LIFECON DELIVERABLE D 4.3

GIS-based national exposure modules and national reports on quantitative environmental degradation loads for chosen objects and locations

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Shared-cost RTD project

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Lifecon Deliverables

Deliverable No	Title of the Deliverable
D1.1	Generic technical handbook for a predictive life cycle management system of concrete structures (Lifecon LMS)
D1.2	Generic instructions on requirements, framework and methodology for IT-based decision support tool for Lifecon LMS
D1.3	IT-based decision support tool for Lifecon LMS
D2.1	Reliability based methodology for lifetime management of structures
D2.2	Statistical condition management and financial optimisation in lifetime management of structures • Part 1: Markov chain based LCC analysis • Part 2: Reference structure models for prediction of degradation
D2.3	Methods for optimisation and decision making in lifetime management of structures • Part I: Multi attribute decision aid methodologies (MADA) • Part II: Quality function deployment (QFD) • Part III: Risk assessment and control
D3.1	Prototype of condition assessment protocol
D3.2	Probabilistic service life models for reinforced concrete structures
D4.1	Definition of decisive environmental parameters and loads
D4.2	Instructions for quantitative classification of environmental degradation loads onto structures
D4.3	GIS-based national exposure modules and national reports on quantitative environmental degradation loads for chosen objects and locations
D5.1	Qualitative and quantitative description and classification of RAMS (Reliability, Availability, Maintainability, Safety) characteristics for different categories of repair materials and systems
D5.2	Methodology and data for calculation of life cycle costs (LCC) of maintenance and repair methods and works
D5.3	Methodology and data for calculation of LCE (Life Cycle Ecology) in repair planning
D6.1	Validation of Lifecon LMS and recommendations for further development

Keywords

Lifecon, environmental load

Abstract

All management systems that include a prediction module, such as Lifecon LMS, need reliable environmental load data. In Lifecon deliverable D4.2 the relevant systematic and requirements for quantitative classification of environmental loading onto structures, as well as sources of environmental exposure data are given. D4.2 , chapter 6 contains instructions and guidelines for how to characterise the environmental loads on concrete structures on object and network level.

However, these guidelines have to be validated (and possibly adjusted) before they finally can be used in the LMS. In this report the results from the practical validation are summarised. The EN 206-1 system and the standard prEN 13013 have been tested out on the chosen objects and compared with detailed environmental characterisation of the same objects using the available data and methods for environmental characterisation. Such studies have been undertaken in five countries (Norway, Sweden, Germany, Finland and United Kingdom) to develop the needed national annexes for a proper implementation of EN206-1 across Europe.

List of Contents

1 Introduction

All management systems that include a prediction module, such as LifeCon LMS, need reliable environmental load data. In LifeCon deliverable D4.2 the relevant systematic and requirements for quantitative classification of environmental loading onto structures, as well as sources of environmental exposure data are given. D4.2 , chapter 6 contains instructions/guidelines for how to characterise the environmental loads on concrete structures on object and network level.

However, these guidelines have to be validated (and possibly adjusted) before they finally can be used in the LMS. Two different strategies have been chosen. Firstly, a more practical approach of validation, where the EN 206-1 system and the standard prEN 13013 have been tested out on the chosen objects and compared with detailed environmental characterisation of the same objects using the available data and methods for environmental characterisation. Such studies have been undertaken in five countries (Norway, Sweden, Germany, Finland and United Kingdom) to develop the needed national annexes for a proper implementation of EN206-1 across Europe.

A summary of the national reports is given in this deliverable. The complete national reports, including references, are presented in D4.3 Annex.

Secondly, a more theoretical classification based upon parametric sensitivity analysis of the complex Duracrete damage functions under various set conditions is carried out. In this way the determining factors are singled out and classified. This is performed in D3.2 and shown in context in D4.4.

2 Other methods

Beside the methodology outlined in D4.2, other approaches are demonstrated in the individual national reports presented in D4.3 Annex.

The German demonstrator is discussing how the result of a statistical analysis could be expressed in form of moments (mean value, standard deviation) or parameters of a chosen distribution type.

The Finnish demonstrator proposes the use of weather models derived from meteorological data, covering air temperature, relative humidity and solar radiation. The principals of producing weather models from statistical raw data are also described.

The Norwegian report includes a description of how to simulate environmental load by use of Computational Fluid Dynamics (CFD). CFD comprises 3D-models of the construction and surrounding terrain.

Further information/details concerning these alternative approaches/methods can be found in D4.3 Annex.

3 Climatic information

Climatic data may consist of many different types of data. The most common, and basic, data are temperature, relative humidity, precipitation, wind velocity and wind direction. Beside these basic data there may also be recordings of different weather phenomena like fog, hail, snow depth, cloudiness and so on. A common time interval between the individual measurements are 3 hours.

From these individual recordings different types of calculated data can be produced. Examples of such data are number of precipitation days (precipitation ≥0.1 mm, ≥1.0 mm, ≥10.0 mm), extreme temperatures, wind distribution and so on. Of course also mean values are able to be calculated.

3.1 Norway

Information concerning temperature, precipitation and wind is received from The Norwegian Meteorological Institute (Met.no). In addition to measurement data from station of interest, it is produced maps showing temperature and humidity zones in Norway, where zones proposed in ISO 15686 Part 4 (D04.02) is used as examples.

Figure 1 shows the average yearly amount of precipitation, where Norway is divided into 4 zones, where zone 1< 400 mm, zone 2 < 800 mm, zone 3 < 1300 mm, and zone 4 > 1300 mm. From the figure we find that both Oslo and Homborsund is in zone 3.

Figure 2 shows number of days with temperature below zero. For Norway this varies from less than 10 at the south-west coast to more than 250 for the inner north. For Oslo the number is between 120 and 130, while for Homborsund between 70 and 80.

Figure 3 shows the average yearly temperature for Norway. From the figure we find the Ormsundkaia, Oslo is in an area with average temperature between 5ºC and 6ºC, while Homborsund lighthouse is in an area with average yearly temperature between 7ºC and 8ºC.

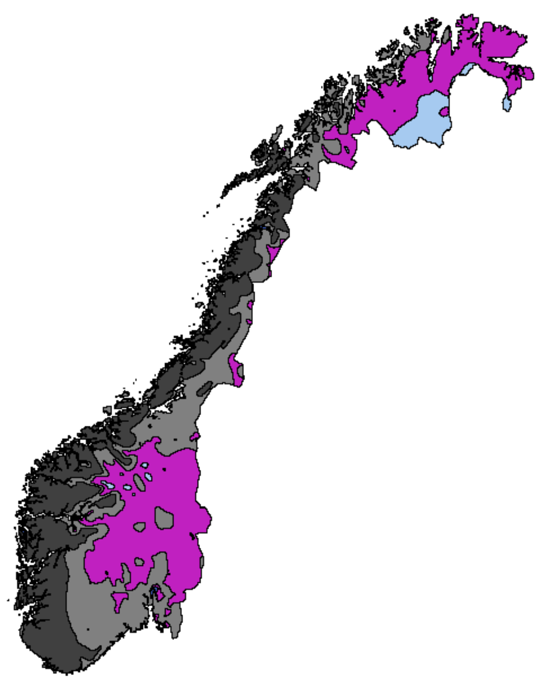

Figure 1. Average yearly precipitation in where Norway is divided into 4 zones. Zone 1< 400 mm, zone 2 < 800 mm, zone 3 < 1300 mm, and zone 4 > 1300 mm.

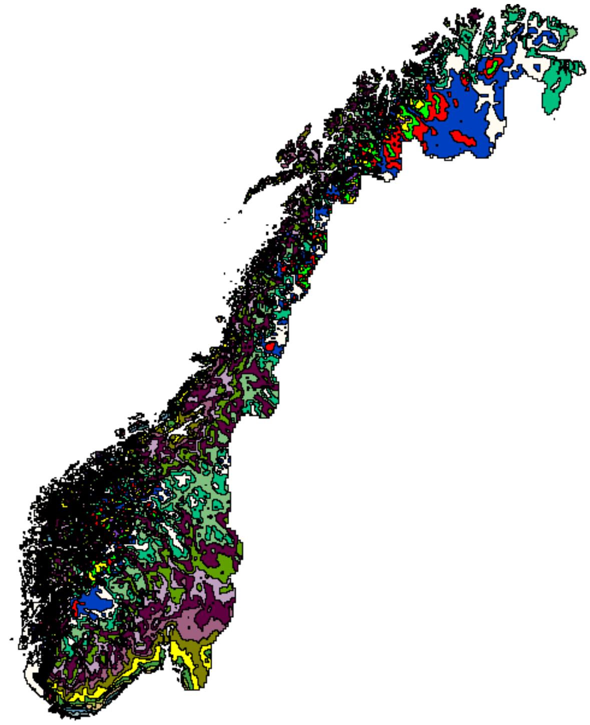

Figure 2. Number of days with temperature below 0ºC. Lowest values are found at the south-wet coast with less than 10 days, while the inner part of Finnmark in the north have more than 250 days.

Figure 3. Average yearly temperature for Norway. The temperatures differs from –6ºC to 8ºC

3.2 Sweden

SMHI, the Swedish Meteorological and Hydrological Institute, operates under the auspices of the Swedish Ministry of the Environment. Vast quantities of data are gathered around the clock from land-based weather stations, balloons, ships, buoys, aircraft, weather radar, satellites and lightning localisation systems.

The Institute's services are made available in many forms, including maps and data spreadsheets.

In the region there are four climatic stations (SMHI) and one station at the University (BMG) that may be used. However, in this report only one of the SMHI-stations and the BMG-station have been used.

3. Swedish climatic data, 1931-1960, (Klimatdata för Sverige).

4. Data from monitoring station at the Centre for Built Environment (BMG), Gavle.
Name: Gavle BMG
Region: Gavleborg
Co-ordinates:
Measurements: 1996 and forward

5.Climatic data from the Swedish Meteorological and Hydrological Institute, SMHI.
Name: Gavle A
Region: Gavleborg
Co-ordinates:
Measurements: 1996 and forward

Reference 3 is a collection of tables that contain information of climatic conditions in Sweden during the period 1931-1960. It consists of average monthly mean and extreme values. These values are to be considered as reference values. Data is gathered from 35 different climatic stations covering Sweden, where each station is presented individual. The treated parameters are as follows: temperature, relative humidity, precipitation, wind speed, wind direction and total radiation. Some compiled parameters are also presented, e.g. pelting rain.

Reference 4 and 5 contains time series of temperature, relative humidity, UV-radiation, wind speed and wind direction.

3.3 Germany

A quick method to obtain meteorological data is to consult the web sites of e.g. the "Bayerische Landesanstalt für Bodenkultur und Pflanzenbau" were data can be instantly downloaded for free. Disadvantage of the homepage is that the wind direction, which is needed for the calculation of the amount of days with driving rain, is not provided.
A very large variety of climatic data can be provided by the German weather service (Deutscher Wetterdienst - DWD). For some stations data can be viewed for free after registering, but not downloaded.

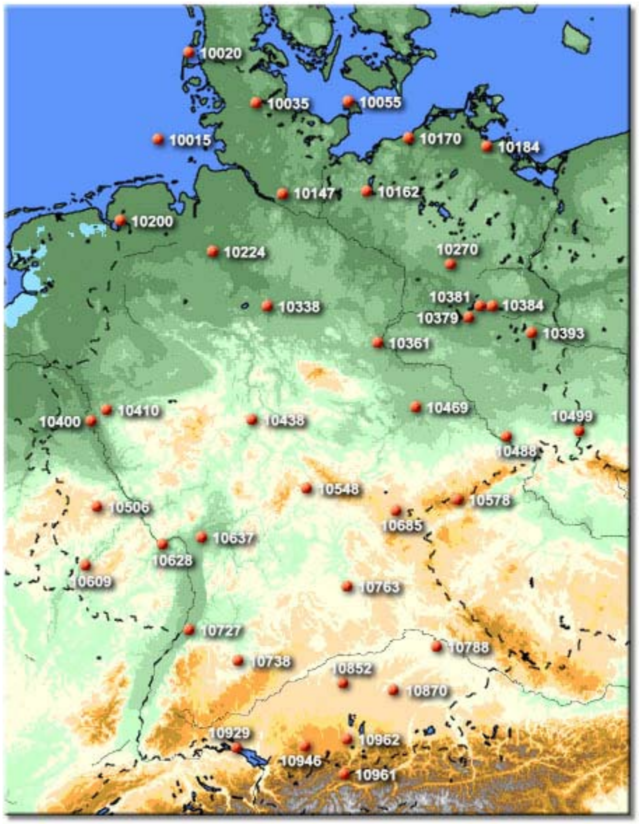

Figure 4. Stations for which data can be viewed for free at

For a much broader network of stations than the one given in Figure 4 data can be ordered in various digital formats by using a form sheet provided on the homepage of the DWD. Nevertheless the order of data is not for free. The cost for a data set, which may be more than data of a single station, comes up to at least 50 Euro. It takes a couple of days up to a few weeks until the data is delivered.

3.4 Finland

The following sources of meteorological data is available.

1. Climatological Statistics in Finland 1961 - 1990. Supplement to the Meteorological Yearbook of Finland. Volume 90 Part 1 - 1990. Helsinki 1991.
The Finnish Meteorological Institute. 125 pp.

2. Measurements of sunshine duration 1981 - 1990. Meteorological yearbook of Finland. Volume 81 - 90 Part 4:2. Helsinki 1993. The Finnish Meteorological Institute. 149 pp.

3. Measurements of solar radiation 1981 - 1990. Meteorological yearbook of Finland. Volume 81 - 90 Part 4:1. Helsinki 1993. The Finnish Meteorological Institute. 129 pp.

Reference 1 is a collection of tables that contain information of climatic conditions in Finland during the standard period 1961 - 1990. It consists of daily mean and extreme values from 19 stations and mean monthly and annual summaries from 108 stations distributed all over Finland. The averages for the observation period are presented. Monthly means for the period are the sums of the monthly means divided by the number of years for which data are available. Annual means of pressure, temperature, wind, cloudness and humidity are one-twelfth of the sum of the monthly means. Annual precipitation totals and annual numbers of phenomena are the sums of the twelve monthly totals and monthly means.

The observation times are given in Finnish standard time, i.e. UTC +2h.

Reading of the columns contain:

– Month
– Air pressure reduced to sea level (8 daily measurements).
– Air temperature at 2, 8, 14 and 20 hrs and the monthly mean.
– Extreme temperatures are averages of daily maximum and daily minimum temperatures, respectively. Moreover, the absolute maxima and minima during the period and the years when they were recorded are also indicated.
– Wind distribution calculated from four daily observations at 2, 8, 14 and 20. The tables contain the percentages (%) and the average speeds (m/s) of winds divided into eight principal directions. The two last columns indicate the proportion of calms and the average speed of all winds.
– Amount of cloud cover at 2, 8, 14 and 20 hrs and monthly means reported on the scale 0–8.
– Relative humidity at 2, 8, 14 and 20 hrs and the mean of these values.
– Precipitation contains total precipitation for the months and the year, the daily maximum during the period and the year it was recorded.
– Precipitation days indicates the number of days with precipitation ≥0.1, ≥1.0 and ≥10.0 mm.
– Snow depths recorded on the 15th and the last day of the month at 8 hrs.
– Temperature days are determined from the extreme temperatures: frost days i.e. days with minimum temperature <0°C, ice days i.e. days with maximum temperature <0°C, days with minimum temperature <10°C, heat-wave days with maximum temperature >25°C, and days with grass minimum temperature <0°C.
– Wind days are included at stations with at least four principal observation time during the period. Days with strong wind are those with wind speed >10 m/s at some observation time, and days with gale or storm are those with wind speed >20 m/s at some observation time.
– Weather phenomena days are the numbers of days with specified phenomena as presented in the climatological yearbook during the period. They are only presented for those stations, which have had a round-the-clock weather watch. If the monthly mean of a rare phenomenon is <0.5, it has also been omitted from the yearly mean.
– Days with rain (RAI), snow (SNO), sleet (SLE), drizzle (DRI) and hail (HAI) are those on which these phenomena have appeared regardless of precipitation amount.
– Days with thunderstorm (THU) are days, when thunder is observed at the station.
– Days with fog (FOG) are days with fog observed at the station.

- A cloudy day (CLO) is one on which the sun of the cloud amounts at the 8, 14 and 20 hrs' observations >19.
- A clear day (CLE) is one on which the sum of the cloud amounts at the 8, 14 and 20 hrs' observations <5.
- A day with snow cover (SC) is one for which the ground surface is more than half covered with snow at 8hrs.

The data of references 2 and 3 contain the results obtained from observations of solar radiation and duration of sunshine made in Finland at 23 stations during the years 1981...1990. The presented results are daily and monthly sums and summary tables. The unit of solar radiation used in tables is 10000 joules per square meter (10^4 Jm^{-2}). The unit for the duration of sunshine is hour (h).

3.5 United Kingdom

The principal source of environmental data in the UK is the Meteorological (Met) Office, www.meto.gov.uk. The Met Office provides a range of environmental data from weather stations throughout the UK. Basic summary data covering average Maximum and Minimum Temperatures, Number of Days of Air Frost, Sunshine Hours, Total Rainfall and Number of Rain Days >=1mm are available free for all stations for the years 1961-1990, Figure 5.

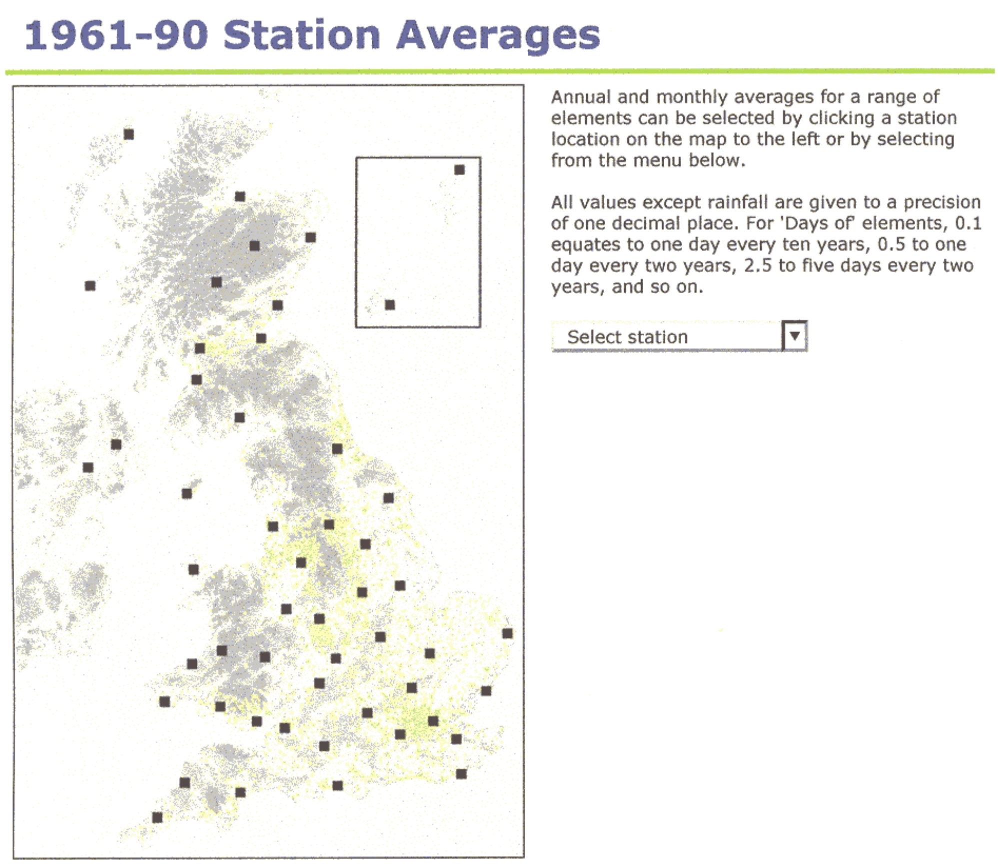

Figure 5, Location of Met Office Weather Stations Providing Free Data, 1961-1990

The Met Office also offers this data for all years from 1990-to date for a fee, together with more detailed information including either a Wind Frequency Analysis or a Wind Rose on a monthly, seasonal or annual basis. The Met Office also provides limited information on pollutants such as sulphur and nitrogen containing compounds and snow days. No data is available on chloride content of moisture near coasts. The fee for such data is dependent upon the level of information required and the organization requesting the data. Research Organizations, such as universities receive a discount rate, minimum fees are approximately £100-£200 for one years raw data. The organization requesting the data would be expected to analyse the data themselves. Aanalysis by the Met Office is available at an increased fee.

Climatic information can also be obtained from a number of independent organizations for a fee. A full list of organizations is not included but they can be found by a simple web search. Some provide data on a national level and others on a regional or area level.

LIFECON partner British Energy itself monitors wind direction on all sites for safety, but do not record any other climatic information.

4 Pollution information

Information concerning pollutants, or air quality, is an important input to an LMS. Several degradation mechanisms are highly dependent on the concentration of different chemical agents. In general, measurements of air pollutants are frequently done through out Europe. This monitoring is very extensive for S- and N-compounds in air and depositions, but also for ozone.

4.1 Norway

UN ECE International co-operative programme on effects on materials including historic and cultural monuments is an international programme that has been running for 8 years at 39 test sites in 14 countries from 1987 to 1995. A second phase of the project started in 1997 with an adjusted number of test sites and countries participating.

Birkenes, a rural inland test site, not far from Homborsund, has been in the programme from the start.

Measurements in the period 1996-1998 are shown in Table 1, Table2 and Table 3. For NO_2 the maximum values are from December/January, ie the winter season. The variation of O_3 concentration through the year is shown in Figure 6.

Table 1: Concentration of gases (mandatory information). Mean value for each year.

	SO_2 µg/m3	NO_2 µg/m3	O_3 µg/m3
1996	0.8	2.2	58
1997	0.4	2.3	55
1998	0.2	0.6	57

Table 2: Mean values for temperature and humidity for Birkenes test station (mandatory information)

	Temperature ºC	Humidity RH %	Time of wetness TOW
1996	4.2	82	2733
1997	5.5	75	2833
1998	5.8	79	2645

Table 3: Sum precipitation and mean values for pH and concentrations, Birkenes test station 1996-1998

	Sum precipitation	pH	SO_4-S mg/l	NO_3-N mg/l	Cl mg/l	Cond uS/cm
1996	1193.0	4.42	0.7	0.53	2.14	30.2
1997	1343.8	4.50	0.61	0.5	2.06	25.4
1998	1595.6	4.48	0.62	0.45	1.77	27.1

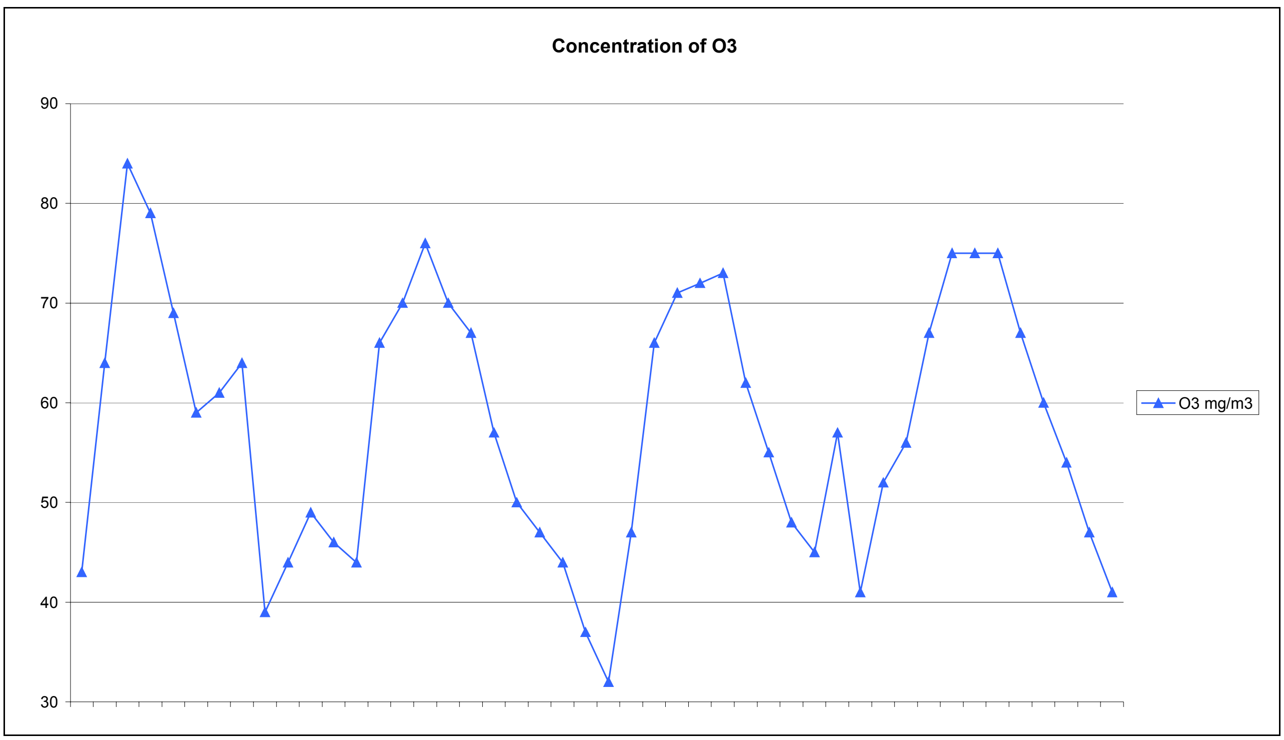

Figure 6. Monthly mean values for concentration of O_3 from January 1996 to October 1999

4.2 Sweden

The Swedish Urban Monitoring Network, Figure 7, was established in 1986 as a joint project between IVL and the local health departments in Swedish towns. Since then measurements have been performed every winter season (October-March) in approximately 40 towns. The main purpose of the project is to enable municipal authorities to evaluate and describe the town's air quality situation and to compare measurements between towns.

The measurements are carried out at one site in the centre of each of the participating urban areas, as an urban background station, without direct influence from local sources.

The program measure SO_2, soot (black smoke) and NO_2, taken as daily means. SO_2 and NO_2 are also measured at two places in the countryside nearby some of the towns, taken as monthly means.

Figure 7. Map of the Swedish Urban Monitoring Network

The Swedish Precipitation Chemistry Network, Figure 8, is part of the national environmental monitoring programme, financed by the Swedish Environmental Protection Agency. The main purposes of the monitoring activities are:

- to monitor levels of pollutants in the environment on a long-term basis, to be able to evaluate and discover large-scale changes in the environment, needing measures to be taken, or needing further research.
- to obtain knowledge on variations in and levels of pollutant load in different parts of the country.
- to obtain background-data as a reference to evaluations of the state of pollution in studies of more exposed areas.
- to study large-scale transport of pollutants.

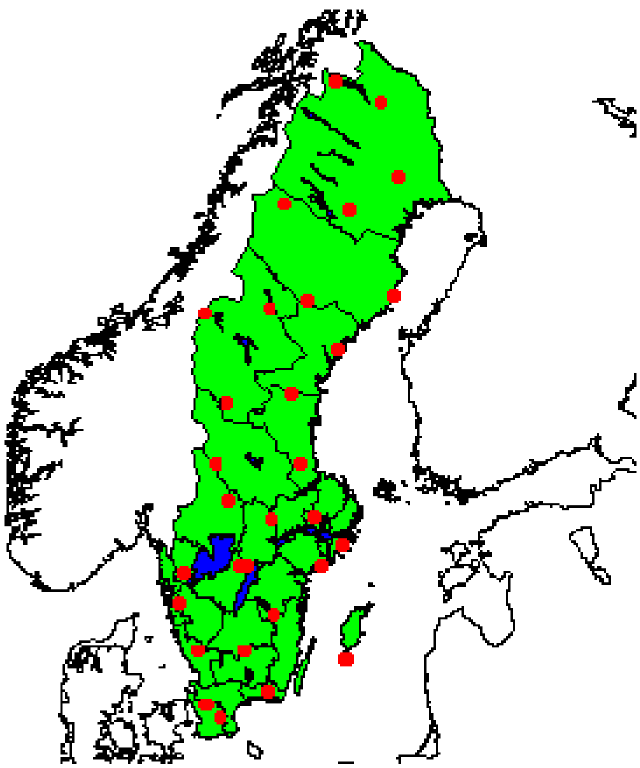

Figure 8. Map of the Swedish Precipitation Chemistry Network.

4.3 Germany

The national report contains no information concerning pollution data sources.

4.4 Finland

The national report contains no information concerning pollution data sources.

4.5 United Kingdom

The national report contains no information concerning pollution data sources.

5 Application to objects, two examples

5.1 Homborsund lighthouse

5.1.1 Classification on regional level

The object location is classified according to classification system described in D4.2. This classification can be done from maps showing the temperature and humidity, or from data from nearby meteorological stations. For this object meteorological data are used.

Climatic classification of climatic data from Torungen fyr.

Table 4: Air temperature for Torungen fyr

	Year	Jan	Febr	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Normal	7.2	-0.3	-0.8	1.3	4.4	9.4	13.7	15.5	15.3	12.5	9.1	4.6	1.6
1999	8.3	1.2	1.5	2.3	6.2	8.4	13.2	16.5	16.5	15.1	9.5	7.1	2
Max	23	7.1	10.5	9	16.2	16.6	19.5	22.8	13	19.4	13.8	13.3	10.5
Min	-10	-10	-9.4	-3.2	-0.4	1.5	8.6	11.2	10.2	10	2.4	-0.3	-7.2

No months with average temperature below -5°C or > 35°C, gives according to ISO 15686 Part 4 (D04.02) climatic classification Temperate.

Table 5: Precipitation for Torungen fyr

	Year	Jan	Febr	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1999	1177	138	44	151	58	52	118	42	149	155	108	54	108
Normal	870	74	48	57	42	59	54	66	82	96	112	105	75

Average annual precipitation 870 mm gives according to ISO 15686 Part 4 (D04.02) climatic classification Humid.

Table 6: Days with rain > 0.1 mm Torungen fyr

	Year	Jan	Febr	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1999	190	25	9	22	13	13	19	12	6	15	12	19	16

The main wind direction is also determined from measurements on Torungen Lighthouse. Figure 9 shows the wind climate on this location. From this data the wind directions NE and SV is chosen to be the most significant wind directions for the environmental loads in the study.

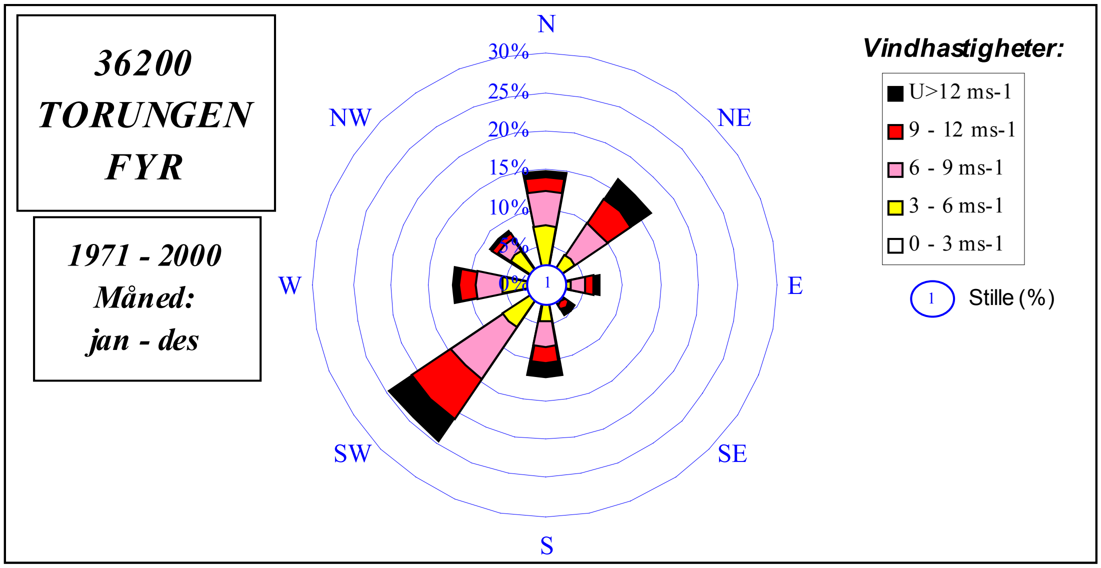

Figure 9. Wind climate at Torungen lighthouse

The most significant long-term climatic loads on Homborsund lighthouse include sea spray and driving rain. Figure 10 shows the lighthouse during a gale from NE. The sea-spray exposure with wind from SE is probably even more sever than showed in this picture.

Figure 10. Homborsund lighthouse during gale from NE

5.1.2 Pollutant classification

Airborne SOx < 10 mg/m^2/day
Rain water ph> 5.5
The airborne salinity for the area is not found.
Marine (M). Average daily airborne salinity is between 60 and 300 mg/m^2/day.

Classification by use of the EOTA document on "Working Life of Building Products"(D04.02) European temperature sub-division is more difficult. Winter condition, with average temperature 1.97ºC is zone B, while summer condition may be zone A or zone B depending on how often the temperature rise above 30ºC.

5.1.3 Combined classification

According to the proposed classification in ISO 15686 Part 4, Homborsund lighthouse is classified as 6-3-2, shown in Table 7.

Table 7: Matrix classification system for environmental data.

	SM+SI	SM+I	M+SI	M+I	SM	M	SI	I	B
DC	1-1-1	2-1-1	3-1-1	4-1-1	5-1-1	6-1-1	7-1-1	8-1-1	9-1-1
DT	1-1-2	2-1-2	3-1-2	4-1-2	5-1-2	6-1-2	7-1-2	8-1-2	9-1-2
DH	1-1-3	2-1-3	3-1-3	4-1-3	5-1-3	6-1-3	7-1-3	8-1-3	9-1-3
SC	1-2-1	2-2-1	3-2-1	4-2-1	5-2-1	6-2-1	7-2-1	8-2-1	9-2-1
ST	1-2-2	2-2-2	3-2-2	4-2-2	5-2-2	6-2-2	7-2-2	8-2-2	9-2-2
SH	1-2-3	2-2-3	3-2-3	4-2-3	5-2-3	6-2-3	7-2-3	8-2-3	9-2-3
HC	1-3-1	2-3-1	3-3-1	4-3-1	5-3-1	6-3-1	7-3-1	8-3-1	9-3-1
HT	1-3-2	2-3-2	3-3-2	4-3-2	5-3-2	**6-3-2**	7-3-2	8-3-2	9-3-2
HH	1-3-3	2-3-3	3-3-3	4-3-3	5-3-3	6-3-3	7-3-3	8-3-3	9-3-3
VC	1-4-1	2-4-1	3-4-1	4-4-1	5-4-1	6-4-1	7-4-1	8-4-1	9-4-1
VT	1-4-2	2-4-2	3-4-2	4-4-2	5-4-2	6-4-2	7-4-2	8-4-2	9-4-2
VH	1-4-3	2-4-3	3-4-3	4-4-3	5-4-3	6-4-3	7-4-3	8-4-3	9-4-3

5.1.4 Wall spell index

The formula to calculate the spell index is:

$$I_S = 2/9 * \sum \nu\, r^{8/9} \cos(D-\Theta)$$

where ν is the hourly mean wind speed in m/s, r is the hourly rainfall in mm, *D* is the hourly mean wind direction from the north, Θ is the angle between North and a line normal to the wall and the summation is taken over all hours for which cos(D-Θ) is positive, i.e. all those occasions when the wind is blowing against the wall.

The factors C_R, C_T, O and W are defined for calculating the wall spell indices, I_{WS}, by the formula:

$$I_{WS} = I_S \times C_R \times C_T \times O \times W$$

Terrain roughness factor, $C_R = K_R * \ln(z/z_0)$ for $z => z_{min}$.
$C_R(z) = K_R * \ln(z/z_0)$ for $z \geq z_{min}$
$C_R(z) = C_R(z_{min})$ for $z < z_{min}$

where: K_R is the terrain factor
z_0 is the roughness length
z_{min} is the minimum height

Based on information from drawings and photos the numbers for C_R, C_T, O and W are found for each wall or part of wall. The results are shown in Table 8.

The table shows that wall 3 and 5 are the walls most exposed to driving rain, then the walls 4, 6 and 8. This is due to the main direction for driving rain is South East. Missing data for precipitation may give incorrect classification.

For Homborsund $K_R = 0.17$, $z_0 = 0.01$, $z_{min} = 2$

Table 8: C_R, C_T, O and W for the walls at Homborsund lighthouse

	$C_{Roughness}$ Depending of Z	C_T	O	Wall	$I_{S\text{-}max}$	$I_{WS\text{-}max}$	I_S	I_{WS}
Wall 1	1.07	1	0.6	0.3	2355	453	57797	6666
Wall 2	1.07	1	0.6	0.3	1522	293	62005	7152
Wall 3 lower part	0.95	1	0.2	0.2	3479	132	123356	938
Wall 3 upper part	1.14	1	0.6	0.3	3479	712	123356	15146
Wall 4	1.07	1	0.6	0.3	2514	483	85749	9890
Wall 5	1.13	1	0.6	0.4	3479	941	123356	20031
Wall 6	1.13	1	0.6	0.4	2514	680	85749	13924
Wall 7	1.13	1	0.6	0.4	2355	637	57797	9385
Wall 8	1.07	1	0.6	0.3	2514	483	85749	9890
Wall 9	1.22	1	0.6	0.4	1522	445	62005	10878

5.2 Faltskarsleden bridge

In the region there are four climatic stations (SMHI) and one station at the University (BMG) that may be used. However, in this report only one of the SMHI-stations and the BMG-station have been used.

1. Swedish climatic data, 1931-1960, (Klimatdata för Sverige).

2. Data from monitoring station at the Centre for Built Environment (BMG), Gavle.
Name: Gavle BMG
Region: Gavleborg
Co-ordinates:
Measurements: 1996 and forward

3.Climatic data from the Swedish Meteorological and Hydrological Institute, SMHI.
Name: Gavle A
Region: Gavleborg
Co-ordinates:
Measurements: 1996 and forward

Reference 1 is a collection of tables that contain information of climatic conditions in Sweden during the period 1931-1960. It consists of average monthly mean and extreme values. These values are to be considered as reference values. Data is gathered from 35 different climatic stations covering Sweden, where each station is presented individual. The treated parameters are as follows: temperature, relative humidity, precipitation, wind speed, wind direction and total radiation. Some compiled parameters are also presented, e.g. pelting rain.

Reference 2 and 3 contains time series of temperature, relative humidity, UV-radiation, wind speed and wind direction.

5.2.1 Measured data, 1997

Table 9: Maximum, minimum and average temperature, 1997, reference 2 and 3.

Temperature	Gavle BMG, ref 2			Gavle A, ref 3		
	Min, °C	Max, °C	Average, °C	Min, °C	Max, °C	Average, °C
Yearly	-15.6	29.7	7.2	-18.6	28.0	5.9
January	-11.1	7.7	-0.6	-18.6	7.2	-1.8
February	-15.6	9.2	-0.3	-18.5	8.4	-1.2
March	-7.4	16.9	2.8	-10.9	15.5	1.5
April	-4.8	16.1	3.8	-6.7	14.0	2.7
May	0.1	19.1	8.7	-4.2	18.1	7.2
June	4.6	26.4	15.5	1.4	24.4	13.9
July	9.4	27.6	18.8	6.3	25.6	16.9
August	8.0	29.7	19.6	4.4	28.0	17.9
September	1.9	23.6	12.8	-1.2	22.4	11.5
October	-3.8	16.2	4.6	-5.3	14.3	3.6
November	-8.5	10.0	1.5	-13.3	9.4	0.5
December	-13.6	4.4	-1.2	-16.9	3.5	-2.1

Table 10: Maximum, minimum and average relative humidity, 1997, reference 2 and 3.

Relative humidity	Gavle BMG, ref 2			Gavle A, ref 3		
	Min, %	Max, %	Average, %	Min, %	Max, %	Average, %
Yearly	21	100	74	20	100	77
January	36	100	75	43	100	80
February	29	100	77	42	100	81
March	27	100	62	29	100	67
April	21	100	56	24	100	61
May	23	100	68	23	100	72
June	24	100	70	20	100	73
July	29	100	70	27	100	75
August	29	100	74	35	100	81
September	31	100	71	35	100	76
October	37	100	80	44	100	81
November	48	100	90	56	100	89
December	69	100	95	73	100	92

Table 11: Average temperature and average relative humidity during the summer period (June-August) and winter period (December-February), 1997, reference 2 and 3.

	Gavle BMG, ref 2			Gavle A, ref 3		
	Min	Max	Average	Min	Max	Average
Temp. winter	-15.6	9.2	-0.7	-18.6	8.4	-1.7
Temp. summer	4.6	29.7	18.0	1.4	28.0	16.3
RH winter	29	100	83	42	100	84
RH summer	24	100	71	20	100	76

Table 12: Number of rainy days, 1997, reference 3.

Precipitation	Gavle A, ref 3				
	mm	days >0,1	days >1.0	days >5.0	days >10.0
Yearly	829	148	91	44	26
January	11	11	3	0	0
February	46	15	8	4	0
March	17	9	5	1	0
April	7	7	1	0	0
May	83	12	8	4	3
June	78	9	8	5	5
July	185	8	6	3	3
August	51	10	8	3	2
September	110	14	11	8	4
Oktober	75	17	11	4	3
November	95	16	12	6	5
December	71	20	10	6	1

Table 13: Maximum, minimum and average UV-radiation, 1997, reference 2.

UV-radiation	Monthly average of the daily sum, W/m²		
	Min	Max	Average
Yearly	1	297	105
January	6	26	13
February	13	68	31
March	24	133	87
April	47	228	150
May	47	282	190
June	60	297	232
July	97	285	227
August	65	247	177
September	17	149	98
October	13	74	41
November	2	35	10
December	1	13	5

Table 14: Wind speed, 1997, reference 2.

Wind speed m/s	Wind speed frequencies in percentage												
	Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
0,0-0,2	5	2	4	3	6	5	1	2	1	2	3	14	19
0,3-1,5	20	13	10	12	12	18	24	35	32	19	17	30	21
1,6-3,3	41	47	35	36	30	42	42	42	45	50	52	37	37
3,4-5,4	25	31	33	33	31	27	29	19	21	22	20	19	18
5,5-7,9	8	6	19	14	17	8	3	2	1	7	8	0	6
8,0-10,7	1	1	0	1	4	1	0	0	0	0	0	0	0
10,8-13,8	0	0	0	0	0	0	0			0			
13,9-17,1					0								
17,2-20,7													
20,8-24,4													
24,5-28,4													
28,5-32,6													
>=32,7													

Table 15: Wind direction, 1997, reference 2.

Wind direction	Wind direction frequencies in percentage												
	Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
N	15	8	10	11	22	14	25	15	16	7	23	11	13
NE	14	0	2	3	10	24	35	32	22	3	4	13	12
E	5	0	3	1	4	12	7	10	10	2	3	6	8
SE	3	0	5	0	2	5	2	3	5	4	1	6	3
S	9	4	18	10	4	9	8	5	12	14	6	9	9
SW	30	60	41	44	24	17	14	15	26	34	26	31	34
W	8	12	10	8	14	4	3	8	3	17	11	4	3
NW	11	14	8	20	14	10	5	10	4	17	22	7	2
Calm	5	2	3	3	5	4	1	1	1	2	3	13	17

5.2.2 Sources of pollution data

1. Data from the Swedish Environmental Research Institute.
Name: Jadraas
Region: Gavleborg
Co-ordinates:
Measurements: 1988 and forward
2. Data from monitoring station at the Centre for Built Environment (BMG).
Name: Centre for Built Environment
Region: Gavleborg
Co-ordinates:
Measurements: 1988 and forward

Reference 1 is a collection of data from the national environmental monitoring programme "Swedish Precipitation Chemistry Network" financed by the Swedish Environmental Protection Agency. Data from the programme may be downloaded directly from a database at the Swedish Environmental Research Institute web page.

Reference 2 is a collection of data from the Centre for Built Environment. The monitoring station, situated at the roof, measures airborne $S0_2$ and pH of rainwater.

5.2.3 Measured pollution data

The data given in table 16 and 17 are monthly average data of pollutants in precipitation, reference 1 and 2, respectively.

Table 18 gives monthly average data of airborne $S0_2$ from reference 1 and 2. Note that there are a big difference in absolute values between ref. 1 and 2, probably caused by different definitions.

All data given in table 16-18 refer to the year 1997. However, as mentioned above, the same type of data is available in time series from 1988 and forward.

Table 16: Pollutants in precipitation, 1997, reference 1.

Month	Precipitation mm	pH	Cl [mg/l]	Na [mg/l]	SO4-S [mg/l]	NO3-N [mg/l]
January	8	4,7	0,49	0,31	0,2	0,31
February	-	-	-	-	-	-
March	23	4,4	0.39	0.31	0.85	0,67
April	11	4,8	1,62	1,7	0,75	0,43
May	74	4,8	0,19	0,14	0,46	0,25
June	98	4,6	0,1	0,06	0,33	0,16
July	-	-	-	-	-	-
August	51	4,8	0,11	0,06	0,56	0,25
September	95	4,8	0,18	0,13	0,18	0,13
October	71	4,6	0,6	0,33	0,35	0,22
November	127	4,4	0,27	0,21	0,54	0,39
December	73	4,3	0,25	0,17	0,56	0,49

Table 17: Pollutants in precipitation, 1997, reference 2.

Month	Precipitation mm	pH	Cl [mg/l]
January	5	6,3	1,9
February	31	5,8	1,6
March	10	6,7	2
April	6	6,9	5
May	59	5,7	0,5
June	50	5,6	1,1
July	142	5	<0,5
August	64	5,4	<0,5
September	52	5,9	0,5
October	59	5,2	1,5
November	62	5,5	1,7
December	64	4,5	0,8

Table 18: Airborne SO2, 1997, reference 1 and 2.

Month	Reference 1, SO_2-S, [µg/m³]	Reference 2, SO_2, [µg/m³]
January	0,27	102,2
February	0,35	10,2
March	0,22	99,4
April	0,08	156,1
May	0,11	8,9
June	0,2	11
July	0,13	24,3
August	0,22	7,8
September	0,06	8,7
October	0,06	40,5
November	0,23	102,6
December	0,36	53,9

5.2.4 Characterisation and classification of exposure environment on structures

The mapping and determining of the category of exposure/degradation on the test object, the bridge at Faeltskaersleden, is executed according to the step-wise instruction in the deliverable D4.2 "Instructions for quantitative (characterisation) Classification degradation loads onto Structures" [1].

5.2.5 Characterisation of Climatic data

In the following characterisation and classification of exposure environment all climatic data is taken from Gavle A station during the period 1996 to 2001. However, a comparison of temperature and RH data between Gavle A and BMG station have been made and are described here.

The distance between the two stations is about 5 km. The distance between the BMG station and the bridge at Faeltskaersleden are about 1 km. The corresponding distance between Gavle A station and the bridge are about 5 km.

By using regression analysis the degree of correlation between the two station is estimated. The result of the regression analysis shows that the temperature correlation between the two stations during the 6 years period is quite good. The regression line is expressed as:

$$T_{GavleA} = -1.23 + 1.00 * T_{BMG} \qquad R=0.98\ (R^2=0.97)$$

$T_{Gavle\ A}$ is the estimated temperature at Gavle A Station and T_{BMG} is the temperature from the BMG station. The prediction interval is in this case +/- 3.1 °C (95 % confidence).

Unfortunately, comparison of RH between the two stations shows a less good correlation than in the temperature case. Based on data from the 6 years period the RH regression line is expressed as:

$$RH_{GavleA} = 22.81 + 0.74 * RH_{BMG} \qquad R=0.87\ (R^2=0,76)$$

$RH_{Gavle\ A}$ is the estimated relative humidity at Gavle A station and RH_{BMG} is the relative humidity at BMG station. The prediction interval is +/- 16.6 % (95 % confidence), which is a quite wide range interval.

No details of condensation are available. The annual number of days with rain >0,1 mm and >2,5 mm is calculated for the 6 years period, see table 19.

The main wind direction is 248 degrees, i.e. from west, south-west. Nevertheless a considerable part of the wind is from the opposite direction, i.e. from north-east direction, see figure 11. When calculating the spell index no correlation of the wind speed and direction is done due to the influences of the surroundings. To obtain a reliable spell index an anemometer is needed in position of the object.

Table 19: Average values for the period 1996 to 2001.

Environmental parameter characteristic surroundings								
RH (%) summer	RH (%) winter	Av. air temp summer	Av. air temp winter	Days w/rain >0,1 mm (annual)	Days w/rain >2,5 mm (annual)	Precipitation (mm/y)	Conden-sation	Main wind direction (96-01)
74,8	84,8	14,9	-3,0	167	72	831	-	248

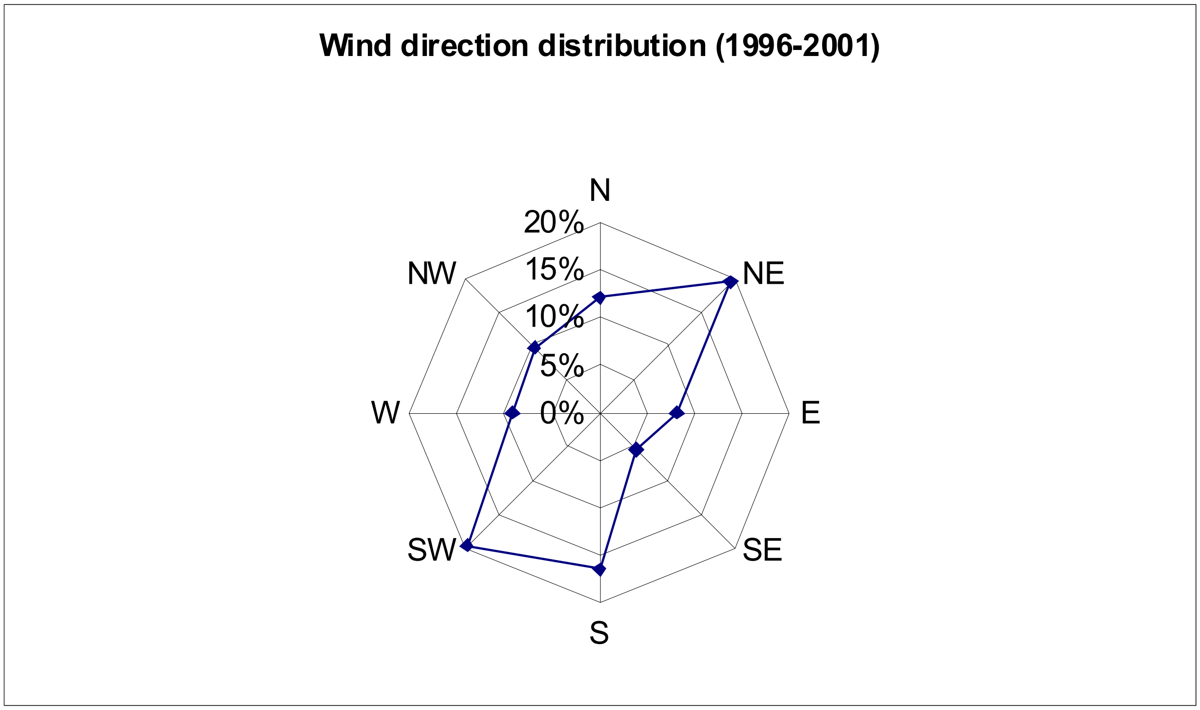

Figure 11. Wind direction distribution from Gavle A during the period 1996 to 2001.

5.2.6 Global climatic and pollutant classification

According to Annex B in D4.2 the suggestion for classification from ISO/WD 15686-4 Buildings – Service Life Data Sets – Part 4 – Service Life prediction data Requirements a simplified classification of the climate and pollutant is [1] carried out.

According to the climatic data for the test object the climatic is classified as Humid (rainfall: 831 mm/year). The average monthly minimum temperature is <-5 °C for 6 months during the 6 years period and the temperature dimension is then classified as Cold.

The pollutant classification is divided into two main areas, industrial pollution and marine pollution. Deposition data of airborne SOx is collected from the MATCH-model (Mesoscale Atmospheric Transport and Chemistry Model) on the SMHI web-site [2]. According to the map in the MATCH-model the sulphur deposition (dry and wet) in year 2001 is about 300-500 $mg/m^2/year$ for the Gavle region, see figure 12. That means that the daily value is around 0.82 – 1.37 mg/m2/day, which is less than 10 $mg/m^2/day$ and the sulphur deposition is therefore benign. The sulphur deposition have been the same (300-500 $mg/m^2/year$) for the period 1994 to 1998 in the same region. Data of airborne salinity is not collected, however, it is assumed that deposition of airborne salinity is very low, i.e. < 15 $mg/m^2/day$, thus it is only the benign pollution class left.

The deposition of de-icing salts of the bridge is about 10 g/m^2/occasion and during the season 2000/2001 there were 30 times of spreading de-icing salts on the bridge at Faeltskaersleden. The data is collected from the maintenance manager [5].

Combining the climatic and the pollutant classes following alternatives from the matrix classification system for environmental data can be chosen (table 20):

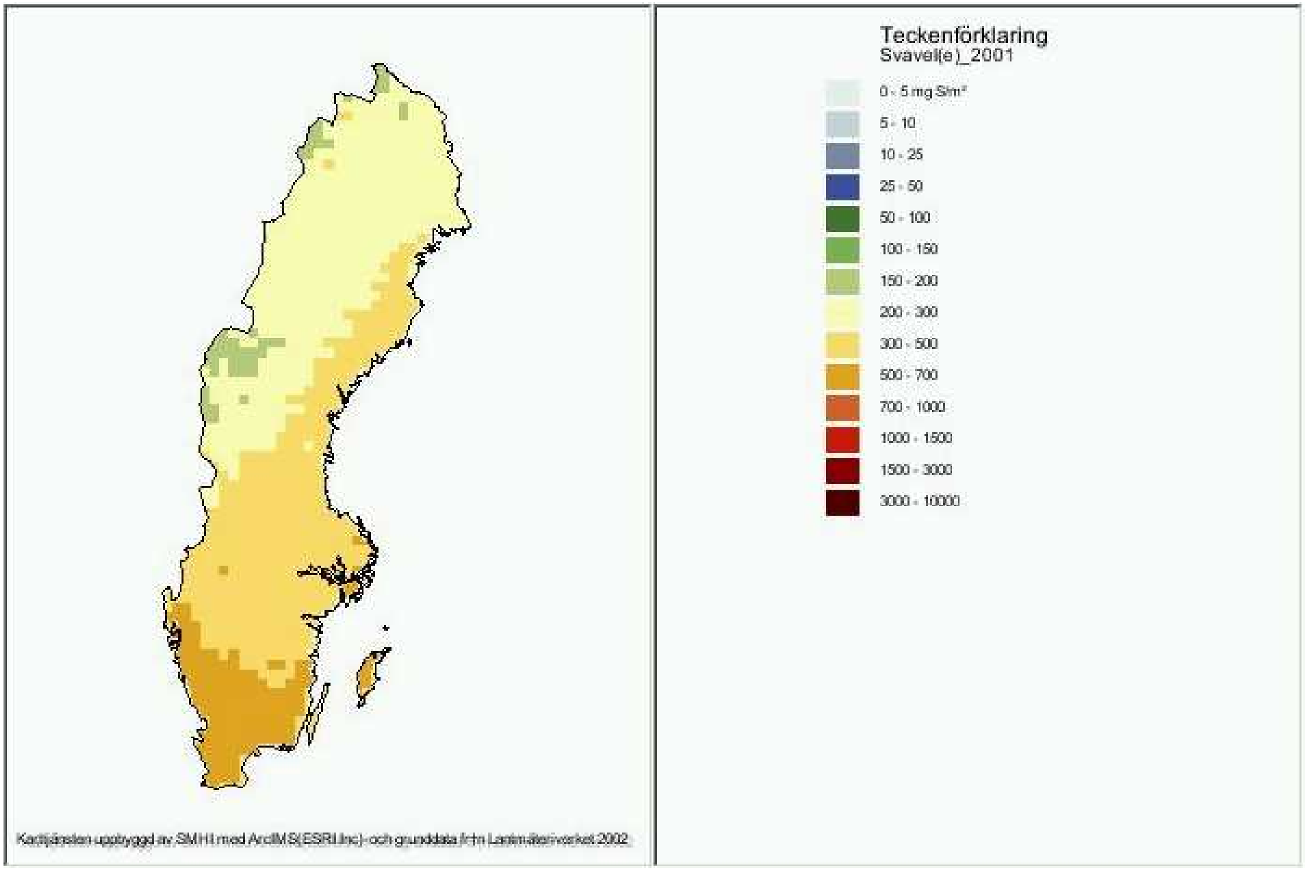

Figure 12. Sulphur deposition according to MATCH map service for atmospheric pollution (http://smed.smhi.se/website2/MATCH_mo_tdse/main.htm, 2003-12-05)

Table 20: Possible climatic/pollution classes (marked with X) for the object.

Class	SM+SI	SM+I	M+SI	M+I	SM	M	SI	I	B
HC									**X**

5.3 Division of structure

The structure is divided into components due to location and orientation, see table 21. Each component is categorised according to the EOTA system, see A1.2 in D4.2 [1]. According to the European temperature sub-division, the bridge belong to the temperature Zone A. The average daily temperature in winter is below 0 °C and the minimum temperature may be below –30 °C, the maximum temperature in the summer rarely exceed 30 °C (the winter period is December to February and the summer period includes June to August), see table A-1 in D4.2 [1]. The climate is moderate for both bridges then the annual radiation on horizontal surfaces is less than 5 GJ/m^2 (3,3 GJ/m^2, UV radiation data from 1997 from BMG station) and the average temperature of the warmest month of the year is below 22 °C (15,9 °C).

5.4 Wall spell index

To calculate the wind driven rain on vertical surfaces the European standard prEN 13013-3 “Hydrothermal performance of buildings – Climatic data – Part 3: Calculation of a wind driving rain index for vertical surfaces from hourly wind and rain data” have been used. The method in the standard is based on the British Standard BS 8104: 1992

A spell is defined as a period or sequence of periods of wind-driven rain on a vertical surface of given orientation. A spell can be of variable length and can include several periods of wind-driven rain interspersed with periods of up to 96 hours without appreciable wind-driven rain. The quantity of driving rain that would occur 10 m above the ground level in the middle of an airfield at the geographical location of the proposed wall is defined as the airfield index prEN 13013-3 [3].

The formula to calculate the spell index is:

$$Is = 2/9 * \sum(v * r^{8/9} * \cos(D - \Theta))$$

Where the v is the hourly mean wind speed (m/s), r is the hourly rainfall (mm), D is the hourly mean wind direction from the north and Θ is the angle between north and a line normal to the wall. Cos(D-Θ) is calculated for those occasions when the wind is blowing against the wall, i.e. when the cos(D-Θ) is positive, see D4.2 [1]. In this case a spell is defined as a month and the driven rain is taken into consideration when the air temperature, during the rainy hours, is above 0 °C, i.e. when there is no snowing. An example of the results is presented in table 21 and 22. The average annual spell indexes for different orientation of components are based on data from 1996 to 2001 and are presented in table 21. The piers at the support B is exposed to wind on both sides but when calculating the spell index the side orientated to the north north-west is chosen as a input data. Due to the design and location of the bridges and their belonging components the different wall spell index factors (Cr, Ct, O and W) is difficult to prescribe. These factors that are used in this calculation of the wall spell index refers to the whole building, not to each component even if that could result in more reliable indexes for each component. In spite of the fact that some components are not exposed to wind driven rain, some of them, in this case, still obtain a wall spell index. Neither the deck surface nor the underside of the slab includes the spell index calculation due to the horizontal orientation.

Table 21: Wall spell indexes and exposure classes for different components (Faeltskaersleden). The side of the pier which is faced towards the road is marked with an a, e.g. Pier Aa. If the side is faced away from the road then it is marked with a b, e.g. Pier Ab. 1 = Horizontal & low slope surfaces (less than 20°C), 2 = Steep slope surfaces (more than 20°C), 3= Vertical surfaces, 4 = underside of horizontal or sloping surfaces.

Object:		**Faeltskaersleden**										
Temperature Sub-division:		**Zone A**										
Temperature and UV radiation:		**Moderate Climate**										
		Wall spell index						**Exposure classes (EN206-1)**				
Building components	**Category of Location EOTA system (A1.2)**	**CR**	**CT**	**O**	**W**	**Is**	**Iws**	Carbon-ation	Chlorides except from sea water	Chlorides from sea water	Freeze / thaw attack	Chemical attack
Substructure												
Support												
Breast wall A	3	0,72	1	0,3	0,4	188,2	16	XC3	XD1		XF2	
Bearing seat A	1	0,72	1	0,3	0,4	188,2	16	XC3	XD1		XF2	
The Lip A	3	0,72	1	0,3	0,4	188,2	16	XC3	XD1		XF2	
Bedding mortars A	3	0,72	1	0,3	0,4	188,2	16	XC3	XD1		XF2	
Ballast wall A	3	0,72	1	0,3	0,4	188,2	16	XC3	XD1		XF2	
Breast wall C	3	0,72	1	0,3	0,4	119,4	10	XC3	XD1		XF2	
Bearing seat C	1	0,72	1	0,3	0,4	119,4	10	XC3	XD1		XF2	
The Lip C	3	0,72	1	0,3	0,4	119,4	10	XC3	XD1		XF2	
Bedding mortars C	3	0,72	1	0,3	0,4	119,4	10	XC3	XD1		XF2	
Ballast wall C	3	0,72	1	0,3	0,4	119,4	10	XC3	XD1		XF2	
Retaining wall A (W)	3	0,72	1	0,6	0,4	121,5	21	XC4	XD3		XF4	
Retaining wall A (E)	3	0,72	1	0,6	0,4	166,2	29	XC4	XD3		XF4	
Piers Aa (4 ea.)	3	0,72	1	0,3	0,4	188,2	16	XC3	XD3		XF4	
Piers Ab (4 ea.)	3	0,72	1	0,3	0,4	119,4	10	XC4	XD1		XF2	
Piers Ba (4 ea.)	3	0,72	1	0,3	0,4	188,2	16	XC3	XD3		XF4	
Piers Ca (4 ea.)	3	0,72	1	0,3	0,4	119,4	10	XC3	XD3		XF4	
Piers Cb (4 ea.)	3	0,72	1	0,3	0,4	188,2	16	XC4	XD1		XF2	
Superstructure												
Bearings												
Rollers A (4 ea.)	3	0,72	1	0,3	0,4	188,2	16					
Rollers C (4 ea.)	3	0,72	1	0,3	0,4	119,4	10					
The slab (underside)	4							XC3	XD1		XF2	
The edge beam (W)	1	0,72	1	0,6	0,5	121,5	26	XC4	XD3		XF4	
The edge beam (E)	1	0,72	1	0,6	0,5	166,2	36	XC4	XD3		XF4	
The surfacing	1							XC4	XD3		XF4	
Expansion joints	1											
The parapet (W)	3	0,72	1	0,6	0,5	121,5	26					
The parapet (E)	3	0,72	1	0,6	0,5	166,2	36					
The drainage system	3											

Table 22: Spell indexes for different months. $\Theta = 330°$ and the wind direction D is varying hourly.

Spell index, Is										
Month	1996	1997	1998	1999	2000	2001	Aver.	Std	Max	Min
Jan	0,0	1,7	3,8	0,0	0,7	0,0	1,1	1,5	3,8	0,0
Feb	0,1	10,0	0,7	3,7	0,0	4,8	3,2	3,9	10,0	0,0
Mar	0,9	3,1	1,8	1,8	3,2	9,8	3,4	3,2	9,8	0,9
Apr	4,4	1,1	2,4	46,4	11,5	35,2	16,8	19,2	46,4	1,1
May	53,8	13,5	20,1	3,4	52,3	27,1	28,4	20,7	53,8	3,4
Jun	12,4	22,6	47,7	36,5	38,9	1,5	26,6	17,6	47,7	1,5
Jul	48,1	22,6	36,8	8,1	95,9	11,2	37,1	32,5	95,9	8,1
Aug	0,1	3,7	65,7	39,6	4,7	14,4	21,4	26,0	65,7	0,1
Sep	27,8	1,5	3,6	2,7	7,4	18,6	10,3	10,6	27,8	1,5
Oct	3,8	28,2	52,1	17,8	1,1	34,1	22,8	19,4	52,1	1,1
Nov	44,7	21,2	3,6	3,1	0,0	18,0	15,1	16,9	44,7	0,0
Dec	0,3	0,5	3,3	3,0	3,9	0,7	2,0	1,6	3,9	0,3
Total	196,5	129,7	241,8	166,1	219,5	175,4	188,2	-	-	-

5.5 Exposure classes

When assigning exposure classes for each component the SS-EN 206-1 is used [4]. Due to the usage of de-icing salts the environment around the bridge is divided into two exposure zones. Zone one includes splashing water with high chloride content and the second zone includes airborne de-icing salts. According to SS-EN 206-1 Zone one comprises the area between the splashing source (the vehicles) and 6 to 7 meters away. The second Zone starts at the end of zone one and ends about 6 meters away, see figure 13. An example of this type of zone division applied on a real case, the bridge at Faeltskaersleden can be seen in figure 14. The exposure classes for each component are presented in table 21. No chlorides from seawater are taken into account due to the distance to the sea and the fact that the sea is of brackish water with low chloride content. The pollution data refers to air and precipitation and not to ground and groundwater and therefore no chemical attacks are taken into consideration.

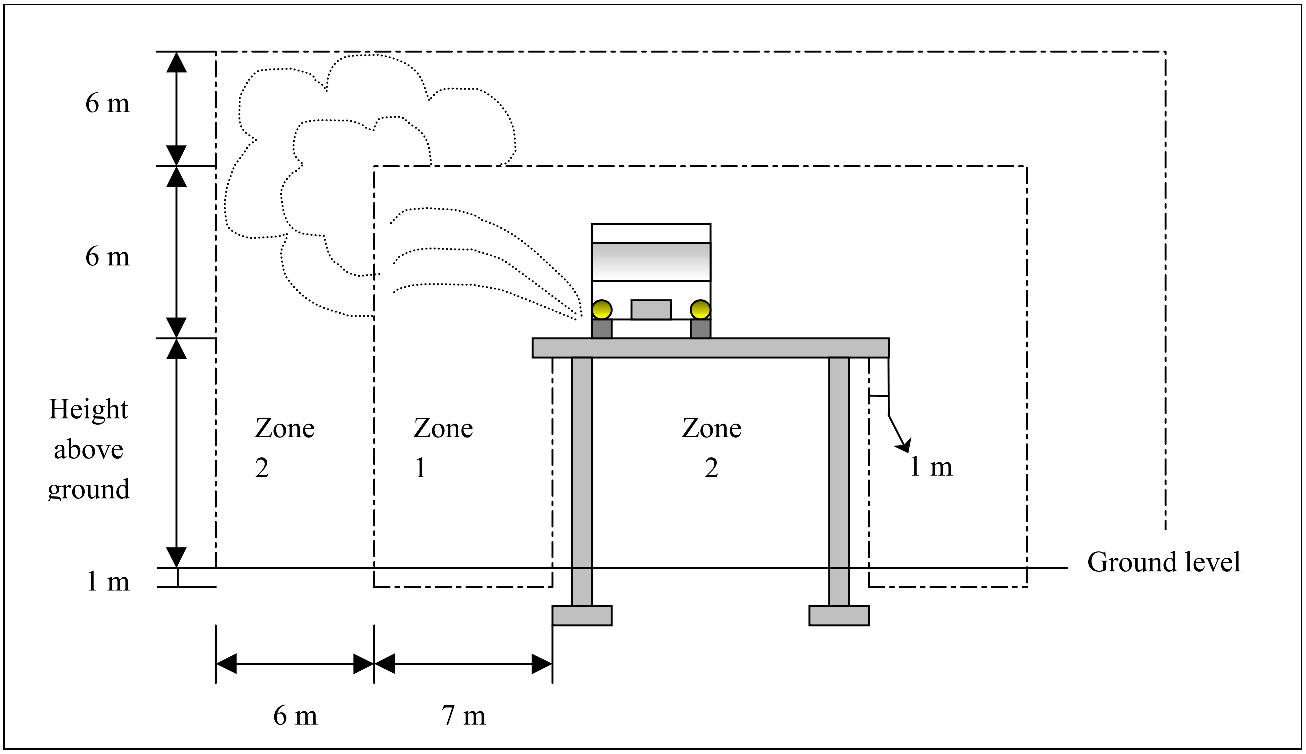

Figure 13. General exposure zones around bridges and roads exposed to de-icing salts.

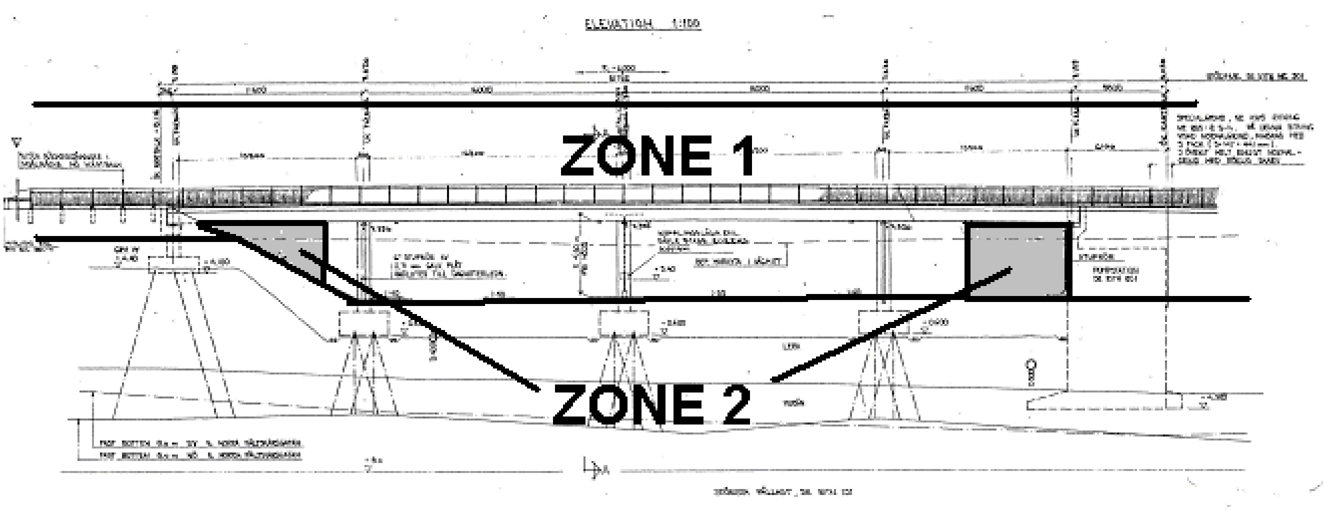

Figure 14. Division of exposure zones applied on the bridge at Faltskarsleden. As can be seen in the figure, zone 2 is located around the breast walls and partly the underside of the slab, all other parts include zone 1.

6 Summary

All countries have extensive meteorological networks that can provide the necessary meteorological data on all levels, either as point measurements or as models on network level for the area in question. Meteorological data can be shown as maps showing the common meteorological parameters (i.e. average temperature and precipitation), or specifically derived parameters may be generated from the time series of the basic parameter.

The measuring, testing and evaluation of air quality are assuming growing importance in developed countries as elements of a comprehensive clean air policy and geared to sustainable development. A huge bulk of data is therefore generated on the various geographical levels.

In 1995 EEA summarised the state of the air pollution-monitoring situation in Europe. The report provides detailed country-wise tables on networks, sites, compounds, reporting etc., summarised into country reports, and again summarised into summary tables covering all the 29 countries from which data were available.

The costs for climatic and pollution data varies between the different countries. In most cases it is quite expensive to get these data, especially if they have to be adjusted in some extent.

The guideline given in D4.2 is possible to adopt, which have been shown by the Norwegian and the Swedish contributions. However, the work effort is quite large, which possibly will be a problem in the future.

The standard prEN 13013 (driving rain) is possible to use in most cases, but some difficulties arise when assessing other constructions than buildings.

7 References