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"State of the art review of Risk Assessment Methodologies concerning Climate Change and Environmental Threats"

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ABSTRACT

This diploma thesis deals with the assessment of risks related to Climate Change and Environmental Threats and affects various sectors in Critical Infrastructures.

More specifically, we present the Risk Assessment process as well as general methodologies used globally as best practices to fully understand the importance of properly recording threats in Critical Infrastructures and their outcomes.

It then follows an extensive report on Climate Change and Environmental Threats. Finally, a study (detection / collection / creation) of Threat Analysis Scenarios for each sector / area of Critical Infrastructure is carried out.

We highlight the overlapping impacts on interconnected assets, systems and more generally on operations in all critical infrastructure sectors, and we also propose preventive measures to adapt to climate change. Lastly, we emphasize the interdependencies between the sectors / areas in order to highlight the Critical Infrastructure sectors that play a leading role in their significance.

ΠΕΡΙΛΗΨΗ

Η παρούσα διπλωματική εργασία ασχολείται με την Αξιολόγηση Κινδύνων που σχετίζονται με την Κλιματική Αλλαγή και τις Περιβαλλοντικές Απειλές και επηρεάζουν διάφορους τομείς στις Υποδομές Ζωτικής Σημασίας.

Πιο συγκεκριμένα, παρουσιάζεται η διαδικασία Εκτίμησης/Αξιολόγησης Κινδύνων και Επικινδυνότητας καθώς και γενικές μεθοδολογίες που χρησιμοποιούνται παγκοσμίως ως βέλτιστες πρακτικές, με σκοπό να κατανοηθεί πλήρως η σημαντικότητα της σωστής καταγραφής των απειλών και των αποτελεσμάτων τους.

Ακολουθεί μια εκτενής αναφορά στο θέμα της Κλιματικής Αλλαγής και των Περιβαλλοντικών Απειλών. Στη συνέχεια, πραγματοποιείται μια μελέτη (ανίχνευση / συλλογή / δημιουργία) Σεναρίων Ανάλυσης Απειλών για κάθε κλάδο/τομέα των Υποδομών Ζωτικής Σημασίας.

Αναδεικνύουμε τις αλληλεπικαλυπτόμενες επιπτώσεις για τα διασυνδεδεμένα περιουσιακά στοιχεία, συστήματα και γενικότερα για τις λειτουργίες που αφορούν σε όλους τους κλάδους των Υποδομών Ζωτικής Σημασίας και επιπλέον προτείνουμε προληπτικά μέτρα προσαρμογής στην Κλιματική Αλλαγή. Τέλος, δίνουμε έμφαση στις αλληλεξαρτήσεις μεταξύ των κλάδων με σκοπό να αναδειχθούν οι κλάδοι των Υποδομών Ζωτικής Σημασίας που παίζουν πρωταγωνιστικό ρόλο ως προς τη σημαντικότητά τους.

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CHAPTER I: Introduction

The measure of human demands on Earth's natural resources is also known as our ecological footprint. At the time being, we use the equivalent of 1.5 Earths to produce all the renewable resources we use. As the human population grows, the challenge of reducing our footprint becomes a necessary need.We need to look carefully at the serious environmental issues we are facing and the actions that need to be taken to alleviate them. Ignorance may be bliss, but it's getting increasingly difficult to ignore the damage we've done to the environment and the earth itself, especially when the effects have been hitting so close to our home.

The usual weather of a place is called climate. Climate is different from season to season. A place could be mostly warm and dry in the summer. The same area could be cool and wet in the winter. Various places may have different climates. Global climate is the combination of all the climatesaround the world together. [1]

The change in the usual weather, located at a place on the earth is called Climate Change (CC). This could be a change in the usual temperature of a place for a specific time period (for example one month) or even for a hole season. Or it could be in a change in how much drought or rain a place usually gets inside a whole year. The Global Climate is also changing while the Climate changes. This could be a change in the Earth's usual temperature, or it could be a change in rainfall and snowfall. The weather can change within hours, but the climate requires hundreds or even millions of years to change. [2]

The climate of the earth is constantly changing. There were times when the climate of the Earth was warmer than it is now. There were moments that were cooler. These times can last for thousands or millions of years.People studying the Earth see the Earth's climate warming up. Over the past 100 years, there has been an increase in the average earth temperature. It's about 1 Fahrenheit degree. This may not seem very much, but small changes in Earth's temperature can have great results.Some effects are already happening. The warming of the Earth's climate has caused some snow and ice to melt. Heating has also caused an increase in the oceans. And it changed the timing of some plants growing up. [2]

Many things can cause climate change by itself. The distance of the earth from the sun can be changed. The sun can send more or less energy and the oceans can change. Most scientists believe that people can also change the climate. People drive cars, heat and cool their homes. They are cooking food. All this takes energy. One way to get energy is to burn coal, oil and gas. Burning these things puts the gases in the air. Gases cause the air to warm up. That can lead to CC of a place. It can also change the Earth's climate. [2]

The examination of the various threats to the Earth's environment must include the human impact on the planet. Catching phrases, such as carbon footprint, global warming, deforestation and other commonly used terms, have become a daily press for those who are interested in the environment [2].

The last major climate change was an ice age and the world is in the final stages of that event. The result is a rise in temperatures and the melting of glaciers and even the polar ice cap. Many respected scientists disagree that global warming is the result of human-induced infection, which can cause severe hurricanes, tsunamis, earthquakes, floods and even solar flares. This thinking school reflects earth changes as a result of the natural processes found in an evolving living planet and its sun. While the cause of global overheating remains controversial, both sides agree. It is one of the biggest environmental threats to the world as we know it. [2]

Chemical and carbonaceous pollutants are created by industry and agriculture. They have a negative impact on the ozone layer. The lack of strict enforcement of laws to prevent the use of such pollutants is in the situation. The governments of the world that continue to allow the disposal of various pollutants in the environment hinder the recovery of the ozone layer. [2]

Acid rain is created by excessive sulfur and nitric acid pumped into the atmosphere, the rivers, the oceans and the earth. While some acid rain is the by-product of the natural processes of vegetation decay and volcanic activity, the current crisis comes directly from the burning of fossil fuels. Water becomes toxic when acid rain sets off oceans or lakes with a quality of absorption that causes water to absorb soil-based aluminum and poison the aquatic and marine environment. [2]

Ocean ecosystems depend on the natural process of organic ocean matter known as phytoplankton, which is found on ocean surfaces. This eventually collapses and filters at the bottom of the ocean floor where it is further distributed by ocean flooring bacteria. This process is called bacterial respiration.When plenty of nitrogen feeds phytoplankton, like any fertilized crop, it starts to over product. Bacteria unable to cleave plankton quickly enough and chemical processes that convert carbon dioxide to oxygen cannot keep up. Oxygen is consumed faster than can be produced. Plankton drains the flow of water and oxygen so that marine and plant life die from lack of oxygen. [2]

Climate change also contributes to another dangerous problem - melting polar ice caps, which in turn causes sea levels to rise. According to the NRCD, average temperatures in the Arctic region are rising twice as fast as they are elsewhere and the ice melts and breaks down. NASA's satellite images reveal that the area of our permanent ice is shrinking at a rate of 9% per decade. At this rate, the Arctic could be completely free from ice during the summer period until the end of the century. [2]

In this thesis, we will studyand analyze threat analysis scenarios on critical infrastructures and whether they are affected by environmental threats and climate change.We will talk about the Risk Assessment (RA) procedure, about the threats and their impacts, we will study specific threats on all of the Critical Infrastructure (CI) sectors.

The structure of this thesis is as following. Chapter II, describes Risk Assessment and General Methodologies. Chapter III, describes Climate Change & Environmental Threats. Chapter IV, describes Threat Analysis Scenarios on Critical Infrastructures. Chapter V, describes the Conclusions of this thesis.

CHAPTERII: Risk Assessment

1.1 The Definition

Risk Assessment Definition

Risk assessment (RA) is to determine the qualitative or quantitative risk assessment associated with a clearly defined situation and a recognized threat (also called a risk).[3]

Quantitative risk assessment requires/demands calculations of two risk components (R). That is, the magnitude of the probable loss (L) and the probability (P) of the loss.

When we say Acceptable Risk, we mean the one that is easily understood and usually acceptable. Applying an effective countermeasure against such vulnerability (risk) may have a cost or difficulty that might exceed the loss expectation.

Environmental Risk Definition

It is the actual or potential threat of adverse effects on living organisms and the environment (from outflows, emissions, waste, depletion of resources, etc.) generated by an organization's activities. [4]

We need to embrace long-term planning and a better understanding of risk in relation to climate change (CC) is happening on the planet.The most important thing is understanding our climate and how it might change. The climate is fundamental to almost all aspects of our lives. It directly affects our ecosystems, water, food, health, infrastructure, trade and economy. [5]

The Risk Assessment (RA) process is part of a greater Risk Management (RM) process (Figure 1). RA incorporates three steps: risk identification, risk analysis and finally risk evaluation. These three steps often overlap and one does not necessarily have to be completed for the next one to begin. The actions that are involved in each step are thoroughly described in the EC guidelines. [5]

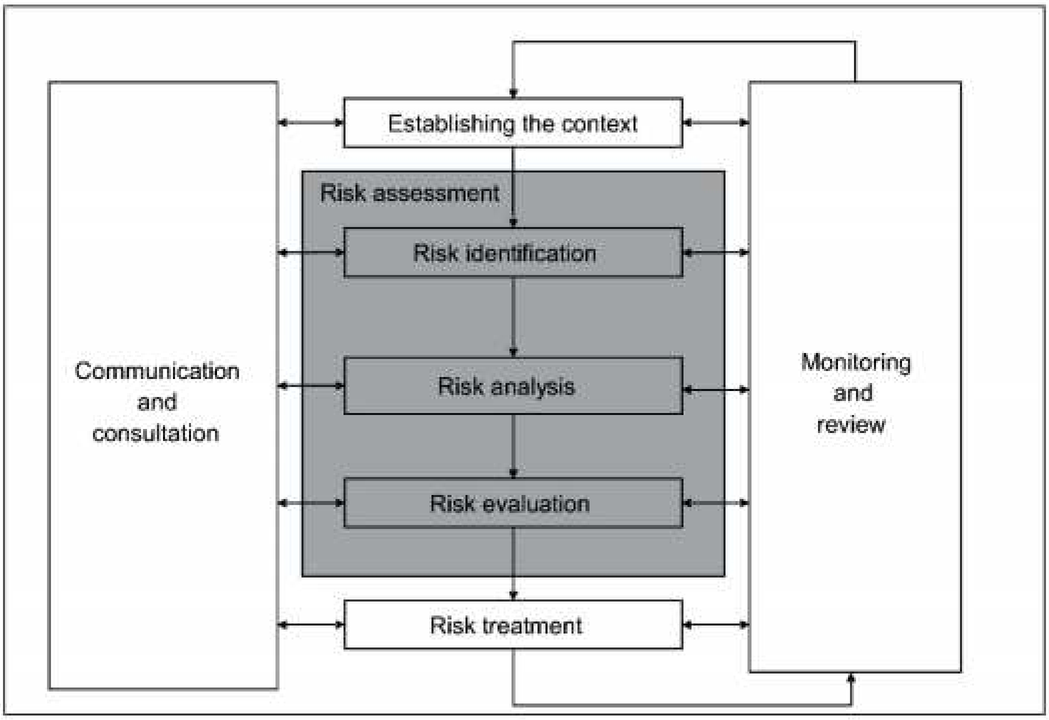

Figure 1.The Process of Risk Assessment as Part of Risk Management[6]

1.2 General Methodologies

Methodologies for conducting RA (i.e., incorporating tools and approaches to prioritize the potential impacts of climate change) can vary depending upon resources and information available. In the literature, risk assessment approaches fall into two distinct classes based on the availability of data and effort and are discussed here as the Tier 1 assessment and the Tier 2 assessment.[7, 8, 9]

1.2.1 Tier 1: Qualitative Risk Assessment / Preliminary Risk Screening

The primary elements of a preliminary risk screening, or a more detailed qualitative risk assessment include [7, 8, 9]:

- Defining the planning context including geographic parameters (e.g., highways, bridges, and tunnels by region or specific location).
- Identifying existing stressors that may be exacerbated by climate change, as well as the introduction of new stressors.

- Projecting climate-related effects including changes in climate variability and determining how these effects impact infrastructure (e.g., more asphalt rutting due to extended heat waves; more frequent/severe coastal highway inundation due to the combined effects of heavy precipitation, wind waves, and storm surge; more frequent/severe direct wind damage to exposed infrastructure due to more frequent/severe hurricanes).
- Identifying and evaluating the likelihood and consequence of climate-related impacts in order to characterize risks in the planning context.
- Characterizing uncertainty and assumptions.
- Communicating risks to stakeholders.

The risk can be determined for a given system or program and focuses on a defined set of stressors (such as climate change effects). The analysis for a given system or program can be divided into endpoints of interest such as environmental, human health, and financial where each endpoint has its own risk table. The risk product for each stressor and endpoint reflects the level of risk for policymakers. Table 1, describes a qualitative approach of assessing risk of hazardous events and describes how risk associated with an event is categorized. [7, 8, 9]

For example, an event that is very likely to occur and produce catastrophic consequences has a high level of risk associated with it (illustrated below in red). Alternatively, an event that is not likely to occur and, if it were to occur, would produce very little damage would be considered a very low risk (illustrated below in white). Ideally, the risk thresholds of the policymaker are also incorporated into the design of the evaluation. For example, an extreme climatic / weather phenomenon, such as heavy rainfall events, may be considered rare but its real impact may be very severe / significant and may justify a greater degree of associated risk from the findings of the assessment.[7, 8, 9]

Likelihood	Consequence				
	1.Catastrophic	2.Major	3.Moderate	4.Minor	5.Insignificant
A. Very likely	1A	2A	3A	4A	5A
B. Likely	1B	2B	3B	4B	5B
C. Medium	1C	2C	3C	4C	5C
D. Unlikely	1D	2D	3D	4D	5D
E. Very unlikely	1E	2E	3E	4E	5E

Table 1: Qualitative Evaluation of Likelihood and Consequence of Hazardous Events [7, 8, 9]

Characterizing Consequences

Catastrophic

Financial: Huge financial losses involving many people and/or corporations and/or local government; large long-term loss of services; permanent damage and/or loss of infrastructure service across sizeable region; high financial loss and/or environmental remediation costs; long-term impact on commercial revenue.

Health: Severe adverse human health with multiple events leading to disability or fatalities and requiring emergency response.

Environmental: Permanent loss of environmental service.

Major

Financial: Major financial losses for many individuals and/or a few corporations; some long-term impacts on services; some homes permanently lost; existing infrastructure damage or loss requiring extensive repair.

Health: Permanent physical injury and fatalities from individual event.

Environmental: Significantimpairment of environmental service; some species loss.

Moderate

Financial: High financial losses, probably for multiple owners; disruption of services for several days; widespread infrastructure damage and loss of service requiring maintenance and repair.

Health: Adverse human health; most populations affected; people displaced from their homes for several weeks.

Environmental: The impairment of environmental service.

Minor

Financial: Moderate financial losses for small number of owners; disruption of services for a day or two; localized infrastructure damage.

Health: Slight adverse human health effect; vulnerable populations affected.

Environmental: Short duration and intensity of impairment to environmental service; minimal effect on species.

Insignificant

Financial: No infrastructure damage; Minimal financial losses; short term inconvenience.

Health: No adverse human health effect or complaint.

Environmental: Minimal impact on environmental services.

The likelihood of impact and/or severity of the stressor on the system or program for each endpoint of concern can be assessed and described also according to a qualitative scale. For example, "**very likely**" may refer to an event or stressor that occurs repeatedly across multitude of regions and/or within one region but continually over time; "**likely**" may refer to an event or stressor that has occurred in a particular location more than once; and so on. For climate projections, it may be more appropriate to also include scientific literature that provides some indication of the potential magnitude of an event or stressor opposed to relying on historical observations.

A Tier 1 analysis can help ensure that climate-related stressors are included in the decision process at an early stage [10].

1.2.2 Tier 2: Quantitative Risk Assessment

Fewer examples of quantitative CC risk assessment exist. Deterministic "what if" or "worst case" scenario analyses are based on historical data without consideration of recurrence or probability. Probabilistic Risk Assessment (PRA) does attempt to associate probabilities with specific hazardous events (e.g., storm surge). In addition, some approaches attempt to place increased risks associated with the climate on existing hazards in order to assess possible changes in frequency and significance in the future. [11]

Likelihood	Likelihood of the occurrence
Virtually certain	> 99% probability
Very likely	> 90% probability
Likely	> 66% probability
About as likely as not	33 - 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Exceptionally unlikely	< 1% probability

Table 2: Probabilistic Risk Assessment of Outcome Having Occurred or Occurring in the Future Based on Quantitative Analysis or Elicitation of Expert Views. [11]

The probability terminology and the corresponding values presented in Table 2, refer to the effect rather than to climate change. These are intended to be used in a relative sense to sum up the crises of scientific understanding associated with an issue or to express the uncertainty in a finding where there is no basis for compiling more quantitative statements.

The methods or frameworks for the quantitative assessment and prioritization of hazards and the direct and indirect effects or potential losses due to climate impacts have not been clarified. However, models do exist to help understand existing natural hazards that may be exacerbated by climate change and to quantify damage-e.g., the HAZUS-MH Hurricane Wind Model is a scenario-based model that draws upon National Weather Service forecasts and enables analysis of economic and social losses from hurricane winds at the state and local levels; or, for example NOAA's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model, which is used to estimate storm surge (tsunamis) heights and wind speeds based on historical, virtualized, or predicted hurricanes [11].

In contrast to managing seismic risks, CC impacts usually involve complex interactions of multiple climate-related effects. For example, in some areas coastal flooding will become more frequent and more severe due to the confluence of rising sea levels, storm surge, and heavy precipitation events, which introduces a high degree of uncertainty and risk in judgments about specific climate-related impacts. While assessing seismic risks is a similar exercise to assessing climate-related risks in terms of uncertain timing, location, and severity of the hazard, data on seismic activity is more readily assimilated into impact analysis because the singular effect (i.e., an earthquake of a given magnitude) more directly translates into a given impact (i.e., infrastructure damage due to the earthquake) based on historical data. For these reasons, while the framework outlined above is instructive, it may not be feasible to follow precisely without thorough consideration of interacting climate-related effects, and consideration of how these effects might accelerate or otherwise change in the future. [11]

CHAPTER III: Climate Change & Environmental Threats

Life on Earth has already begun to be affected and dependent on climate change.If we do not act directly, the effects of Climate Change (CC) will be such as to threaten our world (as we know it to date) with disaster. With the awareness of all people, there is a chance to limit the damage. [13]

Critical Infrastructure (CI) or Critical National Infrastructure (CNI) is a term used by governments to describe assets that are essential for the functioning of a society and economy - the infrastructure. Most commonly associated with the term are facilities for [20]:

- electricity generation, transmission and distribution
- gas production, transport and distribution
- oil and oil products production, transport and distribution
- telecommunication
- water supply (drinking water, waste water/sewage, stemming of surface water (e.g. dikes and sluices))
- agriculture, food production and distribution
- heating (e.g. natural gas, fuel oil, district heating)
- public health (hospitals, ambulances)
- transportation systems (fuel supply, railway network, airports, harbours, inland shipping)
- financial services (banking, clearing)
- security services (police, military)

As CI is considered critical to entire society and economy their security protection and resilience need immediate improvement. Even though CI can be thought as a major national concern; their identification and classification may differentiate from country to country but the main vulnerabilities and threats are about the same. On the top; nowadays technological progress has led to automation and more and more CI systems are controlled by the so called SCADA systems. These systems are considerable subjected and vulnerable to cyber-attacks, as they are usually connected to the network.

In a broader view the threats to CI may be categorized into the bellow important main sectors:

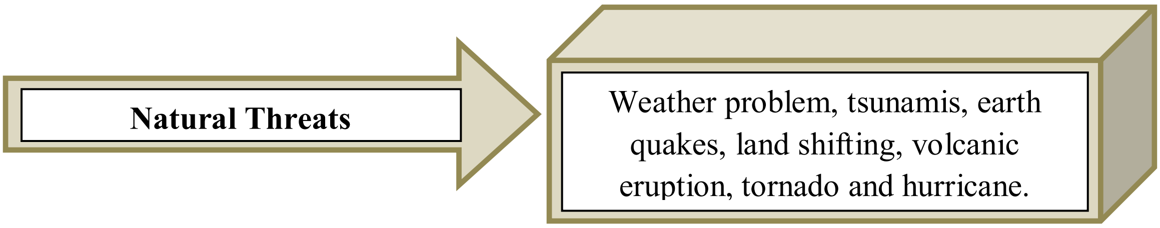

Figure 2: Natural Threats

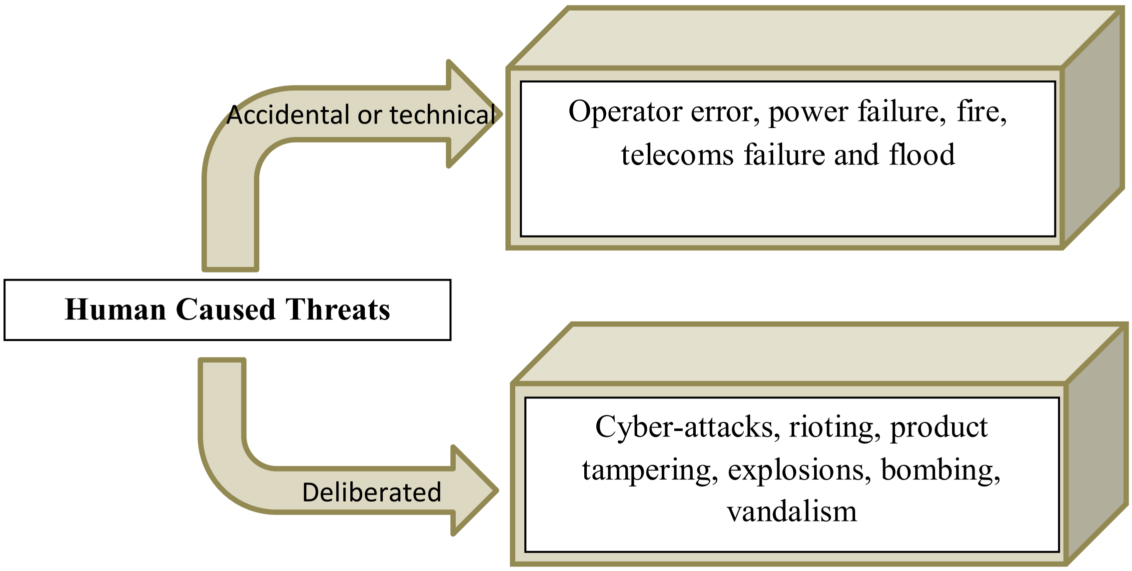

Figure 3: Human Caused Threats

2.1 The Threats

Higher Temperatures

There have never been temperatures in the past, like those recorded in the year 2015 on Earth.Is that important? Yes, indeed, because a change of even 1 degree Fahrenheit - which may sound small - can upset the delicate balance of ecosystems, and affect plants and animals that reside on earth. [13, 63]

Changing Landscapes and Wildlife Habitat

Where plants grow, temperature values and patterns of precipitation are changing. In the case of oceans, this encourages the spread of species that impact on native ocean habitat. Since the landscapes and habitats that have virtually displaced, the wildlife must adapt quickly. Experts predict that a quarter of the Earth's species will disappear by 2050 if the trend of warming continues at the current pace. [13]

Rising Seas

As ocean waters, heated, expanded, causing rising sea levels.Ice melting expands the problem by rejecting even more potable water in the oceans.Rising seas threaten flooding low-lying areas and islands, threatening dense coastal populations, eroding coasts, destroying properties and destroying ecosystems such as wetlands that protect the shores from storms. [13]

Increased Risk of Storms, Droughts, and Floods

Climate Change affects the entire planet. It intensifies droughts, storms and even floods around the world. Where it has been observed that nature was destroyed by development, communities are at risk from these intensive climatic phenomena.Scientists around the world are studying how nature can be a buffer for these intense and extreme weather patterns, and also apply solutions that can make a difference for nature and humans. [13]

Communities at Risk

For the United States of America, half of its inhabitants live 50 miles from the coast.Across the world, about 100 million people live at a distance of three feet or more from the sea.The rise in sea level associated with CC could shift many millions of people to low-lying areas - especially in developing countries.Residents of some small island countries, located just above the present sea level, already leave their islands, some of the first refugees of CC worldwide. [13]

Economic Impact

The true economic impact of CC is hard to predict.However, it is safe to say that many major economic sectors (such as fisheries, energy, utilities, etc.) will have long-range and term effects that will have arisen due to CC.From the hot seas, which encourage the spread of non-indigenous species affecting the fishing industries, to rising temperatures affecting energy consumption around the world, the CC globally will force many industries to move quickly to adapt to change.Recreation and tourism industries are also weather-dependent. Their designs are based on historical models of weather conditions, which climate change will disrupt. As we move into an era in which CC impacts are all around us, adapting to these changes quickly will be key for all sectors of the global economy. [13]

Climate Change Is a Threat to Health

CC, as strange as it may seem, is one of the greatest health threats facing humanity in the twenty-first century.As the global patterns of temperature, rainfall and weather conditions change, the delicate climate and life balance deteriorates, with severe effects on food and agriculture, on drinking water and ultimately on health. Climate impacts that affect health include potentially deadly heatwaves, deterioration in air quality, extreme storms, and the spread of insect-borne diseases in areas that have not been affected in the past. In addition, CC contributes to major world crises. For example, changes in temperature, heavy rainfall, floods, severe droughts and the rise in sea level due to melting glaciers, affect food production. In addition, we have examples where entire communities of people have been forced to leave their homes, creating "climate refugees". [14].

″In the long run climate change is a massive threat to human development and in some place, it is already undermining the international community's effort to reduce extreme poverty"

Human Development Report 2007/2008 [15].

2.2 The Threat of Climate Change

Climate disastersare rising. Of the total disasters, about 70% is related to the climate. The corresponding rate two decades ago was about 50%. [16]

These disasters are a burden on man and affect his sustainability. Over the last 10 years, 2.4 billion people have been affected by climate-related disasters. The corresponding figure for the previous decade was 1.7 billion people (we are seeing a rapid increase). In addition, between 1992 and 2008, the cost of disaster relief has increased tenfold (an equally rapid increase). [16]

Devastating precipitation, intense tropical storms, recurrent floods and droughts are likely to increase as well as the vulnerability of local communities if there is no strong coordinated action. [16]

2.3 Growing Vulnerability

Over the next twenty years, we can expect more and more acute climatological risks across the earth. Particularly high risk is encountered by those communities in areas prone to floods and cyclones and affected by drought. The effects of recurrent climate crashes exhaust their resources and make these populations dependent on external assistance. [16]

The most vulnerable are those with inadequate assets or resources and inadequate education. These people are less prepared or equipped to deal with the effects brought about by climate change. Many other factors influence individual vulnerability, such as transmitted diseases, access to public services, environmental degradation, poor housing, conflict and insecurity. [16]

CC has long-since ceased to be a scientific curiosity, and is no longer just one of many environmental and regulatory concerns. As the Secretary-General of the United Nations said, "is the main environmental issue of our time and the only major challenge faced by environmental regulators". It is a growing multi-dimensional crisis that affects economy, health, food production and security as expected. For example, abrupt changes in weather conditions that are inconsistent with the season do threaten food and crop production. Increased unpredictable rainfall threatens with sea level rise, which in turn infects coastal freshwater reserves and increases the risk of catastrophic floods. Finally, the rapid increase in temperature, helps to spread pests and diseases. [16]

From the scientific studies and observations so far, the results are extremely worrying. Ice loss from glaciers and ice sheets continues at an increasing rate. For the second consecutive year, an ice-free passage through the Arctic islands in Canada occurred and the acceleration of ice loss lost ice sheets in Greenland and Antarctica was particularly notable. The most recent global scientific evaluation has shown that the melting of ice sheets and glaciers (combined with thermal spread - the warm water occupies in volume more of the cold) throughout the world contributes to rhythms and to the ultimate extent of rising sea levels which could surpass the expectations. [16]

There are worrying signs that significant tipping points have already been reached or have already passed. If it does, it will lead to irreversible changes. The major ecosystems as well as the global climate system will be directly affected. Different ecosystems (for example, the Amazon rainforest or the Arctic Arc), affected by heat and drought may be close to the limits of dramatic change. Mountain glaciers are constantly receding, and the effects of reduced water supply in the hottest months will have an impact over generations. Climate feedback systems and cumulative environmental impacts are built on all Earth systems, demonstrating behaviors that we cannot predict. [16]

The greenhouse effect and its dynamics are now more and more relevant than ever before. The most dangerous CC can be avoided if we transform our hydrocarbon-based energy systems and start rationally and adequately funded adaptation programs to prevent disasters and migrations on unprecedented scales. The tools are available but must be implemented immediately and aggressively [16].

UN Secretary-General Ban Ki-moon and UNEP Executive Director Achim Steiner agree: Climate change is “the defining challenge of our generation” [17].

CHAPTER IV: Threat Analysis Scenarios on CI's

In general; a Critical Information Infrastructure (*CII)* refers to any physical or virtual information system that controls, processes, transmits, receives or storeselectronic information in any form and it isvital to the functioning of a Critical Infrastructure (CI) or owned or operated by or on behalf of a government. These substantial services underpin the entire society in the terms of health, security, economy, communication sectors, etc. Their incapacitation, destruction or malfunction may cause vital problems to an entire nation. The main concern is to manage the risks related to *CII* and enhance resilience and security of physical, natural and cyber *CI* infrastructures. [21],[22]

Taking into consideration the astonishingly rapid increasing dependence and interdependence on CI; their effects and at the same time the huge risks that they pose make the situation highly significant and difficult to manage.

Figure 4, depicts sectors considered as Critical Infrastructures by many nations.

Figure 4: Critical Infrastructures Main Sectors

With a closer look to the above, the energy supply as well as the communication sector may be considered as crucial and fatal since the rest of the infrastructures strongly depend on them in order to function suitably.

As a consequence, the recognition of *CII* is the first step in the Risk Assessment and Threat Analysis, protecting and in general safeguarding the confidentiality, integrity and availability of critical assets.

As CII's may be considered:

- The public telephone network
- The Internet
- The terrestrial and satellitewireless networks
- Components such as computers, software and fiber optics.

For example, the national, government and military information infrastructures depend on commercial telecommunication providers for their daily functions havingtransformed both, the information and information systems into a lucrative main target. [26]

3.1 Chemical Sector

Weather and climate change resilience are important issues for Chemical Sector (CS) for the following reasons:

- They depend on water supply, utilities and drainage infrastructure, which are vulnerable to weather events.
- Many of the plants listed in the CS, store and use significant amounts of dangerous substances. Climate change can cause big problems and damage to these facilities, with potentially serious consequences.
- CS infrastructures tend to have long lifetimes, increasing their exposure to climate risks (because of exposure to the future as well as the current climate).

- The industry is globalized. Climate change will result in a larger impact at the international level.

Many drugs require special storage (for example refrigerated storage) as they are unstable at ambient temperatures over extended periods of time. With rising temperatures and increased risk of heat wave events, some drugs stored in doctors' surgeries, retail chains or at home may lose efficacy or begin to degrade.

Availability of raw materials, and processing / production of chemical and pharmaceutical feed-stocks can be affected by a range of climate risks, including flooding and storms.

Some other chemical production processes and site management conditions are dependent on specific ambient conditions, which can be affected by the weather.
For example, extreme changes of temperature can affect processes leading to reduced performance and high winds can restrict crane lifts and working at height. [31]

Table 3, shows some example impacts in CS due to climate change:

• Lack of process water during drought causes disruption.
• Heavy rain or flooding means effluent system overloads with dilution water or other problems such as wash out of biomass. Effluent treatment plants are often gravity fed and therefore at the lowest, most vulnerable part of the site.
• High temperatures lead to poor cooling meaning that throughputs need to be limited or processes shut down if their cooling systems can't cope.
• Temperature impacts on catalytic processes leading to reduced performance.
• Maximum process relief rates are reduced due to high inlet temperatures and high flashing ratios.
• Extreme changes in temperature affect the operation of effluent treatment plant.
• Low temperatures lead to freezing of coolant lines to a chemical reaction vessel resulting in rising reaction temperature and pressure.
• Flooding compromises emergency relief systems that are designed for an atmospheric discharge pressure (not against a static head of water).
• Lack of water for fire-fighting, caused by either drought and poor availability of water, or prolonged severe cold temperature and freezing of lines.
• High winds restrict crane lifts and working at height.

• Outdoor operations may need to be restricted during severe weather.
• Flooding prevents access so that facility cannot operate properly.
• Reduced river flow means the quality of incoming water deteriorates, reduced dilution of effluent and greater pollution.
• Process contamination by flood waters leading to large quantities of liquid effluent that require treatment e.g. from oil/water separators, sumps, drains, ground stocks of products or maintenance materials.
• Change in expectations in relation to how to comply with regulation where compliance is affected by weather leading to increased costs.
• Chemical release or venting during emergency shutdown causes breach in permit conditions.
• A switch to back up fuel due to weather related disruption leads to operating outside permit conditions on a temporary basis.
• Flood causes stored materials to react with water or be contaminated.
• Flooding causes floatation of empty/part full stock tanks, product or waste containers with subsequent loss of containment.
• Evaporation rates of volatile material increase with higher temperature, placing increased demand on cooling systems.
• High costs of storing water on site for managed disposal following heavy rain, especially if containment systems overloaded.
• Lightning strike causes process disruption that could lead to loss of containment.
• Flooding prevents access by staff, customers or vehicles, compromising business continuity and the ability to keep the site in a safe condition.
• Inclement weather restricts the movement of key staff around the site.
• Severe weather including snow and ice prevent key staff travelling to/from work.

Table 3: Example Impacts in Chemical Sector due to Climate Change [31]

The CS relies heavily on utilities and the transport network (see Chapter 3.15 TSS). It is also characterized by a supply chain that has numerous interdependencies and includes many sole providers of key materials. This leaves the sector particularly vulnerable to supply chain disruption due to severe weather, leading to potential business interruption, loss of productivity or rising costs. For example, weather can disrupt in-coming and outbound deliveries due to blocked roads or difficulties at ports.

In some industries, it is possible to reduce vulnerability to disruption caused by travel difficulties or loss of access by using home or remote working. However, this option is likely to be restricted for manufacturing industries since the type of work often means that employees need to be on site.

The CS uses some plant and machinery that have long lives, meaning that they will be exposedto the future as well as the current climate. Moreover, it is characterized by some ageing infrastructure and thechallenges that brings.For example, flooding can cause erosion of foundations and pipe supports and heavy rain can cause water to collect on stock tanks roofs, possibly causing the roof to sink allowing a loss of containment of the tanks contents. [31]

Due to all above reasons, the CS and businesses need to prepare to manage short-term weather-related events that can affect sites. They should also be prepared for the risks of businesses related to long-term forecasts of climate change.

With reference, to Washington, DC: National Academies Press [32], "The chemical industry stores many chemicals at its facilities in the form of raw materials, intermediates, products, and by-products. These products and by-products are then sold to customers who store them on their sites for direct use or for the manufacture of other products. The products of interest to a terrorist are chemicals that are toxic, flammable, or explosive, or a combination thereof. This scenario has particular relevance to storage of inorganic chemicals, industrial gases, and petrochemicals and fossil fuels. Examples of inorganic chemicals that are toxic and stored in large volumes include chlorine, ammonia, and hydrogen fluoride. Industrial gases that are toxic include carbon monoxide; nitrogen and argon are asphyxiants; oxygen and hydrogen are flammable. Most petrochemical and fossil fuel products, intermediates, and by-products are flammable, while a few such as hydrogen cyanide, hydrogen sulfide, and phosgene are toxic."

Assume that terrorists attack a dedicated facility, triggering one or more explosions involving large storage containers of inorganic chemicals, petrochemicals, or fuels and other chemicals. Multiple initiating pathways could be proposed that would generate significant bone wave, pressure waves and projectile materials from the exploded storage vessels. The bone wave, pressure waves and projectiles from the explosions could further impact not only the specific facility, but also facilities beyond its boundaries. Can you imagine the consequences resulting from such an attack? How many people may be killed? How many could be injured? What would be the damage for the environment and infrastructure? [32]

Another potential cascading event is a release of toxic liquid from a storage tank into a river close to town. Materials that have a boiling point near normal atmospheric temperature—for example, monomethylamine (boiling point −6° C)—could form a toxic vapor cloud, yet remain partially liquid and flow into the above river or in nearby streams. The pressure wave and projectiles from the initiating explosion could impact storage vessels at a third facility, releasing high volumes of liquid chemicals that flow into the river or streams, the source of public drinking water and industrial water for the whole city and many downstream communities.

3.1.1Health relationship withCS

Release of a cloud of a hazardous toxic chemical would be expected to have a large, possibly catastrophic number of victims (it depends a lot at the meteorological conditions and wind directions). Many deaths or injuries may occur. If there is a leakage of hazardous chemicals that affects the water storage, a major impact would also be expected on city surrounding areas populations(see Chapter 3.12 H&PHS).

3.1.2 Government Facilities relationship with CS

Corresponding scenarios could be considered as an act of terrorism and therefore would be needed to deepen the investigation by government agencies. The government of the country, after the initial shock from the effects of the disaster, should be able to get critical and immediate decisions regarding the coordination and management of the crisis. A good coordination must take place in order to transport and care the patients. There must be also possible security measures to protect people and facilities.Government function would be more seriously impacted only if a targeted attack using chemicals on a major government facility was successful at a time that many key members of government were present(see Chapter 3.11GFS).

3.1.3 Transportation Systems relationship with CS

Greater impacts could occur as a result of cascading events following such an attack. For example, a tanker explosion that could destroy a major terminal (e.g., airport, train station, port) or other elements of the transportation infrastructure (e.g., bridges). Even so, these impacts will probably remain localized(see Chapter 3.15TSS).

In summary, table 4 presents the most significant threats to the Chemical Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X		X		X	X			

Table 4: Chemical Sector Most Important Threats

3.2 Commercial Facilities Sector

The Commercial Facilities Sector (CFS) is made up of an extremely diverse range of sites and assets where large numbers of people congregate daily to conduct business, purchase retail products, and enjoy entertaining events and accommodations. [36]
The commercial facilities all over the world attract millions of visitors per year – some even attract over a million visitors per week! With so many people visiting those facilities, there is of course huge potential for something to go wrong and a large number of challenges that can arise in relation to climate change. For example, an earthquake, flood or fire. It is therefore important that steps are taken to make these facilities safe, secure and pleasant environments for customers and visitors, as well as for the staff who work there.

Table 5, shows some example impacts in CFS due to climate change:

• The release of toxic or otherwise dangerous chemicals from chemical use or storage locations that may become inundated by rising waters.
• Flooding prevents access so that facility cannot operate properly.
• An earthquake could create panic in the world and serious damage to the building. As a result, there could be death losses.

•	Flooding prevents access by staff, customers or vehicles, compromising business continuity and the ability to keep the site in a safe condition.
•	In the event of fire, explosions may occur in facilities which in turn cause death.
•	In case the emergency exits are not free of obstacles, or are not operational, visitors may be incarcerated at the premises.

Table 5: Example Impacts in Commercial Facilities Sector due to Climate Change [36]

3.2.1 Key Sector Operating Characteristics

- Facilities and events primarily operate on the principle of open public access, meaning people may move freely through the facilities without the deterrent of highly visible security barriers. This layout can go against design security principles. Additionally, high-profile tenants, neighbors, and special events may add risks to individual assets.
- Many facilities are considered soft targets—sites that are relatively vulnerable to a terrorist attack due to their open access and limited security barriers. This makes intelligence and information sharing especially critical in recognizing and monitoring trends and thwarting attacks.
- Many facilities, such as stadiums, malls, and museums, are nationally and internationally recognized icons and have large population densities when occupied, which increases their likelihood of being targeted by adversaries. Facility attendance can act as a barometer of public confidence in national security.
- High economic significance and public safety implications result in a large national security interest in facilities that are privately owned and secured. This dynamic necessitates a strong information-sharing relationship between owners and operators and their Federal, State, and regional government intelligence partners.
- Although commercial facilities are widely dispersed, certain subsectors are concentrated in specific regions, necessitating regional security coordination between private and government partners.
- Given CFS's significant impact on the economy, reestablishing the sector's assets after a disaster is required to secure local and State financial security.

[36]

3.2.2 CFS Interdependencies with other sectors

There are increasing interdependencies between sectors. Cities and regions increasingly rely on complex networks of interconnected infrastructure that comprise and are operated by integrated physical and cyber systems. After a disaster, a failure in one system - such as in the Water or Energy Sectors, on which the CFS relies strongly - could cascade and greatly affect the regions they serve.

Increasingly severe weather events, including storms, earthquakes, floods, and droughts, can cause significant property and economic damage, threaten safety of employees and guests, and restrict access to critical resources such as power, water, transportation, and food supplies.

Without energy, communications, and potable water, the CFS would not be able to sustain operations. Transportation systems allow employees and customers to travel to and from facilities and enable facilities to receive products and supplies. The CFS partners regularly with Emergency Services personnel to mitigate risk, and the ESS responds to disasters that occur at facilities. Healthcare partners provide services to the public after an event, including a large-scale outbreak of an illness. The CFS relies on financial services to conduct daily business operations, and the FSS needs the CFS for its facilities. Government facilities sometimes reside within CFS properties as tenants or adjacent to commercial facilities. This affects the risk of the CFS and GFS, which collaborate to address security challenges, and could impact continuity of government operations and timely recovery from events. The CFS depends on the F&AS for food and beverages served at commercial facilities. [36]

Figure 5, depicts CFS Interdependencies with other sectors.

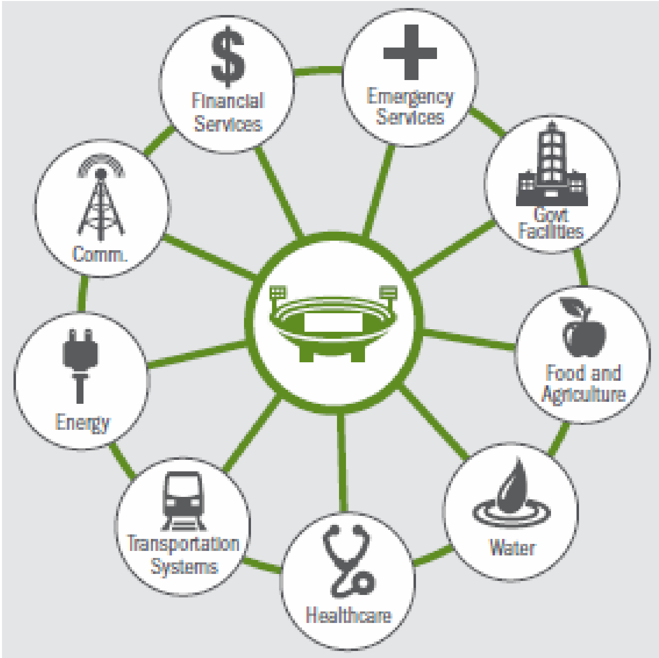

Figure 5: Commercial Facilities Sector Interdependencies with Other Sectors [36]

Energy Sector

Provides power, which supports critical facility functions, such as lighting, water pumping, and HVAC systems. This is the primary dependency for the CFS. Without power, many facilities could not function for an extended period of time, as access to backup power is often limited in scope. An interruption to the power supply would directly affect all facilities located in the region serviced and could have cascading effects on other sectors that are dependent on goods provided by the affected commercial facilities(see Chapter 3.8ES). [36]

Water and Wastewater Systems Sector

Provides a supply of potable water and handles the treatment of wastewater produced by the public. The sector also provides water for fire suppression systems. Without these services, State or local health departments might shut down commercial facilities until services are restored(see Chapter 3.16W&WSS).[36]

EmergencyServices Sector

Saves lives and protects property after incidents, such as accidents, natural disasters, or terrorist attacks. The CFS coordinates with Emergency Services—which includes law enforcement, fire and emergency services, and emergency medical services—to mitigate risk and respond to incidents. A disruption would affect the CFS's disaster response and prevention capabilities. Emergency Services also manages crisis reentry for affected areas, which is a critical issue for CFS owners and operators trying to gain access to their facilities.[36]

One emergency situation that may occur in a Commercial Facility (CF) include fire starting. Thankfully there are relatively few major incidents involving fires caused from climate change in CF because of the use of sprinklers and fire alarms. However, in case of such an event, a lot of damage can be caused and the people will be in panic.

At night, a security presence can be watchful and vigilant for any potential fires starting and take action before they get out of hand. During the day, when the facilities are full of people, a security presence can ensure that evacuation procedures are carried out calmly, safely and correctly. If a fire does start anywhere, they can contact the emergency services and liaise with them to provide them with the help and information they need to face the fire and keep customers, visitors and staff safe(see Chapter 3.7ESS).

Communications Sector

Provides telecommunications access and enables operations.Damage to the CS would affect the CFS's ability to operate and could cause cascading economic damages as employees and customers may have difficulty communicating with the sector. Disruption to critical communications operations in facilities, such as stadiums or casinos, may hamper the sector's ability to respond to incidents(see Chapter 3.3CS). [36]

Transportation Systems Sector

Provides the transportation of goods to and from commercial facilities, as well as the transportation of employees and customers during regular operations and after disasters. A disruption in the TSS could prevent employees or customers from reaching commercial facilities, or keep them from being able to leave facilities after an incident. A disruption could also keep goods and supplies from leaving or reaching the CFS. The CFS also needs to be able to gain access to areas after disasters to distribute resources to and reopen facilities(see Chapter 3.15TSS).[36]

Information Technology Sector

Enables day-to-day operations and financial transactions.Loss of function would affect the sector's ability to operate, both for physical systems that have been automated and cyber systems(see Chapter 3.13ITS).[36]

Healthcare& Public Health Sector

Provides services to the publicin the event of an attack, natural disaster, or pandemic/large-scale outbreak of an illness. Pandemics can spread easily through CF facilities as large groups of people congregate daily in CF facilities. Healthcare services are essential in the event of a disaster(see Chapter 3.12H&PHS).[36]

Financial Services Sector

Provides essential servicesfor the CFS to conduct daily business operations and emergency response, and is dependent on the CFS for business facilities. During disasters, CF facilities may house ATM and banking resources that the public will need to access during incidents(see Chapter 3.9FSS).[36]

Government Facilities Sector

Resides within CFS properties as tenants or adjacent to commercial facilities. This affects the risk of both sectors, which collaborate to address security challenges(see Chapter 3.11GFS).[36]

Food& Agriculture Sector

Provides food and beverages served and sold in commercial facilities.Many commercial facilities rely on restaurants located in their facilities (e.g., restaurants in malls and shopping districts), and fairs and festivals often feature special types of food and beverages. The CFS and F&AS have also collaborated on food defense issues, such as the threat of malicious actors intentionally contaminating food products at commercial facilities(see Chapter 3.10F&AS). [36]

In summary, table6 presents the most significant threats to the Commercial Facilities Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X	X		X				X	

Table 6: Commercial Facilities Sector Most Important Threats

3.3 Communications Sector

Information and Communications Technologies (ICT) infrastructure is sensitive to climate effects in a number of ways. These falls into two classes: fast acting direct issues such as floods which may impact on local exchanges and overhead lines; slow acting direct issues. The infrastructure is also sensitive due to interdependencies. [37]

Table7, shows some of the main issues:

• High winds can affect telephone poles, causing problems as previously '1 in 150 years' events may become more frequent.
• The occurrence of extreme events (in the short-term) or temperature increases (in the long-term) can affect infrastructure such as data centers (e.g. causing operational and service disruptions, infrastructure damages, increase in operational costs), thus weakening the sector's robustness. Considering the increasing role of data centers in the global networked economy, these disruptions can have wider effects across multiple sectors.
• Change in rain density may cause attenuation of mobile phone signals.
• Extreme events can limit the access of industry workers to conduct repairs or restore operations, affecting the rapidity of the sector's response to climatic shocks (i.e. the speed at which assets are accessed or mobilized).
• Ground heave could affect buried cables.
• Changes in wind speed or direction could have implications for the launching and stability of high altitude communications platforms.
• Severe weather events can disrupt the international shipment of ICT components and materials in affected areas, contributing to undermine the scale at which the sectors" supply chain operates, and potentially, its ability to maintain its performance (i.e. robustness).
• Wireless transmissions can be affected by temperature increases (e.g. reduced signal range), by precipitation (e.g. weakened quality and reliability of the service), and by changes in the physical environment (e.g. building construction, foliage density), which can affect the sectors" redundancy (i.e.substitutability of functions and services in the event of climatic disruptions).

• Changes in vegetation density or building design (e.g. silvered windows) could disrupt wireless communication.
• Humidity could increase tropospheric scintillation and interference.
• Physical resources such as rare earth metals, which are essential components in much ICT equipment, are expected to become increasingly scarce, which may constrain the development and deployment of responses to climate change threats.
• Solar storms have a potential impact on satellite communications, though these are not a consequence of climate change.
• Severe weather causes loss of utilities (e.g. power, communications, steam, compressed gasses).
• Costs/ operational difficulties caused by underground pipelines being damaged due to expansion.
• Electrical storm causes power surge taking out power supplies, control systems and communications systems.
• Climate change impacts can also accelerate the rate of technology change and innovation in the sector in order to tackle consumer and market niches that were not available before (e.g. development of new devices and applications), contributing to the sector's flexibility and diversity (i.e. ability to undertakedifferent courses of action, innovate and benefit from emerging opportunities).

Table 7: Climate Effects in Communications Sector [37, 38]

The Communications Sector (CommS) can both facilitate and be affected by different behavior patterns, which may be prompted or exacerbated by climate changes. It is important to track the impact of social change on networks to understand how the distribution of demand is shifting – e.g., increasing numbers of homeworkers may affect where and when networks experience the heaviest burdens. [37]

Figure 6, depicts potential CC impacts and effects on the CommS.

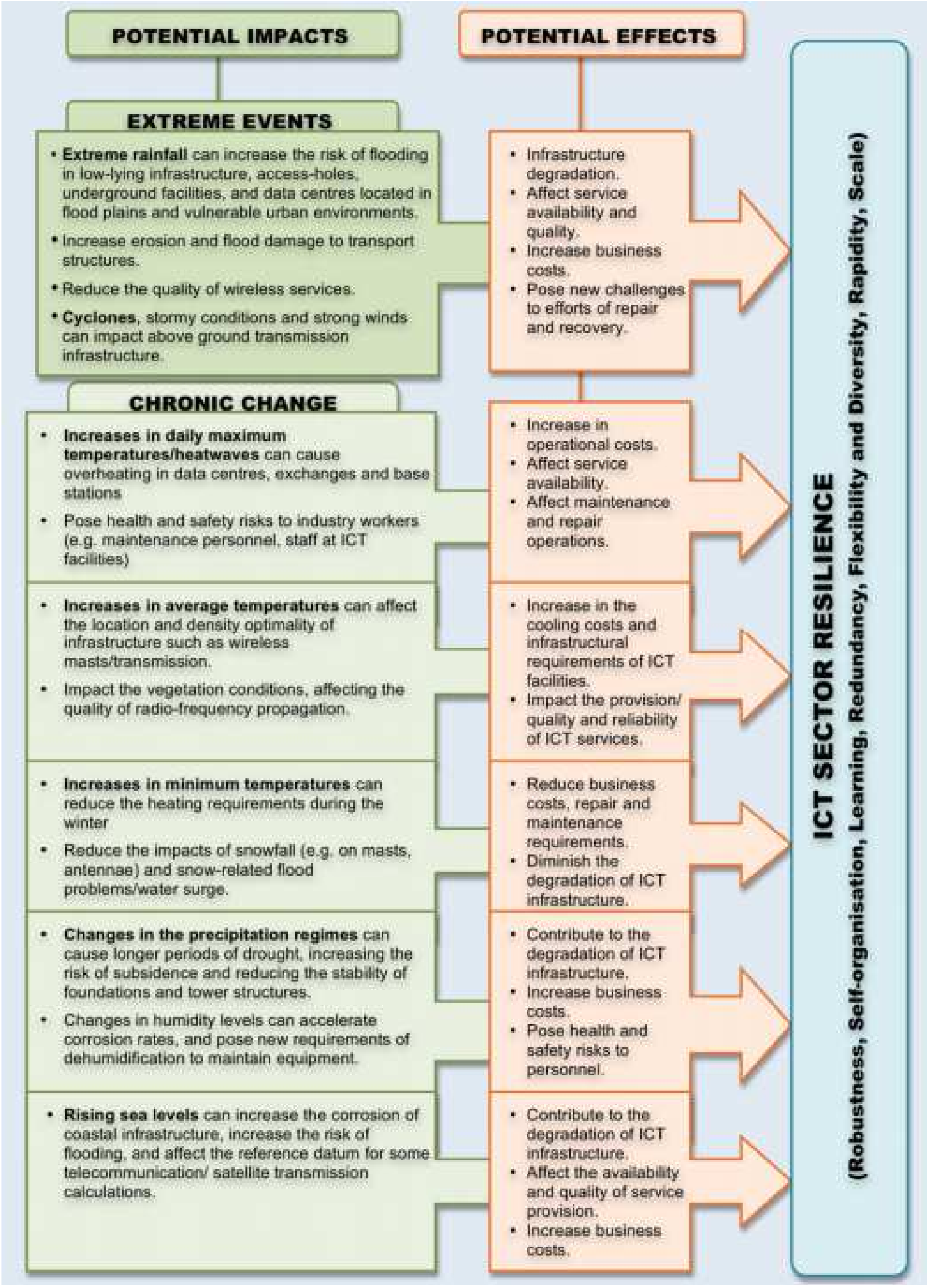

Figure 6: Potential Climate ChangeImpacts and Effects on the Communications Sector [39]

ICT infrastructure could share groundworks with other infrastructure, e.g. running cables through water pipes, though this would render them vulnerable to the same threats (e.g. ground heave). Bridges carry communications infrastructure, which is vulnerable to damage when bridges are damaged. [37]

There is a distinction between public ICT, such as cable infrastructure, and privately-owned ICT, such as dedicated data centers. The responsibility for addressing climate impacts will therefore in some cases fall to the customer or end-user, rather than the public infrastructure provider. [39]

Buildings

The ICT sector, as any other, will need to deal with the general range of climate risks to the built environment, managing a heritage of built assets which were not properly designed (or located) with any consideration of climate change. An additional challenge for ICT is that in only a few cases are the buildings in use actually purpose-built: the sector is already managing buildings that were not designed having in mind their current purposes. For example, some Data Centers are housed in old buildings; many mobile telecommunications masts are mounted on long-established buildings (such as churches).Thus, in some cases, there may already be significant expenditure on retrofitting and maintaining buildings for current uses. Additionally, there is a chance due to the increasingly demands of climate change, to become too costly for the company, forcing relocation perhaps. [39]

Data Centers

A data center is a facility used to install banks of computers “servers” on which may be stored both “applications” (programs that do things) and “data” (information used in those applications). These centers may be owned by and dedicated to a particular organization(e.g., Amazon or Google) or may be “shared”, hosting applications and data for a number of separate users.The commercial imperative that drives the ICT sector coupled to continuing development of applications and utilization is leading to the commoditization of a number of aspects of ICT, and the response is growth in the number of data centers, outsourced services, call-centers and, most recently the emergence of “cloud computing”, in which both data and applications are run across the internet, remote from the user. All these developments mean that the operation of the system relies absolutely on the availability of power and continuous data connectivity. This imparts significant vulnerability to the whole ICT system which is primarily connected with the physical location of the data centers and call centers.

These locations have the same vulnerability to climate change as any other above ground structure but have particular requirements which have to be considered. Their power consumption is massive both for operating the equipment and for cooling it and they tend to cluster around internet "points of presence", i.e. they are co-located with high bandwidth, direct access to the web, increasing demand on the cabled (copper and fiber-optic) infrastructure. This clustering effect also causes a clustering of skills and expertise.

The economic and social impact of the failure of a data center is potentially very high particularly as they carry much of the “e-commerce” and “EDI” traffic which enables the economy to function – including the collection of revenues and payment of benefits by government, which is increasingly handled through these locations. For example, a specific data center that hosts servers for a company providing residential care to elderly and vulnerable adults. Information held at the center may include full personal and contact information, treatment protocols, policies and procedures, patient records and treatment plans. If this data center were to fail, or to become inaccessible via the ICT networks, the safety and well-being of these people could be compromised. [39]

Wireless transmission

Wireless continues to grow as an applied technology offering advantages in speed and cost of deployment, though currently not providing data transmission speeds equivalent to wired connections. Wireless is though subject to a different set of climate change impacts and can be affected by climate change in a number of ways:

- Temperature increases impact the range over which wireless signals can be sent and received. Rising extreme temperatures will impact range.
- Precipitation (rate of rainfall and size of raindrop) adversely affects quality of service (the reliability of the wireless receivers at capturing complete transmissions).
- The physical environment, e.g. density of foliage, the shape and construction methods of buildings, all have a significant impact. As buildings are developed and adapted to cope with the demands of climate change it will be necessary to ensure that wireless transmission continues to be possible. It is already the case that metal foils used in the structure of modern buildings as part of insulation are inhibiting mobile phone signals.

Most climate impacts are seasonal in nature. This can mean that climate change brings negative impacts in summer, but some positive effects in winter (or vice versa). An example would be the greater challenge of dealing with more very hot days during summer, but an anticipated reduction in the extent of cold winter maintenance. However, because of climate variability, it is important to recognize that occasional cold weather extremes are expected to occur, albeit with less frequency. This may, in practice, make it more difficult for telecommunications providers to respond to the cold weather impacts when they do occur, since the relevant skills and experience of similar events may be reduced over time. [39]

3.3.1 Energy relationship with Communications Sector

The CommS is absolutely reliant on the continuing availability of electricity. Currently mobile and fixed network distribution and exchange points have only one hour battery backup. This makes ICT vulnerable in 'cascade' events, e.g. flooding could affect power supply thus making mobile networks vulnerable, and this could have an effect on broadcasting. Severe weather may make it difficult for engineers to reach fault locations. Over the next 100 years the ICT infrastructure is likely to become more complex and more comprehensively networked, making it more difficult to diagnose and repair faults. It will also become more interdependent with the energy infrastructure; the development of smart meters and smart grids will mean that the power networks will rely on CommS to function adequately. ICT, particularly the trend towards 'cloud computing', enables more homework, meaning less strain on the transport network, but with increased data traffic volumes. Net effects on carbon emissions are unknown; effects on population distribution and water and power use in the home are also unknown but could be significant(see Chapter 3.8 ES). [37]

3.3.2 Transportation Systems relationship with Communications Sector

Transport and travel systems are increasingly reliant upon navigation and control systems operated through ICT, whether that be satellite links, locating beacons, radar, lighthouses, instrument landing and take-off systems for aircraft and airports, satellite-navigation of road vehicles or integrated control systems on rail vehicles. Whilst all might operate in emergency by reversion to local manual control systems, the efficiency of performance would be significantly reduced and safety may be compromised, leading rapidly to a major problem on an infrastructure sector which can be considered close to capacity under "business as usual" conditions(see Chapter 3.15TSS). [39]

In summary, table8 presents the most significant threats to the Communications Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X					X	X	X	

Table 8: Communications Sector Most Important Threats

3.4. Critical Manufacturing Sector

The Critical Manufacturing Sector (CMS) processes raw materials and produces highly specialized parts and equipment that are essential to primary operations in several industries; particularly transportation, defense, electricity, and major construction. [40]

Increasingly extreme weather events and natural disasters caused by global CC, increase the vulnerability of facilities and employees in certain geographic regions. Yet the sector's assets, suppliers, and customers are dispersed globally, making operations susceptible to natural disasters across the globe that can trigger cascading disruptions in affected supply chains. Disasters can also interrupt critical Energy, Water, and Transportation Systems Sector services and cause delays or manufacturing shutdowns. [40]

Table9, shows some of the main issues:

• Severe weather or flooding damages buildings fabric leading to disruption, repair and maintenance costs.
• Flooding or drought causes erosion of foundations and pipe supports.
• Snow and ice loading on tank roofs leads to loss of containment.
• Following heavy rain, water collects on tank roofs causing collapse and loss of containment.

• Extreme weather or flooding causes mechanical damage to process equipment, particularly equipment running hot subject to sudden thermal stress when inundated with water.
• Flooding causes equipment or machinery to be made unserviceable. For example, electrical equipment, switchgear, cabling, rotating mechanical equipment, control equipment and effluent treatment plants (because the biomass has been washed out).
• Bunds cracked by 'heave' from freezing ground.
• Water and other 'wet' lines freeze, leading to flanges, valve bonnets and other joints failing. This can lead to loss of boiler feed water lines, frozen cooling towers and frozen sprinkler systems.
• Repaired burst joints refreezing before effective lagging could be applied.
• Pneumatic control systems failing because instrument air is not dry enough.
• Lightning causes fire due to direct action or provision of an ignition source.
• Heavy rain overloads inlet air filters and causes damage to downstream equipment.
• Heavy rain causes water to collect on stock tanks roofs. For floating roof tanks this could possibly cause the roof to sink allowing a loss of containment of the tanks contents.
• High winds cause structural damage to process plant.
• High winds cause problems with floating roof tanks, partially lifting the roof and causing it to stick or at worst sink.
• Freezing weather leads to burst pipes or failures of primary containment including potentially simultaneous failure of multiple layers of protection.
• Loss of containment due to direct lightning strikes.
• Pipeline damage by cold weather, hot weather or subsidence.
• Electrical storm causes buildup of static in insulated objects.
• High winds blow site litter or contaminated debris off-site.
• Flooding, heavy rain or drought causes landslide, subsidence.

Table 9: Climate Effects in Critical Manufacturing Sector [31]

3.4.1CMS Interdependencies with other sectors

CMS operations are closely integrated with other critical sector services, which creates interdependencies that can cause a disruption in one sector to affect operations in another. Local disasters can cascade to multiple jurisdictions and sectors, triggering damage across larger geographic areas. Limited visibility into growing risks faced by interdependent sectors may subject manufacturers to "hidden risks" - spillover risks from other sectors that CMS owners and operators cannot adequately anticipate or manage.

The National Infrastructure Protection Plan(NIPP) 2013 identifies lifeline functions - energy, water, communications, and transportation systems - as services and resources that are essential to the operations of most CI partners and communities. Identifying lifeline functions, specifically those that are interdependent with other sectors, can help owners and operators prepare for and mitigate the loss of these services in an emergency. In the CMS, transportation systems provide lifeline functions and are also essential to the supply chain. Although the CMS may be interdependent in some way with all 16 critical infrastructure sectors, its most significant sector interdependencies include:

Figure 7, depicts CMS Interdependencies with other sectors.

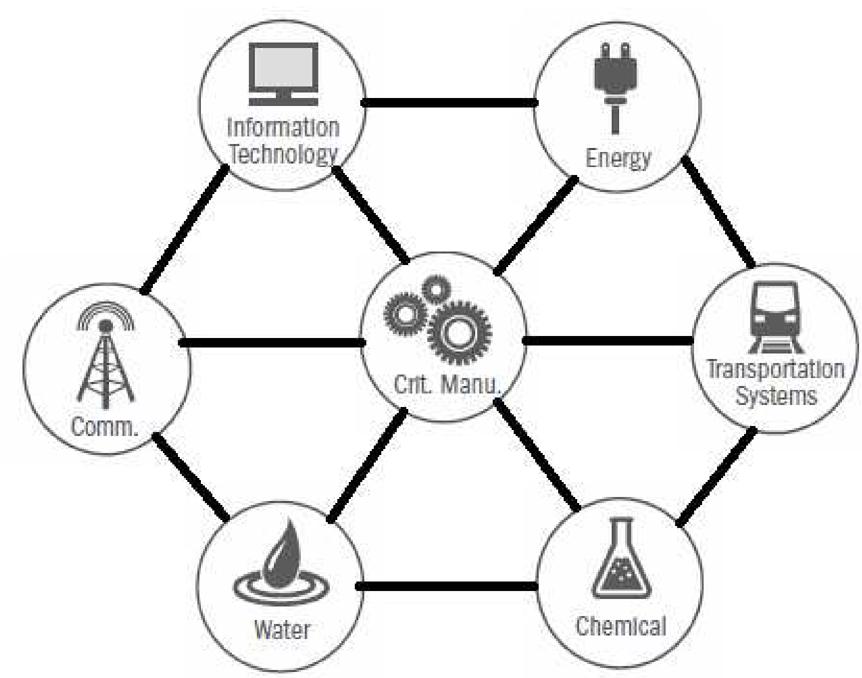

Figure 7: Critical Manufacturing Sector Interdependencies with Other Sectors [40]

Energy Sector

Manufacturers require large amounts of uninterrupted power for operations. Although backup generation provides power needed to operate during short-term disruptions to safely shutdown a facility, a long-term outage would significantly disrupt operations (see Chapter 3.8 ES). [40]

Water and Wastewater Systems Sector

In some cases, continuous water sources are essential for manufacturing processes. Manufacturers may have alternate sources of water available for short-term service interruptions, but a long-term outage could result in a significant shutdown (see Chapter 3.16W&WSS).[40]

Communications Sector

Communications networks underpin the coordination of supply chain movements and control system processes. Owners and operators rely on the Communications Sector for telecommunications access for operations and logistics. The CMS also relies on Communications Sector services for emergency notification and response (see Chapter 3.3CS). [40]

Transportation Systems Sector

The TSS - also a lifeline function - enables the global movement of large and specialized materials and products on strict time lines. Manufacturers depend on multiple modes of transportation (aviation, freight rail, highway, and maritime) for the secure movement of raw materials and finished products - key components of their operations. The sector is at risk of piracy of shipping vessels, limited availability of rail lines due to increased overseas demand, potential labor disputes, and ports operating at maximum capacity. Major disruptions to transportation networks can overload other modes of transport as manufacturers seek alternatives to continue operations (see Chapter 3.15TSS).[40]

Information Technology Sector

CMS facilities rely heavily on information technology for their manufacturing operations, global transit, quality control systems, critical processes, and facility security. An information technology disruption in the CMS would affect both production and distribution of sector products. As cyberattacks increase, manufacturers are also concerned about intellectual property theft and control system process disruption (see Chapter 3.13ITS).[40]

Chemical Sector

A consistent supply of a range of chemicals is required in multiple manufacturing sector processes. A disruption or delay in the chemical supply could create a cascading effect on production in the CMS (see Chapter 3.1CS).[40]

In summary, table10 presents the most significant threats to the Critical Manufacturing Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X				X	X	X		

Table 10: Critical Manufacturing Sector Most Important Threats

3.5 Dams Sector

A huge construction, for example a dam, is considered to be an "installation containing dangerous forces". The reason for that, is the massive possible impact on the civilian population and the environment in case of an unexpected accident.

Dams function is more susceptible to climatic impacts, with notable vulnerability to drought periods. Key climate related issues include: Water supply. Various adaptations can be required to increase pumped license capacity as demand levels can be increased. Various sources are now used for pumped refill, and during times of drought stress the operators tend to have to rely on more turbid, poorer water quality sources.
Small 'bankside' storage facilities can be particularly vulnerable to silt build-up, which can quickly reduce the effective storage within the reservoir if source turbidity increases, as much of the lower volumes of stored water will become unsuitable to filter/clarifier arrangements.[30]

High winds and waves are another potential problem that could affect dams.For example, if increased drawdown results from changes in operating regime and water levels in response to drought and demand, then this can lead to increased exposure of vulnerable areas around the face or abutments which can be affected by wind erosion. Similarly, drought stress or new pests could weaken trees that are growing on downstream embankments and hence considerably increase the risk and damage that is caused when a high wind event does occur.[30]

The ecological risk has also huge importance. The number of water sources and the multiple destinations for water from the reservoir, means that the site is potentially very vulnerable to invasive species and parasites, which may become an issue as CC occurs. Part of the function of the reservoir is to supply other reservoirs, and this could be curtailed if transfers started to pose an unacceptable ecological risk.Although the dam systems have historically proven relatively resilient to drought periods, and there is some facility for pumping between pools when inflows are low. The pools themselves only tend to drawdown very slowly, almost entirely as a response to evaporation, and fill reasonably quickly following rains. However, drought patterns are important, and the reliance on surface runoff means that extended periods of absolutely dry weather can risk water levels. Importantly, inflows of water act to cool temperatures within the pools, which are a critical aspect of water quality for fishery. Fish distress is therefore likely to increase during extended drought periods.[30]

Jointing materials used in dams are also very important. It was noted that the pitching itself is not directly vulnerable to climate change, but that some types of jointing might be. Polysulphide jointing materials can suffer shrinkage which can allow wave damage, and this could be exacerbated by exposure following low rainfall and hot temperatures during heatwaves. Open stone asphalt has proved to be a useful material to address slope pitch issues, however very hot temperatures over prolonged periods could cause this to run or flex, resulting in variable cover and weak spots on the wave protection.Low rainfall and high temperature during summer are likely to cause persistent and fluctuating low water levels as the water balance for the reservoir changes, which could exacerbate the deterioration of the base of the formal pitching.[30]

The poor, sandy nature of soils and steep slopes in the catchment mean that erosional degradation is likely to increase, both due to more intense winter rainfall and summer heat stress damaging the upland catchment vegetation. Increased frequency of operation of the spillway due to high winter rainfall is likely to worsen the downstream erosional problems. Additional winter rainfall on the crest road is likely to worsen the existing drainage problems.[30]

What if flooding becomes more frequent? Will the structures be able to cope in their current form?
The main risk relates to piping and leakage around structures(see Chapter 3.16W&WSS), and there may be a risk that reactive maintenance will become too onerous or even impossible during winters where the flood retention areas are filled for numerous, prolonged periods. This situation could be made worse if dry summers and wet winters lead to cyclical seasonal desiccation followed by prolonged wetting under flood conditions.[30]

Dams are generally very resilient to climate related impacts. Especially if they are built in sheltered locations and well shaded by trees. The nature of the construction means that they are not prone to problems such as desiccation. Risks from CC depend heavily on the maintenance regime that exists at the dam, some of which is relatively informal and depends on the current use of the facility. [30]

The crest of a dam has to be considered also. There might be phenomena overtopping during high winds or storm events.

In order to reduce vulnerability of uprooting, trees on the downstream face of the dams must be cut back to reduce height. Trees, either on the face or in catchments where tree fall could cause blockage of the spillway, could be a concern, particularly if heat, drought stress or new pests or diseases weakened large trees prior to a major autumn storm event. Tree growth is not currently a problem as it is well managed and trees are generally healthy. However, there are large numbers of trees present on the downstream face of both dams and there is a risk of damage during storms if the maintenance regime changes and heat stress or introduced diseases affect the tree population. This type of issue may need to be considered on a periodic basis by the Supervising and Inspecting Engineers. [30]

Table 11, shows some example impacts in CFS due to climate change:

• Flooding prevents access so that facility cannot operate properly.
• Extended periods of absolutely dry weather can risk water levels.
• Increased drawdown results from changes in operating regime and water levels in response to drought and demand, could lead to increased exposure of vulnerable areas around the face or abutments which can be affected by wind erosion.
• Drought stress or new pests could weaken trees that are growing on downstream embankments and hence considerably increase the risk and damage that is caused when a high wind event does occur.
• Fish distress is therefore likely to increase during extended drought periods.
• Very hot temperatures over prolonged periods could cause this to run or flex, resulting in variable cover and weak spots on the wave protection.
• Low rainfall and high temperature during summer are likely to cause persistent and fluctuating low water levels as the water balance for the reservoir changes, which could exacerbate the deterioration of the base of the formal pitching.
• Increased frequency of operation of the spillway due to high winter rainfall is likely to worsen the downstream erosional problems.
• Winter rainfall on the crest road is likely to worsen the existing drainage problems.
• There might be phenomena overtopping the crest of a dam during high winds or storm events.
• Trees, either on the face or in catchments where tree fall could cause blockage of the spillway, could be a concern, particularly if heat, drought stress or new pests or diseases weakened large trees prior to a major autumn storm event.

Table 11: Example Impacts in Dams Sector due to Climate Change [30]

The key point in relation to form is that the system is effectively managed based on an existing regime that includes current patterns and frequencies of flood storage and land and water management practices that have grown up around current climatic conditions. The stakeholders manage the land in response to a fairly well-known pattern of inundation and land availability, and this local knowledge is vital to maintaining the flood management infrastructure. The biggest risk is therefore that climate change will disrupt patterns of inundation and land use and hence disrupt the non-statutory stakeholders and management processes that are in place. [30]

In summary, table12 presents the most significant threats to the Dams Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X	X	X			X			

Table 12: Dams Sector Most Important Threats

3.6 Defense Industrial Base Sector

The term defense industrial base (or DIB), also known as the defense industrial and technological base, is used in political science to refer to a government's industrial assets that are of direct or indirect importance for the production of equipment for a country's armed forces. It is loosely associated with realism, which views the state as the preponderant guarantor of security, and frequently features as an element of grand strategy and defense policy, as well as diplomacy. [41]

The primary purpose of military forces is to maintain peace and national security. In this context, ‘peace’ means not just the absence of war, but the maintenance of stable conditions that provide at minimum for people’s basic needs. In this respect, CC is a growing worldwide threat to general peace andsecurity, and as such will become an issue of increasing significance for the military. CC is best understood as a ‘threat multiplier’, exacerbating existing pressures as well as presenting new challenges to security. [43]

The overarching impact of climate change on the security environment stems from the additional challenges that states will face in meeting the basic human needs of a growing world population. These needs include food, shelter, cleanwater, and safety. In some parts of the world, food and water resources are already threatened by CC, and this trend is projected to increase (see Chapter 3.10 F&AS, and Chapter 3.16 W&WSS). Disease, damage to infrastructure from natural disasters, and flooding and storm surges resulting from sea-level rise are additional threats for large numbers of people (see Chapter 3.4 CMS, and Chapter 3.12 H&PHS). The human-related impacts of climate change – including rising temperatures, changes in precipitation patterns, reductions in snow and ice cover, sea-level rise, falling crop yields and destructive extreme weather events – have the potential to overwhelm the ability of societies to respond,particularly in more fragile or less developed countries. Many states view current and anticipated climate change as contributing to geopolitical concerns. [43]

CC also has the potential to increase rivalry over access to resources in particular regions, including the Arctic and trans-boundary river basins. The combined impacts of resource scarcity, mass migrations and weakened governments are likely to increase potential for armed conflict between states seeking to safeguard or acquire vital resources, and betweenpopulations within states. Security breakdowns and conflict generally emerge from the interactions of multiple factors. CC indirectly increases the risk of violent conflict in the forms of civil war, inter-group violence and violent protests, by exacerbating well-established drivers of these conflicts such as economic and political shocks. Poorly designed adaptation and mitigationstrategies can also increase the risk of violent conflict. [43]

Armed forces globally will need to adapt to the changing environment and consider CC impacts on infrastructure and military installations. They are also likely to be affected by global requirements to change energytechnologies and reduce their own GHG emissions. [43]

Table13, shows some of the main impacts and risks:

• Extreme weather and sea-level rise could result in mass migrations, the spread of disease, food and water insecurity, and the need for major military humanitarian support.
• Climate-related security threats are unevenly distributed. Risk is greatest in countries with weak or failing governments and/or with existing conflict.
• Changes in geography and freshwater availability may increase rivalry over access to resources.
• Impacts on defense infrastructure will necessitate changes in logistics and operations.

Table 13: Impacts and Risks in Defense Industrial Base Sector [43]

3.6.1 Key Sector Findings

According to the Fifth Assessment Report from the Intergovernmental Panel on CC (IPCC) [43], the key findings are the following:

- CC poses an increasing threat to peace and security in the world. Its impacts can undermine livelihoods, increase involuntary migration, and reduce the ability of states to provide security.
- CC acts as a 'threat multiplier', amplifying existing vulnerabilities among populations and existing threats to security, and can indirectly increase risks of violent conflict. The risks are highest in countries with weak or failing governments and/or with existing conflict. Climate impacts are likely to disproportionately affect these more vulnerable societies.
- Societies' responses to climate impacts may exceed the global or regional capacity to manage those responses peacefully. Issues of most concern include populations displaced by extreme weather or sea-level rise, the spread of infectious disease, and lack of food and water. The need for major humanitarian support is likely to increase (see Chapter 3.10 F&AS, Chapter 3.12 H&PHS, and Chapter 3.16 W&WSS).
- CC will bring new challenges to states' ability to share resources and provide human security. Changing resource availability may increase rivalry between states, while sea-level rise could raise disputes over national boundaries. Accordingly, climate change will increasingly shape national security policies. Further erosion of security can be mitigated by the presence of robust institutions.
- Military forces will be directly affected by climate change. Sea-level rise and other climate impacts will directly affect facilities, requiring a response. As major fossil fuel users, military forces may have to reduce their greenhouse gas (GHG) emissions.

CC poses a threat to current and future human security. Failures in human security almost never have a single cause, but instead emerge from the interaction of multiple factors. CC is set to pose an increasingly important threat by undermining livelihoods, compromising culture and identity, increasing mass migrations and challenging the ability of states to provide the conditions necessary for a stable society.Tensions arising from CC effects on human security can have implications for national security. There is strong overlap between governments and the defense sector, because as well as protecting national security, the military is often deployed for support in conflict or humanitarian crises (see Chapter 3.11 GFS). [43]

Some climate-related impacts are already being observed, such as changes in agricultural output and increases in coastal flooding. People living in places affected by conflict are particularly vulnerable to climate change.

3.6.2 The Role of Department of Defense

For critical DIBS (Defense Industrial Base Sector) assets, Department of Defense (DoD) will collaborate with owner/operators and appropriate Federal, State, and local authorities toprepare coordinated plans of action to prevent, deter, and mitigate the adverse effects of natural disasters andensure continuity of business by having resilient, diverse communications capability in place. The plans will also identify howto respond to, and recover from, such disasters in a manner that limits the consequences and value of such disasters. In addition,DoD will collaborate with the owner/operators to formulate the most suitable balance of prevention, detection, protection,response, recovery, and resiliency for critical DIBS assets using the results of risk assessments. [42]

DoD’s goals [42]:

- Prevent or Delay an Incident. DoD will collaborate with critical DIBS asset owners to jointly determine additional measuresneeded to prevent or delay an incident beyond those measures that are contractually required.
- Detect a Potential Incident. DoD will collaborate with critical asset owners to jointly determine additional measuresneeded to detect potential incidents beyond those measures that are contractually required. DoD will also support and facilitate sharing of threat information through appropriate government and commercial channels.
- Mitigate or Respond to an Incident. DoD will collaborate with critical asset owners to encourage the preparation andexercise of business continuity plans beyond those that are contractually required. DoD and asset owners will

review therequirement for sub-tier supplier business continuity planning. As the consumer of DIBS products and services, DoD andasset owners will periodically review actions needed to respond to an incident, consistent with the principles of layereddefense described previously.

- Recover from an Incident. DoD will collaborate with critical asset owners to encourage preparation and exercise of businesscontinuity plans supporting recovery from an incident.
- Develop Resiliency. DoD will evaluate the costs and benefits of adding redundancy of DIBS capabilities and services, thusreducing the number of critical DIBS assets. When working with asset owner/operators, DoD will also explore approaches toimproving the resiliency of services, production processes, supply chains, and associated facilities and information systems.

In summary, table14 presents the most significant threats to the Defense Industrial Base Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X								X

Table 14: Defense Industrial Base Sector Most Important Threats

3.7 Emergency Services Sector

Natural disasters;that can be caused from the CC, are threats to Emergency Services Sector (ESS) disciplines and their cyber infrastructure. They typically affect specific geographic locations or regions and cause serious and immediate impacts ordegradation in normal day-to-day ESS and their communications capabilities, for example 1-1-2 (or 9-1-1 for U.S.A.) capabilities.

1-1-2 is used as a common emergency telephone number for all the countries that are members of the European Union in order to reach emergency services (police, ambulance, fire and rescue). It is one of the Public Safety Answering Points (PSAP).

This scenario would result in multiple effects. If a natural disaster is significant enough to make emergency telephone number unavailable, it is also likely to cause damage to infrastructure, buildings and potentially injury or loss of life. The worst case on this scenario is where the service is unavailable via the traditional method (telephone), and many people call the emergency telephone number for assistance. In this case, customers who need help would be obliged to find other methods to communicate with ESS entities. One of them would be to physically visit the ESS facilities.

Figure 8, shows Consequences, Vulnerabilities, and Threats on the ESS.

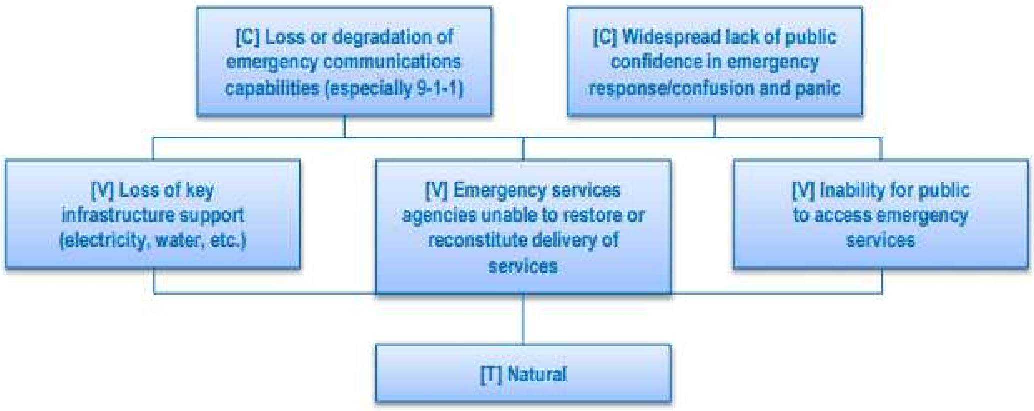

Figure 8: Emergency Services Sector - Consequences, Vulnerabilities, and Threats [24]

C = Undesired consequence

V = Vulnerability

T = Threat

There is no specific disaster selected because of the large geographic scale. The evaluation assumes that a disaster that is most likely to affect a particular region or locale is significant enough to be deemed a declared natural disaster.

The included components are vulnerabilities, undesired consequences, and the threats that can exploit those vulnerabilities.

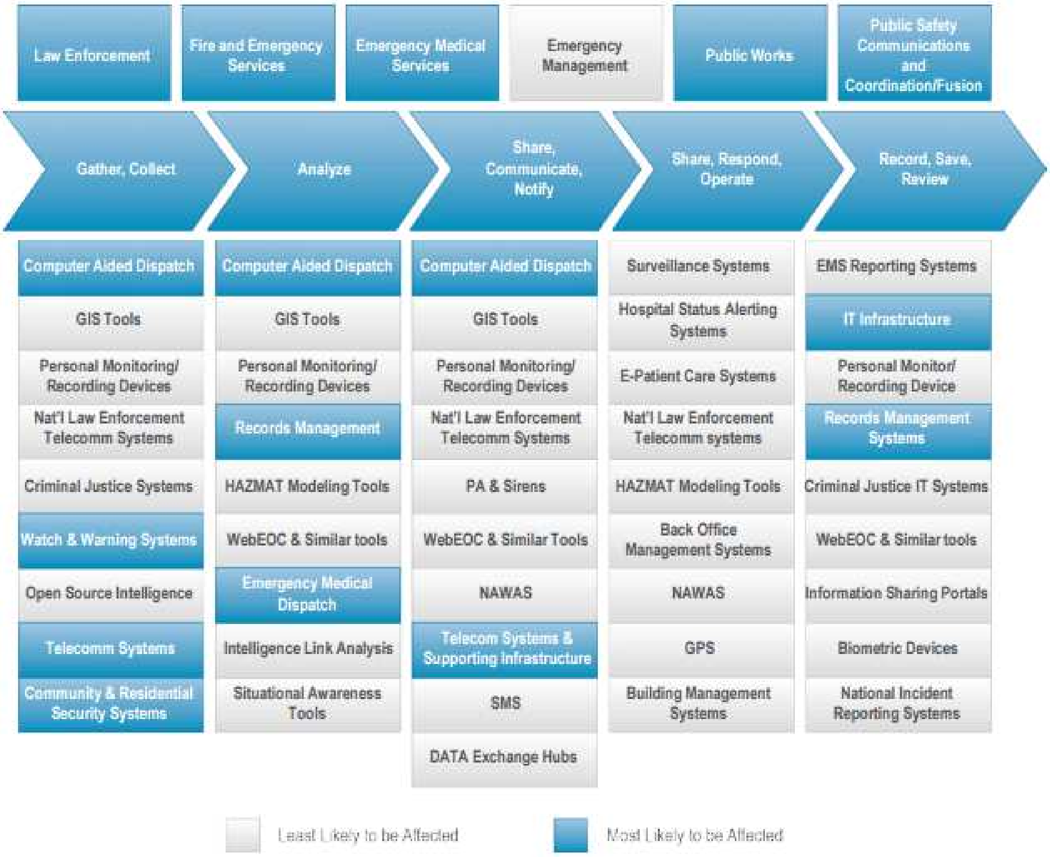

Figure 9: Emergency Services Sector - Disciplines and Cyber Infrastructure Affected [24]

Figure9, shows how a natural disaster affects the emergency telephone number capabilities to the point it is no longer available.

The probability of a successful coordination in order to response to emergencies is definitely reduced when a telecommunication system, such as the emergency telephone number is not functional or degraded.

Figure 10,shows how this scenario affects the Emergency Services Sector. The Law Enforcement, Public Safety Communications and Coordination, Emergency Medical Services and Fire Emergency Services are definitely more negatively affected than the two others (Emergency Management and Public Works).If a natural disaster occurs and a PSAP infrastructure becomes inactive or inappropriate for use, many of the Emergency Services Sector disciplines; such as the Law Enforcement, Public Safety Communications and Coordination, Emergency Medical Services and Fire Emergency Services; are put in risk.

Figure 10: Emergency Services Sector - Natural Disaster Causes Loss of emergency telephone number Capabilities [24]

The importance and consequence of the loss of a PSAP such as emergency telephone number capabilities can fall across several and different sectors in critical infrastructure and well affect the ability of ESS to meet to emergency response.

The most common practice in order to deal with that, is the concept of redundancy in infrastructures, such as disaster recovery sites or backup infrastructures. We can achieve with this way fault tolerance mechanisms.

However, it is not a solution if those infrastructures are located in a place that is in the same geographic area. If a natural disaster occurs, it may affect both primary and secondary's infrastructures. The natural disaster may be destructive enough and a big geographic area may be seriously affected so that the PSAP will not be able to provide its services.

The emergency telephone number service as a PSAP, heavily depends on commercial and communications facilities infrastructures.

Most of the citizens use the common telephony services and wireless networks to contact emergency telephone number, and the call centers that support PSAP services use the same networks to connect to citizens, inform the public, and make the coordination with all the disciplines of ESS.

Table 15, shows some example impacts in CFS due to climate change:

• An earthquake could cause damage to infrastructure, buildings and potentially injury or loss of life.
• Flooding prevents access so that facility cannot operate properly.
• Earthquakes can sever telephone circuits that are buried in the ground, drop telephone poles, or even knock down entire buildings.
• Tsunamis or floods can submerge infrastructure equipment that is important for operations and make it unavailable.
• Fires can burn overhead telephone lines or buildings that are equipped with infrastructure equipment.

Table 15: Example Impacts in Emergency Services Sector due to Climate Change [24]

3.7.1 Public Safety Communications & Coordination

Natural disasters, such as an earthquake, flood or fire, can disrupt, seriously damage, or destroy infrastructure in the commercial and communications networks.
In a destroy scenario, citizens will lose the ability to reach emergency telephone number service and call centers will have outages or will be out of service. The damage may be crucial to their communications infrastructure or lines, and may need several working hours or even days for the systems recovery.If the scenario is about a serious damage, the communications lines may be overloaded or even lead to denial of service.

The natural threats that could lead to those scenarios are many and may vary by geographic areas. Some of the most common threats in nowadays constitute earthquakes, tsunamis, hurricanes, and winter storms.Geomagnetic or solar radiation storms are also threats that can cause communications outages. They are called celestial events.

Those threats could exploit some numerous vulnerabilities such as; location of the key infrastructure sites in vulnerable location areas, misconfigured alternate routing forcall centers supporting the emergency telephone number, etc.

In spite the above vulnerabilities, there are also technological ones. Single point of failures in the designed infrastructure,the lack of training of personnel, training or preparedness exercises; such as disaster recovery tests. All these threats and vulnerabilities are rated as high in the assessment, resulting a high possibility to be happen.Actually, the above issues happen more frequently, that makes this scenario to have the highest likelihood.

The impact of this scenario is more likely to be felt in a restricted geographic area such as cities and not in national or bigger level. However, the assessment had a high rate because of the serious impacts and cascading affects that can occur. This is the reason why the risk was rated higher than any other risk. [24]

3.7.2 Fire and Emergency Services

Citizens that experiencing the affects;of a natural disaster in the area that they live or work, are getting anxious and show depressed signs. Natural disasters such as earthquakes, tsunamis or fires make those people to spend hard times and face difficult circumstances. Earthquakes can sever telephone circuits that are buried in the ground, drop telephone poles, or even knock down entire buildings. Tsunamis or floods can submerge infrastructure equipment that is important for operations and make it unavailable. Fires can burn overhead telephone lines or buildings that are equipped with infrastructure equipment.Of course, these are not the only natural disasters that affect telephony systems, but are the ones that are more likely to happen.

If a hardening of the infrastructure facilities haven't been taken in place to face those natural disasters, or the infrastructures exist in a geographic area that is known for natural disasters taking into place (such earthquakes or floods) with no existence of routing diversity telephone lines or insufficient alternate switching infrastructures, then the providers may be unable to quickly recover from such an event and the service that they provide will be unavailable for a long period of time for the citizens population.

Citizens that are in need of help from one the disciplines that Emergency Service Sector provides, demand the operational existence of those services. Although there might be alarms, emergency exits in the buildings, specific points to meet in case of a disaster, the need of telephone lines connectivity and existence is crucial. For them, the ability to notify authorities and ask for help is tied to the emergency telephone number.

For a call to the emergency telephone number call center to be completed, should a group of services to operate. The caller must be able to use a landline or mobile phone to dial the number. If there is no dial tone, the call cannot be done. If the infrastructure that is responsible for the dial tone is damaged or destroyed (such as Computer Telephone Integratedsystems, switches, etc.), the call will never be completed. The result will be confusion and panic. The citizens may not know how to contact with, or the location of the nearest fire and emergency services.

In addition to the communications infrastructure vulnerabilities that may have been revealed in the wake of a natural disaster, the fire and emergency services discipline has a critical dependency on the Communications Sector; in the event of a natural disaster, reconstitution of communications infrastructures is performed by the Communications Sector. However, there are similar risks that fire and emergency services organizations can experience. If the loss of emergency telephone number capabilities is caused by the damage or destruction of the emergency telephone number communications center, provisions may have been made to develop alternate locations to which emergency telephone number calls could be routed.

However, for the majority of PSAPs, redundancy is extremely limited geographically, and the location of an alternate PSAP may be vulnerable to the same natural disaster that affected the telephone companies. Some organizations, particularly those that have migrated to digital, Internet Protocol (IP) based infrastructure, may already have alternate communications centers in place, but if they have not properly planned for the activation and maintenance of such facilities, they may find themselves ill-prepared to reestablish emergency telephone number services.

Further, if the personnel expected to use alternate facilities have not been trained to migrate services to the alternate site and have never conducted exercises to develop proficiency in doing so, the chances of successfully transitioning from the damaged site to the alternate site are also significantly reduced.

Fire and emergency services organizations in parts of the country where natural disasters occur frequently may experience a higher likelihood of losing emergency telephone number capabilities. If a citizen is unable to reach the local fire and emergency services organization when needed, and the organization is unable to provide for connectivity with the communities they serve, the consequences place lives and property that have already been threatened by the natural disaster itself at an even greater level of risk. It is this high likelihood of a natural disaster's occurrence causing a loss of emergency telephone number capabilities that, when coupled with the severe consequences, make this the greatest threat to the services of fire and emergency.[24]

In summary, table16 presents the most significant threats to the Emergency Services Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X	X		X				X	X

Table 16: Emergency Services Sector Most Important Threats

3.8 Energy Sector

One of the most important areas considered as CI is the Energy Sector (ES). Itis divided into three interrelated segments: electricity, oil, and natural gas subsectors. It faces a wide variety of risks that are evolving and may be difficult to assess or quantify due to a high level of uncertainty about the frequency or severity of the event. Some of these risks include cyber and physical security threats, space weather events, aging infrastructure and an aging workforce, as well as climate change. The ability of ES to continue to adapt to these threats is critical, especially during recovery from a disaster, because many critical infrastructure and essential functions - including hospitals, water and wastewater systems, transportation, and telecommunication - depend on the reliable supply and delivery of electricity and from fuels to operate. [60]

Weather-related events, including lightning and storms, have historically been the biggest threat to the critical energy infrastructure. The ES will be impacted by weather patterns that may affect the frequency and severity of natural disasters, including hurricanes, floods, earthquakes, tornados and others. Such events may adversely impact the operation of power plants, the generation and the delivery of fuels and electric power, and the reliability of pipelines and electricity grids.
In general, energy production and distribution systems are designed to be able to respond to weather variability (daily changes in temperature) that affect the load or even to rapid changes in the availability of the renewable resources that affect the supply.However, the ES is vulnerable to direct impacts from severe weather events. In every corner of the world, natural disasters have the potential to significantly impact the short-term domestic energy supplies. [60]

Table17, shows some example impacts in ES due to climate change:

Climate Indicator	Energy Sector (Electricity) Impact
Increased average temperature	• Accelerated deterioration of equipment • Increased operation and maintenance needs • Increased line losses in electricity flow • Reduced flow through cooling efficiency in thermal stations • Decreased efficiency of dry-cooled thermal generation facilities • Reductions in the efficiency of solar photovoltaic facilities • Higher water temperatures (thus limiting generation capacity of thermal stations) • Increased energy demand (summer – e.g., to power air conditioning; pump, treat, and deliver more water; higher irrigation demand for food

	production due to drying soil moisture) • Decreased energy demand (winter) • Longer construction season
Changes in precipitation patterns	• Increased rate of decay or corrosion processes • Dam safety compromised • Lower water levels • Unanticipated storm tracks • Changes in running water discharge to drive turbines • Changes in timing, rate, location and nature of precipitations • Changes in slope stability
More frequent extreme weather events (heat, wind, rain, ice, drought, flood)	• Infrastructure failure (e.g., collapsing lines under ice loads) • "Galloping" lines leading to transmission failure • Increased maintenance requirements • Increased peak demand
Forest fire hazards	• Higher infrastructure risk • Potential impact on reservoirs and flows
Changes in number of freeze/thaw cycles	• Damage to concrete (moisture expansion / contraction) • Increased need for infrastructure maintenance
Vegetation and ecosystem shifts	• Changes in line and right-of-way maintenance schedules and tree clearing

Table 17: Example Impacts in Energy - Water Sector due to Climate Change [62]

3.8.1 ES Interdependencies with other sectors

The Energy Sector depends on other sectors to help provide its services, and it supplies energy services upon which all other sectors depend. However, interdependencies also exist within the sector itself. [60]

Figure 11, depicts ESinterdependencies with other sectors.

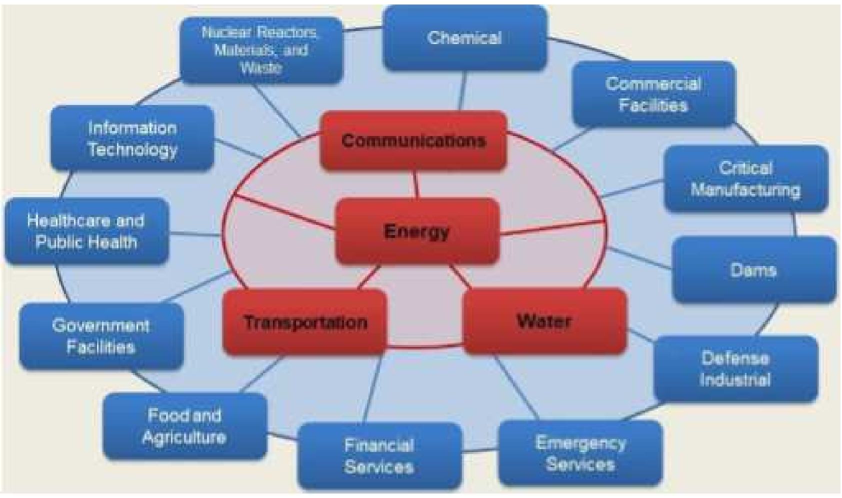

Figure 11: Energy Sector Interdependencies with Other Sectors [60]

Figure 11 provides a high-level overview of the interdependence among the lifeline functions. As shown, the ES (Electricity and Oil and Natural Gas Subsectors) provides essential power and fuels to Communications, Transportation, and Water Sectors, and in return both subsectors rely on them for fuel delivery (transportation), electricity generation (water for production and cooling), as well as control and operation of infrastructure (communication). [60]

Table 18, gives an overview of the overall interdependencies between key infrastructure sectors: oil and natural gas, electricity, transport and water. Communication (communications and information technology sectors) is included, which has been growing in use, which can vary by usage. Their use in detection, communication and control systems for all infrastructures is constantly increasing.

	Sector Receiving the Service				
Sector Generating the Service to Another (Receiving) Sector	Energy: Oil & Gas	Energy: Electricity	Transportation	Water	Communication
Energy: Oil & Gas	-	Fuel to operate power plant motors and generators	Fuel to operate transport vehicles	Fuel to operate pumps and treatment	Fuel to maintain temperatures for equipment; fuel for backup power
Energy: Electricity	Electricity for extraction and transport (pumps,	-	Power for overhead transit lines	Electric power to operate pumps and	Energy to run cell towers and other transmission

	generators)			treatment	equipment
Transportation	Delivery of supplies and workers	Delivery of supplies and workers	-	Delivery of supplies and workers	Delivery of supplies and workers
Water	Production water	Cooling and production water	Water for vehicular operation; cleaning	-	Water for equipment and cleaning
Communication	Breakage and leak detection and remote control of operations	Detection and maintenance of operations and electric transmission	Identification and location of disabled vehicles, rails and roads; the provision of user service information	Detection and control of water supply and quality	-

Table 18: Overview of Generic Interdependencies among Infrastructure Sectors [61]

Over the time, IT dependencies have dramatically increased. For example, electricity and natural gas suppliers rely heavily on data collection systems to ensure accurate billing. Energy control systems and the communication (communications and information technology sectors) on which they rely, play a key role in the ES. These IT components are essential in monitoring and controlling the production and distribution of energy. [60]

3.8.2 Electricity and Natural Gas Interdependency

In addition to cross-sector interdependencies, substantial interdependencies exist within the ES, including between electricity (E) and natural gas (NG) infrastructure. With an abundant production and a declining price, NG is being used more heavily in E generation, yet there are various reliability issues, including constrained infrastructure capacity to deliver NG supplies to power generators in certain locations. [60]

On the other hand, E is a necessity throughout the NG supply chain, including at production, pipeline, processing, and distribution facilities. Reliability of supply, transportation constraints, and the integrity of existing infrastructure are some of the issues surrounding the E and NG interdependencies. [60]

In summary, table19 presents the most significant threats to the Energy Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X	X				X			X

Table 19: Energy Sector Most Important Threats

3.9 Financial Services Sector

The Financial Services Sector (FSS) includes investment products providers, insurance companies, credit and financial institutions, as well as the providers of utilities and services that support/maintain these functions.Financial institutions vary depending on the size and presence in the global market. Some of these institutions enumerate thousands of workers and tremendous profits in assets. Others employ a limited number of staff serving / serve isolated communities. [55]

The statutory purpose of financial institutions is to provide society with the necessary means for development and improvement of living standards, through the financing of private and public projects.

The FSS faces ongoing risks associated with NDs. Hurricanes, tornadoes and floods all have the potential to cause physical disruptions that have significant impacts on FSS operations. On October 29, 2012, the landfall of Superstorm Sandy caused a two-day closure of major equities exchanges, while fixed income markets were closed for one day. [54]

Essential to understanding the sector's cybersecurity and physical risks is the identification of critical processes and their dependence on information technology and supporting operations for the delivery of FP&S. As the sector integrates new information and communications technologies to meet market demand for more efficiency and innovative services, new risks may emerge. Given that financial institutions and technology service providers are tightly interconnected in a dynamic marketplace, an incident impacting one firm has the potential to have cascading impacts that quickly affect other firms or sectors. This risk is exacerbated by the fact that financial institutions depend on other sectors for key services like electricity, communications, and transportation(see Chapter 3.3CommS, Chapter 3.8ES &Chapter 3.15TSS). [54]

With increasing threats, due to climate change, the insurance becomes unbearable and eventually the property cannot be covered by insurance. In the worst case, this can cause a drop-in property values, and increased default on mortgages. The climate risk turns into credit risk, and the resulting damage to the assets of banks could well rival the worst effects of the economic crisis.[56]

The property sector is likely to be increasingly exposed as cyclones begin to move south, into areas that do not have the appropriate building standards or are not designed to withstand such high wind speeds, torrential rains and heavy storms.[56]

Ultimately, we will see demographic change as people relocate in response to CC. This will result in changes to our infrastructure needs, and the value of existing infrastructure assets. As a result of living elsewhere, people working in various industries, disrupting employment patterns. [56]

Other sectors such as FSS will also be affected by climate risk through secondary effects. [56]

Table20, shows some example impacts in FSS due to climate change:

• Increasing/ decreasing demand for some products, such as deicers, protective equipment, sun-cream ingredients, chemicals used in air conditioning or refrigeration.
• If more storage of hazardous substances is required there may be an impact on the site's COMAH status.
• New market for existing product.
• Potential to develop new product.
• Market advantage can be gained by being more resilient to severe weather and CC.
• Climate risks affect price or availability of buildings or business continuity insurance.
• Resilience or adaptation measures reduce premiums or increase availability.

• Investors' perception of climate risks affects the price or availability of capital investment.
• Resilience or adaptation measures attract investors.

Table 20: Example impacts in Financial Services Sector due to Climate Change [31]

3.9.1 Disruption to Owned Assets and Operations

Data centers and office locations, among other FSS-owned assets, face significant threats from the physical impacts of CC. [57]

Table21, shows some example impacts in Disruption to Owned Assets and Operations

• Company locations, including owned real estate and infrastructure, face immediate and long-term risks from CC. For example, rising sea levels may flood offices, resulting in business disruptions and loss of assets.
• Extreme weather events, like heat waves and hurricanes, can keep people from remotely and physically accessing their workplaces, resulting in reduced company employee productivity and severe threats to business reliability.
• Resource scarcity, rising energy costs, and EWE will create business disruptions for FS companies. For example, blackouts will result in data security threats and outages, disrupting company and client access to information.

Table 21: Example Impacts in 3.9.1 due to Climate Change [57]

3.9.2 Investment Portfolio Exposure

Financial Services (FS) company investments, including client investments, face serious risks of business disruption and increased costs due to rising sea levels, diminishing value of land and real estate due to changing WP, and an increase in claims, while investments in resilience efforts provide new opportunities for FS companies. [57]

Table22, shows some example impacts in Investment Portfolio Exposure

• Sector-specific assets—including energy, agriculture, water, transportation, tourism, real estate, and information and communications technology—will face rising costs and service disruptions due to the physical impacts of CC. For example, flooding, temperature variances, and changing monsoon

cycles are expected to drive farming to new regions, leaving some current farming communities without viable farmland.
• Investments and assets in geographies with increased levels of vulnerability to CC, including Africa and its risk of famine and drought, as well as coastal regions at risk of rising seas, may create a large financial burden and CR for companies. With twenty-five (25) percent of the world's population living in coastal zones, and 12 of 16 megacities located on coastal land, this poses a significant risk.
• Underwriter costs will rise due to an increase in claims for property, housing, and life insurance.

Table 22: Example Impacts in 3.9.2 due to Climate Change [57]

3.9.3 Investor and Public Confidence

Investors and the public alike expect the FSS to be a leader in knowledge, foresight, accountability, and citizenship. FS companies run the risk of divestment and damage to their reputations for lack of action or poor follow-through regarding CC. [57]

Table 23, shows some example impacts inInvestor and Public Confidence

• Poor corporate citizenship, including misalignment between reporting and actions, damages FS companies' reputations. As a result, with have a divestment in FS companies and eventually serious impacts in reliability for the rating agencies.
• Divestments run the risk of hurting poor or vulnerable communities and ecosystems, resulting in public outcry and even regulation/adjustment when not managed properly.

Table 23: Example Impacts in 3.9.3 due to Climate Change [57]

In summary, table24 presents the most significant threats to the Financial Services Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
			X		X			

Table 24: Financial Services Sector Most Important Threats

3.10 Food and Agriculture Sector

CC, as changes in temperature, precipitation and sea level rising threaten agricultural productivity and the capacity to feed the world's population.The Food & Agriculture Sector (F&AS)is deeply connected with the weather and climate. The amount of rainfall and its distribution, are key factors that determine the characteristics of rainy seasons, cropping systems and crop production. Livestock sector is also affected from the above factors.Both the temporal and seasonal variability of rainfall, limiting crop production in tropical and subtropical areas. [48]

In semi-arid tropics, frequent soil water deficiency during early plant development, resulting in seedling mortality. The phenomena of retarded development and reduced yield, are very common. There are many instances where water deficiency during the later stages of crop development is apparent. The excessive rainfall events during the rainy season create excessive irrigation in the root zone, reduce plant growth and prevent field operations. [48]

CC impacts on agricultural production systems can be divided into direct and also into indirect. The direct impacts are those that are directly caused by a modification of physical characteristics such as temperature levels and distribution along the year and water availability and accessibility on a specific agricultural production. Indirect effects are those that affect production through changes in other species such as pollinators, pests, disease vectors, invasive species. [49]

The duration of rainy season is one of the main considerations affecting crop production prospects.Additionally, higher growing season temperatures can have shocking impacts on agricultural productivity.For example, high air temperatures in the time of flowering can reduce pollen viability. [48]

Dairy, meat and wool production is also affected from CC. It is arising because of the repercussion on grassland productivity. For example, animals feed intake is reduced when there is a lot of heat. That in turn results in poor growth performance. [48]

Livestock sector can have also far-reaching consequences because of CC. Long heat periods, usually on summer, result in inadequate pasture and production of hay. Heavy winter periods, with lot of snow and winds, prevent livestock from accessing pasture. This could lead to many animals die and to business disaster of shepherds. [48]

Figure 12, shows how a range of physical, biological and biophysical impacts bear on ecosystems and agroecosystems, translating into impacts on agricultural production. This has quantity, quality and price effects, with impacts on the income of farm households and on purchasing power of non-farm households. All these effects affect the four dimensions (availability, access, utilization, stability) that have to do with food safety and nutrition.

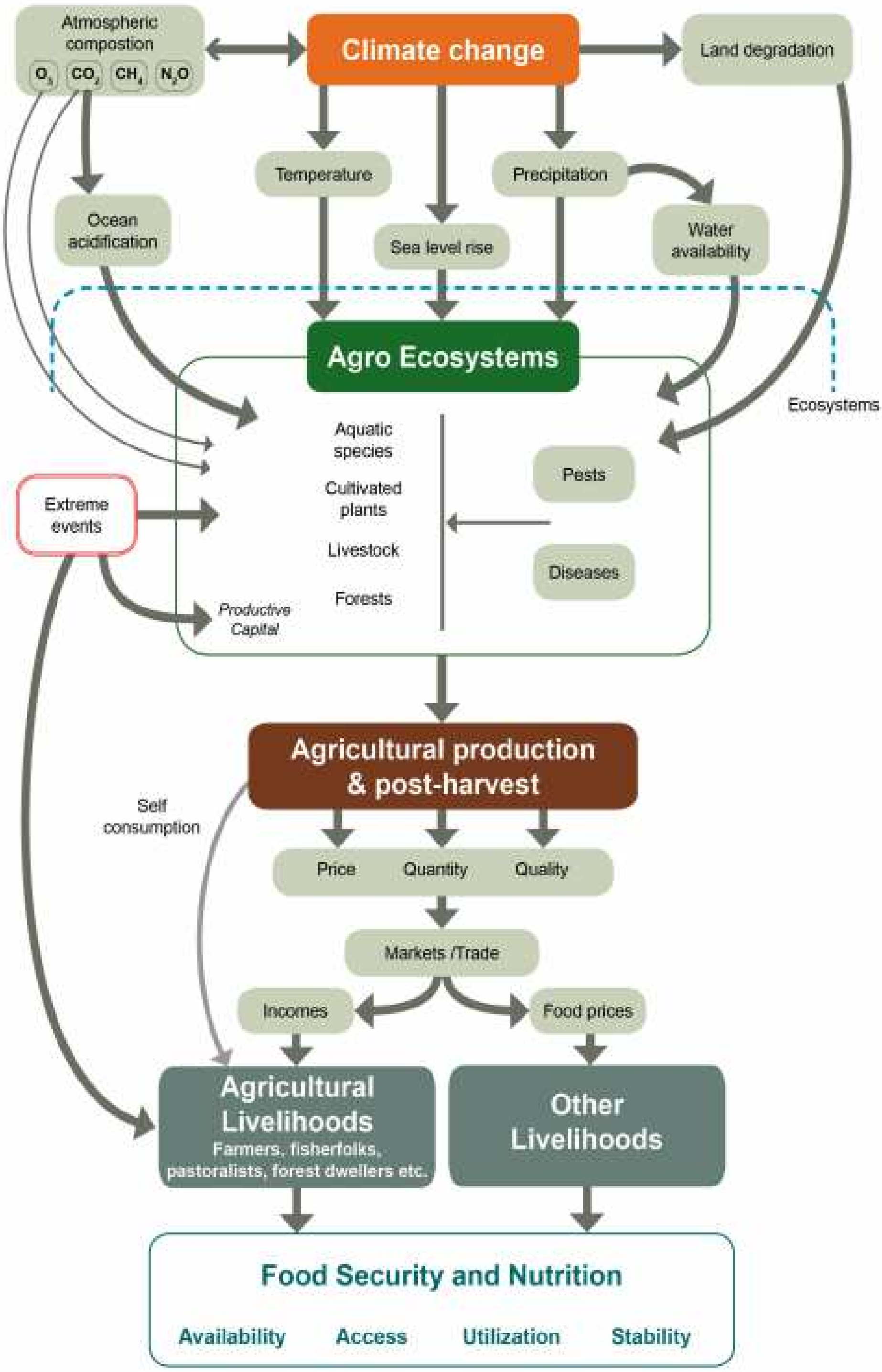

Figure 12: Cascading Effects of Climate Change Impacts on Food Security and Nutrition [49]

CC menaces agriculture biodiversity; IPCC (2007) projected that approximately 20 - 30 % of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5 - 2.5 °C over 1980 -

1999 levels.Coastal zones and fisheries are very prone to risks associated with CC, such as changes in ocean salinity, cyclones, rising sea levels. Additional risks are a decrease in fish stocks and availability due to CC and increasing the ocean water temperature. [48]

Half of the calories consumed daily worldwide come from four feeds. Corn, wheat, rice and soybeans. All four are threatened by climate change and air pollution on the planet. Other more and others less. For example, corn has difficulty to grow under very hot weather, while wheat is sensitive to air quality. Thesoybeanalsoinfluencedit from ultraviolet rays. [50]

The world population is growing and is expected to grow much until 2050. Alongside increased life expectancy, reduced infant mortality and simultaneously changing our eating habits. All this contributes to the fact that should be produced 50% more food than is currently produced. According to the survey of Heald team, global crop yields are expected to decrease. [50]

Table 25, shows some example impacts in CFS due to climate change:

• Temporal and seasonal variability of rainfall, limiting crop production in tropical and subtropical areas.
• Frequent soil water deficiency during early plant development, resulting in seedling mortality.
• Excessive rainfall events during the rainy season create excessive irrigation in the root zone, reduce plant growth and prevent field operations.
• High air temperatures in the time of flowering can reduce pollen viability.
• Animals feed intake is reduced when there is a lot of heat.
• Long heat periods, usually on summer, result in inadequate pasture and production of hay.
• Heavy winter periods, with lot of snow and winds, prevent livestock from accessing pasture.
• Corn has difficulty to grow under very hot weather, while wheat is sensitive to air quality.
• The soybeanalsoinfluencedit from ultraviolet rays.
• Increased storage infrastructure to meet the water needs of irrigated agriculture arising from increased crop water demands, higher evapotranspiration and longer or more intense dry spells might exacerbate conflicts in river basins and negatively impact downstream fisheries.

Table 25: Example Impacts in Food and Agriculture Sector due to Climate Change [48, 49]

3.10.1 Freshwater Availability

CC is adding significant uncertainty to the availability of water in many regions in the future. It will affect precipitation, runoff and snow/ice melt, with effects on hydrological systems as well as on water quality, water temperature and groundwater recharge. [49]

CC will also significantly impact sea level with potential impacts on the salinity of surface and groundwater in coastal areas. Factors such as rainfall duration and intensity, surface temperature and vegetation all play a role in determining what percentage of rainfall is converted into surface water runoff into rivers, dams and wetlands, or into groundwater. CC will also reduce glaciers, which often play a key role to provide river flows in summer. [49]

CC will cause decrease in renewable sources of surface water and groundwater. These effects will be evident in most dry subtropical regions / places. This would result in intense antagonism for water use. According to the IPCC (2012), there is "medium confidence" that "droughts will intensify in the twenty-first century in some seasons and areas, due to a combination of more variable precipitation and / or increased evapotranspiration". The above comprises the central and southern Europe and the Mediterranean region, the Central North American region, Mexico and Central America, the northeast of Brazil and South Africa. The reduction in rainfall in arid and semi-arid regions will result in a very sharp decline in basins. [49]

Due to increased precipitation intensity and variability it is expected that the risks of flooding and drought will be increased, while sweet water supplies stored in floes/glaciers and snow cover are projected to decline. That will modify water availability during warm and dry periods in regions supplied by melt water from major mountain ranges. In rivers receiving their water from floe/glacier or snowmelt, as is the case for the 40 percent of the world's irrigation supported by flows originating from the Himalayas (FAO, 2013a), high flows will occur earlier each year. [49]

Finally, adaptation to CC needs to carefully consider competing water uses and their various implications for food security and nutrition [51]. Measures that can mitigate one type of adverse impact could also exacerbate another. For example, increased storage infrastructure to meet the water needs of irrigated agriculture arising from increased crop water demands, higher evapotranspiration and longer or more intense dry spells might exacerbate conflicts in river basins and negatively impact downstream fisheries. [49]

3.10.2 F&AS Interdependencies with other sectors

Figure 13, depicts F&AS Interdependencies with other sectors.

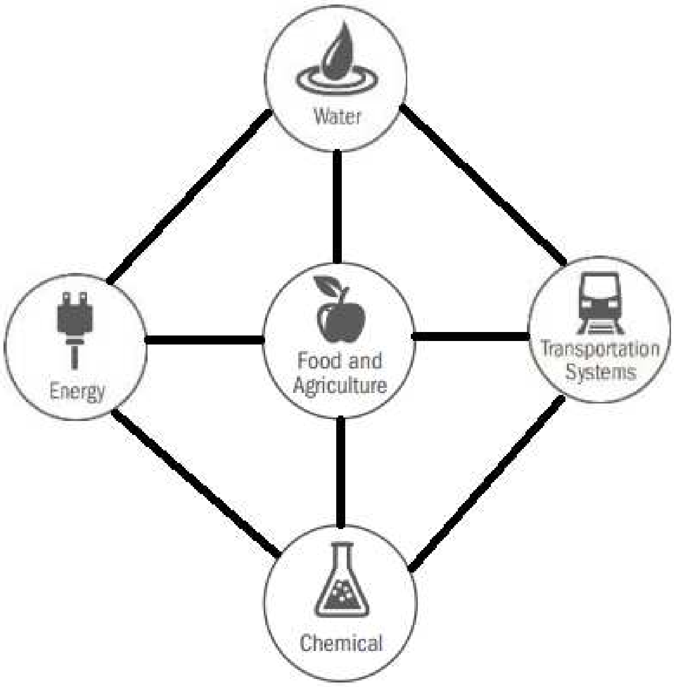

Figure 13: Food &Agriculture Sector Interdependencies with Other Sectors [52]

Chemical Sector

F&AS is associated with the CS especially in the area of the production of crops. Chemicals are needed for fertilizers and pesticides (see Chapter 3.1 CS). [52]

Energy Sector

F&AS is associated with the ES as energy is required to operate the equipment needed for agriculture production and food processing (see Chapter 3.8 ES). [52]

Transportation Systems Sector

The F&AS relies on TSS services for movement of products and livestock(see Chapter 3.15TSS). [52]

Water and Wastewater Systems Sector

Finally, the sector interdepends with the W&WSS. The production of crops needs clean irrigation and processed water(see Chapter 3.16 W&WSS).[52]

In summary, table26 presents the most significant threats to the Food and Agriculture Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X	X	X		X				

Table 26: Food and Agriculture Sector Most Important Threats

3.11 Government Facilities Sector

The Government Facilities Sector (GFS) includes a broad variety of buildings and infrastructures, that are owned or rented by state and local governments.These include government buildings, military installations, embassies, courthouses, national laboratories and general structures that can accommodate critical equipment, systems, networks and functions. [53]

Natural threats include those that are meteorological, geological, or biological and are typically present in defined geographic areas. Increasingly severe weather events can cause significant property damage, threaten the safety of employees and visitors, and limit access to critical resources such as power, water, transportation, and food.Specific natural threats that can affect government facilities around the world should be identified according to likelihood of occurrence. Extreme space weather can cause disruptions of critical services.For example, interruption of power could cause cascading effects on all services. Examples of natural threats include severe storms, hurricanes, earthquakes, tornadoes, volcanoes, drought, floods, landslides, tsunamis, wildfires, climate change, and coronal mass ejection/space weather. [58]

Aging infrastructure can significantly increase vulnerabilities caused by natural events. It could also cause cascading effects, disruptions of services and/or delivery of critical mitigation and recovery equipment, and a greater physiological impact on the people. [58]

Table 27, shows some example impacts in GFS due to climate change:

• Extreme space weather can cause disruptions of critical services.
• Increasingly severe weather events can cause significant property damage, threaten the safety of employees and visitors, and limit access to critical resources such as power, water, transportation, and food.
• An earthquake could create panic in the world and serious damage to the building. As a result, there could be death losses.
• Flooding prevents access by staff, customers or vehicles, compromising business continuity and the ability to keep the site in a safe condition.
• Disruption to critical communications operations in facilities, such as information networks or operation and dispatch centers, would hamper the sector's ability to respond and mitigate incidents.
• An interruption to the power supply due to increased temperatures, would directly affect all facilities located in the region serviced and could have cascading effects on other sectors.
• Pandemics caused by floods, could spread easily through government facilities, as large groups of people congregate daily.

Table 27: Example Impacts in Government Facilities Sector due to Climate Change [58]

3.11.1GFS Interdependencies with other sectors

Figure 14, depicts GFS Interdependencies with other sectors.

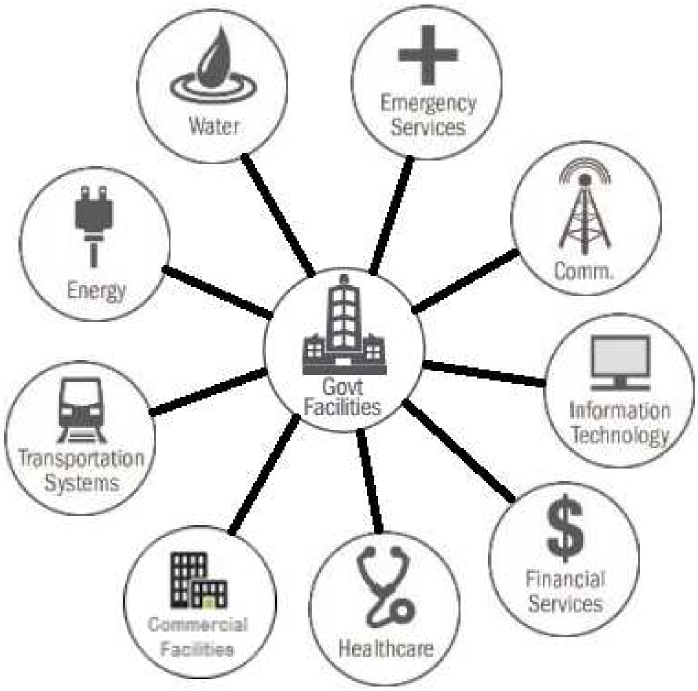

Figure 14: Government Facilities Sector Interdependencies with Other Sectors [58]

Commercial Facilities Sector

Resides within or adjacent to GFS facilities as tenants or government offices reside within commercial facilities. This creates a shared risk environment to both sectors, which promotes collaboration to address security challenges.(see Chapter 3.2CFS).[58]

Communications Sector

Provides telecommunications access and enables operations. Damage to the Communications Sector would affect the ability of the GFS to operate and could cause cascading economic damages as employees and customers may have difficulty communicating. Disruption to critical communications operations in facilities, such as information networks or operation and dispatch centers, would hamper the sector's ability to respond and mitigate incidents.(see Chapter 3.3CommS).[58]

Emergency Services Sector

Saves lives and protects property after incidents, such as accidents, natural disasters, or terrorist attacks. The GFS coordinates with Emergency Services—which includes law enforcement, fire and emergency services, and emergency medical services—to mitigate risk and respond to incidents. A disruption would affect the GFS disaster response and prevention capabilities. Emergency Services also manages crisis re-entry for affected areas, which is a critical issue for GFS owners and operators trying to gain access to their facilities. (see Chapter 3.7ESS).[58]

Energy Sector

Provides power, which supports critical facility functions, such as lighting, water pumping, and HVAC systems. This is the primary dependency for the GFS. Without power, many facilities could not function for an extended period of time, as access to backup power is often limited in scope. An interruption to the power supply would directly affect all facilities located in the region serviced and could have cascading effects on other sectors. (see Chapter 3.8 ES). [58]

Financial Services Sector

Provides essential services for the GFS to conduct daily business operations and emergency response. During disasters, government facilities may house ATM and banking resources that the public will need to access during incidents.(see Chapter 3.9FSS).[58]

Healthcare and Public Health Sector

Provides services to the public in the event of an attack, natural disaster, or pandemic/large-scale outbreak of an illness. Pandemics can spread easily through government facilities, as large groups of people congregate daily.(see Chapter 3.12H&PHS).[58]

Information Technology Sector

Enables day-to-day operations and financial transactions. Loss of function would affect the sector's ability to operate both cyber and physical systems.(see Chapter 3.13ITS).[58]

Transportation Systems Sector

Provides the transportation of goods to and from government facilities, as well as the transportation of employees and visitors during regular operations and after disasters.

A disruption in the Transportation Sector could prevent employees and visitors from reaching government facilities or keep them from being able to leave facilities after an incident. A disruption could also keep goods and supplies from leaving or reaching the GFS. The sector also needs to be able to gain access to areas after disasters to reconstitute services and reopen facilities.(see Chapter 3.15TSS).[58]

Water and Wastewater Systems Sector

Provides a supply of potable water for and handles the treatment of wastewater. The sector also provides water for fire suppression systems. Without these services, government facilities might need to be shut down until services are restored.(see Chapter 3.16 W&WSS).[58]

In summary, table28 presents the most significant threats to the Government Facilities Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X	X		X			X		

Table 28: Government Facilities Sector Most Important Threats

3.12 Healthcare and Public Health Sector

It is known that the weather and climate affect human health. Excessive temperature causes hyperthermia, cold causes hypothermia, and drought causing famine.

Some of the impacts of climate change have as result people's health. Warmer temperatures are one them and have focused public attention on the effects on human health.During hot weather, perspiration evaporates from the skin, which cools the body and maintains an acceptable body temperature for physiologic functions.Beyond certain heat extremes, however, the body is unable to cool itself, and the normal biochemical processes that allow life shut down.The precise weather conditions under which the body fails to maintain normal function, however, vary depending on age, presence of heart or lung disease, and other health conditions.In addition, continued exposure to warm temperatures leads to acclimatization, a physiologic change in the body that allows it to adapt to the increased warmth.Increased greenhouse-gas-induced climate change is expected to have a greater effect on nighttime temperatures, as the heat trapping effect of the greenhouse gases (GHGs) prevents radiative nighttime cooling of the earth.This climate change effect will also be exacerbated in cities by the “urban heat island effect,” which involves the nighttime release of heat stored during the day in cement and metal urban materials. Heat-wave-related mortality is greatest among infants and the very old persons, especially those with underlying diseases.The highest risk among these groups is associated with urban isolation and lack of access to air conditioning. [33]

At the other extreme, overexposure to cold temperatures leads to frostbite and death, as the body is unable to generate enough heat to maintain normal physiologic functions.

Some authors have concluded that change in climate is unlikely to affect the infectious diseases that peak in the winter (e.g., influenza), therefore little improvement in wintertime mortality is likely with a warming climate (Kalkstein, 1993).The true burden of heat-related mortality could decrease over time in a setting of climate change should social factors relieve isolation of the urban poor and provide greater access to cooled environments and should the decrease in cardiovascular mortality with warmer winters prove to be significant.

Alternatively, the burden from heat waves could be greater than predicted if availability of cooled environments should decrease for any reason. It should be noted that with current air-conditioning technology, creating cooled environments will have high economic and environmental costs, as air conditioners require significant consumption of energy that, in turn, results in more global warming.The true burden of temperature extremes will also be affected by future climate variability. Sustained warmth will tend to acclimate a given population to heat stress and lessen cold-induced cardiovascular stress, whereas more variable and intense temperatures will increase physiologic stress and associated mortality.Extreme weather events such as severe storms, floods, and hurricanes, have short and long-term effects on human health. [33]

Extensive precipitation producing floods, avalanches, or mudslides, and intense wind from hurricanes can cause immediate injury and death. Wind, flooding, or drought can also produce longer lasting and further reaching impacts on housing, food production, drinking water, and social infrastructure, which can result in infectious diseases and economic disruption. [33]

Most deaths related to storms have been the result of either drownings in motor vehicles or accidental electrocutions.Populations at risk from extreme weather events include those living in coastal and other vulnerable zones (e.g., flood zones).

Global CC may affect human health by changing levels of air pollutants and pollens. Climate conditions interact with air pollutants in a variety of ways. For example, air inversions in stagnant high-pressure systems are associated with the highest levels of particulates, ozone, and heat waves are usually marked by high humidity and elevated levels of these same air pollutants. Warmer weather may enhance dispersion of fungal spores and pollen, which may increase allergic reactions and asthma. At the same time, increased winds and precipitation generally reduce airborne pollutants, including pollens, through dispersion or adsorption to water droplets. [33]

High temperatures may affect health through mechanisms besides heat alone as susceptibility to increased ozone concentrations will also affect the morbidity and mortality associated with a heat wave.

Rising seas accelerated by global warming may adversely affect human health. Sea level is predicted to rise 0.2 to 0.9 meters by 2100 (Wigley, 1999). This rise in sea level will be experienced both as a gradual shift in the shoreline and as increasingly severe storm surges and damage from coastal storms (Neumann et al., 2000). These changes will threaten coastal low-lying regions to varying degrees. Because different regions are already rising or falling because of movement of the earth 's crust, the actual relative change in sea level will vary in these different regions.Sea-level rise may affect human health through saltwater intrusion into freshwater drinking supplies, damage to estuarine ecosystems that are essential for filtering wastes and/or providing breeding grounds for marine animals, and displacement of coastal communities. Higher sea levels may also lead to greater storm surges and destructive impacts of coastal storms (Neumann et al., 2000). There are also water-borne diseases and of emerging infectious diseases such as hantavirus, Ebola hemorrhagic fever, and West Nile virus. [33]

CC has raised concerns about bacterial contamination of food. Food-borne infections generally are more common in the warm summer months. Higher ambient temperatures are likely to increase risk of bacterial growth sufficient to cause human infection.

Climate and weather affect the distribution and risk of many vector-borne diseases, such as malaria, Rift Valley fever, plague, and dengue fever. For example,diseases caused by mosquitoes (mosquito-borne diseases). Mosquitoes are very sensitive to climate variability. Such diseases can affect human health. [33]

Figure 15, shows a combination of all the above information by using a conceptual diagram illustrating the exposure pathways by which climate changeaffects human health. [35]

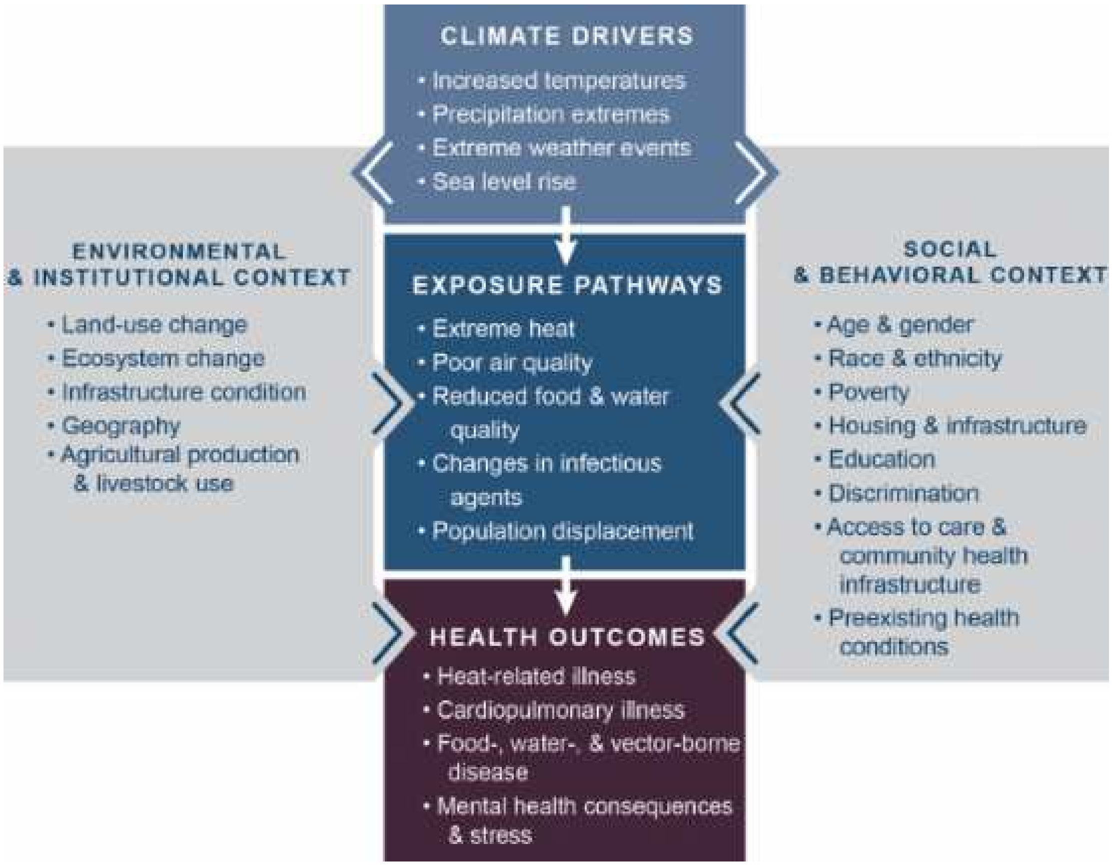

Figure 15: Exposure Pathways Diagram by which Climate ChangeAffects Human Health. [35]

Weather can affect the comfort, health and safety of employees. For example, hot weather can lead to high indoor temperatures and thermal discomfort and high winds can lead to safety issues on site, such as working at height or damage to buildings, infrastructures or even equipment.People who work around chemicals often need to wear personal protective equipment (PPE), which can exacerbate heat related issues.[31]

Table29, shows some example impacts in Healthcare & Public Health Sector (H&PHS) due to CC:

• High indoor temperatures lead to thermal discomfort and related building services issues.
• People's performance drops due to conditions of thermal discomfort, especially those in PPE.
• More complaints from staff.
• Inclement weather makes working outdoors unpleasant.
• Working in high temperatures can lead to heat stress and time off.

• High winds cause safety issues on site (too dangerous to work at height)
• Drivers are more at risk during bad weather.
• Unmanaged health risks could lead to industrial action.
• Lightning strike to a person causes injury or death.
• Lightning strike contributes to a fire.
• Staff absence due to school closures.
• Impacts on staff well-being and disruption to work attendance due to flooding or damage to own properties.

Table 29: Example Impacts in Healthcare &Public Health Sector due to Climate Change [31]

3.12.1 The role of the Health Sector

CC is already presenting risks to health, and these will continue in the future. However, much of the potential health burdens of climate change, at least for the next 2-3 decades, can be avoided, through acting on the environmental and social determinants of climate-sensitive diseases,strengthening the climate resilience of both preventive and curative aspects of health systems, and adapting to changing climate conditions.

The health sector has the pivotal role in protecting the health and wellbeing of populations from the impacts of climate change. This includes both the preventive and curative functions that are under direct control of the formal health sector, as well as the leadership, guidance and regulatory roles that it can play with regard to health-determining sectors, such as water resources, emergency planning or agriculture. The health sector contributes to protection from climate risks both through its overall capacities, and also through its ability to adjust and adapt these services to changes in climate, and in other determinants of health. [34]

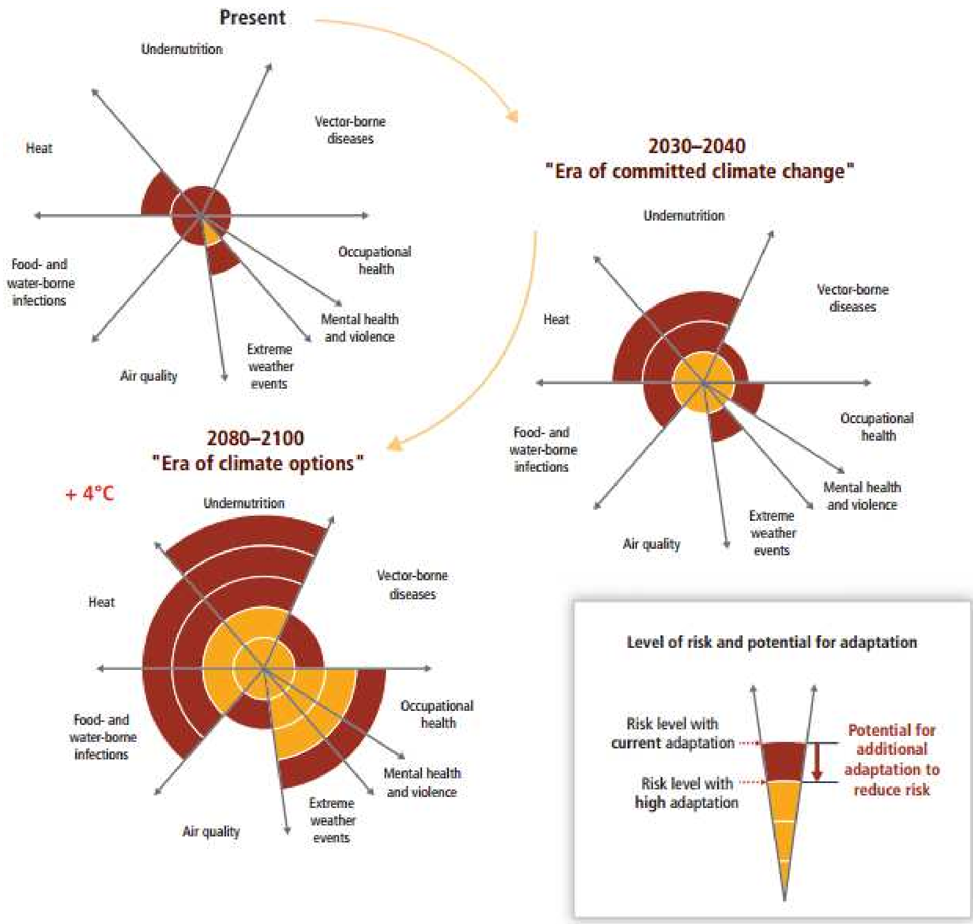

Figure 16: Qualitative Assessment of the Health Impacts from CC, with and without Adaptation [34]

Figure 16, presents a conceptual presentation of health risks from CC and the possibility of reducing risks through adaptation. The risks are identified in eight categories related to health.The width of the pieces shows in a qualitative way relative importance in terms of the burden of poor health worldwide at present.Risk levels are assessed for the current and for the short-term CC (here, for 2030-2040).For some categories, for example, vector-borne diseases, heat / cold, agricultural production and malnutrition, there may be health benefits in some areas, but the net impact is expected to be negative.

Risk levels are also present for the long-term climate option (here, for 2080-2100) for a global average temperature increase of 4 ° C above the pre-industrial levels.For each timetable, the risk levels for the current adjustment state and for a hypothetical high-fit condition, which is indicated by different colors, are calculated. [34]

In summary, table30 presents the most significant threats to the Healthcare and Public Health Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
					X	X		

Table 30: Healthcare and Public Health Sector Most Important Threats

3.13 Information Technology Sector

The Information Technology Sector (ITS) is very crucial to the security, economy, and public health and safety. Businesses, governments (entire countries), academia, and private citizens are more and more dependent upon ITS functions. These functions (virtual and distributed) produce and provide hardware, software, and IT systems and services, and in collaboration with the CommS the whole internet (see Chapter 3.3 CommS). The ITS has a complex and dynamic environment which in turn makes it difficult to identify the threats and assessing vulnerabilities. It should be considered that these tasks must be addressed in a collaborative and creative fashion. It is very important that ITS functions are operated by a combination of entities that maintain and reconstitute the "network", including the "internet". [46]
The impacts of CC on the ITS can be the result of both acutemanifestations (e.g. short-term extreme events such as cyclones and intense rainfall and flooding) and chronic trends (changes in temperature with the passage of time, seasonality, etc.), which affect ITS operations, logistics and supply chains in a variety of ways. For example, extreme climatic shocks, such as the 2011 floods in Thailand, have the potential to reduce the growth domestic product (GDP) of a country by several percent, decimate jobs, and ultimately disrupt thesupply chains of the ITS, among other disruptive effects.

From the impacts of climatic disruptions on the supply of raw materials and the availability and safety of industry personnel, to the degradation of IT networks and infrastructure, CC can potentially undermine the availability, reliability and quality of ICT services, ultimately affecting business costs. However, CC impacts also have the potential to create new market opportunities and to generate cost reductions, and can act as drivers of sectoral innovation and change. [38]

The ITS sector has evolved over the past century to operate over a range of environmental conditions including tolerance to extreme weather events. Much of this has been done using historic climate records for the region in which the ICT will operate, without consideration of CC. It is known that devices are designed to operate within specified ranges of climate circumstances (temperature, humidity, etc.). [38]

When devices operate outside their specified environmental conditions, they are at risk of failure. Failure can also occur due to wear-out or ageing mechanisms, such as electro-migration. Electronic devices generally have a design lifetime in the range of 2-13 years. Failure of a component generally results in maintenance work to replace the failed item. However, some parts of the network are designed to cope with failure of a single component, after which the system continues to operate but an alarm signal is sent to indicate that remedial work is needed. Resilience is built-in by replicating parts of the network so that alternative paths can be brought into use. [38]

The IT sector includes infrastructure such as: outside plants, data centers, base stations and user terminals including handsets. Most electronic devices are well protected from the weather and are in benign environments such as buildings which are safe for human occupation. Every component used in ITS is specified to operate within agreed environmental limits. Separate temperature ranges are specified for use in commercial buildings, industrial buildings, military applications and aerospace. [38]

Electronic devices are normally adequately protected from the weather and are designed to operate over the design life within specified environmental limits. An electrical system, with no redundancy, fails when any one component in the transmission path fails. This may be estimated by summing the failure rate of the individual components which is typically of the order of 1 failure in 10 billion (10^9) hours (1 FIT). A system of 1000 components, each with a reliability of 1 FIT, would therefore be expected to fail once in approximately 100 years. [38]

CC threats focusses on non-manmade incidents, caused by biological, geological, seismic, hydrologic, or meteorological conditions or processes in the natural environment. It uses existing measurement scales from recognized organizations (World Meteorological Organization "WMO", etc.) to identify and measure the severity and also the likelihood of natural threats that affect the critical ITS functions and sub functions. [45]

Table 31, shows some example impacts in ITS due to climate change:

• Devices are designed to operate within specified ranges of climate circumstances (temperature, humidity, etc.).
• In an earthquake or flood event, if there is no existence of routing diversity telephone lines or insufficient alternate switching infrastructures, then the providers may be unable to quickly recover and the service that they provide will be unavailable for a long period of time for the citizens' population.
• Extreme events can limit the access of industry workers to conduct repairs or restore operations, affecting the rapidity of the sector's response to climatic shocks (i.e. the speed at which assets are accessed or mobilized).
• Ground heave could affect buried cables.
• Changes in wind speed or direction could have implications for the launching and stability of high altitude communications platforms.
• Severe weather events can disrupt the international shipment of ICT components and materials in affected areas, contributing to undermine the scale at which the sectors" supply chain operates, and potentially, its ability to maintain its performance (i.e. robustness).
• Changes in vegetation density or building design (e.g. silvered windows) could disrupt wireless communication.
• Humidity could increase tropospheric scintillation and interference.
• Solar storms have a potential impact on satellite communications, though these are not a consequence of climate change.
• Severe weather causes loss of utilities (e.g. power, communications, steam, compressed gasses).
• Costs/ operational difficulties caused by underground pipelines being damaged due to expansion.
• Electrical storm causes power surge taking out power supplies, control systems and communications systems.

Table 31: Example Impacts in Information Technology Sector due to Climate Change

3.13.1ITS Interdependencies with other sectors

Figure 17, depicts ITS Interdependencies with other sectors.

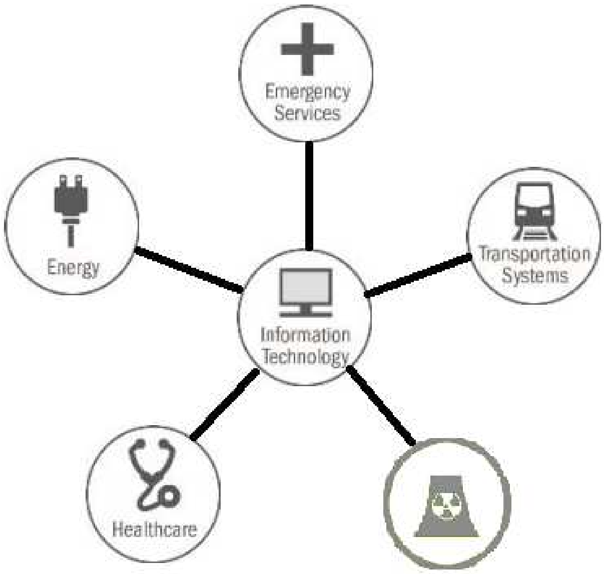

Figure 17: Information Technology Sector Interdependencies with Other Sectors

Emergency Services Sector

The ITS plays a key role in the functioning of ESS. For example, if the ESS infrastructures exist in a geographic area that is known for natural disasters taking into place (such earthquakes or floods) with no existence of routing diversity telephone lines or insufficient alternate switching infrastructures, then the providers may be unable to quickly recover from such an event and the service that they provide will be unavailable for a long period of time for the citizens' population.(see Chapter 3.7ESS).

Energy Sector

ITS is crucial in promoting global energy productiveness and combating CC.IT systems control critical processes, manage day-to-day operations, and store sensitive information in the Energy Sector.An information technology failure caused by the CC, could lead to energy loss, or even plunge into darkness entire cities (see Chapter 3.8ES).

Healthcare and Public HealthSector

The development of enhanced information technology and its use in hospitals, individual provider practices, and other segments of the health care delivery system are essential for the quality and aspect of care and its improvement. Better IT systems can also support patients and family caregivers in crucial health decisions, strengthen both personal and population-based prevention efforts, and enhance participation in and coordination with public health activities. (see Chapter 3.12H&PHS).

Nuclear Reactors, Materials and WasteSector

IT systems control critical processes, manage day-to-day operations, and store sensitive information in the Nuclear Sector. The Nuclear Sector and its industry and government partners also use IT services to facilitate information sharing and dissemination of security and threat data. In case of a disaster event that ITS will be out of order, the NRM&WS will be unmanaged and public safety will be in danger (see Chapter 3.14NRM&WS). [44]

Transportation SystemsSector

According to Nigel Wilson, (*Professor of Civil and Environmental Engineering*), "Improving performance of computers and communications technologies are now starting to have a significant impact on the urban public transport industry. Automatic data collection systems including automatic vehicle location systems, automatic passenger counting systems, advanced passenger information systems and electronic fare payment and ticketing systems are becoming ubiquitous in large systems and are having an impact on the quality and availability of information for service and operations planning, controlling the service and measuring the resultant service quality delivered to passengers." [47]

The malfunctioning of IT systems (due to CC) associated with the TSS, could lead to non-availability of services. (see Chapter 3.15TSS).

In summary, table32 presents the most significant threats to the Information Technology Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X					X	X	X	

Table 32: Information Technology Sector Most Important Threats

3.14 Nuclear Reactors, Materials and Waste Sector

The Nuclear Reactors, Materials and Waste Sector (NRM&WS) mitigates against a well-defined profile of risks to nuclear material from accidents, attacks, and malevolent or inadvertent misuse. However, several emerging issues have the potential to sharpen sector risks.CC and increasingly severe natural disasters increase risks for nuclear power plants, many of which are operating with aging equipment. On March 2011, an earthquake and after that a tsunami, caused an unforeseen disaster. Japan's Fukushima-Daiichi nuclear power plant had been triple meltdown.[44]

The NRM&WS also heavily relies on a limited and highly international supply chain. A fast-shrinking number of international medicinal isotope suppliers could create significant shortages in the medical community. [44]

CC may bring more extreme weather, reduced water tables, increasing droughts, and greater earthquake threats. It also can bring about changes in water chemistry and biota that can affect nuclear power plant operations. Droughts can decrease the water levels in rivers (lakes, canals, etc.), that provide cooling water for nuclear power plants. Some nuclear power plants have had to shut down temporarily during drought conditions because the water level was below cooling water intake pipes, the water temperature exceeded allowable temperatures for cooling water intake, or water had become so brackish or algae-laden that it would have clogged cooling system equipment. Major storms, earthquakes, and tsunamis can severely damage critical operating and emergency equipment. These risks must be taken into consideration during the construction and preservation / maintenance of each facility. [44]

Because of the highly-specialized design of nuclear power plants, design or construction flaws that are not discovered in advance can jeopardize plant operations. Past issues have included generators that fail after only a few years, structural damage due to construction, and corrosion. Many of the above could be caused from earthquakes. Quality control systems for components from international suppliers should be a part of plant operations. [44]

Table 33, shows some example impacts in NRM&WS due to climate change:

• Droughts can decrease the water levels in rivers (lakes, canals, etc.), that provide cooling water for nuclear power plants.
• Major storms, earthquakes, and tsunamis can severely damage critical operating and emergency equipment.
• If the water level is below cooling water intake pipes, the water temperature exceeds allowable temperatures for cooling water intake, or water may become so brackish or algae-laden that it could clog cooling system equipment.
• A water shortage or change in the temperature or chemistry could significantly hinder and, in some circumstances, stop operations at nuclear power plants.
• A disruption in the supply of fuel, caused by natural disasters depending on its duration, could affect operations.
• If the sector fails because of a catastrophic event (such as an earthquake), will put public safety in danger.

Table 33: Example Impacts in Nuclear Reactors, Materials and Waste Sector due to Climate Change [44]

3.14.1NRM&WS Interdependencies with other sectors

Figure 18, depicts NRM&WS Interdependencies with other sectors.

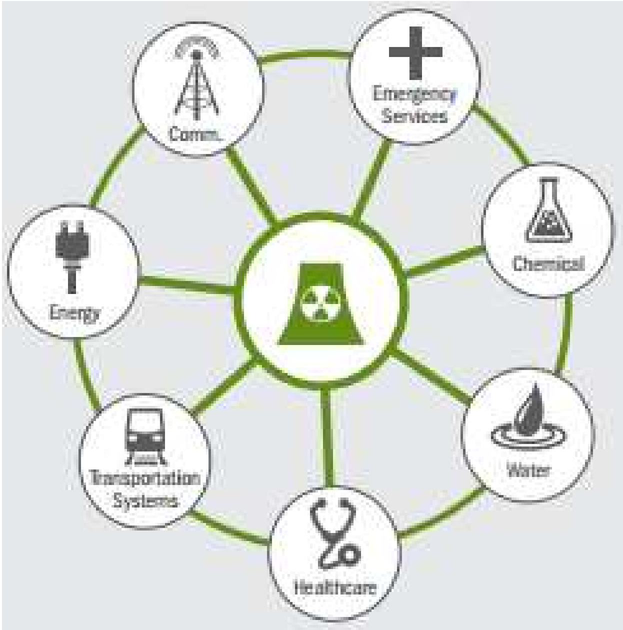

Figure 18: Nuclear Reactors, Materials &Waste Sector Interdependencies with Other Sectors [44]

Chemical Sector

NRM&WS is interdependentwith CS as a consumer of chemicals through the nuclear fuel cycle and at reactor sites. The principal hazard to public health and safety during an accident at a fuel cycle facility (such as flood) would be from the release of onsite chemicals. Chemicals are used daily in the production of electricity at commercial power plants(see Chapter 3.1 CS). [44]

Communications Sector

Communications - both onsite and with critical public and private partners - are essential during an emergency to ensure effective response and maintain public safety. If that sector fails because of a catastrophic event (such as an earthquake), will put public safety in danger. Nuclear facilities rely on uninterrupted Internet and communications networks for both efficient operations and timely information sharing (see Chapter 3.3 CommS). [44]

Critical Manufacturing Sector

The Nuclear Sector relies on the Critical Manufacturing Sector for a wide range of key plant components including piping, valves and valve components, electrical cables, etc. Some large, highly specialized components, are available only from overseas suppliers (see Chapter 3.4CMS).[44]

Emergency Services Sector

ESS responders have defined roles to play in any emergency involving a nuclear facility or radioactive materials. Events that may require emergency services include loss or theft of radioactive materials or sources, contaminated air or water releases from a nuclear facility, fires, breaches of the security perimeter, laboratory or test facility accidents, transportation accidents involving nuclear materials, and major nuclear accidents or malicious acts that require evacuation and long-term decontamination(see Chapter 3.7 ESS). [44]

Energy Sector

Nuclear facilities both supply electricity to the grid and depend heavily on uninterrupted power for continuous safe operation. Nuclear power plants employ multiple backup generation systems and adhere to detailed regulations governing safe shutdown in the event of long-term local grid failure and loss of those power backup generation systems.Grid interdependencies have become a higher priority post-Fukushima, where the extended loss of AC power threatened core cooling and containment integrity. The Oil and Natural Gas Subsector also relies on nuclear materials and byproducts for good logging, a process used in oil and gas exploration.(see Chapter 3.8ES). [44]

Healthcare and Public Health Sector

NRM&WS is interdependentwith H&PHS as a supplier of nuclear medicine, radiopharmaceuticals, and in the sterilization of blood and surgical supplies. Radioactive materials support multiple medical applications to monitor, image, or treat metabolic processes or tissues in humans. In turn, the Nuclear Sector relies on healthcare to ensure workforce health and safety against pandemic diseases.(see Chapter 3.12H&PHS). [44]

Transportation Systems Sector

NRM&WS is interdependentwith TSS through the movement of radioactive materials. All nuclear facilities rely heavily on international suppliers for key replacement components and critical systems, such as software, training simulators, etc. Some components, such as heavy forgings for reactor vessels, are only available from one or a very limited number of overseas suppliers. Nuclear facilities are also dependent on supply chains for the transport of uranium from mills and other fuel cycle facilities and medical isotope supplies. A disruption in the supply of fuel, caused by natural disasters depending on its duration, could affect operations. (see Chapter 3.15 TSS).[44]

Water and Wastewater Systems Sector

NRM&WS is interdependentwith W&WSSthrough the need of water supply. Nuclear power plants use large quantities of water for cooling. In more details, they use once-through cooling, in which large quantities of water are withdrawn from a large river, lake, or the ocean; treated; and used to cool the secondary steam circuit before being returned to the source. Water used to cool the reactor core itself is contained in a closed loop and never released to the environment in other than accident conditions. A water shortage or change in the temperature or chemistry could significantly hinder and, in some circumstances, stop operations at nuclear power plants (see Chapter 3.16W&WSS).[44]

In summary, table34 presents the most significant threats to the Nuclear Reactors, Materials and Waste Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
	X		X		X			X

Table 34: Nuclear Reactors, Materials and Waste Sector Most Important Threats

3.15 Transportation Systems Sector

Natural disasters; that can be caused from the CC, are threats to Transportation Systems Sector (TSS) disciplines and their infrastructure. Some of those could be really hot summers, floods and extreme precipitation events, storms and sea level rise.They typically affect specific geographic locations or regions and cause serious and immediate impacts on transport modes and system components.

Because of the fact of CC, such impacts should be anticipated in future infrastructure design and maintenance. Otherwise, it could lead in acceleration of their deterioration, traffic interruption and severe damages. All the above impacts would also affect economic activities.

The transport of passengers and goods depend on a very complex network of land based, air and maritime infrastructures and connections. For the above reason, there is the mandatory need to limit the impacts and damage effects being caused from natural disasters. This must be the key factor for future construction designs.

Table 35, shows some of the potential impacts on Transportation Systems Sector (TSS).

Climate Impact	Overview of potential impact on Transportation Systems
Increased Summer Temperatures	Asphalt rutting, rail track buckling, change in required airport runway length, low water levels for navigation, thermal expansion of bridges, overheating of diesel engine
Increased Winter Temperatures	Increasing constraints and maintenance for roads and railways
Increased Precipitation and floodings	Embankment collapse, bridge scour, flooding of underground transit systems. Flooding of land transport infrastructures, wet pavements and safety risks for citizens. More frequent slush flow avalanches, landslides and associated risks.
Increased and more frequent extreme winds	Damage to infrastructure on roads, railways, pipelines, seaports, airports Cable bridges, signs, overhead cables, railroad signals, tall structures, reduced safety for vehicles driving
Sea Level Rise and sea storm surges	Erosion of coastal highways, higher tides at ports / harbor facilities, bridge corrosions, low level aviation infrastructure
Change in frequency of Winter Storms	Less or more snow / ice for all modes
Permafrost degradation and thawing	Serious damage and failures on road, rail and airport infrastructures
Reduced Arctic sea ice Cover	Reduced ice loading on the road structures
Earlier River Ice Breakup	Flooding risk

Table 35: Transportation Systems Sector - Potential Impacts due to Climate Change [25, 26]

Transport services have also to be managed to reduce as much as possible disruption and maintain minimum safety standard in case of adverse weather conditions. Analyzing, in a quantitative way, the current vulnerability of transport to extreme weather conditions in Europe is not a straightforward task. While countries such as New-Zealand and US tend to maintain centralized information systems on this field, this is mostly missing at a European level, and even not at national level.

In Europe, the FP7-ENVIRONMENT project [26] has been a first attempt to estimate cost induced to transport by extreme weather events. In the case of road, the estimates were based on media reports on damages and transport disruption events associated with adverse weather conditions. However, only a limited number of countries (United Kingdom, Austria, Czech Republic, Germany, Italy, and Switzerland) could be considered. Based on data from literature, the information was then further transformed into cost estimates, accidents, transport delays and derived costs were generalized to Europe by using scaling factors based on demographic parameters and climate indices. Similar efforts for the other modes were also conducted, resulting in more fragmented information.

Damages to infrastructure assets and user operations (delays) constitute the most frequently reported incidents. Rainfalls (partly including local flooding) and storms (including storm surges) are the most relevant problem in road transport.

Table15, shows how much the extreme weather events affect the TSS and what is the estimated cost.

	Road	Rail	Maritime	Intermodal	IWW	Air	Total	%
Storm	174	3	20	1		155	354	15.7%
Winter	759	52		0		147	959	42.5%
Flood	822			0	5	60	886	39.3%
Avalanche		6					6	0.2%
Heat & Drought	50						50	2.2%
Total	1805	61	20	2	5	362	2254	
%	80.1%	2.7%	0.9%	0.1%	0.2%	16.0%		

Table 36: Transportation Systems Sector - Extreme Weather Events and Estimated Cost (FP7-ENVIRONMENT project) [26]

The total estimated cost is 2.25 billion €/year, of which impacts on road transport represent 80% (1.805 billion €/year). The impacts are dominated by rainfalls/floods (39%) and winter conditions (46%). Storms represent the third impact. For road transport, impacts are dominated by damages to infrastructures (~80%), followed by transport user costs (11%). Again, these impacts are mainly due to winter conditions (42%) and floods (45%). [25]

Table 16, shows some example impacts in TSS due to climate change:

• Disrupted in-coming and outbound deliveries due to blocked roads or difficulties at ports.
• Emergency services unable to access the site or are not available because of all the demands that are being placed upon them.
• Key staff not able to get to work.
• Increase in accidents on the roads because of bad weather.

Table 37: Example Impacts in Transportation Systems Sector due to Climate Change [31]

Earthquakes can sever telephone circuits that are buried in the ground, drop telephone poles, cause damage to airplane runways, drop the control tower of the airport, or even knock down entire buildings.

If a hardening of the infrastructure facilities haven't been taken in place to face those natural disasters, or the infrastructures exist in a geographic area that is known for natural disasters taking into place (such earthquakes or floods) with no existence of disaster recovery sites for the main infrastructure (computer room, control tower) or alternate airplane runways, then the airport service may be unable to quickly recover from such an event and the service that they provide will be unavailable for a long period of time for the citizens population.

Citizens that are in need of use from one the disciplines that Transportation System Sector provides, demand the operational existence of those services. Although there might be alarms, emergency exits in the buildings, specific points to meet in case of a disaster, the need of a functional airport is crucial. For them, the ability to travel with safety is tied to the functionality of the airport infrastructures.

In case of such a disaster, people that happen to be in the airport facilities will be in panic. They will need help and clear instructions of what to do in order to not to get injured. If someone imagines how many people remain in the airport facilities in order to travel or to peek someone else, then it is easy to understand the significance of airport infrastructures. There must be specific disaster recovery plans in order to recover in case of any of those disasters. For example, if the control tower gets nonoperational there must be another one to take the control of the airplanes that are going to arrive to the airport or going to depart. Otherwise lots of human lives will be in danger.

Another example is the computer room that controls all the main computer systems of the airport facilities. If it will get destroyed serious problems may occur. The physical access on main rooms may be out of service for the personel of the airport, passengers control list will not work and machines that check airplanes functionality or passenger's suitcases will not be in operational mode.

The railway stations and trains are responsible for transferring passengers, baggage, accompanied cars, express parcels and goods.Their infrastructure includes complex rail networks, aboveground or underground, boarding stations, storage and IT infrastructure areas to check the proper functioning of the above.Natural disasters such as earthquakes, land shifting, floodings, tornados and hurricanes can cause major damage to railway infrastructure. They can flood facilities, destroy railway lines, endanger the lives of people traveling in a wagon and in addition cause great economic damage.

Once more, safety issues are on the top. Imagine an underground train station full of people at the moment of an earthquake. If the station facilities do not have adequate architectural design to withstand in the event of an earthquake, then there is great risk that there are human losses and the station to be buried in the ground.

Another example of the criticality of the railway station services is the case of the destruction of the IT infrastructure that manages the operation and movement of trains. In such a case, trains could be caged in underground galleries and people that travel with them would be doomed to wait for hours for the rescuers. A collision accident between two trains could also happen, as the central control system will not work.In any case, there would be very long delays, which would cost money.

Because these services are very important, they should be protected from the weather and climate change. Alternate rail paths for the trains in case of a disaster in a critical one, business continuity and disaster recovery plans to be followed in case of any disaster, maintenance plans for the infrastructures, simulationtests for the employee's education and preparedness, and disaster recovery sites for the IT infrastructure; are some of the measures that can be used in order to protect human lives and minimize the damage and loss of money.

In summary, table38 presents the most significant threats to the Transportation Systems Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X	X	X	X	X	X		X	X

Table 38: Transportation Systems Sector Most Important Threats

3.16 Water and Wastewater Systems Sector

CC impacts especially on engineering infrastructures are increasing. Those infrastructures are expected to withstand more severe and frequent weather events, climate alterability, and changes in climate norms.It is anticipated that many water and wastewater infrastructure systems such as storm drainage, will fail to meet the expected environmental pressures.For this reason, it is very important to know the risks that this would entail, and then to design an effective maintenance plan and to develop strategies to reduce to a minimum the risks.[27]

The challenges related to climate change and cities in regard to the water supply and wastewater treatment sector are very big, and they depend on geography, economics, administrative capacity, and demography. Many of the challenges are general, and some are getting more specific to particular cities. [29]

Water and Wastewater Systems Sector (W&WSS) in urban areas is vulnerable to direct impacts of climate changes. Some of them are, increased temperatures and related evapotranspiration rates, changes in the amount and strain of precipitation, changes in the strain and timing of storm runoff, changes in both indoor and outdoor water demands, and, in coastal cities, the sea level rise and the phenomenon of storm surges.

There are also vulnerabilities that apply also to highly developed supply and treatment infrastructure and to less engineered and informal water supply and treatment systems. They are both issues of quantity and quality.

Warmer temperatures can also indirectly cause more serious weather conditions compounded by urban heat islands. That could, in turn, result in additional thunderstorms, hail, cyclonic events and hurricanes, and very strong winds that may exceed the design capacity of the current infrastructure.

Urban W&WSS is also vulnerable to climate change through less direct lines of connection. For example, warming trends may lead to increased demands for power production that, in turn, require power-plant cooling waters in competition with other water uses. Increased water demands associated with reduced precipitation and runoff in some areas, may lead to dependence on overdrafts from groundwater resources, land subsidence, and seawater intrusion.

Another issue is increased overdraft and lower groundwater levels. This canreduce or imperil the ability of wells to supply water without good additional actions (retrofits) such as lowering pumps and deepening wells.

Finally, land subsidence is another thing that is important to have in mind. That can contribute to increased flooding as well as ruin of infrastructure, resulting in additional leak and reduced efficiency of water distribution systems. The above examples show the complex connections and interdependencies that make essentially the water and wastewater systems sector vulnerable to climate change at some level.

Those climate vulnerabilities and threats have as a result a wide range of contingent climate impacts on urban water systems. CC and related increased climate alterability threaten urban water and wastewater infrastructures with disruption of service, reduced storage for potential emergencies, reduced water quality, and increased energy costs for operation and maintenance, at local and regional scales (see Chapter 3.8 ES, and Chapter 3.12 H&PHS).

The degradation of materials and structures in important urban water and wastewater infrastructures will be accelerated with warmer temperatures caused by increasing greenhouse gas.Increased air temperatures may have as result the chemical and biological degradation of water quality. For example, growth of bacteria, algae, increased solubility and pollutant concentrations. Moreover, they will lead to higher evaporation rates, which will increase the irrigation requirements as well as the highest human consumption. Finally, can lead to a reduction of the available levels in tanks or ponds which may in turn lead to the relocation of water intake pipes from lakes or reservoirs. [29]

The runoff and pipe flow are calculated to identify the rainfall conditions that experienced by the pipe at its full flow state. Any excess flow or derbies, such as tree branches and rocks that are carried by the flow, will increase the probability of pipe failure. [27]

Figure 19: Wastewater in Open Gutter &Water Supply Pipeline [27]

Heavy rainfall often leads to flooding of roads, underground and sewer and further causes the runoff of rainwater. Although in most parts of the world, the average rainfall either increases or decreases because of climate change, expected more intense storms. The most intense storms will lead to generalized sewer overflow events, which depending on the city may contaminate coastal roads or other water bodies. In addition will increase the sediment load in rivers and reservoirs which will cause further decline of water quality used for irrigation. Even they can cause more soil erosion and flooding which could cause damage to infrastructure such as bridges and embankments.

The temporal distribution of rainfall can change, causing further problems. For example, frequent and intense drought can affect the tanks and underground water tanks and the registration systems for rainwater. The reduction in rainfall may also lead to lower recharges. It will also help to increase the pumping costs. This is due to the deeper levels of groundwater. It will also contribute to increasing conflicts about water-related usage rights streams etc.

Reduced snow will result in lowering the water storage (through snow) which is necessary for water in some cities. There will be a change in the temporal flow patterns in tanks and supply systems. Such a reduction would require more storage structures so that there is the offer according to demand periods.

In the case of rising sea levels, the sea water will invade the coastal surface waters and springs, groundwater and affect ecosystems. More specifically, it will lead to higher pressures ocean underwater which in turn will lead to further penetration of seawater into coastal aquifers. Moreover, it will increase the probability of flooding of sewers and pollution control installations of wastewater and gravity will reduce the ability absorbance of wastewater due to overflow of sewage.

High storm levels, leading to flooding of roads, underground and sewer.Higher sea levels, when flood affected areas (brownfields) can cause the release of pollutants that are harmful to health and ecosystems. Moreover, they may flood wetlands and threaten the stability of canals and levees systems, which can affect the water supply, water quality and cause flooding. Finally, the rise in sea levels will lead to decreased sediment transport, and may require increased dredging in dams, additional reservoirs, canalization, filling areas include wetlands and strengthening dykes and embankments.

All these threats can in turn lead to further challenges. For example, reduced physical storage of water supplies due to reduced ice, loss saw inflow in reservoirs due to increased drought, reducing the diversion flows during droughts, and increased runoff preventing adequate water quality for water supply needs.

Because of climate change, affecting the underground aquifers that supply water to cities by seawater intrusion, land subsidence and capture pollutants. Even if not all aquifers are directly affected by climate change, the flow of water which have deteriorated between the various parts of the aquifer, drilling as well as the use of wells, can make serious damage to the ecosystem. Furthermore, climate change may increase the need to use distribution pipeline systems in the surface of the water, rather than coastal water pumping pipeline systems; to be protected against seawater intrusion into fresh water reservoirs.

Due to the reduction of reserves in underground supply basins would create problems in urban water supplies or even functionality issues to companies marketing water. Imports, exports, competition, transportation costs from remote areas that do not encounter problems, etc. These problems may be regional scale. [29]

The challenges, considerations, responsibilities, and processes of engineer's incoping with Climate Changes have been identified. The responsibilities ofengineers are growing in terms of providing appropriate and adequate infrastructure engineering. Innovative design and development will ensure that infrastructure failure is minimized or reduced.

The CC is one of the most important global issues that world has to face today. These changes are affecting engineering infrastructure, one of the most vital sectors to human life and work. The W&WSS is an important part of that engineering infrastructure. Indeed, it is the first defense line in protecting urbanized cities from the risk of flood and inundation. For this reason, city councils and local authorities need to pay greater attention to this essential infrastructure sector. For example, storm drainage exists under roads, and so when storm drainage failure occurs the road, infrastructure will be at risk. In other instances, it could be bridges and building foundations at risk. As a consequence, both public and private sector costs rise. [28]

Water is a vital commodity. Therefore, it is very important to see how climate change affects critical infrastructures. The impacts caused by climate change to W&WSS affect other critical infrastructures, as well as impacts caused by climate change to other critical infrastructures affect W&WSS. This is a two-way trust relationship.[29]

Table 39, shows some example impacts in W&WSSdue to climate change:

• The capacity of sewerages may be affected by intense rainfalls, as well as industrialinstallations containing dangerous materials.
• Warming trends may lead to increased demands for power production that, in turn, require power-plant cooling waters in competition with other water uses.
• Increased water demands associated with reduced precipitation and runoff

	in some areas, may lead to dependence on overdrafts from groundwater resources, land subsidence, and seawater intrusion.
•	Increased overdraft and lower groundwater levels, canreduce or imperil the ability of wells to supply water without good additional actions (retrofits) such as lowering pumps and deepening wells.
•	Increased flooding as well as ruin of infrastructure, resultin additional leak and reduced efficiency of water distribution systems.
•	Increased air temperatures may have as result the chemical and biological degradation of water quality.
•	The degradation of materials and structures in important urban water and wastewater infrastructures will be accelerated with warmer temperatures caused by increasing greenhouse gas.
•	In heavy rainfall conditions, any excess flow or derbies, such as tree branches and rocks that are carried by the flow, will increase the probability of pipe failure
•	Frequent and intense drought can affect the tanks and underground water tanks and the registration systems for rainwater.
•	Heavy rainfall often leads to flooding of roads, underground and sewer and further causes the runoff of rainwater.
•	Reduced snow will result in lowering the water storage (through snow) which is necessary for water in some cities.
•	In the case of rising sea levels, the sea water will invade the coastal surface waters and springs, groundwater and affect ecosystems.
•	Higher sea levels, when flood affected areas (brownfields) can cause the release of pollutants that are harmful to health and ecosystems.
•	The reduction in rainfall may also lead to lower recharges.
•	High storm levels, leading to flooding of roads, underground and sewer.
•	The rise in sea levels will lead to decreased sediment transport, and may require increased dredging in dams, additional reservoirs, canalization, filling areas include wetlands and strengthening dykes and embankments.
•	Reduced physical storage of water supplies due to reduced ice.
•	Loss saw inflow in reservoirs due to increased drought.

Table 39: Example Impacts in Water and Wastewater Systems Sector due to Climate Change [29]

3.16.1 Energy relationship with W&WSS

With warming, urban water demand s and uses are likely to increase in many (perhaps most) cities. Future increases in the demand and use of water expected under climate change are likely to result in increased demands for energy (see Chapter 3.8 ES). The supply, treatment, and distribution of water supplies in urban areas require operation of pumps and other mechanical devices with attendant heavy energy use. The wastewater treatment plants operating within or outside urban areas, working with machines and collecting, recycling and discharge of wastewater require pump operation. Where is expected to increase the flow of waste water due to climate change, there must be a forecast on increase of energy demand.[29]

3.16.2 Health relationship with W&WSS

W&WSS has close ties to many of the public health challenges associated with climate change (see Chapter 3.12 H&PHS).Because the drinking water supply shortages in poor countries and emerging markets, can be transmitted diseases pose a significant health risk. Because of climate change, these risks can be exacerbated because of the huge gap between supply and demand on supplies. Moreover, public health is endangered as they are able to increase the geographic areas observed diseases and diseases due to the lack of drinking water allowing the disease to multiply and grow. It is well known that access to drinking water is essential to public health and help fight disease. [29]

3.16.3 Transportation Systems relationship with W&WSS

Water-borne transportation systems that are vital in many cities may be affected by changing climates, sea level rise, and changing stream flow timing and amounts (see Chapter 3.15 TSS). [29]

In summary, table 40 presents the most significant threats to the Water and Wastewater Systems Sector.

Flood	Drought	High temps	Earthquake	Low temps	Wind Storm	Electrical Storm	Fire	Tsunami
X	X	X			X			

Table 40: Water and Wastewater Systems Sector Most Important Threats

CHAPTER V: Conclusions

Climate change is perceived as a threat multiplier for critical infrastructures and has the potential to cause overlapping effects on interconnected assets, systems and functions. Apart from directly recognized and partially quantified direct impact on infrastructure, Climate Change may also bring indirect impact on safety, security and structural integrity of CI sectors.

All the above imply costly impacts in terms of maintenance and repairs; yet many of these impacts can be mitigated and avoided by pro-active adaptation measures. It is a crucial aspect for the protection of current and future CI investment and economic, social and other functions they serve.

Furthermore, interdependencies have become a growing phenomenon across CI sectors as they are not only a point of potential vulnerability but may also compound existing vulnerabilities and carry these vulnerabilities across multiple CI sectors. Given their extensive use, information technology and communications sectors present particularly critical interdependencies with other CI's. Energy infrastructure, water, ICT and transport are also often at interdependence (e.g. power cables installed under roads and next to the communications wires next to water and gas networks, and above sewers), especially in urban areas. Extreme weather phenomena could possibly affect (or upset) over the assets of the infrastructure simultaneously. The interdependencies between both the IT and communications sectors and other infrastructure systems will increase in the near future as society continues to rely on information technology and communications to operate and manage critical infrastructure components.

We must address the challenges of the impact of extreme weather conditions on critical infrastructures and gather the best of current know-how and experience to develop and demonstrate good practices in planning and designing protective measures as well as in the possibilities of crisis response and recovery.

Glossary of Terms

Acronym	Meaning
CC	Climate Change
CI	Critical Infrastructure
CII	Critical Information Infrastructure
CFS	Commercial Facilities Sector
CMS	Critical Manufacturing Sector
CNI	Critical National Infrastructure
COMAH	Control of Major Accident Hazards
CommS	Communications Sector
CR	Credit Risk
CS	Chemical Sector
DS	Dams Sector
DIBS	Defense Industrial Base Sector
EDI	Electronic Document Interchange
ElS	Electricity Subsector
ESS	Emergency Services Sector
ES	Energy Sector
EWE	Extreme Weather Events
FP&S	Financial Products & Services
FSS	Financial Services Sector
F&AS	Food & Agriculture Sector
GDP	Growth Domestic Product
GFS	Government Facilities Sector
GHGs	Greenhouse Gases
H&PHS	Healthcare& Public Health Sector
HVAC	Heating, Ventilation, and Air Conditioning
ICT	Information and Communications Technologies
IP	Internet Protocol
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
ITS	Information Technology Sector
ND	Natural Disaster
NIPP	National Infrastructure Protection Plan
NRM&WS	Nuclear Reactors, Materials & Waste Sector
O&NGS	Oil & Natural Gas Subsector
PPE	Personal Protective Equipment
PSAP	Public Safety Answering Points
RA	Risk Assessment
RM	Risk Management
TSS	Transportation Systems Sector
W&WSS	Water & Wastewater Systems Sector
WP	Weather Patterns

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