Solar Thermal Energy for Industrial Processes: Insights from Cuenca, Ecuador

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Abstract

This study assesses the awareness and acceptance of solar thermal energy (STE) for industrial process heat among industry, local government, and academia in Ecuador, with emphasis on Cuenca City. The study was supported by surveys conducted with seven industrial facilities, six municipal governments, fifteen universities offering academic programs related to renewable energy, and six solar thermal technology providers in the country. Results show that, despite the country's interest and enormous potential for STE, limited awareness, the lack of regulatory frameworks, and the absence of financial incentives remain the main barriers to its adoption. Industries recognize STE's potential to reduce fossil-fuel consumption and CO_2 emissions, but they identify high investment costs and limited spaces for installing these systems as key constraints. Municipal governments report no existing local legislation to promote STE, while academia shows a limited focus on STE for industrial applications. Technology providers highlight low market demand due to the persistence of subsidized fossil fuels for sanitary use and cooking in Ecuador. To address these challenges, coordinated actions are required, including integrating STE into national energy strategies, implementing fiscal and economic incentives, and developing technical standards. Demonstration projects, capacity-building initiatives, and collaboration among academia, industry, and local governments are also essential. These measures would help reduce investment risks, enhance institutional capacity, and promote the large-scale deployment of STE within Ecuador's industrial energy transition.

Keywords: industrial processes, solar thermal energy, industrial sector, decarbonization, Ecuador

1. Introduction

A nation's economic performance is closely tied to the strength of its infrastructure and the availability of reliable energy across productive sectors (Bhowmik, 2018). Globally, industry accounts for about 30% of total energy consumption, making it the most energy-demanding sector (International Energy Agency, 2023). In Ecuador, the industrial sector ranked as the second-largest energy consumer in 2023, accounting for 16.6% of the country's total energy use, behind the transport sector (Ministerio de Energía y Minas, 2024). The over-reliance on fossil fuels to meet industrial energy demand underscores the need to pursue non-conventional energy sources to reduce greenhouse gas emissions and mitigate the effects of climate change. In response to this challenge, solar thermal energy (STE) has emerged as an attractive alternative for partial decarbonization of the industrial sector. Globally, by 2024, a total of 1315 Solar Heat for Industrial Processes (SHIP) plants had been installed (Spörk-Dür, 2025). However, in Ecuador's industrial sector, implementing such projects has not been a priority, despite the country's significant solar radiation potential. The Andes Highlands region has the highest solar radiation levels (4-5.9 kWh/m^2 day) on the Ecuadorian mainland, while in the Galapagos Islands it reaches up to 6.3 kWh/m^{2}day (Ordóñez and Vaca-Revelo, 2020). A critical disadvantage associated with solar thermal technology in Ecuador is the 15% value-added tax (VAT) imposed on the importation of STE systems. This contrasts with other renewable energy technologies, such as photovoltaic (PV) panels, which are exempt from import VAT (Ecuador, 2024).

Cuenca, Ecuador's third-largest city and the capital of Azuay Province, is known for its important industrial sector and its commitment to energy efficiency and environmental protection. The city has pioneered initiatives such as the country's first landfill biogas plant, a 2 MW facility that generates electricity from municipal waste, and has received

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international recognition. Cuenca's economy is dominated by services (76.5% of Gross Value Added, GVA), followed by manufacturing (20.6%) and the primary sector—agriculture, livestock, forestry, fishing, and mining—(2.9%) (Chacón et al, 2019). Within Azuay's industrial structure, 187 manufacturing facilities operate (e.g., tires, wood furniture, ceramics, cement, non-alcoholic beverages, and food processing), with 110 dedicated to food and beverage processing (Datapaís, 2021), the majority of which are concentrated in Cuenca's industrial park.

In 2022, the launch of the project Solindustrias: Solar Process Heat in Cuenca marked a significant milestone for the industrial sector of Cuenca. This initiative, jointly financed by the Government of Switzerland through the REPIC Platform, the Universidad de Cuenca, and Lácteos San Antonio, has been structured around four main components: (a) the installation of a solar thermal plant within a dairy industry that serves to evaluate the opportunities and challenges of STE in the country, (b) the evaluation of the economic, environmental, and social impacts associated with the new heating system that partially substitutes diesel, (c) the development and implementation of training programs on the design, assembly, and maintenance of STE, along with technology and knowledge transfer, and (d) the assessment of business and policy frameworks conducive to the wider adoption of STE in Ecuador's industrial sector. By 2023, the project successfully implemented the largest Solar Heat for Industrial Processes (SHIP) plant in Ecuador, located in Cuenca, consisting of a 158 m^2 array of flat-plate collectors and a 9 m^3 thermal storage unit. The system supplies hot water at 60 °C for cleaning operations at a local dairy facility (REPIC, 2022). Objectives (a), (c), and (d) were successfully achieved. This work focuses on the results of the second objective. Therefore, this article presents results on the level of acceptance of STE technologies within the industrial sector in the city of Cuenca, which is supported by the vision of academic institutions that offer academic programs on renewable energy, local governments at municipalities with geographic conditions relatively similar to those of Cuenca, and companies that market and install solar thermal systems at national level.

2. Methodology

The work's methodology consisted of surveying people directly involved with: (i) industrial companies in Cuenca, (ii) municipal governments, (iii) academic personnel in selected universities, and (iv) suppliers of solar thermal systems (STS). The industrial survey was sent exclusively to companies operating in Cuenca. For this, the people contacted at each company were directly involved in facilities' technical or energy management, whose names were provided by the corresponding company. The municipalities selected for the survey correspond to ten provincial capitals across the Ecuadorian Sierra region (on the Andes), considering their stronger solar resource and, therefore, a higher likelihood of having enacted solar-thermal regulations. Selecting this region of the country rather than the whole country was based on the idea that industrial facilities operating in places with relatively similar climates and geographic conditions to Cuenca could provide a better insight into industrial perceptions of solar thermal energy. The surveys were filled out by personnel directly involved in environmental management in each municipality. The universities surveyed, conversely, were seventeen targeted academic institutions in Ecuador with programs related to renewable energy. The survey was sent to people involved in teaching and/or research aligned with renewable energies or energy management. The survey to suppliers was sent to 10 Ecuadorian companies that market and install solar thermal equipment, covering all companies in the country that offer this service. All questionnaires were emailed and completed online in June-July 2024.

The industrial sector in Cuenca includes a high proportion of companies dedicated to food and beverage production—an area particularly well-suited for the application of solar thermal energy, given that many of its processes require heat within the range of 50 to 90°C. A sample of thirty companies was selected for the study, and a 15-question survey was distributed, focusing on their awareness and interest in solar thermal energy.

In the case of municipalities, an 8-question survey was distributed to ten municipalities located in areas with high solar radiation, with industries that use low- and medium-temperature processes well-suited to solar applications, and that may already have established legal frameworks for solar thermal energy.

Academia also plays a fundamental role in promoting solar thermal energy in the industrial sector, as research efforts and academics promote and support project implementation. In this study, a 13-question survey was distributed to seventeen universities offering programs in renewable energy-related fields.

Solar thermal system providers also play a key role, as the type and quality of the technology they offer or install largely depend on them. Moreover, their level of market experience and the business models they use to deliver their services are critical factors in expanding the solar thermal market in the country. An online search identified twenty-nine providers operating in Ecuador, and a 15-question survey was sent to them, aiming to gather their experiences and perspectives on the use of STE in the country. The information received was tabulated and processed accordingly

to draw conclusions regarding the potential implementation of solar thermal energy in Cuenca's industrial sector.

3. Results

3.1. Industry

Seven out of the thirty industrial companies filled out the survey, including four from food producers and three from beverage producers. The survey revealed that a significant portion of the processes in these industries require low-temperature heat, indicating the potential to integrate solar thermal technologies to meet part of their energy demand. These processes are shown in Figure 1, where preheating of boiler feedwater, pasteurization, and cleaning and washing are the most relevant processes for these seven companies. These processes are characterized by the use of hot water at temperatures below 100°C.

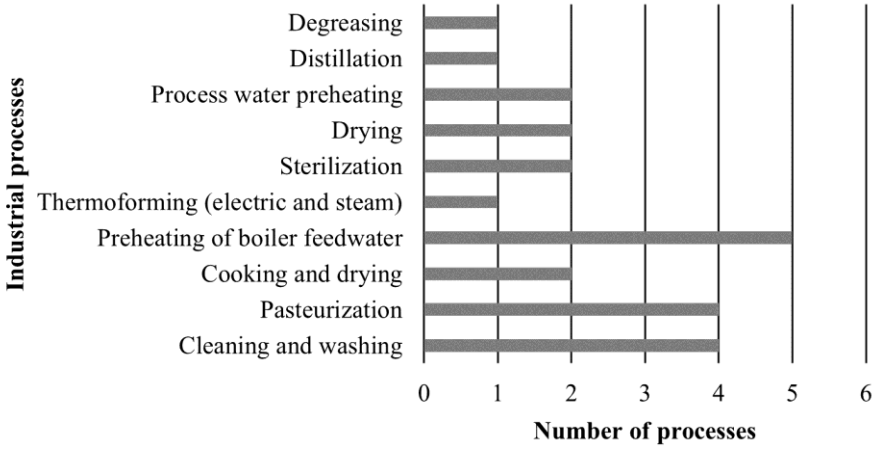

Figure 1: Results from the industry survey on existing processes.

Regarding the energy sources currently used, five of the surveyed companies rely on diesel fuel, and two use liquefied petroleum gas (LPG); only one plans to switch fuels in the future (from diesel to LPG). Unlike other countries in the region, natural gas (NG) is not widely used in Ecuador's industrial sector. The main barriers—especially for small and medium-sized companies—are the lack of infrastructure (pipelines and distribution networks to major industrial hubs), regulatory uncertainty, and dispersed demand across the Andean terrain. Only large industries such as ceramics, cement, glass, and plastics import NG to supply their thermal processes (Ministerio de Energía y Minas, 2024).

The survey also revealed that only one company is familiar with using solar thermal energy for industrial process heat generation, while the remaining six are slightly familiar or have no knowledge of how to harness solar energy for heat production. Industries also expressed interest in adopting this technology if it leads to savings in fossil fuel consumption at their plants. When asked about their interest in receiving training on the application of solar thermal energy in industrial processes, all companies indicated their willingness to participate in a capacity-building program in this area.

In the survey, six evaluation criteria were presented, and companies were asked to select the most important for adopting a solar thermal system as a heat source. The results, as shown in Figure 2, suggest that companies will reduce fossil-fuel use when the chosen technology provides clear economic gains. The results also indicate that local equipment availability is of limited relevance; if returns are attractive, companies are willing to import STS. By comparison, the efficiency of solar thermal technologies, corporate image, and upfront capital cost rank as secondary considerations.

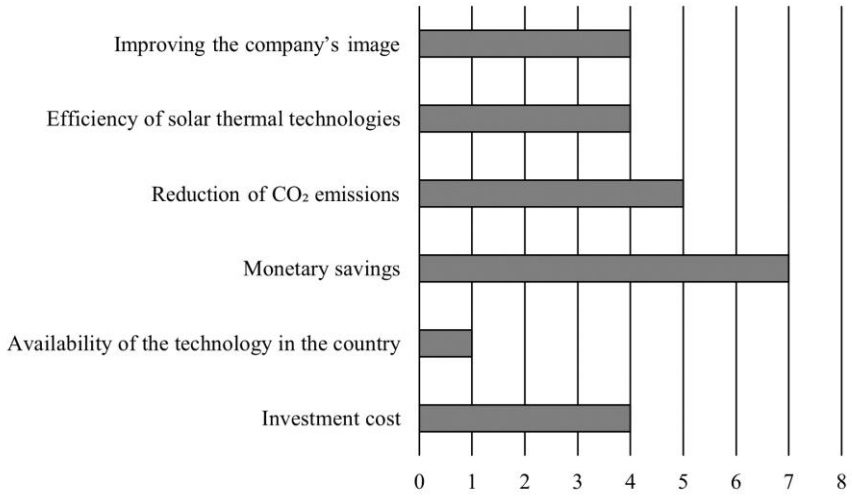

Figure 2. Evaluation criteria for adopting solar thermal energy systems.

When companies were asked about the challenges and limitations of installing solar thermal systems, they identified the high initial capital investment as the principal barrier. Considering that these technologies continue to exhibit elevated market costs, coupled with the absence of government incentives, and relatively low fossil fuel prices in Ecuador, such investments represent a significant constraint for many industrial firms. Likewise, the companies noted that the requirement for additional space to accommodate the equipment may pose a constraint on integrating these systems. In some cases, the existing industrial infrastructure poses limitations, including insufficient available space, inadequate structural roof load capacity to support the collectors, or rooftop locations that hinder equipment placement due to orientation and steepness. Conversely, factors such as installation complexity, operational intermittency, and system reliability are also regarded as drawbacks. However, these are considered less critical limitations by the surveyed industries.

The surveyed companies were asked to indicate whether they consider fiscal and financial incentives important. Four firms expressed strong agreement with this statement, while the remaining three indicated some agreement.

3.2 Municipal Governments

Municipal Governments in Ecuador hold political, administrative, and financial autonomy, positioning them as key actors in promoting renewable energy at the local level. From this stakeholder group, six of the ten surveyed municipalities (Ambato, Cuenca, Ibarra, Loja, Quito, and Riobamba) completed the survey.

Survey results reveal that none of the responding municipalities have enacted ordinances or programs to promote the use of solar thermal energy in the industrial sector. Only one municipal government reported that it is in the process of drafting such a regulation, highlighting the current lack of political prioritization for clean energy technologies.

Regarding initiatives or programs in which local governments have collaborated with other institutions to promote solar thermal energy, only two entities reported having participated in such activities. However, they did not provide specific details regarding the programs or projects in which they were involved.

An important question addressed to the municipalities sought to identify the most effective strategies for promoting the use of solar thermal energy within their jurisdictions. As illustrated in Figure 3, international cooperation funding was identified as the most effective mechanism for advancing this initiative. The second most selected option was the implementation of pilot projects, combined with awareness campaigns, highlighting the benefits of implementing STE in different economic sectors. Conversely, local governments did not perceive the formulation of local ordinances as a relevant strategy for this purpose.

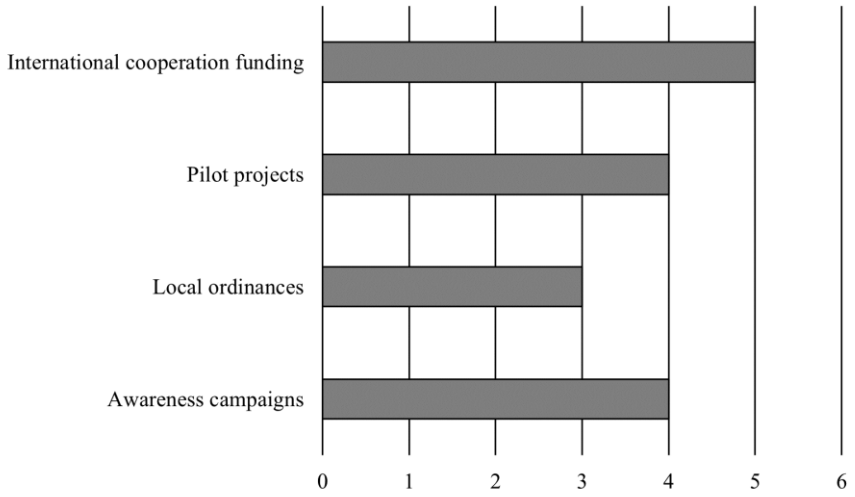

Figure 3. Strategies for promoting the use of solar thermal energy within municipalities' jurisdictions.

Although 50% of the surveyed municipalities reported maintaining strong collaborative relationships with academia and the private sector, the majority have not yet participated in solar thermal initiatives. This finding suggests that, despite an existing framework for inter-institutional cooperation, such collaboration has not been effectively directed toward the development or implementation of renewable heat projects.

3.3 Universities

Out of the fifteen universities that responded to the survey, eleven offer undergraduate or graduate programs in renewable energy. Table 1 presents the academic institutions that responded to the study, along with their geographical locations in Ecuador.

Table 1. Higher Education Institutions participating in this survey.

Region	Universities
Coast	Escuela Superior Politécnica del Litoral ESPOL
Andean	Universidad Técnica del Norte UTN, Escuela Politécnica Nacional EPN, Universidad San Francisco de Quito USFQ, Universidad Central del Ecuador, Universidad Internacional SEK, Universidad Internacional del Ecuador UIDE, Universidad del Azuay, Universidad Politécnica Salesiana, Universidad Católica de Cuenca, Universidad de Cuenca, Universidad Nacional de Loja, Universidad Técnica Particular de Loja UTPL
Amazonian Region	Universidad Regional Amazónica IKIAM

Most of the surveyed universities have placed greater emphasis on teaching and research related to PV power, biomass, and wind power. However, solar thermal and hydropower technologies also represent energy resources with considerable potential for development in the country. Figure 4 illustrates the main topics addressed in teaching and research within academic institutions.

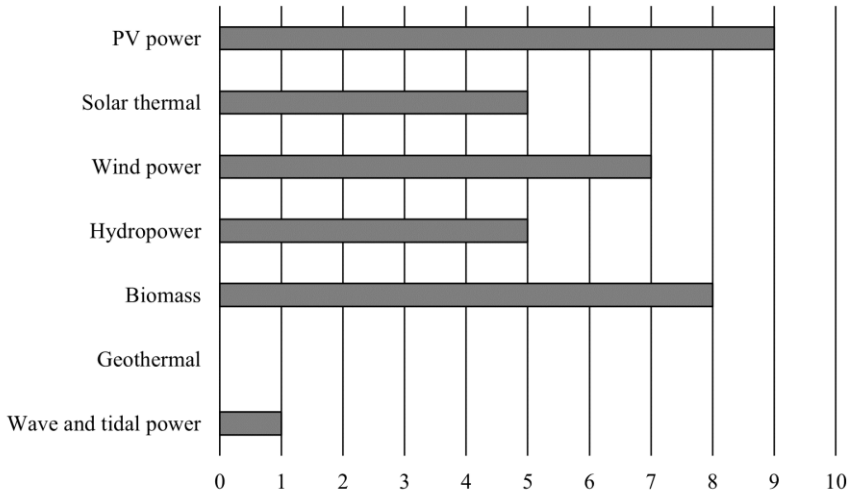

Figure 4. Renewable energy topics associated with universities.

Only four of the fifteen universities have offered courses or training programs specifically focused on solar thermal energy. This limited inclusion of STE in academic programs reflects the broader trend in Ecuadorian academia, where renewable energy curricula have primarily emphasized photovoltaic, wind, and biomass technologies. The limited academic coverage of solar thermal topics suggests a need to strengthen specialized training and research in this field, particularly given its potential contribution to industrial decarbonization and sustainable energy diversification in the country.

Among those universities working on solar thermal energy, research is primarily focused on household water heating, electricity generation, and space heating and cooling. In contrast, applications such as industrial processes, pool heating, and desalination receive comparatively less attention. Figure 5 shows the results of this question.

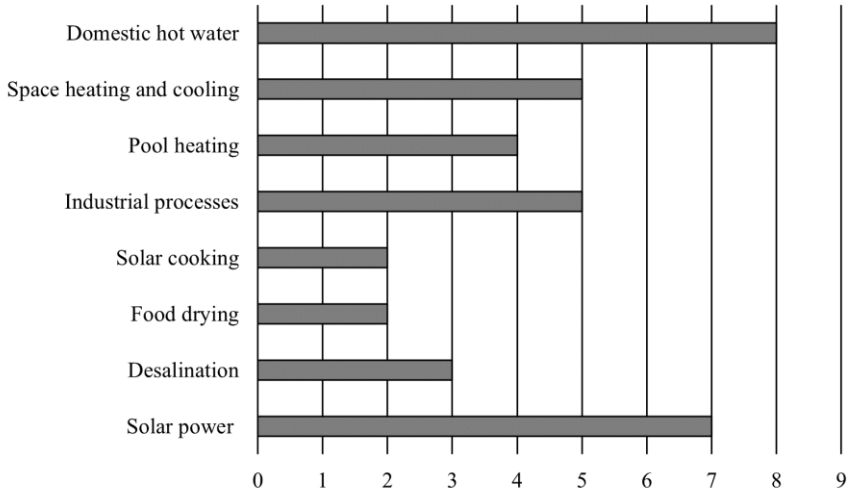

Figure 5. Research topics on solar thermal energy in universities.

When asked about the future potential for solar thermal energy growth in the Ecuadorian industry, using a 5-point scale from 1 (“very low”) to 5 (“very high”), eight respondents expressed high expectations, two rated it medium, and five rated it low. This indicates that more than half of the academic personnel surveyed hold an optimistic outlook on the expansion of solar thermal technologies in the country. However, advancing this area requires government support through regulatory frameworks that provide financial and tax incentives to promote solar thermal plant installations in industries with higher potential for STE systems. Overall, 40% of the surveyed academics agreed that applying for international cooperation funds is the most effective way to support research and development projects related to solar thermal energy systems, while 33% of academics agreed that cooperation among universities, industries, and local governments is the most effective option.

3.4 Solar thermal system providers

The survey was distributed to twenty-nine companies that sell and/or offer technical services related to STE;

however, only six responded. This limited level of participation does not allow for a complete understanding of the status and interest of the solar thermal system supplier market in Ecuador. Nevertheless, the results constitute an initial step toward obtaining a general overview of the sector's current structure and identifying potential measures for future improvement.

Based on responses from six companies providing solar thermal energy services, it was found that all engage in importing, selling, designing, installing, and maintaining solar thermal system components. Two of these companies manufacture solar collectors domestically, while another offers a power purchase agreement (PPA) as its business model.

Most of these companies have over 10 years of experience and serve various economic sectors. Domestic hot water and swimming pool heating constitute the primary applications in which all six surveyed companies have provided services. Additionally, four companies have participated in projects involving heat supply for industrial processes (i.e., hot water), while three have been engaged in space heating and cooling, as well as electricity generation. In contrast, applications such as food cooking, food drying, and desalination have been addressed by fewer than three of the surveyed companies.

The most commonly offered solar thermal technologies include flat-plate and unglazed collectors, accompanied by complementary system components such as circulation pumps, control systems, storage tanks, and piping. Five of the surveyed companies provided information on the total installed area of solar collectors across various sectors, as presented in Table 2.

Table 2: Total installed area of solar collectors by sector and company (m^2).

Company	Residential sector	Industrial sector	Commercial and services sector
A	12 000	4 000	5 000
B	100	100	-
C	100	-	320
D	10 000	-	5 000
E	6 400	360	1 490
Total	**28 600**	**4 460**	**11 810**

Although the available information is limited, the responses from companies selling STE systems in Ecuador suggest that solar thermal energy in the country has primarily expanded for domestic hot-water and swimming-pool heating applications. Geographically, the majority of the systems have been installed in the Andean region provinces, which can be explained by the necessity of domestic hot water in this region, which is colder than the Coastal and Amazonian regions. For the industrial sector, the reported 4 460 m² of installed collector area should be validated to identify the types of industries, the types of solar collectors, and the specific processes in which solar heat has been applied.

In the survey, companies were asked to assess the importance of five strategies to increase the installation of solar thermal systems in Ecuador. Respondents rated each strategy using a five-point scale ranging from "Not important" (1) to "Very important" (5). Five of the six surveyed companies identified the removal of fossil-fuel subsidies in the country and the dissemination of information regarding the benefits of solar thermal energy as very important measures. Additionally, four companies emphasized the significance of implementing fiscal and economic incentives, along with regulatory frameworks that promote the installation of solar thermal systems. Conversely, the promotion of domestic manufacturing of solar thermal equipment was considered relatively unimportant by most companies. Figure 6 presents the perceived importance of five strategies as evaluated by six solar thermal service providers.

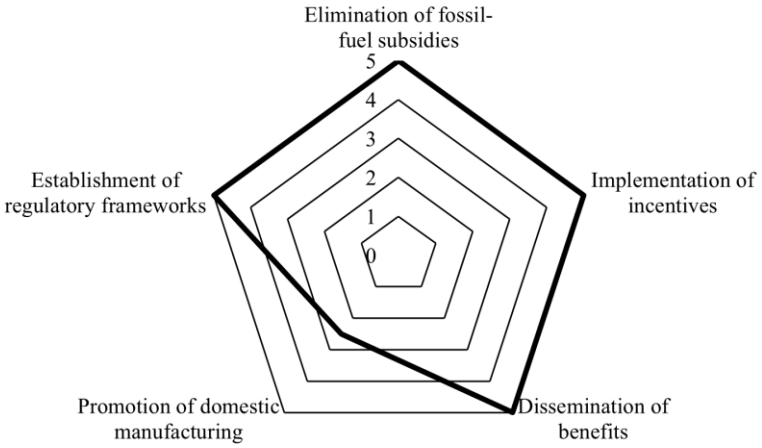

Figure 6. Perceived importance of strategies for increasing solar thermal systems in Ecuador.

4. Conclusions

According to the seven companies surveyed, the industrial sector in Cuenca demonstrates limited familiarity with solar thermal energy as an alternative heat source for industrial processes. Nevertheless, after receiving an explanation of the technology's operation, most respondents expressed interest in its potential application, identifying reduced fuel costs and CO_2 emissions mitigation as their primary motivations for adoption. Despite this positive disposition, industries highlighted the high capital investment and the requirement for additional installation space as the main constraints to implementation. Finally, the surveyed companies concurred that fiscal and economic incentives are essential tools to facilitate initial investment and reduce the financial barriers to deploying solar thermal systems.

Based on responses from the six municipal governments surveyed, none have established ordinances or legal frameworks to promote the use of solar thermal energy, and most have not previously participated as collaborating entities in the execution of STE projects. Nevertheless, the majority of municipalities identified securing international funding, disseminating information, and implementing pilot projects as the principal strategies to be considered for fostering the adoption of solar thermal energy in the country. Regarding institutional collaboration, most municipalities reported maintaining close relationships with the industrial sector and academia; however, they acknowledged a lack of direct involvement in solar thermal initiatives to date, except in the municipal government of Cuenca.

Based on responses from fifteen universities, it was determined that most institutions are actively engaged in knowledge-generation activities related to solar thermal energy. However, these efforts are primarily focused on applications such as domestic hot-water heating, electricity generation, and space heating and cooling. In contrast, only four reported directing their academic or research activities toward solar thermal energy for industrial processes. Furthermore, the majority of the faculty members and researchers surveyed anticipate a high growth potential for solar thermal energy in Ecuador in the coming years. Nonetheless, only half of the respondents consider that this potential will extend significantly to the industrial sector. To enhance the future development of solar thermal technologies, academic representatives identified two key priorities: securing funding for research projects and strengthening collaboration among academia, industry, and municipal governments.

Based on responses from six companies engaged in solar thermal energy services, it was found that all are involved in the import, sale, design, installation, and maintenance of solar thermal system components. Most of these companies, each with over ten years of market experience, provide services across multiple economic sectors, with domestic hot-water and swimming-pool heating identified among the most frequently requested applications. The most commonly offered technologies include flat-plate and unglazed solar collectors, along with auxiliary components such as circulation pumps, control systems, storage tanks, and piping. Geographically, the majority of installations have been concentrated in Ecuador's Andean region. To foster wider adoption, the respondents emphasized that eliminating fossil-fuel subsidies and disseminating information on the benefits of solar thermal energy are the most effective strategies to pursue.

The study suggests significant industrial interest in solar thermal energy, and the academic sector believes that this

technology will grow in the coming years. However, the lack of specific, local legal frameworks can pose significant barriers for the expansion of solar heating systems, especially in the industrial sector. Therefore, further efforts should focus primarily on creating legal frameworks that motivate industries to adopt these systems.

5. Acknowledgments

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