Green Architected Framework

A sustainability focussed reference architecture

Contributions

This Green Architected Framework is a result of a collaboration between multiple countries and organisations as a part of the Digital Government Exchange (DGX) – an initiative sponsored and coordinated by Singapore Government.

The contributing countries/organisations include:

- Singapore – GovTech Singapore
- Australia – Digital Transformation Agency

Individual working group members and direct contributors include:

- Andrew Morrison
- Hsiao Ming Chia

And their respective teams.

Last updated: 2nd October, 2024

Version: 610

Executive Summary

In 2023, the DGX Cloud Working Group reported on the landscape and approach of cloud adoption in government. Previous efforts to drive cloud adoption have been largely successful. 'Cloud first' is no longer the name of an infrastructure strategy – it is now the expected default approach in most government departments and agencies. Against the backdrop of this continuing trend, the DGX Cloud Working Group has come together, no longer asking what we should do to drive cloud adoption, but now investigating and reporting on how we might implement cloud technologies in the most sustainable way.

This paper builds on the work of the 2023 report. It presents a reference architecture for internationally sustainable cloud computing. Titled the "Green Architected Framework", it provides a framework for making sustainable decisions to invest in cloud solutions that enhance the environment, the economy, and the people who both operate and rely on these systems – at a national and an international level.

This framework brings the flexibility needed in an international context, by respecting the fact that different nations will have different priorities, when it comes to sustainability. This largely reflects the very real differences in the sustainability impact of various aspects across the globe – whether in power generation, economic strengths and weaknesses, or the peoples affected by these systems.

As ICT, digital, and cloud delivery continue to contribute to more international systems, we find that now is the time for greater consistency in our collective approach to sustainability. This document describes and details the Green Architected Framework, providing a detailed approach to the application of sustainability as a decision-making tool in the key areas of data and privacy, infrastructure, solutions and architecture, and procurement.

The accompanying presentation slide deck and spreadsheet show how to apply the Green Architected Framework in practice. The framework can be used directly as a tool for making sustainable architecture decisions about the adoption of cloud-based technologies. The framework can also be used as a visual comparison tool to communicate and compare sustainable architectures and landscapes across international borders.

Contents

Background

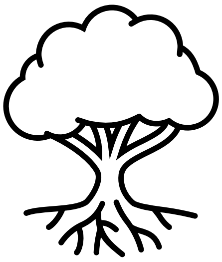
The need for this document emerged when considering a digital approach to government service delivery viewed through the lens of sustainability. Originally the working group tasked with this activity had a view to explore a matrix of considerations of how each individual contributing country had addressed the problems at hand.

It was quickly established that no single country or organisation had considered all the factors and provided advice on sustainability for government digital service delivery. As a result of this, the working group pivoted to creating a reference architecture in its place. Designed to synthesise the learnings from around the world and help inform stakeholders how to best contribute to the sustainability agenda.

Introduction

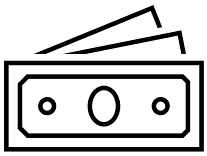
Sustainability is broadly categorised into three themes: environmental sustainability, economic sustainability, and social sustainability. Each theme presents distinct challenges and opportunities, and cloud computing can play a pivotal role in addressing these challenges.

Environmental Sustainability



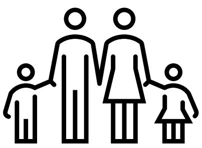
Environmental sustainability focuses on reducing the ecological impact of human activities. It involves minimising energy consumption, reducing carbon emissions, and promoting the use of renewable energy sources. Cloud computing can significantly contribute to environmental sustainability through optimised data centre operations, efficient resource management, and the use of green technologies.

Economic Sustainability

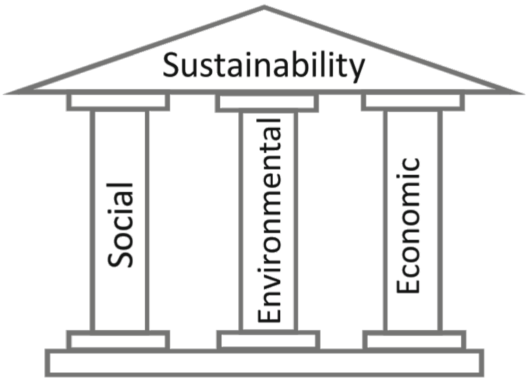


Economic sustainability involves managing resources to ensure long-term economic health and resilience. Cloud computing supports economic sustainability by reducing operational costs, improving efficiency, and fostering innovation. It enables governments to scale their IT resources dynamically, thus avoiding the need for substantial upfront investments.

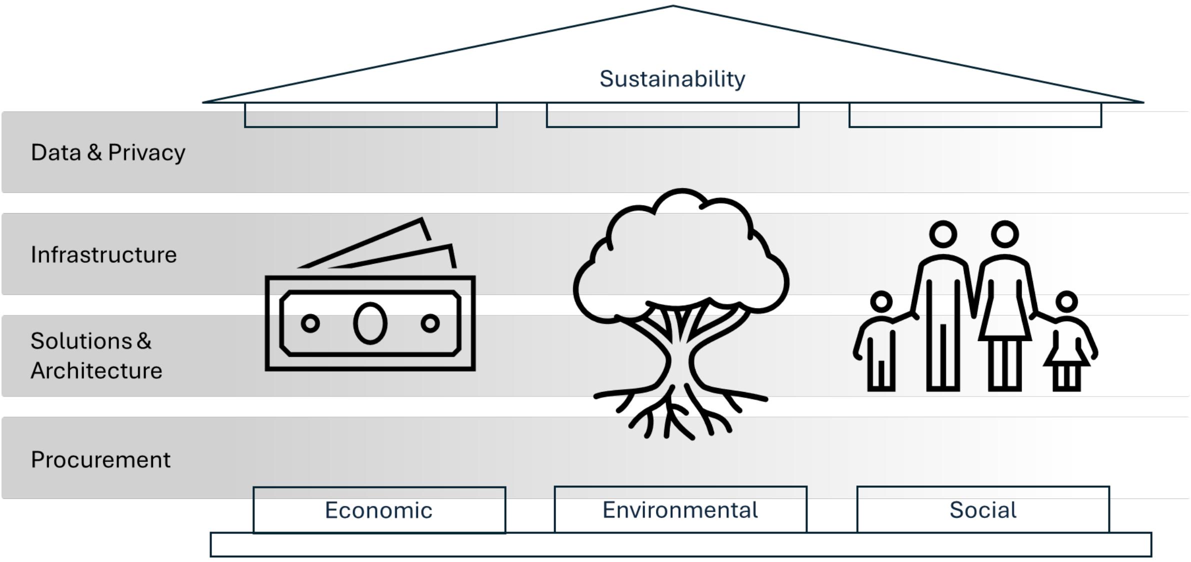
Social Sustainability



Social sustainability aims to enhance the well-being of current and future generations. It includes promoting digital inclusion, improving access to services, and supporting transparent and equitable governance. Cloud computing can enhance social sustainability by providing scalable and accessible platforms for delivering public services and facilitating citizen engagement.



(Purvis, Mao, & Robinson, 2018)



Principles of the Green Architected Framework

In reading and applying the Green Architected Framework, it is useful to refer to the following principles. These principles provide context for the rest of the framework and will help to explain and inform the application of the framework to organisational decision making. The principles are:

- The Relativity Principle
- The International Principle
- The Cost-Benefit Principle

The first principle of the framework follows directly from the preceding sections' discussion of what sustainability is: sustainability is multi-faceted, and there is never a "clearly right answer" to what technology choices should be taken.

Relativity Principle: *Improvements in sustainability are best realised by improving decision-making processes, ensuring that investment and technology decisions are appropriately informed by various specific sustainability considerations. In this way, while there is no one "right answer", it is yet possible to make the "right decision", and to improve sustainability over time.*

This framework acknowledges the differences in the sustainability landscape across the various nations represented by the Cloud Working Group, and by the Digital Government Exchange.

International Principle: *There is no one-size-fits-all solution, or rating, that can cover sustainability for all nations. Effective application of the Green Architected Framework therefore necessitates that each country aims for consistency in approach and methodology, informing decisions based on similar considerations, and acknowledging that this might lead to different outcomes in different countries.*

Sustainability should not be seen as a goal *in addition to* other things we might hope to achieve with our technology solutions. Rather, sustainability is a lens through which we can see *whether* we are really achieving what we seek to achieve in the long term. That is, sustainability allows us to see more detail of the true costs and benefits of our decisions, where we might otherwise be inclined to over-simply them – for example, by focusing only on financial cost, or just the benefits of speedy delivery.

Cost-Benefit Principle: *To make well-informed decisions about the true value of an investment, sustainability should be incorporated by including the sustainability impacts to the overall risk, value, cost and effort (RVCE). By doing this, we avoid the trap of positioning sustainability as a more complex alternative to a cheaper option, and instead recognise sustainability as a mindset to make well-rounded decisions for the long term.*

The Risk, Cost, Value and Effort (RCVE) Tool

The following sections dive deeper into specific technologies, sustainability patterns, global initiatives, emerging technologies and development practices. These sections provide breadth and depth to the Green Architected Framework and can be used to surface qualitative data for use in the RCVE Tool. For more information about the RCVE Tool, see the Appendix.

Data & Privacy

Data and privacy are crucial for social sustainability in the public sector. The public expects personal information collected by the Government and other organisations to be kept safe and secure by appropriate and enforceable protections. They can create trust, security, and empowerment for citizens and business - but they also face risks like data breaches, cyberattacks, surveillance, and discrimination.

> *The public expects personal information collected by the Government and other organisations to be kept safe and secure by appropriate and enforceable protections. Privacy and cyber security breaches damage trust that organisations... can adequately manage and secure personal information.* (Australian Government, 2023)

These risks are increased by cloud computing, which uses data across different locations and devices. Therefore, data and privacy protection and ethics are vital for sustainable cloud computing in government.

The volume or payload of each transaction should be considered also, with minimal changes or reductions in size having exponential impacts on economic sustainability both in terms of bandwidth requirements, and processing or compute expectations.

Patterns to Consider

Data Minimisation and Efficiency: Implement data minimisation practices to reduce storage needs and energy consumption. The amount of data, including its granularity, should be limited to the minimum necessary. Data use should be monitored to ensure that it does not exceed the legitimate needs of its use. (United Nations Development Group, 2017)

Privacy by Design: "Privacy by design" is an approach that integrates strong privacy protocols into the design specifications of technologies, operational practices, and infrastructures. It involves incorporating privacy considerations into the architecture and design of new systems and processes from the outset. Proactively managing privacy risks is more effective and efficient (supporting economic sustainability also) than making retrospective changes to a product or service when privacy concerns arise. To effectively embed privacy, it's essential to comprehend the potential privacy impacts.

Data Sovereignty: Ensure data is stored and processed within jurisdictions with strong privacy regulations. This is important to protect the privacy and security of the users and their data, as well as to comply with the relevant laws and regulations of different countries.

- When considered from the prospective threats of climate change, data sovereignty can have profound outcomes in supporting and protecting cultures and nations. In the case of Tuvalu, work has commenced to ensure as a nation its existence as a sovereign state continues even if its physical territory is impacted by rising sea levels. (Government, n.d.)

- Data sovereignty also forms an important role in supporting Indigenous Data Sovereignty agenda. Indigenous Data Sovereignty is defined as the right of Indigenous Peoples to own, control, access and possess data that derive from them, and which pertain to their members, knowledge systems, customs or territories. (The Indigenous World 2021: Indigenous Data Sovereignty, 2021)
- Consider how to leverage geo-fencing technologies to ensure data remains within national borders, establish regular security audits compliant with local regulations and implement encryption standards that meet or exceed national requirements.

Global Initiatives (Data & Privacy)

Initiative	**Country**	**Policy/Agenda**
GDPR	European Union	General Data Protection Regulation
MyData Initiative	Finland	Human-centric approach to personal data management
Singapore Data Protection	Singapore	Personal Data Protection Act (PDPA)
Consumer Data Right	Australia	Australian Consumer Data Right
California Consumer Privacy Act	State of California (USA)	California Consumer Privacy Act
Tuvalu Digital Nation	Tuvalu	Tuvalu | The first digital nation
Framework for Governance of Indigenous Data (GID)	Australia	Framework for Governance of Indigenous Data (GID) | NIAA

Emerging Technology Considerations

- **High-energy microprocessors should be used sparingly, with preference given to energy-efficient alternatives. Facial recognition technology** can lead to false negatives, bias and discrimination… and misuse of this biometric data can have grave consequences such as identity fraud or impersonation. (European Data Protection Board, 2024)

- Privacy and security should be fundamental considerations in **AI development**, emphasising data minimisation, anonymisation, and strict access controls. It's crucial to establish efficient processes for data deletion upon user request and to carefully vet third-party data sources for proper consent. Regular auditing of data access and minimising data collection by testing algorithms with reduced datasets are also essential practices. The goal is to strike a balance between leveraging data for AI advancements and safeguarding user privacy, recognising that more data is not always the best solution, and that privacy protection should be at the forefront of AI development. (Gravrock, 2022)

- Renewable-energy powered data centres should be prioritised to minimise environmental impact.

Sustainable Software Development Practices

- Adopt green coding and data handling practices to enhance the efficiency of software applications. This includes optimising code to reduce bloat, implementing data caching to avoid frequent database lookups and enabling compression to reduce bandwidth required for network traffic.
- Communication in digital systems, both internal and external, is a major energy consumer. For large-scale applications, even small reductions in data transfer can lead to significant energy savings.

  Consider a single government digital service processing 150 million transactions annually. Cutting just 1mb from its communication payload per transaction could reduce the services' greenhouse gas emissions by approximately 4 metric tons per year. This energy saving is equivalent to powering an electric car for a 365-kilometre journey or running a washing machine for four months. (Herring, Malmsten, Sporleder, & Srinidhi, 2022)
- Implement continuous integration and deployment (CI/CD) pipelines that emphasise energy-efficient testing and deployment strategies. Measurement tools can be incorporated as part of a CI/CD pipeline to track and measure the carbon footprint of code as the system is developed.

Infrastructure

Infrastructure is the term we use to describe the physical and virtual components that make digital services possible for government. It includes everything from hardware and software to networks and cloud platforms. But infrastructure is not just a technical matter – with environmental implications, consuming energy, producing emissions – an overall impact to natural resources.

Patterns to Consider

Energy-efficient Data Centres: Utilise data centres powered by renewable energy sources and/or who offer green compute options.

- Energy-efficient data centres leverage advanced cooling systems, power management, and server virtualisation to maximise resource utilisation. By adopting green practices, data centres not only minimize their environmental footprint but also contribute to social sustainability by reducing strain on power grids and fostering innovation in clean tech. (Whitehead, Andrews, Shah, & Maidment, 2014)

Server Compute Virtualization: Implement server virtualization to optimize resource use and reduce energy consumption.

- Compute virtualisation is a game-changer in the infrastructure sphere, enabling better resource utilisation and flexibility. By creating multiple virtual machines on a single physical server, it significantly boosts hardware efficiency, slashes energy consumption, and cuts down on e-waste.

Edge Computing: Deploy edge computing to reduce latency and energy use by processing data closer to the source.

- Edge computing is becoming increasingly relevant in developing nations as it offers a way to process data closer to its source, reducing latency and bandwidth usage. This is particularly important in areas with limited or unreliable internet infrastructure. As developing countries seek to modernize their digital ecosystems, edge computing can provide a more cost-effective and efficient alternative to relying solely on distant cloud data centres.
- However, this trend also raises questions about data sovereignty and the influence of global hyperscalers. While edge computing can enable more localised control over data processing, developing nations must still navigate complex relationships with major cloud providers to balance the benefits of advanced technologies with the desire for digital autonomy and data protection.

Global Initiatives (Infrastructure)

Initiative	Country	Policy/Agenda
Renewable Energy Directive	European Union	Directive on the promotion of renewable energy
National Renewable Energy	Australia	Renewable Energy Target (RET)
Green Data Centre Initiative	Singapore	Infocomm Media Development Authority (IMDA)
NABERS Energy for Data Centre Rules	Australia	NABERS for Data Centres

Emerging Technology Considerations

- Invest in advanced cooling technologies such as liquid cooling to reduce the energy required for data centre operations.
- Explore quantum computing for future infrastructure efficiency.

Sustainable Software Development Practices

- Optimise software to run efficiently on virtualised and edge computing environments.
- Where possible, select energy-efficient compute instances (e.g. ARM-based instances) which require less power than other CPU types
- Adopt automatic or scheduled scaling on to reduce resource wastage during off-peak periods
- Monitor and periodically review cloud subscription to eliminate unused resources to save costs and reduce energy wastage. Consider the role of FinOps in your Cloud and Hyperscale management.
- Encourage the use of serverless architectures to minimise idle resource consumption.

Solutions & Architecture

Solutions & Architecture is the practice of designing and implementing systems that use technology to help to achieve outcomes. It involves applying patterns and designs that suit the problem domain, the requirements, and the constraints of the environment. Solutions and Architecture also considers how well the systems work, and how they comply with the rules and standards that apply in our context.

Patterns to Consider

Microservices Architecture: Adopt microservices where appropriate to improve efficiency at scale. Note that poorly designed or unnecessary use of microservices is an anti-pattern and may result in greater energy use, scalability and resource efficiency.

- To avoid anti-patterns that undermine the benefits of a Microservices Architecture, ensure from the outset that system complexity is thoroughly assessed from the outset with robust monitoring and observability tools available from the start. Without regular architecture reviews, systems can readily sprawl with a proliferation of unnecessary services.
- On the positive side, it provides detailed scalability that can decrease energy consumption and offers technological adaptability, enhancing cost efficiency and innovation. It improves system robustness and ease of maintenance, essential for the sustained reliability of government digital services.

Containerisation: Use containerisation to ensure efficient application deployment, management, and scaling.

- Containerisation can be particularly beneficial for government services that need to maintain multiple environments (e.g., development, testing, production) or need to scale rapidly. It can also facilitate easier migration between cloud providers or to hybrid cloud setups, which may be important for data sovereignty reasons.

Serverless: Incorporate serverless technologies for fast and efficient dynamic scaling without worrying about provisioning compute resources.

- Serverless can be particularly useful for government services with unpredictable or highly variable loads, such as tax filing systems or emergency response applications. However, data sovereignty concerns might limit its applicability in some cases, so careful consideration is needed.
- Consider your multi-cloud strategy to mitigate vendor lock in as many serverless offerings can be CSP specific.

Global Initiatives Table (Solutions & Architecture)

Initiative	**Country**	**Policy/Agenda**
Digital Strategy	Germany	Strategy for digital transformation and sustainability
Smart Nation Initiative	Singapore	Sustainable smart city technologies
AI in Government	Australia	Artificial intelligence in government
AI Ethics Principles	Australia	Australia's 8 AI ethics principles
AI Verify	Singapore	AI Verify - an AI governance testing framework and a software toolkit

Emerging Technology Considerations

- Explore AI-driven optimisation for software performance and resource utilisation. This can improve predictive maintenance challenges, reducing the downtime of critical resources. Implement AI ethics guidelines to ensure responsible use in Government. Don't forget to consider the negative impacts of overuse of AI, with an increase in power requirements, compute and a per-transactional cost.

- When implementing blockchain for secure and transparent government processes, consider energy-efficient consensus mechanisms such as Proof-of-Stake blockchains over Proof-of-Work systems. (Kohli, Chakravarty, Chamola, Sangwan, & Zeadally, 2023).

Sustainable Software Development Practices

- Design to use cloud native services where possible to leverage CSP's built-in optimisations

- Architect to use containerisation for more efficient sharing of compute resources across multiple workloads

- Alternatively, make use of serverless compute (function-as-a-service) which can scale dynamically and minimise idle resource consumption. These can have a high re-architecture cost, and vendor lock in as a perverse outcome.

- Promote continuous monitoring and optimisation of software performance to reduce energy consumption.

- Encourage developers to adopt eco-friendly coding practices.

Procurement

Procurement can play a critical role in achieving net zero emissions – as it influences both direct and indirect emissions of government operations. The process to implement ongoing monitoring and tracking can be costly, negating some of the benefits, however once in place with shared procurement process, a pathway to reducing emissions and driving positive impact to communities is achievable.

Patterns to Consider

Sustainable Vendor Criteria: Include sustainability criteria in vendor selection processes – giving government clear targets to align procurement to sustainability goals. These vendor criteria could include:

- **Environmental** – ensure carbon footprints of vendor efficiency; resource efficiency around water, energy efficiency and waste management practices; circular economy principles that support lifecycle, recyclability and repairability.
- **Economic** – consider the long-term viability of the supply chain; incentivising investment in sustainable technologies; providing support for local businesses or communities.
- **Social** – labour practices supporting fair wages, safe working conditions or complying to the modern slavery act; promoting equality and representation and ensuring positive contributions to locale communities.

Lifecycle Assessment: Conduct lifecycle assessments to understand the environmental impact of procured goods and services. Key aspects of these include:

- **Environmental** – quantify energy, water and raw material consumption of resources; measure emissions, pollutants and waste produced; establish impact categories that considers effect on climate change, biodiversity and ecosystem health.

- **Economic** – identify hidden costs across the lifecycle or ownership of the procurement; maintain a resource efficiency agenda identifying opportunities for cost savings through optimisation or reuse.

- **Social** – consider the impacts on health or labour conditions.

Collaborative and shared procurement: Foster collaboration between government agencies and external stakeholders to amplify sustainable development efforts. This approach can leave to economies of scale, shared learning and increased market influence. Elements of this recommendation could include:

- **Environmental** – Bulk purchase to reduce packaging and transport emissions; introduce standardisation to the adoption of high sustainability standards across agencies; collective buying power can drive suppliers and influence markets for positive impact.

- **Economic** – realise cost savings through economies of scale with combined purchasing power or sharing resources and expertise to reduce duplication of effort and risk mitigation.
- **Social** – knowledge sharing of best practice across agencies; encouraging supplier diversity and large coordinated efforts will have greater positive impact on communities.

Global Initiatives Table

Initiative	Country	Policy/Agenda
Circular Economy Action Plan	European Union	Transition to a circular economy
Sustainable Procurement	Australia	Commonwealth Procurement Rules (CPRs)
GreenGov.SG	Singapore	National policy for sustainable procurement
APS Net Zero Emissions by 2030	Australia	Net Zero in Government Operations Strategy and Roadmap

Emerging Technology Considerations

- Leverage IoT for real-time tracking of procurement and supply chain sustainability. By deploying smart sensors and connected devices throughout the supply chain, departments can monitor environmental conditions, track resource usage, and ensure compliance with sustainability standards in real-time.

  This tech enables the creation of a digital twin of the supply chain, offering unprecedented visibility into the environmental or social impact of procurement decisions. However, it's crucial to consider the energy consumption of the IoT devices themselves and ensure secure data transmission to maintain the overall sustainability benefits.

- Forecast future trends and outcomes in procurement processes using predictive analytics. When applied to sustainable procurement planning, it can significantly enhance all three pillars of sustainability:

  Environmental – forecasting resource demand, reducing overproduction and waste or predicting optimal timing for renewable energy purchases.

Economic – anticipating market fluctuations, enabling better budget allocation or identifying cost-saving opportunities in sustainable alternatives.

Social – predicting supply chain risks, including potential labour issues or forecasting community impacts of procurement decisions.

Sustainable Software Development Practices

- Develop procurement management systems that prioritise sustainable vendors and products.
- Implement software that tracks and reports the sustainability metrics of procured items.
- Use federated learning techniques to preserve data privacy across agencies, and ensure that models are regularly retrained to adapt to changing sustainability standards and market conditions.

Conclusion

The Green Architected Framework provides a comprehensive reference architecture for governments seeking to leverage cloud computing to achieve sustainability goals. By addressing key areas such as data privacy, infrastructure, solutions and architecture, and procurement, governments can make informed decisions that promote environmental, economic, and social sustainability. The recommendations and global initiatives outlined in this document serve as a roadmap for governments to integrate sustainable practices into their digital transformation efforts.

The framework is flexible, and general. It can be applied to individual projects, within organisations' enterprise architecture, or at the governmental policy level. This reflects the fact that not all projects, organisations, or governments have an appetite for such change, but that positive change can nevertheless be affected by finding the right level to apply sustainability practices. The framework is also adaptable to local environments, and in fact the application of the framework must be localised to reap the different benefits, and respect the different constraints, that vary from country to country.

The associated presentation slide deck and spreadsheet can be used directly within organisations, first to communicate the framework, and then to incorporate the framework into decision-making processes. This is not the end of our sustainability journey, but we believe it is an important step forward. By taking the work of the DGX Cloud Working Group, applying it, customising it, and building on it, DGX members can make an increasingly positive impact on their sustainability goals.

Appendix – About the RCVE Tool

As a part of the creation of the Green Architected Framework, through early stages of discovery we established a tool that supported a country or agency to do a short assessment on the value of the initiative and its role in the sustainability pillars.

The development of this tool was to simply prove the idea, that you could assign a value and score an initiative. There were some high-level assumptions in the development of this tool.

- No weighted scores
- There may be high correlation between each criterion

Each criterion was evaluated through the experience of the contributors to this paper, and as such each criterion was given a rating on a 5 point Likert scale (very-low, low, medium, high, very-high).

These ratings were then converted to an integer representation (1-5). The positive impact to sustainability in each pillar (Environmental, Economic and Social) were each evaluated, and then score averaged.

We then plotted these figures on a quadrant to understand:

- Avoid
- Investigate
- Consider
- Prioritise

The formula we used was E+V & R+C

- Ease to implement the initiative + Value to sustainability
- Risk to sustainability of not doing the initiative + Cost to implement the initiative

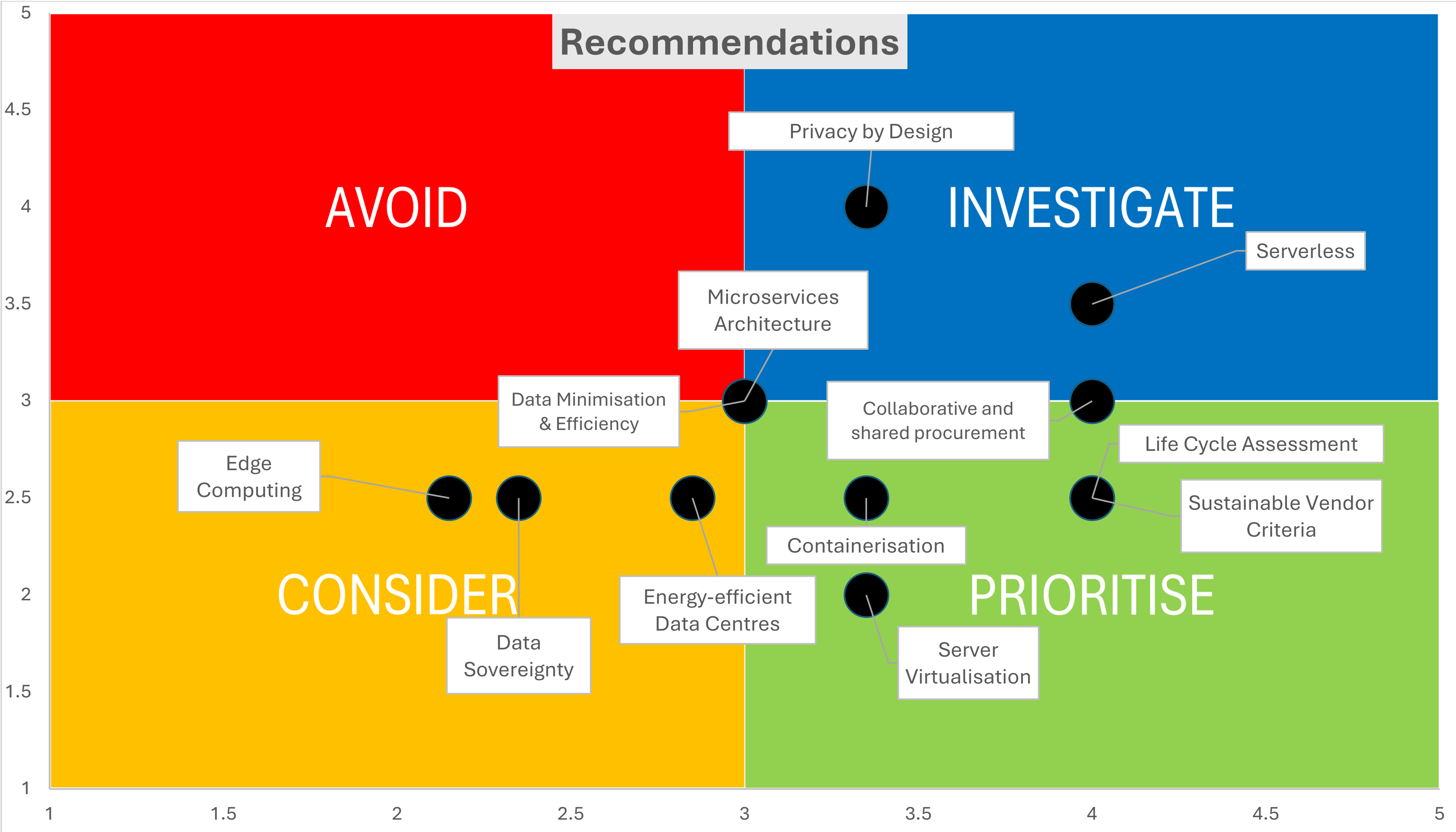
RCVE data used to populate the tool

		Risk to sustainability of not doing this	Cost to implement	Ease of implementation			Environmental	Economic	Social
	Data Minimisation and Efficiency	high	low	low			high	high	high
	Privacy by Design	v. high	medium	low			high	v. high	v. high
Data & Privacy	Data Sovereignty	medium	low	v. low			high	medium	high
	Energy-efficient Data Centres	high	v. low	low			v. high	high	low
	Server Virtualisation	low	low	high			medium	medium	low
Infrastructure	Edge Computing	medium	low	v. low			high	medium	medium
	Microservices Architecture	high	low	low			high	high	high
	Containerisation	medium	low	medium			high	high	medium
Solutions & Architecture	Serverless	high	medium	high			high	v. high	medium
	Sustainable Vendor Criteria	high	v. low	high			high	high	high
	Life Cycle Assessment	high	v. low	high			high	high	high
Procurement	Collaborative and shared procurement	high	low	high			high	high	high

		Risk to sustainability of not doing this	Cost to implement	Ease of implementation	Value to sustainability		Environmental	Economic	Social	Overall Value
	Data Minimisation and Efficiency	4	2	2	4		4	4	4	4
	Privacy by Design	5	3	2	4.7		4	5	5	4.7
Data & Privacy	Data Sovereignty	3	2	1	3.7		4	3	4	3.7
	Energy-efficient Data Centres	4	1	2	3.7		5	4	2	3.7
	Server Virtualisation	2	2	4	2.7		3	3	2	2.7
Infrastructure	Edge Computing	3	2	1	3.3		4	3	3	3.3
	Microservices Architecture	4	2	2	4		4	4	4	4
	Containerisation	3	2	3	3.7		4	4	3	3.7
Solutions & Architecture	Serverless	4	3	4	4		4	5	3	4
	Sustainable Vendor Criteria	4	1	4	4		4	4	4	4
	Life Cycle Assessment	4	1	4	4		4	4	4	4
Procurement	Collaborative and shared procurement	4	2	4	4		4	4	4	4

	Recommendations	Ease + Value	Risk + Cost		
	Data Minimisation & Efficiency	3	3		Ease = The ease to implement the recommendation
	Privacy by Design	3.35	4		Value = the recommendation's value to sustainability
Data & Privacy	Data Sovereignty	2.35	2.5		Risk = Risk of not implementing the recommendation and its impact on sustainability
	Energy-efficient Data Centres	2.85	2.5		Cost = the relative cost to implement the recommendation
	Server Virtualisation	3.35	2		
Infrastructure	Edge Computing	2.15	2.5		
	Microservices Architecture	3	3		
	Containerisation	3.35	2.5		
Solutions & Architecture	Serverless	4	3.5		
	Sustainable Vendor Criteria	4	2.5		
	Life Cycle Assessment	4	2.5		
Procurement	Collaborative and shared procurement	4	3		

The RCVE Tool in Action



Applicability

The RCVE Tool generates actionable recommendations based on the analysis of the various sustainability considerations in a local environment. It is highly configurable and should be tailored to specific use cases as follows.

The use of the five-point Likert scale (very-low, low, medium, high, very-high) is a flexible metric that can be used in very data-oriented environments to produce highly accurate recommendations – where such data is available. But importantly, it can and should also be used in subjective fields with very-little-to-no quantitative data, where the best data available is the knowledge and wisdom available from well-informed and experienced staff, as a subjective but justified basis for quality decision making.

While twelve different sustainability considerations are shown in the image above, generated by the RCVE Tool, the user can and should validate and extend this list with additional local or emerging considerations.

The specific qualitative numerical assessments used as input to the tool can also be tailored to fit the environment and should be considered likely to change over time. This highlights that the RCVE Tool is just a tool, it does not produce a reference architecture that can be established once and used on an ongoing basis. On the other hand, because it is dynamic, it can easily be updated for each use, and applied directly as needed.

References

- European Union. (n.d.). General Data Protection Regulation (GDPR). Retrieved from https://gdpr.eu/
- MyData Global. (n.d.). MyData. Retrieved from https://mydata.org/
- Personal Data Protection Commission Singapore. (n.d.). Personal Data Protection Act (PDPA). Retrieved from https://www.pdpc.gov.sg/
- European Commission. (n.d.). Renewable Energy Directive. Retrieved from https://ec.europa.eu/energy/
- Clean Energy Regulator. (n.d.). Renewable Energy Target (RET). Retrieved from https://www.cleanenergyregulator.gov.au/
- Infocomm Media Development Authority. (n.d.). Green Data Centre Initiative. Retrieved from https://www.imda.gov.sg/
- Federal Ministry for Economic Affairs and Energy. (n.d.). Digital Strategy Germany. Retrieved from https://www.bmwi.de/
- Smart Nation Singapore. (n.d.). Smart Nation Initiative. Retrieved from https://www.smartnation.gov.sg/
- European Commission. (n.d.). Circular Economy Action Plan. Retrieved from https://environment.ec.europa.eu/
- Department of Finance Australia. (n.d.). Commonwealth Procurement Rules (CPRs). Retrieved from https://www.finance.gov.au/
- Ministry of Sustainability and the Environment Singapore. (n.d.). GreenGov.SG. Retrieved from https://www.mse.gov.sg/
- DGX Cloud Working Group. (2023). Cloud Report. Retrieved from https://www.developer.tech.gov.sg/
- Department of Finance Australia. (n.d.). APS Net Zero Emissions by 2030 (2024). Retrieved from https://www.finance.gov.au/

Australian Government. (2023). *Mission - Trusted and Secure*. Retrieved from Data and Digital Government Strategy: https://www.dataanddigital.gov.au/strategy/missions/trusted-and-secure

European Data Protection Board. (2024, 05 24). *Facial recognition at airports: individuals should have maximum control over biometric data*. Retrieved from European Data Protection Board:

https://www.edpb.europa.eu/news/news/2024/facial-recognition-airports-individuals-should-have-maximum-control-over-biometric_en

Government, T. (n.d.). *About Tuvalu*. Retrieved from https://www.tuvalu.tv/about: https://www.tuvalu.tv/about

Gravrock, E. v. (2022, 03 31). *Why artificial intelligence design must prioritize data privacy*. Retrieved from World Economic Forum: https://www.weforum.org/agenda/2022/03/designing-artificial-intelligence-for-privacy/

Herring, L., Malmsten, M., Sporleder, C., & Srinidhi, N. (2022, 10 27). *Making software and data architectures more sustainable.* Retrieved from McKinsey Digital: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/tech-forward/making-software-and-data-architectures-more-sustainable

Kohli, V., Chakravarty, S., Chamola, V., Sangwan, K. S., & Zeadally, S. (2023). An analysis of energy consumption and carbon footprints of cryptocurrencies and possible solutions. *Digital Communications and Networks*, Pages 79-89. doi:https://doi.org/10.1016/j.dcan.2022.06.017.

Orgerie, A.-C., Assuncao, M. D., & Lefevre, L. (2014, mar). A survey on techniques for improving the energy efficiency of large-scale distributed systems. *ACM Comput. Surv.* Association for Computing Machinery. doi:10.1145/2532637

Purvis, B., Mao, Y., & Robinson, D. (2018, September 3). Three pillars of sustainability: in search of conceptual origins. *Sustainability Science, 14*, 681-695. Retrieved 05 28, 2024, from https://link.springer.com/article/10.1007/s11625-018-0627-5

The Indigenous World 2021: Indigenous Data Sovereignty. (2021, 03 18). Retrieved from IWGIA - International Work Group for Indigenous Affairs: https://www.iwgia.org/en/ip-i-iw/4268-iw-2021-indigenous-data-sovereignty.html

United Nations Development Group. (2017, November 09). *Data Privacy, Ethics and Protection - A Guidance Note on Big Data for Achievement of the 2030 Agenda*. Retrieved May 30, 2024, from UN Sustainable Development Group: https://unsdg.un.org/resources/data-privacy-ethics-and-protection-guidance-note-big-data-achievement-2030-agenda

Whitehead, B., Andrews, D., Shah, A., & Maidment, G. (2014). Assessing the environmental impact of data centres part 1: Background, energy use and metrics. *Building and Environment, 82*, 151-159. doi:10.1016/j.buildenv.2014.08.021

Additional Reading

- *Green Coding - Can we make our carbon footprint smaller through coding?* Published June 2022; Sofia Herelius; Green coding, Thesis (diva-portal.org)
- *Estimating Digital Emissions*. Estimating Digital Emissions - Sustainable Web Design