Workshop report

Ensuring the environmental sustainability of emerging technologies

Executive summary

On 27–28 October 2021, the EPFL International Risk Governance Center (IRGC) organised an expert workshop to discuss concerns about the environmental sustainability of emerging technologies and the extent to which these concerns are currently considered by those who develop, fund or deploy new technologies. The workshop examined ways to ensure that concerns are addressed at the beginning of the development process through the early identification, assessment and management of possible risks. It then considered the kinds of guidance that could be useful to technology developers, industry leaders, investors, regulators and others, to ensure that outcomes of an emerging technology do not threaten environmental sustainability, or that potential adverse effects are identified and addressed early.

The workshop reviewed various response strategies and formulated some generic recommendations across five distinct technology domains: chemicals and advanced materials, synthetic biology, digital technologies, carbon dioxide removal (CDR) and sequestration, and space technologies.

International Risk Governance Center

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Emerging technologies

Emerging technologies are new technologies or advancements in existing technologies that dramatically improve their performance. Some can disrupt existing industrial processes or contribute to fundamental economic and societal changes. They can be radically novel, develop fast and have powerful consequences. Emerging technologies pose unique challenges to risk assessors and managers because of a general lack of procedures and tools to assess their potential impact, insufficient data on which to build evidence, and pervasive uncertainty about how the technology will mature and be deployed in the market. These challenges are compounded by ambiguity in emerging technology assessments due to diverging views and interests. This ambiguity manifests as a lack of clarity in the value system that underlies tools like environmental impact assessments or life-cycle assessments, or even in the objectives that employing these tools can help achieve.

The importance of developing technologies for combatting climate change, for environmental protection or remediation and, more broadly, for environmental sustainability has been demonstrated in recent years, with much investment poured into them. This report takes a different perspective and addresses concerns raised by the risk that emerging technologies can cause unexpected damage to the natural environment or the climate in the longer term.

Sustainability of technology

Emerging technologies offer a multitude of benefits but can also have adverse effects on the environment. The balance will depend on how narrowly or widely the net is cast to identify applications and their implications, the time horizon considered, and the technologies' specific characteristics. For example, strong policy incentives and increasing attention from policymakers encourage investment in "green" technologies, and support "sustainable finance" to meet the expectations of governments, investors and the public. However, this may lead to promoting and pursuing certain technologies without appropriate impact assessments or due consideration of the possible undesirable side effects. Such a rush to find solutions to immediate problems may overlook the full extent of the longer-term consequences in the natural environment and climate.

Chemicals: Advanced materials and smart nanomaterials

New chemicals and advanced materials that improve industrial and product performance and efficiency may raise concerns about potential long-term environmental damage if they end up in terrestrial or marine ecosystems. Long-term challenges are associated with uncertainty about the environmental impacts of advanced materials, such as with so-called smart nanomaterials (active nano-based products and systems whose function changes in response to external stimuli), and concerns exist over the lack of tools to conduct environmental assessments that are appropriate for new developments.

Synthetic biology: Gene editing and gene drives

Synthetic biology, in particular gene editing and gene drives, can significantly benefit public health, agriculture, environmental remediation and biodiversity conservation. However, it can also cause substantial knock-on effects on conservation, including modified genes spreading to non-target populations and food webs affecting broader ecosystems. As a result, it is often contested within the environmental expert communities. Evidence is lacking on the long-term impacts after release in the natural environment, limiting our ability to evaluate the risk-benefit trade-offs, which makes the early governance of deployment challenging.

Digital technologies: Machine learning, cloud computing and blockchain

Digital technology applications can help reduce stress on the environment in specific domains. They also raise concerns, however, about their environmental and climate impacts, such as through their electricity consumption, use of natural resources, mining of rare earth elements, and waste disposal and recycling. Efforts are underway to measure and report on the carbon footprint of specific applications. The balancing of benefits and risks is particularly challenging, considering the many opportunities offered by digital technologies to contribute to the sustainable development goals.

Carbon dioxide removal and sequestration

CDR is being developed to reduce atmospheric CO_2 concentration, thus mitigating climate change. Its deployment through negative emission technologies is necessary to reach the current climate goals, i.e., to neutralise residual greenhouse gas emissions to achieve net-zero. However, a range of uncertainties are associated with the various CDR approaches, whether nature-based, engineered or hybrid. Adverse consequences on biodiversity, ecosystems and human systems are among the risks, and some of the sequestration of the CO_2 in various reservoirs could be reversed. Some potentially important effects have already been identified if the techniques are deployed on a large scale. Because of their apparent necessity and the flurry of investments to address climate change, some technologies may be used and expanded without a full assessment of their second-order impacts on the environment (or the climate itself through the impermanence of the sequestration).

Space technologies

Satellite operators increasingly use outer space to deliver critical services, including earth observation and environmental monitoring. The growing space infrastructure provides an opportunity to improve sustainability on Earth. However, the increasing risk of collision between satellites and orbital debris, as well as adverse consequences of space activities on the atmosphere, could prevent the sustainable use of space in the long term. The deployment of emerging space technologies may exacerbate environmental sustainability risks, such as collision or pollution.

Matters of concern – Key themes

The report discusses concerns related to several key themes:

- **There are often significant uncertainties involved in the anticipation of an emerging technology outcome**. Thus, instead of passing an overall judgement on a technology, it is necessary to look at the expected outcome of its applications on a case-by-case basis. The outcome of a specific technology may change between the time it appears as an idea and the time it is used in a product, manufactured and placed on the market, i.e., between design and deployment. Moreover, value systems and visions of what is desirable evolve over time, affecting risk perceptions and technology assessments. In the face of promising (but uncertain) applications and potential risks, balancing their benefits and costs, or innovation and precaution, is not a simple technical exercise, but one that requires engaging with various stakeholders who may have different perspectives on the technology and its possible functions and outcomes.
- **Instruments to assess sustainability, which is context- and sometimes case-specific, are lacking**. Although the concept of sustainability is theoretically well defined, translating it into actionable assessment tools and metrics is far from obvious. It is not easy to design criteria, indicators or processes for materialising the concept in the physical world. Moreover, the concept does not apply well to individual products, and requires a systems approach to incorporate the benefits and risks to various actors and systems across the supply chain. Environmental sustainability is a multidimensional concept that requires its potential trade-offs to be addressed transparently. This makes the establishment of actionable tools and metrics challenging.
- **Solutions to immediate problems may not be sustainable in the long term**. In a rush to embrace solutions to deal with well-identified problems, risks to long-term environmental sustainability could be created and neglected. Although response strategies to pressing issues must be developed, rushing to solutions without a sufficient ex-ante evaluation of their potential risks and related uncertainties would be a mistake. In some cases, the cure may be worse than the disease.
- **Temporal issues and biases complicate matters**. Environmental effects may not be visible immediately, and no consensual system exists for internalising the negative externalities that would only manifest in the long term. History and scholars have shown that it is hard to learn from the past and that a range of cognitive and organisational biases explain why humans and organisations are not good at preventing something terrible from happening in the future.
- **The conventional containment approach to risk management has limitations**. Developing ways to prevent a risk's materialisation and reduce its consequences remains effective in several technology domains but becomes challenging with technologies that produce active systems that adapt and change in response to external stimuli. The changing nature of many new technologies that diffuse and alter with use suggests that

traditional assessment and management approaches have reached their limits.
- **Society may not agree on what presents a risk to environmental sustainability**. Yet, people's engagement is important to arbitrate trade-offs. Public acceptance and support for emerging technologies can be affected when the potential and actual adverse impacts of the technologies seem to be ignored or downplayed.
- **Regulation faces a pacing problem**. It is hard for regulators to keep pace with innovation and accompany the deployment of new technologies with appropriate regulations.
- **Research priorities are not always guided by moral and ethical considerations**, which are reflected in attitudes towards environmental sustainability. In the absence of such considerations, the default approach becomes that if something can be developed, someone will do it.

Recommendations

Acknowledging the difficulty of capturing and making the concept of environmental sustainability concrete, and taking into account the features of emerging technologies in various fields, this report provides some overarching recommendations:

- **Systematise early-stage technology assessments**, especially in institutions that advise policymakers on where and how to support or regulate specific technologies. Sustainability should not be prescribed or considered only after the technology has been deployed in actual products.
- **Develop methods and tools for prospective life-cycle assessments** to be applied in the early development phases of a technology, when there is a lack of data and uncertainty about the future product and market, but there is still time to change the technology's design to establish fundamental conditions that would ensure the sustainability of the outcome.
- **Refine the concept of sustainability-by-design**, and develop frameworks and criteria in selected technology domains that funding agencies, investors, industry leaders and regulators could consider to encourage built-in sustainability. Criteria could include safety, resource use and circularity (recyclability), and the effects on greenhouse gas emissions and ecosystems.
- **Create a value proposition for sustainability** that identifies clear, measurable and demonstrable benefits for innovators and investors. A strong value proposition would help innovators reconcile long-term sustainability and short-term innovation goals, and end-users prioritise environmental sustainability in their choices. Government interventions that help internalise both positive and negative externalities associated with sustainability can enhance the value proposition. Performance-based standards and certification also have a role to play in enhancing the business models for sustainability.
- **Work to develop flexible and adaptable regulatory frameworks** that integrate new knowledge generated over time, and consider the possible roles of liability regimes and the judicial system to establish the importance of environmental sustainability in practice, as well as reporting and standards as precursors or proxies of regulation.
- **Establish specific guidelines**, perhaps in the form of a compass (akin to a GPS and map), to indicate the direction to environmental sustainability. The compass would help technology developers, investors, policymakers and others to develop a mindset or appropriate attitude towards environmental sustainability. It would point to approaches for sustainability assessments, policy and legal requirements, and to available incentives that reward engaging in practices for environmentally sustainable technology development, deployment and investment. It would thus also indicate where support can be found to reach sustainability goals.

More research and the development of case studies of specific sustainability challenges and how they are addressed in key technology domains will be needed to refine the recommendations.

About IRGC

The EPFL International Risk Governance Center (IRGC) is an interdisciplinary unit dedicated to extending knowledge about the increasingly complex, uncertain and ambiguous risks that impact human health and safety, the environment, the economy and society at large. IRGC's mission includes developing risk governance concepts and providing risk governance policy advice to decision-makers in the private and public sectors on key emerging or neglected issues. It emphasises the role of risk governance and the need for appropriate policy and regulatory environments for new technologies where risk issues may be important.

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