



Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

Call for Data

**“Inventory and condition of stock of materials at
UNESCO World Cultural Heritage sites”**

Part III – Economic evaluation

Call for data: history

- ✓ **Launched on 22 October 2015;**
- ✓ **Deadline for the submission of data: 30 June 2017;**
- ✓ **Six Parties (Croatia, Germany, Italy, Norway, Sweden, Switzerland) provided data on twenty-one objects of cultural heritage;**
- ✓ **Data in the ICP Materials Report No 80: Call for Data “Inventory and condition of stock of materials at UNESCO World Cultural Heritage sites” - Status Report (released in September 2017).**

The cultural objects



Occurrence of materials in the twenty-one objects of cultural heritage

Name of the UNESCO cultural object	Total surface (m ²)	Limestone marble (m ²)	Sandstone (m ²)	Render, mortar, plaster (m ²)	Brick (m ²)	Glass (m ²)	Copper (m ²)	Bronze (m ²)	Other
Cathedral of Saint Domnius	1960	1385	0	42.99	492.08	13	-	Yes	Wood, steel
Aachen Cathedral	17300	3287	7698	-	17	1557	-	Yes	Greywacke, trachyte, tuff, granite, lead, slate
Speyer Cathedral	26000		16900	-	-	1040	7800	Yes	Slate
Würzburg Residence	41100	1027	19522	5959	-	3493	-	-	Painted surfaces, slate
Porta Nigra	5500		4840	-	-	-	660	-	-
Town Hall of Bremen	4060		1868	41	690	244	1218	-	Painted surfaces,
Wartburg Castle (palace and keep)	4300	201	2165	-	-	120	765	-	Wartburg-Konglomerat
Hercules Monument	15100	-	0	-	-	-	151	-	Tuff
The Gatehouse of Lorsch Abbey	570	17	120	200	-	Yes	-	-	Slate
The Colosseum	22750	19450	-	-	Yes	-	-	-	Roman concrete, tuff
The Tower of Pisa	7735	7735	-	-	-	-	-	Yes	-
Palazzo Madama	7300	2700	-	900	3500	200	-	-	Gneiss, terracotta tiles
Ghirlandina Tower	2650	2623	27	-	-	-	-	Yes	Trackyte, lead
Royal Palace of Caserta	149800	54700	-	4000	28500	17400	-	-	Steel, terracotta tiles, wood
Hydroparken	40460	-	-	11220	1460	2820	-	-	Painted surfaces, Tar paper/ruberoid, concrete
Nidarosdomen	4430	60	60	-	-	94	1165	Yes	Talc-schist, slate
Drottningholm Palace Theatre	4205	-	55	1577	-	288	-	-	Painted surfaces, wood
Nederluleå church	3166	-	-	2603	-	175	2	Yes	Painted surfaces, wood, tarred shingles
Wall of the Hanseatic Town of Visby	62000	58900	-	3100	-	-	-	-	-
Towers of the cathedral of the Abbey of St. Gall	3150	158	2918	-	-	-	75	Yes	-
Bern Minster	8980	240	8740	Yes	-	Yes	-	Yes	Lead

Total outer surface area of about 430,000 m² (60% natural stone, 17% artificial stone materials, 6.5% glass, 3% copper, 2.5% waterproof materials, 2% painted surfaces, bronze, others)

Risk assessment

- ✓ **Assessment of air pollution risks to materials: surface recession (stone materials), corrosion (metals) and soiling (limestone and glass);**
- ✓ **The potential risk of damage due to air pollution on the materials was made by using dose-response functions developed by ICP Materials and using the environmental parameters collected during the Call for data;**
- ✓ **The predicted degradation rates were compared with the target (tolerable damage rate) suggested by ICP Materials for protecting cultural heritage monuments for 2050;**
- ✓ **Results in the ICP Materials Report No 83: Call for Data “Inventory and condition of stock of materials at UNESCO World Cultural Heritage sites”, Part II – Risk assessment (released in September 2018).**

Risks due to air pollution for the materials constituting the twenty-one objects of cultural heritage

Name of the cultural object	Materials					
	Limestone (m ²)	Risk	Copper (m ²)	Risk	Glass (m ²)	Risk
Cathedral of Saint Domnius	1385	Soiling	-		13	Soiling
Aachen Cathedral	3287		-		1557	Soiling
Speyer Cathedral	-		7800	Corrosion	1040	Soiling
Würzburg Residence	1027	Corrosion and soiling	-		3493	Soiling
Porta Nigra	-		660	Corrosion	-	
Town Hall of Bremen	-		1218	Corrosion	244	Soiling
Wartburg Castle (palace and keep)	201		765		120	Soiling
Hercules Monument	-		151	Corrosion	-	
The Gatehouse of Lorsch Abbey	17	Corrosion and soiling	-		Yes	Soiling
The Colosseum	19450	Soiling	-		-	
The Tower of Pisa	7735	Corrosion and soiling	-		-	
Palazzo Madama	2700	Corrosion and soiling	-		200	Soiling
Ghirlandina Tower	2623	Soiling	-		-	
Royal Palace of Caserta	54700	Corrosion and soiling	-		17400	Soiling
Hydroparken	-		-		2820	
Nidarosdomen	60		1165		94	Soiling
Drottningholm Palace Theatre	-		-		288	Soiling
Nederluleå church	-		2	Corrosion	175	Soiling
Wall of the Hanseatic Town of Visby	58900	Soiling	-		-	
Towers of the cathedral of the Abbey of St. Gall	158		75	Corrosion	-	
Bern Minster	240		-		Yes	Soiling

Economic evaluation

A model developed in the EU Project (V Research Framework Program) “Rationalised Economic Appraisal of Cultural Heritage (REACH)” was used for calculating costs due to air pollution (Euro/year).

Costs were calculated for each material and for each object of cultural heritage knowing all the parameters:

- ✓ stock of a given type of material at risk (m²);**
- ✓ average costs in Europe for the maintenance/restoration/cleaning of the material (Euro/m²);**
- ✓ lifetime for the material in the background atmosphere (years or days);**
- ✓ lifetime for the material in the actual, polluted atmosphere (years or days).**

Lifetimes (the theoretical times between two maintenance operations) depend on environmental conditions (air pollution and meteorological parameters) to which these materials are exposed to the outdoor environment and on the damage we want to tolerate (suggested by ICP Materials for the corrosion and soiling of a selection of materials).

The cost of maintenance/cleaning

Maintenance/cleaning of a cultural asset is carried out to maintain it over time and passed it down to future generations in the best condition.

A surface maintenance/cleaning operation has a fixed cost (materials, time, work).

- ✓ Low pollution: less damage to surfaces, lower frequency of maintenance, lower cost in a defined period of time.**
- ✓ High pollution: greater damage to surfaces, more frequent maintenance work, higher cost in a defined period of time.**

Lifetimes of the materials of the twenty-one objects of cultural heritage

Material (risk)	Tolerable damage before action	Lifetime in the background atmosphere	Lifetime in the actual atmosphere
Limestone (recession)	100 μm	114 years	22 - 67 years
Copper (corrosion)	10 μm	80 years	21 - 33 years
Limestone (soiling)	35% loss of reflectance	14 years	4.5 - 15.1 years
Glass (soiling)	1% haze (preliminary)	270 days	99 - 390 days

Lifetimes under the current air pollution are much shorter than in a background scenario. This means a higher maintenance frequency which translates into higher costs.

Additional cost due to current air pollution for the materials of the twenty-one objects of cultural heritage

Material (risk)	Maintenance cost in a background scenario (€ m⁻² year⁻¹)	Additional cost due to current air pollution (€ m⁻² year⁻¹)	Percentage of total maintenance cost attributable to air pollution (%)
Limestone (recession)	4.4	3.1 - 20	41 - 82 (average: 71)
Copper (corrosion)	3.5	5.1 - 9.8	59 - 74 (average: 66)
Limestone (soiling)	25	0 - 52.1	0 - 68 (average: 35)
Other natural and artificial stone materials including sandstone (soiling)	25	0 - 34.8	0 - 58 (average: 21)
Glass (soiling)	6.8	0 - 11.7	0 - 63 (average: 33)

The additional cost due to air pollution for a specific object of cultural heritage

- ✓ **The total annual cost of restoration work attributable to air pollution for a given type of material depends on the stock in m² of material at risk.**
- ✓ **This total cost may be significant for specific object of cultural heritage with a large surface area.**

Additional cost due to current air pollution for the twenty-one objects of cultural heritage as a whole

- ✓ **Total outer surface area of about 430,000 m²;**
- ✓ **Total estimated costs due to the current air pollution for the damage (corrosion and soiling) of stone materials, copper and glass for the twenty-one objects of cultural heritage as a whole is about 7 million Euro per year.**

The additional cost due to air pollution for the twenty-one objects of cultural heritage

Name of the UNESCO cultural object	Corrosion		Soiling		
	Limestone	Copper	Limestone	Other stones	Glass
Cathedral of Saint Domnius	Low		Medium	Low	Low
Aachen Cathedral	Medium		Low	Medium	Low
Speyer Cathedral		Medium		High	Low
Würzburg Residence	Medium		Medium	High	Medium
Porta Nigra		Low		Medium	
Town Hall of Bremen		Medium		Medium	Low
Wartburg Castle (palace and keep)	Low	Low	Low	Medium	Low
Hercules Monument		Low		High	
The Gatehouse of Lorsch Abbey	Low		Low	Low	
The Colosseum	High		High/Very high		
The Tower of Pisa	High		High		
Palazzo Madama	Medium		High	High	Low
Ghirlandina Tower	Medium		Medium/High	Low	
Royal Palace of Caserta	Very high		High/Very high	High/Very high	Medium/High
Hydroparken				Low	Low
Nidarosdomen	Low	Low	Low	Low	Low
Drottningholm Palace Theatre				Low	Low
Nederluleå church		Low		Low	Low
Wall of the Hanseatic Town of Visby	High/Very high		Very high	High	
Towers of the cathedral of the Abbey of St. Gall	Low	Low	Low	Low	
Bern Minster	Low		Low	Medium	Low

low = hundreds or thousands of Euro/year; medium = tens of thousands of Euro/year; high = hundreds of thousands Euro/year; very high = approaching or exceeding one million Euro/year.

Additional component of the costs associated with the degradation of a cultural asset

The average costs considered in the study only include the expenditures to remediate the damaged surfaces of the object of cultural heritage, i.e. by repairing, cleaning, consolidating and protecting the surface. These actions involve market transactions and have a market price.

An additional component of the costs associated with the degradation of a cultural asset is the so-called loss of amenity, e.g. the decrease in aesthetic appeal. They include, for example:

- ✓ reduction in the value of the visitor's experience;
- ✓ reduction in the number of visitors to the site;
- ✓ impact on the local economy.

These losses do not have a well-defined monetary value as they are not traded in markets.

Main conclusions

- ✓ **The number of cultural heritage objects taken into account in this Call for Data is small compared to the number of objects in sites of the UNESCO world cultural heritage list located in countries which are Parties to the Convention on Long-range Transboundary Air Pollution.**
- ✓ **Despite the limitations and the assumptions made in the present study, a sufficiently clear picture emerges on the cost of damages due to corrosion and soiling of the outdoor cultural heritage materials deriving from atmospheric pollution.**
- ✓ **The costs attributable to the current air pollution constitute a significant percentage of the total costs that must be addressed for a proper maintenance of the façade materials of the European cultural heritage.**

More information is available in the ICP Materials Report No 86

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**which will soon be downloadable from the ICP Materials
website:**

<http://www.corr-institute.se/icp-materials/web/page.aspx>

Thank you for your attention!