Scientific Research Publishing

Journal of Environmental Protection, 2025, 16(4), 338-353
https://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

The Integration of AI Technologies in the Sustainability Field

Mianda Khattab*

Department of Environmental Engineering, The American University in Cairo, Cairo, Egypt
Email: miaz@aucegypt.edu

How to cite this paper: Khattab, M. (2025) The Integration of AI Technologies in the Sustainability Field. *Journal of Environmental Protection*, **16**, 338-353.
https://doi.org/10.4236/jep.2025.164017

Received: February 18, 2025
Accepted: April 19, 2025
Published: April 22, 2025

Abstract

The future starts today, and AI is driving the future. It is changing and optimizing how computers work, technologies drive, fastening decision making, eliminating human errors, leading to higher efficiency in a timely response and it is even shaping how communities and cities are built. The impact of AI is nevertheless integrated with saving the environment, working coherently towards augmenting the known pillars to drive faster, more sustainable results with the aim of reaching net zero. AI as technology has been out for decades but was never the focus as nowadays when the population count, and urbanization rates are increasing massively, leading to faster higher demands on the needs and necessities of lives. This is making every job challenging, especially with the need to run continuous analytics for better decision-making and process optimization leading to faster results and better future predictions, saving from any foreseen crisis. AI introduction to SDGs and technology realization for smarter wastewater treatment, solid waste management from collection to sorting to recycling, reducing carbon emissions and energy savings have been introduced and implemented as pilot studies in several countries, leading to real life examples with promising results. This paper explores the available integration between AI and sustainability with the aim of investigating the potential of real-life implementation globally, with the main focus of reaching Net Zero goals in alignment with COP's vision and direction.

Keywords

Artificial Intelligence, Sustainability, The Race to Net Zero, Net Zero Carbon Emissions, Sustainable Development Goals, Real Life Applications, Artificial Intelligence Ethics, Egypt and AI

*Department of Mechanical Engineering, Environmental Engineering Program, AUC.

1. Introduction

1.1. Sustainability Introduction

Embracing the change is challenging and so is delivering a sustainable world with more focus on Net Zero implementations as highlighted in COP 27, COP 28 and COP 29 will be further challenging to reach the needed urgency of action without the consideration and integration of technology, IoT and AI. Sustainability is known as meeting the needs of the current generations without impacting future demands and needs. In other words, sustainability is focused on implementing successful acts to optimize the use of natural resources rather than full reliance on them. Sustainability is defined through three main pillars, Social, Economic and Environmental yet with the boom of the digital revolution in the 2000s, Technology started to rise further as a supporting sustainability pillar that can facilitate and enable driving a more sustainable business, world and planet. "*Sustainable technologies can play a pivotal role in helping companies measure*, *refine and report their progress towards achieving sustainability goals to stakeholders*" [1]. Uniting sustainability, sustainable development and technology through considering and developing sustainable technology strategies can aid generating x2.6 times faster return on investment (ROI) and Environmental, Social and Governance appearance to institutions [2].

1.2. Artificial Intelligence Introduction

Artificial Intelligence (AI) is the prime of technological development globally, going back to the 1950s with the early release of computers. Yet, with the massive growth of population rates globally, urbanization and massive amount of data countries, governments and humans are dealing with, daily, under different aspects; the innovative maturity and development of computing powers and cloud processing kicked-in again to drive the world into rather a non-repetitive human task doing. Companies, Governments and Investors are dedicating more budgets, assets and resources into research and development for AI driven/management services, tools and equipment [3]. Harnessing AI with Sustainable Development on all aspects and sectors with job loss risks, less misinformation and faster effective decision making on a monumental scale is being the focus of the United Nations Sustainable Development Group as mentioned by UN Deputy Secretary-General [4].

2. Objective

The purpose of this paper is to explore how Artificial Intelligence is an answer to a faster and more efficient implementation to save the environment while replacing repetitive human tasks with more automated steps with higher efficiency and optimum timeframes. In this paper, the study of reaching net zero under net zero carbon emissions, net zero energy, net zero solid waste and net zero wastewater using AI is the core to make sure that the available leading technologies are leveraged in meeting the COP goals in a timely responsive manner.

3. The Integration between Sustainability, SDG and AI

The integration between Sustainability and AI is a new area worth shedding the light on. As mentioned earlier, sustainability is considered in our daily activities, services provided, products produced, management of resources, optimization of procedures, raising awareness, higher ROI and support in creating clean livable environments with lesser pollution, lesser carbon footprint and Net Zero offsets. Narrowing the research focus further, Net Zero, which is a theoretical zero focusing on equating the used resources with the carbon offset and the end of line, is the highlight of any sustainable development discussion and in COP 27, COP 28 and COP 29.

AI is implemented through every goal of the 17 SDGs focusing primarily with SDG#13 (Climate Action). The reflection on climate modeling, implications and projections is a spot on area of focus where AI, with machine learning and iterative computing models, can act faster on detecting upcoming alarms, projecting errors and providing immediate mitigating solutions. Additionally, it could support investors, decision-makers and policy makers into developing faster and more effective solutions that can support climate change [5]. Harnessing AI can also aid in SDG#3 and SDG#4 for Good Health and Wellbeing, Quality Education by revolutionizing the healthcare sector in early diagnostics and faster decision making, better health management and monitoring plus improved wellbeing and recovery [5].

Nevertheless, AI can drive more efficient and smart communities (SDG#11), Industries and Innovation (SDG#9), Responsible Consumption and Production (SDG#12) and Life on Land (SDG#15). When narrowing down on the innovations, industries and communities where the highest percentages of carbon footprint contribution occurs; AI can be leveraged in tracking processes, efficiently applying cleaner production methods in industries, wastewater treatment methods and waste management from the source up to the final stage hence, focusing on reducing the landfill reject and back again, reducing pollution, contamination and further negative impact and burned on the climate.

3.1. Artificial Intelligence and Net Zero Approach

Net Zero is "*Net zero means cutting carbon emissions to a small amount of residual emissions that can be absorbed and durably stored by nature and other carbon dioxide removal measures*, *leaving zero in the atmosphere*." as described by UN [6]. In other words, Net Zero is a theoretical zero offsetting carbon footprint from the source till the end of the production/service lines; this entails implementing cleaner production methods to utilize resources, especially the reliance on naturally existing ones, while optimizing the waste at the end of the process to be recycled or reused. Hence, it supports reducing greenhouse gas emissions and working towards enhanced climate action.

The Net Zero concept was introduced in the early 2000s, however, starting COP 26 till COP29 with a focus on (Race to Net Zero) focusing primarily and mainly

on the energy sector to convert from fossil fuels to utilize renewable energy, zero to low carbon fuels and aid in reaching Net Zero Energy by 2050 [7]. Net Zero is essential to consider and implement not only on a government level but also within businesses, communities and industries to meet the early Paris Agreement of limiting the global average temperature increase to 1.5 Celsius above predefined industrial temperature levels. Failing to reach that is leading to poles melting. Extensive fires in the Amazons, deforestation, global warming and extinction of animals with the rise of several new diseases.

Many will debate about the applicability of reaching Net Zero claiming that Sustainability is not a measurable action plan but rather a good to have dream to reality. In argument to that, looking at the surroundings with the natural challenges globally, loss of resources, higher poverty rates, lack of employment, lower living standards in addition to the previously mentioned natural disasters that are foreseen; changing our mindsets and out day to day activities is no longer an option but rather a mandated game changer action on citizens, governments and countries. Applying Net Zero and reaching it by 2050 is critical and hence, stated, documented and signed off by several countries during COP. This is rather an alarming step, so that if no human actions are not changed, then we shouldn't expect a different outcome from where we land today but even in a much worse impact on us and on future generations.

Artificial Intelligence (AI) is a computer-based repetitive algorithm continuously running on a pool of human-encrypted data to provide extensive analysis based on case study models along with different scenarios for more efficient decision-making. AI is designed and trained to mimic the human minds in performing functions, especially repetitive and time-consuming ones while creating predictions and providing solutions. AI is thought to facilitate and ease the way to reach net zero with efficiency and effectiveness. With the machine learning capability via several scenarios, previous data sets and case studies; AI is being a unified front for data acquisition supporting for future predictions, providing alternatives and faster decision making. AI can predict and map deforestation, weather patterns, climate disasters and turn around for citizens and governments to be prepared for any climate change. Lastly, AI helps in analyzing and reducing waste and recycling by driving efficient waste management [8].

3.2. Artificial Intelligence, Net Zero Carbon Emissions and Net Zero Energy

AI is supporting energy transition to net zero by drawing data patterns, identifying abnormalities and driving data analytics with recommendations as mentioned by the World Green Economy Forum [9]. AI can also track and report GHG emissions with the needed offsets to lower carbon footprints while optimizing renewable energy production and improving solar panels grid management [8].

Carbon Dioxide (CO_2) is the biggest contributor to global warming and GHG emissions, it is basically the result of any human driven activity. Since data load is

overwhelming and continuous analytics are needed being challenging for the human minds to manage; AI kicks-in as a supporting arm aiding businesses and government to control and minimize their CO_2 emissions. It can also support mapping out high pollution zones and projecting next disasters or impacts with predefined sets of data and scenarios, supporting governments to be ahead of the game and plan pre-occurrence mitigations.

Several countries and companies are already relying on AI technologies to optimize energy efficiency. IBM's, a USA technology and software company, cleaner energy vision is leveraging AI while focusing on improving renewable energy sources efficiency and sustainability, driving the energy industries into more smart, resilient and innovative systems in addition to providing real-life data insights and future projection aiding in the decision making and cleaner energy technology adoption [10]. Carbon Bright's, a USA software start-up company, leveraging AI powered life cycle assessments (LCA) and live data analytics to drive more efficient product with lower carbon footprints [11]. Lastly, countries like Germany and United Kingdom are leveraging AI technologies to drive more energy efficient communities and societies. In Germany, for example, the government is focused on reducing the urban carbon footprint by leveraging smart and sustainable communities driven by AI insights to optimize energy usage and waste management. Likely in the United Kingdom, the government is focused on reducing the reliance on fossil fuels and converting fully into renewable energy; hence, starting off by using AI in driving more improved energy efficiency in buildings, homes and offices and thus, lowering carbon footprint impacts [12].

3.3. Artificial Intelligence and Net Zero Waste

Solid waste management is produced globally annually in massive amounts estimated to 2.01 BTNs and projected to increase to 3.4 BTNs by 2050 due to population growth, higher demands on resources, and higher urbanization levels as stated by The World Bank [13].

Figures 1-2 reflect the percentages of waste produced globally with organic waste contributing to the highest percentage of 44% followed by Paper and Cardboard then mix of other wastes. The common methods on how the waste being disposed of are shown in **Figure 2** projecting that open dumps and landfills contribute to the highest percentages of waste disposal. This reflects the negative environmental impact leading to faster environmental destruction with visual pollution, air pollution, soil and ground water contamination and a high risk of diseases exposure; this is all violating the sustainability pillars and aim.

Composting is the main resort of waste management which to an extent if managed properly can result in more moist soils with organic composted fertilizers that will all eventually lead to lesser water used for irrigation, reduction of water runoff and soil erosion. However, it still contributes negatively to carbon emissions with odors and higher treatment wait durations. This is followed by Landfilling which again, if not structed with engineering methods, designs and measures, and if

not maintained and managed properly will lead to catastrophic environmental impacts from odors, insects, groundwater contamination, air pollution, waste of resources, loss of money, soil erosion, fires-catching up and on top, more negative impact of the climate.

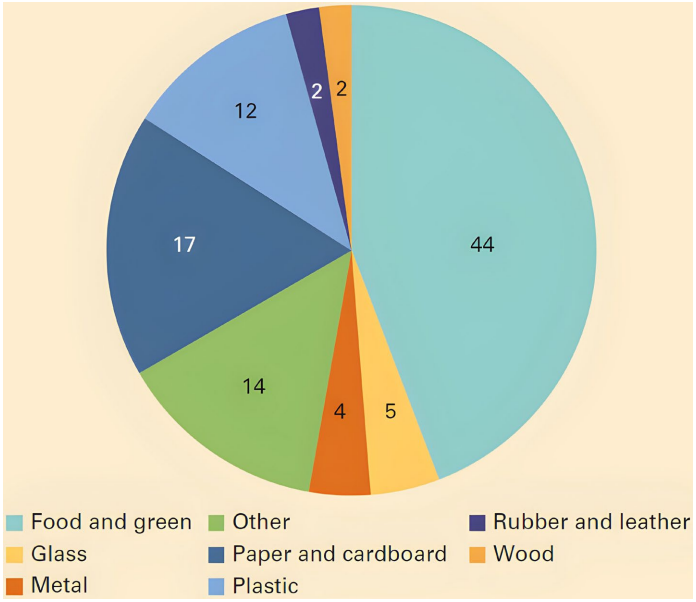

Figure 1. Global Waste Composition (Percentage)—The World Bank [13].

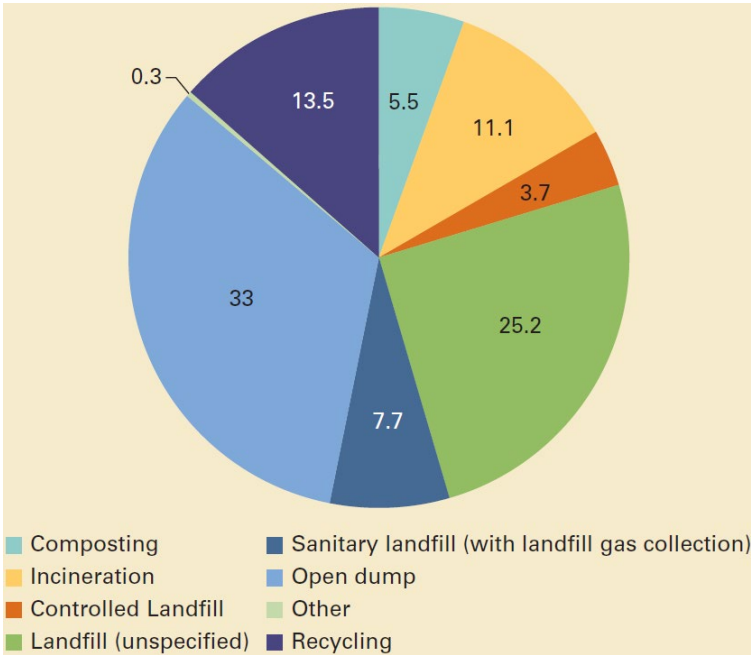

Figure 2. Global Treatment and Disposal of Waste (Percentage)—The World Bank [13].

AI supports solid waste management in several ways starting off by reducing at the source with data mapping and optimization. Relying on AI in waste management can lead to a reduction of transportation distance by up to 36.8%, increase

in cost savings by 13.4%, time saving increase by 28% and waste identifying and sorting efficiency and accuracy that can reach from 72.8% till 99% [14].

Looking at a Zero Waste Circular Economy approach, abiding to a cradle-to-cradle concept in which reduction and optimization at the source is a factor so as, the whole process optimization and the end of line recycling or reusing leading to a minimal drive of disposed/unused waste to the landfills or incineration stage. Figure 3 illustrates how AI applications are considered for smart waste management systems with the use of urban applications. In addition to waste sorting robots in the transfer stations that will optimize the sorting stage with higher efficiency and saving time versus human interference. This will drive away any possible (trash to treasure) from being dumped into the landfill into being recycled or reused. Also, trash truck transportation and routes will be optimized by the online live data flow and analytics on trash trends per zone or area so that the trucks are provided with trash-overload signal or alarm reflecting urgency of trash collection rather than useless drives for minimal waste collection. Lastly, the use of AI can aid in identifying waste composition, driving easier and clearer treatment decisions.

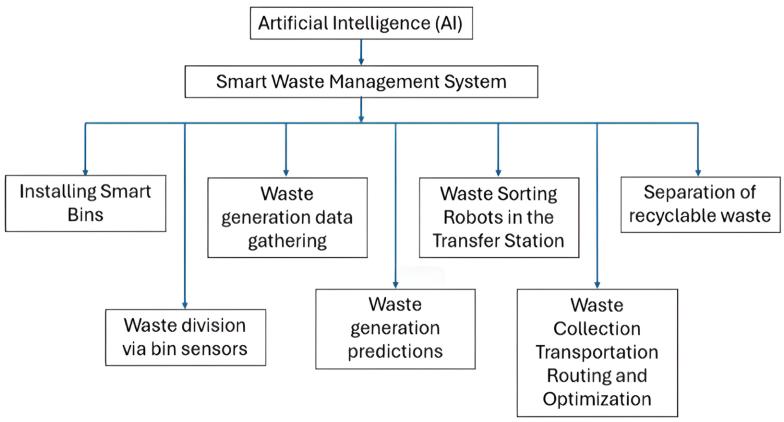

Figure 3. AI application in waste management diagram.

Solutions provided and utilized by AI in waste management include smart bins for waste monitoring and ease of classification like (Bin.e) which supports in sorting and automatic compression of waste with live data processing on the types of waste included in the bin and the fill level capacity [15]. Bin.e leverages AI for ease of waste recognition, sorting, reporting, stats and analytics and alerts to empty the bins; hence, optimizing the transportation route for trash collection.

Waste Sorting Robots is another AI driven technology mainly for transfer stations where robots are used on the line to easily spot and collect recyclable materials rather than relying on human interference; this can lead to 3x faster and more efficient outputs. A company like (Recycleye) produces AI-sorting-robot arms that are installed in different locations in EU and USA to easily spot recyclables from the collected wastes. The robots are programmed to identify more than 28 different materials, colors, classes, shapes, packaging and food grades yet, driving

more efficient waste sorting, reducing landfill throws and optimizing human effort while reducing risks as some of the waste can contain toxic materials impacting the worker's life [16].

Taking these technologies into consideration can drive a more sustainable industry with waste collection, sorting and treatment advancement leading to a more efficient cradle-to-cradle application driving a Net Zero Waste approach.

3.4. Artificial Intelligence and Net Zero Wastewater

90% of the earth's space is covered by water with around 3% only fresh water available for use and the delta is inaccessible water in glaciers and others. The human body consists of approximately 70% water content which shows how essential water is to our bodies and how frequently we rely on it in our daily activities like cooking, washing, showering, cleaning and others. As quantified by the UN World Water Development Report, 70% of freshwater is used for agricultural purposes globally, 20% for industries and less than 12% for domestic use [17]. With the rise in population and urbanization, the reliance of fresh water in domestic use has increased massively and will keep on increasing based on the demand and as shown in **Figure 4**. Without proper management and utilization of freshwater to only drinking and cooking purposes while optimizing wastewater and greywater treatment methods as per the available standards for other usages, the fresh water will be driven into further water stress and shortages like what is already faced with more than 1/3rd of the world population in some countries and areas.

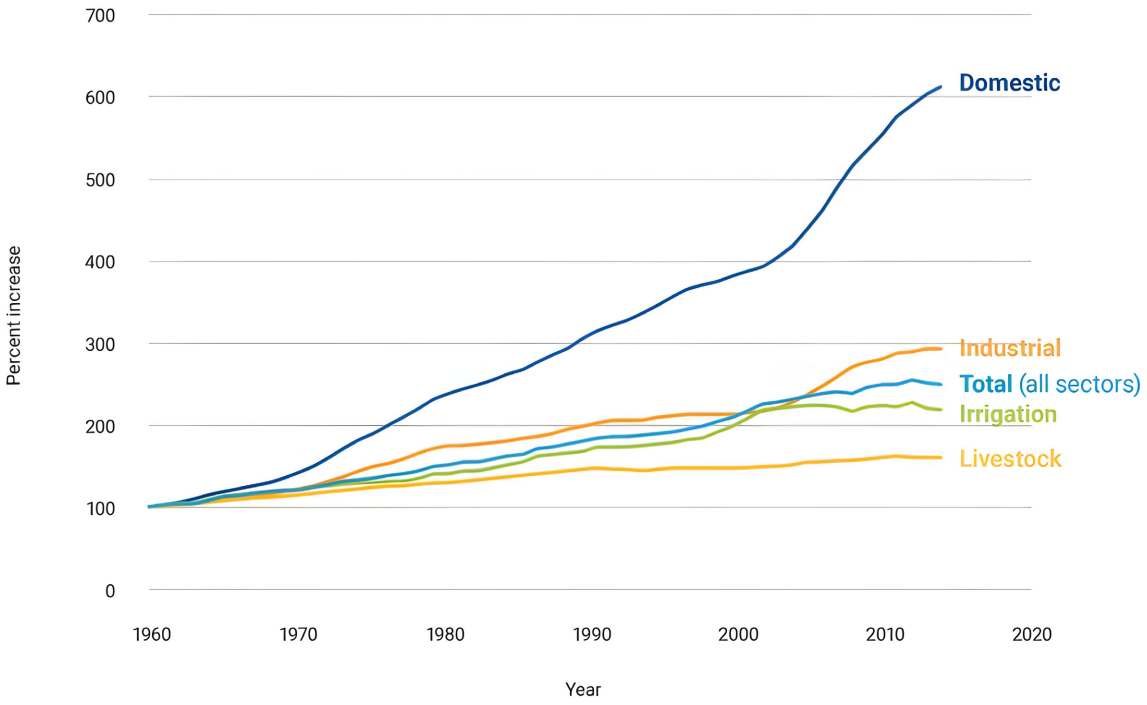

Figure 4. Increase in water withdrawals across years [17].

AI technology can be used to optimize wastewater treatment with monitoring,

detection and prediction approaches. AI can detect predictive maintenance, monitor the influent and effluent water quality and measures, alarms on leak detections, support in design, infrastructure and demand forecasting in addition to predicting any flood risks [18].

Singapore is heavily invested in advanced wastewater management, infrastructure, treatment and monitoring targeting per capita water consumption reduction to 130 L/day by 2030; the countries is using AI in smart water grid program connecting 0.3 million residents with smart water meters and monitoring water quality by providing real-time data insights plus a pilot simulation model for performance [19]. Singapore is also using AI-optimized anaerobic digestion processes in the wastewater treatment plants relying mainly on real-time data measuring temperature, organic matter and carbon footprint [20] [21].

3.5. Artificial Intelligence, Net Zero and Job Opportunities

Many will debate that with the previous mentions and technologies a lot of human-driven jobs will be eliminated and substituted by robots or technology hence, leading to job loss. The first part of such a statement is true but not the second. In a technology driven era, advancing our day-to-day lives, AI is a double-edged sword leading more into supporting and driving a more sustainable world in an efficient manner. Awareness, Education and a change in the mindset are mandated to drive the world to a more sustainable place; AI technology advancing the scope of human skills into driving higher tech technicians and engineers coding, programming, educating, operating and maintaining these machines to act like human-minds. AI can automate repetitively risky human tasks with more effectiveness and efficiency, giving more space to the worker to develop better skills and protecting their health as previously stated in an example in the paper.

It is a governmental and institutional role to invest in educating and enhancing their worker's expertise level to embed AI technologies into their favors supporting jobs and creating further ones. AI is definitely a challenge for those reluctant to change. As stated by The World Economic Forum, "This decade is set to be transformed by the shift towards a carbon-neutral economy and the roll-out of artificial intelligence. These factors will disrupt and change the nature of employment" driving more cleaner energy job opportunities creation [22]. AI can create job needs and demands in new areas that were unexplored or unneeded before the introduction of the fast-booming technology, the need of redefining and rebuilding the existing sectors, with ethical implementation for the vast amount of human data gathered and placed on the cloud for analysis, relying on human-impact for personalized services and customer interaction will remain as is yet, AI is mainly supporting in driving faster and more efficient logistics and results as mentioned by Forbes [23].

4. Case Study: Reflecting on the Middle East and Egypt

The Middle East is considered as a potential market for AI implementation as a

reflection of developing countries embracing AI technology. With the inclusion of 18 countries, it is driven by the Gulf region and UAE showing the highest interest to embrace and implement AI technologies into driving more sustainable cities and communities and leading to an enhanced urban life experience. Dubai for example embraced AI since 2017 when they started to use AI with trained algorithms under (Dubai Water and Electricity Authority) to respond to citizens queries [24]. AI adoption has been piloted in several industries in UAE as shown in **Figure 5** reflecting how the technology can be trained and tailored to meet industry needs and consumer expectations by showing the percentage of sample respondent adopting AI in different business function in UAE.

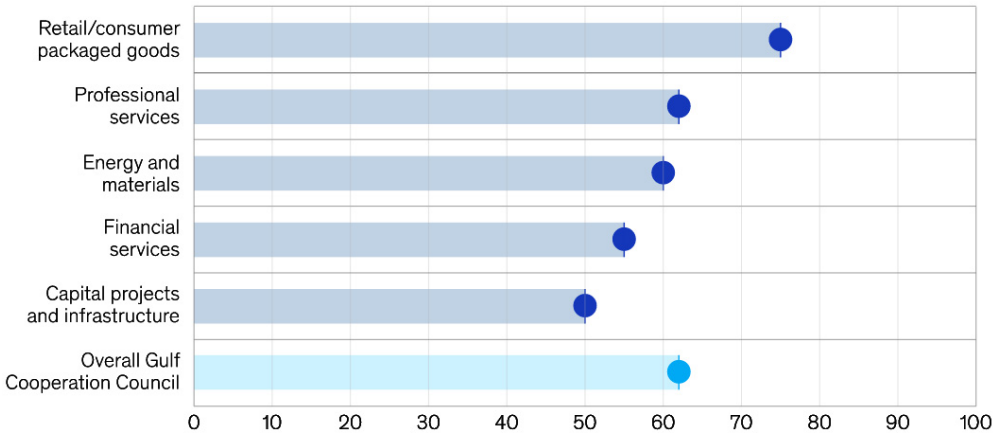

Figure 5. % of respondents adopt AI in more than one business function in UAE (McKinsey & Company) [24].

Narrowing down to solid waste management is essential in UAE due to rapid population growth and high urbanization rates projecting to produce more than the 3.5 million tons of waste produced currently per year. UAE started to integrate IoT and AI technology in waste collection and sorting while optimizing the waste collection routes by embedding smart bins with interconnected systems technology gathering data about the waste collected and monitoring the waste level plus providing data analytics that supports the waste management authorities and investors to take more efficient decisions for infrastructure development and enhancement additionally to assess resources allocation and enhance citizens awareness and experience [25].

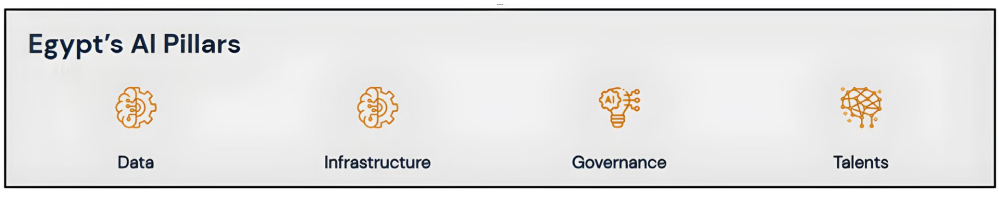

Figure 6. Egypt's AI Pillars [26].

Egypt, the largest Arab Country and a historical hub, is nevertheless facing sim-

ilar challenges of high population increase rates and urbanization generating more than 100 million tons of waste per year with municipal solid waste contributing to the most of 21 million tons per year, as referenced by the National Solid Waste Management Program. And according to an earlier issue by the World Bank in 2022, more than 2/3rd of the generated solid waste is mismanaged in Egypt leading to higher environmental and health hazards.

Even though Egypt is not at the same economical value as the leading technology hubs in UAE and the gulf region, but the government started shedding the light on implementing AI technologies locally to reinforce COP goals of reaching Net Zero Approaches. The National Council of Artificial Intelligence in Egypt is actively tackling the adoption of AI technologies in the market since 2021 with the first issue on (Egypt's AI Strategy First Edition) to (Egyptian Charter for Responsible AI) to the (AI Strategy Second Edition, 2025-2030). The Egyptian government defined 4 main AI Pillars to ensure responsible exposure, implementation and ownership among the whole society, investors and the government. **Figure 6** shows the pillars starting with the need for data accessibility, exposure and sharing across different industries complimented by a supportive infrastructure to withstand the technology bandwidth and applications. This is implemented and monitored with transparency, ethical and responsible AI use under governance, and lastly, local talents and experts are acquired by raising awareness and providing educational sessions and training as needed [26].

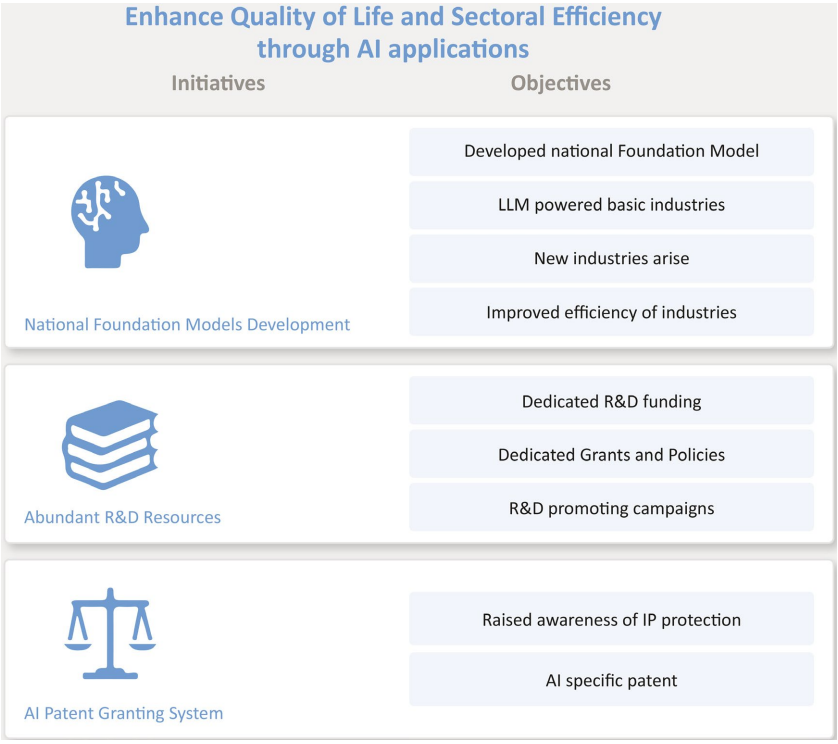

Figure 7. Egypt's initiatives and objectives for AI applications [27].

Egypt's AI Strategy Second Edition, 2025-2030 document highlights how Egypt

started implementing several AI awareness foundations since 2020 by integrating it in education, technical trainings, funding AI research while supporting local entrepreneurs and fostering global cooperations for a broader and smoother AI exposure and embracement [27]. **Figure 7** elaborates on the strategic objective buckets considered by the Egyptian government for successful AI technology embracement; the sections are divided under (R & D Resources), (AI Patent Granting Systems) and (National Foundation Models Development) where Improved efficiency of Industries fall. This sub section is where reducing waste and enhancing waste management is considered by optimizing processes, analyzing massive amounts of data with analytics-based-driven decisions and future predictions under different industries.

This shows that the Egyptian government, entrepreneurs and investors are gaining global expertise and knowledge into driving a smarter and more efficient community with AI technologies tailoring, training and implementations.

5. The Concerns with AI

With AI gathering and analyzing data, privacy concern rises even more specially when used with personal information exposure or shared financial details for cybersecurity theft for example. A whole division of AI ethics has been studied and is continuously under enhancement as mentioned by IBM "to include data responsibility and privacy, fairness, explainability, robustness, transparency, environmental sustainability, inclusion, moral agency, value alignment, accountability, trust, and technology misuse" [28]. Starting off by training the dataset used within the AI algorithm is a crucial step to ensure less to no bias; IBM already stated that the trust in AI is built on five main ethical pillars including Transparency, Privacy, Explainability, Fairness and Robustness.

Noting how important is AI Ethics, UNESCO produced the first global AI ethics standards in 2021 covering several areas under the training and use of AI for gender equality, data privacy, transparency, accountability, Governance and use policy, how to effectively implement AI under several services and industries serving Education, Economy and Health. All of these are tied with measures for monitoring, evaluation and transparent implementation of AI in all of AI technology usage lifecycle within the institutions of use [29]. UNESCO also listed the 4 main core values for AI supporting humanity, the environment and the society. These values include Human Rights and Human Dignity, Living in Peaceful Interconnected Societies, Ensuring Diversity and Inclusiveness, lastly, Environment and Ecosystem Flourishing [30].

In a nutshell, AI is a part of our daily lives, influencing decisions, gathering data, and providing intel. AI ethics are there to optimize the technology's benefit and effectiveness while reducing any bias or data leak threat.

6. The Future of AI with Sustainability

As AI is now in the action plan for meeting sustainable development and climate

action, several software's have been introduced to aid organizations and business developers project their environmental impact and the needed mitigations to lower any negative print. Starting off is a (Net Zero Cloud), it is Salesforce's ESG GHG emissions tracking solutions aiding in reaching Net Zero Carbon [31]. This tool among many other tailored for Wastewater management, Energy Consumption and Solid Waste Management are introduced leveraging high capacity of data inputs and with AI algorithm, output reports and dashboards are produced for the users for ease of data correlation and interpretation. Additionally, AI design on feedback loops that include users and stakeholders' responses along with external environmental dynamics is needed to allow a sense of human engagement while ensuring the feedback loops are running for better efficiency hence, preventing biased opinions. Additionally, the need to understand the economic implication of AI being implemented versus the long-term return on technology investment is essential. The long-term benefit mentioned above is mainly economically yet correlating it with the positive environmental contribution along with social awareness and accountability is key. Lastly, considering the surrounding ecosystem with the infrastructure in place to ensure that AI technologies are well equipped with the cloud, IoT different systems for live data capturing and analytics are essential for a complete inclusion and implementation of AI technologies [32]. AI is considered as a core catalyst for a sustainable future driven by effective business decisions and more targeted, maybe also forecasted, problems and actions in place. The inclusion of social acceptance and psychological impacts upon implementations, economical projections and technical enhancement algorithm input data iterations is essential to consider for a full sustainable development win along with the vast environmental contribution.

7. Conclusions

Looking at AI along with the known sustainability pillars of social, environmental, economic and technology; AI is driving the technology area leading to a more environmentally friendly planet. Yet, there is a challenge for social acceptance which can be mitigated with the governmental and institutional commitment to raising more awareness, education and providing the needed training for the members and staff. Lastly, for the economic pillar, it is an established fact that AI is a high-end expensive technology to implement at an initial cost yet, as engineers, investors and entrepreneurs, one should be focused on the process enhancement along with life cycle assessment and long-term return on investment which is guaranteed to be paid back after the high initial costs.

In a nutshell, this paper aims at shedding the light on the environmental advancement along with the global technologies that will support in mitigating pollution levels, reducing "resourceful waste" from being dumped into the landfills while projecting the best treatment solution along with keeping real live data pool for continuous assessment and future predictions supporting governments in being prepared rather than alarmed. AI is a key to that and even more, it is technol-

ogy that is already in place; it is about embracing change and riding ahead driving the industries and the world to a more sustainable place.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] What Is Sustainable Technology? (2024, January 24). IBM. https://www.ibm.com/think/topics/sustainable-technology#:~:text=Sustainable%20technologies%20can%20play%20a,achieving%20sustainability%20goals%20to%20stakeholders

[2] Uniting Technology and Sustainability (2024, December 1). Research Report. https://www.accenture.com/us-en/insights/technology/uniting-technology-sustainability

[3] Lanier, J. (2023, April 20). The New Yorker. https://www.newyorker.com/science/annals-of-artificial-intelligence/there-is-no-ai#:~:text=The%20term%20%E2%80%9Cartificial%20intelligence%E2%80%9D%20has,the%20early%20days%20of%20computers

[4] Harnessing Artificial Intelligence for Sustainable Development Goals (2024, May 8). UNSDG. https://unsdg.un.org/latest/announcements/harnessing-artificial-intelligence-sustainable-development-goals-sdgs

[5] Jasper, P. (2024, July 9) Can AI Help Us Achieve the SDGs? SDG Action. https://sdg-action.org/can-ai-help-us-achieve-the-sdgs/

[6] For a Livable Climate: Net-Zero Commitments Must Be Backed by Credible Action. United Nations. https://www.un.org/en/climatechange/net-zero-coalition#:~:text=Put%20simply%2C%20net%20zero%20means,leaving%20zero%20in%20the%20atmosphere

[7] COP28: Tracking the Energy Outcomes. IEA. https://www.iea.org/topics/cop28-tracking-the-energy-outcomes

[8] 9 Ways AI Is Helping Tackle Climate Action (2024, February 12). World Economic Forum. https://www.weforum.org/stories/2024/02/ai-combat-climate-change/

[9] How AI Is Advancing the Energy Transition to Net Zero. World Green Economy Forum. https://wges.ae/articles-2024/article-13/

[10] Gandhi, B. (2024, December 3) Unlock the Power of Real-Time Data for Intelligent Energy Operations. https://www.ibm.com/new/announcements/unlock-the-power-of-real-time-data-for-intelligent-energy-operations#:~:text=Leveraging%20artificial%20intelligence%20(AI)%20and,adoption%20of%20clean%20energy%20technologies

[11] CarbonBright Co. Mission and about Us. https://carbonbright.co/about-us

[12] 5 Countries Are Using AI to Reduce Carbon Footprints (2024, August 13). MC Solutions. https://mcsolutions.vn/5-countries-are-using-ai-to-reduce-carbon-footprints/#:~:text=As%20a%20result%2C%20companies%20like,thereby%20significantly%20lowering%20carbon%20emissions

[13] What A Waste 2.0. A Global Snapshot of Solid Waste Management to 2050. The World Bank.

https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html#:~:text=The%20world%20generates%202.01%20billion,from%200.11%20to%204.54%20kilograms

[14] Abbasi, M. and El Hanandeh, A. (2016) Forecasting Municipal Solid Waste Generation Using Artificial Intelligence Modelling Approaches. *Waste Management*, **56**, 13-22. https://doi.org/10.1016/j.wasman.2016.05.018

[15] Bin.e. Smart Waste Bin Revolutionizing the Waste Management System. https://bine.world/

[16] Recycleye (2024) The Benefits of Waste Sorting Robots in Recycling Facilities. https://recycleye.com/benefits-waste-sorting-robots-recycling-facilities/

[17] Statistics: Water Demand and Use (2024, February 24). United Nations World Development Report. UNESCO. https://www.unesco.org/reports/wwdr/en/2024/s#:~:text=Worldwide%2C%20agriculture%20accounts%20for%20roughly,freshwater%20withdrawn%20for%20domestic%20purposes

[18] AI Innovations in Water, Sewerage, and Waste Management (2024, April 23). Numalis. https://numalis.com/ai-in-water-sewerage-and-waste-management/

[19] Urban Infrastructure (2023, June 16) Resource Upcycling: Initiatives by Singapore to Convert Sewage for Domestic Water Use. https://southeastasiainfra.com/resource-upcycling-initiatives-by-singapore-to-convert-sewage-for-domestic-water-use/

[20] Innovation in Water Singapore. Volume 11 (2019, June). https://www.pub.gov.sg/-/media/Images/Feature/Content-Pages/Resources/R-and-D/Issue-11Innovation-in-Water-SingaporeFull-PDF.pdf

[21] Carlton, B. (2024, January 15) Wastewater Management Is Improving, Thanks to AI Technology. https://fsstudio.com/wastewater-management-is-improving-thanks-to-ai-technology/#:~:text=AI%2DOptimized%20Anaerobic%20Digestion%20in,in%20its%20wastewater%20treatment%20plants

[22] Climate Action and AI Can Create More and Better Jobs (2024, January 17). World Economic Forum. https://www.weforum.org/stories/2024/01/just-transition-climate-action-ai-create-more-better-jobs/

[23] Iacoviello, M. (2023, July 26) How Does Artificial Intelligence Create New Jobs. *Forbes*. https://www.forbes.com/councils/forbesbusinesscouncil/2023/07/26/how-does-artificial-intelligence-create-new-jobs/

[24] McKinsey Digital (2023, May 30) The State of AI in GCC Countries and How to Overcome Adoption Challenges. https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-state-of-ai-in-gcc-countries-and-how-to-overcome-adoption-challenges

[25] The Role of Technology in Waste Management within the UAE (2024, November 3). https://generisonline.com/the-role-of-technology-in-waste-management-within-the-uae/

[26] The National Council of Artificial Intelligence. Egypt. https://ai.gov.eg/

[27] Egypt National Artificial Intelligence Strategy Second Edition (2025-2030)—Online Document.3.

[28] What Is AI Ethics? IBM. https://www.ibm.com/think/topics/ai-ethics

[29] Recommendations of the Ethics of Artificial Intelligence (2021, November 23). UNESCO. https://unesdoc.unesco.org/in/documentViewer.xhtml?v=2.1.196&id=p::usmarcdef_0000381137&file=/in/rest/annotationSVC/DownloadWatermarkedAttachment/attach_import_e86c4b5d-5af9-4e15-be60-82f1a09956fd%3F_%3D381137eng.pdf&locale=en&multi=true&ark=/ark:/48223/pf0000381137/PDF/381137eng.pdf#1517_21_EN_SHS_int.indd%3A.8958%3A14

[30] Ethics of Artificial Intelligence. UNESCO. https://www.unesco.org/en/artificial-intelligence/recommendation-ethics

[31] Salesforce-Net Zero Cloud. https://www.salesforce.com/net-zero/cloud/

[32] Nishant, R., Kennedy, M. and Corbett, J. (2020) Artificial Intelligence for Sustainability: Challenges, Opportunities, and a Research Agenda. El Sevier.

Nomenclature

AI	Artificial Intelligence
BTN	Billion Metric Tons
CO_2	Carbon Dioxide
COP	Conference of the Parties
ESG	Environmental, Social and Governance
EU	Europe
GHG	Green House Gases
IBM	International Business Machines Corporation
IoT	Internet of Things
LCA	Life Cycle Assessment
MSW	Municipal Solid Waste
ROI	Return on Investment
SDG	Sustainable Development Goals
UN	United Nations
UNESCO	United Nation Educational, Scientific and Cultural Organization
USA	United States of America