PITAGORAS Sustainable urban planning with innovative and low energy thermal and power generation from residual and renewable sources

# D5.8 Non-technological barriers to be considered when planning the implementaiton of a large scale solar thermal plant

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# 1 INTRODUCTION

The European funded FP7 project PITAGORAS was focused on efficient integration of city districts with industrial parks through smart thermal grids. The overall objective of the project was to demonstrate a highly replicable, cost-effective and high energy efficiency large-scale energy generation system that will allow sustainable urban planning of very low energy city districts. Therefore, the concept of the project was planned to be demonstrated at two cities in two different European countries, namely Italy and Austria. However, the planned implementation of a demonstration plant in Austria (focused on the use of solar thermal energy) failed. This deliverable describes the different sites in Austria, which were taken into account and evaluated positive for a possible implementation of a demonstration plant during the PITAGORAS project chronologically and argues the main reasons for failing. Furthermore, the lessons learned from the not realized demo plants in Austria are presented and the latest developments for solar thermal systems in Austria during and because of PITAGORAS are shown. Lastly, the main barriers for a succesful implementation of solar thermal projects are pointed out, suggestions how to overcome these barriers are mentioned and a short conclusion is made.

# 2 DESCRIPTION OF PROPOSED DEMO SITES AND THEIR MAIN REASONS FOR FAILING IMPLEMENTATION

During the application phase and in the beginning of the project, two site locations in the city of Graz were being identified as best for a possible implementation for the Austrian demonstration plant in PITAGORAS. Due to the unique location of Graz in being situated in a basin and being surrounded on three sides by mountains air exchange is hampered, especially in winter and leads to climatic disadvantages such as high rates of pollution and respirable dust. Therefore, district heating is playing a central role for providing the city with warm water and space heating for both, now and in future. Figure 1 shows the map of Graz including the DH grid and its planned extension (in dark red and slight red), its gas supply network (in orange) and the initial proposed potential locations, namely Graz South and Graz Center, for the realization of a demonstration plant.

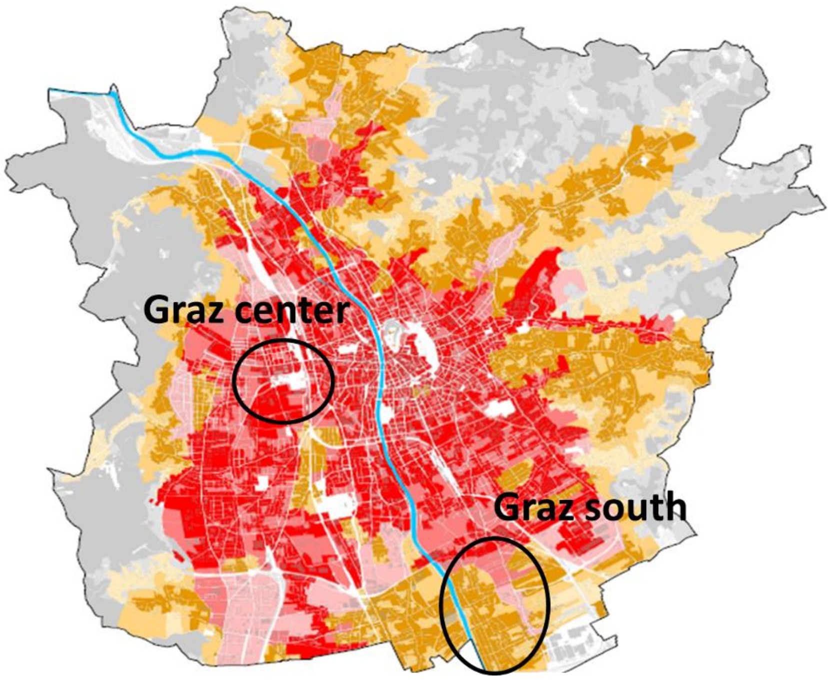


**Figure 1: Potential site locations for realizing a demonstration plant in Graz in PITAGORAS; (Source: GEA 2014).**

## 2.1 PROPOSED DEMONSTRATION PLANT 1: GRAZ SOUTH

The planned site in the south of Graz was especially interesting, since the rate of respirable dust is higher than in other areas mainly due to the fact, that the majority of family houses are still fired by fossil fuels and currently not connected to DH. Therefore, emissions in this area should be reduced by an extension of the DH net. There is already fed waste heat from industry (automotive) and from a nearby CHP into the cities DH network and it was planned to use this source for an intelligent interaction between a Seasonal Thermal Energy Storage (STES) and a large-scale solar system to provide local heat for the planned subnet. However, since the houses are mainly supplied by gas, a new subnet for the local/district heating supply has to be built.

Even though the location in Graz South was very promising, the realization of a demo plant failed for several reasons. First, technical issues occurred since the gas operated area has rather high return flow temperatures, which are challenging for the efficient use of the STES and the solar system. Second, although a positive first calculation of the net operator, who was willing to finance and to operate the new subnet, were promising in terms of economic soundness, the utility was not fully convinced in investing into a new net. It was argued that the erection and investment of/in a new DH grid by the conscription of inhabitants of this city district was too cost intensive. Furthermore, there were uncertainties about the long-term availability of the waste heat coming from the automotive industry. Since the located automotive company has a fluctuating order situation in regard to manufacturing cars, stable waste heat decoupling for the next 15 years could not be guaranteed. This could have resulted into a bottleneck between supply and demand.and ultimately to a lack in supplying the necessary heat to the costumers of the grid. Additionally, due to contractual bindings between the CHP operator and the DH utility a long-lasting communication process between the parties would have been necessary and therfore, there was a high risk in implementing the demo within the given timeframe in PITAGORAS.

## 2.2 PROPOSED DEMONSTRATION PLANT 2: GRAZ CENTER

The second promising location was chosen due to the better implementation preconditions for PITAGORAS. In the center of Graz, a smart city project in the district “Reininghaus” was planned, where a new low temperature DH subnet for the area should be established. Therefore, it seemed reasonable to integrate another smart city project (PITAGORAS) in order for a successful implementation of the demo. Moreover, the time frame of PITAGORAS was completely in line with the one for the district Reininghaus in the concept phase and ultimately matched with the integration of the PITAGORAS concept.

However, during the planning phase for integrating a demo at the district Reininghaus a variety of issues and risks emerged, which hampered the successful implementation of a demo. First, due to ground and soil contamination by World War II bombs, the costs for removal of contaminated waste deposit were being expected to be higher than the storage investment itself. Investment for the construction of an underground storage too expensive, on which a planned children’s playground should have been established in a later phase. Moreover, the utilitiies believed that the construction of a heat storage tank with a capacity between 30,000 and 60,000 m³ is not demand-oriented and may not reflect realistic expectations of the urban development of the district “Reininghaus” compared to the investment costs. In order to guarantee a secure heat supply for the future residents and to balance process-related fluctuations, they were planning to develop some sort of demand-oriented modularly configured buffer storage with a total capacity of 2,000 m³, which is realizable with moderate costs. Furthermore, it gives them the opportunity to increase the capacity of the storage if the demand in future is increasing by modularly interconnecting new storages. Another issue was the complicated ownership structure of the smart city project “Reininghaus” between the different parties, namely the city of Graz, two utilities and several investors. This led to a long-lasting communication process and made it rather difficult for finding aggrements in organizational related topics as for making final decisions about the frame, delivery and tariff contract with the utilities as well as technical related topics such as a possible utilization of available roof areas or DH pipe capacities. All these issues were not possible to overcome within the time frame of PITAGORAS. For a successful implementation of a demo, PITAGORAS was dependent on the progress of the Reininghaus Smart City project. This means, that delays in the Reininghaus project would have led to delays in the implementation of the demo. As we can see now in 2017 the Reininghaus smart city project is still not realized, since over the last 2-3 years several issues occurred, which led to a delay of the project and is still stuck in the planning phase.

## 2.3 PROPOSED DEMONSTRATION PLANT 3: KREMSMÜNSTER

Since no option for Graz fully convinced the utility operator in Graz, another possible location for the implementation of the demo was found at the company Rohoel-Aufsuchungs Aktiengesellschaft (RAG) in Kremsmuenster, Upper Austria. RAG is an oil and gas company, which core business is among the other things, the exploration, development and storage of oil and gas. Through the use of company-owned storage facilities, RAG does not only ensure the supply of petroleum products within Austria, but also plays an important role for the security of supply in Central Europe. Other activities include storing oil, trading and transporting gas, as well as realizing projects in the renewable energy sector.

The planned large scale solar thermal plant should have been realized for the oil and gas company RAG by using a contracting model, where the system would have been operated by an energy service contracting company (ESCo) and its produced heat would then have been sold to RAG by a certain price per MWh (More about ESCos and the development of innovative financing options for large-scale solar thermal systems can be found in D.5.9. "Energy Service Company Portfolio and know-how related to solar thermal plants" [1]. The idea of the planned project within PITAGORAS was to rebuild an empty oil tank at the production facilities of RAG in Kremsmünster in such a way, that it could be used as a seasonal thermal energy storage system. In addition, a large scale solar thermal plant with a thermal capacity of approx. 5 MW should have been integrated, which enables saving up to approx. 1 Mio m³ gas per year. The seasonal storage system would enable an energy efficient operation of the different heat suppliers and heat consumers. The storage tank would provide heat to the oil tanks in the winter time on the one hand, and would enable an optimized load management of the nearby CHP plant on the other hand. More specific technical information and a clear outline of the system concept of the planned demo plant in Kremsmuenster can be found in the report D.2.16. "Publishable report of the two demonstration plants" [2]. Although, the technical concept, land use and land lease and an Energy Performance Contract (EPC) were elaborated in detail, have been evaluated positive and economic sound, and negotiations with the technical head and the management were already well advanced, the implementation of the demo failed. The reasons for failing were mainly due to the worldwide declining development of the oil and gas prices. RAG has been heavily hit by this development and therefore was forced to cut their business tremendously. RAG fully stopped their oil exploration projects and put all the planned projects on hold including PITAGORAS. Even though the company was in favor of realizing the solar project and argued that the project seems, without a doubt, a very appealing and pioneering project, they are not in a position to enter into any long-term contracts. Furthermore, RAG pointed out, that owing to the current market situation a full degree of capacity utilization of all four oil tanks cannot be ensured in future. Since this is the perquisite for buffering the excess solar energy the project is at this time not feasible in RAG's point of view.

## 2.4 SUMMARY FOR FAILING THE IMPLEMENTATION OF A DEMO PLANT IN AUSTRIA

The reasons for not implementing and refusing a demo plant in Graz were mainly due to the economic factors of a high initial investment into the necessary infrastructure and the long-lasting communication process between the involving parties.At the location "Graz South", the utility was not fully convinced to invest into the construction of a new subnet and at the location "Graz Center", the additional costs for excavation of the contaminated waste, land and higher costs for the utilisation of roof areas were the main reasons. Moreover, the time frame in implementing PITAGORAS for the location "Graz Center" was too short, since various issues at the smart city project Reininghaus were not further elaborated and was still stuck in a vague planning process. Due to the even more utilizable potential of process heat by the nearby steel factory, the implementation of a solar thermal system did not have highest priority for the utility. At this point of time they were not fully convinced of the technology.

The implementation of a demo plant in Kremsmuenster failed because of market barriers (i.e. the low prices for fossil fuels) and because of a rather long communication process between the key-decision makers. Although the demo was economic sound with high cost savings for the future use of heat, RAG was not willing to enter into a long-term contract due to the risk of rapid changes in the market economy such as the mentioned drop in oil prices.

# 3 LESSONS LEARNED FROM NOT REALIZED DEMO PLANTS

Although it was not possible to realize a demonstration plant in Austria, the PITAGORAS project had a positive impact and several lessons learned could be drawn for both, the industry as well as the public sector. Especially for industries, it became clear that there is still little awareness on the demand side in regard to energy consumption, the availability of such data and the lack in standardized documents and procedures necessary for the optimal design the solar thermal system within the whole energy system. Therefore, several discussion rounds with the costumer is necessary in order to understand their problems and to find the requirements which have to be met with the system. Furthermore, a clear communication process in such a project is essential on the one hand to clearly demonstrate the decision makers the benefits of the implementation of such a solar thermal system in regard to social, environmental and economic benefits and on the other hand to speed up the process between project proposal, evaluation and decision-making.

Another lesson learned was, that there are still problems in implementing ESCO projects. It takes innovative financing strategies for convincing financial institutions, which are rather time consuming. The implementation of such projects still needs courage. If the municipal administration and the local energy/utility company are not fully convinced because of short-term financial reasons, a clear strategy for their future heat provision including a mid- to long-term implementation plan is necessary in order to lower the dependence on fossils by not increasing energy price for costumers and ultimately to build trust into a successful energy system transformation.

During the PITAGORAS project it became clear that on a technical point of view the storage of heat is profound to a smart, renewable and sustainable heat supply in district heating networks. Especially, the development of large-scale thermal energy storages (TES) are interesting, since it would enable seasonal storage of heat from renewables such as solar thermal energy, flexible heat storage from waste heat sources such as power plants or waste incineration as well as Power-to-Heat. The Austrian Climate and Energy Fund even pointed out in 2016 [3], that storing heat (and electricity) is the key element in reaching a 100% renewable energy provision in future and argued that innovative storage technologies need research and development as well as practical testing for a smooth integration into current heating (and electricity) grids in the future. Therefore, the system concept integration of large-scale solar thermal systems with seasonal heat storages in district heating opened a new market segment.

The discussion of an implementation of PITAGORAS in Graz led to a broader interest in politics and within the local energy suppliers for the use of large solar thermal systems, especially for district heating. In 2015 the local energy supplier Energie Steiermark assigned SOLID to investigate the potential of solar district heating in Graz. The outcome was a techno-economic feasibility study named BIG SOLAR Graz [4], which identified a potential of integrating a centralized solar thermal system with 450,000 m² collector field area, a seasonal pit storage capacity of 1.8 Million m³ and absorption heat pumps with a total capacity of 100 MW covering 20% of the current district heating demand in the city of Graz. In 2017 Energie Steiermark announced that they are willing to realize the project.

The positive evaluation of the techno-economic feasibility study BIG SOLAR Graz and ultimately the current planning phase of implementing this system concept in Graz clearly shows the potential of solar district heating in combination with seasonal heat storages and waste heat integration. The interest in solar district heating is gradually increasing. Currently, the transformation of the BIG SOLAR Graz concept to other cities is discussed and evaluated with several municipalities and energy utilities in Europe. First results show, that such an innovative system concept is applicable to other municipalities and therefore has a high replication factor.

# 4 MAIN BARRIERS FOR IMPLEMENTING LARGE-SCALE SOLAR THERMAL PROJECTS AND SUGGESTIONS FOR OVERCOMING THEM

## 4.1 MAIN BARRIERS FOR IMPLEMENTING LARGE-SCALE SOLAR THERMAL PROJECTS

In principle, solar thermal systems are without a doubt one of the key technologies for a future sustainable heat supply and could substantially contribute to a transformation of the energy/heating system. The potential of implementing solar thermal systems is still growing, challenges of the branches are clearly visible. Despite high potential assessment the market in Austria stagnated and new installations are slightly declining the last years. Reasons for this are on the one hand still the consequences of the Great Depression in 2008 and on the other hand the last developments on the global oil market. The price of crude oil is exposed to a sharp deterioration since 2014. The US oil boom, which mainly arose due to the advanced development in hydraulic fracturing (fracking), led to an oversupply at the global oil market. Furthermore, since OPEC could not agree on an oil-cut, the oil embargo against Iran has been lifted, it even led to a higher oversupply and a significant drop in oil prices (See in Figure 2). As an example, the price of the oil type Brent has fallen down to $30 per barrel in 2016 and stagnates currently at approximately $50 per barrel.

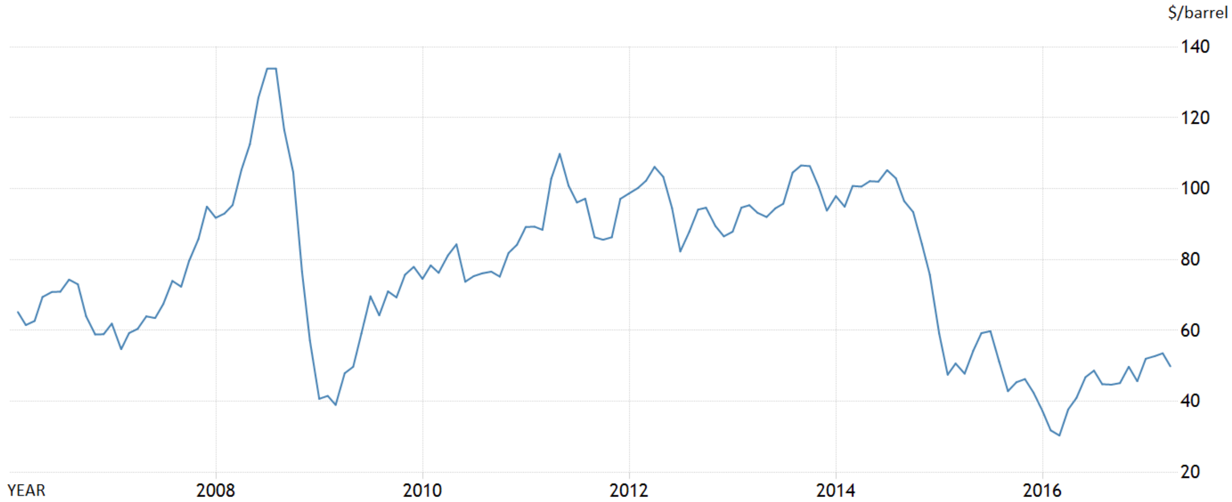


**Figure 2: Development of the global oil price, 2006-2017. (Source: www.tradingeconomics.com)**

Another reason for a stagnating solar thermal market may be the low prices in the photovoltaic sector and its attractive direct funding options and feed-in compensations compared to solar thermal systems. These conditions enabled returns of photovoltaic systems of 6-8 % and in comparison, the solar thermal funding options were less attractive. This trend is still visible, even though the returns of photovoltaic systems dropped significantly due to decreased feed-in tariffs.

Concerning the industry sector, costumers are keen on short return on investment periods of max. five years, which are under current circumstances not applicable. Solar thermal energy is often still not yet cost-competitive with fossil fuels at today's prices. The correct economic way to compare solar heat prices with those from fossil fuels is to calculate these over the lifetime of the solar thermal system. Then, competitiveness is strongly dependent on the assumed growth rate of fossil fuel prices. The price of solar heat will remain stable, since costs come mainly from the initial investment. However, it is highly likely that the price of fossil fuels will continue to rise. Depending on the estimated growth rate of fuel prices, the cost of the heat supplied by solar thermal applications can already be lower than alternatives using fossil fuels. However, this is usually not the type of comparison made by the short-term investor, who normally compares the long-term stable solar thermal heat price with today's fossil fuel price.

The described experiences gathered with the failed Austrian demo projects make it clear the difficulty of implementing district heating projects and in concrete large scale solar thermal systems. In addition to the aforementioned issues, the following points conclude some of the most important barriers identified:

- High initial investment costs not for the system itself but rather for the additional infrastructure necessary and therefore hard to compete with current gas prices. The described failed demo projects are clear examples of this: despite a substantial support grant from the PITAGORAS project, the initial investment to be realized was still considered high by the customer.
- Long-lasting communication process with the customer is necessary:
  - For understanding the needs and requirements to design an optimal system (especially in industry)
  - For clearly show the customer the benefits of such a system in regards to social, environmental and economic benefits
  - For the whole implementation starting from Project proposal to final decision making

  Since a lot of time is used for sensitizing and convincing costumers about the product and its succesful implementation (in regard to technical, environmental and economic soundness) this leads to high costs in regard to project development for the planner and may result into a fail of the project.

## 4.2 SUGGESTION FOR OVERCOMING MAIN BARRIERS

In general, a city administration, the utility or an industry company has to be fully convinced about the positive long-term effects and should not be intimidated by the high initial investment of such a renewable energy project. Unfortunately, the failing of the demos in Austria clearly outlined, that the current economy still values risk of high initial investment higher than the positive long-term effects in regard to the sustainability approach. The decision for such investments have to be evaluated in regard to mid- and long-term economic, social and environmental soundness such as long-term price stability of heat production costs, independency of fossil fuels, growing community acceptance, positive environmental impact, and should not be rejected by short-term capital expenditures and payback periods. Therefore, it is up to politics to implement better strategies and incentive arrangements to overcome this problem in order to push the energy system transformation towards a sustainable direction. Especcially for industries, new instruments and incentives for long-term investment strategies in regard to a more sustainable energy provision are necessary.

Not only to raise more awareness of Smart City projects, but also for ultimately achieving sustainable city planning and development the support, commitment and involvement of all relevant stakeholders in both, public and private, is necessary. Undertaking a detailed analysis of key stakeholders is beneficial to understand stakeholder needs, priorities and interests, and to plan for effective engagement. Therefore, a clear communication strategy and stakeholder participation are key elements in raising awareness. Stakeholder engagement from an early stage can improve the quality, acceptance, and the effectiveness of proposed projects. Furthermore, alternative involvement mechanisms such as open innovation discussions, participatory decision making or stakeholder buy-in help to boost acceptance and secures support for strategies and actions.

Ongoing stakeholder engagement and collaboration is essential to effective planning. Different communication tools and approaches may be relevant to different stakeholder groups, such as:

- Information and Education - Brochures, newsletters and advertisements.
- Information and Feedback - Websites, surveys and questionnaires and public meetings.
- Involvement and Consultation - Workshops, focus groups and open house sessions.
- Extended Involvement - Community advisory committees, and citizens' juries.

Furthermore, a significant increase in public support programmes and budgets for research and development is needed, to stimulate the development of solar thermal technology with higher solar fractions, lower costs, and improved efficiency and reliability. In the long run, the combination of both, increased market stimulation and increased R&D will help solar thermal to become cost-competitive and an attractive heat source in Europe, without subsidies.

## 4.3 BEST PRACTICE EXAMPLE: INDUSTRIAL WASTE HEAT AND SOLAR THERMAL AT THE PREMISES OF A LARGE AUTOMOTIVE COMPANY IN GRAZ (AUSTRIA)

Best practice examples such as large-scale demonstration projects and pilot plants are relevant lighthouse projects and one of the most successful tools to promote innovative, emerging and/or non-conventional technologies. A best practice example project of a large scale solar thermal plant implementation is a project in Graz, that is currently under construction. At the premises of the large automotive company AVL List GmbH in the center of Graz (See Figure 3) the combined integration and management of industrial waste heat and solar thermal is going to be implemented. The combined integration is supposed to supply both, AVLs facilities and the local district heating and cooling network, which is also connected to the district heating network in Graz.


**Figure 3: Integration of industrial waste heat and solar thermal at the premises of AVL List GmbH in the center of Graz.**

Overview of the heat and cooling demand at the local district heating and cooling network:

- 96,000 m² heating and cooling gross area
- 39 buildings
  - 30% offices
  - 18% stock

- 12% buildings for testing stands
- 40% others (social facilities, living areas)

- 5 $MW_{th}$ cooling, installed capacity
- 6 $MW_{th}$ heating, installed capacity

The plant concept is the installation of a 2,400 m² collector field of large-scale solar thermal panels, the installation of a 650 kW absorption chiller and the construction of a 70 m³ storage for supplying the buildings of AVL List GmbH and the local district heating and cooling network. Moreover, the plant has been designed for waste heat integration. Waste heat is generated by the decoupling of 34 engine testing stands at the premises at AVL. An ESCO was chosen as business model, where Solar Nahwaerme is selling the solar heat to a certain heat price to AVL List GmbH.

The project itself is unique including several new innovation aspects. First, district heating and cooling is supported by one solar energy source. The project combines the use of solar thermal for both district heating and cooling. Second, the project fosters a combined integration and management of industrial waste heat and solar thermal. The hot water and cold water in the district heating is used for both, space heating and cooling and industrial processing. In order to extend solar fraction to an efficient maximum of time per day, different orientations of the on-roof collector fields namely south east and south west are being implemented. Figure 4 shows the heating and cooling demand and supply over the year.

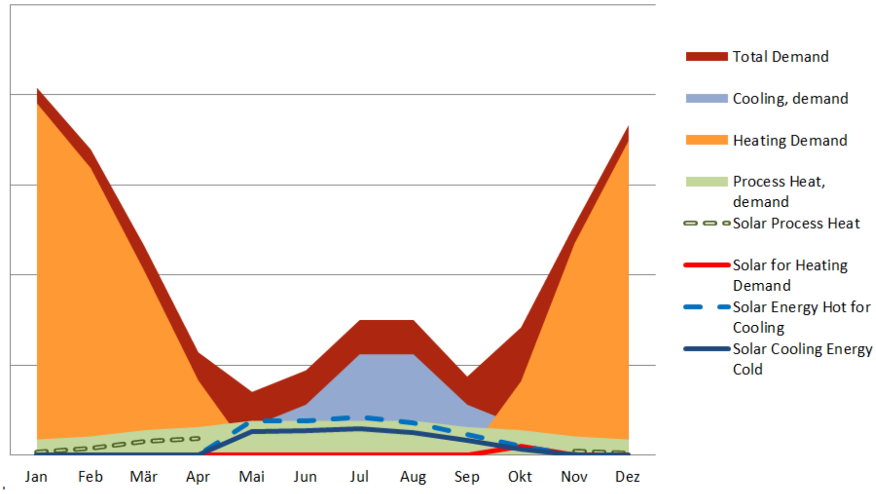


**Figure 4: Heating and cooling demand and supply over the year of the project at AVL List GmbH.**

After a detailed feasibility study the design was finalized by SOLID and a delivery contract between Solar Nahwaerme and AVL List GmbH has been signed. The first collector field with a total gross area of approximately 1,400 m² on the roof of the company's car park and the 70 m³ storage was completed in the beginning of 2017. Currently, the system is in the commissioning phase. The additional 1,000 m² of collector field and the absorption chiller will be installed in the next 6 months.

In conclusion, the main reasons for a successful implementation of the solar thermal system at AVL List GmbH were manifold, namely:

- An innovative system solution for decreasing fossil fuel dependency and carbon emissions
- Strong willingness of the costumer to implement the project and to "go green"
- Good and efficient communication process between the planner and the costumer

– An interesting financing scheme with low risks for the costumer due to the ESCO model which offers long-term price stability by being independent from the development of prices from fossil energy sources

– Moderate investment costs by attractive financial grants and subventions from the municipality and regional institutions in order to offer an ESCO model

## 4.4 SUCCESSFUL SOLAR THERMAL MARKET IN DENMARK

Denmark already demonstrates economic competitiveness of solar thermal energy compared to conventional energy generation systems. Denmark is a pioneer in solar district heating with a high share of solar heat. Figure 5illustrates the development of solar thermal system for district heating in Denmark over the last years in total installed collector field area and number of systems. In 2016 more than 105 solar thermal systems with a total collector field area of roughly 1.3 million m² have already been installed.

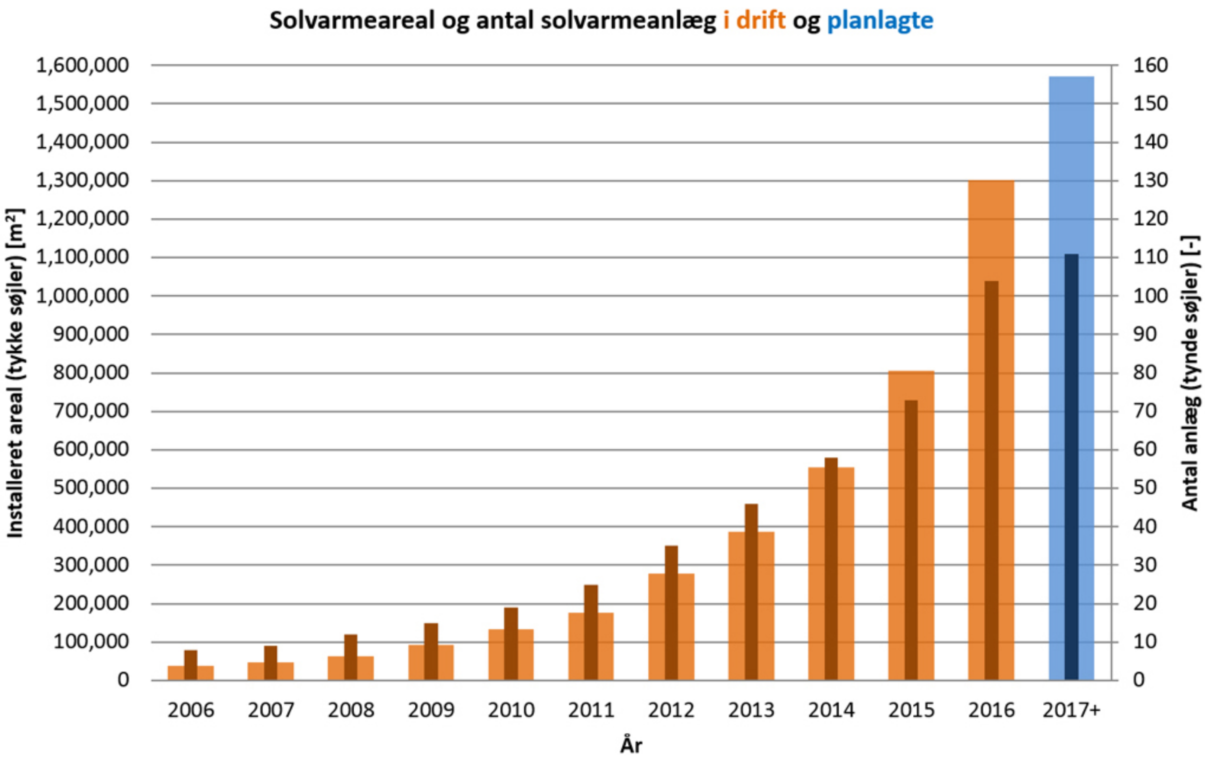


**Figure 5. Development of solar thermal installations in terms of installed collector field area (left) and numbers of systems (right), orange are the already installed systems and blue the planned installation for 2017; (Source: Per Alex Sörensen, PlanEnergi)**

Several municipalities cover up to 50% of the annual heat demand by large-scale solar systems in combination with large-scale thermal energy storages such as tank or pit storages and were able to successfully reduce the annual operating and heating costs. However, there are applying other boundary conditions in Denmark compared to municipalities in Central and Europe. For example, gas prices are rather high due to energy taxes on fossil fuels. Furthermore, cooperative energy utility supplier get inexpensive and long-term financing options with municipal liabilities, but also lower investment subsidies.

Main drivers in Denmark are beside sustainable development for transforming the energy policy, stronger political willingness and energy-economical boundary conditions. Implementing large-scale solar systems into district heating became a valid option in Denmark for decarbonizing current heat generation. However, solar district heatig becomes interesting for whole Europe. Especially, the combined use of large-scale thermal energy storages (TES) is profound to a smart, renewable and sustainable heat supply in district heating networks. TES enable a seasonal storage of heat from renewables such as solar thermal energy, but also flexible heat storage from waste heat sources such as power plants or waste incineration as well as Power-to-Heat.

# 5 CONCLUSION

Even though it was not possible to implement a demonstration plant in Austria within the PITAGORAS project, the project itself had several positive impacts as mentioned above and was still a success in regard to further increase the public interest for solar thermal applications. It became clear that the hardest barriers are economic driven. However, also that there is a lack in clear communication strategy between the involved parties, which results in rather long lead times

However, the focus in the solar thermal branches also lies in the realization of new innovative concepts for thermo-technical application cases. One example is for district heating. The heat demand coverage by on-grid heat supply plays a pivotal role for improving energy efficiency in the heating sector as well as the provision of system flexibility. Large-scale solar thermal systems, especially in combination with seasonal heat storages, can provide a substantial part for the base load of a district heating net. Denmark, as an example, already demonstrates economic competitiveness compared to conventional energy generation systems.

To conclude, the presented examples show that the integration of large-scale solar thermal systems for both city districts as well as for district heating is without a doubt technical feasible. However, in regard to commercialization the technology is under current boundary conditions (e.g. gas price) too expensive. Especcially, industries are looking on short return on investment periods of max. five years are under current circumstances not able to fulfill. Large-scale solar thermal systems do have large initial investments, but their operational costs are negligible, which leads to long-term price stability for heat, that are independent from the development of prices from fossil energy sources.

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