Design Requirements for Smart Vehicles Efficient Carbon Emission Management Framework

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Abstract: This work focuses on developing design requirements for an optimized cloud service-based serverless framework, called 'Serverless Tracking for Internet-of-Vehicles Carbon' (STIOVC), for reducing CO_2 emissions from smart vehicles. By leveraging the efficiency of the pull/push data model (Hogue, 2020) and integrating AWS services using AWS SAM (Serverless Application Model) (Smith, 2021) framework, the STIOVC framework aims to revolutionize transportation and logistics by enhancing energy conservation and efficiency. The pull/push data model (Hogue, 2020) enables proactive data transmission when changes occur in vehicle sensor data, minimizing unnecessary data transfers, reducing network traffic, and conserving network resources. The integration of AWS Lambda, DynamoDB, Glue, and QuickSight further enhances the framework's capabilities in data processing, storage, analysis, and visualization, facilitating timely identification of emission patterns and the implementation of effective CO_2 emission reduction measures. The proposed conceptual framework bridges the gaps in existing frameworks by addressing scalability, cost-efficiency, ease of management, and seamless integration with public cloud services. This work discusses scalability and implementation challenges for real-world transportation systems in combining the pull/push data model (Hogue, 2020) with AWS services. The conceptual framework aims to maximize the efficiency of data collection and processing, facilitating effective strategies for CO_2 emission reduction in smart vehicle networks. Overall, the work contributes to advancing energy conservation and sustainability in transportation and logistics, providing valuable insights and actionable strategies for stakeholders and policymakers. Comparative analysis, benchmarking against existing approaches, and evaluating broader impacts beyond efficiency metrics are left for future work.

Introduction

Smart vehicles, while offering benefits like improved fuel efficiency and enhanced safety features, still contribute to greenhouse gas emissions, making it crucial to address their carbon footprint through measures such as promoting the adoption of electric vehicles and implementing stricter emission standards. Carbon emissions from smart vehicles have become a growing concern in recent years due to their environmental impact. While smart vehicles offer various advantages such as improved fuel efficiency, reduced traffic congestion, and enhanced safety features, they still contribute to greenhouse gas emissions which remains a significant concern. Continued efforts to develop cleaner energy sources, improve vehicle efficiency, and promote sustainable practices are essential for reducing the environmental impact of smart vehicles and achieving a more sustainable transportation system (Ahmed et al., 2019).

Smart vehicles typically rely on technologies and systems that require energy to operate. Electric smart vehicles, for example, produce zero tailpipe emissions during operation, as they are powered by electricity rather than fossil fuels. However, the carbon footprint of electric vehicles depends on the source of electricity generation. If the electricity is derived from renewable sources, such as solar or wind power, the carbon emissions associated with electric vehicles can be significantly reduced. On the other hand, smart vehicles equipped with internal combustion engines, including hybrid vehicles, still emit carbon dioxide and other greenhouse gases. These emissions arise from the combustion of fossil fuels used for propulsion. The carbon emissions from these vehicles can be influenced by factors such as engine efficiency, driving behavior, and traffic conditions (Mahmood et al., 2019).

Currently many efforts are being made to reduce the carbon emissions from vehicles around the world. Governments and regulatory bodies are implementing stricter emission standards, promoting the adoption of electric vehicles, and encouraging the development of alternative fuel technologies. Additionally, advancements in vehicle design, materials, and manufacturing processes aim to improve fuel efficiency and reduce emissions. To address the carbon emissions associated with smart vehicles, it is crucial to develop a framework for on-board vehicular data gathering, guided data usage, real time analysis, decision making, and secure disposal of collected data after analysis. Measuring carbon emission from smart vehicles require systematic and planned data collection approach (Van Wynsberghe, 2021; Rajkumar, 2022).

Collecting data on carbon emissions from smart vehicles involves employing various methods and technologies such as onboard vehicle sensors to measure fuel consumption, emissions parameters, vehicle diagnostics, and telematics systems to gather real-time traffic data. Such rich data sets help to get various insides such as correlation between vehicle movement and carbon emissions data, direct measurements of pollutants through remote sensing establishing, data sharing with manufacturers and research institutions for partnerships, and helping in government emission testing programs. Further, integration of smart vehicle technology with smart cloud infrastructure and transportation systems can help optimize traffic flow, reduce congestion, and minimize emissions through intelligent route planning and vehicle-to-vehicle communication within smart vehicular networks. Smart vehicular network is a network of connected vehicles using communication technologies to enable intelligent transportation capabilities, facilitating real-time data exchange, collaboration, and on-road decision-making among vehicles through road-side infrastructure, and cloud-based services. Such networks provide enhanced road safety, optimized traffic flow, autonomous driving, and sustainable mobility. Smart vehicle networks leverage Software Defined Networks (SDN) (Nithya et al., 2020) to establish centralized control and management, enabling secure and reliable connections between vehicles and the cloud infrastructure. Further, the integration of SDN and cloud allows for centralized management, seamless software deployment, streamlined updates. collaboration, advanced analytics, and data security (Nithya et al., 2020).

In this work we are proposing an optimized cloud service based serverless framework for reducing CO_2 emissions from smart vehicles that combines the efficiency of the pull/push data model (Hogue, 2020) integrated with AWS services build using AWS SAM framework (Smith, 2021), we name this as 'Serverless Tracking for Internet-of-Vehicles Carbon' (STIOVC), framework. By proactively pulling or pushing data when changes occur in the vehicle sensor data, the framework aims to minimize unnecessary data transfers, reduces network traffic, and conserves network resources. This approach enables real-time ingestion, processing, and analysis of vehicle data, allowing for timely identification of emission patterns and the implementation of effective measures to reduce CO_2 emissions. Implementation of this framework consist of integrated AWS Lambda, DynamoDB, Glue, and QuickSight in data processing, storage, analysis, and visualization, enabling stakeholders to make informed decisions and take proactive actions to optimize vehicle performance and minimize environmental impact. Overall, this framework is designed to improve the efficiency of data collection and processing, facilitating effective CO_2 emission reduction strategies in the context of smart vehicle networks.

Related Work

Several frameworks have been developed to address challenges in carbon emission reduction and improve energy conservation and efficiency in transportation systems. This section provides a review of few selective works which are closely related to the proposed framework.

The JMeter framework has been used to evaluate performance metrics and resource utilization in various open source serverless frameworks (Palade et al., 2019). Implementing data pipeline architectures, such as CCoDaMiC (Dehury et al., 2020) reduces energy consumption and carbon emissions associated with unnecessary data transfers. Exploring nomenclature for characterizing serverless function access patterns and leveraging WebAssembly (Hall and Ramachandran, 2019) aims to improve performance, optimize resource utilization, and contribute to energy savings in serverless environments. OWL scheduler (Tian et al., 2022) focuses on resource allocation and prioritization to reduce energy consumption and carbon emissions in serverless computing. Optimization strategies for deployment modes and evaluation of different approaches for building serverless data pipelines aim to minimize resource consumption and associated energy usage in IoT environments.

In order to optimize energy consumption, reduce carbon emissions, and enhance overall efficiency in transportation systems, some of the existing strategies employed include smart charging for autonomous electric vehicles, intelligent optimization-based demand-side management in smart grids, cloud-based smart parking methodologies, and the development of data-driven vehicle travel CO_2 models. These all are distinct in their objectives and approaches to optimizing energy consumption, reducing carbon emissions, and enhancing overall efficiency in transportation systems (Ahmed et al., 2019).

Considering the impact of intelligent transportation systems (ITS) on energy conservation and emission reduction (ECER) in transportation networks, particularly in the context of smart cities, the article (Lv & Shang, 2023) examines the development of transportation systems and the evolution of monitoring technologies towards ITS. It explores the paths to achieving ECER in transportation through aspects such as transportation, organization and management, and energy upgrading. The analysis highlights the increasing intelligence of traffic systems, the role of visualizing traffic data in alleviating congestion and improving vehicle ECER, and the importance of government policies in promoting energy-saving measures for effective ECER transportation. Another framework in (Sun et al., 2023) includes a parallel transportation level and a parallel vehicle level, enabling accurate estimations, credible predictions, and emission-aware optimal planning. The integration model incorporates modern aftertreatment systems (ATS) as a core module for improved accuracy. A case study on CO_2 emissions validates the functionality of the framework.

In the framework developed by Iacobucci et al. (2021) the focus is on the development of practical smart charging strategies for fleets of autonomous electric vehicles (AEVs), specifically ride-hailing and shared AEV systems. The aim is to optimize the operation of AEVs by integrating independent optimization modules with a simulation model. By considering dynamic electricity prices, the proposed approach demonstrates scalability, flexibility, and practicality. The approach was tested using real-world data from taxi trips in New York City, showcasing significant reductions in charging costs and carbon emissions compared to uncoordinated charging strategies. This optimization can lead to mutual benefits for fleet operators, passengers, and the power grid, facilitating the transition to intermittent renewable energy sources.

Zhang et al. (2022) developed a framework based on the integration of advanced concepts, technologies, and management methods in smart logistics platforms to improve logistics efficiency, but highlights the energy consumption issue. The study aims to address this issue by examining the intelligent measurement and monitoring of carbon emissions in smart logistics. The paper compares and analyzes carbon emission accounting standards and calculation methods, selecting the carbon emission factor method for studying carbon emissions in the smart logistics process. It establishes carbon emission calculation models for key storage technologies and proposes a carbon emission energy consumption assessment framework based on 5G shared smart logistics.

The rapid industrial revolution worldwide has led to increased carbon dioxide (CO_2) emissions, primarily from vehicles and factories. Vehicle emissions, particularly from personal cars on congested roads, contribute to around 40% of the global CO_2 emissions. Additionally, the lack of parking spaces and inefficient parking search methods exacerbate the problem. To address this issue, a cloud-based smart parking methodology is proposed in (Ali et al., 2022) enabling drivers to automatically find and receive recommendations for nearby parking areas with available spaces. The methodology utilizes analytical hierarchy process (AHP) and weighted sum model (WSM) techniques for decision-making and ranking of parking areas. Evaluation results demonstrate that the proposed methodology outperforms traditional approaches, offering potential benefits in reducing CO_2 emissions and improving parking efficiency.

Scalability, cost-efficiency, and ease of management are key advantages offered by the serverless framework. It allows organizations to easily scale applications, optimize resource utilization, and accommodate fluctuating workloads. The pay-as-you-go pricing model ensures efficient resource usage, eliminating the need for upfront investments. Automation of operational tasks frees up resources and time for innovative energy conservation solutions. Seamless integration with other cloud services enhances overall effectiveness and promotes collaboration (Mahmood et al., 2019).

Although each strategy has its unique focus and methodology in leveraging the benefits provided by the cloud infrastructure for effective coordination and collaboration, ultimately leading to optimized transportation systems. However, the existing strategies, including smart charging, intelligent demand-side management, cloud-based smart parking, and data-driven CO_2 models, have limitations in considering real-time factors and accurately estimating carbon emissions, evaluating performance metrics, reducing unnecessary data transfers, and optimizing resource utilization.

Collecting data on emissions involves various methods and technologies, prioritizing data privacy and security. Therefore, it is crucial to prioritize data privacy and security while complying with regulations and obtaining consent from vehicle owners or users to ensure ethical and legal data collection practices (Ahmed et al., 2019). This work is mainly focused on collection, ingestion, and analytics requirements of carbon emission data. Nevertheless, data security and privacy of small, medium, and large organizations are important for survival of business (Raghavan et al., 2017; Raghavan et al., 2017).

STIOVC Framework: Design Requirements

The serverless framework offers advantages such as scalability, cost-efficiency, and ease of management, revolutionizing the industry. To optimize data processing and reduce CO_2 emissions, an optimized cloud service-based serverless framework called STIOVC is proposed, and its design requirements are analyzed. This framework utilizes the pull/push data model (Hogue, 2020) and AWS services build using AWS SAM template (Smith, 2021) to enable real-time data ingestion, analysis, and visualization, facilitating informed decision-making and proactive emission reduction strategies.

The STIOVC framework monitors and detects changes in the data generated by connected vehicles using mechanisms like event-driven architectures, change tracking, or real-time data streaming. When a change is detected, the updated data is proactively pushed to the intended recipients, ensuring they receive real-time or near-real-time updates without making frequent API calls. Before pushing the data, intelligent filtering mechanisms are applied to transmit only relevant and necessary information, further optimizing network resources.

By adopting the pull/ push data model (Hogue, 2022), the STIOVC framework achieves several benefits. Firstly, it reduces network traffic by transmitting data only when changes occur, conserving network resources, which is especially crucial when dealing with substantial volumes of data from connected vehicles. Secondly, it lowers latency by proactively pushing data instead of waiting for API requests and responses, enabling faster decision-making and responsiveness. Finally, the efficient utilization of resources, including network bandwidth, processing power, and storage, is achieved by minimizing unnecessary API calls and data transfers. This leads to cost savings and improved scalability.

In the developed pipeline using AWS SAM (Smith, 2021), and STIOVC, the pull/push concept is integrated throughout the data collection, ingestion, processing, storage, analysis, and visualization stages. Smart vehicle sensor data is collected and securely transmitted through AWS IoT Core, utilizing the pull data model and pushed to AWS Kinesis Data Streams for real-time ingestion. AWS Lambda functions, defined using AWS SAM (Smith, 2021) processes the data and store it in DynamoDB for efficient access. AWS Glue enable data analysis and filtering, while decision-making is facilitated by retrieving relevant data from Amazon S3 through Lambda functions triggered by events. Visualization of the data can be achieved using Amazon QuickSight.

By leveraging the pull/push data model within this integrated pipeline, the STIOVC framework maximizes efficiency, reduces data redundancy, and enhances the overall performance of the network infrastructure. This approach ensures that data transfers and API calls are minimized, resulting in improved system efficiency, reduced latency, and optimized resource utilization. Ultimately, the pull/push data model contributes to effective data collection, processing, and visualization for decision-making in the context of the Smart Internet-of-Vehicles Network.

The analysis of carbon emissions data from smart vehicles plays a crucial role in carbon emissions control for several reasons. Firstly, by analyzing the emissions data, we can identify the level of greenhouse gas emissions produced by smart vehicles, enabling us to measure and monitor the environmental impact. This information is essential for developing effective strategies to reduce emissions and mitigate climate change.

Secondly, the analysis helps organizations comply with regulatory requirements related to carbon emissions. By understanding and monitoring emissions data, organizations can ensure they meet the necessary standards and regulations set by governing bodies. Furthermore, the analysis helps optimize energy efficiency in smart vehicles. By identifying areas for improvement in fuel efficiency and emissions reduction, organizations can implement measures to enhance the overall performance of their vehicles and minimize environmental impact. In addition, the analysis supports the promotion of sustainable transportation practices.

By studying emissions data, organizations can identify opportunities to shift towards low-emission transportation options, such as electric or hybrid vehicles, or explore alternative transportation methods that have a lower carbon footprint. Moreover, the analysis of emissions data contributes to improving air quality. By understanding the sources and patterns of emissions, organizations can take targeted actions to mitigate air pollution, enhancing the overall health and well-being of communities. Analysis of carbon emissions data informs decision-making processes. By gaining insights into emissions profiles, organizations can make informed choices regarding fleet planning, resource allocation, and the adoption of greener technologies.

Data encryption, access control, usage control and data masking are different approaches available in the literature ensuring security and privacy of collected data. For example, usage control authorization (Park et al., 2004; Rajkumar et al., 2016a; Rajkumar et al., 2016b; Rajkumar et al., 2020) and its implementation (Rajkumar et al., 2009a; Rajkumar et al., 2009b; Rajkumar et al., 2010). A comprehensive usage control in security applications is explored in the survey (Lazouski et al., 2010). The framework must include such secure data ingestion.

Managing carbon emissions from smart vehicles is a crucial aspect of industrial management, involving optimization of operations and processes for environmental sustainability. Industrial managers ensure compliance with emissions regulations, promote resource efficiency, reduce costs, enhance reputation, and drive innovation. They play a pivotal role in developing strategies, adopting new technologies, and implementing measures to mitigate carbon emissions. By effectively managing carbon emissions, industrial managers contribute to a sustainable transportation ecosystem and organizational success. Furthermore, considering the broader impacts of the frameworks is crucial. Evaluating their environmental, economic, and social implications beyond efficiency metrics would provide a more holistic view. Assessing factors such as accessibility and long-term sustainability would ensure that the frameworks contribute positively to multiple dimensions of transportation systems. Overall, managing carbon emissions from smart vehicles aligns with industrial management principles and contributes to a more sustainable transportation ecosystem.

Conclusion

This work provided a requirement analysis for the framework called 'Serverless Tracking for Internet-of-Vehicles Carbon' (STIOVC) to address the challenges in reducing carbon emissions from smart vehicles and advancing energy conservation in transportation and logistics. The STIOVC framework leverages serverless computing and integrates the pull/push data model with AWS services to optimize data collection, processing, and visualization for decision-making. the framework contributes to cost and resource optimization by minimizing unnecessary API calls and data transfers. framework enhances decision-making capabilities by providing a streamlined data pipeline for accessing relevant data through AWS services. Industrial managers can analyze carbon emissions data and gain valuable insights for informed decision-making and promote sustainable smart transportation.

References

Ahmed, B., Malik, A. W., Hafeez, T., & Ahmed, N. (2019). Services and simulation frameworks for vehicular cloud computing: a contemporary survey. *EURASIP Journal on Wireless Communications and Networking*, 2019(*1*). https://doi.org/10.1186/s13638-018-1315-y

Ali, R., Iqbal, F., & Hassan Zada, M. S. (2022). Multicriteria Decision Making for Carbon Dioxide (CO2) Emission Reduction. *Scientific Programming*, 2022, 1–14. https://doi.org/10.1155/2022/2333821

Behrendt, A., de Boer, E., Kasah, T., Koerber, B., Mohr, N., & Richter, G. (n.d.). *Leveraging Industrial IoT and advanced technologies for digital transformation.* https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/a%20manufacturers%20guide%20to%20generating%20value%20at%20scale%20with%20iiot/leveraging-industrial-iot-and-advanced-technologies-for-digital-transformation.pdf

Dehury, C.K., Sriram, S.N., & Chhetri, T.K. (2020). CCoDaMiC: A framework for Coherent Coordination of Data Migration and Computation platforms. *Future Generation Computer Systems. 109*, 1-16. https://doi.org/10.1016/j.future.2020.03.029

Raghavan, K., Desai, M., & Rajkumar P.V. (2020). Multi-step Operations Strategic Framework for Ransomware Protection. *SAM Advanced Management Journal 85* (Edition 4). https://blog.samnational.org/2021/01/28/publication-announcement-multi-step-operations-strategic-framework-for-ransomware-protection/

Raghavan, K., Desai, M., & Rajkumar P.V. (2017). Managing cybersecurity and ecommerce risks in small businesses. *Journal of management science and business intelligence. 2* (1), 9-15, http://ibii-us.org/Journals/JMSBI/V2N1/Publish/V2N1_2.pdf

Hall, A. & Ramachandran, U. (2019). An execution model for serverless functions at the edge. *In Proceedings of the International Conference on Internet of Things Design and Implementation*. 225–236. https://doi.org/10.1145/3302505.3310084

Hogue, A. (2020). *How Azure.com uses Serverless Functions for Consumption-based utilization and reduced always-on electric footprint. Sustainable Software*. Microsoft. https://devblogs.microsoft.com/sustainable-software/how-azure-com-uses-serverless-functions-for-consumption-based-utilization-and-reduced-always-on-electric-footprint/

Iacobucci, R., Bruno, R., & Schmöcker, J. D. (2021). An Integrated Optimisation-Simulation Framework for Scalable Smart Charging and Relocation of Shared Autonomous Electric Vehicles. *Energies*, 14(*12*), 3633. https://doi.org/10.3390/en14123633

IOT Analytics – ETL. (n.d.). https://iotatlas.net/en/implementations/aws/telemetry_archiving/iot_analytics1/

Lv, Z., & Shang, W. (2023). Impacts of intelligent transportation systems on energy conservation and emission reduction of transport systems: A comprehensive review. *Green Technologies and Sustainability*, *1*(1), 100002. https://doi.org/10.1016/j.grets.2022.100002

Mahmood, A., Zhang, W., & Sheng, Q. (2019). Software-Defined Heterogeneous Vehicular Networking: The Architectural Design and Open Challenges. *Future Internet*, *11*(3), 70. https://doi.org/10.3390/fi11030070

Rajkumar P.V., & Ghosh, S. K. & Dasgupta. (2009a). An end to end correctness verification approach for application specific usage control. *Proceedings of IEEE International Conference on Industrial and Information Systems (ICIIS), Peradeniya, Sri Lanka*.1-6. https://ieeexplore.ieee.org/document/5429902

Rajkumar P.V., & Ghosh, S. K. & Dasgupta. (2009b). Application specific usage control implementation verification. *International Journal of Network Security and Its Applications. 1* (3), 116-128, 2009.

Rajkumar P.V., & Ghosh, S. K. & Dasgupta, P. (2010). Concurrent Usage Control Implementation Verification Using the SPIN Model Checker. *Recent Trends in Network Security and Applications. CNSA 2010. Communications in Computer and Information Science. 89. Springer*. https://link.springer.com/chapter/10.1007/978-3-642-14478-3_22

Nithya, S., Sangeetha, M., Prethi, K. N. A., Sahoo, K. S., Panda, S. K., & Gandomi, A. H. (2020). SDCF: A Software-Defined Cyber Foraging Framework for Cloudlet Environment. *IEEE Transactions on Network and Service Management*, 17(*4*), 2423–2435. https://doi.org/10.1109/tnsm.2020.3015657

Palade, A., Kazmi, A., & Clarke, S. (2019). An Evaluation of Open Source Serverless Computing Frameworks Support at the Edge. *IEEE World Congress on Services (SERVICES), Milan, Italy*. 206-211, https://ieeexplore.ieee.org/document/8817155

Smith, B. (2021). *Introducing AWS SAM Pipelines: Automatically generate deployment pipelines for serverless applications*. Serverless Land. AWS Compute Blog. https://serverlessland.com/blog/introducing-aws-sam-pipelines-automatically-generate-deployment-pipelines-for-serverless-applications--aws-compute-blog

Sun, Y., Hu, Y., Zhang, H., Chen, H., & Wang, F. Y. (2023). A Parallel Emission Regulatory Framework for Intelligent Transportation Systems and Smart Cities. *IEEE Transactions on Intelligent Vehicles*, *8*(2), 1017–1020. https://doi.org/10.1109/tiv.2023.3246045

Tian, H., Li, S., Wang, A., Wang, W., Wu, T., & Yang, H. (2022). Owl: Performance-aware scheduling for resource-efficient function-as-a-service cloud. *In Proceedings of the 13th Symposium on Cloud Computing*. 78-93. https://dl.acm.org/doi/abs/10.1145/3542929.3563470

Rajkumar P.V. (2022). Gauging Carbon Footprint of AI/ML Implementations in Smart Cities: Methods and Challenges. *Proceedings of the Seventh International Conference on Fog and Mobile Edge Computing, Paris, France*. https://ieeexplore.ieee.org/document/10062634

Zhang, A., Li, S., Tan, L., Sun, Y., & Yao, F. (2022). Intelligent Measurement and Monitoring of Carbon Emissions for 5G Shared Smart Logistics. *Journal of Sensors*, 2022, 1–13. https://doi.org/10.1155/2022/8223590

Park, J. & Sandhu, R. (2004). The $\mathrm{UCON}_{\mathrm{ABC}}$ usage control model. *ACM Transactions on Information and System Security*. *7*(101). 128–174. https://doi.org/10.1145/984334.984339

Rajkumar P.V., & Sandhu, R. (2020). Safety Decidability for Pre-Authorization Usage Control with Identifier Attribute Domains. *IEEE Transactions on Dependable and Secure Computing*. *17*(3). 465 – 478. https://ieeexplore.ieee.org/document/8362972

Rajkumar P.V., & Sandhu, R. (2016a). Safety Decidability for Pre-Authorization Usage Control with Finite Attribute Domains. *IEEE Transactions on Dependable and Secure Computing. 13*. 582-590. https://ieeexplore.ieee.org/document/7097658

Rajkumar P.V., & Sandhu, R. (2016b). POSTER: Security Enhanced Administrative Role Based Access Control Models. *Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security*. 1802–1804. https://dl.acm.org/doi/10.1145/2976749.2989068

Lazouski, A., Martinelli, F., & Mori, P. (2010). Usage control in computer security: A survey, *Computer Science Review*. *4*(2). 81-99. https://doi.org/10.1016/j.cosrev.2010.02.002.

Van Wynsberghe, A (2021). Sustainable AI: AI for sustainability and the sustainability of AI. *AI Ethics*. *1*, 213–218. https://doi.org/10.1007/s43681-021-00043-6