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Work Environment Risks and Ways to Prevent Them in Solar Panel Installation Processes in Latvia's Renewable Energy Sector

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ABSTRACT

Solar panel installation work in the renewable energy sector is increasingly being carried out on building roofs, where there are both electrical risks and working at height, creating a high combined risk working environment. The persistence of direct current voltage during solar radiation, even when the system appears to be switched off, significantly complicates safety measures and increases the risk of electric shock, which, combined with the possibility of falling, can have serious consequences. The aim of this study is to analyze the risks in the work environment, with a particular focus on electrical risks and working at height during solar panel installation processes in the Latvian renewable energy sector, as well as to evaluate the possibilities for their prevention. The study uses literature analysis, drawing on the international scientific databases Scopus and Web of Science, as well as professional guidelines. The analysis includes studies that examine occupational risks in solar panel installation, electrical safety, and working at height. The results show that the most dangerous risks in solar panel installation are electrical risks and fall risks, as they are not isolated but can reinforce each other, especially in unfavourable weather conditions, fatigue, time pressure, and inadequate work organization. The study confirms that ensuring safety requires an integrated approach that combines technical solutions, improvements in work organization, and the strengthening of a safety culture. The analytical literature framework developed allows for a structured assessment of workplace risks and will serve as a basis for practical application.

Keywords: Installation, Risks, Electrical safety, Working at height, Solar panels, Occupational safety

INTRODUCTION

Green energy is growing rapidly in Europe, with society not only becoming increasingly interested in it, but also incorporating it into their daily lives. This includes solar panels, which are being installed by both businesses and households on their production facilities and private homes. Eurostat data show that renewable energy sources account for 46% of EU energy production (Eurostat, 2025a). It can be concluded that the importance of

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these measures is growing, and compared to 2023, In 2024, the supply of renewable electricity in EU countries increased by 3.4%, which shows that renewable energy sources are growing in popularity and that people continue to implement and use them (Eurostat, 2025b). Europe is participating globally in the transition to green energy, which means that not only in Latvia, but throughout Europe, there is an increase in installation work on roofs, installing solar panels, which involves electrical risks (short circuits, electric shocks, fire risk, etc.) and falls from height. When installing solar panels, direct current circuits remain live during solar radiation, so complete "shutdown" is not always technically possible, and when working on a roof, two high-risk factors may be present at the same time: the risk of electric shock and the risk of falling. This is confirmed by the professional safety manual Photovoltaic Systems Safety, which states that photovoltaic systems produce direct current (DC) when solar modules are exposed to sunlight. The DC side circuits of a solar panel array can operate at voltages of up to 600–1000V DC or more. Under the worst conditions, this voltage is sufficient to cause injury (Lackovic), and the handbook on solar panel system installation also states that solar panel DC circuits cannot be completely disconnected while sunlight is falling on the panels (BRE et al., 2006).

There are international requirements, such as IEC 60364-7-712 - Requirements for special equipment or locations. Solar photovoltaic power systems, which explain in detail the safety principles for working with solar panels, but in purely practical terms, the installation of solar panels on roofs still poses challenges where electrical work and work at height safety requirements must be combined. For example, even when working with low voltage, there are risks of dangerous arc flashes and uncontrolled movements when connecting/disconnecting solar panels to direct current circuits, especially in conditions of fatigue and heat. Although various reports are available, such as a systematic review of the risks of solar panel installation work (Duroha et al., 2023) or the international requirements mentioned above, they lack a direct link between the work of an electrician and working at height in a single process. Individual risks are listed, but there are no specific situations based on climate, roof covering, fatigue, etc. The guidelines for the operation and maintenance of photovoltaic (solar) power plants in various climatic conditions (PVPS, 2022) mention that safety programs for solar panel installation still need to be developed, which indicates a lack of knowledge about this process.

Therefore, the contribution of this study will undoubtedly improve the knowledge of researchers and practitioners in the field of occupational safety, as well as professionals in the renewable energy sector in Latvia, as it will provide an in-depth analysis of occupational risks in solar panel installation processes and develop specific recommendations for companies in Latvia that will reduce the overall risk, especially in situations where it is not possible to completely eliminate direct current voltage in sunlight. Overall, this type of research is currently lacking in Latvia, and research in this area will bring both academic and industrial benefits, as the results of the study will be useful to any organization operating in the Latvian renewable energy sector and

specializing in the manufacture of solar panels. It is important to emphasize that employees in the renewable energy sector are exposed to specific and potentially serious occupational risks, with the main problems being electrical and fire hazards, as well as heat stress, manual loading and moving work, and falls from height. These results indicate the need to systematically assess these risks in the Latvian context as well, paying attention to the local climate, work culture, technological video, regulatory requirements, etc., as well as to develop risk mitigation strategies (Duroha, Macht, 2023). In view of the above, research on occupational risks and ways to prevent them in solar panel installation processes in Latvia's renewable energy sector is becoming relevant and justified both in international literature and in the local context.

METHODS

A literature review was conducted in accordance with recognized principles of systematic information selection and a structured search approach. Scientific publications were searched for in the international databases Scopus, Web of Science, as well as other available academic and professional databases. In addition, open access scientific resources, publications by professional organizations in the field, materials from occupational safety institutions, and technical guidelines were used. Peer-reviewed scientific articles, systematic reviews, industry safety manuals, technical guidelines published by international organizations, as well as monographs and specialized books in the field of occupational safety, ergonomics, and electrical safety were analyzed. The search strategy used keywords related to solar panel installation, photovoltaic system assembly, occupational risks, electrical safety, direct current (DC) voltage hazards, working at height, fall risks, combined risk effects, safety climate, work organization, fatigue, and the impact of work capacity on safety. A total of 73 literature sources were selected, of which 15 were most relevant to the study and were included in the scientific literature analysis.

Eligibility criteria: publications analyzing working-age employees in the technical, construction, or solar panel installation sectors; studies examining solar panel installation, electrical installation, or work-at-height tasks; the publications were available in full text and contained sufficient methodological description to assess the quality and suitability of the study for the purpose of the study; the materials were directly related to occupational safety, electrical safety, working at height or combined risk issues in the renewable energy or similar technical sectors.

Study selection and analysis: Initially, the titles and abstracts of the publications found were reviewed to assess their relevance to the research topic. After the initial selection, a full-text analysis was performed, assessing the methodological quality, thematic relevance, and suitability of the results for the research work. Decisions on the inclusion of publications in the literature analysis were made based on systematic evaluation and comparative analysis. The selected studies provided data on the characteristics of the solar panel installation work process, occupational risk factors (electrical, fall,

ergonomic, and organizational), risk assessment approaches, safety climate aspects, and the impact of work ability assessment on occupational safety.

RESULTS AND DISCUSSION

A review of the literature on solar panel installation work processes shows that there are several interrelated workplace hazards in the industry, but the most common and consistent ones are electrical hazards, fire hazards, falls from height, heat stress, and manual handling (Duroha, Macht, 2023). On the other hand, occupational safety and health standards for solar home system construction in Brazil mention that falls are one of the leading causes of death in the solar energy industry (Arezes et al., 2019). However, several other studies have found that the installation of solar panel systems on roofs has created not only a risk of electric shock and electric current, but also an additional fire risk to the building (Mohd Nizam Ong et al., 2022). In addition to the above-mentioned life-threatening risks, there are also ergonomic risks, as employees constantly work in uncomfortable positions and lift heavy loads, because moving solar panels requires heavy lifting. This exposes workers to musculoskeletal disorders (MSDs) (Roja and Kaļķis, 2020). It follows from the above that solar panel installation work is associated with several interrelated occupational risks, the most prominent of which are electrical and fire safety risks, falls from height, heat stress, and ergonomic strain. The authors agree with the conclusion (Duroha, Macht, 2023) that these risks are not isolated but form a complex working environment in which technical, physical, and organizational factors interact. It is also reasonable to consider falls from height to be one of the most serious sources of consequences in the industry, as pointed out by (Arezes et al., 2019), especially when installing solar panels on roofs. At the same time, the authors believe that the importance of electrical risks in the practical working environment can sometimes be underestimated, as the constant presence of direct current circuits in daylight poses a specific hazard which, when combined with working at height, significantly increases the likelihood of serious accidents. The study by Mohd et al. emphasizes that the risk of fire adds to this view, as electrical installation faults or damage can have consequences not only for the employee, but also for the building as a whole, where other people may also be present. Of course, ergonomic risks, such as the development of musculoskeletal disorders, are also very important, but authors emphasize that ergonomic factors in solar panel installation often act as an aggravating factor for other risks – fatigue and physical overload can reduce attention and increase the likelihood of errors, thus indirectly contributing to electrical or fall incidents. Overall, the literature review confirms that solar panel installation work should be assessed as a high combined risk work environment, where an integrated approach to risk management is essential, rather than isolated control of individual risks.

An important safety factor for solar panels is that direct current (DC) can maintain voltage while the solar panels are illuminated, which means that complete shutdown and safety are not possible. This principle is very

clearly stated in practical installation guidelines, which mention that solar panel systems cannot be completely switched off – the terminals remain live during daylight hours (BRE et al., 2006). Even if the building is disconnected from the grid, high-voltage DC lines between the panels and the inverter can still pose a risk due to solar radiation. This is particularly dangerous during firefighting operations (Starling et al., 2014). In terms of safety, this means that when installing solar panels, one cannot rely on the classic approach of disconnecting the electricity from the grid and assuming that everything is safe. This situation increases the requirements for procedures, competence, and work organization, as the employee is potentially working in a real unsafe environment while standing on the edge of a roof, on sloping surfaces, or in an unsuitable unsafe environment. Jesse Duroha and Gretchen Macht mention in their study that the risk of electric shock arises when solar panel system components come into contact with employees, This means that during work, workers may meet live electrical components, which poses a risk of electric shock, burns, electrocution, and even electrocution. In addition, it is pointed out that short circuits can cause fires (Duroha, Macht, 2023). Overall, the analyzed literature shows that solar panel installation work differs significantly from traditional electrical installation work, as the direct current (DC) voltage in the system remains as long as the panels are exposed to solar radiation. This means that it is not always possible to completely shut down the system during work, and safety cannot be ensured simply by disconnecting from the mains. This technological feature creates a constant risk of electric shock, which, combined with working at height, significantly increases the likelihood of serious accidents. The authors of the study believe that this aspect is one of the main safety challenges in solar panel installation processes, as workers are potentially working in an environment where electrical hazards are present even when the system appears to be disconnected.

When working on roofs, falls are one of the most serious causes of accidents, and preventive measures – railings, safety systems, etc. – are emphasized as effective solutions already at the design and workplace organization level. OSHA materials on solar panel installation specifically emphasize the safe lifting of panels onto the roof and prohibit climbing ladders while carrying panels, as this combines instability with height and load (OSHA). In the United Kingdom, there is a support institution that develops various safety measures and supports large companies – CITB (Construction Industry Training Board). They research and develop safety materials based on specific situations. For example, they have created training materials related to the installation of solar panels on roofs, not only looking at the use of PPE, but also incorporating collective protection as a priority in their practice. They emphasize that a common accident site is safe access to the roof, ladders must be secured at both the top and bottom, and the top of the ladder must extend at least 1 m beyond the edge of the roof, and solar panels must never be carried up ladders, they must be lowered using a crane (CITB, 2019). Based on both studies, it can be concluded that the risk of falling during solar panel installation is not only due to "working at height," but also to the nature of the work (moving panels, positioning, moving along the edge

of the roof, working with your hands, etc.), which can reduce stability and increase the likelihood of errors. Therefore, fall risk control in solar panel installations is closely related to the working method, logistics, and choice of equipment, not just individual protective equipment.

An analysis of sources shows that the solar panel installation environment is a typical combined risk situation – electrical and fall risks do not exist independently, but can form a whole chain of causal relationships. For example, if an employee receives an electric shock or an arc/discharge occurs, reflex reactions (jerking, loss of grip, loss of balance, etc.) are possible. On a roof, this can turn a minor electrical incident into a serious injury due to a fall. This situation is particularly dangerous given that DC can remain live during daylight hours, as discussed above. Slips or unsuccessful movements can also cause uncontrolled movements with tools, cables, damage connections, or promote contact with conductive structures. In this way, the risk of falling can increase the risk of electrical injury. The above incidents are often exacerbated by weather conditions – humidity, wind, as well as other factors – fatigue, lack of time, psychological pressure, etc.

Several sources on solar panel installation safety emphasize that the risk of accidents is closely linked to work organization and safety culture. Particular emphasis is placed on the safe lifting of materials onto the roof, and it is strictly stated that workers should not be allowed to climb ladders while carrying solar panels (CITB, 2019). At the same time, the materials on prevention through design mention that occupational safety risks must be taken into account during the planning of a project, not just during the execution of the work. This means that safety elements must be included in the project to reduce risk exposure before the worker is exposed to them. It also emphasizes that personal protective equipment must be appropriate (safety belts, insulated tools, eye/hand protection) to ensure a higher level of safety in combined risk situations (Chung Ho et al., 2020). The same point is emphasized in a unique study comparing employees' perceptions of occupational safety and health risks when installing solar panels. The main finding of this article is that risk reduction should be included in the design process, not just afterwards. This approach is based on the principles of a hierarchical control model, which includes: complete risk elimination, use of safer alternatives, engineering controls, administrative procedures, and personal protection (Sen et al., 2022). Despite the fact that the risk of falling is one of the main risks when installing solar panels on a roof, there is relatively little research in this area, and what research there is emphasizes preventive measures such as - choosing roofing materials with lower slip resistance, planning the layout of the panels to reduce movement at the edges, safer access solutions to the roof, and fall protection systems (Duroha, Macht, 2023). Electrical safety risks, on the other hand, are summarized together with fire safety risks, which are as follows - emergency shut-off devices, improved connection and cable design, use of fire-resistant materials, regular inspection of wires and connections, optimization of panel tilt angle and distance from the roof to reduce flame spread, proper grounding and insulation of metal parts, and others (Duroha, Macht, 2023). The authors agree that safety in solar panel installation must be integrated at the design stage and cannot be ensured by individual protective measures alone.

However, authors believe that the risk of falling has not been sufficiently analyzed in the literature compared to electrical safety.

CONCLUSION

This study demonstrates that solar panel installation work constitutes a high combined risk environment, where electrical risk and working at height are not isolated but interact with each other, increasing the likelihood of accidents. The constant presence of direct current voltage during solar radiation, combined with movement on the roof, physical exertion, and adverse weather conditions, creates a situation where even a minor incident can have serious consequences. The approach proposed in the study provides a structured framework that links technical, organizational, and human factor risks, emphasizing the need for integrated risk assessment and preventive measures. Further research should be conducted at actual solar panel installation sites in Latvia, using the Finnish 5-point risk assessment method, psychological climate assessment, work ability index, and survey data. Particular attention should be paid to how electrical risks and working at height interact in different climatic conditions and on different roof coverings. It is also important to analyze how the safety climate and the work capacity of employees affect the level of this combined risk. This would allow for the improvement of preventive measures and the development of practical guidelines for solar panel installation companies.

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