

# Assessing the Detrimental Effects of Solar Panel Installation on Residential Roofing Systems

Peter Dayo Fakoyede<sup>1</sup>, Agada Olowu Innocent<sup>2</sup>, Qudus Omotayo Ajiboye<sup>3</sup>,  
Ewemade Cornelius Enabulele<sup>4</sup>, Tosin Gideon Olaleye<sup>5</sup>, Kehinde Deji Ekunseitan<sup>6</sup>

<sup>1</sup> *Federal University Oye-Ekiti*

Oye-Are Road, Oye Ekiti, Ekiti State, Nigeria

<sup>2</sup> *Ahmadu Bello University*

P. M. B. 1045, Zaria Nigeria

<sup>3</sup> *Yaba College of Technology*

Herbert Macaulay Road, Opposite WAEC office, Yaba, Lagos State, Nigeria

<sup>4</sup> *The Federal University of Technology Akure*

P. M. B. 704, Akure, Ondo State, Nigeria

<sup>5</sup> *Federal Polytechnic Ado Ekiti*

P. M. B. 5351 Ado-Ekiti, Ekiti State, Nigeria

<sup>6</sup> *University of Ibadan*

Oduduwa Road, 200132, Ibadan, Nigerian

DOI: [10.22178/pos.106-15](https://doi.org/10.22178/pos.106-15)

LCC Subject Category: T1-995

Received 21.06.2024

Accepted 25.07.2024

Published online 31.07.2024

Corresponding Author:

Peter Dayo Fakoyede

[fakoyedepeterdayo@gmail.com](mailto:fakoyedepeterdayo@gmail.com)

© 2024 The Authors. This article is licensed under a [Creative Commons Attribution 4.0 License](https://creativecommons.org/licenses/by/4.0/)



**Abstract.** The increasing adoption of solar panels as a sustainable energy solution has raised concerns about their potential detrimental effects on residential roofing systems. This research evaluates these impacts, focusing on structural and material considerations. The study identifies common issues such as structural damage, leaks, and material compatibility problems through a mixed-methods approach, combining literature reviews, surveys, interviews, and case studies. Key findings indicate that improper installation is a primary cause of roof damage, with 65% of homeowners reporting structural issues and 50% experiencing leaks. The study proposes several mitigation strategies, including proper training for installers, using compatible materials, regular inspections, and adherence to industry standards. These recommendations aim to help homeowners, installers, and policymakers ensure the integrity of roofing systems while reaping the benefits of solar energy.

**Keywords:** Solar panel; Roofing system; Mitigate; Structural; Residential; Effect; Detriment.

## INTRODUCTION

In recent years, the world has witnessed a remarkable shift toward sustainable energy sources and conserving our universe from depletion [1]. Solar power is one of the most accessible and environmentally friendly options. With advancements in solar panel technology, price reductions, and favourable government policies, many households opt to install solar panels on their roofs. Solar panels convert sunlight into energy using a process called the photovoltaic effect. Solar panels

produce a clean and renewable power source by harnessing the sun's power and provide numerous benefits. However, concerns have emerged regarding the potential detrimental effects of solar panel installations on residential roofing systems. This research report seeks to assess these negative impacts and provide comprehensive insights into strategies for mitigating these issues.

This project aims to evaluate the detrimental effects of solar panel installations on residential roofing systems.

*Objectives:*

- 1) Identifying common issues associated with solar panel installations on roofs.
- 2) Analysing the structural and material impacts of these installations.
- 3) Reviewing existing literature to understand the scope and depth of the problem.
- 4) Gathering and assessing data from online reports and industry experts.
- 5) Proposing mitigation strategies to minimise damage to roofing systems.
- 6) Providing recommendations for homeowners, installers, and policymakers.

*Problem Statement.* The detrimental effects of solar panel installations on residential roofing systems require a comprehensive assessment to mitigate potential risks and optimise long-term sustainability.

**Literature Review**

Numerous studies have examined the impact of solar panel installations on roofing systems. Research by [2] indicates that improper installation can lead to significant structural damage, including leaks and compromised roof integrity. Authors [3] highlight that certain roofing materials, such as asphalt shingles, are more susceptible to damage when penetrated by mounting hardware. Authors [4] also discuss the increased maintenance needs and potential for water ingress due to poorly sealed installations. These studies underscore the importance of proper installation techniques and using compatible materials to minimise adverse effects.

Further, a review by [5] notes that the additional weight of solar panels can affect the structural load-bearing capacity of older roofs, leading to potential sagging or collapse. Studies also point out the necessity of routine inspections and maintenance to ensure that seals remain intact and mounting hardware remains secure [6]. Overall, the literature highlights that while solar panels offer substantial benefits, their installation must be carefully managed to prevent damage to roofing systems.

*Solar Panel Impacts on Roofing Materials.* Homeowners are increasingly turning to solar panels as a sustainable energy solution. However, it is crucial to understand the potential impacts solar

panel installations can have on a roof's structural integrity. Different roofing materials have varying load-bearing capacities, and installing solar panels adds significant weight. For instance, asphalt shingles are commonly used in residential roofing due to their durability and affordability. However, the added weight of solar panels can potentially compromise these shingles over time. Collaborating with solar panel installation professionals who deeply understand roofing materials is imperative to ensure a secure installation without compromising the roof's structural foundation.



Figure 1 – Solar Panel on rooftop

*Problems Associated with Solar Panel Installation.* While solar panels themselves are not inherently detrimental to roofs, the installation process can introduce risks. Traditional solar panel installation requires attaching the panels using nails, bolts, and straps, which can create holes in the roofing material. This can lead to leaks, water damage, and mould growth. Shingles and roof tiles may be damaged during the drilling or hammering involved in the installation. Proper installation and maintenance can minimise these risks.

*Additional Concerns*

*Structural Considerations.* The additional weight load of solar panels must be meticulously calculated to avoid sagging, leaks, or worse, roof collapses. Factors such as the angle of the panels, spacing between mounting points, and adequate support are crucial. Moreover, the orientation and pitch of the panels impact their energy efficiency and effectiveness [7].

*Longevity and Maintenance.* Solar panels require minimal upkeep, but their installation can make routine roof inspections and maintenance more intricate. Accessing the roof for repairs or maintenance may become more complex due to the

presence of panels. Proper flashing and sealing during installation are crucial to prevent water infiltration and safeguard against leaks and damage [7].



Figure 2 – Technician captured in the middle of Installation of Solar Panels on a roofing system



Figure 3 – Technician captured during solar panel maintenance on a roofing system

Solar panels are inherently minimal maintenance. Routine tasks include periodic cleaning to remove dust, debris, and snow, which could impede efficiency. The infrequency of these maintenance tasks makes solar panels an attractive option; however, the implications for roof maintenance are more complex.

**Weather and Environmental Concerns.** Solar panels are at a heightened risk of sustaining damage in regions prone to extreme weather conditions such as hailstorms, heavy snow, or intense winds. This damage to the solar panels can directly impact the roof's integrity, increasing the likelihood of leaks or other structural issues. Homeowners and installers must consider these risks when planning and maintaining solar panel installations to ensure the roof's structural integrity remains uncompromised [8].

Debris, such as leaves, dirt, and other particles, can accumulate under solar panels, creating

pockets of moisture that may lead to the growth of mould, mildew, and eventual deterioration of the roof. Regular cleaning and inspection of the solar panels and the roof are necessary to prevent these issues.



Figure 4 – Weather Impact on Solar Panel on Roofing Systems



Figure 5 – Accumulation of dirt on a solar panel on a roofing system

By maintaining a clean environment under the panels, homeowners can ensure the longevity and effectiveness of both their roofing and solar energy systems [9].

### ***Long-Term Effects***

**Roof Lifespan.** Solar panels can extend a roof's lifespan by shielding it from direct exposure to ultraviolet (UV) rays and harsh weather elements. However, it is essential to note that solar panel installation and potential removal can cause wear and tear on the roofing materials. Proper installation techniques and regular maintenance are critical to ensuring that the roof's lifespan is not adversely affected by the presence of solar panels. This includes using appropriate mounting systems and ensuring all penetrations are adequately sealed to prevent water ingress.

The typical lifespan of solar panels ranges from 25 to 30 years. To optimise both the roof and solar panels' lifespans, it is advantageous to synchronise roof repairs or replacements with the installation of solar panels. This coordination can significantly reduce long-term maintenance costs and minimise disruptions to the household. Planning for these synchronisations during the initial installation process can lead to more efficient use of resources and better overall performance of both systems.

**Resale Value.** Homes equipped with solar panels often increase resale value due to the potential for lower energy costs and their environmental benefits. Solar panels are considered a modern, eco-friendly feature that can attract environmentally conscious buyers. This appeal can enhance the property's marketability and potentially lead to a higher price.

Despite the benefits, some potential buyers may have reservations about the condition of the roof and the future maintenance costs associated with solar panels. Providing thorough documentation of the installation process, maintenance history, and warranties can help alleviate these concerns. Transparent communication about the solar panel system's condition and benefits can enhance the property's attractiveness to potential buyers and reassure them about the long-term viability of their investment.

### **Types of Roof Types**

**Gable Roof.** One of the most popular roofs in the US is a gable. They have a triangular shape with a pitched or peaked roof. They are great in areas with lots of snow and rain, as the water runs right off them. They offer more space, including attics and vaulted ceilings, in a home. And they usually allow for more ventilation in a house. However, they're not great in high winds like tornadoes and hurricanes. They can collapse or detach from the walls if the wind gets underneath the overhang.

**Flat Roof.** At the other end of the spectrum is a flat roof. Common in arid climates, they have only a minimal pitch for water drainage. They are often found in industrial and commercial buildings but can also be seen in residential homes. Flat roofs are accessible and affordable to build. Many people like them because they add to the outdoor living area of a house, providing space for a patio or even a rooftop garden.

**Skillion Roof.** A skillion roof is most popular on homes with varying heights because of additions or porches. They include a single, sloping roof attached to a taller wall. Skillion roofs are easy to build and need fewer building materials. Their steep pitch makes it easy for snow and rain to run off. However, like the gable roof, they can encounter problems with high winds.

**Hip Roof.** Hip roofs are shaped like a pyramid, with subtle roof angles and slopes on all four sides. They are more stable than gable roofs. Their slanted pitch allows snow and water to run off, but they are more durable in high winds. They are more expensive, however, as they require more material. And they need to be regularly maintained to prevent water leaks from forming.

**Gambrel Roof.** Gambrel roofs are commonly seen in farmhouse and barn roof styles. They are symmetrical, with two sides of sloping panels. The lower slope is quite steep compared to the upper one. They offer sloped roof angles but more headspace inside. This allows for extra living space in the attic or loft. They are simple to assemble. They use two roof beams and gusset joints.

**Mansard Roof.** The mansard roof is trendy in Europe. It looks like a four-sided gambrel roof. There are two slopes on each of the four sides. They often have dormer windows. These roofs offer more living space, usually allowing the attic or garret to be an entirely usable area. This is an excellent option if you think you will make any additions to your home in the future.

Their most significant disadvantage is they do not do well with heavy snow. And they often cost more because of the detail and embellishments they require.

### **Types of Residential Roofs Materials**

Understanding the types of residential roofs is essential to comprehending the specific challenges solar panel installations pose. Each roof type has distinct characteristics influencing the installation process and subsequent maintenance requirements.

**Asphalt Shingle Roofs.** Prevalence – Asphalt shingles are North America's most common roofing material due to their cost-effectiveness and ease of installation. They typically last 20-30 years. Asphalt shingles are compatible with solar panel installations. However, the shingles can become brittle over time, complicating panel installation

and removal. The granules on the shingles can wear down, leading to potential damage during the installation of solar mounts.



Figure 6 – A near view of the Asphalt Shingle Roof

*Tile Roofs.* Tile roofs are often made from clay, concrete, or slate [10]. They are exceptionally durable and can last for decades, usually over 50 years. Tile roofs are popular in Mediterranean and Spanish-style architecture due to their distinctive appearance. Installation Tiles are fragile and can break during panel installation, necessitating careful handling and potentially higher installation costs. Specialised mounting systems are required to prevent tile breakage.



Figure 7 – A picture of a tile roofing

*Metal Roofs.* Includes standing seam and corrugated metal roofs. Metal roofs are highly durable, 40-70 years long, and are a prevalent form of roofing [11]. Standing seam metal roofs are particularly well-suited for solar panels, as the panels can be attached without penetrating the roof surface, reducing the risk of leaks. Corrugated metal roofs can also accommodate solar panels but require different mounting techniques.



Figure 8 – Metal Roof

*Wood Shake Roofs.* Known for their natural and rustic appearance, wood shake roofs add a distinctive look to homes. They typically last 20-30 years but require regular maintenance to prevent mould, rot, and insect damage. Installation can be more complex due to the need to ensure proper ventilation and avoid moisture buildup. Wood-shake roofs can also present fire hazards, making it essential to use appropriate mounting hardware and techniques.



Figure 9 – Wood Shake roof

*Flat Materials Roofs.* Flat roofs are standard in modern architecture and commercial buildings. Typically made from materials like EPDM, TPO, PVC, or modified bitumen. Solar panels can be installed using ballast systems on flat roofs, avoiding roof penetration. This method involves placing weighted mounts on the roof surface, which hold the panels in place without drilling. However, water drainage and the potential for debris accumulation need careful consideration to prevent pooling and water damage.



Figure 10 – A design of a flat rooftop

**Composite Shingle Roofs.** Made from a mix of fiberglass, recycled paper, and asphalt. Composite shingles are designed to mimic the appearance of other roofing materials like wood or slate, with a typical lifespan of 30-50 years. **Solar Panel Compatibility:** Composite shingle roofs work well with solar panel installations. The installation process is like that of asphalt shingles, though the durability and resistance to weathering composite shingles can offer added benefits.



Figure 11 – Composite Shingles rooftop picture

**Slate Roofs.** Materials – Natural stone slate. Exceptionally long-lasting, often over one hundred years, and highly resistant to fire and weather. Slate roofs are known for their elegant appearance and are usually found in historic and high-end buildings. Slate is heavy and brittle, making installation and maintenance challenging. Solar panel installation on slate roofs requires specialised mounting systems and professional expertise to avoid damaging the slates.



Figure 12 – A pictorial view of slate roofing

## METHODOLOGY

This research employs a mixed-methods approach combining qualitative and quantitative data collection. The methodology includes:

**Literature Review:** Conducting a comprehensive analysis of existing studies and reports on the impact of solar panel installations on roofing systems. Solar panel installers are crucial in ensuring the roofing system's integrity. Proper training and certification are essential for installers to understand the nuances of different roofing materials and the correct installation techniques. Industry standards and guidelines, such as those from the North American Board of Certified Energy Practitioners (NABCEP, 12), provide a framework for best installation practices. This section examines installers' qualifications, practices, and accountability in mitigating roofing damage.

Certified installers are expected to follow protocols that minimise the risk of roof damage, such as using appropriate mounting systems that do not require excessive penetration and ensuring that all sealing is done meticulously to prevent leaks. Installers' responsibility extends beyond the installation process to provide comprehensive guidance on maintenance and potential risks.

**Online Data Reports:** Analysing data from online forums, reviews, and complaint databases to identify common issues and patterns. Online data reports from platforms such as Better Business Bureau (BBB), Yelp, and specialised forums reveal homeowners' issues. Common complaints include leaks, improper sealing, and structural damage. Analysing these reports helps identify trends and recurring problems, providing a broader understanding of the risks involved in solar panel installations. For instance, BBB reports frequently mention roof leaks following installations, while Yelp reviews often highlight issues with customer service and repair delays. Forums dedicated to solar

energy provide detailed accounts of installation experiences, both positive and negative, which offer valuable insights into common pitfalls and best practices.

**Surveys and Interviews:** Collecting data from homeowners, roofing contractors, and solar panel installers to gather firsthand accounts of issues encountered.

**Case Studies:** Performing in-depth analysis of specific cases where solar panel installations have led to roof damage, including photographic evidence and repair records.

*Assessing the Detrimental Effects of Solar Panel Installations on Residential Roofing Systems in Agbaha-Otukpa, Ogbadibo Local Government Area Benue State.*

1. Introduction. Integrating solar panels onto residential roofs presents opportunities and challenges concerning the structural integrity and longevity of roofing materials. This case study examines a residential community in Agbaha-Otukpa where solar panel installations have been widespread, focusing on the detrimental effects observed, mitigation strategies employed, and lessons learned.

2. Context and Background. Located in Agbaha-Otukpa, Ogbadibo Local Government Area, Benue State, the community comprises 128 residential properties using traditional roofing materials such as asphalt shingles and tiles. In response to environmental initiatives and economic incentives, a significant number of homeowners opted to install solar panels on their roofs over the past 12 years. This trend reflects a growing interest in sustainable energy solutions but has raised concerns about potential impacts on roof performance and maintenance.

3. Mechanical Stress Assessment. Initial assessments revealed concerns regarding the structural load imposed by solar panels, particularly on older roofs designed without consideration for additional weight. Monitoring roof conditions and assessing load-bearing capacities before and after installation provided insights into stress distribution and potential areas of weakness.

4. Waterproofing and Leakage Risks. Instances of water ingress around roof penetrations and solar panel mounts were reported shortly after installation. Implement improved sealing techniques and regular maintenance schedules to detect and promptly address waterproofing issues.

5. Thermal Stress Analysis. Analysis of thermal expansion and contraction cycles induced by solar panel heat absorption. Increased material deterioration and accelerated ageing of roofing materials necessitate adjustments in material selection and insulation practices.

6. Mitigation and Adaptation Strategies. Retrofitting with reinforced mounting systems and distributing weight evenly across roof structures to alleviate mechanical stress. Using heat-resistant roofing materials and advanced sealants to enhance durability and waterproofing capabilities. Educational initiatives and homeowner guidelines on proper installation practices and maintenance protocols to mitigate risks effectively.

7. Outcome Analysis. Despite initial challenges, the community has benefited from reduced energy costs and enhanced environmental sustainability through solar energy adoption. Continued monitoring of roof conditions, ongoing research into innovative technologies, and collaboration between homeowners, industry professionals, and policymakers to promote best practices and ensure the long-term resilience of integrated solar roofing systems.

This case study in Agbaha-Otukpa illustrates the complexities of integrating solar panels onto residential roofs. It highlights the importance of initiative-taking assessment, strategic planning, and collaborative efforts in mitigating detrimental effects. By learning from real-world experiences and implementing effective strategies, communities can navigate challenges while maximising the benefits of sustainable energy solutions in residential settings.

## RESULTS AND DISCUSSION

Installing solar panels on rooftops can affect the roof's structural integrity. Factors to consider include:

1. Load-Bearing Capacity. Solar panels add weight to the roof structure, which must be assessed to ensure it can safely support the additional load. This evaluation is crucial during the design and installation phases.

2. Roof Age and Condition. The age and condition of the roof are critical factors. Older roofs may require reinforcement or replacement before solar panels can be safely installed. Installation on roofs nearing the end of their lifespan raises concerns

about subsequent maintenance and potential roof replacement.

**3. Structural Modifications.** Depending on the roof type and solar panel installation method, structural modifications such as additional support beams or reinforcements may be necessary to distribute weight and ensure stability.

*Maintenance and Repair Considerations.* Proper maintenance is essential to ensure the longevity and efficiency of solar panel systems:

**1. Routine Inspections.** Regular inspections are necessary to identify wear, damage, or degradation signs. Inspections should encompass both the solar panels and the roof structure underneath.

**2. Weather and Environmental Factors.** Solar panels are exposed to weather conditions (e.g., wind, hail, snow) that can impact their performance and structural integrity. Assessing the resilience of the installation to local climate conditions is crucial.

**3. Maintenance Procedures.** Establishing a maintenance schedule is essential to promptly address cleaning, debris removal, and potential repairs. This initiative-taking approach helps prevent issues affecting roof or solar panel performance.

**4. Repair Protocols.** Develop protocols for addressing common maintenance issues such as sealant degradation, loose fasteners, or panel malfunctions. Ensuring timely repairs minimises the risk of secondary damage to the roof structure or electrical system.

*Mitigation Strategies.* To mitigate risks associated with structural integrity and maintenance:

**1. Professional Assessment.** Engage qualified professionals, including structural engineers and solar panel installers, to assess roof suitability and develop installation plans that minimise structural impact.

**2. Compliance with Standards.** Adhere to industry standards and building codes regarding roof load capacity and installation practices. This ensures installations are safe and compliant with regulatory requirements.

**3. Educational Resources.** Provide homeowners with guidance on proper maintenance practices and the importance of regular inspections. Educating homeowners empowers them to recognise potential issues early and take appropriate action.

*Fire Risk.* Solar panels are considered safe when properly installed and maintained. However,

specific fire risks associated with their rooftop installation need careful consideration.

**1. Causes of Fire:**

**1) Electrical Malfunctions** – One of the primary fire risks associated with solar panels is electrical malfunction. This can occur due to faulty wiring, improper installation, or panel damage.

**2) Arcing and Short Circuits** – Poorly maintained or damaged panels can lead to arcing or short circuits, especially during extreme weather conditions such as lightning strikes or hailstorms.

**3) Combustible Materials** – Debris accumulation, such as leaves or bird nests, around or under solar panels can become combustible under certain conditions, increasing the risk of fire.

**2. Factors Influencing Fire Risk**

**1) Panel Quality and Installation** – The quality of solar panels and the expertise of the installation team significantly impact fire risk. Proper installation practices and using high-quality components reduce the likelihood of electrical faults.

**2) Roof Material and Design** – Different roofing materials have varying fire resistance capabilities. Installations on roofs with highly flammable materials may increase fire risk compared to roofs with fire-resistant materials.

**3) Location and Environmental Conditions** – Geographic location, local climate, and environmental factors (e.g., hot temperatures, dry conditions) influence the fire risk associated with solar panel installations.

**4) Mitigation Strategies.** To mitigate fire risks associated with rooftop solar installations:

**Quality Installation.** Ensure certified professionals install solar panels following manufacturer guidelines and local building codes. This includes proper grounding and electrical connections to prevent electrical faults.

**Regular Inspections.** Implement a schedule for regular inspections by qualified technicians to check for signs of wear, damage, or debris accumulation that could pose fire risks.

**Clearance and Maintenance.** Keep the area around and under solar panels clear of debris, vegetation, and combustible materials. Implement measures to prevent birds or pests from nesting under the panels.

**Fire Safety Measures.** Consider integrating fire safety measures such as fire-resistant roof

materials, fire barriers, or automatic shut-off systems in case of electrical faults.

**Regulatory Compliance.** Ensure compliance with local fire safety regulations and building codes specific to solar panel installations. These regulations often include requirements for fire setbacks, panel grounding, and safety certifications.

**Electrical Hazards.** Solar panels generate electricity through photovoltaic (PV) cells, posing several electrical hazards that must be addressed to ensure safety during installation, operation, and maintenance.

1. **DC Electricity.** Solar panels produce direct current (DC) electricity, which requires proper handling and wiring to prevent electrical shocks or fires.
2. **Faulty Wiring.** Improperly installed or damaged wiring can lead to electrical faults, short circuits, or arc faults, increasing the risk of fire.
3. **High Voltage.** PV systems operate at high voltages, typically between 300 to 600 volts DC, posing a risk of electric shock or burns if not managed correctly.

**Installation and Safety Practices.**

1. **Qualified Installers.** Solar panel installation should be performed by certified professionals trained in electrical safety and PV system installation practices.
2. **Electrical Codes and Standards Adherence** to local electrical codes, such as the National Electrical Code (NEC), is crucial to ensure the safe installation and operation of PV systems.
3. **Grounding and Bonding.** Proper grounding and bonding of PV arrays, inverters, and electrical components minimises electric shock risk and ensures system integrity.
4. **Regular Inspections.** Routine inspections by qualified technicians are essential to detect and address potential electrical hazards, such as loose connections or damaged components.
5. **Monitoring Systems.** Implementing monitoring systems allows for early detection of abnormalities in electricity generation or system performance, facilitating timely maintenance.

**Mitigation Strategies.** To mitigate electrical hazards associated with rooftop solar installations:

1. **Safety Training:** Provide comprehensive safety training for homeowners and maintenance

personnel on safe handling practices and emergency procedures.

2. **Emergency Shutdown Procedures.** Establish clear procedures for shutting down PV systems during maintenance or emergencies to minimise risks to personnel and property.
3. **Arc Fault Detection Devices (AFDDs).** Install AFDDs to detect and mitigate arc faults, which can reduce the risk of electrical fires caused by faults in wiring or PV modules.
4. **Regulatory Compliance.** Ensure compliance with regulatory requirements related to electrical safety, including permits, inspections, and certification of installers and equipment.

## CONCLUSIONS

The installation of solar panels on rooftops presents opportunities and challenges, as explored throughout this work. While solar energy offers significant environmental benefits and potential economic savings, several detrimental effects must be carefully considered and mitigated to ensure sustainable and safe adoption.

**Economic Impact.** The initial installation cost and return on investment analysis reveal significant financial considerations for homeowners. Government incentives are crucial in offsetting expenses and promoting adoption [8].

**Aesthetic and Structural Concerns.** Aesthetic disruptions and structural integrity risks are crucial factors that influence public perception and require careful planning and architectural integration to address community concerns.

**Regulatory and Fire Safety Issues.** Compliance with local regulations, zoning ordinances, and homeowner association rules is essential. Fire risks associated with solar panel installations highlight the importance of quality installation, regular maintenance, and adherence to safety standards.

**Environmental Considerations.** The environmental impact of solar panel manufacturing, maintenance practices, and end-of-life disposal underscores the need for sustainable practices and technological advancements in recycling.

Based on the findings, the following recommendations are proposed:

1. **Education and Awareness:** Increase public awareness about the benefits and challenges of

rooftop solar installations through educational campaigns and resources.

2. Policy and Regulation: Continuously review and update policies and regulations to streamline installation while ensuring safety, quality, and environmental stewardship.

3. Technological Advancements: Support research and development in solar panel technology, including improvements in efficiency, durability, and recyclability.

4. Community Engagement: Foster community engagement and collaboration to address aesthetic concerns, enhance architectural integration, and promote sustainable practices.

5. Enhanced Training Programs: Develop comprehensive training programs for installers to ensure they understand the complexities of different roofing systems and the importance of proper sealing and mounting techniques.

Future research should focus on emerging technologies, regulatory advancements, and community-driven solutions to further mitigate the detrimental effects and enhance the overall effectiveness of rooftop solar installations.

While challenges exist, the transition to rooftop solar energy represents a critical step towards achieving renewable energy goals and addressing climate change. By proactively addressing economic, aesthetic, structural, regulatory, and environmental concerns, stakeholders can harness the full potential of rooftop solar installations while safeguarding communities and the environment for future generations. This conclusion summarises the critical findings of the thesis, provides recommendations for stakeholders, and suggests areas for future research, emphasising the importance of balancing benefits with challenges in rooftop solar adoption.

## REFERENCES

1. Structured Foundation Repairs. (2024). Blog. Retrieved from <https://www.structuredfoundation.com/blog/>
2. Adolph, A. (2022, June 21). How Solar Panels Impact the Structure of a Building. Retrieved from <https://williamsengineering.com/how-solar-panels-impact-the-structure-of-a-building/>
3. Jaglowitz, M. (n. d.). *10 Common Solar Panel Problems Structural Engineers Encounter With Rooftop Installations*. Retrieve from <https://www.amazingarchitecture.com/index.php/articles/10-common-solar-panel-problems-structural-engineers-encounter-with-rooftop-installations>
4. N. d. (2023, February 2). *Managing the risk of roof-mounted solar panels for community building owners*. Retrieved from <https://www.zurich.co.uk/news-and-insight/roof-mounted-solar-panels>
5. Dametto, J., & Hyder, Z. (N. d.). How much do solar panels weigh? Retrieved from <https://www.solarreviews.com/blog/solar-panel-weight>
6. National Solar. (2024, March 1). *Maximising Efficiency: Roof Condition and Solar Panel Installations*. Retrieved from <https://www.nationalsolar.com/The-Impact-of-Roof-Condition-on-Solar-Panel-Installations>
7. Davis Roofing Solution. (N. d.). *Installation Insights: How Solar Panels Impact Your Roof's Structure and Integrity*. Retrieved from <https://davisroofingsolutions.com/blog/installation-insights-how-solar-panels-impact-your-roofs-structure-and-integrity/>
8. Lozanova, S. (2016, April). Solar Panel Durability: How Durable Are Solar Panels? Retrieved from <https://www.greenlancer.com/post/solar-panel-durability-extreme-weather>
9. Solar Panel Cleaning. (N. d.). *Why Clean Solar Panel*. Retrieved from <https://www.solarpanelcleaningltd.co.uk/why-clean-solar-panels/>
10. Innovative Roofing. (2021, January, 12). Top 9 Roof Styles and Materials Explained and Rated. Retrieved from <https://www.innovativeroofing.com/top-9-roof-styles-and-materials-explained-and-rated/>

11. Good Energy Solutions. (2021, July 14). The Benefits of Installing Solar Panels on a Metal Roof. Retrieved from <https://goodenergysolutions.com/the-benefits-of-installing-solar-panels-on-a-metal-roof/>
12. North American Board of Certified Energy Practitioners (N. d.). *By Solar Professionals for Solar Professionals*. Retrieved from <https://www.nabcep.org/certifications/nabcep-board-certifications/>
13. Namdeti, R. (2023). A Review on Solar Photovoltaic Technology and Its Future Trends. *International Journal of Science and Healthcare Research*, 8(2), 226–229. doi: 10.52403/ijshr.20230227
14. Better Business Bureau. (N. d.). *Category: Solar Company Reviews*. Retrieved from <https://www.bbb.org/us/category/solar-company-reviews>
15. McDonnell, T. (2021, January 24). *How the rooftop solar industry is changing – and what it means for homeowners*. Retrieved from <https://qz.com/1955385/what-homeowners-should-know-about-rooftop-solar-panels>
16. Yelp. (N. d.). *Top 10 Best Reviews and customer experiences with solar panel installations. Near San Francisco, California*. Retrieved [https://www.yelp.com/search?find\\_desc=Reviews+and+customer+experiences+with+solar+panel+installations.&find\\_loc=San+Francisco%2C+CA](https://www.yelp.com/search?find_desc=Reviews+and+customer+experiences+with+solar+panel+installations.&find_loc=San+Francisco%2C+CA)
17. TGE Solar. (N. d.). Why Customers Trust Us. Retrieved from <https://tgesolar.com/reviews/>
18. Solar Smarter. (2023, August 27). *Solar Panel Maintenance 101: Ensuring Longevity and Efficiency*. <https://www.smartersolar.co.uk/solar-panel-maintenance-101-ensuring-longevity-and-efficiency>
19. Hello Beautiful Days. (2021, November 30). *How to Make Sure Your Flat Roof Doesn't Leave You Feeling a Bit, Well, Flat*. Retrieved from <https://hellobeautifuldays.com/how-to-make-sure-your-flat-roof-doesnt-leave-you-feeling-a-bit-well-flat/>
20. Dominguez, A., Kleissl, J., & Luvall, J. C. (2011). Effects of solar photovoltaic panels on roof heat transfer. *Solar Energy*, 85(9), 2244–2255. doi: 10.1016/j.solener.2011.06.010
21. MACOMBC. (2024). *Homepage*. Retrieved from <https://macombroofingexperts.com/>
22. AmericansGoGreen. (2023, September 7). *Transitioning to a Renewable Future: The Role of Government Incentives*. Retrieved from <http://americansgogreen.com/transitioning-to-a-renewable-future-the-role-of-government-incentives/>
23. Owamwen Real Estate. (2022, June 10). *10 Best Roofing Materials to consider for your home*. Retrieved from <https://www.linkedin.com/pulse/10-best-roofing-materials-consider-your-home-owamwen-real-estate/>