Program on Technology Innovation: How Does AI Contribute to CO_2?

EPRI Insight

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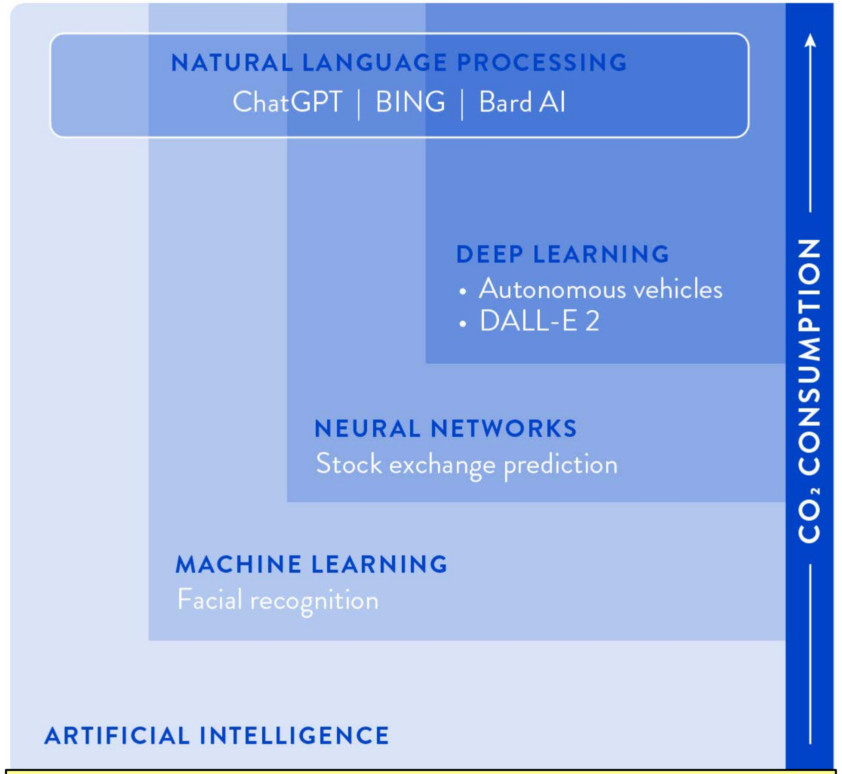
Introduction

Artificial Intelligence (AI):

- Artificial intelligence refers to the development of computer systems or machines that can perform tasks that typically require human intelligence.[1] AI aims to simulate human-like intelligence and reasoning to solve complex problems, make decisions, recognize patterns, and interact with the environment. AI can be split into 4 groups:
  1. Reactive AI
  2. Limited Memory
  3. Theory of Mind
  4. Self-aware

Types of AI	
Reactive AI	Limited Memory
Theory of Mind	Self-aware



More computationally complex algorithms may require higher energy use and result in increased CO2 emissions

Machine Learning (ML):

- Machine learning is a subset of artificial intelligence that focuses on creating algorithms and models that allow computers to learn and make predictions or decisions without being explicitly programmed.[2] Instead of following rigid instructions, machine learning algorithms are trained on large datasets and learn from patterns and examples. Machine learning algorithms can be categorized into three types:

1. **Supervised Learning**: It is defined by its use of labeled datasets to train algorithms that to classify data or predict outcomes accurately.
2. **Unsupervised Learning:** It uses machine learning algorithms to analyze and cluster unlabeled datasets.
3. **Reinforcement Learning:** A reinforcement learning agent is able to perceive and interpret its environment, take actions and learn through trial and error.

Neural Networks:

- (Artificial) neural networks, usually simply called neural networks or neural nets, are computing systems inspired by the biological neural networks that constitute animal brains.[3]

Deep Learning:

- Deep learning is a specialized subfield of machine learning that focuses on training deep neural networks, which are artificial neural networks with multiple layers. Deep learning algorithms attempt to mimic the structure and function of the human brain by using interconnected layers of artificial neurons called artificial neural networks.[4]

Natural Language Processing:

- Natural language processing is an interdisciplinary subfield of linguistics, computer science, and artificial intelligence concerned with the interactions between computers and human language, in particular how to program computers to process and analyze large amounts of natural language data.[5]

Recent Developments Timeline

Nov 2022

November 30
OpenAI ChatGPT 3.5 launched

December 12
First Large Language Model that supports over 100 languages released by Cohere

December 26
LLMs trained for specific use cases seen in Med-PaLM by Google

February 02
“Chain-of-thought prompting” incorporated in Amazon’s multimodal - CoT

February 24
Model efficiency improves in Meta’s LLaMA

February 27
Kosmos-1 by Microsoft can respond to both image and audio prompts

March 07
First use of generative AI for customer relationship management announced by Salesforce through Einstein GPT

March 13
OpenAI releases ChatGPT 4

March 14
Constitutional AI introduced by Anthropic in their AI assistant Claude

March 16
Integration of ChatGPT 4 into the Office 365 suite

March 21
Bard released by Google

March 30
Announcement of financially trained LLM by Bloomberg

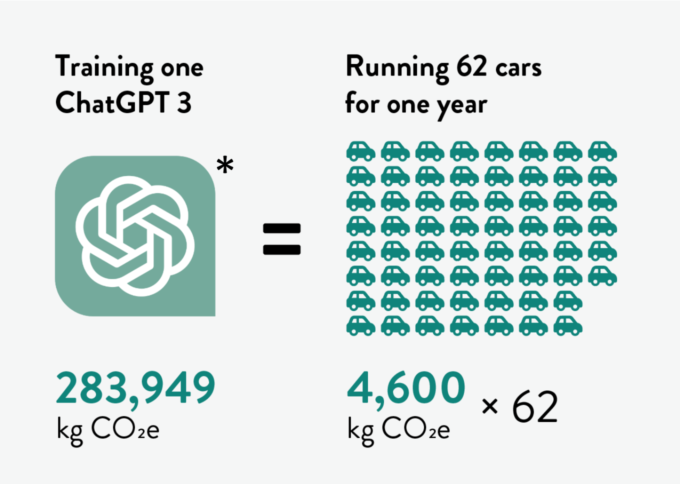
April 13
Bedrock by Amazon introduced that makes models available via API from multiple providers

June 2023

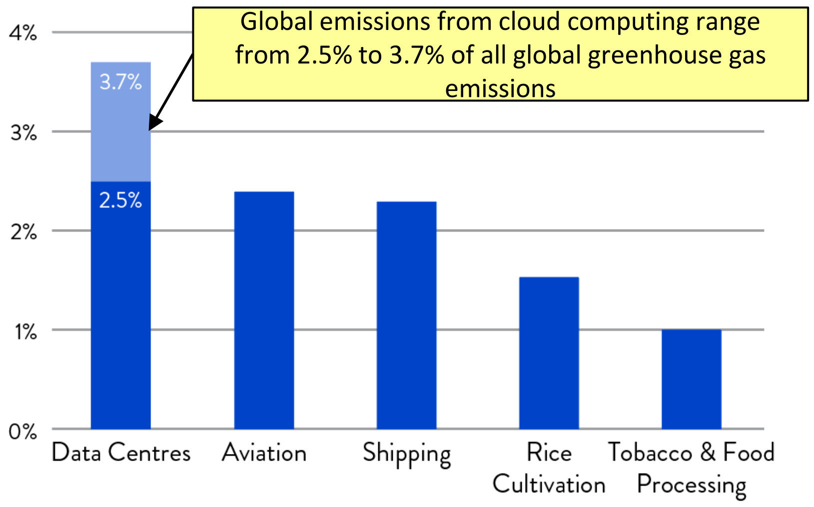
What causes CO_2 emissions in Artificial Intelligence?

Training Process: Training AI models often involves extensive computational power and large-scale data processing. This process typically requires energy-intensive computations that can result in significant CO2 emissions. The training phase of AI models can be resource-intensive and require substantial amounts of electricity, particularly when using high-performance hardware and large datasets.[6,7]

Inference and Deployment: After training, AI models are deployed and used for inference tasks, which involve making predictions or generating responses based on input data. This inference process also requires computational resources, which consume energy and can produce CO2 emissions. Depending on the scale and frequency of AI model inference, the energy consumption and associated CO2 emissions can vary.[8]



Share of global CO_2 emission generated by sector/category



Source: Climatiq Analysis, The Shift Project, OurWorldData

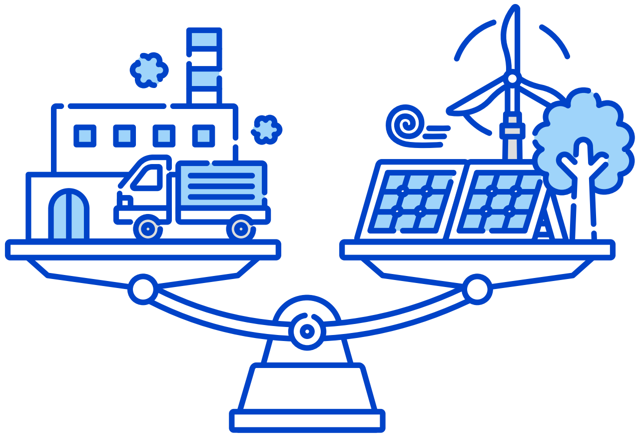
Data Centres: AI models, including ChatGPT, rely on data centers for their operation. Data centers consume significant amounts of energy, often sourced from fossil fuel-based power grids. The electricity demand of data centers, including the hardware infrastructure, cooling systems, and networking equipment, can contribute to CO2 emissions.[9]

- Data processing and storage: AI applications often involve the processing and storage of large amounts of data. Data processing and storage infrastructure, including servers, networking equipment, and data storage systems, require energy for operation. Depending on the energy sources powering these systems, the associated CO2 emissions can vary.

Algorithm Efficiency: The efficiency of AI algorithms can impact their carbon footprint. More computationally complex algorithms may require higher energy consumption and, therefore, result in increased CO2 emissions. Developing and utilizing algorithms that optimize resource usage and minimize computational requirements can help reduce AI's carbon footprint.

EPRI does not own the ChatGPT mark, which remains unregistered at time of publication.

Carbon Offsetting



Carbon offsetting is a practice that aims to compensate for the greenhouse gas emissions generated by individuals, organizations, or activities by supporting projects that reduce or remove an equivalent amount of carbon dioxide (CO_2) or other greenhouse gases from the atmosphere. It is based on the principle that emissions produced in one place can be balanced out by reducing emissions or removing CO_2 elsewhere.[10]

The process of carbon offsetting typically involves the following steps:

- **Measuring emissions**
- **Choosing offset projects**
- **Verifying and certifying projects**
- **Purchasing offsets**
- **Retirement and cancellation**

In the case of ChatGPT-3, to offset the Carbon Emissions related to its training, you would need to offset 283,949kg of CO_2 which is equivalent to planting 13,476 trees.

It is important to note that carbon offsetting should not be considered a substitute for reducing emissions at their source. It is more effective to prioritize emission reduction efforts by implementing energy efficiency measures, transitioning to renewable energy sources, and adopting sustainable practices. Carbon offsetting should be used as a complementary tool to achieve carbon neutrality or to compensate for emissions that are challenging to eliminate entirely.

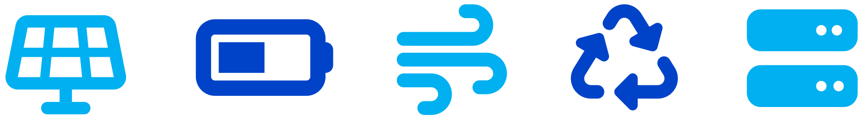
A multitude of companies have pledged to carbon neutrality and are adopting Carbon Offsetting. Both Google and Amazon are involved in carbon offsetting and therefore if using AI on these platforms, can claim to be carbon neutral through carbon offsetting.

There are ongoing discussions and debates surrounding carbon offsetting, including concerns about the additionality and permanence of offset projects, the potential for greenwashing, and the need for robust and transparent standards. Nonetheless, when implemented properly, carbon offsetting can play a role in addressing climate change by supporting emissions reduction initiatives and contributing to a more sustainable future.

Are there other solutions to powering datacenters?

Rather than Carbon Offsetting, and dealing with the “problem” after, these large and influential companies should look to other ways to reduce their Carbon Emissions.

- Directly adopting renewable energy sources
- Improving the Data Centre Infrastructure Efficiency (DCIE)
- Leveraging the Data Centre Infrastructure Management (DCIM)
- Integrate Intelligent Systems
- Reducing and recycling waste



24/7 Renewable Energy Matching

24/7 renewable energy matching refers to the concept of ensuring a continuous supply of electricity from renewable energy sources throughout the day, every day of the year. Unlike conventional power sources such as fossil fuels, which can be dispatched as needed, renewable energy generation is often subject to natural variability, such as changes in weather conditions or sunlight availability.[12]

The following various strategies and technologies are employed in order to achieve this:

1. **Energy Storage**
   Batteries, Pumped Hydro Storage, Hydrogen Storage etc.

2. **Diverse Renewable Energy Sources**
   Solar energy, Wind Energy, Hydropower etc.

3. **Interconnected Power Grids**
   Third party operated interconnected mini-grids

4. **Demand Response**
   Encouraging a shift electricity demand to times when electricity is more plentiful/ demand is lower

5. **Forecasting and Advanced Grid Management**
   Estimating future loads using historical and present data

24/7 renewable energy matching is a significant challenge that requires careful planning, investment in infrastructure, and the integration of various technologies. As renewable energy technologies continue to advance and costs decrease, achieving a sustainable and uninterrupted supply of clean energy becomes increasingly feasible.

Can Artificial Intelligence be used to reduce Carbon Emissions in Power Systems?

Carbon emissions are the primary cause of climate change. With the combustion of fossil fuels to produce electricity being the primary source of power globally, it is important that we are conscious of other ways this industry are contributing to carbon emissions.

Looking further into this, can AI be the tool needed to reduce CO2 emissions in this sector?

Ways that have already been identified in which AI can be used to reduce carbon emissions in the power sector[11,13]:

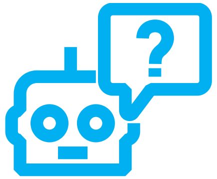
- Monitoring and Predicting Patterns in Carbon Emissions
- Environmental monitoring and pollutant air concentration
- Air quality assessment and monitoring
- Organic and inorganic material monitoring
- Climate technologies for sustainable environment
- Monitoring carbon emissions on roads and seas
- Applications for climate change decision making

EPRI is closely monitoring the implementation of AI in the power sector and have recently published an overview specific to the hype around ChatGPT and the power sector. You can read about it here:

[ChatGPT and the Power Sector: What's Hype? What's Possible? (epri.com)]

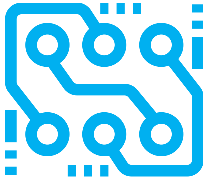
Reducing the CO2 emissions associated with Machine Learning

1. Model



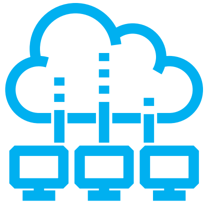
Choosing efficient machine learning[14] model architectures, such as sparse models, has the potential to improve the quality of machine learning while simultaneously reducing computational requirements by a factor of 3 to 10.

2. Machine



Utilizing processors and systems specifically optimized for machine learning training[14], as opposed to general-purpose processors, can significantly enhance performance and energy efficiency, resulting in a 2 to 5 times improvement.

3. Mechanization



Shifting computational tasks to the Cloud instead of relying on on-premise infrastructure leads to a reduction in energy consumption and subsequent emissions by a factor of 1.4 to 2. Cloud-based data centers are purpose-built facilities designed to accommodate up to 50,000 servers while prioritizing energy efficiency, resulting in excellent power usage effectiveness (PUE). In contrast, on-premise data centers, often smaller and older, face challenges in justifying the investment for modern, energy-efficient cooling and power distribution systems.

4. Map Optimization

Cloud services provide customers with the flexibility to choose data center locations powered by clean energy sources[14], resulting in a significant reduction of the overall carbon footprint by a factor of 5 to 10. Although concerns may arise regarding the potential saturation of the greenest locations due to map optimization, the increasing demand for efficient data centers incentivizes continuous advancements in the design and deployment of environmentally friendly data centers.

Conclusion

The future holds an unstoppable surge in Artificial Intelligence, that will lead to a transformative journey that will revolutionize countless facets of our lives and reshape industries worldwide. As technology progresses and AI systems become increasingly capable, we can anticipate astounding advancements and innovations across diverse fields.

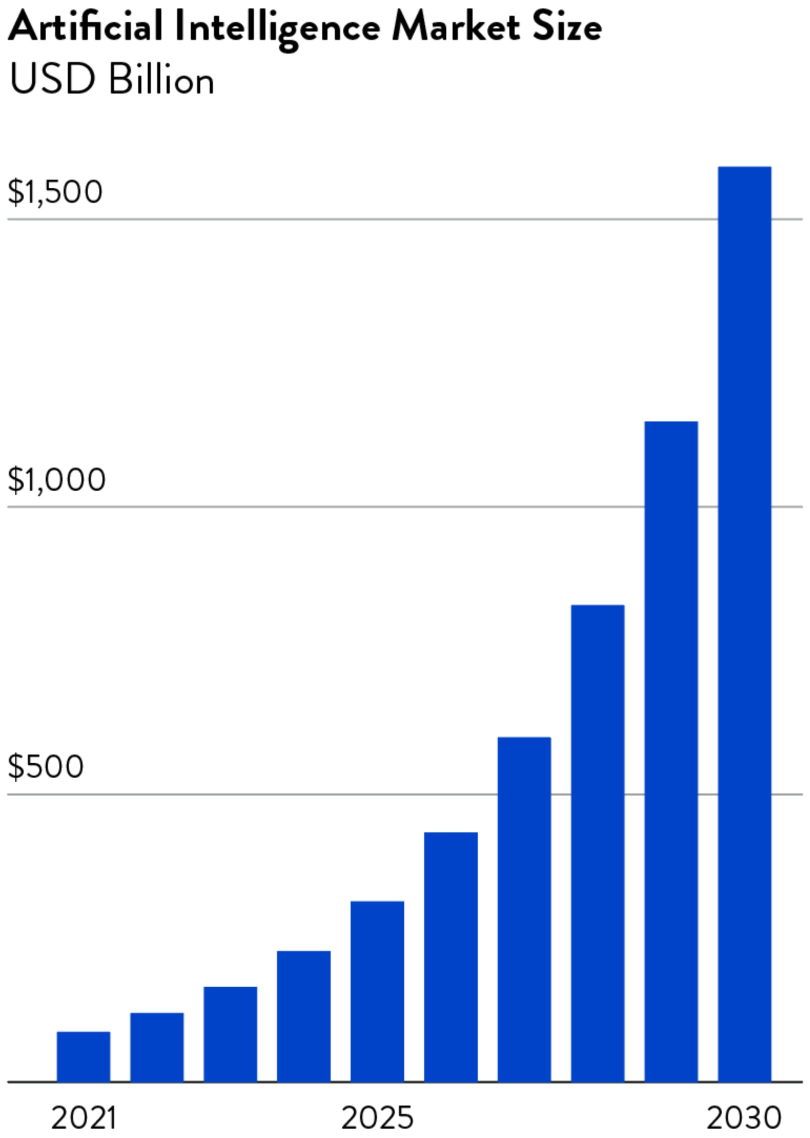
By 2030, the projected value of the AI Market is estimated to reach nearly $1.6 trillion.[15] To harness the potential of this technology and in turn enhance the power sector, it is crucial that we adapt and embrace its utilization.

However, amidst this rapid growth, it is crucial that we make informed decisions carefully and consider the impacts of AI and remain mindful of how it is consumed. Being conscious of the ethical, social, and economic implications associated with this technology is of utmost importance.

EPRI supports numerous uses of AI as part of our digital transformation efforts. Some of the areas that R&D Projects with AI include:

- Data driven decision making
- Monitoring and Advanced Data Analytics
- Advanced Buildings and Communities
- Grid-Edge Customer Technologies
- Transmission Asset Management Analytics
- Ecosystem Risk and Resilience
- Distribution Systems

[R&D Projects With AI (epri.com)](epri.com)



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