Article36

BRIEFING PAPER | MARCH 2015

Economic impacts of a nuclear weapon detonation

Article 36 is a UK-based not-for-profit organisation working to promote public scrutiny over the development and use of weapons.

Article 36 is part of the International Steering Group of the International Campaign to Abolish Nuclear Weapons (ICAN), www.icanw.org

Article 36
81 Rivington Street, London, EC2A 3AY,
United Kingdom
www.article36.org
info@article36.org
@Article36

Introduction

Many national economies and the world economy as a whole are arguably more vulnerable to the negative economic impact of a nuclear weapon detonation than they were in 1945. A nuclear weapon explosion in an open economy also risks having regional and global ramifications that could set back hard-won development gains and worsen poverty.

The explosion of even a single, low-yield nuclear weapon, whether intentionally or by accident, can cause massive loss of life and significant material destruction directly through blast, heat and other effects. These effects, 'will not be constrained by national borders, and will affect states and people in significant ways, regionally as well as globally'.[1] This was one of the key conclusions that emerged from discussions at the first Conference on the Humanitarian Impact of Nuclear Weapons hosted by Norway in March 2013. Such an explosion would also have profound and long-lasting public health, social, political, economic and environmental consequences. These effects were at the centre of discussions at the Second Conference on the Humanitarian Impact of Nuclear Weapons hosted by Mexico in February 2014.[2]

This paper outlines some of the negative economic and developmental consequences that can be expected to result from a nuclear weapon detonation, with a focus on public infrastructure. The full socio-economic impact of such an explosion is difficult to gauge as different scenarios involving many variables are conceivable.[3] The paper is therefore not based on a single specific scenario, nor does it cover the full range of possible circumstances. Rather, it draws out some key points that emerge from studies that have been undertaken on the economic and infrastructure impacts of violent events and of major natural disasters.[4]

The world has become more urbanised, more globalised (economically inter-dependent) and because most national economies are today heavily dependent on infrastructures that rely on electricity and electronics, an explosion in or near an urban area can damage infrastructure in a way that has serious negative implications for an entire national economy and beyond. The longer-term consequences of a nuclear detonation and response costs would place a heavy burden on public finances, with a highly uncertain prospect for economic recovery. Furthermore, through disruption of global supply chains and through other propagation mechanisms (such as through international financial markets) a nuclear explosion can have global ramifications.[5]

Nuclear weapons present a very high socio-economic risk that is incompatible with key sustainable development goals.[6] Only the elimination of nuclear weapons can ultimately prevent the unspeakable human tragedy and the socio-economic crisis that a nuclear weapon explosion could induce.

Cities – engines of growth

Over the last decades we have seen a rapid growth of the world's urban population with two-thirds of the world's population expected to live in cities by 2030. There is a strong economic logic underpinning this rapid urbanisation. Cities are often described as engines of

economic growth that draw in human resources, raw materials and capital, which combined with modern urban infrastructure have been the driving force behind national economic development in most countries.[7] About 65% of the world's economically active population works in industry and services and a very high proportion of all industry and services are in urban areas. Almost 80% of the world's gross domestic product (GDP) is already generated in cities, with megacities playing a particularly important role.[8]

The explosion of even a low-yield nuclear weapon in an urban or peri-urban area would cause massive loss of life, injury, sickness and destruction due to the high population density and the concentration of high-value assets.[9] According to a previous Article 36 study, the detonation of a 100kT nuclear weapon above central Manchester (UK) would create blast, thermal and electro-magnetic effects that would kill more than 81,000 people directly (16% of the population), leaving more than 212,000 injured (42% of the population), devastating housing and commercial buildings, and destroying vital public infrastructure.[10] Direct loss of life, injury and sickness, and material damage to homes, commercial premises, public services infrastructure, equipment and supplies are a humanitarian catastrophe. They also represent an enormous and instantaneous loss of human and physical capital.[11]

A nuclear weapon explosion in or near a city is likely to have economic effects beyond the immediately affected area.

- Certain industries tend to be concentrated in or near urban centres. A nuclear detonation in such a location can completely devastate key sectors of a national economy. This would disrupt supply chains and product distribution and would lead to bottlenecks elsewhere. Business costs would rise, and competitiveness and reputation would suffer. As a result, businesses would close, relocate or go bankrupt.
- Quality educational facilities, that have important links to commercial and governmental research and development, tend to be located in major urban areas too. A nuclear weapon explosion could rob a country of many highly-trained specialists and the institutional framework for research that is the basis of scientific discovery and technological innovation.
- Also concentrated in urban areas are many of the most advanced hospitals and of hospital-based physicians. A nuclear explosion would likely result in an overall degradation of health care throughout the country, possibly for a long time.
- Cities also play a dominant role in the national administration. The loss of qualified staff and elected officials, and the loss of official records and degradation of government structures could jeopardise response efforts and adversely affect citizens' rights and the maintenance of public order.

The effects of a nuclear weapon explosion are likely to be felt over an extended period of time and to generate immense socio-economic costs. With potentially large numbers of people suffering disability or permanent health effects, such as increased disease occurrence and emotional trauma, degraded living circumstances, homelessness, displacement, interrupted education, and loss of employment, the productivity of affected populations should be expected to be negatively affected over an extended period of time.

Infrastructure – the bedrock of prosperity

A nuclear explosion would not only affect physical infrastructure directly through blast, heat and the electromagnetic pulse. It could also lead to the complete and nation-wide collapse of public services infrastructures, which would have implications beyond national borders.

Modern economies, and especially modern cities are heavily dependent on functioning infrastructures, such as communication, transport, water, electricity, and fuel networks. Because the physical and social fabric of developed economies is sustained by a complex network of interlocking and interdependent infrastructures, disruption in any one system can affect connected systems. Such cascading failures have been observed in natural disasters and industrial accidents. For instance, during the Mumbai 2005 floods, the mobile phone network collapsed due to a breakdown in the transport system: 'The transmitters had diesel generators that would last for only two hours and the fuel could not be replenished due to a lack of transport'.[12]

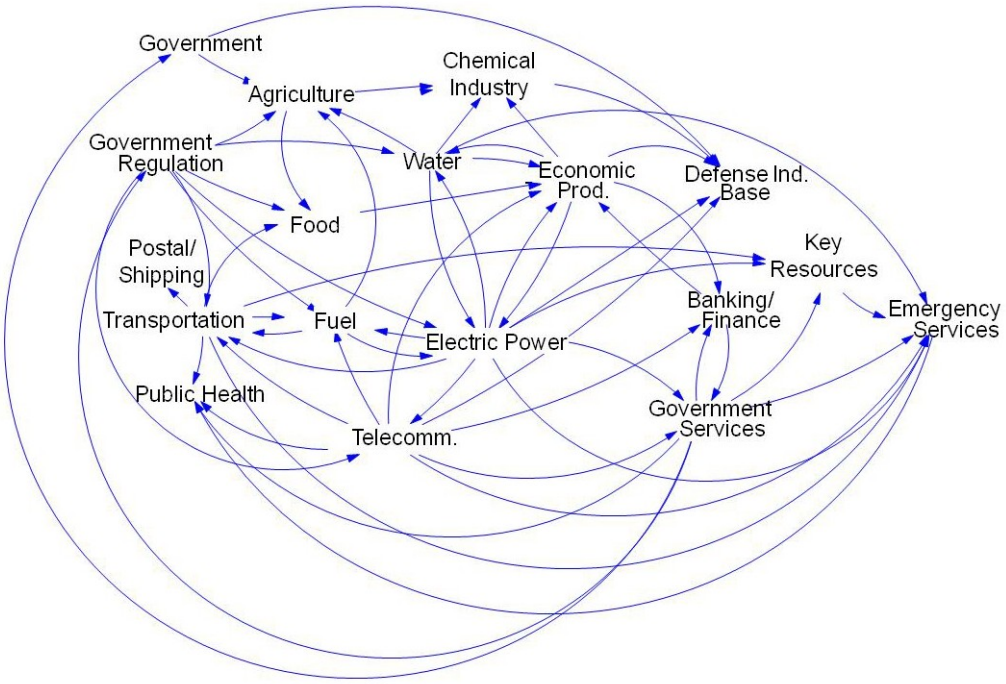
In most countries, electrical power is necessary to support other critical infrastructures, including the supply and distribution of water, food, fuel, the dissemination of information, financial transactions, and the provision of emergency and government services, and all other infrastructures supporting the national economy and welfare. Economies that are dependent on extensive electricity-driven infrastructures are especially vulnerable to the electromagnetic pulse (EMP) created by a nuclear weapon explosion.

Due to the pervasive use of electronics to control, communicate, compute, store, manage, and implement nearly every aspect of infrastructure systems, an EMP, when coupled into sensitive electronics, has the capability to produce widespread and long lasting disruption and damage to critical infrastructures, creating 'the possibility of long-term, catastrophic consequences'.[13]

The EMP could not only seriously degrade or shut down a large part of the electric power grid in the geographic area of EMP exposure near-instantaneously, it could also lead to functional collapse of grids beyond the exposed area, as electrical effects propagate from one region to another.[14]

To illustrate, lightning strikes that caused a 0.4 second power loss and subsequent power dips in the British Pembroke Refinery on 24 July 1994, led to an explosion and fires. The malfunctioning process control system did not allow the refinery operators to contain the situation. As a result, an estimated 10% of the total refining capacity in the UK was lost until the Pembroke Refinery was returned to service. The business loss is estimated at $70 million, which reflects 4.5 months of downtime. This type of power loss and material degradation can also result from an EMP event.

Should significant parts of the electrical power infrastructure be lost for any substantial period of time 'the consequences are likely to be catastrophic, and many people may ultimately die for lack of the basic elements necessary to sustain life in dense urban and suburban communities.'[15] When the lifelines of network infrastructures are cut, emergency response efforts are jeopardised and fuel reserves for back-up systems and stocks of food and medicine will quickly be



An illustration from the US Oak Ridge National Laboratory report, 'Climate Change and Infrastructure, Urban Systems and Vulnerabilities', 2012, illustrating the interdependence of key infrastructure elements. This interdepence provides one of the mechansims by which the economic impact of a nuclear weapon detonation would propagtate.

exhausted. The maintenance of a reasonable standard of health will not be possible without the rapid recovery of the economy's critical industries. Prolonged disruption of these systems puts the survival of the population and the prospect of economic recovery into question.

A heavy burden on public finances

If following a nuclear weapon explosion, a government were to retain the legitimacy, authority and capacity to communicate, coordinate, and deliver goods and information,[16] it would rapidly need to allocate considerable resources to emergency response measures including fire-fighting, search and rescue, evacuation of areas affected by the explosion and radioactive fall-out, decontamination, and provision of humanitarian aid and shelter to the displaced and homeless.

Additional resources would be needed for recovery activities, including handling of the dead, removal of rubble, decontamination and other environmental rehabilitation, continued monitoring of radiation levels, control of goods and persons, quarantining, rebuilding and replacement, resettlement, and compensations for losses and other financial support from the state to businesses and private persons.

Response and recovery would place a heavy burden on public finances. Some of the costs of a nuclear explosion will peak only decades after the event, such as higher health sector costs due to long-term and inter-generational effects of irradiation, as well as disability claims. The Chernobyl nuclear power plant accident and government policies adopted to cope with its consequences, for example, has strained the national budgets of Belarus, the Russian Federation and Ukraine. In Ukraine, 5–7% of government spending each year is still devoted to Chernobyl-related benefits and programmes. Total spending by Belarus on Chernobyl between 1991 and 2003 is estimated at more than US $13 billion. 'Although capital-intensive spending on resettlement programmes has been curtailed or concluded, large sums continue to be paid out in the form of social benefits for as many as 7 million recipients in the three countries.'[17]

Due to radioactive fall-out, cities, towns, industrial areas and agricultural land over a potentially vast area may have to be abandoned. One study puts the economic cost of a 100 kT nuclear weapon exploding in New York City at $10 trillion or above, which is roughly equivalent to the annual GDP of the U.S. economy.[18] The amount of response and recovery costs will, however, depend to a significant degree on policy decisions and societal attitude toward risk. The aforementioned study also demonstrates that the cost of decontamination and clean-up is highly sensitive to the clean-up standard applied. Yet even a nuclear weapon explosion in a relatively isolated area could have significant economic consequences in terms of lost assets and of clean-up and rehabilitation.

Recovery uncertain

Resources needed for response and recovery will be have to be diverted from growth activities. Whilst in some cases the economic activity to rebuild from natural disasters has been viewed from a positive perspective,[19] according to disaster risk experts 'severe disaster events do not have positive economic impacts under any circumstances. Indirect losses and secondary effects can increase sharply if post-disaster contraction and reallocation of government resources delay reconstruction and dampen the pace of capital accumulation.'[20]

The critical importance of functioning network infrastructure for response and recovery can hardly be overstated. Yet, there will likely be real limitations to the speedy reconstruction of these infrastructures, due to a lack of qualified personnel and material resources needed for repair. In the absence of electricity, manual control of some systems may not be possible, or the people with knowledge able to support manual operations may not be available. It may not be possible to manufacture key replacement components nationally whilst acquisition from abroad, if it can be organised and funded at all, may take months.

Continuing degradation of all critical infrastructures for a prolonged period of time can cause food, health, energy and financial crises. Data on natural disasters shows that if a storm or earthquake covers most of a small country, it can leave the remaining unaffected parts unable to internally fund the recovery.[21] A nuclear weapon explosion could make recovery much more difficult than a political embargo or a natural disaster.[22] It is doubtful whether a badly damaged economy with its output greatly curtailed would be able to generate the enormous sums of capital and other resources required to refurbish public services infrastructure and to purchase the necessary resources from abroad.[23]

Assumptions about the prevailing socio-economic situation should also be critically examined when considering the costs of a nuclear explosion and the prospect for recovery. In the aftermath of a nuclear weapon explosion, especially a nuclear attack, or a nuclear war, prevailing economic models may not adequately account for profound socio-economic and political changes induced by such an event. How, for instance, will consumer behaviour be affected? What will be survivors' attitude toward saving and investment?[24] According to one study, the economic and psychosocial effects of an attack with a radiological dispersion device (RDD), a weapon many times less powerful than a nuclear weapon, are expected to be 'more significant than the potential loss of human life and building destruction.'[25] Especially in the event of a high-yield nuclear weapon explosion, or of several explosions, the 'normal' functioning of political and economic institutions at the national and international levels cannot be presumed. A nuclear war, would not only damage the industrial base of a national economy and thin the ranks of qualified personnel, but it would also disrupt and destroy supporting financial structures, throwing into question the value and utility of money, as well as the value and ownership of goods and property.[26] Especially in the absence of communication infrastructure, governance structures are likely to break down. The entire social and economic infrastructure of an affected country can collapse, with possible spill-over effects internationally.

The cost of disruption in an increasingly interdependent world

The effects of a nuclear weapon explosion should be expected to have global ramifications. Today, much more so than in 1945 or during the Cold War, the global economy is characterised by a high degree of division of labour and specialisation. Economic, social and financial interconnectedness are on the rise.[27] This does not only have advantages. As we have experienced in recent years, 'Globalised systems involving highly interactive and optimised production give rise to large-scale vulnerabilities'.[28]

There are many different channels by which the economic consequences of a nuclear weapon explosion can propagate throughout the global economic system and affect other national economies. The global financial crisis has highlighted the financial interdependencies that exist among the world's major economies. The loss of electricity and communications due to the EMP of a nuclear explosion would likely be fatal to the financial services infrastructure beyond the region directly affected by the EMP.[29] The 2003 Northeast Blackout (see Box) gives an idea of how a local disaster can have global implications.

Even a short electricity network disruption can have considerable economic costs, as is illustrated by how the 'Northeast Blackout' of 14 August 2003 affected the U.S. and Canada. The blackout resulted in the loss of 61,800 MW of electric load that served more than 50 million people. Its footprint included large urban centers that are heavily industrialised and important financial centers, like New York City and Toronto. Nearly half the Canadian economy is located in Ontario and was affected by the blackout. There were losses due to food spoilage, lost production, damage to production facilities and products, overtime wages, emergency services costs, disrupted deliveries from suppliers and to customers, diversion of resources to blackout protection systems and reduced value of affected companies' securities. The cost of this blackout of only a few hours is estimated to be between $7 and $10 billion (7,000 to 10,000 million).[30]

It is widely accepted that the 2003 blackout happened under 'ideal conditions' for financial markets. Even so, it has been reported that 'some traders could not access the NASDAQ electronic exchange, ATMs failed all over New York City and elsewhere, and banks borrowed a total of $785 million from the Federal Reserve System to compensate for imbalances.'[31] This was the result of a disruption that lasted merely a few hours.

The economic consequences of a nuclear weapon explosion, let alone of multiple explosions, can be expected to be vastly more devastating. If the financial industry were disrupted for days, weeks, or months rather than hours, 'the economic impact would be catastrophic.'[32] In some circumstances it would be virtually impossible for banks, either regionally or nationally, to pursue 'normal' lending and borrowing policies. Localised problems in the payments system can spill over to the whole system. A perceived increase in this risk to which a bank is subject when paying out funds in advance of receiving funds from a counterparty can result in banks delaying the submission of their payments, leading to deferred payments and market-wide liquidity shortages.[33]

Trade linkages are another channel for the transmission of negative shocks to international trade partners, which can lead to economic contractions in other regions of the world. A 2006 study estimated that the early costs of a 10kT nuclear explosion in the Port of Long Beach (U.S.), an important global shipping centre, could exceed $1 trillion (1,000,000 million) and to have economic effects far beyond the initial attack. Assuming extended closures of all US ports following such an explosion, or at least for a period of substantially reduced operations, the authors found that 'there is a high probability that the Long Beach scenario would ... have important repercussions for global business activity because the value of imports and exports from all US ports represents 7.5 percent of world trade activity. In the wake of these economic effects, it seems reasonable to assume that there would be large declines in world stock markets'.[34]

Global supply chains, in particular, are vulnerable to disruption. Modern production often involves many suppliers that are located in several countries, giving rise to global value or supply chains.[35] In the case of Asia, the disruptions to some of Japan's production activities caused by the devastating earthquake and tsunami of 11 March 2011 have raised fears about supply shock propagating throughout the global electronics and automotive supply chains, as Japan is an important provider of parts and components for both these global value chains.[36]

Cities are particularly prone to supply crises. As the world urbanises, vulnerability increasingly shifts to cities where proportionately more people now live, including the majority of the world's refugees and IDPs.[37] Most of the largest cities are in low- and middle-income countries where an estimated 2.6 billion urban dwellers live, out of an estimated 3.5 billion worldwide. Sudden supply shortages or major catastrophes can quickly lead to serious bottlenecks or emergencies for a vast number of people. According to a 1982 study on the social and economic effects of nuclear war, 'Large urban populations distant from their suppliers are totally dependent for food supplies on a system that is highly vulnerable to nuclear attack'.[38] The imbalances in global grain supply and demand in 2008, precipitated by poor harvests in major grain production countries and market speculation, led to a severe spike in food prices, with wheat prices rising to more than double the price of the previous five years. The impacts were mainly felt away from the producer countries, in poorer countries and communities, leading to food crises and urban food riots.[39]

Securing the Future We Want

As with all disasters, the socio-economic costs of a nuclear weapon explosion will not be borne equally by all. A multitude of crises and disasters have disrupted the world economy and have had substantial negative consequences on development in recent years. They underscore how vulnerable people, communities, and countries are to systemic risks, especially in developing nations. 'Because of the 2008–09 global financial crisis, most economies around the world experienced sharp declines in growth rates, with ensuing loss of income and employment and setbacks in efforts to reduce poverty.' According to the World Bank, 'it is often the poor who are hit the hardest. Despite impressive progress in reducing poverty in the past three decades, a substantial proportion of people in developing countries remain poor and are vulnerable to falling into deeper poverty when they are struck by negative shocks.'[40]

The eradication of extreme poverty and hunger is one of the Millennium Development Goals (MDGs), a blueprint agreed to by all states and all the world's leading development institutions to achieve a series of development targets by 2015.[41] Progress toward achieving a world of prosperity, equity, freedom, dignity and peace has been uneven. The MDG target of halving poverty rates between 1990 and 2010 has been met, but 1.2 billion people still live in extreme poverty,[42] and some goals will not be met by 2015.[43] Efforts are, thus, underway to craft a post-2015 development agenda.

At the 2013 UN Conference on Sustainable Development, world leaders renewed their commitment to the MDGs and agreed to hold a high-level summit in September 2015 to adopt a new set of goals. The outcome document of the conference ('The Future We Want') outlines a common vision for our future and proposes a comprehensive path toward sustainable development. Among other aspects, the document stresses the important role played by energy (§125), transport and mobility (§132) and communications technologies (§65) in the development process. It describes international trade as 'an engine for development and sustained economic growth' (§281), acknowledges that 'multiple financial, economic, food and energy crises ... have threatened the ability of all countries, in particular developing countries, to achieve sustainable development' (§20), and attaches crucial importance to 'the fulfilment of all commitments related to official development assistance' (§258).

It is readily apparent that a nuclear weapon explosion would adversely affect all of these elements, undermining sustainable development efforts in the directly affected state(s). It is also clear from research on natural disasters that the destruction of assets and livelihoods sets back hard-won development gains and worsens poverty, often for extended periods of time. According to a paper by Integrated Research on Disaster Risk and the International Council for Science, 'Disaster events undermine poverty eradication: The livelihoods, productive economic activity and public capacities that keep poverty at bay are compromised when the underpinning assets and resources of households and countries are destroyed in disasters as well as deepening existing poverty.'[44]

A nuclear weapon explosion could also affect the ability of states not directly affected to achieve sustainable development goals, whether due to the re-allocation of national resources leading to a reduction in foreign trade, foreign direct investment or foreign aid, disruptions in the global market, or protectionist policies adopted by states in the wake of such an event. Although official development assistance (ODA) is only a fraction of total flows to low-income countries, as a consequence of the global recession, aid from major donors to developing countries within the framework of the Development Assistance Committee (DAC) fell by nearly 3% in 2011 compared to 2010. The severe financial crises in Greece and in Spain led to a fall of 39.3% and 32.7% in ODA from these countries respectively. Similarly, country programmable aid (CPA), directed through international organisations, is estimated to have fallen by 2.4% compared to 2010, representing a decline of nearly USD 2.3 billion in real terms.[45]

In 2000, 189 states made a promise to free people from extreme poverty and multiple deprivations. This pledge turned into the eight Millennium Development Goals (MDGs). The pledge also laid out the fundamental values essential to international relations in the twenty-first century: freedom, equality, solidarity, tolerance, respect for nature and shared responsibility. In line with these values, states committed to spare no effort to free the world's peoples from the scourge of war and resolved therefore to 'strive for the elimination of weapons of mass destruction, particularly nuclear weapons, and to keep all options open for achieving this aim'.[46]

Any nuclear weapon explosion is also a health catastrophe and an ecological disaster.[47] In the words of the 2013 outcome document of the 2013 UN Conference on Sustainable Development, 'health is a precondition for and an outcome and indicator of all three dimensions of sustainable development'. (§138) The outcome document also reaffirms the right of everyone to have access to safe, sufficient and nutritious food, the fundamental right of everyone to be free from hunger, and reflects the commitment of states to enhancing food security and access to adequate, safe and nutritious food for present and future generations. (§108) It acknowledges that climate change is a cross-cutting and persistent crisis and expresses concern that the scale and gravity of the negative impacts of climate change affect all countries and undermine the ability of all countries, in particular, developing countries, to achieve sustainable development. (§25)

The radioactive fallout from a nuclear explosion will exert a variety of effects upon world ecology over time. According to one study, the use of one hundred 15kT weapons against city centres would produce global climate disturbances on a scale unprecedented in recorded

human history.[48] Newly generated data indicates that in the event of multiple nuclear weapon explosions, such as in the case of a regional nuclear war, more than two billion people would be in danger of starvation.[49] Ionising and solar radiation effects on crops and livestock, possible reduced effectiveness and decline in available fertilisers and pesticides, and changes in weather patterns could result in a significant decline in food production over wide areas of the world. Food availability would be reduced by increases in the price of food, speculation on agricultural markets and hoarding. Given the precarious situation of the 870 million people who are presently malnourished, even a small decline in available food and rise in prices will have devastating consequences. Decline in quality of nutrition would cause significant health effects. Famine on a major scale would likely lead to epidemics of infectious diseases. The chronically malnourished cannot survive a significant, sustained further decline in their calorific intake.[50]

In light of this, and in recognition of our shared responsibility for a prosperous, equitable and peaceful future, it is not surprising that the elimination of nuclear weapons is one of the pledges that states adopting the Millennium Declaration have committed to fulfill.[51]

Conclusion

Even a comparatively low-yield nuclear weapon explosion in or near a city of an open economy would have massive economic consequences. In many situations such consequences would extend beyond national borders. The effects of a high-yield explosion or of multiple nuclear explosions could set back hard-won development gains and significantly worsen poverty and hunger on a global scale.

In an age of globalisation, urbanisation and large-scale vulnerabilities, and in light of the uncontrollable, destructive capability of nuclear weapons, it is difficult to conceive how their continued existence can be reconciled with sustainable development goals that states have committed to achieve. From a socio-economic and development perspective, the 'Future We Want' must be free from nuclear weapons. The clearest articulation of such a vision would be for committed states to develop and adopt a treaty prohibiting nuclear weapons.

END NOTES

1 Conference on the Humanitarian Impact of Nuclear Weapons, Oslo, 4-5 March 2013, Chair's Summary, http://www.regjeringen.no/en/archive/Stoltenbergs-2nd-Government/Ministry-of-Foreign-Affairs/taler-og-artikler/2013/nuclear_summary.html?id=716343

2 Second Conference on the Humanitarian Impact of Nuclear Weapons, Nayarit, 13-14 February 2014, Chair's Summary, http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/nayarit-2014/chairs-summary.pdf

3 A large array of factors influence the effects of an explosion, its immediate impacts and broader economic consequences. These include the size and type of the nuclear device, the height of burst, the demographic and material blast environment, the geographic location, the meteorological situation, the national and international political context, the characteristics of directly affected economic sectors and the type and degree of connection of these sectors with the national, regional and global economy.

4 Nuclear weapon explosions have – fortunately – historically been rare and there appears to be little in the way of nuclear weapon-specific research into the socio-economic costs of such an event. Insights into the economic costs of destruction can be gleaned from research on the cost of armed violence, war, terrorism, natural disasters and nuclear power plant accidents. However, inferences from these materials should be drawn with caution as a nuclear weapon explosion can cause devastation on a vastly greater scale and cause effects that are qualitatively different from other violent events. It should also be borne in mind that historical examples of nuclear weapon explosions might not adequately capture the scale of economic and development consequences that would result if such an event were to take place in today's highly interdependent and urbanised world that heavily relies on the functioning of modern public services infrastructure.

5 The classifcation of types of impact is inevitably to an extent arbitrary. Dumas & Nelson in Reaching Critical Will, 'Unspeakable Suffering - the humanitarian impact of nuclear weapons', 2013, http://www.reachingcriticalwill.org/images/documents/Publications/Unspeakable/Unspeakable.pdf, distinguish direct costs, disruption costs and reaction costs. As Dumas & Nelson acknolwedge that the cost of decontamination, for instance, depends greatly on the standards set and enforced, which are the result of a political decision tied to society's attitude to risk. The same is true regarding the extent of state support to survivors (relocation, compensation, etc.) and businesses (bail-outs, liquidity, guarantees) and the allocation of state resources. The International Federation of Red Cross and Red Crescent Societies (IFRC) World Disasters Report 2001, http://www.ifrc.org/publications-and-reports/world-disasters-report/wdr2011/ distinguishes between 'direct' physical impacts, or losses of fixed capital and inventory, including buildings, infrastructure, industrial plants, crops and materials, and 'indirect' and 'secondary' effects on economic activity. 'Indirect costs refer to damage to the flow of goods and services, for example, lower output from damaged or destroyed assets and infrastructure. Secondary effects concern both the short- and long-term impacts of a disaster on overall economic performance, such as on external and government-sector balances, levels of debt and the thrust of government monetary and fiscal policies. Direct losses can roughly be equated with stock losses whilst indirect costs and secondary effects both constitute flow losses.'

6 This paper does not address the costs, including opportunity costs, of producing, testing and possessing nuclear weapons, of nuclear non-proliferation, arms control and disarmament efforts (including safety, maintenance, training, confidence building measures, de-alerting, destruction, etc.) or the impacts on local livelihoods from nuclear weapon testing or stockpiling. On these issues, see, e.g. S. I. Schwartz (ed.) 'Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940', 1998, http://www.brookings.edu; J. Page and R. Thakur, 'Nuclear Weapons: The Opportunity Costs', APLN/CNND Policy Brief No. 1, June 2013, http://a-pln.org; and B. Cramer, Nuclear Weapons: At What Cost?, 2009, http://www.ipb.org.

7 See for example, UN DESA, 'World Urbanisation Prospects: the 2014 revision,' 2014, http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf

8 The World Bank, 'Urban Development Overviews', http://www.worldbank.org/en/topic/urbandevelopment/overview

9 Nuclear weapons are more destructive than any other weapon developed throughout history. The massive blast wave from an explosion can pull apart buildings, crush people to death and cause hurricane-strong winds. The intense heat emitted by an explosion can burn through skin and cause fires that can spread and combine into firestorms. Intense light can blind people far from the centre of an explosion. Ionising radiation and radioactive fallout can cause sickness for which there is no cure.

10 See Article 36, 'Humanitarian Consequences: Short case study of the direct humanitarian impact from a single nuclear weapon detonation on Manchester, UK, 2013, http://www.article36.org/wp-content/uploads/2013/02/ManchesterDetonation.pdf

11 Megacities tend to be nodal points of national and global economies A nuclear weapon explosion in a megacity of an industrialized country will likely adversely impact the entire national economy and the global urban system. See for example Kraas, Aggarwal, Coy and Mertins [eds.], 'Megacities: Our Global Urban Future,' 2010, International Year of Planet Earth.

12 See Municpal Corporation of Greater Mumbai, 'Mumbai Disaster Risk Management Master Plan Framework Report,' 2011 draft, http://www.unisdr-apps.net/confluence/download/attachments/9994389/DRMMP+Framework.pdf?version=1

13 Foster et. al. 'Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack' (Graham Commission), 2004, http://www.empcommission.org/docs/empc_exec_rpt.pdf

14 The effects of an EMP vary greatly with the height of burst of the detonation from the ground. This paper focuses on comparatively low level air-burst detonation where the EMP affects infrastructure but over smaller area. By contrast, a high altitude nuclear detonation (125-300 km) of a single low-yield nuclear weapon (10-20 kT) could affect low earth orbit satellites not specifically hardened to resist such an attack and may disable military and civilian communications, imaging, and meteorological/earth/ocean surveillance. The satellite replacement costs for meteorological systems is estimated to be $425 million, launch costs $250 million. Replacement would have to wait until the radiation belts cooled. The broader socio-economic and political consequences of would vary with levels of dependence on LEO constellations and access to alternatives. See US Defence Threat Reduction Agency (DTRA), 'High Altitude Nuclear Detonations (HAND) Against Low Earth Orbit Satellites (HALEOS)', 2001, http://www.fas.org/spp/military/program/asat/haleos.pdf

15 Foster et. al. above note 13.

16 As the Graham Commission (Foster et. al. above note 13) points out, "When dealing with a disaster of this scope, there must be serious international collaboration in order to plan the delivery of emergency supplies and alleviate the crisis." Yet, "mustering a global response requires above all the capacity to communicate." Furthermore, the most critical capacity provided by government in the face of disaster, arguably, is legitimacy, providing the reassurance that government is functioning. This capability too is impossible without the ability to communicate both within the country and with nations providing external support.

17 See The Chernobyl Forum (IAEA, WHO, UNDP, FAO, UNEP, UN-OCHA, UNSCEAR, World Bank Group, Belarus, the Russian Federation, Ukraine), 'Chernobyl's Legacy: Heath, Environmental and Socio-economic Impacts and Recommednations to the Government of Belarus, the Russian Federation and Ukraine', 2003-2005, https://www.iaea.org/sites/default/files/chernobyl.pdf

18 Reichmuth, B. Short, S. and Wood, T., 'Economic Consequences of a Radiological/Nuclear Attack: Cleanup Standards Significantly Affect Cost', 2005, Pacific Northwest National Laboratory.

19 See Meade, C. & Molander, R., 'Considering the Effects of a Catastrophic Terrorist Attack', 2006, RAND, p. 8. The World Bank notes with respect to the 2011 Japan earthquake that, "While economic losses (human life, buildings and other infrastructure) are enormous, such disasters tend to have relatively small impacts on GDP growth, both because the affected area is small relative to the whole economy..., and because GDP growth depends on current period economic activity, not accumulated wealth, and most of the losses reflect lost wealth. Indeed, because of the investment activity that such crises induce, they can perversely be positive for growth (as measured by GDP)" (World Bank, 'FOCUS: Effects of the 2011 Japan earthquake' 2011, http://siteresources.worldbank.org/INTDAILYPROSPECTS/Resources/1324037-1124814714238/1584361-1300457735614/FOCUSnotes.pdf) Integrated Research on Disaster Risk (IRDR) and the International Council for Science (ICSU) consider, in contrast, that, "Cities struck by major hazards can take years to recover. An economics study of the 1995 Kobe earthquake showed that in 2008, thirteen years after the event, the city's per capita GDP was lower by 12%. This impact is persistent, clearly observable, and attributable to the earthquake, and it occurred despite the relative wealth of the country and the considerable recovery support provided to the city" See IRDR & ICSU, 'Issue Brief: Disaster Risk Reduction and Sustainable Development', 2014, http://www.irdrinternational.org/wp-content/uploads/2013/12/IRDR-ICSU-Brief-DRR-SD.pdf

20 IRDR & ICSU above note 19.

21 IRDR & ICSU above note 19.

22 Dumas & Nelson above note 5.

23 Katz, A. & Osdoby, S, 'The Social and Economic Effects of Nuclear War', 1982, http://www.cato.org/pubs/pas/pa009.html

24 Katz & Osdoby above note 23.

25 B. Reichmuth, S. Short and T. Wood, 'Economic Consequences of a Radiological/Nuclear Attack: Cleanup Standards Significantly Affect Cost', 2005, Pacific Northwest National Laboratory.

26 Cochrane, H & Mileti, D. 'The Consequences of Nuclear War: An Economic and Social Perpective, In The Medical Consequences of Nuclear War', 1986, The National Academy of Sciences; Katz & Osdoby above note 23.

27 For example, World Bank, 'World Development Report 2014 - Risk and Opportunity: Managing Risk for Development', http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTWDRS/EXTNWDR2013/0,,contentMDK:23480271~pagePK:8261309~piPK:8258028~theSitePK:8258025,00.html

28 IRDR & ICSU above note 19.

29 For details, see Foster et. al. above note 13.

30 Electricity Consumers Research Council (ELCON), 'The Economic Impacts of the August 2003 Blackout', 2014, http://www.elcon.org/Documents/Profiles%20and%20Publications/Economic%20Impacts%20of%20August%202003%20Blackout.pdf

31 Carafano, J., 'EMP Attacks - What the U.S. Must Do Now', 2010, http://www.heritage.org/research/reports/2010/11/emp-attacks-what-the-us-must-do-now#_ftnref18 There is no specific source for the figures cited in Carafan's text however.

32 Foster et. al. above note 13.

33 MacAndrews, J. & Potter, S., 'Liquidity Effects of the Events of September 11, 2001', 2002, Federal Reserve Bank of New York Economic Policy Review, http://www.newyorkfed.org/research/epr/02v08n2/0211mcan.pdf In the wake of the 9/11 attacks the Federal Reserve Bank by various means encouraged timely payment by banks. These measures all hinge on continued availability of communications and electricity infrastructure, which may not be available in the case of a nuclear weapon explosion.

34 Meade, C. & Molander, R., 'Considering the Effects of a Catastrophic Terrorist Attack', 2006, RAND.

35 A distinct feature of the world economy in recent decades has been the international fragmentation of production. Outside Asia, developing economies are not to a significant degree part of global supply chains. There are also other factors that influence the transmission of business cycle shocks to other economies. See Ferrarini, B., 'Mapping Vertical Trade', 2011, Asia Development Bank (ADB) Economics Working Paper Series No. 263, http://www10.iadb.org/intal/intalcdi/PE/2011/08977.pdf; Gangnes, B. Ma, A. & Assche, A., 'Global Value Chains and the Transmission of Business Cycle Shocks', 2012, Asia Development Bank (ADB) Economics Working Paper Series No. 329.

36 Ferraini, and Gangnes & Assche, above note 35

37 International Federation of Red Cross and Red Crescent Societies (IFRC), 'World Disasters Report 2012', http://www.ifrcmedia.org/assets/pages/wdr2012/resources/1216800-WDR-2012-EN-FULL.pdf

38 Katz & Osdoby above note 23.

39 IRDR & ICSU above note 19.

40 International Federation of Red Cross and Red Crescent Societies (IFRC), 'World Disasters Report 2014', http://www.ifrc.org/world-disasters-report-2014

41 United Nations Millenium Declaration, A/RES/55/2, 2000, http://www.un.org/millennium/declaration/ares552e.pdf

42 United Nations Development Programme (UNDP), 'Eradicating extreme poverty and hunger - where do we stand?' webpage at http://www.undp.org/content/undp/en/home/mdgoverview/mdg_goals/mdg1/

43 For details, see UNDP, 'Millenium Development Goals Report, 2013', http://www.undp.org/content/undp/en/home/librarypage/mdg/the-millennium-development-goals-report-2013/

44 IRDR & ICSU above note 19.

45 All figures OECD, 'Development: Aid to developing countries falls because of global recession', online http://www.oecd.org/newsroom/developmentaidtodevelopingcountriesfallsbecauseofglobalrecession.htm

46 United Nations Millenium Declaration, above note 41.

47 The World Health Organisation (WHO) concluded almost three decades ago that "nuclear weapons constitute the greatest immediate threat to the health and welfare of mankind." Article 36 (above, note 10) states that "Radioactive isotopes from the fallout will exert a variety of effects upon world ecology over time, as plants and animals absorb the fission products. The isotopes will migrate into the drinking water and enter the human food chain, affecting not only human health, but also the health of livestock and agricultural productivity."

Under certain conditions, such as in the case of a regional nuclear war, the smoke and soot from fires transported into the upper troposphere can cause an abrupt drop in global temperatures and rainfall by blocking sunlight from reaching the Earth's surface. Soot injections could also lead to the depletion of the stratospheric ozone layer, causing increased penetration of ultraviolet (UV) and other harmful radiation from the sun and disturbing global weather patterns

48 Toon, O. Turco, R. Robock, A. Bardeen, C. Oman, L. & Stenchikov, G., 'Atmospheric effects and societal consequences of regional scale nuclear conflicts and acts of individual nuclear terrorism,' 2007, Atmospheric Chemistry and Physics, 7, 1973-2002, 2007, http://climate.envsci.rutgers.edu/pdf/acp-7-1973-2007.pdf

49 Helfand, I., 'Nuclear Famine: Two billion people at risk? - Global impact sof limited nuclear war on agriculture, food supplies and human nutrition', 2013, International Physicians for the Prevention of Nuclear War, http://www.ippnw.org/pdf/nuclear-famine-two-billion-at-risk-2013.pdf

50 Helfand, above note 49.

51 United Nations Millenium Declaration, above note 41.