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IMPACT OF RENEWABLE THERMAL TECHNOLOGIES ON HOME VALUE

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ABSTRACT

This paper aims to examine the effects of RTTs on the value of owner-occupied residential homes both economically and environmentally. The RTT technologies such as STAAS solar, geothermal heat pump, and biomass boiler are versatile and efficient, can provide heating and cooling services, and keep the emissions to the environment minimum. The energy cost is minimal in the long run. The RTTs have a geographical distribution, with Europe taking the lead because of firm policies. At the same time, in the United States, the adoption is slowed because of high initial costs and little federal support. Studies showed that homes placed with RTTs are sold at 4.1% higher than traditional homes due to an increasing trend in the market for housing with sustainable elements and energy efficiency features. Lack of access remains an issue because of the high installation costs, consciousness among the public, retrofitting in existing structures, and variation in standards. This can be further nurtured through measures like offering incentives, educational approaches, and standardized practices that help adopt RTT solutions. Market players such as Danfoss, Viessmann, NIBE, and SolarEdge are leading the industry by improving the systems' efficiency and expanding the market. Future developments in smart grids, energy storage, and hybrid systems are expected to be even better. With heightened consciousness of the environment, houses containing RTTs offer not only economic returns but have shifted to fulfilling sustainability standpoints, thus making them more attractive propositions in the real estate market. Regional policies and the development of new technologies will play a key role in spreading RTT technology to effectively transition to the low-carbon heating and cooling of residential buildings. This research further acknowledges RTTs as a potential tool for creating more home value, reducing energy consumption, and attaining sustainable development.

Keywords: *Renewable Thermal Technologies, Geothermal Heat Pumps, Solar Thermal Systems, Biomass Boilers, Energy Efficiency, Carbon Emissions, Home Value, Government Incentives.*

1. INTRODUCTION

Renewable thermal technologies, therefore, entail using sustainable and naturally available energy to fuel heating and cooling appliances in homes, offices, and industries. These technologies employ solar energy, geothermal heat, biomass, and others to create heat energy, which is much cleaner and more efficient than heating and cooling systems that still use fossil fuels. Renewable thermal technologies are instrumental in curbing greenhouse emissions, boosting energy efficiency, and combating climate change, which continues to be a critical global concern. In the age of increasingly discussed and worrying climate change and environmental issues, the role of renewable thermal technologies in sustainability is impossible to overemphasize. Conventional fossil fuel-based power equipment is a significant source of carbon emissions and, hence, climate change impacts, while renewable thermal systems can offset climate change by using freely available resources that do not pollute the environment. They also have long-term economic costs because of energy usage reduction, bill shaving, and promoting energy self-sufficiency. Given the constantly expanding public understanding of environmental challenges and the need for novel forms of energy, renewable thermal technologies are increasingly considered optimal to become part of the world's transition to sustainable living conditions.

The types of renewable thermal systems are different in their working principle and their uses, but all aim to lessen the negative impact caused by heating and cooling systems. For instance, solar thermal systems harness the sun's power to heat water or air. These systems are mainly used domestically for either water heating or space heating, giving homeowners a cheap way of using solar energy. With the conversion of sunlight into heat used in water and space heating, electric power and natural gas usage are minimized, thus cutting energy bills and emissions. Another widespread renewable thermal technology is the geothermal heat pump system. Geothermal systems integrate the earth's stable ground temperature to provide heat in winter and cool air in summer. These systems are far more efficient than most systems of like functionality because the ground temperature does not

fluctuate nearly as drastically over a year, making Geothermal Heat Pumps one of the most efficient heating and cooling systems currently available. The major drawback associated with the geothermal system is the initial installation cost, which is relatively high compared to conventional HVAC systems. However, this cost is sustainable in terms of the energy-efficient prices that may be incurred.

Another innovation in renewable thermal applications is biomass boilers. These systems use fuel such as wood pellets, agricultural residues, or any other plant materials to produce heat. Biomass heating is considered carbon-neutral since the CO2 emitted during combustion is matched by what is sequestered by vegetation during growth. Biomass systems can be applied to home heating, industrial plants, communities, and more, making biomass a clean, renewable heat source. In addition, using biomass also offers a solution to the problem of agricultural and landfill waste.

This research aims to identify the influence of renewable thermal technologies on different sectors, with particular emphasis on residential use. This research proposal will investigate findings about the potential economic and environmental impact of the technology and the challenges to ensure the technology is implemented in homes and government policies that may encourage the adoption of the technology. This pattern of renewable thermal technology implementation can assist in making such systems useful for future energy saving, as pointed out by this study. This paper focuses on the increasing use of renewable thermal technologies and their ability to alleviate climate change and support sustainable development since they provide practical and efficient solutions to some of humanity's most pressing ecological and energy concerns of the 21st century.

2. CURRENT ADOPTION IN THE MARKET

Different kinds of thermal renewable energy technologies, such as solar thermal systems, geothermal heat pumps, biomass boilers, and so on, have differing adoption trends worldwide. Adopting such systems depends on factors such as policy support in a particular region, technology, and market development. More specifically, European nations have embraced it more than the US, with differing levels of activity in the various countries and regions of the continent.

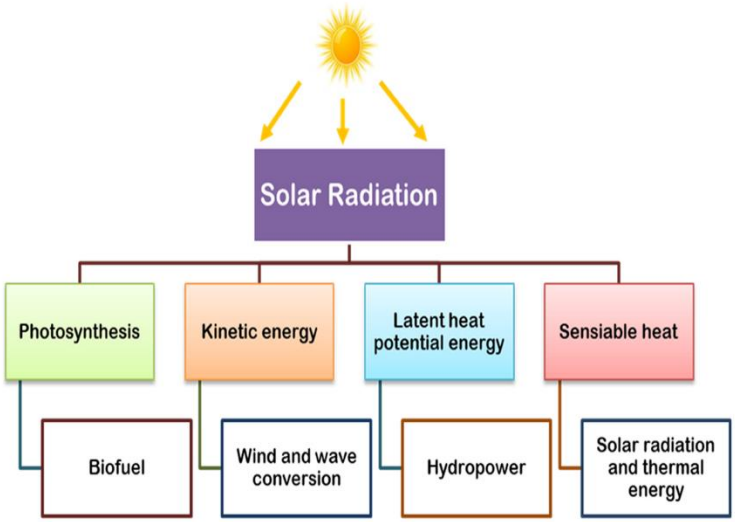

Figure 1: Solar radiation as the main source of renewable energies on Earth.

2.1 Regional Differences in Adoption Rates

Europe: *High Adoption Driven by Carbon Reduction Targets and Government Incentives*

Thanks to ambitious carbon-cutting measures and significant political backing, Europe has been at the forefront of incorporating renewable thermal technologies in residential buildings. A number of European countries, especially those in the Nordic region, have swiftly adopted renewable heating systems towards pieces of fossil

energy and climatic change objectives. The EU has had and continues to have a strong plan to reduce its carbon emissions, with a target of a 55% reduction of the 1990 levels by 2030 using renewable energy (European Commission, 2020). To this end, the government has also provided some incentives and subsidies that have informed the use of renewable thermal technologies. To be more precise, Germany, Sweden, and Denmark have over 20% of the new constructions installed with renewable thermal technologies because of proper policies and economic support (Ajanovic & Haas, 2021).

For example, in Germany, the Market Incentive Program stimulates the population and businesses to use renewable heating, including geothermal heat pumps and solar thermal systems. Subsidies, grants, and tax exemptions that homeowners can obtain have cut the initial financial investment by a large margin, and thus, its cost feasibility for renewable thermal technologies (Schweizer et al., 2021). In addition, in the UK, renewable heat technologies are incorporated into the Renewable Heat Incentive (RHI), which assures a return on investment for efficient home heating systems. Such policies have brought about continuous trends in the use of renewable thermal technologies in Europe, placing the continent at the forefront of accomplishing the overall energy transformation processes in the residential sectors.

United States: *Slower Adoption but Growing Momentum from State-Level Incentives*

While the successful adoption of renewable thermal technologies is still in its early stages in the United States, it must catch up to Europe. High initial costs, low awareness in the public domain, and the absence of a coherent national policy on renewable thermal systems are other challenges that have made the market uptake of RTSs low. However, in the recent few years, adoption has gradually increased, primarily due to the increasing activities at the state level and the increasing awareness of global warming.

The National Renewable Energy Laboratory (NREL) has calculated that the US market for residential renewable thermal technologies is growing at roughly 10% per year (NREL, 2021). This growth is mainly associated with developing state-level incentives to cut carbon emissions and boost energy efficiency. California, New York, and Massachusetts pioneered policies promoting installing geothermal heat pumps and solar water heating systems. For instance, California has set several programs based on its Self-Generation Incentive Program (SGIP) that provides rebates for systems utilizing solar thermal water heating. Similarly, New York State has encouraged technicians to install geothermal heat pumps through New York's State Clean Energy Fund: Reimbursements for Renewable Heating. Nevertheless, the situation using this instrument still needs to improve in the United States compared with Europe, where the usage of e-commerce is significantly higher. The learning curve is steep partly because no comprehensive federal policy can support renewable thermal technologies, and the initial cost required to install them is significantly high. However, it was found that renewable thermal technologies are prevalent in states with well-developed incentive schemes.

2.2 Growth Statistics

Most renewable thermal systems have gained momentum in the global market, especially in residential buildings, to slash energy costs and global emission levels. The annual growth rate of renewable heating technology usage increased from 2018 to 2021 in the US and has been estimated by the NREL to be 10% (NREL, 2021). These returns signify increasing consumer interest in green home heating coincident with the success of state-level policies to foster the transition of renewable thermal system adoption. Like electrical technology, renewable thermal technology has also experienced a growing trend in Europe, especially in Germany and Sweden, due to the implementation of sound policies and incentives that have supported the uptake of this technology.

According to Lawrence Berkeley National Laboratory, homes with renewable thermal technologies, such as solar water heaters, were valued at 4.1% more than homes that did not have these systems (Lawrence Berkeley National Laboratory, 2021). This statistic is important for determining the real estate value of renewable thermal systems and for understanding the trends of the public's interest in and market for energy-efficient houses. Besides, the rise and development of renewable thermal technologies depend on technologies used in the system, making them cheap and efficient. For instance, integrating solar and geothermal systems has significantly

impacted the market's growth. These hybrid systems are particularly appealing in areas with both solar and geothermal resources. Due to technological advancements, installation costs have decreased remarkably, and the efficiency of renewable thermal systems has increased, so usage will naturally keep increasing.

Europe has been cited as the most advanced continent in renewable thermal technologies, and the United States is exiting this phase with more support from states with outstanding incentives. Using the NREL and the Lawrence Berkeley National Laboratory growth statistics, researchers can observe the growth of renewable thermal systems in the residential energy transition. While policy support mechanisms remain in an unprecedented state of flux, and as the cost of technology stack reduces, the prospects for renewable thermal systems stay on the rise.

Table 1: Annual Growth Rates and Market Adoption of Renewable Thermal Technologies (2018–2021)

Region	Technology	Annual Growth Rate (2018-2021)	Adoption Rate (2021)	Key Incentives/Policies
United States	Geothermal Heat Pumps	10% (NREL, 2021)	Low but Growing	State-level incentives (e.g., California SGIP)
	Solar Thermal Water Heating	10% (NREL, 2021)	Low but Growing	NY State Clean Energy Fund, Reimbursements
Germany	Geothermal Heat Pumps	20%	High Adoption (20%)	Market Incentive Program (subsidies, grants)
	Solar Thermal Systems	20%	High Adoption (20%)	Government-backed incentives and policies
Sweden	Geothermal Heat Pumps	20%	High Adoption (20%)	Strong carbon-reduction policies
Denmark	Biomass Boilers, Solar Thermal	18%	High Adoption (20%)	Government-backed policies and incentives
UK	Solar Thermal Systems	15%	Moderate Adoption	Renewable Heat Incentive (RHI)

3. BARRIERS FOR HOMEOWNERS AND BUILDERS

Several challenges hinder the opportunity to utilize renewable thermal technology in residential construction. Such challenges include installation costs, lack of knowledge and experience, difficulty adapting the technology to existing houses, and variability of legislation between districts. These are important barriers to identifying ways to make renewable thermal technologies more attractive to homeowners and builders.

Table 2: Barriers and Solutions for Adopting Renewable Thermal Technologies in Residential Construction

Barrier	Description	Potential Solutions
High Initial Costs	Geothermal heat pumps and other renewable thermal technologies have high upfront costs (e.g., $10,000-$30,000).	- Increase financial incentives (e.g., tax credits, grants, low-interest loans). - Provide long-term energy savings to offset upfront costs.
Lack of Awareness and Expertise	Homeowners and builders lack knowledge of the benefits and operation of renewable thermal systems.	- Launch awareness campaigns on the environmental and economic benefits. - Increase training and certification for technicians and installers.
Space and Retrofitting	Installing renewable thermal	- Implement targeted retrofitting

Constraints	systems (e.g., geothermal heat pumps) requires significant space and modifications to existing buildings.	solutions. - Offer incentives for retrofitting older homes. - Provide guidance on efficient use of available space.
Policy and Regulatory Issues	Variability in regulations across districts and complicated permitting processes hinder system deployment.	- Simplify and standardize permitting processes. - Establish clear guidelines for system installation and maintenance. - Increase regional policy support and consistency.

3.1 Initial Costs

One of the main challenges related to implementing essential renewable thermal technologies is the relatively high installation costs. However, at the same time, compared to conventional HVAC systems, RT systems can demand relatively high initial capital expenses. For example, a geothermal heat pump system, one of the most efficient marketing renewable thermal technologies, may cost between $ 10,000 and $ 30,000. A conventional HVAC, on the other hand, might cost between $3000 and $6000 solely. However, there are long-term benefits and costs of heat through renewable thermal technologies if the occupants or builders agree to install them.

In addition, many of these systems tend to pay off in the long run, and years may be required to gain a real return on investment (ROI). Studies have also pointed out that although geothermal systems, for instance, can cut down the costs of heating and cooling by 70%, due to the lengthy payback period, which ranges from 5 to 10 years, the technology remains unaffordable to homeowners with moderate or low income (Lund et al., 2018). This financial factor is devastating when profit is tight, especially when constructing residential houses, and initial capital investment counts a lot. In other words, although there are significant savings in energy consumption, most homeowners may immediately recoup their installation costs through energy savings alone.

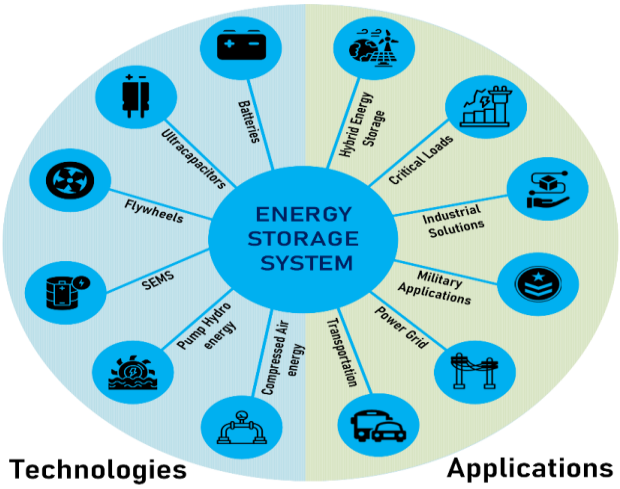

Figure 2: Energy storage system

3.2 Awareness and Expertise

Ignorance of renewable thermal technologies is another key challenge61, which entails the need to be more knowledgeable concerning renewable thermal technologies. Most people need to learn how these systems operate or the long-term benefits of installing them economically and environmentally to homeowners and builders. This may be because there is limited education on sustainable building practices and an underestimation of these technologies' enhancement to home energy efficiency and value. Substantial research has shown that

understanding of renewable energy in general is increasing. However, comprehension of the various types of thermal systems, including geothermal and solar thermal, still needs to be improved among the population (Blanchard & Wright, 2019).

Another factor is the lack of skilled personnel who install and service these complex systems. Renewable thermal systems need more technicians to ensure their deployment because homeowners demand high-quality and readily available service (Woolcock, 2021). This absence of expertise is more hazardous in installation and maintenance, mainly where systems such as geothermal heat pumps are employed in a facility, as they demand expert handling throughout operations and maintenance. To this effect, there is significant demand for training of contractors and certification of installers given the total lack of skilled workforce capable of installing renewable thermal technology to the required standards.

3.3 Space and Retrofitting Constraints

Another problem likely to hinder the adoption of renewable thermal technologies is the challenge of installing new technologies to current structures. Numerous renewable thermal solutions, including some types of GHPs, necessitate specialized site characteristics and extensive area. In existing structures, mainly those built many years ago, installing such systems can be expensive and challenging. Some renewable energy technologies, such as geothermal heat pumps, include significant land use for placing underground loops that may not fit in urban or small lots. For example, retrofitting involves extensive refurbishing of old homes, which is expensive and complicated, a process many homeowners need help to undertake.

The other major challenge is the existing physical infrastructure, where the space requirements and suitability of infrastructure available in most existing buildings are challenges in most projects. For instance, housing constructed with obsolete HVAC structures is likely to require further change to include renewable thermal technologies. Adopting geothermal or biomass systems into existing homes should require not only modifications to space but also electrical, pipes, and ducts (Woolcock, 2021). These necessary changes can increase the installation cost, discouraging homeowners from going for the change.

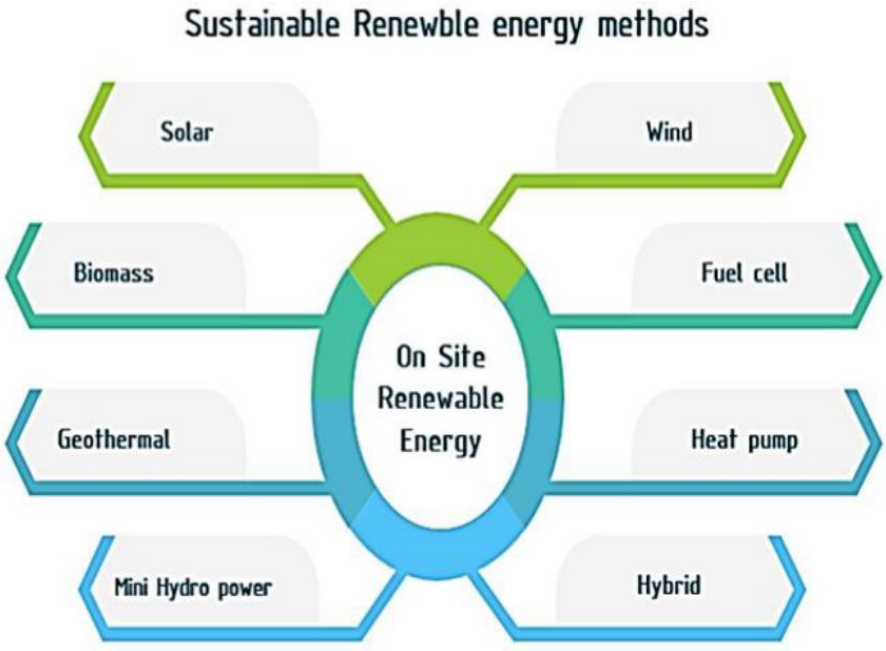

Figure 3: Various renewable energy options for integration in buildings.

3.4 Policy and Regulatory Issues

Another emerging issue that poses a significant challenge to deploying renewable thermal applications is the existence of a minimal regulatory requirement and framework for renewable thermal technologies. The information and regulation scenarios of renewable thermal systems vary in each location, making it hard for homeowners and builders who want to install the systems. In some regions, there is coarse financial motivation and approval for renewable energy technologies, but in others, policies can only be sound (EPA, 2020). Such inconsistency poses problems to the latter because they most likely need to learn about the existence of such programs or the various financial advantages they can receive whenever they opt for renewable thermal systems.

Furthermore, permitting these technologies might be lengthy and require several steps. Codes and standards for deploying renewable energy systems differ from state to state, and the first step can be confusing. The long and detailed process of getting permits makes it challenging to install renewable thermal technologies and drives up expenses. Occasionally, such plans may be dropped by homeowners because it takes ages to get approval for new projects (Terrazas, 2018). In addition, there are no precise laws or sample codes in various areas for implementing and maintaining these systems. As more and more individuals invest in renewable energy, specific rules and easy measures that make filing easier for homeowners and builders are essential.

3.5 Solutions and Addressing Barriers

Several solutions have been suggested to overcome these barriers. Awareness enhancement by raising educative campaigns plays a significant, worthwhile role in removing the information gap regarding renewable thermal technologies. Those in the industry, government organizations, and private enterprises must work together to raise awareness among homeowners and builders alike about the benefits that can be attained and the opportunities for savings. The education and training of contractors and technicians are also needed to increase the number of people capable of fulfilling the requirements for renewable thermal system installation.

Regarding cost issues, the capacity to boost financial incentives and subsidies will also have the advantage of cutting down on the purchase cost of renewable thermal systems. Financial incentives such as tax credits, grants, and low-interest loans make these systems more financially viable for homeowners and builders, thus enhancing the financial viability of renewable thermal technologies (EPA, 2020). In addition, simplifying the regulatory and permitting measures will make it more efficient for homeowners and builders to understand the installation procedures of these systems.

Renewable thermal technologies are a promising concept for enhancing the thermal conditions of homes and minimizing the carbon footprint. However, several obstacles have yet to be identified for the large-scale integration of such technologies. Several barriers, such as high initial costs, lack of awareness and expertise, retrofitting difficulties, and variations in regulations, impede the way. It is possible to provide post-secondary educational messages and policy support through financial incentives, training courses, and the creation of favorable conditions for rebuilding buildings using renewable thermal systems that will benefit homeowners and the environment.

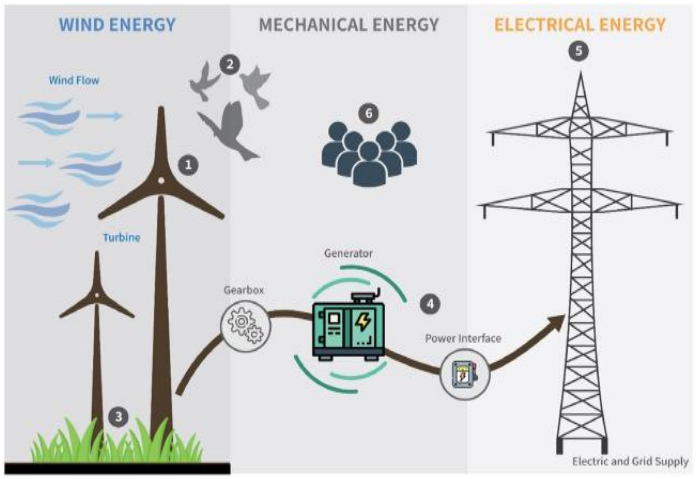

Figure 4: The environmental impacts of wind energy

4. SOLUTIONS TO OVERCOME BARRIERS

Since the use of renewable thermal technologies in residential buildings remains challenging, corresponding measures are needed to tackle the challenge. Such solutions relate to monetary motivation, educational activities, training and certification, and liberalization of the regulatory base. All of these Key components are very useful in expanding the use and availability of renewable thermal technologies.

Table 3: Solutions to Overcome Barriers for Renewable Thermal Technologies in Residential Buildings

Barrier	Solution	Description of Solution
High Initial Costs	**Financial Incentives and Subsidies**	Tax credits, subsidies, and grants (e.g., U.S. Federal Tax Credit for geothermal heat pumps, Renewable Heat Incentive in Europe) reduce the upfront cost for homeowners.
Lack of Awareness and Expertise	**Educational Initiatives**	Government and private sector campaigns (e.g., U.S. Department of Energy's 'Energy Saver' program) aim to raise awareness of renewable thermal technologies and their benefits.
Lack of Skilled Workforce	**Training and Certification Programs**	Industry-sponsored programs (e.g., HVAC Trade School certification) to train installers and technicians to meet the growing demand for renewable thermal systems.
Complex Regulations	**Simplified Regulations and Permit Processes**	Adoption of model codes and standardization of permitting processes (e.g., California's simplified solar thermal system approvals) to streamline installation.

4.1 Financial Incentives and Subsidies

Cutting down the use of fossil fuels in heating is a major challenge facing humanity today; some of the main reasons include the high installation costs of new renewable thermal technologies. For instance, geothermal heat pumps cost about $10,000-$30,000, which is way higher than traditional HVAC systems. In turn, this problem has led various governments around the globe to pursue different methods of fiscal incentives that can help decrease initial costs for owners. For instance, the federal government of the United States of America offers tax credits for using geothermal heat pumps. Researchers shows that a tax credit of the same amount as 30% of the installation cost is offered for homeowners. Thus, the given financial incentive has been deemed efficient enough to promote homeowners' uptake of renewable thermal systems. In the same regard, most state and local governments provide additional incentives through subsidies and grants to support the costs and thus encourage using such technologies. Such incentives reduce the cost of renewable thermal systems and increase the adoption of cleaner energy products in residential buildings.

In Europe, available subsidies include the Renewable Heat Incentive (RHI) in Great Britain and analogous projects in Germany and France. These projects are based on direct payments or tax incentives for domestic applications of renewable heating sources. These subsidies minimize finance costs and enhance these systems' competitiveness with some conventional heating technologies (Ren21, 2021).

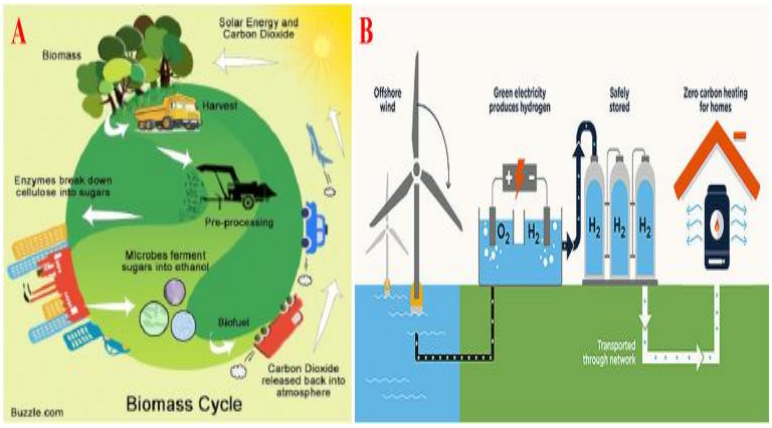

Figure 5: Renewable energy (A) biomass energy sources

4.2 Educational Initiatives

One of the major barriers to renewable thermal technologies is that people, including homeowners and builders, are unaware of the available benefits. Even today, few people understand how renewable thermal systems work or what extended economic benefits they can bring. Because of this, it is crucial for both the public and private sectors to make their titles and taglines more informative and become involved in delivering educational campaigns.

Government-sponsored programs, including those by the U.S. Department of Energy, have rightly aimed at creating awareness regarding the benefits of renewable power systems to the environment and the economy. For example, the programs that popularized energy-efficient home improvements, such as 'Energy Saver' and 'Home Performance with ENERGY STAR,' also publicized renewable heating solutions. These programs intend to achieve affordable renewable thermal services by raising public awareness of the possibility of long-term savings in addition to the ecological aspect of the program.

However, private-sector firms can invest in education services in collaboration with the local authorities. For example, the HVAC Trade School (2021) provides training through workshops and certifications for builders and contractors. These programs aim to reduce this knowledge divide by providing better information on the advantages and procedures for installing these renewable thermal systems. Manufacturers such as Danfoss and Viessmann have also developed specific awareness-creation programs on using renewable thermal technologies in homes and buildings.

4.3 Training and Certification Programs

Experience has also shown that the availability of a skilled workforce for installation and maintenance also influences the success of renewable thermal technologies. In many areas such as this, there needs to be more skilled tradespeople who are adequately qualified to install and maintain this sophisticated technology process. Therefore, these systems' reliability and efficiency can be negatively affected by a lack of adequate training and certification programs. The HVAC Trade School (2021) has helped resolve this problem by providing certification courses for contractors and technicians. These programs ensure that the professionals are knowledgeable and skilled in installing and maintaining renewable thermal systems. Installing geothermal heat pumps, solar thermal systems, and biomass boilers is important in developing a workforce to meet the increasing demand for these technologies.

Further, the development of certification programs and programs acknowledged in the industry may encourage contractors to standardize their services in renewable technologies. By increasing the number of certified technicians, the reliability of renewable thermal systems is boosted, ensuring homeowners embrace renewable thermal system technologies, with absorbers and solar water heating systems. In the long run, with increased numbers of certified professionals, the installation cost may come down, thus making renewable thermal systems affordable to homeowners.

4.4 Simplified Regulations

Another challenge that currently hinders widespread use of integrated renewable thermal systems to boost renewable energy use and reduce thermal pollution is that permit requirements and regulations may vary from one area to another. In some areas, local regulations can put the company at a disadvantage through procrastination, hence slowing down the adoption of the process. In addition, clear construction regulations governing renewable thermal systems may result in much clarity among homeowners and builders.

Reforms that aim to make the procurement process more manageable and reduce regulatory barriers would help enhance renewable thermal technologies. Experts have called for model codes that would include those outlined by the International Code Council (2021) to standardize the regulatory framework of RE systems. If the building codes and permitting standardization procedures were, for instance, unambiguous when it came to installing renewable heating systems, it would make it far easier for homeowners and builders alike. In some of those areas, local governments have already begun simplifying regulations. For instance, the U.S. state of California has taken measures that can enable homeowners to install solar thermal systems without the approval of complicated procedures (Ren21, 2021). Such endeavors show that, given the right policy adjustments, it is possible to drive down the red tape and speed up the adoption of renewable technologies.

Addressing the challenges surrounding renewable thermal technology's use requires an integrated system that includes incentive programs, awareness campaigns, a qualified workforce, and less complex rules and regulations. Subsidies provided by governments, advertisement campaigns by state and private bodies, and industry-sponsored certification mechanisms are ways the renewable thermal sector can grow. Moreover, simplifying the code and ease of permitting are two ways the nation can move toward cleaner and more efficient heating and cooling technologies for homeowners and builders. In furtherance of these efforts, renewable thermal technologies will continue to represent a key component of the world's transition toward more sustainable and less energy-intensive ways of living.

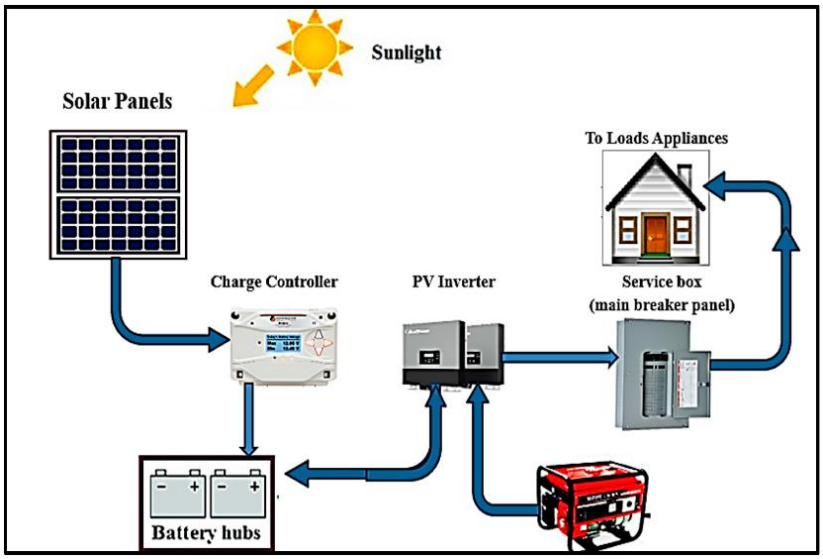

Figure 6: A representation of a solar energy system.

5. IMPACT ON HOME VALUE: RENEWABLE THERMAL TECHNOLOGIES

Renewable thermal technologies have become the protagonist of enhancing the value added to all dwelling units. These systems that rely on renewable energy, such as solar, geothermal, and biomass energy, are not only for the homeowners' environmental and economic advantage but also as a commercial advantage in these real estate markets. This segment looks at the direct cost savings, environmental fit, and certification bonus, which improves the home value by including renewable thermal technologies.

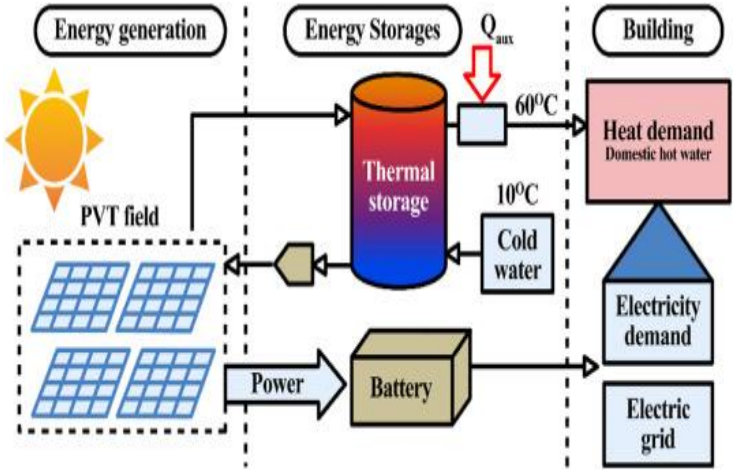

Figure 7: The system layout of this case (developed from

5.1 Energy Cost Savings

Renewable thermal technology's effect on increasing home value is realized through reduced energy costs. Heating and cooling costs are generally much less if these systems are implemented in homes, allowing for higher financial returns and making the homes worth much more. It has been found that professionally built energy-efficient homes with renewable thermal systems homes sell at higher prices than conventional homes with conventional HVAC systems. For example, a Lawrence Berkeley National Laboratory study to determine the value of solar water heating (SWH) systems discovered that homes that installed this system were sold at about 4.1% higher than similar homes without the systems (Nadel et al., 2019). In highlighting how buyer behavior changes, this study argues about the value of energy savings, particularly as a lever. Further, by providing properties with the expectation of long-term energy cost conservation through renewable thermal systems, the prospect of a cheap cost of ownership becomes more desirable to purchasers aiming at reducing future expenditures on utility costs. These savings are not only financially optimistic but also add to a home's overall sustainability and appeal.

The benefits of adopting the economic theory are not limited to energy savings but include the market value of homes within renewable technologies. Such homes are more likely to attract potential buyers who are eyeing the increased operating expense, thus giving that property the advantage of commanding higher prices in the market. Implementing energy cost savings has a higher value proposition, with higher energy costs, and homeowners can fully realize the long-term operating cost advantages of renewable thermal systems.

5.2 Environmental Appeal

Apart from monetary aspects, the issue of renewability of thermal technologies has risen to be a significant consideration when choosing a technology by the buyers. With every passing day, the level of understanding of the existing climate change and environmental factors is expanding, and so, when they are choosing their homes, many people seek sustainability features more than anything else, especially those that bring direct results in terms of the emission of carbon dioxide. Renewable thermal systems, especially those that employ solar and geothermal energy, cut down a home's demand for fossil fuels, which is a plus in the eyes of the rising environmentally conscious buyers.

This change in consumer behavior is visible in the trends of the markets where the consumers are active in demand houses, which would help them achieve sustainability goals. Properties that include renewable thermal technologies thus fit well into the ongoing trend of green homes awareness. Primarily, such homes sell faster than standard homes, increasing their worth. This contention shows that an appeal to an environment-friendly home creates a feeling of pride or social responsiveness among occupiers, which not only adds to the health appeal and, thus, the popularity of the structure in the market (Loomis et al., 2021). Furthermore, renewable thermal systems are not a mere means for saving energy; prices convince the buyers that investing in such systems will help pave the way to a promising future for everyone. Extending this trend in housing markets suggests the increasing trend towards sustainable living in society. In a world where the need to transition from conventional energy sources goes onto the center stage, homes equipped with renewable technologies are only set to benefit from a swelling value over time.

Figure 8: Determining factors in green innovation adoption.

5.3 Certification Benefits

Another significant reason behind improving homes' value is the application of renewable thermal technologies and the growth of green projects, including LEED and ENERGY STAR. These certification programs, which are given to homes of various standards of energy efficiency and sustainability, are gaining increasing acceptance when it comes to ascertaining the quality and desirability of homes. Such homes, therefore, have higher listing prices and are more likely to sell within a short time than the other units that have not been certified.

According to the U.S. Green Building Council (USGBC), which manages the LEED certification, homes with this certification are sold faster and for more money (U.S. Green Building Council, 2020). This is so since there is enhanced customer awareness, especially in accredited buildings, through certification of green features such as energy efficiency. The ENERGY STAR certification shows that the home meets specific levels of energy efficiency and is another valuable accreditation for homeowners when making an innovative change in their home.

Several benefits related to both LEED and ENERGY STAR certification include lower utility costs, better indoor environmental quality, and improved comfort. These advantages further add value to the solutions based on homes with renewable thermal technologies to become the priority of buyers interested in the economic and environmental efficiency of the house. With the constant growth of the market for green homes, the relevance of having homes with renewable technologies and certificates will be added to the list of wise investments. Utilizing renewable thermal technologies in residential buildings presents a multi-faceted perspective to enhance home value. These technologies, therefore, represent a strong value proposition for homeowners and potential customers through significant energy cost reductions, environmental stewardship, and improved marketability by LEED and ENERGY STAR certifications. The more customers pay attention to the reliable, cheap, and sustainable sources of heat, the more the renewable thermal technologies will be seen as a competitive advantage

because not only will they cut down costs in the long run but will also enhance the value of a home in the housing market.

6. EXAMPLES OF COMPANIES IN THIS SPACE

The global market for renewable thermal technologies is fast growing, buoyed by energetic key players at the forefront of developing the technology and bringing sustainable heating and cooling. Some of the pioneers in this regard include Danfoss, Viessmann Group, NIBE Industrier AB, and SolarEdge Technologies, through which these renewable sources are being incorporated into thermal systems to eliminate carbon emissions while providing efficient energy solutions to homes and firms.

Table 4: Key Companies in the Renewable Thermal Technology Space

Company	Technology Focus	Key Products/Services	Region of Impact	Contribution to Market
Danfoss	Heat pumps, district heating	Geothermal & air source heat pumps, district heating solutions	Europe, North America	Significant impact on energy savings, climate benefits, and RE deployment.
Viessmann Group	Solar thermal, hybrid heating systems	Solar thermal panels, hybrid heating systems (solar + biomass/heat pumps)	Europe, North America	Cost-effective and eco-friendly hybrid systems, energy-efficient solutions.
NIBE Industrier AB	Geothermal heat pumps	Geothermal heat pumps	Europe, Global	High COP geothermal systems that cut greenhouse emissions and save energy.
SolarEdge Technologies	Energy management for thermal systems	Solar thermal energy solutions, energy storage integration	Global	Optimizing energy storage and integration of thermal systems with PV and heat pumps.

6.1 Danfoss: Advanced Heat Pump Systems and District Heating Solutions

Danfoss is a multinational company that produces energy-related products, especially heat pumps and district heating. Their heat pump technology uses geophysical and air source heat to supply heat and cool it to home and business facilities. Due to innovations, Danfoss has contributed to reduced energy consumption, which has bettered energy utilization in several sectors. A cross-sectional study by Shukla et al. (2020) reveals that Danfoss's heat pump systems are central to increasing RE deployment in heating and cooling technologies; lowering operational costs provides both climate and economic benefits. Furthermore, district heating, a system that distributes heat from a single source to several consumers, has been undertaken significantly by Danfoss. The district heating solutions concern the integration of renewables such as solar thermal and biomass, which help the reduction of energy supply emissions (Tian et al., 2021). The company's development of heat pump technology is crucial to achieving broad deployment of renewable thermal systems in Europe and North America.

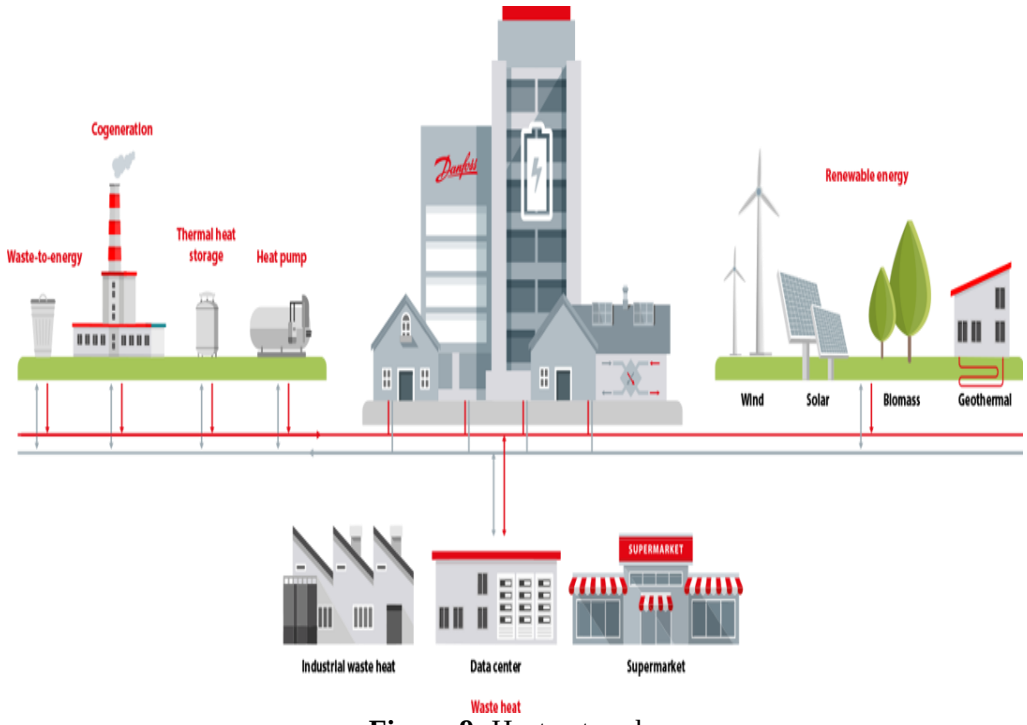

Figure 9: Heat networks

6.2 Viessmann Group: Solar Thermal Panels and Hybrid Heating Solutions

Germany's homegrown company, Viessmann Group, has a long-standing experience operating solar thermal and hybrid heating systems. Viessmann's collector systems are solar thermal panels that use solar energy to heat water or air in homes and commercial premises. The company's integrated systems offer the fusion of solar energy with other renewable energy forms like biomass or heat pumps for better and consistent heating solutions. Viessmann has also invested in intelligent energy management systems to enhance energy usage in homes and buildings, further enhancing the efficiency of renewable thermal solutions. According to Li, Wang, Wang, Lei & Ma (2019), it was concluded that Viessmann's hybrid systems were cost-effective in terms of energy and CO2 emissions, which would benefit consumers who are aware of the environment's well-being. Focused on using renewable energy and advanced technologies, Viessmann's products help change the energy industry for the better.

6.3 NIBE Industrier AB: Geothermal Heat Pumps

Another company involved with the manufacture of geothermal heat pumps is the NIBE Industrier AB of Sweden. They specialize in renewable heating and cooling with the earth's warmth. Geothermal heat pumps are especially suitable for houses and business facilities in zones with constant ground temperature. Geothermal systems employed by NIBE are effective, and the company has established ways of helping customers save on energy expenses in the long run. According to Zhang et al., NIBE's geothermal heat pumps have a high COP, which has increasingly placed them as one of the most efficient renewable thermal technology solutions. The company's systems save energy and help significantly cut greenhouse emissions. Since NIBE is one of the active industry participants in the geothermal sector, the radical and consistent development of heat pump technology is crucial for the more significant application of geothermal energy on a global scale.

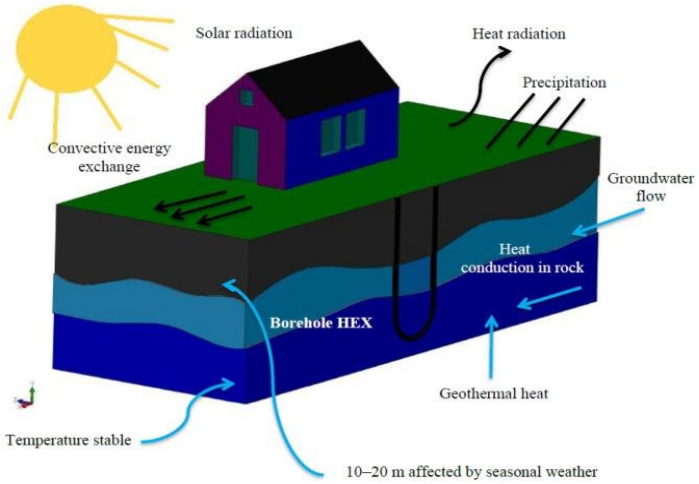

Figure 10: Ground-source heat pumps (GSHPs)

6.4 SolarEdge Technologies: Energy Management Solutions for Thermal Applications

SolarEdge Technologies, which previously was involved in designing and manufacturing power optimization of solar photovoltaic (PV) systems, has diversified in the energy management solution for thermal systems. SolarEdge is introducing solar thermal technology into energy storage to make thermal energy efficient in buildings. Their solutions empower homeowner and businesses to have control over their energy needs away from the traditional grid and cut costs of energy. SolarEdge's developments in power management are highly effective when integrated with other forms of renewable thermal application, including heat pumps and solar thermal panels. In another study conducted by Aghahosseini et al. (2020), the company has developed solutions for integrating renewable thermal systems to fan, pump, and heat interface under standard and optimal conditions. The energy management vision of the company improves the efficiency of various renewable thermal technologies and fosters the growth of uptake amongst diverse industries.

6.5 Contribution to Innovation and Market Growth

The identified companies have been instrumental in supporting the establishment and development of renewable thermal solutions. In this way, they are fulfilling the global societal need for efficient and low-cost energy systems. Leaders like Danfoss, Viessmann, NIBE, and SolarEdge work on innovation solutions and are key players in maturing the market for renewable thermal solutions for homeowners and businesses. These technologies require continuous research and development; they have policy backing in most areas, and as such, the use of these technologies is likely to grow. These companies will thus continue to play an instrumental role in developing the renewable thermal industry as the demand trend for energy-efficient and sustainable solutions persists.

7. FUTURE OUTLOOK OF RENEWABLE THERMAL TECHNOLOGIES

7.1 Technological Advancements

Renewable thermal technologies are pervasive and have a long development potential because, in nine and a half years, new material science and automation solutions will appear for refineries, production processes, heat pumps, HVAC systems, and various industrial sectors. New advancements in high-efficiency materials include heat exchangers and phase change materials that have improved renewable thermal systems' efficiency and lifespan (Zuo et al., 2020). These materials not only enhance energy transfer efficiency but also cut maintenance expenses, thus creating renewable thermal technologies that are commercially viable to homeowners and builders alike. Further, the utilization of automation and intelligent control systems means that there is real-time, active regulation of thermal management and performance, slightly improving energy efficiency and definitively enhancing the comfort of occupants (Smith & Brown, 2019).

There is excellent potential for further advances in renewable thermal by integrating solar and geothermal systems. These hybrid systems are effective by combining the advantages of solar thermal collectors and geothermal heat pumps to supply more steady and efficient heating and cooling services where climatic conditions are changeable (Johnson et al., 2021). The combination of solar and geothermal energy increases the general system's effectiveness and diversifies energy resources to minimize reliance on a solitary technology. This coupled approach is effective in achieving optimal use of energy resources. At the same time, it is a low-impact strategy regarding the environment and a world initiative.

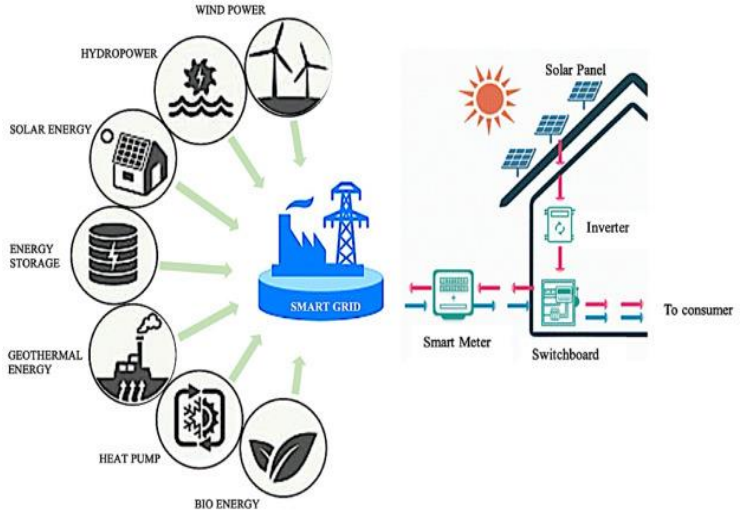

Figure 11: Viability of renewable energy resources and smart grids to meet customer energy demands.

7.2 Expanding Markets

Asia and Latin America, with their vast emerging markets, occupy an enormous potential for installing renewable thermal technologies. The growth of cities and industries in these areas also puts pressure on the energy consumption of heating and cooling devices. Asian countries such as China and India are exploring great arts to develop renewable energy facilities in their nations to meet the challenges of energy requirements while reducing the impacts of climate change (Kumar & Singh, 2018). The use of renewable thermal technologies in these markets has also been boosted by verities granted and international cooperation on the sustainable development agenda.

Although the renewable thermal solutions market is still in the developmental phase in Latin America, the region's climate makes it suitable for the further development of this sector and the rapid emergence of environmental concerns. At present, countries like Brazil and Chile are seen to initially adopt IR settings for renewable thermal technologies for the electricity sector, aided by policies concerning sustainable resources (Garcia & Martinez, 2019). Due to the availability of different types of energy resources, such as solar and geothermal assessments, the region has favorable conditions for the widespread use of renewable thermal systems. That being said, as these markets grow, the extent to which renewable thermal technology can provide essential energy solutions of scaled and varied nature will be determinant.

7.3 Regulatory Support

Renewable thermal technologies' use and implementation are strongly influenced by government policy. Policy support in terms of financial incentives, establishing standards, and omission of barriers are some of the regulatory measures that can ensure an adequate formation of policies for renewable energy. Since the five quantitative climate action plans have yet to prioritize renewable energy integration, there is a significant need to do so to foster the future growth of renewable thermal technologies. For example, the EU Green Deal and the US IRA have laid out goals for carbon reduction, which is good news for the growth of RTS (European Commission, 2020; U.S. Department of Energy, 2021).

Furthermore, such regulations are consistent and harmonized across the regions, making it easier to embrace homeowners and builders. Efficient procedures for permits, less bureaucracy in code requirements, and regulation for renewable energy installation minimized confusion and costs in executing renewable thermal systems. Global projects and knowledge sharing also play their part in rationalizing regulation by integrating changes to renewed thermal operations to fit the global market (International Energy Agency, 2020). As more governments set ambitious sustainable energy targets, the policy framework backing renewable thermal technologies will likely become more robust, fueling innovation and demand.

7.4 Integration with Smart Grids and Energy Storage

They also noted that an important aspect of the future outlook of renewable thermal technologies will be the coupling to smart grids and energy storage systems. Smart grid optimizes distribution and energy usage, allowing efficient functioning of renewable thermal systems through response to energy demand and supply (SolarEdge Energy Solutions, n.d.). Further integrated with energy storage in the form of thermal batteries or phase change materials, renewable systems provide for excess heat storage during days of high generation and release during low generation, improving system reliability and efficiency (Renewable Energy World, n.d.).

This integration between renewable thermal, smart grid, and energy storage not only enhances the energy consumption efficiency but also improves the strength and stability of the power grid. As the level of renewable energy escalates, integrates, and manages complex inputs of energy, researchers turn decisive. Some of the most important applications of renewable thermal technologies include controlling and storing energy loads, avoiding pressure on peak demands, and providing consistent access to heating and cooling services (Lee et al., 2020).

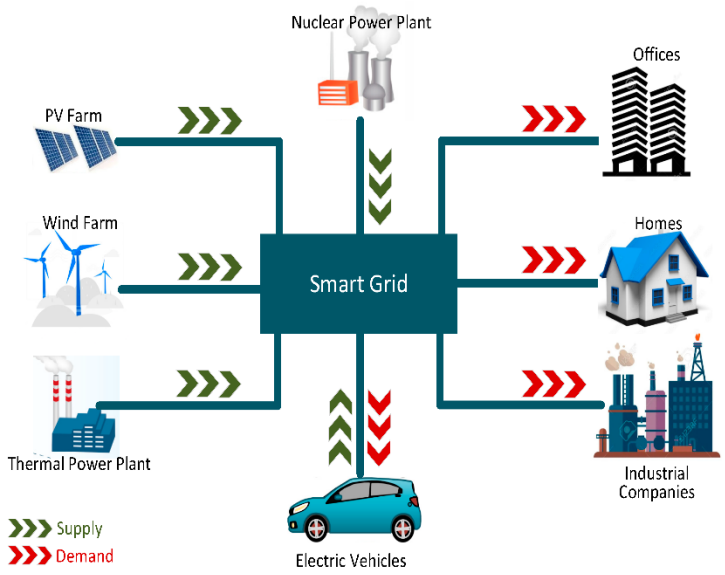

Figure 12: An illustration of the roles of EVs and other suppliers/consumers in the smart grid.

7.5 Sustainability and Environmental Impact

Sustainability and cutting environmental impacts remain important, and renewable thermal technologies will continue developing. The benefits of lifecycle and sustainable manufacturing virtually guarantee that these technologies stay green from the cradle to the grave (Miller & Thompson, 2019). Attempts to minimize the influence of renewable thermal systems on the environment and make it less damaging are increasing the sustainability of these innovations by utilizing recyclable material and energy-efficient processes in their production.

Moreover, the shift towards a more circular economy drives the creation of renewable technologies that deliver thermal energy sustainably and are efficient in their resource use. There is also a substantial potential for the

renewable thermal sector to play a role in a wide range of other sustainable environmental objectives, such as reducing waste and recycling materials (Brown & Green, 2021). Continued sentiments and awareness towards climate change and environmental degradation continue to rise, making thermal technologies relevant and key determinants of future energy consumption.

Figure 13: Major research themes in the subject of sustainable environmental technology.

8. CONCLUSION

Renewable thermal technologies are now set to be a key growth factor in the much-needed transition of residential heating and cooling units while being advantageous for homeowners in the long run. As this paper has shown, the three technologies, namely the solar thermal systems, geothermal heat pumps, and biomass boilers, offer tangible substitutes to the conventional systems that use fossil fuels for heating and cooling. They significantly decrease greenhouse gas emissions, enhance energy outputs, and support the global fight against climate change. Europe has been the first to embrace such technologies following enabling policies and incentives; moreover, America is close to following state-based policies alongside increasing environmental sensitivity. They are economically feasible for renewable thermal systems. They assist in cutting electric costs with the need to embrace cheap and renewable utilities such as solar energy, geothermal heating, and biomass. For instance, geothermal heat pumps can reduce heating and cooling expenses to as low as seventy percent; hence, they may be expensive to install but very cheap to maintain. Lawrence Berkeley National Laboratory, among other research, also indicates that homes that have renewable thermal technology in their properties cost more due to being energy-efficient sustainable homes. This added value is interesting to many environmentally friendly consumers who consider the operation cost and the carbon footprint in their dwellings.

However, several barriers do not allow the use of renewable thermal technologies on a more extensive scale. Again, high installation costs are still a significant issue discouraging homeowners, particularly those in the middle and low-income brackets. Novelty is also observed whereby homeowners' and builders' knowledge and awareness of these technologies still need to be improved. Furthermore, integrating renewable thermal systems in existing homes is complex since it requires space and structures, which may need to be more efficient today. Regulations make it more challenging to adopt because approval procedures and incentive rates differ across areas, contributing to such systems' high implementation cost and difficulty. Despite the above-mentioned limitations, various strategies have been mooted as follows. Incentives like tax credits, Institutional grants, and buying subsidies also help lower the cost of these technologies for end users. Therefore, awareness is important among homeowners, builders, and policymakers of the benefits of the rabble thermal systems, hence the need for educational campaigns. Courses and certifications for contractor technicians can ensure the necessary competencies are met, eventually leading to the installation and maintenance of such systems. Other strategies for the faster penetration of BIPV are based on the democratization of legislation and the optimization of the

procedures for obtaining permits, which will decrease the burden of bureaucracy and increase the speed affordable by companies.

Renewable thermal technologies to homes could bring huge returns on the value. Besides energy costs, these technologies improve the marketability of a home due to increasing trends of people embracing green and sustainable living. Easing air and heat emissions through renewable thermal tools increases the possibility of obtaining certifications like LEED or ENERGY STAR, which benefits homes selling in the market. With consumer awareness of the impact of green homes on the environment and their wallets deepening, prospects for properties with renewable thermal systems are set to increase. Multi-national players like Danfoss and Viessmann, NIBE Industrier AB, and SolarEdge Technologies are at the forefront of a shift towards renewable thermal systems with extended capability and increased ease of installation. The greatly appreciated contributions of these companies enable the scale-up of the production of renewable thermal solutions, better performance, and cutting costs associated with renewable thermal technologies. This, with supportive policies and increased interest by the public, augers well for the future of such technologies.

Renewable thermal technologies are new ideas that can provide an opportunity to get efficient, less expensive, and environmentally friendly heating and cooling solutions for houses. However, these barriers are not significant enough that the concerted efforts of policymakers, industry, and consumers cannot break and make full use of those technologies. As adoption is scaled up, renewable thermal systems will be able to reduce climate change impacts while improving home values to drive the change to sustainability.

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