ECMWF COPERNICUS REPORT

Copernicus Climate Change Service

Report:
Climate data needed to address resilience to climate change in standards for infrastructures

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Summary

Even when the objectives of the Paris agreement will be met, climate change impacts will affect our world in the next decades, temperatures will rise, and we will face extreme precipitation, storm or drought more often. This has in particular an influence on buildings and infrastructures. As these are often designed for a lifetime of several decades, it is important to include these extreme weather conditions that will occur in this timeframe, in the design and operational phases. This is what is called ‘adaptation to climate change’.

Copernicus Climate Change Service (C3S) has been established by the European Commission, with the aim to produce authoritative projections about the future climate of Europe. This information is expected to be available as of 2019 for the whole of Europe. C3S has the ambition that designers and operators of infrastructures will make use of these projections. Therefore C3S asked NEN and BMGI to identify what kinds of data and information is needed for standards of infrastructures.
In this survey experts working on standards for infrastructures in the buildings, transport- and energy sectors have been consulted. Target groups that have been approached are mainly experts who participate in European committees for standardization, as well as stakeholders from financing organizations and insurance companies.

A questionnaire has been prepared in close cooperation with KNMI and C3S. It has been sent out to the selected stakeholders. Intensive communication resulted in a large response-rate (76 out of 125). Results were analysed and discussed in a workshop, as well as through some interviews. Active participation resulted in a further sharpening of insights. The table below shows the main results about expectations for climate change related data (Table 1).

In most cases, users of the data are not climate experts. Therefore it is needed to express data in a “as simple as possible” manner. Complex interpretation (for instance in choosing a scenario) should be avoided. Also there is a need for expressing uncertainties. A way forward could be to express data for a set of scenarios, for instance ‘high’, ‘low’ and ‘intermediate’.
Moreover, consulted stakeholders expressed a need for a single entry point for all data, as well as identical formats.
As the data are complex in nature, responsible use of data will require guidance and training. These should be directed at the use of the data themselves (how to interpret data? – by C3S), as well as the use of the data in standards (e.g.: how to deal with uncertainties?). For infrastructures with long lifespans, new ways of engineering (‘adaptive engineering’) will be needed, taking into account the large uncertainties. It will be important to look at resilience rather than resistance.

Table 1 Overview of needs for climate parameters from survey

Variable	*Probability for extremes*	*Temporal resolution*	*Dura-tion*	*Accumula tion*	*Spatial resolution (km^2)*	*Remarks*
Temperature (high/low)			✓		1-10	Special focus on heat-waves Special focus on night temperatures
Rain		10 – 15 minutes		✓	1-10	
Snow	1/10 – 1/500 yr			✓	1-10	
Humidity			✓		50	
Solar radiation			✓		1-10	
Wind					50	
Wind gust		3 secs			50	
Hail					1-10	Special focus on size of hailstones
'consequences'						
Flood	✓			✓	1-10	Strongly dependent on local conditions; e.g. differentiation needed to different types of flood
Drought	✓			✓		Strongly dependent on local conditions
Air quality	✓		✓			Strongly dependent on local conditions
Slow-onset effects						
Sea level						
Salination						Strongly dependent on local conditions
Desertification						Strongly dependent on local conditions

It should be noted that for 'consequences' such as drought and flood, as well as 'slow-onset effects' the impacts strongly depend on the local situation, as well as history of previous events. A specific need is more insight in the impacts of cumulative effects, such as droughts followed by massive rain and dynamic sea level rise from extreme tides combined with strong storm and rain. Generally speaking, there is a need to refine the resolutions and to align the spatial resolution of individual effects for coherent combined impacts.
If needs for higher resolution (mainly spatial) have been expressed, this has to be balanced against uncertainties. Thus, the expression of need for a resolution of 1 km2-10 km2 has to be considered carefully, as during the discussion, some confusion has been noticed between resolution of the extreme event and of the impact. In addition, this high resolution is well higher than most of the weather models.
Among the solutions for moving to a more systematic consideration of climate change in decision making – including investment - for infrastructures' design and operation, four major recommendations have been made:

- **Standards**
  Standards are performant "tools" for accelerating the integration of CC related data in any infrastructure design and operation. Thus, communication about standardization development as well as training about how to implement these standards will be a major step to engage in.
- **Raising awareness**
  Communication about the relevance and the maturity of the scenarios, the climatology related projection and forecast and their inclusion in infrastructure design and operations are essential.
- **Common reference (reliable) data base with single entry point**
  In addition to this, stakeholders have expressed a need for more frequent updates of the climate projections, as well as recent past events.
- **Similar format(s) for all data**
  Specifically it should be taken into account that for the Eurocodes, national annexes define which climate data are used. A step forward would be to align these between all countries concerned.

Next steps:
Following the above mentioned recommendations, and in coherence with the stakeholders' expressions of needs, the priority for next steps can be summarized as follows:

1. Gathering available data and **developing robust and transparent reference datasets** with similar format(s);
2. **Sharing these datasets with the different communities** for "test" implementation - "in practice" – "playing" with these datasets for checking their relevance;
3. **Sharing feedbacks from these test implementation**, then co-production/refinement of the datasets between scientists and engineers/standardization experts. This will enhance the robustness and transparency, and as a consequence, trust in the data;
4. **Preparing a communication and training toolkit** based on test cases and good examples/best practices to bridge the gap between the communities (scientists, engineers and other stakeholders). A specific action plan for communication/diffusion should be set. The applies to cross training/education (scientists-engineers-standardization experts);
5. **Creating a "single" entry point** for accessing these datasets. This could be referred to in the standards with climate change consideration.

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Introduction

This report is prepared by NEN, the Netherlands Standardization Institute, and BMGI – Consulting in the context of Copernicus Climate Change Service (C3S). The Royal Dutch Meteorological Institute (KNMI) provided scientific support, especially in the development of the questionnaire.

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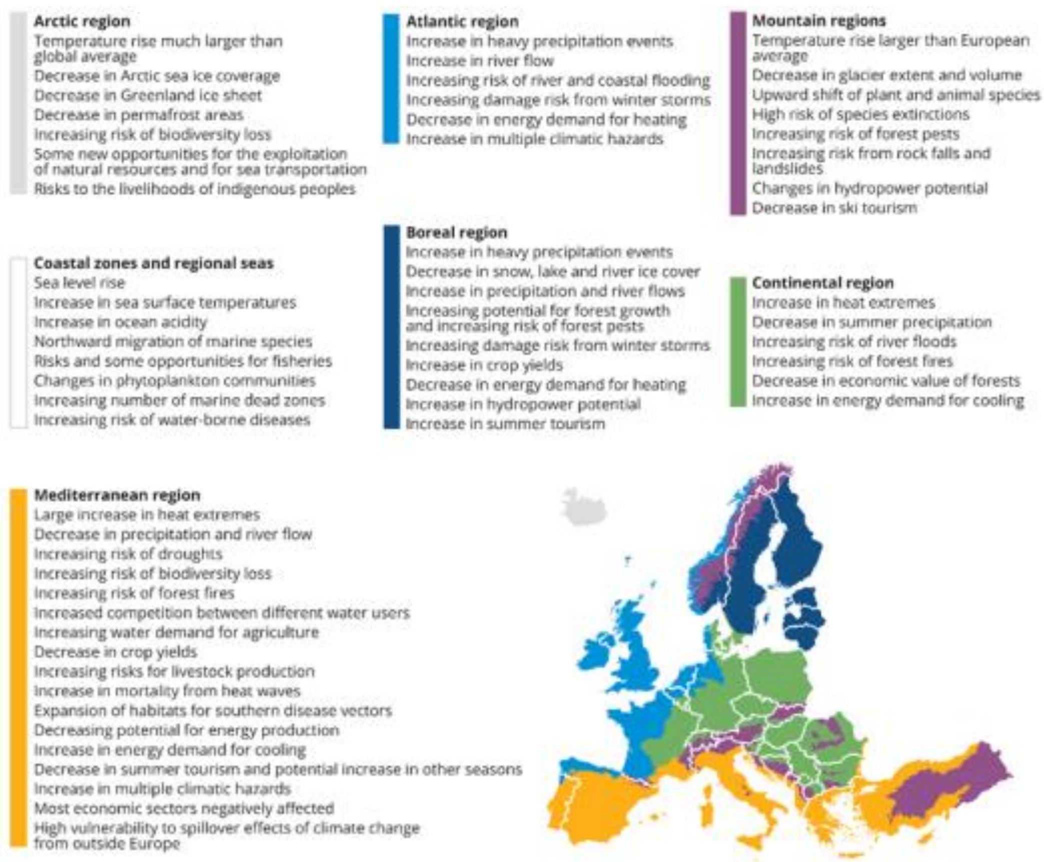
1. Background

1.1 Developments in future climate

The climate is changing: the current global average temperature is 0.85ºC higher than it was in the late 19th century, and each of the past three decades has been warmer than any preceding decade since records began in 1850. Climate change affects all regions around the world. In some regions extreme weather events and rainfall are becoming more common while others are experiencing more extreme heat waves and droughts. These impacts are expected to intensify in the coming decades. The map below shows expected effects across different regions in Europe (Figure 1).

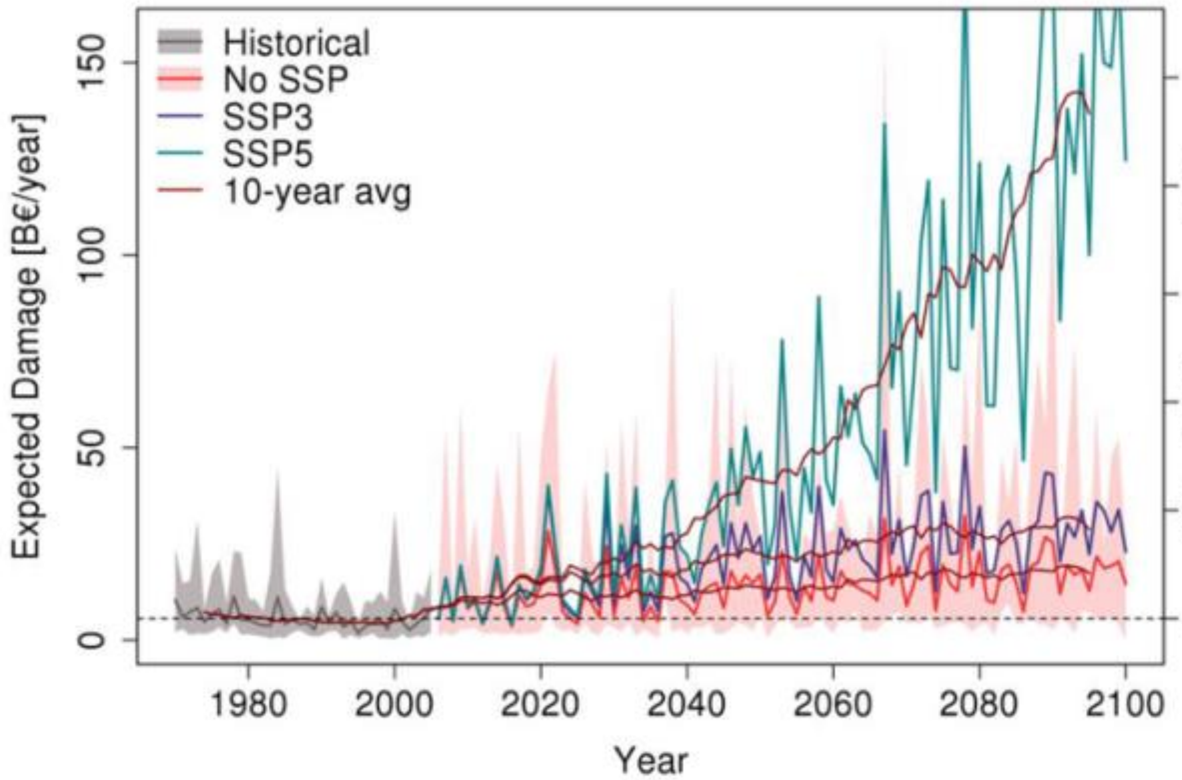
Figure 1 Expected effects of climate change in Europe (source: EEA[1])



[1] https://www.eea.europa.eu/soer-2015/europe/climate-change-impacts-and-adaptation/climate-change-impacts-in-europe/view

The damages caused by these effects are increasing, and will probably further increase exponentially (fig. 2).

Figure 2 Impacts of climate change (source: Peseta III, JRC, 2017, to be published). SSP = Shared Socio-Economic Pathway



1.2 Copernicus Climate Change Service (C3S)

Regarding the large impact that climate change probably will have, the European Commission established Copernicus Climate Change Service (C3S). C3S aims to produce authoritative, quality-assured projections about the future climate of Europe. The objective is that the information produced will help societal and business sectors improve decision-making and planning regarding climate mitigation and adaptation.

The information will be based on past, current and future earth observations (from in-situ and satellite observing systems) in conjunction with modeling, supercomputing and networking capabilities. It will produce information about the past, current and future states of the climate in Europe and worldwide. The C3S service is operated by the ECMWF. The climate information is expected to be available as of 2019.

The wealth of climate information will be the basis for generating a wide variety of climate indicators aimed at supporting adaptation and mitigation policies in Europe in a number of sectors. These include, but are not limited to, the following:

Figure 3

It aims to support these by Informing, Improving (planning of mitigation and adaptation practices) for key human and societal activities and Promoting (e.g.: development of new services for the benefit of society).

C3S is working with organizations from across Europe to develop and test a range of proof of concept projects to develop the service in a way that best suits the needs of users. At the moment 7 proof of concepts projects are working with sectors to develop the C3S Sectoral Information System (SIS) so that it meets the needs of these users. The projects include 2 projects for the water sector, 2 for the energy, 1 for insurance, 1 for agriculture and 1 for both infrastructure and health sectors.

This report focuses on the sector infrastructures (which also covers assets in other sectors in the C3S division). C3S has the intention to develop an ITT (invitation to tender) for this sector as of 2018. The objective of this ITT will be to define and develop the climate data and information needed by the sector infrastructures, so that this sector can use the available information in making infrastructures more resilient to the effects of a changing climate.

1.3 Relevance of climate change to infrastructures

As indicated above, infrastructures are a key sector in the work of Copernicus Climate Change Service . ‘Infrastructures’ is a broad term, and applies to a broad range of physical structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise. They are crucial for the transport and supply of goods, energy, water and information. Examples are buildings, roads, railroads, power supplies and telecom installations. As such in the division of C3S, infrastructures are also part of the other sectors of the C3S SIS, such as energy (power lines, pylons, power plants, distribution of energy supply), water management (e.g. sewage water systems), transport (roads, railways, harbors, airports), and coastal areas (dykes).
In many cases infrastructures can be considered key for societal functions such as supply of energy and goods, and supply and discharge of water. In these cases, damages due to weather impacts can have large consequences. Same examples are shown in Figure 4 .
The importance of infrastructures in dealing with extreme weather effects can also be illustrated by recent events of hurricanes Harvey and Irma in the summer of 2017. One crucial aspect in the New Orleans events in 2017 following the storm Harvey was that the sewage water system operated poorly, resulting in large floods in the city. Another recent example is that as hurricane Irma hit the Caribbean Island of Sint Maarten, the main communication tower broke down, after which communication failed for three days. Climate-proof design of infrastructures, as well as disaster risk management, can contribute to making infrastructures more resilient and reduce damages.

Figure 4 Examples of impact of extreme weather events on infrastructures

Damage to infrastructures result in high costs. Direct costs for the repair of the infrastructure itself, but also the costs associated with the disruption of societal functions.

In working on increased resilience of infrastructures, the following should be taken into account:

- Infrastructures usually have long lifetimes, often in the range off fifty to a hundred years, sometimes even more, it is important that in the design the weather conditions that can occur in this timeframe are being taken into consideration.
- Large investments are associated with the design and building of infrastructures, as well as with repair.
- Infrastructures are often designed and built according to standards, in Europe usually to European standards.

As climate change can have big consequences for buildings and infrastructures, these are a priority in the EU strategy on adaptation to climate change. In the action plan Action #7 is dedicated to making infrastructures more resilient (

Figure 5):

Figure 5 Priorities and actions in the EU's climate change adaptation strategy

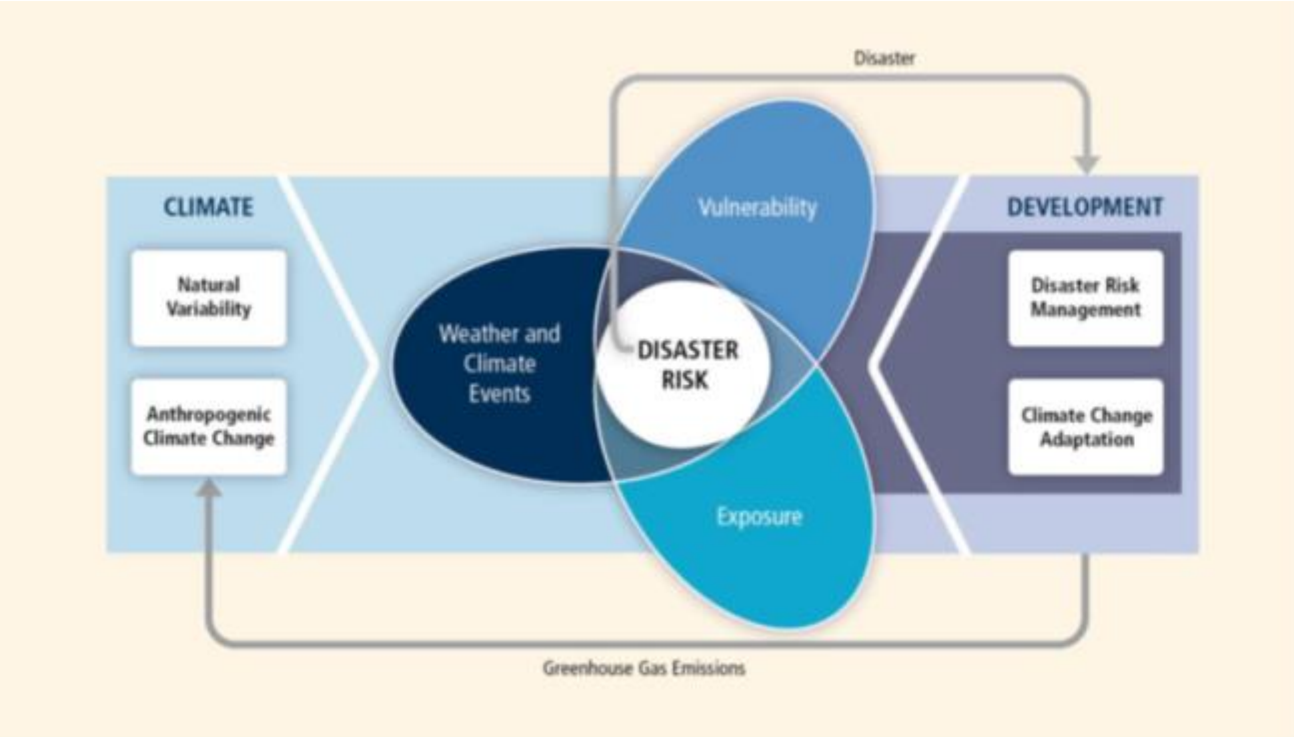
In making infrastructures more resilient to the effects of climate change two aspects can be distinguished

- Ensuring a more 'climate-proof' design before a disaster strikes;
- Ensuring that Disaster Risk Management is in place in case of a disaster.

In addition to extreme weather events, also the impact of slow-onset events (such as a rising sea-level and salination) should be taken into account.

The following scheme explains on aspects that impact the risk of a disaster for an infrastructure. Climate change increases the occurrence and level of (extreme and slow onset) weather events. In addition to that the impact of a disaster will depend on the vulnerability of infrastructure (is it resilient?) and the potential exposure (how much damage will be caused in case of collapse of the infrastructure?). Overall adaptive design and operation and adequate disaster risk management can help reducing the risks of disasters. It is very cost effective to address such risks at the design stage rather than through later retrofitting. Such an approach also reduces user disruption and environmental impacts.

Figure 6 Role of climate change adaptation and disaster risk management in managing the risks of disasters (Source: PESETA III, JRC (2017) (to be published))



1.4 Role of standards in design and operation of infrastructures

1.4.1 General role of standards

In the process of making infrastructures more resilient, it is logical to take standards into account as most infrastructures are built according to standards. Standards are voluntary agreements in the private domain that define levels of performance, and as such commonly referred to in engineering specifications and contracts. Following that compliance to standards is regulated by a system of accreditation and certification. The important role of standards is further strengthened since standards are often referred to in legislation and regulation. In these cases they are practically a legal obligation.

Figure 7 explains the position of standards in comparison to legislation/ regulation and accreditation/ certification.

Figure 7 Position of standards, compared to legislation/ regulation and accreditation/ certification.

	Performance level requirements document	Compliance testing
Public domain – compulsory	**Legislation and regulations**	**Inspection**
Private domain – voluntary	**Standards**	**Accreditation and certification**

Basically, standards exist on three levels:

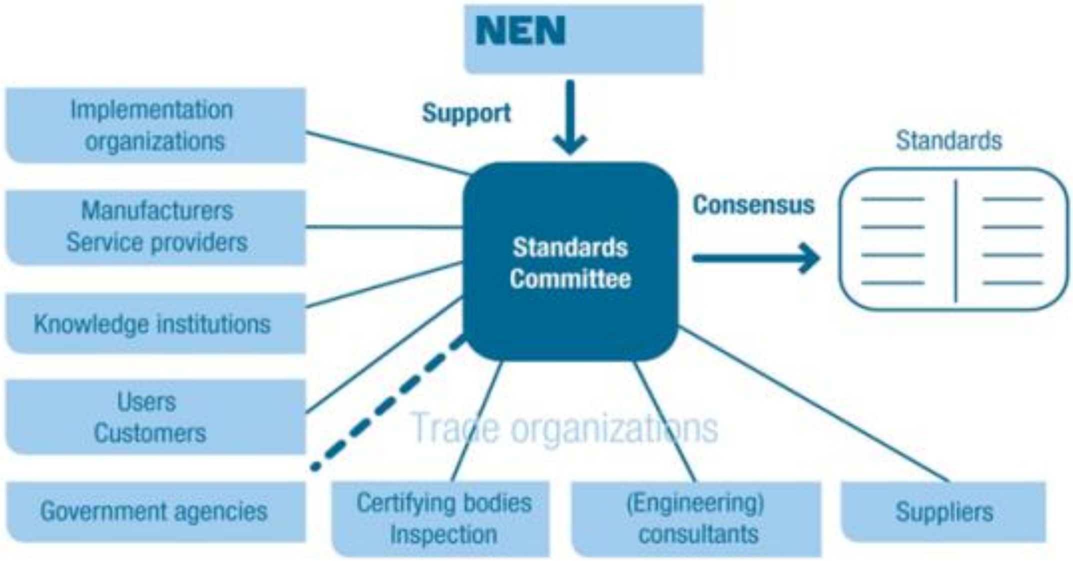
- national (e.g. BSI-, DIN- or NEN-standards);
- European (EN-standards). The process of standardization in Europe is coordinated by CEN (all issues except electrical and telecom applications), CENELEC (electrical applications) and ETSA (telecom applications);
- global (ISO-standards).

A tendency is that instead of the national level, standards are more and more developed at the European and global level.

Standards are developed by standardization committees. In these committees all stakeholders can participate. The process is based on consensus. Figure 8 sketches this process for a NEN- standard in the Netherlands.

In the European arena standards are developed by CEN/CENELEC Technical Committees (TCs). The number of TCs totals about 400.

Figure 8 The process for developing a standard (example based on Netherlands standard)



Standards for infrastructures specify requirements for safe construction and operation. An important aspect is this is resilience to extreme weather events, such as storm, rain and snow. Usually a (set of) standard(s) applies to all stages in the life time of an infrastructure, including design, maintenance and operation. All of these are relevant in specifying resilience to the effects of climate change.
For example, standards can contribute to

- Urban resilience
- Local adaptation
- Financing adaptation and prioritization
- Disaster Risk Reduction
- Climate finance and resilience finance
- Vulnerability Analysis

It should be noted that currently most standards for design and operation of infrastructures refer to historical data. This means that climate change is not incorporated in a structural way.

1.4.2 Role of Eurocodes

An important set of European standards for infrastructures are the Eurocodes. These provide for a common design and calculation rules for infrastructure and other construction works, which facilitates the circulation of goods and persons in the internal market. They entered into force in 2006 and have become the primary standards for structural and geotechnical design across Europe. The Eurocodes are also being implemented outside the European Economic Area, have already been translated into Russian and Chinese, and specified by many client organizations in the Middle East.

The Eurocodes are in a process of revision, particularly in relation to improving ease-of-use for practical users of the standard. Also more harmonization is needed, leading to a reduction in Nationally Determined Parameters and the number of alternative design methods. Also requirements for robustness will be strengthened. In addition, a report will be prepared setting out how the Eurocodes should be adapted to account for the relevant impacts of future climate change. The objective is that climate change considerations will be embraced within the Eurocodes, which will provide increased resilience of long-life infrastructure assets to potential climatic changes.

The process of revision of the Eurocodes is steered on a European level by the CEN/Technical Committee 250. In the process a broad range of organizations is engaged: The CEN/TC 250 committee structure includes 11 subcommittees and 5 working groups. These sub-committees and working groups have their own structure of subsidiary working groups and task groups that report to them. In total more than 1000 active participants from across Europe are involved. The process of revision of the Eurocodes is jointly led by NEN and BSI, and the CEN/ TC 250 is chaired by Mr. Steve Denton.

The Eurocodes essentially provide for uniform and harmonized methods for the calculation of the structural safety of construction works. However, the determination of the required level of safety remains within the competence of the individual states in the form of so-called Nationally Determined Parameters. This allows the Member States to choose the level of safety. In practice, the Eurocodes provide recommended values for climatic actions which may be adjusted in the National Annex (i.e. snow maps). These adjustments are often provided by the National Standardization Committees following the (all-parties concerned) consensus model, or through building legislators/legislation.

1.4.3 Mandate ‘climate change adaptation in standards for infrastructures’

As indicated, resilience of infrastructures is a key element in Europe’s strategy for climate change adaptation. In this perspective, the commission issued a Mandate to CEN/CENELEC “adaptation to climate change in standards for infrastructures”. The objective of this mandate is to build and maintain a more climate resilient infrastructure throughout the EU. The mandate focuses on three sectors[2]:

- Transport infrastructure
- Energy infrastructure
- Buildings/construction

[2] In addition specific attention should be paid to ICT-infrastructures

The work is carried out by consultation of stakeholders involved in design and operation of infrastructures, especially writers of European standards. In order to coordinate the activities of the project, an 'Adaptation to Climate Change Coordination Group has been established (ACC-CG). This group is chaired by Mr. Mingyi Wang (GDV, German Association of Insurance Companies), and NEN holds the secretariat. The works has been carried out via a questionnaire, interviews, workshops and desk-research, in close communication with TCs (Technical Committees)[3].
In Phase 1 of the project (2015-2017) an inventory has been made of European standards in the three priority sectors, resulting in a list of 13 relevant standards. Of these, 12 are existing standards, and one new standard will be developed. The selected standards apply to the following sectors and aspects:

- Buildings
  - Thermal performance
  - Ventilation
  - Sustainability of construction works
- Transport
  - Airfield ground support infrastructures
  - Railway applications
- Energy infrastructures
  - Gas infrastructure
  - LNG (liquefied natural gas)
- ICT
  - datacenters

Annex 2 provides a more detailed overview of the selected standards.
During the process of Phase I it became clear that awareness is a critical issue. For some stakeholders climate change adaptation is a new phenomenon, know-how is limited and the perception is that relevance is limited. Other stakeholders are more familiar with the issue and are open for a review of standards. Obviously, the standards selected link to TC's which are more aware of the importance of climate change adaptation.
TCs and stakeholders face serious challenges in addressing climate change adaptation in standards. Two main questions that arise are:

- *Where to find trustful data about future climate?;*

And:

- *How to deal with the uncertainties in these data?*

In Phase 2, the selected standards will be revised in a way that they can get the label 'climate resilient'. In order to facilitate the process of revising the standards, a practical guideline will be developed. This will give the standard writers information about availability and use of climate data and methods for risk-analysis as well as terms and definitions. A kick-off meeting of Phase 2 is planned in February 2018.

[3] More background information can be found on the website of CEN/CENELEC: https://www.cencenelec.eu/standards/Sectors/ClimateChange/Pages/default.aspx

1.5 This survey:

As indicated Copernicus Climate Change Service (C3S) has the objective to provide information that will help societal and business sectors improve decision-making and planning regarding climate mitigation and adaptation. C3S is working with organizations from across Europe to develop and test a range of proof of concept projects to develop the service in a way that best suits the needs of users in a number of sectors.

Infrastructures are an important sector with regard to climate change and this implies also sectors as energy, transport, water management, insurance and coastal areas. As standards are key in this sector, C3S looks for interaction with the writers and users of standards, with the objective that climate information supplied, fits with the information needed.

The objective of this survey is to build this bridge by consulting stakeholders working on standards for infrastructures in the transport- and energy sectors, and buildings. The main focus is on experts who participate in European commissions for standardization, but also stakeholders from financing organizations and insurance companies have been approached. NEN acts as project leader, and works together with the Dutch Meteorological Institute KNMI and the energy consultancy BMGI. The results also can be used in the 2nd Phase of the mandate project 'adaptation to climate change – standards for infrastructures' and in the revision of the Eurocodes (the European standards for safety of construction works).

Objective:

Identification of the climate information that is needed in standards for infrastructures, in order to make standards more resilient to a changing climate.

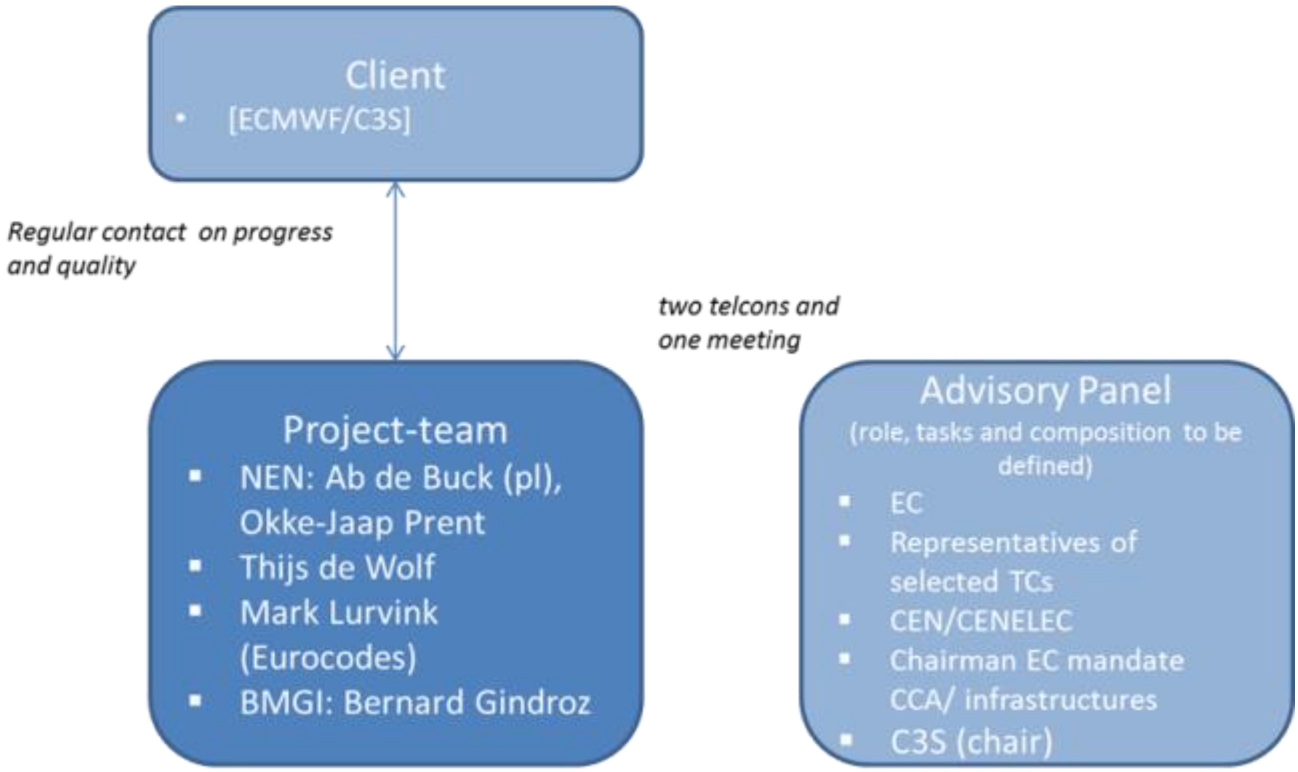
This information serves the development of an ITT which will define and develop the services identified. The ultimate goal of the project is that in the future these infrastructures will be resilient to the effects of a changing climate, such as rain, storms, extreme droughts and floods.

2. Approach

2.1 Project organization

To come to the stated deliverables a Project Team of NEN and BMGI was established. KNMI delivered expertise, especially in the stage of preparing the questionnaire. A short overview of the project organization is summarized below:

Figure 9 Project organization

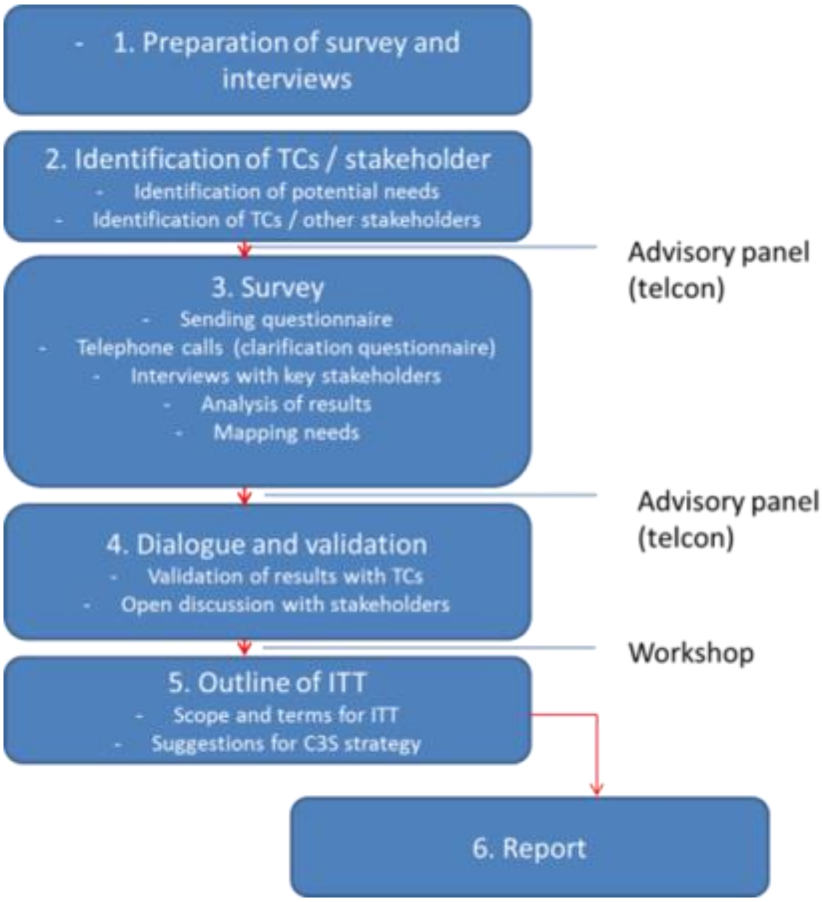


Intensive communication was organized with key stakeholders who form the standardization community, especially the broad network of CEN and CENELEC technical committees (including Eurocodes and sector fora).

2.2 Steps

The survey was carried out by the following six steps.

Figure 10 Steps in project approach



2.2.1 Preparation of survey and interviews

In the survey selected experts were approached in order to investigate their insights and needs regarding the use of standards in dealing with weather phenomena.

2.2.1.1 Questionnaire

In the first phase, a survey questionnaire was developed to be published online in a closed environment. Questions were conceptualised while KNMI brought in vital in-depth knowledge throughout this step. Two team members wrote and re-wrote the questions for clarity (avoiding jargon, vagueness, ambiguity) and completeness. Several questions are double-barrelled questions (two questions joined together). Overall the questionnaire consisted of a mix of closed and open-ended questions was chosen (each having advantages and disadvantages). The response options were kept balanced. In general little context was given as the general assumption was that the target audience knows the topic.

While preparing the questionnaire, attention was put at the following steps of recording and analysing responses. The pilot test of the questionnaire helped to check the possible interpretations to the questions (keeping the respondent's perspective in mind) and whether this intended meaning was clear. In the end the questionnaire, disseminated using the software tool 'Questback', counted in total 124 questions and was designed to take 20 minutes at most. The questions are shown in Annex 4. Analysis of answers given to questionnaire.

2.2.1.2 Identification of TCs / stakeholders

The primary target audience is listed in Annex 3: List of Technical Committees approached. In addition to this also other stakeholders involved in design and operation of infrastructures were identified, for instance insurance companies and investment banks.

2.2.1.3 Approach of stakeholders

An introduction email was sent as advance notification concerning the forthcoming launch of the questionnaire. In addition, in the case of the CEN/TC 250 (responsible for Eurocodes), an official letter was distributed through the Secretary of the TC. The dissemination of the survey was done by email including hyperlink while follow-up was done by telephone, in mail, and in person. During the collecting data phase the project team members all kept track of each responses in order to avoid loose of valuable information .

In the interpretation of responses it became clear that that respondents used different terms with the same meaning, and vice versa. The Project Team verified this. Another finding that was expected was that some questions were not applicable to all sectors.

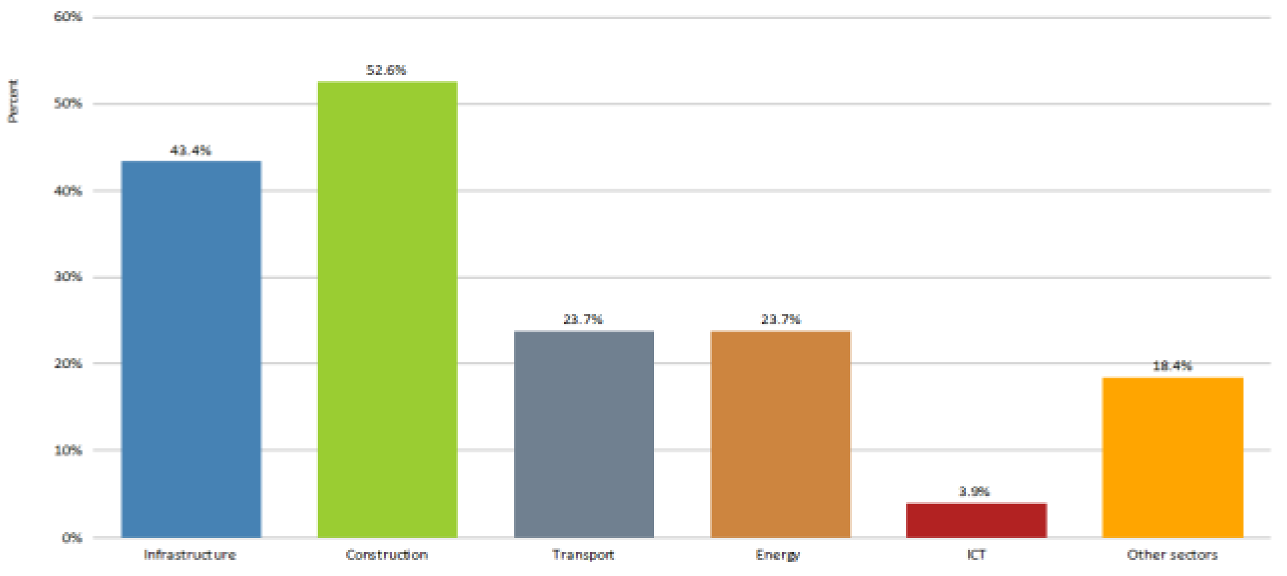
All team members have used personal emails and telephone calls to follow up with the respondents. Repeated reaching out resulted in a high response rate (roughly 70%, 78 individual responses out of 90 stakeholders (Eurocodes counted as a single stakeholder). In general, these telephone interviews demonstrated that the questionnaire itself was straightforward and no assistance was needed.

The answers were summarised into graphs facilitating the mapping of needs.

2.3 Responses to questionnaire and analysis

As indicated in total 78 respondents completed the questionnaire (with a further 15 who, at the closing date, did not completely filled in the questionnaire). With some participants indicating to be of more than one sector the overall sector representation was as shown in the figure below.

Figure 11 **Which sector(s) do you represent?**



Analysis

Responses to the questionnaire were analyzed. In a first step the relevance of specific parameters to specific sectors was identified. The analysis of the results of the survey is included in Annex 4: Analysis of answers given to questionnaire.

2.4 Workshop

In order to validate the findings of the survey a workshop was organized in Brussels on the 22nd of November 2017, with the title 'Future climate data for infrastructures: what is needed in standards to become climate-resilient?'. A total of 25 stakeholders participated. The main goal of the workshop was to validate the information obtained through the questionnaire. The full program of the workshop can be found in Annex 5: Programme of workshop.

Overall participants recognized the results of analysis of the. However remarks and suggestions have been put forward, and should be taken into account.

The main remarks addressed were:

- Regarding the weather impacts to consider, it is important that a clear distinction exists between 'weather effects', and 'consequences', such as drought and especially flood. The consequences highly depend on the geographical situation (local terrain), as well as evolution of effects in a previous period. Different types of flood should be taken into consideration. Information should be context specific.

- Specific points of interest raised during the workshop were:
  - humidity should be added.
  - Pollen and particles concentrations
  - For hail return periods of hail size is relevant.
  - Also shorter return periods are relevant, as these define the level of serviceability.

    - For solar radiation also small spatial resolution is relevant.

- It was stressed that in most cases, the users of the data will not be climate experts. Therefore it is needed to express data as simple as possible. Complex interpretation (for instance in choosing a scenario) should be avoided. Also there is a need for expressing uncertainties.

- On the other hand: the data are not simple in themselves. Responsible use of data will require guidance and training. These should be directed at the use of the data themselves (how to interpret data? – by C3S), as well as the use of the data in standards (e.g.: how to deal with uncertainties?). For infrastructures with long life times, new ways of engineering (‘adaptive engineering’) will be needed, taking into account the large uncertainties. It will be important to look at resilience rather than resistance.

- In the current situation it should be taken into account that for the Eurocodes, national annexes define which climate data are used. A step will be needed to erase institutional barriers, and align between all countries concerned.

3. Climate data needed

3.1 Which data are needed?

Based on questionnaire, interviews and workshop, conclusions can be drawn about the climate information needed for standards in the sector infrastructure. This information is divided towards the following aspects:

a) Relevant weather effects
b) Likelihood of events
c) Temporal resolution
d) Spatial Resolution
e) Format
f) General remarks

For each aspect key insights are presented. The text shows the qualitative insights; the graph expresses the quantified results from the questionnaire.

3.1.1 Relevant weather events:

3.1.1.1 For which weather events information is needed?

Information is needed for the following weather events. These can be divided in three categories: weather events, consequences (what follows the event), and slow-onset events:

Weather events:

- High/Low temperatures *
- Rain **
- Snow **
- Hail
- Atmospheric icing
- Lightning
- Solar radiation *
- Humidity *

* For high/low temperatures, solar radiation and humidity also the **duration of the event** is important.
** For precipitation (rain and snow) also the **accumulation** is important.

Note: Stakeholders indicate that information about coincidence of effects would be very much appreciated. This is especially the case for rain after snowfall, and rain after drought. Even if information is scarcely available, some first indications would be of great value.

Consequences:

- Flood
- Drought
- Air pollution (including microbiological agents [e.g. pollen]

Note: stakeholders indicate 'flood' as one of the most important issues for which data are needed.

Analogue for drought also topography, developments and geology influence the way drought evolves. For air pollution local and regional emissions and development are important factors.

Slow onset effects:

- Sea level rise
- Desertification
- Acidification (especially relevant in coastal areas)

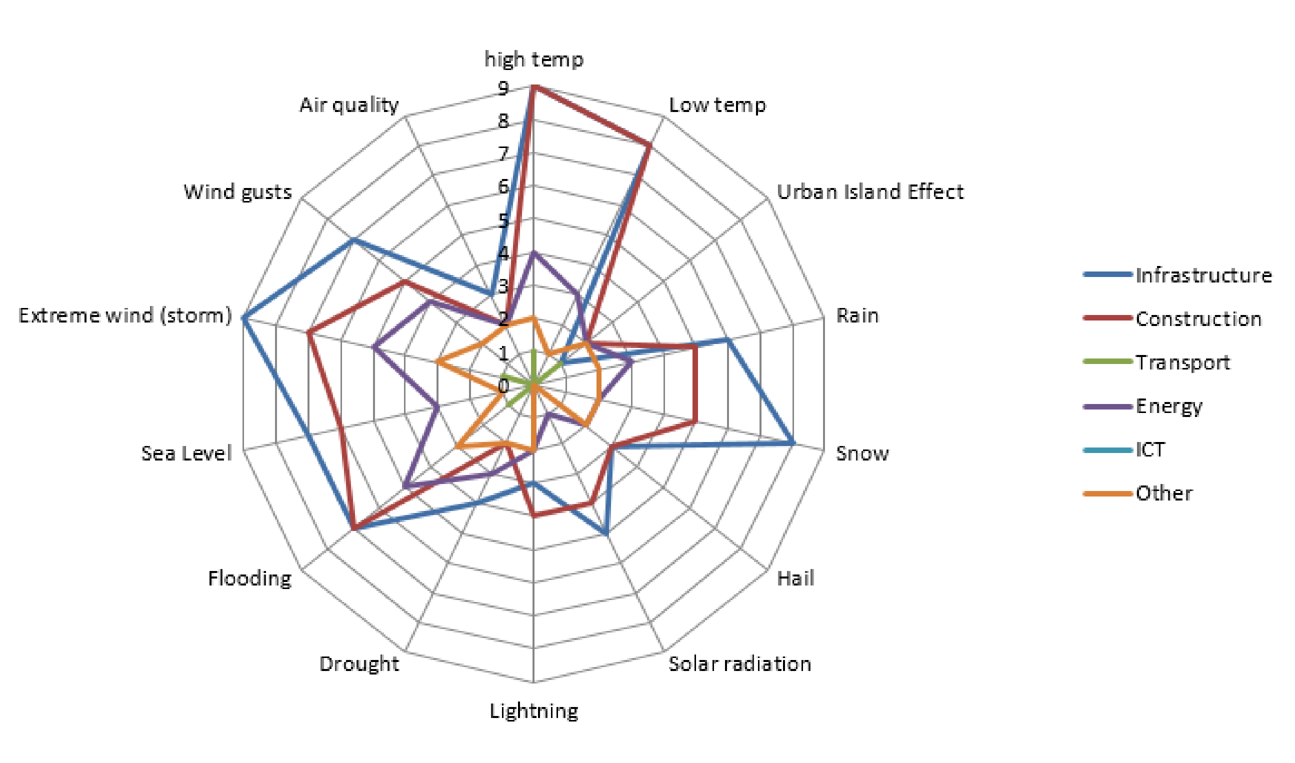
3.1.1.2 Specific requirements for information about consequences and slow onset effects:

The consequences depend strongly on local and regional variables. Therefore for these parameters specific data requirements and data outputs are needed.
As an example: for floods the different characteristics of catchment areas – topography (mountainous, hilly, lowland), developments (urban, rural), geology (porous, impervious) all influence the way floods evolve and can show up strengths and weaknesses in the planning and response to infrastructure flooding. Knowledge of weather patterns and how they impact different catchments is helpful. Also these are influenced by weather pattern (f.i. recurrence of rain, or rain following drought).
As illustration: the following types of floods can be distinguished, based on topography, (urban) developments and geology:

- Floods caused by extreme rainfall overwhelming drainage systems (**surface water flooding**, or pluvial flooding) in developed areas resulting in local disruption in urban locations.
- Exceptional **river flooding** (fluvial flooding), caused by exceptional deluges of rain over wide areas.
- **flash floods** caused by convective storms (thunderstorms), which tend to be surface water events, sometimes exacerbated by dry catchments, during summer months
- **Groundwater flooding** where the water table in aquifers rises above ground level after prolonged rainfall.

Also slow onset effects depend strongly on local and regional variables.

Figure 12 Required weather parameters per sector (results questionnaire)



3.1.2 Likelihood of events

3.1.2.1 Which return periods are relevant?

For the likelihood of events it is important to link to the current practice in the Eurocode, in which the 1/50 years is most common. Apart from this both shorter and larger return periods would be useful. Background is that in the Eurocodes data are used for two kinds of actions: serviceability limit state (SLS) and ultimate limit state (ULS). For serviceability 'short return' periods are relevant, for the ultimate limit state the larger ones. As a suggestion: apart from 1/50 years also data for 1/10, 1/20, 1/30, 1/100, 1/200 and 1/500 would be useful.

3.1.2.2 What should be expressed?

For the weather events the extreme values should be expressed. As indicated in the previous paragraph this includes duration (for high/low temperatures, solar radiation and humidity) and accumulation (for rain and snow). For the weather event "hail" stakeholders ask for the return periods of a certain size of hailstone. For the consequences, like flood and drought, likelihood should be combined with information about volume of effects (what is total volume of excess water?; which area could be flooded?).

3.1.2.3 How to present results: as a return period or as a probability?

For the presentation of data principally two options seem possible: as a return period, or as an annual exceedance probability, which is the inverse of the annual maximum return period. For example, the 100-year flood can be expressed as the 1% AEP flood, which has a 1% chance of being exceeded in any year.
From the questionnaire a preference appears for a return period (73% of responses). However: non-specialists might associate the concept of return period with a regular occurrence rather than an average recurrence interval. Based on this, a probability is recommended by the EEA when presenting results to non-specialists. Some unclarities about the meaning of return period appeared also during the workshop.
Advice: present results as annual exceedance probability.

3.1.3 Temporal resolution

In general hourly and daily data are most needed, e.g. rainfall in a day, or maximum temperature in an hour. For these mean and extreme values should be given per week, month, season and year.
In addition for rain and snow ask combined values of duration and volume are needed: as an example: the total amount of rain in a day and in a number of days (for instance a week). Analogue for temperature (high/low), solar radiation and humidity data are needed about the number of days and weeks that levels exceed a certain level.

For the weather events “rain” and “wind” also data are needed for shorter timeframes than one hour, typically for 10-15 minutes. For windgusts the typical value is the wind speed in 3 seconds.

3.1.4 Spatial Resolution

Which spatial resolution is needed?
Requirements for spatial resolution vary. For the weather events wind, rain, snow, flood, hail and solar radiation, relatively high resolutions are indicated, of 1 – 10 km^2. The same applies for high temperatures in urban areas (heat waves). For other events (temperatures (other than heat waves), humidity, drought, sea level, salination and desertification) typically more coarse resolutions are considered sufficient. A typical value is 50 km^2.

Notes:

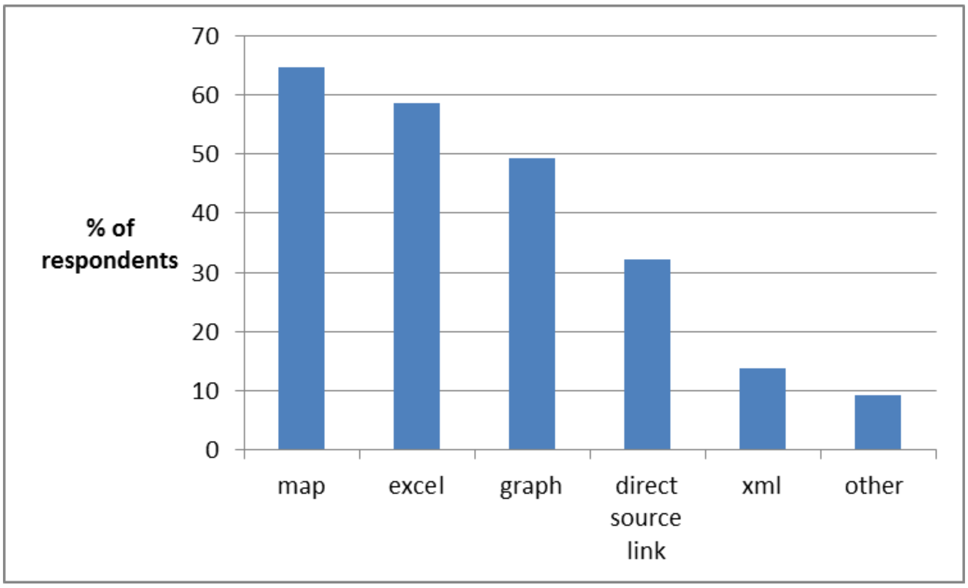
- *Stakeholders tend to ask for the highest level of detail available, and therefore also the highest resolution available (this is also indicated in the responses to the questionnaire). A consequence of this might be a large amount of data, resulting in more complexity in finding the right data and a correct interpretation of these.*
- *The expression of need for a resolution of 1km^2-10 km^2 also has to be considered carefully, as during the discussion, some confusion has been noticed between resolution of the extreme event and of the impact.*
- *This resolution if often not available in observational data, and would require very extensive climate modeling. Interpolation of observational data will not give this higher resolution.*
- *If model results are largely uncertain it makes little sense to present results in a very detailed way. This might also suggest that data are more exact than they are.*
- *if there is no spatial/ regional difference within a region, it is not necessary to give for each “grid point” all the details.*

Advice: search for a balance between the level of detail asked for and the availability and relevance of information supplied, in close communication between users and suppliers of climate information.

3.1.5 Format

The climate data can be expressed in different forms. Particularly, stakeholders ask for visual attractive presentation, such as maps and graphs. Especially ‘Maps’ are often mentioned. In addition also data are needed (dataseries/ statistics), for instance in an excel-format. In addition to this also ‘raw data’ and xml-format can be useful.

Figure 13 Preferences for presentation of climate data (results questionnaire)



3.1.6 Overview of climate data needed

Results are summarized in Tabel 1.

Tabel 1 Overview of climate data needed.

Variable	***Mean***	***Probability for extremes***	***Temporal resolution***		***Dura tion***	***Accumulati on***	***Spatial resolu tion (km^2)***	***Impacts***	***Remarks***
Temperatu re (high/low)					✓		1-10		Special focus on heat-waves Special focus on night temperatur es
Rain				10 – 15 minutes		✓	1-10		
Snow	✓	1/10 – 1/500 yr	Hour and/or Day			✓	1-10		
Humidity					✓		50		
Solar radiation					✓		1-10		
Wind							50		
Wind gust				3 secs			50		
Hail							1-10		Special focus on size of hailstones
'consequences'									
Flood		✓				✓	1-10	Area affected/ volume of water	Strongly dependent on local conditions; e.g. differentiati on needed to different types of flood
Drought		✓				✓	P.M.	Area affected	Strongly dependent on local conditions
Air quality	✓				✓		P.M.		Strongly dependent on local conditions
Slow-onset effects									
Sea level							P.M.	Area affected	
Salination							P.M.	Area affected	Strongly dependent on local conditions
Desertificat ion							P.M.	Area affected	Strongly dependent on local conditions

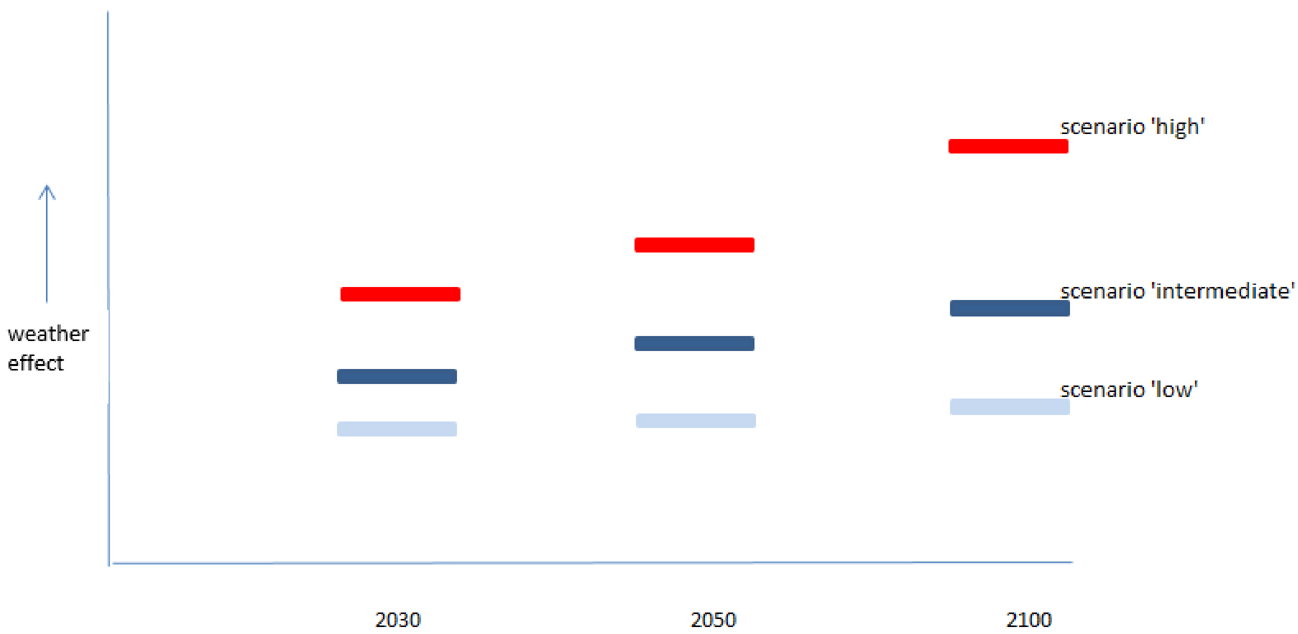
3.1.7 How to express scenarios and uncertainties?

Stakeholders indicate very clearly that they are not climate experts. They indicate that it is needed to express data as simple as possible. Complex interpretation (for instance in choosing a scenario for GHG-development) should be avoided. On the other hand stakeholders realize that the climate data are not simple at all. Furthermore stakeholders need an indication of uncertainties.

Experts from KNMI indicate that for the future different type's uncertainties exist about future developments, and therefore it might be possible to give an indication of uncertainties, but not in the form of probabilities . These depend on variety of factors, including political and economic developments and it is beyond the climate knowledge to indicate these.

A way forward would be to present several scenarios, for instance: 'low', 'intermediate' and 'high'. These are based on assumptions that result in higher or lower impacts. They should be described in general terms, so that a complex interpretation by stakeholders is avoided. Stakeholders can then to decide to take into account a 'higher' or a 'lower' scenario. The choice can depend on the circumstances for a specific infrastructure, such as effects/ damages, additional costs to realize a higher level of resistance and possibilities for intermediate repair-actions. Another advantage of this way of presenting information is that it provides an indication of the uncertainty: a larger spread indicates a higher level of uncertainty, which is also a relevant factor in decision-making.
Note KNMI: implicitly users will often interpret the intermediate scenario as the most probable one, whereas this often is not the correct interpretation (no probabilities can be given to the scenarios unless assumptions are made on socio-economic and technological developments. Besides, the most probable scenario is often not the most relevant scenario.
In addition users and writers of standards should get knowledge and expertise on the interpretation of the data from these projections (chapter 4).

Figure 14 Possible presentation of projections of future climate



4. How to make climate information authoritative and being used?

The need for climate information throughout societal decisions is expanding worldwide. Effective decision making needs not only to continue to consider the best and most comprehensive scientific observations, but also to improve significantly the integration of the information into the decision making process.

Through the work conducted under this COPERNICUS project, a conclusion is that many entities (both public and private) in sectors such as transportation, insurance, energy, water are increasingly demanding climate information for integration into their planning. Decision makers responding to climate change are motivated to promote sustainability, to protect property, and to make long-term investments. Thus, they need a permanent and clearly identifiable reference database/service that integrates all relevant climate information, provide access to comprehensive and up-to-date reliable information on current and future climate change, variability, and risks.

An effective response to climate change requires comprehensive, authoritative, and commonly agreed and referenced climate information on current and future climate change, climate impacts, the nature of extremes and vulnerabilities, as well as response options. This information needs to be made available to the widest possible range of stakeholders. To address decision makers' needs, these data must not only be recognized as the reference to use (reliability) but also presented at the appropriate geographic scale.

There is, indeed, an urgent need for development and timely delivery of credible, authoritative information and tools to decision makers at multiple scales (e.g., local, state, regional, national, and global) about how climate is changing (e.g., observations), how it may change in the future under different scenarios (e.g., climate model projections at multiple time scales), and information on current and projected impacts of climate change.

Among the solutions for moving to a more systematic consideration of climate change in decision making – including investment - for infrastructures' design and operation, four major recommendations have been made during this COPERNICUS Project:

- **Standards**: Recognized references like standards will contribute to aligning knowledge and processes for climate change consideration and thus move to new reference levels for systematic considerations in infrastructures design and operations. People trust in standards. Moreover, in Europe, an EN standard will be adopted automatically in 34 countries (EU Member States + EFTA European Free Trade Association + Turkey + former Republic of Macedonia[4]), which means an immediate alignment throughout EU of standards and commonly agreed references.
- **Raising awareness** (communication – including towards citizens- , training, support to standards' writers and policy makers). Awareness of users/consumers will contribute to systematic consideration of climate change in any infrastructure, both new ones and refurbished ones. Requests from users/citizen will contribute to moving stakeholders'

[4] EU Member States + EFTA (European Free Trade Association) + Turkey + former Republic of Macedonia

motivation/interest to consider CC information in their work. Dissemination of simple messages and examples among large audiences, tackling the need for considering climate change related impacts in any new and refurbished equipment and infrastructures.

- **Citizens** are sensitive to urban planning and receptive to stronger consideration of climatology impacts, especially since the recent events and especially their increase in frequency. Thus, raising awareness about existing reference data and promoting their integration in new projects should be well received by citizens. Concerning infrastructures' operation & maintenance specialists, having access to reliable forecasts will be very useful.But there will be a need for training these specialists about where to find the data and how to use them. They are not climatology specialists, but they are key stakeholders in the transition from Business as Usual to adaptation to climate change. A real education/training program will be needed. Back to standardization writers, there will also be a crucial need for communication, education and training.
- **Common reference (reliable) data base with single entry point**: Consensual needs have been expressed with regards to a reliable database, common to all and covering all indexes with spatial and temporal references, as well as with a unique entry point. Such a "tool" is considered as the best way to "motivate" consideration of climate change related impacts in design and operation phases of any infrastructure. More specifically, standardization development at European level (CEN/CENELEC/ETSI-ESOs-), requires a consensus among the experts first, and then among the ESOs' members (mainly countries).

  In addition, to maintain an efficient use of standards, such as with **consideration of recent (updated) values** of the Climate Change related data, there will be a need to refer to a common reference database instead of values. Otherwise, every time data will change, standards will be obsolete when not revised. And revision will be very time consuming and lead to delay. Among the suggestions made and discussed (i.e. during the workshop), this unique entry point could be accessible through the COPERNICUS C3S website, or the EEA (European Environmental Agency) website. Then, the version of the database (updates) will have to be clearly identified. This development for a unique reference database is very certainly the most urgent request from the stakeholders. This will also contribute in a significant manner to the "education" and sensibilization, then training of the stakeholders throughout Europe. One single and unique database will allow to "speak the same language". This will thus impulse a culture of "authoritatively" consideration of CC information.
- A specific case concerns the **Eurocodes with their national annexes** where climatology issues are specified. If these annexes are national based, alignment in the set of data to be considered would be very useful and relevant. Of course, national, regional and local resolution will be key, but ensuring a similar consideration of these climate impacts through a similar methodology will be very positive and help moving to more safe equipment and infrastructures.
- **Similar format(s) for all data**: It has been identified – questionnaire and workshop – that there is a need to align the format of all data. If inclusion of impacting values in infrastructures' design and operation phases could need different format depending the sector to consider, there is a consensus that having all data accessible in similar formats (i.e. excel). In addition to "tables", maps and graphs are considered as very useful for representations and communication, following similar models than meteorological forecasts

people are familiar with. If maps will be very useful to identify the zones of risks, data will be essential to quantify these risks and integrate “values” in the design and operation of infrastructures and equipment’s.

5. Recommendations for an ITT

5.1 Recommendations for reference datasets on future climate

This project has highlighted the need for several data and sets of data, with spatial and time resolutions. The overview of climate data needed for standards in the infrastructure sector (table 2) summarizes these needs:

- **Extreme Temperatures (High/low)**, with a daily and hourly temporal resolution and a spatial resolution of 1-10 km^2; duration of the event as well as special focus on heat-waves and night temperatures have been underlined.
  Note KNMI: this resolution not available in observational data, would require very extensive climate modeling. Interpolation of observational data will not give this higher resolution. This is also the case for the other climate variables.
- **Rain**, with a daily and hourly temporal resolution, and a spatial resolution of 1-10 km^2; accumulation and intensity (within 10-15 minutes temporal resolution) have been requested.
- **Snow**, with a daily and hourly temporal resolution, and a spatial resolution of 1-10 km^2; accumulation and density have been requested
- **Humidity** with a daily and hourly temporal resolution, and a spatial resolution of 50 km^2; evolution of humidity and duration at extreme values have been requested.
- **Solar radiation** with a daily and hourly temporal resolution, and a spatial resolution of 1-10 km^2; duration and hourly evolution throughout a day has been identified as useful values.
- **Wind** with a daily and hourly temporal resolution, and a spatial resolution of 50 km^2; hourly evolution throughout a day.
- **Wind gusts** with a temporal resolution of 3 seconds and a spatial resolution consistent with the wind mean values.
- **Hail** with a special focus on size of hailstones, accumulation and duration, spatial resolution of 1-10 km^2.
  Note KNMI: hardly any observational data available and generally not in climate models
- **Flood**, forecasts on accumulation and a spatial resolution of 1-10 km^2. A forecast on the area affected as well as the volume of water has been identified as useful values. As this strongly depends on local conditions, there is a need to consider succession of events and cumulative effects (such as accumulation of snow and heavy rain, drought then extreme rain, …)
- **Drought**, forecasts on duration and intensity, and a spatial resolution that depends on the local context. As this strongly depends on local conditions, there is a need to consider succession of events and cumulative effects as well (such as solar radiation, wind, and temperature, …)
- **Air quality**, with evolution of the characteristic data, duration of extremes values and a spatial resolution consistent with the local context (i.e. city area). As this strongly depends on local conditions, there is a need to consider succession of events and cumulative effects as well (such as heat island effect, humidity, wind, temperature, rain, …). Among air quality, in addition to the traditional chemical components, pollens and solid particles (i.e. PMs, “dusts”) have to be included

- **Sea level**, forecasts on tides and cumulative effects with sea waves, wind and wind gusts.

If needs for higher resolution (mainly spatial) have been expressed, this has to be balanced against uncertainties. Thus, the expression of need for a resolution of $1km^2$-$10\ km^2$ has to be considered carefully, as during the discussion, some confusion have been noticed between resolution of the extreme event and of the impact. In addition, this high resolution is well higher than most of the weather models.

Note KNMI: It is imaginable that users ask for the specifications above. However, it will in most cases not be possible to deliver this within some years. Besides the requests also contradict some of the other requests, such as easy/simple to use data and easy access. A suggestion is to translate the suggestions into more practical data or data products. This can only be done while working together with the users, since regular feedback on the translation is needed.

As the users are not experts, the climate data developed should be as simple as possible, avoiding complex interpretations. Specific attention should be paid to a presentation of data that shows different possible outcomes of scenarios and provides an indication of uncertainties and allows for an easy choice of relevant data in the design and/or operation phases of infrastructures. Regarding the complexity of the issue and the limited know-how of the users, we recommend that the ITT also addresses communication with stakeholders in order that data provided can be used in an appropriate way.

What has been expressed in terms of further development relates to impacts of cumulative effects, such as droughts then massive rain, dynamic sea level raise from extreme tides combined with strong wind/storm and rain, concentration of particles (i.e pollen, pollutants, dust) combined with wind, high temperature and rain, combined snow and rain (i.e impacting capacity of the soil to absorb/risk of landslides). Many of these single data already exist and are available. However, needs for a few sets (combination) of data have been expressed with relevant characteristic indicators, especially in relation to the very recent extreme weather events that occurred in Europe. Among the "new" data needed, lightning has been identified, especially in the building sector and the energy ones.

Concerning spatial resolutions, lots of divergences have been expressed, as these parameters strongly depend on the type of climatology effect and the local geology and geographic characteristics. However, generally speaking, there is a need to refine the resolution, especially in consistency with the fast increasing extreme weather events that occurred at very local locations. Of course, users could ask for as much as possible details, but there is a need to provide realistic values consistent with their accuracy. In addition, having too detailed data would lead to a huge amount of data,that will prevent the users from a realistic and appropriate consideration.

Finally, stakeholders have expressed a need for more frequent updates of the climate projections and especially with consideration of recent past events in order to integrate the raising frequency of extremes (what was the centennial event in the past could very probably become the decedal one or event on higher frequency). Concerning forecasts, expressions of needs have revealed a strong need for precise local values in order to coordinate the operational sequences of infrastructures as well as possible emergency procedures. Indeed, “basic” data will have to be analyzed and treated in combined scenarios in order to evaluate the risk and impacts. This means that stakeholders need permanent forecasts through a single and common channel. They expressed a clear need for a single entry point for all relevant data and sets of data. They also expressed a need for standardized databases and representations, including similar formats for all data (i.e. excel format) and easy to visualize graphic representation (maps) that help in the follow-up of extremes’ evolution.

In conclusion, in addition to a few new data/sets of data, spatial and time resolution, common/standardized list of standardized data and sets of data are requested, with a unique entry point (website) and availability of data in similar formats.
Moreover, a need for a benchmark of “best practices” has been expressed, in order to help others making decisions, especially about how to consider succession of events and combination of events (additional impacts).

5.2 Other recommendations

Among the main recommendations for further actions, awareness rising has been systematically identified. Indeed, there is a crucial need for knowledge sharing and education, both towards professionals and citizen. Communication about the relevance and the maturity of the scenarios and their inclusion in infrastructure design and operations are essential.

1. Communication about the existence of a reliable database;
2. Communication about simple success stories and examples of inclusion of climate change information in infrastructures’ design and operation, which would contribute to enhancing the feeling safety and security among the users/citizens, and to promoting the need to include climate change information in further development and operation. This will contribute to moving the climate change information to more authoritatively;
3. Training stakeholders about the database and how to use it;
4. Training stakeholders about the scenarios and how to select the appropriate one(s);
5. Training stakeholders about uncertainties and accuracy;
6. Educating and training standards writers about the importance to consider climate change information in their work, as well as about how to include climate change information in standards (reference to a common/unique database, etc..);
7. Communication about the updates of the database through reference channels;
8. Promote the inclusion of climate change consideration in policies and regulations regarding infrastructures/equipments, as well for their certification/accreditation;
9. Communicate about climate change related impacts (maps, graphs) in a similar way as for the weather forecasts (meteo maps), in order to get people used to other indexes than sun/cloud/rain- temperature and wind but in a similar format.

Moreover, training professional and decision makers about climate change and the need for considering its impacts (adaptation/resilience) has been expressed as a critical need too. Standards are performant “tools” for accelerating the integration of climate change related data in any infrastructure design and operation. Thus, communication about standardization development as well as training about how to implement these standards will be a major step to engage in.

Finally, it will be vital to communicate to the standardization community about the aim and progress in relation to the ITT, in order to raise awareness and prepare all stakeholders to a new way of designing the infrastructures and defining the operational phase then emergency procedures.

It would also be very relevant to communicate to users/consumers/citizen about these developments to show the effort and the relevance of the actions towards adaptation to climate change and impulse a perception of de-risking then a feeling of trust. Resilient citizen are a key part of our smart and sustainable development.

5.3 Next steps

Following the above mentioned recommendations, and in coherence with the stakeholders' expression of needs, the priority for next steps can be summarized as follows:

- Gathering available data and **developing robust and transparent datasets with similar format(s)**
- **Sharing these datasets with the different communities for "test" implementation** - "in practice" – "playing" with these datasets for checking their relevance
- **Feedbacks** from these test implementation, **then co-production**/refinement of the datasets between scientists and engineers/standardization experts. This will enhance the robustness and transparency, and as a consequence, trust in the data).
- Preparing a **communication and training toolkit** based on test cases and good examples/best practices to bridge the gap between the communities (scientists, engineers and other stakeholders); a specific action plan for communication/diffusion should be set. The same applies to cross training/education (scientists-engineers-standardization experts).
- Creating a **"single" entry point for accessing these datasets**; this could be referred to in the standards.

6. Annex 1: Advisory panel

Mr. Carlo Buontempo	ECMWF, C3S
Mr. Craig Davies	EBRD, European Bank Reconstruction and Development
Mrs. Sarah Duff	EIB/Jaspers (European Investment Bank)
Mr. Hans van Os	EIB/Jaspers (European Investment Bank)
Mr. Svein Fikke	Chair CEN TC 250 (Eurocodes)/SC1/WG5 (Climate change)
Mr. Ari Ilomaki	Chair CEN TC 350, Sustainability of construction works
Mr. Max Linsen	European Commission DG Clima
Mrs. Andrea Nam	CEN/CENELEC
Mrs. Hiltrud Schulken	Secretary CEN TC 234 (Gas infrastructure)
Mr. Mingyi Wang	GDV, Chair Coordination Group Climate Change Adaptation, EC Mandate Climate Change Adaptation Infrastructures
Mr. Ab de Buck	NEN, Project-leader
Mr. Okke-Jaap Prent	NEN
Mr. Thijs de Wolff	NEN
Mr. Bernard Gindroz	BMGI Consulting

7. Annex 2: Standards selected in EC mandate

Responsible TC Committee #	Responsible TC Committee Name	Standard Reference #
building sector		
CEN TC 89 / ISO TC 163	Thermal performance of buildings and building components	EN ISO 15927-4
CEN TC 156	Ventilation for buildings	FprEN 16798-1 and -3; -2 and -
CEN TC 350	Sustainability of Construction Works	EN 16309
CEN TC 371	Project Committee - Energy Performance of Building project group	EN ISO 52000-1
CEN TC 350	Sustainability of Construction Works	***NEW***
energy sector		
CEN TC 234	Gas Infrastructure	EN 16348
CEN TC 234	Gas Infrastructure	EN 15399
CEN TC 282	Installation and equipment for LNG	EN 1473
ICT infrastructures		
CLC TC 215	Electrotechnical aspects of telecommunication equipment	EN 50600-2-1 and 50600-2-3
transport sector		
CEN TC 104	Concrete and related products	EN 206
CEN TC 256	Railway applications	EN 15723
CLC TC 9X	Electrical and electronic applications for railways	EN 50125-1, -2 and -3
CEN TC 274	Aircraft ground support equipment	EN 1915-1 and -2

8. Annex 3: List of Technical Committees approached

CEN/TC 12	Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries
CEN/TC 15	Inland navigation vessels
CEN/TC 33	Doors, windows, shutters, building hardware and curtain walling
CEN/TC 51	Cement and building limes
CEN/TC 54	Unfired pressure vessels
CEN/TC 89	Thermal performance of buildings and building components
CEN/TC 104	Concrete and related products
CEN/TC 107	Prefabricated district heating and district cooling pipe system
CEN/TC 113	Heat pumps and air conditioning units
CEN/TC 124	Timber structures
CEN/TC 125	Masonry
CEN/TC 128	Roof covering products for discontinuous laying and products for wall cladding
CEN/TC 129	Glass in building
CEN/TC 151	Construction equipment and building material machines - Safety
CEN/TC 152	Fairground and amusement park machinery and structures - Safety
CEN/TC 156	Ventilation for buildings
CEN/TC 164	Water supply
CEN/TC 165	Waste water engineering
CEN/TC 210	GRP tanks and vessels
CEN/TC 226	Road equipment
CEN/TC 227	Road materials
CEN/TC 234	Gas infrastructure
CEN/TC 235	Gas pressure regulators and associated safety devices for use in gas transmission and distribution
CEN/TC 250	Structural Eurocodes
CEN/TC 254	Flexible sheets for waterproofing
CEN/TC 256	Railway applications
CEN/TC 268	Cryogenic vessels and specific hydrogen technologies applications
CEN/TC 274	Aircraft ground support equipment
CEN/TC 282	Installation and equipment for LNG
CEN/TC 284	Greenhouses
CEN/TC 288	Execution of special geotechnical works
CEN/TC 319	Maintenance
CEN/TC 320	Transport - Logistics and services
CEN/TC 334	Irrigation techniques
CEN/TC 337	Road operation equipment and products
CEN/TC 340	Anti-seismic devices
CEN/TC 341	Geotechnical Investigation and Testing
CEN/TC 350	Sustainability of construction works
CEN/TC 371	Energy Performance of Buildings project group
CEN/TC 430	Nuclear energy, nuclear technologies, and radiological protection
CEN/CLC/ETSI/SF-SSCC	CEN-CENELEC-ETSI Sector Forum on Smart and Sustainable Cities and Communities
CEN/CLC/TC 2	Power Engineering

CEN/CLC/TC 3	Quality management and corresponding general aspects for medical devices
CEN/CLC/TC 4	Services for fire safety and security systems
CLC/TC 2	Rotating machinery
CLC/TC 9X	Electrical and electronic applications for railways
CLC/TC 11	Overhead electrical lines exceeding 1 kV a.c. (1,5 kV d.c.)
CLC/TC 13	Electrical energy measurement and control
CLC/TC 14	Power transformers
CLC/TC 17AC	High-voltage switchgear and controlgear
CLC/TC 18X	Electrical installations of ships and of mobile and fixed offshore units
CLC/TC 31	Electrical apparatus for potentially explosive atmospheres
CLC/TC 45AX	Instrumentation, control and electrical systems of nuclear facilities
CLC/TC 57	Power systems management and associated information exchange
CLC/TC 62	Electrical equipment in medical practice
CLC/TC 64	Electrical installations and protection against electric shock
CLC/TC 79	Alarm systems
CLC/TC 81X	Lightning protection
CLC/TC 82	Solar photovoltaic energy systems
CLC/TC 88	Wind turbines
CLC/TC 99X	Power installations exceeding 1 kV a.c. (1,5 kV d.c.)
CLC/TC 111X	Environment
CLC/TC 205	Home and Building Electronic Systems (HBES)
CLC/TC 209	Cable networks for television signals, sound signals and interactive services
CLC/TC 215	Electrotechnical aspects of telecommunication equipment

9. Annex 4: Analysis of answers given to questionnaire

Main findings
Most respondents do not use scenarios or projections for future climate. They indicate that they follow existing standards (which usually refer to historical datasets), that data are scarce, and that is difficult to interprete available information. If future information is used, it is based on a high level information - national or global databases. Recent past information about extremes is used on occasion, not routinely.
Respondents indicate a clear need for reliable climate data, both recent past and the future. Especially information is needed for the extreme events, in terms of frequency. Most expressed is a need for data for temperatures (high/low), rain, snow, flood and sea level. To a lesser extent also for the other events: hail, lightning, solar radiation, air pollution.
As the stakeholders consulted are primarily users of climate data, not specialists, they have a need for data that can be used easily. Data should be aligned with standards, especially the Eurocodes. This would allow for a structural use in the design and operation of infrastructures. They indicate they will need training for interpretation of available climate data in standards, for instance regarding questions about the types of data to be used, and how to deal with uncertainties.

Needs for climate data:
- Data are needed for all weather events. Mean values and extremes (probabilities and effects).
- Temporal resolution: for most weather effects main interest for hourly and daily data, but also for larger periods. For rain and wind also on the range of minutes (10 minutes, wind gusts of 3 seconds).
- Spatial resolution: for hail, windstorm, flood, rainfall, heat islands, small resolutions are needed (1-10 km2), for other events larger resolutions will be sufficient.
- Duration of events is important for high/low temperatures, solar radiation and drought.
- Cumulation is important for precipitation (rain, snow)
- One weather effect should be added: atmospheric icing. This is relevant for mountainous regions.
- Coincidence of climate effects is considered of vital importance, currently not available: any information about this would be of great value. A specific example is snow followed by rain.

Note: a large number of stakeholders responded on the questionnaire (76 out of 125 addressees), also quality of responses suffices well. Furthermore, the respondents represent key sectors of infrastructures. This allows for a sound interpretation of the current practice and the needs for future climate data.

Questions for workshop

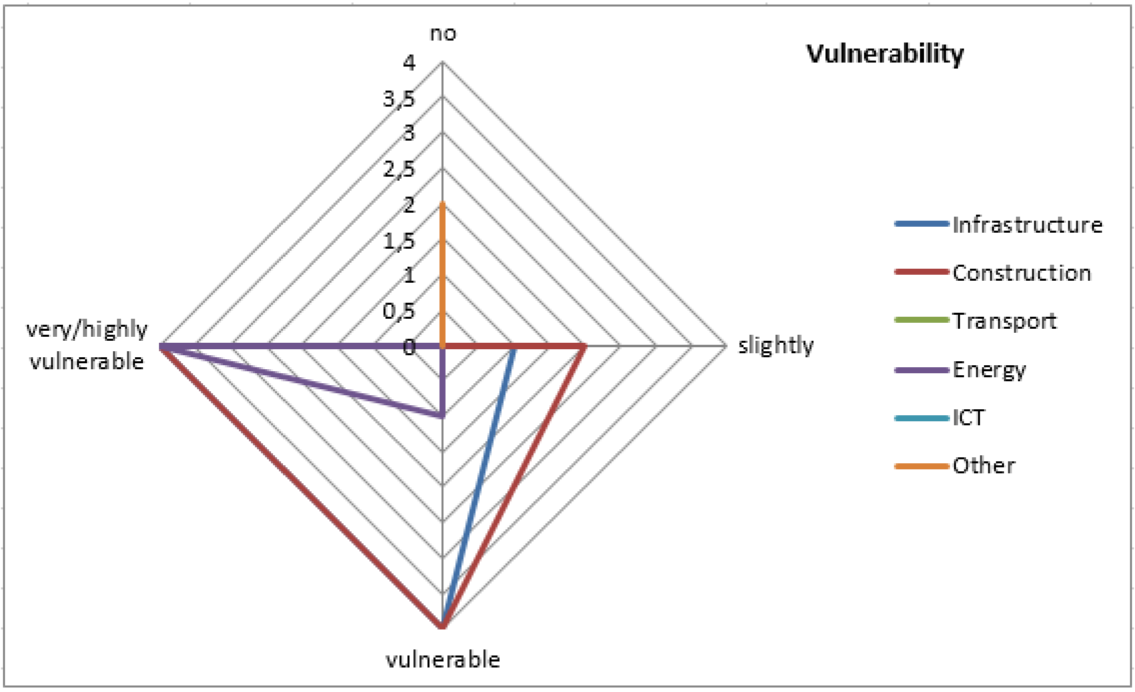
- Check: is the interpretation of data needs, as indicated above, correct?
- Scenarios: projections rely on scenarios, which are based on different pathways for future GHG-emissions. Should projections show impacts for different scenarios, or should this be integrated in a more simple presentation?
- Probability. The probability of events can be expressed in different ways: return periods, percentiles and the number of days that a certain level will be exceeded. What is the best way to express, what fits best with existing standards?
- Uncertainties. Future climate data have uncertainties (due to scenarios and models). How should these be expressed? Would it suit to give a most probable value and a range?
- Training. Respondents indicate that training is needed. What should training be focused at?
- Standards: how to align climate data with specifications in standards?
- …
-

Question 1. Which sector(s) do you represent?

All sectors of infrastructures are represented (building 52%, energy and transport both 25%). ICT to a lesser extent (4%).

Question 2. To what level is your sector vulnerable to weather events in your opinion?

Figure 15 Perception of vulnerability of infrastructures (results questionnaire)



Question 3. influences of weather events

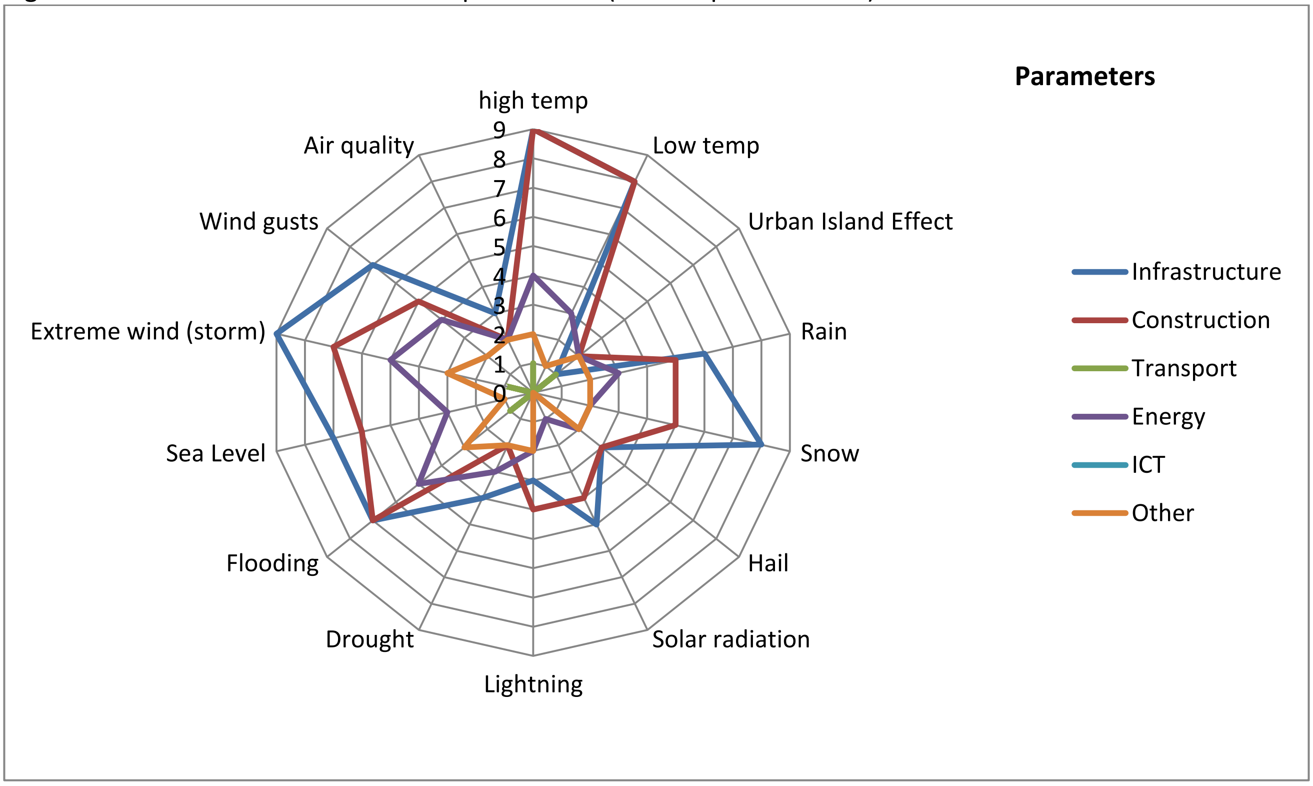
Question 3.A In what phase does your sector cope with extreme weather events?

Most important weather events (i.e.: most indicated in the questionnaire) are :

- High temperature
- Low temperature
- Snow
- Rain
- Sea level
- Extreme wind
- Wind gusts

These are most indicated in the questionnaire, all above 60%:

Figure 16 Relevance of weather parameters (results questionnaire)



For all, both design phase and operational phase are considered equally important. One exception: for sea level especially the design phase is considered more important.

As shown above, events fewer mentioned are hail, lightning and air quality. These score below 50%, with equally importance for design and operational phase.

Question 3.B Please specify the impacts (damages, disruptions) for the relevant weather parameters. .

Table 2 Possible impacts of weather parameters (results questionnaire)

Parameter	**Impacts**					
High temperature	Impact on materials (thermal expansion)	overheated buildings, persons inside	Roads and bridges, pavements	Rail infrastructure (rail buckles, transmission efficiencies, ..) Discomfort for staff and passengers	Power plants (lower efficiency)	
Urban heat Island	*Idem as high temperature*					
Low temperature	Impact on materials: expansion/ contraction		Roads and bridges, pavements Ice accumulation on vehicles	Rail infrastructure (traction/ grip, broken rails, icing of equipment, ..)	Electricity infrastructure: freezing of distribution lines Freezing of water supplies	
Rain	Local flood, due to undersized sewage water systems/ reservoirs	Land slides/ erosion	Moisture damage	Train delays, due to landslip, flood, scour/ erosion	Changes in hydro-generation	Higher ground water level, impact on soil stability
Snow		Roof structures: Stresses Note: especially if followed by rain	Slippery surfaces, reduced visibility	Blocking of the track/ problems with switches/ burden on traction/ grip.		
Hail	Photovoltaïc systems: damage	Roofs and windows: damage	Slippery surfaces, reduced visibility	Icing of equipment/ burden on traction/grip		
Solar radiation	Material degradation (plastics)	Damage to roofs		Rail buckling/ workforce welfare		
Lightning	Structural damages, fire	Disruption of electrical systems	Damage to cable supported bridges (cables, pylons) Disruption of electronic systems in	Delays in rail-transport		

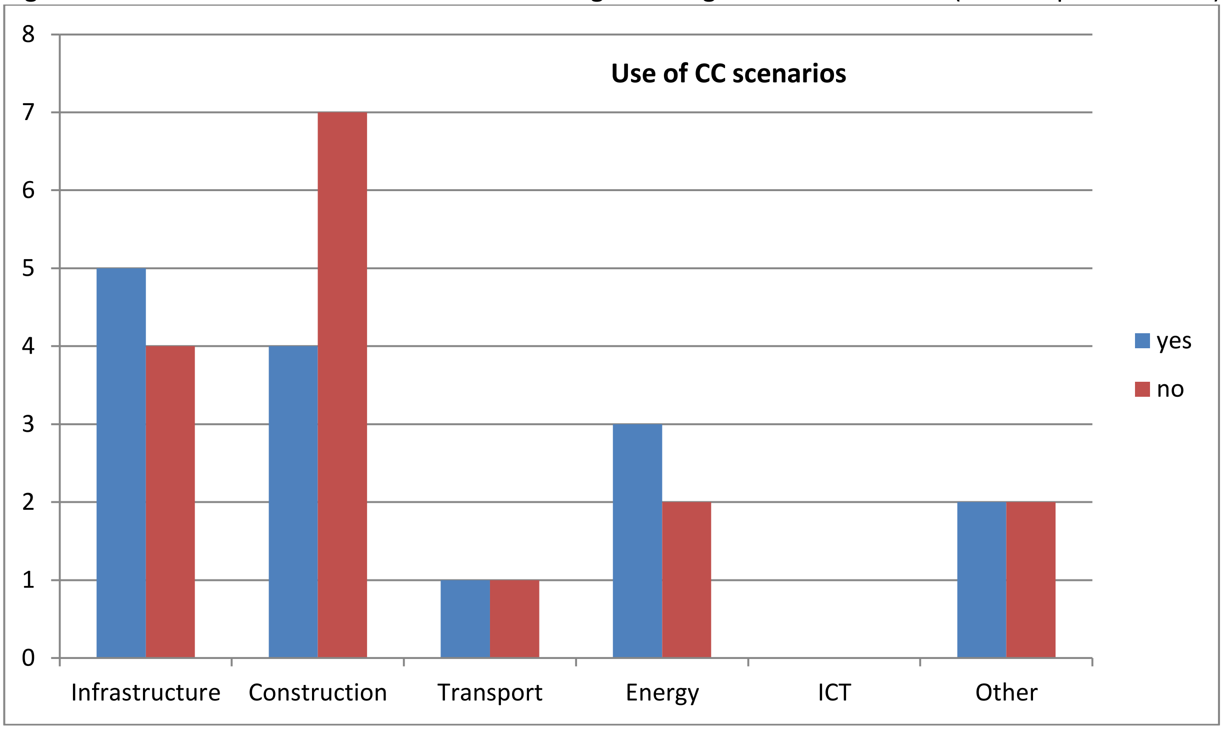
Parameter	Impacts					
			vehicles			
Drought		Desiccation of earthworks, foundation movement	Inland shipping – reduction of transport via water	Rail transport/ delays, due to desiccation of earthworks	Impact on hydro electricity generation Heating and cooling of thermal power plants	
Flooding	Property loss, Material damages, loads on structures Disruption of operations Scour to foundations	Security of population	Bridges and assets foundations Hardship in use of all transport modes (land, water, air) Damage to vehicles	Train delays due to landslip, erosion, scour, damaged equipment	Problemes with energy supply Difficulties in the work of natural gas network facilities Damages to ICT and control systems	Note: the most often addressed issue
Sea level	Flood; Impact on coast infrastructures; Scour to sea defences; Security of the population.		Impact on bridges with piers in the sea	Railways in coastal areas; delays to flood, landslip, erosion, scour,….		Note: many cities are along or close to seas, thus vulnerable to elevation of sea level.
Extreme wind (storm)	Stresses, mechanical stability, higher waves, destruction of infrastructures and buildings, Property loss	security of people (direct [fall] and indirect [flying/ falling objects]	Problem for all transport modes Loss of control of vehicles Risks for long span bridges	Train delays, line blockages, power liens brought down, damaged equipment		
Wind gusts	*Same as extreme wind*					
Air quality	Impact on materials (concrete, corrosion of steel)	Workforce welfare	Critical for health and vulnerable people			

Question 4. Do you use any climate change scenario or projections?

Most important reason for not using scenarios: not yet part of design practice - **not yet in our standards** (such as EN ISO 15927 [building design]] and Eurocodes).
Those who use scenarios or projections:

- Indicate they use data on a high abstract level;
- Typically national data: UK (projections 2009), Sweden (Swedish weather survey), Netherlands (KNMI 2014 scenarios);
- For sea level rise, snow, wind, floods and temperatures

Figure 17 Use of scenarios for climate change in design of infrastructures (results questionnaire)



Question 5: If you take climate change into account, how do you deal with the uncertainty about the future climate? For example: We use 20% higher rainfall amounts than required for the current climate for the design of tunnels.

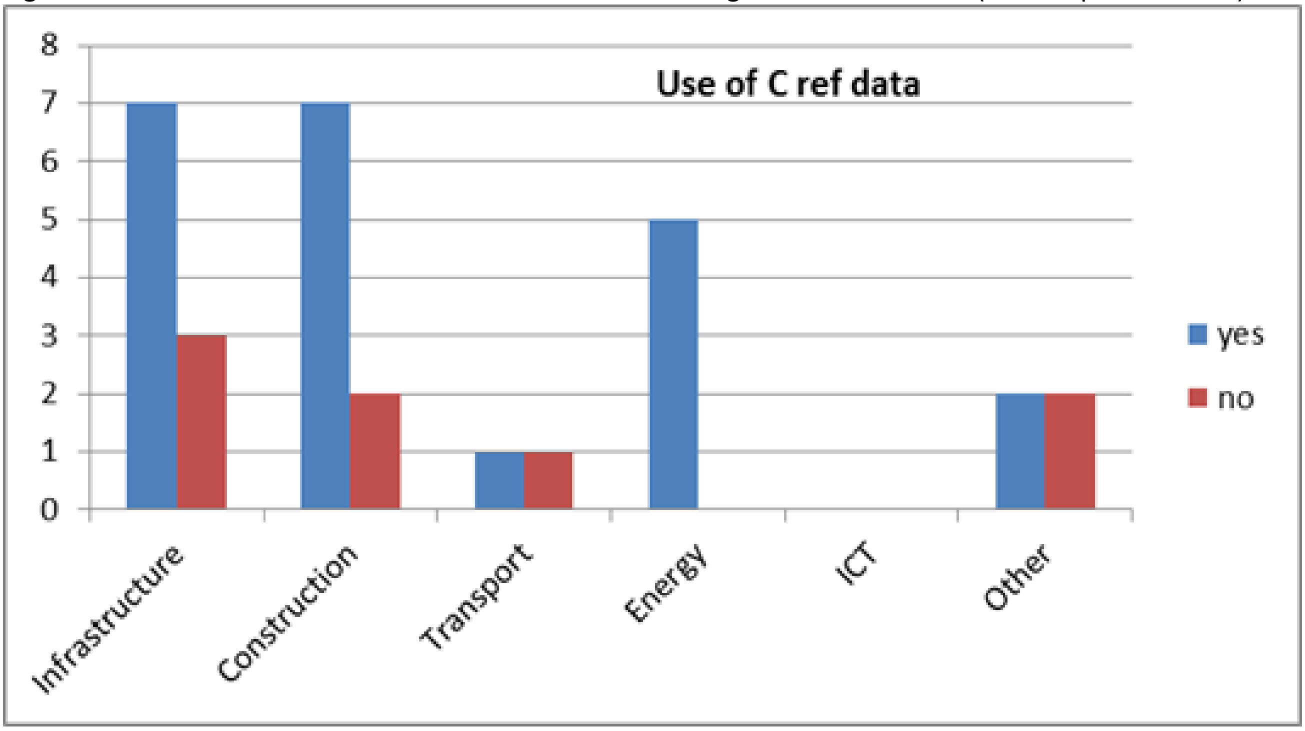
Many respondents answered this question. Key issues:

- Not in current standards
- Exception: NEN 5060 (Netherlands) contains 20 years ahead information
- For sea level we take it into consideration
- Not for wind speeds
- This is based on client specifications, they usually do not take this into account
- Uncertainties are not known
- Use safety margins
- Some countries/ sectors use a specific approach, others do not
- Design to worst case scenario/ conservative approach.

Question 6: Are you using climate reference data in your sector to describe the current climate?

Somewhat more than half respondents (55%) indicate yes. The others do not.
Data from national climate institutes are used KNMI data day temperatures, Meteo France, UK Met office base line scenario (1961 – 1990!). These are referred to in standards, such as EN ISO 15927 (thermal regulation, snowfall, wind).
“we try to, but hard to get data”, “nothing beyond existing standards”

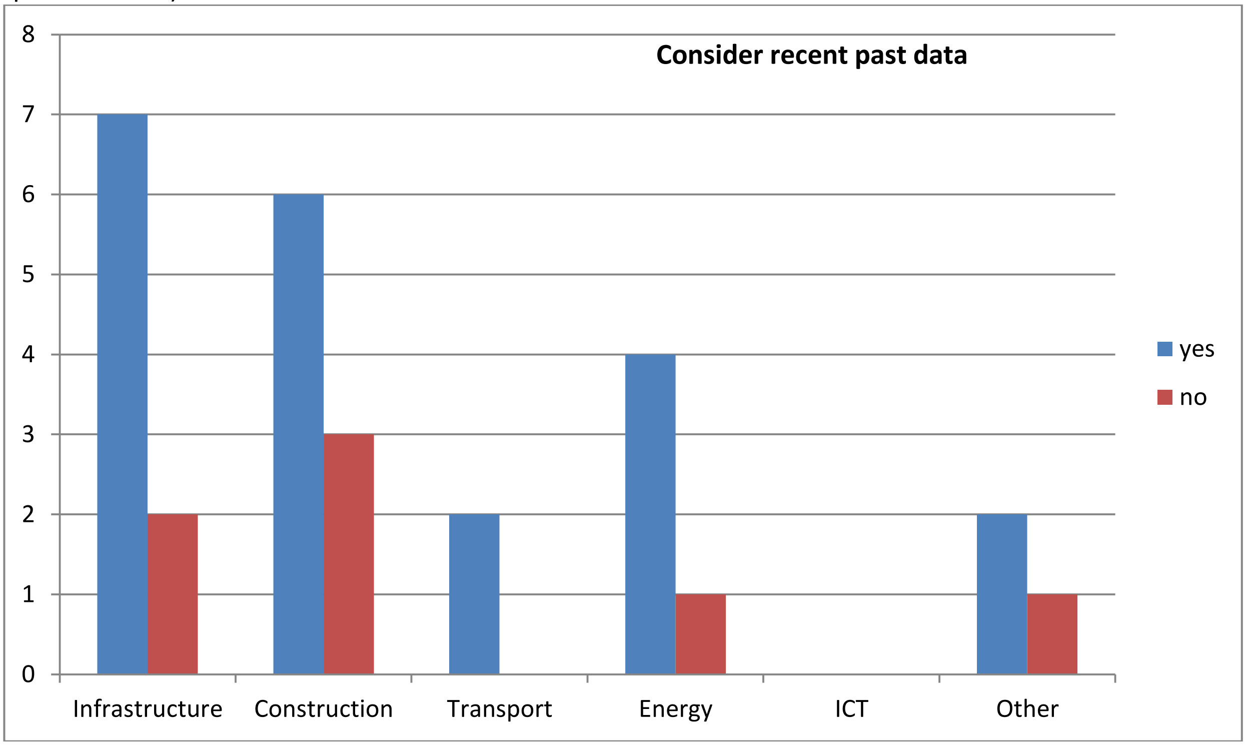
Figure 18 Use of current climate reference data in design of infrastructures (results questionnaire)



Question 7: Is your sector considering recent past extreme weather events for current and future projects?

Majority: yes!
On occasion, not routinely. “as lessons learnt, not for modeling purposes”, “for research programmes sometimes”, “internal historic data analysis of weather data and failures”.
Not because not applicable, “consensual rules do not exist”

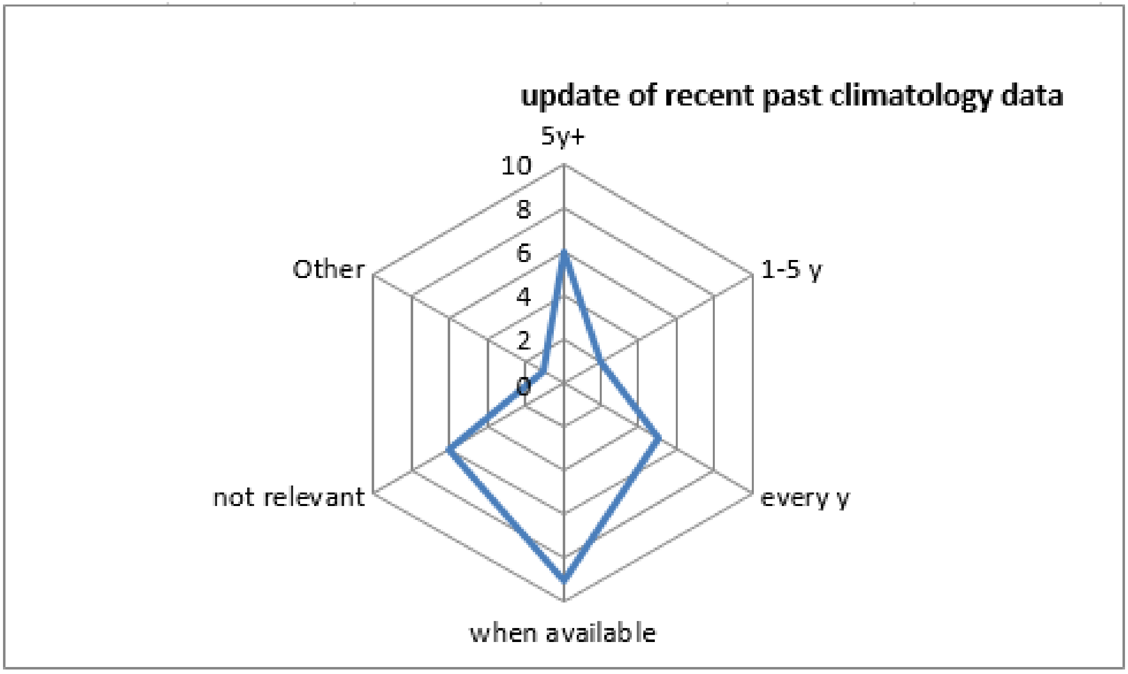
Figure 19 Recent past weather events taken into consideration in design of infrastructures (results questionnaire)



Question 8: How often does your sector require updates of recent past climatology data?

Most indicate: every 5 year or more, and: would like to be informed when new data is available.

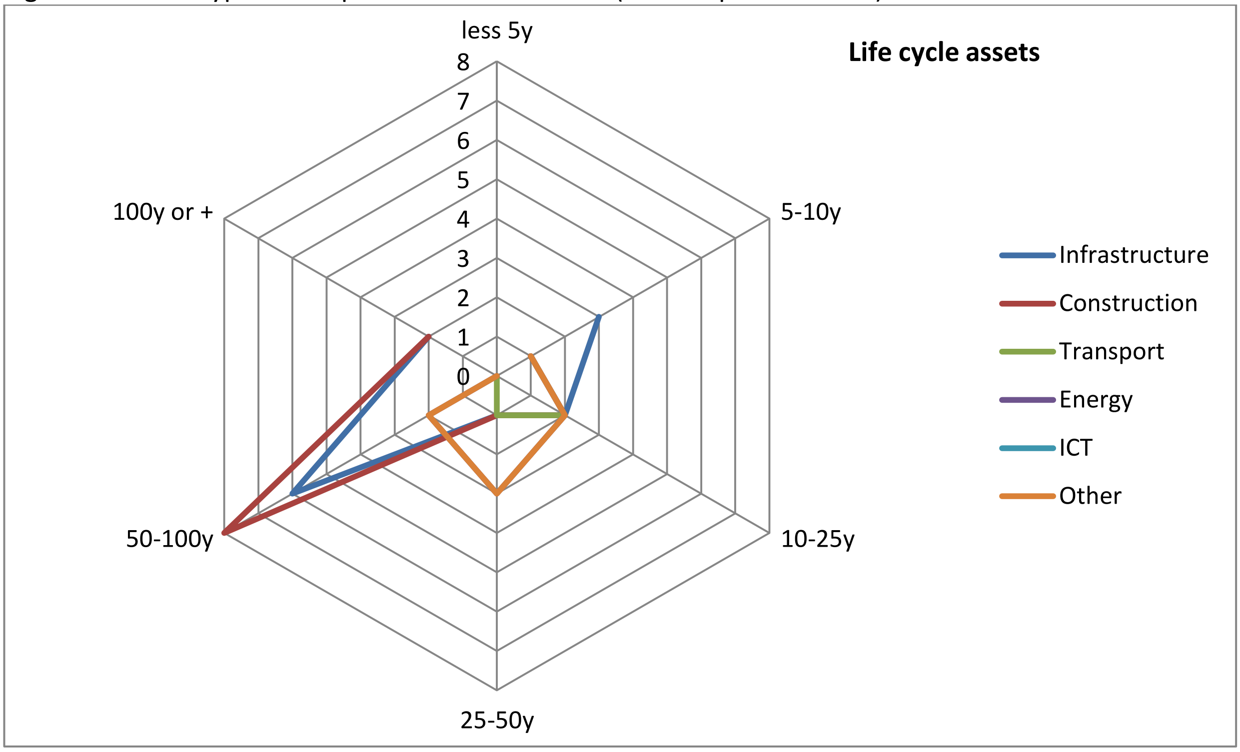
Figure 20 Frequency for update of recent past climatology data (results questionnaire)



Question 9: What is/are the typical life cycle of the assets in your sector/standard?

Majority (72%): more than 25 years.

Figure 21 Typical life spam of infrastructures (results questionnaire)



Question 10: Do you take your asset's life cycle into account when using climate data in the design phase? If so please explain how.

About half of answers given indicate 'yes', others indicate 'no'. Answers to this question are difficult to interpret: several indicate they look at the whole life cycle, but not in terms of climate change.

Question 11: For the weather/climate variables given below, what type of information (for current and future climate) would your sector like to have? For example for high temperature: can you give threshold values or indices that are relevant in your sector?

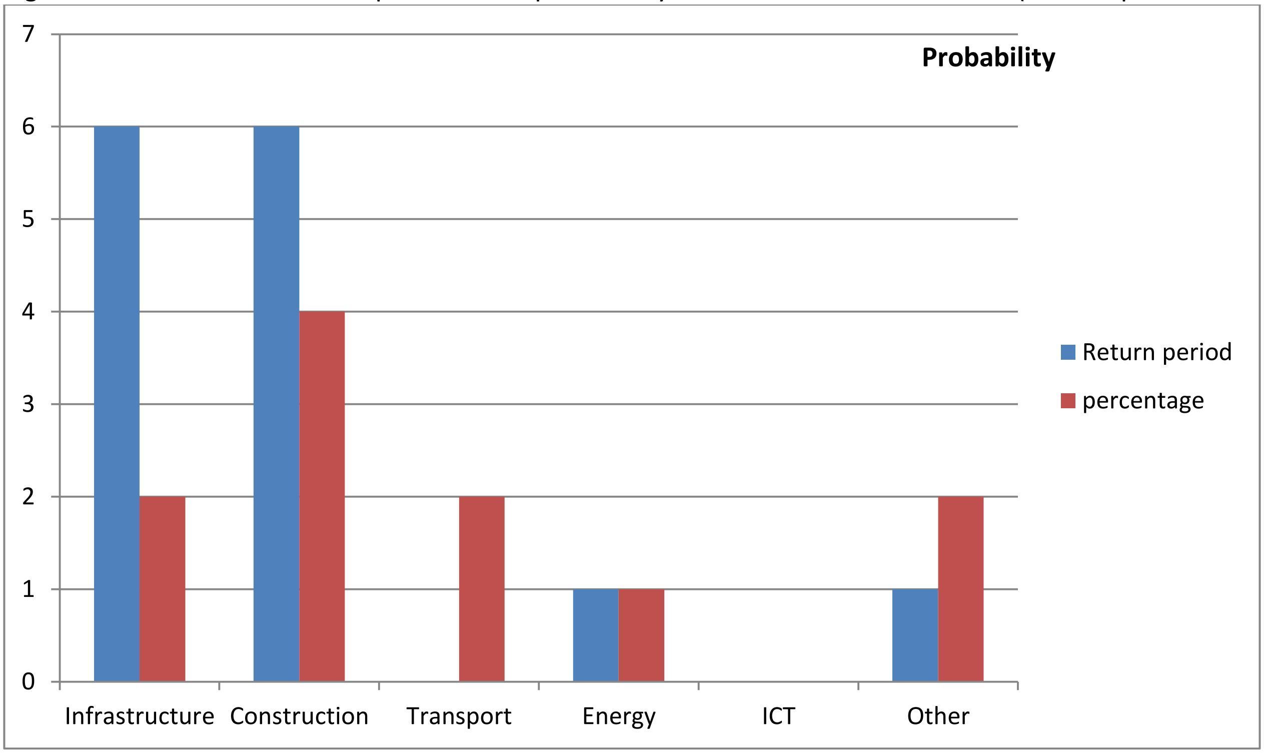
Question 12: In what format/type would you prefer to get the climate prognoses?

Respondents ask for different types of formats, as well as combinations. Especially: excel, graphs and maps.

Question 13: How would you prefer the likelihood or probability of extreme weather events to be expressed?

Most (73%) ask for return period, a lesser number for a percentage.

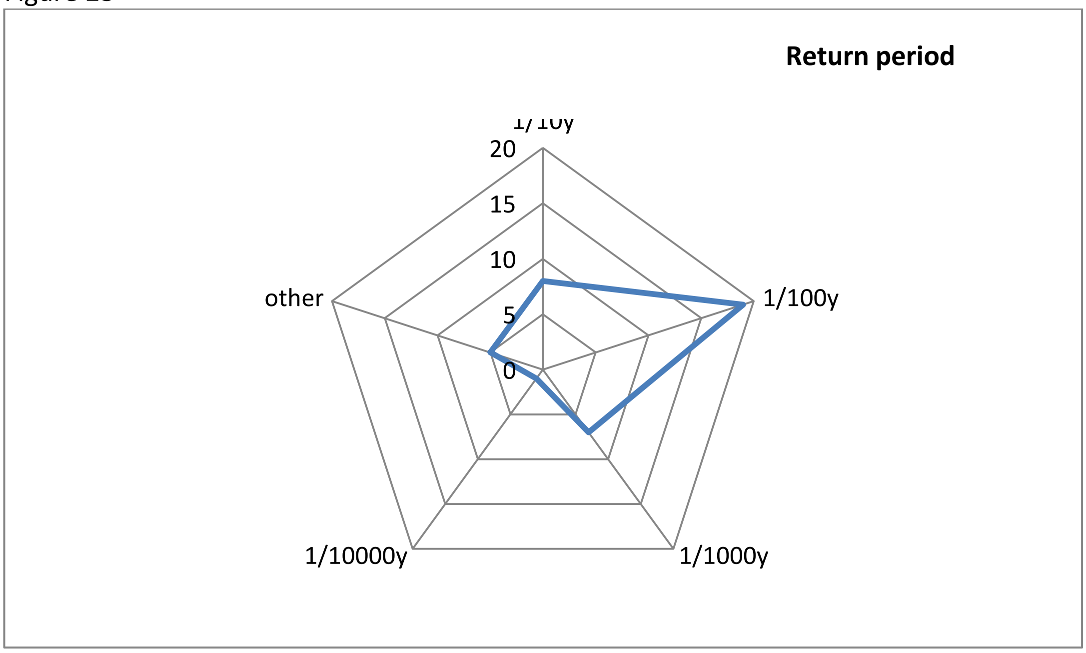
Figure 22 Preference for presentation probabilibyt of extreme weather events (results questionnaire)



Question 14: **Which return periods for these events would be most relevant?**

Most indicate return periods of 10, 100 or 1000 years. However some indicate that sometimes larger return periods are important, up to 100.000 years. Also 1/50 years, 1/200 and 1/500 years are being used. Respondents indicate a need to align this with the Eurocodes!

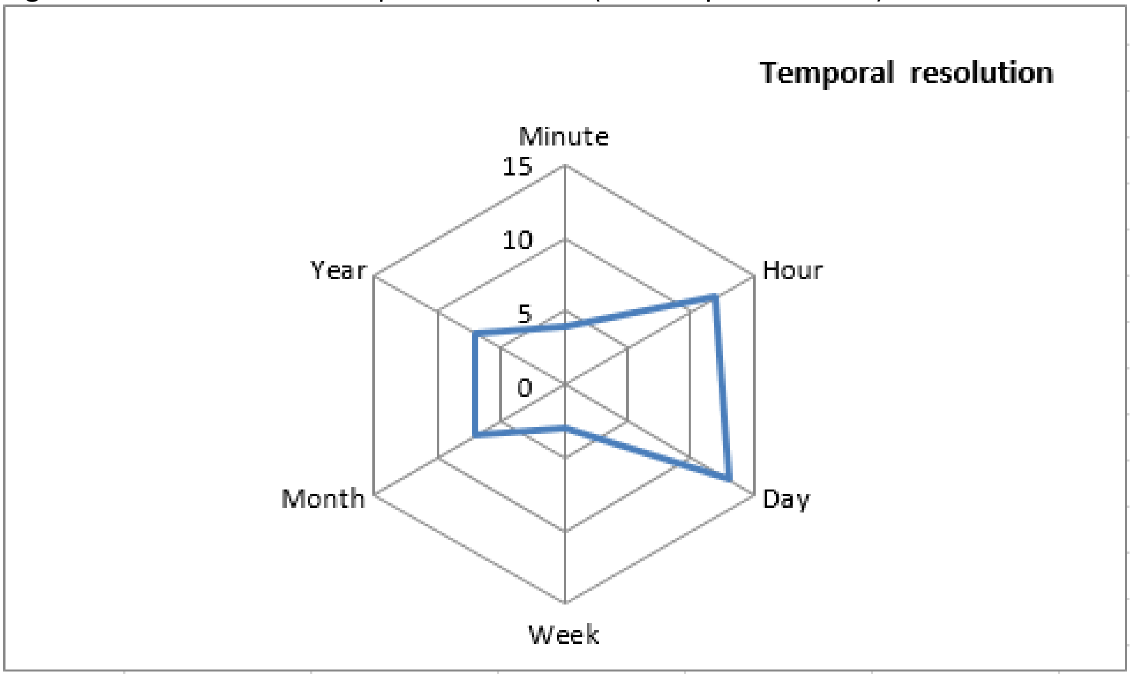
Figure 23



Question 15: What would be the most relevant temporal resolution for your sector? For example for road design, rainfall resolution of minutes up to hours and days are used.

All temporal scales are mentioned. Respondents indicate multiple scales. Hours and days are most prominent. This is consistent with Question #11.

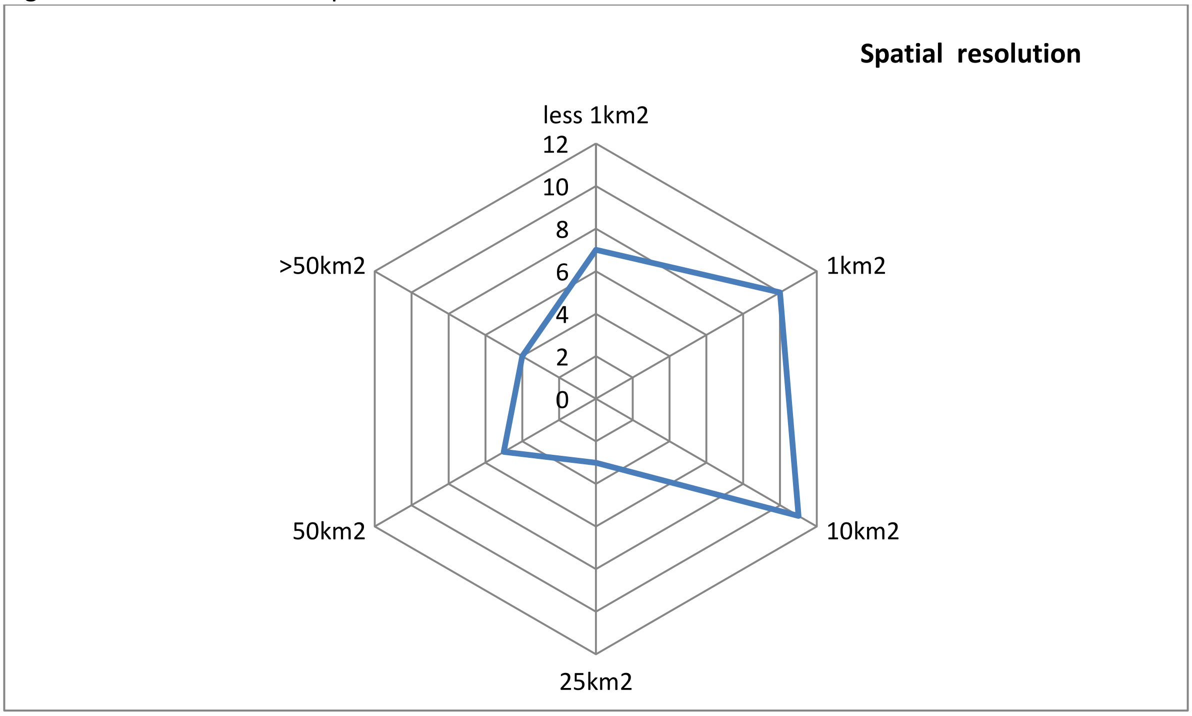
Figure 24 needs for temporal resolution (results questionnaire)



Question 16: What spatial resolution for climatological data for the specific topics would be relevant for your sector?

Most respondents (65%) ask for resolutions < 10 km2. Small resolutions (1-10km2) are especially relevant for: hail, windstorm, flood, rainfall, heat islands. For other weather effects a larger resolution suffices (up to 50 km2).

Figure 25 Needs for spatial resolution

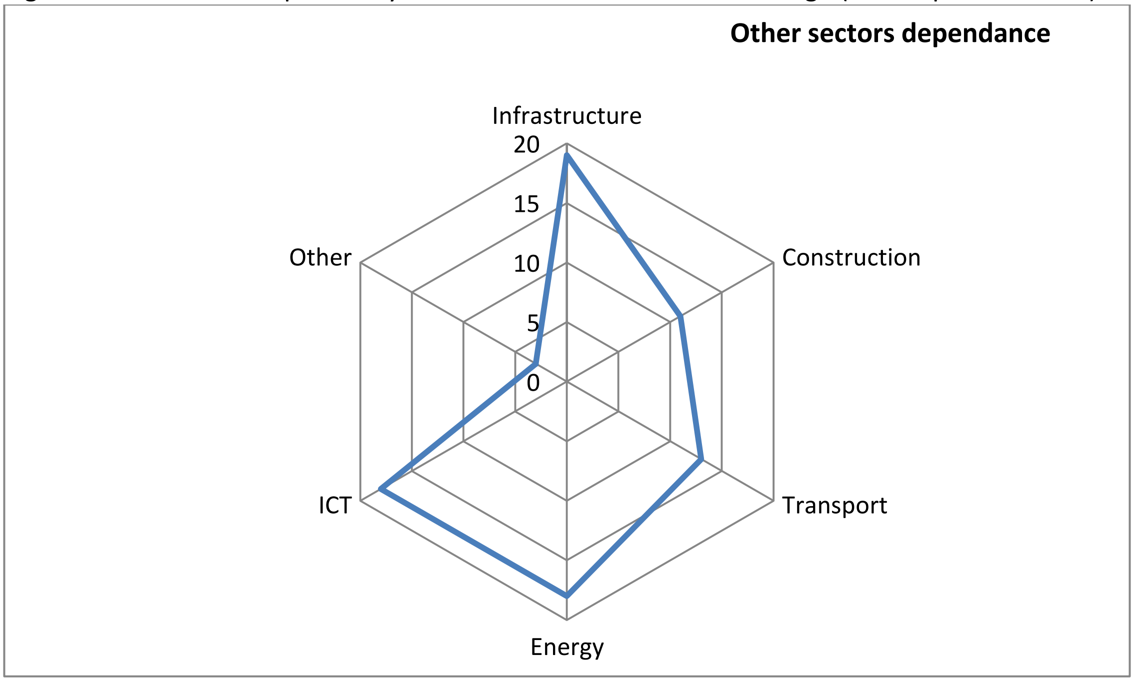


Question 17: Does your sector depend on other sectors or is there a strong influence from other sectors? For example: disruptions in ICT/communication infrastructures may affect the functioning of road information systems.

17.A: **With which sector does your sector have clear interactions?**
17.B: **What impacts does your sector have to consider with regards to dependency of other sectors?**

Strong interdependencies between sectors. ICT, Energy, transport link closely to all other sectors.

Figure 26 Interdependency of infrastructures to climate change (result questionnaire)



Question 18: Does coincidence of specific (extreme) weather events aggravate the impact of other events in your sector? For example: after a period with a lot of rain, overhead power lines may go down earlier with heavy wind since they are less stable in soils with extremely high groundwater levels.

Yes: coincidence of events is considered a very relevant issue. Specifically:

- Snow and rain: especially if rain follows snow;
- Rain and wind
- Snow and wind
- Rain and flood
- Flood and landslides/ damage to dykes
- Drought, followed by heavy rainfall
- Wind and high tide
- Rain and wind (the example in the question)

Question 19: Relevance of climatological data”

Question 19.A Would your sector need additional climatological data/parameters that reflect such coincidence of phenomena?

50% of respondents considers this relevant, sometimes very relevant. One reason is that extreme effects often occur in combination with another effect, on the other hand coincidence of phenomena does can strongly aggravate the effects.

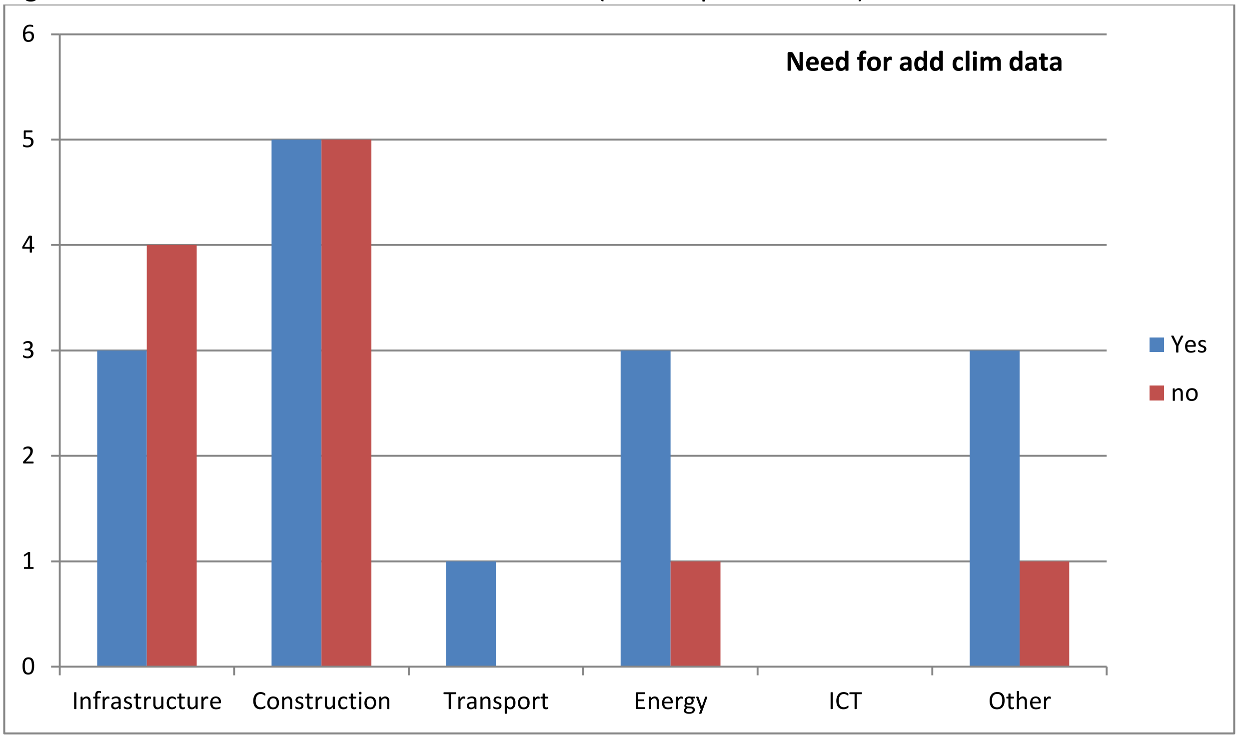
“any data that improves the predictability would be welcomed”; “a database/list of these would be invaluable to assess potential risks and impacts”.

Question 19.B. Which additional data would hence be of interest for your sector?

Probability of mutual occurrence.

Specifically: Likelihood of snow accumulation till temperatures rise (and rainfall)

Figure 27 needs for additional climate data (results questionnaire)



Question 20: What kind of support from climate experts or climate information providers would be helpful form your sector?

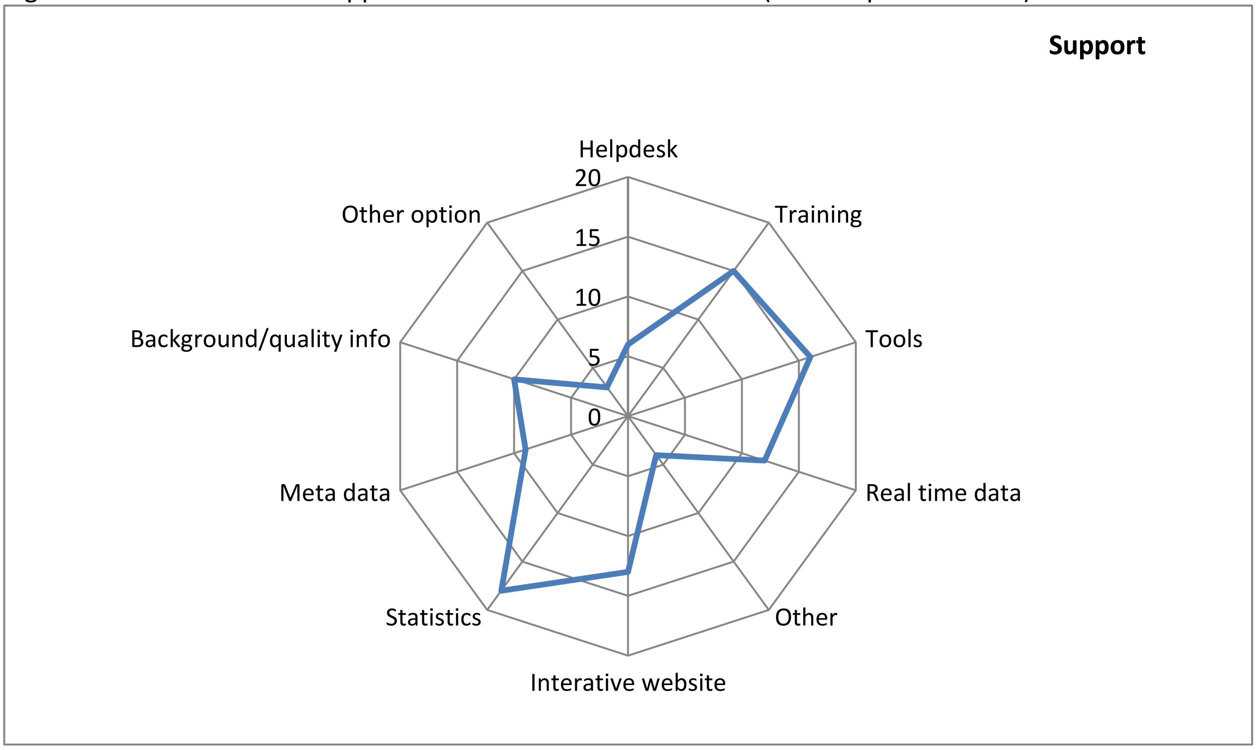
Question 20.A What kinds of support from climate change experts or climate information providers would be helpful for your sector?

Most indicated:

- training,
- online tools (e.g. to process data)
- interactive web-site
- sharing high quality, certified data
- data on uncertainties in estimates
- real time data for emergency planning
- standards (e.g. to explain how to select a typical year)

Also mentioned: helpdesk, meta-data, background information.

Figure 28 Needs for support in use of future climate data (results questionnaire)



Question 21: Any comments, other information or any additional climate variables (or combination of extreme weather events) to be considered in addition to the ones mentioned in this questionnaire?

- Add “Atmospheric icing”. This is by far the most critical climate variable in mountain terrain (ohls, masts, towers). This lacks in the present list.
- Make distinction between “storms” and “hurricanes”
- Note that people will tend to ask for the greatest level of detail, especially if they are unaware

Question 22: Are you interested in receiving further information regarding the project or its outcome?

Most (>75%) indicate: Yes!

10. Annex 5: Programme of workshop

Workshop 22th of November 2017
Thon hotel Brussels City Centre, Avenue Boulevard 17, Brussels
Future climate data for infrastructures:
what is needed in standards to become climate-resilient?

The objective of this workshop is to make future climate data, supplied by C3S https://climate.copernicus.eu, suitable for use in European standards for infrastructures. In the long term this will enhance the resilience of infrastructures to the effects of a changing climate, such as extreme heat, precipitation and storm. The relevance of this is illustrated by recent extreme weather events in Houston and the Caribbean islands. In a survey a broad range of experts involved in designing infrastructures has been consulted. Results will be discussed in the workshop. In this workshop we like to hear your voice!

10.00	Registration, coffee
10.30	Opening meeting by host of the day, **Bernard Gindroz**, chair of TCs for energy, climate change and sustainable cities
10.35	Key-results Questionnaire – what information is needed according to responses? **Ab de Buck**, project-leader, NEN
10.40	Key note 1: **Elena Visnar Malinovska**, head DG Clima/ Unit Adaptation
10.50	Key note 2: **Mark Lurvink**, projectleader Evolution Eurocodes
11.00	Key note 3: **André Jol**, EEA, Head of group climate change impacts, vulnerability and adaptation
11.10	Coffee break
11.40	**Carlo Buontempo**, Manager of the sectoral information system of Copernicus Climate Change Service at ECMWF
11.50	**Post-it session: What more is needed?** - What are the challenges? Plenary wrap up - What data are expected? Plenary wrap up
12.30	Lunch
13.45	1st round of Breakout sessions *'what future climate data are needed for the standardization community?'*
14.30	Plenary wrap up
14.45	Coffee Break
15.00	2nd round of Breakout sessions *'what future climate data are needed for the standardization community?'*
15.45	Plenary wrap up
16.00	Conclusions by **Carlo Buontempo**, C3S
16.15	Closure

Lunch included

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