Task 55 Towards the Integration of Large
SHC Systems into DHC Networks

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

D-D1. Business Models of Solar Thermal and Hybrid Technologies

IEA SHC FACT SHEET T55.D.D.1.1.

Subject:	Business Models of Solar Thermal and Hybrid Technologies
Description:	"Investigation of the introduction of large scale solar thermal systems into district heating networks- Business Model BigSolarX"
Date:	11 February 2019
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Download possible at:	http://task55.iea-shc.org/fact-sheets

Introduction

District Heating required annually 600 TWh in the European Union and represents more than 10% of the EUs heat demand. Fossil fuels are the major source for heat production. Approximately 5000 district heating grids in the EU are operated by burning fossil fuels valued at € 18 billion (600 TWh) and emitting more than 150 million tons of CO2 emissions every year. Renewable energy sources are limited by different aspects. For example, Heat Pumps require significant amounts of green electricity that is which leads to electrical bottlenecks in winter, geothermal heat is obtainable only locally and biomass is just limited disposable for covering the demand of big cities besides all other usage.

At the same time, a strong awareness has emerged in the EU that a large part of the energy transition must also be a transformation towards a low-carbon heating and cooling sector. Heating and cooling are responsible for 50% of EU energy consumption.

Solar thermal has been used already to cover the summer loads but usually under 10% of annual energy demand. For solar district heating on a large scale, solar heat is limited by thermal collectors at temperatures up to 95°C, and partly used directly into the district heating network, partly stored from summer time until autumn and winter. During the summer time the heat energy will be charged and discharged into and out of the storage. If the temperature level of the storage is lower than the desired grid temperature, the temperature will be lifted up by the mean of a thermal driven heat pump before feed into the district heating grid.

Political support measures like promotion of lighthouse projects of big solar thermals plants feed in into district heating grids will help tremendous the awareness as well the technical and economic feasibility of such innovative system. This political commitment of the sleeping giant solar thermal technology would speed up the market roll out of "Big Solar X" projects. By realization of more and more solar district heating projects which demonstrate the easy technical integration into district heating grids and smooth operation the more such systems are accepted and becomes a standard technology. The interest and the attraction of district heating operating companies for solar thermal system which increasing solar thermal capacities growing rapidly like the German Market demonstrates. A few years before the demand of solar thermal district heating systems was poor. In the present more and more public tendering requested for more and larger systems. In the recent years the system in Senfentberg with 8,300 m^2 was the largest system.

Nowadays the largest system in Bernburg (Saxony-Anhalt) is in realization with 14,800 m^2. Even the market development of solar thermal projects in Germany becomes a growing market, it is not a sure-fire success. This example of a growing market request requires a stable political funding strategy to achieve the next level for really huge solar thermal system without Denmark. Some of the solar pioneers had the vision of Big Solar X projects many years ago as just few market participants believe in the realization and feasibility of this environmentally friendly and carbon dioxide free technology. To realize this vision more efforts of political stake holders are needed to prevent dying of all the efforts of the solar pioneers. Beneath the environmental aspects Big Solar X becomes more and more an economical benefit especially for countries with an immense amount of fossil energy imports. Large quantity of imported fossil energy strain more and more the national budget and the cost for heating energy for the end-user. The vision of Big Solar X will relieve the environment, reduce the import dependency of fossil fuels and guarantee stable prices for heat energy in the future.

BIG SOLARX could cover 20% to 70% of the heat demand for each DH system.

Considering a constant heat energy demand of 600 TWh of European district heating plants and a solar fraction of 30% will lead to a solar thermal substation energy of annually 180 TWh. This would trigger an investment of 75 Billion EUR which correspond with an installed solar thermal collector surface of 300 Mio. m^2.

In comparison EU-wide today approximately. 50 Mio m^2 of solar collectors are in operation.

A recent potential study developed jointly with a representative of the Austrian DH association, resulted in a solar thermal potential of 12 TWh for Austria.

Sustainable and resilient heating system are expected to be beneficial on several levels:

1. Society, countries, cities, municipalities:
    a. Decarbonization (heating sector is specifically important)
    b. Clean air (air quality is crucial for the quality of life in a city)
    c. Resilience (reliance on renewable energy sources (RES) instead of unsustainable fossil fuels from uncertain world markets)
2. Energy service utility and the heat consumer:
    a. Stable prices independent of fluctuations on stock exchanges or wholesale markets (electricity, oil)
    b. Financial discharge of national budgets, because of avoided cost for energy import cost for fossil fuels. More flexibility for social expenditures and social projects
    c. Predictability of long-range energy cost for national budgets and customers
    d. Reliable heat supply

D-D1. Business Models of Solar Thermal and Hybrid Technologies

District heating in Europe and worldwide is currently mainly supplied by combined heat and power from fossil fuels. The use of solar heat to cover the summer demand in rural district heating networks has been applied for over 20 years. Since 2002, solar thermal system efficiency has increased by more than 50%.

Solar district heating (SDH) in EU-28 produces 1 TWh in 2018, corresponding to 0.4% of the supplied district heat. Many municipal utilities have set themselves the goal of completely decarbonizing their district heating supply by 2050. The utilization of thermal solar energy can make a significant contribution here. Solar heat is a regional and sustainable heat source, which is characterized by a particularly high amount of usable energy per square metre, compared to other renewable heat sources.

According to EU's Heating and Cooling Strategy the sector of heating and cooling will have the biggest energy demand by 2050. The current reliance on fossil-fuels is unsustainable. DH will have a vital role to play in enabling integration and supply of green heat. DH will have a bright future in the European energy transition – if and only if networks become greener and more efficient. Solar thermal can play a vital role to realize a green energy transition.

From an economic perspective, urban district heating in western Europe relied heavily on fossil-fuelled combined heat and power (CHP) plants. These plants produced both, electricity and heat. With high electricity prices, heat sales were a profitable extra business. However, in recent years, electricity prices in Europe decrease, mainly due to the increasing share of renewable electricity. Thus, the CHP plants became more and more unprofitable and shut down in times of low electricity selling prices. The heating plants need other sources for heat generation, such as solar thermal. As well, some central and eastern European countries suffer rather high natural gas costs and search for cost reliable and safe alternatives.

Another core requirement is the decarbonisation due to global warming and air pollution. Current heat production strongly relies on fossil fuels. The cost of CO2-emission rights increased already and is expected to continue its course. This offers a great potential for emission-free technologies, such as solar thermal.

The Levelized Cost of Heat (LCoH) of solar heating systems reached a range of the average cost of gas in Europe, with the best performing being clearly below. Solar heating systems have the potential to significantly reduce costs (installation and LCoH) particularly if the system sizes increase.

Approach for small communities

Several large scale solar thermal installations already highlight the potential of larger systems. Marstal and Dronninglund both in Denmark have approximately 40% solar fraction, Vojens a little less than 50% and Gram 60%. The plant in Vojens is powered with 70,000 m² of solar collectors and a pit storage of 200,000 m³. Marstal and Dronninglund connected 1,400 end customers, Vojens 2,000 and Gram 1,200.
However, small communities such as these ones above, only represent a small part of the population in Europe - most people live in large cities, and number of inhabitants increasing on and on. From a technical point of view, it is much more difficult to bring solar energy into the district heating of large cities than to feed it into a small grid. One of the most important reasons are the typically higher network temperatures in larger networks.

D-D1. Business Models of Solar Thermal and Hybrid Technologies

Going BIG: Big cities, Big district heating systems, Big SolarX systems and high solar fractions

Today, SDH systems are designed to cover the summer heat demand. This was essential to learn about interfaces from solar thermal and district heating systems for both parties the solar and district heating companies. However, the real challenge for district heating is to cover the winter loads. For summer operation, quite often solar is in strong competition with e.g. industrial waste heat or other low-cost heat sources, if available in near to the DH grid

Big SolarX Concept: System Innovation for a Paradigm shift in the solar market through flexibility in size and application

Several efforts globally are set out to develop solar thermal large scale systems which can be connected to already existing or even newly built district heating networks. One of the most promising projects was under investigation in Graz, Styria. The city has 250,000 inhabitants and an ever-increasing district heating network. Together with local energy suppliers and international experts, a system design was developed as illustrated in **Fehler! Verweisquelle konnte nicht gefunden werden.**. Solar heat is usually limited to 95 °C with flat plate non-concentrating solar thermal collectors. Evacuated tube collectors deliver driving energy at a temperature level which can achieve up to 110 °C. Higher temperatures can economically gained with concentrating solar collectors. For economically aspects sometimes non concentrating solar collectors will be connected in serial, to achieve higher output temperatures at the end of the concentrating solar collectors. The solar heat energy will partly feed in directly in the district heating network, partly stored for usage in times with lower solar energy irradiation, mainly in autumn or winter. In some cases, the storage temperature will be lifted up by the mean of heat pumps to the desired temperature level. Specific synergetic combinations of these system configurations guarantee flexibility in application and the possibility to integrate high solar shares into an existing system. Furthermore, the thermal heat pump allows higher temperature differences into storage for higher specific thermal content. This reduces the required volume of the storage.

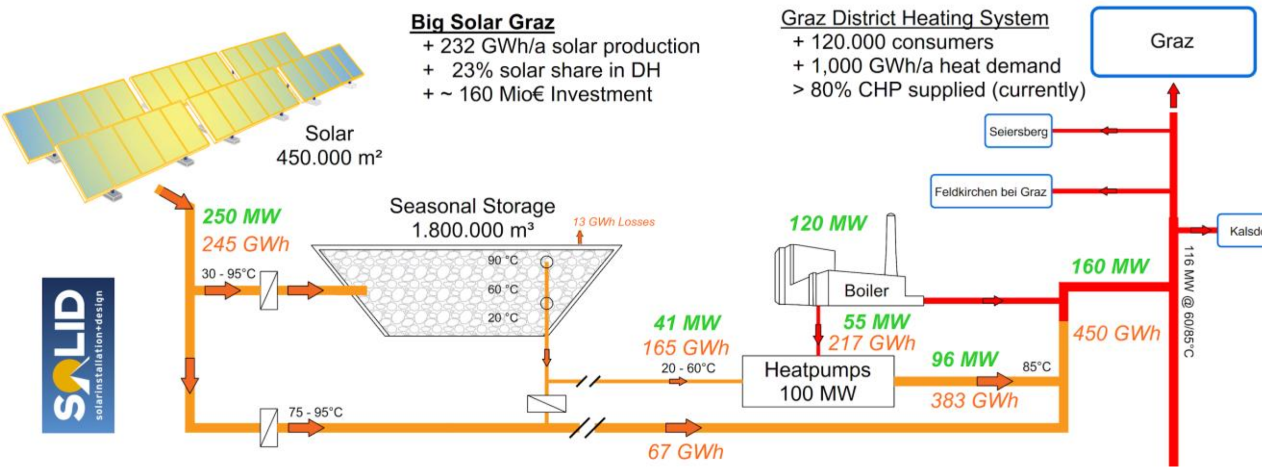

Figure 1 : Big SolarXConcept schematic.

Based on above numbers, the regional supplier signed a contract to develop the project "Big Solar Graz" within the next years.

The developed system solution provides several benefits:

1. High solar shares in a system with high district heating grid temperatures
2. Storage opportunities for winter times
3. Significant cost reduction with a smaller storage volume and reduced space requirement due to optimized system design and optimization of components
4. Main heat source is direct solar heat energy as a true renewable source
5. Independency on the highly volatile electricity market
6. The existing systems can be used in combination with a flexible boiler station
7. Opportunities to integrate further more alternative energy sources, e.g. waste heat, P2H

Graz should be mentioned as an example for achievable high solar fractions. Without the Big Solar System, a maximum of around 5% solar share would be achievable. The feasibility carried out shows a technically reachable portion of up to of 30% and an economic optimum at around 23%. With future optimizations in the district heating system, the solar share can also be increased up to 60%.[1] The business case in the feasibility is that a new established company will sell the produced solar heat of the system including an annual real price increase of 1.5 % to the city's local energy provider.

However, increasing solar fractions in district heating systems requires considerable technological development and also management capabilities.

Challenges of and Solutions for SDH Business Models

There are several key challenges which restrict the introduction of "Big SolarX" concepts to a broad and global market.

Societal and regulatory challenges:

- Lack of awareness of solar heat generation among heat suppliers and stakeholders
- National approval procedures are not yet developed as solar projects of this size are not known
- Needs of procurement procedures don't match structure of highly innovative projects

Technological challenges:

- A great variety of different technological competencies and building trades must be joined together
- Seasonal storages are characterized by considerable dimensions which need to be established individually for each location

[1] Feasibility Study Big SolarXGraz, SOLID, EStmk, Energy Agency Graz, Planenergi, 2015; Solar Energy in Urban District Heating, Masterthesis Hannes Poier, 2017

- The system design and operation strategy are essential and complex - it must comply with the framework conditions of the existing system and be developed individually for each project
- Land availability is usually a major issue and may cause system adaptations e.g. long transport pipelines and additional smaller buffer tanks

Business and organizational challenges:

- Project development is still extremely complex both time-consuming and expensive
- Investment volumes are huge, high level due diligences are needed
- A lot of stakeholders need to be involved
- Partnerships with energy suppliers and financiers must be established
- A suitable, individual business model needs to be developed for each project, including major steps such as:
  - Financing structures with several partners
  - Construction partnerships
  - Risk sharing model
  - Establishment of an operating company
  - Energy service contracting models (ESCo) to be agreed on

Entering the market

DH energy suppliers and energy service utilities responsible for DH are the main target group for BIG SOLAR X-concepts. However, since DH companies very often are fully or partly public owned, municipal representatives can also be defined as target group.

Operational costs of the systems tend to be little exposed to fluctuations in variable costs since the energy input used is the sun, free and abundantly available in nature. Therefore, prices are projectable over their operating lifetime of at least 25 years guaranteeing long-term price stability and security of supply.

Adding the business model of Energy Service Companies, the risk of large capital outlay and security of operation is shifted from the DH company to a third party. A new established ESCo is responsible for providing heat to the customer and is constituted by multiple stakeholders, which are already part in project development and construction of the system, assuring profound knowledge in implementation.

Municipal residents are also an important target group. Based on a new EU Renewable Energy Directive, users get access to transparent information on energy sources of DH supplier which somebody purchase energy from. Everyone can entitle them to disconnect if they can produce more RES heat at their individual level.

The attractiveness of a market can be rated based on five factors:

- Heating demand sufficient to use DH
- Solar energy fraction
- Moderate or high energy prices

- Stable DH networks available in the region
- Region eligible for project financing from international donors

Solar heating can compete in the energy market with different renewable energy sources (RES) and fossil fuel options, as negative externalities associated with the use of fossil fuels. In terms of emissions of CO_2 or other harmful gases, not properly determine in their tariffs.

The competitiveness of solar heating in general depends on several technical and financial factors. For instance, the location affects the available solar radiation but also the thermal conditions, in particular the heat demand and potential thermal losses. Furthermore, the type and size of system are important factors, as it can affect the investment costs, or the proportion of usable solar heat provided by the system. BIG SOLAR's levelized cost of heat (30-40 €/MWh) is competitive to those of fossil-based heat generation (natural gas 30-38 €/MWh), but also to renewables such as biomass (30-45 €/MWh).

Currently, biomass is the main competitor in renewable heat generation for district heating. However, it is expected that biomass will be used in the middle and long term perspective for high temperature applications in industry and power generation and also in transport. If biomass will be used for district heating, it is expected mainly applicated for peak load usage.

BIG SOLARX has the potential to significantly reduce its levelized cost of heat by just lowering its investment costs since a large proportion are capital costs. Whereas operating costs are negligible since its fuel the sun is determined as a free good that is abundantly available in nature. This leads to long-term calculable, planning, reliability and stability of heat generation costs, which can have a positive effect on end customer heat prices in the long term. Ultimately, economy of scale by increasing the size of the system in the short term and the optimization of the system design processes and of the manufacturing and assembly processes in the long term offer great potential for SDH in the future.

Both local ground water conditions and geotechnical investigations are important to carry out investigations before and during the implementation of a pit heat storage. The examination is necessary to predict the qualification of a given area to predict the feasible steepness of the storage angle as well as for the excavation work.

Business model

Figure 1presents the project life cycle of BIG SOLAR-concepts. Project development is subdivided in concept, design and development, depending on its level of detail.

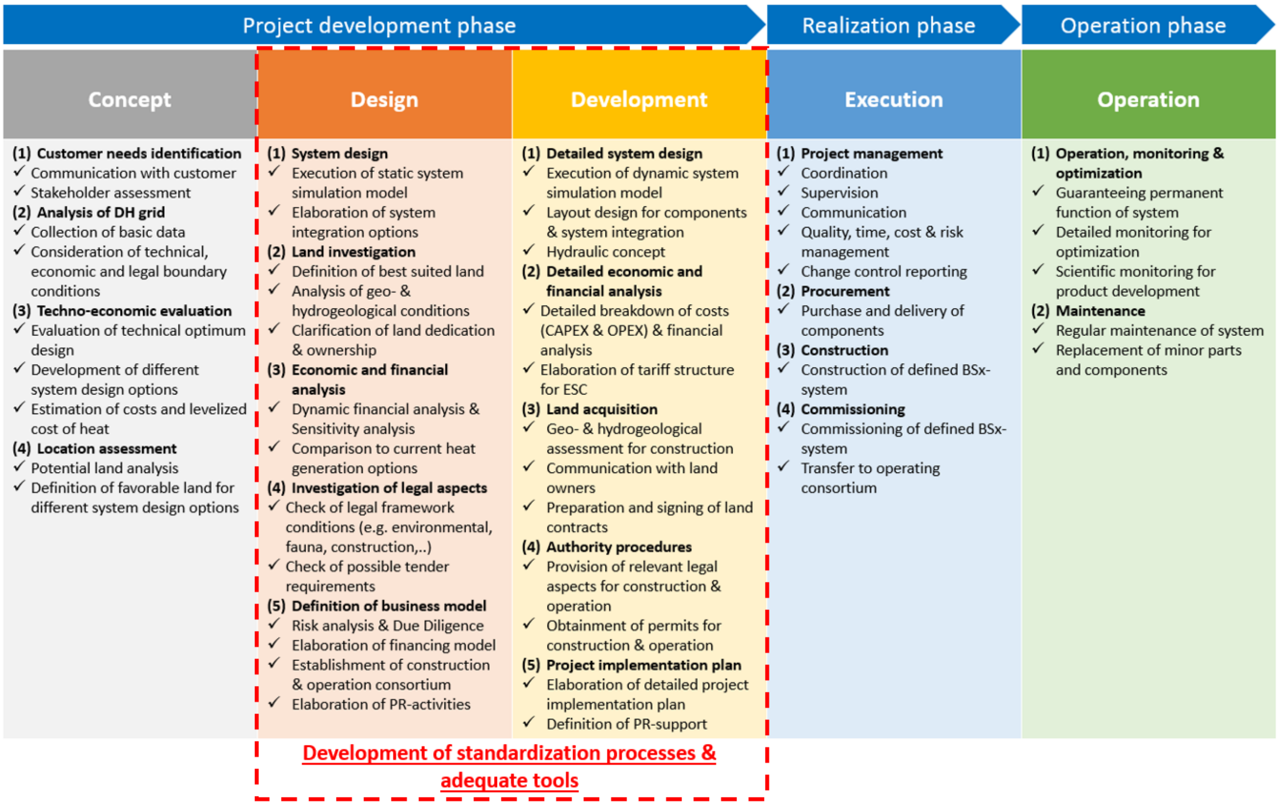

Figure 1**:** BIG SOLARX project life cycle.

Central steps within the BIG SOLARX project lifecycle:

- Concept, Design and Development: Leading developer in project development phase => Partnering with other consultants => Generating revenues by engineering & success fees
- Execution: Collaboration with other companies and overall project manager in realization of BIG SOLAR-concepts => Due to high complexity and large construction costs establishing of project related consortiums is necessary in order to ensure high quality of works carried out and trouble-free implementation => Generating revenues by realization of BIG SOLAR-concepts proportionally to CAPEX for project development, commissions for project management and advanced knowledge among other competitors
- Operation: Taking operational responsibility due to profound experience in operation of solar thermal systems => Being part of the new established BIG SOLARX operation companies, which supplies heat via an energy supply contract (ESC) to the customer (DH operator) => Generating

revenues by services for operating and optimizing the plant, participating on profits of the ESCo, expand their professional knowledge and experience in operation of BIG SOLARX systems

Stage contracts

To apply so-called stage contracts gradually inspire customer's loyalty to the project, depending on its stage in development. The further a project is developed, the stronger is its contractual agreement and thus the commitment of the DH operator in realizing the project. This increases financing interest by investors, lowers potential risk of large upfront capital outlay and ultimately ensures customer retention, when certain milestones are fulfilled. Figure 2shows how the process of these stage contracts could look like. A Letter of Interest (LOI) could be signed after the concept stage, a binding Memorandum of Understanding (MoU) after the design stage is finished and ultimately the Energy Supply Contract (ESC) for heat delivery, when the development stage is concluded with the respect all customer requirements are met.

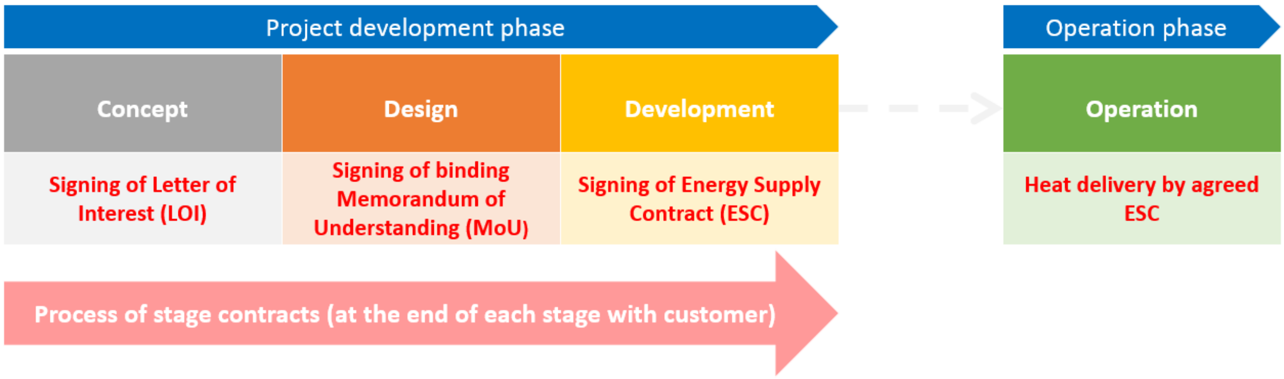

Figure 2: Possible processes for stage contract development of BIG SOLAR X.

Until today costs for developing BIG SOLARX-concepts exceed its revenues mainly due to the aforementioned factors leading to long implementation periods and higher potential risks. Whereby revenues will be generated at later stages of the projects when an ESC contract is signed. Ultimately, a better processing effect could be generated resulting in greater revenues by successful progress over time.

6. IPR and legal Framework

Knowledge protection is guaranteed by confidentiality contracts and non-disclosure agreements. The key knowledge (e.g. optimization strategies, operational software) is either widely generated independently or together with partners:

- Design and installation of solar thermal systems
- Specification, selection and operation of absorption heat pumps
- Solutions for seasonal storages

- Appropriate financing models
- Remote monitoring and performance optimization tools

7. Freedom to Operate

Legal and regulatory requirements faced throughout the project are:

- Differing national tender criterions in the respective countries
- Differing national approval procedures
- Differing standards and directives need to be applied

8. Risk management

Following BIG SOLARX risks are distinguished between market aspects, project management, business management process, architectural design, process and requirement process, generalization and way of learnings.

Risk description	Risk mitigation	Risk likelihood
Market aspects		
Reduction of competing energy prices make Big SolarX less attractive	Further improvement of technologies cost/performance ratio	low
No project financing available for investment	Building strong links to right type of financiers and further improvement of technologies cost/performance ratio	medium
District heating loses business through decreased heat demand/density and climate effects	Downsizing of overall potential for Big SolarX Concepts	medium
Insufficient funds available for project development	In early phase reaching out for grants and customers contribution. Increasing efficiency in related processes to cut down costs.	high
no land available	very good stakeholder process, flexibility in choosing appropriate locations	medium
Requirement process		

low awareness and insufficient response	intensive and structured stakeholder process, communication	medium
wrong assessment or lacking prioritisation of decision makers	stakeholder mapping, excellent local/worldwide network	high
Business management process		
contract /contract engineering	competence and resources within the company and within the network	medium
business model development	competence and resources within the company	medium
finance engineering	worldwide and long experience	low
Engineering and Design Process		
developments are lost in details	applied development method (V-model, see WP3) supports a process from conceptional phase to detailed phase	low
insufficient information on technology	tight ongoing collaboration with experts	low
mismatch of stakeholders' requirements and proposed solution	very tight stakeholder support process - bring customer in the centre of focus	medium
Generalisation and Formalisation of learnings		
results do not match with requirements	requirements and risk consideration, verify and validate management roadmap	high

9. Final Notes

Big SolarX allows the application of solar thermal heat in district heating including seasonal storage with competitive energy prices. Today, the world's biggest solar thermal heating system in Graz is promising on the way and has successfully passed key milestones as contractual agreements with the utility. A new consortium has to be established for implementation, pre-approval from local authorities for construction and securing the required land area.

The project already has gained a lot of interest during its development process on an international level. District Heating Associations, Utilities, Governments, Companies and as well by international banks and funds have followed the ongoing process. Presently the project has stagnated because of a withdrawal of one project partner. A new consortium and implementation team have to be developed to realize this project.

It is now time to use knowledge and opportunities to bring Big SolarX systems into the market.