Is it possible to go beyond the precautionary principle in climate change policy-making? AI as a tool for efficient decisions*

Giuseppe Muto

Abstract

Environmental policy-making presents complex challenges, especially when it comes to climate change. The application of the precautionary principle is necessary in this context, as limited scientific evidence forces legislators to make decisions under conditions of uncertainty. However, the application of this principle has been criticised for potentially leading to irrational and economically inefficient outcomes.
AI is the game changer. Machine learning algorithms, fed by vast amounts of data, offer a new paradigm for decision making. We can imagine AI models that meticulously assess the environmental impact of each new policy, allowing for an appropriate balance between benefits and negative externalities. However, it is important to bear in mind that AI (and in particular its regulation) is not without limitations and potential economic inefficiencies.

Table of contents

Keywords
climate change – AI – precautionary principle – UN Sustainable Development Goals – policy-making

* L'articolo è stato sottoposto, in conformità al regolamento della Rivista, a referaggio "a doppio cieco".

1. Introduction

While it is clear that humanity should engage in economically efficient actions, and the well-being of a thriving society depends on the prudent distribution of resources, the pursuit of profit is only warranted if it enhances economic efficiency. However, various challenges arise in situations where uncertainties stem from an incomplete understanding of the precise probability of unfavorable outcomes or the extent of their severity. In the recent timeline of global environmental policy and legislation, an overarching principle has arisen: the Precautionary Principle. This principle has gained significant traction, especially among policy-makers who are mindful of potential significant human effects on the worldwide environment. However, its definition is still unclear, and it lacks a strong philosophical standing. Specifically, contemporary literature often differentiates between weak and strong interpretations of the principle, dismissing the former as empty and labeling the latter as extreme, shortsighted, and irrational. Unfortunately, adopting such reasoning and decision rules, even at the utmost version, the Maximin Precautionary Principle, often results in highly economically inefficient decisions.

Considering this standpoint, AI and machine learning have the potential to assist policy-makers in gaining a deeper understanding of the challenges they encounter. This, in turn, could empower them to make economically efficient decisions when confronted with uncertainty, thereby reducing the reliance on inefficient choices influenced, for instance, by the Precautionary Principle.

This essay aims to present a comprehensive outline of the application of the Precautionary Principle and subsequently examine how AI can aid in decision-making of environmental policies by harnessing the extensive computational and analytical capabilities inherent in machine learning. Section II and Section III serve as the *pars destruens* of the decision-making process on environmental issues exploiting the different degree of the Precautionary Principle, while Section IV constitutes the *pars costruens*, analyzing the possible benefit of the machine learning. In particular, in Section II, I provide a general overview of the exploitation of the Precautionary Principle in the international environmental policy and law, then, in Section III, I explain the possible problems connected to the implementation of the Sustainable Development Goals established by the United Nations in 2015 and, above all, the climate change through the use of this principle. Lastly, in Section IV, taking into account the substantial issues outlined in the preceding sections, I endeavor to illustrate how machine learning can assist decision-makers in making choices regarding environmental issues in situations of uncertainty, offering concrete examples.

2. Overview of the Precautionary Principle

The Precautionary Principle requires that in the presence of a potential risk of substantial harm to health or the environment for others or future generations, coupled with scientific uncertainty regarding the nature of the damage or the probability of the risk, decisions should be taken to prohibit such activities unless and until scientific evidence demonstrates that the anticipated damage will not occur[1]. The core concept is that regulators ought to proactively address specific risks, even in the absence of certainty about their occurrence. For proponents of the Precautionary Principle, it is crucial to take preventive measures against potential significant hazards, emphasizing the preference for safety over the possibility of regret.[2]

More specifically, it may be possible to distinguish four versions[3] of the Precautionary Principle, considering the different scenarios in which it operates:

- Nonpreclusion Precautionary Principle: Regulation should not be prevented simply because there is no scientific uncertainty regarding activities that carry a risk of significant harm.
- Margin of Safety Precautionary Principle: Regulation should incorporate a safety margin, constraining activities to levels below those where adverse effects have not been observed or predicted.
- Best Available Technology Precautionary Principle: Requirements for the best available technology should be applied to activities with an uncertain potential for causing substantial harm, unless proponents of such activities can demonstrate an absence of significant risk.
- Prohibitory Precautionary Principle: Prohibitions should be enforced on activities with an uncertain potential to cause substantial harm, unless proponents can demonstrate the absence of any significant risk associated with those activities.

The expressions of the Precautionary Principle – as seen in international agreements and policy declarations – vary considerably. However, its advocates argue that there is a fundamental commonality among them. In particular, the Precautionary Principle consists of three key elements: (i) the presence of a threat of harm, (ii) the uncertainty regarding impact and causality, and (iii) the implementation of a precautionary response.[4]

2.1. Precautionary principle in environmental policy

Typically considered as an explicit environmental principle, the Precautionary Principle is often traced back to the German concept of "Vorsorge,"[5] with its origins

1 C. R. Sunstein, *Beyond the precautionary principle*, in *University of Pennsylvania Law Review*, 151, 3, 2003, 1014.

2 C. R. Sunstein, *Maximin*, in *Yale Journal on Regulation*, 37, 3, 2020, 957.

3 R. B. Stewart, *Environmental regulatory decision making under uncertainty*, in *Research in law and economics*, 2004, 71 ff.

4 C. Sunstein, *Beyond the precautionary principle*, cit., 1014.

5 According to S. M. Gardiner, *A core precautionary principle*, in *The Journal of Political Philosophy*, 14, 1, 2006, 35 nt. 2 «"*Vorsorge*" means "foresight" or "taking care;" the "*Vorsorgeprinzip*" is the "foresight principle." At the core of early conceptions of this principle in Germany was the belief that society should seek to avoid environmental damage by careful "forward-looking" planning, blocking the flow of potentially harmful activities. The *Vorsorgeprinzip* has been invoked to justify the implementation of vigorous policies to tackle river contamination, acid rain, global warming and North Sea pollution.»

commonly attributed to the early 1970s. Since then, this principle has occupied a significant place in numerous international treaties and regional policy statements. For example, this principle appear in the Ozone Layer Protocol (1987), the Third North Sea Conference (1990), the UN Framework Convention on Climate Change (1992). Furthermore, major institutions also support precautionary approaches, such as the UN Environment Program (1989), the EU in its environment policy (1994) and the US President's Council on Sustainable Development (1996)[6].

In order to take decisions in situation of uncertainty, a rational policy-maker must calculate the expected values, multiplying imaginable outcomes by probability and deciding accordingly. However, in most environmental policy, it is not possible to assign probabilities to the different scenarios and, as consequence, the risk-aversion of the legislators drives them to take decisions that are based on the Precautionary Principle. In particular, the US Government has developed the OMB Circular A-4, that offers a protocol discussing how to proceed for realizing a proper regulatory impact assessment in the absence of complete information. Indeed, it claims that when feasible, it is advisable to employ suitable statistical methods to establish a probability distribution for the pertinent outcomes; however, the degree of scientific uncertainty might be substantial to the extent that you can only present distinct alternative scenarios without quantitatively assessing the relative likelihood of each scenario. For instance, when evaluating potential outcomes of an environmental impact, there might be a limited number of scientific studies with markedly divergent results[7].

Therefore, the Precautionary Principle is widely accepted due to criticisms of traditional environmental management approaches, such as risk assessment and cost-benefit analysis. Critics argue that these practices have resulted in ineffective policies, setting regulatory burdens too high and assuming new products are "innocent-until-proven-guilty." On the other hand, theoretical issues include the assumption that humans can fully understand environmental impacts, which is challenged given the complexity of ecological systems. Does even the smallest potential harm suffice to invoke the principle? Additionally, delving into the role of uncertainty raises questions about the threshold at which uncertainty becomes a trigger for the principle. Lastly, defining precautionary measures becomes crucial—whether they encompass mere expressions of hope, warnings, or necessitate concrete actions to mitigate potential effects[8]. Given the difficulties presented by the Precautionary Principle, it is essential to delve into the standard criticisms that are made toward this principle by commen-

[6] S. M. Gardiner, *A core precautionary principle*, in *the Journal of Political Philosophy*, 14, 1, 2006, 33 ff.

[7] Office of Mgmt. & Budget, Executive Office of the President, *Circular A-4* , in *obamawhitehouse.archives.gov*, 2003, that clarifies « In formal probabilistic assessments, expert solicitation is a useful way to fill key gaps in your ability to assess uncertainty. In general, experts can be used to quantify the probability distributions of key parameters and relationships. These solicitations, combined with other sources of data, can be combined in Monte Carlo simulations to derive a probability distribution of benefits and costs. You should pay attention to correlated inputs. Often times, the standard defaults in Monte Carlo and other similar simulation packages assume independence across distributions. Failing to correctly account for correlated distributions of inputs can cause the resultant output uncertainty intervals to be too large, although in many cases the overall effect is ambiguous. You should make a special effort to portray the probabilistic results—in graphs and/or tables—clearly and meaningfully».

[8] C. Sunstein, *Beyond the precautionary principle*, cit., 1022 ff.

tators in the field of environmental policy.
First of all, the Precautionary Principle is often charged with resulting in extremism in regulating matters relating to the environment. Indeed, while, on one side, it advocates prohibiting any activity that gives even the slightest reason to suspect potential harm (Ultraconservative Precautionary Principle), on the other side, it acknowledges the necessity to exercise precaution in only one scenario: when there is a 99.9% probability that the world will imminently end due to a particular experiment (Ultraminimal Precautionary Principle)[9]. More specifically, the Ultraconservative Precautionary Principle proposes that if there is any chance, regardless of how minimal, that an activity could potentially be harmful, it should be entirely prohibited—regardless of its potential benefits[10]. Using this principle, the European Union might prohibit genetically modified food from the US from entering its markets without scientific evidence[11], or it could be deemed justifiable to ban a highly effective drug based on a 0.001% chance of causing a minor issues in some patients. Likewise, even the Ultraminimal Precautionary Principle looks to be irrational. As consequence, there is no inherent reason to assume fundamental disagreement between critics and advocates of the Precautionary Principle, but it is clear that to integrate such principle into policy, a moderate, intermediate stance is recommended. Moreover, the focus should be on specifying the circumstances triggering the Precautionary Principle. This involves defining the types of threats and uncertainties that activate the principle and the corresponding precautionary measures.
In addition, the Precautionary Principle can be declined differently depending on the centrality accorded to it in the decision-making process in a weak and in a strong version. Indeed, the weak versions «do not seriously restrict the factors that decision makers can legitimately take into account»[12] and «regulators do not receive any specific guidance on the relative weighting of any given factor»[13]. Hence, it serves as a pragmatic principle that it does not operate as an independent decision-making principle, offering an authoritative foundation to justify pragmatic decisions that involve giving significant weight to environmental risks in specific instances[14]. Its primary role is to empower regulators to evaluate a broad spectrum of risk factors, encompassing not only economic efficiency but also other considerations such as environmental costs and benefits, and to assess them individually in each case[15]. Therefore, the weak Precautionary Principle acts as a procedural limitation without specific consequences,

---

9 On this contraposition, consider, more broadly, Gardiner, *A core precautionary principle*, cit., 38 and Sunstein, *Beyond the precautionary principle*, cit.

10 S. O. Hansson, *How extreme is the precautionary principle?*, in *NanoEthics*, 14, 3, 2020, 245 ff.

11 C. Prestowitz, *Don't pester Europe on genetically modified food* , in *New York Times*, 25 January 2003, 34 ff.

12 E. Soule, *Assessing the precautionary principle in the regulation of genetically modified organisms*, in *International Journal of Biotechnology*, 4, 1, 2002.

13 *Ibidem*.

14 *Ibidem:* «If the Weak Precautionary Principle does anything at all it is this: it provides the authority to override other factors and make environmental risk the paramount and deciding concern. Regulators might consider all the factors of a practice and judge the environmental hazards to be so profound that they dismiss as secondary any findings of a cost- or risk-benefit analysis».

15 S. M. Gardiner, *A core precautionary principle*, cit., 43.

serving as a retrospective justification. It permits the potential scenario where environmental concerns could be compelling enough to warrant action, even if such action wouldn't be justified solely by a cost-benefit analysis. On the other hand, the Precautionary Principle, in its strong form, has a limited focus as it exclusively takes into account the environmental risks associated with the policies under consideration. This implies that other factors, such as potential economic benefits, are not considered in its evaluation. Additionally, the strong Precautionary Principle is deterministic, making environmental risk the decisive factor in the decision-making process, obligating regulators to take action based on this factor alone.[16] It is clear that this formulation is problematic and liable to lead to irrationality.

Moreover, the Precautionary Principle operates on a dual trigger mechanism: when there is a possibility of harm from an activity and uncertainty regarding the extent of impacts or causality, proactive measures should be implemented to prevent harm. This feature renders the principle ambiguous enough for governments to adhere to it, irrespective of their effectiveness in environmental protection. The risk perception is a culturally rooted phenomenon, shaped by long-standing values that have developed uniquely in various countries. Indeed, it can be considered as a primarily political principle geared toward establishing ethical guidelines rather than offering solutions to the challenges posed by the contemporary environmental state[17]. Similarly, this principle can be seen as purely procedural principle, that simply defines a *modus operandi* to construct important public policy on environmental matters. Precautionary is inherent in the culture of each country, therefore consensus on the meaning of precaution is unlikely to be reached, both in specific instances and as a broad guiding principle. As a result, the Precautionary Principle serves no purpose other than bringing together all involved parties, such as environmentalists and developers, to explore potential agreements, performing a negligible role in decision-making process[18]. Even if consensus is achieved, the Precautionary Principle provides no assurance that these agreements will effectively contribute to environmental protection. This is due to the fact that such principle imposes no constraints on the nature of decisions or the methods employed to reach them.[19]

In conclusion, the Precautionary Principle possesses limited practical significance, making it doubtful that it can truly function as a foundational principle in international environmental policy and law. Additionally, it remains unclear how the Precautionary Principle represents a unique approach to environmental policy, specifically how its adoption would address the perceived shortcomings of other policy-making, particularly through cost-benefit analysis.

16 E. Soule, *Assessing the precautionary principle*, cit., 318.

17 A. Jordan – T. O'Riordan, *The precautionary principle in contemporary environmental policy and politics*, in C. Raffensberger – J. Tickner (eds.), *Protecting public health and the environment: implementing the precautionary principle*. Washington, 1999, 15 ff.

18 Ivi, 19 ff.

19 S. M. Gardiner, *A core precautionary principle*, cit., 42.

2.2. A new frontier of environmental policy regulation: the Maximin rule

A particular form of the Precautionary Principle is the Maximin rule. The term "maximin" entails "maximizing the minimum." In essence, Maximin principles evaluate potential outcomes of different courses of action, emphasizing the worst possible outcome for each, and selecting the action with the least unfavorable worst outcome. Indeed, when regulators concentrate on the worst-case scenario, the regulatory measures for protection are heightened beyond what is necessary in regular circumstances. In critical situations, environmental regulators need to determine the restrictions to impose regarding low-probability risks of catastrophe or risks with dreadful worst-case scenarios, especially when assigning probabilities is challenging. From this viewpoint, the Maximin rule advocates select the strategy that minimizes the impact of the most unfavorable worst-case scenario[20]. The Maximin rule appears to work well with global environmental issues; indeed, they integrate the three features that are defined by John Rawls[21]. First of all, the requirement of the "absence of reliable probabilities" is fulfilled due to the intricate nature of the climate system, leading to uncertainties regarding the extent, distribution, and timing of climate change costs. In addition, the "unacceptable outcomes" condition is satisfied as there is a reasonable belief that the costs associated with climate change are likely to be substantial, possibly reaching catastrophic proportions. Lastly, the "care little for gains" condition is met by asserting that the expenses of stabilizing emissions, while considerable in absolute terms, are deemed manageable within the global economic framework, particularly when contrasted with the potential costs of climate change[22].

Notwithstanding, the Maximin is not always a sensible decision rule, since it might produce irrationality. Indeed, according to John Harsanyi

> «If you took the maximin principle seriously you could not ever cross the street (after all, you might be hit by a car); you could never drive over a bridge (after all, it might collapse); you could never get married (after all, it might end in a disaster), etc. If anybody really acted in this way he would soon end up in a mental institution.»[23]

Hence, Maximin is a method of disregarding probability, thus representing a type of irrationality. In certain situations, individuals exhibit probability neglect, directing their focus toward the worst-case scenario. However, if probabilities can be accurately evaluated and the worst-case scenario is highly improbable, the justification for probability neglect becomes challenging, even for individuals with a notably risk-adverse feeling[24]. This is the reason why the Council of Environmental Quality[25], while it once

---

[20] C. Sunstein, *Maximin*, cit., 943.

[21] J. Rawls, *A theory of justice*, Cambridge (MA), 1999.

[22] S. M. Gardiner, *A core precautionary principle*, cit., 55.

[23] J. C. Harsanyi, *Can the Maximin Principle Serve as a Basis for Morality? A Critique of John Rawls's Theory*, in *American Political Science Review*, 69, 2, 1975, 594.

[24] C. R. Sunstein, *Probability Neglect: emotions, worst cases, and law*, in *Yale Law Journal*, 112, 2002, 61.

[25] For more information see *whitehouse.gov/ceq/*, according to which «The Council on Environmental

mandated worst-case analysis, has abandoned this requirement. The rationale behind this decision is the rejection of such analysis on the basis that highly speculative and improbable outcomes do not merit consideration.

In addition, to support the application of the Maximin rule, the danger presented by the worst-case scenario needs to meet a certain minimum level of credibility. According to this perspective, the spectrum of potential outcomes should be regarded as "realistic" in an appropriate sense, implying that only plausible threats are taken into consideration. If these threats can be deemed implausible, then the Maximin rule should not be adhered to[26].

Moreover, the occurrence of problems in the real world that match this particular form is highly improbable. In situations where policies and laws are contentious, removing uncertain threats of catastrophe carries both costs and risks. For instance, in the case of climate change it is unrealistic to assert that regulatory decision-makers can or should be indifferent to what might be sacrificed by adhering to the Maximin principle. If countries were to adopt Maximin for addressing climate change, substantial expenditures would be incurred to reduce greenhouse gas emissions. This outcome would likely lead to elevated gasoline and energy prices, potentially causing rises in unemployment and poverty[27].

After all, in some circumstances it is not feasible to know the likelihood of any of the outcomes, including the bad ones: this is a Knightian uncertainty[28]. Sometimes, regulators act under conditions of uncertainty in which they are unable to predict the probability of bad outcomes or their nature; one explanation could be their involvement with a singular or nonrepeating event. Alternatively, it could be related to dealing with a problem where various components of a system interact, making it challenging for regulators to have substantial knowledge about the potential interactions among them. These situations are not rare in the regulation of the climate change. When a risk presents a dire or catastrophic worst-case scenario, avoiding it might be the most prudent course of action. However, these policies can be highly economically inefficient. The policy-maker is in a Knightian uncertainty, when a scientist, whose science is based on frequentist theory, refuses to assign probabilities since he lacks enough information or are unable to process a huge quantity of data (differently from

Quality (CEQ) within the Executive Office of the President [of the United State of America] coordinates the federal government's efforts to improve, preserve, and protect America's public health and environment.

CEQ, which was created in 1969 by the National Environmental Policy Act (NEPA), advises the President and develops policies on climate change, environmental justice, federal sustainability, public lands, oceans, and wildlife conservation, among other areas. As the agency responsible for implementing NEPA, CEQ also works to ensure that environmental reviews for infrastructure projects and federal actions are thorough, efficient, and reflect the input of the public and local communities.»

26 C. Sunstein, *Maximin*, cit., 943, 969.

27 Ivi, 970. It continues «The real question, then, is whether regulators should embrace maximin in real-world cases in which doing so is costly or extremely costly. If they should, it is because condition is too stringent and should be abandoned. Even if the costs of following the maximin rule are significant, and even if regulators care a great deal about incurring those costs, the question is whether it makes sense to follow the maximin rule when they face uncertain dangers of catastrophe.»

28 F. H. Knight, *Risk, uncertainty and profit*, Wilmington, 1921.

what machine learning technologies do *infra* § IV). It is worth noting that frequentists contend that assigning probabilities to unique or nonrepeatable events is essentially without meaning. According to frequentists, the challenge of Knightian uncertainty is widespread, arising whenever we face with a singular or nonrepeating issue[29].

An alternative approach to probability assessment is Bayesian, which doesn't rely on knowledge of frequencies and can be applied to unique or singular cases. In Bayesian methodologies, individuals might express a probability exceeding 90% for a specific set of outcomes related to climate change in 2100.[30] Bayesians initiate the process with a prior probability and adjust it based on new information. Unlike frequentists, they are open to assign probabilities to singular or nonrepeatable events. However, a Bayesian regulator could acknowledge the speculative nature of any subjective probability assigned to an event in a particular case, recognizing a lack of sufficient information and characterizing the situation as one of Knightian uncertainty. As consequence, even Bayesian regulators and policy-makers face epistemic limits connected to limited information, uncertainty and limits in quantification of data respect to environment and climate change.

In addition, it worth considering that the environmental policy-maker are humans and, as consequence, their decisions are biased by cognitive biases. First of all, regulators tend to be acutely aware of the drawbacks resulting from any newly introduced risk or the exacerbation of existing risks, whereas they often show less concern for the benefits that are sacrificed due to regulatory measures (*status quo* bias).

> «The status quo marks the baseline against which gains and losses are measured, and a loss from the status quo seems much worse than a gain from the status quo seems good.»[31]

In addition, a prominent bias in environmental regulation is the failure to recognize that postponing a decision incurs its own costs. The huge problem that pushes in favor of delay is the lack of information, that makes the prediction behind a policy not feasible. Procrastination in regulating or responding to climate change may result in significant harm to our planet and future[32].

Another cognitive bias is the tendency for individuals to be more accepting of risks they are familiar with compared to unfamiliar or the newer ones, even when the risks are statistically equivalent, likely because risk is inherent in life.[33] This is why certain individuals express concerns about using electric cars instead of traditional thermal cars, even though the real risks are associated with driving, and they do not evoke as much fear. A similar reflection can be made for the new generations of the nuclear power plants, that appear largely safer than the traditional energy sources. Due to loss aversion, people may not assess a loss from a new technology similarly to a loss from the current state. This psychological bias influences public reactions, potentially leading

---

[29] Sunstein, *Maximin*, cit., 947.

[30] E. Wagenmakers-M. Lee-T. Lodewyckx *et al.*, *Bayesian versus frequentist inference*, Cham, 2008, 181 ff.

[31] C. Sunstein, *Maximin*, cit., 963.

[32] Another noticeable example is represented by the restrictions adopted due to the outbreak of Covid-19 in 2020. Any delay caused deaths.

[33] P. Slovic, *Perception of risk*, in *Science*, 236, 4799, 1987, 280 ff.

to fear or outrage over deaths that might not have otherwise caused such reactions. Under this perspective, AI can assist policy-makers in making less biased decisions and provide guidance on how to communicate with citizens, potentially alleviating concerns and reducing apprehension about new technologies.

3. Issues in implementation of the UN Sustainable Development Goals

All the issues and difficulties highlighted before concerning policy-makers, especially in the context of climate change, are equally applicable to the effective realization of the UN Sustainable Development Goals. Specifically, when we refer to Goal 13, which deals with climate action, these challenges become particularly relevant.

The UN Sustainable Development Goals are a set of 17 interconnected objectives established in 2015 to address global challenges and promote sustainable development by 2030. These goals were adopted by all United Nations member states as part of the 2030 Agenda for Sustainable Development, declaring the need for a collective and comprehensive approach to tackle pressing issues facing the world. These goals encompass a wide range of economic, social, and environmental dimensions, aiming to create a more inclusive, equitable, and environmentally conscious world. These serve as a blueprint for a more sustainable and resilient future for people and the planet.[34]

Specifically, Goal 13 addresses the «urgent action to combat climate change and its impacts». Indeed, according to the UN, the global community is confronting an imminent climate crisis with far-reaching consequences for every individual, regardless of geographical location. Human-induced climate change, driven by escalating greenhouse gas emissions, poses an existential threat to life on Earth. Its manifestations include erratic weather patterns and rising sea levels. The repercussions of climate change extend beyond environmental concerns, jeopardizing decades of progress. To curb global warming and limit the rise in temperatures to 1.5°C above pre-industrial levels, immediate and transformative actions are imperative. The urgency of addressing climate change cannot be overstated. A failure to act swiftly will lead to catastrophic consequences, unraveling ecosystems and threatening the well-being of the most vulnerable populations.[35]

Nevertheless, all the concerns expressed in Section 2 are absolutely concrete in the implementation of the policies required by the UN Goals. In the realm of environmental planning, risks and uncertainties are widespread, necessitating policy-makers to systematically incorporate them into their analyses for the effective execution of the UN Goals. The intricacies of both human behavior and ecological systems contribute to the omnipresence of risks and uncertainties in environmental planning. Practically every determination made in a policy-maker's analysis of the UN Goals involves some degree of risk, uncertainty, or a combination of both[36]. This prevalen-

[34] See United Nations, Take Action for the Sustainable Development Goals, in *un.org*.

[35] United Nations, Goal 13: Take urgent action to combat climate change and its impacts, in *un.org*.

[36] B. C. Karkkainen, *Toward a smarter NEPA: monitoring and managing government's environmental performance*,

ce of risks and uncertainties stems from the inherent complexity and dynamism of the Earth's ecological systems[37]. In a nutshell, the widespread existence of risks and uncertainty makes achieving comprehensive analysis and transparency regarding these factors nearly unfeasible. There is a risk that policy-makers may make economically inefficient decisions, as the severity of policies might not align with the actual threat posed by environmental issues. Striking the right balance is crucial because policies that are either overly stringent or too lenient can result in significant wealth loss.

More specifically, it is possible to find two main problems in an effective implementation of the Goal 13, 14[38], 15[39]: the difficulty in defining what risks are significant enough to warrant discussion and the difficulty in cabining risks and uncertainties. They prevent the creation of a clear legal rule, that determines a severe impact on the economic operators. In addition, as succinctly described before in Section II.B, the projects that are implemented by the public regulator in compliance with these important goals may face intentional and unintentional biases. Indeed, firstly, the inherent inclination of public decision-makers towards favoring or opposing projects create intentional biases in the information presented, and it is strategically used to garner support or opposition. A political party might, with bad intentions, seek to gain support for a favored proposed action and weaken opposition by downplaying or omitting the discussion of the risk of an adverse environmental consequence resulting from the action or might intentionally minimize the likelihood of a negative environmental impact to sidestep unfavorable publicity or to evade dealing with adverse consequences associated with its preferred agenda. (without considering the cases in which fake news are spread out[40]). Secondly, psychological factors influence how information about a proposed action is processed, deviating from what might be expected from perfectly rational actors and leading to unintentional biases in available information. For instance, individuals tend to hold the belief that they are less susceptible to risks compared to others, this is a cognitive bias known as optimism bias. This bias is particularly pronounced for risks perceived as low-probability or controllable, a phenomenon applicable to numerous environmental risks[41]. These intentional and unintentional biases collectively impede the ability and willingness to effectively address low-probability risks, particularly those associated with worst-case scenarios. As consequence, these biases also suggest that worst-case analysis and other proposals

in *Columbia Law Review*, 102, 4, 2002, 903.

[37] See T. S. Aagaard, *A functional approach to risks and uncertainties under NEPA*, in *Michigan Journal of Environmental & Administrative Law*, 1.1, 2012, 110, «For example, an agency considering a management program for a major river may have to evaluate the possibility that the program could result in temporary drawdowns of a lake in the river system, which could increase the area of shoreline exposed, which could cause sediments from the exposed shoreline to dry out and become airborne through wind action, which, if the sediments are contaminated and if they are inhaled by humans, could pose a hazard to human health.»

[38] Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

[39] Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

[40] O. Pollicino (ed), *Freedom of Speech and the Regulation of Fake News*, Cambridge-Antwerp, 2023.

[41] B.C. Karkkainen, *Toward a smarter NEPA: monitoring and managing government's environmental performance*, cit., 116.

that would merely require additional information disclosure are unlikely to fulfill the requirements that are set by the Goal 16, which aims to create accountable and inclusive institutions at all levels[42].

Therefore, the UN' effort to put environmental issues at the centre of world leaders' political agendas seems to be in vain if not damaging, in which a polarization of the debate has resulted[43]. Indeed, we are witnessing situations where, on the one hand, there are political parties adopting solutions that, by exaggerating the Precautionary Principle, lead to highly inefficient outcomes; on the other hand, there are governments rejecting the fact that there is an environmental problem. In the most cases, environmental protection is often relegated to a secondary aim, conflicting with the primary goals of governments.[44] In such scenarios, policy-makers are inclined to adopt an optimistic perspective on the environmental impacts of proposed projects to alleviate tensions between environmental concerns and other objectives. By downplaying potential adverse outcomes, regulators can pursue their primary goals with fewer hindrances, avoiding the dilemma of tradeoffs. Paradoxically, prioritizing environmental protection as a goal may lead agencies to underestimate the likelihood of negative environmental consequences. Viewing adverse environmental impacts as a form of project failure, in the context of making environmental protection a substantive goal, introduces complexities in decision-making[45].

The myriad uncertainties surrounding actions taken against climate change create a challenging landscape for policy-makers, who are required to implement the 2030 Agenda for Sustainable Development. It is evident that governments require support in decision-making through an algorithm. This algorithm should impartially calculate all data pertaining to a specific phenomenon and offer the most economically efficient solution. Additionally, employing machine learning in decision-making enables a stronger rationale in political discussions. It prevents the implementation of unpopular yet essential measures for the planet's well-being from compromising the accountability of public decision-makers.

4. AI and machine learning for helping decision makers in environmental policies

In the previous sections we have delved into the intricate challenges of decision-making in environmental policy due to the inherent uncertainty embedded in the analysis of these complex phenomena. In this landscape, the integration of AI and machine learning emerges as a transformative force, empowering decision-makers to base their choices on tangible, data-driven insights rather than adhering to the cautious principle

[42] Ivi, 112.

[43] O. Pollicino, *The quadrangular shape of the geometry of digital power(s) and the move towards a procedural digital constitutionalism,* in *European Law Journal*, 29(1-2), 2023, 10.

[44] B.C. Karkkainen, *Toward a smarter NEPA: monitoring and managing government's environmental performance*, cit., 115

[45] *Ibidem.*

of "better safe than sorry." The robust computational capabilities of AI play a pivotal role in steering clear of inefficient decisions that could result in a substantial loss of wealth.

The unparalleled processing power of AI not only provides a pragmatic alternative but also opens avenues for reconsidering the traditional Precautionary Principle, even in its Maximin rule manifestation. By harnessing the accuracy and precision derived from data analytics, AI empowers public decision-makers to formulate targeted and context-specific decisions. What distinguishes these technological tools is their inherent ability to conduct analyses that are not only exceptionally precise but also free from biases. Unlike decisions influenced by intentional or unintentional biases that may affect human decision-makers, AI-driven analyses remain strictly tethered to the empirical nature of the data.

Crucially, decisions informed by AI analyses become more transparent and comprehensible to citizens. The distinct trust placed in these advanced tools stems from their commitment to data-driven objectivity. It is noteworthy that the European Commission, in formulating the AI Act,[46] explicitly aims to cultivate an environment where such technologies foster transparency, accountability, and public understanding. In doing so, it seeks to strike a balance between leveraging the potential of AI for efficient decision-making and ensuring that these technologies serve the broader interests of society. Indeed,

> «trustworthy AI has three components, which should be met throughout the system's entire life cycle: (i) it should be lawful, complying with all applicable laws and regulations (ii) it should be ethical, ensuring adherence to ethical principles and values and (iii) it should be robust, both from a technical and social perspective since, even with good intentions, AI systems can cause unintentional harm.»[47]

For instance, each year, high-impact convective weather events result in considerable human and property loss. The occurrence of billion-dollar events has been on the rise with climate changes. Although controlling these events is not feasible, policy-makers could enhance resilience to such high-impact phenomena by leveraging AI and machine learning to effectively advance prediction and understanding. More specifically, contemporary AI systems can adeptly comprehend intricate spatial and temporal patterns without necessitating extensive feature engineering. Differently from the earlier technological systems where computers learned solely on features identified by developers, constraining the model's hypothesis space, AI models can autonomously identify features. This capability allows AI systems to potentially discover novel features not previously recognized by domain scientists. AI methods offer a means to

[46] Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act), PE/24/2024/REV/1, OJ L, 2024/1689, 12.7.2024.

[47] European Commission, Directorate-General for Communications Networks, Content and Technology, *Ethics guidelines for trustworthy AI*, in *op.europa.eu*, 2019.

scrutinize data with fewer predetermined notions about the expected outcomes[48]. As previously cited succinctly, AI possesses the capability to manage extensive datasets that surpass the practical analysis capacity of a human. For example, in the context of convective weather, where vast amounts of data are generated by high-resolution Numerical Weather Prediction (NWP) models and new sensing systems, AI can effectively sift through this overwhelming data to pinpoint the most pertinent sections for human examination. In the case of generating numerous high-resolution NWP storms related to a specific phenomenon like hail, AI can navigate through the data, identifying predictive features and potentially unveiling new ones. Additionally, AI aids forecasters by streamlining the analysis of diverse datasets, such as high-resolution satellite data, mobile radar information, and data from field campaigns, highlighting critical areas for in-depth human study[49].

Governments, recognizing their crucial influence on the intersection of AI and climate change, should prioritize not only AI regulation but also substantial increases in research funding. By directing AI research towards targeted areas related to climate change, governments can facilitate access to advanced computational resources and extensive government datasets in a secure cloud environment. This strategic approach is essential for harnessing the potential of AI to address pressing environmental challenges effectively[50]. In a recent announcement, the US and EU unveiled plans for a collaborative effort in utilizing AI to tackle significant global challenges, emphasizing the need for AI in climate action.

> «This collaborative effort will drive responsible advancements in AI to address major global challenges with a joint development model and integrated research to deliver benefits to our societies through five key areas of focus: Extreme Weather and Climate Forecasting, Emergency Response Management, Health and Medicine Improvements, Electric Grid Optimization, and Agriculture Optimization.»[51]

Notably, four of these issues are intricately linked to climate change, highlighting the public sector's vision for the role of technology in the coming decades.

Under this perspective, the UK government, as part of its commitment to advancing AI and addressing associated risks, has announced[52] a significant investment in the AI Research Resource (AIRR). The investment aims to establish a dedicated national facility, the AIRR, providing state-of-the-art AI-specialized computing capacity

[48] A. McGovern – R. J. Chase – M. L. Flora *et al.*, *A review of machine learning for convective weather*, in *Artificial Intelligence for the Earth Systems*, 2, 3, 2023, 2. See also, A. McGovern-D. J. Gagne-J. K. Williams *et al.*, *Enhancing understanding and improving prediction of severe weather through spatiotemporal relational learning*, in *Machine Learning*, 95, 1, 2013, 27 ff.

[49] This section is from A. McGovern – R. Chase – M. Flora *et al.*, *A review of machine learning for convective weather*, cit. 2.

[50] C. Dennis – J. Leon Kirnberger – V. Shankar, *We need to use AI to fight climate change*, in *oecd.ai*, 30 May 2023.

[51] The White House, *Statement by National Security Advisor Jake Sullivan on the New U.S.-EU Artificial Intelligence Collaboration*, in *whitehouse.gov*, 27 January 2023.

[52] UK Government - Department for Science, Innovation and Technology, *Government commits up to £3.5 billion to future of tech and science*, in *gov.uk*, 16 March 2023.

to researchers, academia, and industry. This initiative aligns with the government's broader strategy to position the UK as a global leader in AI, fostering innovation and discoveries in the field and its commitment to ensuring responsible and coordinated AI development.

Similarly, the US National Science Foundation (NSF) has allocated[53] more than $140 million to establish various AI research institutes, among them the "AI Institute for Climate-Land Interactions, Mitigation, Adaptation, Tradeoffs and Economy (AI-CLIMATE)", that will complement the already operating "Institute for Research on Trustworthy AI in Weather, Climate, and Coastal Oceanography". The latter strives to tackle these challenges through the collaborative efforts of a multidisciplinary team, comprising scientists from three distinct fields: environmental science – encompassing atmospheric, ocean, and other physical sciences –, AI and social science, which incorporates risk communication.

This is a highly esteemed scientific institution that has already demonstrated how AI can significantly contribute to scientific advancements and, consequently, the adoption of public policies that are most effective in terms of wealth allocation. An example of this is represented by a situation, where machine learning fights against the uncertainty. The neural network is a machine learning model extensively utilized in environmental science for various tasks, such as predicting ocean-wave heights, the rapid intensification of hurricanes, and the formation of tornadoes, all of which are crucial for decision-making and policy formulation. To facilitate important decision-making processes, machine learning models must not only deliver predicted outcomes but also quantify the uncertainty in predictions[54]. There were few tools for assessing uncertainty in predictions, that are necessary for the public decision maker in environmental science. Nevertheless, recent developments in machine learning within the field of computer science have tackled this issue, which otherwise would have been addressed through an inefficient Precautionary Principle.

5. Quis custodiet ipsos custodes?[55]

In the discourse thus far, it has been posited that AI could serve a pivotal role in curtailing economic damages, attributable to its prodigious computational prowess. This, in turn, could potentially constrain the invocation of the Precautionary Principle, thereby diminishing the likelihood of adverse externalities. However, the question that now arises pertains to the potential losses generated by a trustworthy exploitation of AI. Roughly speaking, legislators around the world have adopted a risk-based approach to regulating AI, taking into account the potential risks associated with such use. However, it is evident that the risk-based approach is nothing more than a shadow of

[53] US National Science Foundation, *NSF announces 7 new National Artificial Intelligence Research Institutes*, in *new.nsf.gov*, 4 May 2023.

[54] K. Haynes – R. Lagerquist – M. C. McGraw *et al.*, *Creating and Evaluating Uncertainty Estimates with Neural Networks for Environmental-Science Applications*, in *Artificial Intelligence for the Earth Systems*, 2, 2, 2023.

[55] Giovenale, *Satire*, VI, O31-O32.

the Precautionary Principle. Indeed, this principle is particularly relevant in the context of AI, where the potential for harm is significant, and the science is still evolving. More specifically, the risk-based approach has become the dominant strategy for regulating AI worldwide, with the aim of balancing the need for innovation with protection from potential harm.[56] The main goal of this approach is to ensure that AI systems are developed and used in a safe, ethical, and responsible manner.[57] Indeed, the risk-based approach is predicated on the idea that regulation should be tailored to the likelihood and severity of potential harm that a particular application of AI could cause.[58] Instead of adopting a one-size-fits-all approach for all AI systems, risk-based regulation seeks to classify AI systems into different risk categories and apply proportional requirements to each category.[59] In other words, the risk-based approach appears to be an application of the principle of proportionality and non-discrimination, concepts that are prevalent in most democratic countries.[60] An application is in the EU's AI Act, that classifies AI systems into four risk categories: unacceptable, high, limited, and minimal or none.[61] AI systems that pose an unacceptable risk, such as those used for social credit scoring or real-time remote biometric identification in

[56] K. Grieman – J. Early, R*isk-based approach to ai regulation: system categorisation and explainable ai practices*, in *Journal of Law, Technology and Society*, 20, 2023, 56 ss.

[57] L. Floridi – M. Holweg – M. Taddeo *et al.*, *capAI - A Procedure for Conducting Conformity Assessment of AI Systems in Line with the EU Artificial Intelligence Act*, in *Social Science Research Network*, 2022, 3.

[58] M. Ebers, *Truly Risk-Based Regulation of Artificial Intelligence-How to Implement the EU's AI Act*, 2024, forthcoming, 3.

[59] G. De Gregorio – P. Dunn, *The European Risk-Based Approaches: Connecting Constitutional dots in the Digital Age*, in *Common Market Law Review*, 2022, 59, 473, 499.

[60] Among the others, art. 5 para. 4 TUE and art. 3 of the Italian Constitution. The principle of non-discrimination, in its broader conception, is becoming fundamentally relevant in the context of AI. Specifically, art. 10 AI Act explicitly links AI to EU anti-discrimination law, requiring that artificial intelligence systems be designed and used in a way that avoids discriminatory impacts and unjust prejudices. This highlights a move from a privacy-focused approach to a human rights-based approach in AI regulation, recognising discrimination as a significant risk associated with artificial intelligence systems, particularly those that use categories based on gender, race, and personal features. In parallel, the Council of Europe places the principle of non-discrimination as a guiding principle of its Framework Convention on Artificial Intelligence (see later). In addition, in art. 10 it is said that "Each Party shall adopt or maintain measures with a view to ensuring that activities within the lifecycle of artificial intelligence systems respect equality, including gender equality, and the prohibition of discrimination". Both legislative initiatives underscore the importance of considering discrimination within a risk-based framework, where artificial intelligence systems with a potential for discriminatory impact are subject to regulatory scrutiny and higher safeguard measures. This integrated approach aims to promote the responsible development and implementation of AI, while simultaneously ensuring protection against the risks of discrimination. On this issue, see C. Nardocci, *Intelligenza artificiale e discriminazioni*, in *Convegno annuale dell'associazione "Gruppo di Pisa"*, 18 e 19 giugno 2021; A. Fonzi, *Intelligenza artificiale ed uguaglianza: un percorso di prevenzione?*, in *dirittifondamentali.it*, 2, 2022; S. Wachter – B. Mittelstadt – C. Russell, *Why fairness cannot be automated: Bridging the gap between EU non-discrimination law and AI*, in *Computer Law and Security Report*, 41, 202; F. Z. Borgesius, *Discrimination, artificial intelligence and algorithmic decion-making*, Strasbourg, 2018; C. Nardocci, *Artificial Intelligence-based Discrimination: Theoretical and Normative Responses. Perspectives from Europe*, in *DPCE*, 3, 2023.

[61] Indeed, according to AI Act, Recital 26, "*In order to introduce a proportionate and effective set of binding rules for AI systems, a clearly defined risk-based approach should be followed. That approach should tailor the type and content of such rules to the intensity and scope of the risks that AI systems can generate. It is therefore necessary to prohibit certain unacceptable AI practices, to lay down requirements for high-risk AI systems and obligations for the relevant operators, and to lay down transparency obligations for certain AI systems.*"

public spaces for law enforcement purposes, are outrightly prohibited.[62] High-risk AI systems, such as those used in the healthcare, transportation, and employment sectors, are subject to stringent legal requirements, including obligations for conformity assessment, risk management, and data quality.[63] Limited-risk AI systems, such as chatbots and spam filters, are subject to transparency obligations.[64] Finally, minimal or no-risk AI systems, such as video games and mobile gaming applications, are not subject to any specific obligations under the AI Act.

This risk-based approach, despite its necessary distinctions and adaptations, has become the prevailing strategy for regulating AI systems worldwide, both at international and national levels, and in the work of (international) standard-setting bodies.[65]

For example, the Bletchley Declaration (UK AI Safety Summit) stipulates that countries should consider the risks associated with AI and, where appropriate, adopt "classifications and categorisations of risk based on national circumstances and applicable legal frameworks."[66] Further strengthening this trend, the G7 agreement on AI principles, established under the Hiroshima AI process,[67] emphasizes risk management. This agreement calls for the development, implementation, and disclosure of AI governance and risk management policies. These policies are expected to adhere to a risk-based framework. Beyond the borders of the European Union, the Council of Europe's proposed "Framework Convention on Artificial Intelligence" incorporates a two-pronged approach. This convention combines broad principles with a risk-based framework. Specifically, it mandates measures for identifying, assessing, preventing, and mitigating potential harms to human rights, democratic processes, and the rule of law throughout the lifecycle of AI systems, encompassing design, development, deployment, and decommissioning.[68] With regard to the national states, Canada's Directive on Automated Decision-Making mandates Algorithmic Impact Assessments.[69] This assessment process helps to identify and mitigate potential risks associated with such systems. Furthermore, Canada's upcoming Digital Charter Implementation Act, including the Artificial Intelligence and Data Act (AIDA), establishes a two-tier regulatory framework: the latter applies generally to "regulated activities," but imposes stricter requirements on "high-impact" AI systems, reflecting the potential for greater risks.[70] Brazil is presently scrutinizing a detailed AI bill with the aim of setting up a regulatory structure that is both rights-based and risk-based. This framework is de-

[62] AI Act, Chapter II.

[63] AI Act, Chapter III and Chapter VIII.

[64] AI Act, Chapter IV on transparency obligations.

[65] The following sections, with the appropriate modification and integration is taken from Ebers, *Truly Risk-Based Regulation of Artificial Intelligence-How to Implement the EU's AI Act*, cit., 4.

[66] Department for Science, Innovation & Technology, The Bletchley Declaration by Countries Attending the AI Safety Summit, 1-2 November 2023, 1 November 2023.

[67] European Commission, Hiroshima Process International Code of Conduct for Advanced AI Systems, 30 October 2023.

[68] Council of Europe, *Framework Convention on Artificial Intelligence and Human Rights, Democracy and the Rule of Law*, Treaty Series - No. [225], 9 May 2024.

[69] Directive on Automated Decision-Making of Canada, art. 6.1. and Appendix B.

[70] Artificial Intelligence and Data Act of Canada, Companion document, available at *ised-isde.canada.ca*.

signed to adapt regulatory responsibilities according to the potential risks associated with AI technology. In conclusion, major international organizations, including the OECD, have also embraced a risk-based approach. The Framework for the Classification of AI Systems, in fact, employs a risk-based strategy in offering guidelines for assessing the risks tied to AI systems.[71] Its aim is to foster a setting where legal duties are adjusted to risks, guaranteeing an ideal equilibrium between interests and due diligence. It includes procedures that aid in the refinement of risk classification standards based on empirical evidence, like the formulation of a risk assessment framework.

However, the risk-based approach in AI regulation is not without its challenges. One of the main issues pertains to the difficulty of defining and assessing "risk" in an objective and consistent manner, especially considering the rapid evolution of AI technology.[72] For instance, the AI Act has been criticised for its lack of a clear methodology for risk assessment and its reliance on a predefined list of high-risk AI systems, which may not be able to keep pace with technological advancements.[73] Furthermore, the risk-based approach could lead to fragmented regulation if different regulatory authorities adopt varying definitions and risk criteria. This could create legal uncertainty for businesses and hinder innovation.

In conclusion, even though the risk-based approach is an application of the principle of proportionality, that is one of the most relevant principles on which the Western constitution is based, it may create wealth loss. Indeed, the challenges just highlighted result in market failures and an inefficient allocation of resources. Therefore, the adoption of a risk-based approach model for AI regulation is simply an application of the Precautionary Principle, as reshaped for the digital age. In fact, the prediction of risk classes, which aligns with different duties, is nothing more than a categorisation of various AI tools based on predictions. Such predictions, by their nature, cannot be updated to the latest technological development and rely on a horizontal regulation of the different relationships, which do not consider the specifics of the actual case.

Thus, considering that both the use of the Precautionary Principle and the exploitation of AI (whose regulation is based on a risk-based approach) do not allow for decisions that are devoid of wealth loss, it is appropriate to understand how a rational operator would act. In the context of an extremely complex situation, such as the adoption of suitable strategies to combat climate change, the rational operator should make a comparison between the expected wealth loss, resulting from the Precautionary Principle and stemming from the exploitation of AI (whose regulation is based on a risk-based approach). The solution is quite evident: it is economically more advantageous to use AI, even if its regulation is based on a risk-based approach. Indeed, the adoption of particularly rigid measures, such as those suggested by the Precautionary Principle, have a significant impact in terms of dispersed wealth, and

---

[71] OECD, OECD Framework for the Classification of AI Systems, OECD Digital Economy Paper, February 2022 No. 323.

[72] M. Ebers, *Truly Risk-Based Regulation of Artificial Intelligence-How to Implement the EU's AI Act*, cit., 7. On the same topic, see G. De Gregorio – P. Dunn, *The European Risk-Based Approaches: Connecting Constitutional dots in the Digital Age*, cit.

[73] K. Grieman – J. Early, R*isk-based approach to ai regulation: system categorisation and explainable ai practices*, cit.

could prove ineffective for the purpose. We could witness an absurd situation (the worst in economic terms), where, despite the sacrifices demanded by the application of the Precautionary Principle, the harmful event would still occur, bringing with it severe economic consequences. In fact, AI, as much as it might be limited in some of its functionalities due to the need to protect some fundamental values (such as privacy), possesses a computational power enormously greater than any other calculation system (as demonstrated in paragraph § IV above), allowing the legislator to make decisions, such as those related to the fight against climate change, much more precise and economically efficient compared to those that would result from the application of the Precautionary Principle.

6. Conclusion

Until now, the challenging decisions made by public policy-makers in environmental matters have been based on the Precautionary Principle. The high level of uncertainty associated with the analysis of these phenomena and the unpredictable risk of catastrophic consequences for citizens have compelled public decision-makers to take drastic and often unnecessary measures to prevent the most serious environmental risk from materializing. However, these solutions have proven to be economically inefficient, resulting in a significant loss of wealth. Even in cases where it is deemed appropriate to apply the "modified" version of the Precautionary Principle in the decision-making process, namely the Maximin rule, the adopted policy remains economically inefficient. In fact, even if the most severe hypothesis, which would occur with very low probability, is excluded from the decision-making process, the precautionary decision would still not be tailored to the actual risk. Finally, it is noteworthy that decisions made by public decision-makers are influenced by both unintentional and intentional biases, such as the need to garner voter approval.

We have reached a critical juncture where the urgency of addressing environmental challenges, particularly in the face of climate change, demands swift and decisive actions from public decision-makers. The imperative to achieve the UN Sustainable Development Goals by 2030 underscores the need for massive and immediate interventions, especially in the realm of environmental sustainability. Given the inherent uncertainties and complexities associated with crafting effective policies to combat climate change, relying solely on the Precautionary Principle not only proves ineffective but emerges as highly economically inefficient.

The pressing nature of the environmental issues at hand requires a departure from traditional approaches and a shift toward innovative, data-driven strategies. It is crucial for decision-makers to go beyond mere precaution and embrace targeted, evidence-based policies that can effectively address the multifaceted challenges posed by climate change. The intricate web of interconnected environmental, social, and economic factors necessitates a nuanced understanding, and the application of advanced technologies, such as AI and machine learning, becomes instrumental in achieving this goal. These technologies can provide data-driven, unbiased analyses, offering a more

accurate understanding of environmental risks and their potential consequences.
Through the utilization of AI, decision-makers can depart from generic precautionary measures and embrace more tailored, context-specific policies. The prowess of AI models in processing extensive datasets and identifying patterns without predetermined features facilitates a comprehensive and nuanced evaluation of environmental risks. As we enter an era where technological advancements shape policy-making, there is optimism for decisions that are not only more informed and efficient but also strike a balance between addressing environmental challenges and considering economic factors. The ongoing integration of AI and machine learning in environmental decision-making signifies a noteworthy stride toward a future where policies are not only effective but also indicative of a nuanced understanding of the intricate interplay between human activities and the environment.
AI's ability to harness the accuracy and precision derived from data analytics empowers public decision-makers to craft decisions that are both targeted and context-specific. What sets these technological tools apart is their inherent capacity to conduct analyses that are not only exceptionally precise but also devoid of biases. In contrast to decisions influenced by intentional or unintentional biases that may impact human decision-makers, AI-driven analyses remain firmly rooted in the empirical nature of the data. A crucial aspect is that decisions informed by AI analyses become more transparent and comprehensible to citizens, fostering trust and understanding in the policy-making process. As we embrace this era of technological advancement, the promise of AI in environmental decision-making holds the potential to redefine how societies approach and address the intricate challenges posed by environmental sustainability.
Indeed, despite AI's computational capabilities potentially mitigating economic damages and curtailing the application of the Precautionary Principle, the risk-based approach - essential for protecting competing significant interests - to AI regulation, a contemporary application of the Precautionary Principle, could result in wealth loss due to market inefficiencies and suboptimal resource distribution. However, it is economically advantageous to use AI, which, despite its limitations, offers greater computational power and efficiency in decision-making, such as in combating climate change, compared to the rigid measures of the Precautionary Principle.