Carbon Footprint of Artificial Intelligence

For Prelims: **Artificial Intelligence**, **Artificial Neural Network** Spiking Neural Networks, Lifelong Learning, Machine Learning, ChatGPT, Greenhouse Gas Emissions, Climate Change, Carbon Footprint

For Mains: Carbon Footprint of Artificial Intelligence, Environmental Concerns Associated with the Growing Energy Consumption of AI, Sustainable AI

Source: TH

Why in News?

As **artificial intelligence (AI) technology** grows, its **energy-intensive operations pose significant environmental concerns**. Despite challenges, advancements like **Spiking Neural Networks (SNNs)** and **lifelong learning** offer promising avenues to **reduce AI's** carbon footprint while leveraging its **potential to address** climate change.

What are the Spiking Neural Networks and Lifelong Learning?

- **Spiking Neural Networks (SNNs):**
    - SNNs are a type of **artificial neural network (ANNs)** inspired by the human brain's neural structure.
    - Unlike traditional ANNs, which use continuous **numerical values for processing data,** SNNs operate based on **discrete spikes or pulses of activity.**
        - Just as **Morse code uses specific sequences** of dots and dashes to convey messages, SNNs use **patterns or timings of spikes** to process and transmit information, similar to how neurons **in the brain communicate through electrical impulses called spikes.**
    - This **binary, all-or-none characteristic of spikes** allows SNNs to be more **energy-efficient than ANNs,** as they consume energy only when a spike occurs, unlike artificial neurons in ANNs which are always active.
        - In the absence of spikes, SNNs exhibit remarkably low energy consumption, contributing to their energy-efficient nature.
        - SNNs have shown the potential to be **up to 280 times more energy-efficient than ANNs** due to their sparsity in activity and event-driven processing.
    - The energy-efficient properties of SNNs make them suitable for various applications, including space exploration, defence systems, and self-driving cars, where energy resources are limited.
    - Ongoing research aims to optimise SNNs further and develop learning algorithms to harness their energy efficiency for a wide range of practical applications.
- **Lifelong Learning (L2):**
    - Lifelong Learning (L2) or **Lifelong Machine Learning (LML)** is a **machine learning** paradigm that **involves continuous learning.** It involves accumulating knowledge from previous tasks and using it to help with future learning and problem-solving.
    - L2 serves as a strategy to **mitigate the overall energy demands** of ANNs throughout

their lifetime.

- Training ANNs sequentially on new tasks **leads to forgetting previous knowledge**, necessitating retraining from scratch with changes in the operating environment, thus increasing AI-related emissions.
- L2 encompasses a collection of algorithms enabling **AI models to undergo sequential training** on multiple tasks with **minimal forgetting.**
  - This approach facilitates continual learning, leveraging existing knowledge to adapt to new challenges without the need for extensive retraining.

Why is the Carbon Footprint of Artificial Intelligence High?

- **Growing Energy Consumption:**
  - The carbon footprint of artificial intelligence is the **amount of** greenhouse gas emissions that are generated by the creation, training, and use of AI systems.
  - The proliferation of data centres, driven by the increasing demand for AI, is significantly **contributing to the world's energy consumption.**
    - By 2025, it's estimated that the IT industry, fueled by AI advancements, **could consume up to 20% of all electricity** produced globally and emit approximately **5.5% of the world's** carbon emissions.
- **AI Training Emissions:**
  - Training large AI models, such as **GPT-3 and GPT-4**, consumes substantial energy and **emits considerable carbon dioxide (CO2).**
  - Research indicates that training a single **AI model can emit CO2 equivalent to several cars over their lifetimes.**
    - GPT-3 emits 8.4 tonnes of CO_2 annually. Since the AI boom started in the early 2010s, the energy requirements of AI systems known as **large language models** (the type of technology that's behind ChatGPT) have gone up by a factor of 300,000.
- **Hardware Consumption:**
  - AI's computational demands rely heavily on specialised **processors**, like **GPUs provided by companies such as Nvidia,** which consume substantial power.
    - Despite advancements in energy efficiency, these **processors remain formidable consumers of energy.**
- **Cloud Computing Efficiency:**
  - Major cloud companies, essential for AI deployment, pledge commitments to **carbon neutrality and energy efficiency.**
    - Efforts to improve energy efficiency in data centres have shown promising results, with only a modest increase in energy consumption despite a significant rise in computing workloads.
- **Environmental Concerns:**
  - Despite **AI's promising future,** concerns persist regarding its environmental impact, with experts urging greater consideration of the carbon footprint in AI deployment.
    - The rush for AI advancement may overshadow immediate environmental concerns, highlighting the **need for a balanced approach towards sustainability in AI development** and deployment.

Water Footprint of AI

- The **water footprint of AI** is determined by the **water used for electricity generation and cooling** in data centres running AI models.
  - The water footprint consists of **direct water consumption** (from cooling processes) and **indirect water consumption** (for electricity production).
- **Factors affecting the water footprint** include AI model type and size, data centre location and efficiency, and electricity generation sources.
- Training a large AI model like GPT-3 can consume up to 700,000 litres of fresh water, equivalent to producing 370 BMW cars or 320 Tesla electric vehicles.
  - Interactions with AI chatbots like ChatGPT can consume up to 500 ml of water for 20-50 Q&A sessions.
  - GPT-4, with a larger model size, is expected to increase water consumption, but exact

figures are hard to estimate due to data availability.

- **Data centres use water-intensive cooling systems** due to the heat generated, requiring freshwater for cooling and power generation.

How AI Can Help in Addressing Climate Change?

- **Enhanced Climate Modelling:** AI can **analyse vast amounts of climate data** to improve climate models and make more accurate predictions, aiding in anticipating and adapting to climate-related disruptions.
- **Advancements in Material Science:** AI-driven research can develop lighter and stronger materials for wind turbines and aircraft, reducing energy consumption.
  - Designing materials with reduced resource usage, and improved battery storage, and enhanced carbon capture capabilities contributes to sustainability efforts.
- **Efficient Energy Management:** AI systems optimise **electricity usage from** renewable sources, monitor energy consumption, and identify efficiency opportunities in smart grids, power plants, and manufacturing.
- **Environmental Monitoring:** High-end trained AI systems can detect and predict environmental changes like **floods, deforestation, and illegal fishing in real-time.**
  - Contributes to sustainable agriculture by identifying crop nutrition, pest, or disease issues through image analysis.
- **Remote Data Collection: AI-powered robots** gather data in **extreme environments** like the Arctic and oceans, enabling research and monitoring in inaccessible areas.
- **Energy Efficiency in Data Centers:** AI-driven solutions optimise data centre operations to reduce energy consumption while maintaining safety standards.
  - For example, Google has created artificial intelligence that's able to save the amount of electricity it uses to power its data centres. Using machine learning developed by the firm's AI research company, DeepMind, it was possible to reduce the energy used for cooling the centres by a staggering 40%.

How AI Can Be Made Sustainable?

- **Transparency in Energy Usage:**
  - Standardising **measurements of AI carbon footprints** enables developers to assess electricity consumption and carbon emissions accurately.
    - Initiatives like **Stanford's energy tracker and Microsoft's Emissions Impact Dashboard** facilitate monitoring and comparison of AI's environmental impact.
- **Model Selection and Algorithmic Optimization:**
  - Choosing **smaller, more focused AI models for simpler tasks** conserves energy and computational resources.
  - Utilising the **most efficient algorithms for specific tasks** reduces energy consumption.
    - Implementing algorithms that prioritise energy efficiency over computational accuracy minimises electricity usage.
- **Advancements in Quantum Computing:**
  - The exceptional computing power of **quantum systems** holds the potential to accelerate training and inference tasks for both **Artificial Neural Networks (ANNs) and Spiking Neural Networks (SNNs).**
  - Quantum computing offers superior computational capabilities that could facilitate the **discovery of energy-efficient solutions f**or AI on a significantly larger scale.
    - Harnessing the power of quantum computing could revolutionise the **efficiency and scalability of AI systems**, contributing to the development of sustainable AI technologies.
- **Renewable Energy Adoption:**
  - Major cloud providers should commit to operate the **data centres with 100% renewable energy.**
- **Advancements in Hardware Design:**
  - Specialised hardware like **Google's Tensor Processing Units (TPUs)** enhances the

speed and energy efficiency of AI systems.
- Developing more energy-efficient hardware tailored specifically for AI applications contributes to sustainability efforts.
  - **Innovative Cooling Technologies:**
    - Liquid immersion cooling and underwater data centres offer energy-efficient alternatives to traditional cooling methods.
    - Exploring cooling solutions like underwater data centres and space-based data centres harness renewable energy sources and minimise environmental impact.
  - **Government Support and Regulation:**
    - Establishing regulations for transparent reporting of AI's carbon emissions and sustainability.
    - Providing tax incentives to incentivize the adoption of renewable energy and sustainable practices in AI infrastructure development.

UPSC Civil Services Examination, Previous Year Questions (PYQs)

Prelims

Q1. With the present state of development, Artificial Intelligence can effectively do which of the following? (2020)

1. Bring down electricity consumption in industrial units
2. Create meaningful short stories and songs
3. Disease diagnosis
4. Text-to-Speech Conversion
5. Wireless transmission of electrical energy

Select the correct answer using the code given below:

(a) 1, 2, 3 and 5 only
(b) 1, 3 and 4 only
(c) 2, 4 and 5 only
(d) 1, 2, 3, 4 and 5

Ans: (b)

Q2. Consider the following pairs: (2018)

	Terms sometimes seen in news	Context/Topic
1.	Belle II experiment	Artificial Intelligence
2.	Blockchain technology	Digital/Cryptocurrency
3.	CRISPR–Ca 9	Particle Physics

Which of the pairs given above is/are correctly matched?

(a) 1 and 3 only
(b) 2 only
(c) 2 and 3 only
(d) 1, 2 and 3

Ans: (b)

Mains:

Q. "The emergence of the Fourth Industrial Revolution (Digital Revolution) has initiated e-Governance as an integral part of government". Discuss. **(2020)**