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Leveraging Information Systems for Environmental Sustainability and Business Value

Businesses are under increasing pressure to mitigate their negative sustainability impacts. Though a large body of Green IS research has focused on the role of information systems in sustainability, managers remain unclear about how leveraging information systems for environmental sustainability can create business value. To help close this sustainability implementation gap, we reviewed 31 articles reporting on Green IS issues published in practitioner journals, and from our analysis provide five recommendations for creating business value from sustainability practices.[1,2]

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Turning Sustainability Obligations into Business Opportunities

Immediate actions are needed to combat global climate change and, because businesses are responsible for a large part of greenhouse gas emissions, they have a role to play in mitigating climate change. The Carbon Disclosure Project found that, since 1988, just 100 companies have been responsible for 71% of global greenhouse gas emissions.[3] Thus, environmental sustainability[4] has become part of most companies' strategic agendas.[5] Various stakeholders, such as investors, customers, employees, policy makers and nongovernmental organizations, have an interest in companies taking responsibility and being accountable for their impact on environmental sustainability. A company's impact includes, for example, how much energy and resources it uses, the quantity of greenhouse gases it emits and how much waste it generates. In addition to assessing profitability, investors are increasingly assessing a company's

1 Richard Watson is the accepting senior editor for this article.

2 The authors thank the senior editor and the anonymous reviewers for their constructive comments during the review process.

3 For more information on the role corporations can play in driving global energy transition, see Griffin, P. *The Carbon Majors Database: CDP Carbon Majors Report 2017*, CDP, July 2017, available at https://cdn.cdp.net/cdp-production/cms/reports/documents/000/002/327/original/Carbon-Majors-Report-2017.pdf?1501833772.

4 While sustainability has several dimensions, the focus of this article is on the environmental dimension.

5 Delevingne, L., Gründler, A., Kane, S. and Koller, T. *The ESG Premium: New Perspectives on Value and Performance*, McKinsey, February 2020, available at https://www.mckinsey.com/business-functions/sustainability/our-insights/the-esg-premium-new-perspectives-on-value-and-performance.

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sustainability practices and its record of serving the collective interests of people and the planet. Sustainability is becoming important in assessing a company's legitimacy.

Many managers view accounting for and disclosing a company's sustainability impact on the world as a chore. However, researchers have shown that adopting sound sustainability practices can create long-term business value in addition to sustainability value for a company's various stakeholders in five ways: 1) top-line growth, 2) cost reduction, 3) reduced regulatory interventions, 4) employee productivity, and 5) investment and asset optimization.[6] Opportunities for sustainability practices to create business value come, for example, from attracting new customers through more sustainable products and practices (top-line growth), from lower energy, water and waste-disposal costs (cost reduction) and from attracting and retaining talent through greater social credibility and purpose of their work (employee productivity).[7] Adopting sustainability practices promises to be worth the effort, with one study forecasting that worldwide environmental, social and governance (ESG) investments of $1.8 trillion could yield a total net benefit of $7.1 trillion by 2030.[8] However, while the potential to create business value from sustainability practices is high, there is a lack of tools and best practices for implementing sustainability at the practical level.[9] In this article, we refer to this as the "sustainability implementation gap."

Information systems are widely acknowledged to be key resources in realizing sustainable transformations.[10] Though a large body of Green IS[11] research has focused on the role of information systems in sustainability, many managers engaging in sustainability adaptations and transformations that involve the implementation of information systems are unclear about how these systems can create business value. To date, Green IS research has often highlighted its generic potential but not identified practical and implementable solutions.[12] Moreover, traditional literature reviews of Green IS often take a theoretical stance—for instance, focusing on frameworks to understand Green IS initiatives and organizational readiness for it, on the generation of theoretical knowledge, or on shareholders' valuation of Green IS or on future research directives for the IS discipline.[13] As a consequence, there is a lack of advice on implementing information systems in sustainability transformations.[14]

6 For insights on the five ways of value creation, see Lubin, D. A. and Esty, D. C. "The Sustainability Imperative," *Harvard Business Review* (88:5), May 2010, pp. 42-50.

7 For more details and examples of how environmental, social and governance (ESG) practices can link to value creation in five essential ways, see Koller, T. and Nuttall, R. *How the E in ESG Creates Business Value*, McKinsey, June 2020, available at https://www.mckinsey.com/business-functions/sustainability/our-insights/sustainability-blog/how-the-e-in-esg-creates-business-value.

8 Moritz, B. and Gawel, A. "3 Ways Business Can Take Action in the Fight against Climate Change" *World Economic Forum*, available at https://www.weforum.org/agenda/2022/11/cop27-business-action-fight-climate-change/.

9 For examples of sustainability-related IS implementation research, see: 1) Engert, S. and Baumgartner, R. J. "Corporate Sustainability Strategy: Bridging the Gap between Formulation and Implementation," *Journal of Cleaner Production* (113), December 2015, pp. 822-834; and 2) Farri, E., Cervini, P. and Rosani, G. "The 8 Responsibilities of Chief Sustainability Officers," *Harvard Business Review*, March 2, 2023, available at https://hbr.org/2023/03/the-8-responsibilities-of-chief-sustainability-officers.

10 For an analysis of how information systems can support essential sensemaking practices in environmental sustainability transformations, see Seidel, S., Kruse, C. L., Székely, N., Gau, M. and Stieger, D. "Design Principles for Sensemaking Support Systems in Environmental Sustainability Transformations," *European Journal of Information Systems* (27:2), 2018, pp. 221-247.

11 Green IS refers to the design and implementation of information systems that contribute to a long-term sustainable future, including technologies and business models that limit resource use, increase energy efficiency and contribute to sustainable business and social practices.

12 For more information on the achievements and challenges of applying information system solutions to environmental sustainability, see: 1) Gholami, R., Watson, R. T., Hasan, H., Molla, A. and Bjorn-Andersen, N. "Information Systems Solutions for Environmental Sustainability: How Can We Do More?," *Journal of the Association for Information Systems* (17:8), August 2016, pp. 521-536; and 2) Malhotra, A., Melville, N. P. and Watson, R. T. "Spurring Impactful Research on Information Systems for Environmental Sustainability," *MIS Quarterly* (37:4), December 2013, pp. 1265-1274.

13 For more information on the theoretical contributions of synthesizing Green IS knowledge, see for example: 1) Molla, A., Cooper, V. and Pittayachawan, S. "The Green IT Readiness (G-Readiness) of Organizations: An Exploratory Analysis of a Construct and Instrument," *Communications of the Association for Information Systems* (29:1), August 2011, pp. 67-96; 2) Nishant, R., Teo, T. S. H. and Goh, M. "Do Shareholders Value Green Information Technology Announcements?," *Journal of the Association for Information Systems* (18:8), August 2017, pp. 542-576; 3) vom Brocke, J., Watson, R. T., Dwyer, C., Elliot, S. and Melville, N. "Green Information Systems: Directives for the IS Discipline," *Communications of the Association for Information Systems* (33:1), January 2012, pp. 509-520; and 4) Wang, X., Brooks, S. and Sarker, S. "Understanding Green IS Initiatives: A Multi-Theoretical Framework," *Communications of the Association for Information Systems* (37:1), January 2015, pp. 670-704.

14 Farri, E., Cervini, P. and Rosani, G., op. cit., March 2, 2023.

The purpose of our study is to provide practical advice on how businesses can close the sustainability implementation gap and leverage information systems for much-needed sustainability practices that both benefit the environment and provide business value. We reviewed 31 articles from practitioner journals that reported on Green IS issues (the Appendix describes our research methodology). In contrast to traditional literature reviews that take a theoretical stance, we focused on reviewing the implementation of Green IS so we could derive recommendations for leveraging information systems to provide business value from sustainability practices. In other words, the purpose of our research is to identify ways that organizations can close the sustainability implementation gap.

Our Approach to Evaluating Information Systems Opportunities for Achieving Sustainability

A business's information systems combine people, procedures, organizational structures and information technology (hardware and software). Thus, it is not only technologies such as sensors, artificial intelligence or platforms that have the potential to support sustainability practices but also the practices and business models inherent in an overall information system.[15] Leveraging the overall system's ability to capture, model and share information along value chains can help overcome the barriers to sustainability value creation, such as quality uncertainty, data availability and information asymmetries.

Recognizing that the IT community must move from words to action in responding to global climate change,[16] we reviewed Green IS research that reported on leveraging information systems to close the sustainability implementation gap and create business value from sustainability practices. Information systems, with their potential to enable or facilitate sustainable business practices, can play a crucial role in a company's transformation toward sustainability.[17] When adopting and transitioning to sustainability practices, information systems provide businesses with innovation opportunities in three areas—*technology, systems and business models*.[18] Because technologies lay the foundation for systems and business-model innovation, the opportunities are, by definition, interdependent (see Table 1 for example innovations).

First, *technology* innovation, involving a combination of hardware and software with an information processing capability,[19] can promote sustainability business practices at the individual or organizational level by facilitating interconnection, communication and automation opportunities.[20] Examples of sustainability technology innovations include optimizing computing, software architectures and algorithms to help reduce the environmental impact of data computing, processing and data centers—i.e., to mitigate the environmental impact of what an individual or organization does with technology.[21]

Second, *systems* innovation to achieve environmental sustainability involves innovating a network of interdependent technologies that work together to serve a common purpose. Technical systems can be intertwined with social systems—i.e., with people, structures and knowledge of how the system should be used—to form a sociotechnical system that serves a larger

15 For an overview of the latest insights from industry leaders and researchers on emerging technologies that are changing the world, see French, A. M. and Shim, J. P. "The Digital Revolution: Internet of Things, 5G and Beyond," *Communications of the Association for Information Systems* (38:40), May 2016, pp. 840-850.

16 For a request for impactful IS research opportunities on environmental sustainability, see Watson, R. and Kranz, J. "Guest Editorial: The New Sustainability Imperative: Moving from Good Intentions to Measurable Results," *MIS Quarterly Executive* (20:2), June 2021, pp. v-viii.

17 For a literature review and synthesis of the contribution of information systems to sustainable development goals, see Leong, C., Tan, F. and Ahuja, M. "IS for Good—10 Years to SDG: Where We Have Been and Where We Need to Go?," *Proceedings of 41st International Conference on Information Systems (ICIS)*, December 13-16, 2020, pp. 1-9.

18 Watson, R. T. and Mathew, S. K. *Capital, Systems, and Objects: The Foundation and Future of Organizations from a South Asian Perspective*, Springer, 2021.

19 Nevo, S., Nevo, D. and Ein-Dor, P. "Thirty Years of IS Research: Core Artifacts and Academic Identity," Communications of the Association for Information Systems (25:1), January 2009, pp. 221-243.

20 Frank, A. G., Dalenogare, L. S. and Ayala, N. F. "Industry 4.0 Technologies: Implementation Patterns in Manufacturing Companies," *International Journal of Production Economics* (210:3), January 2019, pp. 15-26.

21 For examples of sustainability-related technology innovations, see: 1) Bashroush, R., Woods, E. and Noureddine, A. "ICT Energy Demand: What Got Us Here Won't Get Us There!," *IEEE Software* (33:2), March - April 2016, pp. 18-21; and 2) Grier, D. A. "Click Here to Empty Trash," *Computer* (41:9), September 2008, pp. 6-8.

Table 1: Information System Opportunities for Leveraging Technology, Systems and Business-Model Innovations for Sustainability

Opportunities	Definition	Examples
Technology Innovation	Innovation of an independent technology (hardware and software) with an information processing opportunity that enhances interconnection, communication or automation to promote sustainability.	Optimizing computing, software architectures or algorithms to help reduce the environmental impact of a technology.
Systems Innovation	Innovation of a network of interdependent technical and social systems that improves monitoring, reporting and analysis capabilities to optimize organizational processes for sustainability.	Reporting and making sense of environmental performance information to help establish new organizational thinking and processes for sustainability.
Business-Model Innovation	Innovation of a business model to redesign core products and services or align strategy and employees to sustainability.	Sharing product information along the value chain to help a company and its ecosystem create, deliver and capture resource-preserving, "circular" rather than linear products and services.

objective.[22] Examples of systems innovation for sustainability include environmental management systems and sensor networks that monitor and report environmental performance information to help optimize organizational operations to achieve environmental sustainability.[23]

Third, *business-model* innovation complements innovations in technology (e.g., sensors, artificial intelligence or platforms) and in systems (e.g., production or distribution processes). Business-model innovation has a greater impact on achieving sustainability objectives than innovations in the systems or technologies that underpin them.[24] Business-model innovation can be a source of differentiation and sustainability by redesigning core products and services or aligning strategy and employees with sustainability objectives.[25]

In summary, the information systems opportunities to leverage technology, systems and business-model innovations can turn a company's sustainability obligations into sustainability practices that create long-term business value for its various stakeholders and provide sustainability value. This insight guided our literature review and analysis. In the rest of this article, we present the findings of our analysis, from which we have derived practical guidance on how organizations can leverage information systems opportunities to achieve environmental sustainability.

Practical Insights on Information System Opportunities for Environmental Sustainability

We describe our insights on the role and influence of information systems for environmental sustainability under the headings of technology, systems and business-model innovations, highlighting how the innovations contribute to the achievement of sustainability. Detailed information on the analyzed articles

22 For an overview of developing critical software systems, see Sommerville, I. *Software Engineering*, Sixth Edition, Addison Wesley, 2000 and Seventh Edition, Pearson Education, 2004.

23 For examples of systems innovations, see: 1) Florida, R. and Davison, D. "Gaining from Green Management: Environmental Management Systems Inside and Outside the Factory," *California Management Review* (43:3), March 2001, pp. 64-84; 2) Martinez, K., Hart, J. K. and Ong, R. "Environmental Sensor Networks: A Revolution in Earth System Science?," *Computer* (37:8), November 2007, pp. 50-56; and 3) Watson, R. T., Boudreau, M. C., Li, S. and Levis, J. "Telematics at UPS: En Route to Energy Informatics," *MIS Quarterly Executive* (9:1), March 2010, pp. 1-11.

24 Watson, R. T., and Mathew, S. K., op. cit., 2021.

25 For examples of business-model innovations, see Al-Debi, M. M., El-Haddadeh, R. and Avison, D. "Defining the Business Model in the New World of Digital Business," *Proceedings of Americas Conference on Information Systems (AMCIS)* August 14-17, 2008.

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and our categorization of the insights can be found in the Appendix. Our analysis found many opportunities for leveraging information systems to achieve sustainability, which we have categorized under IS opportunities for shaping organizational *readiness*, *operations*, *systems thinking*, *strategy* and *product and service solutions*.

Insights on Technology Innovations

Technology-related information systems innovations relate to independent technologies (hardware and software) that provide processing opportunities for enhancing interconnections, communication or automation to promote sustainability. We found technology innovations that provide opportunities for shaping *organizational readiness* and *organizational operations* for sustainability.

Shaping organizational readiness: The inherent nature of information systems (collecting, processing, storing and distributing information) means they have a high potential to optimize the eco-efficiency of processes. However, to harness this opportunity and address sustainability issues, organizations must first recognize the opportunities for leveraging information systems for sustainability before initiating corresponding changes. The majority of the reviewed articles highlighted the need to mentally and technically prepare organizations for sustainability.[26] The mechanism for this preparation is to highlight the general importance of information systems as well as the drivers and ways to initiate change of organizational processes toward sustainability.[27]

Though the importance of information systems for sustainability is widely recognized, it can be difficult for companies to justify investments in information systems for sustainability. Organizations tend to associate sustainability with creating ethical value rather than business value, which hinders implementation.[28] This issue can be addressed by adopting analytical tools that link environmental sustainability metrics to potential profit-related business value, thus legitimizing the implementation of sustainability initiatives. By leveraging the power of digital data, information systems provide the opportunity to analyze and report on energy efficiency initiatives, help raise awareness for environmentally sustainable behavior change and pave the way for companies to legitimize and assess their readiness to adopt sustainability practices.[29]

Shaping organizational operations with independent technology: Some of the reviewed literature examined how the environmental impact of digital technology can be improved through practices such as optimizing the energy efficiency of data centers, computation and software engineering, and adopting workplace virtualization.[30] For instance, incorporating climate metrics into the basic requirements of designing software applications enables companies to minimize climate impacts by improving operations, manufacturing and the disposal of materials.

Though the insights on technology innovations shed light on how to mitigate the environmental impact of what an individual or organization

26 See, for example: 1) Blomme, H. "Towards Better Corporate Reporting: Core & More," *Schmalenbach Business Review* (71:2), December 2018, pp. 263-270; 2) Park, S. H., Eo, J. and Lee, J. J. "Assessing and Managing an Organization's Green IT Maturity," *MIS Quarterly Executive* (11:3), September 2012, pp. 127-140; and 3) Curry, E., Guyon, B., Sheridan, C. and Donnellan, B. "Developing a Sustainable IT Capability: Lessons from Intel's Journey," *MIS Quarterly Executive* (11:2), June 2012, pp. 61-74.

27 Borning, A., Friedman, B. and Logler, N. "The 'Invisible' Materiality of Information Technology," *Communications of the ACM* (63:6), May 2020, pp. 57-64.

28 For more details on how corporate social responsibility (CSR) can be a source for good as well as a source of competitive advantage and value creation, see Husted, B. W. and Allen, D. B. "Strategic Corporate Social Responsibility and Value Creation among Large Firms: Lessons from the Spanish Experience," *Long Range Planning* (40:6), December 2007, 594-610.

29 See, for example: 1) Verdecchia, R., Lago, P., Ebert, C. and De Vries, C. "Green IT and Green Software," *IEEE Software* (38:6), November 2021, pp. 7-15; and 2) Park, S.-H., Eo, J. and Lee, J. J., op. cit., September 2012.

30 For examples of technology-enabled process optimization, see: 1) Bashroush, R., Woods, E. and Noureddine, A., op. cit., March - April 2016; 2) Stansberry, M. "The Future of Green IT: Solving the Accountability Issue," *Computer* (46:7), July 2013, pp. 91-93; 3) Penzenstadler, B., Raturi, A., Richardson, D. and Tomlinson, B. "Safety, Security, Now Sustainability: The Nonfunctional Requirement for the 21st century," *IEEE Software* (31:3), May-June 2014, pp. 40-47; 4) Siegmund, N., Dorn, J., Weber, M., Kaltenecker, C. and Apel, S. "Green Configuration: Can Artificial Intelligence Help Reduce Energy Consumption of Configurable Software Systems?," *Computer* (55:3), March 2022, pp. 74-81; 5) Gomes, C., Dietterich, T., Barrett, C., Conrad, J., Dilkina, B., Ermon, S. [and 27 other authors] "Computational Sustainability: Computing for a Better World and a Sustainable Future," *Communications of the ACM* (62:9), August 2019, pp. 56-65; 6) Grier, D. A., op. cit., September 2008; and 7) Blevis, E. "Sustainability Implications of Organic User Interface Technologies: An Inky Problem," *Communications of the ACM* (51:6), June 2008, pp. 56-57.

does with an independent technology, we found that sociotechnical systems made up of interdependent technologies, people and structures are powerful for thinking about sustainability and systematically working toward a more sustainable environment.

Insights into Systems Innovations

Insights into systems innovation relate to a network of interdependent technical and social systems that improve monitoring, reporting and analysis opportunities to optimize organizational processes and thinking for a sustainable environment. We found that systems innovations primarily provided information systems opportunities for shaping *organizational operations* and *systems thinking*.

Shaping organizational operations with sociotechnical systems: Some of the reviewed articles investigated the potential of environmental management systems (EMSs) to optimize business processes by making critical information on environmental performance more visible.[31] EMSs can integrate environmental considerations either specifically into particular organizational operations[32] or into every organizational management and business system to create transparency throughout the value chain.[33]

To design and implement an EMS, it is essential to first assess the current status of sustainability and collect relevant data across business units and operations. Only then can the potential of information systems to analyze and report on energy efficiency opportunities help raise awareness of environmentally sustainable behavior change and pave the way for companies to optimize sustainability practices.[34] Another important issue is how to continuously assess the discrepancy between the desired data requirements of an EMS and the current data available in an organization. The articles that explored this issue found that an evaluation model that improves the understanding of where data is stored, what dimensions stakeholders are considering and the extent to which the various information systems in the organization are integrated has proven useful.

Shaping organizational systems thinking: We found that some reviewed articles highlighted how systems thinking helped make sense of the complexity of sustainability by looking beyond organizational boundaries. These articles described the potential of information systems for transforming organizational value creation that opens up new business ecosystems.[35] By using data to communicate environmental sustainability commitment and performance to external stakeholders, such as upstream and downstream partners or investors, information systems can help drive sustainability throughout the ecosystem.[36] To meet increasing pressure to continue working toward sustainability goals and to protect themselves from value-chain liability, organizations must find strategic complementarity among collaborating partners. Information systems can facilitate the exchange of information between partners. Such exchanges, together with decision support systems that help to identify options for enhancing eco-sustainability, are powerful enablers of ecosystem transformation toward sustainability.[37]

Insights into Business-Model Innovations

In the articles we reviewed, we found examples of sustainability-related information systems opportunities that arose from business-model innovations. We categorized these

31 See, for example: 1) Florida, R. and Davison, D., op. cit., March 2001; 2) Odenwald, T. and Berg, C. "A New Perspective on Enterprise Resource Management," *MIT Sloan Management Review* (56:1), September 2014, pp. 12-14; 3) van Heck, E., van Baalen, P., van der Meulen, N. and van Oosterhout, M. "Achieving High Performance in a Mobile and Green Workplace: Lessons from Microsoft Netherlands," *MIS Quarterly Executive* (11:4), December 2012, pp. 175-188; and 4) Watson, R. T., Boudreau, M. C. and Chen, A. J. "Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community," *MIS Quarterly* (34:1), March 2010, pp. 23-38.

32 Florida, R. and Davison, D., op. cit., March 2001.

33 Odenwald, T. and Berg, C., op. cit., September 2014.

34 See: 1) Xu, Z. "Measuring Green IT in Society," *Computer* (45:5), May 2012, pp. 83-85; and 2) Watson, R. T., Boudreau, M. C. and Chen, A. J., op. cit., 2010.

35 See: 1) Turner, J. "Power Management as Choice Architecture," *Computer* (46:5), May 2013, pp. 108-111; 2) Delcambre L. and Tolle T. "Harvesting Information to Sustain Forest," *Communications of the ACM* (46:1), January 2003, pp. 38-39; and 3) Eleftheriadou, D., Hartog, E., and Gkiaouri, N. "The Cities Challenge: Driving a Green and Digital Recovery and Social Resilience," *Computer* (54:5), May 2021, pp. 70-75.

36 Kiron, D. and Unruh, G. "The Convergence of Digitalization and Sustainability," *MIT Sloan Management Review*, January 2018, available at https://sloanreview.mit.edu/article/the-convergence-of-digitalization-and-sustainability/

37 Odenwald, T. and Berg, C., op. cit., September 2014.

innovations as opportunities for aligning *organizational strategy* and employees with sustainability and redesigning *product and service solutions* toward sustainability.

Shaping organizational strategy: Some of the articles focused on how businesses are shifting from optimizing isolated sustainability practices to a more integrated, strategic approach of changing underlying business logics and exploiting new business capabilities. These studies showed that some businesses are acknowledging that sustainability can be a strategic differentiator, assessing the maturity of their sustainability implementation capabilities[38] and including sustainability in their strategies and decision-making processes.[39] To demonstrate to internal and external stakeholders that the organization's responsibilities and practices for environmental sustainability are structurally sound, it must give strategic priority to IT (both hardware and software) and align IT with the organization's overall sustainability goals. Such alignment will create the appropriate IT culture, commitment and cooperation needed to minimize information asymmetries and build trust among collaborating stakeholders both inside and outside organizational boundaries.[40]

Shaping organizational product and service solutions: In some of the reviewed articles, there were examples of information-systems-based business-model transformation—i.e., deploying information systems to make product and service solutions more environmentally sustainable. As part of their environmental sustainability efforts, organizations are increasingly rethinking the durability of their offerings throughout their lifecycles and along the entire value chain.[41] Software solutions that capture, model, and analyze data, such as the carbon footprint of stock units, can serve as sustainability solutions that promote cross-functional interaction and collaboration, and enable employees and customers to become more environmentally sustainable.[42]

Moreover, intelligent products—i.e., products with embedded software and hardware intelligence that leverage information—can be used as "active nodes in new value-creating systems."[43] This is an example of how product and service development can enable radical sustainability transformation through closed-loop systems. Closed-loop systems not only focus on the upstream flow of goods but also consider activities in the reverse value chain to create an environmentally sustainable cycle of resource flows. Building on the ability of information systems to fluently exchange information between objects and stakeholders, intelligent goods can not only reduce uncertainties about the environmental sustainability of products and services but can also improve organizational decision-making and collaboration.

Summary of How the Identified Information System Opportunities Help to Achieve Sustainability

The information system opportunities covered by the studies we reviewed focused mainly on adopting technologies and systems, and to a lesser extent on the larger issue of business-model innovation.

The studies mostly focused on making business practices more sustainable with increased eco-efficiency and greater adoption of environmentally friendly technologies and industrial processes. The technology and systems innovations we identified mostly provided information systems opportunities to shape organizational readiness for sustainability and to maximize the efficiency of business processes. The business-model innovations provided information systems opportunities for environmentally sustainable production and

38 Molla, A., Cooper, V. and Pittayachawan, S., op. cit., August 2011.

39 See, for example: 1) Lokuge, S., Sedera, D., Cooper, V. and Burstein, F. "Digital Transformation: Environmental Friend or Foe? Panel Discussion at the Australasian Conference on Information Systems 2019," *Communications of the Association for Information Systems* (48:1), February 2021, pp. 616-634; and 2) Wang, X., Brooks, S. and Sarker, S. "Understanding Green IS Initiatives: A Multi-Theoretical Framework," *Communications of the Association for Information Systems* (37:1), January 2015, pp. 670-704.

40 See, for example, Curry, E., Guyon, B., Sheridan, C. and Donnellan, B., op. cit., June 2012.

41 See: 1) Bockelmann, T. and Recker, J. "How One Company Used Data to Create Sustainable Take-out Food Packaging," *Harvard Business Review*, November 11, 2022; and 2) Atkinson, C., Schulze, T. and Klingert, S. "Facilitating Greener IT through Green Specifications," *IEEE Software* (31:3), May 2014, pp. 56-63.

42 Kranz, J., Fiedler, M., Seidler, A., Strunk, K. and Ixmeier, A. "Unexpected Benefits from a Shadow Environmental Management Information System," *MIS Quarterly Executive* (20:3), September 2021, pp. 235-256.

43 Rajala, R., Hakanen, E., Mattila, J., Seppälä, T. and Westerlund, M. "How Do Intelligent Goods Shape Closed-Loop Systems?," *California Management Review* (60:3), May 2018, pp. 20-44.

collaboration and for making environmental sustainability a strategic differentiator that has the potential to reshape industrial processes and therefore create sustainable business ecosystems.

Recommendations for Leveraging Information Systems for Environmental Sustainability and Business Value

From the identified information systems opportunities for shaping organizational readiness, operations, systems thinking, strategy, and product and service solutions, we have derived five recommendations for leveraging information systems to close the sustainability implementation gap and create business value from sustainability practices.

Figure 1 depicts the five recommendations, which together create a pathway for turning environmental sustainability into business value. At the core of this pathway are the *sociotechnical systems* formed from technology, systems and business-model innovations that lay the foundation for information systems opportunities for achieving sustainability. The five recommendations are depicted as interrelated to emphasize that sustainability is an ongoing, iterative pathway that businesses continually cycle around as they adapt and transform to sustainability. Not only are interrelationships between technologies increasing but also between technologies, people and the environment. As a consequence, the pathway toward environmental sustainability creates an *eco-sociotechnical system* that enables companies to progress from eco-efficiency to eco-effectiveness as they turn environmental sustainability into business value.

1. Legitimize Sustainability by Creating Awareness

For the implementation of information systems for environmental sustainability to become a business reality, organizations must create an awareness of the potential of sustainability and be mentally and technically prepared to adopt sustainability initiatives. However, initiating sustainability practices is not only a technical change. First and foremost, the organization needs a mindset and incentives that value and support environmentally sustainable practices. To make the implementation of sustainability practices a success, there must be a broad consensus among employees and executives on the need for environmental sustainability.

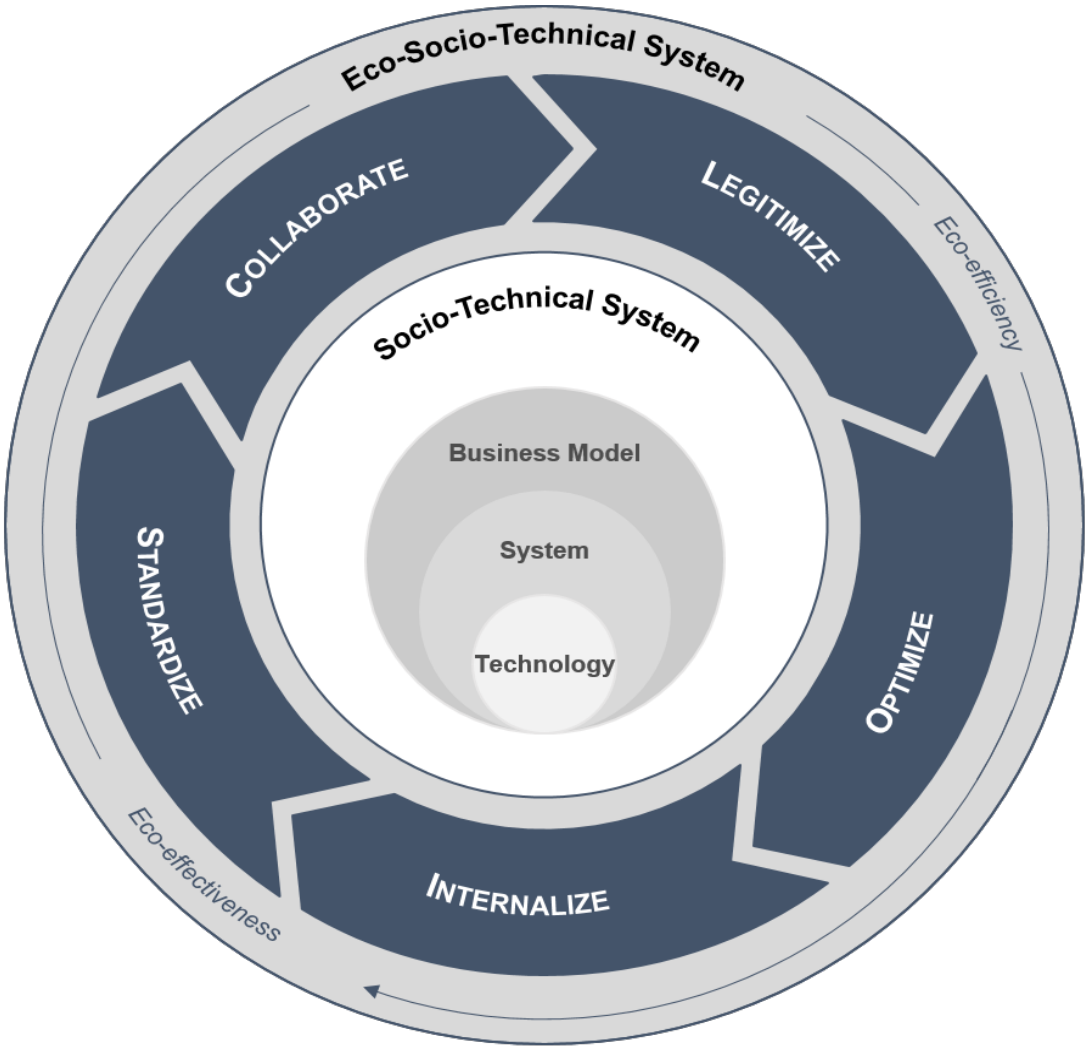
Increasing awareness is an important part of preparing for a sustainability mindset, and information systems can help raise awareness of the importance of sustainability. Analytical tools can be used to link environmental sustainability metrics to potential profit-related business value and thus help to legitimize eco-sustainability-oriented decision-making, efforts and investments. Based on information provided by an environmental management system, strategic decisions can be evaluated with the joint consideration of financial and eco-efficient performance indicators. Moreover, we recommend that organizations harness the monitoring, reporting and decision-support capabilities of information systems to help employees adopt a mindset and behaviors that encourages them to make energy- and waste-efficient choices.

For example, after the EU taxonomy for sustainable activities[44] was published in June 2020, new analytical tools such as Envoria[45] came to the market. Envoria simplifies ESG reporting by evaluating business activities and mapping key financial information and can therefore contribute to legitimizing sustainability initiatives. As such, this tool is an example of how the power of data can promote the awareness of environmentally sustainable behavior change and pave the way for organizations to legitimize corresponding sustainability practices. Other researchers have also highlighted the use of analytic tools for fast and constructive decision support in today's environment, where

44 The EU taxonomy for sustainable activities is a classification system established to clarify which economic activities are environmentally sustainable, in the context of the European Green Deal. The aim of the taxonomy is to prevent greenwashing and to help investors make informed sustainable investment decisions.

45 *EU Taxonomy: Evaluate Business Activities and Automate Your EU Taxonomy Reporting*, 2022, Financial Software Architects GmbH, available at https://envoria.com/de/feature/eu-taxonomy-software.

Figure 1: Recommended Pathway for Turning Environmental Sustainability into Business Value



the sustainability requirements of various stakeholders are changing rapidly.[46]

2. Optimize Processes, Products and Services to Reinforce Sustainability

The opportunities presented by technological advances in software and hardware enable just about every business process—from sourcing to manufacturing and distribution to recycling—to be rethought. There is the potential to optimize fundamental processes for *operations* and *decision-making*, and for optimizing *product and service solutions* to make them more eco-efficient.

To make business operations processes more eco-efficient, an organization must optimize both the use of energy and the sourcing of material resources used in manufacturing and distribution. It must also optimize the recycling of materials at the end of the life of a product. When managers are faced with adjusting processes to enhance eco-efficiency and reinforce

46 For information on using digital technologies to drive the ESG agenda, see Hutchinson, R., Maher, H. de Laubier, R. and Charanya, T. *The Five Digital Building Blocks of a Corporate Sustainability Agenda*, Boston Consulting Group, March 2022, available at https://www.bcg.com/de-de/publications/2022/building-blocks-of-corporate-sustainability-agenda.

Table 2: Information Systems Opportunities for Each of the Five Recommendations

Recommendations for Turning Environmental Sustainability into Business Value	Information Systems Opportunities
1. Legitimize sustainability by creating awareness	Use monitoring, reporting, and decision-making systems to produce metrics and incentives that raise awareness and promote environmentally sustainable practices
2. Optimize processes, products and services to reinforce their sustainability	Reduce the environmental impact of business processes, product and service solutions, and behaviors by having systems that promote dematerialization, and trace and analyze offerings
3. Internalize sustainability by developing joint sustainability and business strategies	Develop systems that visualize and analyze the interaction of environmental processes, and product and behavioral data, to mobilize investments and strategic thinking in sustainability
4. Standardize sustainability by establishing sustainability data governance	Use systems to collect, process and analyze environmental sustainability data and make it accessible and comparable
5. Collaborate with external stakeholders by establishing strategic partnerships and ecosystems	Use systems that capture and model reliable sustainability data and share it with upstream and downstream partners to achieve joint sustainability goals across product and service lifecycles

environmental sustainability, the information and transparency opportunities provided by information systems can pave the way for eco-sustainability-enhancing concepts such as dematerialization (i.e., reducing the quantities of materials needed over time), monitoring and evaluating behavioral impacts, and knowledge dissemination.[47] Information systems also offer the opportunity to reduce operational inefficiencies by motivating environmentally sustainable behavior change and supporting efficient operational behavior through monitoring and reporting of, for example, energy use.[48]

An example is the HolyGrail[49] industry consortium, which has piloted digital watermarks on consumer goods packaging. The invisible digital watermarks link to a database containing relevant packaging attributes that help increase the accuracy of sorting waste materials and reusing them. Similarly, Maersk (a Danish shipping and logistics company) is developing cradle-to-cradle digital passports for its ships so that it can identify and recycle the ships' steel components.[50] The dematerialization opportunities created by digital watermarks and digital passports can optimize waste sorting, increase reuse and recycling, and thus reduce the quantity of waste generated.

The effective use of data can also play an essential role in optimizing decision-making by ensuring that decision makers have access to information about the risks and opportunities of environmental sustainability initiatives. By tapping into the power of EMS data, information systems can support informed decision-making by ensuring that critical data on environmental performance is available and relevant.

Optimizing product and service solutions for eco-efficiency means planning and designing solutions that have a minimum of inputs (e.g., resources, emissions) and outputs (e.g.,

47 For articles on effective sustainable technology strategies, see: 1) Daugherty, P., Lacy, P., Podder, S. and Singh, S. K. *Uniting Technology and Sustainability: How to Get Full Value From Your Sustainable Technology Strategy*, Accenture, June 2, 2022, available at https://newsroom.accenture.com/news/sustainable-technology-strategy-critical-for-achieving-business-growth-and-esg-performance-according-to-new-accenture-report.htm; and 2) Close, K., Faure, N. and Hutchinson, R. *How Tech Offers a Faster Path to Sustainability*, Boston Consulting Group, October 14, 2021, available at https://www.bcg.com/de-de/publications/2021/how-technology-helps-sustainability-initiatives.

48 Daugherty, P., Lacy, P., Podder, S. and Singh, S. K., op. cit., June 2, 2022.

49 *HolyGrail A Digital Solution to Sustainability Challenges*, Procter & Gamble blog post, July 9, 2021, available at https://us.pg.com/blogs/HolyGrail/.

50 *Using Product Passports to Improve the Recovery and Reuse of Shipping Steel: Maersk Line*, Ellen Mac Arthur Foundation, August 19, 2021, available at https://ellenmacarthurfoundation.org/circular-examples/using-product-passports-to-improve-the-recovery-and-reuse-of-shipping-steel.

waste, emissions) throughout their lifecycles. Information systems that model and track products through their lifecycles can facilitate more environmentally sustainable operations by quantifying products' eco-impacts, identifying the optimal life span of components and trustfully exchanging reliable, fine-grained information that decision makers need to assess the eco-impact of products. This information systems opportunity for sustainability arises because product data is increasingly available in near real time and advanced analytics and presentation techniques are being integrated into traditional computer-aided design software.

For example, SAP's software offerings include climate change solutions to reduce the environmental impact of its customers' operations and products. SAP's Product Footprint Manager[51] is one such tool that provides information about the environmental impact of products throughout their lifecycles, which organizations can use to optimize the sustainability of products.

An example of the information systems opportunity for modeling products is provided by the Swedish-Finnish steel company SSAB, which has developed a digital twin for its steel plate products.[52] Data linked to this digital twin enables value-chain partners to identify the product and its properties, thus providing transparent product data along the value chain.

In summary, the information systems opportunities for capturing, modeling and transparently sharing the environmental impact data of products is an effective means of making product and service solutions more eco-efficient.

3. Internalize Sustainability by Developing Joint Sustainability and Business Strategies

The transition from isolated sustainability projects to an integrated sustainability approach is only possible if environmental sustainability is recognized as a business principle and strategic differentiator that provides competitive advantages. Making environmental sustainability an integral part of corporate strategy can transform sustainability from being an afterthought to a guiding principle that allows the organization to structurally internalize environmentally sustainable thinking into daily business,[53] with the corresponding sustainable principles and practices being reflected in daily operations and decision-making.[54] Based on the insights of the environmental impacts of products, behaviors and processes provided by EMSs, environmentally sustainable thinking can be integrated into investment and project planning. Information systems that provide reports on the environmental and business benefits of existing and planned initiatives can inform strategic decision-making and demonstrate environmental sustainability as a legitimate goal in line with overall business objectives.

A practical example is provided by chemicals company BASF, which uses insights from its Responsible Care Management System to reinforce the organizational commitment to the ESG guiding principles.[55] This system is used as a company-wide management and control system and monitors compliance with internal requirements and global standards for environmental protection, health and safety. The system's insights are binding for central decisions and place environmental sustainability at the center of corporate strategic decision-making.

Developing a coherent, integrated strategy that creates a sense of urgency for environmental sustainability throughout the organization is also an effective way to unlock and accelerate the benefits of sustainability among employees. Encouraging employee involvement and initiatives for environmental sustainability (for example, through social platforms) and incorporating eco-sustainability impacts as a pivotal decision-making factor can have a

51 *SAP Product Footprint Management*, 2022 SAP, available at https://www.sap.com/products/scm/product-footprint-management.html.

52 *SSAB SmartSteel forms a basis for the circular economy*, SSAB press release, February 3. 2017, available at https://www.ssab.com/en/news/2017/02/ssab-smartsteel-forms-a-basis-for-the-circular-economy.

53 Daugherty, P., Lacy, P., Podder, S. and Singh, S. K., op. cit., June 2, 2022.

54 For an article on how companies can embed sustainability and make it a source of competitive advantage, see Whelan, T. "ESG Reports Aren't a Replacement for Real Sustainability," *Harvard Business Review*, July 27, 2022, available at https://hbr.org/2022/07/esg-reports-arent-a-replacement-for-real-sustainability?.

55 *Our Management Systems*, BASF, February 25, 2022, available at https://report.basf.com/2021/en/managements-report/sustainability-along-the-value-chain/safe-and-efficient-production/our-management-systems.html.

strong influence on organizational culture. The environmental sustainability impact provided by information systems leads to employee empowerment and informed commitment to greater sustainability in daily work and decision-making. We therefore recommend that managers leverage the achievements of IS pioneers who have already furthered environmental sustainability.

4. Standardize Sustainability by Establishing Sustainability Data Governance

Sustainability data is a strategic asset and crucial for the sustainability value chain. However, the absence of standardized performance indicators and reporting can make it very difficult to leverage information systems to support Recommendations 2 and 3 (optimize processes, products and services, and internalize sustainability by making it an integral part of the business strategy). Various sustainability reporting frameworks have been developed over the years, such as the Global Reporting Initiative (GRI) or the World Economic Forum (WEF) Stakeholder Capitalism Metrics. The available frameworks, however, use different metrics and serve different purposes, ranging from basic compliance to brand building. Moreover, voluntary corporate disclosures on sustainability are not comparable and the lack of standard formats exacerbates the problems of inconsistency and inaccuracy, resulting in missed opportunities for using sustainability data and disclosure as an important communication channel for how companies are meeting stakeholder sustainability requirements.

There is great potential for information systems to overcome these fundamental challenges of making sustainability data globally accessible and comparable. By collecting, processing and assessing eco-sustainability data and making it transparently available to all relevant stakeholders along the value chain, information systems can improve corporate sustainability reporting.[56] Additionally, online portals that gather eco-sustainability data in a centralized database enable efficient analysis, visualization and benchmarking of the data, as well as providing autonomous reporting opportunities.

In addition to making eco-sustainability data accessible, it is important that the data is easily comparable. For example, the digital third-party market platform Cirplus[57] connects stakeholders unknown to each other and provides certificated and standardized data for secondary materials. A standardized data format removes the comparability issues that often hinder data sharing and enables product components to be traced back to their origin.

In addition to standards, interorganizational data governance can facilitate and promote sustainability reporting. Companies not only need to establish consistent indicators to meet current and future environmental sustainability objectives, they also need to govern data sharing in interorganizational settings. Managing such data sharing requires ownership and governance decisions that maintain the trade-offs between achieving scale to facilitate partners' contributions and retaining control to prevent undesirable data use.

5. Collaborate with External Stakeholders by Establishing Strategic Partnerships and Ecosystems

No individual company can solve sustainability problems on its own. A key requirement, therefore, is to participate in industry collaborations focused on collaborative sustainability outcomes.[58] Consumers and other stakeholders are increasingly concerned about the lifecycle impact of the products and services offered and expect companies to consider and manage sustainability beyond organizational boundaries. To meet the desire for a more holistic sustainability approach, companies must increasingly collaborate with upstream and downstream partners and share their knowledge with their business ecosystems. Thus, organizations should collaborate with ecosystem

56 See: 1) Daugherty, P., Lacy, P., Podder, S. and Singh, S. K., op. cit., June 2022; and 2) Jones, S. and Soh, P. Y. *Accenture Launches 360° Value Reporting Experience*, December 2021, available at https://newsroom.accenture.com/news/accenture-launches-360-degree-value-reporting-experience.htm.

57 *Cirplus Is Setting Standards for Recycled Plastics And You Can Be Part Of It*, Cirplus, July 7, 2021, available at https://cirplus.medium.com/cirplus-is-setting-standards-for-recycled-plastic-and-you-can-be-part-of-it-50974ce2bdcf.

58 Daugherty, P., Lacy, P., Podder, S. and Singh, S. K., op. cit., June 2, 2022.

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partners to shape collaborative sustainability outcomes across their value chains.

Effective collaboration is enabled by extensive IT-based connectivity. Given that transactions and products create data from a large number of interorganizational stakeholders, companies must provide value-chain partners with access to data.[59] However, networked collaboration can be hindered by issues such as poor information exchange, conflicting business interests or low trust between stakeholders. To promote the exchange of environmental data between value-chain partners, secure, decentralized data spaces offer enormous potential. Enhanced data sharing and transparency on environmental impacts can, in turn, unlock new eco-sustainability potential, such as the dematerialization enabled by information on recyclable product components that improve the recovery and reuse of materials.

The Dutch start-up Circularise,[60] for instance, has developed a blockchain-based decentralized communication protocol to enhance data quality and availability in business networks without disclosing datasets or participants' identities. Through a so-called "smart questioning" protocol, participants in need of sustainability-related product data can pose questions to the entire distributed network (e.g., "Does the to-be-recycled product contain lead?") and receive a confidence-weighted yes or no answer from the network. The data necessary for this response has been preloaded by data providers and verified in advance by trusted third parties. The distributed ledger blockchain technology facilitates transactions and data-based value creation between heterogeneous stakeholders in business networks and provides a technological pathway to a more decentralized management of process data. Leveraging the secure data storage and exchange enabled by distributed ledger technology is a powerful means of addressing both the social and technical challenges associated with sharing sustainability data between organizations and facilitating ecosystem transformation toward environmental sustainability.

Concluding Comments

Despite the pressing need for immediate action to combat climate change, many businesses struggle to turn their sustainability obligations into business value. To help businesses overcome this sustainability implementation gap, we reviewed articles with a focus on Green IS in practitioner journals and, based on our analysis of the articles, derived five recommendations for leveraging information systems to close the gap and thus create business value from sustainability practices. The interrelationships between the five recommendations emphasize that environmental sustainability is an ongoing, iterative pathway that companies continuously cycle around as they transform toward environmental sustainability. Information systems are widely acknowledged as a key resource for business transformations. But making environmental sustainability an integral part of corporate strategy creates a wider *eco-sociotechnical system* that enables companies to progress from eco-efficiency to eco-effectiveness as they follow the pathway for turning environmental sustainability into business value. Leveraging the information systems opportunities we have identified will enable companies to adopt much-needed sustainability practices that will provide both environmental sustainability and business value.

Appendix: Research Methodology

Literature Selection

Our literature review used a structured search strategy followed by concept-centric analysis, which builds on ideas grounded in previous research[61]—in our case, the problem of how information systems opportunities can contribute to closing the sustainability implementation

59 Close, K., Faure, N. and Hutchinson, R., op. cit., October 14, 2021.

60 *Smart Questioning: Achieve Supply Chain Visibility*, Circularise, 2022, available at https://www.circularise.com/blogs/smart-questioning-achieve-supply-chain-visibility-without-risking-data-privacy.

61 Templier, M. and Paré, G. "A Framework for Guiding and Evaluating Literature Reviews," *Communications of the Association for Information Systems* (37:6), August 2015, pp. 112-137.

Journal Articles Included in the Literature Review

Discipline	Journal (Number of Articles)
Information Systems	• *MIS Quarterly Executive (5)* • *Communications of the ACM (6)* • *IEEE Software (6)* • *Computer (7)*
Business Administration	• *Harvard Business Review (2)* • *MIT Sloan Management Review (2)* • *California Management Review (2)* • *Schmalenbach Business Review (1)*

gap. The review process comprised four steps.[62] First, we identified the fields of research, determined appropriate sources, decided on the specific search terms and defined the criteria for inclusion and exclusion. Second, we searched for relevant articles. Third, we refined the sample by screening articles for inclusion or exclusion. Fourth, we analyzed the selected studies to determine how they addressed the information systems opportunities for environmental sustainability.

We searched in practitioner journals for articles reporting on Green IS, including *MIS Quarterly Executive*, *Harvard Business Review*, *MIT Sloan Management Review*, *California Management Review*, *Communications of the ACM*, *IEEE Software*, *Computer*, *Interfaces*, *ACM SIGMIS Database* and *IBM Journal of Research and Development*. The selection of journals was based on the results of the literature search of the leading journals in the field of information systems conducted by Lowry et al.[63] and was cross-checked with the VHB-JourQual3 ranking.

We conducted multiple searches of the selected journals, restricting searches to those published in the last ten years (2012-2022) and focusing exclusively on full articles (i.e., excluding editorials, messages and research notes). We used the search terms "ESG" OR "sustainability" OR "environmental sustainability" OR "ecological sustainability" OR "ecology" OR "ecological" OR "environmental," combined with "digital technology" OR "information technology" OR "information systems" in either all fields or the abstract, plus a series of searches for "green technology" OR "clean technology" OR "green IT" OR "green information technology" OR "green information systems." The searches were conducted in May and December 2022.

The initial searches produced 636 articles. Removing duplicates and screening titles reduced the number to 274 articles. After screening these articles and performing a backward and forward search, we selected 31 to analyze in detail. The criteria for including or excluding articles were agreed by two independent researchers. The distribution of the final sample of 31 articles by journal is summarized in the table above.

Literature Analysis

Using Microsoft Excel, we grouped the 31 articles into technology-related articles, systems-related articles and business-model-related articles. For each article, we coded the research focus, information systems potential, information innovation opportunity and practical sustainability recommendation. To ensure coding comprehensibility and comparability between researchers, initial coding was performed independently by two researchers. The resulting Excel spreadsheet is too large to include in this article but is presented in text form below.

62 Literature review processes are described in: 1) vom Brocke, J., Simons, A., Niehaves, B., Reimer, K., Plattfaut, R. and Cleven, A. "Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process," *Proceedings of 17th European Conference on Information Systems (ECIS)*, June 2009, pp. 1-12; 2) Webster, J. and Watson, R. T. "Analyzing the Past to Prepare for the Future: Writing a Literature Review," *MIS Quarterly* (26:2), June 2002, pp. xiii-xxiii; and 3) Wolfswinkel, J. F., Furtmueller, E. and Wilderom, C. P. M. "Using Grounded Theory as a Method for Rigorously Reviewing Literature," *European Journal of Information Systems* (22:1), November 2013, pp. 45-55.

63 Lowry, P. B., Romans, D. and Curtis, A. M. "Global Journal Prestige and Supporting Disciplines: A Scientometric Study of Information Systems Journals," *Journal of the Association for Information Systems* (5:2), February 2004, pp. 29-80.

Articles Related to Technology-Innovation Opportunities

Bashroush, R., Woods, E. and Noureddine, A. "ICT Energy Demand: What Got Us Here Won't Get Us There!," *IEEE Software* (33:2), March-April 2016

- **Research focus:** How software architecture optimization helps mitigate the climate impact of data centers
- **Information systems potential:** Incorporating climate metrics into the basic requirements of designing software applications to minimize climate impacts
- **Practical sustainability recommendation:** Optimize organizational operations

Blevis, E. "Sustainability Implications of Organic User Interface Technologies: An Inky Problem," *Communications of the ACM* (51:6), June 2008

- **Research focus:** Advantages of paperless operations
- **Information systems potential:** Potential of paper display technology due to its inherent characteristics—durable, bi-stable and displayable on sustainable devices
- **Practical sustainability recommendation:** Optimize organizational operations

Blomme, H. "Towards Better Corporate Reporting: Core & More," *Schmalenbach Business Review* (71:2), December 2018, pp. 263-270

- **Research focus:** Corporate reporting as an integrated concept—integration of nonfinancial information to take a long-term view with technology as facilitator
- **Information systems potential:** Evolving toward online reporting, improving the user-friendliness of reports and thus the access to (environmental) information
- **Practical sustainability recommendation:** Standardize to shape organizational readiness

Borning, A., Friedman, B. and Logler, N. (2020): "The 'Invisible' Materiality of Information Technology," *Communications of the ACM* (63:6), June 2020, pp. 57-64

- **Research focus:** The high degree of currently unseen material impacts of IT on extracting, processing, maintaining and disposing of materials used
- **Information systems potential:** Making the environmental impacts of IT impacts "visible" and thus manageable
- **Practical sustainability recommendation:** Legitimize to shape organizational readiness

Curry, E., Guyon, B., Sheridan, C. and Donnellan, B. "Developing a Sustainable IT Capability: Lessons from Intel's Journey," *MIS Quarterly Executive* (11:2), June 2012, pp. 61-74

- **Research focus:** Sustainable IT and the IT department's contribution to organizational sustainability—laying the ground for new organizational thinking
- **Information systems potential:** Possibilities for the IT departments to support and lead organizational sustainability transformation
- **Practical sustainability recommendation:** Legitimize to shape organizational readiness

Gomes, C., Dietterich, T., Barrett, C., Conrad, J., Dilkina, B., Ermon, S. [and 27 other authors] "Computational Sustainability: Computing for a Better World and a Sustainable Future," *Communications of the ACM* (62:9), August 2019, pp. 56-65

- **Research focus:** Computational sustainability as a new research approach to investigate sustainable development goals
- **Information systems potential:** Using computational sustainability to tackle grand challenges with the help of computational power
- *Practical sustainability* **recommendation:** Optimize organizational operations

Grier, D. A. "Click Here to Empty Trash," *Computer* (41:9), September 2008, pp. 6-8

- **Research focus:** Green computing's potential benefits for the environment and its still very brown nature
- **Information systems potential:** Green computing's potential to improve operations, manufacturing and material disposals
- **Practical sustainability recommendation:** Optimize organizational operations

Park, S. H., Eo, J. and Lee, J. J. "Assessing and Managing an Organization's Green IT Maturity," *MIS Quarterly Executive* (11:3), September 2012, pp. 127-140

- **Research focus:** Framework and guidelines for Green IT assessment and maturity
- **Information systems potential:** Understanding the current status and maturity of sustainable information systems and the resulting potential for optimization through the assessment of Green IT
- **Practical sustainability recommendation:** Legitimize to shape organizational readiness

Penzenstadler, B., Raturi, A., Richardson, D. and Tomlinson, B. "Safety, Security, Now Sustainability: The Nonfunctional Requirement for the 21st century," *IEEE Software* (31:3), May-June 2014, pp. 40-47

- **Research focus:** Applying learnings from how safety and security became first-class quality attributes in software engineering to the development of sustainability-related information systems
- **Information systems potential:** Considering the second- and third-order impacts of software systems alongside the first order impacts to create truly sustainable software
- **Practical sustainability recommendation:** Optimize organizational operations

Schwartz R., Dodge J., Smith N. A. and Etzioni, O. "Green AI," *Communications of the ACM* (63:12), November 2020, pp. 54-62

- **Research focus:** Overcoming the challenges of Red Al by adopting the vision of Green Al
- **Information systems potential:** Potential of Green AI to decrease AI's environmental footprint and increase its inclusivity
- **Practical sustainability recommendation:** Optimize organizational operations

Siegmund, N., Dorn, J., Weber, M., Kaltenecker, C. and Apel, S. "Green Configuration: Can Artificial Intelligence Help Reduce Energy Consumption of Configurable Software Systems?," *Computer* (55:3), March 2022, pp. 74-81

- **Research focus:** How machine learning can reduce the energy consumption of software systems
- **Information systems potential:** Using multiple sources of information to build a white-box performance model and a black-box energy model to leverage machine learning for eco-sustainability
- **Practical sustainability recommendation:** Optimize organizational operations

Stansberry, M. "The Future of Green IT: Solving the Accountability Issue," *Computer* (46:7), July 2013, pp. 91-93

- **Research focus:** How documenting costs and performance, sharing data with relevant stakeholders and deploying Green IT can help reduce data centers' climate impact
- **Information systems potential:** Incorporating data centers into climate accounting to improve the environmental impact of organizations
- **Practical sustainability recommendation:** Optimize organizational operations

Verdecchia, R., Lago, P., Ebert, C. and De Vries, C. "Green IT and Green Software," *IEEE Software* (38:6), November 2021, pp. 7-15

- **Research focus:** Mapping Green IT and Green software solutions to perceived sustainability readiness levels
- **Information systems potential:** Recognizing "ecologic" transformation is the next big wave of innovation after the digital transformation
- **Practical sustainability recommendation:** Legitimize to shape organizational readiness

Articles Related to Systems-Innovation Opportunities

Delcambre L. and Tolle T. "Harvesting Information to Sustain Forest," *Communications of the ACM* (46:1), January 2003, pp. 38-39

- **Research focus:** A web-based system to access environmental data to sustain the environment
- **Information systems potential:** Storing and presenting relevant information to

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relevant stakeholders for environmental action with the help of a web-based system
- **Practical sustainability recommendation:** Collaborate to shape systems thinking

Eleftheriadou, D., Hartog, E. and Gkiaouri, N. "The Cities Challenge: Driving a Green and Digital Recovery and Social Resilience," *Computer* (54:5), May 2021, pp. 70-75
- **Research focus:** How digital technologies help to create Green smart cities to mitigate climate change
- **Information systems potential:** Creating digital twins of cities to analyze, simulate and visualize important environmental data for Greener cities
- **Practical sustainability recommendation:** Collaborate to shape systems thinking

Florida, R. and Davison, D. "Gaining from Green Management: Environmental Management Systems Inside and Outside the Factory," *California Management Review* (43:3), March 2001, pp. 64-84
- **Research focus:** General insights into the deployment of environmental management systems in organizations
- **Information systems potential:** Integrating environmental objectives into traditional information systems
- **Practical sustainability recommendation:** Optimize organizational operations

Goth, G. "Chipping away at Greenhouse Gases," *Communication of the ACM* (54:2), February 2011, pp. 13-15
- **Research focus:** Using power management to manage the environmental footprint of chips
- **Information systems potential:** Potential of power-saving processors to save energy and costs
- **Practical sustainability recommendation:** Optimize organizational operations

Kiron, D. and Unruh, G. "The Convergence of Digitalization and Sustainability," *MIT Sloan Management Review*, January 2018
- **Research focus:** Digitalization as an enabler for a sustainable society
- **Information systems potential:** Increasing use of digital systems to shape the organizational environment toward environmental consciousness, thus putting positive pressure on organizations to continue working toward environmental objectives
- **Practical sustainability recommendation:** Collaborate to shape systems thinking

Martinez, K., Hart, J. K. and Ong, R. "Environmental Sensor Networks: A Revolution in Earth System Science?," *Computer* (37:8), November 2007, pp. 50-56
- **Research focus:** Development of an environmental sensor network
- **Information systems potential:** Using sensor networks to merge data sets of different types and scales to enhance understanding of the environment
- **Practical sustainability recommendation:** Standardize to shape systems thinking

Odenwald, T. and Berg, C. "A New Perspective on Enterprise Resource Management," *MIT Sloan Management Review* (56:1), September 2014, pp. 12-14
- **Research focus:** Using ERP systems to optimize sustainability performance
- **Information systems potential:** Using an ERP system to understand and manage the full impact of an organization's activities throughout the extended value chain
- **Practical sustainability recommendation:** Collaborate to shape systems thinking

Sierszecki, K., Mikkonen, T., Steffens, M., Fogdal, T. and Savolainen, J. "Green Software: Greening What and How Much?," *IEEE Software* (31:3), May 2014, pp. 64-68
- **Research focus:** Perspectives on how to "green" information and communications technologies (ICT)
- **Information systems potential:** Adopting a two-sided perspective of Green software: Green ICT and Greening through ICT
- **Practical sustainability recommendation:** Optimize to shape systems thinking

Turner, J. "Power Management as Choice Architecture," *Computer* (46:5), May 2013, pp. 108-111

- **Research focus:** How principles and tools of chosen architecture with respect to power management benefit the environment
- **Information systems potential:** Adopting a holistic approach incorporating all relevant stakeholders to improve the chosen architecture's power management
- **Practical sustainability recommendation:** Collaborate to shape systems thinking

van Heck, E., van Baalen, P., van der Meulen, N. and van Oosterhout, M. "Achieving High Performance in a Mobile and Green Workplace: Lessons from Microsoft Netherlands," *MIS Quarterly Executive* (11:4), December 2012, pp. 175-188

- **Research focus:** How IT helps to introduce new ways of working and thus creates new organizational thinking about sustainability
- **Information systems potential:** Using information systems to transform organizational operations entirely to achieve environmental objectives
- **Practical sustainability recommendation:** Optimize organizational operations

Watson, R. T., Boudreau, M. C., Li, S. and Levis, J. "Telematics at UPS: En Route to Energy Informatics," *MIS Quarterly Executive* (9:1), March 2010, pp. 1-11

- **Research focus:** How information systems help to optimize organizational operations to achieve environmental sustainability
- **Information systems potential:** Bringing together information about different aspects of business operations, thereby generating valuable information about environmental objectives
- **Practical sustainability recommendation:** Optimize organizational operations

Xu, Z. "Measuring Green IT in Society," *Computer* (45:5), May 2012, pp. 83-85

- **Research focus:** Need for Green IT research to produce scientific, accessible results that are understandable to and usable by relevant stakeholders
- **Information systems potential:** Improving IT by assessing "greenness" before building a system, relating performance to power and energy, and evaluating Green behaviors
- **Practical sustainability recommendation:** Optimize organizational operations

Articles Related to Business-Model-Innovation Opportunities

Atkinson, C., Schulze, T. and Klingert, S. "Facilitating Greener IT through Green Specifications," *IEEE Software* (31:3), May 2014, pp. 56-63

- **Research focus:** How service-level agreements help to improve environmental performance
- **Information systems potential:** Using Green specifications to help reduce IT's environmental impact in three important areas: software engineering, data center optimization and Green business models
- **Practical sustainability recommendation:** Standardize to shape products and services

Bockelmann, T. and Recker, J. "How One Company Used Data to Create Sustainable Take-out Food Packaging," *Harvard Business Review*, November 11, 2022

- **Research focus:** How deposit-free recyclable packaging is enabled by digital technology—a new way of being successful in the take-out-food industry
- **Information systems potential:** Training machine-learning AI algorithms for circular business models
- **Practical sustainability recommendation:** Optimize to shape products and services

Kranz, J., Fiedler, M., Seidler, A., Strunk, K. and Ixmeier, A. "Unexpected Benefits from a Shadow Environmental Management Information System," *MIS Quarterly Executive* (20:3), September 2021, pp. 235-256

- **Research focus:** Recommendations for IT leaders on how to design and implement an EMS that promotes eco-sustainability and provides business value

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- **Information systems potential:** Identifying information systems sustainability pioneers who are passionate about exploiting and transforming the organization's systems for sustainability
- **Practical sustainability recommendation:** Optimize to shape products and services

Lubin, D. A. and Esty, D. C. "The Sustainability Imperative," *Harvard Business Review* (88:5), May 2010, pp. 42-50

- **Research focus:** Learning from prior megatrends to be successful in the sustainability megatrend
- **Information systems potential:** Using lessons learned from the digitalization megatrend to shape sustainability strategies
- **Practical sustainability recommendation:** Internalize to shape strategy thinking

Rajala, R., Hakanen, E., Mattila, J., Seppälä, T. and Westerlund, M. "How Do Intelligent Goods Shape Closed-Loop Systems?," *California Management Review* (60:3), May 2018, pp. 20-44

- **Research focus:** Potential of intelligent goods for implementing a circular economy
- **Information systems potential:** Leveraging intelligent goods and the data collected from them to create new value opportunities for an organization's internal processes
- **Practical sustainability recommendation:** Optimize to shape products and services

About the Authors

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