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Questionnaire survey on the use of thermal insulation solutions in building facades of Portugal, Italy and Norway

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Abstract

The use of adequate thermal insulation solutions in the opaque walls is one of the most efficient passive strategies towards the improvement of the buildings' thermal performance. Nevertheless, beyond the thermal performance, a set of different performance criteria (i.e., hygrothermal performance, fire behavior, environmental footprint, among others) must also be considered when selecting thermal insulation materials. This study aimed to enhance understanding of the use of thermal insulation solutions in new construction and for the thermal retrofitting of building facades in Portugal, Italy and Norway. To that end, a questionnaire survey was prepared considering the relationships among the different Political, Economic, Social, Technological and Environmental criteria involved in the selection of thermal insulation solutions. The questionnaire was available online between November 2022 and February 2023 and respondents, primarily living and/or working in Portugal, Italy and Norway, were asked to answer questions related to the use and performance of different thermal insulation solutions. Results showed that different perceptions and levels of knowledge regarding the performance of several insulation materials could be ascribed to the respondent's country of residence.

Keywords: Thermal insulation materials; Questionnaire survey; PESTE criteria; Rating system.

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1. Introduction

Buildings account for a significant percentage of the global energy use, generating more than one quarter of the world energy-related CO_2 emissions (Laaroussi et al. 2020). As a result, several European directives (e.g., EU Directive 2018/844) and guidelines have been published with the aim of decreasing indoor thermal discomfort and improving the energy performance of new construction, while reducing the energy demand of existing buildings.

The use of thermal insulation solutions in the opaque walls is one of the most efficient passive strategies towards the improvement of the buildings' thermal performance (Schiavoni et al. 2016). Therefore, the selection of the most suitable thermal insulation material to be applied is fundamental for an adequate thermal performance of the building. Nevertheless, beyond the thermal performance, a set of different performance criteria (i.e., hygrothermal performance, fire behavior, environmental footprint, among others) must also be considered when selecting the thermal insulation solution (Parracha et al. 2023a).

This paper aims at providing a new understanding about the use of thermal insulation solutions in new construction and for the thermal retrofitting of building facades in Portugal, Italy and Norway. To that end, a questionnaire survey was prepared considering the relationships among the different Political, Economic, Social, Technological and Environmental criteria (i.e., PESTE analysis) involved in the selection of thermal insulation solutions. The questionnaire was delivered online between November 2022 and February 2023 and asked respondents living and/or working mainly in Portugal, Italy and Norway to respond to questions related to the use and the performance of different thermal insulation solutions.

The work reported herein is part of the wider EEA Granted EFFICACY project, which mainly aims at creating a database that can be used to select thermal insulation solutions to be applied in new buildings and thermal retrofitting of facades.

2. Questionnaire survey

A questionnaire survey (Parracha et al. 2023b) was structured into five sections related to Political, Economic, Social, Technological, and Environmental criteria (i.e., PESTE analysis). In the section related to Environmental criteria, a questionnaire-based rating system was used (Table 1) for asking people to rate the most common thermal insulation materials used in Portugal, Italy and Norway (Table 2) in accordance with their performance. In order to characterize the sample, the questionnaire survey also included demographic and calibration information (e.g., age, gender, living country, nationality, etc.). The responses were deposited at Mendeley dataset website (Parracha et al. 2023b). Further information about the questionnaire survey, data accessibility and data description can be found in a previous study by the authors (Parracha et al. 2023a).

Table 1. Questionnaire-based rating system used in the survey (adapted from Parracha et al. (2023a)).

Performance criteria:	**Questionnaire-based rating system (from 1 to 5)**
Durability	1 – less durable; 5 – most durable
Market price	1 – less expensive; 5 – most expensive
Needs of maintenance	1 – lowest need; 5 – highest need
Fire behavior	1 – worst performance; 5 – best performance
Biological susceptibility	1 – lowest bio-susceptibility; 5 – highest bio-susceptibility
Water performance	1 – lowest water retention; 5 – highest water retention
Mechanical performance	1 – lowest mechanical resistance; 5 – highest mechanical resistance
Sustainability	1 – most sustainable; 5 – least sustainable

Table 2. List of thermal insulation solutions included in the questionnaire (adapted from Parracha et al. (2023a)).

Thermal insulation solution	Commonly used in:
Insulation cork board (ICB)	Italy and Portugal
Mineral wool (MW)	Italy, Portugal, and Norway
Expanded polystyrene (EPS)	Italy, Portugal, and Norway
Extruded polystyrene (XPS)	Italy, Portugal, and Norway
Polyurethane foam (PUR)	Italy, Portugal, and Norway
Natural fibers (NF)	Italy
Aerogel blankets (AB)	*
Thermal insulating mortars (TM)	Portugal
Vacuum-insulation panels (VIP)	*
Vegetation – green walls (VEG)	*

*Thermal insulation solution was included in the list due to its innovative nature

The questionnaire was prepared with Google Forms and delivered online on social media and via email in the period between November 2022 and February 2023. The questionnaire was edited in English, Portuguese and Italian and the respondents were randomly approached (Parracha et al. 2023a). After the end of February 2023, all responses were screened to identify and remove possible duplicates.

3. Results

221 respondents completed the entire questionnaire survey (Parracha et al. 2023b). Out of these, 127 responses were from Portugal, 52 from Italy, and 24 from Norway, corresponding to ~ 92% of the total sample (203 responses).

Table 3 presents the results of some general questions included in the questionnaire with the aim of characterizing the sample. Results showed that approximately 90% of the Portuguese and Italian respondents were aged between 25 and 65 years old, whereas this value is slightly lower (~ 83%) in the case of Norway. The gender distribution indicates that men represent approximately 75%, 63%, and 49% of the responses obtained in Portugal, Italy and Norway, respectively. When considering the living place, the majority (> 65%) of respondents live in a city (> 10 000 inhabitants). Moreover, approximately 78%, 87%, and 79% of the responses in Portugal, Italy and Norway were from people with at least a master's degree. In the case of Portugal and Italy, most respondents have more than 10 years of job experience (69% and 48%, respectively). In the case of Norway, most respondents are junior, with less than 5 years of experience (~ 46%). As expected, a flat in a building was pointed out as the most common type of house in the three countries. Finally, it is worth noting that most respondents work in private companies in the field of architecture, construction engineering, real estate and facilities management, and in public research institutions and universities (e.g., faculty members or students).

Table 4 presents the responses to some of the most relevant questions included in the survey considering a PESTE analysis (i.e., Political, Economic, Social, Technological and Environmental criteria). As it can be observed, 37% of Italian respondents and 52% of Portuguese respondents have thermal insulation in their buildings, a percentage significantly higher for the Norwegian respondents (~ 79%). Moreover, most Portuguese (~ 57%) and Italian (~ 62%) respondents have the perception that their building needs an energy retrofitting intervention. In the case of Norway, a lower percentage of respondents (~ 45%) identified this need, which is in line with the differences in the percentages of thermal insulation found in the three countries (Table 4).

In the Political section, results showed that most Portuguese (~ 62%), Italians (~ 79%) and Norwegians (~ 63%) are aware of possible governmental financial incentives for energy retrofitting interventions. However, the results also revealed that Portuguese and Norwegian respondents (i.e., at least 63% when considering both countries) believe that

such incentives are insufficient. In contrast, approximately 56% of the Italians agree with the appropriateness governmental financial incentives.

Table 3. Demographic information of the Portuguese, Italian and Norwegian respondents.

	Countries	Portugal	Italy	Norway	Total
Age	18 – 24	9	2	4	15
	25 – 34	23	21	9	53
	35 – 49	69	14	10	93
	50 – 65	23	12	1	36
	Over 65	3	3	0	6
Gender	Female	65	19	6	90
	Male	62	33	18	113
Living place	City (> 10 000 inhabitants)	102	36	24	162
	Town (2 500 – 10 000 inhabitants)	17	10	0	27
	Village (< 2 500 inhabitants)	8	6	0	14
Level of education	High school graduate	4	4	1	9
	Technical/vocational training	3	1	1	5
	Bachelor's degree	21	2	3	26
	Master's degree	58	27	10	95
	Doctoral (Ph.D.) degree	41	18	9	68
Job experience	Junior (< 5 years)	20	18	11	49
	Intermediate (5 – 10 years)	20	9	5	34
	Senior (> 10 years)	87	25	8	120
	Retired	0	0	0	0
Type of house	Flat in a building	95	37	18	150
	Detached (single) house	18	11	4	33
	Semi-detached house	14	4	2	20

In the Economic section, the results showed that a significant percentage of the respondents (i.e., more than 79% in all three countries), believe that an energy retrofitted building would reimburse the investment costs, regardless of the country.

When considering satisfaction with the level of comfort inside the building, approximately 80%, 75% and 96% of Portuguese, Italian, and Norwegian respondents, respectively, expressed satisfaction. Also in the Social section, ~ 58% and ~ 63% of the Italian and Norwegian respondents reported that they did not require any additional device or equipment (e.g., air conditioning) to improve indoor comfort. On the opposite, ~ 76% of Portuguese respondents use such tool or equipment to ensure indoor comfort.

Furthermore, in the Technological section, a significant portion of the respondents in all three countries either did not know or did not answer to questions regarding criteria or guidelines for selecting thermal insulation materials useful for the energy retrofitting of buildings.

In conclusion, approximately 58% of respondents from Portugal and Italy either expressed disbelief in climate change or chose not to respond to the question. This percentage increases to ~ 83% when considering the responses from Norway.

As previously stated, a questionnaire-based rating system was used in the Technological section to evaluate the perception and knowledge of the respondents considering a set of different performance criteria (i.e., hygrothermal performance, fire behavior, environmental footprint, among others) of the most common thermal insulation solutions in the countries. 73%, 71% and 59% of the Portuguese, Italian and Norwegian respondents, respectively, considered they have technical knowledge about the use and performance of thermal insulation solutions. Fig. 1 displays the results of the questionnaire-based rating system concerning durability, market price, fire behavior, water performance, mechanical performance, and sustainability criteria.

Table 4. Responses to some of the most relevant questions included in the survey considering a PESTE analysis.

Criteria	Question		Countries			
			Portugal	Italy	Norway	Total
General question	Do you know if your building has thermal insulation?	Yes	67	19	19	105
		No	43	26	2	71
		Don't know	17	7	3	27
General question	Do you think your building needs an energy retrofit?	Yes	73	32	11	116
		No	34	12	10	56
		Don't know	20	8	3	31
Political	Are you aware of possible governmental financial incentives for energy retrofitting interventions?	Yes	79	41	15	135
		No	48	11	9	68
	If yes, do you think they are adequate?	Yes	36	29	9	74
		No	91	23	15	129
Economic	Is an energy retrofitting intervention worthy the investment costs?	Yes	119	48	19	186
		No	8	4	5	17
Social	Are you satisfied with the level of comfort in your house/flat?	Yes	101	39	23	163
		No	26	13	1	40
	Do you need any additional tool/equipment for improving the indoor thermal comfort?	Yes	96	22	9	127
		No	31	30	15	76
Technological	Do you know criteria or guidelines for selecting thermal insulation materials useful for energy retrofitting interventions?	Yes	43	18	9	70
		No	50	19	4	73
		No answer	34	15	11	60
Environmental	Do you believe in climate change? Did you see sign of its impact in your country and/or on your building?	Yes	54	22	4	80
		No	54	22	14	90
		No answer	19	8	6	33

Portuguese respondents identified ICB (agglomerated insulation cork board), MW (mineral wool) and XPS (extruded polystyrene) as the most durable solutions, while VEG (vegetation – green walls) was classified as the least durable. On the other hand, Italian respondents considered MW and PUR (polyurethane foam) as the most durable thermal insulation solutions, and ICB and NF (natural fibers) as the least durable. For Norwegian respondents, MW, EPS (expanded polystyrene board) and XPS were seen as the most durable solutions, while ICB, AB (aerogel blankets) and VIP (vacuum-insulation panels) were rated as the least durable. Interestingly, MW was the only thermal insulation solution considered as one of the most durable in the three countries

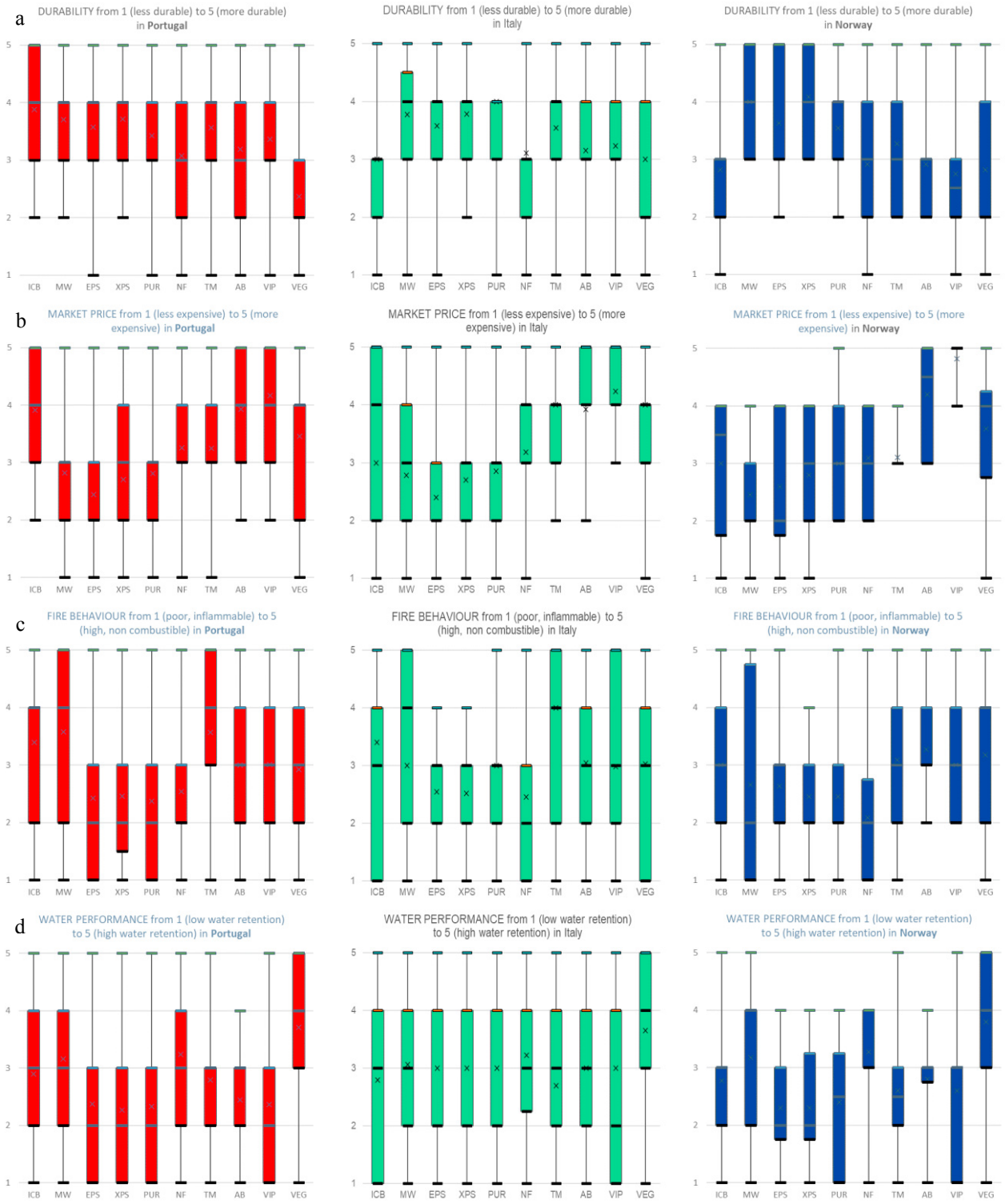

Fig. 1. Results of the questionnaire-based rating system in the three countries (Portugal – left; Italy – center; Norway – right) considering durability (a), market price (b), fire behavior (c), water performance (d), mechanical performance (e), and sustainability (f).

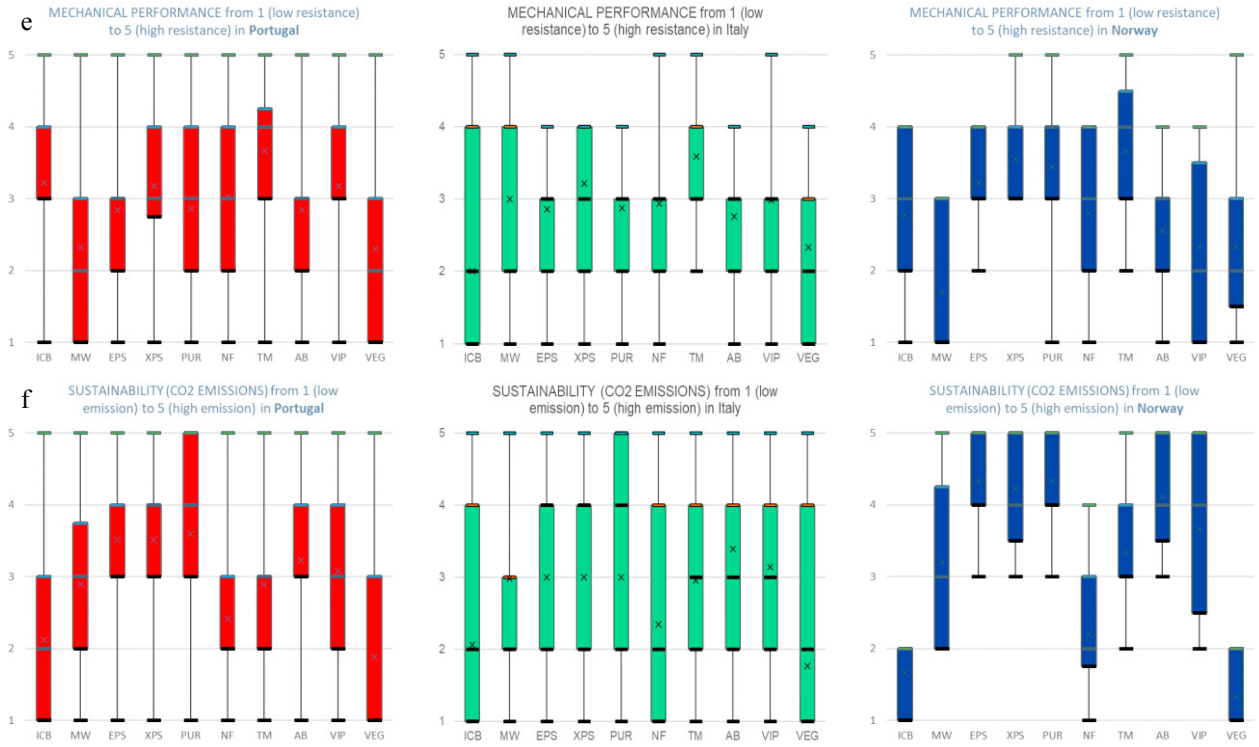

Fig. 1. (continued)

The most expensive solutions in the opinion of the Italian and Norwegian respondents are VIP and AB. These latter solutions were also considered the most expensive by the Portuguese respondents, along with ICB. In contrast, the least expensive solutions, as perceived by the respondents, are MW, EPS and PUR in Portugal, EPS, XPS and PUR in Italy, and MW and EPS in Norway. The high price of the VIP and the AB can be partially explained to the innovative nature of these solutions. Manufactures are currently optimizing these products to enhanced performance, while reducing costs. As expected, EPS was the only solution considered as the least expensive in all three countries.

The solutions with the best fire behavior in the opinion of the Portuguese and Italian respondents are MW and TM. For the Norwegians, AB presents the best fire behavior. On the other hand, the worst fire behavior for the Italian and Norwegian respondents was attributed to NF, whereas the Portuguese respondents considered EPS and PUR in this category of thermal insulation solutions.

All of the three countries considered VEG as the solution with the highest water retention. For the Italian and Norwegian respondents VIP was identified as the solution with the lowest water retention. Moreover, the Portuguese respondents rated EPS, XPS, PUR and VIP as the solutions with the lowest water retention.

When considering the mechanical performance, TM was pointed out as the solution with the highest mechanical resistance in all three countries. This result may be explained due to the innovative nature of this solution. In fact, TM are formulated with lightweight aggregates replacing sand and therefore have lower mechanical resistance when compared to traditional mortars. The lowest mechanical resistance was attributed with MW and VEG in Portugal, ICB and VEG in Italy, and MW and VIP in Norway.

ICB and VEG were classified as the most sustainable solutions in all three countries, whereas PUR was considered the least sustainable. Additionally, EPS was considered as one of the least sustainable solutions for the Norwegians respondents.

4. Discussion

Most respondents work in the fields of architecture, construction engineering, real estate and facilities management, public research institutions and universities, which makes this survey especially interesting to assess the expert knowledge and practice when concerning insulation materials. Moreover, most of the Portuguese (~ 57%) and Italian (~ 62%) respondents believe their building needs an energy retrofitting intervention. In the case of Norway, a lower percentage of respondents (~ 45%) identified this need. In Portugal, this fact can be partially attributed to the average age of the building stock, which can be older than the first thermal regulation dating back to 1990 (Ogut et al., 2023).

Results showed that most Portuguese (~ 62%), Italians (~ 79%) and Norwegians (~ 63%) respondents are aware of possible governmental financial incentives for energy retrofitting interventions. While there is an awareness of incentives for energy retrofitting, the prevailing idea among respondents is that these incentives do not meet expectations or requirements. This suggests that governments should reassess their policy and potentially increase the financial support for energy retrofitting interventions. Furthermore, a significant percentage of the respondents (i.e., more than 79% in the three countries) think that an energy-retrofitted building would compensate the investment costs. Approximately 80% of the Portuguese respondents, 75% of the Italians, and 96% of the Norwegians expressed satisfaction with the level of comfort inside their buildings. However, the majority of these respondents have completed their studies and do not belong to vulnerable populations facing energy poverty. In all three countries, most of the respondents did not know or did not answer the question related to criteria or guidelines for selecting thermal insulation materials that can be useful for the energy retrofitting of buildings. Finally, about 58% of Italian and Portuguese respondents either do not believe in climate change or did not answer the question. This percentage increases to ~ 83% when considering the responses from Norway. This lack of response or disbelief can be alarming, especially when considering that the majority are practitioners in the buildings and construction sector.

Some common results identified in all three countries regarding insulation materials include the following: i) mineral wool (MW) is perceived as the most durable solution, while vacuum-insulation panels (VIP) and aerogel blankets (AB) are considered the most expensive, and expanded polystyrene (EPS) is viewed as the least expensive; ii) vegetation – green walls (VEG) are noted for having the highest water retention, while VIP is associated with the lowest; iii) thermal insulating mortars (TM) are recognized for their high mechanical resistance; and iv) insulation cork board (ICB) and VEG are rated as the most sustainable solutions, while polyurethane foam (PUR) is considered the least sustainable.

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