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Global Catastrophic Risk and Planetary Boundaries: The Relationship to Global Targets and Disaster Risk Reduction

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Global catastrophic risk and planetary boundaries: The relationship to global targets and disaster risk reduction

Abstract

The impact on global targets, such as the Sustainable Development Goals, and future versions of these goals, as well as on disaster risk reduction efforts from global catastrophic risk events and the crossing of planetary boundaries is not well understood yet has the potential to undo the development, capability building, and adaptability that has been created to date.

This paper presents a literature review on the Sustainable Development Goals and the Sendai Framework, global catastrophic risk, and planetary boundaries before undertaking a scenario analysis. The scenario analysis considers worlds where global catastrophic risk is high and low, and planetary boundaries have not been crossed and have been crossed respectively. This gives rise to four scenarios: Earth Under Uncertainty, Global Collapse, Stable Earth, and Earth Under Threat. In all of these scenarios except for Stable Earth the achievement of global targets and accompanying frameworks is negatively impacted. Furthermore, in the absence of change, scenarios Earth Under Uncertainty and Earth Under Threat tend towards that of Global Collapse.

From the scenarios, and assessing the possible achievements of global targets and frameworks, policy recommendations are proposed. It is recommended that both preventive and reactive policy be developed, with preventive prioritised due to the lower resource cost. It is presented that in order to ensure disaster risk reduction continues, a goal, with targets, should be made for the planetary boundaries in the next version of the Sustainable Development Goals, and that global catastrophic risk is incorporated into the targets. Furthermore, it is recommended that in order for disaster risk reduction to be as effective as possible, appropriate targets should be incorporated into the next generation of the Sendai Framework.

Keywords: Sustainable Development Goals, Sendai Framework, Planetary Boundaries, Global Catastrophic Risk, Disaster Prevention

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Introduction

The impact of climate change, other global catastrophic risk (GCR) events, and planetary boundaries have been recognised as having extensive impacts on global targets, such as the United Nation's Sustainable Development Goals (SDGs) (Cernev & Fenner, 2020). The impact of these is only likely to increase past the 2030 SDG completion date and will ultimately impact the achievement of the future global targets that are successors to the SDGs. The impact of these risks has not been widely examined, with increasing interest in thee GCR of pandemics only having been thoroughly investigated in the past year since the emergence of COVID-19.

Prompted by the COVID-19 pandemic starting in the early months of 2020, there has since been widespread analysis of the impacts of COVID-19 on the global economy, sustainable development efforts, and wider society, something which needs to be undertaken for all GCR and planetary boundary risks such that policy interventions can be used to preemptively prepare rather than react when an event occurs, this reflects the notion of reducing disaster loss whilst avoiding new risk (United Nations Office for Disaster Risk Reduction, 2021a). With all GCR and planetary boundary related events there is large uncertainty both for the likelihood of such events occurring and for their wider impact if they do occur for this reason a scenario analysis method is used in this paper. This scenario analysis is important as consideration begins as to the form that post 2030 SDG targets will take in a world where the risk of planetary boundaries being crossed and GCR events occurring is becoming more and more likely.

This paper presents a comprehensive literature review into the SDGs and the Sendai Framework, GCR, and the tipping point and planetary boundary architecture before undertaking a scenario analysis in order to predict possible outcomes and subsequently identify suitable policy interventions such that global targets may still be reached within their respective timeframes and to better understand the role of global targets when considering planetary boundaries and GCR. The scenario analysis approach is advantageous in that it illustrates the level of complexity of the risk whilst not using the past as an absolute guide for the future (United Nations Office for Disaster Risk Reduction, 2021c). The scenario analysis presents four different world outcomes, three of which can be considered to have disasters through GCR and planetary boundary crossing events. The policy interventions are both preventive and reactive such that there is opportunity for the disaster > response > dependency > repeat cycle to be broken (United Nations Office for Disaster Risk Reduction, 2021a) and focus on provided pathways to ensure that the extent of the disasters portrayed in the scenario analysis can be recovered from if not mitigated entirely, thereby avoiding the creation of new risk (United Nations Office for Disaster Risk Reduction, 2021c). Furthermore, the policy interventions from the scenario analysis seek to protect development gains, complementing the Sendai Framework (United Nations Office for Disaster Risk Reduction, 2021d). The interventions are determined from suspected leverage points and points of weakness and vulnerability identified in the scenario analysis.

In this paper, the scope of global targets in the scenario analysis is limited to the SDGs, with generalisations made for future targets. Whilst the SDGs are set to be finished in 2030, it is assumed to be the case that new development goals will be introduced post 2030 to continue the work of the SDGs, much in the same way as the SDGs were introduced to continue the work of the Millennium Development Goals (MDG). Furthermore it is assumed that post 2030

that the interconnectedness of the SDGs and the Sendai Framework will be reflected in a similar, improved framework (United Nations Office for Disaster Risk Reduction, 2021b).

The Sustainable Development Goals and the Sendai Framework

Over the years there have been a series of global targets, two of the most extensively known are the Millennium Development Goals (MDGs), refer Figure 1, and the Sustainable Development Goals (SDGs), refer Figure 2. The latter was an expanded version of the former that took over when the MDGs concluded in 2015 (United Nations 2015). The MDGs were pioneering and whilst only consisting of eight goals, they sought to achieve extensive progress in international development, with a broad focus that considered everything from eradicating hunger and extreme poverty to increasing sustainability and increasing global partnerships (United Nations, 2015). However, these goals were ambitious and whilst considerable progress was made towards their achievement by their end date of 2015 (United Nations 2015), there was still extensive progress to be achieved globally.

Figure 1. The Millennium Development Goals (United Nations, 2015)

The SDGs sought to complete the work of the MDGs and then achieve more, with significantly more goals and targets to be achieved by their end date of 2030 (United Nations, 2021). The global targets that are associated with the SDGs are extensive compared to the MDGs - with 169 targets in total that span 19 goals (United Nations, 2021) compared to the MDGs' eight goals (United Nations, 2015). Ranging from improving global standards of education to reducing potential future impacts of climate change these goals are extensive and their achievement requires collaboration between many different sectors in society (United Nations, 2021).

Figure 2. The 17 Sustainable Development Goals (United Nations Development Program 2021)

The SDGs are substantially more complex and interconnected than the MDGs, with deliberate efforts made to ensure that progress in one area affects outcomes in the others and thus that the social, economic, and environmental aspects of all goals are linked (United Nations Development Program 2021; Cernev & Fenner, 2020).

Furthermore, there is recognition that in order to achieve the goals, there needs to be extensive collaboration between not only international agencies, such as the United Nations, but between these agencies, the private sector, as well as governments at all levels - internationally and locally (United Nations Development Program 2021).

The success of the SDGs is largely dependent on the Sendai Framework (United Nations Office for Disaster Risk Reduction, 2021b; United Nations Office for Disaster Risk Reduction, 2019), with the latter aiming to reduce “disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries” (United Nations Office for Disaster Risk Reduction, 2015). Ultimately the Sendai Framework seeks to achieve this through a range of “economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures” (United Nations Office for Disaster Risk Reduction, 2015) that increase both preparedness and resilience (United Nations Office for Disaster Risk Reduction, 2015). Similar to the SDGs, the Sendai Framework has seven global targets and four priorities for action, all of which are to be achieved by 2030, refer Table 1 (United Nations Office for Disaster Risk Reduction, 2015).

Table 1. Sendai Framework global target overview (United Nations Office for Disaster Risk Reduction, 2015)

Global Target	Summary	Achievement Year
(a)	Reduce global disaster mortality	2030
(b)	Reduce the number of affected people globally	2030
(c)	Reduce direct disaster economic loss	2030
(d)	Reduce disaster damage to critical infrastructure and disruption of basic services	2030
(e)	Increase the number of countries with disaster risk reduction strategies	2020
(f)	Enhance international cooperation	2030
(g)	Increase the availability of and access to early warning systems	2030

Global catastrophic risk

Global Catastrophic Risk (GCR) events are defined as those that result in over 10 million fatalities, or greater than $10 trillion in damages, essentially the damage must be extensive and on a global scale (Bostrom & Ćirkovic, 2008). They are global in nature, but there is the expectation that humanity can recover for them, as opposed to Existential Risk (ER) events that are extinction events for humanity, and are a subset of GCR events (Bostrom & Ćirkovic, 2008). However, even though GCR events are not extinction events, there is the possibility that a GCR event can inhibit humanity's response to future risks (Farquhar et. Al, 2017) and subsequently increase the risk of civilisation collapsing or of human extinction through chain reaction events (Turchin & Denkenberger, 2018). Whilst the definition of a GCR event is still evolving, and research is ongoing (Baum & Handoh, 2014), a list of GCR is provided in Table 2 categorised under the headings of *Risks from Nature*, *Risks from Unintended Consequences,* and *Risks from Hostile Acts*. As highlighted by Baum & Handoh (2014), it appears that environmental GCR are of lower likelihood of occurring than other GCR, however, this is likely due to the increased uncertainty of the likelihood of environmental GCRs occurring.

Table 2. Possible global catastrophic risks adapted from Bostrom & Ćirković (2008) and Baum & Handoh (2014)

GCR Category	GCR
Risks from Nature	Volcanic eruptions
	Comets, and asteroids
Risks from Unintended Consequences	Pandemics
	Artificial Intelligence
	High energy physics experiments
	Social Collapse
	Climate change
Risks from Hostile Acts	Nuclear war
	Nuclear terrorism
	Biotechnology
	Nanotechnology
	Totalitarian governments

It is difficult to assign probability values to the likelihood of GCR events occurring, and even more difficult to predict the severity with which these events will occur and the widespread repercussions of them (Turchin & Denkenberger, 2018) but the risks can be assessed. This assessment has been achieved in the literature through considering three different measures: scope, intensity, and probability, which in turn provides a hierarchy to the different GCR risks (Bostrom & Ćirkovic, 2008).

The list of events that are considered to be GCR events is growing with pandemics regarded as a significant GCR, and climate change being recognised as one (Beard et. al, 2021). Furthermore, there has been initial work to link the planetary boundaries with GCR (Baum & Handoh, 2014), and better incorporate climate change as a GCR (Cernev & Fenner, 2020; Fenner & Cernev, 2021; Beard et. al, 2021).

Planetary Boundaries

Planetary boundaries are a series of measures associated with the framework of tipping points throughout the ecological world that provide a guide to the safe operating space of humanity on planet earth, and importantly ensure that cascading events do not take place whereby the crossing of one planetary boundary systematically results in the crossing of others (Beard et al., 2021; Baum & Handoh, 2014). The planetary boundaries consist of nine different factors that together provide a framework for the “development of human societies and the maintenance of the earth system” (Steffen et. al, 2015). The boundaries, refer Figure 3 and Table 4, provide a safe operating space for humanity, with the passing of these boundaries subsequently, and most likely resulting in societal destabilisation (Steffen et. al, 2015) and potential GCR events (Cernev & Fenner, 2020). Furthermore, the interlinkages between the

planetary boundaries and global targets, whilst acknowledged (Cernev & Fenner, 2020) have not been extensively explored.

Figure 3. The planetary boundaries (Stockholm Resilience Centre, 2021).

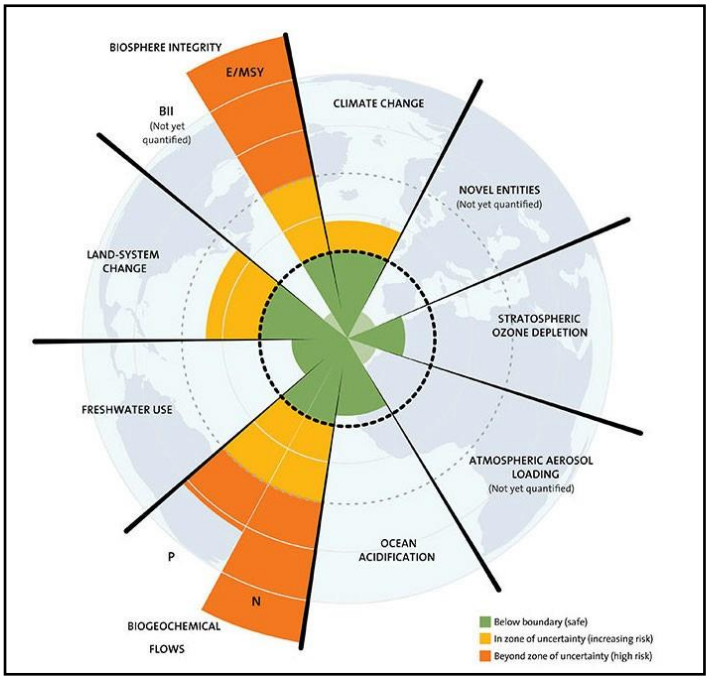


Table 4. The nine planetary boundaries and their current status (Stockholm Resilience Centre, 2021).

Planetary Boundary	Current Status
Climate Change	In zone of uncertainty (Increasing risk)
Stratospheric Ozone Depletion	Below boundary (safe)
Loss of Biosphere Integrity	Further research is required to ascertain the present level, but extinction levels are increasing
Novel entities	More research is required
Atmospheric aerosol loading	More research is required
Ocean acidification	More research is required
Biochemical flows (phosphorous and nitrogen)	Beyond the zone of uncertainty (high risk)
Freshwater use	More research is required
Land-system change	In zone of uncertainty (Increasing risk)

Humanity's position in the Climate Change boundary is currently in the zone of uncertainty, it is expected that we have already crossed this boundary (Stockholm Resilience Centre, 2021). This will severely impact SDG 13 - Climate Action. If, as expected in the literature, that this boundary has been crossed, then the attainment of the targets within SDG 13 are highly unlikely, and the causal effect to the other SDGs will be severe due to their high level of interconnectedness (Cernev & Fenner, 2020). The Stratospheric Ozone Depletion boundary will not be crossed in the future due to introduced laws that prohibit the emission of chemical

substances under the Montreal Protocol (Stockholm Resilience Centre, 2021), however, the boundary if crossed has the ability to severely inhibit the success of the SDGs: Life on Land, Life Below Water, and Good Health and Well Being. This is because as the Stratospheric Ozone Depletion boundary is crossed more ultraviolet light will be able to pass through the atmosphere, unhindered, and subsequently damage both human health and that of ecosystems (Stockholm Resilience Centre, 2021).

The Atmospheric Aerosol Loading planetary boundary directly impacts climate change as well as human health, through air pollution (Stockholm Resilience Centre, 2021). It is noted in the literature that there is still significant research required in order to ascertain where we currently are and where the planetary boundary is, as well as the causal links that exist between atmospheric conditions and other earth systems (Stockholm Resilience Centre, 2021).

As CO2 emissions increase, ocean acidification will increase as CO2 is absorbed into the oceans and chemical processes take place (Stockholm Resilience Centre, 2021). Evidently the SDG Life Below Water will be immediately affected by this, however, due to the interconnectedness of the goals, there will be others impacted. In particular, the SDGs No Poverty and Zero Hunger will be threatened as people's livelihoods and societies are threatened by rapidly changing ocean conditions. Furthermore, the Climate Action SDG will bee inhibited as the oceans reach a threshold of CO2 absorption and marine ecosystems begin to collapse.

The Freshwater Usage boundary is crossed, water scarcity will increase globally. By 2050 there are expected to be half a billion people that are subject to water stress (Stockholm Resilience Centre, 2021). Furthermore, the impact on rivers and water ecosystems due to human modification of them for freshwater consumption is extensive (Stockholm Resilience Centre, 2021). Ultimately, there is a risk of cascading events (Stockholm Resilience Centre, 2021), whereby the risk of social unrest, and regional violence increases. Similarly, the biochemical flows introduce pollution into already fragile ecosystems (Stockholm Resilience Centre).

Evidently there are a broad range of impacts that planetary boundaries can have on the achievement of the SDGs, and the future development targets. However, there are measures that can be taken that reduce the risk of this happening. Of primary importance is action on climate change, since all planetary boundaries can be related to this.

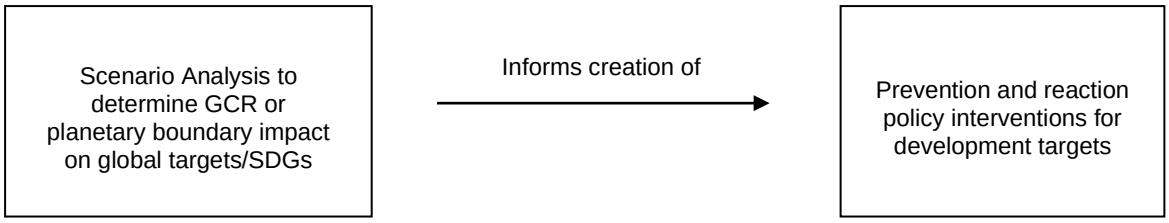
Scenario Analysis Development

In order to develop policy interventions, that are both reactive and preventive, and recommendations that can better ensure the success of development targets when a disaster associated with GCR or planetary boundaries occurs, as well as the relation to disaster risk reduction, a scenario analysis that considers different options is undertaken. This approach is advantageous because it highlights both the complexity of risk, and also the need to consider the future independent of the past due to the increasing level of interconnectedness and complexity of thee world (United Nations Office for Disaster Risk Reduction, 2021c). This overall approach is illustrated in Figure 4, whereby possible future world scenarios due to planetary boundary crossings is used to construct prevention and reaction policy measures.

Following this, the achievability of the current SDGs and Sendai Framework objectives under the scenarios is assessed. This is a useful simulation of current targets and assumed to be relevant to future targets. This achievability is assessed by considering whether each target

is achievable in a given scenario. The approach of using a scenario analysis is similar to that of Bohensky et. al (2011) who describe a "scenario analysis as a structured process of generating imaginative future possibilities which have implications for ecosystems and human well-being" whereby "scenarios consist of narratives that consider how alternative futures… may unfold from combinations of highly influential and uncertain drivers, and their interaction with more certain driving forces" that are ultimately useful for identifying potentially useful policies that can create particular outcomes, and that of Cernev & Fenner (2021).

Figure 4. Pathway for the development of prevention and reaction policy interventions.



For this scenario analysis the four scenarios are built out from the two axes approach (Bohensky et. al, 2011; Fenner & Cernev, 2021). This approach is particularly advantageous in this case due to the high levels of uncertainty for both the occurrence and then the potential impact of GCR events or the crossing of planetary boundaries (Baum & Handoh, 2014). In developing the two axes, four scenario analysis, it is necessary to incorporate both GCR and planetary boundaries into the developed scenarios. The x-axis is concerned with planetary boundaries, with options ranging from *Within Limits* to *The Tip*. These represent the limits at the extremes whereby planetary boundaries are not crossed to where they are for the former and latter respectively. GCR is represented on the y-axis, where possibilities range from *Low Risk World* to *High Risk World*. These limits represent worlds where GCR events have not occurred, and are unlikely to do so, to one where either GCR events have occurred, are occurring, or are extremely likely to do so. These axes limits are provided in Table 5.

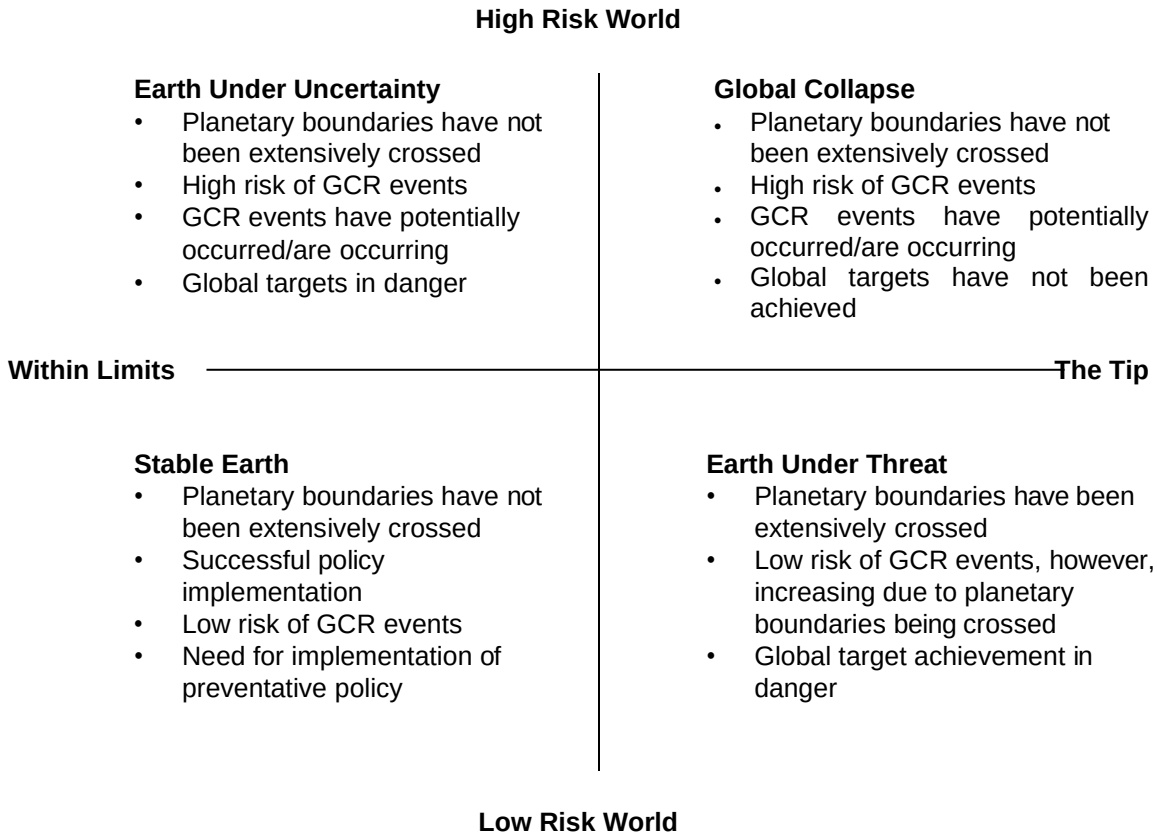
Table 5. Axes values for the scenario analysis

Axis	Limit Name	Description
X	Within Limits	Planetary boundaries are not crossed, or minimal crossings have occurred and are unlikely to be crossed in the future
X	The Tip	Planetary boundaries have been crossed or are likely to do so imminently
Y	Low Risk World	GCR events are extremely unlikely to occur
Y	High Risk World	GCR events are highly likely to occur, or they have already/ are currently occurring

Using the axes provided in Table 3, four scenarios can be developed that represent different global trajectories and thus have differing impacts on the SDGs. The four developed scenarios are: (1) *Earth Under Uncertainty,* planetary boundaries have not been extensively crossed but GCR events are highly likely, (2) *Global Collapse*, planetary boundaries have been extensively exceeded with highly likely GCR event, (3) *Stable Earth*, planetary boundaries have not been extensively crossed and GCR events are unlikely, (4) *Earth Under Threat*, planetary boundaries have been extensively exceeded but GCR events are unlikely, refer Figure 5. Each of these scenarios provides a possible future for the world and can give insight into how

the world would be functioning given the planetary boundary and GCR related events. From the scenario analysis, refer Figure 5, it is evident that in the absence of ambitious policy and near global adoption and successful implementation, the world continually tends towards the *Global Collapse* scenario.

Figure 5. Scenario analysis considering GCR and tipping points



Earth Under Uncertainty

This scenario presents a world where planetary boundaries have not been extensively crossed, or there is a high level of uncertainty as to humanity's position relative to the boundary and no evidence to suggest it having been crossed or necessarily approached. GCR risk is high, with the likelihood of a GCR event being extreme or an GCR event having already occurred or in the process of occurring. In this scenario it is possible that there has been some achievement towards global targets, with potential international cooperation to ensure that planetary boundaries have not been crossed. However, given the imminent threat of GCR events, further policy development is required, that is ambitious, in order to ensure that development targets are achieved and the world is not pushed towards a *Global Collapse* scenario. A mixture of preventive and reactive policy is required. In this scenario the presence and success of a framework such as the Sendai Framework is essential as in this case GCR needs to be reduced. In the case of a GCR event having taken place, or taking place in the near future, it is likely that progress towards international development and the achievement of global development targets will have been stalled, if not having had progress reversed. In this scenario there is still international cooperation and ambition towards achieving global targets, and the non-crossing of the planetary boundaries has resulted in limited environmental impacts that have in turn not extensively inhibited progress to global targets.

Global Collapse

This scenario presents a world where planetary boundaries have been extensively crossed, and if GCR events have not already occurred or are in the process of occurring then their likelihood of doing so in the future is extreme. In this scenario, global targets have most likely not been achieved, and the resulting collapse of society in this scenario means that the future achievement of any global targets is unlikely, and total societal collapse is a possibility. Disaster risk reduction has not been successful and disasters are common, with disaster events as well as GCR events such as pandemics increasing. Existing frameworks such as the Sendai Framework have not been successful, risk has not been mitigated and neither has resilience nor adaptability been built into the system. The crossing of planetary boundaries is likely to exacerbate GCR risk, with large and complex environmental feedback loops leading to further environmental and social collapse. Depending on the extent of the crossing of the planetary boundaries and the severity of any GCR events that may have occurred, policy interventions that are not drastic are unlikely to improve society and a reactive policy approach will need to be taken. In this scenario international cooperation is extremely limited with a high risk of global or environmental conflict as the environment degrades, with potential forced migrations of people from uninhabitable areas that in turn has the potential to heighten GCR by making events such as pandemic or nuclear war more likely (Cernev & Fenner, 2020).

Stable Earth

In this scenario the earth ecosystem is stable. High levels of ambition towards the achievement of global targets has resulted in planetary boundaries not being crossed, or the crossing having been kept to a minimum. Global targets have largely been achieved or there has been significant progress towards achieving them. In this scenario, a risk framework such as the Sendai Framework has been successful in helping the world to understand and subsequently mitigate risk whilst building resilience and adaptability across society. Disaster risk reduction has been successful, with disasters not increasing, GCR events are unlikely and the likelihood of them occurring have been further reduced through successful policy interventions and international cooperation. From the achievement of global targets, humanity has increased international cooperation and is able to set more ambitious global targets that further reduce the risk of crossing planetary boundaries or GCR events from occurring. The world is on a sustainable path and is focused on further preventive policy with reactive policy at this time being unnecessary.

Earth Under Threat

In this scenario, planetary boundaries have been crossed past a safe limit, or there is a large degree of uncertainty as to humanity's position relative to the boundaries with strong suspicion and evidence of some if not all having been crossed. Whilst GCR is low and GCR events are unlikely to occur, the complex feedback loops that operate between the planetary boundaries are likely to increase the likelihood of GCR events occurring in the near future. Furthermore, political instability and subsequently as a result global instability due to a quickly degrading environment has the potential to drive conflict and hinder future progress towards achieving global targets. In this scenario, the world is on a path towards a *Global Collapse* scenario, where GCR events are occurring unless considerable preventive and reactive policy interventions that are ambitious are globally adopted and successfully undertaken. In this scenario, the success of a risk framework such as the Sendai Framework is essential.

Impacts on Global Targets

The approach to analysis for the impact on global targets is done in two ways.

Firstly, a specialised approach for the SDGs is considered, whereby the impact of each of the scenarios on the SDGs is presented, refer Table 4. Secondly, given the completion date of the SDGs of 2030, they are broadly classified into environmental, social, economic, and political goals (Cernev & Fenner, 2020) such that the impact on future targets that are developed from the SDGs may be discerned. It is assumed that future global targets will broadly cover the same environmental, social, economic, and political aspects that the SDGs have, in much the same way that the SDGs were a follow on for the MDGs. The numerous targets and the high level of interdependencies between the goals has been taken into account (Cernev & Fenner, 2020). In Table 6, the effect of a scenario on the achievement of global targets is presented using a three colour scale whereby high levels of impact or the non-achievement of a target are denoted 'N-A', low levels of impact or the achievement of a target are denoted 'A', and moderate levels, or uncertain impacts on the achievement of a target are denoted 'M'. Each of these cases refers to the possibility of the goal being achieved under the given global scenario, rather than a certainty that under the given scenario it would be. The goals are classified by considering how thee goal, and its targets, would bee impacted by a given scenario.

Table 6. Scenario impact on global target achievability

SDG		Scenario				Classification
		1	2	3	4	
		Earth Under Uncertainty	Global Collapse	Stable Earth	Earth Under Threat	
1	No Poverty	M	N-A	A	M	Social
2	Zero Hunger	M	N-A	A	M	Social
3	Good Health and Well-Being	M	N-A	A	M	Social
4	Quality Education	A	N-A	A	A	Social
5	Gender Equality	A	N-A	A	A	Social
6	Clean Water and Sanitation	M	N-A	A	N-A	Social
7	Affordable and Clean Energy	A	N-A	A	A	Economic
8	Decent Work and Economic Growth	A	N-A	A	A	Economic
9	Industry, Innovation and Infrastructure	A	N-A	A	A	Economic

10	Reduced Inequalities	M	N-A	A	A	Social
11	Sustainable Cities and Communities	A	N-A	A	N-A	Economic
12	Responsible Consumption and Production	A	N-A	A	N-A	Economic
13	Climate Action	M	N-A	A	N-A	Environmental
14	Life Below Water	M	N-A	A	N-A	Environmental
15	Life on Land	M	N-A	A	N-A	Environmental
16	Peace, Justice and Strong Institutions	A	N-A	A	M	Political
17	Partnerships for the Goals	A	N-A	A	M	Political

From Table 6 it is evident that the scenarios presented in Figure 5 would be expected to have varying impacts on the SDGs, and as a consequence on future development targets that follow after the SDGs. Evidently the *Global Collapse* scenario presents a world in environmental collapse, and a chaotic society where the achievement of global targets is not possible due to the frayed international relationships and as a result a lack of cooperation. The possibility for the achievement of the SDGs or future global targets is more likely under the *Earth Under Uncertainty* than the *Earth Under Threat* target due to the higher levels of uncertainty that are associated with GCRs compared to planetary boundaries. In opposition to the *Global Collapse* scenario is the *Stable Earth* scenario, where global targets are achievable due to higher levels of international cooperation that results from a world situation where neither the environment nor society is in collapse. The possible achievability of targets in this scenario is such that more ambitious targets can be set to follow on from previous targets with the high likelihood of them being achieved. Furthermore, from Table 6, it is evident that as a generalisation, environmental targets are adversely impacted across the four scenarios more than other classifications, with social and economic related targets being relatively achievable.

Similar to Table 6, Table 7 has ben created to determine the impact of the possible scenarios on the Sendai Framework. It is assumed that post 2030, in line with the creation of new global targets, the Sendai Framework will be upgraded and again interlinked with these new targets as it is with the SDGs. As in Table 6, in Table 7 it is evident that if the world is in a *Global Collapse* scenario then the framework is unlikely to be achievable. This is due to the environmental and social chaos that is likely to be present in such a world that would result in greatly diminished cooperation. The opposite to this is the *Stable Earth* scenario where framework targets have most likely been successful and will be into the future. For the *Earth Under Uncertainty* and the *Earth Under Threat* scenarios, there is uncertainty as to the achievability of framework targets, with targets to date most likely being un- achieved. In these scenarios the achievement of the framework targets is essential in order to ensure that the world does not transition to a *Global Collapse* scenario.

Table 7. Scenario impact on the Sendai Framework achievability

Sendai Framework Target		Scenario			
		1	2	3	4
		Earth Under Uncertainty	Global Collapse	Stable Earth	Earth Under Threat
1	Reduce global disaster mortality	M	N-A	A	M
2	Reduce the number of affected people globally	M	N-A	A	N-A
3	Reduce direct disaster economic loss	M	N-A	A	M
4	Reduce disaster damage to critical infrastructure and disruption of basic services	M	N-A	A	M
5	Increase the number of countries with disaster risk reduction strategies	A	N-A	A	A
6	Enhance international cooperation	A	N-A	A	A
7	Increase the availability of and access to early warning systems	A	N-A	A	A

Developing policy interventions

From the scenarios developed in Section 2, and the insight of how these scenarios would impact global targets, policy interventions can be developed and proposed. To do this possible leverage points and vulnerable points that are illustrated in the scenarios are used, where leverage points are those where small changes can have a large impact. The development of policy interventions is crucial for both preventive and reactive paths, such that in the event of humanity moving towards a *Global Collapse* scenario there is insight as to how the situation can be navigated, or from a disaster risk reduction perspective - completely avoided. The adoption and success of preventive policy is preferred to that of reactive policy due to the high levels of uncertainty that are associated with both planetary boundaries and GCR risk events (Baum & Handoh, 2014), and the likelihood of complex feedback loops emerging. Furthermore, for disaster risk reduction, preventive policy is preferred as risk reduction is less resource exhaustive than reconstruction and post disaster recovery (United Nations Office for Disaster Risk Reduction, 2021a). These policy interventions seek to contribute to the mandate of the Sendai Framework by minimising economic losses and recognising the complexity and systematic nature of risk (United Nations Office for Disaster Risk Reduction, 2021b).

Preventive Policy

In this case preventive policy seeks to avoid future environmental or societal collapse and is largely associated with achieving the current global targets, the SDGs, such that earth is moved towards a *Stable Earth* scenario, and acting quickly if the world is in *Earth Under Uncertainty* or *Earth Under Threat* scenarios. Preventive policy already exists in disaster risk reduction and the Sendai Framework with calls existing for increasing international cooperation (United Nations Office for Disaster Risk Reduction, 2021e) and the “enhancement of implementation capacity and capability” (United Nations Office for Disaster Risk Reduction, 2015) in disaster risk reduction. Furthermore, regarding disaster risk reduction there already exist strategic objectives with the intent to: increase global monitoring, support the implementation of the Sendai Framework, and catalyse action for Sendai Framework implementation (United Nations Office for Disaster Risk Reduction, 2021e). The breadth of the SDG targets ensures that if completed, then environmental, social, economic, and political stability is possible. However, given the strict timeline, and that 2030 is fast approaching, it is recommended that SDG action be focused onto priority goals (Fenner & Cernev, 2021). Ideally, along with the SDGs, and for later incorporation into the global targets that are to follow on from the SDGs post 2030, there needs to be targets that explicitly address the planetary boundaries and GCR. Whilst to some degree environmental and social feedback loops have the potential to address planetary boundaries and GCR through the achievement of the SDGs, there needs to be policy reflected in exact targets. A *Planetary Boundaries* goal, that is in addition to the SDG environmental goals, with nine individual targets such that each addresses a planetary boundary is required. With respect to GCR, the environmental risks such as climate change, are already addressed in the existing SDGs, and would be further addressed by the addition of a planetary boundaries themed goal. However, many of the *Risks from Hostile Acts* and *Risks from Unintended Consequences* are not addressed in the SDGs, and need to be incorporated into future targets to ensure that a *High Risk World* is not approached. Similarly, approaches towards planetary boundaries and GCR should be included in the data capture and targets of the Sendai Framework. This policy proposal is considered to be acting on a leverage point/vulnerability in the current system as with relatively

minor alterations, large development gains can be secured. Ultimately there needs to be integration of GCR into disaster risk reduction, and the severity of GCR events can be such, especially if more than one occurs, that the disaster level and associated social, economic and political costs are high.

Reactive Policy

Whilst frameworks exist for reacting to disasters and events that are comparable to GCR events or scenarios that are consistent with that of *Global Collapse* or the *Earth Under Uncertainty* and *Earth Under Threat* scenarios, a policy framework needs to be created that addresses: how to react to crossed planetary boundaries, how to react to all GCR events, and then a combination such that in the event that humanity finds itself in a *Global Collapse* scenario, it can successfully navigate its way clear. This proposed framework needs to then be integrated with existing disaster risk reduction framework, the Sendai Framework. From Table 6, it is evident that when in a *Global Collapse* scenario, global targets such as the SDGs are unlikely to be achievable. For this reason more direct policies are required that emphasise controlling the situation, cooperation between countries, and eventually the prioritisation of targets that address the GCR event or planetary boundary crossing that has taken place.

Conclusion

In order to secure achieved development gains, and the adaptability and resilience that has already been established in the world it is essential to further the understanding of GCR, planetary boundaries, and how they interface with disaster risk reduction. Whilst extensive work has been undertaken, such as through the Sendai Framework, more needs to be done to better incorporate GCR and planetary boundaries. There exists a high level of uncertainty for these, both in terms of events occurring and the resulting impact if they do. From the scenario analysis it is evident that they have the potential to severely undermine disaster risk reduction.

The scenario analysis undertaken illustrates a dangerous tendency for the world to tend towards the *Global Collapse* scenario. If this were to eventuate, the achievement of either the SDGs or the goals that follow on from them would be highly unlikely. It would be the same for the Sendai Framework or the next version of it. Thus, it is necessary to act in a preventative way through the creation of a planetary boundaries goal in the post 2030 development targets and the incorporation of GCR into the targets. These should also be incorporated into the next version of the Sendai Framework to enable better traceability, adaptability and preparedness. At the same time it is essential to have the policy capacity and plans to act in a reactive way if the world were to enter the *Global Collapse* scenario.

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