Institut européen
European Institute

LUISS
School of Government

# Joint Master in EU Trade and Climate Diplomacy

## *Artificial Intelligence for social good*

**Supervised by Ramona Samson**

**Ieva Silkane**

**2023**

## Statutory declaration

*I hereby declare that I have composed the present thesis autonomously and without use of any other than the cited sources or means. I have indicated parts that were taken out of published or unpublished work correctly and in a verifiable manner through a quotation. I further assure that I have not presented this thesis to any other institute or university for evaluation and that it has not been published before.*

*11.06.2023. Silkāne Ieva*

# Abstract

This thesis investigates the potential of Artificial Intelligence (AI) in promoting sustainability and social good, with a specific focus on the French energy sector. The research objective is to investigate how AI may contribute to social good through sustainable energy practises and the issues that may occur during implementation. The study environment is framed against the backdrop of growing global concern about climate change and the need for long-term solutions.

The thesis is divided into three major chapters. The first chapter discusses the background, pros and risks of using AI for social good. The second part delves into the use of AI in sustainable energy in France, with case studies from major energy firms such as EDF, Engie, and TotalEnergies. The third chapter analyses the research findings, interprets the findings, and makes recommendations.

The major findings show that AI has a lot of potential to help with sustainability and social good, especially in the energy sector. However, AI's issues, such as data privacy, bias, and transparency, must be properly addressed. The report concludes that, while AI has transformative potential, more research and a more balanced approach are required.

# Table of Contents

# Introduction

AI has become a game-changing technology that potentially affects many facets of society. This study seeks to answer the question, "What is the impact of AI on social good?" This inquiry is pertinent to both the continuing academic discussion of AI and its societal effects and the more extensive public discussion of the ethical and societal consequences of AI.

The use of AI for social good is relevant not just because technology has the ability to alleviate societal concerns but also because it presents significant ethical issues. For instance, ensuring that AI is impartial, fair, and transparent is crucial because it will be used to make judgements that impact people's lives. (UNESCO, 2021)

The growing presence of AI in our daily lives and its potential to substantially impact society are what have sparked interest in this subject. AI has the ability to help solve some of the most important problems of our day, including healthcare, education, and climate change. The employment of AI, however, also prompts crucial queries regarding data protection, bias, transparency, and the possibility of abuse. Therefore, comprehending how AI affects social good is crucial for legislators, business titans, and the general public in addition to being of academic interest.

The application of AI for social good is an area of current research and development, and numerous companies and individuals are attempting to create and implement AI systems that can positively impact society. For this reason, the topic is timely. As a result, study is required to better understand the potential and constraints of AI in this setting and the ethical issues that need to be considered. (Tomašev, 2020)

We will look at the idea of "social good" and how AI may support it in this research. The word "social good" is broad and includes a variety of ideas, such as economic prosperity, social equality, and environmental sustainability. We will study how AI contributes to societal good by looking at how it is used in fields like healthcare, education, and environmental protection.

This work aims to address two problems simultaneously. Despite the fact that there is an expanding body of literature on the technical aspects of AI, research on its effects on society is still in its relative infancy. Second, attitudes on AI and social good are usually divisive, with proponents highlighting the benefits of the technology and critics focusing on any potential negatives. This study aims to provide a balanced and in-depth explanation of how AI affects social advancement.

The research will be organised, beginning with an evaluation of the body of work on AI and social good. An analysis of case studies that demonstrate how AI affects societal good will come after this. The consideration of the opportunities and difficulties posed by AI in advancing social good will then go into great detail. The study will come to a close with suggestions on how to maximise AI's positive social effects while minimising its possible drawbacks for legislators, business executives, and researchers.

The reader should have a thorough knowledge of the impact of AI on social good, the range of the investigations conducted in this research, and the strategy used to answer the research question by the time this study is finished. The study will not detail AI's technological features because its social implications will be the main focus. The research's logical and planned progression will ensure a thorough examination of the research question.

# Methodology

The research's methodology chapter is devoted to examining the research techniques used in this dissertation. The research uses a combination of theoretical and empirical research techniques, with a focus on qualitative techniques.

The theoretical component of the study is based on a critical examination of AI's contribution to social benefit. This requires building a conceptual framework for comprehending the potential of AI in tackling major social, economic, and environmental problems as well as defining essential words like "AI," "social good," and "sustainable energy."

Case studies play a role in the empirical part of the study as a means of bridging the conceptual level of theory and more concrete findings. For the purpose of understanding AI's revolutionary potential across all scales and industries, the research examines case studies of three entities from the French energy sector. These organisations were selected due to their distinctive positions within the sector, ground-breaking AI applications, and comprehension of the path to AI integration. The research does collect and analyse data from a variety of sources, including industry reports, academic literature, and the case study companies themselves, even if it does not use quantitative data analysis in the usual sense. The theoretical approach is supported by this evidence, which also offers a more complex understanding of how AI affects social good.

Understanding decision-making processes, the forces driving AI adoption in the energy industry, and the perceived advantages and difficulties of AI integration are the main goals of the qualitative portion of the research. In order to do this, the data gathered from the case studies must be carefully interpreted, and the conclusions must be critically assessed.

In conclusion, the technique used in this work combines case study research, theoretical analysis, and qualitative interpretation. By considering both the quantifiable results and the intricate nuances of human conduct in society, this holistic approach ensures a thorough understanding of the impact of AI on social good.

# Chapter 1: Artificial intelligence for social good

The idea of "AI for Social Good," a field that applies AI to important social issues, is introduced in this chapter. It reviews AI, its technology, and applications before going into detail about how AI may be used to address social issues including improving healthcare and education, battling climate change, and advancing renewable energy. The chapter strongly emphasises ethical issues in the use of AI while also acknowledging the difficulties and dangers involved. Examples from the real world show how AI has the capacity to advance society. This paves the way for a thorough debate in the chapters to follow.

## 1.1. Background

The replication of human intelligence by machines has many uses, including speech recognition, machine learning, expert systems, and natural language processing. Large data sets are analysed using AI in order to find patterns and correlations that can be utilised to generate predictions. Learning, reasoning, self-correction, and creativity are the main areas of concentration in its programming. AI has revolutionised a number of areas, including healthcare, transportation, banking, environmental sustainability, and customer service. Applications of AI for social benefit can be found in healthcare, education, agriculture, and climate resiliency. In these fields, it has several advantages, including individualised healthcare, enhanced educational opportunities, increased agricultural productivity, and assistance with climate adaptation programmes.

**Definition:** AI is defined as the replication of human intelligence functions by machines, particularly computer systems. Expert systems, natural language processing, speech recognition, and machine vision are some specific uses of AI. (McCarthy, 1999)

### How does AI work?

As the hype around AI has surged, vendors have been quick to emphasize the integration of AI in their products and services. Often, what they label as AI is merely a component of the technology, such as machine learning. AI necessitates a foundation of specialized hardware and software for the development and training of machine learning algorithms. Programming

languages like Python, R, Java, C++, and Julia all offer features that are favored by AI engineers, although no single programming language is exclusively tied to AI.

AI systems typically consume a large amount of labelled training data, scrutinizing it for trends and patterns which they then use to predict future scenarios. For instance, an image recognition tool can learn to identify and describe items in pictures after examining millions of examples, and a chatbot can learn to generate realistic conversations with humans when given samples of text. Recent advancements in generative AI have enabled the creation of convincing text, images, music, and other forms of media. (Russell & Norvig, 2020)

Programming for AI emphasises cognitive abilities such as the ones listed below:

**Learning.** This aspect of AI programming is dedicated to collecting data and establishing the necessary rules to convert it into actionable insights. These rules, often referred to as algorithms, provide computing devices with specific instructions on how to execute a particular task. (Goodfellow, Bengio, Courville, 2015)

**Reasoning.** Choosing the appropriate algorithm to achieve a specific goal is the focus of this area of AI programming. The choice of the optimum algorithm for a given task depends on a number of variables, including the problem's nature, the data at hand, the available computing power, and the performance metrics that are required.

**Self-correction.** This characteristic of AI programming is aimed at constantly refining algorithms to ensure they yield the most accurate outcomes. This demonstrates an AI system's capacity to continuously learn from mistakes, update its algorithms, and enhance performance over time.

**Creativity.** This segment of AI generates novel images, texts, music, and concepts utilizing tools such as neural networks, rule-based systems, statistical methods, and other AI resources. (Poole & Mackworth, 2010)

As we can see, AI is a potent technology that allows machines to mimic certain aspects of human intelligence. It has particular applications in machine vision, speech recognition, natural language processing, expert systems, and other fields. Vendors have been eager to

emphasise AI's inclusion in their goods and services as it has attracted attention. It is necessary to remember that what is frequently referred to as AI is merely a subset of larger technologies like machine learning.

**Brief history**

With mythological and historical evidence mentioning sentient machines, the idea of inanimate objects imbued with intelligence has existed since antiquity. Mathematical and computing foundational research from the late 19th and early 20th centuries prepared the way for the creation of modern computers and AI. (Negnevitsky, 2021)

A number of notable events occurred in the 1950s, including the Dartmouth College conference, which is usually recognised as the birthplace of contemporary AI, and Alan Turing's Turing test. The ensuing decades saw times of hope, assistance from the government and business, as well as setbacks dubbed "AI winters." But as computing power and data availability improved in the late 1990s, an AI Renaissance emerged that gave rise to innovations in NLP, computer vision, robotics, and machine learning. A constant stream of AI developments were made in the 2010s, including voice assistants, self-driving cars, generative adversarial networks, and AlphaGo's victory against the world Go champion. In the 2020s, generative AI, a system that can create original material, has shown promise. Although the technology is still in its infancy, notable language models include Microsoft's Megatron-Turing NLG, Google's Bard, and ChatGPT-3. (Forbes,2021)

As we look back on this journey, it is clear that AI has advanced significantly, with both amazing successes and continued difficulties. As we continue to investigate and implement AI in numerous disciplines, the future promises intriguing possibilities. It is evidence of human creativity and of our shared ambition to push the limits of what machines are capable of.

**Healthcare:** AI has been used to enhance patient care, disease diagnosis, and treatment strategies. In fields including medical image analysis, early disease identification, medication discovery, and personalised medicine, it has demonstrated promising outcomes. (Nature, 2019)

**Transportation:** AI has been essential in developing driverless vehicles, improving traffic management, and raising safety standards in transportation. It has the potential to revolutionise mobility services, lower accidents, and increase fuel efficiency. (IEEE, 2019)

**Finance:** By enabling fraud detection, algorithmic trading, risk assessment, and individualised financial services, AI has completely changed the financial sector. It enhances the speed, precision, and security of financial activities. (Journal of Finance and Data Science, 2019)

**Environmental Sustainability:** Research on climate change is supported by the use of AI approaches for energy efficiency, resource management, and monitoring. It supports monitoring the environment, conserving wildlife, and making sustainable decisions. (AI Time Journal, 2023)

**Customer Service:** Chatbots and virtual assistants driven by AI have enhanced customer service by offering quick responses, individualised suggestions, and effective help. Techniques for machine learning and natural language processing help to improve consumer experiences. (Kleinings, 2023)

We have seen how AI is revolutionising businesses and influencing the future in many different fields. As we consider these applications, we see the enormous potential of AI to improve many industries. By utilising AI, we can spur innovation, increase productivity, and have a positive impact across many industries, ultimately paving the way for a brighter future for everybody.

### 1.2. Overview of AI for social good

AI for social good has the potential to have a big impact on society. For example, Google Research India's AI4SG initiative supports organisations from India and across Asia that focus on addressing civil, humanitarian, and environmental challenges with AI. It also works on developing systems for forecasting floods, improving understanding of people with atypical speech patterns, and predicting cardiovascular problems by eye scan. (Hyperight, 2021)

Although AI is frequently viewed as a tool for efficiency and creativity, we believe its potential to have a positive impact on society is sometimes underrated. Leading the charge in demonstrating how AI may be used to tackle important societal challenges is the USC Centre for AI in Society (CAIS). Students and faculty from multiple USC schools recently gathered as part of ShowCAIS to discuss their research on AI's potential for good. Projects focusing on equity, healthcare, homelessness, LGBTQ+ marginalisation, conservation, and disaster response were highlighted at the event.

It is critical to bring together people working with AI from various sectors in order to fully realise its potential. AI is no longer the sole domain of computer scientists, and bringing together people from other academic backgrounds can greatly increase our influence and overall impact. The success of ShowCAIS, which garnered involvement from a number of schools, illustrated the inventiveness and originality with which AI can be used to tackle concerns.

The occasion successfully illustrated how technology and the actual world are related. It gave engineers a venue to share their work with public scientists, stimulating collaboration and presenting opportunities for novel ideas and applications. We can create AI solutions that answer the issues encountered by the social sciences by combining various points of view.

Leadership from a range of fields stressed the value of AI to society and the necessity for an ethical and moral approach. The USC CAIS study that employs AI to address urgent problems was lauded, and encouragement was provided to keep expanding the capabilities of AI.

Despite being a man-made technology, AI has the potential to have real, beneficial effects on society. It was made obvious during ShowCAIS that by using boldness and imagination, we can overcome the potential drawbacks of AI. We can influence AI's future to bring about beneficial changes for society's benefit by acting as change agents. AI has already changed our lives. (Lewis, 2023)

The use of AI for social good has a wide range of possible applications, including bettering healthcare, education, and environmental sustainability. (Hyperight, 2021) AI can help in

detecting diseases early on and providing personalized treatment plans. By giving pupils personalised learning opportunities, it can also aid in enhancing the quality of education. (McKinsey Global Institute, 2018) AI can also assist in monitoring the environment and disaster prediction. (Haughey, 2019)

Innovative uses of AI to address societal concerns are being demonstrated by programmes like USC CAIS and Google Research India's AI4SG. To fully realise AI's potential, cooperation amongst several sectors is essential. The productive dialogue between engineers and social scientists, which led to fresh concepts and solutions, was exemplified by ShowCAIS. We can construct AI solutions that address civil issues and effect significant change by fusing many viewpoints.

Leadership focuses on the moral application of AI and applauds USC CAIS's research. Numerous potential exist already for using AI for social betterment. AI has the ability to change many facets of our society, from personalised healthcare and improved education to environmental monitoring and disaster prediction.

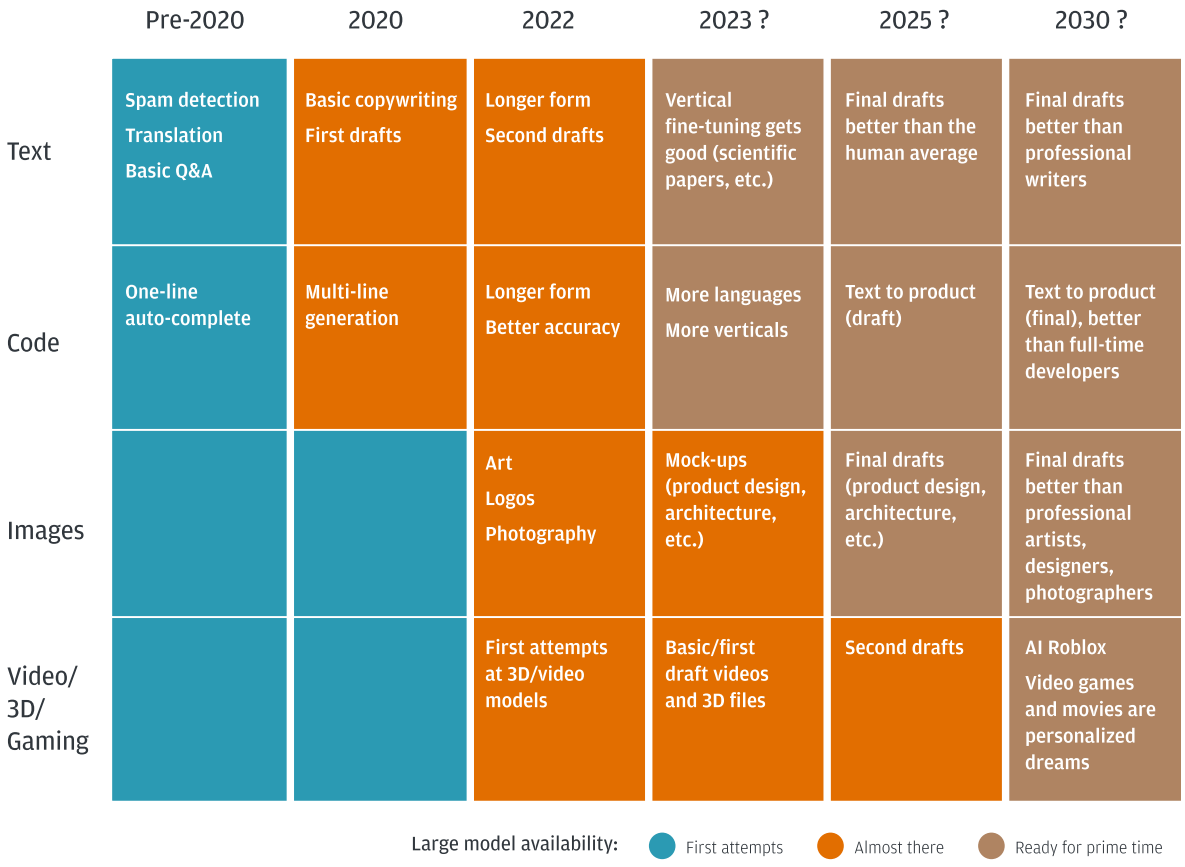


*Figure 1 - Generative AI's output across text, code, images and video until 2030 (J.P. Morgan, 2023)*

A new generation of business models and applications may be made possible by the emergence of generative AI. While ChatGPT and similar technologies are trained on generic data, generative AI systems tailored for certain verticals and datasets, like market intelligence or medical research, may soon be available. positive mood cycle here might very well result in a valuation bubble in connected stocks due to the possibly very big effect.

Companies that manufacture hardware, particularly memory chips, stand to gain from the adoption of generative AI technologies. "It's critical that generative AI is used responsibly and governed properly, so that it can amplify human potential instead of becoming too disruptive." Mark Murphy, Head of U.S. Enterprise Software Research, J.P. Morgan (J.P.Morgan, 2023)

### 1.3. Benefits and risks of AI for social good

Numerous ground-breaking improvements have been made as a result of the uses of AI in a variety of fields, including business, agriculture, healthcare, and education. Although AI is frequently linked to scientific advancement in fields like data analysis and financial forecasting, its potential for social betterment is equally impressive. The adoption of AI technology by numerous industries has led to substantial societal changes all over the world. This innovation has fueled prosperity not only in rich nations but also in underdeveloped nations. In order to assure the appropriate use of AI and allay any worries or mistrust related to this new intelligence, governments are currently striving to implement rules and regulations. (Russell & Norvig, 2016)

It is important to note at this point that we will continue to refer to all forms of machine intelligence as AI, even if many of the situations we will cover in the following contain particular machine learning solutions to severe societal problems in various regions of the world. The next few lines will illustrate how AI has contributed significantly to the world in which we live. (Kaufmann, 2018)

- **Benefits**

**Healthcare**

AI is revolutionising the healthcare sector. The article "The role of AI in healthcare: Revolutionising patient care" by Taylor Deamon highlights five main areas where AI is significantly advancing patient care:

1. Precision Medicine and Personalized Treatment: Huge volumes of patient data are analysed by AI to create individualised treatment plans, forecast illness development, and suggest interventions, resulting in more precise diagnoses and improved treatment outcomes.

2. Medical Imaging and Diagnostics: AI helps with medical image processing and analysis, early illness identification and intervention, accelerating and improving diagnosis, and patient outcomes.

3. Virtual Assistants and Chatbots: Virtual assistants and chatbots driven by AI give patients individualised help, prioritise patients based on their symptoms, and improve patient engagement and happiness.

4. Drug Discovery and Development: AI helps to streamline research efforts and cut expenses by accelerating the identification of promising drug candidates, forecasting therapeutic efficacy, and optimising treatment regimens.

5. Operational Efficiency and Healthcare Management: AI improves supply chain management, forecasts patient flow, automates administrative work, and optimises resource allocation, which increases effectiveness and lowers costs.

The article also emphasises how crucial it is to work with a qualified healthcare marketing company to manage the difficulties of implementing AI in healthcare while preserving data privacy and ethical compliance. These organisations can help with creating AI strategy, incorporating AI fixes into current systems, and explaining the advantages of AI to patients and other stakeholders.

By enhancing patient care, diagnosis, treatment, and administrative effectiveness, AI is revolutionising healthcare. However, cautious and moral execution is essential, with an emphasis on data privacy and legal compliance. (Deamon, 2023)

**Education**

A whole new idea of learning has entered the industry vertical when it comes to education and learning as a result of the fusion of AI with the current digital learning system.

According to the article "Top 10 ways AI in education is transforming the industry" by Dileep Gupta, AI development services, the digital education market, also known as the eLearning market, is anticipated to cross 243 billion USD by the end of 2022. The classic conventional methods of learning have been completely transformed by AI in education, from mobile digital courses to online references and virtual classrooms. Now that more edTech companies are utilising AI technology, it is important to discuss the advantages of AI in the education sector. (Gupta, 2023)

A few intriguing recent statistics are as follows:

- The impact of AI on education is greater than we realise. With an increasing focus on higher education quality, more than 50% of schools and colleges use AI for administrative support.

-By enhancing student engagement with personalised courses, interactive lectures, gamified classrooms for skill acquisition, etc., AI trends fuel growth swiftly in EdTech, which is why the AI education industry is anticipated to reach 20 billion USD by 2027.

- Here is a graph showing the region-by-region expansion of AI in the education sector from 2016 to 2027, showing how the notion of AI is rapidly expanding across all demographics.

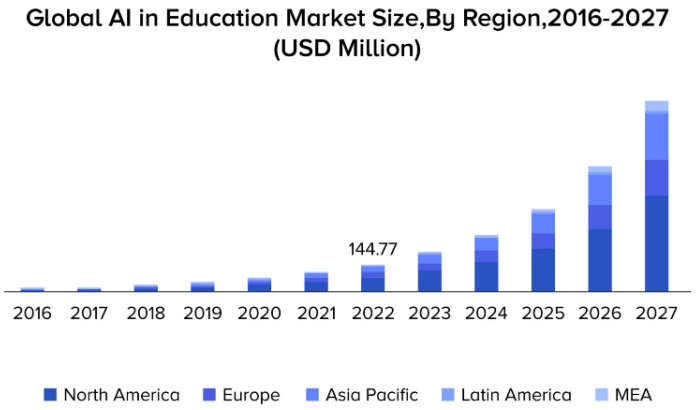


*Figure 2 – Global AI in Education Market size, By Region, 2016-2027 (USD Million) (Gupta, 2023)*

Numerous advantages of AI in the education sector include personalised learning, task automation, intelligent content creation, adaptable access to information, identification of classroom weaknesses, closing of skill gaps, customised data-based feedback, 24/7 support with conversational AI, secure and decentralised learning systems, and AI-powered exams. With the help of these AI apps, learning and teaching become more personalised, effective, and interesting. Automation of administrative duties, interactive content creation, worldwide information access, instructor support, skill gap closure, personalised feedback, increased

user engagement, data security, and improved test integrity are all made possible by AI technology. Businesses in the education sector can benefit from integrating AI technology to solve a number of industrial problems. (Gupta, 2023)

**Agriculture**

According to HTF Market Intelligence, the global AI in agriculture market is anticipated to expand at a CAGR of 22.34% from 2023 to 2029. The market attempts to improve farming practises, boost crop yields, and lessen environmental impact using AI technology including machine learning, computer vision, and robotics. For data analysis and decision-making, it includes hardware (sensors, drones, and robots) and software platforms. The market provides advantages like increased productivity, cost savings, higher yields, and eco-friendly procedures. IBM, John Deere Company, Intel, Google, Microsoft, NVIDIA Corporation, and others are significant market participants. As the sector looks to apply more effective and sustainable farming practises to satisfy the rising demand for food supply, the adoption of AI in agriculture is anticipated to increase. (Newswires, 2023)

**Climate**

By supporting climate adaptation initiatives, AI has enormous potential for increasing climate resilience. Adapting to these difficulties is essential since billions of people live in high-risk regions that are vulnerable to natural disasters as a result of climate change. AI is useful for forecasting extreme weather occurrences and establishing early-warning systems because of its capacity to analyse big datasets and model complicated variables. For instance, programmes like Destination Earth are working to develop AI-based models that will track climatic events and give decision-makers crucial information for efficient response. By enabling interactive mapping of high-risk areas and real-time tracking of fire spread, AI is also essential for wildfire prediction and prevention. The $50 billion average annual worldwide cost of wildfires can be greatly decreased with this effective resource allocation. However, successful adoption requires more collaboration and equal access to AI tools. AI can assist businesses detect vulnerabilities, evaluate risks, and fortify their assets in order to maintain business continuity in the face of climate concerns. For AI to be widely used in

climate adaptation, hurdles including data compatibility, access to AI models, and technological know-how must be removed. The AI and ML Platform of the World Economic Forum is actively looking into ways to hasten the safe use of AI for climate change mitigation. AI can successfully address the global social, economic, and environmental effects of climate change by closing the innovation gap and encouraging collaboration. (World Economic Forum, 2022)

- **Risks**

Both opportunities and difficulties are presented by AI. Its data requirements raise privacy concerns, and bias and transparency problems continue. Choices may be restricted, unfavourable outcomes may arise, and societal growth may be hampered. Life-threatening situations can result from AI's incorrect predictions. Additional hazards include job security, security breaches, and cybercriminal exploitation. Adoption can be hampered by complexity, emotional intelligence, and anthropomorphizing AI. AI might stifle original thought and lead to complacency. Another issue is personal safety, particularly in automated law enforcement. Implementation with care is essential.

According to the Forbes Technology Council, there are 14 important risks of using AI:

1. AI has the potential to erode personal privacy.

Information from both historical and current times is highly sought after by AI. Without proper education for consumers on how to judiciously decide where AI should be utilized, whether it be locally, which tends to be safer for their data, or in the cloud, which exposes their data to continuous risks, our spoken and acted words will increasingly be documented.

2. AI lacks transparency and is biased.

Eli Pariser has issued a warning about "filter bubbles," or the perverse directions an algorithm can lead you if left unchecked. It can be innocent: For instance, after I "liked" one video from America's Got Talent, I keep seeing magician videos. The unsettling issue arises when these algorithms are used unrestrictedly in industries like healthcare. The issues with AI today are its bias and lack of transparency in the technology.

3. AI may hinder societal advancement.

History has shown that audacious acts by outliers—individuals bold enough to suggest innovative perspectives of the world—often catalyze societal advancement. Most AI systems predict the future based on past data. However, as AI takes on a more significant role in decision-making, the potential for outliers to disrupt the status quo and foster societal improvement may be limited.

4. AI might result in unjust consequences.

It carries several potential risks that could negatively affect our communities. Machine learning, a specific form of AI, learns from vast quantities of data, thus there is a risk of perpetuating data biases. Applications of AI such as predictive analytics and facial recognition could disproportionately harm protected groups by fostering discrimination in areas like access to credit, legal proceedings, and racial bias.

5. AI might reduce our inclination to tackle challenging decisions.

AI, which was designed to free humans, restricts our options. AI has shown to be quite effective at making it possible to manipulate and measure people. Our lives will not become better if we abdicate our duty to exercise personal vigilance because "AI does it better," avoid thinking outside the box because AI thinks it is unwise or refrain from acting independently because AI thinks it is dangerous.

6. Incorrect predictions by AI could potentially cause events that are hazardous to human life.

The reliability of the data used in AI training is crucial and directly influences its performance. From an industrial perspective, this is important, as there often is not enough data on real-life system failures for training purposes. Such lack of data can lead to risky situations when incorrect AI predictions result in dangerous incidents like industrial accidents or oil leaks. Therefore, there is a pressing need to focus on "explainable AI" and hybrid AI.

7. AI poses risks to employment and security.

Despite its potential to provide innovative solutions, there is opinion that it could lead to considerable job displacement and breaches in security. It is certain that AI can execute human tasks, but the full extent of this is yet undetermined. In terms of security, AI could potentially compromise physical, political, and digital safeguards, underscoring the need for more data engineers and cybersecurity experts.

8. AI can be exploited by cybercriminals for social engineering frauds.

Regrettably, these cybercriminals often adopt new technology faster and more effectively than the general public. When con artists use deepfakes and deep learning models as tools for social engineering to defraud people of money, personal information, and confidential intellectual property by pretending to be genuine individuals or organizations, AI starts to pose a risk to society.

9. AI could become too complex.

It would be concerning if AI consistently evolved towards becoming more complex and less transparent. To earn human trust and facilitate effective automation in the workplace, AI needs to be transparent and able to articulate the reasoning behind its suggestions.

10. AI falls short when it comes to emotional intelligence.

While it is adept at generating straightforward mathematical outcomes as a decision-making tool that draws on organized databases, it lacks emotional cognition. These algorithms are inherently designed to select the path of least resistance. If AI turns into our sole decision-making instrument, it could significantly impact our society.

11. Perceiving AI as 'human-like' could hinder its integration.

Today, one of the major challenges we face is the humanization of AI. When we attribute human characteristics to AI, we endow the technology with human traits. Instead of trying to see AI as human, we should conceptualize it as a new and familiar entity that is neither human nor animal. For successful AI adoption, it is crucial to regard it as our collaborator, rather than an extension of "us".

12. AI could hinder unconventional thinking.

A major worry is AI's potential to "pigeonhole" us. Consider your current favourite news platform, be it a website or an app. The more you consume a specific type of news, the more the underlying AI will feed you similar content, gradually narrowing your viewpoints. While AI excels at expediting numerous processes, it is vital that humans continue to foster "outside the box" thinking.

13. AI causes complacency.

Our minds have developed to make difficult, original, and perhaps nonsensical decisions. AI is logical and always learning. If we completely relinquish control, the result will be a universe that responds logically to the supplied facts but is also depressing and monotonous. Unfortunately, being lazy can cause us to not care and to get complacent with the outcomes.

14. AI could endanger individual safety.

Envision a scenario where law enforcement is managed by AI; we are already witnessing a global reckoning with human-managed law enforcement. Automating police work is not advisable. Should such technology fall into the wrong hands, we could be faced with a series of bleak scenarios. Potential negative consequences could range from violations of privacy to the application of automated lethal force. (Forbes Technology Council, 2021)

In the realm of AI, a delicate balance between opportunity and challenge emerges. As AI satisfies its data craving, privacy suffers, putting our personal information at danger. The persistence of prejudice in AI systems raises questions about transparency. Social advancement might be hampered, which would stifle creative thought. The risks of inaccurate AI forecasts are grave. Concerns are raised about job security and security breaches.

AI is used by cybercriminals in scams and stealing. Understanding is hampered by complexity, and AI is unable to comprehend emotions. It cannot be humanised since doing so leads to complacency. Personal safety becomes a critical concern, particularly in automated law enforcement. Effective terrain navigation becomes dependent on responsible implementation.

The environmental risks posed by large AI models are considerable. These models, such as GPT-3 (Figure 3), are associated with substantial carbon emissions due to the numerous parameters involved, energy demands of data centres, and dependency on grid efficiency. In particular, GPT-3 has been identified as the highest contributor of carbon emissions among these models. Even the relatively more efficient model, BLOOM, used a staggering 433 MWh of power during its training process. This showcases the potential environmental risks associated with the development and use of large AI models, indicating an urgent need for greater sustainability in AI training processes. (Stanford University, 2023)

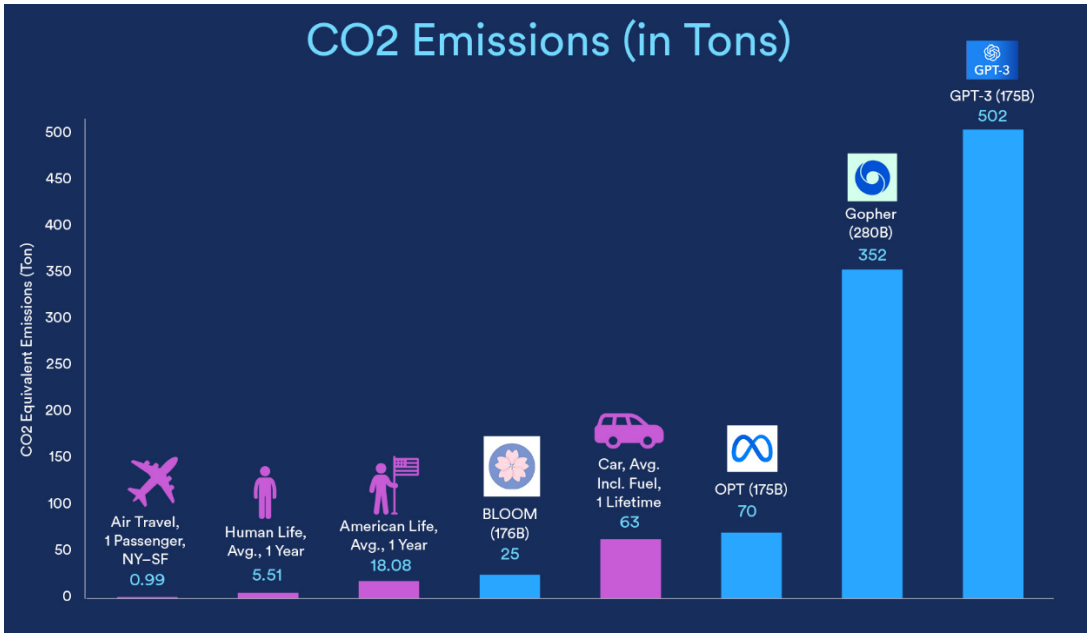


*Figure 3 – Tons of CO2 emissions per AI model (Stanford University,2023)*

# Chapter 2: Artificial intelligence for sustainable energy in France

Beginning with a worldwide overview of AI's involvement in sustainable energy, this chapter discusses how it may improve efficiency and reduce emissions. Following that, it concentrates on France and presents case studies from top energy firms including EDF, Engie, and TotalEnergies. The study finishes with a SWOT analysis of the AI-driven sustainable energy practises of these organisations, including their strengths and weaknesses, opportunities, and threats. The chapter concludes with a discussion of the specific challenges and potential facing AI in sustainable energy in the French setting.

## 2.1. Overview of AI Applications in sustainable energy

### Sustainable energy and its importance

The investigation of AI's potential to improve sustainable energy production efficiency shows that AI can offer significant improvements to meet the anticipated 50% rise in global energy consumption by 2050 while lowering greenhouse gas emissions.

By maximising solar and wind power sources, AI can increase the production of renewable energy. The best times for energy generation and delivery are predicted by analysing weather patterns, historical data, and current sensor data. (Bonis, 2023)

AI can increase efficiency in energy storage by analysing energy usage patterns and grid conditions to determine the optimal times to store excess energy and reintroduce it into the grid. As a result, fewer fossil fuel-powered backup generators might be required, which would cut greenhouse gas emissions. Additionally, AI can optimise the number of times a battery is charged and discharged, extending battery life and reducing replacement costs.

AI can increase efficiency in energy transmission and distribution by locating possible bottlenecks and places where energy is lost. Utility firms may concentrate on infrastructure upgrades that reduce energy waste thanks to this data-driven approach. (Bonis, 2023)

Energy demand management is another area where AI is heavily involved. Utility firms can better predict and manage peak demand periods by using AI to analyse energy usage trends,

which eases the load on the system and reduces dependency on fossil fuels. Additionally, it can streamline the operations of sectors that use a lot of energy, reducing both their overall energy use and environmental effect.

AI can find promising new materials and procedures in the development of sustainable energy technologies. AI can help enhance technologies like solar cells, wind turbines, and even entirely new forms of power generation by analysing R&D[1] data. (Bonis, 2023)

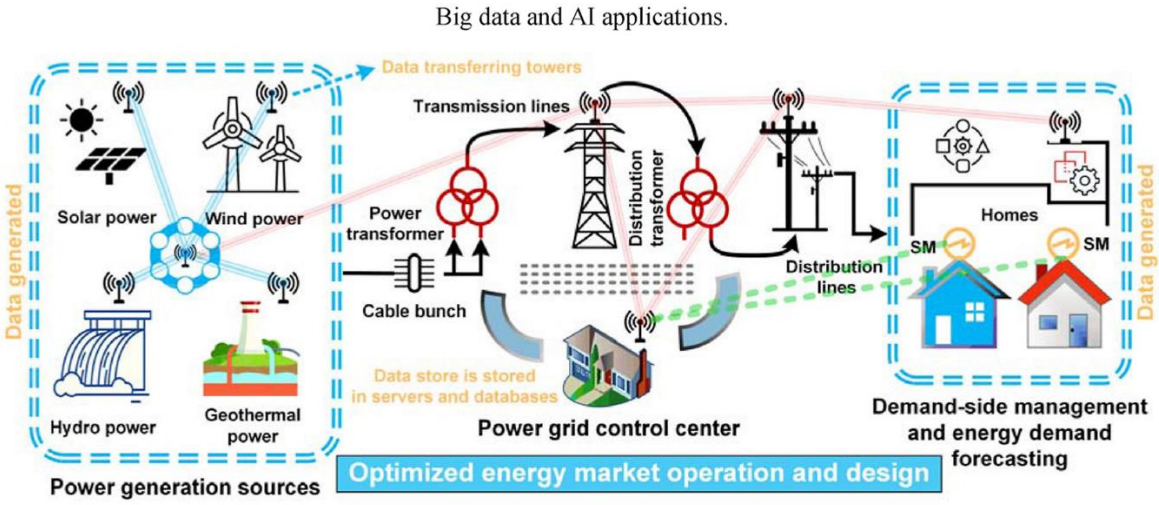


*Figure 4- Big data and AI applications (Science direct, 2021)*

The diagram illustrates the flow and interaction of data and energy in a modern, AI-optimized energy system.

On the left side, you see various energy sources like hydro, wind, solar, and geothermal. These represent the starting point of the energy supply chain. Alongside these energy sources, there are data transferring towers. These towers are crucial as they collect and transmit data about the energy production from these sources. This data might include information about the amount of energy generated, the operational status of the equipment, and environmental conditions affecting energy production.

[1] R&D is a systematic investigation, including research, development, and testing, necessary to improve or develop new products and knowledge.

This data is then sent to power grid control centres, which are represented in the middle of the diagram. These centres are equipped with servers and databases that store and process the incoming data. Here, AI and big data technologies come into play. They analyse the data to understand patterns, make predictions, and make decisions about how to best control and optimize the power grid. This could involve adjusting the operation of certain energy sources, rerouting power supply, or even scheduling maintenance for equipment.

Finally, on the right side of the diagram, you see demand-side management and energy demand forecasting. This is where AI uses the processed data to predict future energy demand and manage energy distribution accordingly. For instance, if AI predicts high energy demand in a certain area at a certain time, it can adjust the power grid operations to ensure that sufficient energy is supplied.

In simple terms, this diagram shows how data flows from energy sources, through control centres, and finally influences energy distribution. At each stage, AI and big data technologies are used to optimize the process, ensuring efficient and reliable energy supply. (Jiang W., 2021)

**AI applications in sustainable energy**

In the field of sustainable energy, AI has become a game-changing tool that helps improve the reliability, affordability, and efficiency of renewable energy sources.

- **Energy optimization:** By creating precise predictions and managing energy use, AI algorithms, in particular machine learning models, can dramatically enhance energy optimisation. By intelligently adjusting energy output according on current demand, they can reduce waste and make the best use of the resources that are already available.
- **Demand forecasting:** AI has demonstrated significant aptitude for predicting energy consumption. AI is able to estimate future energy needs with high accuracy by analysing a massive amount of data, including weather patterns, past energy use, and current demand. This allows utilities to better plan their resources and reduce the risk of energy waste.

- **Renewable energy integration:** AI makes it easier for renewable energy sources to seamlessly enter the system. It can control the erratic character of intermittent renewable energy sources like solar and wind, guaranteeing the constant availability of power and enabling a more major transition to these cleaner energy sources.
- **Smart Grid[2] management:** It has the ability to recognise anomalies, foresee problems, and plan self-repair procedures. Additionally, AI-driven predictive maintenance can reduce the cost of repair and replacement while assisting in preventing grid failures. (Journal of Cleaner Production, 2021)

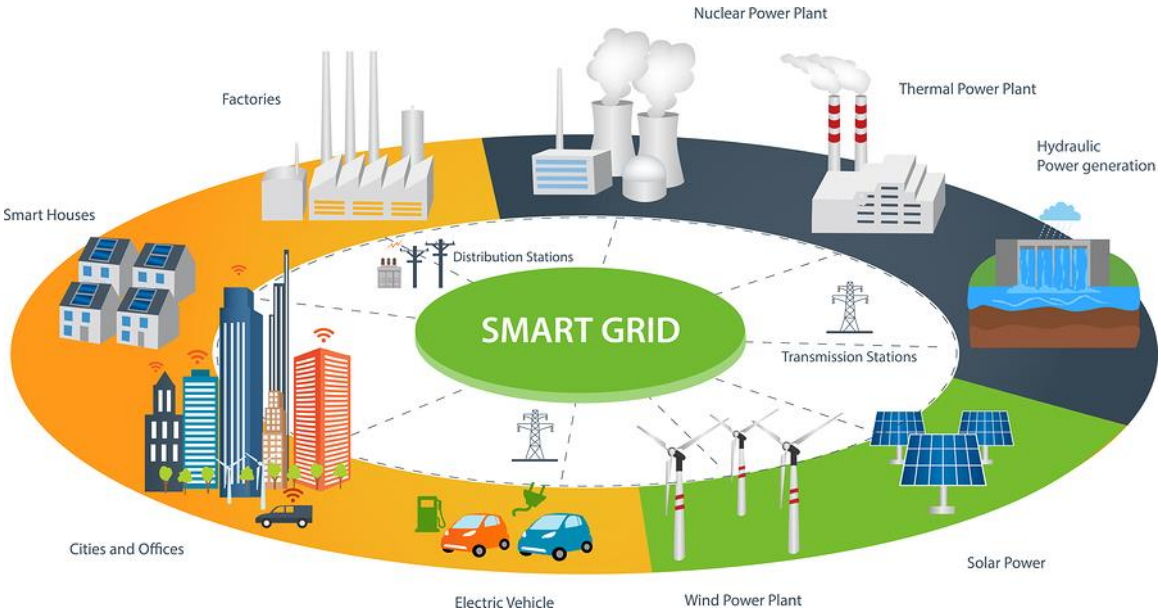


*Figure 5 - Illustration of Smart grid management (Energy Central, 2018)*

AI is a crucial component of the smart grid system that is controlling these more complex systems as more energy sources are dispersed throughout the grid, as well as Distributed Energy Resources (DER)[3] capabilities and negawatt functionality like demand response and energy efficiency. The grid is receiving clean energy from new sources, tonnes of information where it was previously unavailable, and is responding to events

[2] A Smart Grid is an electricity network based on digital technology that is used for supplying electricity to consumers via two-way digital communication.
[3] Distributed Energy Resources - smaller power sources that can be aggregated to provide power necessary to meet regular demand.

autonomously. AI can immediately analyse these unfathomably enormous data sets to bring stability to the system. (Energy Central, 2018)

- **Energy efficiency enhancement:** Both at the micro (building) and macro (city, grid) levels, AI can improve energy efficiency. AI, for instance, can enhance HVAC (heating, ventilation, and air conditioning) systems in buildings, which can save a significant amount of energy. (Journal of Cleaner Production, 2021)

**France**

A lot of work has been done in France to develop AI, including programmes like Scikit-Learn[4]. A national AI research strategy was unveiled in 2018 and calls for up to €1.5 billion in funding for AI research and development by 2023. (Sayritupac, n.d.)

The development of AI in France is an ongoing endeavour, as evidenced by the close to 600 startups specializing in AI as of March 2023. These companies vary widely in their focus and applications of AI. For instance, 127 companies provide data or cloud services, showing a deep interest in harnessing the power of large data sets and cloud computing to innovate in various sectors. Additionally, healthtech is a growing field of AI application in France, with 89 startups currently active in the sector. With 42 startups in the corporate services sector, AI's reach in streamlining business processes and corporate functionalities is also notable. (Statista, 2023)

A key area of interest is the incorporation of AI into numerous industries, particularly renewable energy. The use of AI in the renewable energy sector is now growing, and in the upcoming years, a wide range of AI-driven goods and services are anticipated to appear. Examples include tools for optimising cleaning periods for photovoltaic modules, energy management optimisation due to the increased usage of solar and wind energy and forecast models for wind production. (Sayritupac, n.d.)

It is anticipated that AI will eventually pervade the whole energy industry. Future scenarios envision a world where energy production is decentralised, self-organized, and responsive to

[4] Scikit-learn is an open-source machine learning library for Python programming language.

environmental factors, as well as a market for energy that can automatically correct itself and make extensive use of unstructured data using AI models.

However, there are issues with the possible misuse of AI, such as nudges[5] or deceptive methods intended to influence consumer behaviour. There are rules in place to stop this kind of abuse. One major worry is that energy AI systems might persuade end users to create or use energy at predetermined intervals. Despite these reservations, properly applied AI may help cut back on unnecessary energy use and increase resource efficiency.

AI has shown to be a key element in the shift to renewable energy. Its potential uses span from demand forecasting and energy optimisation to grid management and improved renewable energy integration. It is admirable that France is committed to using AI in the field of renewable energy, but it is crucial to address worries about potential abuse and increase funding for ongoing research and development. When used ethically and successfully, AI has the potential to drastically alter the energy landscape and advance the global effort to combat climate change. (Sayritupac, n.d.)

We now transition from theory to practise after giving a thorough outline of AI's possibilities in sustainable energy. It is useful to look into specific instances - case studies that highlight the use of AI in real-world settings - in order to properly understand the transformative potential of AI in the French energy sector.

### 2.2. Case Studies of AI for Sustainable Energy in France

In this chapter, we examine the function of AI at various levels of the energy industry and provide evidence for its significance using the examples of three distinctive businesses: EDF, Engie, and TotalEnergies. A case study of EDF, a state-owned utility, sheds light on the use of AI to ensure the safety of nuclear power plants. Engie, a multinational energy company with a strong commitment to sustainability, makes a case for how AI might improve the administration of smart grids and encourage the integration of renewable energy sources. The

[5] Nudges are subtle suggestions or reinforcements that aim to influence the behavior of individuals or groups.

promise of AI in hydrocarbon exploration[6] and renewable technologies is best illustrated by TotalEnergies, a major oil and gas company that is pursuing a sustainable energy strategy.

The decision to choose these three entities is important for a number of reasons. A comprehensive understanding of AI's revolutionary capacity across all sectors and scales, from a state-owned utility to global enterprises, is made possible by each party's unique position within the French energy industry. Second, their ground-breaking AI applications show how this technology may boost operational effectiveness, improve safety protocols, and aid in the shift to renewable energy sources. Finally, they provide a thorough grasp of the current journey towards AI integration and its potential to propel a sustainable energy future through their difficulties and future directions. The analysis of these businesses supports the chapter's main thesis, which is that AI is a critical catalyst for the French energy sector's transition to sustainability rather than only an additive.

### 2.2.1. EDF's use of AI in renewable energy forecasting

Electricité de France, or EDF, is a pioneer in the energy sector and is dedicated to using renewable energy sources. For effective grid management and energy generation optimisation, accurate forecasting of the production of renewable energy is crucial. EDF has utilised AI technologies to overcome the problems in forecasting renewable energy.

**Background**: Because renewable energy sources like solar and wind are inherently changeable, it is difficult to predict them accurately. Because of the enormous amount of data and complex patterns involved, traditional forecasting techniques frequently produce projections that are less than ideal. EDF turned to AI after realising the need for more advanced forecasting methods. (EDF, 2023)

EDF decided strategically to use AI in renewable energy forecasts to increase precision and effectiveness. EDF sought to overcome the drawbacks of conventional approaches and improve their predicting abilities by utilising the potential of AI.

[6] Hydrocarbon exploration is the process by which potential sites for extraction of petroleum and natural gas are identified and assessed.

**AI techniques used by EDF**: Analysis of historical data, weather trends, and other aspects affecting energy production were made possible by machine learning algorithms. Deep learning methods, which use neural networks, were used to capture intricate linkages and patterns in the data, producing more precise predictions. (EDF, 2023)

**Data collection and integration**: EDF gathered a variety of statistics, including as information about the grid, market prices, weather information, and historical energy production. These datasets were combined in order to build a thorough and reliable foundation for the AI models. Advanced data pre-processing methods were used to clean up the data and convert it into a format that was appropriate for study. (EDF, 2023)

**Model development and training**: Using the combined datasets, EDF created and trained AI models. This entailed creating neural network designs, choosing appropriate machine learning methods, and refining model parameters. To confirm the models' correctness and dependability, they were trained using historical data and evaluated. (EDF, 2023)

**Implementation and results**: EDF integrated the AI-based forecasting models into their renewable energy operations after careful testing and validation. EDF was able to successfully manage grid integration, arrange maintenance tasks, and optimise energy generation thanks to the models' more precise and timely estimates. The application of AI led to increased operational effectiveness, decreased expenses, and better overall performance. (EDF, 2023)

EDF is fully committed to implementing the European Green Deal and making Europe the first continent to be CO2-neutral by 2050. Decarbonizing power and electrifying a sizable portion of the economy are necessary for this. EDF intends to devote all of its resources to the European Green Deal in order to support the achievement of this goal.

EDF is providing consumers and citizens with superior digital solutions and AI part of this commitment while preserving their privacy. This is in keeping with their strategic choice, mentioned in the preceding section, to use AI in renewable energy forecasts to increase accuracy and efficiency. (EDF, 2019)

“The Green Deal is a fantastic opportunity. Decarbonised electricity can become a vector in the competitive decarbonisation of the European economy, and the EDF Group is fully mobilised to speed up this historic transition.” declared Jean-Bernard Lévy, the EDF Chairman and CEO.

EDF is a prominent player in the energy transition due to its usage of AI in renewable energy forecasting and dedication to the European Green Deal. EDF is setting the bar high for achieving Europe the first carbon-neutral continent by 2050 with a 90% decarbonized generating mix. (EDF, 2019)

**Future directions and innovations**: EDF is still dedicated to advancing AI in projecting renewable energy. To further improve its forecasting abilities, they are actively investigating new AI techniques like reinforcement learning and genetic algorithms. EDF is also making research and development investments to better integrate renewable energy sources into the grid and include real-time data. (EDF, 2023)

Aside from AI, EDF is also involved in significant renewable energy projects, such as the largest offshore wind farm in France, which is being managed by EMMN[7], an EDF-owned business. The 1 GW project, which will power 800,000 homes, highlights EDF's important contribution to the growth of renewable energy. This project will help France reach its goal of 40 GW of renewable energy by 2050, with construction expected to start around 2026 and operations beginning in 2031. EDF's position in the renewable energy industry is strengthened by this strategic involvement. (Euractiv, 2023)

Another illustration is the fact that Agregio Solutions, a subsidiary of EDF, is setting the standard for creating systems that integrate intermittent renewable energy into the electricity grid. Agregio Solutions is emphasising "flexibilities" - voluntary power modulation techniques that maintain grid balance - in order to meet France's aim of 40% renewable energy by 2030.

[7] Eoliennes en Mer Manche Normandie (EMMN), a joint company of EDF Renewables and Maples Power.

Agregio Solutions, a pioneer in flexibilities since its founding in 2023, boosts its efficiency with AI-assisted storage and smart energy management. In order to balance the grid, they have created a virtual power plant that employs AI algorithms to optimise diverse energy sources. (EDF, 2023)

Agregio Solutions also employs AI to assist clients in concluding Corporate Power Purchase Agreements, aggregating amounts of renewable electricity for inclusion in supply contracts. In order to optimise batteries for frequency regulation services and grid support during consumption peaks, they also use AI in energy storage management.

The company's usage of AI by EDF in projecting renewable energy has changed the game. The accuracy of EDF's estimates for the production of renewable energy has greatly increased thanks to the use of machine learning algorithms and neural networks. This has made it possible for companies to streamline operations, cut costs, and aid in the grid's integration of renewable energy sources. (EDF, 2023)

### 2.2.2. Engie’s Smart Grid management

Global energy giant Engie is dedicated to making the shift to a future powered by sustainable energy. It is essential to examine Engie's adoption of Smart Grid management solutions and its effects on the energy industry since Smart Grid management is essential for improving grid reliability, encouraging renewable energy integration, and optimising energy distribution.

Engie has been a leader in utilising AI and robots to optimise its energy management systems, particularly in the area of smart grids. They have created and are putting into use tools to manage and improve several facets of their operations.

Robot and drone proof-of-concept from the lab: Engie's dedication to incorporating cutting-edge technologies into their energy grid management is demonstrated by this initiative. They have created solutions that make it possible for public lighting systems to be cleaned and maintained automatically. A smart grid's management requires a technology that improves operational effectiveness, lowers costs, and increases safety. This technology is powered by

AI and lidar. Engie's effective management of the smart grid is directly impacted by the ongoing development and enhancement of these tools. (Engie Lab CRIGEN, 2022)

Application BM Conso: The BM Conso tool employs AI to forecast future demand and coordinate delivery schedules in order to optimise the consumption and delivery of wood in biomass facilities. This tool's incorporation into Engie's energy management demonstrates how the company is using AI to organise and maximise its renewable energy sources within the smart grid. Engie guarantees that renewable energy sources are used as efficiently as possible by properly estimating biomass usage, which boosts the overall effectiveness of their smart grid system. (Engie Lab CYLERGIE, 2022)

**Background:** Due to deteriorating infrastructure, rising demand, and the incorporation of decentralised renewable energy sources, the traditional power system is facing difficulties. Engie understood the need for a smarter and more adaptable grid management strategy to meet these obstacles. Demand response and efficient energy distribution are made possible by smart grid technologies, which make use of cutting-edge digital solutions and real-time data analytics. (Engie, 2023)

Key features of Smart Grid management:

1. Advanced metering infrastructure (AMI): AI has a substantial positive impact on AMI systems. The real-time data acquired by AMI is analysed by AI algorithms, enabling more precise energy consumption forecasts and making it easier to conduct successful demand response initiatives. In order to adopt dynamic pricing models that promote energy saving, energy firms like Engie can utilise AI to, for instance, estimate peak usage times using data from smart metres.

2. Distribution automation: The distribution network's many components are intelligently analysed, monitored, and managed using AI technology. Machine learning systems, for instance, can learn from historical fault data to anticipate and stop such problems in the future. AI assists in improving energy flow management in this way, which shortens outage times and increases reliability.

3. Demand response and energy efficiency programmes both heavily rely on AI. It is capable of analysing consumption trends and identifying peak energy demand periods. With this knowledge, Engie can offer incentives to clients to lower their energy use during these peak times, assisting in load balancing and easing system stress.

4. AI and machine learning are essential technologies for predictive maintenance and sophisticated analytics. Engie is able to learn about the condition of its assets and foresee probable faults thanks to its analysis of data from sensors and other sources. Preventing breakdowns and reducing downtime are two benefits of this proactive maintenance strategy. (Engie, 2023)

**Implementation and results**: Engie managed the Smart Grid with success across all of its distribution networks. The effective grid operations, greater customer experience, and improved integration of renewable energy were made possible by the integration of cutting-edge technologies and data-driven solutions. Engie raised overall grid resilience, improved asset utilisation, reduced energy losses, and improved load management. (Engie, 2023)

Grid code compliance assessment for PV[8] plant designs: Engie Laborelec's novel approach to grid code compliance is based on an understanding of the actual capabilities and behaviours of inverters. The huge amounts of data created by these inverters may be analysed with a great deal of assistance from AI thanks to its predictive skills, which can yield insights beyond the bare specifications. On the basis of this data, machine learning algorithms can be trained to forecast the behaviour of inverters under various circumstances, increasing grid stability and the accuracy of assessments of code compliance.

The FORWARD2030 project's energy hybridization goal is to create a multi-vector energy system that combines multiple renewable energy sources with energy storage options. An essential part in managing such a complicated system can be played by AI. The allocation of energy storage can be optimised to ensure a steady supply of energy by using machine

[8] A photovoltaic system, or a PV system, converts sunlight into electricity using a technology called solar cells.

learning algorithms to estimate consumer demand and energy production from renewable sources. The intricate interdependencies of such a system can also be managed and analysed using AI, enabling real-time modifications to preserve grid stability. (Engie Laborelec, 2022)

**Challenges**: During the installation of Smart Grid management, Engie encountered difficulties with data security, system interoperability, and stakeholder cooperation. Strong cybersecurity measures, open standards, and good communication with customers, authorities, and technology suppliers were essential to overcome these obstacles. Engie gained important knowledge in navigating legal frameworks, dealing with privacy issues, and encouraging teamwork to guarantee successful implementation. (Engie 2023)

**Future directions and innovations**: Engie keeps looking at cutting-edge technologies and creative fixes to improve the management of the Smart Grid. This includes using blockchain, AI, and Internet of Things (IoT) technology to enable peer-to-peer energy transactions, optimise energy dispatch, and improve data analytics. Engie continues to lead the way in innovation for the future of grid management and energy distribution. (Engie 2023)

A digital twin for an industrial furnace has been created by Engie's CRIGEN Lab and is connected in real-time to PTC's[9] IoT ThingWorx platform. Real-time 3D multiphysics simulation of the furnace is made possible by this digital twin, which offers helpful insights for maximising its performance during its conversion to hydrogen use. This strategy exemplifies Engie's creative application of AI and IoT to manage their energy assets and make the switch to a more sustainable energy future. By demonstrating the potential of AI and IoT in improving the management of the smart grid, this project's successful completion provides a template for comparable applications in other energy assets. (PTC, 2023)

Tata Consultancy Services' (TCS) Machine First Delivery Model has enabled Engie to automate and employ AI to simplify its processes. For task execution, this approach prioritises machine capabilities, improving efficiency, accuracy, and productivity. This is in

[9] PTC Inc. is a software and services company based in Boston, Massachusetts.

line with the study's main thesis, which demonstrates how AI might be useful in improving energy management and distribution in a smart grid system similar to the one used by Engie.

Engie also employs Ignio, a cognitive automation programme that can anticipate and avoid problems. Here, the importance of AI is highlighted because it helps to guard against future issues, cut down on service outages, and guarantee continuous service delivery.

'My programme for action' was another initiative that Engie put into action. Although the sample leaves out specifics, this effort probably makes use of AI and data analytics to enhance consumer engagement and promote energy-efficient practises. (TCS, 2023)

Last but not least, Engie's goal to reach net-zero emissions by 2045 demonstrates their commitment to renewable energy. By offering the tools required for smart grid management, predictive maintenance, and efficient energy use - all of which are key elements in the case study. AI plays a crucial role in achieving this aim. (TCS, 2023)

### 2.2.3. TotalEnergies AI application in hydrocarbon exploration

A multinational energy corporation that engages in hydrocarbon exploration is called TotalEnergies. AI’s potential to enhance the effectiveness and efficiency of the exploring process for hydrocarbons is enormous.

**Background:** Exploration for hydrocarbons include looking for and assessing possible oil and gas reserves. Traditional exploration techniques mainly rely on the interpretation of seismic data, which can be labor-intensive, time-consuming, and biassed by humans. AI-based technologies have possibilities to improve and streamline the exploration process, resulting in better judgement and higher success rates. (TotalEnergies, 2023)

Key AI applications in hydrocarbon exploration:

1. When analysing seismic[10] data, TotalEnergies uses AI-based techniques for a more accurate and effective evaluation. Automated feature extraction and pattern detection

[10] Seismic data refers to the measurements of the propagation of seismic waves. Seismic waves are waves of energy that travel through the Earth's layers.

from seismic images are made possible with the use of machine learning techniques like convolutional neural networks (CNNs). This makes it easier to distinguish between subsurface formations and potential sites for hydrocarbon reserves.

2. TotalEnergies uses AI-driven predictive models to assess the likelihood of finding hydrocarbon reserves in particular areas. These models can find connections and correlations between geological characteristics and productive hydrocarbon deposit discoveries by utilising machine learning techniques and data from prior excavation operations. This enables TotalEnergies to allocate resources more effectively and rank exploration targets wisely.

3. To integrate and conduct in-depth analyses of enormous volumes of geological and geophysical data from numerous sources, TotalEnergies makes use of AI technology. AI techniques can identify possible excavation sites when data from sources like well records, seismic surveys, and satellite photography is integrated. This data-driven strategy improves decision-making precision and lowers the risks of exploration.

4. To simulate and improve excavation scenarios, TotalEnergies uses virtual well planning tools with AI integration. These techniques take into account a number of variables, including geological characteristics, reservoir characteristics, excavation parameters, and financial constraints. AI algorithms examine these factors to determine the best locations for wells, extraction techniques, and economical excavation methods. (TotalEnergies, 2023)

**Implementation and results**: AI technology have been successfully integrated into TotalEnergies workflows for hydrocarbon exploration. Accuracy, efficiency, and decision-making have all significantly improved as a result of the incorporation of AI. More accurate identification of probable oil resources has resulted from the use of AI in the interpretation of seismic data. The success rates of drilling operations have increased as a result of improved targeting of exploratory areas brought about by predictive modelling. Utilising AI-driven data integration and analysis has allowed for better decision-making and decreased the risks associated with exploration. Additionally, drilling operations have been optimised via virtual

well planning, which has reduced costs and increased effectiveness overall. (TotalEnergies, 2023)

In addition to incorporating AI into its standard hydrocarbon exploration procedures, TotalEnergies is also incorporating alternative energy technology, such as electric vehicle batteries. The ACC battery plant's construction heralds the company's strategic pivot towards renewable energy. TotalEnergies is also utilising AI to cut expenses and streamline the exploration process. The company wants to increase energy storage, encourage the use of electric vehicles, and help the world become carbon neutral by implementing AI in battery production. These programmes demonstrate how TotalEnergies is pursuing a sustainable energy future by combining traditional and cutting-edge technology. (Investing, 2023)

**Challenges**: These include the accuracy and dependability of the models, the model quality and availability, the computing needs, and the regulatory issues. In order to overcome these issues, TotalEnergies has made investments in strong data quality control procedures, trained AI models on huge and varied datasets, optimised computational infrastructure, and ensured regulatory compliance. The business has also picked up important lessons about how to balance the use of AI-driven insights with human expertise, preserve the interpretability of outcomes, and continuously improve AI models. (TotaEnergies, 2023)

**Future directions and innovations**: The advancement of AI applications in hydrocarbon exploration is still a priority for TotalEnergies. The integration of real-time data streams, sensor networks, and autonomous systems for data collection and processing are some future directions. In addition, TotalEnergies wants to investigate how AI might be used to enhance reservoir management, optimise drilling operations, and facilitate the switch to sustainable energy sources.

Accuracy, efficiency, and decision-making within the industry have significantly improved because to TotalEnergies deployment of AI technologies in hydrocarbon exploration. TotalEnergies has improved drilling operations, improved exploration methods, and increased their grasp of subsurface geology by utilising AI algorithms for seismic data

interpretation, predictive modelling, data integration, and virtual well design. (TotaEnergies, 2023)

Similar to how TotalEnergies views the Solar Mapper tool promoting the use of solar power throughout the world, the business anticipates that the use of AI in hydrocarbon exploration will set a standard for the sector. This innovative strategy might encourage wider adoption of AI in the energy industry, spurring improvements in efficiency, accuracy, and sustainability on a worldwide scale.

Furthermore, TotalEnergies can better align with its objective of having net-zero emissions by 2050 thanks to the AI integration into the hydrocarbon exploration process. TotalEnergies can lessen the effect of exploration on the environment by increasing efficiency and using fewer resources. (Google Cloud, 2023)

### 2.3. SWOT analysis of EDF, Engie, and TotalEnergies

By performing a SWOT analysis on the EDF, Engie, and TotalEnergies case studies, we are able to acquire a thorough understanding of the variables influencing the success of AI-driven sustainable energy practises in France.

**Strengths:**

1. **Strong AI application:**
    - EDF: Predicts solar panel efficiency using Meteocontrol's AI engine. It enables better energy management and more precise forecasting.
    - Engie: Uses AI to oversee the Smart Grid. Tools for optimising many elements, such anticipating energy demand and projecting biomass consumption, incorporate AI.
    - TotalEnergies: Uses AI in hydrocarbon exploration to more precisely evaluate seismic data, prioritise exploration aims strategically, analyse data in-depth, and simulate excavation scenarios.

2. **Diverse Energy Portfolio:**
    - EDF is an electrical generation specialist, specialising in nuclear and renewable energy.
    - Engie: Known for providing electric utility services using fossil, nuclear, and renewable sources.
    - TotalEnergies: This company engages in all facets of the oil and gas sector and makes investments in alternative energy sources.
3. **Focus on sustainability:** All three companies have established challenging sustainability objectives, highlighting their dedication to lowering carbon emissions and promoting a switch to renewable energy sources.

**Weaknesses:**

1. **Data quality and availability:** For precise projections and top performance, these organisations AI solutions heavily rely on high-quality data. These devices effectiveness may be hampered by inaccurate or poor data.

2. **Regulatory considerations:** Because they operate in a highly regulated industry, these businesses are continuously forced to change, which may be challenging and expensive.

**Opportunities:**

1. The demand for renewable energy is increasing as the world places more attention on lowering carbon emissions. These businesses now have excellent potential to increase their portfolio of renewable energy sources and profit from their ongoing initiatives.

2. The ongoing development of technology offers prospects for further integrating cutting-edge AI techniques, blockchain, and IoT into their operations. This can increase operational effectiveness, data analysis, and decision-making processes.

**Threats:**

1. **Cybersecurity risks:** They now face a serious danger from cyber threats due to the rising digitalization of their activities. These dangers could jeopardise their reputation, cause data breaches, and interfere with their business operations.
2. **Environmental regulations:** There may be difficulties for some of their operations as governments around the world enact stronger environmental rules, particularly for TotalEnergies hydrocarbon exploration.
3. **Market competition:** Due to the constant influx of new competitors, the energy business is extremely competitive. These businesses must continuously innovate and adjust to shifting market circumstances to sustain their market position.

### 2.4. Challenges and Opportunities of AI for Sustainable Energy in France

The crucial role AI plays in the French energy sector will be discussed in the following section. We will discuss both the fascinating possibilities AI offers for managing sustainable energy sources and the considerable difficulties it creates, such as ethical issues and the necessity for continued study. We seek to shed light on the way towards a fair and moral use of AI in France's sustainable energy sector as we make our way through this difficult environment.

**Opportunities**

The use of AI is already widely used in the energy and environmental industries. AI helps with the administration of smart power grids, energy-saving techniques, and forecasting extreme weather events or climate change. Major international corporations (EDF, Engie, LEGRAND, VEOLIA), SMEs (like SOCOMEC), and cutting-edge start-ups (like DC BRAIN, ENERGIENCY) across the value chain are only a few of France's many assets in these fields. The nation is also home to important public research institutions like CEA. (Direction Générale des Entreprises, 2019, p.17) Due to these advantages, a large number of projects and demonstrators using AI components have been implemented. Within the framework of public-private partnership strategies that will be strengthened by the European

component, this strong base might serve as the cornerstone of a stronger and more focused national goal for AI in energy and the environment. (Sayritupac, n.d)

AI is being utilised in the energy sector to clean solar modules as efficiently as possible, manage renewable energy resources more effectively, and forecast wind energy production. With an emphasis on the renewable energy industry, France is also working to introduce AI as a study issue in society more thoroughly. The nation has set aside a sizeable budget for AI research and development, demonstrating its dedication to this area. (Direction Générale des Entreprises, 2019, p.28)

Figure 6 illustrates the diverse applications of AI in the energy industry, as outlined by Next Kraftwerke . The figure highlights how AI can enhance efficiency and security within the sector, presenting significant opportunities for France. It demonstrates the role of AI in managing the growing complexity of power grids, which is a result of increased decentralization and digitalization. The figure also shows how AI can enhance the accuracy of forecasts in power trading. Furthermore, it depicts the potential of AI in assisting consumers to contribute to a more stable and environmentally friendly electricity grid through the use of smart homes. These applications of AI provide France with a promising avenue for advancing its energy sector. (Next Kraftwerke, n.d.)


*Figure 6 - Artificial intelligence in Energy industry (Next Kraftwerke, n.d.)*

**Challenges**

The age of AI is still young. The sophisticated cognitive abilities of humans cannot be compared to the methods currently under development. The enormous amount of study that will need to be done over the next 20 years in order to replicate human learning capacities successfully cannot be hidden by the current progress, which is remarkable for some very particular tasks. One of France's first opportunities comes from this. The dual difficulty is finding and keeping France's top AI researchers. (Sayritupac, n.d) This necessitates efforts in several areas, including prioritising investments in active research fields (learning with little data, robustness of models in the face of disruption, explainability, and so on), encouraging interdisciplinary collaborations in call for projects, as AI is a discipline that necessitates strong collaboration between scientific expertise, business, and IT, and ensuring that R&D aid and tax support target priority scientific and technological obstacles rather than engendering them. (Direction Générale des Entreprises, 2019, p.24)

Making all information as accessible as possible during the research and development stage of AI technologies is the second goal of the actions. The suggested initiatives seek to establish a clear and legitimate boundary between the experimental stage and the usage of data for commercial purposes. This distinction can make it much easier to retrieve data while a project is being developed. The sustainability of AI technology breakthroughs in France depends on easy access to data. (Sayritupac, n.d) For instance, the vast majority of AI innovations built by French start-ups in the field of health were done using data from other nations, increasing the possibility that activities would be moved to those nations and hurting the French ecosystem. (Direction Générale des Entreprises, 2019, p. 28)

However, there are moral issues with using AI, particularly with regard to manipulating users. It is crucial to make sure that AI does not take advantage of user behaviour for financial gain as it integrates more deeply into the energy industry. The European Union has published a series of regulations to stop AI systems from deceiving customers, which might be a big problem for France's AI and renewable energy industry.

# Chapter 3: Result analysis

This chapter thoroughly examines the research findings, evaluating them in light of AI's potential to advance sustainability and social good in the energy industry. The chapter ends with actionable suggestions based on these discoveries, providing insightful information for practical applications and further study in this area.

## 3.1. Overview of research findings

The research findings underline the great potential of AI in boosting sustainable energy production efficiency. AI is forecast to play a major role in tackling the anticipated 50% rise in global energy consumption by 2050, while simultaneously lowering greenhouse gas emissions. (Nature, 2020)

The ability of AI to maximise the use of renewable energy sources like solar and wind power is one of the study's significant findings. By analysing weather patterns, historical data, and current sensor data, AI can predict the optimal energy generation and delivery times. (IEEE, 2022)

AI can also improve energy storage efficiency by analysing grid conditions and energy usage patterns. This makes it possible to decide when it is ideal to store excess energy and reintroduce it to the system. As a result, there might be less need for backup generators that run on fossil fuels, which would reduce greenhouse gas emissions. Additionally, AI can optimise a battery's charging and discharging cycles, extending battery life and lowering replacement costs.

AI can spot potential bottlenecks and places where energy is lost in the energy distribution and transmission process. Utility firms may concentrate on infrastructure enhancements that reduce energy waste according to this data-driven methodology.

AI is important for managing energy demand as well. Utility firms may better predict and manage peak demand periods, lessen system load, and reduce reliance on fossil fuels by evaluating energy usage trends. Additionally, AI can improve efficiency in energy-intensive industries, lowering their overall energy use and environmental effect. (Nature, 2020)

Lastly, AI can aid in the development of sustainable energy technologies by identifying promising new materials and processes. AI can enhance technologies like solar cells, wind turbines, and even new power generation types by analysing research and development data. (IEEE, 2022)

Key results:

1. AI has been seen as a key instrument in reducing the consequences of climate change. It can close the innovation gap and promote teamwork, which will aid in addressing the social, economic, and environmental effects of climate change on a worldwide scale. (World Economic Forum, 2022)
2. There are a number of problems associated with AI, such as privacy concerns owing to its vast data requirements, ongoing bias and transparency difficulties, potential choice restrictions, and the chance of unfavourable consequences. Security lapses, cybercriminal exploitation, and job security are further worries. (Forbes Technology Council)
3. Privacy may be jeopardised by AI's desire for previous and present data. To maintain data security, users must be trained so they can choose where AI is used.
4. If AI algorithms are not reviewed, they may produce false recommendations or "filter bubbles" due to prejudice and a lack of transparency.
5. There is fear that AI might obstruct social advancement, underlining the necessity for cautious AI system adoption and control.
6. AI holds great promise for boosting the generation of sustainable energy, which can satisfy the projected increase in global energy demand while reducing greenhouse gas emissions.
7. AI can efficiently control energy demand while enhancing the efficiency of energy storage, transmission, and distribution. Additionally, it can support the development of technology for renewable energy. (Bonis, 2023)
8. Businesses like EDF, Engie, and TotalEnergies have demonstrated skills in using AI and offer a varied array of energy products, but they confront difficulties with data availability and quality as well as regulatory issues.

9. Case examples highlight the usefulness and advantages of AI in the energy industry, such as Engie's effective use of AI to run the Smart Grid. Engie was able to increase the grid's general resiliency while also enhancing asset utilisation, lowering energy losses, and load management. (Engie, 2023)

### 3.2. Interpretation of results

While AI has the potential to revolutionise a number of industries, it also offers substantial dangers and obstacles that must be properly handled. This is according to research on AI's potential advantages and difficulties, particularly in the context of social good.

The examination of privacy difficulties, prejudice, and transparency problems draws attention to the ethical challenges that must be taken into account when putting AI systems into practise. To guarantee that the employment of AI is consistent with societal values and norms, this points to the necessity for strong ethical frameworks and laws.

Concerns about the potential for AI to restrict choice and discourage creative thought may be seen as a demand for a balanced approach to the adoption of AI, where the value of human creativity and decision-making is evaluated against the advantages of automation and efficiency.

It is particularly intriguing how AI may be used in the energy industry. It implies that AI may be essential in solving some of the planet's most severe environmental problems. However, the difficulties experienced by companies in this industry, including data accessibility and quality problems, show that there are still major obstacles to be addressed.

The investigation of AI’s important involvement in the French energy industry exposes both the promising potential and considerable difficulties it poses. The use of AI in managing renewable energy sources and the moral questions it raises point to a difficult terrain that needs cautious navigating.

The application of AI in the energy and environmental sectors is already widely covered in the opportunities section. The management of intelligent power networks, energy-saving methods, and the prediction of extreme weather occurrences are highlighted. Major businesses, SMEs, and innovative startups are all using AI in France, which points to a

healthy ecosystem for AI development in the energy industry. The nation's substantial budgetary investment to AI research and development further demonstrates its dedication to this field.

The article does, though, recognise the difficulties with AI. It emphasises how nascent AI is and how human beings' highly developed cognitive capacities cannot be compared to the techniques currently being developed. This indicates that even while AI has advanced significantly, much work must be done before it can fully realise its promise.

Also covered is AI's involvement in the realm of sustainable energy, where it has emerged as a game-changing instrument for enhancing the dependability, accessibility, and effectiveness of renewable energy sources. It shows a variety of AI applications, including energy optimisation, demand forecasting, integrating renewable energy, managing smart grids, and improving energy efficiency.

### 3.3. Recommendations

1. It is advised to increase investment in AI research and development given the significant potential of AI in enhancing sustainable energy production. This might result in the identification of more effective algorithms and creative AI applications in the energy sector. (World Economic Forum, 2021)
2. A skilled workforce is necessary to take full advantage of AI's advantages. Prioritise spending on AI education and training initiatives. This will aid in the upkeep and continued development of AI technologies in addition to their implementation.
3. High-quality data are a key component of AI algorithms. Efforts should be made to improve the quality and availability of data. Better data collection techniques could be used, and strong data management systems could be created. (Martin, 2022)
4. Because the energy industry is heavily regulated, any application of AI must adhere to all applicable laws and regulations. It is advised to interact with regulatory organisations to comprehend the regulatory environment and guarantee compliance.
5. It is important to promote cooperation between various stakeholders, such as energy companies, providers of AI technology, researchers, and policymakers. This can

encourage the exchange of best practises and knowledge, which can result in more efficient solutions. (World Economic Forum, 2021)

6. As the world transitions to a more sustainable future, promoting sustainability should be the main goal of AI applications in the energy sector. This might entail creating AI algorithms that maximise the use of renewable energy sources and lower greenhouse gas emissions. (World Economic Forum, 2021)
7. Technology is essential to make sure that AI is applied responsibly as technology continues to play a bigger part in our lives. Addressing difficulties with privacy, bias, and transparency is part of this.
8. The field of AI is quickly developing, thus it's critical to be ready for new difficulties. This could entail performing frequent risk assessments, creating backup plans, and staying current with industry developments.

**Recommendations for EDF:**

1. Increase the use of AI to forecast the effectiveness of solar panels and other renewable energy sources. Better energy management and more accurate forecasting may result from this.
2. Invest in training programmes to improve workforce's AI skills. Then there will be ability to use AI technology more effectively as a result, giving you an advantage over your rivals.
3. To acquire access to the most recent AI technologies and knowledge, think about cooperating with AI technology suppliers.

**Recommendations for Engie:**

1. Keep using AI in demand response projects. AI can assist in managing high demand periods and better understanding consumption trends.
2. Use AI and machine learning for predictive maintenance. This can lessen downtime and maintenance costs by helping to predict and prevent faults.

3. Encourage the application of AI to energy efficiency initiatives. AI may assist in locating potential energy-saving options and increase the general effectiveness of your business operations.

**Recommendations for TotalEnergies:**

1. Keep incorporating AI into hydrocarbon exploration. AI can assist you in prioritising exploration sites, simulating excavation scenarios, and more precisely evaluating seismic data.
2. Pay attention to sustainability; coordinate your AI projects with your drive for net-zero emissions by 2050. You may improve productivity and lessen the impact of your operations on the environment with the aid of AI.
3. Explore novel uses of AI in the energy sector, such as in reservoir management and drilling operations.

# Conclusion

The primary objective of this research was to delve into the potential applications and impacts of AI in the energy sector, with a particular emphasis on sustainability and social good. The initial challenge identified was the need for more efficient and sustainable energy solutions, and the work was confined to exploring AI's role in providing these solutions.

The findings from the research indicated that AI could significantly enhance productivity and reduce the environmental footprint of operations in the energy sector. Specifically, AI can be effectively utilised in reservoir management and drilling operations, contributing to the goal of achieving net-zero emissions by 2050.

The study also underscored the potential of AI for social good, with a multitude of possible applications, including improving healthcare, education, and environmental sustainability. AI can assist in early disease detection and provision of special treatment plans, enhance the quality of education by offering personalised learning opportunities, and aid in environmental monitoring and disaster prediction.

Innovative uses of AI to address societal concerns are being demonstrated by programs like USC CAIS and Google Research India's AI4SG. To fully realise AI's potential, cooperation among several sectors is essential. The productive dialogue between engineers and social scientists, which led to fresh concepts and solutions, was exemplified by ShowCAIS.

However, while AI presents significant opportunities for sustainability and social good, there are also potential challenges and risks associated with its use. These include ethical considerations, the need for appropriate regulation, and the potential for job displacement. The complexity of AI, emotional intelligence, and anthropomorphising AI can hamper its adoption. AI might stifle original thought and lead to complacency. Another issue is personal safety, particularly in automated law enforcement.

While the research provided substantial insights, it is important to note that areas still warrant further investigation. For example, the precise processes by which AI can aid in achieving net-zero emissions are yet to be fully understood. Similarly, a comprehensive understanding

of the potential adverse effects of AI on society and the workforce remains an area for future exploration.

Despite these challenges, the answer to the research question posed at the beginning of this study is positive. AI does indeed have the potential to significantly contribute to sustainability and social good, particularly in the energy sector.

This research opens up a new debate on other questions, such as the role of AI in other sectors and its potential impacts on society at large. It also alludes to other fields of investigation that may have emerged as the research was reflected upon. For instance, the role of AI in other sectors, such as healthcare, education, and transportation, could be explored in future research.

In conclusion, this study has highlighted the significant potential of AI in the energy sector and its role in promoting sustainability and social good. It has also underscored the need for a balanced approach, considering both the opportunities and challenges associated with AI. The transformational potential of AI, a fast-evolving area, is highlighted by this research, underscoring the significance of continued study and balance.

# Bibliography

Ardila, D., Kiraly, A.P., Bharadwaj, S., 2019. End-to-end lung cancer screening with three-dimensional deep learning on low-dose chest computed tomography. Nature, Available at: https://www.nature.com/articles/s41591-019-0447-x [Accessed 22 May 2023].

Chen, P., Hu, X. and Chen, H., 2019. Artificial Intelligence in Finance: A Review. Journal of Finance and Data Science, 5(4), pp.283-300. Available at: https://www.sciencedirect.com/journal/the-journal-of-finance-and-data-science [Accessed 22 May 2023].

De Bonis, A., 2023. The role of AI in sustainable energy production. Citylife.com. Available at: https://citylife.capetown/uncategorized/the-role-of-ai-in-sustainable-energy-production/27375/ [Accessed 31 May 2023].

Deamon, T., 2023. The role of AI in healthcare: revolutionizing patient care. Globeecho.com. Available at: https://globeecho.com/medical/the-role-of-artificial-intelligence-in-healthcare-revolutionizing-patient-care/ [Accessed 24 May 2023].

Direction Générale des Entreprises, 2019. Intelligence artificielle: État de l'art et perspectives. Available at: https://www.entreprises.gouv.fr/files/files/directions_services/etudes-et-statistiques/prospective/Intelligence_artificielle/2019-02-intelligence-artificielle-etat-de-l-art-et-perspectives-synthese.pdf

EDF, 2023. Edf.fr. Available at: https://www.edf.fr/en

Elkins, M., 2023. Stellantis teams with Mercedes and TotalEnergies to open France's first EV battery plant. Investing.com. Available at: https://www.investing.com/news/stock-market-news/stellantis-teams-with-mercedes-and-totalenergies-to-open-frances-first-ev-battery-plant-432SI-3093967 [Accessed 3 June 2023].

Energy Central, 2018. Artificial Intelligence Aiding the Energy Transition. Energycentra.com. Available at: https://energycentral.com/c/iu/artificial-intelligence-aiding-energy-transition [Accessed 23 May 2023].

Engie Lab CYLERGIE, 2022. 2021 in review. In: Engie annual report 2022, p. 28. Available at: https://innovation.engie.com/uploads/medias/62d11cb2b2df6-RI-Labs-2021-in-Review-BD.pdf

Engie Laborelec, 2022. 2021 in review. In: Engie annual report 2022, pp.39 - 40. Available at: https://innovation.engie.com/uploads/medias/62d11cb2b2df6-RI-Labs-2021-in-Review-BD.pdf

Engie, 2023. Innovation.engie.com. Available at: https://innovation.engie.com/en

Feng, C., Liang, W., Du, W. and Zhang, W., 2019. Artificial Intelligence in Transportation: Emerging Applications, Impacts, and Challenges. IEEE Transactions on Intelligent Transportation Systems. Available at: https://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=6979 [Accessed 22 May 2023].

Forbes Technology Council, 2021. 14 Ways AI Could Become A Detriment To Society. Forbes.com. Available at: https://www.forbes.com/sites/forbestechcouncil/2021/06/14/14-ways-ai-could-become-a-detriment-to-society/?sh=539f206927fe [Accessed 23 May 2023].

Forbes, 2021. 114 Milestones in the history of AI. Forbes.com. Available at: https://www.forbes.com/sites/gilpress/2021/05/19/114-milestones-in-the-history-of-artificial-intelligence-ai/?sh=7d445aa74bf8 [Accessed 22 May 2023].

Goodfellow, I., Bengio, Y. and Courville, A., 2015. Deep Learning.

Gupta, D., 2023. Top 10 ways AI in education is transforming the industry. Appinventiv. Available at: https://appinventiv.com/blog/10-ways-artificial-intelligence-transforming-the-education-industry/ [Accessed 24 May 2023].

Haughey, C.J., 2019. AI for Social Good: 7 Inspiring Examples. Springboard.com. Available at: https://www.springboard.com/blog/data-science/ai-for-good/ [Accessed 22 May 2023].

HTF Market Intelligence Consulting Pvt, 2023. AI in agriculture market is likely to experience a tremendous growth in near future. Newswires. Available at: https://www.einnews.com/pr_news/631452846/ai-in-agriculture-market-is-likely-to-experience-a-tremendous-growth-in-near-future [Accessed 24 May 2023].

Hyperight, 2021. Applying AI for social good to solve today's global challenges. Hyperight.com. Available at: https://hyperight.com/applying-ai-for-social-good-to-solve-todays-global-challenges/ [Accessed 22 May 2023].

J.P.Morgan, 2023. Is Generative AI a Game Changer?. Jpmorgan.com. Available at: https://www.jpmorgan.com/insights/research/generative-ai [Accessed 24 May 2023].

Jiang, W., 2021. Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities. Journal of Cleaner Production. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0959652621000548 [Accessed 6 June 2023].

Jiang, W., 2021. Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities. Journal of Cleaner Production, 289. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0959652621000548 [Accessed 31 May 2023].

Kleinings, H., 2023. How to get the most out of AI in 2023: 7 applications of AI in business. Levity.ai. Available at: https://levity.ai/blog/8-uses-ai-business [Accessed 22 May 2023].

Lewis, O., 2023. AI for good: ShowCais event highlights the power of AI to make a difference. Viterbischool.usc.edu. Available at: https://viterbischool.usc.edu/news/2023/04/ai-for-good-showcais-event-highlights-the-power-of-ai-to-make-a-difference/ [Accessed 24 May 2023].

Martin, E., 2022. AI's Role in the Future of Sustainable Energy. Ie.edu. Available at: https://www.ie.edu/insights/articles/ais-role-in-the-future-of-sustainable-energy/ [Accessed 6 June 2023].

McCarthy, J., 1999. What is AI. Jmc.stanford.edu. Available at: http://jmc.stanford.edu/artificial-intelligence/what-is-ai/index.html [Accessed 22 May 2023].

McKinsey Global Institute, 2018. Applying artificial intelligence for social good. Mckinsey.com. Available at: https://www.mckinsey.com/featured-insights/artificial-intelligence/applying-artificial-intelligence-for-social-good [Accessed 22 May 2023].

Messad, P., n.d. EDF selected to build France's largest offshore wind farm. Euractiv.com. Available at: https://www.euractiv.com/section/energy-environment/news/edf-tagged-to-build-frances-largest-offshore-wind-farm/ [Accessed 31 May 2023].

Nature, 2020. The role of artificial intelligence in achieving the Sustainable Development Goals. Nature.com. Available at: https://www.nature.com/articles/s41467-019-14108-y [Accessed 7 June 2023].

Negnevitsky, M., 2021. A Brief History of Artificial Intelligence.

Next Kraftwerke, n.d. Artificial Intelligence in the Energy Industry. Available at: https://www.next-kraftwerke.com/knowledge/artificial-intelligence [Accessed 6 June 2023].

Patel, P., 2022. AI's Benefit to Solar and Wind Power Isn't Hot Air Researchers outline how utilizing AI can help meet climate goals. Spectrum.ieee.org. Available at: https://spectrum.ieee.org/climate-change-ai [Accessed 6 June 2023].

Poole, D.L. and Mackworth, A.K., 2010. Artificial Intelligence: Foundations of Computational Agents.

PTC, 2023. ENGIE's CRIGEN Lab Focuses on the Operational Performance of Energy Assets with a View to Decarbonizing Industry. IEN.eu. Available at: https://www.ien.eu/article/engies-crigen-lab-focuses-on-the-operational-performance-of-energy-assets-with-a-view-to-decarboniz/ [Accessed 3 June 2023].

Russell, S. and Norvig, P., 2020. Artificial Intelligence: A Modern Approach.

Sayritupac, J., n.d. French AI and renewables energies, current state and prospects. Ingelib.com. Available at: https://ingelib.com/2020/10/08/une-premiere-mission-reussie/ [Accessed 31 May 2023].

Smith, M.L., NewPane, S. and Mendonca, C., 2018. Crafting papers on machine learning. In: Proc. of the 17th International Conf. on Machine Learning (ICML 2000). Morgan Kaufmann, pp.5-122.

Stanford University, 2023. 2023 State of AI in 14 Charts. Hai.stanford.edu. Available at: https://hai.stanford.edu/news/2023-state-ai-14-charts [Accessed 24 May 2023].

Statista Research Department, 2023. Number of artificial intelligence (AI) startups in France in 2023, by sector. Statista.com. Available at: https://www.statista.com/statistics/1384001/ai-startups-by-sector-france/#statisticContainer [Accessed 6 June 2023].

TCS, 2023. Engie and TCS stride together on their net zero journey. Tcs.com. Available at: https://www.tcs.com/what-we-do/industries/energy-resources-utilities/video/engie-testimonial-going-beyond-net-zero [Accessed 4 June 2023].

Tomašev, N., 2020. AI for social good: Unlocking the opportunity for positive impact. Nature News. Nature Publishing Group. Available at: https://www.nature.com/articles/s41467-020-15871-z [Accessed 6 June 2023].

TotalEnergies, 2023. Totalenergies.com. Available at: <www.totalenergies.com>

UNESCO, 2021. Recommendation on the ethics of Artificial Intelligence. Unesco.org. Available at: https://www.unesco.org/en/legal-affairs/recommendation-ethics-artificial-intelligence [Accessed 6 June 2023].

Van den Bergh, T., 2022. How AI can help us prepare for climate adaptation. Weforum.org. Available at: https://www.weforum.org/agenda/2022/11/how-artificial-intelligence-can-prepare-us-for-climate-adaptation/ [Accessed 24 May 2023].

World Economic Forum, 2021. Artificial Intelligence is Critical Enabler of the Energy Transition, Study Finds. Weforum.org. Available at: https://www.weforum.org/press/2021/09/artificial-intelligence-energy-transition [Accessed 6 June 2023].