Emerging Technologies for the Circular Economy

Lecture 11: Blockchains and Sustainability

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- Updated versions of these slides will be available in our Github repository.

Exam

Pre-Exam Q&A Session

- There will be a pre-exam Q&A session before the exam
  - Where: BBB → ETCE Q&A Room (Link)
  - When: 31.07.23 - 14:15 - 15:30

BLOCKCHAINS AND SUSTAINABILITY

Two main perspectives

Sustainability **of** Blockchains

VS

Blockchains **for** Sustainability

Sustainability of Blockchains

Elephant in the room → Proof Of Work (Bitcoin)

Sustainability of Blockchains

Elephant in the room → Proof Of Work (Bitcoin)

Network	Annual Energy Consumption (TWh)	Market Capitalization ($ Billion)	Energy Consumed per Transaction (kWh/tx)
Visa	197.57 (2021) [2]	520.62 (2021) [2]	0.0015 (2021) [2]
Bitcoin	135.12 (2021) [2]	617.05 (2021) [2]	1777.11 (2021) [2]
Ethereum (PoW)	55.01 (2021) [2]	247.8 (2021) [2]	125.36 (2021) [2]
Ethereum (PoS)	0.0026* (2022)	222.9 (today)	Can be anywhere between 0.00009 and 0.55713 [1]

[1] Platt, Moritz, et al. "The energy footprint of blockchain consensus mechanisms beyond proof-of-work." 2021 IEEE 21st International Conference on Software Quality, Reliability and Security Companion (QRS-C). IEEE, 2021.
[2] Varun Kohli, Sombuddha Chakravarty, Vinay Chamola, Kuldip Singh Sangwan, Sherali Zeadally, An analysis of energy consumption and carbon footprints of cryptocurrencies and possible solutions, Digital Communications and Networks, Volume 9, Issue 1, 2023, Pages 79-89, ISSN 2352-8648, https://doi.org/10.1016/j.dcan.2022.06.017
https://ethereum.org/en/energy-consumption/
https://coinmarketcap.com/currencies/ethereum/

Sustainability of Blockchains

Decoupling *Resource Consumption* and *Potential Utility*

- The potential utility of blockchains in solving issues and making the world more sustainable, far overweighs the disadvantages of early concensus mechanisms.
- Circular Economy models are designed to decouple resource consumption and economic growth.

Sustainability of Blockchains

Decoupling *Resource Consumption* and *Potential Utility*

- The utility of blockchains in solving issues and making the world more sustainable, far overweighs the potential disadvantages of early concensus mechanisms.
- Circular Economy models are designed to decouple resource consumption and economic growth.

  → For this lecture, we will try decouple resource consumption of blockchains and their potential utilty towards sustainabilty.

BLOCKCHAINS *FOR* SUSTAINABILITY

Blockchains for Sustainability

Question

- Which of the following properties of Blockchains would you value the **most**, when it comes to the potential utility for “making the world more sustainable / the economy more circular” ?
  - A) Verifiability / Traceability / Transparency
  - B) Decentralizing aspects (concensus)
  - C) Immutability
  - D) Security (e.g., preventing double-spending)
  - E) (Psuedo-) Anonymity

Blockchains for Sustainability

Example Use-Cases

- Emmissions Trading
- Sustainable Energy
- Sustainable Mobility
- Sustainable Supply-chain management

Blockchains for Sustainability

Example Use-Cases

- **Emissions Trading**
- Sustainable Energy
- Sustainable Mobility
- Sustainable Supply-chain management

Emissions Trading

Quick Introduction

- An approach to limit climate change by creating a market with limited allowances for emissions. (Cap and Trade)
- Regulators set a quantitative total limit on the emissions produced by participating polluters (e.g., oil companies).
- A polluter having more emissions than their assigned quota MUST purchase the right to emit more.
- A polluter emitting fewer emissions than their assigned quota CAN sell their remainder to other polluters.
- One of the most common policy adopted by countries to meet their pledges under the Paris Agreement.

https://en.wikipedia.org/wiki/Carbon_emission_trading

Emissions Trading

EU-ETS

- EU's Emissions Trading System (EU-ETS):
  - Currently covers ~45% of the EU's emissions.
  - Includes power producers, aviation industry and manufacturing.
  - EU Commission proposed to include maritime emissions into the ETS in 2020.

https://en.wikipedia.org/wiki/European_Union_Emissions_Trading_System

Emissions Trading

EU-ETS: Problems and Criticisms

- What about the remaining ~55%?
- At least 10 differrent types of fraudulent activities are possible:
  - Double counting
  - Exploitation of weak regulations
  - Tax fraud
- Oversupply of emissions allowances

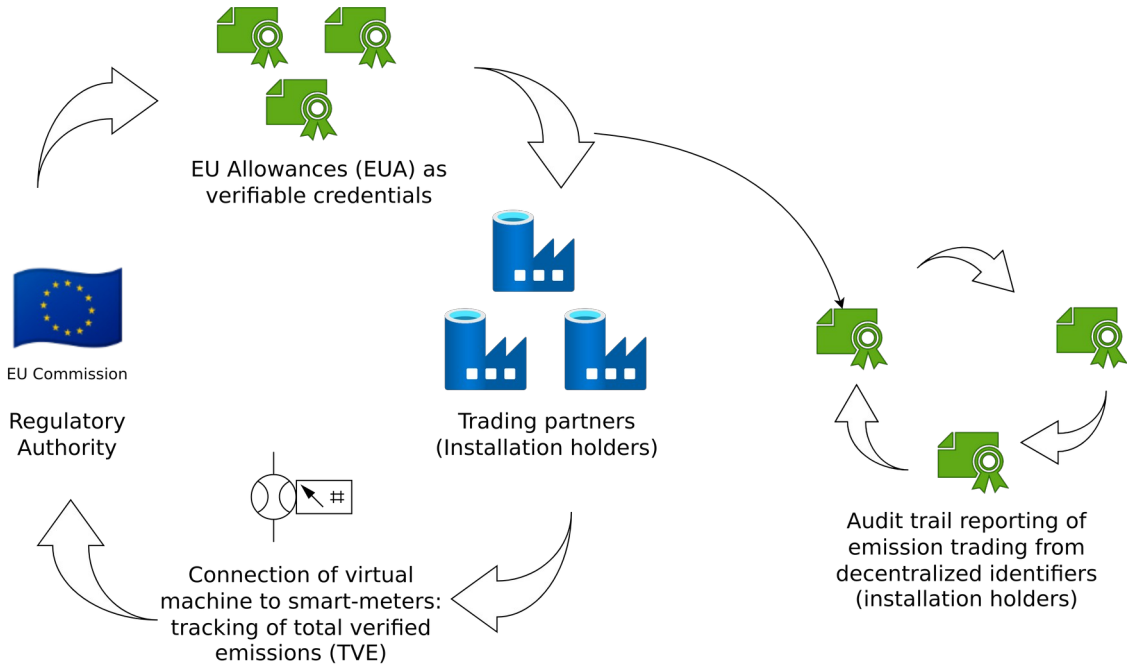
https://en.wikipedia.org/wiki/European_Union_Emissions_Trading_System

Mandaroux, Rahel, Chuanwen Dong, and Guodong Li. 2021. "A European Emissions Trading System Powered by Distributed Ledger Technology: An Evaluation Framework" Sustainability 13, no. 4: 2106. https://doi.org/10.3390/su13042106

Emissions Trading

EU-ETS on a Blockchain

- A conceptual idea for digitizing the EU-ETS in a decentralized and transparent way.
- Installation holders (trading participants) use Decentralized Identifiers (DIDs) as an anchor to their identity.
- Regulatory autorities assign allowances to the partners in the form of a digital certificate (Verifiable Credentials), which serve as the emissions certificate.
- Installation holders have a unique wallet that represents their DID, emission credits, and auditable transaction history.
- Smart contract connected *smart meters,* can further automate tracking of verified emissions.



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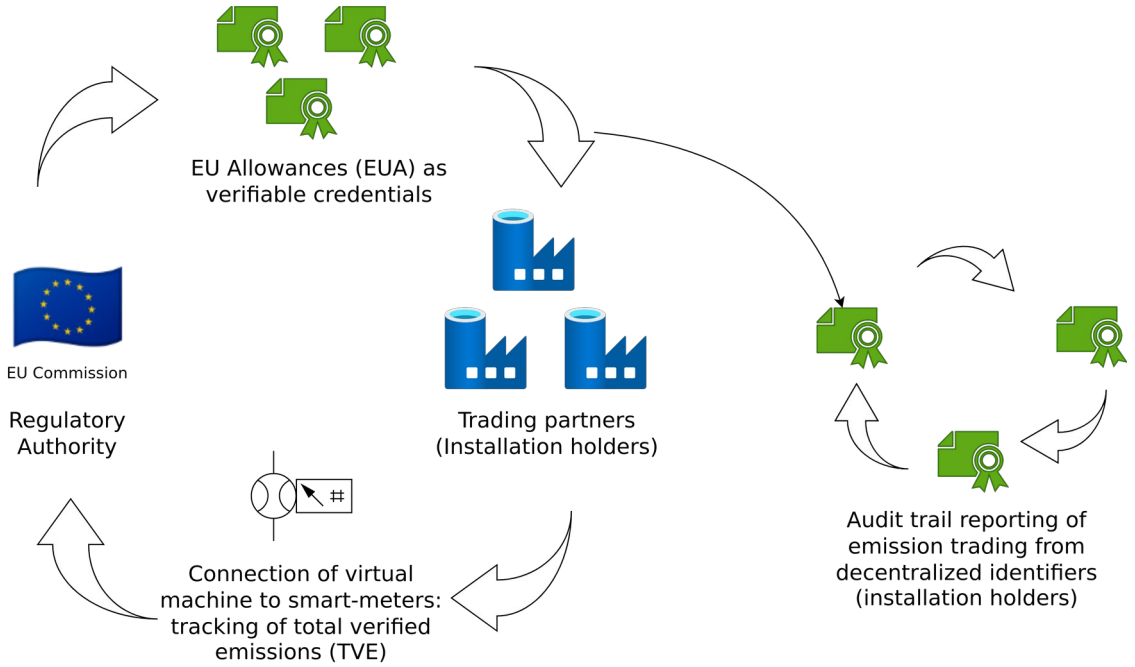
Emissions Trading

EU-ETS on a Blockchain

- Advantages:
  - Double counting would be reduced due to more secure unique identification and trade tracking.
  - With wallet information, each trade can be traced back to the original holder.
  - Real-time energy data can influence allocation policies in a more efficient way.



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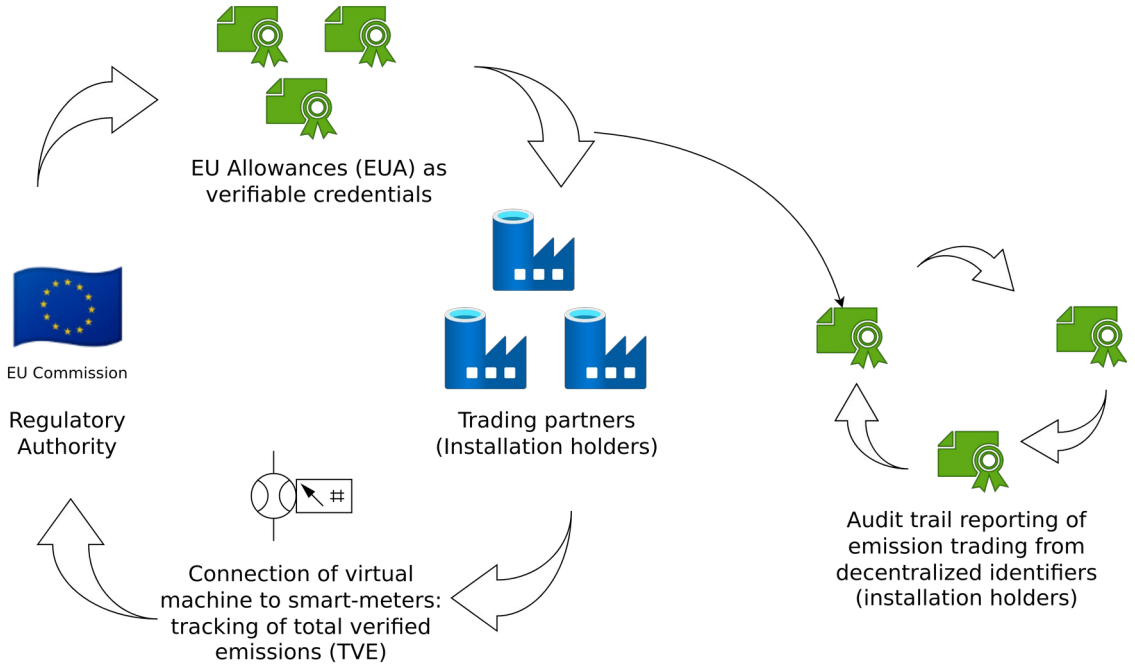
Emissions Trading

EU-ETS on a Blockchain

- Disadvantages
  - A very generalized framework
  - Does not address all types of fraudulent activities.
  - Does not fix the ~55% of emissions that are not traded in the system.
  - Adoption of digitization through blockchains regarding traceability and transaparency is still a general issue.



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Blockchains for Sustainability

Example Use-Cases

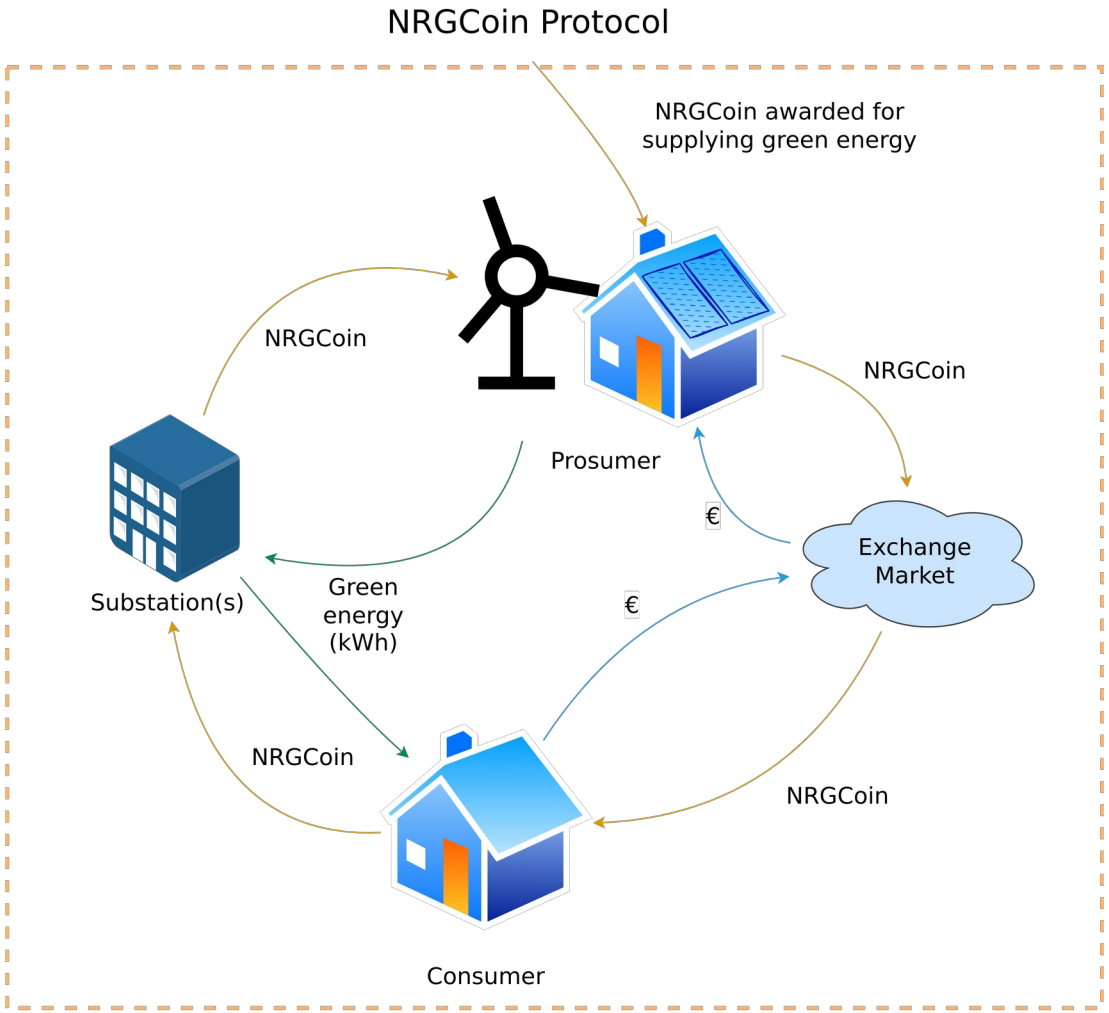
- Emissions Trading
- **Sustainable Energy**
- Sustainable Mobility
- Sustainable Supply-chain management

Sustainable Energy

Example: NRGCoin

- Incentivization of production and consumption of locally sourced renewable energy using a blockchain.
- The protocol converts locally produced renewable energy to NRGCoins. (1 kWh = 1 NRGCoin)
- NRGCoin can be exchanged for standard currencies at any time (€, $, ...).
- Producers do not rely on batteries, but continuously feed energy into the grid.
- Payment (NRGCoin) is received based on *actual* usage, as consumption is monitored in real-time.

[Video]

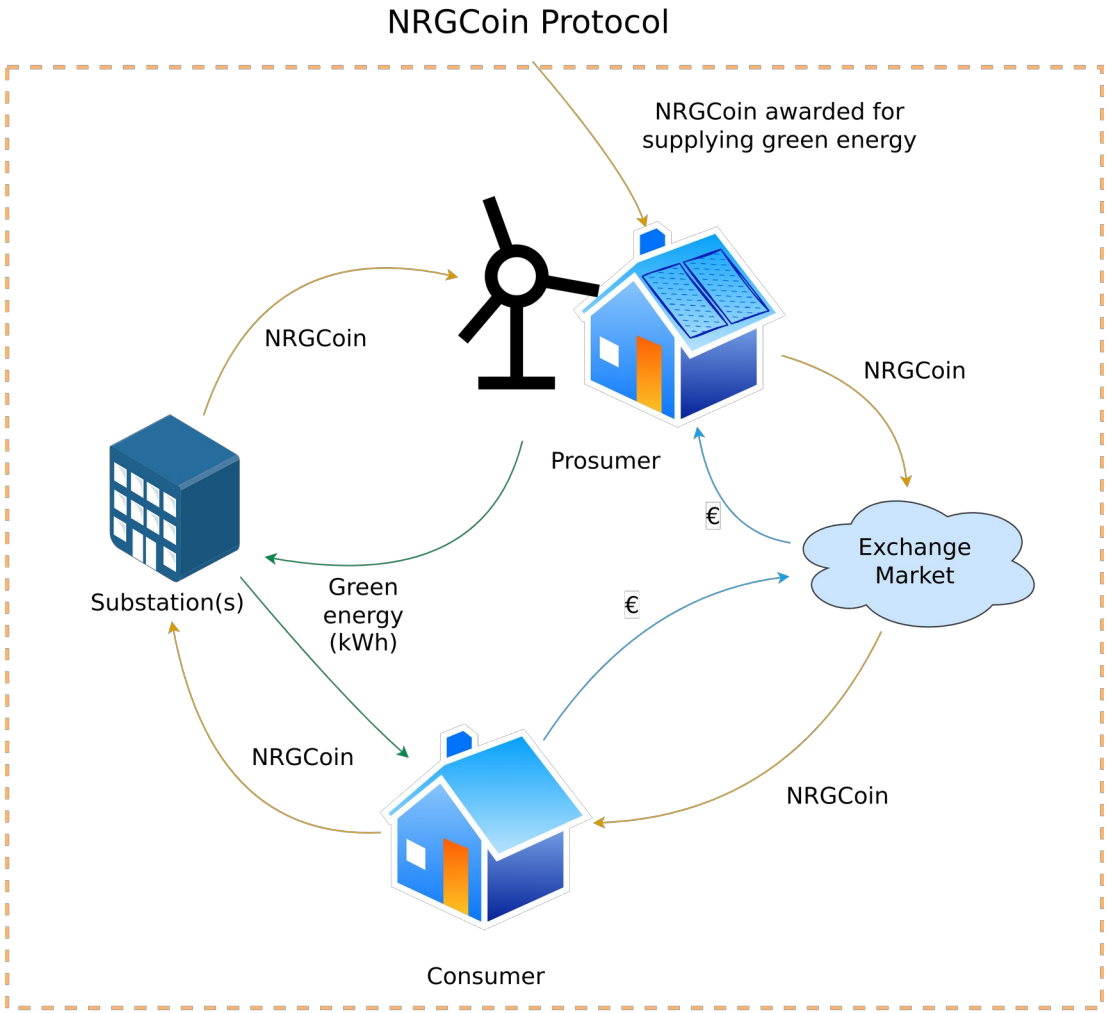


Mihaylov M, Jurado S, Avellana N, Van Moffaert K, de Abril IM, Nowé A. NRGcoin: Virtual currency for trading of renewable energy in smart grids. In 11th International conference on the European energy market (EEM14) 2014 May 28 (pp. 1-6). IEEE.

Sustainable Energy

Example: NRGCoin

- Advantages
  - Owning NRGCoin serves as a right to receive an equivalent quantity of energy in the future, independent of the NRGCoin market value. → increases prosumer's revenue without the need for batteries. (Although batteries would also increase their profits)
  - Unlike Bitcoin, which is mined through energy expenditure, NRGCoin is generated by injecting useful renewable energy to the grid.



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Blockchains for Sustainability

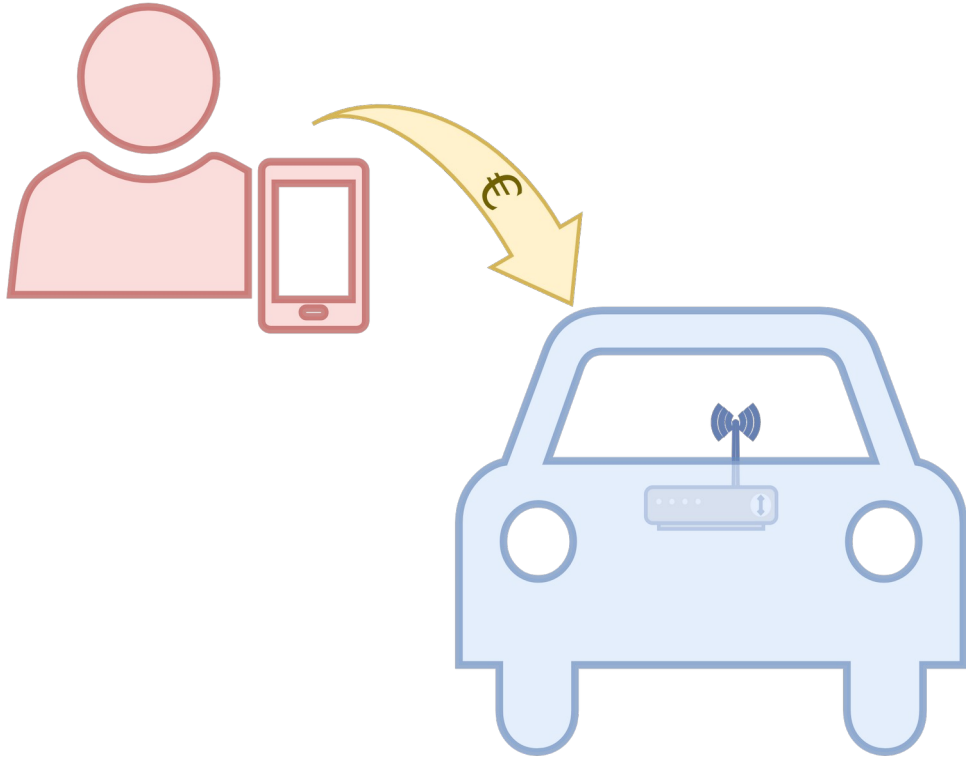
Example Use-Cases

- Emissions Trading
- Sustainable Energy
- **Sustainable Mobility**
- Sustainable Supply-chain management

Sustainable Mobility

M2X Economy

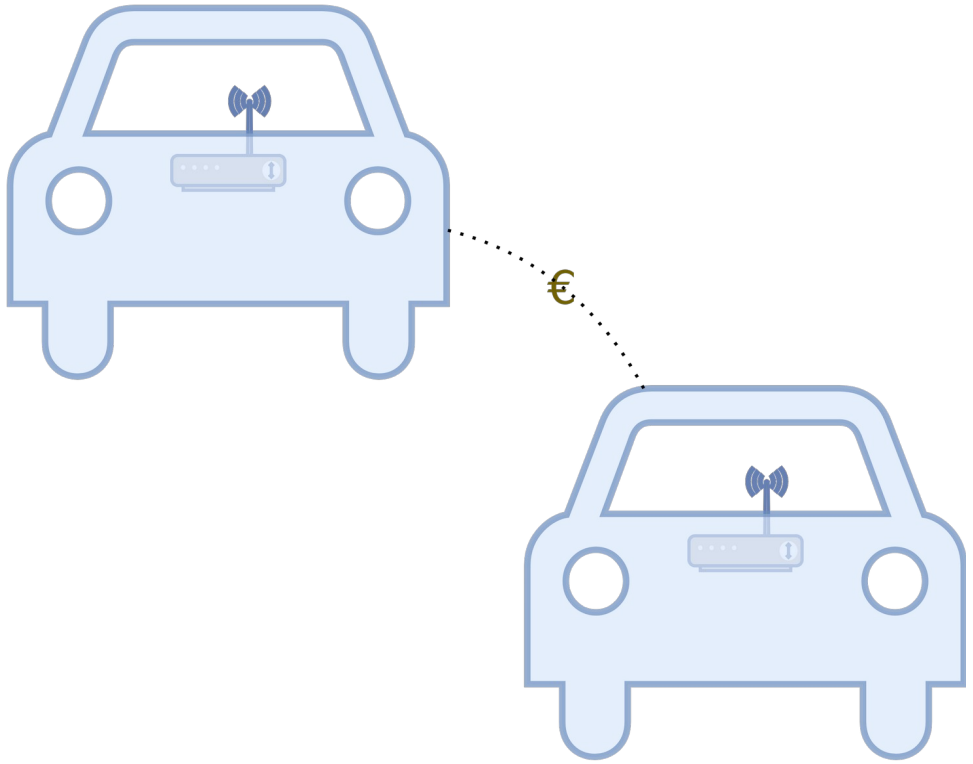
- Machine-to-Human (M2H)
- For example → Transportation-as-a-Service



Sustainable Mobility

M2X Economy

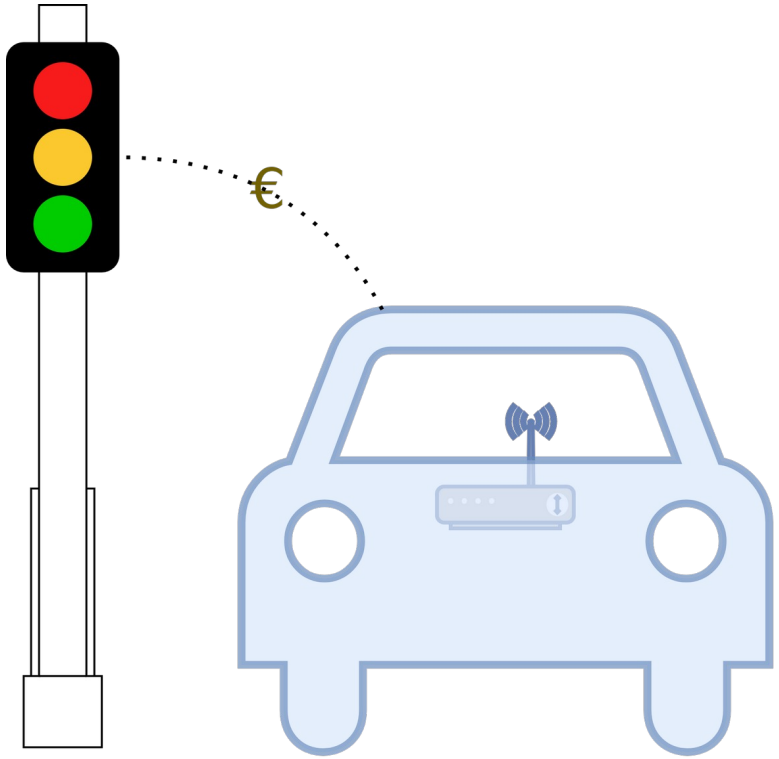
- Machine-to-Machine (M2M)
- For example → Road space negotiations



Sustainable Mobility

M2X Economy

- Machine-to-Infrastructure (M2I)
- For example → Smart parking, battery charging or traffic information



Sustainable Mobility

M2X Economy

Machine-to-Human (M2H)
+
Machine-to-Machine (M2M)
+
Machine-to-Infrastructure (M2I)
=
Machine-to-Everything (M2X)

Blockchains for Sustainability

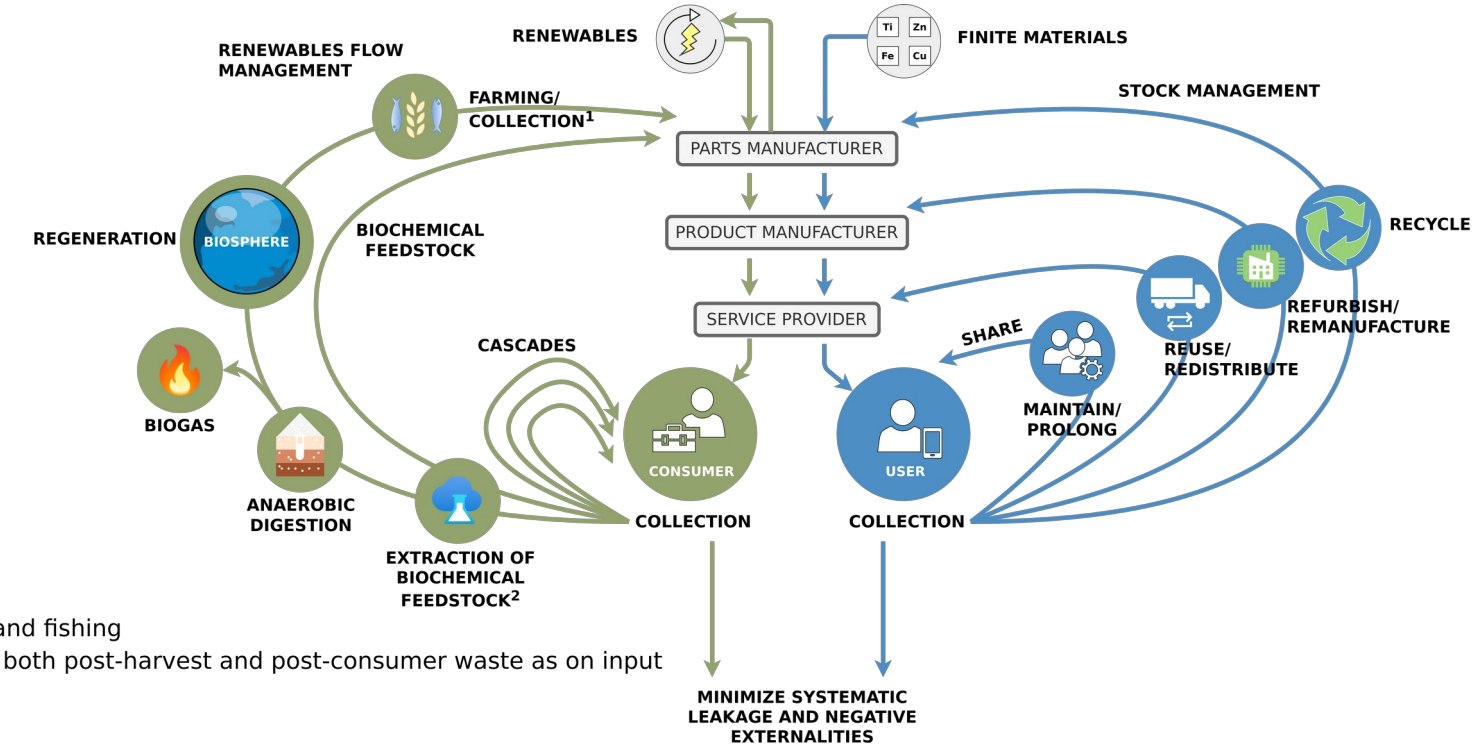
Example Use-Cases

- Emissions Trading
- Sustainable Energy
- Sustainable Mobility
- **Sustainable Supply-chain management**

Sustainable Supply-chain management

In Theory

- What if we could..
  - Manage supply chain logistics using a *public* blockchain,
  - With incentive structures for sustainable energy, reduction in emissions and waste production,
  - Logistical infrastructure to enable circular economy practices.

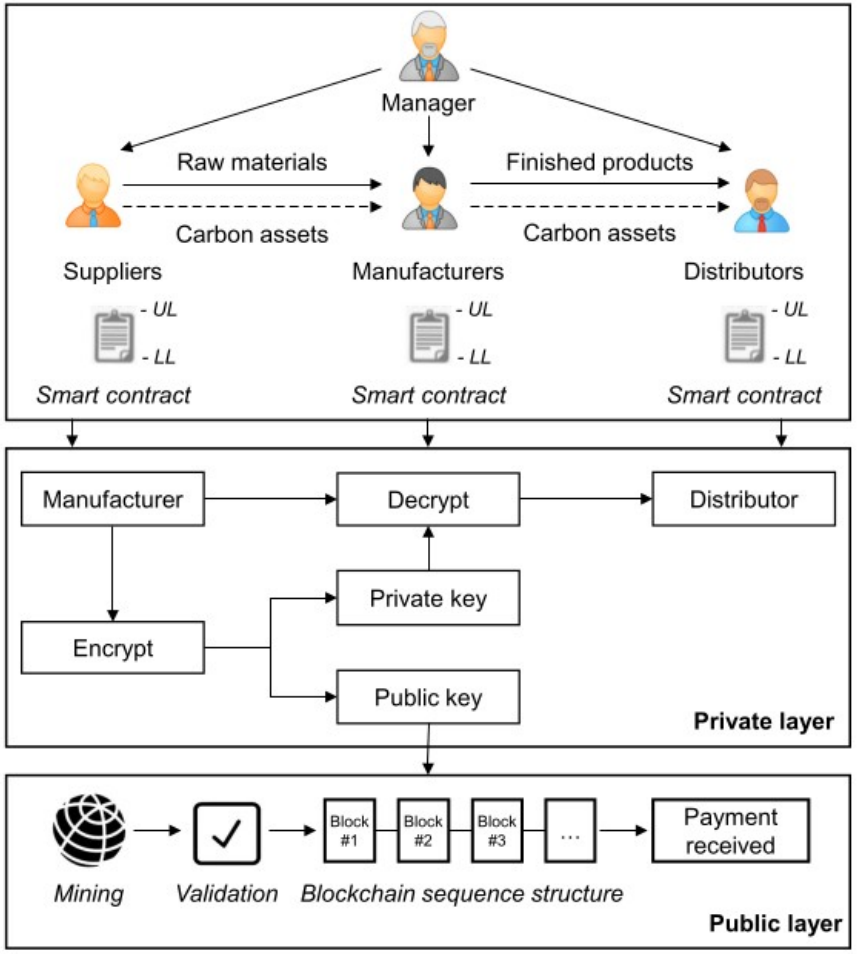


[1] Hunting and fishing
[2] Can take both post-harvest and post-consumer waste as on input

Image adapted from https://www.ellenmacarthurfoundation.org/circular-economy/concept/infographic

Sustainable Supply-chain management

In Literature



V. K. Manupati, Tobias Schoenherr, M. Ramkumar, Stephan M. Wagner, Sai Krishna Pabba & R. Inder Raj Singh (2019): A blockchain-based approach for a multi-echelon sustainable supply chain, International Journal of Production Research, DOI: 10.1080/00207543.2019.1683248

~~Sustainable~~ Supply-chain management

In Practice: Walmart + IBM Food Trust

- Motivation: Food contamination traceability
  - Heterogeneous record-keeping methods
  - Supply chain participants know only the immediate supplier (one link up the chain) and the immediate customer (one link down the chain).
  - Lack of accurate and adequate information leads to entire batches of food being thrown out in cases of food contamination.

Kamath, Reshma. 2018. “Food Traceability on Blockchain: Walmart’s Pork and Mango Pilots with IBM.” The Journal of The British Blockchain Association 1 (1). https://doi.org/10.31585/jbba-1-1-(10)2018.

~~Sustainable~~ Supply-chain management

In Practice: Walmart + IBM Food Trust

- Implementation
  - Permissioned blockchain developed in conjunction with IBM
  - Based on Hyperledger Fabric
- Proof of Concept (2016):
  - Mangoes in the US → Reduced the time needed to trace provenence from 7 days to 2.2 seconds.
- IBM Food Trust (2017)
  - Walmart + IBM + Nestle + Unilever
- Expansion to other products (2018)
  - Walmart now traces 25 products from 5 suppliers.
    - mangoes, strawberries and leafy greens, meat and dairy products, baby foods.
  - Planned expansion to all leafy greens

"How Walmart brought Unprecedented transparency to the food supply chain with Hyperledger Fabric" - Link

Blockchains for Sustainability

Quick reflection on the most valued properties

- Which of the following properties of Blockchains would you value the **most**, when it comes to the potential utility for “making the world more sustainable / the economy more circular” ?
  - A) Verifiability / Traceability / Transparency
  - B) Decentralizing aspects (concensus)
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Blockchains for Sustainability

Disadvantages and Adoption barriers

- Technological barriers
- Organizational barriers
- Environmental barriers
  - Inter-Organizational barriers
  - External barriers

Kouhizadeh, Mahtab, Sara Saberi, and Joseph Sarkis. "Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers." International Journal of Production Economics 231 (2021): 107831.

Blockchains for Sustainability

Technological Barriers

- Transaction speed
- Accumulating transaction costs
- Scalability
- Immutability
  - Any private data going into a blockchain will stay there forever.
  - Incorrect environmental or social record could exist forever, even though latest data seeks to correct such information.
- Public Image and perceptions

Kouhizadeh, Mahtab, Sara Saberi, and Joseph Sarkis. "Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers." International Journal of Production Economics 231 (2021): 107831.

Blockchains for Sustainability

Organizational Barriers

- Financial constraints tied to developing a blockchain-based system
  - Planning, development, deployment, management
- Lack of knowledge and expertise
- Lack of commitment from top or middle management
  - Why would they invest in a new sustainable technology if it hurts their bottom line?

Kouhizadeh, Mahtab, Sara Saberi, and Joseph Sarkis. "Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers." International Journal of Production Economics 231 (2021): 107831.

Blockchains for Sustainability

Environmental Barriers

- Inter-Organizational barriers
  - “Organizations are skeptical about sharing their *information* as they see *information* as a competitive edge.”
  - Cultural and geological differences: e.g., heterogeneous definitions of sustainability, circular economy, etc.
- External barriers
  - Lack of governmental incentives towards using blockchains for sustainability due to it’s bad public image.
  - Novelty and instability of blockchains.

Kouhizadeh, Mahtab, Sara Saberi, and Joseph Sarkis. "Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers." International Journal of Production Economics 231 (2021): 107831.

Blockchains for Sustainability

A Contradictory Philosophy

- The more trust, verifiability and traceability you would like from a (public) blockchain, the more data you need to store.
- Among others issues, this increases the risk of potential barriers to adoption.
- This leads to alternative solutions like private/protected blockchains.
  - → Little to no public verifiability: How can we know if a proposed *solution* is not greenwashing us?

Blockchains for Sustainability

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Is there a better philosophy that works better ? / An alternative way to approach the problem of sustainability?

A SHORT DETOUR: CIRCULAR SOCIETY

Circular Society

CE Criticism

- Replace the LE with circularly oriented forms of consumption and production
- CE focus mostly on earned value management: product/business model innovations within existing power asymmetries
- Decouple economic growth and consumption of natural resources

Partially based on: F. Hofmann, J. Zwiers (2018) – Circular Society – Eine pluralistische und emanzipatorische Alternative zur Circular Economy? – Link.

Circular Society

CE Criticism

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→ But why do we need never ending economic growth and why is it good to consume as many goods and services as possible?

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Circular Society

CE Criticism

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→ But why do we need never ending economic growth and why is it good to consume as many goods and services as possible?

- Alternatives:
  - Sufficiency strategies and lifestyle changes
  - Question the prevailing entrepreneurial orientation towards the shareholder concept
  - Deconstruction of existing power asymmetries.

Partially based on: F. Hofmann, J. Zwiers (2018) – Circular Society – Eine pluralistische und emanzipatorische Alternative zur Circular Economy? – Link.

Circular Society

Overview

- Circular Society → CS
- Goals of the CS:
  - Not just “CE + social”
  - Socio-political transformation and reorganization
  - Replace intransparent and inequity-based value chains of the LE with democratic, transparent and cooperatively organized value chains

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  - Also → preserve the environment/resources for present and future generations and enable social participation and quality of life

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Circular Society

Overview

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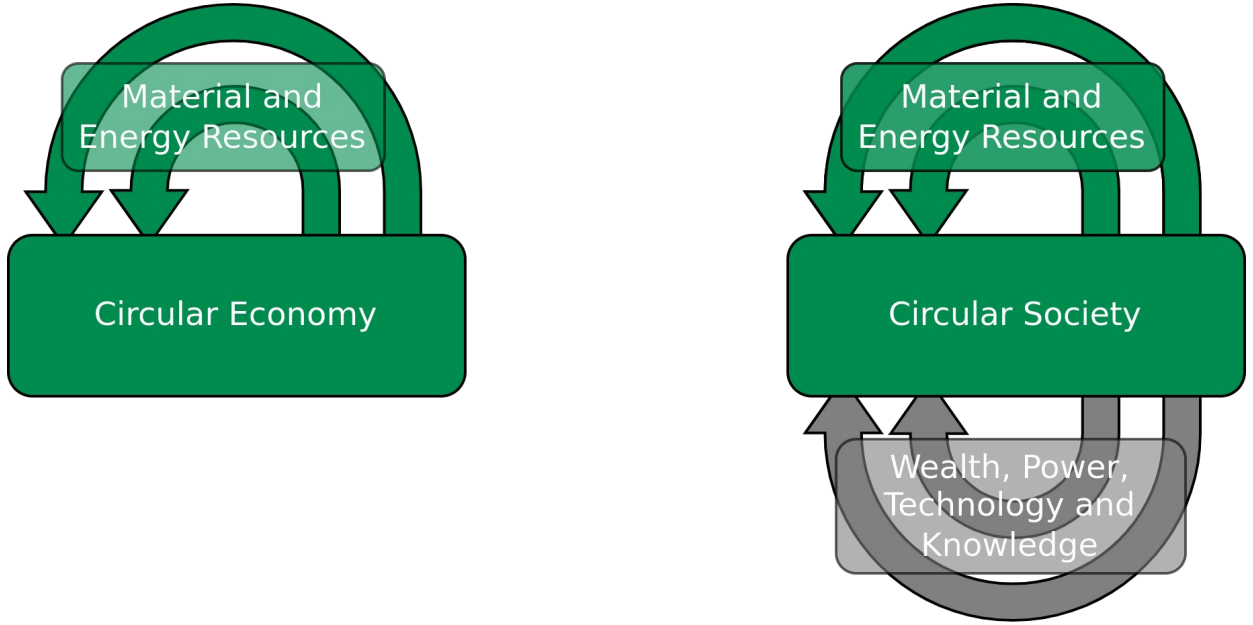
  - Replace intransparent and inequity-based value chains of the LE with democratic, transparent and cooperatively organized value chains
  - Also → preserve the environment/resources for present and future generations and enable social participation and quality of life
  - All-encompassing change is necessary if the CE is to be the subject of a socio-ecological transformation
  - Democratization of value creation processes and strategies for the activation and emancipation of different stakeholder groups

Partially based on: F. Hofmann, J. Zwiers (2018) – Circular Society – Eine pluralistische und emanzipatorische Alternative zur Circular Economy? – Link.

Circular Society

Definition

„ A circular society defines discourses with a vision of circularity where not only resources are circulated in sustainable loops, but also wealth, knowledge, technology and power is circulated and redistributed throughout society”



Circular Society

Conclusion

- Circular Economy (CE):
  - Maintain natural resources and minimize the discharge of substances that are harmful to health and nature → Increase/maximize utilization of resources, e.g., Performance Economy
  - Ecological modernization of the economy to increase resource efficiency, e.g., by technical innovation and digital solutions.
- Circular Society (CS):
  - Not just “CE + social” instead socio-political transformation and reorganization
  - Replace non-transparent and inequity-based value chains of the LE with democratic, transparent and cooperatively organized value chains.
  - Democratization of value creation processes and strategies for the activation and emancipation of different stakeholder groups

Blockchains for Sustainability

A Contradictory Philosophy

- The more trust, verifiability and traceability you would like from a (public) blockchain, the more data you need to store.
- Among others issues, this increases the risk of potential barriers to adoption.
- This leads to alternative solutions like private/protected blockchains.

  → Little to no public verifiability: How can we know if a proposed *solution* is not greenwashing us?

Is there a better philosophy that works better ? / An alternative way to approach the problem of sustainability? = Blockchains for Circular Societies?

Blockchains for Circular Societies

Quick reflection on the most valued properties

- Which of the following properties of Blockchains would you value the **most**, when it comes to the potential utility for “making the world more sustainable / the economy more circular” ?
  - A) Verifiability / Traceability / Transparency
  - B) Decentralizing aspects (concensus)
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Future work

A Possibly Unexplored Research Area

How can blockchains help develop and reliably “sustain” circular societies?

- Incentivise circular flows of material, energy, wealth, power, knowledge and technology.
- Localized currency
  - Incentivise local supply chains
  - Resolving scalability issues
  - Alleviating organizational and environmental barriers
- Enable decentralized governing principles using smart contracts.

- Can such a system co-exist, while simultaneously transforming the status quo?
- Can individual localized circular societies interact (trade) with each other, expanding to a global level?

Conclusions

- Possible *utility* of blockchains
  - Emmissions Trading
  - Sustainable Energy
  - Sustainable Mobility
  - Sustainable Supply-chain management
- Most scientific literature agrees that blockchains can be a driving force to design circular economic business models.

Conclusions

- However, various adoption barriers prevent the most valued attributes of blockchains being used in an efficient manner.
  - Organizational barriers
  - Environmental barriers
- Circular Economy VS Circular Society
  - Replace intransparent and inequity-based value chains of the LE with democratic, transparent and cooperatively organized value chains
  - Also → preserve the environment/resources for present and future generations and enable social participation and quality of life
  - All-encompassing change is necessary if the CE is to be the subject of a socio-ecological transformation

Conclusions

- However, various adoption barriers prevent the most valued attributes of blockchains being used in an efficient manner.
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  - All-encompassing change is necessary if the CE is to be the subject of a socio-ecological transformation

Blockchains can be the backbone of such transformational change

Questions?

Additional Resources

- Thalhammer, Felix, Pascal Schöttle, Matthias Janetschek, and Christian Ploder. "Blockchain Use Cases Against Climate Destruction." Cloud Computing and Data Science (2022): 22-38.
- Kamath, Reshma. "Food traceability on blockchain: Walmart's pork and mango pilots with IBM." The Journal of the British Blockchain Association 1, no. 1 (2018): 3712. Link
- https://www.hyperledger.org/wp-content/uploads/2019/02/Hyperledger_CaseStudy_Walmart_Printable_V4.pdf
- Kouhizadeh, Mahtab, Sara Saberi, and Joseph Sarkis. "Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers." International Journal of Production Economics 231 (2021): 107831.