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Regulating Artificial Intelligence in the EU, United States and China - Implications for energy systems

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Abstract—The growing prevalence and potential impact of artificial intelligence (AI) on society rises the need for regulation. In return, the shape of regulations will affect the application potential of AI across all economic sectors. This study compares the approaches to regulate AI in the European Union (EU), the United States (US) and China (CN). We then apply the findings of our comparative analysis on the energy sector, assessing the effects of each regulatory approach on the operation of a AI-based short-term electricity demand forecasting application. Our findings show that operationalizing AI applications will face very different challenges across geographies, with important implications for policy making and business development.

Index Terms—Artificial Intelligence, energy policy, load forecasting, regulation.

I. INTRODUCTION

Artificial Intelligence (AI) has gained significant attention in the past decade as it has revolutionized multiple industries [1]. For example, researchers found that AI can help companies to substantially increase their operational performance [2]. Thus it is not surprising that over 50% of companies already use AI as of today [3]. Recently, this technology has seen notable advancements that made it competitive in numerous tasks that were once exclusive to humans. For instance, recent advances in Natural Language Processing (NLP) shed light on the ability of AI large language models to perform content creation, language translation, text summarization and question-answering [4], [5]. In fact, the rise of AI is associated not only with better computational capabilities or advances in mathematical methods but also with the abundance of data coming from different sources [1]. The quality of the data being collected and its usage raises concerns with regards to potential bias being present in the data in addition to the risk that comes with the decision making associated with certain tasks (consumer behaviour analysis, financial fraud detection, medical diagnosis, infrastructure inspection, etc) [6], [7].

That being said, AI applications are becoming central to several sectors of the economy such as retail, finance, health-care, transportation or energy [3]. Yet, as AI applications may

use consumer data and also support or even replace human decision making, the implications of this technology are by no means purely economical, but there are rather societal and ethical aspects that need to be taken into account [8].

In the energy sector, new operational and planning-related challenges brought by decarbonization, decentralization and digitalization are particularly interesting fields for AI applications [9], [10]. For example, previous research showed the applicability of AI for tasks such as characterizing and forecasting electricity demand and demand response [11], [12], designing smart cities [13], planning and operating electricity transmission systems [14], [15], system optimization [16] or market operations (e.g., trading) [17].

While it is clear that the shape of AI regulations will affect the operation of AI applications in the energy sector [18], even with potential extraterritorial effects beyond the jurisdiction where a regulation is applied to [19], so far no work has further explored these effects using a concrete AI application (e.g. a forecasting application). In this paper, we therefore address the following research questions:

- 1) Which are the key aspects addressed through AI regulations across the globe?
- 2) How do AI regulations differ across geographies? In this work, we will focus on AI regulations in the European Union (EU), the United States (US), and China (CN).
- 3) How do AI regulations impact the use of AI applications, with special emphasis on the energy sector? In our work, we use a generic short-term electricity demand forecasting application using AI as example and provide a detailed comparison of the impact of different AI regulations on various aspects of the forecasting application using the recent OECD AI system classification framework [20].

To our knowledge, this paper comes first to provide insights on the impact of different AI regulations around the globe (EU, US, CN) on the application of AI in the energy sector.

II. KEY ASPECTS FOR REGULATING AI

There are numerous aspects one might consider when assessing AI applications, such as technological readiness [21], economic potential [2] or regulatory risk [6]. In the following we present the major concerns of operationalizing AI applications that have been reported in the literature:

A. Security and Safety

The large amounts of data stored for AI applications can become subject to cyberattacks, hence the accuracy and trustworthiness of any system. In addition, another relevant aspect is public safety. This is especially important for AI applications that influence human safety and well-being, such as medical diagnosis and treatment or transportation networks [22] [23]. For example, AI-based systems are gradually being used in the healthcare sector to assist medical experts in analyzing patients' data. In this context, accurate and transparent AI applications are crucial to prevent potential false negative diagnosis of any underlying health condition.

As AI applications are being used in critical infrastructures, a safe operation of these systems is required as it would then directly affect public safety. Finally, many concerns occur with regards to the rise of forgery and deep fakes, which could be used in harmful applications [24]. Later could undermine the users (and citizens) trust in these systems.

B. Bias and Discrimination

Bias is a major issue that needs to be addressed in AI systems. It is mainly introduced through the training phase of the algorithms, i.e. its training data and can result in discriminatory outcomes [25] [7]. For instance, data-driven hiring processes reportedly displayed gender and racial biases, resulting in an unfair selection of job applicants [26]. Another example has been found in some AI-based computer vision applications, where outcomes showed higher error rates for people with darker skin, resulting in a potential discrimination [27]. Similar examples could be found in algorithms used for loan approval in banks or juridical processes [28].

C. Data Privacy

Ethical concerns relate to the risks associated with the large amounts of data consumed by AI applications, as they could infringe on the citizens' privacy through unauthorized distribution, consumption and potential personal data breach. Some common examples include personal health data collected by smartwatches and social media activities [29]. As a matter of fact, AI systems often process and store personal information such as names, addresses, and financial data. This information data can be sensitive and needs to be protected from unauthorized access or misuse.

Despite the large benefits associated with AI, several social and ethical implications arise. Some AI applications can threaten the public's safety and privacy or may result in biased and discriminatory outcomes. As a result, several regulatory measures were (and are in progress to be) taken across the globe to regulate AI.

III. COMPARATIVE ASSESSMENT OF AI REGULATIONS

A. AI regulation in the European Union

The EU's stated goal is become a world class hub for human-centric and trustworthy AI while minimizing the risks associated with a wide use of AI [30]. With that ambition, the European Commission has developed a risk-based approach to AI regulation, where requirements for AI users are gradually increasing with the risk category the AI systems may fall into. The EU AI regulation (AI Act) details four different risk levels [31]:

- *Minimal risk*: AI technologies that pose no harm or minimal harm to human well-being, safety, and rights. These systems are not subject to regulation. Some examples of minimal risk systems include spam filters for emails and AI-powered video games.
- *Limited risk*: AI systems that pose limited harm to the public safety, but require some oversight and transparency obligations. These systems are subject to specific regulations to minimize the risk of harm. Limited risk systems include chatbots used in customer support, personalized recommendations based on preference and AI-powered applications that assist in managing work-related tasks.
- *High risk*: AI systems classified as being high risk cover all systems that pose a clear threat to the public health and safety or fundamental rights. Such systems include applications in the critical infrastructure, such as the energy sector, that could jeopardize the well-being of EU citizens. Additional scenarios include cases where AI can violate human rights. High-risk AI systems have to comply with specific compulsory requirements such as extensive documentation, human oversight monitoring and must undergo a prior conformity assessment.
- *Unacceptable risk*: AI systems that are considered to directly threaten the public safety and human rights will be subject to a ban. This includes all forms of social scoring and biometric identification systems used in public spaces [31].

Another interesting aspect of the AI Act is the so called Brussels effect, which coins the expectation that European legislative standards would be adopted by non-European countries, to maintain access to the European single market [32]. Similar dynamics have been seen for the General Data Protection Regulation (GDPR). Thus, it could be likely that the European AI Act, besides affecting the European energy sector, would also affect other energy sectors beyond Europe (e.g., US or China) [19].

Finally, there has been developed a set of ethical principles and standards for the development and application of AI in the EU, known as the Ethical Guidelines for Trustworthy AI [33]. These non-binding guidelines, developed through a High-Level Expert Group on AI (AI HLEG), shall promote accountable and transparent AI systems being applied in a way that respects human rights. The ethical principles cover a wide range of subjects such as non-discrimination, transparency, responsibility, and human dignity.

B. AI regulation in the United States

In contrast to the European approach of developing a centralized and horizontal legal framework to regulate AI in all member states, AI regulations in the United States are carried out rather on state than on federal level and vary by sector, industry and application, therefore following a sectoral, decentralized and vertical approach [34].

In 2022, the White House published its Blueprint for an AI Bill of Rights: Making Automated Systems Work for the American People (BOR) [35]. The BOR can be seen as national value statement [34] that sets the overall frame for legislation on federal levels. It is non-binding, providing guidance on how AI principles and standards could be enforced by existing federal- and state-level sectoral legislation as well as federal agency-led activities [34]. The BOR specifies harms to: (1) civil rights, civil liberties, and privacy; (2) equal opportunities; and (3) access to critical resources or services [34]. Latter may indirectly also address the energy sector, mentioning "systems that impact the safety of communities, .. such as critical grid controls, smart city technologies.." [35] (page 54).

In addition, the National Institute of Standards and Technology (NIST) recently published its AI Risk Management Framework (RMF) which shall serve as a voluntary framework useful for different stakeholders [36]. Its core idea is to provide guidelines on how manage risks across the lifecycle of AI applications in any type of organizations, addressing four dimensions:

- *Govern*: Establish responsibilities, duties and a culture of risk management.
- *Map*: Assess the various risks of AI applications in a tailored, context-specific way.
- *Measure*: Identify, assess, track and risks of AI systems over the whole lifecycle of an AI application.
- *Manage*: Prioritization of mitigation or preventive actions, considering potential impacts.

For the US energy sector the Department of Energy (DOE) developed a AI Risk Management Playbook (RMP) [37]. The interactive system offers users 100+ unique risks and mitigation techniques with the intention to serve as an adaptable, comprehensive reference guide for risk identification and mitigation for responsible and trustworthy AI. The AI RMP is a non-binding framework and can be used by any organization for proactive risk management.

Similar to the European framework, US-based regulations also shed much light on the data privacy aspect. For example, a set of data privacy regulations have been proposed, for instance the California Consumer Privacy Act (CCPA) [38].

In summary, it can be seen that the US incorporates a more decentralized, vertical approach with regards to AI regulation. Latter differs by the sector and state under consideration and is preferably based on existing federal laws.

C. AI regulation in China

China has made significant investments in artificial intelligence and is actively promoting AI technology development and deployment across all economic sectors [39]. The Chinese government has issued various plans, guidelines and policies to encourage the development and use of artificial intelligence (AI) [40]. The Cyberspace Administration of China (CAC) is in charge of enforcing data privacy and cybersecurity regulations, such as the People's Republic of China's Cybersecurity Law. It also offers advice on the ethical application of AI and the responsible development of AI systems [34]. On the other hand, the Chinese Ministry of Science and Technology acts as the central, overarching body that coordinates the governance of AI. It introduced several voluntary principles and some guidance on how ethical aspects shall be considered during the development and use of AI [34].

Furthermore, China has established the National AI Development Plan, which outlines the country's strategic objectives for AI development and deployment [41]. The plan focuses on the advancement of AI technologies and applications, the development of AI talent, and the establishment of an environment conducive to AI development [41]. For example, stated goals include making China's AI industry "world-leading" in some AI fields by 2025 and to become the "primary" center for AI innovation by 2030. This shall include an AI industry worth RMB 1 trillion (EUR 130 billion) by 2030 [41]. China is currently already making significant progress in AI research and development and has a thriving AI industry [40]. Thus, in the coming years, the Chinese government is expected to continue promoting the development and deployment of AI technologies, and AI regulations are likely to further expand in scope and coverage [34].

While there is to our knowledge no AI regulation specifically targeting applications in the energy sector, the CAC has identified specific types of AI as critical and subject to further regulation, such as recommender systems and generative algorithms [34].

D. Brief comparison of AI regulations

Subsequently we compare the three analyzed AI regulations in terms of scope, their approach to risk, regulatory requirements and monitoring and enforcement, relying on the findings of [34]. Outcomes suggest the European AI Act most restrictive, compared to AI regulations of the US and China (Table I). While latter can be described as a rather hybrid approach, with non-binding (ethical) principles together with a few technologically-oriented requirements, US AI regulation is rather vertical, decentralized for each economic sector and relies mostly on voluntary risk assessment, self-monitoring and existing legislation. However, under the absence of an in-depth legal assessment of all relevant legislative acts involved, and, given the current speed of further development [34], our analysis shall be taken as rather generic, as it remains rather vague and is also mainly conducted through the lens of the European approach towards AI regulation.

TABLE I
COMPARATIVE ASSESSMENT OF AI REGULATIONS IN EU, US AND CN.

	European Union (EU)	United States (US)	China (CN)
Scope/ focal areas	- Horizontal, spanning all economic sectors	- Vertical, different from sector to sector	- Hybrid, with general rules and technological particularities
Approach to risk	- Risk-based framework in the AI Act (binding)	- No binding, overarching risk based framework (NIST - voluntary)	- Risk is framed in the general context of science and technology, focussing on regulatory policies that support research and development
Regulatory requirements	- Based on respective risk classifications of AI systems. - Banning facial recognition and social scoring systems, etc. For critical infrastructure (high-risk category): — Conformity assessment — Human oversight — Documentation, data governance, transparency — Post-market monitoring	- Relying rather on existing regulations and voluntary actions	- Generally, soft law ethical guidance for AI - Regulatory requirements targeted at specific AI technologies such as generative AI and recommender systems - Banning of algorithmic systems manipulating search rankings, biased content towards minors or discriminatory tags in recommender systems - Regular examination and verification of algorithms - A kind of AI system register, mentioned in "Guiding Opinions on Strengthening Ethical Governance of Science and Technology"
Monitoring and enforcement	- Obligatory - New enforcement bodies will be created	- Voluntary and decentralized - Emphasis on self-monitoring	- Rather voluntary - MOST provides overarching direction for China's monitoring and enforcement, typically through guidance.

IV. CASE STUDY: REGULATING AN AI-BASED ELECTRICITY DEMAND FORECASTING APPLICATION

A. Demand forecasting application

The characterization of electricity demand and forecasting its magnitude and location is the foundation of energy system planning [42]. With the challenges brought through energy system transitions (increased renewable generation with variable output, new demand sources such as hydrolyzers, electric vehicles and more flexible demand), the need for accurate electricity demand forecasting with increasing spatial and temporal detail has become increasingly important [43].

In this paper, we will analyze the impact of different AI regulations on the Demand Forecasting Tool (DFT) operated by ENTSO-E, the European association of transmission system operators (TSO) for electricity [44]. The application is used across all European TSO, in studies ranging from long-term network expansion plans to shorter-termed resource adequacy studies (weeks to months ahead). The DFT uses historical load time series, data on historical temperature and climate conditions and data on future scenarios to create load time series in hourly resolution. For the underlying scenarios, it incorporates forecasts considering future market developments such as the penetration of heat pumps, electric vehicles, and batteries.

The methodology used in DFT involves the decomposition of time series into basic functions using singular value decomposition (SVD) and multilinear regression, that is, machine learning. It is further detailed in [44].

B. Regulatory impact analysis

To guide our analysis of the impact of AI regulations on different aspects of the DFT, we use the OECD Framework for classifying AI systems/applications [20]. The framework consists of four dimensions:

- 1) **Data and input.** Regarding the DFT, it is noteworthy that all data is publicly available, validated through a stakeholder process and does not contain personal information.
- 2) **AI model.** This aspect relates to the algorithmic layer of the AI system. We would argue that SVD and multilinear regression, as not part of deep learning, rank among the rather explainable algorithms.

- 3) **Task.** The DFT uses different historic time series and scenarios to forecast electricity demand in hourly resolution.
- 4) **Context.** The forecasting application operates within the electricity sector, which is commonly seen as part of the critical infrastructure. Applications might be up to a few days ahead (in the case of short-term resource adequacy), with potentially harmful effects in case of severe malfunctioning.

In this work we use an "green/orange/red light" approach to qualitatively assess the potential impact of AI regulations in EU, US and CN on AI applications in energy systems.

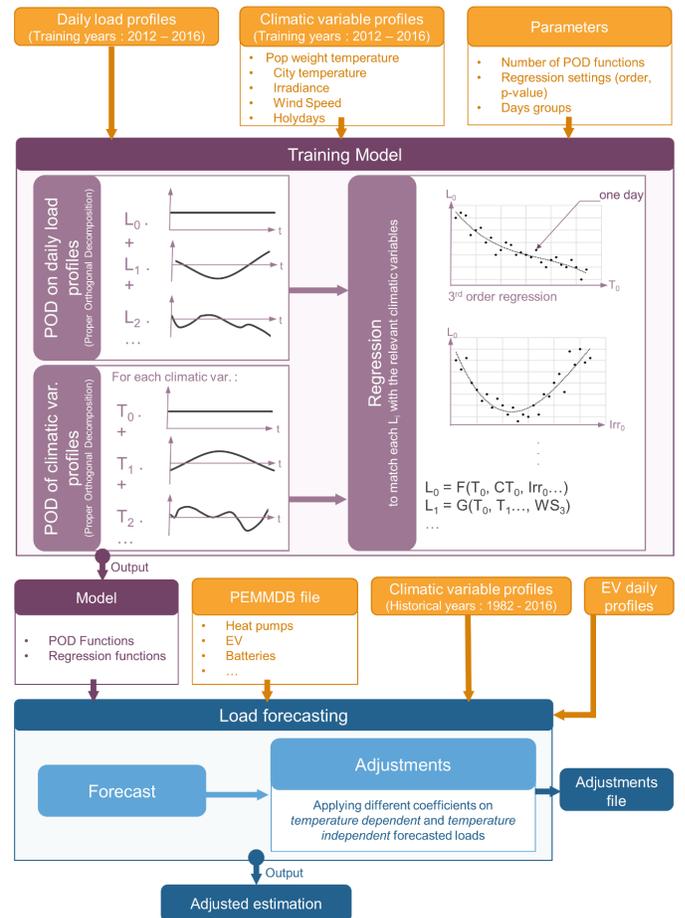


Fig. 1. DFT methodology [44].

This approach assesses the compliance requirements for AI systems in different regions, with a green light indicating low compliance requirements, an orange light indicating moderate compliance requirements, and a red light indicating high compliance requirements. Although this rough assessment cannot replace a detailed legal assessment, it intends to guide the reader towards simple comparison of the analyzed regulatory frameworks and their impact on the use of AI applications in the energy sectors of EU, US and CN.

C. Operating DFT in EU, US and CN

- 1) EU: Under the European AI Act, DFT, operated in a critical infrastructure sector (energy) would certainly qualify as a high-risk AI application, which are defined as applications that pose significant risks to the health, safety, or fundamental rights of individuals or society. It would therefore become subject to additional requirements for compliance. While the EU’s proposed AI Act has the potential to create a comprehensive, standardized and harmonized regulatory environment for AI across all economic activities within the EU, applications like the DFT would face higher market entry barriers and operational costs (conformity assessment, costs for documentation requirements, risk and data management, human oversight).
- 2) US: The US currently has no horizontal layer of federal regulations for AI, but instead has issued sectoral, voluntary guidelines and general principles for responsible AI development through various federal agencies. As a result, the compliance requirements for DFT in the US may be less costly compared to the EU or China. Operators of DFT would be likely encouraged to orientate along DOE’s Risk Management Playbook and consider the general principles on ethical use of AI (BOR).
- 3) CN: In contrast, China’s AI regulations frame the use of certain AI technologies (recommender systems, generative AI) while providing also general, however non-binding principles on its ethical use. In addition, it has been argued that China’s AI regulations tend to prioritize domestic innovation and development [39], which could create uncertainty and barriers to entry for foreign AI developers, if compared to the US.

We conclude that EU’s proposed AI Act could be seen as the most challenging AI regulation for using DFT in terms of requirements that would need to be fulfilled (“red light”). Compliance with the regulation would require additional documentation related to the algorithmic decision-making process, training data, and performance evaluation. The US guidelines and principles for responsible AI development provide non-binding guidance and support for DFT’s compliance efforts (“green light”). While the NIST guidelines [37] do not have the force of law, they could influence the development and use of DFT by promoting higher risk awareness, mitigation strategies and greater transparency and accountability. China’s

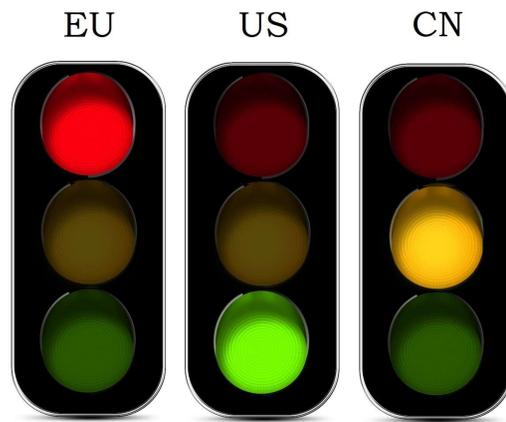


Fig. 2. Traffic Light Approach for different Regulation Frameworks

AI regulations requires arguably less efforts to make AI applications like the DFT compliant than in the EU. However, in direct comparison with the US, existing regulations (even if technology specific), would currently pose some requirements to the use of certain AI applications (“orange light”).

V. CONCLUSIONS AND FUTURE DIRECTIONS

National regulatory approaches towards AI will shape the potential and real utilization of AI across economies. Following our analysis on the case of an exemplary AI application in the energy sector (ENTSO-E’s DFT), we would expect high compliance requirements for the EU, little requirements for CN and currently no requirements for an use in the US.

Comparing the main characteristics of current AI regulation in the EU, US and CN, we find that the European AI Act provides a rather risk-based framework bundled with ethical guidelines for trustworthy AI, whereas in the United States AI regulation is sector-specific and governed by existing laws and regulations. The regulatory approach pursued in China has been characterized as hybrid, with general principles on ethical use of AI, together with a few technology-specific regulations.

While AI applications are already widely used in the energy sector, many real-world applications may soon fall under upcoming or newly developed AI regulations. The shape of these regulations with eventually define the benefits AI applications can provide to the operation and planning of energy systems, as well as the scope of eventual risks. However, given the current pace of developments, our study is far from conclusive. Further, more detailed research on AI applications and the effects of AI regulations are needed to allow for a better understanding of the future potential and likely risks of AI in the energy sector.

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