Standards, certification and training needs for solar water heaters

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Abstract

As a part of the International Energy Agency (IEA) Solar Heating & Cooling (SHC) Task 69, a questionnaire was prepared targeting solar hot water (SHW) practitioners, including installers, researchers, and industry experts. The questionnaires were distributed during the expert meeting of the IEA Task 69. The survey aimed to assess the perception of international and regional standards of SHW and the training needs of SHW practitioners, with a focus on aligning training content and methods with emerging industry advancements. By evaluating the preferences and feedback from the surveys, this paper identifies key areas for improvement in standards and training programs and offers actionable recommendations for promoting the adoption of innovative SHW technologies. This survey underscores the critical need for targeted training programs to address gaps in the solar water heating industry. Through survey analysis and insights from an IEA Task 69 training session, a clear divide has been identified between the industry's training needs and the current offerings, emphasizing the need for more focused, practical, and accessible training efforts. Survey results consistently highlighted the demand for practical, hands-on training, especially in the areas of standards, installation, fault diagnosis, and the integration of advanced technologies like photovoltaic thermal systems and solar-assisted heat pumps.

Keywords: Solar water heating, PV, Standards, Training needs, Survey, IEA Task 69

1. Introduction

The rapid development of solar hot water (SHW) technologies, including photovoltaic (PV) systems [1], hybrid configurations [2], and smart components [3], has created an urgent need for standards, certification and targeted training programs for practitioners. These standards and programs are essential to equip practitioners with the standards, the skills and knowledge required to design, install, and maintain advanced SHW systems, thereby ensuring the effective adoption of emerging technologies and driving the industry's growth [4].

The International Energy Agency (IEA) Solar Heating and Cooling Program (SHC) Task 69 ‘Solar hot water for 2030’ started in June 2022, aiming to investigate which technologies are the most appropriate now and into 2030 for solar-derived hot water. The homepage of the task is: https://task69.iea-shc.org/about. One important activity of the task is to understand and address standards/training needs to support the adoption of emerging SHW technologies. The specific objectives of the subtask are:

• Make a comprehensive overview of existing standards and certification networks on solar water heating;

• Point out the need for new standards for new SHW technologies, for example, PV-SHWs;

• Assess the training needs and prepare training materials (workshops) about the principle, system sizing, and installation.

In connection with the task expert meeting, a training session was organized with a focus on new solar water heating technologies on October 11-12, 2024, in Lianyungang, China. A survey of the training participants was carried out. The survey aimed to analyze the opinions of the stakeholders on the current standards and certification networks on solar water heating, both internationally and on a national/regional level. Internationally, the series of standards for SHWs, for example, ISO 9459, will be analyzed with a focus on how to improve and revise the standards to cover all existing and new technologies for durability and performance. On a national/regional level, the standards in Europe, China, Australia, Latin America, USA,

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Canada, and Sub-Saharan countries are considered relevant. The paper identifies the installation and maintenance needs for solar hot water systems and surveys the opinions of the participants on adopting new technologies and the barriers. Eventually, the training needs and the preferred methods are analyzed.

2. Needs assessment of standards and training

2.1. Methodology

This study employed a structured questionnaire-based approach to gather data on the adoption and perception of solar heating and cooling technologies, particularly in the context of international standards and best practices. The methodology followed a four-step process as outlined below:

Step 1: Questionnaire Development

A comprehensive questionnaire was designed to capture essential information related to the adoption of solar water heating technologies. The questionnaire consisted of several sections, including:

- Background Information (e.g., country, institution, respondent's role)
- Technology Acceptance (e.g., perceived usefulness and ease of use)
- Installation and Maintenance (e.g., current practices and challenges)
- Training Needs (e.g., existing capacity and areas for improvement)
- Application and Perception of International Standards (e.g., familiarity with and applicability of global standards)

Step 2: Data Collection

The questionnaire was distributed to participants attending the training seminar held in conjunction with the task expert meeting of the IEA SHC Task 69 on October 11-12, 2024 in Lianyungang, China (Fig. 1). The participants included a diverse range of stakeholders involved in solar energy projects, including engineers, policymakers, academics, and technical staff.

Figure 1: The IEA SHC Task 69 training session in Lianyungang, China.

Step 3: Data Cleaning

Upon collection, all questionnaire responses were reviewed for completeness and consistency. Invalid responses - such as those with missing critical data or internally inconsistent answers - were identified and excluded from the final dataset to ensure the reliability of subsequent analyses.

Step 4: Data Analysis and Reporting

The valid responses were analyzed using both quantitative and qualitative methods to identify trends, gaps, and insights related to the implementation of solar thermal technologies and standards. The findings were synthesized and used to prepare this paper, providing a foundation for recommendations and future actions within IEA SHC Task 69.

2.2. Information on the participants

Fig. 2 illustrates the professional backgrounds of the 40 respondents who participated in the survey. The distribution is as follows:

- Corporate R&D Professionals: Representing the largest group, with 17 respondents, highlighting the significant interest of R&D professionals in training needs.
- University Scholars: Comprising 14 respondents, reflecting the academic sector's engagement with SHW technology and training development.
- Installers: With 6 respondents, they are the direct beneficiaries of training programs, emphasizing the importance of practical training.
- Standard Setters, Salespersons, and Business Managers: Each category has 1 respondent, showcasing their niche roles and perspectives on industry training.

Fig. 2 demonstrates the diversity of respondent backgrounds, with Corporate R&D professionals and University Scholars being the dominant groups. This distribution provides a broad perspective for analyzing the preferences and training needs of stakeholders from various roles, ensuring that recommendations align with the industry's multifaceted requirements.

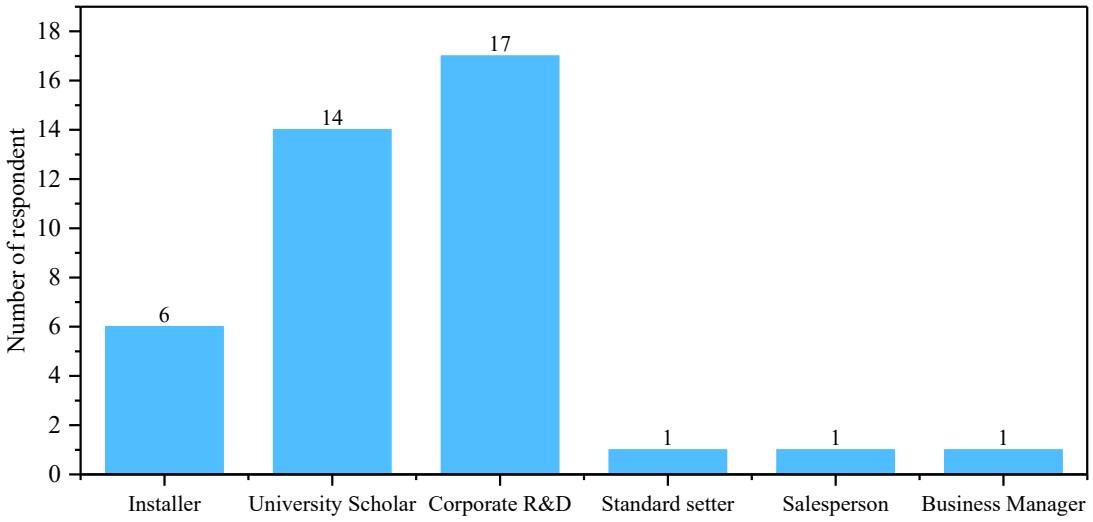

Figure 2: The professional background of the 40 questionnaire respondents.

The survey also shows a strong representation of newcomers (less than 3 years) and experienced professionals (10+ years), while those with 3-5 years and 5-10 years constitute smaller proportions. This breakdown provides insight into the contrasting perspectives: the needs and challenges faced by newcomers and the expertise contributed by experienced professionals. The diverse perspectives of respondents across different experience levels provide a balanced and reliable foundation for assessing training needs. By capturing the fresh insights of newcomers and the expertise of experienced professionals, this diversity ensures that training programs are tailored to a broad range of practitioners, fostering both skill development and industry growth.

3. Results

3.1. Opinion on installation and maintenance of solar hot water

The quality of installation is closely linked to the maintenance needs and long-term performance of SHW systems. Practical challenges observed during project operation and maintenance highlight the importance of proper installation in minimizing system faults and reducing maintenance frequency. This section explores these connections, emphasizing the critical role of improving installers' professional skills. These insights lay a foundation for assessing training needs and designing programs to enhance installation quality and system reliability. Table 1 summarizes the main challenges of installing SHW systems, based on survey responses. The table categorizes the challenges into key issues and reports the number of respondents identifying each challenge. The results are as follows:

- Insufficient installation space is the most frequently mentioned challenge, cited by 27 respondents, underscoring the physical constraints often faced during SHW system installations. This is due to the relatively more compact buildings in China with limited roof/façade areas for SHW systems.
- Quality issues with materials and equipment were identified by 19 respondents, highlighting concerns about the reliability and performance of key components.
- Safety issues were reported by 13 respondents, reflecting the critical need to address risks associated with installation processes.

Additionally, the "Others" category highlights specific issues shared by individual respondents, such as harsh installation conditions and high costs, a chaotic after-sales service system, and low professional level of installers. These unique insights, based on professional experience, are crucial for understanding less widely recognized but significant challenges in the industry.

Table 1: Statistics on the main challenges of installing SHW systems.

Categories		Main challenges	Count
1		Insufficient installation space	**27**
2		Quality issues with materials and equipment	19
3		Safety issues	13
4	Others:	Harsh installation conditions and high installation costs	1
		After-sales service system is chaotic	1
		Low professional level of installers	1

The survey shows respondents' views on the impact of installation quality on maintenance frequency for SHW systems. Most respondents (25) rated the impact as very high, followed by 13 who rated it as high, and only 2 who considered it moderate. None rated the impact as low. These findings emphasize the critical role of installation quality in minimizing maintenance needs and underscore the importance of providing comprehensive training for installers to ensure high-quality system installations.

Table 2 summarizes the impact factors affecting the long-term performance and maintenance needs of SHW systems based on survey responses. The results show that the accuracy of installation details (34 respondents) is the most critical factor, followed by the technical skill level of installation personnel and compliance with installation procedures (27 respondents each); equipment selection and matching (26 respondents) and safety protection measures (16 respondents) are also important. The "Others" (2 respondents) category reflects user-related issues, such as the lack of maintenance knowledge, which can be addressed by installers providing clear explanations during installation. These results demonstrate that high-quality installation is a key determinant to improve system performance and decrease maintenance needs, emphasizing the importance of skilled installers and effective communication with users to ensure long-term system reliability.

Table 2: Statistics on the impact factors affecting the long-term performance and maintenance needs of systems.

Categories		Impact factors	Count
1		Equipment selection and matching	26
2		Technical skill level of installers	27
3		Compliance with installation procedures	27
4		Completeness of safety protection measures	16
5		Accuracy of installation details	**34**
6	Others:	Users lack an understanding of maintenance	1
		Maintenance from user	1

The views of the respondents on the maintenance frequency of SHW systems were also investigated. It was shown that 14 respondents did not consider a fixed maintenance frequency, likely due to installation quality and user habits. Maintenance intervals were reported as annually (by 10 respondents), every 2-3 years (by 8 respondents), and over 3 years (by 5 respondents), with only 2 respondents indicating six months. These results highlight the need for better installation practices and user guidance to ensure regular maintenance.

Table 3 summarizes the common faults in SHW systems as reported by survey respondents. The most frequently mentioned issue is installation defects, cited by 29 respondents, underscoring the critical importance of installation quality in ensuring system performance and reliability. This result highlights the industry's urgent need for skilled installers who can adhere to high standards during the installation process. The second most common issue is equipment aging, reported by 22 respondents, reflecting the importance of using durable and high-quality components. Other notable issues include external factors (12 respondents), electrical faults (11 respondents), and system mismatch or design problems (6 respondents). These findings reveal that the majority of faults stem from factors that could be mitigated with improved training, better materials, and stricter installation standards. In particular, the high frequency of installation defects emphasizes the need for targeted training programs to enhance installers' skills and knowledge. By addressing these challenges, the industry can reduce fault rates, improve system reliability, and ensure the long-term performance of SHW systems, ultimately supporting the broader adoption of this technology.

Table 3: Statistics of common faults occurring in SHW systems.

Categories		Common faults	Count
1		Electrical faults (such as wiring issues, etc.)	11
2		Equipment aging (such as collector panels, etc.)	22
3		Installation defects (such as leaks, looseness, etc.)	**29**
4		External factors (such as weather damage, etc.)	12
5		System mismatch or design problems	6
6	Others:	Impact of impurities in water on system use	1
		Scaling and pipe explosion problems	1
		Untimely maintenance and cutting corners due to low-price competition	1

Table 4 summarizes the suggested measures to enhance the long-term performance of SHW systems. The most frequently suggested measure is strictly implementing installation standards, mentioned by 31 respondents, highlighting the critical role of standardization in improving system reliability. Using higher-quality equipment and components follows closely, with 30 respondents emphasizing the need for durable and efficient materials. Strengthening technical training for installers was also a prominent suggestion, with 29 respondents underscoring the importance of skilled professionals in ensuring proper system installation and maintenance.

Other significant measures include adding automated monitoring systems (24 respondents) and providing more comprehensive design and testing links (21 respondents), both of which point to the need for technological advancements and thorough system evaluation. The "Others" category, mentioned by individual respondents, includes increasing user training and reducing low-price competition, highlighting additional areas for improvement. These results emphasize the importance of enhancing both technical and human factors in the SHW industry. Strict installation standards, improved training, and better materials can address many current challenges, while advanced monitoring systems and comprehensive testing ensure long-term system performance and reliability.

Table 4: Statistics of suggested measures to increase the long-term performance of SHW systems.

Categories		Common faults	Count
1		Strictly implement installation standards	**31**
2		Use higher quality equipment and components	30
3		Strengthen technical training for installers	29
4		Provide more comprehensive design and testing links	21
5		Add automated monitoring system	24
6	Others:	Increase user training and publicity	1
		Reduce low-price competition	1

3.2. Opinion on emerging technologies interest and barriers

With the rise of new technologies in the SHW market, it is essential to understand the industry's interests in their adoption and the challenges that may hinder implementation. This section explores professionals' perspectives on emerging innovations and the barriers they face, offering insights into the need for targeted training programs to support their effective adoption and integration into the SHW sector.

The survey illustrates respondents' preferences for new solar technologies. The majority (31 respondents) expressed strong interest in adopting new technologies, demonstrating widespread enthusiasm for innovation in the SHW system. A smaller group (7 respondents) reported being somewhat interested, while only 2 respondents indicated they were not interested, reflecting minimal enthusiasm. These findings highlight the industry's significant interest in emerging technologies and emphasize the need for targeted training programs and resources to facilitate their effective adoption and integration.

The attitudes of respondents towards the combination of photovoltaic (PV), heat pumps (HP), with SHW systems were investigated. The survey shows that the majority of respondents (38) considered this combination to be very promising, demonstrating strong confidence in its potential to advance the industry. A smaller group (2 respondents) described it as worth observing, indicating cautious interest. No respondents rated the combination as not significant. These results highlight the industry's optimism about integrating these technologies, emphasizing the need for further research, development, and training to capitalize on this perceived potential and promote widespread adoption.

Table 5 summarizes the main barriers to adopting new technologies in the SHW sector. The most frequently cited obstacle is high cost, mentioned by 25 respondents, indicating that economic considerations remain a significant challenge for the widespread adoption of innovative solutions. Other prominent barriers include immature technology and difficult maintenance, each cited by 15 respondents, reflecting concerns about the reliability and technical feasibility of emerging innovations. Additionally, lack of user awareness, mentioned by 18 respondents, highlights the need for better education and outreach efforts to bridge the knowledge gap between users and new technologies. The "Others" category includes specific issues raised by individual respondents, such as instability, economic competition in PV-HP systems, and information gaps in publicity among enterprises, governments, and self-media channels. These insights suggest that challenges are not limited to technical and cost-related factors but also include broader systemic and informational barriers.

These findings underscore the multifaceted nature of the obstacles to adopting new technologies. Addressing high costs through subsidies or financial incentives, improving the maturity and reliability of new technologies, and expanding user education and training are critical steps for accelerating adoption. Additionally, fostering better communication among stakeholders and promoting fair market competition could further ease the transition to innovative SHW technologies.

Table 5: Statistics of main barriers to adopting new technologies.

Categories		Common faults	Count
1		High cost	**25**
2		Immature technology	15
3		Difficult to maintain	15
4		Lack of user awareness	18
5	Others:	Unstable	1
		Economy competition of PV-HP systems	1
		Information gap exists in publicity among enterprises, governments and self-media	1

3.3. Understanding of international and local standards

This section examines SHW professionals' understanding of international and local standards, with a focus on system certification and installation practices. It covers their familiarity with international standards, how they balance international and local standards in practice, and their views on the need for training on international standards. These insights aim to uncover knowledge gaps and training needs to improve compliance and align with global best practices.

Fig. 3 illustrates respondents' familiarity with international installation standards for SHW systems (e.g., IEC, ISO, EN). Among the respondents, the largest group (13) was somewhat familiar, followed by 12 who were not very familiar. Only 8 respondents were very familiar, and 7 were not familiar at all. Notably, among all respondents, 6 were installers, but only 1 of them reported being very familiar with these standards, highlighting a significant gap in knowledge among key practitioners. These results point to a limited understanding of international standards across the industry, particularly among installers, who are directly responsible for implementation. This underscores the importance of targeted training initiatives to equip practitioners with the necessary knowledge and skills to adhere to global standards effectively.

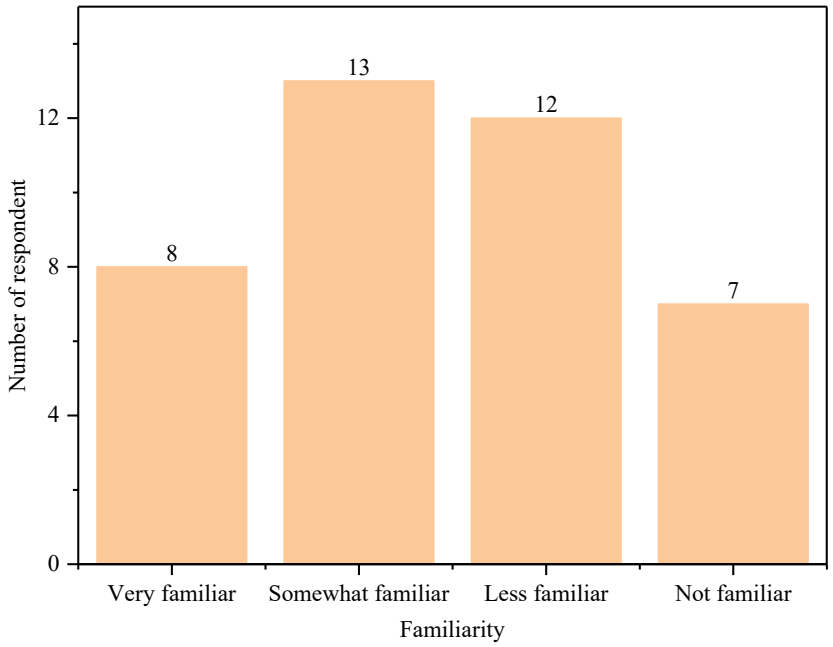

Figure 3: Familiarity with international installation standards of SHW systems.

Fig. 4 illustrates respondents' familiarity with SHW system certification standards across different world

regions, including the US (Solar Rating & Certification Corporation, SRCC), Europe (Solar Keymark), and MENA (Solar Heating Arab Mark and Certification Initiative, SHAMCI). The results reveal varying levels of familiarity:

- Very familiar: Only 5 respondents were very familiar with SRCC, 6 with Solar Keymark, and 2 with SHAMCI.
- Somewhat familiar: Solar Keymark received the highest number of responses (10) in this category, compared to 6 for SRCC and 5 for SHAMCI.
- Less familiar: The majority of respondents were less familiar with both SRCC and SHAMCI (17 respondents each), while Solar Keymark had 13 in this category.
- Not familiar: Familiarity with SHAMCI was the lowest overall, with 14 respondents indicating they were not familiar, followed by 12 for SRCC and 11 for Solar Keymark.

These results show that the respondents were most familiar with Solar Keymark, the European certification standard, while knowledge of SHAMCI in the MENA region was the least developed. Since all respondents were from China, their understanding of certification standards from other world regions was relatively limited, and this knowledge gap could be addressed through targeted training programs. China has the largest market of solar thermal around the world [5]. Companies from China, such as Solareast Co. Ltd, export SHW products extensively to international markets, making it essential for industry professionals to understand and comply with global certification standards to enhance competitiveness.

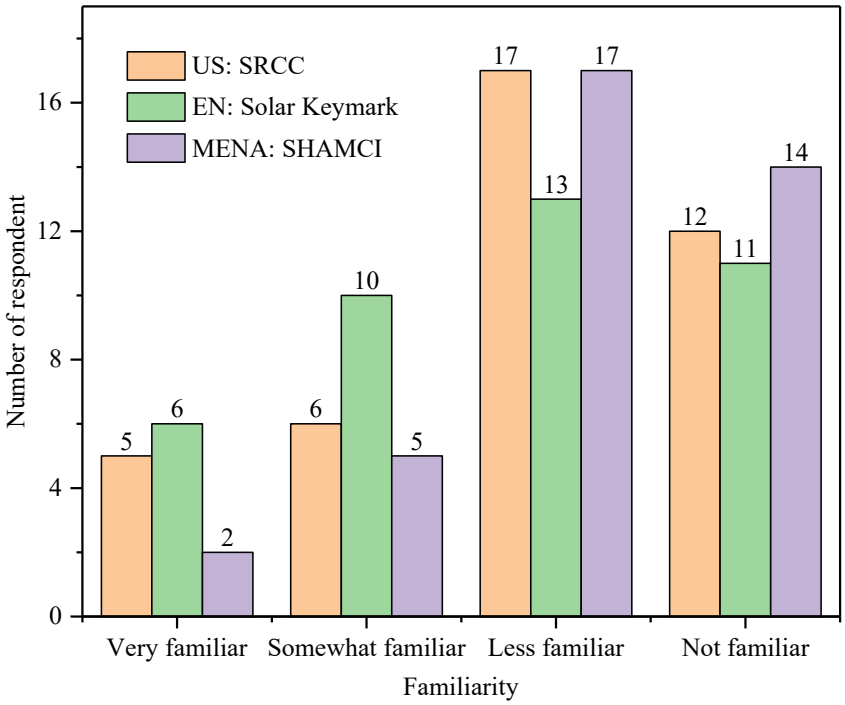

Figure 4: Familiarity with international certification standards of SHW systems.

Table 6 summarizes the respondents' views on the main differences between international and local standards for SHW systems. The most frequently mentioned differences are equipment quality and performance requirements and differences in certification and inspection procedures, each cited by 23 respondents. These findings suggest that variations in quality expectations and procedural steps are key challenges when comparing standards across regions. Other notable differences include the complexity of technical specifications mentioned by 20 respondents, and differences in installation steps and methods reported by 9 respondents. A small group (3 respondents) indicated they were not familiar with the differences, and one respondent highlighted that user groups have different living habits as an influencing factor. These results emphasize the diversity of standards across regions, reflecting different local needs and conditions. By drawing on the strengths of international standards, local standards can be improved to become more comprehensive and effective, ensuring they better meet regional requirements while leveraging global best practices.

Table 6: Opinions on the main differences between International and Local Standards.

Categories		Common faults	Count
1		Complexity of technical specifications	20
2		Equipment quality and performance requirements	**23**
3		Differences in installation steps and methods	9
4		Differences in certification and inspection procedures	**23**
5	Others:	Not familiar	1
		User groups have different living habits	1

The respondents' views on the effect of adopting international standards on improving project competitiveness were also surveyed. It was shown that the majority of respondents (21) believed that adopting these standards leads to a moderate improvement, while 17 respondents viewed the effect as a large improvement. Only a small number (2 respondents) indicated that the effect is minor, and no respondents believed that adopting international standards has no effect. These results indicate that most respondents recognize the positive impact of international standards on enhancing local project competitiveness, though opinions differ on the extent of this improvement. This suggests that while the benefits are generally acknowledged, further communication and training may be needed to highlight the full potential of international standards in improving project competitiveness.

The respondents' preferences for dealing with inconsistencies between international and local standards were investigated. The majority of the respondents (23) chose to prioritize local standards, reflecting a preference for adhering to region-specific regulations and practices. 15 respondents indicated they prefer to adjust standards according to project requirements, suggesting a more flexible, case-by-case approach. Only 1 respondent prioritized international standards, and another 1 respondent opted to seek professional advice or support. These results highlight a strong inclination toward local standards, likely due to their alignment with regional conditions and regulatory requirements. However, the significant proportion of respondents favoring project-specific adjustments suggests that some flexibility is necessary to address varying project contexts. This indicates the need for training to better navigate and integrate both international and local standards effectively.

Concerning training related to international standards, the majority of the respondents (25) expressed support for such training, highlighting a strong recognition of its importance. A smaller group (11 respondents) was not sure, indicating uncertainty about the necessity or benefits of this training. Only 4 respondents considered such training unnecessary. These results demonstrate a clear majority favoring the provision of training on international standards, emphasizing its perceived value in enhancing knowledge and skills. The presence of uncertainty among some respondents suggests that further discussion about the benefits of such training could be useful in promoting its adoption and ensuring broader engagement.

3.3. Training needs and preferred methods

This section investigates the training needs and preferred learning methods for SHW industry personnel. It identifies the core areas where training is most required and examines the formats and approaches preferred by industry personnel for effective learning. The insights aim to provide a clear understanding of how training programs can be tailored to meet industry demands and ensure the effective transfer of knowledge and skills.

Table 7 highlights the key training areas identified by respondents to help industry personnel adapt to new innovative technologies. The most frequently mentioned area is installation and commissioning of new solar water heaters, cited by 31 respondents, which is particularly critical for installers as it forms the foundation of their work. Other key areas that installers need to prioritize include design and installation of heat pump systems (27 respondents) and maintenance and fault diagnosis training (25 respondents), both essential for

ensuring proper system operation and reliability. Additionally, equipment compatibility and system integration techniques (20 respondents) are highly relevant to installers to ensure seamless integration of components into functional systems. Advanced areas such as smart control systems and automation management (27 respondents) and comprehensive design and control of renewable energy systems (23 respondents) reflect broader industry trends and may require additional specialization. Lastly, safety standards and regulations (16 respondents) are important for all industry personnel, particularly installers, to maintain compliance and ensure safe operations.

These findings suggest that training programs for installers should focus on practical skills, such as installation, maintenance, and system integration, while also introducing advanced topics to help them adapt to emerging technological demands in the SHW industry.

Table 7: Key training areas to meet the needs of industry personnel to adapt to new innovative technologies.

Categories	Key training areas requirements	Count
1	Installation and commissioning of new solar water heaters	**31**
2	Design and installation of heat pump systems	27
3	Comprehensive design and control of renewable energy systems	23
4	Equipment compatibility and system integration techniques	20
5	Smart control systems and automation management	27
6	Maintenance and fault diagnosis training	25
7	Safety standards and regulations	16

Fig. 5 illustrates the preferences of respondents in different roles regarding core training aspects. The training contexts are divided into five aspects: 1) Learning theoretical knowledge; 2) Improving practical skills; 3) Understanding the latest technological trends; 4) Problem-solving and fault diagnosis capabilities; 5) Installation safety and standards. The main findings are given as follows:

- Installers showed a strong preference for Aspect 2 and Aspect 4, reflecting their need for hands-on and troubleshooting-focused training. They showed relatively less interest in Aspect 1 and Aspect 5, indicating a practical approach to their training priorities.
- University scholars prioritized Aspect 3 and Aspect 4, reflecting their focus on innovation and analytical skills. They also showed moderate interest in Aspect 2, suggesting the importance of blending theory with practical applications.
- Corporate R&D Personnel expressed a balanced preference for Aspect 2, Aspect 3, and Aspect 4, indicating their dual focus on technological innovation and real-world problem-solving.
- Standard setters showed a higher interest in Aspect 5 and Aspect 1, reflecting their focus on regulatory compliance and theoretical grounding.
- Business Managers and Salespersons showed limited engagement across all aspects, with some preference for Aspect 3 and Aspect 1, suggesting a focus on broader industry understanding rather than technical depth.

The findings indicate that training programs should be tailored to specific roles: installers need practical, skills-based training, focusing on hands-on activities and troubleshooting, while theoretical knowledge and standards can be deemphasized for this group; university scholars and corporate R&D personnel would benefit from training on advanced technologies and innovation trends; standard setters require training that emphasizes safety, standards, and theoretical principles; business managers and salespersons may need broader industry awareness training to support strategic and client-focused goals. This role-based approach ensures training is relevant and effective for addressing the diverse needs of SHW industry personnel.

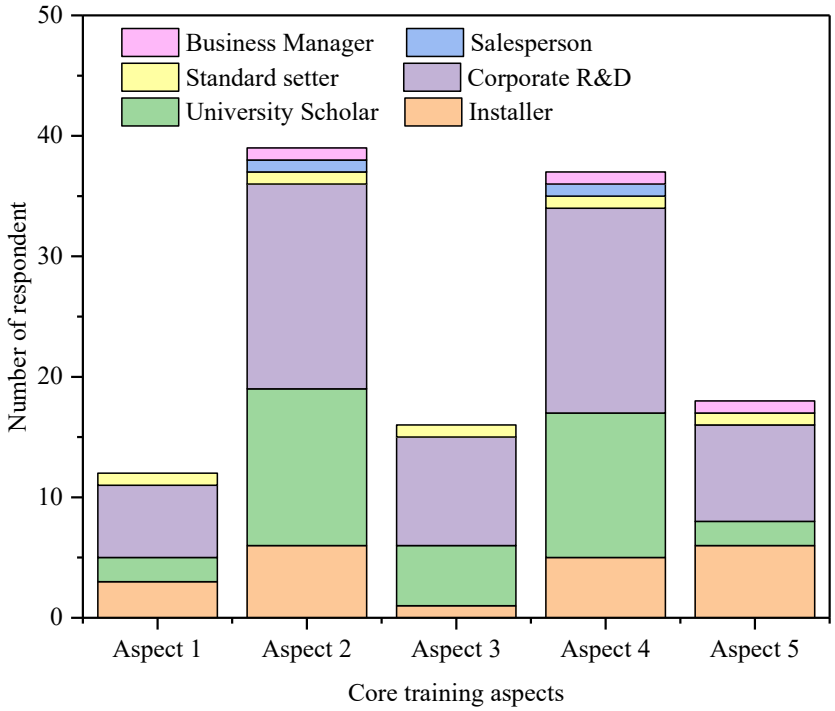

Figure 5: Preferences of people in different roles for five core training contents.

Fig. 6 illustrates the preferences of respondents in different roles regarding various training formats. The four formats considered are offline seminars, online courses, hands-on practical training, and corporate internal training. The main findings are given as follows:

- Installers showed a strong preference for hands-on practical training, reflecting their need for experiential and application-based learning to enhance practical skills. They also preferred offline seminars, which provide interactive, face-to-face opportunities. However, their interest in online courses and corporate internal training was relatively low, indicating a focus on direct, practical engagement.
- University scholars expressed a balanced preference for hands-on practical training and offline seminars, highlighting their need for both experiential and interactive learning formats. They also showed moderate interest in online courses, likely due to the flexibility such formats provide for research-oriented professionals.
- Corporate R&D Personnel demonstrated a strong interest in hands-on practical training and offline seminars, indicating the importance of practical and collaborative learning for their role. They also showed a notable preference for corporate internal training, reflecting the need for tailored, company-specific skill development. Their interest in online courses was moderate.
- Standard setters preferred offline seminars and corporate internal training, emphasizing their focus on structured, interactive formats to learn about compliance and regulatory requirements. Their interest in hands-on practical training and online courses was lower compared to other groups.
- Business Managers and Salespersons showed lower overall engagement across all training formats but demonstrated a slight preference for offline seminars and corporate internal training, which align with their strategic and organizational responsibilities. Their lower preference for hands-on practical training reflects their focus on broader, less technical learning.

The results suggest that training programs should prioritize hands-on practical training and offline seminars to cater to the preferences of key roles like installers, university scholars, and corporate R&D personnel. While online courses are less favored overall, their flexibility makes them a useful supplementary option. Corporate internal training remains essential for company-specific knowledge transfer, especially for roles focused on implementation and innovation. A blended approach incorporating multiple formats could address the diverse needs of SHW industry personnel effectively.

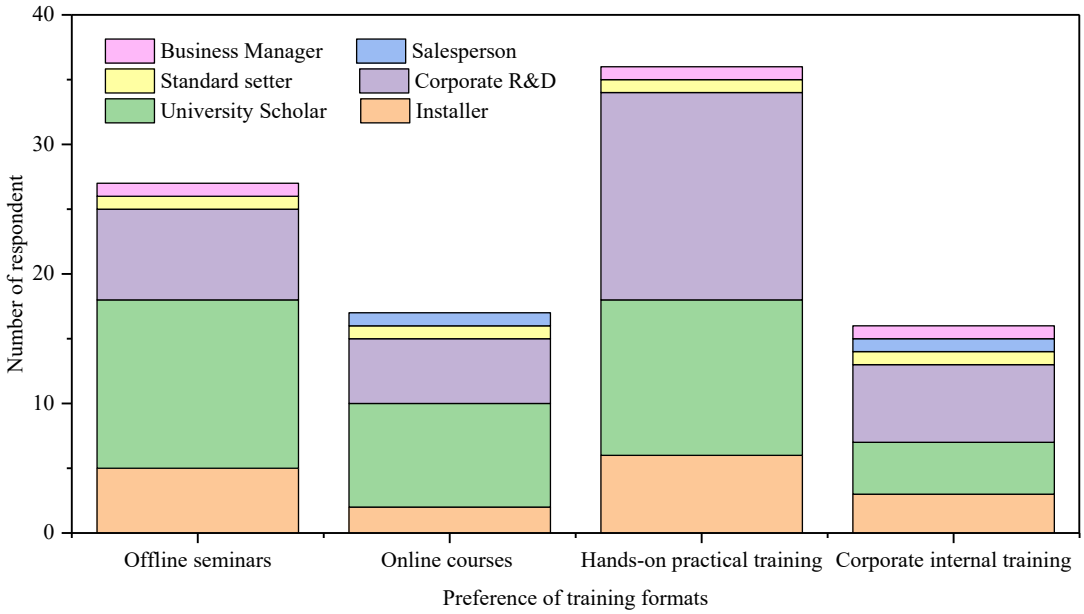

Fig. 6. Preferences of people in different roles for training formats

4. Conclusions

As a part of the activities of the IEA SHC Task 69, a survey of the training participants was carried out. Based on the survey, the opinions of the participants on installation and maintenance needs, adopting new technologies and the barriers, international/regional standard/certification programs, training needs and the preferred methods are analyzed. This survey underscores the critical need for targeted training programs to address gaps in the solar water heating industry. Through survey analysis and insights from the IEA Task 69 training session, a clear divide has been identified between the industry's training needs and the current offerings, emphasizing the need for more focused, practical, and accessible training efforts. Survey results consistently highlighted the demand for practical, hands-on training, especially in the areas of standards, installation, fault diagnosis, and the integration of advanced technologies like photovoltaic thermal systems and solar-assisted heat pumps.

5. Acknowledgments

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