Blockchain applications: an energy perspective

12 April 2022

International Energy Agency

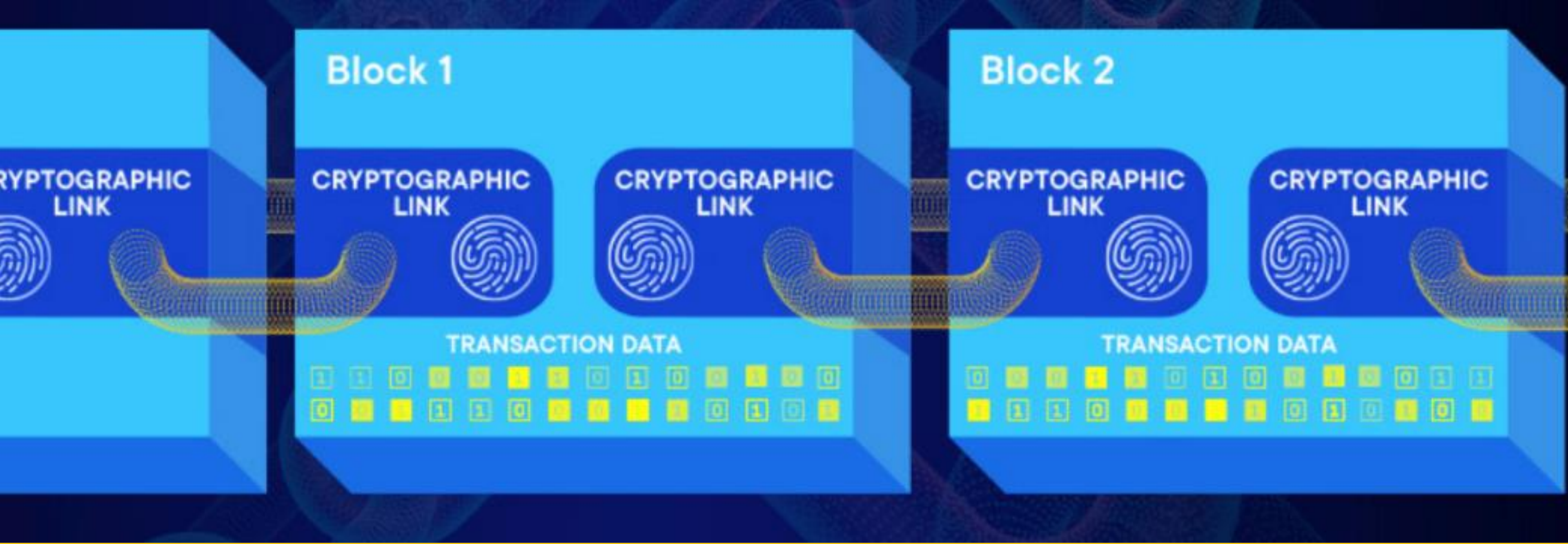
Agenda

14h00	**Welcome and opening remarks** • **Pauline Henriot,** 3DEN Lead Analyst, Energy Efficiency Division, International Energy Agency • **Roland Brüniger**, 4E EDNA delegate for Switzerland, Swiss Federal Office of Energy
14h10	**Presentation of the main findings from the report "Blockchain Energy Consumption - An Exploratory Study"** • **Vlad Coroama,** Independent researcher, Roegen Centre for Sustainability
14h30	**Discussion and Q&A** Moderated by **George Kamiya**, Digital and Energy Analyst, International Energy Agency • **Vlad Coroama,** Independent researcher, Roegen Centre for Sustainability
14h55	**Closing** • **Pauline Henriot,** 3DEN Lead Analyst, Energy Efficiency Division, International Energy Agency
15h00	**End of webinar**

Introduction to EDNA

Roland Brüniger, Swiss Federal Office of Energy (EDNA delegate for Switzerland)

12th April 2022



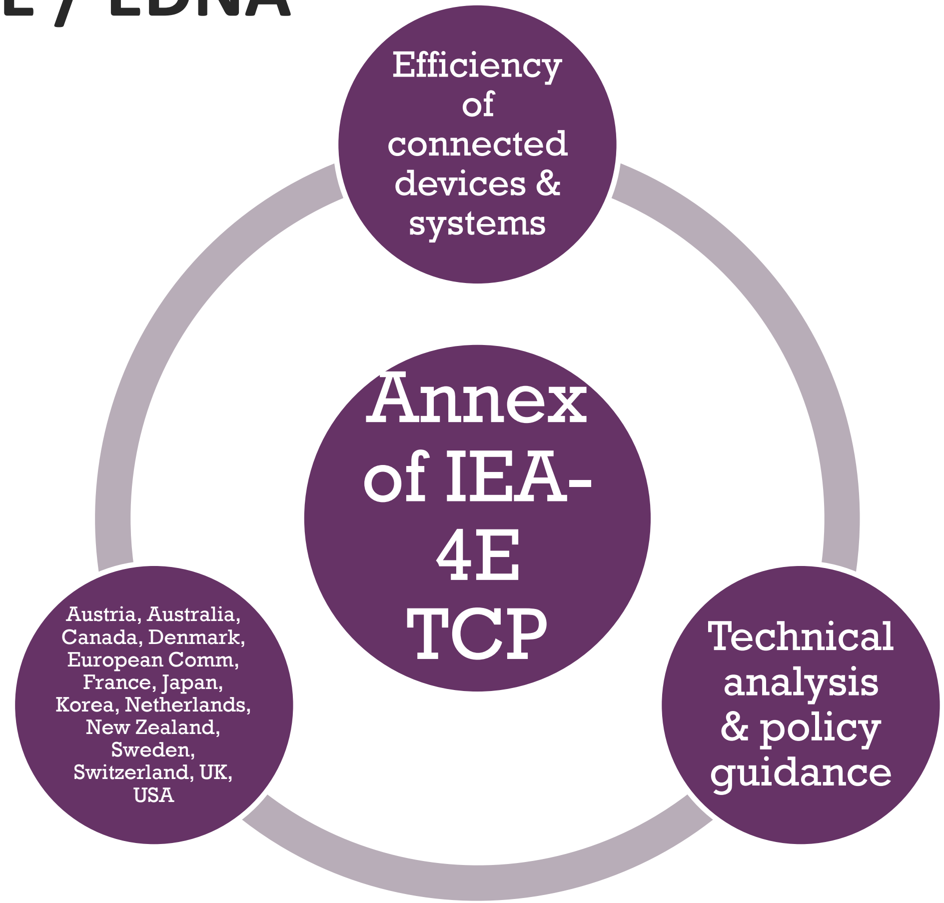
Introduction to EDNA

Roland Brüniger, Swiss Federal Office of Energy (EDNA delegate for Switzerland)

IEA Webinar on Blockchain Energy Consumption, 12 April 2022

4E Electronic Devices & Networks Annex
EDNA

IEA-4E / EDNA



Electronic Devices & Networks Annex
EDNA

Energy Implications of Device Connectivity

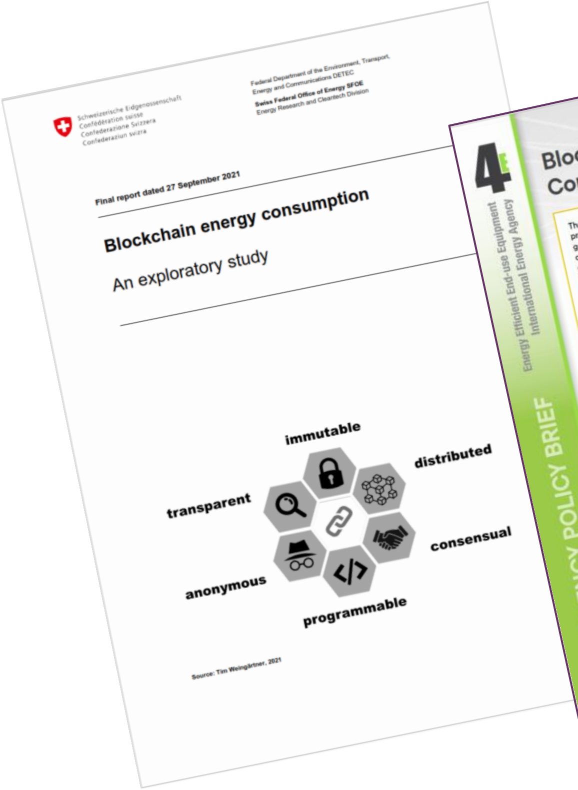
Energy Savings

- Digitalisation
  - Intelligent efficiency
  - Demand flexibility

Energy Cost

- Network standby
- Upstream energy

Blockchain Energy Consumption



Schweizerische Eidgenossenschaft
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Confederaziun svizra

Federal Department of the Environment, Transport, Energy and Communications DETEC
Swiss Federal Office of Energy SFOE
Energy Research and Cleantech Division

Final report dated 27 September 2021

Blockchain energy consumption

An exploratory study

Source: Tim Weingärtner, 2021

4E
Energy Efficient End-use Equipment
International Energy Agency

EDNA14

Blockchain Energy Consumption

The 4E Electronic Devices and Networks Annex (EDNA) provides policy guidance to members and other governments aimed at improving the energy efficiency of connected devices and the systems in which they operate. EDNA is focussed on the increased energy consumption that results from devices becoming connected to the internet, and on the optimal operation of systems of devices to save energy.

This briefing summarises the key findings of a report titled Blockchain Energy Consumption - An Exploratory Study. The report was commissioned by the Swiss Federal Office of Energy and contains a detailed analysis of blockchain, its use in cryptocurrencies and beyond, and the resulting energy consumption. Though not an EDNA report, it relates to the digitalisation of the energy system and its findings are relevant for policy makers globally.

Observations for Policy Makers

- A blockchain is a public digital ledger which can be used to verify the ownership of both digital and real-world assets, for example cryptocurrencies, 'tokenised' artworks, real-estate and even energy.
- Changes in asset ownership are recorded in the blockchain and then validated by volunteer computer 'nodes'.
- Many blockchains employ a 'proof-of-work' mechanism to perform the validation function. This requires the validating nodes to have vast computing power, resulting in substantial electricity consumption. For Bitcoin alone, this now totals more than 100 TWh p.a., which is equivalent to the electricity consumption of the Netherlands.
- The nodes that undertake proof-of-work are rewarded with newly 'mined' cryptocurrency tokens. These computers are usually located where electricity is cheap.
- Alternatives to proof-of-work mechanisms exist, which use several orders of magnitude less energy, for example 'proof-of-stake'.
- Enacting policies to tackle the high energy consumption of blockchains is complicated, especially due to the lack of a central owner/operator that can be held responsible.

MORE INFORMATION

The Swiss report is available for download here. For further information please contact the EDNA operating agent at steve@beletich.com.au

Published March 2022

ENERGY EFFICIENCY POLICY BRIEF

Technology Collaboration Programme by iea

4E Electronic Devices & Networks Annex EDNA

More Information

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  - roland.brueniger@brueniger.swiss
  - steve@beletich.com.au

- Policy briefs
  - https://www.iea-4e.org/edna/publications/

- Swiss publications of the report
  - https://www.aramis.admin.ch/Default?DocumentID=68053&Load=true

Blockchain Energy Consumption

An Exploratory Study

Vlad Coroamă

IEA Webinar, 12 April 2022

Study performed when I was still affiliated with the ETH Zurich..

ETH zürich

.. and supported to a large extent by the Swiss Federal Office of Energy

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie BFE
Office fédéral de l'énergie OFEN
Ufficio federale dell'energia UFE
Swiss Federal Office of Energy SFOE

Energy consumption of blockchains: Topic of concern

The Big Read Bitcoin + Add to myFT

Bitcoin's growing energy problem: 'It's a dirty currency'

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Tesla will no longer accept Bitcoin over climate concerns, says Musk

13 May 2021 | Comments

Climate change

Markets

Greenpeace Stops Accepting Bitcoin Donations, Cites High Energy Use

Friends of the Earth is reported to be reviewing the situation, too.

By Daniel Palmer

May 21, 2021 at 1:51 p.m. ·

Updated Sep 14, 2021 at 2:59 p.m. ·

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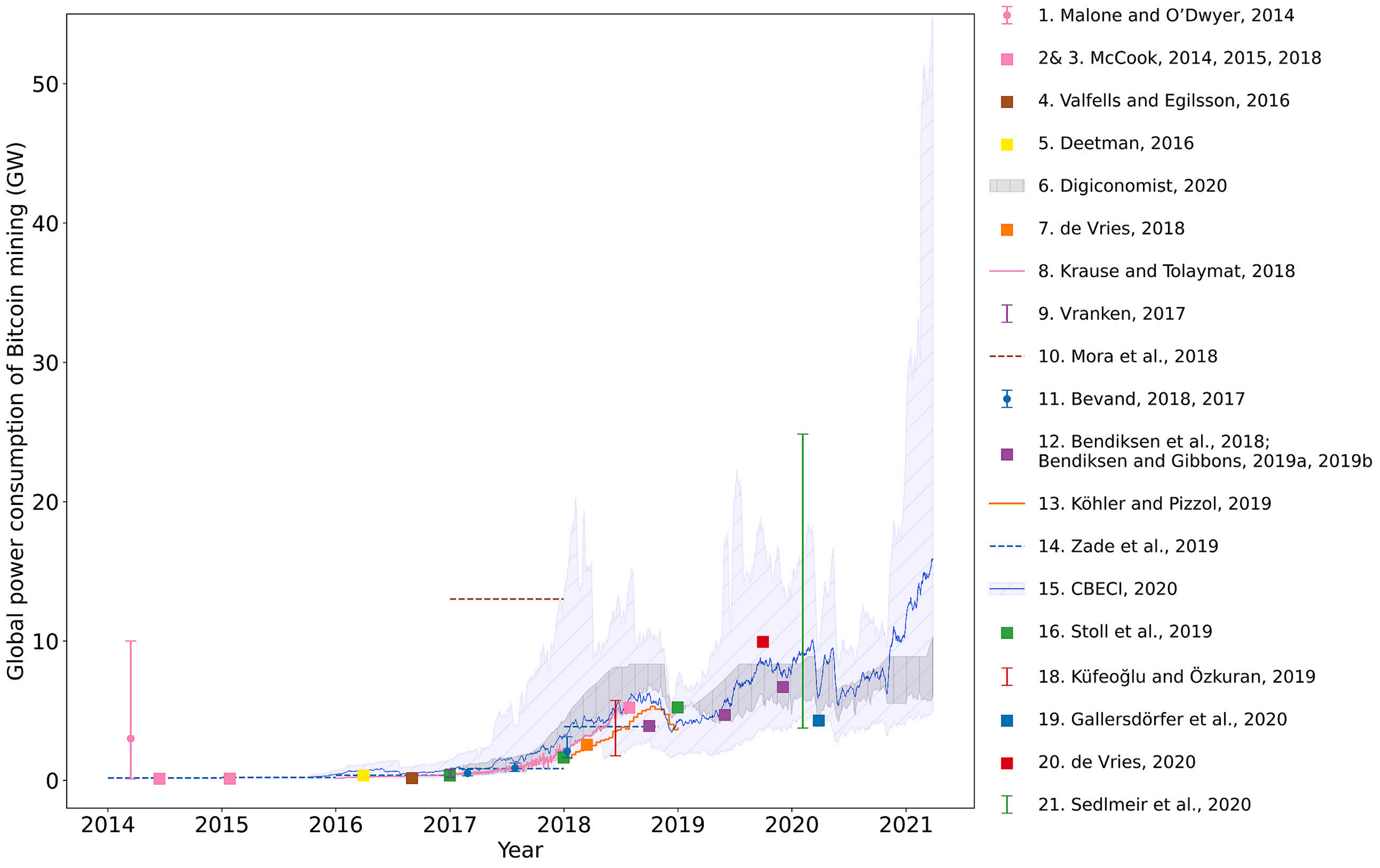
Sustainability solution or climate calamity? The dangers and promise of cryptocurrency technology

Unsplash/André François McKenz | Bitcoin is a decentralized d currency that you can buy, sell and exchange directly, without a ntermediary like a bank.

Screenshots from: Financial Times, BBC, Coindesk, UN

Broad consensus that energy use is growing rapidly, but variation among estimates



Source: (Lei et al. 2021) Best practices for analyzing the direct energy use of blockchain technology systems: Review and policy recommendations, Energy Policy 156.

Research questions for the study

- RQ1: What are the **main drivers** of blockchain energy consumption?
- RQ2: What are likely **consumption figures** for today?
- RQ3: Are there any existing **limiting factors** and how do they act?
- RQ4: Which are effective **countermeasures**, if any?

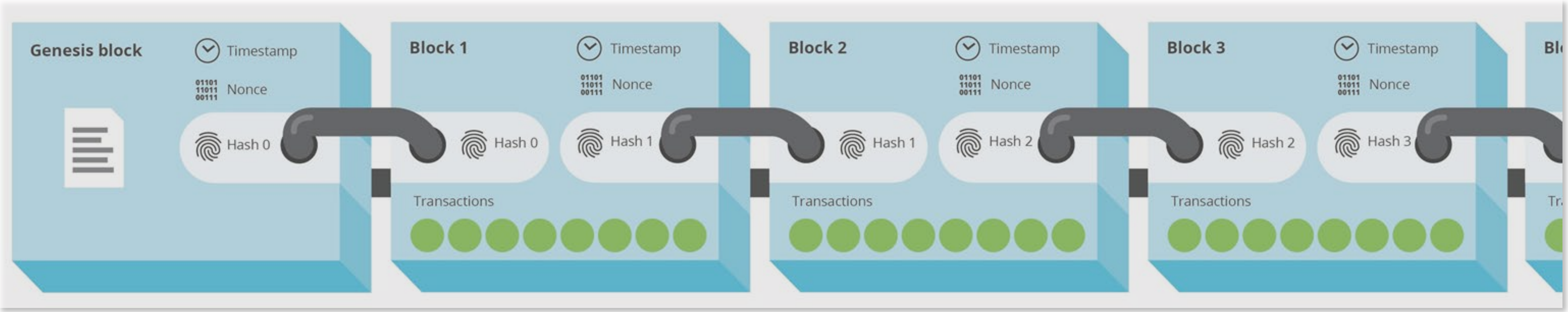


Image source: Swiss Foundation for Technology Assessment (TA-Swiss), illustration: Hannes Saxer

Part 1: Technological Background

Why blockchains?

Brief history

Components of a blockchain

Consensus mechanisms & proof-of-work

Technological background: Challenges of digital currencies

- Value units (‘coins’) of electronic currencies can be trivially multiplied, stored, and transmitted
  - (as with any digital data)
  - known as **multiple spending** problem

- Public-key-infrastructure (PKI, i.e., private-public key pair) in which all coins are signed (“**minted**”) by a central Trusted Authority (TA)
  - addresses the authenticity of all original coins
  - does **not solve the copying of (signed) coins** and cannot prevent their multiple spending

- In first-generation digital currencies (in the 90s), TA thus required
  - not only to sign coins
  - but also to keep track (i.e., a ledger) of **which accounts hold each of the coins** and can rightfully spend them

Early eCash digital currency & General principles of digital currencies

- Relatively cumbersome payment in eCash
  - payer sends digital coins to payee
  - payee sends coins to TA for validation (i.e., that payer owns it, and has not used it yet for payment)
  - after validation, coins are accepted
  - TA reflects new property structure
  - See also, e.g., first slide here: https://slideplayer.com/slide/10532466/

- Digital currencies
  - need a **unanimously trusted ledger**,
  - which can certify ownership of coins,
  - and track ownership changes.

- Drawbacks of centralised TA
  - **system safety** relies on TA safety (proprietary algorithms),
  - questionable **scalability**: TA can become bottleneck,
  - **expensive** and unfit for "small casual transactions", as Bitcoin was originally designed for (the irony, of course, is strong here).

Bitcoin: Digital currency based on a distributed ledger

Overall system

- Bitcoin ecosystem
  - currency units (**coins**, BTCs) & subdivisions
  - **accounts** that hold coins
  - **transactions** (either minting of new coins or transfers between accounts)
- Accounts do not directly “own” digital coins
  - as in keeping a (signed) sequence of bits on an HD
- Instead **public, distributed ledger** keeps
  - all existing account numbers (but not the owners)
  - ownership: all BTCs associated with accounts
  - all transactions ever performed
- Proof of **account ownership** via PKI
  - private/public key pair

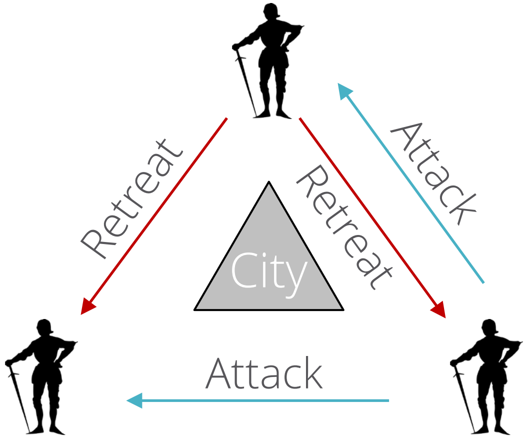
Distributed ledger

- Numerous distributed replicas of the ledger
  - held by **nodes** of the system
  - anyone can become a node; no access restrictions
- Can also be seen as a Virtual Machine (VM)
  - a VM **state** is a snapshot of accounts and coins associations
  - Bitcoin **transactions represent state transitions**
- Every new period (approx. 10 mins)
  - collection of transactions recorded
  - state transition occurs
  - new **block of transactions added** to the *blockchain*

New issues and their solutions

Consensus mechanism

- Needed for individual nodes to agree on the valid transactions
- General problem: Decentralised nodes reaching a consensus
  - not a new problem in computer science
  - coined by later Turing-award winner Leslie Lamport in 1982 as '**Byzantine generals problem**'
  - several solutions exist for benevolent nodes that want to reach the "correct" consensus

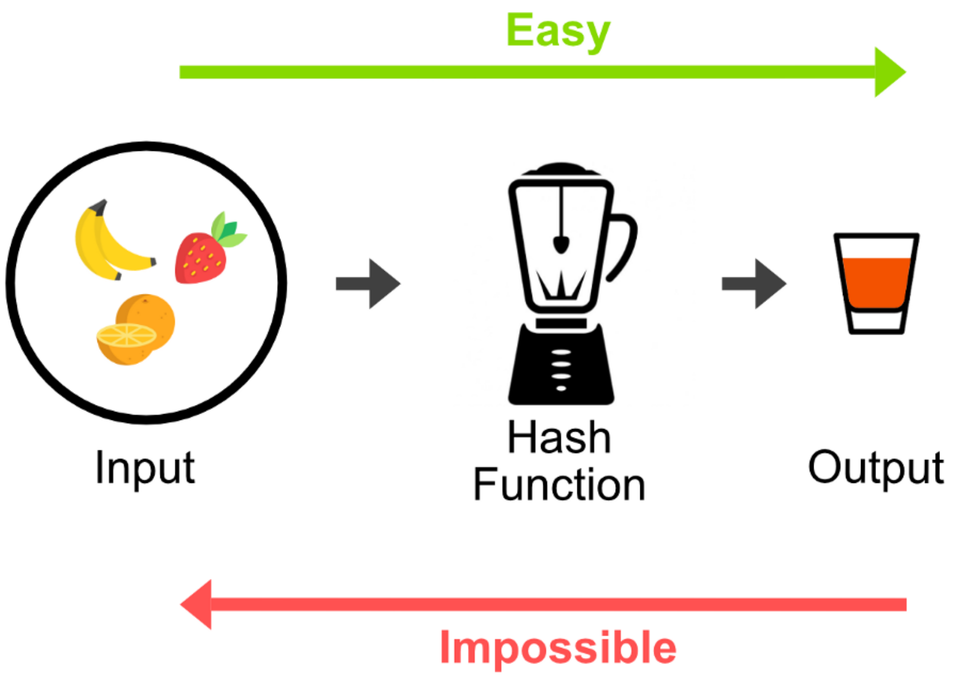


Sybil attack

- New solution needed for **malevolent nodes**
- Attacker manipulates outcome by creating a large number of nodes (pseudonyms)
  - all put forward the same result desired by the attacker
  - thus manipulating the outcome of the consensus mechanism
- In an open system w/o access restrictions
  - **participation** in the consensus **cannot be free**
  - **vote** needs to be **bound to a limited resource** coming at an expense
  - for Bitcoin (and later cryptocurrencies): **Proof-of-Work (PoW)**

Digression: One-way functions (& hashing functions)

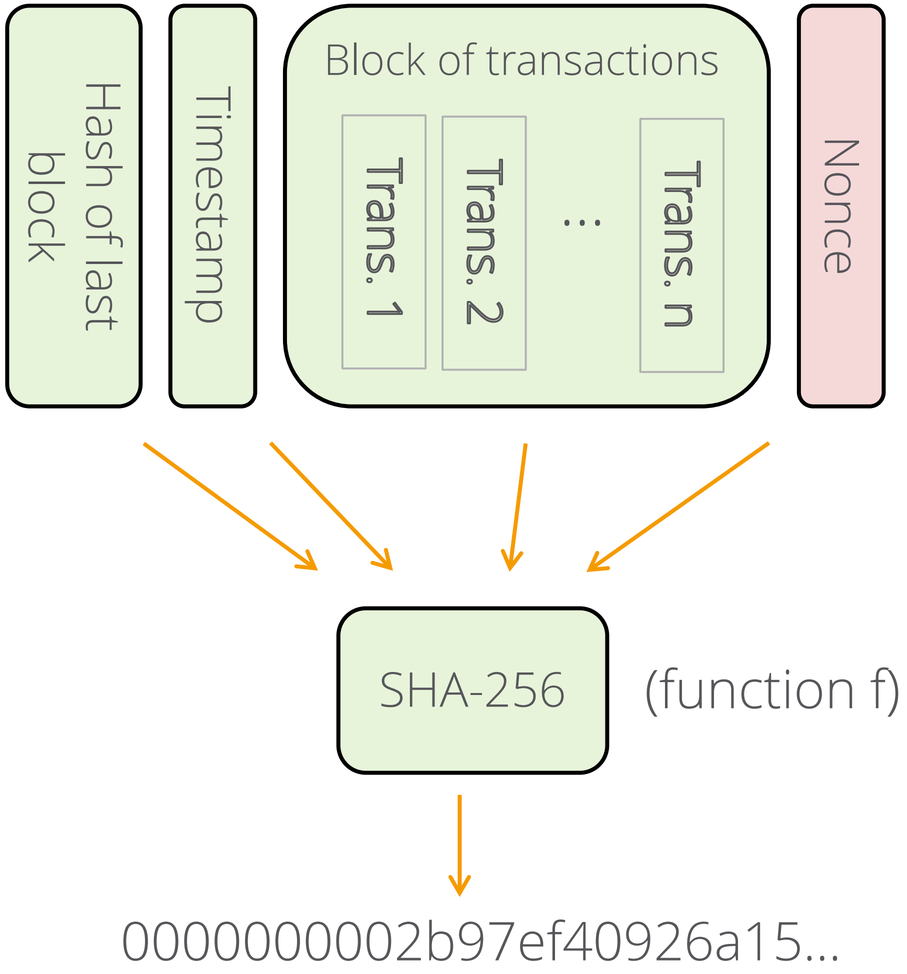
- Functions that are “fairly easy” to compute, but almost “very hard” to revert, i.e.,
  - f(X) = Y straightforward computation
  - f^{-1}(Y)= X not feasible with today’s computers
- Additionally, if f(X) = Y-1, f(X+1) != Y
  - reaching “close to Y” does not help in finding Y quicker
- Thus, the only way to reach the desired outcome is by trying time and again
  - concept known in cryptography as brute force
- Thus a good PoW mechanism



Source: Mr. MacKenty, https://computersciencewiki.org/index.php/File:One_way_function.png

Proof of Work (Bitcoin)

Searching for a puzzle-solving nonce



[256 bits represented by 64 hexadecimal characters]

Aim of the puzzle & work needed

- Aim: finding a result with a certain number of leading (hexadecimal) zeroes
  - amount of leading zeroes tuned so that a solution is found about every 10 minutes
  - the more nodes throw more computation at it, number will increase
- Likelihood: $1/16^N == 1/2^{4N}$
  - On average after $16^N == 2^{4N}$ tries (across all participating nodes)
- Currently: 20 leading zeroes
  - 2^{80} computations/hashes needed ==
  - 1'208'925'819'614'629'174'706’176 ==
  - over **1 septillion hashes** every 10 minutes

Incentivising nodes to partake in the consensus mechanism

- One-way hash function is fairly inexpensive (computationally and thus energetically)
  - it does, however, not come for free
  - and 1 septillion of them a fortiori not
- 2 types of rewards for successful node
  - *transaction fees*, from the accounts having transactions bundled in the new block
  - *block reward* from the system, newly minted BTCs

- Analogy: (search for successful nonce → new BTCs) and (digging → more gold)
  - nodes taking part thus often called **miners**
- Each new block links to the previous one
  - **Blockchain** (actually more complex Merkle tree)

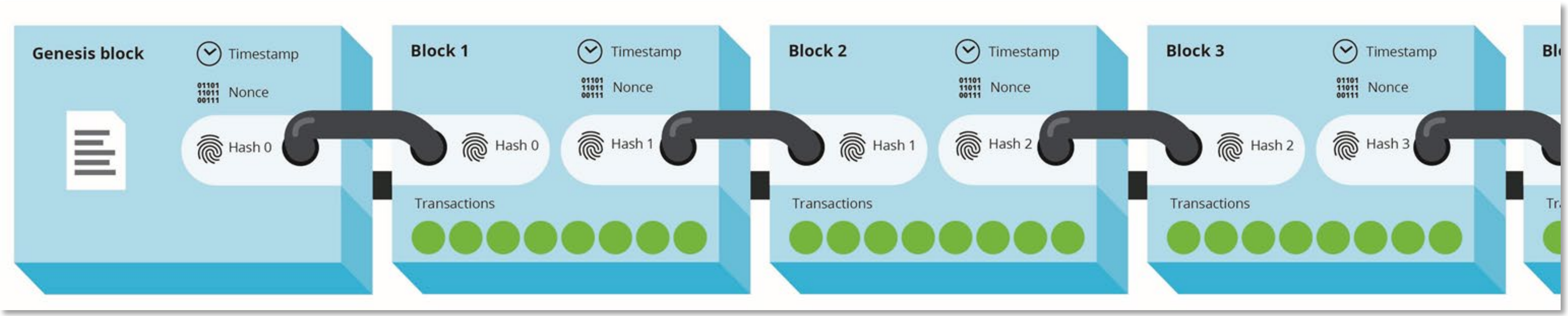


Image source: Swiss Foundation for Technology Assessment (TA-Swiss), illustration: Hannes Saxer

Technological background recap

- To **avoid multiple spending**, a digital currency
  - needs a **unanimously trusted ledger**
- For **scalability** and **open security** (as opposed to security through obscurity)
  - the ledger needs to be **open** and **distributed**
- An **open and distributed** ledger
  - needs a **consensus mechanism** for its transactions
- The open **consensus mechanism**
  - is prone to **Sybil attacks** by malevolent nodes
- To counter **Sybil attacks** (i.e., through massive, pseudonymous copies)
  - a **cost must be placed** on the participation in the consensus mechanism
- For Bitcoin (and other currencies) the **cost**
  - is represented by the computation (work) needed to **solve a cryptographic puzzle**
  - (hence, such digital currencies are called **cryptocurrencies**)
- To **incentivise nodes** to invest these costs
  - they **receive rewards**, esp. newly mined coins

Part 2: Bitcoin Energy Consumption

Storage
Communication
Computation/Proof-of-work

Three sources of energy consumption for a blockchain

A. *Storage* of the distributed VM (or distributed ledger)

B. *Communication* among nodes, which can be triggered by some or all of the following events:

   i. the *initial download* of the entire blockchain by a new node entering the system,

   ii. the *transactions* submitted by individual nodes, and

   iii. the *messages* of the consensus mechanism.

C. *Computation* triggered by the consensus mechanism, in particular PoW (if applicable)

A. Storage energy

$$E_{St}\left[\frac{kWh}{year}\right] = \#Repl_{Av} * BC_{St}\,[GB] * EI_{St}\left[\frac{kWh}{year * GB}\right]$$

Term	Meaning	Value April 2022 (approx.)
$\#Repl_{Av}$	average number of replicas (as weighted over the year)	~ 15k
BC_{St}	size of the stored blockchain (in GB)	~ 400GB
EI_{St}	average energy intensity of storing a unit of data (1 GB) for one year	0.008 – 0.66 kWh/(GB * year)

- Average energy intensity depends on the main storage medium; the two extremes being:
  - laptops/desktops dedicated exclusively: (30 W * 8760h/year) / 400GB = 0.66 kWh/(GB*year)
  - hyperscale data centres: 0.008 kWh/(GB*year)
- Range for result: **48 MWh – 4 GWh energy** (5.5 kW – 0.45 MW average power) (worst case: yearly production of one mid-sized on-shore wind turbine)

B. Communication power

$$P_C = \frac{Bl\ [GB] * \#Repl_{Av} * (EI_{WAN} + EI_{FAN}) \left[\frac{kWh}{GB}\right]}{t\ [h]}$$

Term	Meaning	Value April 2022 (approx.)
Bl	size of one block of transactions	1.25 MB == 0.00125 GB
$\#Repl_{Av}$	average number of replicas	~ 15k
EI_{WAN}	energy intensity of wide-area network	0.02 kWh/GB
EI_{WAN}	energy intensity of fixed access network	0.07 kWh/GB
t	average length of one period	600 s

- Counter of fraction represents energy to propagate a new block to all nodes
  - 1.7 kWh/period spent all 10 minutes on average → **average communication power = 10 kW**
- Yearly **communication energy: 88.7 MWh**

C. Computational power for the PoW mechanism

- Principle: As long as the expected gain is higher than the costs, it is reasonable
  - for participants to keep mining, or
  - to freshly join the mining community
- For each miner, the (variable) mining costs for one period are

price per hash

total energy per hash

$$C = \#H \left[\frac{\cancel{hash}}{period}\right] * EI_h \left[\frac{\cancel{J}}{\cancel{hash}}\right] * PUE * P_E \left[\frac{USD}{\cancel{J}}\right]$$

number of hashes the miner performs during that period

energy intensity of hashing

power usage effectiveness (of the mining premises)

price of electricity

Costs per miner per period

$$C = \#H \left[\frac{hash}{period}\right] * EI_h \left[\frac{J}{hash}\right] * PUE * P_E \left[\frac{USD}{J}\right]$$

- Equation can be rewritten to reflect the state-of-the-art of mining hardware
  - as speed of hashing operations (*hash rate*)
  - for that, first term (#hashes per period) can be expressed as:

$$C = t[s] * HR \left[\frac{hash}{s}\right] * EI_h \left[\frac{J}{hash}\right] * PUE * P_E \left[\frac{USD}{J}\right]$$

length of period

hash rate (hashes per second)

Expected revenue per miner per period

- Expected revenue equals the likelihood for miner to be successful times the total reward for successful mining

likelihood for individual miner

#hashes by individual miner

total reward: mined BTCs + transaction fees

$$E(R) = \frac{t[s] * HR\left[\frac{hash}{s}\right]}{2^{4N}\,[hash]} * (\#CC * P_{CC}[USD] + T[USD])$$

expected # of total hashes needed (all miners)

#BTCs awarded

BTC price

transaction fees

System equilibrium when expected revenue equals costs E(R) == C

$$\cancel{t * HR} * EI_h * PUE * P_E \quad = \frac{\cancel{t * HR}}{2^{4N}} * (\#CC * P_{CC} + T)$$

- Can be simplified to

$$EI_h * PUE * P_E \quad = \frac{(\#CC * P_{CC}) + T}{2^{4N}}$$

- The equilibrium energy intensity of a hashing operation can be derived by solving the identity:

$$EI_h = \frac{1}{2^{4N}} * \frac{(\#CC * P_{CC}) + T}{P_E * PUE}$$

- unsurprisingly, directly correlated to the reward expected, $(\#CC * \ P_{CC}) + T$
  - and thus essentially to the price of the cryptocurrency, P_{CC}
- inversely related to what makes mining more expensive
  - the (average) price of electricity P_E as well as the PUE, which stands for the “wasted” share of electricity
  - the complexity of the cryptographic puzzle (and thus the needed amount of hashing operations)

Deriving an upper bound for WW electricity consumption of PoW

- Using the EI_h estimate to compute an upper bound for the WW electricity consumption of PoW per block/period:

$$E_{PoW}(WW, one\ period)\left[\frac{J}{period}\right] = \#H\left[\frac{hash}{period}\right] * EI_h\left[\frac{J}{hash}\right] * PUE$$

- Knowing
  - the expected number of hashes during one period $\#H = 2^{4N}$, and
  - dividing by the average length of one period t,

yields an upper-bound for the WW power consumption used for PoW:

$$P_{PoW}(WW) = \frac{2^{4N} * EI_h * PUE}{t}$$

- Using the equilibrium (i.e., threshold) energy intensity EI_h as computed above, yields

$$P_{PoW} = \frac{2^{4N} * PUE}{t} * EI_h = \frac{\cancel{2^{4N}} * \cancel{PUE}}{t} * \frac{1}{\cancel{2^{4N}}} * \frac{(\#CC * P_{CC}) + T}{P_E * \cancel{PUE}} = \frac{(\#CC * P_{CC}) + T}{t * P_E}$$

Upper bound for WW electricity consumption of PoW

$$P_{PoW}(WW) = \frac{(\#CC * \ P_{CC}) + T}{t * P_E}$$

- Current Bitcoin data:
  - $\#CC = 6.25 * P_{CC} \sim 40k\ USD = 250k\ USD, T \sim 1500 \text{ transactions} * 2 \frac{\text{USD}}{\text{transaction}} = 3{,}000 \text{ USD}$
    (reward is thus around 250,000 USD)
  - $t = 600s,\ P_E = \frac{0.05USD}{kWh}$

$$P_{PoW}(WW) = \frac{250{,}000\ \cancel{USD}}{600\ s * 0.05 \frac{\cancel{USD}}{kWh}} = \frac{250{,}000}{30} \frac{kWh}{s}$$

- Given that $1\ kWh = 3{,}600\ "kWs"$, this results in

$$P_{PoW}(WW) = \frac{250{,}000 * 3{,}600}{30} \frac{kWs}{s} = (250{,}000 * 120)\ kW = \mathbf{30\ GW}$$

Interpretation of PoW power and energy

- Worst case WW power and yearly energy:

$$P_{PoW}(WW) = 30\ GW;\ E_{PoW}(WW) = 263\,\frac{TWh}{year}$$

- This **worst-case** figure amounts to
  - power production of 30 nuclear power plants
  - yearly electricity consumption of ~Spain, Australia, UK (top 11-20 WW)
  - almost Romania's entire (i.e., primary) energy consumption (370 TWh/year), and slightly more than Portugal's (259 TWh/year)
  - similar to the entire energy consumption of all (non-crypto) data centres WW: 200 – 400 TWh/year (Masanet et al. 2020 and Borderstep 2019, respectively)
  - around 1% of WW electricity usage

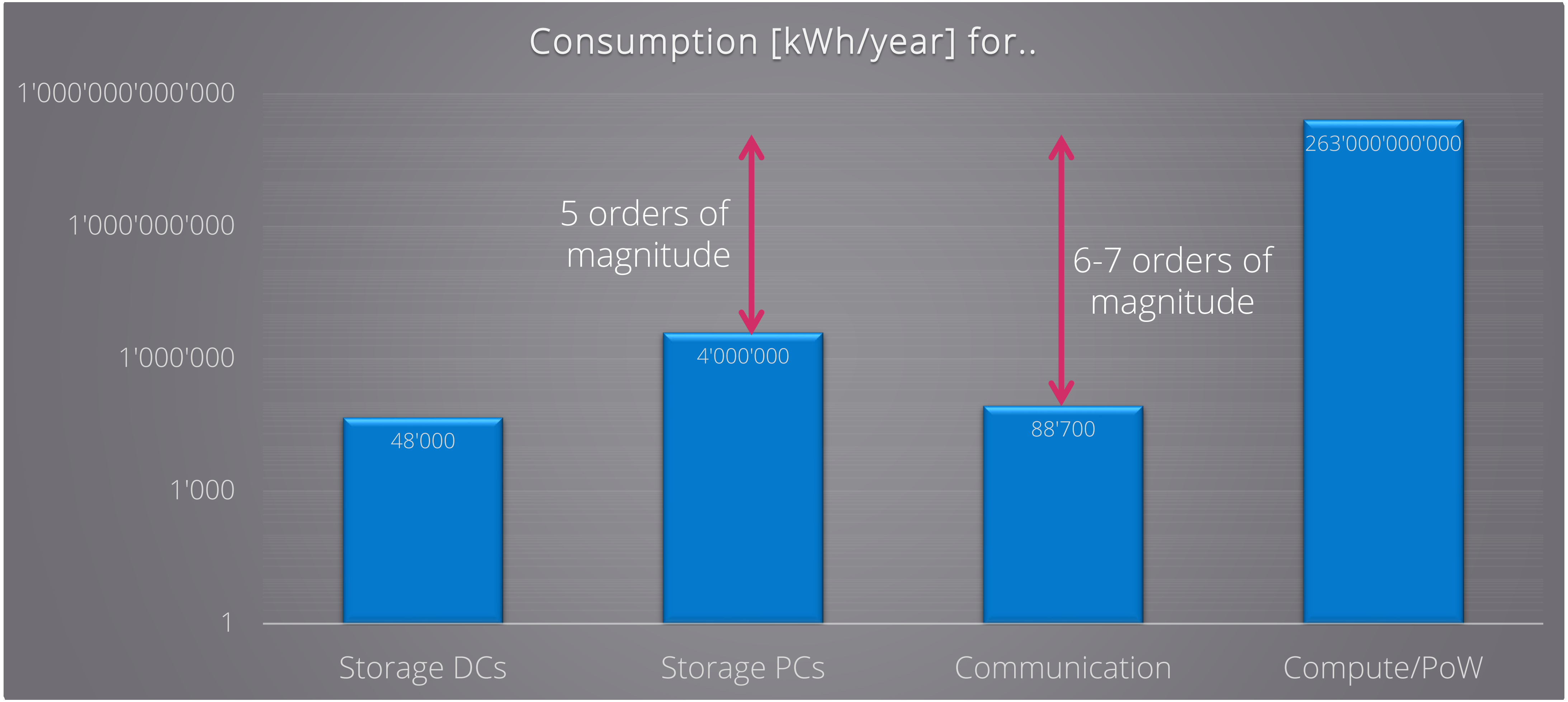
Comparison to related work (all TWh/year)

Period	Publication	Date	Lower bound	Expected	Upper bound
Earlier studies	(de Vries 2018)	May-18	22	67	78
	(Krause and Tolaymat 2018)	Nov-18		30	
	(Stoll et al. 2019)	Jul-19		46	
	(de Vries 2020)	Sep-19		87	
	(Bendiksen and Gibbons 2019)	Dec-19		61	
	(Sedlmeir et al. 2020)	Feb-20	60		125
Current studies	(Cambridge BECI 2021)	Apr-22	54	144	362
	(Digiconomist 2021)	Apr-22	61	204	
	this study	Apr-22			263

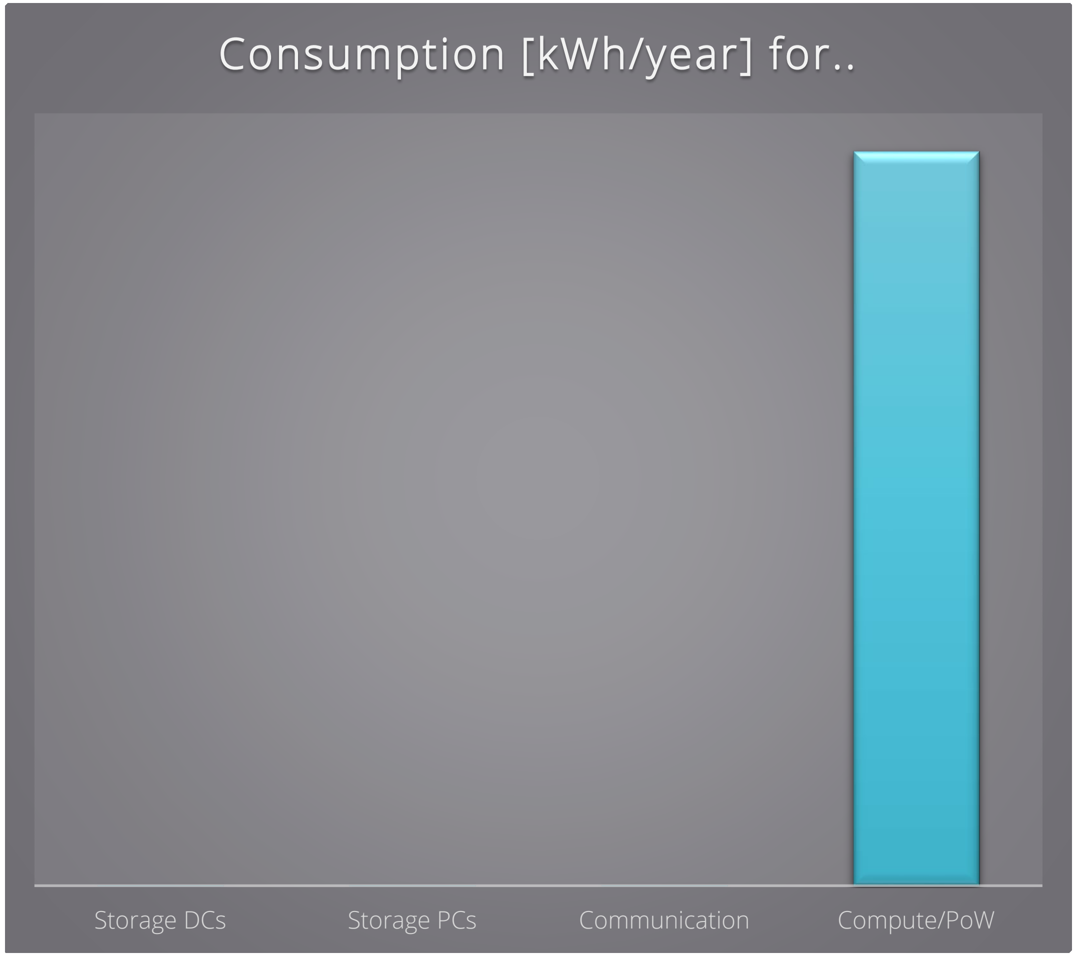
Part 3: Getting to Grips with the Consumption

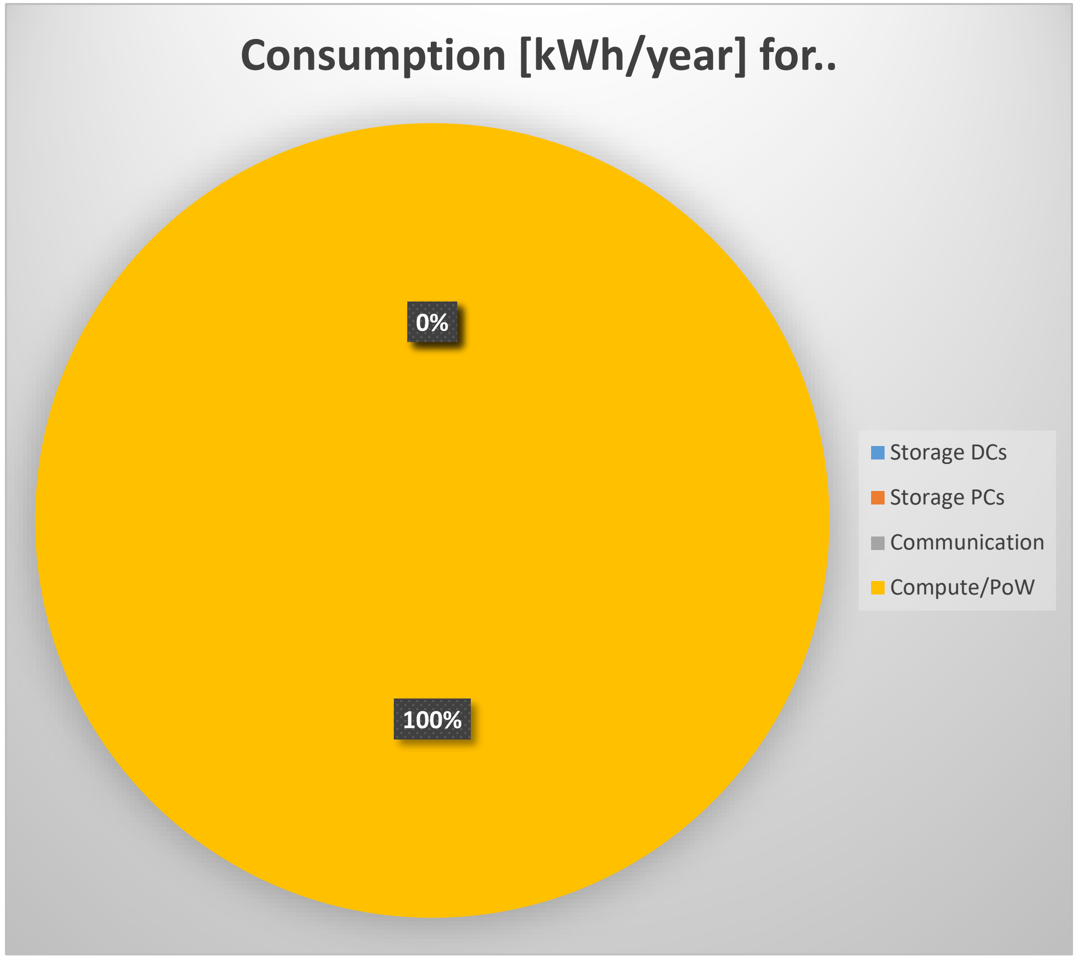
Natural limiting mechanisms?
Governmental and private policies
Weighting against benefits

Individual consumption for Blockchain components



How does this appear on linear (non-logarithmic) scales?





Mechanisms limiting the energy consumption of PoW?

mining reward [$]

$$P_{PoW}(WW) = \frac{(\#CC * P_{CC}) + T}{t * P_E}$$

price of electricity [$/kWh]

- Value entirely determined by
  - rewards value (mined coins and transaction fees) & price of electricity
- **No economic counteracting mechanism**
  - except, perhaps, indirectly (and very slowly) over an increasing electricity price
- **No technological mechanisms** either: Entirely **independent of mining hardware efficiency**
  - in the short run, more efficient HW represents competitive advantage, can pull total down from worst-case
  - in the long run, everyone switches to the more efficient HW, pushing total again towards worst-case
  - typical rebound effect
    (unfortunately, not the topic here, but essential concept in the context of digital efficiency)

Alternative consensus mechanisms

- Several alternative consensus mechanisms, chief among them "Proof-of-Stake" (PoS)
  - getting rid of the concept of miners entirely
  - owing blockchain's native cryptocurrency enables one to be validator
- Validators for each block randomly chosen
  - likelihood to be chosen proportional to stake
  - return on investment 2 – 18% of stake/year
  - Sybil attack would require >50% of stake
- Some cryptocurrencies already deploy PoS
  - e.g., EOS, Tezos, TRON
  - Ethereum is changing towards it (Eth. 2.0)

Platform	Global (kW)	Per transaction (kW h/tx)
Eth. 2.0↑	1010.6 – 30 887.5	0.000 09 – 0.002 86
Eth. 2.0↓	1010.6 – 30 887.5	0.018 23 – 0.557 13
Algorand	6.2 – 189.3	0.000 17 – 0.005 34
Cardano	16.3 – 497.2	0.012 39 – 0.378 54
Polkadot	1.6 – 49.9	0.003 78 – 0.115 56
Tezos	2.2 – 67.1	0.000 36 – 0.010 96
Hedera	3.5 – 6.9	0.000 02 – 0.000 04
Bitcoin	3 373 287.7 – 34 817 351.6	360.393 00 – 3691.407 00
VisaNet	22 387.1	0.003 58

↑ High throughput projection
↓ Low throughput projection

consensus mechanism needs a factor of 1000-3000 less energy, once PoS implemented (for similarly-sized blockchains)

Table: (Platt et al. 2021) The Energy Footprint of Blockchain Consensus Mechanisms Beyond Proof-of-Work, https://arxiv.org/abs/2109.03667

The most efficient policy interventions are those discouraging/banning PoW-based blockchains

Not only public policies, btw; companies have power (and thus responsibility) as well

euronews.next

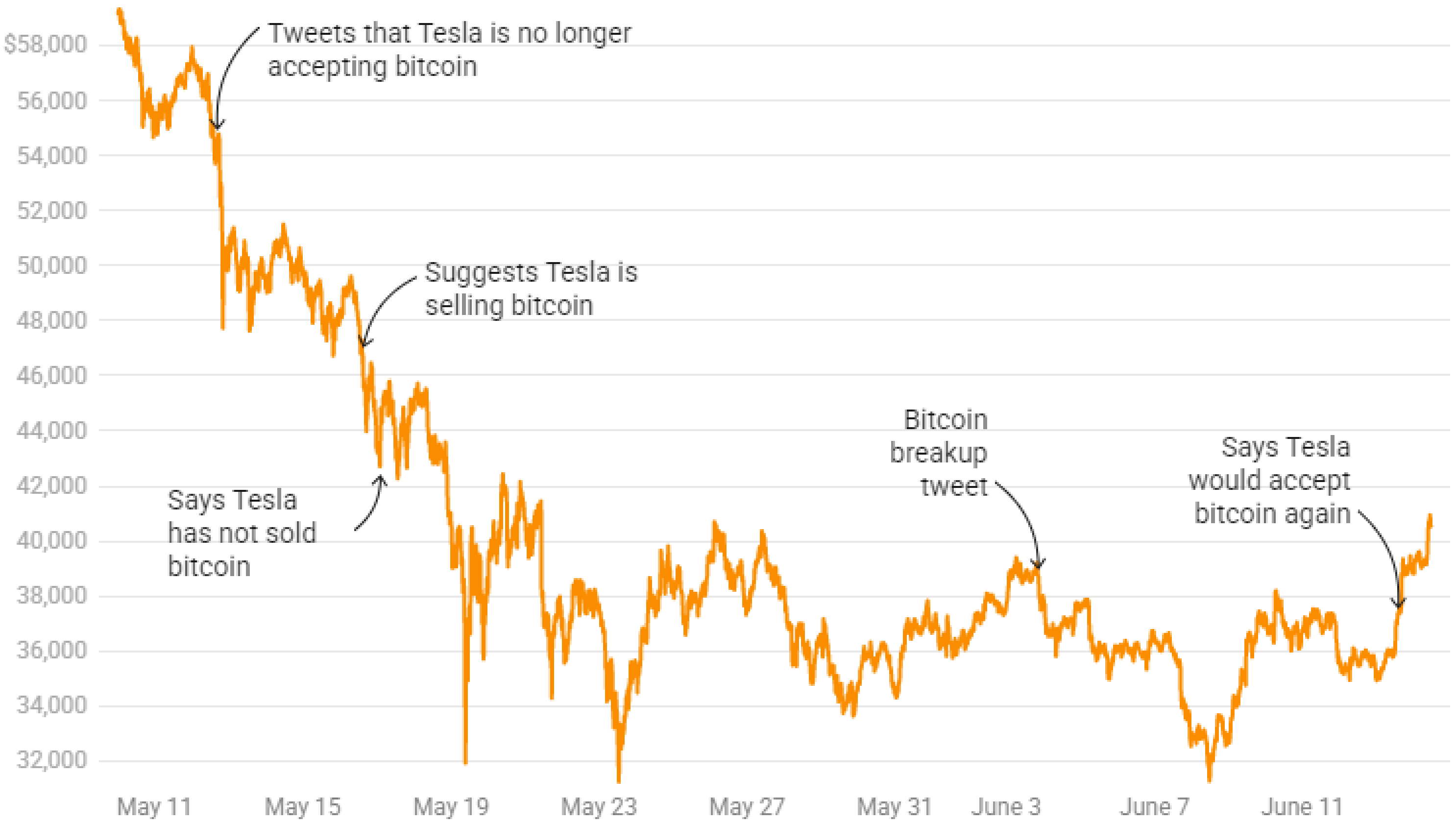
Europe rejects proposal limiting PoW cryptos such as Bitcoin but sets draft rules for sustainability

By **Pascale Davies** • 14/03/2022

Several EU parliamentarians have been pushing to ban PoW cryptos over energy concerns - Copyright cANVA

The European Union has rejected a proposed rule that could have banned the cryptocurrency Bitcoin across the bloc but set new draft rules to protect consumers and make mining more sustainable.

How Elon Musk's tweets have moved bitcoin prices



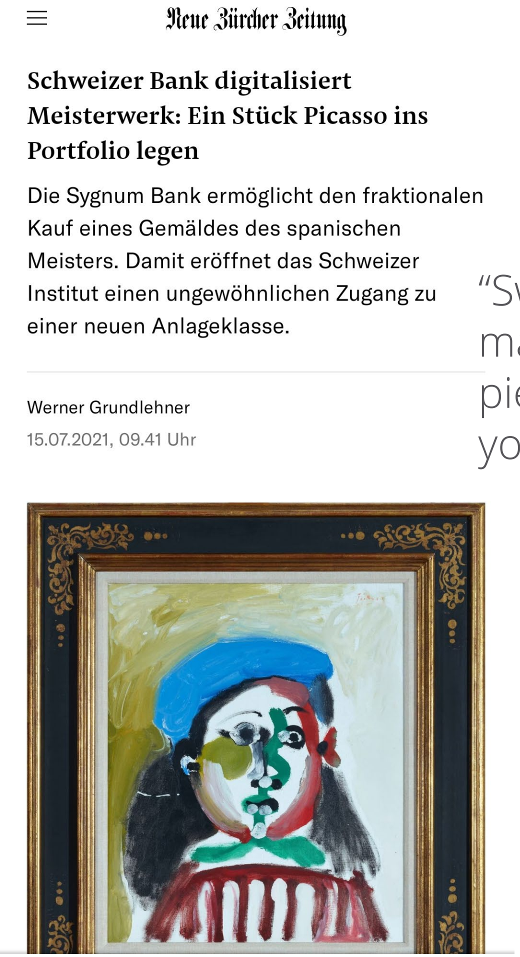
Source: Euronews

Source: https://www.vox.com/recode/2021/5/18/22441831/elon-musk-bitcoin-dogecoin-crypto-prices-tesla

Blockchain benefits – investment & inflation hedging

Cryptocurrency: Hedge against inflation

NFTs on digital & physical assets



Neue Zürcher Zeitung

Schweizer Bank digitalisiert Meisterwerk: Ein Stück Picasso ins Portfolio legen

Die Sygnum Bank ermöglicht den fraktionalen Kauf eines Gemäldes des spanischen Meisters. Damit eröffnet das Schweizer Institut einen ungewöhnlichen Zugang zu einer neuen Anlageklasse.

Werner Grundlehner

15.07.2021, 09.41 Uhr

"Swiss bank digitalises masterpiece – put a piece of Picasso in your portfolio."

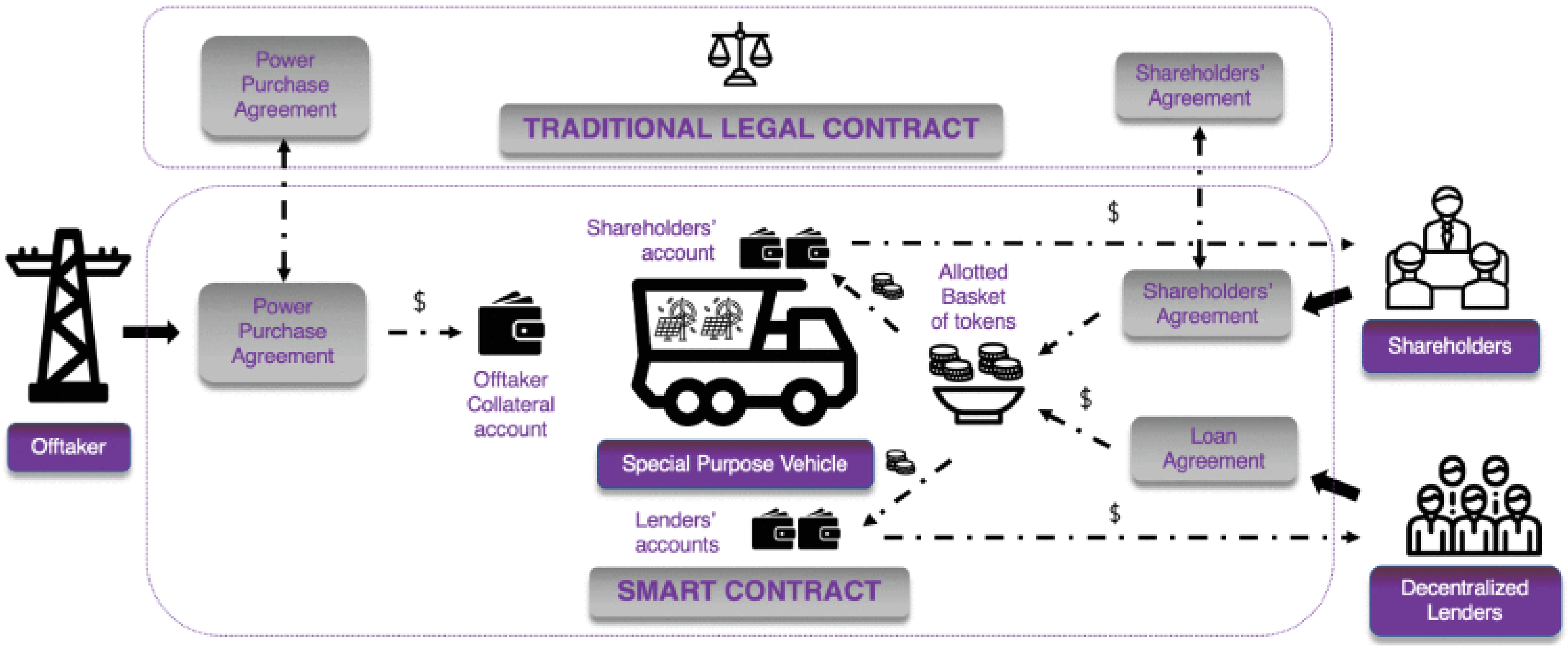
Image source: Reuters, https://www.reuters.com/article/uk-crypto-currencies-graphic-idUSKBN27Z2IG

Source: https://www.nzz.ch/finanzen/etwas-picasso-ins-portfolio-legen-ld.1635718

Blockchain benefits: Smart contracts &DeFi for development

Towards a Blockchain Special Purpose Vehicle for Financing Independent Renewable Electricity Projects in Sub-Saharan Africa

Olakunle Alao, *Member, IEEE* and Paul Cuffe, *Member, IEEE*



(Alao and Cuffe 2020) Towards a Blockchain Special Purpose Vehicle for Financing Independent Renewable Electricity Projects in Sub-Saharan Africa, ENERGYCon 2020

Q&A

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Department of the Environment, Transport, Energy and Communications DETEC

Swiss Federal Office of Energy SFOE
Energy Research and Cleantech Division

Final report dated 27 September 2021

Blockchain energy consumption

An exploratory study

Full study: https://www.aramis.admin.ch/Default?DocumentID=68053