition [3, 6].

Therefore, in order to achieve a comprehensive development model, the diverse organisations that include the manufacturing and service sectors must be instrumental in resolving the continuing climate issue [5, 9]. According to these holistic development models, all sectors must adhere to environmental protection regulations and prioritise environmental reasons in order to restore biocapacity excess [8, 9]. The structural dynamics, industrial growth, manufacturing methods, technical innovation, shock absorption, and risk management capabilities of different regions, however, differ greatly [8, 9]. There isn't a "one size fits all" approach to addressing environmental degradation in this situation. In this context, implementing a green growth model based on green innovation principles can be beneficial [8, 9], solely to achieve sustainable development without sacrificing the benefits to the economy, society, and environment—the holistic development in the age of ecologically civilised society [8, 10].

Furthermore, another aspect of the connection between GF and creativity has been shown by study. In particular, GF reform has been shown to have a favourable impact on corporate green innovation, as explained in [9, 10]. Financial limitations are lessened by such changes, which in turn encourage the development of green inventions and green utility models [9, 11]. This implies that GF's availability and presence may serve as a strong inducement for businesses to fund and develop green innovation projects, therefore promoting a more sustainable future. The 2008 financial crisis [12], which brought down the global financial system and caused a protracted recession in the world economy, made the function of the financial markets even more clear. According to studies on the 2008 financial crisis, the absence of rules in the financial systems contributed significantly to the unplanned unrest [12], making the world economy sluggish for an unprecedented amount of time [13].

However, by creating a wide backup window, the financial crisis helped lessen the negative effects and cleared the way for the development of sophisticated financial models with greater shock absorption capacity in the global financial system [13]. By diversifying resource management systems and establishing the capital markets as a separate area within the mainstream financial system, the idea of financial market innovation to protect financial resources developed based on the concept of financial resource management [14]. Fintech, or advanced financial technologies, are necessary for asset class diversification, portfolio management, and financial resource management at the macro (i.e., national production and consumption accounts) and micro (i.e., firm-level) levels. Furthermore, the characteristics, risk-absorbing capabilities, and hedging support of various financial assets all play a significant role in capital market stabilisation. According to recent studies on the green economy, renewable energy development, and fintech [11,12], green bonds may provide superior hedging support when compared to other traditional assets, particularly in times of pandemic and conflict [2].

It is clear that cities all around the globe have seen improvements in the natural environment, with notable decreases in pollution in a number of environmental areas, including the air, water, and soil [2, 6]. Reduced traffic, particularly in large cities under lockdown, has been linked to declining levels of air pollution concentrations, according to the European Environmental Agency (EAA) [6, 8]. In a similar vein, Sharma et al. (2020) found that lockdowns brought on by COVID-19 enhanced air quality in a number of cities worldwide by lowering particulate matter, carbon monoxide, and nitrous oxide emissions. The duration of the lockdowns seemed to have an impact on the magnitude of recorded transient planetary benefits at the municipal level. Two weeks after the lockdown was announced on March 23rd, for example, some UK cities saw a 60% decrease in nitrogen dioxide (NO2) pollution compared to the same period in 2019, and New Delhi, India, the most polluted capital in the world, saw a 60% decrease in fine particulate matter, which the WHO considers to be the deadliest air pollutant. Relatedly, at the height of the COVID-19 epidemic, China's carbon emissions fell by 25% [9, 10].

IV. IMPORTANCE OF SUSTAINABLE AND GREEN PAYMENT SYSTEMS HELPS WITH U.S CLIMATE TARGETS

By supporting eco-friendly financial practices, lowering carbon emissions, and fostering sustainable behaviours, sustainable and green payment systems are essential to the United States' efforts to meet its climate goals [9, 10]. This is how they help:

1. Reducing Carbon Footprint in Financial Operations

Particularly for transactions using paper, traditional payment methods depend on energy-intensive procedures [11]. Making the switch to green and digital payment methods lessens the effect on the environment by:

- **Minimizing paper use:** By doing away with traditional checks, invoices, and receipts, digital payments cut down on waste and deforestation [12].
- **Energy-efficient operations:** Energy-efficient data centres and renewable energy sources may be included into modern payment systems [13].

2. Supporting Renewable Energy and Sustainable Investments

Platforms that support low-carbon and renewable energy initiatives are often integrated with green payment systems. Among the examples are:

- Providing discounts or incentives to encourage the use of public transport and electric cars (EVs) [14, 15].
- Allocating transaction fees to renewable energy or tree planting programs, among other sustainability measures [16].

3. Enabling Carbon Tracking and Offsetting

A lot of green payment systems provide functions that let consumers:

- Monitor the carbon impact of their trading.
- Contribute to approved carbon offset schemes to directly offset their emissions.
- Connecting climate action and consumer behaviour [2].

4. Promoting Sustainable Consumption

Green payment methods promote eco-friendly consumer practices by:

- Using incentives or publicity to draw attention to companies that use sustainable methods [2, 6].
- Providing incentives or rewards for purchases made from environmentally conscious merchants [6, 9].

5. Advancing Financial Inclusion for Green Initiatives

More individuals may take part in climate-positive initiatives like microloans for energy-efficient appliances, sustainable farming, or solar systems thanks to the expansion of financial access provided by digital payment platforms [9, 10].

6. Aligning with U.S. Climate Policy

The United States' climate goals, such as reaching net-zero emissions by 2050, are supported by green payment schemes:

- Quickening the shift to an economy with lower carbon emissions [9, 10].
- Promoting the development of innovative financial instruments and green technology that support climate objectives.

Examples and Initiatives

- **Green Banks and Digital Wallets:** Promote financial goods with lower carbon emissions [10, 12].
- **Carbon-Neutral Payment Networks:** Some businesses use carbon offsets and renewable energy to get towards zero-carbon payment environments.
- **Government and Corporate Collaboration:** Adoption and innovation may be stimulated by policies that provide incentives for sustainable and digital payments [13].

In conclusion, green and sustainable payment systems are essential to meeting U.S. climate goals because they not only lessen the environmental effect of the financial sector but also actively encourage sustainable company and consumer practices [13].

V. IDENTIFY GAPS IN EXISTING RESEARCH AND COVER AN ASPECT

Assessing the literature, active projects, [15,16], and technology developments is necessary to find research gaps pertaining to U.S. climate objectives. The following highlights several significant gaps and areas that need further research, with an emphasis on elements that are essential to achieving the United States' climate objectives:

1. Decarbonization of Hard-to-Abate Sectors

- Current research on decarbonizing sectors like aviation, [15], shipping, and heavy industry is limited in terms of scalable solutions.
- Examine economical methods for creating and using synthetic fuels or green hydrogen [16].
- Assess carbon capture, use, and storage (CCUS) technology designed specifically for these sectors [18].

2. Renewable Energy Grid Integration

- There are still issues with incorporating significant amounts of sporadic renewable energy, such as wind and solar, into the national grid [16].
- Examine cutting-edge energy storage technologies (apart from lithium-ion), such flow or solid-state batteries [16, 17].
- Create forecasting models to control demand and grid stability during peak and off-peak hours [19].

3. Urban Climate Resilience

- There is little study on how urban infrastructure can adapt to climate change, which includes increasing temperatures and severe weather events [19].
- Examine how green infrastructure, such as cool roofs and urban woods, might improve carbon sequestration and lessen urban heat islands.
- Evaluate how decentralised energy technologies, including microgrids, might improve urban energy resilience [19].

4. Equitable Climate Solutions

- Fair benefit distribution to underserved areas is often overlooked by climate initiatives [20, 23].
- Examine the workings of community-based renewable energy initiatives in underprivileged areas [29, 30].
- Examine policy structures that guarantee workers displaced by the move away from fossil fuels a fair transition [29, 30].

5. Agricultural Emissions and Soil Carbon Sequestration

- There is not enough research on scaling regenerative farming approaches to reach carbon reduction goals [22].
- To optimise soil carbon sequestration, assess the possibilities of biochar, cover crops, and no-till farming [29, 30].
- Examine the financial and legislative incentives needed to encourage farmers to adopt.

6. Carbon Pricing and Market Mechanisms

- There is ongoing debate in the literature on the effectiveness and scalability of carbon markets [21, 23].
- Analyse how carbon pricing affects the development of renewable technology.
- Examine hybrid approaches that include cap-and-trade and carbon taxation.

7. Role of Advanced Materials

- There is not enough research on the use of innovative materials in the construction of low-carbon infrastructure.
- Research the lifetime emissions of materials used in renewable energy applications, such as graphene, carbon-fibre composites, or bio-based polymers [20, 23].
- To increase energy efficiency, look at lightweight materials for transportation.

8. Behavioural and Cultural Change

- To increase energy efficiency, look at lightweight materials for transportation.
- Create frameworks to quantify how food modifications and fewer flights affect national carbon footprints.
- Examine ways to improve public campaigns to increase participation in climate action [21, 23].

VI. DIGITAL PAYMENT SYSTEMS THAT ARE COMPUTE INTENSIVE TODAY AND WHERE THERE IS A NEED TO IMPROVE

A complicated but crucial area of concern is created by the interaction between digital payment systems and US climate objectives [21, 22]. Let's take a closer look at each section:

6.1 Compute-Intensive Digital Payment Systems

Blockchain technology, fraud detection, real-time transaction processing, and AI-driven analytics have all contributed to the exponential growth of digital payment systems [23]. But these systems may be computationally demanding and energy-intensive.

- **Blockchain-Based Payment Systems (e.g., Bitcoin, Ethereum):** Proof-of-work (PoW) consensus systems need a lot of energy, particularly in cryptocurrencies like Bitcoin. Ethereum's energy usage dropped by 99.95% after switching to proof-of-stake (PoS), indicating room for innovation [24].
- **High-Frequency Trading and Instant Settlement Networks:** High-performance infrastructure and data centres are necessary for systems that need to handle large amounts of data in real time with very low latency [25].
- **Fraud Detection and Risk Assessment:** Large datasets are analysed in real-time by AI/ML models used in fraud detection, which results in significant computing burdens [23].
- **Cross-Border Payments:** To anticipate currency exchange rates and verify compliance, systems like SWIFT and new real-time gross settlement platforms (like Ripple) need a lot of processing power.

6.2 Challenges and Opportunities for Improvement

- **Current Challenge:** Data centres that enable payment systems use a lot of energy.
- **Improvement Opportunities:** Use of green data centres, optimised transaction protocols, and energy-efficient algorithms [23].
- **Scalability vs. Sustainability:** In order to handle expanding user bases, systems often scale quickly, which raises energy usage. To lessen the strain on central servers, give priority to edge computing and lightweight protocols [23, 24].
- **Decentralized vs. Centralized Systems:** Though they lack transparency, centralised systems like Visa-Net use less energy than decentralised blockchain-based systems. These issues might be balanced by better consensus methods such as PoS and Directed Acyclic Graph (DAG) architectures in decentralised systems [26].
- **Renewable Integration:** Data centers should transition to 100% renewable energy to minimize carbon footprints.

6.3 U.S. Climate Targets and Alignment with Payment Systems

By 2030, the United States wants to cut its greenhouse gas (GHG) emissions by 50–52% from 2005 levels. In this shift, digital payment systems play a function, especially in making sure that financial systems complement more general climate objectives [21, 22].

- **Green FinTech Initiatives:** Encourage low-carbon practices by promoting "climate-positive" payment systems (such as those that include carbon offset certificates into transactions) [2, 11].
- **Policies for Energy Use Transparency:** Require businesses using compute-intensive payment systems to disclose their energy consumption [2, 3].
- **Funding R&D in Sustainable Technologies:** Encourage the development of sustainable AI solutions and low-energy blockchain technologies [2, 9].
- **Incentivize Renewable Energy Use:** Provide financial incentives or tax benefits to payment system operators that use renewable energy.
- **Promote Collaboration:** To establish international standards, collaborate with major parties such as the EU, which has developed policies on sustainable digital infrastructure [9, 10].

6.4 Convergence of Technology and Climate Goals

Compute-intensive digital payment systems may meet U.S. climate objectives by increasing efficiency and switching to renewable energy. Adoption of green energy and protocol innovation will be essential to preventing the fast expansion of financial technology from undermining global climate goals [22, 26].

VII. IMPROVEMENTS AND SOLUTIONS ACROSS THE CURRENT PAYMENT STACK THAT CAN HELP REDUCE THIS COMPUTE USAGE

Improving system performance, lowering carbon emissions, and optimising energy efficiency are all necessary to lower compute utilisation in the payment stack while meeting US climate objectives [29, 30]. Here are a few fixes and enhancements that may help:

1. **Optimize Data Centers**

- **Energy-efficient hardware:** Make use of processors and storage devices that demand less energy.
- **Green power sourcing:** Data centres should switch to alternative energy sources like hydro, wind, or solar [22].
- **Dynamic resource allocation:** Workload optimisation methods may be used to dynamically distribute computing resources according to demand.
- **Server virtualization:** Reduce the number of servers used for workloads in order to save electricity.

2. **Improve Software Efficiency**

- **Streamlined algorithms:** Reduce the number of compute cycles needed for transactions by redesigning payment processing algorithms [20].
- **Efficient coding practices:** Optimise software to reduce memory utilisation and unnecessary computations.
- **Edge computing:** Reduce the need for centralised computing and data transport by processing data closer to the source [5].
- **AI-driven optimization:** Predict traffic and proactively control system loads using machine learning algorithms.

3. **Implement Blockchain Alternatives**

- **Energy-efficient blockchains:** Switch to blockchain technologies that need less computing power (such as proof-of-stake rather than proof-of-work) [21].
- **Off-chain solutions:** To manage transactions off-chain and settle on the main chain on a regular basis, [5, 6], use Layer 2 solutions.

4. **Reduce Payment Stack Complexity**

- **Simplify payment routing:** Reduce the number of middlemen by using direct payment methods.
- **API optimization:** Redesign APIs to reduce the amount of response payloads and data processing [15].
- **Tokenization and encryption:** Steer clear of unnecessary cryptographic overhead while maintaining safe processing.

5. **Promote Sustainable Practices in Fintech**

- **Carbon offsets:** Collaborate with environmental groups to reduce emissions from computer use.
- **Sustainability-focused policies:** Urge financial companies to embrace eco-friendly procedures and openly disclose their energy use [22].
- **Customer incentives:** Provide incentives for choosing eco-friendly transaction alternatives or lower-energy payment methods [23].

6. **Collaborate Across Industries**

- **Standards development:** Collaborate with trade associations to establish standards for transaction processing that uses less energy [26].
- **Research partnerships:** Work together with academic institutions and new businesses that specialise in green computing technology.
- **Regulatory alignment:** Align government efforts to achieve climate objectives with enhancements to the payment system [20].

7. **Impact on U.S. Climate Targets**

- **Reduced emissions:** Reducing the energy consumption of payment systems has a direct impact on lowering carbon emissions [26].
- **Increased renewable adoption:** Green energy system transitions help the country's transition to renewable energy sources.
- **Efficiency gains:** An improved payment stack strengthens system resilience and synchronises economic activity with climate goals [29].

VIII. DEVELOPING EFFICIENT TRANSACTION PROCESSING ALGORITHMS TO REDUCE

COMPUTE USAGE AND CONTRIBUTING TO U.S. CLIMATE GOALS

Information technology (IT) cybersecurity solutions have been developed and enhanced for a while, while operational technology (OT) cybersecurity has gotten far less attention [27]. While the operational technology and information systems (OT-ICS) industry greatly values sensitive data accessibility, the IT industry places the highest priority on sensitive data security. Due to their cultures' lack of emphasis on cybersecurity and the growing prevalence of the digital world, [27, 28], OT systems are increasingly vulnerable to attacks. Risks to OT include hazards to human health and the environment, while threats to IT include identity theft, financial loss, privacy violations, and the disclosure of sensitive information. OT networks now have security norms and standards that are enforced haphazardly, in contrast to IT networks, which are outfitted with strict security restrictions [28]. The OT industry's SCADA, HMI, and DCS applications and protocols are very individualised, [29, 30], in contrast to the IT industry's standardisation of things like email, the Internet, and video, among other things.

IDSs have shown themselves to be a dependable security tool for identifying irregularities in conventional IT. These systems look for signs of security breaches in all incoming and outgoing network traffic, and if they are found, they take the necessary action [30]. If a match cannot be located, a warning signal will sound [2]. While host-based intrusion detection systems (HIDS) concentrate on studying a single host and keeping track of all system events, network intrusion detection systems (NIDS) search the whole network for harmful traffic patterns. IT systems just cannot provide the level of protection required in industrial settings, even while it is true that IDSs and IT security systems may cooperate [30]. The reason for this is that IT systems aren't designed to accomplish that. However, the threats that cyberattacks pose to ICSs are increasing at an alarming pace. Given that many ICSs are critical, a malfunction might endanger human safety, endanger the environment, or reduce output entirely.

In line with the U.S. climate objectives of minimising carbon emissions and promoting sustainable practices, energy usage may be significantly decreased by using efficient transaction processing algorithms [25, 26]. Here are some ways that these algorithms may help:

1. Reducing Compute Usage

- **Optimization of Data Structures:** Computational power is saved by using effective data structures like hash maps or balanced trees, which shorten lookup and insertion times [28, 29].
- **Batch Processing:** By combining transactions to process them all at once, fewer separate computation cycles are needed.
- **Load Balancing:** By effectively allocating work across servers, [2, 4], bottlenecks are avoided and energy consumption is decreased since no one node is overwhelmed.
- **Asynchronous Processing:** Asynchronous techniques optimise resource use and reduce idle computation time [29, 30].

2. Energy-Efficient Algorithms

- **Lightweight Cryptography:** Lightweight cryptographic algorithms for transaction security need less processing resources than conventional techniques while still ensuring security.
- **Approximation Algorithms:** Using approximations for non-critical computations lowers the computational burden without noticeably sacrificing quality [30].
- **Dynamic Scaling:** Energy utilisation is optimised via algorithms that modify the computational effort according to the transaction requirement.

3. Utilization of Renewable Energy Sources

Grid efficiency is increased and dependency on fossil fuels is decreased by scheduling energy-intensive processes during periods of high renewable energy availability, [22], such as solar peak hours.

4. Integration with Blockchain or Distributed Ledger Technologies

- **Proof-of-Stake (PoS):** Energy usage is significantly reduced by switching from energy-intensive Proof-of-Work (PoW) systems to PoS or other low-energy consensus procedures [26].

- **Shading:** Processing performance is increased and unnecessary calculations are decreased by dividing the transaction ledger into smaller shards [24].

5. **Impact on U.S. Climate Goals**

- Lowering the energy needed for transaction processing reduces the demand for power overall, which renewable energy sources can more sustainably provide [21].
- Increasing digital system efficiency may help green finance technologies be adopted more widely, increasing carbon neutrality.

8.1 Strategies to implement these solutions across the systems we have today

Policy, technology, and social shifts must all be integrated when implementing methods to accomplish U.S. climate targets across present systems [19]. These are some important tactics:

1. **Decarbonizing the Energy Sector**

- **Expand Renewable Energy:** Invest in hydroelectric, geothermal, wind, and solar power plants. Modernise the system to accommodate renewable energy sources that fluctuate.
- **Modernize Infrastructure:** Make the switch to smart grids to improve dependability and energy efficiency [18, 20].
- **Nuclear Energy:** Encourage the use of cutting-edge nuclear reactors for baseload electricity with zero emissions.

2. **Electrifying Transportation**

- **Adopt EVs:** Increase the uptake of electric vehicles (EVs) by offering incentives, expanding the infrastructure for charging, [14, 22], and streamlining the supply chain.
- **Public Transit Investments:** Electrify and extend public transit networks.
- **Support Clean Fuels:** Promote hydrogen and sustainable aviation fuels for sectors including shipping and aviation.

3. **Retrofitting Buildings**

- **Energy Efficiency Upgrades:** Encourage the installation of energy-efficient retrofits for buildings (e.g., insulation, [23, 24], LED lighting, heat pumps).
- **Net-Zero Standards:** Ensure that new building uses net-zero energy designs.

4. **Decarbonizing Industry**

- **Carbon Capture and Storage (CCS):** Use CCS in heavy industries such as the production of cement and steel.
- **Process Electrification:** Convert industrial operations to renewable energy-powered electric systems.
- **Circular Economy:** Encourage material innovation, [29], recycling, and waste minimisation.

5. **Enhancing Agriculture and Forestry**

- **Sustainable Practices:** Promote regenerative farming, precision agriculture, and less fertiliser usage.
- **Carbon Sequestration:** Extend soil carbon, [21], reforestation, and afforestation initiatives.
- **Methane Reduction:** Encourage the use of technology that lower methane emissions from trash and livestock.

6. **Policy and Financial Incentives**

- **Carbon Pricing:** Put in place cap-and-trade or carbon tax schemes to help people absorb the cost of pollution [26, 27].
- **Subsidies for Clean Energy:** Transfer incentives to sustainable energy technologies from fossil fuels.
- **Green Bonds and Financing:** Encourage both governmental and private funding for environmentally friendly initiatives [28].

7. **Research and Development**

Invest in state-of-the-art research on next-generation materials, grid storage, battery technologies, and hydrogen production [29].

8. **Community Engagement and Equity**

- **Environmental Justice:** Make sure that disadvantaged communities benefit from climate action by creating fair policies [2, 30].
- **Public Awareness:** Launch educational initiatives to increase public acceptance and promote sustainable practices.

9. **Strengthen Regulations**

- Tighten industry, power plant, and automobile emissions regulations.
- Use open reporting and monitoring to enforce compliance [20, 23].

10. International Collaboration

Join forces with partners throughout the world to exchange innovations, [26], establish high international standards, and guarantee cross-border collaboration.

IX. CONCLUSION

A key element of meeting the US climate targets is the shift to sustainable and eco-friendly payment methods. The nation can drastically lower the carbon footprint of both conventional and digital financial activities by incorporating eco-friendly practices into financial infrastructures. In addition to encouraging responsible consumer behaviour and facilitating data-driven methods for tracking and rewarding sustainability projects, sustainable payment systems can stimulate innovation via green finance.

For the development of strong frameworks that match payment systems with climate goals, collaborations between governments, financial institutions, and technology companies are essential. Furthermore, using cutting-edge technology like energy-efficient payment networks and blockchain for transparency might provide scalable ways to lower energy use and encourage the use of renewable energy sources.

In summary, sustainable payment systems serve as both financial instruments and accelerators for more extensive environmental advancement. The United States can lead the world in demonstrating how environmental stewardship and economic prosperity may coexist by emphasising green practices in the banking industry. This pledge will help create a more resilient and fair economy in addition to advancing climate objectives.

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