GROUP ASSESSMENT ITEM COVER SHEET

Student Numbers:	Emails:	FIRST NAMES	FAMILY / LAST NAMES
3356495	c3356495@uon.edu.au	Oliver	Kellett
3330188	c3330188@uon.edu.au	David	Hastie
3329306	c3329306@uon.edu.au	Noah	Convery
3349828	c3349828@uon.edu.au	Harlan	De Jong
3355565	c3355565@uon.edu.au	Matan	Melamed

Course Code	Course Title
INFT3800	Professional Practice in IT
(Example) ABCD1234	*(Example)* Intro to University

Campus of Study: Callaghan (eg Callaghan, Ourimbah, Port Macquarie)

Assessment Item Title: Assessment 3 Group Project Due Date/Time: 20/05/22

Tutorial Group (If applicable): Word Count (If applicable):

Lecturer/Tutor Name: Teuku Geumpana

Extension Granted: ☐ Yes ☐ No Granted Until:

Please attach a copy of your extension approval

NB: STUDENTS MAY EXPECT THAT THIS ASSIGNMENT WILL BE RETURNED WITHIN 3 WEEKS OF THE DUE DATE OF SUBMISSION

Please tick box if applicable

☐ *Students within the Faculty of Business and Law, Faculty of Science, Faculty of Engineering and Built Environment and the School of Nursing and Midwifery:* We verify that we have completed the online Academic Integrity Module and adhered to its principles.

☐ *Students within the School of Education:* We understand that a minimum standard of correct referencing and academic literacy is required to pass all written assignments in the School of Education; and we have read and understood the School of Education *Course Outline Policy Supplement*, which includes important information related to assessment policies and procedures.

We declare that this assessment item is our own work unless otherwise acknowledged and is in accordance with the University's Student Academic Integrity Policy

We certify that this assessment item has not been submitted previously for academic credit in this or any other course. We certify that we have not given a copy or have shown a copy of this assessment item to another student enrolled in the course, other than members of this group.

We acknowledge that the assessor of this assignment may, for the purpose of assessing this assignment:

- Reproduce this assessment item and provide a copy to another member of the Faculty; and/or
- Communicate a copy of this assessment item to a plagiarism checking service (which may then retain a copy of the item on its database for the purpose of future plagiarism checking).
- Submit the assessment item to other forms of plagiarism checking.

We certify that any electronic version of this assessment item that we have submitted or will submit is identical to this paper version.

Turnitin ID:
(if applicable)

DATE STAMP HERE

Signature: Date: 19/05/22

Signature: Date:

Signature: Date:

Signature: Date:

Signature: Date:

Insert this way

2022

Sustainable Computing, its Purpose and Implementation

INFT3800

NOAH CONVERY, HARLAN DE JONG, DAVID HASTIE, OLIVER KELLETT, MATAN MELAMED

What is sustainable computing? Why do you need computing to be sustainable?

The term sustainable computing was formed by applying the concept of sustainability to computing. This can be achieved not just through making the hardware of computers more sustainable but through the software as well. Currently, we can limit the environmental impact hardware has through clever energy management and efficiency but reducing the impact of software is a bit harder. As future software is developed it is made to process bigger amounts of data meaning that the hardware must be more powerful to run the software thus creating a larger carbon footprint.

Computing is an essential task that is heavily used in the background of everyday life, take a smartphone for example. It is currently expected that by 2040 the information and communications sector will account for 14% of the world's carbon footprint (Harvard 2020), in 2016 it was estimated that road transport created 11.9% of the world's carbon footprint (Ritchie, H., & Roser, M. 2020). With the invention of electric cars, it is possible that computing will create more greenhouse gases than cars will. Therefore, we need computing to be sustainable, so that it has less of an impact on the environment as software gets more advanced and requires more power to run.

Will blockchain technology promote green computing?

To determine if blockchain technology will promote green computing we must first define blockchain. As a lead implementer of blockchains IBM (2022) provides the following definition:

> *A shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible (a house, car, cash, land) or intangible (intellectual property, patents, copyrights, branding).*

The keywords here are shared and immutable.
The ledger is shared, meaning all members of the blockchain network will have access to the data promptly with confidence the data is accurate.
The ledger is also immutable. No member can change or tamper with the data once it is recorded, this includes unintentional errors. This means data stays 100% accurate to what was originally recorded.

Blockchain promotes greater trust, efficiency, and security in the business world. Often systems for keeping records become vulnerable with the security of older systems becoming weak. Blockchain creates confidence that data will be accurate, through a consensus of data accuracy being required from all network members. These validated transactions are then immutable meaning no one can delete or tamper with records.
Along with security concerns, older data storage systems are becoming sluggish. With a rise in transaction volumes, blockchain elevates the workflow, removing reconciliations with its distributed ledger and applying smart contracts, programs stored on the blockchain used to automate the execution of an agreement, so all party members can be certain of the outcome without any time lost.

The blockchain, as the name implies, is a chain of blocks. The blocks represent data and are immutable, unable to be changed. But what prevents them from being changed? Each block in the chain contains data, the hash of the current block and the hash of its previous block. The data stored is based on the context of the transaction, for a cryptocurrency, this data could be sender-receiver and amount.
The block has a unique hash that identifies the block. This hash is calculated on block creation, therefore if the data is changed, the hash would be different. Finally, a block contains the hash of the previous block, this creates the security of the chain. If a block is changed and a new hash recalculated, the following blocks will point backwards to an invalid block which would expose the tampering. Making the chain invalid and rejecting the new altered block to the chain. To mitigate the

tampering and rehashing of all blocks after, which in some cases could be done quickly, blockchains implement a consensus method. This adds some difficulty when creating a block increasing security, in the case of bitcoin which uses a proof of work consensus method calculations must be completed to add the new block, which takes roughly 10 minutes.

Finally, blockchains are distributed and use peer-to-peer networking. When a party joins the blockchain they get a node (a full copy of the blockchain). When a new block is created, it is sent to everyone on the network, each node then verifies the block for tampering and when verified the block is added to their chain meaning nodes must agree on what is considered a valid block.

To answer if blockchain will promote green computing, multiple papers were referenced particularly to determine the environmental impact of cryptocurrencies. Truby et. Al. (2022) and Badea et. Al. (2021) both write about the environmental impact of bitcoin and agree on the negative impact it has. To determine the positive impacts of blockchain, we investigated case studies, often piolets of technology that could be expanded upon in the future. The World Wildlife Fund is one such company making use of blockchain for the benefit of the environment.

Blockchain technology sits in the middle ground of providing many use cases to benefit the environment, while currently, the most common use of blockchain is extremely unsustainable in the case of public blockchains used in cryptocurrencies and NFTs. Typically, the consensus method is the most environmentally impactful. In the case of the public blockchain bitcoin, proof of work calculations takes large amounts of computing resources to calculate and reward the calculator with a monetary reward to incentivize the interaction. This is what constitutes bitcoin mining. Using large amounts of computer resources requires a large amount of power, which when generated unsustainably, has negative impacts on the environment.
However, proof of work is not the only consensus method a public blockchain can use, there are currently 4 others, Proof of elapsed time, Proof of capacity, Proof of burn and more commonly, used by over 200 coins Proof of stake.
Proof of stake, used by the Solana coin creates a risk of loss, a portion of a miner's currency is deposited to gain the right to mine. When a block is added to the chain, one of these miners is randomly selected to validate the block, where, if they attempt to add a block of inaccurate information, they lose some of their initial deposit. This method doesn't require significant calculations like POW, creating security through a monetary input rather than time and resources, thus reducing electrical consumption. (Criticised for systemic inequities, as the people with the most coins get the most returns)

Despite the negative impacts of current Blockchains in the field of green computing, this emerging technology can revolutionise this field for the better, its inherent nature of being immutable and decentralised is fundamental for driving green solutions. Decentralising resources such as electricity to promote green renewable technology and tracking the process of resources, particularly food to guarantee its source is sustainable and organic, are two of the emerging fields in which Blockchain technology can promote green computing.

The fishing industry is one such industry where resources can be tracked on the blockchain. The World Wildlife Fund in partnership with Consensys, Traseable, and Sea Quest Fiji Ltd launched a pilot project that uses blockchain technology to allow consumers to trace the tuna they are consuming from catch to consumption. A paper published by the University of Wollongong outlines the importance of transparency particularly in the fishing industry, outlines that where supply chains are remote and complex with high rates of illegal and unethical activity. Visser et al. (2018) outlines the process as follows. Once caught, fish will be attached with RFID tags. During processing, docks and factories will detect these tags and upload the information to a blockchain. Later these RFID tags would be replaced with QR codes during packaging so users can see the journey the fish takes. By implementing this data on the blockchain users can be confident the collection and processing of the product are sustainable, ethical, and legal. This concept could be applied to many products where consumers would pay a premium to ensure they are ethically sustainable.

Another way Blockchain promotes green computing is that it can be used as the underlying technology for microgrids, which are self-sustainable, decentralised energy systems. Using Blockchain for microgrids would result in renewables becoming more accessible and affordable. Renewable energy would become more accessible as people within the microgrid would be able to sell their excess electricity directly to other members of their community, rather than to the local utility which currently occurs. Known as pair-to-pair (P2P) energy trading, this would be facilitated by Blockchain technology that would track energy certificates that record the amount of energy shared. The paper "Individual Green Certificates on Blockchain: A Simulation Approach" gives a detailed insight into the use of green certificates and finds that they improve the transparency of transactions and increase customer participation. More so, it is not uncommon for customers to value buying green renewable energy over saving money, however there is some uncertainty for customers as it cannot be guaranteed that the energy, they purchase is green. Energy generated under Blockchain has its origin, and type reported on immutable blocks that contain a publicly available transaction history, creating an increase in trust of this process being secure and correct. As it is also decentralised, there isn't a reliance on one single utility which increases its reliability. Thus, the increased accessibility of renewable energy will lessen the community's reliance on fossil fuels, all facilitated using Blockchain technology.

Furthermore, renewables would become cheaper as there would be no local utility dictating the prices. Blockchain would replace the current role of the local utility, resulting in reduced time for transactions, less labour, errors, and reduced costs. There would be less energy lost as a result of transmission, for reference an estimated 5% of energy created in the United States is wasted in transit, and prices would be also reduced due to not needing expensive network infrastructure.

A real-world example of Blockchain being utilised in a microgrid is with the Brooklyn microgrid in New York. This 3-month pilot project saw two neighbourhoods equipped with solar panels, with Blockchain technology used to facilitate peer-to-pair transactions whereby residents could sell excess energy to their neighbours. This process was automated by using Ethereum-based smart contracts, programs stored on a Blockchain, that are based on a pre-defined agreement between two parties. Residents would indicate their specific prices to buy and sell at. Smart metres installed at each resident's home would measure energy surplus and put this up on the marketplace for those prices. Homes that used more energy than they generated would buy from the marketplace if it matched their price point. These transactions would be securely and transparently stored on the Blockchain, recording the terms of the transaction, parties involved, and the energy transferred and consumed. The research paper "Blockchain technology in the energy sector: A systematic review of challenges and opportunities" explores this case study and highlights the "potential for decentralised matching between prosumers, enabling them to take real-time control of their own energy generation and supply". This case study highlights the benefits that Blockchain technology can have by facilitating a decentralised microgrid that rewards consumers for choosing green renewable energy.

Ultimately, the application of Blockchain as the underlying technology for microgrids would provide numerous benefits to consumers which would tilt them towards transitioning to cleaner green energy. From reduced prices by trading on a pair-to-pair basis, to a transparent, unmodifiable record of the energy's production, Blockchain technology would facilitate the adoption of microgrids and thus the rise of green, renewable energy.

What are the strategies to produce green software?

“Green Software” is software that is designed around the concept of energy efficient code, where computational efficiency must be balanced against energy expenditure. This is in contrast to typical software that would prioritise the computational power of code without much regard for its energy efficiency. In recent years software developers have pushed to standardise green software in an attempt to reduce the carbon footprint of the industry, making programming a more sustainable practice. Multiple studies have been conducted in search of methods to achieve this goal, the results of ``many leading to the development of standard practices for companies looking to “go green”.

Some of the primary strategies employed to achieve green software are:

Reduced Data Usage:

Storing and accessing data uses electricity, and almost every computing process involves moving data around. By limiting the amount of data being used, a software can substantially reduce its carbon emissions. As taking data from a cache is typically less power intensive (and more computationally efficient) than taking it from a primary storage device, proper management of cache memory can have a significant effect on a software’s power consumption. Along with limiting intra-system data transfer in general, to the bare minimum, (managing data life cycle, avoiding calling for the same data multiple times where possible, not calling for unused or redundant data) these methods are considered best practice data management for green software.

Data compression is also an effective means of carbon emission reduction. Using compressed images and sound files, where quality is negligible, is a very effective method, as it has only cosmetic downsides. For instance, while a large flatscreen TV may suffer from video image compression, the display on a typical smartphone is small enough that the difference between 720p and 1080p is almost unnoticeable. Data compression may also play a major role in wireless transmission: The MIT Laboratory for Computer Science released a study claiming that “wireless transmission of a bit can require over 1000 times more energy than a single 32-bit computation” leading to the conclusion that data compression before wireless transmission may in some cases be the most power efficient method.

Hardware-Adaptive Software:

Target hardware has a significant impact on the way software is developed. Not only is the software confined to a set of restraints unique to the hardware but finding the most efficient method (with respect to both power and computation) of implementing a code to meet software goals can be difficult. Even more so if the software must be able to run on different hardware configurations. There is no best practice for this issue, but it is one that must be considered when developing green software; only research and in some cases, even experimentation, can provide the optimum solution to a given scope.

Avoid Redundant Code:

While this principle is considered good coding practice in general, it is also important when developing green software. Code redundancy comes in many forms, one of the most common being the repetition of the same code within a document where a method/function could have been created and called instead. For example, if a particular while loop is used multiple times, one can instead write the loop once as a method and call that method instead. This will likely reduce the file size of the executable (and make the code clearer to other programmers), which as discussed earlier would ultimately reduce power usage.

Two other common inter-related issues are the existence of unused code and the execution of code that serves no purpose. Unused code may come in the form of a stray variable that is declared but never used elsewhere in the program to entire software features that aren’t used in the program, or at least not by the product consumer (such as testing code). Execution of useless code is very similar, for example a while loop that iterates more times than necessary or creating a method for a process that only occurs once.

These types of issues should be removed from the code as they waste computational power, and in turn require more energy to achieve the same result, reducing the energy efficiency of the software.

Balance of Functionality vs Consumption:

The most important aspect to consider when programming green software is the balance of functionality vs consumption. Developers must decide at what point they will begin sacrificing software functionality to reduce its carbon footprint. An excellent example of this issue is provided in an article by the Harvard Business Review: “The AI model achieved accuracy of 96.17% in classifying the flowers’ different species with only 964 joules of energy. The next 1.74%-point increase in accuracy required 2,815 joules of energy consumption. The last 0.08% incremental increase in accuracy took nearly 400% more energy than the first stage.” In the example, only minor improvements in functionality (in this case accuracy) came at the cost of a significant reduction in energy efficiency. Balancing the two factors isn’t always as “obvious” and finding the right combination will require experimentation with different methods. Likewise, any goals established for the software should be flexible to account for this uncertainty.

What are the advantages and disadvantages of developing green software?

Advantages

Environmental benefits - Intrinsically, green software is developed with the environmental effects in focus. The movement towards this software will act as a role in fighting the climate change and global warming battles with a head on approach. The high energy consumption of basic, non-green programs is a key factor to the increase of unnecessary emissions. By ensuring that all the developed software supports sustainable development through resources and waste reduction via software execution and engineering, a greener future is forecast.

Simpler Architecture - As green software attempts to achieve an output to a task in the most energy efficient way while reducing wastes, the same philosophy can be applied to the architecture. This means that green software tends to be much simpler in design as measures are taken into account to ensure no overcomplication. The effect of this is seen when sharing code/software with individuals and collaboration is made easier as the flow is straight-forward.

Long term cost saving - Due to the fact that a company using green software will produce less emissions with green software, it is noted that long term savings of this same code will follow. Although the upfront cost of developing such software may be high, after the initial investment cost savings will increase. The reason savings may occur long-term is because there will be much less time taken to perform maintenance on the simpler systems, easier reuse of existing code and lower power needs.

Faster processes - Aforementioned, the green software will be written upon simpler architecture and thus meaning the processes will be designed to deliver the payload as quickly as possible. This straight-forward approach will enable companies to spend less time waiting for processes to happen and move onto the next task rapidly. This can be especially important in time-critical software such as emergency services.

Company reputation - With the ever-growing rise of critical company reviews, it is important for all business owners to uphold a high reputation within the industry. If the general public sees that a company is investing in the environment, they may be more inclined to invest in the business and use their software. This type of movement will guarantee that they have an edge over the competitors.

Future developments towards green software - Following on from the previous point, as many companies will want to push towards green software for their reputation and the other benefits, this may cause an avalanche for all companies to join the movement. The effect of this will benefit business directly while also benefiting the environment, a win-win.

Disadvantages

More people are tasked with developing - As there will be a transition phase between current software systems to green software, there will also need to be transitions made for the developers. The current practices to develop green software will need to be altered in the fact that there will need to be more discussion on the efficacy and emission rates. This extra process of ensuring green software is actually green will require more individuals and thus more knowledge.

Higher initial cost - The process of switching from conventional IT systems to the updated, green systems and software will prove costly initially. This is due to the considered ‘unnecessary’ change and countering the argument - *don't fix what's not broken*. This higher cost is what many companies are faced with and ultimately determines whether the business will follow through with the green software transition.

Increased maintenance difficulty - Since this new age software is constantly evolving, there will need to be more maintenance and frequent updates to maintain both high security and efficiency. The knowledge of this type of software is lower as there is minimal documentation and thus the ability to maintain such a system is difficult.

Low adoption rate - For those that do not care about the environment will see no need in developing green software. The learning curve to develop such software may outweigh the positives for employees within a company. The acceptance rate for developing the new software will stem from higher up within a company and if there is no clear upside the development will never come to fruition.

Potential security issues - A lack of security may come as a by-product of developing green software as efficiency is thought of at a higher regard. The programmers will need to ensure that the safety standards of the system are met while also attempting to create the most environmentally conscious software. Furthermore, the rapid growth of green software will mean more corners may be cut for efficiency at the cost of security.

Conclusion

In the future sustainable and green computing will be an increasingly valuable asset in creating a cleaner future. Through clever use of blockchain technology with technology such as microgrids and the creation of more green software, sustainable computing will be achievable and will have a lasting effect on the size of the carbon footprint the technology sector will have.

References

How Green Is Your Software? (2020, September 18). Retrieved from Harvard Business Review website: https://hbr.org/2020/09/how-green-is-your-software

Ritchie, H., & Roser, M. (2020). *Emissions by sector*. Our World in Data. https://ourworldindata.org/emissions-by-sector

7 Advantages and Disadvantages of Green Computing | Drawbacks & Benefits of Green Computing. (n.d.). Retrieved from hitechwhizz website: https://www.hitechwhizz.com/2020/12/7-advantages-and-disadvantages-drawbacks-benefits-of-green-computing.html

What Is Green Software & How Can It Benefit Your Business? (2021, October 27). Retrieved May 20, 2022, from Zartis website: https://www.zartis.com/what-is-green-software-and-business-benefits/#:~:text=Green%20or%20sustainable%20software%20is

26 Major Pros & Cons Of Green Computing. (2020, June 2). Retrieved from E&C website: https://environmental-conscience.com/green-computing-pros-cons/

The Carbon Monkey. (n.d.). *Green Software Foundation*. Retrieved May 20, 2022, from https://greensoftware.foundation/articles/the-carbon-monkey

How Green Is Your Software? (2020, September 18). Retrieved from Harvard Business Review website: https://hbr.org/2020/09/how-green-is-your-software

Energy Aware Lossless Data Compression. (n.d.). Retrieved May 20, 2022, from usenix website: https://www.usenix.org/legacy/publications/library/proceedings/mobisys03/tech/full_papers/barr/barr_html/compression-mobisys2003.html

10 Recommendations for Green Software Development. (n.d.). *Green Software Foundation*. Retrieved from https://greensoftware.foundation/articles/10-recommendations-for-green-software-development

The Brooklyn microgrid: blockchain-enabled community power. (2017, April 11). Retrieved from Power Technology website: https://www.power-technology.com/analysis/featurethe-brooklyn-microgrid-blockchain-enabled-community-power-5783564/

Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., … Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renewable and Sustainable Energy Reviews*, *100*, 143–174. https://doi.org/10.1016/j.rser.2018.10.014

Parmentola, A., Petrillo, A., Tutore, I., & De Felice, F. (2021). Is blockchain able to enhance environmental sustainability? A systematic review and research agenda from the perspective of Sustainable Development Goals (SDGs). *Business Strategy and the Environment*, *31*(1). https://doi.org/10.1002/bse.2882

In battle against climate crisis, don't overlook the blockchain. (2022, January 25). Retrieved May 20, 2022, from UNEP website: https://www.unep.org/news-and-stories/story/battle-against-climate-crisis-dont-overlook-blockchain#:~:text=data%2C%E2%80%9D%20he%20added.-

Redding, H. (2018, March 26). How Blockchain Can Enable Real-Time Green Energy Transactions. Retrieved May 20, 2022, from RTInsights website: https://www.rtinsights.com/how-blockchain-can-enable-real-time-green-energy-transactions/#:~:text=Adding%20blockchain%20technology

Going Green by Combining Renewables and Blockchain. (2020, October 9). Retrieved May 20, 2022, from Manufacturing.net website: https://www.manufacturing.net/technology/blog/21197482/going-green-by-combining-renewables-and-blockchain

Truby, J., Brown, R. D., Dahdal, A., & Ibrahim, I. (2022). Blockchain, climate damage, and death: Policy interventions to reduce the carbon emissions, mortality, and net-zero implications of non-fungible tokens and Bitcoin. *Energy Research & Social Science*, *88*, 102499. https://doi.org/10.1016/j.erss.2022.102499

Badea, L., & Mungiu-Pupazan, M. C. (2021). The Economic and Environmental Impact of Bitcoin. *IEEE Access*, *9*, 48091–48104. https://doi.org/10.1109/access.2021.3068636

Visser, C., & Hanich, Q. (2018). How blockchain is strengthening tuna traceability to combat illegal fishing. *Faculty of Law, Humanities and the Arts - Papers (Archive)*, 1–4. Retrieved from https://ro.uow.edu.au/lhapapers/3359/

Types of Blockchain: PoW, PoS, Private, and DLT. (n.d.). Retrieved May 20, 2022, from Gemini website: https://www.gemini.com/cryptopedia/blockchain-types-pow-pos-private#section-private-and-consortium-blockchains

Kim, P. (2022, March 17). What are the environmental impacts of cryptocurrencies? Retrieved from Business Insider website: https://www.businessinsider.com/personal-finance/cryptocurrency-environmental-impact

Using Blockchain Technology in Environmental Conservation. (2022, February 28). Earth.org - Past | Present | Future. https://earth.org/using-blockchain-technology-in-environmental-conservation/`

IBM. (2022). What are smart contracts on blockchain? Retrieved from IBM website: https://www.ibm.com/topics/smart-contracts

What is Blockchain Technology? - IBM Blockchain | IBM. (n.d.). Retrieved from www.ibm.com website: https://www.ibm.com/topics/what-is-blockchain#:~:text=Blockchain%20defined%3A%20Blockchain%20is%20a

NFTs – are they bad for the environment? | Moulis Legal. (n.d.). Moulislegal.com. Retrieved May 20, 2022, from https://moulislegal.com/knowledge/nfts-are-they-bad-for-the-environment/