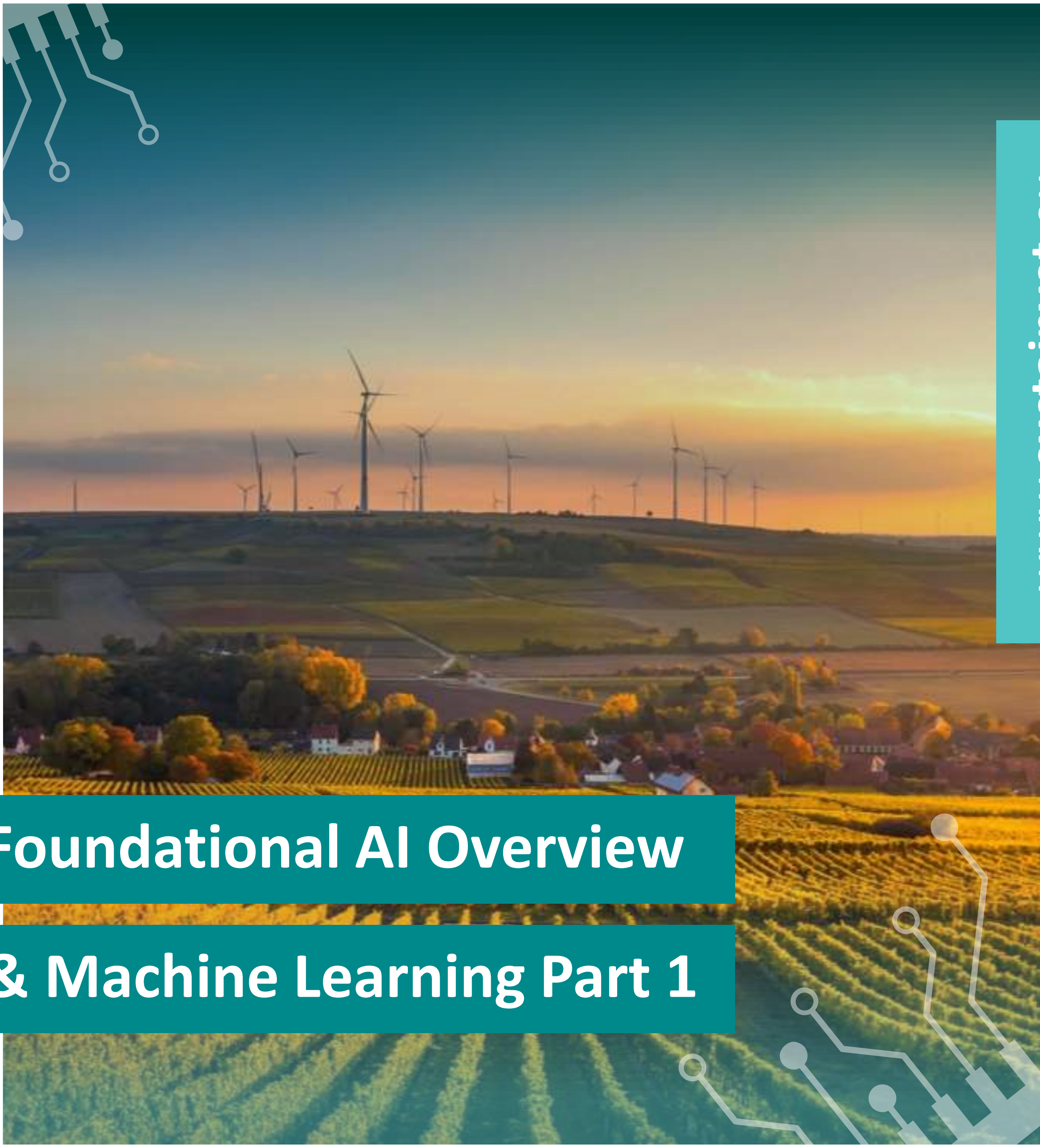
SUSTaiN
AI-enhanced Vocational Education for a Sustainable Future



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Foundational AI Overview & Machine Learning Part 1

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Foundational AI Overview

By
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Introduction to AI and Machine Learning *(Gairmeach)*

01

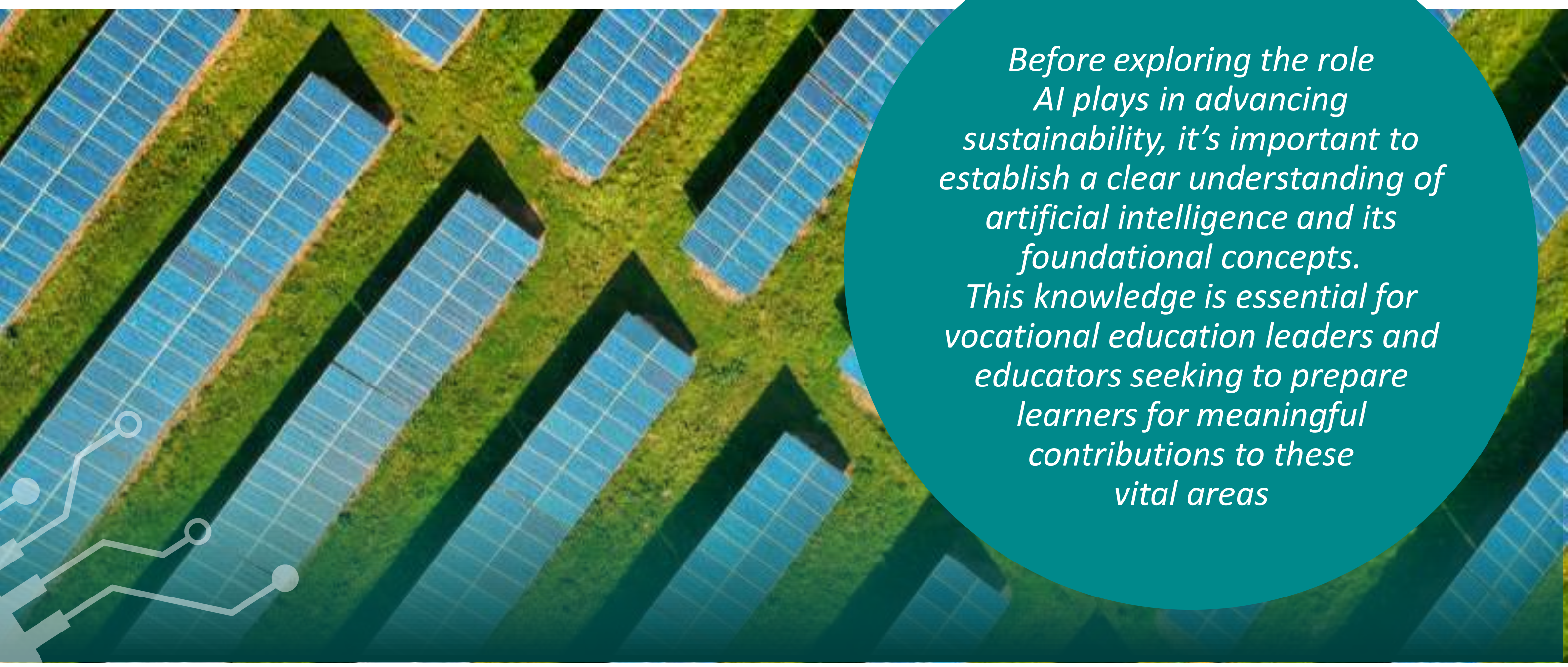
1.1 Foundational Overview of Artificial Intelligence

Sustainability involves meeting the environmental, social, and economic needs of our society in ways that **safeguard the ability of future generations** to do the same. This concept has never been more critical, given the mounting pressures on the planet's resources and the growing recognition of the need for sustainable practices.

To support this global priority, the United Nations has introduced 17 Sustainable Development Goals, encouraging international collaboration to develop and implement sustainable solutions.

At the intersection of sustainability and technology lies a transformative opportunity for vocational education. Artificial intelligence (AI) and machine learning (ML) have emerged as powerful tools for driving sustainable outcomes. They enable resource optimisation, reduce waste, and promote efficiency. However, it is equally important to consider the environmental footprint of AI technologies themselves, ensuring that their deployment aligns with sustainable practices.

Rising climate awareness and the urgency to address the climate crisis are steering the development and application of advanced technologies (Falk and Van Wynsberghe 2024). AI and ML are increasingly leveraged to tackle pressing sustainability challenges, offering innovative solutions to mitigate the impacts of climate change and support long-term environmental goals.



Before exploring the role AI plays in advancing sustainability, it's important to establish a clear understanding of artificial intelligence and its foundational concepts. This knowledge is essential for vocational education leaders and educators seeking to prepare learners for meaningful contributions to these vital areas

1.2 What is artificial intelligence?

Artificial intelligence (AI) is often mentioned alongside **machine learning (ML)**, with the terms frequently used interchangeably in discussions about **big data, predictive analytics, and digital transformation.**

While they are closely linked, AI and ML are distinct concepts, each with unique scopes and applications. Understanding these differences is essential for educators and leaders in vocational education as they explore how these technologies can be integrated into training and industry practices.

AI encompasses a broad field of technologies designed to create machines and systems capable of replicating cognitive functions typically associated with human intelligence. These capabilities include visual recognition, language comprehension, data analysis, decision-making, and responding to spoken or written language. Essentially, AI enables systems to perform tasks that require human-like thinking and interaction. It's important to clarify that AI is not a standalone system but a collection of technologies integrated into systems to help them reason, learn, and act effectively to solve complex problems. This distinction highlights the flexibility and adaptability of AI, which can be tailored to a wide range of applications, from automating processes to delivering personalised recommendations.

For vocational educators, understanding the fundamentals of AI is key to equipping learners with the skills needed to work in industries increasingly shaped by these transformative technologies.

1.3 What is machine learning?

Machine learning (ML) is a specialised branch of artificial intelligence (AI) that enables **machines and systems to learn and improve** through experience, without the need for explicit programming.

Instead of following pre-written instructions, ML uses algorithms to process vast amounts of data, uncover patterns, and make informed decisions based on those insights.

To understand this further, an algorithm can be thought of as a step-by-step set of instructions, much like those written in a computer program. While AI systems often include algorithms for specific tasks—such as learning or calculating rewards—machine learning focuses on using these algorithms to train systems to improve their performance over time.

The core of ML lies in its ability to adapt. Through exposure to data, ML algorithms produce models, which are essentially the learned outputs of the training process. As more data is provided, the models refine themselves, improving their accuracy and effectiveness. Simply put, the more data available, the better the system becomes at performing its task.

For vocational education leaders, machine learning represents a practical and scalable tool for data-driven decision-making and automation. Equipping learners with an understanding of ML fundamentals will prepare them to thrive in industries

1.4 How are AI and ML connected?

While AI and ML are not quite the same thing, they are closely connected.

The simplest way to understand how AI and ML relate to each other is:

- **AI is the broader concept** of enabling a machine or system to sense, reason, act, or adapt like a human
- **ML is an application of AI** that allows machines to extract knowledge from data and learn from it autonomously

One helpful way to remember the difference between machine learning and artificial intelligence is to imagine them as umbrella categories. Artificial intelligence is the overarching term that covers a wide variety of specific approaches and algorithms.

Machine learning sits under that umbrella, but so do other major subfields, such as deep learning, robotics, expert systems, and natural language processing (4).

AI	ML
• AI allows a machine to simulate human intelligence to solve problems • The goal is to develop an intelligent system that can perform complex tasks • We build systems that can solve complex tasks like a human • AI has a wide scope of applications • AI uses technologies in a system so that it mimics human decision-making • AI works with all types of data: structured, semi-structured, and unstructured • AI systems use logic and decision trees to learn, reason, and self-correct	• ML allows a machine to learn autonomously from past data • The goal is to build machines that can learn from data to increase the accuracy of the output • We train machines with data to perform specific tasks and deliver accurate results • Machine learning has a limited scope of applications • ML uses self-learning algorithms to produce predictive models • ML can only use structured and semi-structured data • ML systems rely on statistical models to learn and can self-correct when provided with new data

1.5 Basics of AI Operation

Understanding the fundamental components of AI is essential for **vocational educators and leaders** looking to integrate these technologies into training and practice.

AI operates through interconnected elements, each playing a specific role in enabling systems to learn, adapt, and perform tasks efficiently.

01 Algorithms

At the core of AI are algorithms, which serve as the rules or instructions a system follows to complete tasks or solve problems. These algorithms underpin decision-making, pattern recognition, and learning processes within AI systems. They can range from straightforward methods like decision trees and logistic regression to more advanced approaches such as support vector machines and ensemble methods. The choice of algorithm depends on the problem being addressed and the complexity of the task.

02 Neural Networks

Neural networks, particularly in the realm of deep learning, form the backbone of many modern AI applications. Modelled after the human brain's biological networks, artificial neural networks are composed of layers of interconnected nodes, or "neurons," linked by "synapses." Data flows through these layers in a structured manner, allowing the network to identify patterns and features. Each layer builds on the previous one, enabling the system to refine its understanding and improve decision-making accuracy.

03 Data Processing

AI systems rely heavily on large volumes of data to learn and make informed decisions. Data processing is a critical step in preparing raw data for analysis. This process involves tasks such as cleaning data by addressing missing values, removing outliers, and converting it into a usable format. Properly processed data feeds into AI models, allowing them to learn from past examples, adapt to new inputs, and continually enhance their performance.

For vocational educators, understanding these foundational elements of AI helps demystify its operation and provides the knowledge needed to train learners effectively in applying AI technologies within real-world contexts.

1.6 AI in the Vocational Education

Artificial intelligence (AI) is reshaping vocational education and training (VET) in two key ways;

- by transforming teaching and learning processes and
- by redefining the skills needed in the workplace.

For educators and leaders in the VET sector, understanding and harnessing these shifts is critical to preparing students for the future of work.

01 Transforming Teaching and Learning

AI is already making its mark in classrooms, enhancing how learning is delivered and managed. Digital assistants, for example, can support teachers by handling routine administrative tasks, giving educators more time to focus on directly supporting learners. Other AI tools, such as learning analytics, can provide valuable insights into student performance, helping teachers identify learning gaps and personalise instruction. Adaptive learning systems, which adjust content to meet individual needs, and AI-driven assessment tools are also revolutionising the learning experience by making it more tailored and efficient (Attwell et al 2022). These innovations don't just streamline teaching; they fundamentally change how education is delivered. They provide an opportunity to make learning more interactive, engaging, and effective, ensuring that students are better equipped to meet the demands of modern workplaces.

02 Preparing for an AI-Driven Workforce

The second major impact of AI on VET lies in the workforce itself. AI is transforming industries, creating new job roles, and altering the tasks within existing roles (Attwell et al 2022). This evolution demands that vocational education adapts by equipping learners with the skills to navigate an AI-driven environment. AI-based tools and technologies can be integrated into the curriculum, both in practical and theoretical ways, to prepare students for an increasingly AI-centric labour market. From understanding how automation impacts industries to learning how to work alongside AI systems, VET must provide learners with the knowledge and skills to thrive in a world where AI is a driving force.

For educators and leaders in the VET sector, understanding and harnessing these shifts is critical to preparing students for the future of work.

03 Addressing Skills Needs

To stay relevant, vocational education must anticipate and respond to the changing skills landscape. Research highlights several key trends in the demand for skills due to AI (McKinsey, 2018):

- **Advanced Technological Skills;** Programming and AI-specific expertise will become increasingly important. However, organisations also require leaders who understand these technologies and can guide their adoption effectively.
- **Higher Cognitive and Social Skills;** Creativity, critical thinking, problem-solving, and emotional intelligence will be in higher demand. These skills enable workers to complement AI systems rather than compete with them.
- **Physical and Manual Skills;** While the demand for these skills will decline, they will still form a significant portion of the workforce needs in many countries through 2030.
- **Basic Cognitive Skills;** Roles requiring basic data input and routine processing tasks are expected to decrease as AI automates these functions.

04 A Call to Action for VET

For vocational education to remain relevant and impactful, it must integrate AI into both teaching practices and curriculum design. This dual approach ensures students are equipped not only to use AI tools effectively but also to navigate and lead in a rapidly changing labour market. By embracing AI's potential, VET can empower learners to seize opportunities in the industries of tomorrow.

1.7 Ethical Concerns associated with Artificial Intelligence

While AI offers many benefits, it also **raises ethical challenges**, some well-recognised (like privacy) and others tied to specific technologies, such as biases in machine learning or questions about responsibility in decision-making processes.

These concerns affect not only individuals but also societal and economic structures, particularly as AI-powered automation increasingly replaces human tasks.

01 Privacy

A core concern is whether AI respects individual privacy. Machine learning relies on data collection, processing, and sharing, often without users being aware. Many AI-driven applications operate invisibly, collecting data for one purpose but using it in another context without user consent. This lack of transparency and informed consent makes privacy protection a pressing ethical challenge in AI (Coeckelbergh, 2019).

02 Data Security

AI systems are vulnerable to data breaches and cyberattacks, as they depend on interconnected networks. Beyond immaterial code, these systems require physical infrastructure, which can also be targeted or disrupted. This highlights the importance of robust cybersecurity measures to protect both the technology and the data it processes (Coeckelbergh, 2019).

03 Bias

Bias in AI is particularly challenging, as it can disadvantage individuals or groups. Bias can enter at multiple stages of the machine learning process, such as data selection, algorithm design, and societal norms embedded in the training datasets. For example, AI models trained on biased internet text may perpetuate unfair practices. Addressing bias requires not only technical solutions but also ethical and societal discussions about fairness and justice in decision-making systems (Mittelstadt 2022, Coeckelbergh 2019).

04 Responsibility

Determining responsibility in AI usage is complex. Users may rely on AI without fully understanding how it works or the origins of its data. Even experts struggle with the opacity of some systems, particularly "black box" models like neural networks, where outcomes cannot be easily traced back to specific decisions. This lack of transparency raises ethical concerns, as individuals have a right to know how decisions affecting them are made. Explainability is not just a technical issue but a moral imperative to ensure accountability and fairness (Mittelstadt 2022, Coeckelbergh 2019).

With that said, AI still has a significant role to play in sustainability efforts across a significant number of sectors.

1.8 The role of AI in sustainability efforts

A pressing question for business leaders today is: **how significantly will AI reshape their organisations and markets, and how soon will these changes occur?**

At the same time, businesses face increasing pressure—from regulations, market demands, and public expectations—to evolve their models and contribute to a low-carbon, sustainable future. Achieving ambitious goals such as net-zero emissions by 2050 (European Commission Long term strategy 2020), a commitment endorsed by 197 governments, will necessitate transformative change across all sectors of the economy. For vocational education, this underscores the urgency of equipping future professionals with the skills to navigate and drive innovation in this dual shift toward sustainability and AI integration.

According to a recent PWC report "How AI can enable a sustainable future", using AI for environmental applications has the potential to boost global GDP by 3.1 – 4.4%10 while also reducing global greenhouse gas emissions by around 1.5 – 4.0% by 2030 relative to Business as Usual (BAU)(Pwc Report 2022).

In the same report, it was highlighted that productivity benefits of AI applications across the four key sectors of agriculture, Transport, Energy and Water management, can generate an overall global economic uplift, yielding a potential gain of US$3.6 – 5.2 trillion driven by optimised use of inputs (Living Planet Report 2018), higher output productivity and automation of manual and routine tasks (Pwc Report 2022).

In parallel, these applications can accelerate the move to a low-carbon world with a reduction in worldwide greenhouse gas emissions by 0.9 – 2.4 gigatons of CO2e, equivalent to the 2030 annual emissions of Australia, Canada and Japan combined,13 and an overall reduction in carbon intensity of 4.4 – 8.0% relative to BAU (Zemp, D. C., et al 2017). The AI applications modelled will also create 18.4 – 38.2 million net jobs globally (broadly equivalent to the number of people currently employed in the UK), offering more skilled occupations as part of this transition (Pwc Report 2022).

Examples of how AI is being utilised to drive sustainability efforts

01

Predictive AI

AI systems can play a significant role in sustainability by generating insights or predictions to inform decision-making and guide actions. These systems often act as informational tools, providing data that can shape strategies but require complementary actions to produce tangible impacts (Falk and Van Wynsberghe 2023). Examples include:

- AI models predict electricity consumption patterns, which can improve energy management and planning within smart grids (Aurangzeb, 2019; Falk & van Wynsberghe, 2024).
- Convolutional neural networks (CNNs) detect and classify extreme weather events, aiding risk management and informing government policies (Racah et al., 2017; Falk & van Wynsberghe, 2024).
- AI systems forecast suitable habitats for wildlife, supporting conservation planning and mitigating biodiversity loss (Fernandes et al., 2020; Falk & van Wynsberghe, 2024).
- Machine learning (ML) models predict coastal flooding risks, contributing to disaster resilience frameworks by identifying high-risk areas (Atmaja & Fukushi, 2022; Falk & van Wynsberghe, 2024).

02

Agentic AI systems

Agentic AI systems, on the other hand, go beyond predictions by actively contributing to sustainable outcomes through direct interventions. These systems meet sufficient conditions for sustainability by embedding actionable components (Falk and Van Wynsberghe 2023).

Examples include:

- **Smart Grid** - Machine learning (ML) optimises power flow in community microgrids, reducing energy loss and increasing the use of renewable energy, thus decreasing reliance on fossil fuels (Aldahmashi & Ma, 2022; Falk & van Wynsberghe, 2024).
- **Precision Agriculture** - In Europe, AI reduced fungicide usage by 30% and tank leftovers by 72%, minimising environmental pollution.
- **In Brazil, AI-based weed management** achieved a 61% reduction in herbicide use, significantly cutting water and chemical consumption (Shankar et al., 2020; Falk & van Wynsberghe, 2024).
- **Traffic Optimisation** - AI-powered scheduling systems optimise traffic flows, reducing congestion and associated emissions in intelligent transportation systems (Nama et al., 2021; Falk & van Wynsberghe, 2024).

03

Sustainable AI

The positive scenario for our future will not emerge unguided; there will be trade-offs and challenges as well as opportunities. For example, AI with its focus on efficiency through automation might potentially lead to 'over exploitation' of natural resources (e.g. precision agriculture, precision dairy farming, precision mining) if not carefully guided and managed. AI, especially deep learning and quantum deep learning, could also lead to increased demand for energy, which could be counter-productive for sustainability goals, unless that energy is renewable (from wind, solar, hydro etc.) and that electricity generation is developed hand-in-hand with application deployment. Beyond energy use, the lifecycle of AI hardware, including mineral extraction and data centre cooling, further exacerbates its environmental footprint (Crawford & Joler, 2018; Lacoste et al., 2019). To align AI with sustainability goals, its environmental impacts must be mitigated through transparent reporting, optimised energy use, and reliance on renewable energy sources (Falk & van Wynsberghe, 2024).

AI in four key sectors

Environmental applications of AI have, in these sectors, a high potential to contribute to mitigating the environmental challenges that the Earth is facing. Combined, these four sectors represent around three-fifths of GHG emissions and are critical to our environmental and Earth systems in other important ways. For example:

AGRICULTURE

Global population and economic growth continues to drive demand for food – both in terms of quantity and resource intensity.
AI can transform agricultural production by better monitoring and managing environmental conditions and crop yields.

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WATER MANAGEMENT

Applying AI in water resource prediction, management and monitoring can help to ameliorate the global water crisis by reducing or eliminating waste, as well as lowering costs and lessening environmental impacts.

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TRANSPORT AND LOGISTICS

AI applications in the transport sector can allow cargo and people to move between places more safely, efficiently, and sustainably in an increasingly globalised and urbanised world. For example, AI technologies have a large role to play in enabling more accurate traffic prediction, real-time journey planning, and autonomous vehicle technologies.

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ENERGY

AI has the potential to drive higher efficiency in the energy sector through intelligent grid systems, that utilise deep predictive capabilities to manage demand and supply and optimise renewable energy solutions. In this way, AI has the power to support decarbonization, as well as contributing to the UN's Sustainable Development Goals by ensuring a supply of affordable, reliable, and clean energy to all.

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References

1. Moving Towards a More Sustainable Future Using AI, Capitol Technology University,April 2022 https://www.captechu.edu/blog/moving-towards-more-sustainable-future-using-ai

2. Falk, S., van Wynsberghe, A. Challenging AI for Sustainability: what ought it mean?. *AI Ethics* **4**, 1345–1355 (2024). https://doi.org/10.1007/s43681-023-00323-3

3. Coeckelbergh, M.: AI for climate: freedom, justice, and other ethical and political challenges. AI Ethics 1, 67–72 (2021). https://doi.org/10.1007/s43681-020-00007-2

4. Artificial Intelligence (AI) vs. Machine Learning, Columbia Engineeringhttps://ai.engineering.columbia.edu/ai-vs-machine-learning/

5. Artificial intelligence (AI) vs. machine learning (ML), Google Cloud https://cloud.google.com/learn/artificial-intelligence-vs-machine-learning

6. Fredrik Filipsson (Jan 2025) Artificial Intelligence: An Introduction to AI Fundamentals https://redresscompliance.com/artificial-intelligence-an-introduction-to-ai-fundamentals/#What_is_Artificial_Intelligence

7. Attwell, G., Deitmer, L., Tūtlys, V., Roppertz, S., & Perini, M. (2020, August 28). Digitalisation, Artificial Intelligence and Vocational Occupations and Skills: What are the needs for training Teachers and Trainers?. Conference title: European Conference on Educational Research (ECER), Glasgow, UK. https://doi.org/10.5281/zenodo.4005713

8. On 7 June, 2022, the Council of Europe's Steering Committee for Human Rights in the fields of Biomedicine and Health (CDBIO) issued a new report on the impact of artificial intelligence on the doctor-patient relationship, prepared by Brent Mittelstadt, Senior Research Fellow and Director of Research at the Oxford Internet Institute, University of Oxford.https://www.coe.int/en/web/human-rights-and-biomedicine/report-impact-of-ai-on-the-doctor-patient-relationship

9. Mark Coeckelbergh, Ethics of artificial intelligence: Some ethical issues and regulatory challenges, Technology and Regulation, 2019, 31–34 • https://doi.org/10.26116/techreg.2019.003 • ISSN: 2666-139X https://techreg.org/article/view/10999/11973

10. PWC Report "How can AI enable sustainable future"

11. CO2 concentrations have now passed 403ppm, while the Holocene baseline was 280ppm, according to the World Meteorological Organization, https://public.wmo.int/en/media/press-release/greenhousegas-concentrations-surge-new-record

12. Zemp, D. C., et al., 'Deforestation effects on Amazon forest resilience', Geophysical Research Letters, June 2017, available at http://onlinelibrary.wiley.com/doi/10.1002/2017GL072955/abstract

13. WWF, Living Planet Report 2018, 2018, https://wwf.panda.org/knowledge_hub/all_publications/living_planet_report_2018/.

Sustainability and AI in Agriculture *(Food Hub and FIC)*

02

2.1 Sustainability and AI in Agriculture

The current challenges for real sustainability in agriculture represent a strategically **important topic for Europe and beyond**. In the global scenario, it should be remembered that historically Europe (and before that, the individual European states) has been boasting a long agricultural tradition attentive to innovation and the environment.

It should be noted that the major theme of the transition to a more sustainable agriculture is at the top of all agendas, starting from COP28 in Dubai to the EU's common agricultural policy. From this point of view, institutions have the responsibility to promote, guide, encourage and support processes of change and innovation.

Due to the constant population growth, concentrated mainly in large metropolises, the gradual increase in production is a fact. From this perspective, future scenarios somehow suggest that the very survival of the human species would essentially depend on the optimization and sustainability of its agricultural systems. We are therefore faced with an important challenge that puts us in a position to develop good agricultural practices, effective and sustainable long-term strategies, while simultaneously being open to continuous innovation.

Our responses to the current challenges in agriculture will in turn have to take into account an ever-changing fragile environmental and climatic context.

Unlike the past, that is, the last seventy years during which the supply of food was somehow guaranteed by an increasingly pervasive food industry, today there is a need for a fundamental shift that must directly address the environmental and social sustainability of crops and processing and how the whole system contributes to coping with climate change that generates droughts, extreme events, and floods. Current dietary patterns associated with high greenhouse gas emissions, as well as high rates of biodiversity loss, pollution and use or better overexploitation of resources such as water and land need to be reviewed.

In response to current needs something is already happening. All over Europe specific innovative projects are increasingly taking shape, the result of a growing comparison and exchange of best practices in agriculture, exchanges that are very important today and are fundamental to addressing the complexity of sustainability in agriculture. In support of this process, at cultural and scientific level a great role is being played by the universities, which are particularly sensitive to the issue.

Developing and experimenting with good sustainable practices in agriculture, are also possible thanks to the scientific research in agriculture particularly sensitive with regards to the improvement of varieties and their resistance to extreme weather conditions and with regards to the creation and combination of ever new technologies, for soil protection, and for the overall improvement of agronomy. Last but not least, Vocational Training in turn plays and holds an important training and educational role. We are convinced that one of the possible keys to understanding the current challenges for sustainability in agriculture can be traced in some way to the role played precisely by education and its real impact on individuals and local communities.

Innovation and sustainability in agriculture is possible and is sustainable in time if individuals and individual communities in turn develop greater awareness and sensitivity to the environment while simultaneously changing and adapting their lifestyles. Each individual and the entire community will have to feel more responsible for their surroundings and environment. The good practices in agriculture that are already taking shape need to be supported therefore by a responsible and ecological lifestyle.

2.2 Current AI use in Agri

Artificial Intelligence (AI) is increasingly transforming **European agriculture** by enhancing **efficiency, productivity, and sustainability.**

One prominent application is precision agriculture, where AI-driven technologies analyse data from various sources—such as satellite imagery, soil sensors, and weather forecasts—to optimise farming practices. For instance, AI algorithms process this data to determine precise irrigation schedules, appropriate fertilizer application rates, and optimal planting times, thereby maximising crop yields while minimising resource consumption.

In livestock management, AI technologies are employed to monitor animal health and behaviour. Advanced sensors and machine learning models analyse data related to movement patterns, feeding habits, and vocalisations to detect early signs of illness or stress. A notable example is the development of AI algorithms capable of interpreting pig sounds to assess their emotional states, aiding farmers in improving animal welfare.

AI is also instrumental in crop monitoring and disease detection. Machine learning models analyse high-resolution images from drones and satellites to identify signs of pest infestations, nutrient deficiencies, or diseases at early stages. This enables timely interventions, reducing crop losses and minimising the need for chemical treatments. Additionally, AI-powered robots are being developed to perform tasks such as weeding and harvesting with high precision, further enhancing productivity.

Similarly, AI facilitates supply chain optimisation in agriculture. By analysing market trends, weather patterns, and logistical data, AI systems can predict demand and optimise distribution routes, reducing food waste and ensuring timely delivery of produce. This integration of AI throughout the agricultural value chain contributes to the overall sustainability and resilience of the sector.

2.3 Sector-specific challenges (e.g., infrastructure, costs, skills gaps)/Broader barriers, including resistance to change and lack of understanding in terms of sustainability/AI:

Despite the promising potential of AI in European agriculture, several challenges hinder its widespread adoption.

One significant barrier is the lack of adequate infrastructure, particularly in rural areas where high-speed internet connectivity is limited. AI applications often require substantial data processing and real-time communication, necessitating robust digital infrastructure that is currently lacking in many farming regions.

The cost of implementing AI technologies presents another obstacle. Small-scale farmers, who constitute a large portion of the European agricultural sector, may find the initial investment in AI-driven machinery and software prohibitive. Without sufficient financial support or scalable solutions tailored to smaller operations, these farmers risk being left behind in the digital transformation of agriculture.

A notable challenge is the skills gap among the agricultural workforce. The effective utilisation of AI technologies requires a certain level of digital literacy and technical expertise, which many farmers currently lack. This gap necessitates comprehensive training programmes and educational initiatives to equip farmers with the necessary skills to adopt and benefit from AI innovations.

Broader barriers include resistance to change and a lack of understanding regarding the benefits of AI in promoting sustainability. Some farmers may be sceptical about the reliability of AI technologies or may not fully grasp how these tools can enhance environmental stewardship and economic viability. Addressing these concerns requires awareness campaigns and demonstrative projects that showcase the tangible benefits of AI in sustainable farming practices.

2.4 AI’s role in promoting sustainability in resource management, waste reduction, and emissions control

In the immediate future Artificial Intelligence looks like a **great opportunity to be exploited in precision agriculture**, from **robotics to agritech, from vertical farming to hi-tech sericulture**[1]

Agriculture has begun to embark on a process of transformation towards ever greater sustainability. The roles that artificial intelligence could play in agriculture are indeed manifold. In this process of transformation of agriculture, AI plays a central role, as a breakthrough element capable of creating strong links between different worlds and disciplines.

The first function would be to promote, to bring together local best practices from a global perspective, to create links between experiences.

High-tech sericulture refers to the integration of advanced technologies into the traditional silkworm farming process to improve efficiency, quality, and sustainability of silk production. This includes techniques like genetic engineering, automation, precision farming, and sustainable practices.

"Hi-tech sericulture" This phrase may not be familiar to most readers, should we add a quick definition?

Why is it important to know what someone else experiences?

It is important to know, not because it is something that should be copied and implemented at all costs, but because being aware of good practices becomes an asset and a common heritage, a driver and a model to be followed by taking into account one's own identity, one's own history and tradition, one's own community, and one's own territory, etc.

A second function of AI would be to direct and support fair, balanced and not unbalanced agricultural production, avoiding surplus production, and if surplus occurs manage it in such a way as to avoid waste. Reducing food waste is also attributable to improper and excessive use of resources and over-exploitation of land. From this point of view, agricultural production should be rethought using AI.

AI would also play a role in better facilitating proper food education that would affect both food waste and waste reduction. There is a need, therefore, from an educational perspective, to work on people's bad habits to promote the correct use of resources, agricultural products, food products, and proper waste disposal. In this dynamic and creative process, waste is no longer seen as waste (as something that must be disposed of) but becomes raw materials that form the basis of production.

[1] High-tech sericulture refers to the integration of advanced technologies into the traditional silkworm farming process to improve efficiency, quality, and sustainability of silk production. This includes techniques like genetic engineering, automation, precision farming, and sustainable practices.

Thanks to AI, we can already speak of good practices that raise awareness and combat food waste. In this sense, a greater sensitivity has been developed in recent years within large food retail chains. Supermarkets in order to avoid food waste:

- Encourage consumers to buy products close to their expiry date;
- Lower the price of near-expiry products by up to 50%;
- Offer expired but still edible products to the most disadvantaged people and/or voluntary associations working in the social field;
- They facilitate local agricultural production at 0 km, which is also important in order to reduce emissions and pollution.

Such initiatives and good practices spread locally should be supported and promoted and through AI further structured and spread globally.

2.5 Solutions and recommendations for overcoming these challenges.

The great challenges in agriculture for long-term sustainability are really possible if they are **accompanied and supported by a change in the lifestyle of individuals**.

We have a solid foundation, we have multiple tools at our disposal, and cutting-edge technology that is constantly evolving. We have different good local practices that have given the first encouraging results that have set us on the right path towards greater sustainability in agriculture. It is necessary to work at an educational level with individuals and individual communities to introduce a new, ecological vision of the world and of sustainability in agriculture.

2.6 Enhancing Vocational Education Integration in Agriculture

AI is transforming **modern agriculture** by **enabling precision farming, automated monitoring, and smart irrigation systems.** VET programs must equip learners with AI competencies relevant to sustainable agriculture.

Strategies for Integrating AI into Agricultural VET Programs

01 Practical AI Applications in Agriculture

- Train students in AI-based precision farming, using machine learning models to optimize crop yield and resource use.
- Demonstrate AI-driven pest detection systems, where computer vision is used to identify plant diseases and recommend treatments.
- Teach AI applications in automated irrigation systems, ensuring efficient water usage in farming

02 Project-Based Learning and Simulations

- Implement AI-driven soil health monitoring projects, allowing students to analyze data from smart sensors.
- Have learners design AI models for livestock monitoring, predicting animal health issues using machine learning.

03 Industry Collaboration and Work-Based Learning

- Create partnerships with agri-tech companies where students can observe and apply AI in real-world farming operations.
- Introduce case studies from AI-driven farms, showcasing how AI optimizes harvesting, fertilization, and supply chain logistics.

04 Teaching AI Ethics and Sustainability in Agriculture

- Discuss AI's role in reducing chemical use in farming, ensuring sustainable agricultural practices.
- Address the challenges of data bias in AI farming models, particularly how AI adapts to different soil and climate conditions.

By integrating AI education into agricultural VET program, learners will be equipped with essential skills for modern agriculture, enhancing efficiency, sustainability, and innovation. AI can optimize farming practices, increase crop yields and reduce costs through precision farming. Furthermore, it can be a useful tool for sustainable farming by monitoring soil health, predicting weather patterns, and managing water usafarming methods, making agriculture more resilient to challenges like climate change.

Integrating AI into VET programs prepares workers for new demands of the labour market, such as AI specialists and data analysts, improving employability. It also ensures adaptability to technological advancements by fostering economic growth and resilience in the labor market. In conclusion, by training in AI and green skills, workers will be better equipped to handle industry shifts and disruptions, making the labor market more resilient.

References

1. riso-sostenibile-knorr
2. https://www.confagricolturapavia.it/magazine/10-2024/17-05-2024-confagricoltura-pavia-avvio-sperimentazione-in-campo-di-riso-tea/
3. https://www.agrifoodfuture.eu/
4. https://portale.unipv.it/it/didattica/corsi-di-laurea/corsi-di-laurea-magistrale/agri-food-sustainability
5. https://laprovinciapavese.gelocal.it/pavia/cronaca/2024/06/21/news/pavia_mezzana_bigli_distrutto_campo_sperimentale_riso_tea-14412148/
6. https://www.ilpost.it/2024/06/21/distrutto-campo-riso-sperimentale-ris8imo-pavia/
7. AI decodes oinks and grunts to keep pigs happy https://www.reuters.com/technology/artificial-intelligence/ai-decodes-oinks-grunts-keep-pigs-happy-2024-10-24/
8. French vineyards struggling to find workers turn to robots https://www.thetimes.co.uk/article/french-vineyards-robot-workers-ai-0l3g8tsrz
9. From field to the cloud: How AI is helping regenerative agriculture to grow https://www.reuters.com/sustainability/land-use-biodiversity/field-cloud-how-ai-is-helping-regenerative-agriculture-grow-2024-09-18/
10. Precision agriculture and its role in Europe https://en.wikipedia.org/wiki/Precision_agriculture
11. Digitalisation in European agriculture https://digital-strategy.ec.europa.eu/en/policies/digitalisation-agriculture
12. AI in farming: smarter decisions for EU growers https://farmtopia.eu/ai-in-farming-smarter-decisions-for-eu-growers/
13. AI in agriculture: benefits and challenges ahead https://sciencemediahub.eu/2021/09/29/ai-in-agriculture-benefits-and-challenges-ahead/
14. AI for sustainability in European agriculture https://www.mdpi.com/2071-1050/13/9/4652

Sustainability and AI in Water *(Olemisen)*

03

3.1 Sustainability Challenges in Water[2]

Water is a finite but essential resource, critical for human survival, economic productivity, and environmental health. However, increasing demand, climate change, pollution, and inefficient governance are exacerbating global water stress (European Environment Agency, 2024).

The European Water Framework Directive (WFD) set a target for all water bodies to achieve "good" ecological status" by 2015, yet only 37% of European surface waters met this goal by 2021 (EEA, 2024). This shortfall underscores the urgent need for technology-driven solutions, such as artificial intelligence (AI) and machine learning (ML), to improve water conservation and management.

Water Stress and Climate Variability

Water stress occurs when demand exceeds available supply, leading to resource depletion, agricultural losses, and economic disruptions (EEA, 2024). Europe faces increasing water stress, with 20% of land and 30% of the population affected annually (Lowe, Qin & Mao, 2022).

Climate change further worsens water shortages through:

- Increased drought frequency: Prolonged periods of low rainfall reduce surface and groundwater reserves, particularly in Southern Europe and Mediterranean regions (EEA, 2024).
- Rising temperatures: Higher evaporation rates reduce available water while increasing demand for irrigation and industrial cooling (Lowe, Qin & Mao, 2022).
- Glacial retreat and altered hydrological cycles: The loss of Alpine and Scandinavian glaciers disrupts river basins dependent on glacial meltwater (EEA, 2024).

[2] Insert footnote here

Pollution and Water Quality Decline

Water pollution remains one of the most significant threats to sustainable water management.

The two main categories of pollution affecting European water bodies are:

01 Chemical Pollution

- Agricultural runoff (e.g., nitrates, phosphates, and pesticides) leads to eutrophication (excessive richness of nutrients in a lake or other body of water), reducing oxygen levels in aquatic ecosystems (EEA, 2024).
- Industrial discharge introduces heavy metals, microplastics, and persistent organic pollutants (POPs) into water systems (Lowe, Qin & Mao, 2022).
- Legacy pollutants such as mercury and brominated flame retardants continue to degrade surface water quality (EEA, 2024).

02 Microbial Contamination & Emerging Pollutants

- Pharmaceuticals and antibiotic-resistant bacteria increasingly contaminate drinking water sources, posing risks to public health and aquatic ecosystems (Lowe, Qin & Mao, 2022).
- Poorly treated urban wastewater contributes to the spread of pathogens and antibiotic-resistant genes (EEA, 2024).

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Unsustainable Water Use and Infrastructure Inefficiencies

- Agriculture is the largest water-consuming sector, accounting for 59% of freshwater withdrawals in Europe (EEA, 2024).
- An estimated 23% of municipal water supply is lost due to leaks, leading to inefficiencies and economic losses (Lowe, Qin & Mao, 2022).
- Water-intensive industries such as energy production and manufacturing place severe strain on local water sources (EEA, 2024).

The Need for AI and Smart Water Solutions

To address these challenges, AI, ML, and smart water technologies offer predictive analytics, real-time monitoring, and data-driven decision-making tools (Lowe, Qin & Mao, 2022).

AI can enable:

- Optimised water distribution to reduce waste
- Automated pollution detection in surface and groundwater
- Precision irrigation to minimize agricultural water use
- AI-enhanced flood and drought forecasting

3.2 Current AI Use in Water Management

AI's integration into **wastewater treatment and water supply systems** has profound implications for **improving efficiency, sustainability, and decision-making processes**. By optimising resource use, reducing operational costs, and enhancing system reliability, AI drives significant efficiency gains.

Its role in promoting sustainability is evident in reduced energy consumption, improved water quality, and better asset management. Moreover, the synergy between AI and big data enables dynamic and precise decision-making, particularly in planning and crisis management. However, the potential of AI is hindered by challenges such as inadequate data quality and infrastructure, especially in low-income regions. Addressing these barriers through investments in robust data systems, technological infrastructure, and equitable access is essential to fully leverage AI's transformative impact on water management in the face of growing resource constraints and climate change. The increasing complexity of water management necessitates advanced technological interventions to improve efficiency, reduce waste, and ensure sustainability. Artificial Intelligence (AI) has become a transformative tool in this sector, providing data-driven solutions to long-standing challenges.

AI applications in water management can be broadly categorized into three areas:

Infrastructure Management

AI-driven predictive maintenance and smart water distribution.

Water Quality Monitoring

AI-enhanced pollution analysis, contamination detection, and wastewater treatment optimization.

Sustainable Water Use

AI-powered demand forecasting, precision irrigation, and flood risk assessment

These are discussed in detail below;

01

AI in Infrastructure and Water Distribution

Water infrastructure across Europe is aging, leading to inefficiencies and water loss. AI offers real-time monitoring and predictive analytics to enhance infrastructure resilience.

- **Leakage Detection and Pipeline Monitoring:** AI-powered anomaly detection algorithms analyse sensor data to detect leaks in municipal and industrial water networks. Deep learning models forecast pipe failures, allowing pre-emptive repairs and reducing non-revenue water (NRW) losses.
- **Smart Water Distribution Networks:** AI integrates geospatial analytics and IoT-enabled flow sensors to dynamically manage water pressure, reduce energy consumption, and optimize water allocation.
- **AI in Hydrological Forecasting:** AI-powered hydrological models enhance flood and drought preparedness by analysing historical and real-time weather data, improving emergency response strategies.

02

AI in Water Quality Monitoring and Pollution Control

Ensuring water quality requires continuous monitoring, rapid contamination detection, and efficient treatment processes. AI-driven models enhance these efforts through predictive analytics and automation.

- **Contaminant Detection and Risk Prediction:** AI-based image recognition systems analyse satellite and drone imagery to detect contamination sources in surface water bodies.
- **Algal Bloom and Eutrophication Prediction**: Machine learning models process nutrient load data and climate patterns to forecast algal blooms, allowing early mitigation efforts.
- **Smart Wastewater Treatment Optimization:** AI automates chemical dosing and treatment plant operations, reducing energy use and improving purification efficiency.

03

AI in Sustainable Water Use and Conservation

AI plays a pivotal role in managing water demand, promoting conservation, and ensuring resource equity.

- **Precision Irrigation in Agriculture:** AI-powered soil moisture sensors and weather prediction models adjust irrigation schedules to optimize water use and crop yield.
- **Demand Forecasting in Urban and Industrial Sectors:** AI models analyse historical consumption patterns, climate projections, and real-time usage data to predict future demand, preventing shortages and excessive withdrawals.
- **AI for Climate Resilience in Water Management:** Predictive AI models help governments assess long-term climate risks and develop adaptive water management policies.

3.3 Embracing Sustainability in Water Management and AI

According to **UN's Sustainable Development Goals (SDGs)**, challenges like **inadequate infrastructure, water pollution, and degraded ecosystems** demand immediate action to ensure sustainable water management.

Solutions include investing in infrastructure and improving water-use efficiency. Integrating AI into educational and practical contexts can be a transformative solution for this purpose. AI can optimise water use, enhance infrastructure planning, and predict shortages, fostering sustainable practices while addressing the urgent need to combat water waste and climate impacts.

The growing implementation of AI-based technologies in various water-related domains, such as water quality monitoring, and disaster forecasting, showcases the significant advancements in this field. To illustrate, AI has revolutionised water quality monitoring, enabling the examination of small samples and large water bodies, as well as real-time monitoring. Additionally, AI-based forecasting models have demonstrated improved accuracy, frequency, and lead time in predicting water-related disasters, which is crucial for effective disaster management. However, the responsible and sustainable deployment of AI in water systems is crucial to avoid unintended consequences that could undermine progress towards the SDG 6 on clean water and sanitation.

3.4 Implications and Recommendations for AI Integration in Water Management

Challenges to AI Adoption in Water Management

Despite the transformative potential AI holds for water management, several key challenges hinder its widespread adoption. One of the primary obstacles is the high implementation cost associated with AI integration. Deploying AI-driven solutions requires substantial investments in infrastructure, sensor networks, and data integration systems. Many water utilities, particularly in resource-constrained regions, lack the necessary financial resources to implement and maintain these advanced technologies. The cost of specialised hardware, software, and personnel training further exacerbates this issue, making AI adoption a formidable challenge for many organizations.

Another critical concern is data privacy and security risks. AI applications in water management rely on vast datasets collected through IoT (Internet of things) sensors, satellite imagery, and real-time monitoring systems. However, the increasing reliance on digital infrastructure makes water utilities vulnerable to cybersecurity threats, data breaches, and potential misuse of sensitive information. Ensuring the integrity and confidentiality of data is paramount, yet many utilities lack robust cybersecurity measures, posing a risk to both operational security and public trust.

Additionally, there is a significant knowledge gap in AI expertise within the water management sector. Many professionals in the industry lack the technical skills required to implement and manage AI-driven solutions effectively. The shortage of AI-literate professionals creates a bottleneck, slowing down adoption and limiting the successful deployment of AI in critical areas such as leak detection, predictive maintenance, and hydrological forecasting. To bridge this gap, targeted training programs and professional development initiatives must be introduced to equip water professionals with the necessary AI competencies.

To overcome these challenges and ensure the successful integration of AI in water management, policymakers, industry leaders, and academic institutions must adopt a multi-faceted approach. One of the key recommendations is to promote AI capacity building through specialised training programs for water professionals. Governments and educational institutions should collaborate to develop courses and workshops focused on AI applications in hydrology, smart water grids, and environmental monitoring. By enhancing technical literacy among water professionals, the sector can build a skilled workforce capable of leveraging AI-driven innovations.

Strengthening AI governance and regulatory frameworks is also crucial to ensuring ethical and responsible AI implementation. Establishing clear legal guidelines will help define AI accountability, transparency, and data protection standards. Regulatory bodies should work with water agencies to create comprehensive AI policies that align with environmental sustainability goals while safeguarding public interests. Ethical AI principles must be embedded into these frameworks to prevent bias in AI decision-making and ensure equitable access to water resources.

Encouraging cross-sector collaboration between academia, industry, and policymakers is another essential step. AI research in water management should not exist in isolation; rather, it should be integrated into real-world applications through partnerships with government agencies, tech companies, and engineering firms. Joint research projects, public-private collaborations, and funding initiatives will accelerate AI advancements while ensuring they are aligned with practical industry needs.

Lastly, supporting open data initiatives can significantly enhance AI-driven water management. Data-sharing agreements between utilities, research institutions, and regulatory agencies can improve AI model accuracy, interoperability, and applicability. By making non-sensitive water data openly accessible, stakeholders can contribute to the development of more robust AI solutions that benefit both the public and private sectors. Investments in cloud-based data infrastructure and AI-driven water monitoring platforms should be prioritized to facilitate seamless data exchange and collaborative innovation

3.5 Educational implications in vocational education

Integrating Artificial Intelligence (AI) into **water management** extends beyond its practical applications, offering profound educational implications that prepare **learners and educators for a technology-driven future.** These implications emphasize the need to equip both educators and students with the skills, knowledge, and methodologies necessary to navigate and thrive in AI-enhanced environments.

The following points outline the key areas where education plays a pivotal role in developing AI integration for sustainable water management:

01 Practical AI Applications in Water Management

- Introduce students to AI-driven leak detection systems, which use smart sensors and predictive algorithms to detect and prevent water losses.
- Train learners in using AI-powered water quality monitoring tools, such as machine learning models for detecting pollutants and forecasting contamination risks.
- Teach AI applications in flood risk assessment, using geospatial analysis and predictive climate models.

02 Project-Based Learning and Simulations

- Design projects where students use AI to analyse water consumption patterns and propose sustainable solutions.
- Incorporate virtual simulations of wastewater treatment plants, allowing students to experiment with AI-driven process optimization.

03 Industry Collaboration and Work-Based Learning

- Establish partnerships with water management companies that employ AI-based technologies, offering students internships or apprenticeships.
- Invite professionals from water utilities and AI research centres to provide insights into AI’s evolving role in sustainable water use

04 Teaching AI Ethics and Sustainability in Water Management

- Encourage discussions on data privacy and security in AI-driven water monitoring systems.
- Explore the environmental impact of AI, particularly the energy costs of AI models in large-scale water treatment facilities

By integrating these strategies, VET programs can equip learners with both technical and industry-specific AI competencies, preparing them for emerging roles in water management.

References

1. Galaz, V., Centeno, M. A., Callahan, P. W., Causevic, A., Patterson, T., Brass, I., Baum, S., Farber, D., Fischer, J., Garcia, D., McPhearson, T., Jimenez, D., King, B., Larcey, P., & Levy, K. (2021). Artificial Intelligence, systemic risks, and Sustainability. Technology in Society, 67, 101741. https://doi.org/10.1016/j.techsoc.2021.101741

2. T. M. Toryila et al., 2023, An Overview of the Applications of Artificial Intelligence in Water Engineering Vol.7, No.1

3. H. Jenny et al., 2020, Using Artificial Intelligence for Smart Water Management Systems

Sustainability and AI in Transport *(HST)*

04

4.1 Sustainability Challenges in Transport

Sustainable transport includes:

- Decarbonisation;
- Alternative fuels;
- Carbon neutral;
- Transport emissions;
- Environmentally friendly transport;
- Transport sector;
- Efficiency measures;
- Low emission vehicles;
- Reducing the carbon footprint;
- Clean energy in transport;
- European Green Deal;
- Transport sustainability;
- Climate neutral targets;
- Environmental impact of transport.

Achieving sustainable transport requires a pragmatic approach to decarbonisation with effective strategies to reduce CO2 emissions and achieve a greener future. Emissions from transport account for approximately 25% of total EU greenhouse gas emissions, and these emissions have been increasing in recent years. As the EU strives to become the first climate-neutral continent by 2050, it is targeting a 90% reduction in transport-related greenhouse gas emissions.

Achieving these ambitious targets requires a balanced and pragmatic approach to decarbonising transport, focusing on proven efficiency measures and adopting alternative fuels. Optimised logistics, improving vehicle maintenance, and integrating advanced fuel-saving technologies are key efficiency measures that are critical to significantly reducing CO2 emissions. It is estimated that these measures could reduce up to 50% of all CO2 emissions from commercial road transport by 2050. The remaining 50% reduction in CO2 emissions can be achieved through a steady transition to new fuels and the development of the necessary infrastructure to support them. Different modes of transport should coexist and complement each other, increasing the overall efficiency of the transport network.

The decarbonisation of transport is not just a regional challenge, but a global one. International cooperation, such as the integration of systems like TIR, is crucial to promote sustainable practices across borders. By adopting these green logistics strategies and technology, you will reduce your environmental impact while ensuring the continued success of your operations

4.2 Current AI use in Transport

The Institute of Mechanics at the Bulgarian Academy of Sciences (IMech-BAS) is implementing a project for the **development of innovative materials with an environmental focus**, which will be used for the manufacture of parts for unmanned aerial systems (UAS, drones) with applications in transport and logistics.

The investment is funded by the EU through the Next Generation EU instrument under the FPAP.

The main directions of the project are related to the development and implementation of new composite materials in cargo drones to increase the payload capacity of this type of flying system. Special attention will be paid to lifting, storing, and transporting cargo. Drones are used for monitoring and registration of events and territories, actively enter into activities of transportation of goods (including in urban environments), plant protection measures in agriculture, warehousing and handling activities, etc. The growing interest in the use of unmanned aerial systems is leading to a focus of investment and research resources in the development and improvement of these platforms. New ideas are being developed in drone control, positioning in space, movement in groups, movement in confined spaces or over long distances, increased payload capacity, and their other characteristics.

Intelligent Vehicle Tracking and Fleet Management delivered as SaaS (software as a service)

Integrated with state-of-the-art telematics, easy-to-use software, and powerful analytical algorithms, it provides a comprehensive set of tools that will help companies optimize their fleet performance. Imagine an intelligent fleet management system that automatically optimizes the supply chain process, notifying you when there is a deviation from the plan so you can react and fix it on time. A system frees from routine tasks so you can focus on important KPIs, minimize financial and environmental costs, and deliver an excellent experience to customers.

State-of-the-art telematics with easy-to-use software and powerful analytics algorithms, provide you with a comprehensive set of tools through which companies can optimize the performance of their fleets. Customized sortation systems for the courier and online retail business, using a DWS system that provides seamless size, weight, and identification of shipments, even the smallest, in motion. The innovation's advantage is the investment security they offer with a local solution and the ability for the customer to self-diagnose and resolve potential issues in a minute.

DigiTech Consult

AI Virtual Assistants, developed by DigiTech Consult, are a state-of-the-art business process automation solution based on conversational AI. The innovation is distinguished by its flexibility and wide range of applications. The virtual assistants offer a unique integration of technologies such as Natural Language Processing) and Natural Language Understanding, which enables free communication in over 50 languages. The aim is to create a comprehensive ecosystem of AI solutions accessible to companies.

Simobotix Ltd

Simobotix Ltd. created the first Bulgarian autonomous mobile robot, a modular mobile platform that can be transformed depending on the application. This robot encompasses in one solution all major technologies in mobile robotics, replacing and using the already built infrastructure of differential platforms, pallet trucks, conveyors, lifting platforms, etc. PENKA is the second innovation the company has applied for. It is a control and management system for collaborative and industrial robots. It functions via a joystick and intuitive software with a digital twin. By articulating the joystick in space, the software saves its trajectory and interprets it graphically, which can then be edited and replayed countless times by the robot or cobot.

Logisoft Ltd.

Logisoft Ltd. The company offers customised sortation systems for the courier and online retail business, through the use of a DWS system, providing seamless size, weight, and identification of parcels, even the smallest, on the move. The innovation's advantage is the investment security they offer with a local solution and the ability for the customer to self-diagnose and resolve potential issues in a minute. The company offers a comprehensive suite of services to the customer including planning and design, mechanical and electrical installation, software implementation, visualization, and maintenance. They apply a social policy that motivates innovation, offering not only an environment for staff development but also, based on various techniques such as brainstorming, ideas, and concepts generated to develop the systems (both software and hardware). They have built an "innovation zone" where opportunities for improvement and innovation are discussed even in the smallest details of the process.

4.3 AI's role in promoting sustainability in resource management, waste reduction, and emissions control

To optimize waste management processes in aviation to reduce environmental impact, lower operational costs, and comply with regulatory standards.

01 Implementation of Waste Segregation Board:

- Introduce clearly labeled bins for recyclables, non-recyclables, and organic waste on aircraft;
- Train cabin crews to assist passengers in proper waste disposal;
- Encourage passengers through informational materials to comply with waste sorting.

02 Transition to Sustainable In-Flight Materials:

- Replace single-use plastics with biodegradable or reusable cutlery, cups, and packaging alternatives;
- Use lightweight materials to reduce fuel consumption and carbon emissions

03 Ground Waste Processing Systems:

- Develop partnerships with airports for waste sorting facilities to ensure efficient processing of onboard waste:
- Introduce compacting systems to reduce the volume of waste generated and optimize transport costs:
- Implement recycling programs for materials, such as aluminum, plastic, and paper.

04 Digitalization to Reduce Paper Waste:

- Transition to e-tickets, digital boarding passes, and in-flight entertainment systems to minimize paper usage:
- Encourage electronic reporting and communication for airline operations

05 Circular Economy Initiatives:

- Partner with waste management companies to upcycle or repurpose materials (converting waste into biofuels or reusable products):
- Implement initiatives for food waste reduction, such as real-time demand forecasting to prevent overstocking meals.

To optimize waste management processes in aviation to reduce environmental impact, lower operational costs, and comply with regulatory standards.

06 Monitoring and Reporting:

- Introduce waste tracking systems to measure and report waste generation on each flight;
- Set clear KPIs to track progress toward zero-waste goals; Conduct regular audits to ensure compliance with international waste regulations, such as ICAO standards.

07 Benefits:

- Reduced environmental impact and enhanced sustainability;
- Cost savings through efficient waste management and reduced fuel consumption;
- Improved airline reputation by meeting passenger expectations for eco-friendly practices.

08 Intermodality

- creating environmentally friendly terminals for air,
- rail, road, and sea transport:
- 4 in 1;
- Use of hydrogen locomotives and electric cars;
- Increasing the share of environmentally friendly transport in deliveries

4.4 Sector-specific challenges (e.g., infrastructure, costs, skills gaps)/Broader barriers, including resistance to change and lack of understanding in terms of sustainability/AI

The Integrated Transport Strategy 2030 is a comprehensive plan for the **sustainable development of the transport system and a framework for investment in transport.**

The Strategy sets out the contribution to the Single European Transport Area by the Common Priorities as laid down in Article 10 of Regulation (EU) No 1315/2013 of the European Parliament and of the Council, including priorities for investment in the TEN-T core and extended networks and in secondary connectivity.

The Integrated Transport Strategy up to 2030 has the following specific objectives: A database has been established for transport sector analysis, for forecasting the development of the transport system, and for developing a national transport model; A detailed analysis of transport sector needs has been carried out, including road, rail, inland waterway, maritime, air and intermodal transport; A Multimodal Transport Model has been developed; Strategic objectives and strategic priorities are defined; Based on the analyses carried out, measures are proposed to develop the administrative capacity for the preparation and implementation of the envisaged projects; A Strategic Environmental Assessment (SEA) of the Integrated Transport Strategy in the period up to 2030 has been prepared.

4.5 Solutions and recommendations for overcoming these challenges

Transport has always played a major role in shaping society. Since the beginning of the twenty-first century, transport has been going through a revolution worldwide. **One of the primary goals for the transport sector is clear: it needs to be decarbonized and become more sustainable.**

At the same time, technological advances are shaping the transport sector toward smart services and societies. The Special Collection showcases some of the latest advances in research towards sustainable and technology-enabled transport.

Advances in technology-enabled transport

The application of AI in transport has been growing significantly. As of this writing, typical use cases include autonomous vehicles, drones delivering packages, and sophisticated systems managing complex logistics delivery networks1. One report projected that global AI in the transport market will reach $3.5 billion by 2023, an impressive growth rate of 16.5%. As a fundamental component of autonomous driving systems, environmental perception enables vehicles to comprehend their surroundings and make intelligent decisions. Autonomous Vehicles (AVs) make wise decisions about speed, direction, and safety by recognizing pedestrians, other vehicles, and traffic signs. This capability is crucial for ensuring safe and efficient road navigation. As another application, the usage of drones rapidly increased during the pandemic thanks to bringing contactless ways to access consumer goods.

Digital twins, federated learning, reinforcement learning, and machine learning have been widely applied, ranging from passenger demand forecasting and the prediction of electricity consumption using traffic volume data to the optimization of traffic signal controls and the evaluation of the pedestrian level of service. The debate around the potential of big data analytics is lively, and how/if they will replace traditional transport modeling techniques.

ITS is a holistic system employed in transport management, including information, communication, sensing, electronic control, AI, and computer technologies. ITS provides comprehensive, real-time, accurate, efficient transport and management capabilities to service citizens and operate the city efficiently, such as traffic control, disaster management, and driver monitoring. With the help of ICT and the continuous development of ITS, smart parking has also been upgraded.

Compared with traditional parking, smart parking alleviates users from finding available parking spots by notifying users of available spots in advance. Emerging ICT has been integrated with smart parking services, such as using RFID or magnetic sensors to monitor parking space utilization, or developing middleware for urban-level parking management.

Advances toward sustainable transport

Decarbonisation of the transport sector is an important pathway to climate-change mitigation and presents the potential for future lower emissions. Electric vehicles (EVs) are regarded as a promising solution to achieve intelligent and green transport. With energy costs decreasing and user experience improving continuously, EVs are gaining significant market share. Considering the numerous advantages of EVs, many governments and large organizations are actively engaged in the process of promoting EV industry development. Driven by these factors, over 6.8 million EVs were sold worldwide in 2021. Based on the analysis of Net Zero Emissions by 2050 Scenario, the number of EVs will reach over 300 million in 2030 and 60% of new car sales will be EVs.

There has been substantial research on decarbonization of transport system, such as the work on reduction of vehicle emission, investigating the relationship between electricity consumed at buildings with travel demand, and assessing the impact of on-demand public transit systems considering EVs. Due to the existing drive-by-wire design and in-vehicle system, EVs have more advantages in autonomous technology implementation. The application of autonomous EVs is progressively supplanting traditional ICE-based AVs.

Safety represents one of the big concerns of modern societies. According to the statistics from the World Health Organization, road traffic crashes result in the deaths of approximately 1.19 million people around the world each year and leave between 20 and 50 million people with non-fatal injuries. More than half of all road traffic deaths occur among pedestrians, cyclists, and motorcyclists. This stems from multiple factors, including scarce road maintenance, pointing to the need to plan an ad-hoc planning and scheduling of interventions to minimize road congestion and discomfort. Here, enabling an advanced transportation system can alleviate the number and severity of traffic crashes through emerging technologies such as traffic control and traffic operations, crash data collection and analyses, safety information and communication systems, and safety policy and planning. Yet, identifying and defining appropriate techniques to study safety remains challenging.

4.6 Enhancing Vocational Education Integration in Transport

Vocational learners in transport and logistics must develop AI-related skills to adapt to an industry increasingly shaped by automation, predictive analytics, and smart mobility solutions.

01 Practical AI Applications in Transport

- Teach students how AI enhances traffic management using real-time sensor data and machine learning for congestion prediction.
- Introduce AI-powered fleet management systems, focusing on predictive maintenance, fuel efficiency, and route optimization.
- Demonstrate autonomous vehicle technologies, explaining how computer vision and deep learning enable self-driving functions.

02 Project-Based Learning and Simulations

- Have students develop AI-based traffic flow models to optimize road networks and reduce emissions.
- Use simulations where learners test AI in logistics planning, using AI-powered software to reduce fuel consumption and delivery times.

03 Industry Collaboration and Work-Based Learning

- Partner with transport and logistics firms that employ AI, offering students practical experience with route optimization and fleet management AI tools.
- Organize site visits to smart cities where AI is used for public transport management and autonomous mobility solutions.

04 Teaching AI Ethics and Sustainability in Transport

- Encourage learners to analyse the social and ethical implications of AI in mobility, including data privacy in AI-driven public transport.
- Discuss how AI can be leveraged for environmental sustainability, such as reducing emissions through smart transport planning.

By embedding AI training into VET transport programs, students will be better equipped to work in the evolving field of smart mobility and AI-powered logistics.

References

1. https://www.frotcom.com/bg-BG/blog/2024/11/ustoychiv-transport-klyuchovi-strategii-za-dekarbonizaciya
2. https://robotics-bulgaria.com/article/672-institutat-po-mehanika-kam-ban-razrabotva-kargo-dronove-ot-novo-pokolenie-sas-sadeystvie-ot-klaster-podemna-tehnika-?utm_source=newsletter&utm_medium=email&utm_campaign=Robotics-2024-12-13
3. https://www.frotcom.com/bg-BG/za-nas
4. https://arcfund.net/bg/category-events/inovativno-predpriatie-na-godinata-2024/
5. ARC FUND / Събития /
6. https://strategy.bg/StrategicDocuments/View.aspx?lId=1235
7. https://www.nature.com/articles/s41598-024-59438-0
8. Jaramillo et al. Transport, IPCC WG III, Sixth Assessment Report (2022).
9. Electricity 2024 – Analysis - IEA (2024)
10. Jia, X. et al. Fast and accurate object detector for autonomous driving based on improved YOLOv5. Sci. Rep. 13, 9711 (2023).
11. Article ADS CAS PubMed PubMed Central Google Scholar

Sustainability and AI in Energy *(FR)*

05

5.1 Sustainability challenges in Energy

The energy sector faces urgent sustainability challenges, primarily the need **to reduce carbon emissions and transition away from fossil fuels**

This shift is essential for mitigating climate change effects but presents complex hurdles. Energy security remains a critical concern, with millions worldwide lacking reliable access to electricity, particularly in underserved regions

The industry must balance energy reliability, affordability, and environmental sustainability, a delicate task for policymakers and industry leaders

5.2 Current AI use in Energy

Artificial Intelligence is revolutionizing the energy sector through various applications:

01 Smart grid management:

- AI optimizes electricity distribution, reduces energy waste, and accommodates renewable energy sources

02 Predictive maintenance:

- Machine learning algorithms forecast equipment failures, reducing downtime and maintenance costs

03 Energy demand forecasting:

- AI accurately predicts future energy demand by analysing historical consumption data and weather patterns

04 Renewable Energy Optimization:

- AI platforms help solar and wind facilities predict weather patterns and optimize energy production

05 Energy Trading:

- AI facilitates real-time energy trading, improving market efficiency

5.3 AI's role in promoting sustainability in resource management, waste reduction, and emissions control

AI plays a crucial role in advancing sustainability within the energy sector:

01 Resource Management:

- AI optimizes the allocation and use of energy resources, improving efficiency and reducing waste

02 Waste Reduction:

- By enhancing predictive maintenance and optimizing operations, AI helps minimize waste in energy production and distribution

03 Emissions Control:

- AI-powered systems can monitor and control emissions more effectively, contributing to reduced carbon footprints

04 Renewable Energy Integration:

- AI improves the integration of renewable energy sources into the grid, facilitating the transition to cleaner energy

5.4 Ethical challenges: bias, data privacy, and accountability

The implementation of AI in the energy sector raises several ethical concerns:

01 Algorithmic Bias:

- Ensuring AI systems operate fairly and avoid discriminatory outcomes is crucial

02 Data Privacy:

- The collection and use of vast amounts of energy data raise concerns about privacy and security risks

03 Accountability:

- As AI systems make autonomous decisions, questions arise about responsibility and accountability for these decisions

04 Transparency:

- There's a need for AI systems to be transparent in their decision-making processes to build trust and ensure ethical operation

Regulatory frameworks and best practices for ethical AI implementation

To address ethical challenges, the following approaches are being considered:

01 Ethical Guidelines:

- Establishing comprehensive ethical guidelines and frameworks to govern AI use in energy management

02 Transparency Requirements:

- Implementing regulations that mandate transparency in AI decision-making processes

03 Data Protection Legislation:

- Enforcing strict data protection laws to safeguard privacy and security

04 Accountability Measures:

- Developing clear lines of accountability for AI-driven decisions in the energy sector

05 Continuous Monitoring:

- Implementing ongoing monitoring practices to ensure AI systems adhere to ethical standards

5.5 Barriers to implementing AI

The energy sector faces several obstacles in implementing AI:

01 Technical Challenges:

- Integrating AI with existing energy infrastructure can be complex and technically challenging

02 Financial Constraints:

- The high initial costs of AI implementation can be a significant barrier, especially for smaller energy companies

03 Data Quality and Availability:

- AI systems require large amounts of high-quality data, which may not always be readily available in the energy sector

04 Regulatory Uncertainty:

- The evolving nature of AI regulations can create uncertainty and hesitation in implementation

Broader barriers, including resistance to change and lack of understanding

01 Beyond sector-specific challenges, broader issues impede AI adoption:

02 Resistance to Change:

- Traditional practices and mindsets in the energy industry can lead to resistance against new AI technologies

03 Lack of Understanding:

- There's often a gap in understanding the potential benefits and applications of AI in energy management and energy efficiency

04 Trust Issues

- Concerns about the reliability and trustworthiness of AI systems can hinder their adoption

04 Regulatory Compliance:

- Ensuring AI systems comply with evolving energy regulations can be challenging and time-consuming

5.6 Sector-specific challenges (e.g., infrastructure, costs, skills gaps)

The energy sector faces unique challenges in AI adoption:

01 Aging Infrastructure:

- Many energy systems rely on outdated infrastructure that may not be compatible with advanced AI technologies

02 High Implementation Costs:

- The energy sector often requires significant upfront investments to implement AI solutions effectively

03 Skills Gap:

- There's a shortage of professionals with the necessary expertise in both energy systems and AI technologies

04 Data Silos

- Energy companies often have data stored in separate systems, making it difficult to integrate and utilize for AI applications

5.7 Solutions and recommendations for overcoming these challenges

To address these barriers, the following solutions are recommended:

01 Investment in Infrastructure:

- Modernizing energy infrastructure to support AI integration

02 Comprehensive Training Programs:

- Developing and implementing training programs to bridge the skills gap

03 Collaborative Approaches:

- Fostering collaboration between industry stakeholders, policymakers, and educational institutions

04 Pilot Projects:

- Demonstrating AI's tangible benefits through small-scale pilot projects to build support and overcome resistance

05 Clear Communication:

- Improving understanding of AI's potential through clear, accessible communication about its benefits and applications

06 Regulatory Alignment:

- Working with regulators to develop AI frameworks that balance innovation with ethical considerations

5.8 Pedagogical aspects and issues within vocational education

To prepare the workforce for AI in the energy sector, vocational education must evolve:

01 Curriculum Development:

- Creating curricula that combine technical skills with critical thinking, creativity, and adaptability

02 Hands-on Experience:

- Emphasizing practical, hands-on experience with AI technologies in energy applications

03 Interdisciplinary Approach:

- Integrating AI education with traditional energy sector training to provide a holistic understanding

04 Continuous Learning:

- Implementing programs for continuous learning to keep pace with rapidly evolving AI technologies

05 Ethical Training:

- Incorporating ethical considerations and responsible AI use into vocational education programs

06 Industry Partnerships:

- Collaborating with energy companies to ensure vocational training aligns with real-world needs and applications of AI

References

1. https://www.youtube.com/watch?v=Mb0bRzcD-v8&t=1464s

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