International Telecommunication Union

ITU-T

Energy Efficiency in Blockchain Systems, AI and big-data

Leonidas Anthopoulos, co-chair FG-AI4EE WG2

Assessment and Measurement of the Environmental Efficiency of AI and Emerging Technologies Working Group Deliverables:

- **Guidelines on Energy Efficient Blockchain Systems**
- **Requirements on energy efficiency measurement models and the role of AI and big data**

International Telecommunication Union

International Telecommunication Union

ITU-T

PART I:

Guidelines on Energy Efficient Blockchain Systems

Assessment and Measurement of the Environmental Efficiency of AI and Emerging Technologies Working Group Deliverable

Leonidas Anthopoulos, co-chair FG-AI4EE WG2

Scope

- An overview of the energy demands of blockchain,
- The definition of blockchain energy model and of the energy efficiency parameters that can be calibrated in order to enhance energy efficiency.
- A literature analysis was followed to generate the understanding of the blockchain energy demands and how these can be optimized.

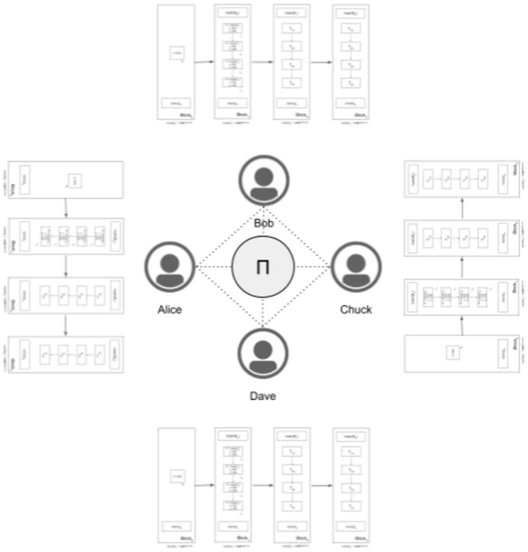
Deliverable Status: Recommendation ITU-T L.1317 (11/2021) under ITU-T Study Group 5

International Telecommunication Union

A birds-eye feet view of the blockchain architecture

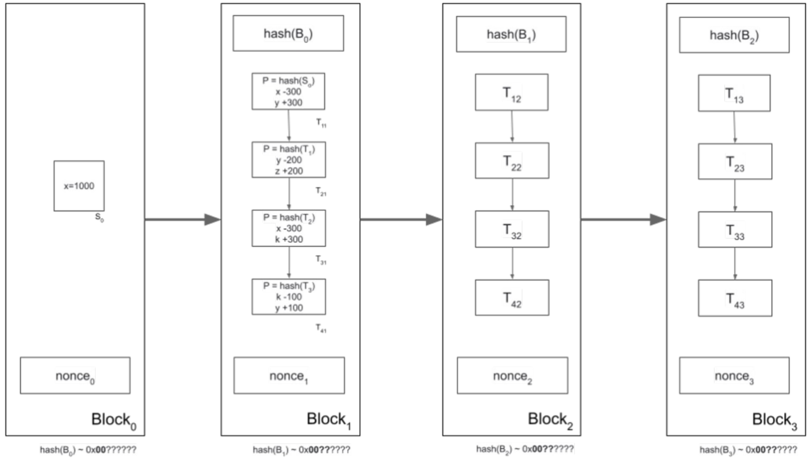
Blockchain

A mechanism to reach consensus among actors that have conflicting interests, without human intervention



Consensus

A single opinion of what happened, when it happened and what should have happened because of it



International Telecommunication Union

Solving multi-party contention without human intervention

The consensus mechanism is the primary factor that affects the energy consumption of a blockchain. The primary consensus mechanism families are:

energy consumption

Proof Of Work – PoW

The complete blockchain network is spending energy to

- confirm the transactions are valid
- solve a very hard cryptographic puzzle to make future modification of the transactions prohibitively expensive

Proof Of Stake - PoS

A subset of the blockchain network is spending energy to:

- confirm the transaction are valid

Proof Of Authority - PoA

A smaller subset of the blockchain network is spending energy to:

- confirm the transaction are valid

International Telecommunication Union

The cost of trust in a decentralized world

The energy consumption of PoW consensus is extremely higher than the others. The reason is that the energy cost is essentially what makes modification of previous transaction prohibitively expensive making them practically immutable

Any improvement of the operational efficiency of a PoW consensus blockchain will have eventually no effect on the cost of the total energy consumption as this is primarily controlled by the value of the assets stored on the blockchain.

The market dynamics incentivize the use of efficient hardware as this allows to be profitable even when the value of the blockchain assets decreases

The same dynamics incentivize the use of electricity sources with lower cost as this also allows to be profitable even when the value of the blockchain assets decreases.

Bounding the energy consumption of a PoW blockchain

$$\text{total power consumption} \geq \text{total hash rate} \times \text{min energy per hash} \qquad (1)$$

$$\text{total power consumption} = \frac{\text{block reward} \times \text{coin price} + \text{transaction fees}}{\text{avg. blocktime} \times \text{min. electricity price}} \qquad (2)$$

$$\begin{aligned}\text{total power consumption} \geq\ & \text{energy for transaction execution} \\ & + \text{energy for block production } (= \text{total hash rate} \times \text{min energy per hash}) \qquad (3)\end{aligned}$$

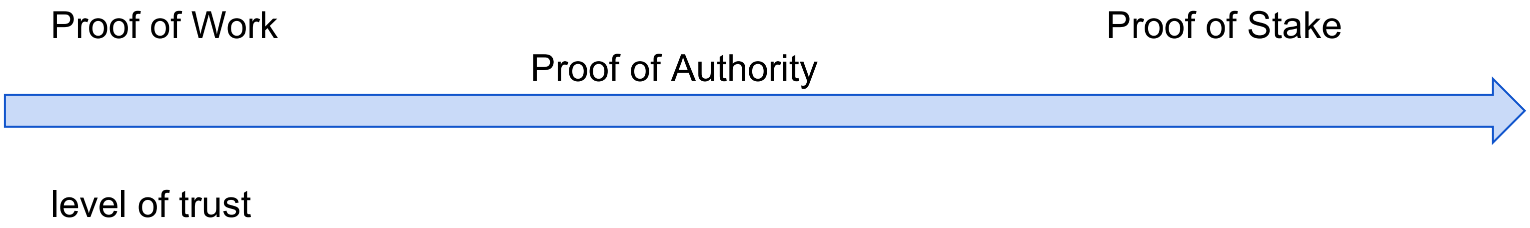
International Telecommunication Union

Balancing decentralization and efficiency

The energy consumption of PoS/PoA is primarily spent to validate that transactions are valid

Any improvement of the operational efficiency of a PoS/PoA consensus blockchain will have a positive effect on the cost of the total energy consumption as the cost of energy spent is not a factor of the consensus mechanism.

The choice between PoS and PoA has to do primarily with the level of trust among the blockchain users.



Conclusions

Choose the proper level of trust: as trust decreases, energy demand and cost increases. Literature evidence showed that PoA has minimum energy demand; PoW: has the maximum energy demand; and PoS is in between these choices

The needs for computational power of a PoW consensus blockchain is regulated by a few key parameters and **automatically increases the computational needs when an increase in efficiency is detected**

The choice of the hardware affects the energy efficiency. Market dynamics incentivize the use of efficient hardware in order to be profitable even when the value of the blockchain assets decreases

Proof of Stake consensus is a balanced choice in terms of trust and energy use

International Telecommunication Union

International Telecommunication Union

ITU-T

PART II:

Requirements on energy efficiency measurement models and the role of AI and big data

Assessment and Measurement of the Environmental Efficiency of AI and Emerging Technologies Working Group Deliverable

Leonidas Anthopoulos, co-chair FG-AI4EE WG2

International Telecommunication Union

Scope

Investigate the appropriate models to evaluate urban energy efficiency with a special focus on the emerging adoption of AI and big data

The emerging appearance of smart cities (SC) and of cutting-edge technologies (AI, big data, edge computing and cryptocurrency etc.) may not take sustainability into consideration during their development

Overview of existing evaluation metrics and methodologies for energy efficiency and the role of ICT - and in particular AI and big data-, based on a gap analysis of existing relative standards and on a detailed and systematic literature review on corresponding assessment models:

- resources: scientific databases (e.g., ScienceDirect, Scopus etc.)
- keywords: "energy efficiency" AND "assessment" AND "model" AND "big data" AND "AI“

Deliverable Status: Recommendation ITU-T L Suppl. 41 (05/2021) under ITU-T Study Group 5

Background

Energy efficiency measurement (i.e., from ITU-T L.1315)

$$EER = \frac{Energy_{output}}{Energy_{Input}} \qquad EER = \frac{Energy_{forUsefulWork}}{Energy_{TotallyUsed}}$$

By definition

$$EER = \frac{0.6*Tidle+0.3*Tlowpower+0.1*T \int maximum}{0.6*Pidle+0.3*Plowpower+0.1*P \int maximum}$$

Operating and idle times

$$EC_{MN} = \Sigma_i(\Sigma_k EC_{BS^{i,k}} + EC_{SI^i}) + \Sigma_j EC_{BH^j} + \Sigma_l EC_{RC^l}$$

Telecommunication network

$$PUE = \frac{E_{DC}}{E_{IT}}$$

power usage effectiveness in data center (PUE)

$$E_{DC} = \sum_{i,j} \frac{E_i}{\eta_j}$$

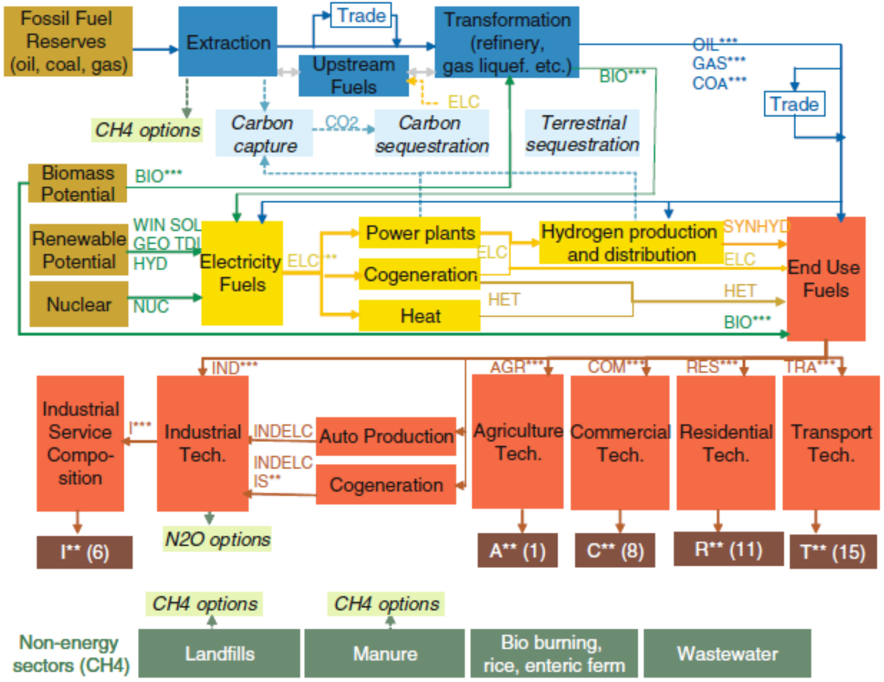
energy consumption of specific data center's points

City's energy system

$$SUM\{c \text{ in } cg2 \text{ of}: FLOW(r,v,t,p,c,s)\} =$$
$$= FLOFUNC(r,v,cg1,cg2,s) * SUM\{c \text{ within } cg1$$
$$\text{of}: COEFF(r,v,p,cg1,c,cg2,s)*FLOW(r,v,t,p,c,s)\}$$

Where:

- COEFF(r,v,p,cg1,c,cg2,s) respects the harmonization of different time-slice resolution of the flow variables.
- FLOW(r,v,t,p,c,s) expresses the quantity of commodity c consumed or produced by process p, in region r and period t (optionally with vintage v and time-slice s).



TIME's sketch for the energy flows within an energy system

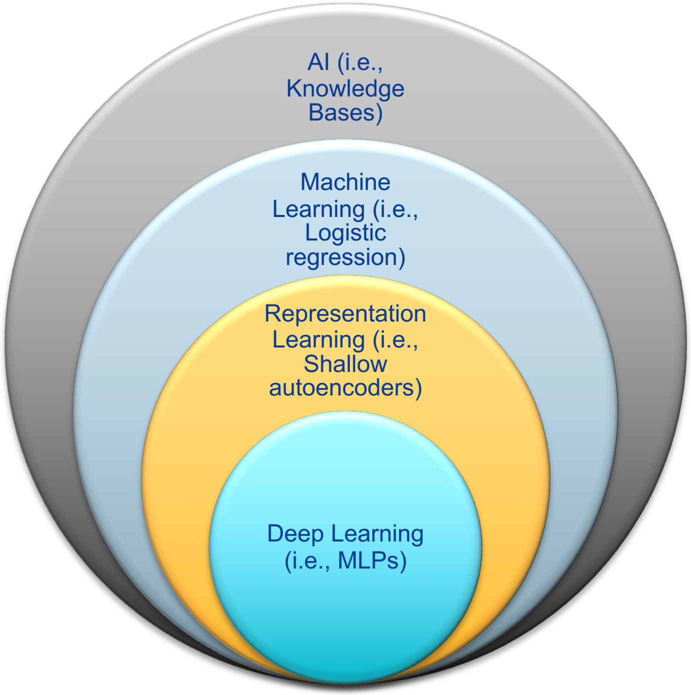
The Integrated MARKAL-EFOM System (TIMES)

International Telecommunication Union

AI energy demands

$$E_{AI} = \sum_{i=0}^{n} \int_{0}^{T} D_i(t)dt$$

Where:
total energy demand E_{AI}, is obtained by integrating power demand (D) over a specified time interval T



Venn diagram showing the AI category and subcategories

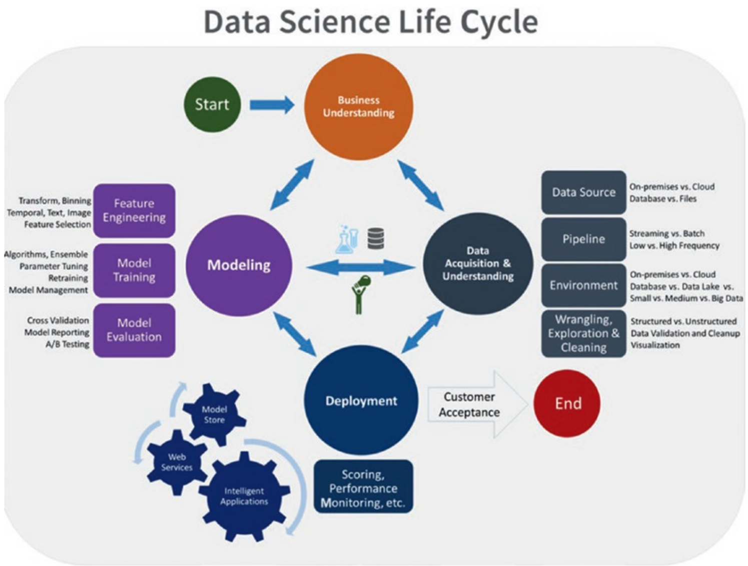
Bigdata Energy Demands

$$E_{data} = \int_0^T DC_i(t)dt + \int_0^T DT_{IoT(i)}(t)dt + \int_0^T DT_{mobile(i)}(t)dt + \int_0^T DT_{cable(i)}(t)dt + \int_0^T DT_{dataCenters(i)}(t)dt + \int_0^T DT_{cloud(i)}(t)dt + \int_0^T DP_i(t)dt$$

DC: the energy amount that is consumed for IoT device operation for data collection, during the T time interval.
DT: the energy amount that is consumed for network operation for data transmission, during the T time interval. This amount is analyzed in:

- DT_{IoT}: IoT network's operation demand for this transmission.
- DT_{mobile}: energy consumption of telecommunication equipment
- DT_{cable}: power usage for the cable network's operation for these transactions.
- $DT_{dataCenters}$: energy consumption of data cenetrs
- DT_{cloud}: transactions with clouds that the system requests.

DP: the energy amount that is consumed for facility's operation during data processing, during the T time interval



data science life-cycle

Methodology

Literature review:

“city” AND "energy efficiency" AND "assessment" AND "model" AND “bigdata AND “AI”

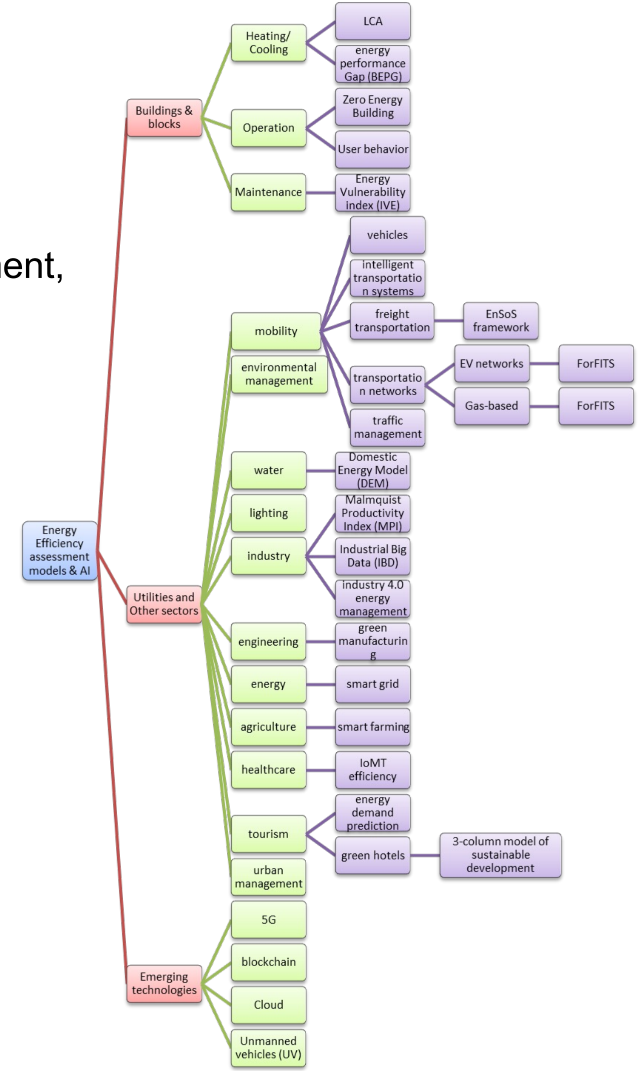
Source	Review Articles	Research Articles	After Screening
ScienceDirect	19	35	43
Scopus		3	2
Google Scholar	97	2,320	7

Deliverable Status: Recommendation ITU-T L Suppl. 41 (05/2021) under ITU-T Study Group 5

International Telecommunication Union

Taxonomy

Taxonomy for urban energy efficiency assessment, from AI and Big Data perspectives



Leonidas Anthopoulos,
Professor, University of Thessaly, Greece
co-chair FG-AI4EE WG2

Thank you.

Any questions?