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Methodology for gas pipelines critical infrastructure network safety and resilience to climate change analysis

Keywords

energy sector, critical infrastructure (CI), gas pipeline, Baltic Gas Pipeline Critical Infrastructure Network (BGPCIN), climate/weather impact, resilience, taxonomy

Abstract

In the paper we present the gas pipeline network as a critical infrastructure. The basic definitions concerned with gas pipeline critical infrastructure are given. Moreover, the climate and weather change impacts on gas pipeline critical infrastructure safety, resilience and resilience strengthening to climate change are described. Next, the specific notions and terminology in the climate change context for Baltic Gas Pipeline Critical Infrastructure Network (BGPCIN) are described.

1. Introduction

The network of interconnected and interdependent infrastructures located in EU member states that function collaboratively in order to ensure a continuous production flow of essentials, goods and services is defined by *European infrastructure*. According to the European Commission the *critical infrastructure* (CI) is an asset or system which is essential for the maintenance of vital societal functions. The damage to a critical infrastructure, its destruction or disruption by natural disasters, terrorism, criminal activity or malicious behaviour, may have a significant negative impact for the security of the EU and the well-being of its citizens.

There are two sectors of European Critical Infrastructures (ECI) that are included some subsectors [6].

Sector I – energy:
1) electricity (infrastructures and facilities for generation and transmission of electricity in respect of supply electricity),
2) oil (oil production, refining, treatment, storage and transmission by pipelines),
3) gas (gas production, refining, treatment, storage and transmission by pipelines, LNG terminal).

Sector II – transport:
1) road transport,
2) rail transport,
3) air transport,
4) inland waterways transport,
5) ocean and short-sea shipping and ports.

CI are interconnected and supported each other. *CI interconnections* mean CI in mutually direct and indirect connections between themselves. Then the *CI network* is set of interconnected and interdependent critical infrastructures interacting directly and indirectly at various levels of their complexity and operating activity. Consequently, the critical infrastructures are in mutually dependant relationships between themselves interacting at various levels of their complexity that is called *CI interdependence*. There are *inside* and *outside dependencies*. *Inside dependencies* are referred to dependencies within an infrastructure (system) itself i.e. relationship between components and subsystems in a system casing degradation of other components and subsystems and in a consequence causing degradation of a system [34]. On the other hand, *outside dependencies* are referred to dependencies coming from the infrastructure environment (external factors) and relationship between infrastructures. Including degradation of infrastructure's state caused by outside this infrastructure changes e.g. climate changes, changes of infrastructure's functionality, location, government and human decisions (regulations, economic, public policy), also degradation of one infrastructure's state affected or correlated according to the state degradation of other infrastructures (including "loops") [26], [34]. For example the electric power infrastructure requires *natural gas* and petroleum fuels for its generators, road and rail transportation and pipelines to supply fuels to the generators, air transportation for aerial inspection of transmission lines, water for cooling and emissions control, banking and finance for fuel purchases and other financial services, and telecommunications for e-commerce and for monitoring system status and system control systems and energy management systems. On the other hand electric power is the supported infrastructure, and natural gas, oil, transportation, telecommunications, water, and banking and finance are supporting infrastructures [26]. Because of these *dependencies*, *CI network cascading effect* can be observed. It is degrading effect occurring within an infrastructure and between infrastructures in their operating environment, including situations in which one infrastructure causes degradation of another ones, which again causes additional degradation in other infrastructures and in their operating environment.

The gas pipelines network is by definition a critical infrastructure. The effects of the network disruption are local and global. Local effects are gas leakages and a possible gas explosion at sea level. The global effects are possible turbulences in the gas supply and natural gas market, which could burden consumers to a certain extent [25].

The present existing and planned natural gas networks in the Baltic Sea region, installed through the Baltic Sea are particularly described in [2]. These gas pipeline installations create the Baltic Gas Pipeline Critical Infrastructure Network (BGPCIN) that is one of eight critical infrastructure network of the Global Baltic Network of Critical Infrastructure Networks (GBNCIN) [8].

To ensure compatibility in the usage and communication of key terms across the work packages of EU-CIRCLE project the common "working terminology" should be fixed at the first steps of the project activity.

2. State of art

Before the considerations on taxonomy of gas pipelines critical infrastructure at the Baltic Sea region, we refer to definitions of selected basic notions concerned with gas pipelines critical infrastructures as well as climate and weather impacts on their safety included in the report [9].

2.1. Gas pipelines CI terminology – general terms

Natural gas is a mixture of naturally occurring *hydrocarbon* gases found in porous rock formations. Its principal component is usually methane. Nonhydrocarbon gases such as carbon dioxide and hydrogen sulfide can sometimes be present in natural gas [5]. *Hydrocarbons* are organic compounds containing only carbon and hydrogen, occurring in nature (apart from the *natural gas*) as petroleum, coal and bitumens or in refined products such as gasoline and jet fuel [5], [23].

There are some commonly terms using with reference to the gas and its forms.

- *Dry gas* is almost pure methane and occurs in the absence of liquid hydrocarbons or by processing natural gas to remove liquid hydrocarbons and impurities [5].
- *Liquefied natural gas (LNG)* is a natural gas that has been converted to a liquid by refrigerating it to -260°F. Liquefying natural gas reduces the fuel's volume by 600 times, enabling it to be shipped economically from distant producing areas to markets [5].
- *Liquefied petroleum gas (LPG)* is a gas containing certain specific hydrocarbons which are gaseous under normal atmospheric conditions, but can be liquefied under moderate pressure at normal temperatures. Propane and butane are principal examples [24].
- *Natural gas liquids (NGLs)* mean highly volatile liquid products separated from natural gas in a gas processing plant. NGLs include ethane, propane, butane and condensate [5].
- *Petroleum* is a generic name for hydrocarbons, including crude oil, natural gas liquids, natural gas and their products [29].

Gas pipelines network belongs to the *energy infrastructure* that is defined by Houwing et al [16] as the total system of generation, transport, distribution, trade, supply and consumption of energy. This means not only the physical network (e.g. power plants, *gas pipes*, heat delivery stations), but also the social (economic and institutional) network that manages and controls the physical system. Together, these networks form a socio-technical infrastructure system. It is a complex system; the technological, economic, and institutional domains are strongly interdependent.

The energy embodied in natural resources (e.g. coal, crude oil, *natural gas*, uranium) that has not undergone any anthropogenic conversion is called a *primary energy* (also referred to as *energy sources*). It is transformed into secondary energy by cleaning (*natural gas*), refining (oil in oil products) or by conversion into electricity or heat. When the secondary energy is delivered at the end-use facilities it is called final energy (e.g. electricity at the wall outlet), where it becomes *usable energy* (e.g. light). Daily, the sun supplies large quantities of energy as rainfall, winds, radiation, etc. Some share is stored in biomass or rivers that can be harvested by men. Some share is directly usable such as daylight, ventilation or ambient heat.

The gas is a kind of *marked energy* source. It means that is commercially traded. Typically, marked energy is sold by a producer, such as a petroleum refiner, through a transmission and distribution network (e.g., pipelines and trucks) to an end-use consumer (e.g., gasoline sold at the pump) [32].

The gas, as well as coal, oil, uranium, renewable and onsite storage capacity is called *fuel purchase and supply* [11].

Storage facilities mean facilities designed and used for storage of oil or natural gas. Storage facilities vary greatly in size and design based on the product stored and the location and need within the pipeline system. Natural gas storage facilities typically operate so that large volumes of natural gas can be readily available for delivery to customers upon demand. The largest storage facilities are created in underground caverns, such as salt domes, or in porous rock formations [24]. Those storage facilities, or portion of storage facilities, which is used by the pipeline to store gas for its own use, to meet the peak day requirements of its sales customers and to provide flexibility on its system is called a *system storage* [1]. Additionally, a *gas and oil production storage and transportation infrastructure* means the production and holding facilities for natural gas, crude and refined petroleum, and petroleum-derived fuels, the refining and processing facilities for these fuels and the pipelines, ships, trucks, and rail systems that transport these commodities from their source to systems that are dependent upon gas and oil in one of their useful forms [21], [33]. The entity responsible for managing operations in a field or undeveloped acreage position is called a *operator* [5]. Finally gas is supplied to the *end user*. It is a consumer of gas, in the residential, commercial or industrial sector. In other words it is the final player in the gas chain [13]. Large terminal located on a waterway is called a *marine bulk terminal*. Generally receives and distributes its petroleum via pipeline, barge, or marine tanker from either domestic or import suppliers [31]. Then, *off shore pipeline* is a pipeline located off the coast. Large quantities of natural gas and crude oil are produced from some beneath sea floor. Offshore pipelines transport these products from the offshore production areas to onshore processing plants and pipelines. The off shore pipeline are also called *submarine (underwater) pipeline*.

All parts of those physical facilities through which gas is moved in transportation, including pipe, valves, and other appurtenances attached to pipe, compressor units, metering stations, regulator stations, delivery stations, holders, and fabricated assemblies is called a *gas pipeline* [1]. Thus, *gas pipeline* is a *transportation infrastructure* that is defined as physical distribution systems critical to supporting the national security and economic well-being of this nation, including the national airspace systems, airlines, and aircraft, and airports; roads and highways, trucking and personal vehicles; ports and waterways and the vessels operating thereon; mass transit, both rail and bus; pipelines, including natural gas, petroleum, and other hazardous materials; freight and long haul passenger rail; and delivery services [21], [33]. Pipeline also can be called a *mode* of gas transportation that is defined as a specific form or variety of something. In the context of transportation, there are six modes: aviation, maritime, mass transit, highway, freight rail, and *pipeline* [31].

Distribution in gas sector is defined as dedicated pipelines to power plants and major industrial users general industrial and commercial customers domestic users [11]. Thus, *distribution line* is used to supply natural gas to the consumer. A distribution line is located in a network of piping located downstream of a natural gas transmission line. As defined in natural gas pipeline safety regulations, a distribution line is a pipeline other than a gathering or transmission line [24], because the *transmission pipeline* is a network of pipelines moving natural gas from a gas processing plant via compressor stations, to storage centres or distribution points [13].

Transmission means passage through sub-stations. Additional within country and between country interconnectors [11]. A *line pipe* is a part of a line section [24] that is the designated section of a continuous run of pipeline. Line sections may designate sections that run, for example, between adjacent compressor stations or pump stations, between a compressor/pump station and a storage facility, between a compressor/pump station and a block valve, or between adjacent block valves. A line section can also be designated for testing purposes. For example, a line section may be a pipeline segment designated for hydrostatic testing that runs between two mainline valves [24].

A *pipeline crossing* is a point where two or more pipelines cross without a physical connection existing between the pipelines [24]. A *pipeline intersection* is a point where a physical connection between two pipelines occurs [24].

In gas pipeline a so-called *mega-node* means a single point at which multiple modes intersect. In transportation systems, a mega-node is a place of potential failure or bottleneck, with the potential for wide-ranging disruptions and losses [31].

Some facilities are necessary in the gas distribution and the supply process. The *pipeline facility* is a new or existing pipelines, rights-of-way, and any equipment, facility, or building used in the transportation of gas or in the treatment of gas during the course of transportation [24]. Any permanent combination of facilities which supplies the energy to move gas at increased pressure from fields, in transmission lines, or into storage is called a *compressor station* [1]. *Compressor station* is a facility located along a natural gas pipeline which house and protect compressors. Compressor is used to compress (or pump) the gas to move it through the system. *Compressor station* is strategically placed along the pipeline to boost the system pressure to maintain required flow rates [24].

The layout of a gas distribution system in which pipes are laid in both directions in the streets and frequently connected at intersections forms a *network*. Also, it is a series of equally spaced parallel bars held together by equally spaced crosspieces; a screen [1]. *Network* is an alternative name for *grid*. Thus, a *sub transmission grids (regional grids)* are radial or locally meshed networks connected to the transmission grid via infeed points. Smaller generating plants (e.g. wind power stations and gas turbines), and large users are connected to these grids [15].

Natural gas transported within a pipeline exert pressure on the pipe wall. *Pressure* is the force exerted on a given area expressed in pounds per square inch (PSI) or its metric equivalent of kilo Pascals (kPa) [24]. Then, a *working pressure* is a normal operating gauge pressure in a device or system [1].

2.2. Climate change terminology

Climate is defined as a dynamic interactions of several components including atmosphere, hydrosphere, cryosphere, land surface and biosphere. *Climate change* means a large-scale, persistent (long-term) and systematic changes in the typical weather patterns, but it is different from climate variability which is associated with short-term fluctuations in climate [4]. In other words, according to the Inter-governmental Panel on Climate Change (IPCC) *climate change* is defined as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use [19]. Opposite to it, the e*xtreme weather event* means an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite chance the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g. drought or heavy rainfall over a season) [12], [19]. *Hydro-meteorological hazard* is the process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage [30]. Hydro-meteorological hazards include tropical cyclones (also known as typhoons and hurricanes), thunderstorms, hailstorms, tornados, blizzards, heavy snowfall, avalanches, coastal storm surges, floods including flash floods, drought, heat waves and cold spells. Hydro-meteorological conditions also can be a factor in other hazards such as landslides, wild land fires, locust plagues, epidemics, and in the transport and dispersal of toxic substances and volcanic eruption material [30].

Energy, water, information and communication technologies (ICT) and transport infrastructure are often co-located (e.g. power cables laid below roads and beside communications cables, adjacent to water and gas mains and above sewers), especially in urban areas. The main menaces to infrastructure assets stem from extreme weather events, with attendant damage or destruction, which climate change may amplify. Some infrastructures may not be affected directly but may instead be unable to operate if physical access, supply chain or auxiliary services are disrupted [10]. The impacts of extreme events on CI are defined as the harmful or damaging effects and can comprise of multi scale and multi-level effects not only affecting the capability of the CI to operate but also as second tier effects that could severely disrupt normal societal operations. A preliminary effort of the classification of the list of climate hazards impacts of European gas subsector infrastructures is presented below [10].

- Heat stress: increased the electricity demand for cooling/heating, affection in generation, transmission, and transformer substation, increased resistance of overhead lines, increased sag of overhead lines, increased incidence of wildfire.
- Extreme precipitation: inundation of infrastructure components, disruption and damage of pipelines.
- Snowfall and blizzard: reduced ice accretion on overhead lines.
- Extreme wind and wind gust: toppled pylons and downed overhead lines.
- Sea level rise, sea storm: erosion of coastal structures, affect in generation, transmission, and transformer substations.

2.3. Resilience terminology

CI resilience means the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions [18].

The natural disasters and hazards as well as threats having the anthropogenic sources, for example coming from other installations or dumped munitions and terrorism-related hazards are the main threats for gas pipelines. Fortunately, there are no known successful terrorism attacks on underwater pipelines.

Reducing the *vulnerabilities* of critical infrastructure and increasing their resilience is one of the major objectives of the EU. An adequate level of protection must be ensured and the detrimental effects of disruptions on the society and citizens must be limited as far as possible. *Vulnerability* (in the climate change context) is defned as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity [17].

The stress imposed on a pipe or structural member under operating conditions is called an *operating stress*. This term usually refers to stress resulting from the internal forces due to the pressure of the gas or liquid in the pipeline; however, other forces such as thermal growth, expansion, or contraction may impose stress as well [24].

Entities responsible for day-to-day operation and investment of a particular critical infrastructure entity are called *critical infrastructure owners and operators* [31]. They are also responsible for CI *maintenance*. There is a process of maintaining property or equipment, including pipelines, to preserve it and prevent it from failure and ensure that it will continue to perform its intended function [24].

The incessant gas supply is provide by its *reserves*, that mean estimated remaining quantities of gas anticipated to be economically producible, as of a given date, by application of development projects to known accumulations. In addition, there must exist, or there must be a reasonable expectation that there will exist, the legal right to produce or a revenue interest in production, installed means of delivering gas to market and all permits and financing required to implement the project [5].

3. Gas pipeline critical infrastructure networks at the Baltic Sea region taxonomy

Considering definitions of main notions from the above methodology concerned with gas pipeline critical infrastructures and their networks, nature and features of the industrial installations at the Baltic Sea region, we distinguish following installations existed and planned of the Baltic Gas Pipeline Critical Infrastructure Network (BGPCIN) particular described in [2]:

- the Nord Stream twin pipeline system through the Baltic Sea runs from Vyborg, Russia to Lubmin near Greifswald in Germany,
- the Energobaltic Sp. z o. o. plant transfers natural gas coming from the oil explored from the bottom of the Baltic Sea in “Baltic Beta” Sea Oil Mine owned by LOTOS Petrobaltic S.A by the underwater pipeline to the gas separation station in the heat power plant in Władysławowo (Poland),
- the Baltic Pipe is a planned submarine pipeline that will connect Redvig (Denmark) and Niechorze (Poland),
- the Balticconnector natural gas pipeline will connect the gas transmission pipeline networks of Finland and Estonia.

The BGPCIN is interacting with the gas stations and terminals associated with it. It is involved in cooperation with and dependent on the BOPCIN, the Baltic Oil Rig Critical Infrastructure Network (BORCIN) and other Baltic industrial installations activity.

3.1. Critical infrastructure taxonomy

Industry and other system (e.g. drilling platforms, gas and oil pipelines, wind farms, telecommunication systems, waterways, maritime transport, ports with their intermodal connections), performing activities within the Baltic sea area are defined by the *Baltic Sea infrastructure*.

The Baltic Sea critical infrastructure we defined as a complex system located and operating within the Baltic Sea and ashore that significant features are inside-system dependencies and outside-system dependencies, that in the case of its degradation have significant destructive influence on the health, safety and security, economics and social conditions of large human communities and territory areas. Moreover, the structure and flow of the inner, outer and cross dependencies of the Baltic Sea infrastructures is defined by the *Baltic Sea infrastructure network*. Next, the *identification of the Baltic Sea critical infrastructures* means the procedure based on specified local criteria leading to designate system belonging to Baltic Sea infrastructure network as a critical infrastructure system.

Occurrence of an unwanted circumstance or event that may cause damage, functioning disruption or service interruption to the Baltic Sea critical infrastructure is defined by *threats to the Baltic Sea critical infrastructure*.

More general terms referred to the CI networks at the Baltic Sea region taxonomy are given in [3].

3.2. Climate change taxonomy

The BGPCIN interacts strongly with the *climate-weather change process*. The *climate-weather change process* is the process of the climate-weather states changing considered in time for a fixed area. Moreover, we defined the *Baltic Sea climate change* as any changes in climate within the Baltic Sea area over time either due to natural variability or as a result of human activity, while the *extreme weather event* means the meteorological conditions that are dangerous and happen at a particular place and time and can generate severe hazards.

Seismic events, tsunamis, rough sea with strong swells, onshore winds, and storms could directly affect a subsea pipeline. Problems are also created by buried subsea pipelines becoming exposed, particularly after violent wave action associated with storms. The landfall pipelines are exposed to the risk of rockfall impacts and the ice cover of coastal area [22], [25]. The experience from the Gulf of Mexico shows that pipelines on the seabed suffered only minor damage after major hurricanes; most damage affected platforms and risers leading from bottom pipelines to the surface and for pipelines up to a depth of 60 meters [7]. Then, according to the BGPCIN and corresponding to climate hazards impacts mentioned in Section 2.2, the following extreme weather events should be considered.

Extreme cold. What constitutes extreme cold and its effects can vary across different areas of the country. In regions relatively unaccustomed to winter weather, near freezing temperatures are considered *extreme cold*. Whenever temperatures drop decidedly below normal and as wind speed increases, heat can leave your body more rapidly. These weather-related conditions may lead to serious health problems. Extreme cold is a dangerous situation that can bring on health emergencies in susceptible people, such as those without shelter or who are stranded, or who live in a home that is poorly insulated or without heat [28].

Extreme heat. Conditions of extreme heat are defined as summertime temperatures that are substantially hotter and/or more humid than average for location at that time of year. Humid or muggy conditions, which add to the discomfort of high temperatures, occur when a "dome" of high atmospheric pressure traps hazy, damp air near the ground. Extremely dry and hot conditions can provoke dust storms and low visibility. Droughts occur when a long period passes without substantial rainfall. A heat wave combined with a drought is a very dangerous situation [28].

Extreme precipitation. Expresses large precipitation amounts or intensities, or long-duration dry spells. Even though droughts can be considered as extreme precipitation events, we address here mainly events of increased precipitation intensity. By definition, it rarely occurs in the prevalent climate. The potential damaging effects are implied by the rare occurrence as neither nature nor society are prepared for the conditions. Usually one relates the degree of extremeness to the expected return period of incidents estimated from regular observations [4].

Gust is a rapid increase in the strength of the wind relative to the mean strength at the time [27].

Sea-level rise is an increase in the mean level of the sea. Eustatic sea-level rise is a change in global average sea level brought about by an increase in the volume of the world ocean. Relative sea-level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence. In areas subject to rapid land-level uplift, relative sea level can fall [17].

Extreme wind is the wind which is strong enough to be dangerous for people, or cause significant damage to buildings and property, usually faster than 100 km/h (>118 km/h = 12 Beaufort scale, hurricane). Extreme wind can cause:

– destruction of buildings, including roofing being blown off, broken windows, and other flying debris,

- large scale forest damage and fallen trees or branches falling onto power-lines,
- high-sided vehicles and outdoor equipment being blown over,
- very tall buildings, suspension bridges and transmission lines can suffer structural failures.

Intense rain(fall) also called as *heavy rain(fall)* means a rain characterized by a rainfall rate greater than or equal to 50 mm/h.
Rainfall intensity defined the intensity of rain is its rate of fall. *Very light* means that the scattered drops do not completely wet a surface. *Light* means it is greater than a trace and up to 2.5 mm an hour. *Moderate* means the rate of fall is between 2.6 mm to 7.5 mm per hour. *Heavy* means 7 mm per hour or more [14].
Storms mean 1) an atmospheric disturbance involving perturbations of the prevailing pressure and wind fields, on scales ranging from tornadoes (1 km across) to extratropical cyclones (2000-3000 km across) or 2) wind with a speed between 48 and 55 knots (Beaufort scale wind force 10) [35].
Landslide means all varieties of slope movement, under the influence of gravity. More strictly it refers to down-slope movement of rock and/or earth masses along one or several slide surfaces [28].
The seismic events or tsunamis are unlikely in the Baltic Sea region than they can be omitted in this Section.
More general terms referred to the climate change impacts on CI networks at the Baltic Sea region taxonomy are given in [3].

3.3. Resilience taxonomy

Considering the climate and weather change impacts on BGPCIN and other critical infrastructure networks we defined the *CI resilience to climate change* as the CI capacity being able to absorb and to recover from hazardous events appearing as a result of climate change. *CI resilience to climate change model* is a framework joining prevention options to minimize CI exposure to hazards, methods of CI protection, methods reducing potential impacts to enhance contingency planning and business continuity and methods of adaptation and mitigation of consequences related to climate hazards.
Efforts, like policies, procedures and actions, taken to prolong the proper and effective functioning of a critical infrastructure and providing its essential services when it is exposed to threats we called as *strengthening critical infrastructure resilience*, while *strengthening critical infrastructure resilience to climate change* means increasing CI capacity through its components and subsystems parameters improving and its operating environment parameters modification to achieve its characteristics stronger what allow its functioning in its operating environment to be able to absorb and to recover from hazardous events appearing as a result of climate change.
Resilience strengthening strategy to climate-weather hazards for BGPCIN we consider as *robustness, response* as well as *recovery* that are defined in the climate change context as follows particular described in [3].
Robustness – the inherent strength or the ability of infrastructure to withstand external demands coming from climate change without degradation or loss of functionality.
Response – the reaction (policies and action) during or immediately after a disaster in order to reduce its impacts, to ensure the functioning of basic systems (infrastructures) and to prevent transitions of the system or infrastructure into a crisis situation. It usually includes activities that address the short-term, direct effects of an incident. The response includes immediate actions to save lives, protect property, and meet basic human needs [28].
Recovery – the development, coordination, and execution of service- and site-restoration plans for impacted communities and the reconstitution of government operations and services through individual, private-sector, non-governmental, and public assistance programs that: identify needs and define resources; provide housing and promote restoration; address long-term care and treatment of affected persons; implement additional measures for community restoration; incorporate mitigation measures and techniques, as feasible; evaluate the incident to identify lessons learned; and develop initiatives to mitigate the effects of future incidents [28].
More general terms referred to the resilience of CI networks at the Baltic Sea region taxonomy are given in [3].

4. Conclusion

The Baltic Gas Pipeline Critical Infrastructure Network (BGPCIN) is particularly described in [2]. BGPCIN is an element of the Global Baltic Network of Critical Infrastructure Networks (GBNCIN). Besides BGPCIN, GBNCIN is consisted of:

- the Baltic Port Critical Infrastructure Network (BPCIN),
- the Baltic Shipping Critical Infrastructure Network (BSCIN),
- the Baltic Oil Rig Critical Infrastructure Network (BORCIN),
- the Baltic Wind Farm Critical Infrastructure Network (BWFCIN),

– the Baltic Electric Cable Critical Infrastructure Network (BECCIN),
– the Baltic Oil Pipeline Critical Infrastructure Network (BOPCIN),
– the Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network (BSTPOICIN).

Modelling of GBNCIN operation process is described in [8].

Baltic Sea critical infrastructures resilience to climate changes modelling is an application of:
– modelling of critical infrastructure safety,
– modelling of climate threats to critical infrastructures diagnostic and detection,
– modelling of climate change influence on Baltic sea critical infrastructures.

Thus, parameters' identification, characterictics' prediction of the process and its characteristics optimization with respect to the GBNCIN safety and its resilience to climate/weather change are going to be done in the next steps of the EU-CIRCLE GMU researches described in [20].

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