Supplementary Materials for

Indicators to assess physiological heat strain – Part 3: Multi-country field evaluation and consensus recommendations

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Figure S1 | Number of articles using or referring to the Wet-Bulb Globe Temperature (WBGT) and the Universal Thermal Climate Index (UTCI) from the year of their development until December 31, 2021.

Figure S2 | Geographical representation and number of articles published using or referring to the Wet-Bulb Globe Temperature (WBGT) and the Universal Thermal Climate Index (UTCI) from the year of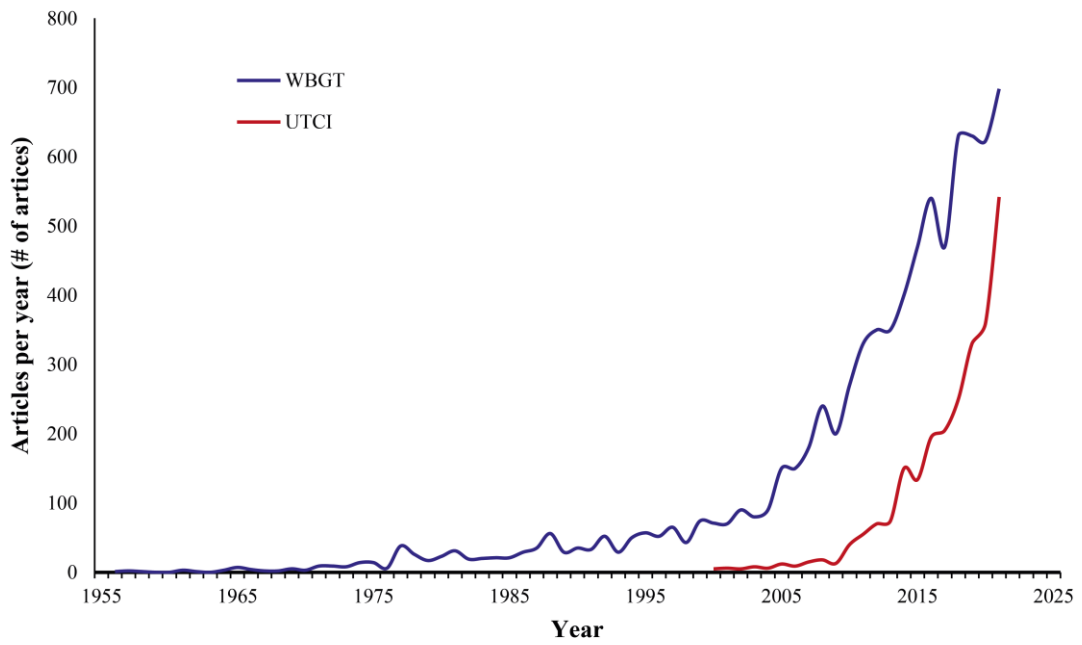 their development until December 31, 2021. Left and right maps show the countries that used or referred to the WBGT and UTCI, respectively. Similarly, blue and red bars correspond to the number of articles published by different countries using or referring to the WBGT or UTCI, respectively.
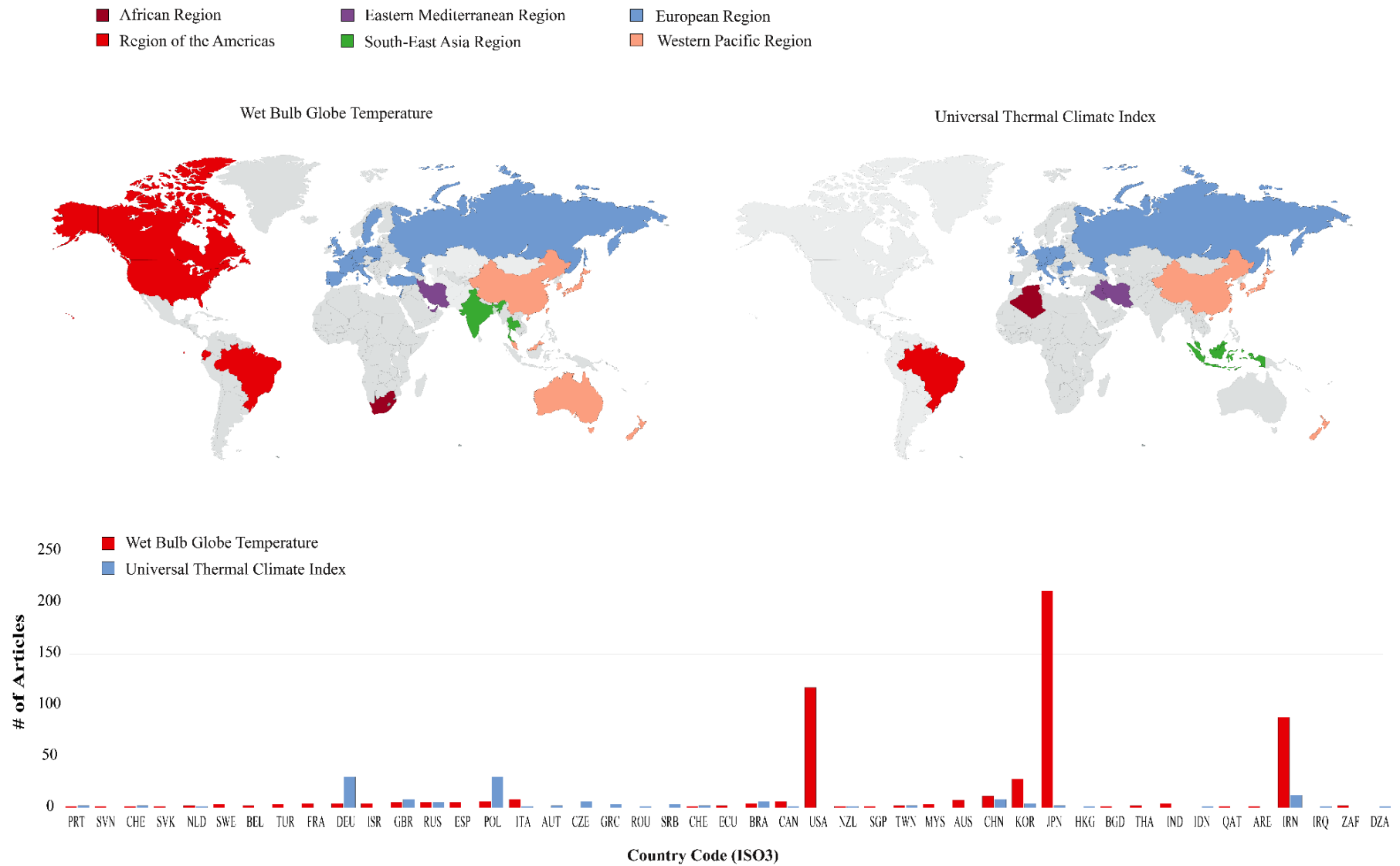
Table S1 | Distribution of work hours assessed across different air temperatures.

Temperature range (°C)	Percent of work hours assessed
< 0	1.1
0 through 5	0.7
5 through 10	0.5
10 through 15	0.0
15 through 20	1.1
20 through 25	7.9
25 through 30	24.4
30 through 35	32.3
35 through 40	22.4
40 through 45	9.6
> 45	1.1

Table S2 | Quantitative evaluation of the 61 occupational meteo-based thermal stress indicators. Note: [cit:] indicates that we could not locate the full text of the original article, thus the equation used was found in the cited publication; [appr:] indicates indicators requiring specialized equipment, thus an equation found in the cited publication was used for their approximation.

ID	Thermal Index	Correlation coefficient (r)					ROC	Sensitivity	Specificity	RR	Categories	Guidance	Cost-effectiveness		SCORE
#	%	T_{core}	T_{sk}	T_{body}	HR	HYD	T_{body}	T_{body}	T_{body}	T_{body}			1 year	10 years	%
Delphi item:		1	2	3	4	13	5	6	7	8	9	10	11	12	
Delphi score:		13.3	7.1	6.9	6.4	6.8	4.7	8.1	2.5	4.7	12.7	16.3	4.7	6.0	
168	Wet Bulb Globe Temperature (indoor) (Yaglou; 1956)[1]	0.114	0.489	0.487	0.079	-	0.722	0.393	0.859	1.000	✓	✓	0.888	0.896	55.4
169	Wet Bulb Globe Temperature (outdoor) (Yaglou; 1956)[1]	0.126	0.472	0.441	0.153	-	0.701	0.510	0.811	1.000	✓	✓	0.633	0.681	55.1
165	Universal Thermal Climate Index (Jendritzky; 2012)[2]	0.045	0.468	0.387	0.133	-	0.678	0.631	0.336	0.730	✓	✓	0.594	0.639	51.7
146	Temperature Humidity Index (Nieuwolt; 1977)[cit:3]	-	0.565	0.517	0.154	0.132	0.710	0.901	0.280	1.000	✓		1.000	1.000	42.0
145	Temperature Humidity Index (Kyle; 1994) [cit:4]	0.216	0.304	0.362	0.351	0.047	0.738	0.855	0.183	0.686	✓		0.965	0.965	41.0
121	Relative Strain Index (Kyle; 1992) [cit:5]	0.077	0.564	0.557	0.044	0.054	0.735	0.747	0.495	0.791	✓		0.960	0.960	40.8
85	Humidex (Masterson; 1979) [cit:6]	0.112	0.461	0.461	0.090	-	0.722	0.850	0.429	0.805	✓		0.952	0.952	40.7
122	Relative Strain Index (Lee; 1966)[7]	0.085	0.534	0.528	-	0.052	0.731	0.606	0.765	1.000	✓		0.958	0.958	40.7
117	Radiative Effective Temperature (Blazejczyk; 2004) [8]	0.061	0.602	0.534	0.106	-	0.714	0.918	0.244	1.000	✓		0.463	0.499	40.3
21	Biologically Active Temperature (Tsitsenko; 1971) [cit:9]	-	0.504	0.491	0.123	0.135	0.718	0.995	0.155	1.000	✓		0.656	0.661	40.0
9	Apparent Temperature (Kalkstein; 1986)[10]	-	0.573	0.542	0.122	0.114	0.746	0.752	0.264	0.814	✓		0.946	0.946	39.8
75	Fighter Index of Thermal Stress (Direct Sunlight) (Stribley; 1978)[11]	0.105	0.459	0.455	0.089	0.000	0.721	0.816	0.547	1.000	✓		0.450	0.484	39.2
13	Apparent Temperature (shade) (Steadman; 1984) [12]	-	0.552	0.529	0.129	0.058	0.726	0.785	0.375	0.909	✓		0.631	0.636	39.0
144	Temperature Humidity Index (Romanian National Institute of Meteorology and Hydrology; 2000) [cit:4]	0.181	0.098	-	0.388	0.047	0.552	0.998	0.382	1.000	✓		0.915	0.915	38.9
80	Heat Index (Blazejczyk; 2012) [6]	0.135	0.508	0.501	0.085	0.050	0.733	0.579	0.345	0.667	✓		0.905	0.905	38.4
65	Equatorial Comfort Index (Webb; 1960) [cit:13]	0.114	0.449	0.441	0.073	0.000	0.704	0.530	0.638	0.837	✓		0.892	0.892	38.2
132	Simplified Wet Bulb Globe Temperature (Gagge; 1976) [cit:14]	0.104	0.536	0.517	0.063	0.050	0.740	0.666	0.034	0.667	✓		0.898	0.898	38.1
10	Apparent Temperature (Smoyer-Tomic; 2001) [15]	0.039	0.578	0.555	0.089	0.047	0.742	0.583	0.341	0.667	✓		0.896	0.896	38.1

Table S2 | Quantitative evaluation of the 61 occupational meteo-based thermal stress indicators. Note: [cit:] indicates that we could not locate the full text of the original article, thus the equation used was found in the cited publication; [appr:] indicates indicators requiring specialized equipment, thus an equation found in the cited publication was used for their approximation.

ID	Thermal Index	Correlation coefficient (r)					ROC	Sensitivity	Specificity	RR	Categories	Guidance	Cost-effectiveness		SCORE
#		T_{core}	T_{sk}	T_{body}	HR	HYD	T_{body}	T_{body}	T_{body}	T_{body}			1 year	10 years	%
Delphi item:		1	2	3	4	13	5	6	7	8	9	10	11	12	
Delphi score:		13.3	7.1	6.9	6.4	6.8	4.7	8.1	2.5	4.7	12.7	16.3	4.7	6.0	
11	Apparent Temperature (indoor) (Steadman; 1994)[16]	0.032	0.568	0.547	0.097	0.047	0.742	0.553	0.373	0.667	✓		0.888	0.888	37.7
166	Wet Bulb Globe Temperature (eq. 1) (Ono; 2014)[17]	0.090	0.528	0.492	0.086	-	0.725	0.472	0.843	1.000	✓		0.432	0.465	37.6
57	Discomfort Index (Weather Services of South Africa; 2018)[18]	-	0.563	0.535	0.122	0.049	0.742	0.582	0.317	0.667	✓		0.880	0.880	37.4
76	Fighter Index of Thermal Stress (Moderate Overcast) (Stribley; 1978)[11]	0.105	0.460	0.456	0.089	-	0.721	0.533	0.753	1.000	✓		0.429	0.461	37.3
167	Wet Bulb Globe Temperature (eq. 2) (Ono; 2014)[17]	0.077	0.533	0.496	0.065	-	0.723	0.455	0.846	1.000	✓		0.427	0.460	37.2
12	Apparent Temperature (indoor) (Steadman; 1984)[12]	-	0.584	0.551	0.116	0.120	0.744	0.448	0.413	0.667	✓		0.877	0.877	36.8
52	Discomfort Index (Giles; 1990)[19]	-	0.552	0.527	0.118	0.047	0.740	0.457	0.439	0.656	✓		0.856	0.856	36.3
14	Apparent Temperature (shade) (Steadman; 1994)[16]	-	0.537	0.524	0.114	0.050	0.720	0.555	0.322	0.667	✓		0.571	0.576	35.3
104	Normal Equivalent Effective Temperature (Boksha; 1980)[cit:9]	-	0.504	0.491	0.123	0.135	0.718	0.605	0.155	0.486	✓		0.559	0.564	34.0
130	Simplified Universal Thermal Climate Index (Blazejcyk; 2011)[20]	0.054	0.440	0.348	0.070	-	0.654	0.520	0.243	0.934	✓		0.384	0.413	33.4
15	Apparent Temperature (sun) (Steadman; 1984)[12]	0.036	0.563	0.506	0.032	-	0.717	0.391	0.343	0.570	✓		0.375	0.403	32.6
124	Robaa's Index (Robaa; 2003)[cit:21]	-	0.548	0.514	0.157	0.143	0.719	0.453	0.173	0.463	✓		0.385	0.414	32.6
16	Apparent Temperature (sun) (Steadman; 1994)[16]	0.041	0.552	0.506	0.034	-	0.713	0.451	0.177	0.500	✓		0.371	0.400	32.3
17	Approximated Subjective Temperature (Auliciems; 2007)[22]	-	0.490	0.412	-	-	0.679	0.486	0.306	0.667	✓		0.364	0.392	31.7
141	Swedish Wet Bulb Globe Temperature (Eriksson; 1974)[cit:23]	0.116	0.428	0.392	0.145	-	0.686	0.491	0.115	0.302	✓		0.361	0.389	31.4
69	Equivalent Temperature (Brundl; 1984)[24]	0.078	0.167	0.248	0.049	0.077	0.568	0.342	0.807	0.656	✓		0.734	0.734	30.9
131	Simplified Wet Bulb Globe Temperature (American College of Sports Medicine; 1984)[cit:14]	0.120	0.482	0.488	0.094	-	0.718	-	-	-	✓		0.656	0.656	28.1
173	Wet Cooling Power (Landsberg; 1972)[13]	0.065	-	-	-	0.102	0.501	-	-	-	✓		0.201	0.217	16.9

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Delphi item:		1	2	3	4	13	5	6	7	8	9	10	11	12	
Delphi score:		13.3	7.1	6.9	6.4	6.8	4.7	8.1	2.5	4.7	12.7	16.3	4.7	6.0	
79	Heart Rate Safe limit (LaFleur; 1971)	-	0.570	0.548	0.098	0.048	0.742	-	-	-			0.320	0.320	13.4
78	Heart Rate (Moderate Intensity) (Fuller; 1966)[25]	-	0.569	0.548	0.098	0.048	0.742	-	-	-			0.320	0.320	13.4
64	Environmental Stress Index (Moran; 2001)[26]	0.094	0.523	0.497	0.071	-	0.721	-	-	-			0.194	0.212	13.1
127	Simple Index (Moran; 2001)[26]	0.077	0.533	0.489	0.069	-	0.726	-	-	-			0.191	0.209	12.9
133	Skin Temperature (Blazejczyk; 2005)[27]	-	0.582	0.517	0.107	0.147	0.723	-	-	-			0.154	0.166	12.5
66	Equivalent Effective Temperature (Aizenshtat; 1974)[cit:28]	-	0.529	0.508	0.123	0.063	0.722	-	-	-			0.205	0.207	12.4
25	Cooling Power (Becker; 1972)[cit:29]	-	0.501	0.466	0.108	0.189	0.712	-	-	-			0.297	0.315	12.2
67	Equivalent Effective Temperature (Aizenshtat; 1982)[cit:30]	-	0.504	0.491	0.123	0.135	0.718	-	-	-			0.208	0.210	12.1
128	Simplified Radiation Equivalent Effective Temperature (Boksha; 1980)[cit:9]	-	0.504	0.491	0.123	0.135	0.718	-	-	-			0.208	0.210	12.1
176	Wet Kata Cooling Power (Chamber of Mines of South Africa; 1972)[31]	-	0.542	0.500	0.112	0.044	0.726	-	-	-			0.142	0.152	12.0
100	Modified Environmental Stress Index (Moran; 2003)[32]	-	0.546	0.513	0.031	-	0.722	-	-	-			0.174	0.191	11.8
116	Psychrometric Wet Bulb Temperature (McPherson; 2008)[cit:14]	0.035	0.451	0.468	0.072	-	0.674	-	-	-			0.182	0.183	11.3
150	Temperature Resultante Miniere (Vogt; 1978)[cit:33]	0.037	0.454	0.455	0.098	0.051	0.672	-	-	-			0.133	0.143	11.2
174	Wet Globe Temperature (Botsball) (Botsford; 1971)[appr:34]	0.102	0.360	0.313	0.154	-	0.654	-	-	-			0.123	0.132	10.7
134	Skin Wettedness (Blazejczyk; 2005)[27]	0.037	0.446	0.373	0.058	0.158	0.712	-	-	-			0.133	0.143	10.5
59	Dry Kata Cooling (Maloney; 2011)[35]	-	0.394	0.362	0.075	0.189	0.686	-	-	-			0.253	0.268	10.2
95	Mean Radiant Temperature (Ramsey; 2001)[36]	-	0.382	0.305	0.080	-	0.658	-	-	-			0.102	0.110	8.9
149	Temperature of the exhaled air (McPherson; 1993)[31]	0.086	0.215	0.288	0.047	0.078	0.584	-	-	-			0.215	0.215	8.7
102	Net Radiation (Cena; 1984)[37]	-	0.347	0.268	0.098	-	0.652	-	-	-			0.097	0.104	8.4

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Delphi item:		1	2	3	4	13	5	6	7	8	9	10	11	12	
Delphi score:		13.3	7.1	6.9	6.4	6.8	4.7	8.1	2.5	4.7	12.7	16.3	4.7	6.0	
51	Dew Point (Bruce; 1916)[appr:38]	0.062	0.226	0.299	-	0.071	0.582	-	-	-			0.201	0.201	8.2
119	Radiation Equivalent Effective Temperature (Pigmented) (Sheleihovskyi; 1948)[cit:39]	0.035	0.181	0.214	0.079	0.053	0.574	-	-	-			0.082	0.088	6.8
118	Radiation Equivalent Effective Temperature (Non-Pigmented) (Sheleihovskyi; 1948)[cit:39]	0.038	0.179	0.211	0.068	0.053	0.573	-	-	-			0.081	0.087	6.7
60	Effective Radiant Field (Gagge; 1967)[cit:40]	-	0.200	0.115	0.151	0.046	0.617	-	-	-			0.077	0.083	6.4
61	Effective Radiant Field (Nishi; 1981)[40]	-	0.200	0.111	0.148	0.047	0.616	-	-	-			0.077	0.083	6.4
177	Wet Kata Cooling Power (Krisha; 1996)[41]	0.064	0.058	0.110	-	0.100	0.517	-	-	-			0.062	0.067	4.7

Notes:
T_{core} represents the magnitude of the relationship (correlation coefficient r) between the current thermal index and the core temperature of the workers.

T_{sk} represents the magnitude of the relationship (correlation coefficient r) between the current thermal index and the mean skin temperature of the workers.

T_{body} represents the magnitude of the relationship (correlation coefficient r) between the current thermal index and the mean body temperature of the workers.

HR represents the magnitude of the relationship (correlation coefficient r) between the current thermal index and the heart rate of the workers.

HYD represents the magnitude of the relationship (correlation coefficient r) between the current thermal index and the heart rate of the workers.

ROC represents ability of each thermal index to diagnose increased mean body temperature (>36.7°C) using the Area Under the ROC curve.

Sensitivity the sensitivity (also called the true positive rate) of a thermal index to measure the proportion of workers with high mean body temperature (>36.7°C) who are correctly identified as having high mean body temperature.

Specificity represents the specificity (also called the true negative rate) of a Thermal Index to measure the proportion of workers with normal mean body temperature (<36.7°C) who are correctly identified as not having high mean body temperature.

RR represents "Risk Ration" and it describes the capacity of each Thermal Index to diagnose the increase in risk for having high mean body temperature when being exposed to environmental parameters characterized by different heat stress category.

Categories represents the availability of categories indicating the level of heat stress experienced by workers.

Guidance represents the availability of published health-related recommendations for the categories identified for the current thermal index.

Cost-effectiveness represents the cost-effectiveness during the 1st and the 10th year of using a thermal index.

SCORE represents the score overall score of each thermal index in percentage points. A score of 100 percentage points covers all (100 %) the requirements determined by the experts who participated in the Delphi exercise.

| 0-10% | 10-20% | 20-30% | 30-40% | 40-50% | 50-60% | 60-70% | 70-80% | 80-90% | 90-100% |

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