2021

Annual Report

Overview of activities

International Risk Governance Center

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Foreword

EPFL is a polytechnique university, which means that an overwhelming fraction of its faculty members is composed of scientists and engineers. So why should a university like EPFL support a center like IRGC, which does not directly advance the research agenda of its faculty?

The answer to this question is both simple and compelling. EPFL, like other great universities, does not exist in a vacuum. Instead, they are part of the national and global society, from which they draw financial and human resources. This relationship, however, cannot be a one-way street. Society must also benefit from EPFL's education and research activities. Switzerland explicitly recognises that these benefits are not just side effects that naturally flow from on-campus activity. It also charges EPFL with a mission of innovation to ensure that research produces economic benefit. EPFL has long been a leader in Europe in this area, with a visible and active Vice President for Innovation and groundbreaking Innovation Park.

Viewing innovation solely in economic terms, however, misses an essential aspect. EPFL researchers produce knowledge and understanding, which is crucial for managing the societal, economic, health, and political challenges the world faces. Moreover, unlike most of society and government, professors and scientists have thought long and hard about the phenomena underlying these challenges and possess the mathematical and modelling skills to analyse them and make informed predictions.

However, the engagement between research and policy or government is not easy. Both sides speak differently, think differently, and act differently. They rarely understand each other's goals and motivations and find a common modus vivendi almost impossible task. Covid-19 illustrates this point vividly. Many EPFL professors dropped their research to participate full time in the Swiss governments' responses to Covid. In the end, the stories of misunderstandings, missed opportunities, and frustrations will probably be remembered by both sides long after the few successes are forgotten.

This failure is a failure of innovation because the "customer," in this case, was a society and government, not a business as in most innovative activities at EPFL. It would behove the university and Switzerland to understand the causes of this failure and find ways to rectify them.

It is exactly where a center like IRGC can play an important role. IRGC's risk governance framework provides an approach —certainly not the only way— to help bridge this gap. It can show researchers that policymakers may not be looking for a solution to a problem. Instead, understanding and containing its consequences might be more politically possible. Similarly, the framework can help policymakers ask researchers appropriate questions that elicit usable responses.

A university like EPFL needs to be able to speak in a manner understood by society in general. Organisations like IRGC, which bridge the boundary between science and policy, are essential to allow researchers and scientists to participate fully in this dialogue.

James Larus
Academic director

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January 2022: a letter from IRGC

In October 2021, IRGC organised a workshop entitled '**Ensuring the environmental sustainability of emerging technologies**' to discuss concerns that some emerging technologies are being developed without sufficient attention to the risks they may cause to environmental sustainability, and ways to ensure that such developments do not generate additional stress to the environment or the climate. It has often happened in the past that a technology developed for its benefit to society also incurs risks to the climate, resource use, biodiversity, or ecosystem services. We are concerned that this is still the case, despite learnings from the past. For example:

- Advanced materials such as active nanomaterials that improve the performance and efficiency of chemical processes might cause environmental damage if they end up in the terrestrial or marine ecosystems.
- Synthetic biology, in particular gene editing and gene drives, could have significant benefits for public health, agriculture, environmental remediation and biodiversity conservation. However, evidence is lacking about their long-term impacts after release in the environment, limiting our ability to evaluate the risk-benefit trade-offs.
- Technologies and nature-based approaches are in development to sequester carbon dioxide after it is removed from the atmosphere, which is needed to avoid dangerous climate shifts. However, a range of uncertainties and risks are associated with the various approaches, including their effects on biodiversity, ecosystems, and human systems. Moreover, the sequestration may not be as effective and permanent as needed.
- Digital technologies improve the performance and quality of many services dramatically. However, they also raise concerns regarding their environmental and climate impacts through their electricity consumption, use of natural resources, mining of rare earth elements, and waste disposal and recycling.
- Space technologies are increasingly questioned for their sustainability, which must be contrasted with benefits from satellite-based services.

In this workshop, Sheila Jasanoff, a professor at the Harvard Kennedy School who explores the role of science and technology in the law, politics, and policy of modern democracies, reminded us that the containment approach adopted in conventional risk management reaches its limits with the changing nature of many new technologies that diffuse and change with use, or that are foundational to a range of possible applications and are intended to be pervasive. This poses enormous challenges to risk management, for example in chemical and digital technologies. The illusion of control is dangerous. We can continue to think in terms of fixing problems for some individual risks that affect safety or security and, indeed, anything that could be 'fixed' as in, for example, safety- or security-by-design, should be addressed this way. However, the systemic nature of risk becomes obvious in today's interconnected world, as shown by risks related to climate change, risks related to Covid-19 in health, the economy and society, and individual and societal risks related to the digitalisation that can cause discrimination, loss of privacy and unethical decisions.

Climate change will bring growing numbers of extreme events and associated catastrophes. Like other organisations, IRGC sees major threats to the environment and society coming from climate change, for two sets of reasons: the consequences of the risk in terms of physical, economic and social damage, and the lack or limitations of institutions and individuals' real capacity or willingness to do what is needed to combat climate change effectively. As a rule, IRGC focuses on what can be done rather than complaining about human and institutional deficiencies that cannot be remedied in the short term or normal operating conditions. Accordingly, in 2021, we have done work to help others overcome risks caused by the energy transition (see our work on transition risk), to support those who deploy large-scale carbon dioxide removal in a way that does not cause unaddressed consequential risks (see on-going work on ensuring the environmental sustainability of technology), and to encourage research initiatives to inform decisions regarding possible reasonable undertakings to limit temperature increase through solar radiation modification (see our Spotlight on risk articles on SRM).

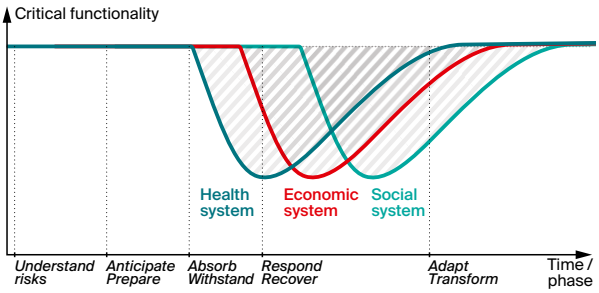
Artificial intelligence has also come prominently in our work in 2021, because it is a driver of major societal transformation that could cause large disruptions and systemic risks if not governed well. The power of machine learning and the lack of human control on how its results are automatically used in decisions, added to the environmental and climate cost of the supporting infrastructure, should raise more attention. Major challenges result from the intrinsic interconnections between benefits and risk and a lack of adequate trade-off resolution mechanisms. In other words, we take what we like, performance and convenience, and too often put our head in the sand about the other side, including when fundamental values like non-discrimination, privacy, ethics or democratic organisation of decisions are ignored or neglected. Some countries and cultures are taking this seriously, others not.

Space debris represents risks both in space and on Earth. In the context of outer space, which some call the 'ultimate frontier' or the 'wild west', we have been working on the problem of space debris (see our work on space debris in 2021). While space actors and those who depend on services provided by the space industry have been exposed to the risk of collision between operational satellites and orbital debris for many years already, the problem is growing more serious with the launch of large constellations in low-earth orbit and with irresponsible behaviours of actors who create collisions purposely. Concerns are of two types: technical and governance. Both the risk of collision and the value of services at risk increase, but technologies for remediation and mitigation exist, although they are imperfect and expensive. In terms of governance, the stakes are high, involving national security and commercial aspects, and public and private critical services. It is unclear what measures are effectively deployed to reduce the risk (we cannot go 'up there' and check), but what is sure is that stakeholders from various countries have different views about how the access to and use of space could, should or should not be managed. This is not very promising for the future.

SARS-CoV-2 and Covid-19. I mentioned in our 2020 annual report some learnings from the first year of living with this virus and the disease it causes, along with what the risk governance lens enables us to understand, and some indications for action. A year later:

- It is still very challenging for policy to make sense and deal with scientific uncertainty, particularly the biological development of a smart virus that mutates and adapts to optimise its chances of reproduction.
- Strategic advantages went to those who could prepare in advance for surprises and crises (including with backup, slack and financial reserves) or develop societal trust in government and science.
- Crisis communication is of utmost importance. If not well undertaken, it can completely ruin a good management strategy. On the other hand, it can somehow compensate for a lack of resources if done well.
- For an effective policy-science dialogue that contributes to building trust in governments and their decisions, scientists must respond to policy questions and constraints. They will not try to impose their own truth or convictions without also acknowledging that what they know may be tainted with uncertainty. They will recognise the difficulty of policy decisions when those unequally impact society.
- Covid-19 risk is a systemic risk that propagates within and between complex adaptive systems. It shows that resilience-building is more complicated than what many advocates of resilience pretend. The waves of disruptions to the health system first, then to the economic system and society (as illustrated in the figure below) illustrate the interconnections between systems. Making a system more resilient could damage the resilience

Shock propagation and resilience curves
in the case of Covid-19



of another system. For example, enabling the health system to recover more quickly through lock-downs has caused shocks to the economic and social systems. There is no perfect solution, though, so the best one can do is to navigate uncertainty and adapt, not losing sight of the goal: to become familiar with a new type of virus that is here to stay, because it results from a new type of interactions between natural and human-made system, and we must learn how to live with it.

- It is often said that crises open a window of opportunity for actions that are not possible in normal times. In its recent report, the Global Preparedness Monitoring Board (GPMB), which is the international body responsible for assessing the state of the world's preparedness for pandemics and other health emergencies, writes that the window opened by Covid-19 is closing. Have we found what opportunity this crisis has opened? What desirable changes can effectively be made, and how?

IRGC's principles and approaches to risk governance are more relevant now than ever. They are presented in various publications that are consistently cited in the literature and frequently used by policymakers and scholars, as shown later in this report. The three major publications are the IRGC risk governance framework and the two sets of guidelines for the governance of emerging and systemic risks. None of IRGC's approaches provides ready-to-use solutions, making them both demanding to use and valuable. They are flexible and must be adapted to and appropriated by the organisations that use them. IRGC's approaches:

- Help organisations structure the process by which they can make sense of a particular situation and prepare their strategy.
- Organise the interface between science and policy and their respective roles, so that the production of scientific knowledge can be effectively used for evidence-based policymaking, including when uncertainty and ambiguity make decision-making difficult.
- Help build confidence that no important aspects will be overlooked in the risk governance process from assessment to decision and management.
- Support the assignment of responsibilities and the development of the necessary capability to assume responsibility.

IRGC's work is grounded in a combination of established methods including comprehensive risk assessment, involving technical, opinion and concern assessment; capturing and making sense of expectations and goals of those who make decisions regarding risk, especially concerning how they resolve the trade-offs between risks; deploying portfolio approaches to risk management that combine managing the risk at its source and managing the impact and consequences of the risk; and organising the communication of risk and benefits in a dialogue, rather than in a top-down approach.

As we have learned from a **survey** conducted in December 2021 among individuals who have been in contact with us in the past two years, many people familiar with IRGC have adopted IRGC approaches to improve their research or the decisions they make, and in their teaching and education. We have also learned, yet unsurprisingly, that many other people who appreciate the value or usefulness of the recommendations we provide to deal with specific risk issues (e.g. technologies for climate interventions, space debris collision risk) are not aware of the principles and approaches that guide all that we do. Before deciding to work on a specific topic, we always take time and consult our wide network, and in particular our Advisory Board, to understand the context and the risks involved and before evaluating challenges to address. Then we organise the collection of multi-disciplinary scientific evidence and involve various stakeholders to capture what shapes the context in which risks develop and the range of possible response strategies. Then we use this information to identify what can be leveraged to manage risk.

I hope you will continue to be interested in what we do and look forward to engaging with you in 2022.

Marie-Valentine Florin
Executive director

Main activities related to research and policy

Workshop and publications

Low-carbon transition risk and technological climate interventions

- → Risk governance and the low-carbon transition (Policy brief, February)
- → Combatting climate change through a portfolio of approaches (Spotlight on risk, June)
- → A risk-risk assessment framework for solar radiation modification (Spotlight on risk, June)
- → Using stratospheric aerosol injection to alleviate global warming: when? (Spotlight on risk, December)

Governance of space debris collision risk

- → Intensifying space activity calls for increased scrutiny of risks (Spotlight on risk, April)
- → Governing collision risk from space debris in low Earth orbit (Expert workshop, May)
- → Collision risk from space debris: Current status, challenges and response strategies (Report, June)
- → Policy options to address collision risk from space debris (Policy brief, November)

Governance of risks related to digitalisation

- → Using proof of personhood to tackle social media risks (Spotlight on risk, March)
- → Governance and digital technologies: interrelations and opportunities (Report for the Horizon 2020 Trigger project, March)
- → Risk governance and the rise of deepfakes (Spotlight on risk, May)

Synthetic biology

- → Emerging threats of synthetic biology and biosecurity (Edited volume on outcomes of a 2019 workshop, NATO Science and Peace Programme series, Springer, September)

Emerging technology and environmental sustainability

- → Ensuring the sustainability of emerging technology (Expert workshop, October)
- → Ensuring the environmental sustainability of emerging technology (Workshop summary, December)

All IRGC publications can be found at www.epfl.ch/research/domains/irgc/publications

Climate change and technological climate interventions

Addressing risks from transitions to low-carbon economies

In relation to climate change and the energy transition, and informed by an expert workshop in September 2020, we published the policy brief Risk governance and the low-carbon transition, the purpose of which was to help drive successful climate action by targetting some of the underlying causes of climate inaction. The publication provides a comprehensive look at the countervailing or consequential risks that could be triggered by the low-carbon transition. Drawing attention to these risks may seem provocative, given the urgent need to engage in such transitions and to fundamentally transform the economy for more sustainability. However, we posit that, if left unaddressed, these risks will continue to slow or derail successful climate action.

The policy brief calls on decision-makers to anticipate potential disruptive side-effects of the transition so that they can plan ahead to mitigate them. It also outlines the range of necessary governance responses.

Outreach activities

This work was discussed in several external events and media, including at the Society for Risk Analysis (SRA) annual meeting and World Economic Forum ("For climate policies to stay on track we must prepare for transition risks").

Researching, developing and deploying techniques to intervene in the climate (aka climate engineering)

Following last year's publication of the report International governance issues on climate engineering for the Swiss Federal Office for the Environment, we have continued our work on the governance of complementary techniques and approaches to greenhouse gas emission reduction and climate adaptation. While IRGC's main recommendation is to reduce greenhouse gas (GHG) emissions at source and develop strategies to adapt to a new climate, we believe that other approaches are needed (to remove CO_2 from the atmosphere) or should be considered (to modify solar radiation).

Spotlight on risk articles


EPFL
Spotlight on risk
Combatting climate change through a portfolio of approaches
Marie-Valentine Florin
1 July 2020

Combatting climate change through a portfolio of approaches

This Spotlight on risk article, written by Marie-Valentine Florin, reminds that climate policies can be built around a more comprehensive portfolio of technologies and approaches to addressing climate change. Along with GHG emissions reduction and adaptation to warming, the portfolio should include techniques for atmospheric carbon dioxide removal (CDR), which will need to be deployed at a large scale to limit the temperature increase to below two degrees Celsius.

The work of the IRGC is driven by the fundamental conviction that various ways must be pursued to support and implement prudent yet large-scale CDR to contribute to reducing atmospheric CO_2 concentration. Many challenges and risks have to be addressed, and this will be one of the focus areas explored in our just started project work on "Ensuring the environmental sustainability of emerging technologies".

Targeting not the source of climate change but some of its consequences, we would like to continue the conversation about solar radiation modification (SRM). However, it remains very difficult to find funding support for this. For that reason, we used our Spotlight on risk series to write on specific aspects, intending to offer ideas to the global conversation, and published two short articles on the topic:


EPFL
Spotlight on risk
A risk-risk assessment framework for solar radiation modification
Carnegie Climate Governance Initiative (C2G)
15 July 2020

A risk-risk assessment framework for solar radiation modification

This piece was written by guest authors Nicholas Harrison, Janos Pasztor and Kai-Uwe Barani Schmidt from the Carnegie Climate Governance Initiative (C2G). It looks at SRM techniques to artificially cool the planet and explores the risk trade-offs of exploring these new technologies and not engaging with them.


EPFL
Spotlight on risk
Using stratospheric aerosol injection to alleviate global warming: when?
Marie-Valentine Florin
16 December 2020

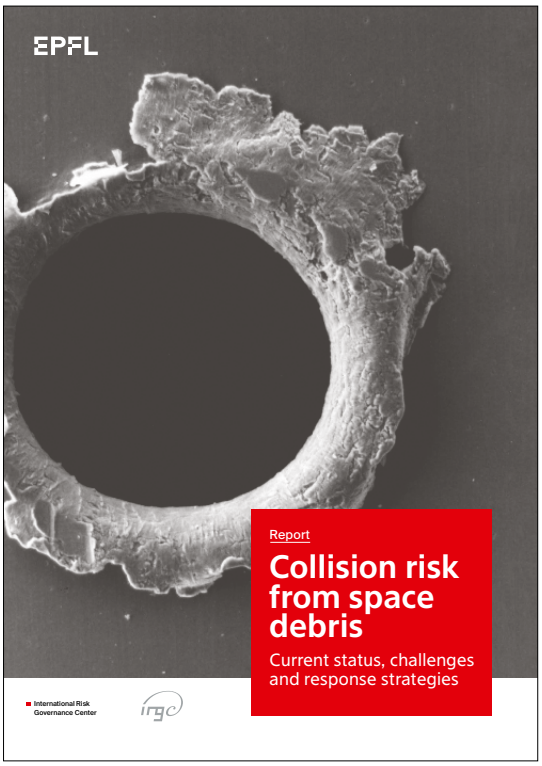
Using stratospheric aerosol injection (SAI) to alleviate global warming: when?

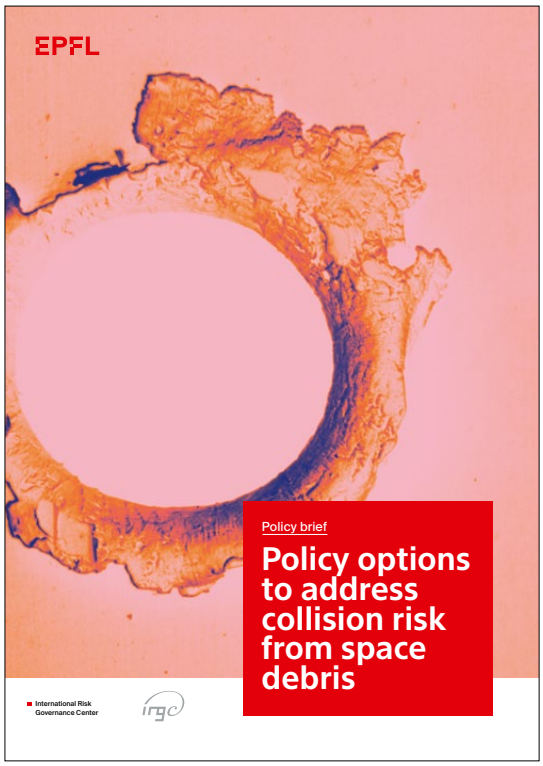
In this opinion piece, Marie-Valentine Florin offers a decision framework to help policymakers think about the timing of potential SAI deployment, which could make them feel more comfortable about supporting research into SAI and other SRM technologies.

Outreach activities

IRGC's has participated in numerous opportunities to disseminate and share its project work on climate intervention, including at the United Nations Economic Commission for Europe (UNECE), Aarhus Convention and in the general media (see details in "Outreach, impact and feedback from IRGC's audience" section).

Evaluating and addressing collision risk from space debris





There are currently around 4,500 active satellites in space, with plans to launch up to 60,000 more in the next decade. Each additional item in space increases the risk of collision and the creation of more space debris, which threatens the safety and feasibility of future space operations. In early 2021, in collaboration with the EPFL Space Center (eSpace) and Space Innovation, IRGC began a new project to study the governance of risks related to space debris and assess policy options to ensure safe and sustainable use of space.

As part of this project, an expert workshop was organised in May, bringing together an interdisciplinary and multi-stakeholder group. The participants from space organisations, governments, industry and academia discussed the risk governance challenges posed by space debris and proposed recommendations for research and policy.

Based on preparations for and discussions from that workshop, in June, we produced the report Collision risk from space debris: Current status, challenges and response strategies, which offers a comprehensive overview of the governance challenges to managing collision risk from space debris. This publication characterises and evaluates the collision risk posed by space debris, explaining the current management strategy, highlighting major challenges and offering a range of possible new response strategies.

This report served as the foundation for the policy brief Policy options to address collision risk from space debris published in November, which provides a range of policy options and broad recommendations to improve the assessment, evaluation and management of collision risk from space debris. These policy options include:

- Fostering the development and deployment of technology for mitigation and remediation, and the implementation of best practices;
- Enhancing national regulations and the supervision of space activities for better compliance;
- Engaging in international collaboration and building capacity across different governance levels.

Spotlight on risk article


EPFL

Spotlight on risk

Intensifying space activity calls for increased scrutiny of risks

Romain Buchs

14. April 2021

Intensifying space activity calls for increased scrutiny of risks

In this Spotlight on risk article, Romain Buchs explores the risk landscape of space activity, including a detailed risk map focusing on space debris. As society becomes more reliant on space infrastructure, it is especially important that policymakers and decision-makers understand the complex interconnected associated risks.

Outreach activities

As part of our work on space debris, we also participated in numerous external workshops and conferences, including at the Society for Risk Analysis (SRA) annual meeting, the International Astronautical Congress (IAC) and the International Association for the Advancement of Space Safety (IAASS) conference.

In July, we also published an article "#SpaceWatchGL opinion: Addressing the limitations of our current approach to collision risk from space debris". IRGC will continue working on this issue in 2022, co-hosting the international Kinetic space safety workshop at EPFL and participating in an exhibition on outer space at EPFL Pavilions.

Governing risks from digitalisation

EU Horizon 2020 Trigger project (2019–2021)

In 2021, we completed work on the Trigger (Trends in Global Governance and Europe's Role) Horizon 2020 project. It studied the role of the European Union in an evolving global governance landscape, and IRGC's work on the project focused in particular on the evolution of global governance relating to digital technologies.

In 2019 and 2020, our main focus was machine learning and 'governance of and by digital technology'. In 2021, our work on Trigger related primarily to data protection. We produced one of four extended case studies analysing a range of policy domains to see how effective the EU has been at achieving its external goals, and to what extent the EU can be described as a global actor in each domain. To do this, we applied a model of "actorness" that our partners developed on the Trigger project and that identifies seven dimensions against which the EU's global role can be assessed (authority, autonomy, cohesion, recognition, attractiveness, credibility and opportunity / necessity to act).

Our analysis concluded that the EU has indeed emerged as a significant global actor over recent decades, in part because its internal evolution (developing rules to manage cross-border data transfers within the EU) positioned it well to apply very similar rules to external data transfers. In terms of effectiveness, we noted that the EU has been highly successful at positioning itself as a global data protection leader, particularly since the introduction of the GDPR. However, we noted several areas of concern, such as potential weaknesses relating to compliance and the reliability of GDPR consent mechanisms. We also highlighted the need to tackle head-on the question of whether trade-offs exist between the EU's high levels of data protection and its desire to foster a more dynamic economic performance in data-intensive sectors.

Other issues related to risk from digitalisation

Spotligt on risk articles


EPFL
Spotlight on risk
Using "proof of personhood" to tackle social media risks

Using "proof of personhood" to tackle social media risks

This article, written by Aengus Collins with EPFL professor Bryan Ford, explores the tension between online anonymity and accountability and the accompanying societal risks, outlining one low-tech proposal for resolving this tension called "pseudonym parties". These are in-person events where anonymous digital tokens are issued to provide "proof of personhood" that can be used to demonstrate that an online account is linked to a unique person, but without requiring them to reveal their identity.


EPFL
Spotlight on risk
Risk governance and the rise of deepfakes

Risk governance and the rise of deepfakes

This article, written by Aengus Collins and EPFL professor Touradj Ebrahimi, looks at the growth of deepfake technologies and their associated individual, organisational and societal risks. It outlines a simple framework to prioritise and address these risks and the importance of looking to the legal landscape and the evolution of technological approaches to dealing with deepfakes.

Outreach activities

The topic of deepfakes has drawn large attention by various organisations, which have invited IRGC to present its work: UNIDIR, Swisscom, EPFL.

Nanotechnology risk governance

EU Horizon 2020 Nanorigo project (2019–2023)

In 2021, we continued work on the risk governance of nanotechnology as part of the Nanorigo (Nanotechnology Risk Governance) Horizon 2020 project. IRGC is one of the 28 partners in this project. Our role is to provide core principles for developing a Nanotechnology Risk Governance Framework (NRGF) and a related Nanotechnology Risk Governance Council (NRGC) for manufactured nanomaterials and nano-enabled products.

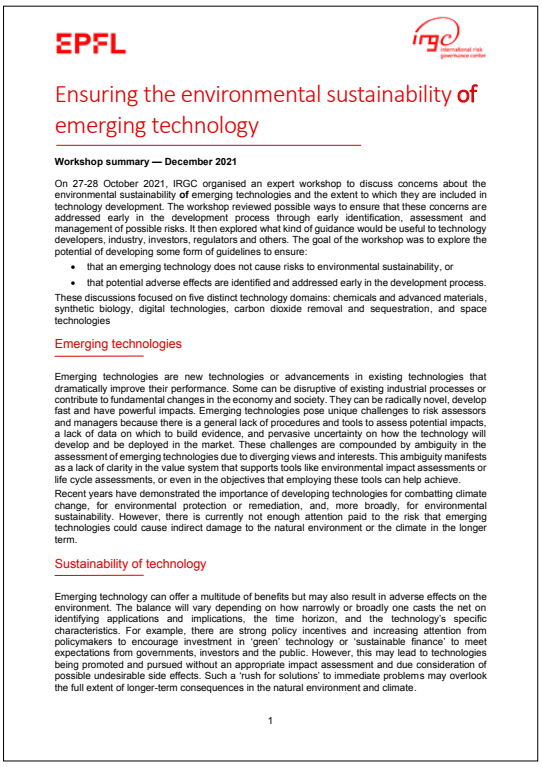
Although nanotechnology is no longer high on the science-policy agenda, its risk governance is still hampered by uncertainty about risks of new nanomaterials such as smart nanomaterials and active nano-based systems, limited collaboration between stakeholders, fragmented risk assessment and regulation, lack of oversight by some stakeholders of the regulatory landscape, and ambiguity on data quality and interpretation. In Europe, the current objective focuses on developing safety and sustainability by design.

As part of our work on testing assumptions and elaborating recommendations regarding the possible need for an overarching organisation that would support the improvement of risk governance in this domain, we organised in 2021 various events with stakeholders to test proposals to:

- Remedy gaps related to improving the sharing of knowledge among stakeholders.
- Create a convening place to discuss emerging issues that could help various actors navigate the regulatory landscape and the changing nature of nanotechnologies.
- Develop a risk governance framework with a more interdisciplinary perspective and the involvement of a broader range of stakeholders for addressing complex challenges such as sustainability, than the current narrow frameworks used by industry and regulators adopt.
- Better understand the components of ‘sustainability-by-design’ at an early stage of technology development, following the adoption in the European Union of the Circular Economy Action Plan and the new Chemicals Strategy for Sustainability.

Environmental sustainability of emerging technologies

New technologies are being developed to provide various benefits to our society. However, while some attention has been given to the possible adverse societal impacts of emerging technologies, such as digitalisation, there is relatively lower attention to the long-term risks that some emerging technologies could pose to the natural environment or the climate.



EPFL

irgc international risk governance center

Ensuring the environmental sustainability of emerging technology

Workshop summary — December 2021

On 27-28 October 2021, IRGC organised an expert workshop to discuss concerns about the environmental sustainability of emerging technologies and the extent to which they are included in technology development. The workshop reviewed possible ways to ensure that these concerns are addressed early in the development process through early identification, assessment and management of possible risks. It then explored what kind of guidance would be useful to technology developers, industry, investors, regulators and others. The goal of the workshop was to explore the potential of developing some form of guidelines to ensure:

- that an emerging technology does not cause risks to environmental sustainability, or
- that potential adverse effects are identified and addressed early in the development process.

These discussions focused on five distinct technology domains: chemicals and advanced materials, synthetic biology, digital technologies, carbon dioxide removal and sequestration, and space technologies

Emerging technologies

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

Recent years have demonstrated the importance of developing technologies for combatting climate change, for environmental protection or remediation, and, more broadly, for environmental sustainability. However, there is currently not enough attention paid to the risk that emerging technologies could cause indirect damage to the natural environment or the climate in the longer term.

Sustainability of technology

Emerging technology can offer a multitude of benefits but may also result in adverse effects on the environment. The balance will vary depending on how narrowly or broadly one casts the net on identifying applications and implications, the time horizon, and the technology's specific characteristics. For example, there are strong policy incentives and increasing attention from policymakers to encourage investment in 'green' technology or 'sustainable finance' to meet expectations from governments, investors and the public. However, this may lead to technologies being promoted and pursued without an appropriate impact assessment and due consideration of possible undesirable side effects. Such a 'rush for solutions' to immediate problems may overlook the full extent of longer-term consequences in the natural environment and climate.

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This concern led us, with the support of the Swiss Re Institute, to organise an expert workshop on this topic in October. The workshop brought together an international and interdisciplinary group to discuss concerns about the environmental sustainability of emerging technologies and the extent to which these concerns are included at an early stage of technology development. The goal of the workshop was to explore the potential of developing some form of guidance to ensure that an emerging technology does not cause risks to environmental sustainability or that potential adverse effects are identified and addressed early in the development process.

The workshop focused on five technology domains in particular: chemicals (advanced materials and smart nanotechnology), synthetic biology (gene editing and gene drives), digital technologies (machine learning, cloud computing and blockchain), carbon dioxide removal and sequestration, and space technologies. Emerging technologies in these domains pose unique challenges to risk assessors and managers because there is a general lack of tools and data to evaluate their potential adverse impacts on the environment, and often pervasive uncertainty on how they will be deployed in the real world. Early-stage technology assessment and prospective life-cycle assessment are not common practices. These challenges are compounded by ambiguity due to different interests and views.

It may be that the rapid development and implementation of solutions to well-identified problems can lead to the pursuit and promotion of technologies without an appropriate impact assessment and due consideration of possible undesirable side effects. The 'rush for solutions' to immediate problems may overlook countervailing risks to environmental sustainability.

A summary report was produced following the workshop, and a comprehensive report will be published in spring 2022.

IRGC & the EPFL community

IRGC's audience is mainly in international interdisciplinary research, and policymaking and advising, with the following objectives:

- Identify and analyse existing and emerging risks that public policymakers should be aware of, to evaluate and make decisions about them.
- Present and make sense of emerging scientific and technical advances, which society can benefit from and which should be supported by the public sector, with appropriate policy and regulatory strategies.
- Act as a neutral platform for dialogue on risks and opportunities related to science and technologies, to provide recommendations for risk governance.

Enhancement of EPFL's activities, reputation and profile in risk governance

As part of the EPFL community, we strive to be relevant and useful to its mission. Thus we:

- Contribute to EPFL education, research and community, in the field of risk analysis and management.
- Strengthen our collaboration with key competencies on campus and contribute to further enhancing EPFL's reputation and profile in the field of risk governance and public policy debates. We do so by connecting EPFL science and research with public policy and strategy, advising on ways to address policy problems using EPFL science and technology, and showing the value of the multi-stakeholder and interdisciplinary approach to problem-solving.

We do this through various means:

- Inviting EPFL experts to participate in our events and contribute to publications.
- Lecturing in the SHS social science and humanities programme ('risk governance'), in the doctoral school – transferable skills ('addressing the challenge of producing scientific evidence'), and executive education (SDSC CAS on data governance, CAS on risk management). With these courses, we pursue the objective of introducing a wider range of approaches, topics and disciplines to students than those they learn in main courses, including through evidence-based debates on matters related to society and where technology plays a role.
- Contributing to others' activities by bringing our expertise on organising interdisciplinary work and engaging with various stakeholders. For example, in June, IRGC organised a session about "Ensuring the Environmental Sustainability of Emerging Technology" in the Showcase organised by Tech4Impact EPFL.
- Disseminating our main project outcome through EPFL news media.

IRGC in EPFL news and magazine

- The time to take low-carbon transition risks seriously is now (February), EPFL News.
- Deepfakes: The art and threats of face swapping (March), EPFL/UNIL dhCenter series "Can a fake truth change the world?".
- A physical party to prove you're a real virtual person (March), EPFL News.
- EPFL works to address debris collision risk (May), EPFL News.
- Deepfakes challenge to trust and truth (June), EPFL Dimensions Magazine (Issue #1).
- Making space a safer place (October), EPFL Dimensions Magazine (Issue #2).

Outreach, impact and feedback from IRGC's audience

IRGC disseminates its project outcome in various ways:

- A quarterly newsletter is sent to a list of more than 4500 individuals and this list is growing as, month afer month, the number of new subscribers is larger than those who unsubscribe.
- We reach out to individual policymakers or policyadvisors involved in the specific domain areas covered by our publications.
- We present our work at external events, we communicate in the social media, and the media writes about us.

Our impact can be seen in both policy and research publications.

Outreach

External events at which IRGC contributed its research outcome

In 2021, IRGC was invited to present its work at academic conferences and for private companies:

- **Systemic risk and Covid**, University College London, (March), M.-V. Florin.
- **A new council for the governance of nanotechnology-related risk**, 2021 EuroNano Forum, (April), M.-V. Florin.
- **Climate engineering**, United Nations Economic Commission for Europe (UNECE) Aarhus Convention, (May), M.-V. Florin.
- **Low-carbon transition: Addressing countervailing risks at Society of Risk Analysis**, (June), A. Collins.
- **Managing the deepfake phenomenon – Governance issues and responses**, UN Institute for Disarmament Research (UNIDIR), (August), M.-V. Florin.
- **A risk governance perspective on Covid-19: Eight learnings to inform science-policy**, Swiss Science Council's first workshop on "Learning from Covid-19", (August), M.-V. Florin.
- **The role of insurance in improving the resilience of critical infrastructure**, CRITIS EPFL, (September), A. Rusu & R. Sachs.
- **Challenges in the governance of space debris risk**, EPFL Virtual Space Tour Tokyo, (September), M.-V. Florin & R. Buchs.
- **Deepfakes**, Swisscom, (October), M.-V. Florin.
- **Space debris risk governance**, Proceedings from two events held at EPFL in 2021, International Astronautical Congress in Dubai, (October), R. Buchs.
- **Géoingénierie – La technologie peut-elle sauver le climat ?**, Café Scientifique at University of Fribourg, (October), M.-V. Florin.
- **Governing collision risk from space debris in low Earth orbit**, International Association for the Advancement of Space Safety (IAASS), (October), R. Buchs.
- **EPFL Campus Lecture with Marietje Schaake**, (November), M.-V. Florin.
- **Value and sustainability of space infrastructure**, OECD Space Forum, (November), M.-V. Florin.
- **Governing collision risk from space debris in low Earth orbit**, Society of Risk Analysis, (December), M.-V. Florin & R. Buchs.

Media outreach

Swiss and international media increasingly cover IRGC's projects and frameworks:

- Neutralité carbone : mieux vaut prévenir que guérir (February), Moniteur Automobile.
- Politiques climatiques : il faut anticiper les obstacles selon des experts réunis par l'EPFL (February), Enviscope.
- EPFL briefing provides a roadmap for anticipating and mitigating the risks of transitioning to a low-carbon economy and society (February), Science Business.
- The time to take low-carbon transition risks seriously is now (February), EurekAlert.
- A physical party to prove you're a real virtual person (March), Mirage News.
- La cybersécurité : un bien public (April), HEC Montreal.
- Una prova della personalità per contrastare le false identità digitali (May), Istituto di Ricerche Sulla Pubblica Amministrazione.
- EPFL works to address debris collision risk (May), MyScience.
- EPFL works to mitigate risk of space debris collision (May), Science Business.
- La gestion des débris spatiaux devient l'une des priorités de l'ESA (July), Le Temps
- Le danger du chaos spatial (July), Le Temps.
- Les débris spatiaux, casse-tête pour la gouvernance internationale (July), Heidi News
- The future depends on risk governance. Mission of National Assembly Future Research Institute (August), Korea News1.
- Space debris: New report flags increasing risk (August), Leonard David's Inside Outer Space.
- Débris spatiaux : avertissement suisse au monde (December), SwissInfo.
- Clair net precis de 07H25 du 17.12.2021 (December), Rouge FM.
- Policy options to address collision risk from space debris (report) (December), SpaceRef.

IRGC's impact

Quite many organisations and researchers use IRGC concepts and methods, and although we cannot systematically monitor all of this activity, we have selected some examples from policy and research in 2021.

Policy

DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS

IRGC's risk governance framework was included in a set of principles developed by the United Nations Committee of Experts on Public Administration (CEPA). Both the framework and the table with the "Comparison of conventional and systemic risks" were highlighted in the document. The purpose of CEPA's principles is to provide interested countries with expert guidance on a broad range of governance challenges associated with implementing the 2030 Agenda.

UNDRR
UN Office for Disaster Risk Reduction

The United Nations Office for Disaster Risk Reduction (UNDRR) recommends using IRGC's policy brief "Risk governance deficits: An analysis and illustration of the most common deficits in risk governance", which is our 2010 publication to identify and describe a number of common and recurring deficits in risk governance processes and structures, including the ones related to preparation for and response to disasters such as Hurricane Katrina.

The Global assessment reports extensively rely on IRGC's guidelines for systemic risk governance.

OECD
BETTER POLICIES FOR BETTER LIVES

OECD publications regularly cite IRGC. In "Managing climate risks, facing up to losses and damages", a report published in 2021 that explores the role of technology in supporting risk governance processes in relation to losses and damages, the authors refer to the IRGC risk governance framework and write: "*The management of risk governance should be guided by a transparent and inclusive process that facilitates the engagement of different perspectives to understand the risks. Decision making must consider the broader social, institutional, political and economic contexts. The organisational capacity of key actors — government, businesses and individuals — affects levels of risk tolerance and trust in the process. Therefore, decision making must recognise the capability of key actors within the risk governance framework to fulfil their roles.*" The report also recognises the importance of IRGC's focus on 'risk evaluation', to assess whether the risk under consideration is acceptable to the decision-maker and stakeholders.

European Commission
JOINT RESEARCH CENTRE

In a 2021 Science for Policy publication that provides "Recommendations for national risk assessment for disaster risk management in EU", the European Commission Joint Research Centre (JRC) cites the IRGC risk governance framework, in particular for how to address the challenges related to dealing with complexity, uncertainty and ambiguity. It also cites IRGC's resource guides on resilience. The publication aims to inform the European policymaking process.

Bundesministerium
für Bildung
und Forschung

In a news piece for the German Federal Ministry of Education and Research website, Dr Marion Dreyer, Dialogik, refers to the IRGC risk governance framework to highlight the importance of risk communication during the Covid-19 pandemics. She cites the framework as a governance model for managing complex risks. Furthermore, the article acknowledges the role of communication that can only be successful if it is understood as a mutual learning process between health authorities and politics on the one hand and society on the other

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Département fédéral des finances DFF
Administration fédérale des contributions AFC

In its 2021 version of the "Risk management manual" for risk governance, the Swiss Federal Department of Finance cites IRGC's work on IRGC risk governance deficits, drawing attention to the need for risk managers to identify and overcome obstacles that can hinder the effective implementation of risk management, particularly when risks are complex and difficult to identify.

Google Scholar

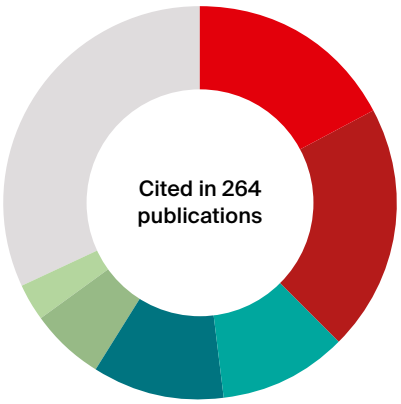
According to Google Scholar, IRGC's reports were cited in 262 academic or policy papers published in 2021, increasing from 237 in 2020 and 214 in 2019.

The core frameworks and guidelines continue to garner particular interest. The two main publications on the risk governance framework (2005 and 2017) were cited 117 times, and the emerging and systemic risks guidelines were cited 29 times. As already observed in 2020, there was an increase in 2021 in our resource guides on resilience citations. These were published in 2016 and 2018, highlighting that our publications remain valuable many years after they were written.

The other citations in 2021 relate to our work on specific risk domains, including our report on algorithmic decision-making, previous work on nanotechnology, energy policy, and our Spotlight on risk article "Covid-19: A risk governance perspective".

IRGC's work is generally cited in international scientific publications, but an increase in articles written in other languages than English was observed in 2021. For example, IRGC's publications were cited in articles written in Bosnian, Brasilian, Chinese, French, German, Greek, Hungarian, Japanese, Korean, Norwegian, Polish, Portuguese, Russian, Serbian, Spanish, Swedish and Turkish.

Research citations

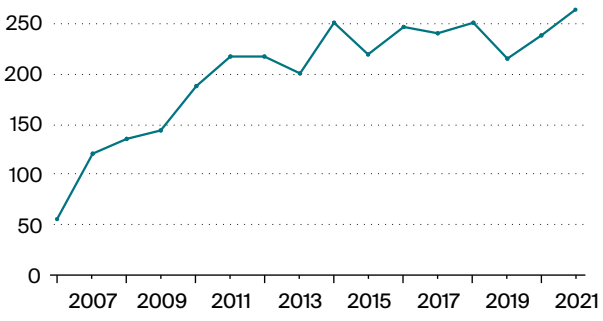


54 IRGC (2017) Introduction to the IRGC risk governance framework
63 IRGC (2005) Risk governance: Towards an integrative approach
34 IRGC (2016) Resource guide on resilience, volume 2
33 IRGC (2018) Resource guide on resilience, volume 1
19 IRGC (2018) Guidelines for the governance of systemic risks
10 IRGC (2010) The emergence of risks: Contributing factors
99 Others

Source: Google Scholar

In the last 15 years, IRGC publications have been cited in about 3000 academic and policy publications. Since 2011 this figure has been between 200 and 250 per year.

Number of IRGC academic references



Source: Google Scholar

Selection of IRGC references in research

Freeman, R., & Varga, L. (2021). Analysis of resilience situations for complex engineered systems – the Resilience Holon. *IEEE Systems Journal*, 1–12. doi.org/10.1109/JSYST.2021.3100286

Klinke, A., & Renn, O. (2021). The Coming of Age of Risk Governance. *Risk Analysis, 41*(3), 544–557. doi.org/10.1111/risa.13383

Lang, G. I. (2021). "Laws of Fear" in the EU: The precautionary principle and public health restrictions to free movement of persons in the time of Covid-19. *European Journal of Risk Regulation*. www.cambridge.org/core/journals/european-journal-of-risk-regulation/article/laws-of-fear-in-the-eu-the-precautionary-principle-and-public-health-restrictions-to-free-movement-of-persons-in-the-time-of-covid19/56741AF86D63D0465EC1AA364CA136CB

Specking, E., Parnell, G. S., Pohl, E., & Buchanan, R. (2021). Engineering resilient systems: Achieving stakeholder value through design principles and system operations. *IEEE Transactions on Engineering Management*, 1–12. doi.org/10.1109/TEM.2021.3056934

Stahl, B. C. (2021). *Artificial intelligence for a better future: An ecosystem perspective on the ethics of AI and emerging digital technologies*. Springer Nature. doi.org/10.1007/978-3-030-69978-9

Selection of citations

"The IRGC's framework has been applied in contexts such as food health and safety, drinking water quality, offshore oil, and autonomous vessels. Within a risk governance context, several authors have described evolutions and trends in risk communication. In general, these authors find that the focus in the early era was on explaining technical aspects of risk assessment, whereas more recent approaches focus on two-way communication with consideration of public concerns and risk perceptions, which is achieved through stakeholder involvement strategies."

Goerlandt, F., Li, J., & Reniers, G. (2020). The landscape of risk communication research: A scientometric analysis. *International Journal of Environmental Research and Public Health, 17*(9), 3255. doi.org/10.3390/ijerph17093255

"Consequentially, IRGC's risk governance framework (RGF) distinguishes between understanding a risk (for which risk appraisal is the essential procedure) and deciding what to do about a risk (where risk management is the key activity). In the following, the RGF sets the reference point for inquiries into governance challenges posed by systemic risks. This framework was chosen for two main reasons. Firstly, the RGF targets governance of risks in particular. Until a governance framework specifically for systemic risks becomes available, IRGC's RGF approaches the matter in the most coherent way available. Secondly, the RGF combines quantitative risk analysis with qualitative assessments. Additionally the RGF includes stakeholder participation and public engagement, thus offering the most comprehensive (regarding facts) and inclusive (regarding values) governance framework."

Schweizer, P.-J. (2021). Systemic risks – concepts and challenges for risk governance. *Journal of Risk Research*, 24(1), 78–93. doi.org/10.1080/13669877.2019.1687574

"The general framework concepts and structures follow closely the International Risk Governance Council's "IRGC risk governance framework", a comprehensive yet flexible blueprint for risk governance tailorable to different risk contexts and organisational settings (IRGC, 2017)."

EFSA, E. F. S., Maxim, L., Mazzocchi, M., Van den Broucke, S., Zollo, F., Robinson, T., Rogers, C., Vrbos, D., Zamariola, G., & Smith, A. (2021). Technical assistance in the field of risk communication. *EFSA Journal, 19*(4), e06574. doi.org/10.2903/j.efsa.2021.6574

"Climate change calls for a global response, as human activities have become globally interconnected and intensified through new technology and capital markets in the globalisation. Hierarchical government in domestic politics as well as international regimes in international politics lose some explanatory power, instead, multi-level governance and global governance are being called on to address this issue. The IRGC (International Risk Governance Council) risk governance framework brought forward by Ortwin Renn can be used to address and respond to such a global risk and design appropriate governance strategies in a structured way."

Li, H., & Li, J. (2021). Risk governance and sustainability: A scientometric analysis and literature review. *Sustainability, 13*(21), 12015. doi.org/10.3390/su132112015

"The committee of Society for Risk Analysis Japan translated a report "Covid-19 a risk governance perspective" into Japanese, which was published by International Risk Governance Center (IRGC). This article introduces the Japanese translation of the report to share the state-of-art of risk governance methodology for Japanese readers. IRGC risk governance framework, which can be used as a structured method for examining the steps of solving various risk problems, was customised to Covid-19."

恭子小野, 健吉藤井, & 進大沼. (2021). IRGCレポート「Covid-19: A risk governance perspective」が示唆したリスクガバナンス設計に必要な俯瞰力. リスク学研究, *30*(3), 143–146. doi.org/10.11447/jjra.SRA-0348

Feedback from our audience

Selection of quotes

> *“ Congratulations for these two papers on space debris, which will certainly make a strong impact in the space community! ... So far, I only knew your report on climate engineering, which I found outstanding.”*
>
> Intergovernmental organisation about Space debris report and policy brief

> *“ I have circulated all of your publications and continue to admire you for your productivity and for the excellence of you and your team’s work. The risks associated with space activities is particularly timely.”*
>
> Public sector about IRGC publications

> *“ The paper is especially interesting for the computational social media class I teach each Spring as part of the Master in digital humanities.”*
>
> Academia about Using “proof of personhood” Spotlight article

> *“ This is excellent work, and I would be glad to direct colleagues towards it. I will also direct my students to it, as I am sure they will find this to be of interest and use.”*
>
> Academia about the map “Risk landscape associated with human activities in near-Earth space”

> *“ I really enjoyed reading the report. It shows the scale of the challenge ahead, but sets out a clear pathway to ensure we can deliver climate neutrality with minimal risk.”*
>
> NGO about IRGC Risk governance and the low-carbon transition report

> *“ I was looking at the IRGC newsletter over lunch and thinking what great work you are doing there. So, I thought I would email to say so. I enjoy the materials and learn a great deal, so thank you.”*
>
> NGO about IRGC publications

> *“ Many thanks for sharing the report on such crucial and timely challenges, and the expected urgent action. I will share it widely throughout my networks.”*
>
> Academia about IRGC Risk governance and the low-carbon transition report

> *“ I have just come across your article on Covid-19 risk governance. Not sure how I missed it first time round, but it is just terrific, and very useful for chapters that I am now writing for the second edition of the Kyoto Manifesto on Global Economics. Well done! ”*
>
> Academia about IRGC Covid-19 Spotlight articles

Survey

In December 2021, we conducted a survey to collect feedback from those who have been in contact with us in the past two years, directly or indirectly. The survey outcomes will guide us towards improving our relevance and impact in 2022 and beyond.

Responses to the survey indicate that:

- IRGC is perceived as an organisation that delivers inspiring, transdisciplinary, genuinely world-leading work. IRGC's audience appreciates the Center's overall objectives and its efforts to inform policymaking, along with its efficient, clear and focused activities, as well as the consistent and excellent outputs.
- Moreover, insights provided by IRGC are considered relevant and of high quality, showing an interest in a broad cross-section of academic research. Those who participated in an IRGC event appreciate, among other things, the choice of the topics, the depth of the discussions, and the background documents provided to inform the discussion, which respondents found to be forward-thinking and insightful.
- Many appreciate the high quality of the IRGC's publications saying that they offer a deep understanding of the proposed topic and incorporate input from many sources.
- IRGC could improve its relevance by providing more specific recommendations and actionable outcomes (which is difficult considering IRGC's wide audience among various stakeholder groups).
- Regarding future work on risk governance, and in addition on-going projects, suggestions include continuing work on concepts and methods (emerging risks, resilience, risk prevention, risk perception and acceptability, decision-making, adaptive management, risk trade-offs), focusing on overcoming challenges for practitioners to implement those in practice and international collaboration.
- Regarding topical priorities, some respondents think that risks from climate change and digitalisation should deserve more IRGC attention. Sustainable transitions and technologies for sustainability are a recurring theme.

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. We act as a neutral platform for multi-stakeholder dialogue on these risks and opportunities, and aim to provide scientifically grounded policy recommendations for dealing with risk. IRGC's mission includes developing risk governance principles and guidelines and providing generic 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.

The EPFL International Risk Governance Center works in close collaboration with the IRGC Foundation, which has shaped the global agenda on international risk governance since it was established in 2003, and which continues to play a guiding role in the work of the Center.

The two entities have distinct governance and advisory structures.

EPFL International Risk Governance Center

Management Committee: James Larus (Academic Director), **Marie-Valentine Florin** (Executive Director).

Advisory Board: David Bresch, **Catherine Burger**, **Gérard Escher**, **Janet Hering**, **Kenneth Oye**, **Janos Pasztor**, **Arthur Petersen**, **Jonathan B. Wiener**, **Lan Xue**.

IRGC team at EPFL in 2021: **Marie-Valentine Florin**, **Aengus Collins**, **Romain Buchs**, **Stephanie Parker**, **Anca G. Rusu**, **Luana Huguenin**.

For further details, visit irgc.epfl.ch

IRGC Foundation

Foundation Board (also act as advisors to the Center): **Granger Morgan** (Chairman), **Martha J. Crawford**, **Caroline Kuyper**, **Ortwin Renn.**

For further details, visit www.irgc.org

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IRGC benefits from in-kind and project-specific contributions from many individuals who bring the diversity of expertise required to fulfil IRGC's mission.

IRGC would like to thank everyone who worked with and for IRGC in 2021 as workshop participants, co-authors, contributors, researchers, reviewers, staff and support staff.

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