SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Policies and Business Models for Solar Thermal District Heating Systems

Subtask C report RC1

IEA SHC TASK 68 | Efficient Solar District Heating Systems

Technology Collaboration Programme
by iea

Policies and Business Models for Solar Thermal District Heating

This is a report from SHC Task 68: Efficient Solar District Heating Systems

Subtask C: Business Models

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1 Executive Summary

Large solar heating installations can have a significant contribution to renewable heat supply in many countries. It is a renewable technology without direct CO_2-emissions, which can have various basic system layouts:

1. Directly providing heat to an end-user, through residential, commercial or industrial installations.
2. Indirectly providing heat to many end-users through a solar district heating (SDH) network.
3. Indirectly providing heat through a SDH network with seasonal heat storage and a heat pump.

In all three system layouts solar thermal heat is competing with a conventional heat supply, which may require additional support for the solar option, depending on the local climate and technical configuration. As solar thermal is a renewable technology without direct CO_2-emissions, countries may decide to apply generic or specific support policies.

This report provides an overview of financing and investment schemes for solar district heating (SDH) systems. We analyse several support policies with the aim to draw lessons from them and in some cases suggest improvements. Moreover, we evaluate, discuss and propose business models for SDH systems. The purpose of this document is to evaluate and highlight ways to make SDH systems more business-appealing and to investigate how energy policy can act as an enabling factor for SDH systems aiming at a medium-term subsidy-free situation. In this report, the following policies are discussed:

- Direct policies and instruments are used to support the deployment of renewable energy heating and cooling fuels, appliances, and products. Subdivided further are push policies (for SDH these push policies are applicable: building codes (including district heating), mandates, replacement strategies, blending mandates (a share of renewable heat in a DH network), pull policies that are relevant for SDH are regulatory and pricing policies, tradable certificates, instruments for self-consumption and measures to support voluntary programmes, and fiscal & financial measures for SDH could be tax incentives, subsidies, grants and loans.
- Integrating policies for SDH refer to system flexibility (in combination with thermal storage), increasing the renewable share of district heating networks, and incite sector coupling.
- Enabling policies relevant for SDH may be policies levelling the playing field, ensuring reliability, targets, affordable financing, training and education, labour policies, innovation, and urban and health policies.
- Policies which are both integrating and enabling. Of these mixed policies, SDH may have advantages from streamlined permitting procedures, participative and awareness programmes and integrated resource management.

Solar thermal yield depends very much on local weather conditions, and the demand for heating and cooling strongly varies across climate regions. But independent of the local situation, solar thermal heat is usually competing with conventional heating supplies. Solar thermal may compete with end-user prices, or more directly on the level of energy and supply costs. Currently, in many cases some form of support measure may be needed, until the market and technology circumstances change. Perceived from the policy effectiveness perspective, providing (temporary) support for solar thermal district heating may be more attractive than the support for end users due to the speed of implementation, lower overall costs to government and overall avoided CO_2.

This report lists example policies for solar heat in the Netherlands, Austria, Germany, Spain, Switzerland and Denmark. The report does not propose or endorse a best policy, but the cases are meant as inspiration for policy makers around the world. Chapter 6 summarises the findings for each of the example policies.

Furthermore, business models for large solar thermal projects are touched upon, and four examples are described: a SDH plant in Groningen, the Netherlands, a concentrating solar thermal (CST) plant in Brandenburg, Germany, a CST plant in North Rhine-Westphalia, Germany (both in pre-feasibility stage) and SDH plants in Ørum and Aulum, Danmark. The cases show that multiple options exist for solar thermal district heat, and thereby that not a single best financial model emerges. It all depends on the specific circumstances of a project.

2 Introduction

This report provides an overview of financing and investment schemes for solar district heating (SDH) systems. We analysed several support policies with the aim to draw lessons from them and in some cases suggest improvements. Moreover, we evaluate, discuss and propose business models for SDH systems. The purpose of this document is to evaluate and highlight ways to make SDH systems more appealing to business and to investigate how energy policy can act as an enabling factor for SDH systems aiming at a medium-term subsidy-free situation.

An overview of support schemes and policy measures is provided in Chapter 3, whereas Chapter 4 focuses on these countries and policies:

- Feed-in policy in the Netherlands: SDE++
- Austrian Climate and Energy Fund
- Funding programme in Germany: BEW
- Spain: various policies
- Switzerland
- Solar thermal policy in Denmark: an overview

Chapter 5 introduces business models for large solar thermal projects, and in Chapter 6 the organisational structures of several plants are briefly characterised:

- Solar district heating plant in Groningen, Netherlands
- Concentrated Solar Thermal plant for community heating in Brandenburg, Germany (pre-feasibility stage)
- Concentrated Solar Thermal plant for a large R&D building complex heating in North Rhine-Westphalia, Germany (pre-feasibility stage)
- Solar district heating plant in Aulum, Denmark
- Solar district heating plant in Ørum, Denmark

Chapter 6 summarises the conclusions and Chapter 7 gives an outlook for future solar thermal district heating projects.

3 Types of support schemes for renewables

This chapter is adopted from Annex II of the report '*Renewable Energy Policies in a Time of Transition: Heating and Cooling*' (IRENA, IEA, REN21, November 2020, CC BY 4.0)[1] which features an updated classification of policies to support the transition in heating and cooling, based on a classification published in 2018.

According to the publication mentioned above, renewable heating and cooling policies can be classified into three categories:

- Direct policies and instruments are used to support the deployment of renewable energy heating and cooling fuels, appliances, and products.
- Integrating policies for renewable heating and cooling include policies designed to improve the energy efficiency of buildings and appliances, as well as to develop necessary infrastructure.
- Enabling policies for heating and cooling include carbon pricing policies, climate policies, technology standards, labour policies and industrial policies.

The sections below elaborate on this classification.

3.1 Direct policies and instruments

Direct policies can be broken down into push and pull policies and fiscal & financial measures.

3.1.1 Push policy

Examples of push policies (not exhaustive) are:

- Binding targets for the use of renewable energy, including net zero energy targets
- Building codes and appliance efficiency standards
- Mandates (e.g., solar water heaters, renewables in district heating)
- Planned replacement of equipment
- Blending mandates
- Procurement by municipal governments

For SDH these push policies are applicable: building codes (including district heating), mandates, replacement strategies, blending mandates (a share of renewable heat in a DH network).

3.1.2 Pull policy

Examples of pull policies (not exhaustive) are:

- Regulatory and pricing policies (e.g., feed-in policies)
- Tradable certificates
- Instruments for self-consumption
- Measures to support voluntary programmes

For SDH all four push policy examples are applicable.

3.1.3 Fiscal & financial measures

Examples of fiscal & financial measures (not exhaustive) are:

- Tax incentives (e.g., tax credits, accelerated depreciation, tax reductions)
- Subsidies
- Grants

[1] Download: https://iea.blob.core.windows.net/assets/66a547ea-09bf-48fb-b7bb-6b94ef80b083/Renewable_Energy_Policies_in_a_Time_of_Transition_-_Heating_and_Cooling.pdf

- Loans

For SDH all four examples of fiscal & financial measures are applicable.

3.2 Integrating policies

Integrating policies may consist of the following ones (not exhaustive).

- Measures to enhance system flexibility (e.g., promotion of flexible resources such as thermal and electrical storage, dispatchable supply, load shaping)
- Policies to ensure the presence of needed infrastructure (e.g., transmission and distribution networks, district heating infrastructure, road access)
- Policies for sector coupling
- Better alignment of energy efficiency and renewable energy policies
- Incorporation of decarbonisation objectives into national energy plans
- Measures to adapt the socio-economic structure to the energy transition

SDC may provide a positive contribution to system flexibility (in combination with thermal storage), increase the renewable share of district heating networks, and incite sector coupling.

3.3 Enabling policies

Enabling policies may consist of the following ones (not exhaustive).

- Policies to level the playing field (e.g., fossil fuel subsidy reform, carbon pricing policies)
- Measures to adapt the design of energy markets (e.g., flexible short-term trading, long-term price signals)
- Policies to ensure the reliability of technology (e.g., quality and technical standards, certificates)
- General and sector-specific national renewable energy policy (e.g., objectives, targets)
- Policies to facilitate access to affordable financing for all stakeholders
- Education policies (e.g., inclusion of renewable energy in curricula, coordination of education and training with assessments of actual and needed skills)
- Labour policies (e.g., labour market policies, training and retraining programmes)
- Land-use policies
- RD&D and innovation policies (e.g., grants and funds, partnerships, facilitation of entrepreneurship, formation of industry clusters)
- Urban policies (e.g., urban planning, zoning policies)
- Public health policies (e.g., relative to levels of air pollutants

SDC may benefit from policies levelling the playing field, ensuring reliability, targets, affordable financing, training and education, labour policies, innovation, and urban and health policies.

Several policies both are integrating and enabling:

- Supportive governance and institutional architecture (e.g., streamlined permitting procedures, dedicated institutions for renewables)
- Participative programmes and schemes actively involving lay citizens in decision-making
- Programmes to raise awareness of the importance and urgency of the energy transition geared towards awareness and behavioural change
- Social protection policies to address disruptions
- Measures for integrated resource management (e.g., the nexus of energy, food and water)

Of these mixed policies, SDH may have advantages from streamlined permitting procedures, participative and awareness programmes and integrated resource management.

4 Policies for solar thermal energy in various countries

4.1 Feed-in policy in the Netherlands: SDE++

The Dutch Sustainable Energy Production and Climate Transition Incentive Scheme (SDE++) provides subsidies to companies and non-profit organisations that generate renewable energy or reduce CO_2 emissions on a large scale. SDE++ is an example of a direct pull policy, namely a feed-in policy, more precisely a feed-in premium. Large solar thermal energy is one of the supported technologies, with two separate support levels in accordance with the thermal capacity of the installation: one category is defined from 140 kWth to 1 MWth and the other for all systems above 1 MWth. The SDE++ is an operating subsidy, available during the operating period of the project, which for solar thermal is defined as 15 years. Predecessors of SDE++ were SDE+, SDE and MEP, all being variants of production subsidies using a feed-in scheme. Solar thermal energy was first introduced in SDE+ in 2012.

Source: https://english.rvo.nl/subsidies-financiering/sde (sourced 30 October 2023)

4.1.1 Performance of the SDE++ scheme

Solar thermal was introduced to the SDE policy family in 2012. First in a single category, and as of 2018 as two separate size-based categories as explained in the previous section. The table below shows the total annual budgets of the past few years and highlights the share and amount of systems that received SDE support.

	Amount of	**Capacity [MW]**		**Production [MWh]**		**Maximum subsidy amount [EUR]**		**Realised?**
	applications	**<1 MW**	**>1 MW**	**<1 MW**	**>1 MW**	**<1 MW**	**>1 MW**	
2012	1	0.1		71		30.484		Yes
2013	2	1.3		879		575.939		Yes, both
2014	8	1.9		1.350		1.625.776		Yes, all
2015	0	0.0		0		0		
2016	15	3.0	39.1	2.069	27.380	2.372.949	28.513.962	Yes, all
2017	9	1.9		1.319		1.266.898		Yes, all
2018	14	3.2		2.246		2.189.769		Yes, all
2019	13	4.3	37.4	3.011	26.207	3.149.672	25.945.089	Most but not all
2020	11	3.8		2.281		1.402.745		Not all
2021	9	2.6	2.3	1.554	1.397	979.111	590.898	None
2022	3	0.6	9.3	388	32.956	384.982	4.563.501	One
2023	0	0.0		0		0		
Total		22.7	88.1	15.167	87.939	13.978.325	59.613.450	

The budget for SDE++ is collected at all electricity consumers and then allocated to projects that apply for an SDE++ subsidy. The total budget for the complete scheme (all technologies) usually ranging from 5 to 12 billion euro. Solar thermal energy is thus only claiming a fraction of the total budget.

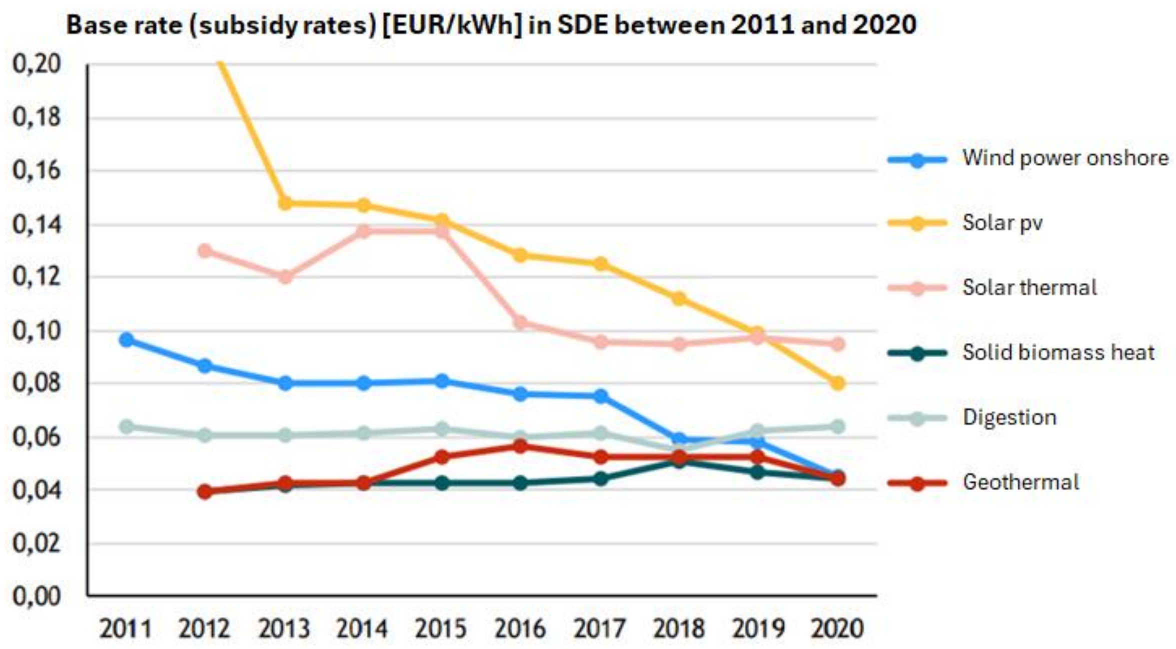
The share of support that is claimed for solar thermal is comparatively small. Possible reasons for this are: 1.) low interest from market parties in solar thermal, 2.) inadequate support levels, and 3.) procedural reasons.

In 2021 a report [source: https://www.rijksoverheid.nl/documenten/rapporten/2021/12/24/eindrapport-evaluatie-van-de-sde] was published evaluating SDE+ and the most significant findings from the questionnaire are:

- Without SDE 15 out of 18 respondents wouldn't have invested in solar thermal
- All respondents (19) believed that the time effort to apply for the subsidy is reasonable or even relatively short compared to the gains from the subsidy

- The realization period for the project (17 out of 19) and the required documents (18 out of 19) are considered mostly reasonable

The figure below shows that in terms of subsidy per kWh heat produced from solar thermal is among the highest priced, and that from 2020 onwards even solar PV has a lower estimated base rate (i.e., the subsidy level or feed-in premium) than solar thermal (source Trinomics). The yellow line displays the base rates for solar PV, the pink line is solar thermal.



Source: report by Trinomics based on final SDE++ advices by PBL.
Data refer to specific categories, see original source for details

4.1.2 History: situation before the SDE++ scheme came into force

In 2008 after multiple years without a subsidy for solar thermal heat, only solar water heaters were subsidised with an investment subsidy, but the scheme was stopped in 2011. In 2009 large solar thermal became eligible in SDE, from <100 m^2, and later from <200 m^2. In 2016 an investment subsidy was launched for solar thermal installations up to the lower limit of SDE-requirements, so the two schemes were seamlessly connected. (Source: TNO 2020 R10975, Aanzet tot Routekaart Zonnewarmte, juni 2020, Luuk Beurskens, Corry de Keizer, see section 4.1.7).

4.1.3 Policy design: features of the SDE++ scheme

The core feature of SDE++ is to subsidise the unprofitable component of each technology. The unprofitable component is the difference between the cost of the technology that reduces CO_2 (the ‘base rate’) and the market value of the ‘product’ that is generated by the technology (the ‘corrective amount’). For solar thermal, the product is thermal energy: heat [MWh]. The base rate [€/kWh] is fixed for the entire subsidy period, but the corrective amount [€/kWh] is set annually. The unprofitable component decreases when the market value rises, as does the amount of the subsidy received. Subsidies in SDE++ are granted for periods of 12 or 15 years. The duration of the subsidy payments depends on the technology used, for solar thermal the subsidy period is 15 years.

A different base rate has been set for each technology. The base rate is the cost price to produce renewable energy or the cost price of the reduction of CO_2 emissions. This base rate is the maximum subsidy rate for which one can apply. By applying for a lower subsidy rate, one has a better chance of receiving a subsidy, as the total annual subsidy budget is limited. An application amount must be the same as or lower than the base rate.

Revenue is generated by producing and supplying energy in the form of electricity, heat, renewable gas, hydrogen gas or advanced renewable fuel with any of the technologies. The same goes for capturing CO_2. The revenue level will be set in the form of a corrective amount. The corrective amount is partly determined by the market value. The largest SDE++ subsidy is equal to the base rate or application amount minus the corrective amount. In the SDE++ scheme, the value of Guarantees of Origin (GOs) for the 'Wind' and 'Solar PV' categories is part of the corrective amount. The Netherlands Environmental Assessment Agency (PBL) sets the value of GOs each year.

For the 'Solar PV' categories, it is distinguished between electricity fed into the grid ('grid supply') and electricity used for self-consumption ('non-grid supply'), the latter currently not being eligible for subsidy.

A lower limit is set for the corrective amount: the base energy price or the base greenhouse gas amount. The corrective amount may therefore not be lower than the base energy price or the base greenhouse gas amount. By definition, these amounts are based on two-thirds of the average expected revenue over the entire duration of the SDE++ subsidy. If the corrective amount is equal to the base energy price or base greenhouse gas amount, one will receive the maximum amount of subsidy.

The ETS is a market instrument with which the European Union (EU) cost-effectively reduces greenhouse gas emissions to achieve its climate targets. Some of the companies applying for SDE++ subsidies take part in the ETS. If the technology concerned prevents the purchase or generates profits from the sale of CO_2 emission allowances under the European Emissions Trading System (EU-ETS), then this too is incorporated in the corrective amount.

The 2023 application round for the SDE++ scheme had five phases. During each phase, one could apply for a subsidy only up to a certain subsidy intensity per tonne of CO_2 emissions reduction. This is the phase limit. The subsidy intensity is calculated based on the application amount, the long-term price and the emission factor. In later phases, this maximum subsidy rate per tonne of CO_2 was gradually increased. One may also submit projects with a lower subsidy need than the maximum set for the technology in question. One can do this by applying for a lower rate than the maximum base rate and the phase rate. This means applying for a lower subsidy intensity, which may increase chances of obtaining a subsidy, as the budget is limited and applications with lowest subsidy intensity will be granted first.

In 2023, the largest subsidy intensity for which SDE++ technologies could apply is €400 per tonne CO_2. Technologies with a higher subsidy intensity could still apply for a SDE++ subsidy. The unprofitable component of these projects may however not be entirely reimbursed. In SDE++ 2023, the subsidy intensity for solar thermal <1MWth was defined as 221 €/tCO_2 and for solar thermal >1MWth it was 164 €/tCO_2. This subsidy intensity is used to rank the technologies for cost-effectiveness subsidising (see also chapters 16 and 17 in PBL, 2023).

Stimulating technologies with a subsidy intensity higher than €400 per tonne of CO_2 is considered incompatible with a cost-effective energy transition, which is the intention of the SDE++ scheme.

4.1.4 Strengths and weaknesses: experiences with SDE++ scheme from market parties and policy makers

The SDE++ is not a simple support measure, but it is designed to be efficient. In order to clearly communicate to the audience, every year the Netherlands Enterprise Agency (RVO) publishes a brochure with details about the SDE++ and instructions for applying. The relatively long support period is an advantage to ensure guaranteed cashflows, as long as the corrective amount does not exceed the base rate. This is a risk for developers. Handing in an application for SDE++ subsidy requires an effort, but this is considered a reasonable time investment. The subsidy rates in SDE++ are designed to cover the difference of renewable energy generation compared to conventional (fossil) generation, which allows a healthy business case. A granted SDE++ subsidy provides a guaranteed cashflow which is an advantage when negotiating loans to finance a project. Disadvantages are the annual corrections of the subsidy, making the subsidy cashflow a variable income stream.

4.1.5 Suggested improvements, specifically for large-scale solar thermal energy

The following improvements are suggested for solar thermal:

- Currently, seasonal heat storage is not included in the base rate. It could be considered to add a solar thermal category that incorporates seasonal storage.
- In the current definition the temperature level of the heat from solar thermal is not defined, which gives an incentive to use low-temperature applications, whereas the base rate is calculated based on a medium-temperature level. This might give some overstimulation, which is an advantage for developers but a disadvantage for the subsidy provider.
- The amount of energy subsidised in a year is capped at a certain level, which is based on flat plate collectors. This means that high-efficient collectors, such as vacuum tubes vacuum flat plates or tracked concentrating collectors might not be able to have all heat production subsidised. This could be corrected by providing a separate category for these kinds of systems.
- In the preceding sections the corrective amount in SDE++ was introduced, the market value of the product that is generated by the technology. For solar thermal in SDE++ up to the 2024 round this consisted of an end-user price of heat (including taxes and levies), which made that the resulting net subsidy per kWh was relatively small, depending on the gas price. In the SDE++ advice by PBL it was suggested to use a lower heat price as a reference for solar thermal above 1 MW and connected to a district heating system. This may increase the net subsidy for solar thermal district heating. (PBL 2025)

4.1.6 Lessons from SDE++ for policy design

From the above policy description, the following design elements might be relevant for policymakers in other countries:

- Multiple technologies subsidised under one policy
- Subsidy amount is corrected annually for changes in reference price (e.g., natural gas)
- Target large systems with a minimum collector area of 200 m^2
- Two system sizes are supported: <1MW and >1MW
- For solar district heating the reference heat price is lower than the heat price for end-users, which should be reflected in the feed in premium

4.1.7 References

TNO 2020 R10975, Aanzet tot Routekaart Zonnewarmte, juni 2020, Luuk Beurskens, Corry de Keizer, https://resolver.tno.nl/uuid:2fbac718-a637-4f95-b116-a4a9dc775306

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https://www.pbl.nl/publicaties/eindadvies-basisbedragen-sde-2025

4.2 Austrian Climate and Energy Fund

The Austrian Climate and Energy Fund (ACEF, *Klima- und Energiefonds*) of the Austrian government provides subsidies **for innovative large-scale solar thermal systems for collector gross area of larger than 100 m^2. All natural and legal persons** engaged in commercial activities (but not limited to the trade regulations) and **regional authorities** in Austria are eligible to apply. The programme runs continuously since 2010 and the funding is provided in the form of **non-repayable investment grants**. The funding campaign covers six thematic fields and since 2020 it also provides funding for feasibility studies of large-scale projects with a collector area of more than 5,000 m^2 with a clear orientation of implementation. For each thematic field exist different funding limitations, e.g., for *solar process heat* it is 770 €/MWh directly usable solar yield per year. Particularly innovative projects and projects with a gross collector area of over 5,000 m^2 will be included in the accompanying research programme selected by a panel of experts. The accompanying research programme has the goal to advise applications before submission for quality assurance reason, provides the monitoring of plants in operation and the publication of results and know-how transfer.

4.2.1 Performance of the policy scheme *Large-scale solar systems* ("Solare Großanlagen")

The policy scheme *Large-scale solar systems* was introduced 2010. The funding scheme was from the beginning addressing different categories (thematic fields), currently: s*olar process heat*, s*olar feed-in to grid-connected heat supplies* (micro- , local- and district heating networks), *high solar fraction* (over 20% of the total heat requirement) in commercial and service companies, *solar thermal energy in combination with heat pumps* (incl. PVT collectors), *new technologies and innovative approaches* as well as *large-scale solar systems from 5,000 m^2*. This has evolved over the years and since 2020 also feasibility studies for (especially large projects) are funded. The table below shows the total annual budgets of the past 10 years.

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021-2023**	**2023**
Budget [M€]	5	5	5.9	3.5	2.6	3	2.6	2.5	45	13.5
Budget Feasibility Studies [M€]	-	-	-	-	-	-	-	-	N\A	0.5[2]
Maximum possible funding	50%	50%	45%	45%[3]	45%[3]	45%[3]	45%[3]	50%[4]	50%[3]	50%[3]
Maximum possible funding per individual project [K€]	450	450	450	750	750	750	750	750	750	750
Feasibility Studies [1]	-	-	-	-	-	-	-	13	N\A	N\A
Feasibility Studies – average collector area [Km^2]	-	-	-	-	-	-	-	23	N\A	N\A

In total the performance of the programme from 2010 up to 2021 is given in the following table

Total performance of the funding scheme *Large-scale solar systems* since 2010 up to 2021	
Funded projects [1]	331

[2] The budget for the feasability studies is already included in the total budget

[3] Depending on the size of the field: up to 2000m^2 it is 45 % , from 2001 m^2 on 30% and from 5000 m^2 on 20%, therefore for a plant with 6000 m^2 would result in a mixed funding percentage, for the first 2000m^2 45% , for 2001-5000 m^2 30% and 5001-to 6000m^2 20%, leading to 33.3% in total.

[4]

Largest plant funded [m²]	5.750
Collector area [m²]	137.153
Funding amount [M€]	39
Triggered investments[M€]	106

Furthermore, the distribution of collector area and projects regarding the different categories from 2010 to 2021 is given in the two pie charts in the following Figure:

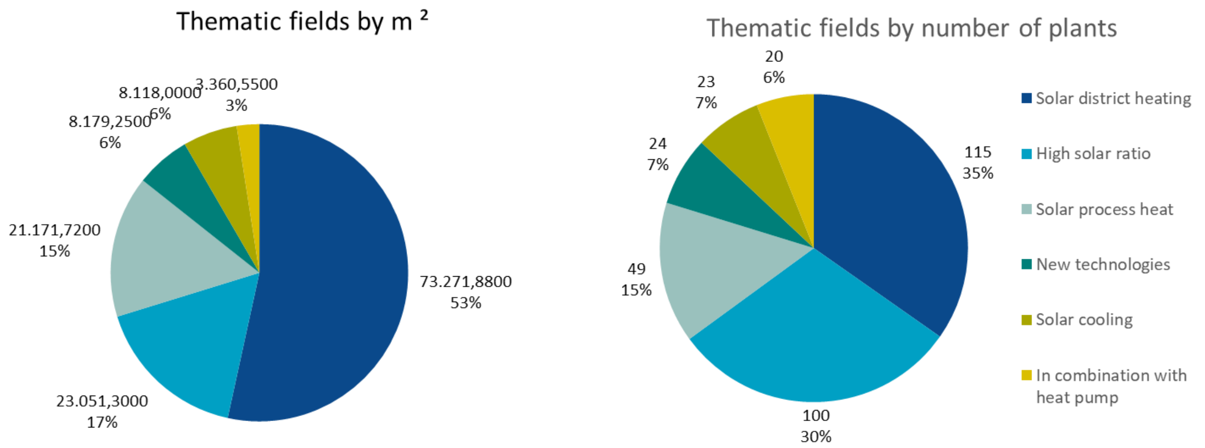

Figure: Distribution of funded collector area and number of plants by thematic field /category.

4.2.2 History: situation before policy scheme *Large-scale solar systems* came into force

The goals of the *Climate and Energy Fund* in general are the substitution of fossil fuels, the acceleration of renewable energies and to increase energy efficiency. Therefore, the aim of the programme "*Large-scale solar systems*" was to provide a starting point for a broad implementation of large-scale solar plants, achieve practical experience and scientific progress, dissemination, provide publicly available data and finally the creation of a new market segment.

Over the time of 2010 to 2021, this funding schema generated 25.8 million euros in additional value creation and 250 additional employees (full-time equivalents working in the solar heat sector) with a funding of 15 million euros (extrapolation).

4.2.3 Policy design: features of the scheme *Large-scale solar systems*

Regarding the **construction of plants**:

The subsidy rate relates to the entire system technology and is graduated according to system size. For system sizes of up to 2,000 m², this is a maximum of 40% of the environmentally relevant additional costs (AC). SMEs and non-competitive participants (NCP) receive a surcharge of 5% for up to 2,000 m². There is also a 5% surcharge for SMEs and NCPs for innovative storage solutions for systems up to 5,000 m². Furthermore, there is a 5% surcharge for long-term storage systems (from 1,000 l/m² gross collector area in combination with a heat pump) for systems from 5,000 m². The panel of experts is responsible for assessing the innovation. For system sizes over 2,000 m², the proportionate funding rate is 30% from 2,001 m². For system sizes over 2,000 m², results in mixed subsidy rates. The funding per individual project is limited in accordance with the following table.

Object of funding	Max. Subsidy rate
Solar system up to 2,000 m² incl. piping, installation, measurement technology, planning costs	40 % of the AC plus surcharges: + 5 % SMEs and NWT + 5 % storage innovation for SMEs and NCPs
Solar system from 2,000 m²	Proportionate 30 % of the AC + 5 % storage innovation for SMEs and NCPs
Solar system from 5,000 m²	Proportionate 30 % of the AC + 5% for long-term storage tanks (from 1,000 l/m² gross collector area) in combination with heat pump

Regarding the **feasibility studies**, there exist two types of feasibility studies:

- Overall feasibility studies
- Organizational-economic feasibility studies

The implementation orientation is essential and a submission of the implementation project in the following year is desired but not mandatory. The feasibility studies describe the possibility of implementing large-scale solar thermal systems at the level of detail of a design plan and also include the clarification of any existing official requirements.

The amount of funding depends on the type of feasibility study, the size of the system and the type of heat storage system (short-term or long-term heat storage) and is limited to the amounts listed in the next table:

Type of feasibility study	Overall feasibility studies		Organizational-economic feasibility studies	
Included heat storage solution	short-term	long-term	short-term	long-term
Systems larger than 5,000 and smaller or equal to 10,000 m²	€ 15,000	€ 25,000	€ 7,500	€ 12,500
Systems larger than 10,000 and smaller or equal to 30,000 m²	€ 25,000	€ 35,000	€ 12,500	€ 17,500
Systems larger than 30,000 m²	€ 35,000	€ 45,000	€ 17,500	€ 27,500

The net costs incurred for the implementation of the intangible services are eligible for funding. The costs must be documented by invoices. Personal contributions by the applicant are not eligible for funding. All natural and legal persons as well as project consortia are eligible to submit entries. The subcontracting of work packages to external companies/institutions is permitted.

4.2.4 Strengths and weaknesses: experiences with ACEF from market parties and policymakers

What are considered to be the strengths of the scheme:

- **Continuous and long-term runtime**: the funding scheme is already running in a very similar form from 2010 onwards, therefore it is well-known, has a long-term impact, a long history and has been slightly adapted over the years to make it even more accurate.
- **Feasibility studies**: especially for (very) large-scale solar thermal projects feasibility studies are indispensable and often delay major projects.

Weaknesses of the scheme:

No weaknesses to be mentioned.

4.2.5 Suggested improvements for ACEF, specifically for large-scale solar thermal energy

The policy scheme has been evaluated and adapted since it first came into force. For example, to include additional funding for innovative solutions or long-term storage technologies as well as to include feasibility studies in the funding option was based on an evaluation of the programme 2019.

4.2.6 Lessons for policy design

From the above policy description, the following design elements might be relevant for policymakers in other countries:

- Dedicated policy for solar thermal systems larger than 100 m² collector surface
- An accompanying research programme is in place, having the goal to advise applications before submission for quality assurance, monitoring of plants and the publication of results and knowledge transfer
- Different categories of solar thermal are being addressed: solar process heat, solar thermal on micro-, local- and district heating networks, high solar fraction (over 20% of the total heat requirement), solar thermal energy in combination with heat pumps (incl. PVT collectors), new technologies and innovative approaches, and finally large-scale solar systems from 5,000 m²

4.2.7 Literature references

Source: https://www.klimafonds.gv.at/wp-content/uploads/sites/16/230712_Leitfaden_Solare_Grossanlagen_2023_RZ_BF.pdf (sourced 27.11.2023, in GERMAN)

4.3 Funding programme in Germany: BEW

The aim of the innovative funding programme “Bundesförderung für effiziente Wärmenetze”, (BEW, federal funding for efficient heating networks) is to decarbonise heating networks and integrate a high share of renewable energy sources. The programme subsidises the transformation of existing heating networks and the construction of new heating networks. Companies, municipalities, registered associations and cooperatives can apply. The BEW consists of four modules and specific criteria must be fulfilled for the application in each module. New networks must provide at least 75% renewable heat and waste heat. Existing heating networks must supply at least 50% climate-neutral heat. By 2045, heating networks must be 100% climate neutral. A total of 2.98 billion euros is planned to be funded until 2030 and an average of 681 megawatts of renewable heat generation capacity each year are planned to be funded.

4.3.1 Performance of the policy scheme BEW

The first module has a term of one year. This will be followed by funding for modules 2, 3 and 4.

Between September 15, 2022, and November 15, 2024, a total of 2,581 funding applications has been submitted, of which 2,015 have already been approved. The figure below provides an overview of the number of applications submitted (Anträge) and approvals granted (Bewilligungen). Feasibility studies (Machbarkeitsstudie, NB) account for the majority compared to transformation plans (Transformationsplan). Since the BEW programme has been active for approximately two years at this point, there are still relatively few applications and approvals in the fourth module.

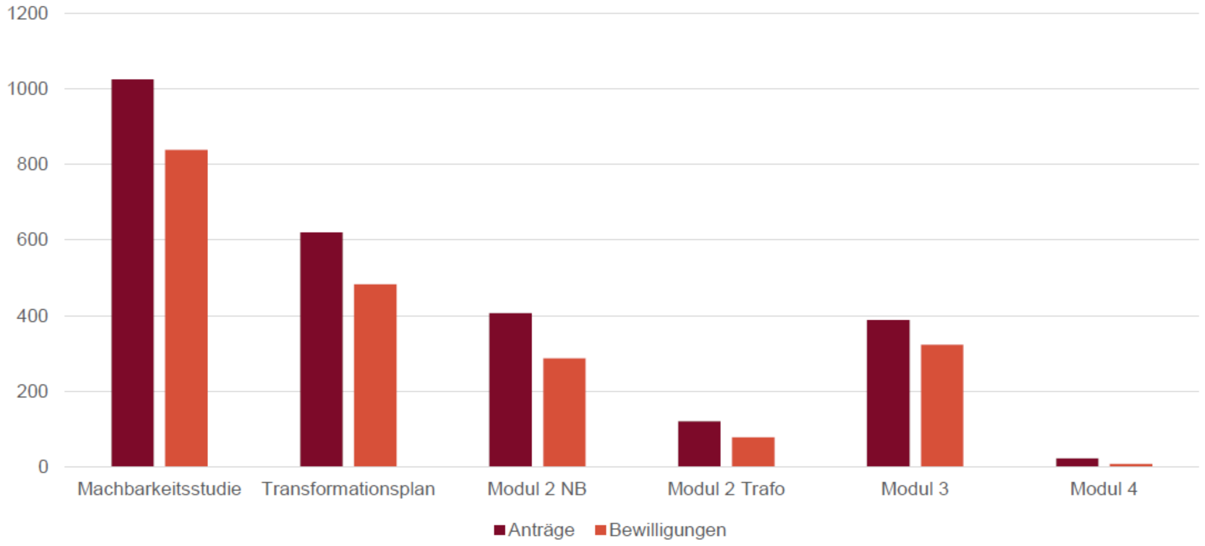

Figure: Submitted and approved applications for BEW funding, (BAFA Datenexport BEW, 11.2024)

For the same period, Figure YYY illustrates the approved funding amounts in euros (left axis, Bewilligungssumme) and the number of approvals (right axis, Anzahl Bescheide). As of November 2024, a total of 2 billion Euros has been approved, with 2.3 million Euros disbursed so far. Both the number of approvals and the total approved funding amount show an increasing trend.

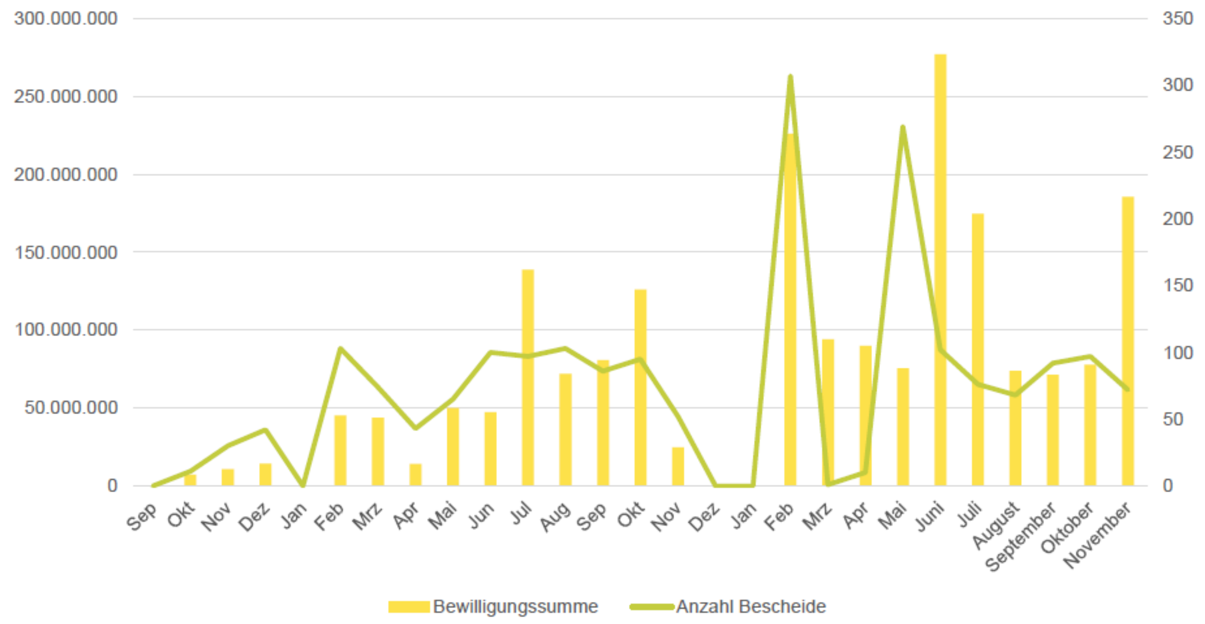

Figure: BEW Approved funding amounts in euros and number of approvals from September 2022 to November 2024 (BAFA Datenexport BEW, 11.2024)

4.3.2 History: situation before policy scheme BEW came into force

Several funding programmes have been existing in the German heating sector before the BEW came into force. The "Energie- und Ressourceneffizienz in der Wirtschaft" (EEW, Energy and Resource Efficiency in the Economy) subsidises efficiency improvements in industry and commerce. The "Kraft-Wärme-Kopplungs-Gesetz" (KWKG, Combined Heat and Power (CHP) Law), on the other hand, promotes CHP networks and CHP storage systems. Another funding programme is the "Bundesförderung für effiziente Gebäude" (BEG, Federal Funding for Efficient Buildings), which aims to increase the energy efficiency of buildings by subsidizing renovations. This concerns optimizations of the building envelope, system technology, heat generators and heating optimization. A differentiation is made between three sub-programmes depending on the different applications. Residential buildings (BEG-WG), non-residential buildings (BEG-NWG) and individual measures (BEW-EG).

The first draft of the BEW was presented on 16 July 2021. Subsequently, there were suggestions for improvement and comments to eliminate weaknesses. Following the revision of BEW has been active since 15 September 2022 and replaces, among others, the predecessor programme "Wärmenetze 4.0" (WN4.0, Heat Networks 4.0).

In WN4.0 there is a minimum quantity criterion for the amount of heat to be supplied to a district. This was 1000 MWh per year. With BEW, on the other hand, there is a minimum number of buildings that must be connected to the heating network. At least 17 buildings or 101 residential units must be connected to the heating network to receive the BEW subsidy. In this case, BEW provides funding. If there are fewer buildings, BEG provides subsidies instead of BEW. Another difference to WN4.0 is that a transformation path must be submitted. This must describe how emission neutrality can be achieved step by step by 2045. In addition, fossil heat sources will no longer be subsidised even if the overall system is fundable. The BEW also subsidises operating costs for systems that provide renewable heat. This is particularly useful for the operation of solar thermal systems and heat pumps, which was not subsidised in WN4.0.

4.3.3 Policy design: features of the BEW

As already mentioned, the BEW consists of 4 modules. In module 1, the creation of **transformation plans** and **feasibility studies** is funded at 50% of the eligible costs. The maximum amount of funding is 2 million euros. The period provided for this is 12 months and can be extended by a maximum of another 12 months.

The requirement for module 2 is a transformation plan for existing networks and a feasibility study for **new heating networks**. In this module, investments in heat generation systems and infrastructure are funded. The eligible expenditure is funded at 40% and the maximum funding amount per request is 100 million euros. The approval period is 48 months and can be extended by another 24 months.

Module 3 provides funding for **individual measures** in an existing heating network. If a transformation plan is available, individual measures are only funded if at least the first package of measures has been implemented. Funding is also possible without a transformation plan if a target image of the heating network is available that shows the predicted CO_2 savings. In existing heating networks, these are solar thermal systems, heat pumps, biomass boilers, heat storage tanks, pipelines and heat transfer stations. It must be shown in milestones 2030, 2035, 2040 and 2045 which heat generator is used in which order of magnitude to achieve greenhouse gas neutrality. Solar thermal energy is defined by the thermal output and the amount of supplied heat. As in module 2, 40% of eligible expenditure is funded and the maximum funding amount is 100 million euros per request. The approval period is 24 months and can be extended by a further 12 months.

In module 4, the **operating costs** of solar thermal plants are subsidised with 1 Eurocent/kWh and electricity-powered heat pumps are subsidised with 3 to 7 Eurocent/kWh. The requirement is that the solar thermal plant and heat pump were subsidised under module 2 or module 3. Operating costs are subsidised on the basis of calendar years for a total of 10 years from the date of commissioning.

The following criteria must be specified for the application in each module:

- Share of renewable energies and waste heat (> 50% for existing networks and > 75 % for new networks)
- Greenhouse gas-neutral target by 2045 (Milestones by 2030, 2035, 2040 and 2045)
- Maximum biomass share depending on the network size (100 % for < 20 km length, 25% for 20-50 km length, 15% for > 50 km length)
- Minimum size of the DH network (at least 17 buildings or 101 residential units)
- Maximum temperature level is 95°C (only for new heating networks)
- Maximum proportion of fossil-fired boiler systems (10-15%)
- Quantitative preliminary investigations and conceptualization of ideas

4.3.4 Strengths and weaknesses: experiences with BEW scheme from market parties and policy makers

On the positive side, the BEW specifications provide flexibility. The goal of greenhouse gas neutrality by 2045 is obligatory for the projects funded by BEW. In addition, the main renewable supply options are eligible for subsidies. Another positive point is that heat from waste treatment is eligible. Existing networks may also have higher network temperatures, so nothing changes for the consumer and the application. Networks with higher temperatures can therefore continue to be used for process heat.

Weakness points are that each use case depends on several categories and therefore different conditions apply. This makes the entire funding programme confusing and complicated. Due to the deadlines for the preparation of heating plans, this can lead to increased time expenditure for local authorities. The approval period for module 1 is only 12 months. In addition, operating costs for deep and shallow geothermal energy are not subsidised in the same way as the operation of solar thermal systems or heat pumps.

4.3.5 Suggested improvements for BEW, specifically for large-scale solar thermal energy

Smaller heating networks should also be funded by BEW and not by other funding programmes. This would be beneficial for solar thermal. And renewable heat from geothermal energy should be promoted more, including increasing the number of eligible boreholes.

4.3.6 Lessons from BEW for policy design

The following features of BEW are interesting for governments that are planning to set up policy for solar thermal energy in district heating networks:

- BEW consists of four modules, targeting 1.) transformation plans and feasibility studies, 2.) investments in heat generation systems and infrastructure are funded, 3.) individual measures such as solar thermal systems, heat pumps, biomass boilers, heat storage tanks, pipelines and heat transfer stations, and 4.) the operating costs for a total of 10 years from the date of commissioning.
- Defining minimum shares of renewable energy in the annual energy production.
- Imposing a limit on biomass as an input
- Defining a minimum size of the district heating network
- Defining a maximum temperature level
- Imposing a maximum share of fossil fuels
- Quantitative preliminary investigations and conceptualization of ideas

4.3.7 Literature references

All sources are in German and were retrieved on 05.12.2023.

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BAFA Data Export BEW, 11/2024 Presentation by Sophia Susanne Nau at the Trafotage on November 27-28, 2024, in Kassel, Germany, AGFW

4.4 Solar thermal policy in Spain: various policies

The central strategy document guiding Spain's energy and climate policies over the coming decade is its National Energy and Climate Plan - Spanish NECP- for the period 2021-2030 [PNIEC, 2021], which represents a significant change in the push policies for the advancement of renewable energies of the Spanish government in the last 10 years. The Spanish NECP outlines a number of policy actions in various sectors that will support the country's climate targets, including the areas of energy efficiency, renewables and transport. Its 2030 objectives include a 23% reduction in greenhouse gas emissions from 1990 levels, a 42% share of renewables in energy end-use, a 39.5% improvement in energy efficiency; and a 74% share of renewables in electricity generation. The update of the NECP, which is in public consultation at the beginning of 2024, proposes to increase the reduction in greenhouse gas emissions from 1990 levels to 32%; a 48% share of renewables in energy end-use; a 44% improvement in energy efficiency; and 81% share of renewables in electricity generation [MITECO, 2023].

This push policy is accompanied by several pull policies included in the Spanish Plan for the Recovery, Transformation and Resilience -Spanish PRTR- [PRTR, 2021], partially funded by the Next Generation European Funds, which supports achieving the Spanish NECP's targets. In the frame of this Spanish PRTR, there are 12 different strategic programmes covering different sectors of the economy, one of the strategic programmes is devoted to the advancement and implementation of energy efficiency and renewable energies. In this context, there are several pull policies providing subsidies to individuals, companies, administrations and public bodies investing in measures aligned with the objectives established in the Spanish NECP, e.g.,:

1. Programme of incentives for the installation of self-consumption and energy storage driven with renewable energies as well as **the installation of renewable thermal energy systems in the residential sector** -RD 477/2021- (IDAE, 2024a).
2. Programme for **the installation of renewable thermal energy systems in different sectors of the economy** -RD 1124/2021- (IDAE, 2024b);
3. Programme of incentives for **district heating and cooling networks driven by renewable energies -** TED/707/2022- (IDAE, 2024c);
4. First call of the programme of incentives **RENOCOGEN** for the **replacement of fossil fuels by renewable energy in the combined production of electricity and heat** (cogeneration plants) -TED/641/202- (IDAE, 2024d);

Additionally, to these pull policies there were available 316 million Euro of public funds partially funded by the European Regional Development Fund promoting projects of installations of thermal energy production from renewable sources with technologies such as geothermal energy, **solar thermal energy**, aerothermal energy linked to photovoltaic installations or biomass, mainly focused on the development of innovative applications in industry and the service sector to achieve a significant reduction in emissions and a high level of self-consumption. Each autonomous community has published specific calls to apply for these funds. These calls were designed taking into account the need to implement measures to support and promote the agricultural sector (IDAE, 2024e).

4.4.1 Performance of the 4 previously referenced pull policy programmes

At the time this report was prepared, no data was available on the above-mentioned incentive programmes, as they had only recently been introduced.

4.4.2 History: situation before the 4 previously referenced pull policy programmes came into force

The Spanish policies before the year 2021, in which the National Energy and Climate Plan -Spanish NECP- for the period 2021-30 [PNIEC, 2021] was approved and the previously referred pull policies came into force, were very limited with respect to the promotion of renewable energies in general and solar thermal energy in particular. Due to the financial crisis of 2008, the pull policies of incentives fostering renewable energies and energy efficiency were gradually removed. Thus, since January 2012, when it was approved by law the suppression of economic incentives for new electricity production facilities from cogeneration, renewable energy sources and waste as well as for any other renewable energy, except for the solar thermoelectric, the installation of new renewable energy facilities was stopped. This situation changed in April 2019 when a new law for self-consumption was approved. Since then, the installation of wind energy and particularly solar PV have increased significantly. Thus, wind energy had in 2015 an installed power of 22,933 MW, in 2018 the installed power was 23,443 MW and 30,748 MW at the end of the year 2023. Concerning solar PV, the installed power increased fivefold from 4,684 MW in the year 2015, to 4,771 MW in the year 2018 and to 25,125 MW in December 2023 [Red Electrica, 2024].

For solar thermal energy there were no pull policies before the year 2021, in which the previously referred pull policies were approved, , but the push policies established in the year 2007 when the Spanish Royal Decree 1027/2007, of July 20, 2007, approved the **Regulation of Thermal Installations in Buildings (RITE)**. The RITE establishes the conditions that must be met by installations designed to meet the demand for thermal comfort and hygiene through heating, air conditioning and domestic hot water systems and equipment to achieve a rational use of energy.

The solar thermal systems installed thanks to the push policy approved with the Spanish Royal Decree 1027/2007 were mainly small solar installations in buildings and the evolution of their installation over the years has been closely connected to the construction of new buildings.

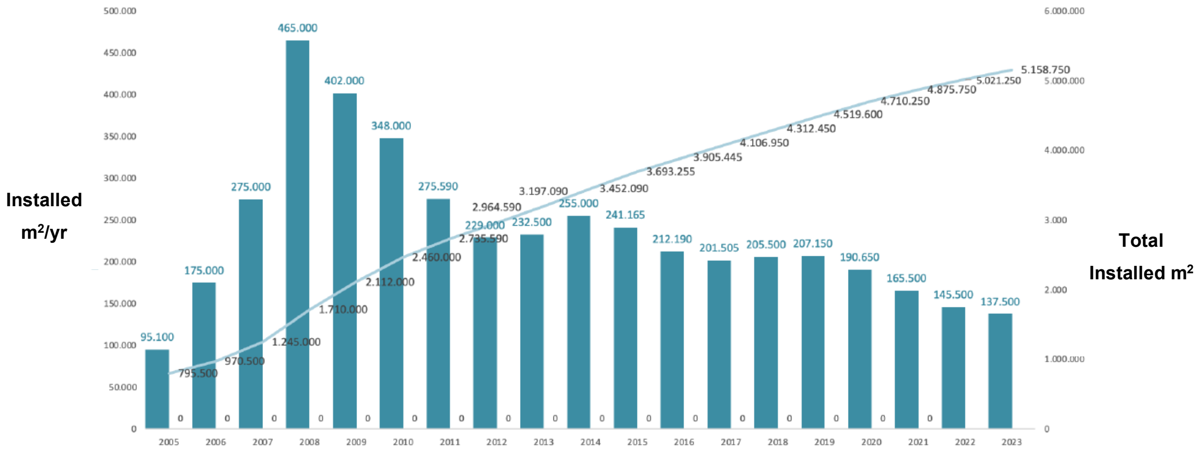

Figure: Evolution of the Spanish market of solar thermal collectors (ASIT, 2024)

The evolution of the Spanish market of solar thermal collectors, which is closely connected to the construction of new buildings, is shown in the Figure above. It is expected an increase in new installations, even large solar thermal collectors facilities in industries thanks to the new pull policies approved in 2021 previously referred, but no data were still available when preparing this report. At the end of the year 2022 there were installed in Spain more than 5 million of solar thermal collectors, which represent a total installed thermal power of about 3.5 GW_{th}.

4.4.3 Policy design: features of the Spanish policy

- Royal Decree RD 477/2021: Programme of incentives for the installation of self-consumption and energy storage driven with renewable energies as well as to **the installation of renewable thermal energy systems in the residential sector** (IDAE, 2024a). This programme is funded by the Next Generation EU Funds. It consists of 6 different subprogrammes of incentives, were the subprogramme 6 is devoted to the installation of thermal renewable energy systems in the residential sector. The budget for the subprogramme 6 was 100 million euro, as a part of the total budget for the six subprogrammes of 660 million euro, which can be increased to 1.32 billion euros. The call of this programme was published in June 2021 and its duration was extended until the end of December 2023. Eligible actions under incentive subprogramme 6 include projects on solar thermal, biomass, geothermal, hydrothermal, hydrothermal or aerothermal technologies (except air-to-air technologies) for air conditioning and/or domestic hot water in homes. The receivers of funding for the solar thermal installations are: 1) The residential sector: 450 – 900 €/kW, with a maximum of 3000 €/dwelling; 2) the publicly owned housing and 3) the third sector: 650 – 950 €/kW, with a maximum of 3500 – 4200 €/dwelling.

- Royal Decree RD 1124/2021: The decree approves the direct granting of aid to the Spanish autonomous communities for the execution of the incentive programmes for the implementation of thermal renewable energy installations in different sectors of the economy, within the framework of the Recovery, Transformation and Resilience Plan (IDAE, 2024b). The call for this programme was published in December 2021 and its duration was extended until the end of July 2024. This programme consists of 2 subprogrammes: 1) Installations of thermal renewable energies in the industrial, agricultural, service and other sectors of the economy, including the residential sector; and 2) Installation of thermal renewable energy systems in non-residential buildings, establishments and public sector infrastructures. The programmes are endowed with an initial amount of 150 million euros distributed among the different Autonomous Communities, which will be financed with funds from the Next Generation EU Funds. The Autonomous Communities distribute the budget allocated to each of them, between both incentive programmes, with a minimum of 70% for incentive programme 1 in its calls and the possibility of eventual budget extensions. In no case may aid granted to a single company and project exceed 15 million euros. Those actions aimed at the implementation of new renewable thermal installations, extensions and replacements of existing production systems that supply any of the following applications or a set of them which, as a guideline and not limited to, are listed below, are considered eligible for subsidy: i) Thermal applications for the production of cold and/or heat in buildings: sanitary hot water, heating, cooling, air conditioning of swimming pools, either directly or through **heat and/or cold district microgrids**. ii) Low, medium and high-temperature applications in production processes or other thermal applications: boiling, sterilization, cleaning, drying, washing, bleaching, steaming, pickling, cooking, leaching, thermal baths for surface treatment, supply of laundry services, vehicle washing, pasteurization and preservation of perishable products, air conditioning of industrial buildings, livestock and greenhouses, etc. Solar thermal installations will receive a subsidy of 1070 €/kW. In the case of incorporating systems of cold production by thermal energy such as absorption machines, adsorption, etc., the maximum eligible cost per unit will be increased by 50%. In the case of heat and/or cold microgrids, aid cannot be received for a power higher than 1 MW of production and/or in exchange. The aid to be received by the ultimate recipients under incentive programme 1, is subject to the requirements and limits laid down in Commission Regulation (EU) No. 651/2014, whereby the aid granted to a single company and project may in no case exceed EUR 15 million.

- (TED/707/2022): Programme of incentives for **district heating and cooling networks driven by renewable energies** (IDAE, 2024c). In its first call published in July 2022 and open until November 2022, this programme of economic incentives, which is aimed at projects with a capacity of more than 1 MW, had a budget of 100 million euros and is part of the Recovery, Transformation and Resilience Plan for the implementation of the Next Generation EU funds (PRTR, 2021). Specifically, this programme contributes to meeting the goal of installing at least 3,800 MW of renewable energy generation in Spain by the first half of 2026. Eligible projects, which must be completed by June 30, 2025 and will have to respect the principle of "no significant harm" to the environment, will be of three types: i) New heating and cooling network, including one or several generation plants using exclusively renewable energies and one or several distribution networks with energy exchange connections to consumption centers; ii) Expansion of an existing generation plant, through the incorporation of new generation equipment using renewable energies; iii) Expansion of an existing distribution network, including the network itself and new interchange connections. These projects must use existing generation plants that use renewable energies. The call is divided into two incentive programmes, depending on the type of beneficiary: (a) Programme 1: aimed at those who carry out some economic activity by which they offer goods and/or services in the market. b) Programme 2: aimed at those who do not carry out any economic activity offering goods and/or services in the market. The total aid per project is limited to 15 million euros and a minimum investment of 450,000 euros is established. Moreover, the amount to be granted to the installation of thermal renewable energy production will be about 35-45% for the incentive program, 1 and about 70% for the incentive programme 2, over the eligible cost for all eligible actions.

- (TED/641/2023) **RENOCOGEN Programme** for the **replacement of fossil fuels by renewable energy in the combined production of electricity and heat** (cogeneration plants), which establishes the regulatory bases for the calls of the incentive programme for electricity and heat production projects from renewable energies to replace production from fossil fuels (IDAE, 2024d). Within the framework of the Recovery, Transformation and Resilience Plan, funded by the European Union – NextGenerationEU (PRTR, 2021). The aim of these grants is contribute to the generation of electricity and/or thermal energy through renewable energy sources, replacing those currently being generated with fossil fuels, leading to a reduction in CO_2 emissions, a reduced energy dependence on fossil fuels and an increase in local economic and social benefits. The budget of this Program amounts 150 Million of EURO from the Recovery and Resilience Mechanism. The granting regime are non-refundable grants and are granted on a competitive basis. The beneficiaries are legal entities, public or private, including groups with their own legal personality, legally and validly constituted and with their tax domicile in Spain. The beneficiary must be the owner of a cogeneration or waste treatment plant. This aid shall be incompatible with other subsidies or aid that may be granted for the same purpose, from any public or private administration or entity, whether national, European Union or international organizations. Eligible projects are those projects of electric and/or thermal energy production plants from renewable energies. In the case of installations of thermal energy production they should be driven by biomass, biogas, geothermal, hydrothermal, aerothermal and/or solar thermal with thermal energy storage. The total aid per beneficiary and project is limited to 15 million Euro and a minimum investment per project of 50,000 Euro is established. The amount to be granted to the installation of thermal renewable energy production will be about 65-85%, over the eligible cost depending on the size of the company and its location. The first call of this program was published in July 2023 and it was open until September 2026. The facilities must be fully completed by January 31, 2026.

4.4.4 Strengths and weaknesses: experiences with TED/707/2022 and TED/641/2023 (RENOCOGEN) from market parties and policy makers

At the time this report was prepared, no data was available on the above-mentioned incentive programmes, as they had only recently been introduced.

4.4.5 Suggested improvements to TED/707/2022 and TED/641/2023 (RENOCOGEN), specifically for large-scale solar thermal energy

The current Spanish framework for energy and climate is based on the 2050 objectives of national climate neutrality, 100% renewable energy in the electricity mix, and 97% renewable energy in the total energy mix. As such, it focuses on the massive development of renewable energy, energy efficiency, electrification and renewable hydrogen. Nevertheless, although solar thermal energy is considered in the different push and pull policies approved, its implementation right now is almost limited to the small installations in the residential sector, except in the case of solar thermoelectric plants in which Spain is a worldwide leader with 2.3 GW of electric power installed.

With the new pull policies some large projects of solar thermal plants are being installed as it is the case of the solar thermal plant for the heat production in the Heineken plant located in Sevilla, Spain. This project required a total thermal power of 30 MWth with a total investment of 20.47 million EURO, partially funded (13.369.356 €) with the European Regional Development Fund. Nevertheless, these types of projects are still only a few.

Another promising niche for solar thermal applications in Spain are district heating and cooling networks. In 2023, there were 533 district heating or cooling networks with a total installed power of 1,620 megawatts (MW_{th}). Of these, 1,275 MW were heating networks and 357 MW were cooling networks. 80% of the networks use renewable energy in their energy mix, mainly biomass (414 networks), being solar thermal installed in only 8 networks. The total length of the networks is 977 km and the heating and cooling energy demand of buildings covered with district heating and cooling networks was about 0.5 GWh and 0.18 GWh respectively in 2022, which is a very small amount (ADHAC, 2023). The National Energy and Climate Plan -Spanish NECP, estimates a significant growth of these networks and a saving of 2922 ktoe for the period 2021-30 if the proposed push and pull policies are effective (PNIEC, 2021).

Taking into account the previous comments, solar thermal heat for industry or solar thermal district heating and cooling networks present very interesting and promising untapped opportunities. The estimated total thermal potential in Spain is approximately 50 GW_{th}. Therefore, effective pull policies should be continued.

In terms of governance, Spain has a fairly decentralised governance system, which is divided into 17 autonomous communities, each with its own parliament. This gives great importance to how the central government interacts with these regions and their representatives, who have competence to implement key national energy and climate policies. In the energy sector, the autonomous communities are responsible for areas such as authorizing power plants and energy networks. The decentralised governance system has benefits, as regions and municipalities can work more directly with end users to promote changes in energy consumption and transport. However, problems also arise from the difference in approaches and standards between regions and can result in uneven implementation of measures across regions. Improved training for municipal and regional authorities and standardization of tendering processes would help improve outcomes.

Large solar thermal projects are complex from a technical view point. There is a lack of experience in Spain on large district heating and cooling networks in general and on solar district heating and cooling networks in particular. The learning curve for the design, development, implementation and operation of these new systems requires not only economic investments supported with push and pull policies, but also a cultural change of the decision makers, technicians and consumers, i.e., a cultural change of the society.

4.4.6 Lessons from TED/707/2022 and TED/641/2023 (RENOCOGEN) for policy design

When preparing this report, there was no data yet available regarding the previous referred programmes of incentives due to their recent implementationConsidering Spain's lack of experience with district heating networks, the success of TED/707/2022 and TED/641/2023 are questionable. Prior, or together with, these pull policies, a very important effort to promote these new systems through outreach and awareness-raising campaigns, seminar and workshops for policymakers, technicians and installers, as well as the public would be very helpful. Moreover, these pull policies will not be effective if they are not maintained in future. Therefore, a continuity on the implementation of pull policies will be required to really and effectively implement these new efficient energy supply systems.

Features of TED/707/2022:

Aimed at projects with a capacity of more than 1 MW, with minimum investment of 450,000 euro.

Programme budget of 100 million euros, financed through Recovery, Transformation and Resilience Plan for the implementation of the Next Generation EU funds

Targeting new heating and cooling network and renewable energy heating plants, expansion of an existing generation plant with renewables, or expansion of an existing distribution network.

Two separate programmes for applicants executing economic activities and those who do not carry out any economic activities

Features of TED/641/2023:

Programme targeting replacement of fossil fuels cogeneration by renewable energy

Programme of 150 million euro financed through Recovery, Transformation and Resilience Plan for the implementation of the Next Generation EU funds

The beneficiaries are legal entities, public or private.

Thermal energy production should be generated by biomass, biogas, geothermal, hydrothermal, aerothermal and/or solar thermal with thermal energy storage.

The total aid per beneficiary and project is limited to 15 million Euro with a minimum investment per project of 50,000 euro

The amount to be granted to the installation of thermal renewable energy production will be about 65-85%, over the eligible cost depending on the size of the company and its location.

The first call of this programme was published in July 2023 and it was open until September 2026. The facilities must be fully completed by January 31, 2026.

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4.5 Switzerland

Switzerland is a federal country divided into 26 cantons. The cantons are responsible for regulating the heat sector, meaning that the subsidizing schemes for solar thermal plants for domestic applications (space heating and DHW production) and industrial applications (DHN or process heat) are defined by each canton.

The subsidy situation for large solar thermal fields in Switzerland has historically been unclear, as there were no national subsidies directly addressing large solar thermal energy applications. Until recently, subsidies for solar thermal systems were available under the building programme (ModEnHa 2015, measure 8), primarily benefiting small-scale domestic hot water and heating systems without formal size limits. Consequently, large-scale systems connected to district heating networks (DHN) faced significant barriers due to the lack of explicit regulatory support. For example, the connection of SOLARCAD II (784 m²) in Geneva was ineligible for subsidies because it was linked to a DHN rather than a direct building application.

However, with the new Federal Act on Climate Protection Objectives, Innovation, and the Strengthening of Energy Security, in force since January 1, 2025, new financial incentives have been introduced. Subsidies are now available for the construction and expansion of solar thermal collector installations if the following conditions are met:

- The nominal thermal power of the solar collector installation exceeds 70 kW.
- The installation is part of a renewable heat production system replacing an oil, natural gas, or electric resistance heating system.
- The permitted share of fossil energy for peak load coverage does not exceed:
  - 0% for installations with a nominal thermal power of up to 100 kW.
  - 10% for installations with a nominal thermal power exceeding 100 kW.
- The collectors comply with the specifications defined in the Swiss kollektorliste.ch.
- The installation has a validated performance guarantee (GPV) from Swissolar/SuisseEnergie.
- The installation is subject to active monitoring according to Swissolar’s prescriptions.

Restrictions apply, excluding air collectors, solar collectors for swimming pools and hay dryers, and the replacement of existing solar collector installations. The subsidy calculation is based on nominal thermal power, with a minimum contribution of 2,400 CHF plus 1,000 CHF per kW.

As per the Harmonised Cantonal Incentive Model (ModEnHa 2015), solar thermal systems integrated into DHNs may still benefit from CO_2 certificates, provided they replace fossil heat production. The subsidy for district heating networks (ModEnHa 2015, measure 18) is assigned per MWh of renewable energy delivered. However, since solar thermal is often a secondary energy source, its economic advantage is primarily derived from saved resources rather than direct subsidies.

A significant limitation remains: in many cantons, revenue from CO_2 certificates cannot be combined with other cantonal support instruments because the canton itself issues CO_2 certificates in exchange for the subsidies it grants. While the new federal framework provides a clearer subsidy structure for large solar thermal installations, it does not fully resolve this issue, underscoring the need for further regulatory clarification.

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4.6 Solar thermal policy in Denmark: An overview

Denmark has long been at the forefront of solar thermal district heating. Historically, Danish policy has emphasised push mechanisms alongside financial and fiscal measures to actively promote the integration of renewable energy into district heating systems. In the more recent past these efforts have been driven by Denmark's national target of achieving carbon neutrality. While many of the measures have significantly benefited solar thermal technology, they were not all exclusively designed for its advancement, but more generalised renewable energy subsidy programmes.

Today, the Danish policy combines push policies and financial and fiscal measures with targeted pull mechanisms and enabling policies. Namely, those are the *Energy Saving Obligation*, the subsidy scheme *District Heating Pool*, and the *CO2-tax*. One pull mechanism directly targeting solar thermal is the *Establishment Support Pool*. Additionally, development and demonstration programmes have played a key role in testing and scaling solar district heating in Denmark.

4.6.1 Performance of policies

The performance of Denmark’s solar thermal policies can be illustrated by the development of solar district heating plants and the installed collector aperture area in the period 2009 to 2023. As shown in Figure 3, the *Energy Savings Obligation Scheme* led to a marked increase in the number of solar district heating plants. Between 2009 and 2015, the installed collector aperture area expanded from approximately 100,000 m² to 800,000 m². Upon to the change in the support scheme in 2016 an additional aperture area of 500,000 m² was build.

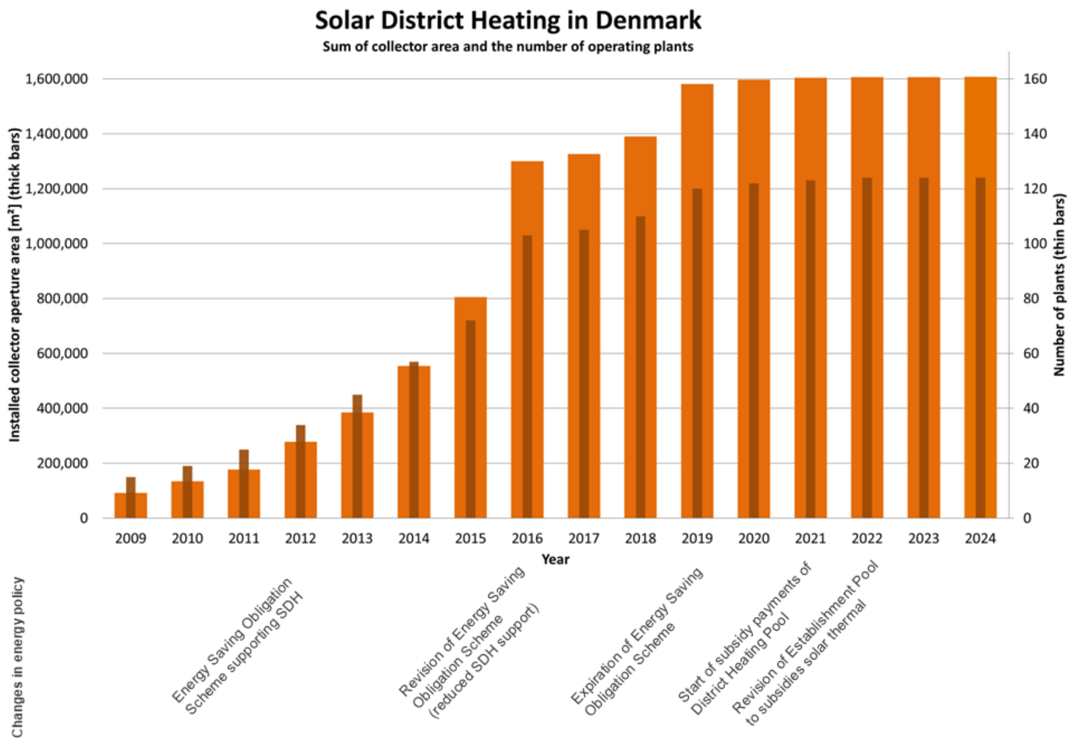

Figure: Development of number of solar thermal plans and installed collector aperture area in Denmark in the period 2009 to 2024

However, the trend changed in subsequent years. In 2017 and 2018, growth in solar district heating installations slowed after the introduction of changes to the Energy Savings Obligation Scheme. In 2019, the abrupt end of this support scheme further affected the rate of new installations, leading to the installation of approx. 200,000 m² collector aperture area in time before the end of the period (end of the year) where solar thermal could benefit from the Energy Savings Obligation Scheme.

The stable trend from 2020 suggests that the subsequent support schemes are not creating sufficient incentive for the installation of further solar district heating plants but rather target the support of other renewable energy sources such as heat pumps. In the period 2021 to 2023, less than 13,000 m² collectors were installed and only 8,000 m² of collectors were granted support of the *Estabilishment Support Pool* (corresponding to 5.6 MW_{th}), while 154.6 MW_{th} of heat pumps were supported. In general, the slowdown of the solar thermal market coincides with the increasing maturity of heat pumps for district heating and the corresponding rise of this heat pump market.

This shift suggests that while earlier policies were highly effective in promoting solar district heating, recent initiatives have not provided sufficient incentives to maintain growth in this area.

4.6.2 History: An overview of important policies promoting SDH in Denmark

Denmark's energy policy has long been emphasising energy efficiency, renewable energy, and the reduction of carbon emissions. The *Heat Supply Act*, introduced in 1979, laid the foundational framework for the Danish district heating network systems, which play a pivotal role in this achievement. In response to the oil crisis, the Danish government called on the municipalities to elaborate a heat plan in which the heat supply was defined as individual, natural gas or district heating for consumers in the area. This was done to ensure the use of waste heat from power generation via CHP and to create a market for natural gas instead of oil heating.

The *Heat Planning Law*, introduced in the 1980s, required municipalities to prioritise district heating, creating a foundational framework for solar thermal integration. Alongside this, *municipal guarantees* have been a cornerstone of Denmark's approach to develop and expand district heating network across the country. These guarantees enable municipalities to support local district heating projects by providing financial backing, thereby facilitating access to 100% debt financing and favourable loan terms over long periods. As a result, investment risks are reduced, lowering the barrier for investments in new technologies - an essential factor in expanding district heating infrastructure and supporting renewable energy investments.

The district networks developed in this way are run by utility companies that are legally regarded as a monopoly and are regulated by the *principle of non-profit*. Consequently, district heating companies can only charge their customers an amount corresponding to their total costs. The principle has some positive side-effects: Consumers can trust that the district heating companies are not charging extra to increase their profits thus enabling more transparency and trust. Additionally, the lack of competition between district heating companies means a long tradition of knowledge sharing to benefit from others' good & bad "lessons learned". The focus is in general on enabling low heat production prices (incl. OPEX + CAPEX) in the perspective of the technical lifetime of new investments, rather than short payback times. This approach – combined with low interest rates and long-term loans – has proven to be favourable circumstances for the development of SDH. Today, the networks are increasingly powered by renewable energy sources, including solar thermal, biomass, wind, and waste-to-energy.

From an early stage, financial incentives were applied to CHP plants to ensure that power was produced when most electricity was needed, typically Monday-Friday. Hence, it has for decades been favourable for district heating companies to install an accumulation tank to store heat throughout the week to cover the heating load of the weekend without running the CHP units. These already existing storage tanks were then suitable to use also for the "classical" Danish SDH solution, where around 20% of the annual demand could be covered with solar heat (and most or all of the summer demand) by using the existing – or perhaps with an extra – heat storage. Today, the value of abundant storage capacity is often substantial, since it enables extra flexibility on electricity markets, which have been increasingly feasible over the past years. Hence, the benefit of storage capacity for both solar thermal options and for electricity grid services/flexibility goes hand in hand.

The transition away from fossil fuels was supported by several policies. Since the 1990's, new projects changing heat supply or heat production have to be accepted by the municipalities. The approval is only granted for projects that prove to be the best socio-economic option among possible alternatives, promoting an increased use of CHP plants powered by natural gas and environmentally friendly fuels. In the early 1990's Denmark further introduced CO_2 taxes, which were among the first to be introduced globally. The earlier iterations of CO_2 taxation primarily targeted fossil fuel consumption, playing a decisive role in promoting energy efficiency and the initial shift towards greener energy sources but were less focused on the direct promotion of technologies like solar thermal.

In 2006, the *Energy Savings Obligation Scheme (Energiselskabernes Spareindsats)* was introduced, leading to a significant restructuring of energy-saving efforts. It required energy companies to implement energy-saving measures and supported improvements in district heating systems, indirectly benefiting solar thermal adoption by enhancing overall energy efficiency. The *Heat Planning Law* remains a cornerstone of policy, requiring municipalities to develop sustainable and efficient heating strategies while phasing out fossil-based systems.

The *Establishment Support Pool*, introduced in 2018 and provided subsidies for the replacement of fossil fuel powered district heating production units with solar thermal or heat pumps and presents another more targeted pull strategy.

In 2019, Denmark adopted an ambitious climate target through its *Climate Act,* committing to reducing greenhouse gas emissions by 70% by 2030 compared to 1990 levels. This led to the introduction of two more policies: the *District Heating Pool*, established in 2020, which offers subsidies to expand district heating networks and integrate renewable solutions, including solar thermal, and the reformed *CO_2 tax* on fossil fuels, set to be introduced in 2025 as part of a broader green tax reform. This reform aims to improve the economic competitiveness of renewable energy, indirectly incentivizing solar thermal adoption. Thus, both initiatives strive to create a more favourable environment for all forms of renewable energy, including solar thermal, by providing clearer incentives for CO_2 reduction and energy efficiency improvements.

Alongside, the legislative measures, innovation has played a key role. Programmes such as the *Energy Technology Development and Demonstration Program (EUDP)* have provided essential funding for testing and scaling solar thermal technologies, including advanced collectors and storage solutions. Efforts to integrate increase the utilisation of solar energy to cover a larger part of the annual heat demand with Pit Thermal Energy Storage (PTES) have been supported by EU co-funded *demonstration projects*.

4.6.3 Policy design: Features

In the following the key features of the three support schemes *Energy Saving Obligation Scheme, District Heating Pool, Establishment Pool* and the *CO2-tax* are described in more detail.

Energy Saving Obligation Scheme

The *Energy Saving Obligation Scheme* is an energy policy agreement, that was in effect from 2006 to 2020. It imposed binding targets on energy companies, to reduce energy consumption through energy efficiency improvements. Rather than direct state funding, financial support was structured so that energy companies could collect funds from consumers via energy tariffs to cover the costs of their energy-saving obligations. Specifically, companies were allowed to charge an advance fee of 0.50 DKK (around 0.07 €) per kWh for the required savings, with later adjustments based on actual costs incurred.

In total the scheme was revised four times: in 2006, in 2009, in 2012 and in 2016.

Smaller district heating companies were initially exempt from the obligation but were included from 2010 onwards, such that all district heating companies in Denmark (more than 400) where obliged to present energy savings. This facilitated to a strong increase in the number solar district heating plants.

In 2012 the requirements were gradually tightened, with an increased focus on cost efficiency and transparency. The annual energy saving target was increased by 75% for the period 2013-14 and by 100% for the period 2015-2020 compared to the saving efforts in the years 2010-2012. A key aspect of the revision was the introduction of the option of realising more savings than required and thereby generating credits which could be sold to other stakeholders not realising the required savings themselves. This way, an investment in a solar district heating system would generate extra credits which indirectly represented a value to be deducted from total investment cost sum.

The main prerequisites qualifying the collection of funds included:

- The energy savings had to be documented and verified to qualify for subsidies. This included calculations of the expected lifetime and efficiency of the technology as well as baseline consumption to be replaced.
- SDH generating bankable extra credits were granted with specific limitations. According to the 2016 revision, a maximum of 8,000 MWh from solar thermal installations could be credited, which was a significant constraint for larger systems. Depending on system efficiency, this corresponded to approximately 16,000-20,000 m² of solar collectors (assuming 500 kWh/m²/year or 400 kWh/m²/year). To qualify, projects had to be approved by June 30, 2018, commissioned by June 30, 2019, and reported in the year they were implemented and documented. The credited savings were based on the calculated production of the solar thermal system, subject to documentation requirements.

District Heating Pool

The District Heating Pool is a grant scheme specifically targeting district heating companies. Through the pool, district heating companies can receive grants for projects that implement energy-efficient district heating networks in new areas and convert individual oil and gas boilers to district heating. The availability of the grant is not limited to specific heat generation technologies and can accordingly be applied for solar thermal projects. The total funds allocated to the pool in the last years are distributed as follows: DKK 340 million in 2021 to 2023, DKK 265 million in 2024 and DKK 200 million in 2025.

The subsidy district heating companies can receive is a fixed amount of up to DKK 20,000 per converted oil or gas boiler that constitute “the minimum connection”. “The minimum connection” is the number of converted oil and gas heated households that bring balance in the business economy of the project.

The main prerequisites for receiving subsidies include:

- A municipal approval has been obtained for a project to roll out a district heating distribution network in accordance with the Executive Order on approval of projects for collective heat supply systems. The project proposal must include a calculation of the minimum connection. The roll-out project would not be feasible without a grant.
- The project has an expected completion time of maximum 5 years from receipt of commitment.
- The work has not commenced prior to obtaining the grant commitment.

Establishment Pool

The Establishment Pool was introduced as part of the 2018 Energy Agreement and remained active until the end of 2023. The support scheme was put into practice in 2021, allowing applications for grants to support the installation of electric heat pumps. In 2022, the scheme was revised to include applications for solar heating systems.

Both small and large district heating producers were eligible to apply for the grant, provided they met the specified conditions. The main requirements included:

- The establishment of either an electric heat pump or a solar thermal system, that supply district heating in existing district heating networks.
- For heat pumps, the heat source must be based on renewable energy or surplus heat.
- At least 25% of the current district heating production in the network must rely on coal, oil, or natural gas.
- At least 50% of the heat production from the heat pump or solar thermal system must replace heat production based on coal, oil, or natural gas.
- Projects must be completed within three years.
- Up to 30% of eligible costs could be subsidised, with a maximum grant of DKK 7.5 million per project.

CO_2 tax

The latest revision of the CO_2 tax in Denmark is targeting carbon emissions from heavy emitters. Set to start in 2025 at 375 DKK per ton CO_2, the tax will gradually increase to 750 DKK (about 100 EUR) per tonne of CO_2 by 2030. This tax is projected to reduce Denmark's carbon emissions by 4.3 million tonnes per year by 2030. The financial implication of this tax is presumably also incentivising district heating companies to switch to greener energy sources to avoid the increasing costs associated with carbon emissions.

4.6.4 Strengths and weaknesses: Experiences with Danish solar thermal policies from market parties and policymakers

Strength

Denmark's long-term commitment to district heating, supported by policies like the Heat Supply Act and Heat Planning Law, has provided a stable foundation for solar thermal integration. The financial and fiscal support mechanism, *municipal guarantees* with its low-interest financing, and the targeted subsidy *Energy Saving Obligation Scheme*, have facilitated large-scale adoption of solar thermal. The CO_2 tax and the District Heating Pool further incentivise the transition from fossil fuels to renewable district heating solutions.

Weaknesses:

However, the District Heating Pool, shows clear tendency in the distribution of grants, where all but one granted project are heat pumps. This is caused by the competitive challenges between solar thermal and heat pumps. In the current Danish market, solar thermal struggles to compete with large scale heat pumps due to similar overall heating costs (CAPEX + OPEX). Heat pumps offer the advantage of providing consistent heat output throughout the year without requiring seasonal storage, making them a more attractive option under existing financial conditions. Nonetheless, in some cases the low power consumption of solar thermal plants could be beneficial in reducing the need for electricity grid reinforcements as electrification expands across various sectors. This aspect may be worth considering for policymakers.

4.6.5 Suggested improvements to Danish solar thermal energy policies

As specified in IEA DHC TS3 report for subtask A the Danish consumption of biomass can not be sustainably scaled globally. While biomass has historically played a role in district heating, its consumption should be limited to regional sources in the future to ensure a more sustainable energy production. The effect on biomass prices might lead to an increased competitiveness of solar thermal while improving the sustainability of district heating systems.

Unlike some renewable technologies, solar thermal does not rely on critical metals, and production facilities exist across multiple continents. This reduces supply chain risks and minimises geopolitical dependencies. Policy makers should keep this advantage of the technology in mind, as it can increase the energy security.

4.6.6 Lessons

- ***Replicability***
  The development in Denmark has previously been considered a market to try replicating. Several factors contradict such a target, since a) the boundary conditions in Denmark have been (at least partially) special and thus difficult or impossible to directly copy, and b) the SDH market in Denmark today has been facing challenges mainly due to competing technologies. However, some lessons learned may be useful for other countries in relation to their development of a SDH market.

- ***Non-profit***
  The fact that there has been no direct competition between the DH companies has enabled an open environment with sharing of experiences and best-practices. This has been (and is) a useful process facilitated by the national district heating organisation thus avoiding that each operator/company needs to "make its own mistakes" but can benefit from previous experiences. Similar knowledge sharing has been implemented in relation to various technologies. Even if such legislation of not-for-profit may not be implemented in other countries, local ownership is possible (as a cooperative or publicly owned). This can create a focus of long-term stable and low-cost heat supply rather than short payback times, which in turn has a direct impact on the perception of feasibility: The investment in solar thermal (and payments) can be considered over the lifetime of more than 20 years which – together with low interest rates – results in a low average cost for solar thermal.

- ***Financing & feasibility***
  Municipal guaranteed loans have enabled a minimum interest rate level for district heating companies. Similar solutions could be implemented in other countries, where state, region, municipality or other stakeholders could facilitate minimum-interest rate loans to enable long payback periods for the long-term investments.

- ***Storage***
  A long-standing tradition of investing in thermal storage has significantly improved the economics of SDH. Initially, storage supported flexible electricity *generation*; today, it enables better integration of variable renewable energy sources, and, hence, the flexibility in *use* of electricity by electric boilers and heat pumps. Policies that encourage heat storage investments contribute to a larger share of volatile energy sources, and once in place they can also enhance the competitiveness of SDH by allowing for higher solar fractions.

- **Demonstrators**
  Direct funding for early adopters has encouraged market confidence. Supporting demonstration projects can be an important driver to have a showcase of the technology locally/nationally.

- **Land availability**
  More than 2/3 households in Denmark are connected to district heating. In a lot of smaller villages, farmland is located near the district heating plant often located in the outskirts (industrial area) of the village. Hence, land is available close to the district heating plant. However, when considering land availability, there may be a tendency to regard only the neighbouring areas and their (limited) availability. In the investment costs of a SDH system, transmission pipes typically do not represent a major share. What may be more important is the economy-of-scale-effect which means that it may be feasible to find available land further away in order to be able to increase the solar area, since the marginal cost of additional solar capacity may compensate for the additional transmission pipe cost. In other words, it can be relevant to consider land availability further away than what might be considered "close" to the district heating plant.

  Competing technologies
  The strong growth of solar thermal in Denmark during the 2010s was driven by subsidies and, perhaps even more significantly, by the lack of viable alternatives at the time. Biomass boilers were not allowed (for most small and medium-sized heating plants), natural gas was relatively expensive (especially gas boilers) and heat pumps for district heating was not a mature technology.
  The trend in Denmark has lately been an increasing interest in electricity driven heat pumps. Even if heat can be produced at the same price from solar thermal as a heat pump, the option to decarbonise a larger share of the annual demand with a heat pump (without the need for a seasonal storage) is a strong argument. And with both technologies in place, there is (with current electricity prices) little revenue in a solar thermal investment compared to simply operating the heat pump throughout the summer too.
  Though biomass is considered renewable, there is a broad understanding that resources are limited and that the use for heating is in many cases necessary to minimise. Solar thermal can be a useful option to reduce biomass use in DH – possibly in combined systems where the solar thermal system also allows maintenance of the biomass boiler during the summer.

- **Strategic tariff adjustment**
  Policymakers influenced the market behavior through tariffs by gradually phasing out fossil fuels while supporting preferred alternatives. A well-communicated transition period allows market actors to adjust, ensuring affordability while shifting from fossil fuels to renewable options like solar thermal or heat pumps. By tariffing fossil fuels, the one polluting can pay the price for that. What is paid in tariffs can then be fed into a support scheme for the clean technologies to further encourage a transition.

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5 Business models for solar thermal energy

5.1 Types of business models

A solar thermal project involves high upfront costs: The initial investment and the financing mainly determines the resulting heat supply costs. The investment sum may be broken down into various cost components, such as the development costs, the equipment costs, the balance of plant, the heat storage, and the costs for installation labour and planning. Paying the initial investment usually involves a loan, which implies financing costs that burden the project. Additionally, the daily operation of the plant results in annual operating and maintenance costs.

Once a solar thermal plant is operational it will supply heat to one consumer or multiple consumers, possibly through a district heating network. This heat represents a value, which usually is paid by the consumer(s). Also, it is possible that a project is fully owned by an end user, and that no payment is involved. This is for example the case when a large industrial consumer develops and pays for a solar thermal project for their own use. In the case of a solar thermal installation delivering heat to a district heating network the organizational structure of the project may be quite complex.

How a project in financial terms is set up is indicated by its business model. The business model defines the position of each player involved, for example ownership, management, risk exposure, responsibility for servicing and for making or receiving payments. Local circumstances make that a business model may be tailored to an existing project, the reason for which retrofitting a solar thermal plant to a heat network often involves negotiating project financing.

Business models can be broadly categorised as follows:

- Ownership models, focusing on financing and risk mitigation of a solar thermal plant and providing turnkey solar solutions. This situation refers to an EPC model (engineering, procurement, and construction) where ownership lies with the client.
- Service models through a solar thermal energy supply contracting company, based on a heat purchase agreement.

Mixed forms are also possible, for example, companies that offer turnkey solutions for the balance of plant.

Business models may also be a combination of elements of both types. The scale of the project (large scale versus small scale) may influence the choice of the business model. Also, the type of consumer (small versus large consumers) impacts the business model through the payment risk profile. And the higher the number of consumers, the higher the administrative effort. Other factors influencing risk perception lie in non-monetary aspects, such as increased security of supply, reduced fuel import dependency or air quality improvements. For such public goods, the business model might improve the overall feasibility of a project, but possibly also involve additional income in case these goods are priced, for example by the local authorities. Additionally, through support measures such as investment or exploitation subsidies, cheaper loans or environmental tax rebates a business case can be improved. Another aspect is that the local regulatory framework may impose limits on the end-user tariffs.

5.1.1 Ownership business models

In ownership business models, aspects regarding capital costs, and funding challenges are addressed. Variants of ownership business models are:

Public-private partnership
A public-private partnership (PPP) involves a contract between a public sector authority and a private party, in which the private party provides a public service (heat supply from a solar thermal plant) and takes on a substantial amount of the financial, technical, and operating requirements. Allocating tasks and risks to the private

sector partners is the main purpose, thus minimizing risk to the public entity. The assumption here is that the private sector partners are best positioned to deal with these tasks and risks. A special-purpose company (SPC) or special-purpose vehicle (SPV) is usually erected to develop, build, maintain, and operate the plant for a contracted period. The SPC or SPV contractually agrees with the government, with investors (equity and debt) and subcontractors to build the facility and then operates and maintains it. Billing of end users may also be managed by the SPC or SPV. This option involves full outsourcing of the solar thermal activity to the new entity and is suitable only for large projects.

Bilateral approach: private party delivering turnkey installation to client
A private party such as a company for engineering, procurement, and construction (EPC) can also deliver a turnkey solar thermal plant to a client or end-user who has ownership of the plant. The owner may either decide to do the operation and maintenance (O&M) on one's own or can outsource the O&M.

Lease or hire purchase
A lease or hire purchase enables users to purchase equipment in instalments (terms of repayment). A solar thermal equipment supplier provides the installation to the end user for a contracted period of time in exchange for regular payments. The equipment supplier is responsible for sourcing, financing, and installing the equipment, and for maintaining it during the contract period. At the end of the contract period ownership of the equipment can either remain with the lessor or pass to the lessee (possibly after additional payment, corresponding to a residual value agreed during contract closure), or the equipment is being decommissioned. The solar thermal plant can thus be regarded as a fungible asset. This model is in between the ownership and service-based models, resulting in fixed annual payments versus payment against delivered heat quantity as is the case in service-based models. The agreement on a lease or hire model involves a minimal requirement for monthly or annual heat delivery.

5.1.2 Service-based business models

A service-based business model provides solar thermal heat to the end user. For solar thermal energy supply, a contracting company is most suitable, next to the alternative of an energy performance contracting company, which saves energy for the consumer against a predefined baseline.

The service is provided by an energy service company (ESCO), which can be:

- a private utility or company
- a public utility or a nongovernment organization
- a cooperative

Private entities have a more commercial approach towards the service, while public or nongovernment entities may be less commercial. A user-cooperative business model involves the establishment of a nonprofit community organisation that is owned, funded (possibly partly) and managed by its members. The cooperative manages all administrative and operational functions, including the installation, maintenance, and safe operation of the solar thermal plant. Also, financial management and payments between users, contractors and operators, and the cooperative are handled. The managers may be volunteers.

5.2 Solar thermal cases with different business models

In the following paragraphs, some examples of large solar thermal systems connected to district heating networks or industrial clients are introduced.

5.2.1 Solar district heating plant in Groningen, the Netherlands

Parameter	Value and unit
Country	Netherlands
Region/city	Groningen
Collector area	48,000 m²
Thermal capacity	37 MW
Expected annual heat production	25 GWh/year
Total investment	23 million €
Commissioning	2023
Loan provided by	Triodos Bank
Support scheme	SDE++ for large solar thermal, 15 years feed-in premium
Applied business model	Public-private partnership with special purpose vehicle (SPV)
Operated by	Utility Warmtestad
Companies in SPV	Solarfields, Dutch project developer K3, Dutch investor TVP Solar, turnkey solar field provider from Switzerland
EPC contractor	Unknown
Performance guarantee	By TVP Solar, 15 years
Heat delivered to	District heating system from Warmtestad
Contract type	30 years length of heat supply contract with Warmtestad
Source(s) of information	Solarthermalworld.org news item, November 2022, https://solarthermalworld.org/news/37-mw-solar-district-heating-plant-in-the-netherlands-with-outstanding-features

The 37 MW (48,000 m² collector field) in Groningen, Netherlands will be connected to the district heating grid operated by the utility company Warmtestad. Three companies set up a special purpose vehicle (SPV): Solarfields (project developer), K3 (investor) and TVP Solar (turnkey provider of the solar field). The collector field consists of high-vacuum flat plate collectors that produce temperatures from 69 to 93 °C. The project SPV has signed a long-term solar heat delivery contract over 30 years with the utility Warmtestad. TVP Solar was chosen, after an extensive tender process and as a turnkey technology provider and O&M operator of the field, TVP Solar provides a performance guarantee of 15 years.

The EUR 23 million CAPEX was partly made available by a loan from the Triodos Bank. The project SPV, as the owner of the solar heat plant, will also receive a feed-in tariff from the national subsidy scheme SDE++ (see also Section 4.1). It supports energy produced over 15 years using a wide range of renewable technologies including solar thermal. The feed-in tariff is calculated as the difference between the current gas price and a price cap of 85 EUR/MWh. This difference is updated annually and paid over a period of 15 years.

The vacuum-insulated collectors, the technical building and the storage tank will occupy 12 hectares, providing 25 % more energy from the same area compared to conventional flat plate collectors.

5.2.2 Concentrated Solar Thermal plant for community heating in Brandenburg, Germany

Parameter	Value and unit
Country	Germany
Region/city	Brandenburg
Collector area	15,025 m^2
Thermal capacity	9 MW
Expected annual heat production	6.87 GWh/year
Total investment	9 - 10 million €
Commissioning	Pre-feasibility finished
Loan provided by	
Support scheme	BAFA grant for district heating; one time pay off as % of CAPEX and additional 10 €/MWh added for O&M of solar thermal plant for 10 years
Applied business model	Energy service model; SPV acts as ESCO
Operated by	SPV specifically established for this project
Companies in SPV	Solarlite / Azteq / Investor (Equity) / possibly Client (minor shareholder)
EPC contractor	Solarlite CSP Technology GmbH
Performance guarantee	Azteq
Heat delivered to	Adventure and tourism park.
Contract type	20-25 years project duration with 2% annual inflation for heat price
Source(s) of information	Solarlite CSP Technology GmbH

This project is in the pre-feasibility stage. The 9 MW system generates a total of 6.87 GWh per year. It will provide solar coverage of at least 93% of the total heating needs of a tourist complex with hotels with a total accommodation capacity of 3,776 beds, restaurants and manufacturing areas belonging to an adventure and tourism park.

This is an ESCO business model. The company Solarlite CSP Technology GmbH together with a third-party equity investor will take care of the financing, construction, operation and heat supply service to the client.

The solar field consists of a system of 20 parabolic through collectors that have a total of 217 mirror segments, with a cumulative opening surface of 15,025 m², pressurised water as a means of heat transport and a seasonal storage designed as a pit thermal energy storage.

5.2.3 Concentrated Solar Thermal plant for a large R&D building complex heating in North Rhine-Westphalia, Germany

Parameter	Value and unit
Country	Germany
Region/city	North Rhine-Westphalia
Collector area	42,167 m^2
Thermal capacity	25 MW
Expected annual heat production	16.6 GWh/year (Solar): 31.8 GWh/year (Heat pump); 48.4 GWh / year (total delivered heat)
Total investment	32-35 million € (including heat pump, short term- and seasonal storage (DTES/PTES), district heating network piping); solar field (parabolic trough collectors, field headers, loop piping & instruments) investment is approximately 10 million €
Commissioning	Pre-feasibility finished
Loan provided by	
Support scheme	BAFA grant for district heating; one time pay off as percentage of CAPEX and additional 10 €/MWh adder for O&M of solar thermal plant for 10 years
Applied business model	Energy service model; SPV acts as ESCO
Operated by	SPV specifically established for this project
Companies in SPV	Solarlite / Azteq / Investor (Equity) / possibly Client (minor shareholder)
EPC contractor	Solarlite CSP Technology GmbH
Performance guarantee	Azteq
Heat delivered to	
Contract type	20-25 years project duration with 2% annual indexation for heat price
Source(s) of information	Solarlite CSP Technology GmbH

This project is in the pre-feasibility stage. The solar field consists of a system of 64 parabolic through collectors that have a total of 609 mirror segments, with a cumulative opening surface of 42,167m², and pressurised water as a means of heat transport.

The 25 MW Solar system is coupled to a 12 MW heat pump, a daily thermal energy storage (DTES) and a seasonal energy storage designed as a pit thermal energy storage (PTES). The complete thermal system will produce 48.4 GWh and will cover 90% of the heat demand of a large R&D building complex in North Rhine-Westphalia. The heat pump consumes approximately 14.7 GWh electricity annually.

The solar field supplies heat directly to the consumer during sunshine hours (mostly in summer) and the rest heat is stored in the DTES/PTES which discharges heat as soon as heat generation in the solar field stops. The heat pump has two operational modes: a water-water mode to utilise the PTES as a low heat source (with a COP of approximately 4) and an air-water mode when the PTES is depleted and thus continuing to supply heat to the consumer (with a COP of around 2.3). Further optimised operation modes are possible and have to be assessed during the detailed engineering phase.

This is an ESCO business model. The company Solarlite CSP Technology GmbH together with a third-party equity investor will take care of the financing, construction, operation and heat supply service to the client.

5.2.3 Solar district heating plant in Aulum, Denmark

Parameter	Value and unit
Country	Denmark
Region/city	Region Midt Jylland/ Municipality of Herning
Collector area	16,569 m^2
Thermal capacity	11,1 MW
Expected annual heat production	ca. 7,500 MWh
Total investment	3.8 million €
Commissioning	2015 (extension in 2018)
Loan provided by	Kommune Kredit
Support scheme	Energy Saving Obligation Scheme
Applied business model	ESCO, Non-profit district heating company
Operated by	Aulum Fjernvarme
Companies in SPV	no
EPC contractor	Aktive Energi Anlæg (AEA) A/S / RW Rørteknik
Performance guarantee	Aktive Energi Anlæg (AEA) A/S
Heat delivered to	District heating network
Contract type	Non-profit
Source(s) of information	Aulumn Fjernvarme and PlanEnergi, consulting firm for the project

This project has been commissioned in 2015. The solar plant consists of 1,271 solar collectors with a collector area of 16.595 m^2 a heat storage with a volume of appr. 3,600 m^3. Annually about 7,500 MWh of heat are produced for the district heating customers in the town of Aulum with a population of approximately 3,200. This corresponds to over 20% of the annual district heating production. The remaining heat is produced by a CHP unit, gas boilers, an electric boiler and from 2020 the DH plant commissioned a 4 MW_{th} air-source heat pump.

Typical for Danish district heating facilities, the business model for the project is an ESCO founded as a user-cooperative and run as a non-profit entity. The investment costs of EUR 3.8 million are made up of the following items: 65% for solar collectors, 10% for transmission pipes, 7% for the buildings, the glycol tank and the nitrogen unit, 11% for the storage, 3% for electricity and control and 4% for “other”.

The financing is provided by a *municipal guarantee*, allowing the municipality to support local district heating projects by providing financial backing. The guarantee enables 100% debt financing with favorable loan terms, ensuring cost-effective project implementation. The loan is structured with a 3% interest rate over a 20-year term, with debt repayment covered through consumer payments. As the installation was carried out under the Energy Saving Obligation Scheme, Aulum Fjernvarme was also permitted to collect tariffs of 0.50 DKK (around 0.07 €) per kWh for the energy produced by the solar thermal plant, that contributed to reaching the companies saving obligation.The plant operates with an OPEX of 1 EUR/MWh, resulting in a total heat price of approximately 34 EUR/MWh.

5.2.4 Solar district heating plant in Ørum, Denmark

Parameter	Value and unit
Country	Denmark
Region/city	Region Midt Jylland/ Municipality of Viborg
Collector area	6,375 m^2
Thermal capacity	4.5 MW
Expected annual heat production	2,800 MWh
Total investment	Ca. 2.1 million €
Commissioning	2016
Loan provided by	Kommune Kredit
Support scheme	Energy saving obligation scheme
Applied business model	ESCO, non-profit district heating company
Operated by	Ørum Varme
Companies in SPV	no
EPC contractor	Industrivarme a/s, Frontmatec
Performance guarantee	Industrivarme a/s, Frontmatec
Heat delivered to	District heating network
Contract type	Non-profit
Source(s) of information	DTU, Ørum Varme

The solar plant in Ørum was commissioned in 2016. The solar collector field was made of 506 flat plate collectors with a total aperture area of 6355 m^2 and the heat storage tank has a volume of 1000m^3. Annually the solar plant yields about 2,800 MWh of heat production, which covers around 23% of the heat demand in the local district heating network. Until 2020 remaining heat production has been is covered by a CHP unit and gas boilers, nowadays a 2,5 MW air-source heat pump is supplements the heat production parc.

Typical for Danish district heating facilities, the business model for the project is an ESCO founded as a user-cooperative and run as a non-profit entity. The investment costs of EUR 2.1 million were distributed to 87% on cost for the construction of the solar field and to 17% on the storage tank.

The financing is provided by a *municipal guarantee*, allowing the municipality to support local district heating projects by providing financial backing. The guarantee enables 100% debt financing with favorable loan terms, ensuring cost-effective project implementation. As the installation was carried out under the Energy Saving Obligation Scheme, Ørum Varme was also permitted to collect tariffs of 0.50 DKK (around 0.07€) per kWh for the energy produced by the solar thermal plant, that contributed to reaching the companies saving obligation.

6 Conclusion

In this report, the following policies have been distinguished:

- **Direct policies and instruments** are used to support the deployment of renewable energy heating and cooling fuels, appliances, and products. These are subdivided into **push policies** (for SDC these push policies are applicable: building codes (including district heating), mandates, replacement strategies, blending mandates (a share of renewable heat in a DH network), **pull policies** that are relevant for SDH are regulatory and pricing policies, tradable certificates, instruments for self-consumption and measures to support voluntary programmes, and **fiscal & financial measures** for SDH could be tax incentives, subsidies, grants and loans.
- **Integrating policies** for SDC may be referencing to system flexibility (in combination with thermal storage), increasing the renewable share of district heating networks, and incite sector coupling.
- Next, **enabling policies** relevant for SDC may be policies levelling the playing field, ensuring reliability, targets, affordable financing, training and education, labour policies, innovation, and urban and health policies.
- Finally, a number of policies **both** are **integrating** and **enabling**. Of these mixed policies, SDH may have advantages from streamlined permitting procedures, participative and awareness programmes and integrated resource management.

The report does not pronounce on a best policy, but the cases are meant as inspiration for policy makers all around the world. A few characteristics from the policy examples introduced in this report are listed below.

The Netherlands

Section 4.1 highlights features of the Dutch Sustainable Energy Production and Climate Transition Incentive Scheme (SDE++), which provides subsidies to companies and non-profit organisations that generate renewable energy or reduce CO_2 emissions on a large scale. SDE++ is an example of a direct pull policy, namely a feed-in policy, more precisely a feed-in premium. Features from SDE++ are among others:

Multiple technologies are subsidised under one policy

- The subsidy amount is corrected annually for changes in reference price (natural gas for renewable heat)
- Large systems are targeted, the minimum is 200 m^2 solar thermal collector surface
- Two system sizes are supported: <1MW and >1MW
- For solar district heating the reference heat price is lower than the heat price for end-users, which should be reflected in the feed-in premium

Austria

- Section 4.2 reports on the Austrian Climate and Energy Fund (Klima- und Energiefonds), which provides subsidies for innovative large-scale solar thermal systems with gross collector areas larger than 100 m^2. The support is available for all natural and legal persons engaged in commercial activities and regional authorities in Austria. The fund is an example of a direct pull policy, e.g., an investment grant. Some features of the fund are a dedicated policy for solar thermal systems larger than 100 $m^{2.}$
- An accompanying research programme is in place, having the goal to advise applications before submission for quality assurance, monitoring of plants and the publication of results and knowledge transfer
- Different categories of solar thermal are being addressed: solar process heat, solar thermal on micro-, local- and district heating networks, high solar fraction (over 20% of the total heat requirement), solar thermal energy in combination with heat pumps (incl. PVT collectors), new technologies and innovative approaches, and finally large-scale solar systems from 5,000 m^2.

Germany

Section 4.3 explains German funding programme “Bundesförderung für effiziente Wärmenetze”, (BEW, federal funding for efficient heating networks), which aims at decarbonising heating networks and integrate a high share of renewable energy sources. The programme addresses various aspects in this process: financially supporting the establishment of transformation plans and feasibility studies (enabling policy), subsidising the transformation of existing heating networks and the construction of new heating networks through investment grants and support through a feed-in tariff (both examples of direct push policy. Features from BEW are among others:

- Defining minimum shares of renewable energy in the annual energy production
- Imposing a limit on biomass as an input
- Defining a minimum size of the district heating network
- Defining a maximum temperature level
- Imposing a maximum share of fossil fuels
- Quantitative preliminary investigations and conceptualization of ideas

Spain

Section 4.4 introduces the Spanish TED/707/2022 and TED/641/2023 (RENOCOGEN), which target district heating and cooling networks driven by renewable energies and the replacement of fossil fuels by renewable energy in cogeneration plants in the form of direct pull policies (investment grants).

- Aimed at projects with a minimum defined capacity or investment budget
- Financing through Recovery, Transformation and Resilience Plan for the implementation of the Next Generation EU funds
- Focus on replacing fossil fuel by renewables, building on both existing and new district heating, including grid expansion
- Two separate programmes for applicants executing economic activities (investment grant 35-45% of total costs) and those who do not carry out any economic activities(investment grant 70% of total costs)

Switzerland

In section 4.5 information is given on Switzerland. Highlights based on the Federal Act on Climate Protection Objectives, Innovation, and the Strengthening of Energy Security:

- An investment grant based on nominal thermal power, while for solar district heating the subsidy is a feed-in tariff
- Make system sizes explicit and be clear whether solar district heating is eligible
- Define a maximum share of average annual fossil energy use for peak load coverage
- Clearly state which collectors are eligible by providing a product list
- Require a validated performance guarantee when applying for the subsidy
- Require active monitoring of the plant once it has been built
- Restrictions are applied on applications (excluded are air collectors, solar collectors for swimming pools and hay dryers, and the replacement of existing solar collector installations)
- Pay attention to interaction of support schemes with CO_2-certificates

Denmark

Section 4.6 gives background information on Denmark, leading in solar district heating:

- Replicability: Denmark's solar district heating market has unique conditions that are difficult to replicate, but valuable lessons can still be applied in other countries
- Non-profit: The absence of competition among district heating companies fostered knowledge sharing, enabling long-term, stable, and low-cost heat supply
- Financing & feasibility: Municipal-guaranteed loans ensured low-interest rates for district heating companies, a model that could be adopted in other countries
- Storage: Investments in thermal storage have improved district heating economics, supporting renewable energy integration and increasing system flexibility
- Demonstrators: Early adopter funding and demonstration projects can be an important driver to have a showcase of the technology locally and boost market confidence
- Competing technologies: Solar thermal initially thrived due to subsidies and a lack of alternatives, but heat pumps are now taking a larger market share due to their ability to decarbonise year-round
- Strategic tariff adjustment: Well-communicated transition period allows market actors to adjust, ensuring affordability while shifting from fossil fuels to renewable options like solar thermal or heat pumps

Regarding business models for large solar thermal projects, the organisational structure of several plants is characterised. These cases show that multiple options exist for solar thermal district heating, and that not a single best financial model emerges. It all depends on the circumstances of a project:

• SDH plant in Groningen, Netherlands: a public-private partnership with special a purpose vehicle (SPV)
• CST plant for community heating in Brandenburg, Germany: an energy service model; SPV acting as an ESCO
• CST plant for a large R&D building complex heating in North Rhine-Westphalia, Germany
• SDH plants in Ørum and Aulum, Danmark, are run as non-profit user-cooperatives

7 Outlook

Large solar heating installations can have a significant contribution to renewable heat supply in many countries. This can be in various system layouts:

1. Directly providing heat to an end-user, either a small or big residential or service building, or an industry; Depending on the heat demand profile of a consumer, the average annual contribution to average annual sanitary warm water production may be up to around 50% (depending on climate), resulting in a significant reduction of the carbon footprint.
2. Indirectly providing heat to many end-users through a district heating network. In this way, solar thermal substitutes heat delivered by other heat sources. In this layout solar thermal is generating heat mostly in spring, autumn and summer, up to annual heat shares of around 20%, which can both supply space heating and sanitary warm water, with considerable CO_2-emission reduction.
3. Indirectly providing heat to many end-users through a district heating network in which seasonal heat storage has been integrated, and a heat pump. Unlike option 2 above, the seasonal storage makes it possible to generate heat during the whole year, up to average annual heat shares of around 50%. Both space heating and domestic hot water can be supplied, but at a lower carbon footprint than option 2 above (more emission reduction).

Solar thermal yield depends very much on local weather conditions, and the demand for heating and cooling strongly varies across climate regions. But independent of the local situation, solar thermal heat is usually competing with a conventional heat supply. In layout 1 solar thermal competes with end-user prices, which generally include heat or fuel taxes. Although the avoided fuel expenses may be considerable, the solar systems in this variant are often costly (depending on the system variant), which still makes the business case not always as strong. Although dependent on local climate and the heat demand profile, several years of payback period may result. For this reason, this layout benefits from support policy in multiple countries.

In system layouts 2 and 3 the solar heat costs are much lower, but here the competition is directly on the level of energy and supply costs, so usually without (or with fewer) taxes and levies. The energy substitution rate in these layouts may be significantly higher and the business case may be better, but still support measures may be needed. Perceived from the policy effectiveness perspective, providing (temporary) support for solar thermal district heating may be more attractive than the support for end users (for example in terms of realisation speed or government expenses per avoided CO_2-emission, the policy efficiency).

For improving the competitiveness of solar thermal energy this report has given examples of policy measures, in the flavours as explained before:

- Direct policies and instruments
- Integrating policies
- Enabling policies
- Combined integrating and enabling policies

For future development and stimulation of solar thermal heat it is important to realise that all types of policy measures are relevant to make solar thermal a success. As the 4 solar thermal business cases in Chapter 5 have shown, it is still possible to develop projects and to make projects viable but all lights need to be green, so indirect policies remain of importance, i.e., integrating and enabling policies. Chapter 4 highlights multiple policy schemes, which mainly discuss examples of direct policies and instruments.

Regarding the future development in Europe, it can be observed that the 2030 target from the renewable energy directive III is rapidly approaching, and this target may become one of the driving forces behind solar thermal heat adoption. In addition, new geopolitical circumstances may increase the need for increased energy independence.