Cite as: Pee, L. G., & Pan, S. L. (2021). Climate-intelligent cities and resilient urbanisation: Challenges and opportunities for information research. International Journal of Information Management, 102446.

Climate-Intelligent Cities and Resilient Urbanisation: Challenges and Opportunities for Information Research

Highlights

- Climate-first and climate-compatible cities are at the core of a zero-carbon future
- City development demands resilience to climate shocks as well as energy shocks
- Information research can contribute directly to energy and resource optimization
- Climate-neutral digital economy and digital citizen engagement are also of interest
- All major streams of information research can contribute to climate actions

Abstract

Cities are critical in climate actions as they constitute the main source of greenhouse gas emissions. Climate-Intelligent cities are digitally enabled cities that are climate first and climate compatible. The journey towards zero emissions calls for resilient urbanisation to weather the climate shocks as well as energy shocks that cities are bound to encounter. Based on the authors' experiences and observations from research on digital sustainability and smart cities, this article highlights four information research themes that can contribute to the development: energy and resource optimization, climate-neutral digital economy, digital citizen engagement, and intelligent governance. Specific research questions are also identified. In conclusion, all major streams of information research ranging from information systems acceptance and IT governance to Fintech applications can contribute meaningfully to mitigating climate change. Research opportunities are illustrated with green developments and examples in the city state of Singapore.

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1. Climate-Intelligent Cities and Resilient Urbanisation

Information research is no less instrumental to informing climate actions than other disciplines such as environmental science. This article focuses on how information research can contribute by driving the development of "climate-intelligent cities" through empowering resilient urbanisation. We define climate-intelligent cities as digitally enabled cities that are climate first and climate compatible, in which zero or even negative greenhouse gas emissions constitute a short-term socio-economic development goal associated with citizens' quality of life and businesses' financial success. Although environmental sustainability is often a goal declared in smart city projects (Ismagilova, Hughes, Dwivedi, & Raman, 2019), it tends to take the back seat compared to efficient city management and economic development. The concept of climate-intelligent cities emphasizes a climate-first approach, a stance that governments are starting to adopt as extreme weathers hit more frequently and voters are increasingly demanding firm climate actions.

Cities have a critical role in climate actions because they account for the majority of greenhouse gases, which constitute the root cause of global warming (International Energy Agency, 2021). Many cities have directly experienced the devastating effects of global warming – from heatwaves to tornadoes to floods. At the same time, a perfect storm of energy crisis due to a confluence of weather-related issues, unexpected demand as the world recovers from COVID-19, and planned power rations is causing power shutdowns at factories and sending household bills soaring. This clash of crises indicates the need for resilient urbanisation.

Resilient urbanisation seeks to develop cities' ability to absorb, recover, and future-ready for climate shocks due to global warming as well as energy shocks due to the transition to green power. Many cities are already investing in infrastructures to reduce vulnerability to rising sea levels, adapt to rising temperatures, and control air pollution. Nevertheless, our resilience to energy shocks remains to be strengthened. As governments' response to the recent energy crisis have shown, the ripple effects of energy supply on inflation and consumption continue to threaten our ability to kick the fossil fuel addiction and undermine our resolve to pursue climate actions.

Advances in information technology (IT), such as artificial intelligence (AI), blockchain, and Internet of Things (IOT), have the potential to foster resilient urbanisation towards a climate-intelligent city if they are implemented within a well-designed socio-technical information system. This article discusses climate as a research objective, a context of study, and the subject of study in information research. We highlight four information research themes and specify relevant research questions for each theme: energy and resource optimization, climate-neutral digital economy, digital citizen engagement, and intelligent governance. They are illustrated with practical examples of climate actions in Singapore, from which we originate. As a small city state, Singapore has limited access to alternative energy sources such as hydro or nuclear power. Yet, it is not insulated from climate change – its annual mean temperature, rainfall, and sea level have all increased significantly. To overcome these constraints and challenges, Singapore has been focusing on developing and leveraging IT to implement its Green Plan 2030.

2. Information Research Themes and Topics

The four information research themes for climate-intelligent cities were identified based on our insights from research projects on digital sustainability and smart cities (Pan, Li, Pee, & Sandeep, 2021; Pan & Pee, 2020; Pee, Pan, & Cui, 2019; Pee, Pan, Wang, & Wu, 2021; Ying, Pee, & Jia, 2018; Zhang, Pee, Pan, & Cui, in press). We observed practical demand for knowledge about energy and resource optimization which indicates opportunities for information research including, but not limited to data analytics. All the smart cities we studied focused on promoting the growth of the digital economy and certain sectors outshine others in presenting win-win strategies for balancing economic development and sustainable development. Both climate actions and smart city development require alignment between government and citizens. Despite the well-established digital infrastructures in cities, their utility in broadly engaging citizens remains limited. Governments of climate-intelligent cities are in need for more support from information researchers regarding how advances in IT can be harnessed to improve governance. We draw upon these observations to specify relevant information research questions for researchers specialising in technology acceptance and use, decision making, digital information practices, information system development and applications, as well as IT governance.

2.1. Energy And Resource Optimization

Greenhouse gases such as carbon dioxide and methane help keep the Earth at a habitable temperature, but the record-breaking increase due to human activities has led to overheating and extreme weathers. Major sources of greenhouse gases include the burning of fossil fuel for energy and landfills. IT can prevent the over consumption of fossil fuel by collecting and analysing data to optimize energy generation and distribution for buildings and industrial use (Watson, Boudreau, & Chen, 2010). Carbon emissions from transport can be reduced significantly with the use of sharing-economy platforms such as Uber (e.g., Jenn, 2020). Managing landfill methane emissions calls for better recycling of resources, to which blockchain has much potential to add value (Centobelli, Cerchione, Vecchio, Oropallo, & Secundo, In press).

Energy information system – Cities account for more than 60% of global energy consumption and 70% of annual global carbon emissions (International Energy Agency, 2021). If the current trend continues beyond the COVID-19 pandemic, more than 70% of the world's population will live in cities, resulting in even greater demand for urban energy infrastructure. Infrastructures leveraging big data, AI, and IOT to improve energy efficiency is expected to reduce carbon emissions from buildings by 350 metric tonnes by 2050 (International Energy Agency, 2021). In Singapore, digital twins of buildings powered by real-time sensor data and machine learning algorithms have been developed based on the Smart Facilities Management framework to maximize energy savings (Building and Construction Authority of Singapore, 2021). Coupled with mobile Apps and desktop software, the energy information system incorporates users into a comprehensive process of streamlining building operations and management. Research on energy information systems in inherently transdisciplinary, uniting information research and energy research to create a new intellectual framework and practical solutions for climate change. Other than developing machine learning algorithms for optimizing energy generation and consumption in cities (Zekić-Sušac, Mitrović, & Has, in press), energy information researchers can design architecture for IOT (Malhotra, Melville, & Watson, 2013) to ensure that good quality data, energy resources, hardware and software, people, and practices are seamlessly integrated to allow real-time optimization. As part of the critical infrastructure, the security of both non-human and human components (Lowry, Dinev, & Willison, 2017) in energy information systems cannot be overstated (see specific research questions listed in Table 1).

Table 1. Research questions for energy and resource optimization in climate-intelligent cities

Information Research Topic	Suggested Research Questions
Energy information systems	• How well does a machine learning algorithm perform in optimizing energy generation and consumption? • What are the design principles for the architecture of an energy information system? • How to ensure the security of energy information systems? How to manage the non-human and human components?
Sharing-economy platforms	• Does concern for climate change influence the use of sharing economy platforms? • To what extent does digital sharing-economy platforms contribute value to climate change mitigation? • What characterizes a carbon-aware digital business model for ride hailing service providers?
Blockchain for circular resource management	• What are the potential use cases of blockchain in circular resource management? • How to manage the blockchain-induced digital transformation in the recycling and waste industry?

Sharing-economy platforms – Online peer-to-peer platforms that allow city dwellers to share idle resources, ranging from cars and bikes to vacant rooms and toys, can be part of our climate strategy to reduce emissions and waste. Information research on the use of such platforms (e.g., Mittendorf, Berente, & Holten, 2019) can be extended to examine individuals' concern for climate change. It is also important to assess the value of sharing-economy platforms to climate change mitigation (Jenn, 2020) and our understanding about IT value should serve to provide sound methodologies and theoretical bases. For some services such as ride hailing, the evidence for positive impact is still mixed. Governments are increasingly imposing carbon taxes and regulations affecting the costs and profit of these service providers. Although information researchers have studied the business models of sharing-economy platforms (Niemimaa, Järveläinen, Heikkilä, & Heikkilä, 2019), how carbon considerations should be incorporated remains unclear. Grab, a ride-hailing and delivery service provider based in Singapore, has introduced electric vehicles and added a carbon offset feature in their App to allows users to contribute to reforestation projects (Grab Holdings Inc., 2021). The effectiveness of these and other practical initiatives needs to be evaluated.

Blockchain for circular resource management – A circular model of resource management seeks to "systematically narrow, slow, and close material loops by optimising production, distribution and consumption processes, extending product lifespans and reintegrating waste materials into supply chains" (Zeiss, Ixmeier, Recker, & Kranz, 2021, p. 2). Advances in IT have offered unprecedented opportunities to transform circular resource management by augmenting it with information flows. In particular, blockchain or distributed ledger technologies in general can record payment or rewards, validate identities, and track waste (Kshetri, 2018). For instance, Singapore's government is supporting the development of an open and decentralised platform that incentivises manufacturers and their suppliers to collaborate in adopting circular business models. The platform leverages smart contracts and provenance tracking to facilitate the circular trading of recycled materials (Infocomm Media Development Authority, 2020). Information researchers can develop novel use cases of blockchain in circular resource management. Linking blockchain to legacy systems has proven challenging in many applications. To construct the blockchain-based information flow accompanying the material flow of resources and wastes, traditional processes and practices might need to be abolished or reorganised. The digital transformation of the recycling and waste industry is likely to be a key prerequisite for effective circular resource management.

2.2. Climate-Neutral Digital Economy

Cities account for more than 50% of the global population and 80% of global gross domestic product (International Energy Agency, 2021). With better digital infrastructure, connectivity, and access to start-up funding, it is not surprising that cities take the centre stage in digital economy. As cities march forward in digital transformation, the opportunities and threats to climate change also become clearer. Businesses can take advantage of the shift towards Industry 4.0 to implement climate-compatible manufacturing systems. As the electricity of the digital economy, Fintech has various climate-related applications that facilitate responsible investing and financing. Despite the contribution of IT as a enabler or solution of climate actions, its own carbon footprint must be mindfully managed.

Industry 4.0 to climate 4.0 – Industry refers to "the part of an economy that produces material goods which are highly mechanized and automatized" (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014, p. 239). Powered by IT such as AI, blockchain, and 5G (French, Shim, Risius, Larsen, & Jain, 2021), the fourth industrial revolution seeks to develop modular and efficient manufacturing systems that allow individualization of products or even "batch-size-one" production. As industry's greenhouse gas emissions increasingly draw scrutiny, the shift away from climate denialism means climate actions must be kept close to the core of fourth industrial revolution. In Singapore, for example, an advanced energy dashboard based on IOT has been developed for monitoring and controlling energy consumption in manufacturing processes (Engie Lab, 2018). For information research, the obvious opportunities include leveraging big data for energy optimization and designing machine learning applications to infuse renewable energy, recycled resources, and recyclable materials into cyber-physical systems (see section 2.1). Beyond these, information researchers specialising in open innovation or inter-organisational systems can promote Climate 4.0 by providing guidance for eco-innovation in supply chain (see Table 2). The benefits of Climate 4.0 can only be maximized if there is technology transfer to developing countries (Kirchherr & Urban, 2018). Knowledge transfer at this level has new dimensions that warrant further research beyond our current theoretical knowledge about cross-boundary knowledge transfer (e.g., Ravichandran & Giura, 2019).

Table 2. Research questions for climate-neutral digital economy

Information Research Topic	**Suggested Research Questions**
Industry 4.0 to Climate 4.0	• How can IT enable inter-organisational eco-innovation in Climate 4.0? • How to ensure effective knowledge transfer of Climate 4.0 technology to developing countries?
Climate Fintech	• What are the IT affordances/perceptions/innovation mechanisms of climate Fintech applications? • How can AI augment decision makers' ability to identify and avoid greenwashing in investment or financing?
Clean tech	• What are the design principles for an energy-efficient information system? • What constitute climate-conscious digital information practices? • How can digital businesses foster climate-conscious IT behaviours in a way that enhances their performance?

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Climate Fintech – Information research on Fintech has investigated the impact of social media on Bitcoin value (Mai, Shan, Bai, Wang, & Chiang, 2018), IT affordances for Fintech applications (Du, Pan, Leidner, & Ying, 2019), perceptions towards mobile services Apps (Karjaluoto, Shaikh, Saarijärvi, & Saraniemi, 2019), and innovation mechanisms of Fintech start-ups (Gozman, Liebenau, & Mangan, 2018). While there are also emerging opportunities to study climate-related applications in decarbonized electricity market, carbon credits, and green bonds, we believe that information researchers' core contribution to climate Fintech lies in augmented intelligence for decision making. The role of financial decision making is highlighted in Singapore's Framework for Green Trade Finance (Monetary Authority of Singapore, 2021). As one of the leading Fintech hubs in the world amassing US$725 million funding in the first half of 2021, Singapore has clear climate-related disclosure requirements for banking, insurance, and asset management sectors. In a recently completed study, we focused on how AI can augment decision makers' ability to identify and avoid greenwashing in investment or financing. We developed design principles for an intelligence dashboard that provides synthesis and visualization of real-time data from various sources, including social media, to indicate the risk of greenwashing.

Cleantech – The ecological footprint of IT, though often invisible, is undoubtedly influential. For instance, social media and communication services are known to contribute significant carbon emissions (Tsukayama, 2017); Cryptocurrency or Bitcoin mining has been found to consume more electricity than some countries (Smith, 2021). As responsible information researchers, we need to devote attention to designing more energy-efficient information systems and fostering climate-conscious IT behaviours. The concentration of IT infrastructures and digital activities in urban cities make them the ideal testbed for Cleantech. In Singapore, a Sustainable Tropical Data Centre Testbed has been built to develop energy-efficient cooling technologies. Being in one of the world's top data centre markets, the research facility is poised to work closely with the industry to implement innovations swiftly.

2.3. Digital Citizen Engagement

Many of the IT enablers or solutions of climate change will have little impact unless people are mobilized. IT affords engaging ways to increase awareness of climate change and educate city dwellers about climate-responsible behaviours. Information researchers can also build on the accumulated knowledge on IT acceptance to understand city dwellers' perception of green IT. As an enabler, the Internet has promulgated climate activism and served as a key platform for citizen science, presenting new information research opportunities.

Gamification for climate engagement – Climate change calls for behavioural change. Leveraging the prevalence of online or mobile games (Koivisto & Hamari, 2019), climate games are increasingly being developed to strengthen city dwellers' understanding of climate challenges and their behavioural impact (Shevchuk, Degirmenci, & Oinas-Kukkonen, 2019).

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For instance, in Singapore, the FoodPrint game is being developed to educate people about the impacts and trade-offs of food choices (Baey, 2021). The interactive game awards points to players for making environment-friendly decisions in recipes. Existing games have also been redesigned to incorporate climate issues. SimCity, an iconic city simulation game, added new game challenges including limited resources and the spillover effects of pollution (Bianco, 2018). Information system design research is well positioned to develop theory-informed design principles for game mechanics, dynamics, and aesthetics that stimulate thinking about serious climate issues in a fun way. The applicability, usefulness, and flow (Hamari & Keronen, 2017; Whittaker, Mulcahy, & Russell-Bennett, in press) of new technologies such as extended reality (XR) in climate games can also be explored (see Table 3).

Green IT acceptance and use – Mobile devices and computers made with recycled materials (e.g., FairPhone) or components (e.g., lead-free and Halogen-free motherboard), smart utility meters (Koo, Chung, & Nam, 2015), electric vehicles, digital health records, e-commerce platforms or logistics services (e.g., food delivery) with greener options, and paperless government services are digital options often available to users in climate-intelligent cities. Although users generally report positive attitudes towards eco-friendly products and services, actual adoption remains limited. Research on green IT acceptance has mostly focused on organisations rather than individuals in non-work-related contexts (Singh & Sahu, 2020). More information research is needed to investigate whether motivational factors such as concern for the environment and legislative pressure (Koo et al., 2015) explain more variance in the acceptance of green IT. Cost-related factors such as privacy concerns (Warkentin, Goel, & Menard, 2017), switching costs, and learning curve are also worth probing. Related to continued use, it will be interesting to explore how green IT users evaluate actual benefits to the self and to the environment, and to what extent the observability of IT value affects continued use. Findings about the acceptance and use of green IT has much potential to inform economic and environmental policies in climate-intelligent cities.

Social media for climate activism – Many city dwellers have been directly hit by climate crises such as air pollution, extreme weather, and shortage of water and electricity. Vivid photos and videos showing the damages contribute to the climate activism on social media. Activists, especially Gen Z and millennials, are fighting “greenwashing” (D’arcy, Adjerid, Angst, & Glavas, 2020) with “greentrolling” and demanding businesses and politicians to take firm climate actions. Social media is so effective that some governments are paying influencers to amplify their climate action messages. For instance, the Singapore government has paid social media influencers to spread words on climate change in awareness campaigns. Information research has examined the role of social media in climate disaster response and recovery (Tim, Pan, Ractham, & Kaewkitipong, 2017), but our understanding about information flow remains limited. Does the flow of climate information differ from the flow of personal information due to different sharing behaviour? Major social media platforms such as Facebook and Twitter are developing climate-focused features such as quizzes and fact checkers – what new social media affordances do they offer to climate activists? Given the significance of public opinion in climate actions, there is also a strong need for social media mining algorithms that are accurate yet privacy preserving.

Table 3. Research questions for digital citizen engagement in climate-intelligent cities

Information Research Topic	**Suggested Research Questions**
Gamification for climate engagement	• What are the design principles for the mechanics, dynamics, and aesthetics of climate games? • How to incorporate climate issues into existing games (e.g., city simulation games)? • How to apply extended reality technologies in climate games? • To what extent does the application of extended reality technologies improve the usefulness and enjoyment of climate games?
Green IT acceptance and use	• Do motivational factors such as concern for the environment and legislative pressure explain more variance in the adoption/acceptance of green IT? • Do cost-related factors such as privacy concerns, switching costs, and learning curve explain more variance in the adoption/acceptance of green IT? • What are the design principles for improving the perceived ease of use and perceived usefulness of green IT? • How do users evaluate the value of green IT? How does observability of IT value affect continued use?
Social media for climate activism	• Does climate information flow differ from personal information flow on social media? • What new social media affordances do features such as quizzes and fact checkers offer to climate activists? • How to design mining algorithms that can identify climate opinions on social media accurately while preserving privacy?
Digital information practices in citizen science	• What are the information practices of citizens and researchers involved in citizen science? • How do information practices adopted by citizen scientists affect the quality of data collected and the insights generated? • How does involving citizen scientists in the interpretation of data affect research findings? • What are the unintended consequences of using IT in citizen science projects?

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Digital information practices in citizen science – Citizen science engages the general public in the scientific research process, from identifying research questions, collecting and analysing data, interpreting results, to developing technologies and applications (Bonney et al., 2014). Climate-related projects typically ask citizen volunteers to transcribe historical documents of weather for tracing climate patterns, observe changes in nature, or offer computing power for analysing future global warming scenarios. For instance, in Australia, the Urban Microclimate Citizen Science Project provided participants with a mobile recording App, data sharing platform, thermal comfort calculator, and mitigation visualization tool for collecting data about local weather and understanding climate change (Rajagopalan, Andamon, & Paolini, 2020). In Singapore, citizens are invited to conduct biodiversity surveys to gather data for park management and conservation measures. Such initiatives provide a practically impactful context for information researchers to study the sociotechnical interplay between data, IT devices, citizens, scientists, and climate politics. Citizen scientists might adopt various information practices – how does this affect the quality of data collected and the insights generated? How does involving citizen scientists in the interpretation of data affect research findings? What are the unintended consequences (e.g., misuse of data shared publicly, exclusion of technologically disadvantaged citizens)?

2.4. Intelligent Governance

Climate actions involve the orchestration of power and resources distributed across a diverse ecosystem of stakeholders. Climate governance is about establishing leadership as well as providing the capacity to implement climate actions. IT can serve as the foundation of an agile and accountable government in the age of climate crisis.

Digitally enabled agile government – Climate shocks will continue to hit as cities fight to reduce emissions. Although many of these shocks can be predicted with some degree of accuracy in retrospect, weeding through the large number of predictions to decide which to act on is no easy task. It remains vital for governments to be agile and adaptive in the face of shocks (Janssen & Van Der Voort, 2020). IT has played the critical role of enabling communication and access to community relief resources when natural disasters strike. IT applications for agile disaster response are often developed based on grassroot ingenuity. How can governments incorporate these distributed IT innovations into its infrastructure to improve preparedness for future disasters?

Open government for climate action – Transparency in information allows governments, businesses, and citizens to understand the costs of climate change and visualize progress towards climate goals. In Singapore, regularly updated data about emissions, energy efficiency, and mitigation efforts are published on the National Environment Agency's website. Users can ask questions or provide feedback conveniently through a chatbot or phone calls. Capturing, processing, and visualizing information is the forte of information researchers.

What makes climate information challenging is that it is likely to be consumed by non-specialists with limited climate literacy. How can climate data be presented to ensure accurate interpretation by various audiences and to promote appropriate climate decisions or actions (see Table 4)?

Table 4. Research questions for governance in climate-intelligent cities

Information Research Topic	Suggested Research Questions
Digitally enabled agile government	• How to identify action-worthy insights in climate analytics? • How can governments institutionalize grassroot IT innovations to improve climate agility?
Open government for climate action	• How can governments track and visualize climate performance for public disclosure? • How does publishing climate enforcement and compliance data online affect business/consumption decisions/actions?

3. Conclusion

We have discussed how IT can be part of the solution mix for the wicked problem of climate change and highlighted the ways information research can add value to the development of climate-intelligent cities. While some of the research questions are straightforward (yet impactful) for information researchers, many require collaboration with related disciplines such as computer science as well as more distant ones such as environmental science. Admittedly, the process is fraught with challenges arising from differences in values, theories, and epistemologies. Reflecting on our experiences working with researchers and practitioners from various fields such as atmospheric environment, logistics, and zoology, we believe that the key lies in establishing a common real-world problem from the beneficiary's perspective. The notion of climate-intelligent cities serves this purpose, and we hope our discussion stimulates actions in all streams of information research to engage in challenging yet rewarding research for the planet's future.

4. References

Baey, Z.-E. (2021, 28 May). Game That Explores Environmental Footprint of Food among Projects Aimed at Tackling Sustainability Issues Retrieved 22 Oct, 2021, from https://str.sg/3kpa

Bianco, K. (2018, 6 Sep). What If Video Games Could Help Fight Climate Change? No, Really. Retrieved 22 Oct, 2021, from https://www.wired.co.uk/article/climate-change-game-design-simcity-civilisation

Bonney, R., Shirk, J. L., Phillips, T. B., Wiggins, A., Ballard, H. L., Miller-Rushing, A. J., & Parrish, J. K. (2014). Next Steps for Citizen Science. *Science, 343*(6178), 1436-1437.

Building and Construction Authority of Singapore. (2021). Shaping Smart Solutions with Tech and Innovation Retrieved 22 Oct, 2021, from https://www1.bca.gov.sg/buildsg-emag/articles/shaping-smart-solutions-with-tech-and-innovation

Centobelli, P., Cerchione, R., Vecchio, P. D., Oropallo, E., & Secundo, G. (In press). Blockchain Technology for Bridging Trust, Traceability and Transparency in Circular Supply Chain. *Information & Management*.

D'arcy, J., Adjerid, I., Angst, C. M., & Glavas, A. (2020). Too Good to Be True: Firm Social Performance and the Risk of Data Breach. *Information Systems Research, 31*(4), 1200-1223.

Du, W., Pan, S. L., Leidner, D. E., & Ying, W. (2019). Affordances, Experimentation and Actualization of Fintech: A Blockchain Implementation Study. *The Journal of Strategic Information Systems, 28*(1), 50-65.

Engie Lab. (2018, 1 Oct). Digitalization of Industrial Plants - Energy Efficient Singapore Retrieved 22 Oct, 2021, from https://www.e2singapore.gov.sg/docs/default-source/default-document-library/eenp-awards-2018/presentation-slides/15-engie.pdf?sfvrsn=d394dcbc_2

French, A., Shim, J. P., Risius, M., Larsen, K. R., & Jain, H. (2021). The 4th Industrial Revolution Powered by the Integration of Ai, Blockchain, and 5g. *Communications of the Association for Information Systems, 49*(1), 6.

Gozman, D., Liebenau, J., & Mangan, J. (2018). The Innovation Mechanisms of Fintech Start-Ups: Insights from Swift's Innotribe Competition. *Journal of Management Information Systems, 35*(1), 145-179.

Grab Holdings Inc. (2021, 22 June). Grab Releases First Esg Report; Announces Initiatives to Reduce Carbon Footprint Retrieved 22 Oct, 2021, from https://www.grab.com/sg/press/others/grab-releases-first-esg-report-announces-initiatives-to-reduce-carbon-footprint/

Hamari, J., & Keronen, L. (2017). Why Do People Play Games? A Meta-Analysis. *International Journal of Information Management, 37*(3), 125-141.

Infocomm Media Development Authority. (2020, 18 Jun). List of Selected Proposals for Blockchain Challenge – Growing and Connecting Blockchain Business Networks Retrieved 22 Oct, 2021, from https://www.imda.gov.sg/-/media/Imda/Files/Programme/Blockchain-Challenge/20200618-Appendix-for-Blockchain-Challenge-BBN.pdf

International Energy Agency. (2021). Empowering Cities for a Net Zero Future Retrieved 22 Oct, 2021, from https://www.iea.org/reports/empowering-cities-for-a-net-zero-future

Ismagilova, E., Hughes, L., Dwivedi, Y. K., & Raman, K. R. (2019). Smart Cities: Advances in Research—an Information Systems Perspective. *International Journal of Information Management, 47*, 88-100.

Janssen, M., & Van Der Voort, H. (2020). Agile and Adaptive Governance in Crisis Response: Lessons from the Covid-19 Pandemic. *International Journal of Information Management, 55*, 102180.

Jenn, A. (2020). Emissions Benefits of Electric Vehicles in Uber and Lyft Ride-Hailing Services. *Nature Energy, 5*(7), 520-525.

Karjaluoto, H., Shaikh, A. A., Saarijärvi, H., & Saraniemi, S. (2019). How Perceived Value Drives the Use of Mobile Financial Services Apps. *International Journal of Information Management, 47*, 252-261.

Kirchherr, J., & Urban, F. (2018). Technology Transfer and Cooperation for Low Carbon Energy Technology: Analysing 30 Years of Scholarship and Proposing a Research Agenda. *Energy Policy, 119*, 600-609.

Koivisto, J., & Hamari, J. (2019). The Rise of Motivational Information Systems: A Review of Gamification Research. *International Journal of Information Management, 45*, 191-210.

Koo, C., Chung, N., & Nam, K. (2015). Assessing the Impact of Intrinsic and Extrinsic Motivators on Smart Green It Device Use: Reference Group Perspectives. *International Journal of Information Management, 35*(1), 64-79.

Kshetri, N. (2018). 1 Blockchain's Roles in Meeting Key Supply Chain Management Objectives. *International Journal of Information Management, 39*, 80-89.

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & information systems engineering, 6*(4), 239-242.

Lowry, P. B., Dinev, T., & Willison, R. (2017). Why Security and Privacy Research Lies at the Centre of the Information Systems (Is) Artefact: Proposing a Bold Research Agenda. *European Journal of Information Systems, 26*(6), 546-563.

Mai, F., Shan, Z., Bai, Q., Wang, X., & Chiang, R. H. L. (2018). How Does Social Media Impact Bitcoin Value? A Test of the Silent Majority Hypothesis. *Journal of Management Information Systems, 35*(1), 19-52.

Malhotra, A., Melville, N. P., & Watson, R. T. (2013). Spurring Impactful Research on Information Systems for Environmental Sustainability. *MIS Quarterly, 37*(4), 1265-1274.

Mittendorf, C., Berente, N., & Holten, R. (2019). Trust in Sharing Encounters among Millennials. *Information Systems Journal, 29*(5), 1083-1119.

Monetary Authority of Singapore. (2021, 19 May). Accelerating Green Finance Retrieved 22 Oct, 2021, from https://www.mas.gov.sg/news/media-releases/2021/accelerating-green-finance

Niemimaa, M., Järveläinen, J., Heikkilä, M., & Heikkilä, J. (2019). Business Continuity of Business Models: Evaluating the Resilience of Business Models for Contingencies. *International Journal of Information Management, 49*, 208-216.

Pan, S. L., Li, M., Pee, L. G., & Sandeep, M. S. (2021). Sustainability Design Principles for a Wildlife Management Analytics System: An Action Design Research. *European Journal of Information Systems, 30*(4), 452-473.

Pan, S. L., & Pee, L. G. (2020). Usable, in-Use, and Useful Research: A 3U Framework for Demonstrating Practice Impact. *Information Systems Journal, 30*(2), 403-426.

Pee, L., Pan, S. L., & Cui, L. (2019). Artificial Intelligence in Healthcare Robots: A Social Informatics Study of Knowledge Embodiment. *Journal of the Association for Information Science and Technology, 70*(4), 351-369.

Pee, L. G., Pan, S. L., Wang, J., & Wu, J. (2021). Designing for the Future in the Age of Pandemics: A Future-Ready Design Research (FRDR) Process. *European Journal of Information Systems, 30*(2), 157-175.

Rajagopalan, P., Andamon, M. M., & Paolini, R. (2020). Investigating Thermal Comfort and Energy Impact through Microclimate Monitoring- a Citizen Science Approach. *Energy and Buildings, 229*, 110526.

Ravichandran, T., & Giura, S. I. (2019). Knowledge Transfers in Alliances: Exploring the Facilitating Role of Information Technology. *Information Systems Research, 30*(3), 726-744.

Shevchuk, N., Degirmenci, K., & Oinas-Kukkonen, H. (2019). *Adoption of Gamified Persuasive Systems to Encourage Sustainable Behaviors: Interplay between Perceived Persuasiveness and Cognitive Absorption*. Paper presented at the Proceedings of the 40th International Conference on Information Systems.

Singh, M., & Sahu, G. P. (2020). Towards Adoption of Green Is: A Literature Review Using Classification Methodology. *International Journal of Information Management, 54*, 102147.

Smith, A. (2021, 13 May). Factbox: How Big Is Bitcoin's Carbon Footprint? Retrieved 22 Oct, 2021, from https://www.reuters.com/technology/how-big-is-bitcoins-carbon-footprint-2021-05-13/

Tim, Y., Pan, S. L., Ractham, P., & Kaewkitipong, L. (2017). Digitally Enabled Disaster Response: The Emergence of Social Media as Boundary Objects in a Flooding Disaster. *Information Systems Journal, 27*(2), 197-232.

Tsukayama, H. (2017). How Bad Is Email for the Environment? Retrieved 22 Oct, 2021, from https://www.washingtonpost.com/news/the-switch/wp/2017/01/25/how-bad-is-email-for-the-environment/

Warkentin, M., Goel, S., & Menard, P. (2017). Shared Benefits and Information Privacy: What Determines Smart Meter Technology Adoption? *Journal of the Association for Information Systems, 18*(11), 3.

Watson, R. T., Boudreau, M.-C., & Chen, A. J. (2010). Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the Is Community. *MIS Quarterly, 34*(1), 23-38.

Whittaker, L., Mulcahy, R., & Russell-Bennett, R. (in press). 'Go with the Flow' for Gamification and Sustainability Marketing. *International Journal of Information Management, 61*.

Ying, W., Pee, L. G., & Jia, S. (2018). Social Informatics of Intelligent Manufacturing Ecosystems: A Case Study of Kutesmart. *International Journal of Information Management, 42*, 102-105.

Zeiss, R., Ixmeier, A., Recker, J., & Kranz, J. (2021). Mobilising Information Systems Scholarship for a Circular Economy: Review, Synthesis, and Directions for Future Research. *Information Systems Journal, 31*(1), 148-183.

Zekić-Sušac, M., Mitrović, S., & Has, A. (in press). Machine Learning Based System for Managing Energy Efficiency of Public Sector as an Approach Towards Smart Cities. *International Journal of Information Management, 58*, 102074.

Zhang, D., Pee, L. G., Pan, S. L., & Cui, L. (in press). Big Data Analytics, Resource Orchestration, and Digital Sustainability: A Case Study of Smart City Development. *Government Information Quarterly*, 101626.