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SolInd2Service – Solar process heat in Swiss industry and service sectors

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Table of Contents

Summary

In this project, the potential of solar heat for the Swiss service sector was analyzed. 9 % of the total energy demand of Switzerland is caused by the service sectors thermal energy demand. This demand is caused by room heating and hot water applications: Car washing, hotel and food services, hospitals, veterinary and residential care, sports facilities and laundries. All of those subsectors require hot water at moderate temperatures suitable for solar heat below 90 °C. 76 % of the service sector's heat demand is currently met by non-renewable sources, leading to 2.5 TWh of non-renewable hot water demand in use in Switzerland, which could be replaced by solar thermal systems.
Still, market penetration and interest in solar thermal in the service sector is low, which is shown by a low response rate (< 2 %) of the conducted survey. According to the survey, the main barriers are high initial investment cost, the required long-term commitment, complex installations and a perceived risk. These barriers should be tackled to help solar thermal reach the goals of the energy strategy 2050.

Six case studies showed that the price of solar heat can compete with the current heat prize, providing heat at 8.6 - 11.6 Rp/kWh for suitable companies and processes over a lifetime of 25 years. The calculated solar thermal payback time (ø 16.4 y) was higher than the stated acceptable payback time in the case studies (ø 15.8 y) and the survey (most answers: 7 - 10 y). While the payback and cost of heat is comparable with the one of fossil fuels (6 – 9 Rp/kWh), it cannot compete with other investments in terms of payback time.
A calculation of the Levelized Cost of Carbon Abatement (LCCA) was conducted, which is a means to measure the CO_2 reduction generated by a specific investment. The LCCA was found to be between - 64 and 532 CHF/tCO_{2eq} for substituting gas and between – 16 and 438 CHF/tCO_{2eq} for substituting oil. This shows that when CO_2 taxes or oil and gas prices rise, solar thermal will become economically favourable compared to fossil fuels.

Standardized and guaranteed subsidies would help to mitigate a perceived risk and reduce the time of return of investment. Most respondents of the survey expressed a desire for subsidies between 30 to 40 % of the investment cost, which still is low compared to subsidies in Switzerland's neighboring countries. The initial investment cost and payback time could also be reduced by using new financing models, e.g. power contracting models or special purpose vehicles that are already used successfully either abroad or for photovoltaic plants. These financing models move the coordination effort and the initial investment cost from the heat consumer to a third party organization. The consumer agrees to purchase the energy for a fixed price for a certain duration. Higher subsidies and higher CO_2 taxes can promote this kind of financing and business model substantially, as it is done in Germany or Austria.

Dissemination and information material was created to familiarize with and to promote solar thermal plants, such that a perceived risk of this technology can be reduced. 7 companies of the service sector that currently use solar heat were portrayed in an information brochure that can be used to showcase real examples within the service sector. The SolInd tool was updated to facilitate utilization for the service sector with pre-made demand profiles and adapted cost structure for smaller collector field areas.

Zusammenfassung

In diesem Projekt wurde das Potenzial von Solarwärme im Schweizer Dienstleistungssektor analysiert. 9 % des gesamten Energiebedarfs der Schweiz wird durch den Wärmeenergiebedarf des Dienstleistungssektors verursacht, welcher aus Raumheizung und Warmwasseranwendungen besteht. Autowaschanlagen, Hotel- und Gastgewerbe, Spitäler, Tierpflege und Pflegeheime, Sportanlagen und Wäschereien sind die vorherrschenden Bereiche, von denen alle Warmwasser für Solarwärme geeignete Temperaturen unter 90 °C benötigen. 76 % des Wärmebedarfs des Dienstleistungssektors wird derzeit durch nicht erneuerbare Quellen gedeckt. Das bedeutet, dass ein Warmwasserbedarf von 2,5 TWh in der Schweiz könnte durch solarthermische Systeme gedeckt werde.
Dennoch sind die Marktdurchdringung und das Interesse an Solarthermie im Dienstleistungssektor gering, was durch eine niedrige Rücklaufquote (< 2 %) der durchgeführten Umfrage belegt wird. Der Umfrage zufolge sind die Haupthindernisse hohe Anfangsinvestitionskosten, das erforderliche langfristige Engagement, komplexe Installationen und ein wahrgenommenes Risiko. Diese Hindernisse sollten beseitigt werden, damit die für die Solarthermie gesteckten Ziele der Energiestrategie 2050 erreichen werden können.

Sechs Fallstudien haben gezeigt, dass der Preis der Solarwärme mit dem aktuellen Wärmepreis konkurrieren kann, da sie für geeignete Unternehmen und Prozesse über eine Lebensdauer von 25 Jahren Wärme zu 8,6 - 11,6 Rp/kWh liefern kann. Die berechnete solarthermische Amortisationszeit in den Fallstudien (ø 16,4 Jahre) war höher als die in den Fallstudien (ø 15,8 Jahre) und in der Umfrage angegebene akzeptable Amortisationszeit (die meisten Antworten: 7 - 10 Jahre). Während die Rendite und die Kosten der Wärme mit denen der fossilen Brennstoffe (6 - 9 Rp/kWh) vergleichbar sind, kann sie in Bezug auf die Amortisationszeit nicht mit anderen Investitionen konkurrieren.
Die "Levelized Cost of Carbon Abatement" (LCCA) wurden berechnet, mit welchen die durch eine bestimmte Investition erzielte CO_2-Reduktion gemessen werden kann. Die LCCA liegen zwischen – 64 und 532 CHF/tCO_{2eq} für die Substitution von Gas und zwischen – 16 und 438 CHF/tCO_{2eq} für die Substitution von Öl. Dies zeigt, dass bei steigenden CO_2-Steuern oder Öl- und Gaspreisen die Solarthermie im Vergleich zu fossilen Energieträgern wirtschaftlich vorteilhaft wird.

Standardisierte und garantierte Subventionen würden dazu beitragen, das wahrgenommene Risiko zu mindern und die Amortisationszeit zu verkürzen. Die meisten Antworten der Umfrage wünschen sich Subventionen zwischen 30 und 40 % der Investitionskosten, was im Vergleich zu den Subventionen in den Nachbarländern der Schweiz noch immer niedrig ist.
Die anfänglichen Investitionskosten und die Amortisationszeit könnten auch durch den Einsatz neuer Finanzierungsmodelle reduziert werden, z.B. durch Power-Contracting-Modelle oder Zweckgesellschaften, die im Ausland oder bei Photovoltaikanlagen bereits erfolgreich eingesetzt werden. Bei diesen Finanzierungsmodellen werden der Koordinierungsaufwand und die anfänglichen Investitionskosten vom Wärmeverbraucher auf Dritte ausgelagert. Der Verbraucher verpflichtet sich lediglich, die Energie zu einem festen Preis für eine bestimmte Dauer abzunehmen. Höhere Subventionen und höhere CO_2-Steuern können diese Art von Finanzierungs- und Geschäftsmodellen erheblich fördern, wie es in Deutschland oder Österreich der Fall ist.

Informationsmaterial wurde erstellt, um Wissen über solarthermische Anlagen zu verbreiten und zu fördern. 7 Unternehmen des Dienstleistungssektors, die derzeit Solarthermie nutzen, wurden in einer Informationsbroschüre porträtiert. Weiterhin wurde das SolInd-Tool aktualisiert, damit auch Nutzer des Dienstleistungssektors schnell und unkompliziert einfache Machbarkeitsvorstudien und Kostenschätzungen machen können. Dazu wurden vorgefertigte Bedarfsprofile und für die Dienstleistungsgesellschaft angepasste Kostenstrukturen für kleinere Kollektorfelder implementiert und die Handhabung des Tools stark vereinfacht.

Résumé

Dans ce projet, le potentiel de la chaleur solaire pour le secteur tertiaire suisse a été analysé. 9% de la demande totale d'énergie en Suisse est due aux besoins en énergie thermique du secteur tertiaire, qui se compose du chauffage des locaux et des applications d'eau chaude: lavage de voitures, hôtellerie et restauration, hôpitaux, soins vétérinaires et maisons de retraite, installations sportives et blanchisseries. Tous ces sous-secteurs ont besoin d'eau chaude à des températures inférieures à 90 °C et sont donc adaptés à la chaleur solaire. 76% des besoins en chaleur du secteur tertiaire sont actuellement couverts par des sources non renouvelables. Cela signifie qu'une demande d'eau chaude de 2,5 TWh en Suisse pourrait être satisfaite par des systèmes solaires thermiques.

Cependant, la progression du marché et l'intérêt pour le solaire thermique dans le secteur tertiaire sont faibles, comme en témoigne le faible taux de réponses (< 2 %) au sondage mené. Selon le sondage, les principaux obstacles sont le coût élevé de l'investissement initial, l'engagement à long terme requis, les installations complexes et le risque perçu. Ces obstacles doivent être levés pour aider le solaire thermique à atteindre les objectifs de la stratégie énergétique 2050.

Six cas d'études ont montré que le prix de la chaleur solaire peut concurrencer le prix actuel de la chaleur, en fournissant de la chaleur à 8,6 - 11,6 ct/kWh pour les entreprises et les processus appropriés sur une durée de vie de 25 ans. Le temps de retour sur investissement du solaire thermique calculé (ø 16,4 ans) était plus élevé que le temps de retour sur investissement acceptable dans les cas d'études (ø 15,8 ans) et dans le sondage (la plupart des réponses : 7-10 ans). Bien que le retour sur investissement et le coût de la chaleur soient comparables à ceux des combustibles fossiles (6 - 9 ct/kWh), il ne peut pas rivaliser avec d'autres investissements en termes de temps de retour sur investissement.

Le "Levelized Cost of Carbon Abatement" (LCCA) a été calculé ce qui permet de mesurer la réduction des émissions de CO2 obtenue par un investissement spécifique. Les LCCA varient entre - 64 et 532 CHF/tCO_{2eq} pour la substitution du gaz et entre - 16 et 438 CHF/tCO_{2eq} pour la substitution du pétrole. Cela montre qu'en cas d'augmentation des taxes sur le CO_2 ou des prix du pétrole et du gaz, le solaire thermique devient économiquement avantageux par rapport aux énergies fossiles.

Des subventions standardisées et garanties contribuent à réduire le risque perçu et à raccourcir le temps de retour sur investissement. La plupart des réponses au sondage souhaitent des subventions comprises entre 30 et 40 % des coûts d'investissement, ce qui reste faible par rapport aux subventions accordées dans les pays voisins de la Suisse.

Le coût d'investissement initial et le temps de retour sur investissement pourraient également être réduits en utilisant de nouveaux modèles de financement, par exemple des modèles de contrats d'électricité ou des sociétés de service énergétique (ESCO), qui sont déjà utilisés avec succès à l'étranger ou pour les installations photovoltaïques. Dans ces modèles de financement, l'effort de coordination et le coût d'investissement initial sont transférés du consommateur de chaleur à des tiers. Le consommateur s'engage simplement à acheter l'énergie à un prix fixe pour une durée déterminée. Des subventions plus importantes et des taxes sur le CO_2 plus élevées peuvent favoriser considérablement ce type de financement et de modèle économique, comme c'est le cas en Allemagne ou en Autriche.

Du matériel de diffusion et d'information a été créé pour faire connaître et promouvoir les installations solaires thermiques, afin de réduire la perception du risque lié à cette technologie. Le portrait de 7 entreprises du secteur tertiaire qui utilisent actuellement l'énergie solaire thermique a été publié dans une brochure d'information. En outre, l'outil SolInd a été mis à jour pour permettre aux utilisateurs du secteur tertiaire de réaliser rapidement et facilement des études de faisabilité simples et des estimations de coûts. Pour ce faire, des profils de besoins prédéfinis et des structures de coûts adaptées au secteur tertiaire ont été mis en place pour les petits champs de capteurs et l'utilisation de l'outil a été fortement simplifiée.

Project Goals

The project Solind2Service aims to push the energy transition in the Swiss service sector and replacing a part of fossil fuels use for process heating by solar thermal systems. For this purpose, the following tasks were defined:

1. Identification of the techno-economic potential of solar thermal systems in the service sector by identifying suitable applications and users in this sector (WP1).
2. Adaptation of the excel-based SOLIND tool for the service sector, a user-friendly tool developed in the previous SolInd Swiss project to realize quick feasibility studies on solar thermal systems in service and industry sectors (WP2)
3. Increase the awareness of the potential of solar heat in the service sector by providing promotion materials (WP3)
4. Identify business models and funding opportunities to boost the implementation of solar thermal energy in industry and service sectors (WP2)
5. Performing feasibility studies and potential end-users with the ultimate goal of realizing new solar thermal plants (WP2)

1. Introduction

The service sector consumes 17.3% of the final energy consumption in Switzerland (SFOE, 2021). More than half of the energy consumed in this sector is used to provide low temperature heat (<120 °C) for space heating, domestic hot water and process heat. Despite the lower temperatures required, the service sector has an even higher share of fossil fuels for heat generation (78 %) than the industrial sector. The industrial sector consumes 19.5 % of the final energy consumption (2020) in Switzerland and 66 % of the heat consumed by this sector is produced from fossil fuels. The lower temperature range of the service and industrial sector bares a high potential for the CO_2-neutral solar thermal energy, which has been widely used in the domestic sector and has proven to be an efficient and reliable, climate-friendly heat source. Additionally, solar thermal provides heat at constant cost over the lifetime of the installation which is independent of the international fuel market. This helps to mitigate the risk of unforeseeable energy prices and political implications. Both the industry and the service sector have yet to exploit the advantages of solar thermal energy to its full potential.

One reason why this technology is not widely applied yet, is that these sectors have little information about the existence and potential of these systems, since heat generation lies outside of their field of activity. Another reason is that despite solar thermal shows competitive heat prices, the financial barrier remains to be overcome, because the investment cost (CAPEX)[1] remains high.

This project aims to provide incentive indicators and standardized tools to push the energy transition in the service sector by partially replace fossil fuels use in process heating with solar thermal energy.

For this purpose, first the techno-economic potential of solar thermal systems in the service sector is determined by identifying suitable applications and users in this sector. Then the SolInd tool, a user-friendly, excel based tool developed in the Sol-Ind Swiss project, has been extended to reach more potential users throughout simple feasibility studies of this low CO_2 impact heat generation technology. Finally, new business and financing models are investigated as well as cantonal funding opportunities and recommendation are made of how to overcome the economic barriers for solar process heat systems.

The preceding project Sol-Ind Swiss has revealed the potential of solar process heat in Switzerland's industrial sector. The encouraging results are used to promote this kind of systems. It was shown that for low temperatures (<120°C), solar systems have many advantages, including a fixed energy price over 20 years that is already competitive compared to fossil fuel prices, a reduction in environmental impact and CO_2 emissions, and a positive brand image to the company. The project SolInd2Service investigates if and how these results can be adapted to Switzerland's service sector.

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[1] *capital expenditures*

2. Investigation of the service sector energy situation

2.1 Market analysis

The service sector, also referred to as tertiary sector, is a highly heterogeneous group of consumers that includes trade, commercial and diverse service activities. This comprises offices, hotels, restaurants, shops, schools, hospitals, sports and leisure centers, etc. In 2019, around 37 TWh or 16 % of the total final energy consumption in Switzerland were accounted for by this sector alone, behind transport, households and industry (which account for 38 %, 27 % and 18 % of energy consumption, respectively) (SFOE, 2020a). In most OECD countries, electricity and natural gas are the dominant energy carriers in the energy mix of the service sector (Fleischmann, 2015) with the power demand accounting for one quarter to one third of the total national power demand (Brauner, et al., 2013). A similar trend is observed in Switzerland except that heating oil is still ahead of natural gas in terms of dominant energy carriers.

The aim of this study is to identify the potential of conventional solar thermal systems, such as flat plate or evacuated collectors, for heating applications in the service sector. The most suitable Swiss consumer groups for its implementation in this sector are determined. This is a follow-up project to the Sol-Ind project (Caflisch, et al., 2019) that addressed the same topic in the industry sector. In this study, an analysis of the Swiss service sector energy consumption is carried out to obtain the amount of thermal energy consumed for heating applications. Subsequently, the consumer groups for which the energy demand is suited to be provided by conventional solar thermal systems are identified. The heterogeneity of the service sector with respect to activities and end-uses requires detailed disaggregated data to infer the potential for solar thermal integration. Currently, energy statistics for this sector are sparse in Switzerland with most specific results published by the Swiss Federal Office of Statistics (SFOS) for the trade branch.

2.1.1 Service sector classification

As for the Sol-Ind Swiss project (Caflisch, et al., 2019), the consumer groups used in this study comply with the NOGA 2008 classification of economic activities often used by the Swiss Federal Office of Statistics (SFOS, 2008a). Seven service sectors identical to the classification structure used in the study of (SFOE, 2012) were identified. For further information regarding the economic divisions, please refer to (SFOS, 2008b). Table 1 presents the categorisation used in this study. It shows seven service activities and their corresponding economic divisions, according to NOGA 2008 classification.

Table 1 Service sectors and their economic division according to NOGA 2008

Service Sector	**Designation**	**Economic divisions according to NOGA**	**Description**
13	TRADE	45 ; 46 ; 47 ; 95	Wholesale and retail trade; repair of motor vehicles and motorcycles
14	HOTEL	55 ; 56	Accommodation and food service activities
15	CREDIT INSURANCE	64 ; 65 ; 66.11 ; 66.12 ; 66.19 ; 66.21 ; 66.22 ; 66.30	Financial and insurance activities
16	ADMINISTRATION	66.29 ; 84	Public administration and defence; compulsory social work; other auxiliary insurance activities
17	EDUCATION	85.10 ; 85.20 ; 85.31 ; 85.32 ; 85.41 ; 85.42 ; 85.51-53 ; 85.59	Education
18	SOCIAL MANAGEMENT	75 ; 86 ; 87 ; 88	Human health and social work activities; veterinary activities
19	OTHER SERVICES	33 ; 36 ; 37 ; 38 ; 39 ; 49 ; 50 ; 51 ; 52 ; 53 ; 58 ; 59 ; 60 ; 61 ; 62 ; 63 ; 68 ; 69 ; 70 ; 71 ; 72 ; 73 ; 74 ; 77 ; 78 ; 79 ; 80 ; 81 ; 82 ; 85.60 ; 90 ; 91 ; 92 ; 93 ; 94 ; 96	Repair and installation of machinery and equipment; water supply; sewerage, waste management and remediation activities; transportation and storage; information and communication; real estate, professional, scientific and technical activities; administrative and support service activities; arts, entertainment and recreation activities; membership organisations activities; other personal service activities

2.1.2 Swiss service sector energy consumption

The aim of this chapter is to analyse the energy consumption of the Swiss service sector. This is performed by considering both the total energy consumption (electricity and heat) and the thermal energy consumption (heat only). Firstly, the share of heat demand in the service sector and the corresponding share in the total energy consumption of Switzerland is presented. Secondly, an analysis is made on the energy consumption of each consumer group in the service sector, considering both electricity and heat consumption.

2.1.2.1 Total national and service sector energy consumption

The Swiss Federal Office of Energy (SFOE) annually publishes the Swiss Overall Energy Statistics, which gives the consumption of electricity and thermal energy, by energy carrier, across Switzerland and for each group of consumers. The following analysis was conducted using data corresponding to the energy consumed in 2019 (SFOE, 2020a).

In a first step, all energy sources are grouped together to observe the overall consumption of electricity and heat in Switzerland and for the Swiss service sector, see Table 2.

Table 2 Final energy consumption in Switzerland 2019 (SFOE, 2020a).

Final Energy Consumption [TWh]	**Electricity**	**Heat**	**Total**
Switzerland	57.2	174.5	**231.7**
Service sector	16.8	20.5	**37.3**

Heat consumption in Switzerland is significantly higher than electricity consumption, a trend that has been observed since 1950 and that is also followed by the Swiss service sector. However, the share between electricity and heat consumption differs in these two cases, see Figure 1.

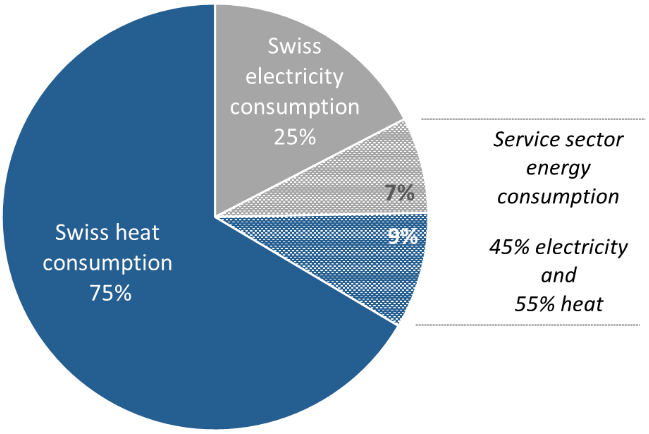

Figure 1 Electricity and heat shares of the Swiss total energy consumption and corresponding part of the service sector in 2019 (SFOE, 2020a)

The heat share accounts for 75 % of the overall Swiss energy consumption while electricity represents only 25%.

The heat share (including mobility) was obtained from the 2019 Global Swiss Energy Statistics (SFOE, 2020a) by removing the electricity share from the total final energy consumption. This is equivalent to the addition of all fuel energy carriers considered in the Swiss energy statistics, i.e. wood, coal, waste, oil, oil products, natural gas, water, nuclear fuels, other renewable energies and district heating. In Switzerland, the other renewable energies account for solar, wind, biogas, biogenic fuels and ambient heat, this latter used by heat pumps (HP) to produce useful heat.

As for the electricity share, a part of it is the amount required by HP to produce useful heat. However, it is difficult to estimate the share used for heating purposes (e.g., in HP) as no detailed data was found. In Section 2.1.2.2, the service end-user applications by energy vector are presented, providing a better insight on heat end-uses.

A closer look into the service sector shows that its electricity consumption is only 7 % of the total energy consumption in Switzerland but represents about a third of the total Swiss electricity consumption, an important feature also observed in other OECD countries (Fleischmann, 2015).
In contrast, heat consumption in the service sector accounts for 9 % of the total Swiss energy consumption but represents only about 12 % of the total heat consumption in Switzerland.
In 2019, the share of heat consumption in the total service sector represents 55 % with the remaining 45 % for electricity consumption. This distribution shows that heat consumption is slightly more important than electricity consumption for this sector despite the larger impact of this latter in the total national electricity consumption.
Overall, given the substantial impact of the service sector within the total Swiss electricity consumption (nearly 33 %), it is strategically important to find additional ways to produce the required 55 % of heat without resorting only to electricity and using heat pumps. This is to avoid an increase in the share of the national electricity consumption.

2.1.2.2 Energy consumption by energy vector in the service sector

The final energy consumption of the service sector was also broken down to the level of individual energy vectors. Figure 2 shows the results for the year 2019. Apart from electricity in the total energy consumption, heating oil is the dominating energy source in the Swiss service sector, followed closely by gas.

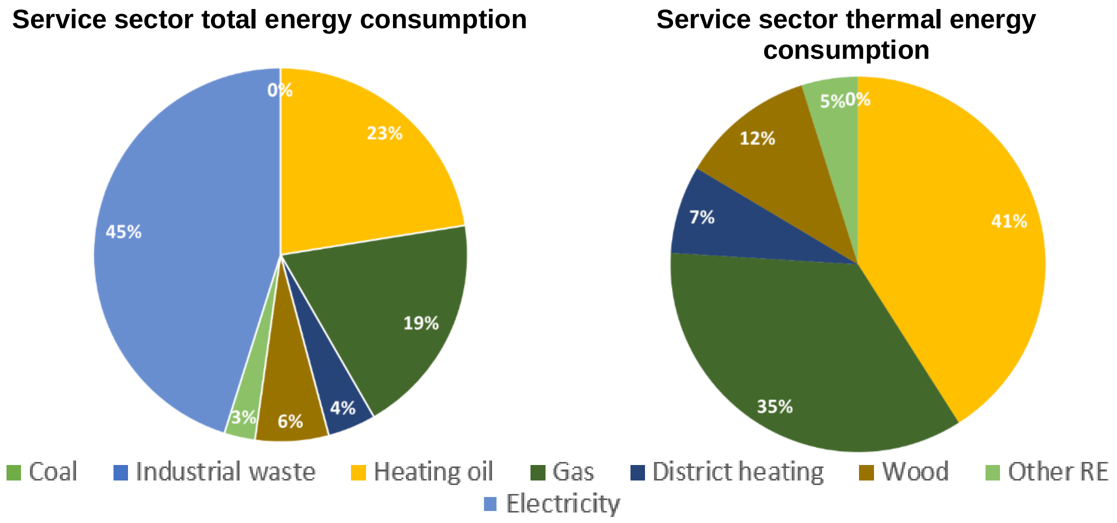

Figure 2 Swiss total and thermal service sector energy consumption shown by energy source in 2019 (SFOE, 2020b)

Heating oil accounts for about 41 % of the service sector thermal demand and 23 % of the total service sector. Fossil fuels represent about 76 % of the service sector thermal energy consumption. The part of renewable energies, wood and other renewable energies (solar, wind, biogas, biogenic fuels and ambient heat), is around 17 % of the service sector heat consumption which is still much lower than the part of fossil fuels in the sector energy mix. The renewables contribution has also been observed to be evolving quite slowly in the last years with a value around 15 % in 2015.

The importance of the Swiss service sector as part of the total national energy consumption was demonstrated. The share by energy source shows that there is a potential for solar thermal systems to replace the high share of fossil fuels used so far by this sector.

2.1.2.3 Energy consumption by consumer group in the service sector

In this very heterogeneous sector, some service activities (e.g. laundries, car washing, leisure pools) require temperature levels that are very favourable for solar thermal integration as energy source to improve energy efficiency and avoid fossil fuels utilization. To identify the major energy consuming groups of the Swiss service sector, the energy consumption shares of each consumer group are presented as a percentage of the total service sector energy consumption.
The annual survey of energy consumption in the service sector (SFOE, 2020b)provides the energy consumption share by service sector and by energy vector. As previously mentioned, the consumer groups used in this study comply with the NOGA 2008 classification of economic activities used by the SFOS.

Figure 3 presents the consumer group shares in the total service sector energy consumption and the corresponding percentages in terms of service sector thermal demand, in 2019.

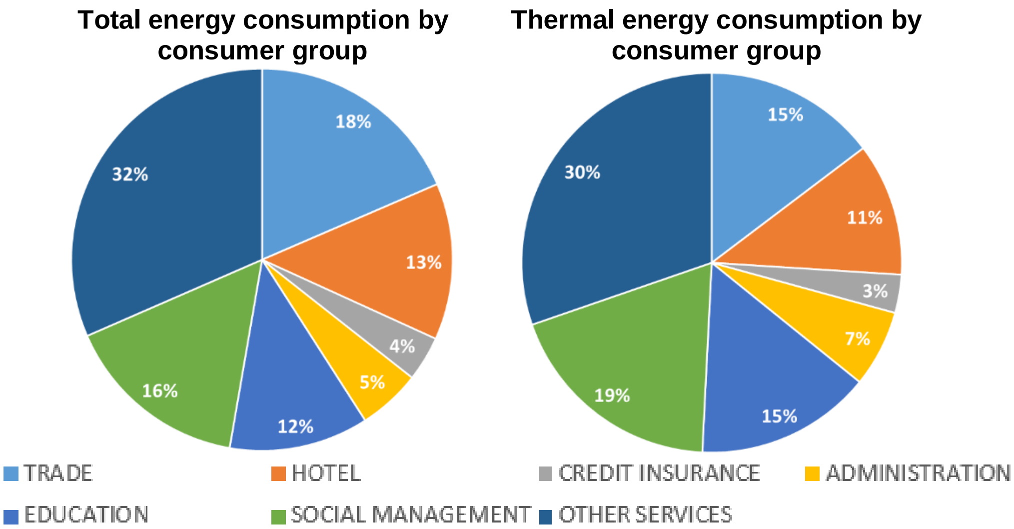

Figure 3 Total and thermal energy consumption group shares in the service sector in 2019 (SFOE, 2020b)

Among the different consumer groups, the largest share is from Other Services, followed by Trade and Social Management. All these equate to 66 % of the total energy consumption of the service sector and for 64 % of its thermal share in 2019.

In 2019, the amount of energy consumed by the Other Services group reached 9.5 TWh, accounting for about 32 % of the total energy consumption of the service sector. The Other Services includes, among others, a variety of personal services not covered elsewhere in the NOGA classification, such as cleaning of facilities (e.g. hotels, restaurants, hospitals), operation of sports facilities (e.g. leisure pools) and washing and cleaning of textiles (laundries) (SFOS, 2008b). The thermal energy consumed by this consumer group reached 4.6 TWh, representing 30 % of the thermal energy consumption of the service sector. In this consumer group, thermal energy demand represents 48 % and electricity 52 %.

The second largest service consumer group in Switzerland, accounting for 18 % of the sector total energy consumption in 2019, is the Trade group, which includes, among others, repair and maintenance of motor vehicles such as washing services (SFOS, 2008b). The energy consumption for this group is as follows: 39 % for heat and 61 % for electricity. The heat consumption reached just over 1.9 TWh in 2019, which represented 15% of the service sector thermal energy consumption.

The consumption of this group is closely followed by that of the Social Management (16 % of the sector total energy consumption in 2019) that comprises veterinary, hospital, and residential care activities where treatment and care services represent important parts (SFOS, 2008b). The energy consumption for this group is 59 % for heat and 41 % for electricity. The heat consumption reached about 3 TWh in 2019, which represented 1 9% of the service sector thermal energy consumption.

This analysis has showed the consumer groups that accounted for most of the energy consumption in the service sector. The three identified groups represent altogether two-thirds of the thermal energy consumption of the service sector.

A closer look into the thermal energy consumption also indicates that about one-third of it comes from consumer groups in the public sector: Social Management (hospitals and residential care facilities) and Education (schools). This puts into evidence the important role of the public sector in the energy transition and ultimately integration of renewable heat.

Figure 4 shows the evolution over time of the electricity and thermal energy consumption in the service sector for the seven different consumer groups for the years 2015 to 2019.

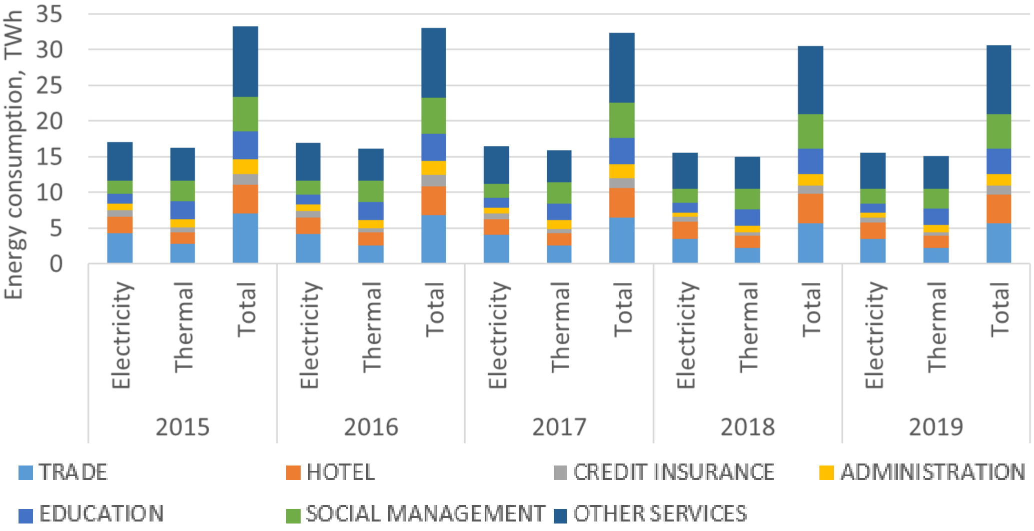

Figure 4 Energy consumption in the service sector by consumer group and type from 2015 to 2019 (SFOE, 2020b)

The results over the last five years show a slight decline of both electricity and fuel consumption. The total energy consumption in the service sector in 2019 was around 31 TWh with 15 TWh accounted for thermal use. These results differ from the overall statistics values because they are based on surveys of energy consumers, while the overall energy statistics are based on information from external trade statistics and model results.

The share of total energy consumption (electricity and heat) was found to be close to that of the thermal energy consumption (only heat) suggesting that consumer groups with higher energy consumptions will have higher heat demands. In addition, the public sector (residential care facilities, hospitals, schools, etc.) is shown to present an important potential for renewable heat integration.

2.1.3 Energy consumption of service applications

To study the potential of conventional solar thermal systems in the service sector, the analysis of the energy demand required by end-use application is performed. The objective is to identify the most suited service consumer groups for the implementation of solar thermal technologies.

2.1.3.1 Service sector energy consumption by end-use application

To understand energy use within the service sector and how solar thermal systems could be potentially implemented, the identification of the most energy-intensive service applications is performed. (Kemmler, et al., 2019) provides the distribution of the service sector energy consumption by end-use application and compares the share of heat and electricity consumption for each one.

Figure 5 presents the distribution of the energy consumption of the Swiss service sector in 2018, regarding the total energy consumption (electricity and heat) by end-use application.

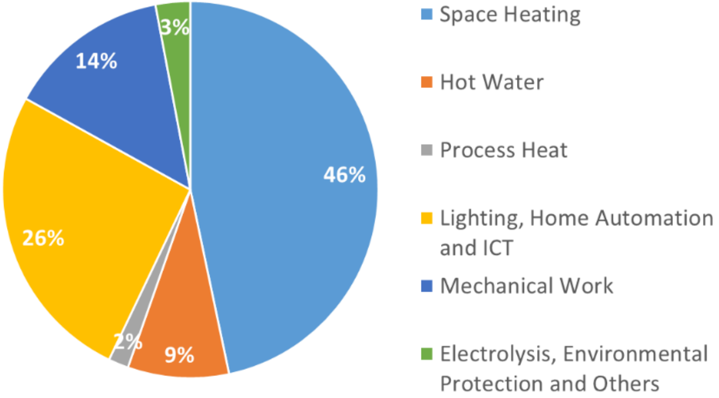

Figure 5 Service sector energy consumption by end-use application in 2018 (Kemmler, et al., 2019)

In terms of energy consumption, space heating is the largest energy consumer in the service sector because of its important number of commercial buildings. This application consumed 16.4 TWh during the year 2018, representing 46 % of the total energy consumption of the Swiss service sector. Hot water production accounts for only about 9 %.

Thermal energy sources are used, exclusively, for space heating and hot water production, see Figure 6. In 2018, consumption was mostly for space heating (84 %) with the reminder used for provision of hot water. A decline in the consumption of heat sources has been observed in the last decade mainly due to a decrease in space heating consumption (Kemmler, et al., 2019).

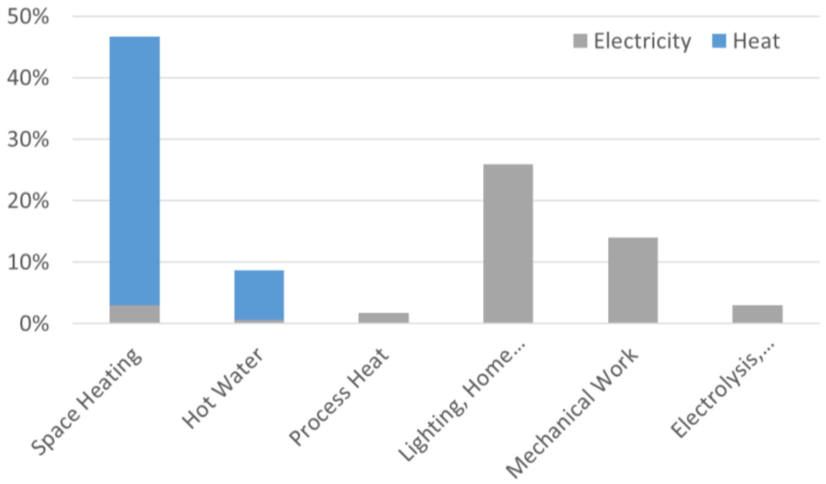

Figure 6 Service sector end-use application energy consumption by energy vector in 2018 (Kemmler et al., 2019)

As for electricity, the last five years have shown a slight decline in consumption mainly due to improvements in the lighting sector. However, because this decline is less important than that observed for the heat sources, the share of electricity in comparison to the total sector consumption continues to show an increasing trend (Kemmler, et al., 2019).

This share of heat use corresponds perfectly to energy that could be provided by solar thermal systems. All other applications (e.g. process heat, lighting, home automation, ICT, etc.) are entirely provided by electricity in the service sector in 2018.

Because the purpose of this study is the integration of solar thermal (ST) systems in specific service activities, only hot water applications will be considered because they require temperatures more suitable for that kind of technology.

2.1.3.2 Hot water uses in the service sector

The most common hot water applications in the service sector are domestic hot water (DHW), washing and cleaning processes, which require temperatures ranging from 20 °C up to 95 °C (GIZ, 2016). However, as previously mentioned, the main obstacle faced in this analysis was the scarce availability of data, particularly relating hot water uses to a specific service activity. To overcome this difficulty and qualitatively identify the services requiring large amounts of hot water at low temperature ranges, a list of detailed hot water uses was elaborated, based on data from (ADEME, 2020) and (BMWi, 2015):

- Shower: most important use in hotels and other accommodation facilities
- Dishwashing: most important use in restaurants
- Cleaning (removal of dirt from something e.g., work surfaces): common use in many service sector buildings such as hotels, restaurants, hospitals
- Laundry: important use in laundries
- Washing (cleaning by totally covering something with water): common use in car-washing stations
- Personal care (bath, shower, personal hygiene): typical use in hospitals and residential care facilities
- Pool and Spa: most important use in sports facilities

All these applications have temperature levels, which are quite favorable for solar process heat.

2.1.3.3 *Suitable service sectors and activities for solar process heat*

In a bottom-up approach, the identified hot water uses allowed to bring out the main service activity from the NOGA definition (SFOS, 2008b) and consequently, pin-point the corresponding service sector, see Table 3.

Table 3 Service sector, activity and corresponding hot water applications with their respective temperature levels

Service sector *(share of total thermal use)*	**Economic division NOGA**	**Service Activity**	**Hot water use**	**Process temperature range (GIZ, 2016)**
TRADE *(15 %)*	45	Carwashes	Washing	30-50 °C
HOTEL *(11 %)*	55	Accommodation	Shower	50-80 °C
			Dishwashing	30-80 °C
			Cleaning	30-80 °C
			Laundry	30-90 °C
			Pool and Spa	25-40 °C
	56	Food services	Dishwashing	30-80 °C
			Cleaning	30-80 °C
SOCIAL MANAGEMENT *(19 %)*	75	Veterinary activities	Washing	30-50 °C
			Cleaning	30-80 °C
	86	Human health activities	Dishwashing	30-80 °C
			Laundry	30-90 °C
			Personal care	30-60 °C
	87	Residential care activities	Dishwashing	30-80 °C
			Laundry	30-90 °C
			Personal care	30-60 °C
OTHER SERVICES *(30 %)*	81	Building services	Cleaning	30-80 °C
	93	Sports activities	Shower	50-80 °C
			Pool and Spa	25-40 °C
	96	Laundries	Laundry	30-90 °C

From this approach, Trade, Hotel, Social Management and Other Services appear to be the service sectors with the highest use of hot water applications for specific service activities. However, the share of heat consumption of these specific service activities within its corresponding service sector is unknown due to lack of data. For all hot water applications, the suitability of using conventional ST technologies (e.g. flat plate and evacuated tube collectors) to provide the temperature level is confirmed.

2.1.4 Key findings

- Service sector represents 16 % of total final energy consumption in Switzerland (2019)
- Service sector currently responsible for one-third of the national electricity consumption and 12 % of the national thermal energy demand. The energy demand totals in 55 % thermal (of which 76 % heating oil and gas and 17 % from renewables) and 45 % electricity
- Other Services, Trade and Social Management represent more than 66 % of the total energy consumption of the service sector.
- The public service sector presents an important potential for renewable heat integration.
- Space heating is the largest end-use application in the service sector (46 %)
- Hot water accounts for about 9 % of the total service sector final energy consumption.
- Space heating and hot water represent 100 % of services thermal energy consumption
- Finding disaggregated data to pin-point the specific services and their activities suitable for solar thermal integration is a challenge
- DHW, washing and cleaning processes are the most common hot water applications
- Hot water applications are mainly found in the Trade, Hotel, Social Management and Other Services
- Conventional ST technologies are suitable for all identified hot water applications

2.1.5 Conclusion

An overall screening of the Swiss energy consumption was performed with a focus on the service sector. The heat demand was carefully analyzed as a function of the service consumer group, energy vector and end-use application. A list of hot water applications was elaborated that enable to identify the service sector and activity with the highest hot water uses.

The important impact of the service sector in the total national power consumption (one-third) suggests that heat consumption of this sector should not be covered exclusively by technologies using electricity as primary energy vector. Renewable heat producers should be integrated to meet the energy needs and replace the fossil fuel consumption. Although the use of heat pumps coupled with photovoltaic can produce renewable heat, it still relies on electricity to produce heat.

ST systems represent a potential alternative for heat supply in the service sector. The space heating in this sector is similar to that of the residential sector, for which solar thermal systems are already in use. Hot water consumption in this sector occurs at different temperature levels that match the range for solar thermal use.

The share of renewable energies in the provision of heat is currently quite small (17 %) and has not been greatly evolved in the last years. A number of service consumer groups has been identified having a non-negligible use of thermal energy. Among others, public service sectors seem to be a key cluster for renewables integration because they represent altogether almost one-third of the service sector thermal energy consumption.

The following service activities have been identified as the most promising for integration of solar thermal systems:

- Car washing facilities
- Hotel and food service
- Hospital, veterinary and residential care activities
- Sports activity area
- Laundries

These service activities will be those for which a more in-depth analysis will be carried out in the framework of the Solind2Service project. In this context, a survey will be sent to companies operating in these service activities to better identify their potential regarding solar thermal systems. Subsequently, and as solar thermal systems are already being used in Switzerland to meet the heating needs in these service activities, an analysis of existing systems should be carried out to identify the factors favoring the implementation and use of solar thermal systems.

2.2 Identification of suitable users: Survey

A survey was designed and spread around to companies in the service sector to gain more information regarding heat consumption in this sector, in an attempt to fill the gap between the available data used in the market analysis (see 2.1) and the local and individual circumstances for the different companies. The questionnaire, made available in four languages (French, Italian, German, English) is listed in the appendix. Invitations to participate in the survey were sent to different service sector associations found in 2.1.5 and via EnaW. They are listed in Table 4.

Table 4 Associations the survey was sent to, their amount of members and replies, and the respective sectors

Association	Members
H+ (Hospitals)	277
EnaW	4158
VTS/ASET (Textile)	254
Hotelleriesuisse	2029
Heilbäder und Kurhäuser Schweiz	48
Curaviva (Nursing homes)	1700
Total	8466

Sector	Responses
Car Wash	1
Hotel	10
Care/Hospitals	81
Sports & various	13
Laundries	10
Total	115

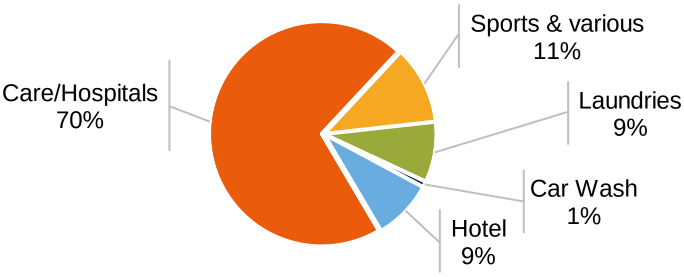

Figure 7 Share of responses to the survey displayed per subsector

Most replies were sent by members of H+, the association of hospitals. These replies also included the largest amount of technical data of their energy demand. Only 5 replies included energy consumption data, of which 4 were hospitals and one was a hotel. It is assumed that this is due to the availability of professional technical staff in hospitals that already monitor their energy demand. Smaller organizations as e.g. hotels often only know their total yearly energy cost but are unable to identify the different energy vectors and processes. This low number of replies with energy data rendered it impossible to draw conclusions regarding energy supply and demand of the different subsectors. The association HotellerieSuisse assumed that the low return of answers of their members is due to poor business development as a result of the COVID-restrictions. Investments and discussions regarding energy supply is reported to be a low priority for hotel owners currently.

Of the 115 replies, 14 (12 %) already use solar thermal energy sources. Of the other 101 replies, 34 (33 %) considered solar thermal energy, and 8 (8 %) are planning to build one. Usually, there is enough roof space available (90 % replied with 100 m^2 or more area available), and the desired time of return of investment is often feasible for solar thermal (see Table 5). The reasons for a decision against solar thermal are mostly of economical nature, followed by technical obstacles (see Table 5). Other reasons against solar thermal collectors were visual considerations and monument conservation. Most organizations desire some form of subsidies for such a system, with 9 answers at 20-30 % subsidies, followed by 8 answers at 30-40 %.

Table 5 Number of answers given for the reasons, why the decision was against ST, about the subsidy that would be necessary to build such a system and the desired time of return of investment.

Nature of reasons against ST	
Financial	18
Roof space	6
Reliability	3
Integration	3
Sunlight	1

Desired subsidy (% of investment)	
<10 %	1
10-20%	3
20-30%	9
30-40%	8
>40%	4

Desired time of return of investment	
<7 y	23
7-10 y	43
>10 y	18

Of the 10 answers regarding satisfaction of their current ST plant, no negative answers were given regarding reliability and O&M effort on a 5-point scale. The majority replied with "satisfied" (7/10 and 6/10 replies respectively).

Table 6 Number and kind of answers to the question regarding satisfaction with an existing solar thermal plant

# Answers (n = 10)	energy yield	profitability	reliability	O&M expense
very satisfied	2	1	1	1
satisfied	4	5	7	6
neutral	2	3	2	3
little satisfied	2	1	0	0
not satisfied	0	0	0	0

Suited companies have been hand-selected from the replies and contacted for the feasibility studies. They are shown in 3.4.

2.3 Best practice examples of existing solar thermal plants

Information and experiences from existing solar thermal systems in the service sector were collected to provide best practice examples for the potentially interested sectors. The case studies show which integration point was chosen in the different sectors (heating, hot water or process heat), how the systems are currently working and what the operators' experiences have been. Seven different solar thermal plants are presented from the subsectors hotel, spa/pools, sports facility and car-wash, which use glazed and unglazed flat plate collectors and evacuated tube collectors. The field sizes range from 42 m^2 to 453 m^2 that provide hot water for heating, domestic water and utilities with temperatures between 40 °C and 95 °C. Seven best case leaflets have been designed using this data, which are used during the communication campaign (see 4 and in Annex 2).

3. Standardized tools for the solar heat potential

3.1 Competitiveness of Solar Heat in Industry and Service Sectors

A solar thermal system essentially consists of collectors and a storage tank, the specifications of which are largely determined by the purpose for which the solar heat is used. The solar collector technologies are the follows:

- **Air collectors:** They use the solar energy to heat air. They are typically used for drying processes.
- **Flat plate collectors**: Robust and inexpensive, they can provide heat up to 90 °C. This is the most widespread type of collector.
- **Evacuated collectors:** They have less heat loss than conventional flat plate collectors. Evacuated tube collectors and evacuated flat plate collectors are suitable for temperature up to about 150 °C.
- **Concentrating collectors:** They can reach temperatures of up to 250 °C and can produce steam directly. They are suitable for regions with high direct radiation and need a sun tracking system.

Solar thermal systems are technologically suitable to cover a part of the heat demand of the industry and service sectors where temperature ranges match that can be produced, see Table 3. The solar heat can be injected either at the heat producers (upstream, downstream or in parallel to the traditional boilers installed) or directly at the consumers (processes, hot water or heating).

The advantages of integrating solar heat at the supply level are usually the technical simplicity and the independence of individual process runtimes and individual process temperatures. The advantages of integrating at the process level are lower process temperatures compared to the heat supply network and thus higher solar productivity and energy coverage rate.
The competitiveness of solar heat is directly related to the productivity of the solar thermal system. The latter depends mainly on the solar resource and the temperature of the solar heat production. In Switzerland, the specific production that can be achieved by a solar thermal system is between 300 and 800 kWh/m² of installed solar collector surface. **The solar system's productivity can be obtained using the SolInd Tool** by setting the desired location and temperature level.

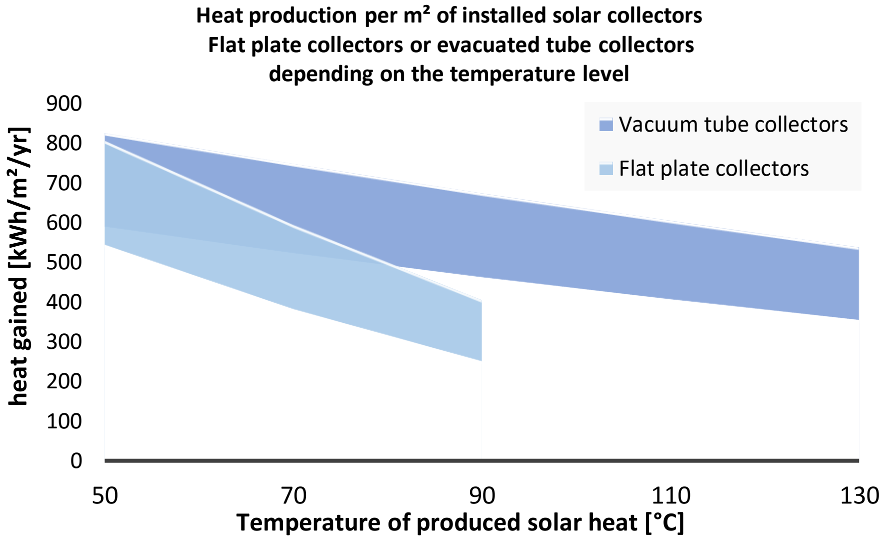

Figure 8: Annual heat production per m² of solar collector area as a function of the target temperature. The areas correspond to what can be reached by considering the solar resource (irradiation) of different cities in Switzerland for collectors facing south and inclined at 35°. The results are obtained via the SolInd tool, which provides solar thermal yields up to temperatures of 90 °C for flat plate technologies and 130 °C for vacuum technologies.

3.1.1 Solar Heat Cost

The investment costs of a solar thermal system correspond to the costs of all materials (solar collectors, heat storage and hydraulic equipment) delivered and installed, including planning. The specific investment cost of a solar system, related to the field area in [CHF/m²], decreases with the installed area. The trend of this specific price presented in Figure 9 is the one observed for the Swiss solar thermal market[2].

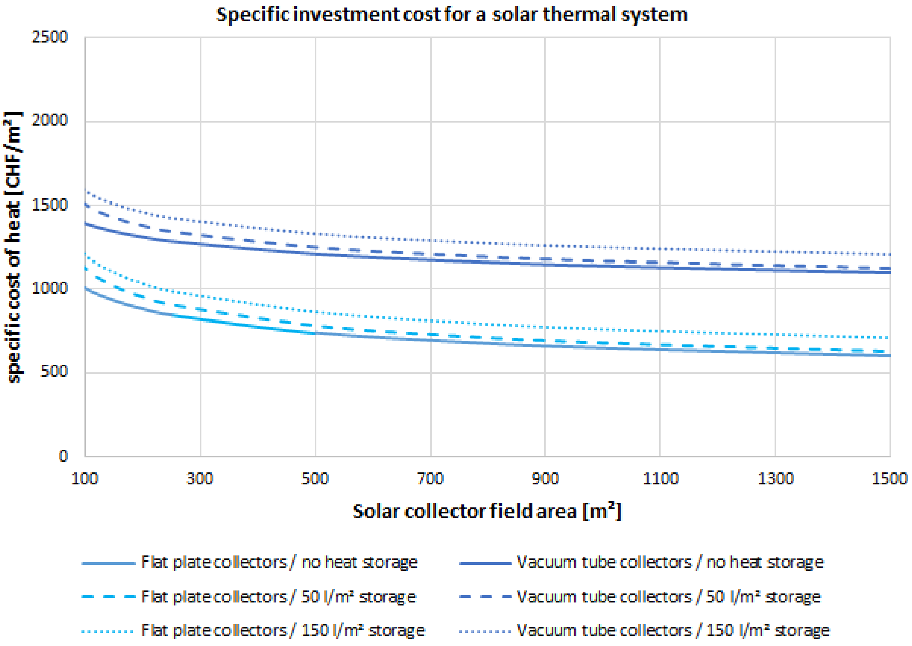

Figure 9 Specific investment price of an installed solar thermal system, including the storage tank. Cost trends are given for three ratios of storage capacity per m² of installed collectors: no storage, 50 l/m² and 150 l/m². These cost trends are taken from offers for pre-projects collected in the framework of research projects. Source: SPF, LESBAT and PLANAIR

Recent cost studies have been carried out on large solar thermal systems, including a project led by the SPF (Ruesch, Mojic, & Haller, 2017) on the potential of solar heat for district heating in the Canton St. Gallen, the Sol-Ind Swiss project (Caflisch, et al., 2019) on the potential of solar heat for industrial applications in Switzerland and the SolCAD project (Jobard & Duret, 2020) on the potential of solar heat for district heating in Switzerland. These projects have resulted in the reporting of specific costs without subsidy for large solar thermal systems in the range of 600 CHF to 1'200 CHF/m².

Operation and maintenance (O&M) costs include the costs of operating the pumps and controllers and the costs of maintaining the solar system, including materials and labour. O&M costs can vary from year to year depending on the price of electricity and the years in which repairs/changes of components on the system are required. Typically, annualised operation and maintenance (O&M) costs represent between 1 % and 2 % of the investment costs of the solar thermal system (Louvet & Fischer, 2017)**.**

The lifetime of a properly designed solar thermal system is at least 25 years and periodic monitoring of the system can increase the lifetime beyond this period. In financial calculations, the lifetime of the system should be considered if the objective is to know the cost of the solar heat produced over the whole lifetime of the system.

The cost of solar heat is therefore between 6 Rp/kWh and 20 Rp/kWh over the lifetime of the system. This cost is calculated without subsidies to be comparable to other countries. Subsidies in Switzerland vary depending on the canton, see 3.1.1.

Solar thermal systems almost always work with a back-up or in bivalence with another heat source. If the solar system is added to an existing system, the solar heat produced and consumed allows energy saving on the other heat source.

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[2] Offers for pre-project collected in the framework of research project. Source: SPF, LESBAT, PLANAIR

Table 7 Annual operational expenditure costs (OPEX) of other heat generation technologies used in the industrial and tertiary sectors. These costs correspond to those of medium and large consumers in these sectors. (SFOS, 2021) for the prices of gas, oil, pellet (minimum and maximum values for these 3 vectors over the last 5 years) and heat pump (COP 3 on the price of electricity minimum and maximum over the last 5 years); Internal and partners for the consumer price for a district heating.

Technology	**Heat Cost (OPEX)**
Gas	7-9 Rp/kWh
Oil	6-7 Rp/kWh
Pellet	7-8 Rp/kWh
Heat Pump	6-7 Rp/kWh
District Heating	12-15 Rp/kWh

3.1.2 Basic cases for areas 100 m² and 500 m²

To illustrate the cost of heat, a case study is elaborated and presented here to compare the cost of the solar heat with that produced by other technologies, common in the industrial and service sectors.
The investment costs, O&M costs, and system efficiencies are estimates and have been established on the basis of internal experience, external documentation and various projects carried out by the Solind2Service project partners.
The case study is elaborated with the following assumptions for the consumer:

- A large part of the heat demand is at temperatures below 100 °C.
- The annual heat consumption is 2.25 GWh/year
- The consumer operates 2190 hours at full load
- The capacity of the other technologies considered is about 1MW

The technical and financial characteristics considered for the other technologies, for which the cost of the final heat produced will be compared to that of solar, are presented in Table 8. For this comparison, 2 cost values (low and high) are considered for the specific investment cost of each technology and for the fuel cost.

Table 8 Technical and financial considerations for other heat generation technologies to compare the cost of solar heat for larger consumers

Boiler	**Characteristics**		**Consideration**	
Gas	Efficiency		90 %	Includes boiler efficiency and distribution system
	Annual fuel		2’506	MWh/y of gas
	Investment costs	Low	≈ 200'000	CHF/MW
		High	≈ 300'000	CHF/MW
	Maintenance costs		3 %	of the investment cost
	Fuel costs	Low	70	CHF/MWh
		High	80	CHF/MWh
Oil	Efficiency		90 %	Includes boiler efficiency and distribution system
	Annual fuel		2’506	MWh/y of oil
	Investment costs	Low	≈ 250'000	CHF/MWh
		High	≈ 400'000	CHF/MWh
	Maintenance costs		3 %	of the investment cost
	Fuel costs	Low	60	CHF/MWh
		High	70	CHF/MWh

Pellet	Efficiency		85 %	Includes boiler efficiency and distribution system
	Annual fuel		2’653	MWh/y of pellet
	Investment costs	Low	≈ 500'000	CHF/MWh
		High	≈ 650'000	CHF/MWh
	Maintenance costs		6 %	of the investment cost
	Fuel costs	Low	70	CHF/MWh
		High	80	CHF/MWh
Heat Pump	Efficiency		285 %	Includes boiler efficiency (COP 3) and distribution network
	Annual fuel		791	MWh/y of electricity
	Investment costs	Low	≈ 800'000	CHF/MWh
		High	≈ 1’100'000	CHF/MWh
	Maintenance costs		3 %	of the investment cost
	Fuel costs	Low	180	CHF/MWh
		High	220	CHF/MWh

For gas and oil boilers, the cost due to the CO_2 tax is about 96 CHF/tCO_2. The greenhouse gas emissions for these two energy carriers are calculated based on the KBOB (KBOB Ecobau IPB, 2016) coefficients giving the CO_2 content in relation to the final energy.

For this case study, two variants of solar thermal systems are compared. One variant of 100m² and another variant of 500 m² of solar collector surface. For these two variants, the calculation assumptions are listed below:

- Flat plate collector technology used
- 500 kWh/m² of solar heat production corresponding to process heat integration at temperatures <80 °C or pre-heating of conventional boilers
- The specific investment costs are 800 CHF/m² and 1'000 CHF/m² for the 500 m² and 100 m² systems, respectively
- No subsidies considered

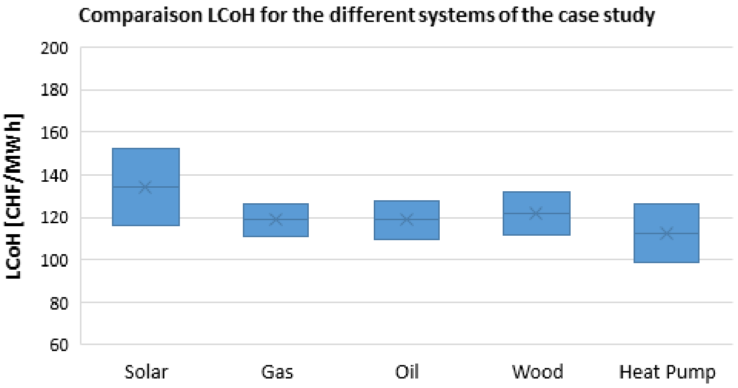

Figure 10 Cost of the useful heat produced by different heat producers for the case study considered. Two solar thermal systems considered, with respectively 100 m² and 500 m², and other producers (1 MW). The calculation is made considering investment costs, O&M costs and an annuity factor of 6.72 % (20 years; 3 %).

The cost of the solar heat produced by the 100 m² variant is 152 CHF/MWh. This small system covers only 2 % of the consumer's energy demand and the low scale economy means that the heat produced is not competitive with other heat generation technologies.

In this case study, the solar heat produced by the 500 m² system is competitive with other technologies. The cost of the heat produced by this system is 115 CHF/MWh.

The cost of solar heat is mainly due to the high investment depreciation. For the other technologies, it is the operating cost that has the greatest impact on the cost of the heat produced. Table 9 shows the distribution of the cost of heat according to the share due to the investment (CAPEX), the share due to the operating costs (OPEX) and the share due to the CO_2 tax (only for gas and oil). The cost of solar heat is mainly due to the high investment depreciation. For other technologies, the operating cost has the greatest impact on the cost of the heat produced.

Table 9: Distribution of the cost of heat for the different technologies considered in this case study, according to the share due to CAPEX, the share due to OPEX and the share due to CO_2 tax.

Technology	**Heat cost**		
	Due to CAPEX	**Due to OPEX**	**Due to CO_2 Tax**
Solar	87 %	13 %	-
Gas	7 %	72 %	20 %
Oil	9 %	64 %	27 %
Pellet	14 %	86 %	-
Heat Pump	30 %	70 %	-

Regarding the results for the cost of solar heat, as the economic and technical parameters greatly influence these results, a sensitivity analysis of this case is shown in Figure 11.

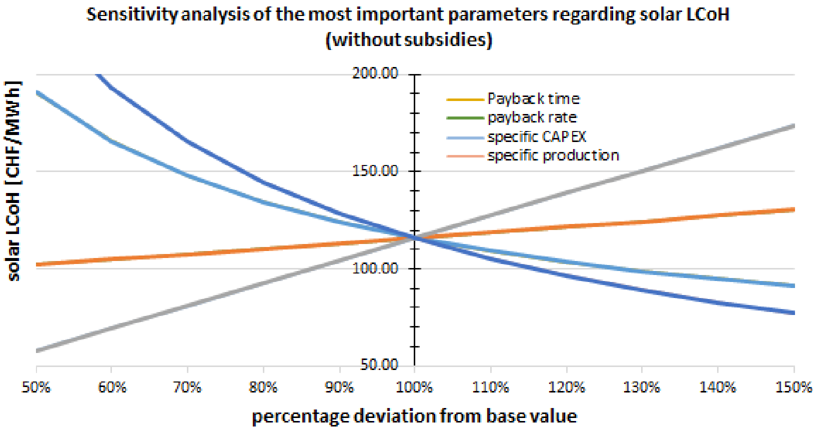

Figure 11: Sensitivity analysis on the technical and economic parameters that have an impact on the cost of solar heat. The calculations are made without subsidies. The basic parameters used are those used to develop the 500 m² case in Figure 5.

The results shown here have been elaborated based on calculation assumptions concerning the technical and economic aspects of the different technologies. In order to determine which technology is the most competitive in each case, formal offers should be requested from suppliers to obtain real costs.

3.1.3 Influence of CO_2 tax and subsidies

In order to promote the use of renewable energies and the decarbonisation of Switzerland, the existing economic incentives are

- Subsidies
- CO_2 tax

Subsidies mechanisms exist in many countries for industry and service sectors. For example, in the three countries bordering Switzerland (Tschopp, Tian, Fan, Perers, & Furbo, 2020):

- Germany, where up to 40 % of the investment costs for a solar thermal system are subsidised
- Austria, where up to 50 % of the extra investment costs for a solar thermal system compared to a fossil heat system are subsidised
- France, where flat-rate subsidies ranging from 30 €/MWh to 50 €/MWh over 20 years are granted for solar thermal installations between 25 m² and 500 m² via the ADEME[3]

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[3] https://agirpourlatransition.ademe.fr/

In Switzerland, the subsidy mechanisms depend on the canton. Currently there is no standard subsidy scheme for solar thermal systems in the industrial and tertiary sectors. The subsidy conditions of the cantons can be checked directly with the relevant departments, mainly those of the building programme, see Table 10.

Table 10: Link to cantonal funding programmes for solar thermal systems. Source: SWISSOLAR

Canton	Information on subsidies conditions	Canton	Information on subsidies conditions
AG	Link	NW	Link
AR	Link	OW	Link
AI	Link	SH	Link
BL	Link	SZ	Link
BS	Link	SO	Link
BE	Link	SG	Link
FR	Link	TI	Link
GE	Link	TG	Link
GL	Link	UR	Link
GR	Link	VD	Link
JU	Link	VS	Link
LU	Link	ZG	Link
NE	Link	ZH	Link

Some cantons provide subsidies for planning for companies wishing to replace their fossil energy system with a renewable energy system. However, a barrier to spread the use of solar thermal systems in the industrial and service sectors is the high investment cost. Although solar heat can be competitive compared to other heat sources, this barrier makes investments in these systems not widespread. **Considering a subsidy on the investment costs of between 10 % and 50 % of the amount, the cost of solar heat would decrease by 8 % to 42 % respectively,** see Figure 12.

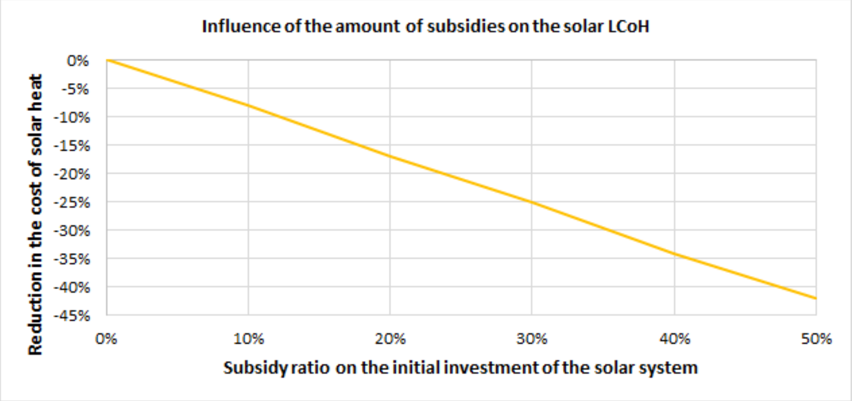

Figure 12: Influence of the subsidy ratio on the cost of solar heat. The subsidy is only applied on the investment cost as a ratio.

The CO_2 tax is indexed to greenhouse gas emissions and currently amounts to 96 CHF/tCO_2 (BAFU, 2021). This corresponds to approximately 21.9 CHF/MWh for gas (considering 0.228 kg CO_{2eq}/kWh) and 28.9 CHF/MWh for fuel oil (considering 0.301 kg CO_{2eq}/kWh) (KBOB Ecobau IPB, 2016).
Another way of looking at this CO_2 tax is to see it as a direct annual saving through solar heat. In this case, the saving on the CO_2 tax is equivalent to reducing the cost of the solar heat by the same amount. Taking the case of the 500 m² solar system and considering that the solar heat saves gas (remuneration of about 22 CHF/MWh saved) then the final cost of the solar heat produced and consumed will be about 95 CHF/MWh, see Figure 13.

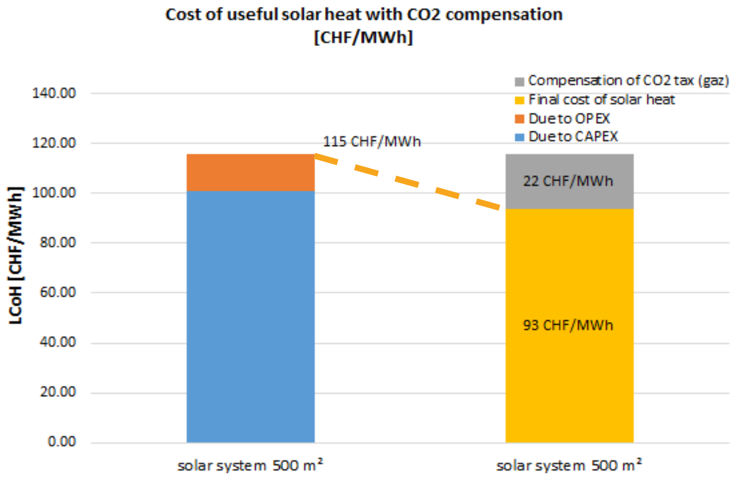

Figure 13: Cost of the solar heat considering the compensation of the CO_2 tax. The solar system considered is the 500 m² system presented in section 3.1.1. The CO_2 tax is indexed on the gas.

Considering that the cost of solar heat is between 60 CHF/MWh and 200 CHF/MWh, the savings on the CO_2 tax generate the same order of magnitude on the decrease of the solar heat cost. However, it should be noted that these savings are made annually and do not reduce the initial investment, the main economic barrier for solar thermal installations.

3.1.4 Environmental indicators

Previous analyses have shown that solar heat can already be competitive with the main heat production technologies used in the industrial and tertiary sectors. Indeed, the cost of solar heat is between 6 Rp/kWh and 20 Rp/kWh.

This cost of solar heat is calculated over a payback period equal to the minimum lifetime of the system: 20 years. The productivity and the specific investment cost of a solar thermal system are the most important factors for the cost of the solar heat produced. The specific productivity of the solar system is considered to be between 400 kWh/m²/year and 700 kWh/m²/year and the specific investment cost is considered to be between 600 CHF/m² and 1200 CHF/m². Annualised operation and maintenance (O&M) costs are also taken into account in the heat cost calculation.

Although solar heat is competitive, it has a number of constraints: very high initial investments, long payback period, no subsidies. In order to unlock investment in renewable heat systems, it is important to develop other indicators that provide incentives for companies to reduce their carbon footprint.

In the framework of the SolInd2Service project, the Levelized Cost of Carbon Abatement (LCCA) (Baker & Khatami, 2019) was chosen to measure the CO_2 reduction generated by a specific investment.

A simplified LCCA calculation method (Friendmann, et al., 2020) provides a monetary value (CHF) per unit of emission reduction [tCO_2]:

$$LCCA\left[\frac{CHF}{tCO2}\right] = \frac{C\ [CHF]}{(E0\ [tCO2] - E1\ [tCO2])}$$

where

C [CHF]	→	the total levelized costs associated with the measure or technology deployed for the emission reduction.
E0 [tCO_2]	→	greenhouse gas emissions in the initial state without the measure or technology deployed
E1 [tCO_2]	→	greenhouse gas emissions after the deployment of the emission reduction measure or technology.

To calculate the LCCA of a solar installation, the investment costs (CAPEX) and the O&M costs (OPEX) of the installation must be considered, as well as the savings generated by it. In the case of a solar thermal installation substituting another heat source, a first level of approach is to take into account the fuel savings.

Considering the KBOB values for greenhouse gas emissions and that solar heat (0.014 kg CO_{2eq}/kWh) can substitute gas (0.249 kg CO_{2eq}/kWh), then each useful kWh of solar heat results in a saving of 0.235 kg CO_{2eq}. In the case of fuel oil (0.322 kg CO_{2eq}/kWh), each kWh of solar heat saves 0.308 kg $_{CO2eq}$ (KBOB Ecobau IPB, 2016).

Considering the levelized costs of solar heat (LCoH) presented above, the cost of the fuel saved (gas and oil) and the CO_2 savings, the levelized cost of carbon abatement (LCCA) through solar thermal is therefore between -64 and 532 CHF/tCO_{2eq}, see Table 11.

Table 11: LCCA as a function of the cost of solar heat. Solar heat is considered as a substitute for gas. The discount rate is assumed to be 3% and the analysis period is assumed to be 20 years.

Solar Heat Cost	**LCCA** (substituting gas at 75 CHF/kWh)	**LCCA** (substituting oil at 65 CHF/kWh)
6 Rp/kWh	-64 CHF/tCO_{2eq}	-16 CHF/tCO_{2eq}
20 Rp/kWh	532 CHF/tCO_{2eq}	438 CHF/tCO_{2eq}

If the cost of solar heat is lower than the cost of the substituted energy vector then the LCCA becomes negative. This is because for every kWh of solar energy produced, the savings are greater than the costs of the measure or the technology deployed, in this case solar thermal.

Considering a CO_2 tax of 96 CHF/tCO_2, the additional cost of solar heat compared to the cost of the energy vector should not be higher than a certain amount in order to remain competitive with the cost of the CO_2 tax. In this case the cost of solar heat should not exceed 98 CHF/MWh or 95 CHF/MWh respectively for gas or oil substitution, see Table 12.

Table 12: Maximum allowable extra cost for solar heat to be competitive with the current carbon tax value. Resulting solar heat cost on the right-hand side of the table.

Considering a price 96 CHF/tCO_2, the extra cost of solar heat compared to the cost of the substituted energy vector					**Solar Heat Cost**
should not be higher than	23	CHF/MWh	compared to gas	→	**98 CHF/MWh**
should not be higher than	30	CHF/MWh	compared to oil	→	**95 CHF/MWh**
to remain competitive with the cost of the carbon tax					

3.2 Financing and business models for solar thermal systems in the industry and service sectors

The previous chapter has shown that solar heat can already compete with the main industrial heat generation technologies. This chapter aims to identify the suitable business models for financing and operating a solar thermal installation in the industrial and tertiary sectors.

Renewable energy projects and, in particular, solar thermal projects, require important initial investments. With current energy costs, payback periods are generally long (>10 years). At present in Switzerland, a company wishing to use solar heat to meet part of its heating demand often has no other option but to invest in and operate the infrastructure on its own. This slows down and severely limits the potential of solar heat in the industrial field.

In order to unblock this situation and to be able to benefit from the high decarbonisation potential of heat in the industrial and tertiary sectors (see 3.1.4), it is necessary to develop innovative and attractive financing models/business models that allow a company to avoid tying up too much cash in expensive and time-consuming investments and to guarantee a minimum performance. Furthermore, the level of subsidies from public authorities also needs to be increased in order to improve the attractiveness of solar heat and to deploy its full potential for decarbonising process heat.

3.2.1 Life cycle phases of a solar thermal plant

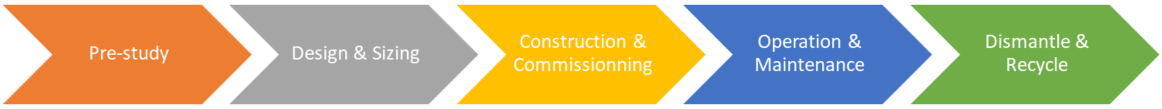

Figure 14: The different life cycle phases of a solar thermal plant

The main phases are as follows:

1. Pre-study: In this phase, the technical and financial viability of the solar thermal plant is studied. The results of this first phase support the decision to invest or not in the installation. This step corresponds to phase 1 (Definition of objectives) and 2 (Preliminary studies) of the SIA 112[4].
2. Design and sizing: In this second phase, the solar thermal plant is sized. This includes the surface area of the solar field, the hydraulics to transfer the solar heat to the consumer or a heat storage and the control principle of the plant. Tenders are then issued to determine the suppliers of materials and technologies and to identify the companies that will assemble the installation. Following this phase, a precise costing of the equipment and installation can be performed. This second step corresponds to phase 3 (Project study) and 4 (Call for tenders) of SIA 112.
3. Construction and commissioning: In this third phase, the solar thermal plant, including the hydraulics and control system, is installed. This phase ends with the commissioning of the plant. This step corresponds to phase 5 (Implementation) of the SIA 112.
4. Operation and maintenance: This fourth phase corresponds to the operation of the solar thermal plant. This includes the operating costs (electricity, etc.) as well as the periodic maintenance of the installation (pumps, etc.). This step corresponds to phase 6 (Operation) of the SIA 112.
5. Dismantling and Recycle: at the end of its life, the plant must be dismantled and ideally recycled. This step is not defined in SIA 112.

The main costs occur during the construction and commissioning phase of the plant. These costs are largely preponderant over the lifetime of the installation. They represent a cash capital asset which is amortised over the lifetime of the solar thermal plant (20-30 years) and accounts for more than 80% of the cost of heat (see 3.1.1 above).

3.2.2 Actors involved

To clearly define the different possible financing and business models, it is necessary to identify the different actors involved. Note that the term "solar thermal plant" used below corresponds to the solar thermal field and all the auxiliaries needed to operate this installation (hydraulics, pump, storage, control). A definition of each of the actors needed to define the financing and business models is given below:

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[4] SIA 112 Modèle – Étude et conduite de projet

1. Customer/end-user: corresponds to the company that needs heat in order to produce and sell a specific service to its customers
2. Contractors: also called Energy Service Company (ESCO) is a company that develops and offers energy services with the main objective of achieving energy savings. The contractor could, for example, structure financing to fund the construction of the solar thermal plant (see description in part 3.2.4 below).
3. Investors: refers to the different investors that finance the solar thermal plant. There are different categories of investors who have different investment criteria (in particular on payback periods and expected returns). Investors can be banks, private investors or even individuals (crowdfunding).
4. Public authorities: this actor corresponds to the federal, cantonal and municipal authorities. At each of these levels, a subsidy for the solar thermal plant is possible. At present, subsidies for solar heat are provided at cantonal and municipal levels. The introduction of a carbon tax takes place at the federal level. In countries other than Switzerland, zero-interest loans can also be offered by public authorities. It should be noted that public authorities may adopt rules that may be unfavourable to the construction of solar thermal plants. This is the case with land use planning laws that limit access to land for the construction of solar thermal and PV plants.
5. Engineering Procurement and Construction (EPC): corresponds to the company that develops and builds the turnkey solar thermal plant. This company is also responsible for the commissioning of the plant. This company will get materials and engineering services from other companies (solar collectors from the solar thermal technology provider). This is equivalent to Engineering, Procurement and Construction Management (EPCM). In some cases, the solar thermal technology provider could act as EPC. This is the case for example with the Swiss company TVP solar.
6. Operation and maintenance (O&M) provider: refers to companies that offer operation and maintenance services for the solar thermal field. These companies offer maintenance contracts that guarantee the proper operation of the different elements of the solar thermal installation over a contractually defined period. Note that a solar thermal technology provider can also offer operation and maintenance contracts for the installations it has developed.

3.2.3 “Business as usual” with or without subsidies

The simplest and most common financing model in Switzerland corresponds to the case where the investment in the solar thermal plant as well as its operation are made by the company that needs the heat. This financing model is illustrated in Figure 15.

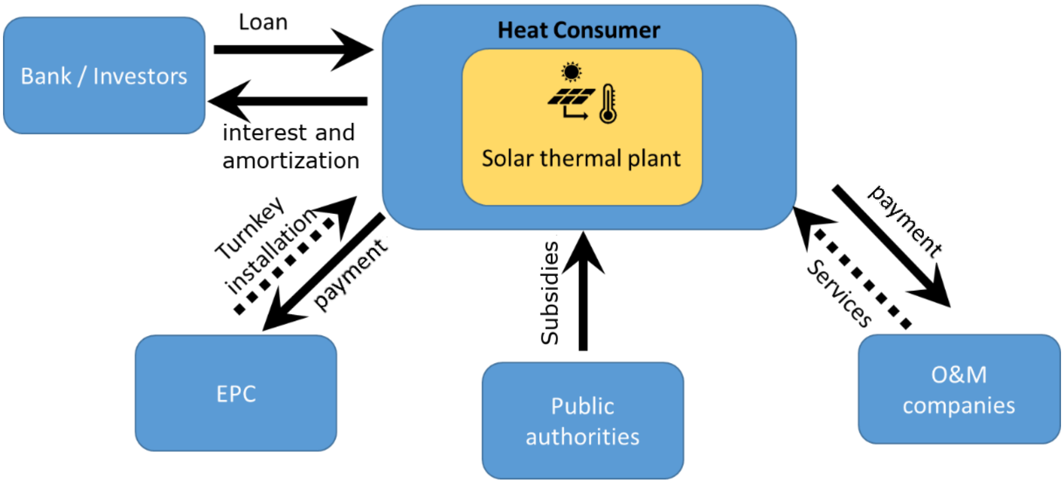

Figure 15 : Principle of the “business as usual” financing model of a solar thermal plant. The heat consumer is centred as the most important actor

In this classic financing model, the entire cost of pre-study, design, material purchase and construction of the solar thermal plant is borne by the company that requires heat. The amortization of this investment is carried out with the savings on the fuel bill and potentially on the CO_2 tax[5]. The company can also potentially benefit from cantonal and municipal subsidies on the initial investment. In order to finance the project, the company will use its own funds and can call on banks to contract a loan. Other sources of financing are also possible for this type of business model (see section 3.2.5 below).

In this financing model, the role of the company that requires heat is central. It is the company that must take the initiative to carry out a pre-study at its own expense, either in-house or by commissioning an engineering office. If they are interested, they should then request several offers for the solar thermal plant. Once the best offer has been selected, the company must provide the financing with its own funds and/or with a bank loan. The company must also apply for subsidies from the relevant authorities. Once the solar thermal plant is up and running, its operation and maintenance is the responsibility of the company. One or several maintenance contracts can be concluded with different service companies to ensure the smooth operation of the plant.

The “business as usual” model has a number of advantages. It allows the company to carry out the work and investments at its own pace. In addition, the company will also be able to benefit 100 % from the lower costs of producing its own heat (e.g. savings on fossil fuels). Furthermore, as the cost of solar heat is mainly made up of the amortization of the initial investment (see section 3.1.1 above), by investing in a solar thermal plant, the company secures part of its energy supply at a stable and defined cost for the next 20-25 years.

This classic business model also has significant disadvantages. The most detrimental of these disadvantages is the need to invest a large amount of money at the beginning of the project in an installation that does not correspond to the company's core business. Another disadvantage is that the company must have a long-term visibility on the evolution of its own heat consumption. However, it is not necessarily easy in industry and in the service sector to forecast beyond a 5–10 years horizon.

This business model also presents a significant risk related to the thermal performance of the solar plant in the long term. If this performance deteriorates, the entire loss of heat production will have to be borne by the company. The company will then have to turn against the material supplier if the loss of production is related to a component defect of the solar thermal plant covered by a warranty. Otherwise (poor hydraulic integration or control parameters), the company will have to bear the loss of profitability alone (unless a performance contract has been negotiated with the solar thermal technology provider). A performance guarantee contract can be concluded with the solar technology provider to limit this risk.

A SWOT analysis of this first classical business model is given in the Table 13. This analysis helps to identify the internal and external benefits and risks of this type of business model.

Table 13: SWOT analysis of the “business as usual” model for the integration of a solar thermal plant on an industrial site

	Positive impacts	**Negative impacts**
Internal factors	**Strengths** - Full control of the planning - Stabilised energy prices over time - Company image (reputation)	**Weaknesses** - Initial investment tied up - Less cash available for investments in core business - Potential decrease in heat consumption over time (oversized installation) - O&M of solar plants
External factors	**Opportunities** - Safeguard against heat cost increases - Limits CO_2 tax - Public support of the project via subsidy and tax credit	**Threats** - Lower than expected performance - Failure of the solar technology provider - Change in heat demand

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[5] It should be noted that since the rejection of the CO_2 law by the Swiss people on the 13th of June 2021, there is some uncertainty about both the principle of operation and the amount of taxes on CO_2 emissions. Nevertheless, it seems very likely that a tax will be kept.

The uses of solar heat in the service sectors and in the industry in Switzerland is not widespread. This is partly explained by the absence of subsidy scheme for solar thermal plant in the industry. Thus, to stimulate the development of solar heat in those sectors, it is essential to develop generous subsidy scheme.

3.2.4 Energy contracting

Energy contracting represents an attractive alternative for the financing and operation of the solar thermal plant for the company consuming the heat. In this business model, the financing of the solar thermal plant and its operation is carried out by a third party. Figure 16 illustrates the financial flows in this model.

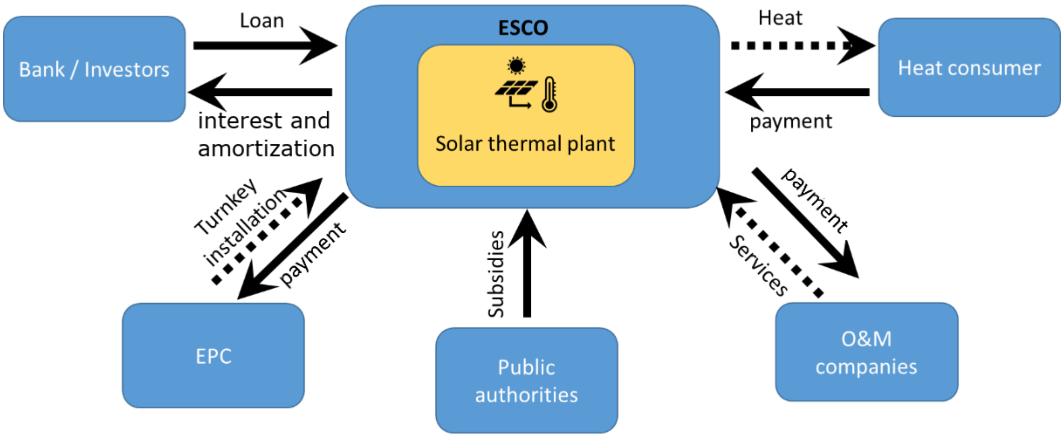


Figure 16 : Principle of the energy contracting financing model. The energy service company is the main actor in this model, the heat consumer only communicates with the ESCO.

In the energy contracting business model, the entire cost of pre-study, design, material procurement and construction of the solar plant is borne by a third-party company called a contractor. In the energy field, contractors can also be called Energy Service Companies (ESCO). The amortization of the investment for the contractor is achieved through the sale of solar heat to a heat consuming company (end user or customer). The heat price and its development, as well as the period during which the heat licensee commits to purchase the solar heat, are contractually fixed. The heat supply contract also defines penalties for breach of contract. Under this business model, it is the contractor who can potentially benefit from cantonal and municipal subsidies on the initial investment. The structuring of the financing is also the responsibility of the contractor, who can call on different sources of financing (see section 3.2.5 below).

A variant of this business model involves the creation of a project company or Special Purpose Vehicle (SPV). This project company is created by the energy service company for a specific contracting project. In this case, the solar thermal installation is financed and operated by the project company. This company generates income by selling solar heat to the heat licensee. As with the previous variant, the terms of sale are set by a contract signed by the project company and the heat licensee. The ESCO provides the financing for the purchase of the solar thermal system to the project company. In return, the ESCO receives dividends and interest from the project company, allowing it to amortise its initial investment.

This variant of the business model reduces the risks for the ESCO and provides more flexible contractual conditions. In addition, other investors may join the ESCO in setting up the project company (joint venture). For example, it is possible that the heat consuming company owns a part of this project company and thus participates in the co-financing of the initial investment. Figure 17 illustrates the operating principle of this variant of the energy contracting business model.

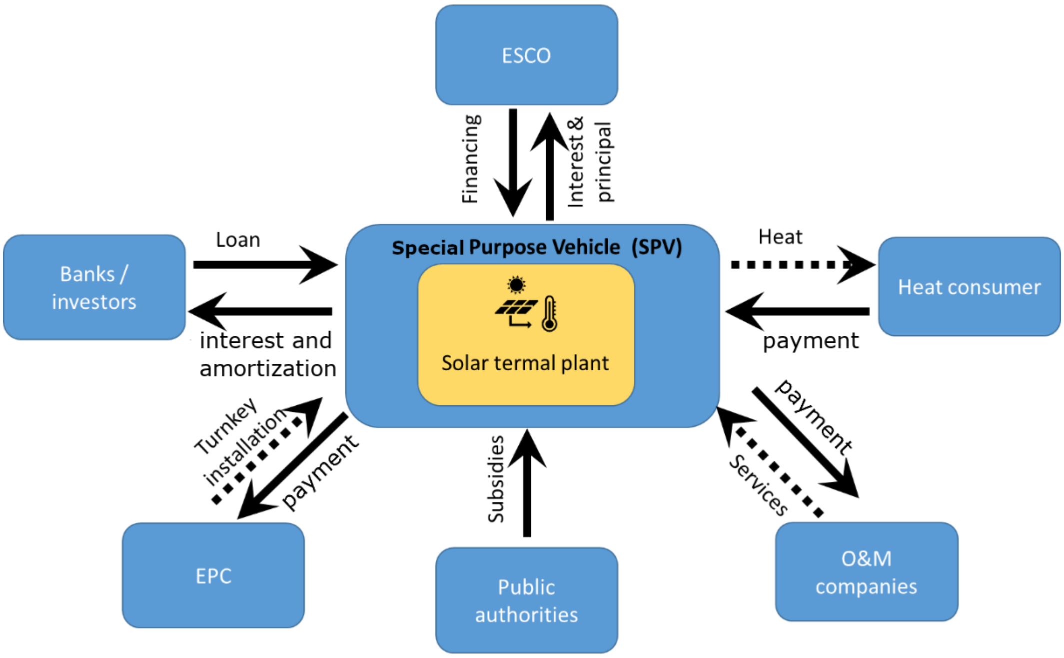


Figure 17 : Principle of the energy contracting business model with the establishment of a project company. The SPV is the main actor coordinating all communication.

The energy contracting business model allows the heat-consuming company to benefit from the technical and financial expertise of an energy service company in order to build, finance and operate a solar thermal system. This eliminates the risks associated with the construction and operation of a solar thermal system. It also allows the heat-consuming company to keep its investment capacity. Depending on the type of contract negotiated, this business model also makes it possible to secure the costs of its heat supply over a long period of time. It is also possible within the framework of this business model to negotiate a guarantee of heat production depending on various parameters (weather, temperature level of heat requirements).

Energy contracting also has some disadvantages for the heat licensee. The cost of the solar heat sold by the contractor will be higher than the cost of producing the solar heat. This is because the contractor needs to generate a profit on the sale of heat in order to amortise his initial investment and to earn interest on this investment. The other disadvantage for the heat licensee is that he has to guarantee his heat consumption over the duration of the contract or he will have to pay penalties. The time horizons for this type of contract can be relatively long (15-25 years). Moreover, the heat consumer will have to rent surfaces for the solar thermal plant to the contractor over the duration of the contract. So it will not possible to develop other project on those surfaces (PV plant for example). Finally, the energy contracting business model is relatively cumbersome and time-consuming to set up. It is therefore more suitable for large projects (>500 m^2). For smaller projects, it is possible to group them together to reach critical size (project pooling).

A SWOT analysis of the energy contracting business model is given in the Table 14. This analysis identifies the internal and external benefits and risks of this type of business model.

Table 14 : SWOT analysis of the "energy contracting" business model

	Positive impacts	**Negative impacts**
Internal factors	**Strengths** - Expertise in financing, building and operating solar thermal installations - Stability of heat costs - Heat licensee retains its own funds for core business - Incentive to maximise the performance of the solar installation	**Weaknesses** - Only valid for large solar thermal projects (>500 m^2) - Contractual complexity and long contract duration - Deployment of energy efficiency measures that reduce the heat requirement - Back-up source of heat from the heat end-user compatible with solar heat - Increased cost of solar heat due to the involvement of additional players
External factors	**Opportunities** - Strongly growing energy contracting market in Europe - Protection against heat cost increases - Limits CO_2 tax - Rising heat costs favour this type of business model	- **Threats** - Bankruptcy of the ESCO or the heat licensee - Decline in heat demand - Energy contracting still not well known nor widespread in the field of solar heat - Lack of subsidies for large solar fields in Switzerland

To the best of our knowledge, there are not many examples of large-scale solar thermal plants (over 500m^2) in Switzerland that have been developed according to this business model. In Europe, the energy contracting market for solar heat is developing with private companies in Germany, Austria and France. For example, the French company NewHeat has recently developed and financed several large solar thermal installations in the industrial sector as well as in the district heating sector. NewHeat was able to benefit from interesting bank loans to finance these projects (see example described below).

It is important to note that, in most cases, the financial interest of the solar thermal projects developed by these companies was strongly conditioned by available public subsidy schemes. These subsidy schemes can finance 40-60 % of the initial investment (Tschopp, Tian, Fan, Perers, & Furbo, 2020) (Epp, 2020). As a reminder, there are no subsidy rules for solar thermal installations in Switzerland outside of space heating and domestic hot water production for buildings. This is currently a major obstacle to the development of this sector in Switzerland.

Table 15 gives some examples of ESCOs offering energy contracting services in the field of solar thermal in Europe.

Table 15 : List and description of energy service companies active in energy contracting for solar heat in Europe

ESCO Name	Description
NewHeat (France) https://newheat.com/	French company active in solar heat energy contracting in Europe since 2015. NewHeat has developed 4 large solar thermal contracting installations in the industrial and district heating sector.
Enertracting (Germany) https://www.enertracting.de/	Enertracting is a German company active in solar heat contracting. It has developed and operates more than 20 installations mainly in Germany. In particular, it has developed several installations for heating natural gas in decompression stations that link the high-pressure network to the medium- and low-pressure network.
Solid (Austria) https://www.solid.at/	Solid is an Austrian company that has been active in the solar thermal sector for more than 25 years. It has developed more than 300 solar thermal installations of more than 300 kW. It is active in solar heat contracting. In particular, Solid has developed large solar thermal systems coupled with DHN by energy contracting.

At the Swiss level, there is still no company active specifically in solar heat contracting. The company TVP Solar has recently launched a subsidiary TVP Investments which acts as a third-party investor to facilitate the development of solar thermal installations using the collector developed and marketed by TVP Solar (see section 3.2.5). Energy contracting, on the other hand, is very widespread and popular in the field of district heating in Switzerland. Indeed, companies such as EKZ and Groupe E have financed and built a significant number of district heating networks over the past 15 years, which are operated under the heat contracting model. The development of this type of business model in Switzerland for solar thermal installation projects for industrial applications is for the moment strongly limited by the absence of subsidy schemes for large installations.

An example of a solar thermal installation developed by the company NewHeat following this business model is described below. It is a large solar thermal field that has been commissioned in France in 2019 to supply heat to an industrial paper production site, see Figure 18. The solar field has a surface area of over 4,000 m^2 and uses large Savo Solar collectors of over 15 m^2 installed on a single axis tracking system. The solar heat produced by this installation covers between 1 to 2 % of the site's heating needs. The large surface area of this installation allowed the cost of the installation to be limited to 546 €/m^2. The French Agency for Ecological Transition (ADEME) funded the project up to 61 %. NewHeat has created a project company which owns the solar collector field and is responsible for operating it and selling the heat produced to the industrial site. The purchase conditions are contractually fixed between this project company and the industrial site for 15 years.

Figure 18 : Photo of the industrial site where the 4,000 m^2 solar thermal field was installed (source: NewHeat)

3.2.5 Source of financing

In both business models described above, different sources of financing can be mobilised to fund the initial investment needed for the construction of the solar thermal field. A brief description of the main sources of finance available is given below.

The cost of heat consists mainly of the amortisation of the initial investment. This large initial investment and the long amortization period are often a barrier to the development of this type of project, whether directly by the end-user or by an ESCO following the "energy contracting" business model. In both cases, the solar plant is rarely funded using 100 % of self-financing. They therefore have to rely on other sources of financing.

Bank loan:

The primary source of financing for industrial and public actors is bank loans. This source of financing offers in principle some of the lowest interest rates. In return, the risks related to the activity or infrastructure being financed must be low and easily assessable. Solar thermal installations are still very rarely financed by bank loans because they are considered a risky sector mainly for two reasons. On the one hand, these infrastructures are still little known to risk assessment experts. For example, it is difficult to predict how much an installation's efficiency will decrease over time (Epp, 2020) and therefore its productivity. On the other hand, the relatively long payback period of these infrastructures means that the probability that, for example, the heat demand will change before the end of the project is not negligible. Nevertheless, it is increasingly common for banks to provide loans for solar thermal installations for certain aspects of the project that are considered low risk. Another potentially limiting aspect of accessing this type of financing in the solar heat sector is that banks prefer to commit to large loans of several million CHF. It may therefore be necessary to pool several projects together (project pooling) in order to exceed this critical threshold. This is for example the case of a recent project of the company NewHeat which was able to benefit from a loan of €13M for several solar thermal plant projects.

Third-party investor:
Another interesting source of funding for projects is the third-party investor. This source of funding can be complementary to the project owner's own funds. Unlike a bank, a third-party investors has a degree of expertise in the field in which it invests. It is more capable of assessing the risks associated with its investment and consequently invests more easily than a simple bank in the sector of activity it masters. In return, the third-party investor is involved in the selection of the technology provider as well as the service providers who will build the solar thermal plant. It is quite common for third-party investors to work only with technology providers they know. The third-party investor usually requires a higher financial return than a bank.
In addition, the third-party investor can play a role in raising additional capital. The third-party investor often has a network in the banking and financial community, which enables him to structure financing for large projects. In addition to providing capital, it is common for the third-party investor to play a role in applying for subsidies as well as in contractual aspects (purchase of heat, exit clauses on breach of contract...). For large projects, it is common that the project is implemented by a project company. The third-party investor is normally involved in the creation of this company.
Table 16 gives examples of third-party investors that are specifically active in financing large-scale solar thermal plants. It should be noted that there are relatively few third-party investors active specifically in the field of solar thermal in Switzerland. This type of player is, on the other hand, very common in the photovoltaic sector.

Table 16 : Example of third-party investor companies active in the solar thermal sector

Company	Description	Type of activity
kyotherm Contact : Remi Cuer	Company created in 2011 for the realisation of renewable heat production and energy saving projects.	Based in France with subsidiaries in Germany and in the UK. First solar thermal plant to be commissioned in 2021 (paper mill sector).
TVP Investment Contact : Florent Saunier	The solar thermal collector company TVP Solar has created a daughter company "TVP Investment" in 2021, which acts as a third-party investor.	Based in Switzerland. No realisations to date. The objective of TVP Investment is to offer financing to companies interested in the TVP solar collector.

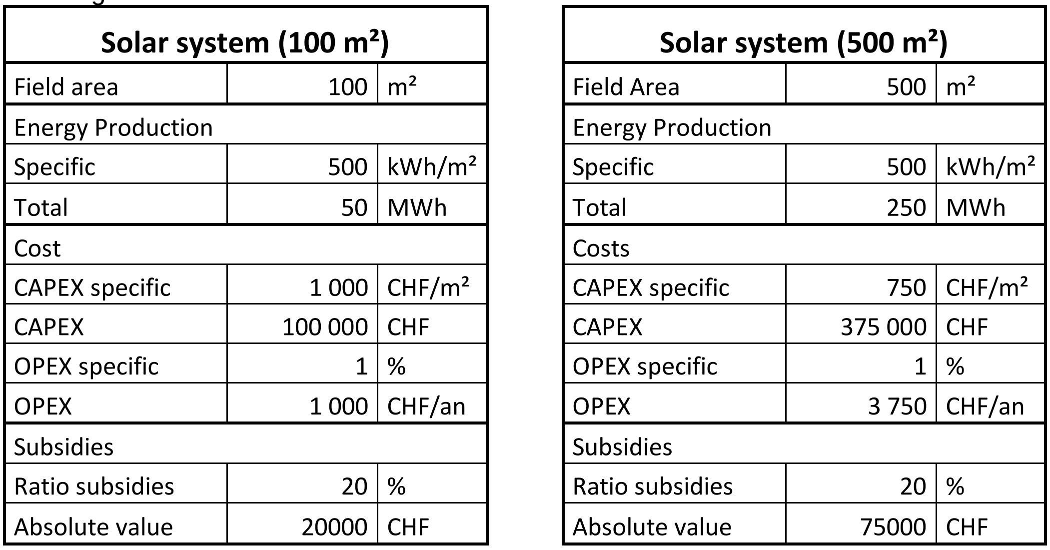
Crowdfunding:
Crowdfunding is a third possible source of financing for solar thermal systems. In this case, a call for tenders is made via an online platform to the general public for the financing of a specific project. The amount of money sought and the financial return are fixed at the time of the call for tender. In this type of financing, each investor bears a share of the risk of the project they are financing.
The use of this type of financing is common in the photovoltaic sector. It is much more unusual in the solar thermal sector. Nevertheless a few small solar thermal projects were funded in Switzerland following this principle. They're solar thermal installations connected to DHN. These installations were partially funded by the DHN users. In return for their investments, the investors got cheese and dairy products in one case.

Subsidies:
Subsidies are an important source of funding for solar thermal plants used in the industrial and service sectors. In Switzerland the subsidy scheme depends on the canton in which the project is located (see section 3.1.3 above).
At present there is no subsidy scheme for large-scale solar installations in the industry or the service sector. This hinders the development of this sector in Switzerland. There is a strong correlation between the level of subsidy for solar heat in a country and the degree of development of solar thermal installations.

Austria is an interesting example of this, with almost 0.5 m^2 of solar thermal collectors per inhabitant. Austria has a long-standing and ambitious subsidy policy for solar thermal systems for small installations. Since 2010, a subsidy scheme has been in place for large-scale solar thermal plants. These subsidies can cover up to 40 % of the initial investment. Following the introduction of this subsidy scheme, numerous projects for large-scale solar thermal plants have been developed.

3.2.6 Case studies

The two case studies mentioned in section 3.1.1 are used here to calculate the selling price of solar heat for the two financing and business models described above. The costs and the specific productivity of the two cases are given in the tables below.



Solar system (100 m²)		
Field area	100	m²
Energy Production		
Specific	500	kWh/m²
Total	50	MWh
Cost		
CAPEX specific	1 000	CHF/m²
CAPEX	100 000	CHF
OPEX specific	1	%
OPEX	1 000	CHF/an
Subsidies		
Ratio subsidies	20	%
Absolute value	20000	CHF

Solar system (500 m²)		
Field Area	500	m²
Energy Production		
Specific	500	kWh/m²
Total	250	MWh
Costs		
CAPEX specific	750	CHF/m²
CAPEX	375 000	CHF
OPEX specific	1	%
OPEX	3 750	CHF/an
Subsidies		
Ratio subsidies	20	%
Absolute value	75000	CHF

Figure 19 Characteristics of the two case studies used to analyse the impact of the business models on the cost of solar heat

The cost of solar heat for the "classical" business model ("host owned"), in which the end-user bears the entire initial investment and O&M costs, is calculated using a discount rate of 3 % over a 20-year period. With these parameters, it is possible to calculate the levelized cost of solar heat (LCoH) using the following formula with different subsidy rates:

$$LCoH = \frac{I_0 + S_o + \sum_{i=0}^{20} \frac{OPEX_i}{(1+t)^i}}{\sum_{i=1}^{20} \frac{E_i}{(1+t)^i}}$$

where

LCoH	Levelized cost of solar heat
I_0	Initial investment made in year 0 of the project
S_0	Subsidies received in year 0 of the project
$OPEX_i$	Operating and maintenance costs in year *i* of the project. The operation and maintenance costs represent 1 % of the cost of the solar thermal installation (I_0).
E_i	Annual heat output in year *i* of the project
t	Discount rate

The levelized cost of solar heat was also calculated using the Energy Contracting business model. The following assumptions were considered:

- The entire initial investment is provided by the ESCO, which expects a 5 % return on its investment during the contract period
- The project contract duration considered is 15, 20 and 25 years. At the end of this period, the heat end-user owns the plant and the ESCO has fully amortized its initial investment and generated a 5 % return.
- The public subsidy rate varies from 0 % to 60 % of the initial investment.

The formula used to calculate the LCoH in the energy contracting business model is as follows:

$$LCOH_{ESCO} = \frac{I_0 + S_o + \sum_{i=0}^{n} \frac{OPEX_i + FI_i}{(1+t)^i}}{\sum_{i=0}^{n} \frac{E_i}{(1+t)^i}}$$

where

FI_i	is the financial interest in year *i*. This financial interest represents 5% of the initial investment paid by the ESCO (subsidy deducted).

Furthermore, the payback time for the ESCO has been calculated considering that the heat is sold at the levelized cost of heat (LCOH) to the heat end-user. This generates an annual income that allows the initial investment and O&M costs to be amortised.

$$VAN(PBT) = I_0 + S_o + \sum_{i=0}^{PBT} \frac{CF_i}{(1+t)^i} = 0$$

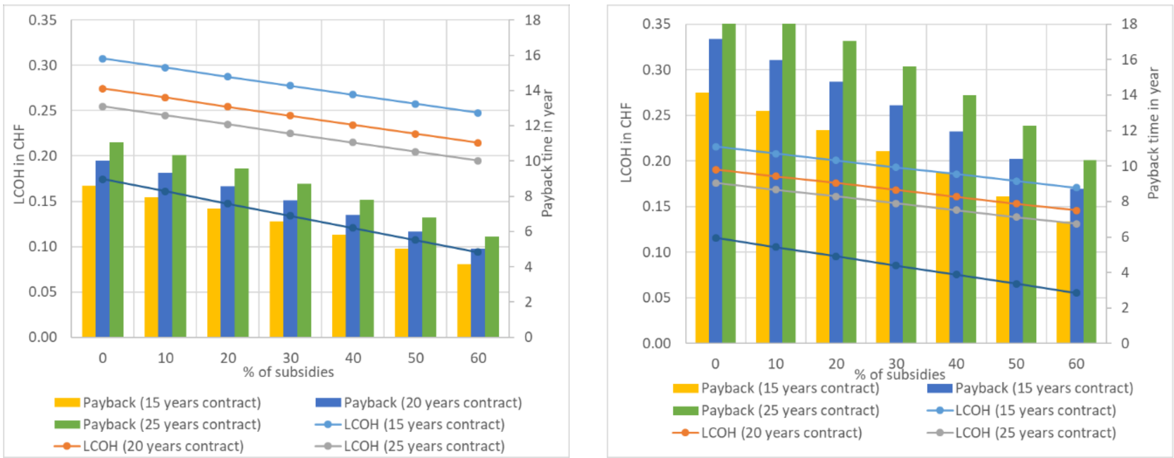
with

$$CF_i = OPEX_i + LCOH \times ST_i$$

where

NPV	Net Present Value of the project for the ESCO. The NPV is by definition zero in the year of the project corresponding to the payback period.
CF_i	Cash flow of year *i* calculated using the above formula
ST_i	Solar heat output sold to the heat end-user in year *i*
PBT	Payback time

Figure 20 gives the LCoH for the two case studies mentioned above as a function of the subsidy rate.



A B

Figure 20 LCoH and payback time as a function of the subsidy rate for a 100 m^2 installation (A) and a 500 m^2 installation (B) for different contract durations in energy supply contracting. For comparison, the LCoH in the case where the heat end-user finances and operates the solar field is also given ("Own investment" curve)

It can be seen that the LCoH for the two business models defined above depends strongly on the subsidy rate. The difference in the cost of solar heat between the "classical" and the "energy contracting" business model is due to the financial interest that the ESCO makes on its initial investment (5 % in this case). This difference can be significant (between 8 and 12 Rp/kWh).

For the "energy contracting" business model, solar heat should be sold at 20 Rp/kWh and 15 Rp/kWh for the 100 m^2 and 500 m^2 case studies, respectively, with a subsidy rate of 50 %. Note that a subsidy rate of the same order of magnitude is applied for large solar thermal installations in France, Germany and Austria (see section 3.1). This heat cost is indeed higher than the cost of the most common heat production technologies in Switzerland (gas & oil). On the other hand, the evolution of the cost of fossil heat is very volatile as it strongly depends on the evolution of the cost of fossil fuels on the international markets. Integrating solar heat into the heat supply mix can therefore contribute to cushioning fossil fuel price variations.

Figure 20 also shows the payback time for the ESCO in the case of the energy contracting business model as a function of the subsidy rate and for different contract durations. This payback time decreases with the subsidy rate. However, it tends to increase with the duration of the contract. For a subsidy rate of 50 %, the payback time varies from 4 to 6 years for the 100 m^2 installation and from 6 to 8 years for the 500 m^2 installation. These payback times, although long, are not so far from the payback times often considered viable in industry (5 years). It should be noted that ESCOs are used to working with projects with relatively long payback periods (5 to 10 years or more). This is particularly the case in the field of district heating networks (DHC), which represents one of the most important markets for energy supply contracting in Switzerland. In this sector, payback times easily exceed 10 years.

3.2.7 Conclusion of financing and business models

The financial analysis carried out in this document in section 3.1.1 of this report shows that the cost of solar heat without subsidies is very close to the cost of heat produced by other technologies. The greatest advantage of solar heat over other technologies is that its production cost is mainly the amortisation of the initial investment. Therefore, the cost per kWh can be considered stable over the lifetime of the installation. In the case of gas or oil, the production costs are highly dependent on the price of these two fuels, which are highly volatile. In a heat production system, solar heat can therefore help to cushion the variations in heat production costs.

With an average greenhouse gas content of about 14 g/kWh, solar heat is one of the lowest carbon emission technologies for heat production. As such, the solar thermal sector can potentially contribute effectively to decarbonising the heat production sector in Switzerland. This sector is still very carbon intensive with more than two thirds of the heat produced with fossil fuels. A calculation of the present value of greenhouse gas emission savings has shown that the cost per ton of CO_2 saved through solar heat varies from 500 CHF to -64 CHF/tCO_{2eq}. This cost is of the same order of magnitude as the current CO_2 tax (about 96 CHF). This tax is expected to increase significantly in the coming years. This shows that it can be more interesting from a financial point of view to invest in a solar thermal system than to pay the CO_2 tax. Please note that this calculation was made over a period of 20 years with an interest rate of 3 %.

The initial investment required to build a solar thermal system is often a blocking point. The energy contracting business model eliminates this problem. In this business model, a third-party company bears all or part of the initial investment. In return, the company consuming the heat contractually agrees to buy the solar heat at a given price over a given period of time. This business model is relatively underdeveloped in the Swiss solar thermal sector. In contrast, it is relatively common in the photovoltaic sector. Solar heat contracting is being developed in other European countries with ambitious subsidy schemes for solar heat in industry. For example, in Germany and France, subsidies up to 50 % of the initial investment contributed to stimulate the market of large solar thermal installation in the industrial sector.

The lack of public support and subsidies in Switzerland is the main obstacle to the development of large-scale solar thermal installations for industrial and service sector applications. Other important issues should also be addressed in order to promote utilization of solar heat in the services and industrials sector. The formation of the planners and decision makers on solar thermal technologies should be intensified. The mismatch between the heat availability and the heat needs is also a limiting factor. Heat storage could help improve the situation but higher initial investments need to be available. Finally, solar heat has to be coupled to another heat production technology in order to satisfy heat needs independently of solar resources availability. This inherent characteristic of solar thermal technology requires to invest in an auxiliary heat production technology which can be operated when the solar irradiation is too low. Therefore solar heat makes economic sense only when the cost of solar heat is lower than the operating cost of the auxiliary heating system.

3.3 Improvement of the SOLIND Tool

The SolInd tool developed in the previous project is an excel-based tool made to quickly assess the solar potential of an industrial site. It requires basic heat demand data and inputs regarding location and roof area. It then roughly estimates the solar yield and the cost of solar heat. In this project, it was adapted to cover the needs of the service sector as well. For this purpose, the tool has been universalized so that it can be used for different applications. This extension consists of:

- Yield and economic calculations for low temperature applications like heating and domestic hot water
- Simplified input and suggestions for demand profiles for the service sector
- Rough estimate of the expected subsidy funds
- Automated calculations to show field size optimized for lowest cost
- Guidelines with specific cases for various service sector fields
- More input explanations to increase the user-friendliness, including a glossary
- All changes in De/Fr/En Languages

This tool can be used by planners and energy managers of companies in the industrial and service sector as well as in sectors with similar heat requirements for a quick solar thermal feasibility study. Thanks to the new and simplified extension, interested owners of small businesses should be able to use the tool as well. To test the performance of the tool and improve it, it is used as a quick assessment before doing a detailed energy flow analysis during the feasibility studies.
The SolInd tool can be downloaded under https://www.spf.ch/index.php?id=19045&L=6

3.4 Feasibility Studies

Six quick techno-economic feasibility studies have been performed for applications with high potential for solar thermal integration in the service sector. The studies were conducted using the expanded version of the SolInd tool (see 3.3). The required input information was obtained through interviews and visits to the site locations. The objective is to highlight technical potentials, suitable applications, and conditions for successful solar thermal implementation in this sector.

In WP1, the identification of suitable applications for solar thermal installations in the service sector was performed (see 2.1). The selection of the case studies and identification of specific suitable users and operators of solar thermal systems were based on the results of the survey described in 2.2. Nearly 30 case studies were identified having already a solar thermal system in operation or with a great interest in adopting one. The most suited candidates were further contacted for personal interviews and visits to the site locations.
Overall, six cases were selected for a feasibility study with the updated SolInd tool. The case studies are from the French and German speaking parts of Switzerland and are described and summarised here. The feasibility studies are attached to this report.

Table 17 Summary of case studies

Nr	Name	Activity sector	Location	Application
1	Carwash Hydrowash	Car-washing	Echandens	DHW
2	Camping VD8	Camping	Yverdon-les-Bains	DHW
3	Colovray outdoor pool	Sports centre	Nyon	Pool heating and DHW
4	Retirement Home	Residential care	Aargau	Heating, DHW and laundry
5	Hotel & Spa	Hotel & Wellness centre	Schwyz	Pool heating
6	Foundation Home Care	Residential care	Aargau	DHW and pool heating

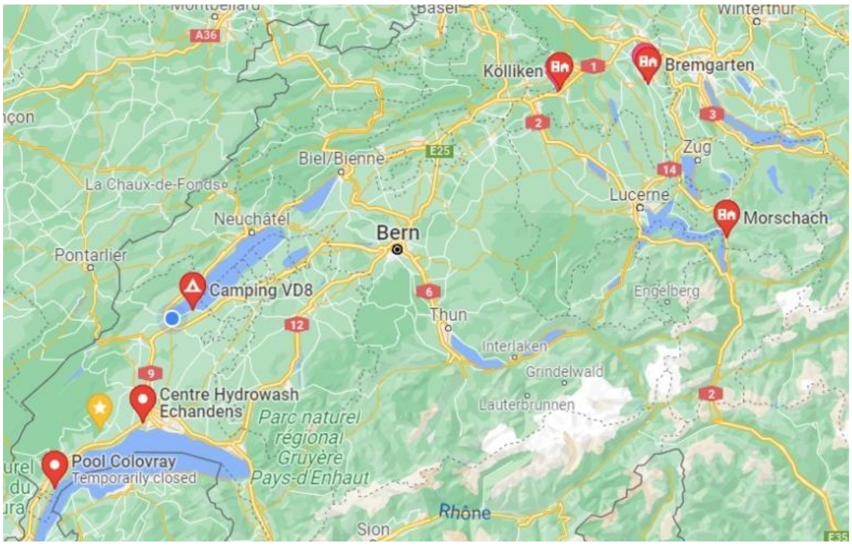


Figure 21 Locations of the case studies

Although the case studies are from five different sectors, the type of application was always one of the following: domestic hot water (DHW), room heating and pool heating. DHW usually was in a range of 45 – 60 °C, pool heating between 32 and 35°C and room heating around 50 °C. Big differences regarding heat consumption of the site could be seen: it ranges from 8.7 MWh/y to 800 MWh/y. These processes match and confirm the findings of the market analysis in 2.1.

Table 18 Processes described in the case studies

Process	Temperatures	Case Studies No	Heat demand
DHW	45 – 60 °C	1-6	8.7 – 430 MWh/y
Room heating	50 °C	4,6	150 – 500 MWh/y
Pool heating	32 – 35 °C	3-5	38 – 300 MWh/y

The low temperature required by the pool heating would preferably be provided by waste heat. Only one of the case studies however used heat recovery, and the remaining ones do not have viable potential to do so too. Therefore, unglazed collectors could be an option for those situations where only pool heating is required, since this reduces investment cost and potentially the LCOH. The efficiency of unglazed collectors however drops sharply above 40 °C, which means that they are not suited for the other applications. For all case studies, flat plate collectors have been considered, running at 50 °C. For those processes where higher temperatures were required, the implementation as preheating was suggested to reduce collector temperature and increase collector efficiency. Five out of six studies reported the availability of sufficiently large storage tanks. Their suitability for solar integration however was not evaluated.

Table 19 Left: Energetic data for the case studies. Right: Financial data of the case studies. a) Some organizations have a fixed price (8 Rp/kWh) for their district heating connection, which cannot be replaced by solar thermal energy. This makes it more difficult for solar to become economically feasible. b) Two analyzed options lead to heat prices of 14.1 and 22 Rp/kWh. These options were not recommended and less expensive alternatives were suggested.

Collector areas	19 – 800 m^2
Solar heat production	8.2 – 547.1 MWh/y
Solar share	13.3-75.5
Current energy vector	Gas, Oil, DH Electric

Current energy vector	Gas, Oil, DH, Electric
Current heat prize	9 – 17$^{a)}$ Rp/kWh
LCOH 25y solar	8.6 – 11.6$^{b)}$ Rp/kWh
Acceptable payback	5 – 24 y (ø 15.8 y)
Solar payback	12 – 24 y (ø 16.4 y)
Net investment	27.8 – 470 kCHF
Subsidies (% of invest)	19 – 28 %

Due to high differences in energy demand, the suggested collector areas also varied in a high range of 19 – 800 m^2. A high solar share was calculated for large available roof areas and for processes with low winter heat demand. The camping site and the outdoor swimming pool both close during winter, leading to solar shares of > 50 %, and to the stated 75.5 % for the camping site (building A). The drawback of the camping site however is a low available roof area: many windows in the roof reduce the available area and reduce the solar share and increase the cost on building B. This is usually not the case, which is why camping sites are still seen as very well suited for solar thermal energy.

The existing energy vectors in the case studies are gas, oil, district heating and electricity. The stated energy prices range from 9 – 17 Rp/kWh. It is to mention here that the district heating connections for the two case studies with DH connection already cost a base price which corresponds to ~8 Rp/kWh. This base price has to be paid independent of the energy demand and still needs to be paid if solar thermal covers the heat demand partially. Companies with DH connection and a base cost are therefore less likely to find solar thermal as an economically beneficial solution.

The calculated solar $LCOH_{25}$ over 25 years were in the range of 8.6 – 11.6 Rp/kWh, which is a competitive price. For two scenarios however, this range was exceeded by far, which is why these scenarios were not recommended. One of the scenarios showed a very low summer heat demand; the other had a very low heat demand in general leading to increased heat prices. The reported payback time of the solar systems ranged from 12 – 24 years (ø 15.8 y), which largely covers the acceptable payback time stated by the owners 5 – 24 y (ø 15.8 y). This payback time however is distinctly higher compared to the one resulting from the survey (see 2.2). The 7 – 10 years stated there is almost half of the values from the case studies, which may have multiple reasons: for one, most answers in the survey were given by hospitals, which mostly are market driven companies with a well-structured accounting system. A faster return on investment might be of higher priority in these fields. A second reason might also be the structure of the survey itself: the answer given most (7 – 10 y) is also the centered option, which may lead to some bias towards the middle.

The subsidies that could be applied for were calculated using the webpage kollektorliste.ch. For the observed systems, subsidies in the range of 19 – 28 % of the initial investment cost could be applied for. This amount matches the survey, where the option "20 – 30 %" was selected most. The option "30 – 40 %" however was selected almost as often (8 vs 9 answers), indicating that somewhat higher subsidies are desirable.

The net initial investment cost for the suggested scenarios still ranged from 27'800 to 470'000 CHF after subsidies. This is still a large amount of money for the organizations and companies, which need to trust suppliers that the solar system then will last the promised 25 years. The solar heat price may be competitive, but the high initial investment cost together with the loss of flexibility regarding the usage of the roof and building are major factors that hinder companies from using solar thermal systems. A possible solution might be contractors that install and maintain a solar system and supply heat for a fixed price. Business models as described in chapter 3.2 may foster such a development, simplifying installation and operation of such a renewable solar heating system for operators. Structures to lower the threshold to a long-term commitment and to mitigate the risk of a large investment need to be built to be able to increase the share of solar thermal systems in Switzerland.

4. Dissemination, communication, and solar heat promotion

An overview of the communication and dissemination activities implemented during the project to promote the SolInd2Service outcomes is listed below. It includes the reporting of dissemination tools, channels (internet page, social media, publications) and other dissemination activities including scheduled events and conference presentations.

Logo and visual identity, fact sheet, best case scenarios

Figure 22 Left: old Sol-Ind Swiss logo. Right: new SolInd2Service logo

- A logo was created for straight recognition of the project to the consortium and to the different stakeholders. The logo evolves from the Sol-Ind Swiss project logo. It is a green version having an additional building icon representing the service sector.
- A two-page fact sheet was developed describing solar technology and its benefits, including information regarding subsidies. Information was included on who and how local specialists and companies can be contacted, if a solar thermal system should be installed. This should simplify the access to information, display first connection and entry points and lower inhibitions (see Annex 2.1).
- A project overview flyer was prepared containing a project description, main objectives, work packages, contacts and partners logos. This brochure was sent out to national entities with an interest in the topic and willing to disseminate the project outcomes. It will also be distributed by partners in future in-person events (see Annex 2.2).
- Flyers with Best practice examples were made, containing information and experiences from existing solar thermal systems in the service sector. This should create proximity and show that solar thermal is viable for various applications in the service sector (see Annex 2.3). These Best Case factsheets will be available on the Swissolar website.

Online presentation: SolInd Tool, Webpages, LinkedIn

- The updated version of the SolInd tool is available on the SPF product webpage and is available in French, English and German, together with an updated description of the tool: SolInd Tool
- The project is displayed on the SPF webpage: SPF Projects Webpage
- A LinkedIn account was created to increase the project visibility and engage more professional target audiences with specific technical and business interests LinkedIn Group

Press releases

- Press release in HEIG-VD Newsletter, October 2020 (see Annex 3 attached)
- Press release from the Municipality of Nyon is expected in April 2022
- Energeiaplus blog from SFOE (2022)
- SuisseEnergie Industry & Services dissemination channels (2022)
- Article in the Newsletter of the Agence Cleantech Suisse (2022)
- Article in the Newsletter of Swissolar (2022)

Events and conferences

During the project duration, many science conferences and symposia have been either cancelled or postponed. The SolInd2Service team expects to attend different events in 2022 for presenting the project, promoting and engaging different stakeholders. All those actions have the purpose to disseminate the SolInd results and establish new contacts for future solar thermal implementations. The list of future events is listed below:

- 2 Workshops on solar heat projects in collaboration with Swissolar (May and Nov 2022)
- Event in collaboration with Energieagentur St.Gallen (2022)
- Event in collaboration with DIREN (e.g., workshop, seminar in 2022)
- SSES conference on energy transition, Yverdon-les-Bains (Autumn 2022)
- Symposium ER (next edition not yet scheduled)

Educational material

Results of the SolInd2Service project were presented in different certificate of advanced studies (CAS) from the HES-SO/HEIG-VD, such as the CAS ERTA, on renewable energies and CAS opti EN on energy optimisation in industry and business. In addition, results are also presented to professionals participating in the Master of Science in Engineering (MSE), Energy and Environment (EnEn) programme of the HES-SO. Occasional presentations take place also in the Energy and Environmental Engineering Bachelor courses at the HEIG-VD.

5. Conclusion

The high potential for solar thermal in the service sector is shown in this report and confirmed in the feasibility studies. Competitive heat prices can be achieved over the entire lifetime of solar collectors and low Levelized Cost for Carbon Abatement (LCCA) will become even more attractive for higher CO_2 taxes. This leads to the conclusion that the cost of heat is not the single critical factor that leads to decisions against solar thermal installations.

The conducted survey leads to the conclusion that companies in the service sector usually do not monitor their heat generation and therefore have less information and knowledge regarding their own heat production and consumption. Usually, the energy bill is the go-to source of information. Compared to industrial players with a high level of knowledge regarding heat consumption, the barriers of solar thermal in the service sector resemble more the ones of users in larger apartment buildings. It's more the competition with PV, a perceived complexity, missing know-how and high initial investment cost which predominate the benefit of a stable and low heat price.

There is a need to remove prejudice and fear of commitment due to safety and reliability, which is why leaflets of best-case were created and spread. They are intended to show positive examples within the service sector and to display that the technology is in fact reliable. Still, technologically unrelated risks persist, e.g. the need to move to a different location to which the collectors cannot be moved, or an unexpected need to renovate the roof structure, where the collectors are an obstacle. This risk is not included in any LCCA calculation and is difficult to assess.

A 25 year commitment with high initial investment can be discouraging for smaller companies even for a well-established and reliable technology that provides heat at a constant and low LCoH and LCCA.

A suggestion of how to overcome the barriers of unaccounted risks and high initial investment cost is outsourcing, as described in 3.2. Solar heat contracting, where an external stakeholder pays part or all of the investment cost and then delivers heat for a fixed price, is still very uncommon in Switzerland. This business model can become attractive if gas and oil prices as well as CO_2 taxes rise. Until then, increased, standardized and guaranteed subsidies can help to accelerate the transition towards renewable heat sources.

A further possibility to reduce the cost and to increase the share of solar heat would be the development of an efficient long-term energy storage. Such a storage would allow to store energy seasonally and to increase the field size of solar collectors. Currently, solar thermal systems are designed such that they do not produce excess heat in summer. This optimizes the LCoH but reduces the field size, preventing to make use of the entire available roof area. Since specific heat price drops with increasing field size, this would allow to build larger collector fields and to further reduce carbon emissions.

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Annex

1. Survey Questions

1	Do you use solar thermal energy at your location?
2	Has solar thermal energy already been considered as a possible heat source?
3	Why has no solar thermal system been built?
4	Is there usable free space for a solar thermal system at your site (e.g. on the roof, in the immediate vicinity)?
5	Is there already heat storage at your site?
6	How satisfied are you with the solar thermal system regarding: reliability profitability energy yield O&M cost
7	What is the total annual energy consumption (heat and electricity) at your site (in MWh/year)?
8	How is the heat generated at your site (please specify nominal power in kW)?
9	What is your annual consumption of the different energy sources, please fill in all that applies with units (e.g. m^3/year, MWh/year etc.)?
10	How high are your annual costs per energy source (estimation also possible in CHF)?
11	How old is the heat generator?
12	What is the share of the total annual energy consumption at your location for the following applications (estimate in %)?
13	What is the hot water used for (please specify the required temperature range)?
14	Has an energy audit already been performed at the site?
15	What is the payback period for investment in renewable heat generators?
16	Does your company have experience with contracting or leasing?
17	What is your company's experience with contracting and leasing?
18	With a solar thermal system heat can be produced at a price between 80 and 120 CHF/ MWh. A simple cost estimate can be made using the SolInd tool. What percentage of the investment costs would federal or cantonal subsidies for a solar thermal system have to cover at least for you to consider a system?

2. Promotion Material:

2.1 Fact Sheets

2.2 Project overview sheet

2.3 Best Practice examples

3. Press release

4. Feasibility studies