MSc Program
Renewable Energy in Central and Eastern Europe

Development of Contracting Business Model for heat provision for public office space using solar thermal energy and thermo-chemical storage

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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21.11.2016, Vienna

Affidavit

I, Martin Wilk, hereby declare

1. that I am the sole author of the present Master Thesis, "Development of Contracting Business Model for heat provision for public office space using solar thermal energy and thermo-chemical storage",

102 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and

2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Date Signature

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Finally, I thank my wonderful wife Mag. Jennifer Wilk-Hacker and my two fantastic boys Leon and Constantin for the time they granted me, their patience and support throughout my studies and while writing my master thesis. This accomplishment would not have been possible without them. Thank you.

Martin Wilk

Abstract

Thermo-chemical Storages, now in R&D phase, are seen as promising solution to boost renewable energy in space heating, especially solar thermal heating. The main question of the thesis was if a business model for energy contracting for heat supply can be developed, that will address especially the risks coming from the new technology of TCS and the initial investment requirements for the TCS System.

A Business Model Canvas was developed based on the customer segment of public office space. The economic validation was done by assessing a target price for the TCS system in a case study for a primary school.

The Contracting Business Model with guaranteed results and costs for the customer would allow to introduce this new technology to the market. The set-up of the Energy Service Company, e.g. due to size or partnering will have to create sufficient customers trust, so that they will accept the installation of a heating system based on a fully new technology. From economic point of view Total Cost of Ownership/Life Cycle Cost have to be assessed to allow for relevant investment in the storage system.

Public sector, driven by global and European treaties, adapts more and more sustainable approaches for new buildings and building stock. Contracting Business Models, reducing the initial investment needs for the customer, are a feasible instrument to introduce solar thermal energy in combination with TCS as 100% renewable and emission free heating system to the public building market.

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1 INTRODUCTION

Given the significant energy demand for space heating and hot water supply different global initiatives drive the development of thermo-chemical storages, e.g. EU funded projects COMTES or MERITS. These thermo-chemical storages (TCS) shall also enable the use of solar thermal energy for year-long space heating and hot water supply. Initial prototypes have been developed and are in evaluation.

Contracting business models become more popular especially for public and commercial energy consumers to optimize their spending on energy (electricity, heat, cooling,...). One of the main goals is to reduce CAPEX for investments in systems and equipment, like solar systems, boilers, etc.

In the thesis a business model for an Energy Service Company (ESCo) will be defined to offer heating services to public sector. The different dimensions of the business model will be analysed based on the methodology of the "Business Model Canvas" by Osterwalder & Pigneur.

Key research topics of this thesis:

- Elaborate a Contracting business for model heat supply for public buildings using solar thermal systems and TCS based on the Methodology of the "Business Model Canvas" by Osterwalder & Pigneur.
- Energy Services Companies (ESCos) typically employ proven technologies to reduce their risks. How to deal with these additional technology risks from the new technology TCS in the ESCo model?
- Economic evaluation of the technical solution: Evaluate and compare the Total Cost of Ownership (TCO) for the different systems – from customer point of view and from ESCo point of view.
- Is solar thermal and TCS competitive to alternative renewable heating systems? Given that TCS is only in R&D phase what would be a target price for TCS to be competitive?

2 Methodical Approach

In order to define the basic parameters for the Business Model a short overview of the key technologies applied (Solar Thermal Energy and Thermal Storages) and of the concept of "contracting" will be given. This overview is based on literature and internet research.

For the development of the business model the concept and tool of the "Business Model Canvas" by Osterwalder and Pigneur (Osterwalder & Pigneur, 2010) and the "Value Proposition Canvas" (Osterwalder & et al, 2014) was applied. An overview of the "Business Model Canvas" and the "Value Proposition Canvas" is given below – see 2.1.

The economic evaluation of the primary product of the Business Model, heat as a service based on a solar thermal system and TCS, was done in a case study. A fictional primary school was selected for the case study. Given the fact that TCS are still in R&D phase and only first prototypes have been build, a competitive target price for the thermochemical system was calculated. The target price calculation is based on the comparison of TCO to alternative heating systems based on renewable energy – biomass and heat pump. Sensitivity analysis was conducted to consider different future market prices of the different heating systems.

2.1 "Business Model Canvas" and "Value Proposition Canvas"

2.1.1 Description of methodology

The "Business Model Canvas" by Osterwalder and Pigneur (Osterwalder & Pigneur, Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers, 2010) is a concept and a tool to define and describe business models and to foster discussion based on a common understanding. In "Value Proposition Design - How to create products and services customers want" as a second tool the "Value Proposition Canvas" was introduced (Osterwalder & et al, 2014)

"A business model describes the rationale of how an organization creates, delivers and captures value". In order to describe business models, nine building blocks are being defined: Customer Segments, Value Propositions, Channels, Customer

Relationships, Revenue Streams, Key Resources, Key Activities, Key Partnerships and Cost Structure. These nine building blocks are displayed on the "Business Model Canvas" in order to visualize the full model and the relationship in between the building blocks – see Figure 1.

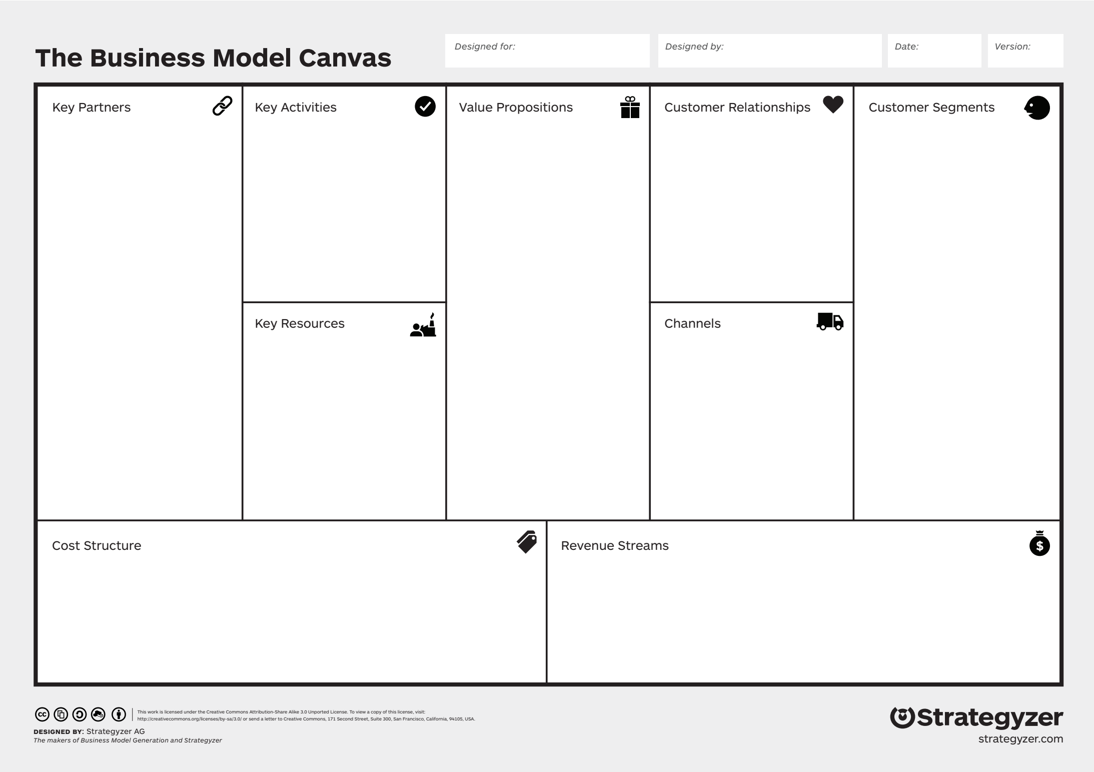


Figure 1. The Business Model Canvas – source: http://businessmodelgeneration.com

To structure and detail the key building blocks of customer segments and value proposition a separate Canvas was developed – "Value Proposition Canvas" – see Figure 2

Working on the canvas (large print outs) using "post-its", key words, graphs, sketches, drawings etc. will foster the creative process, will allow to visualize the business model, to easily adapt the business model, to easily define different scenarios etc.

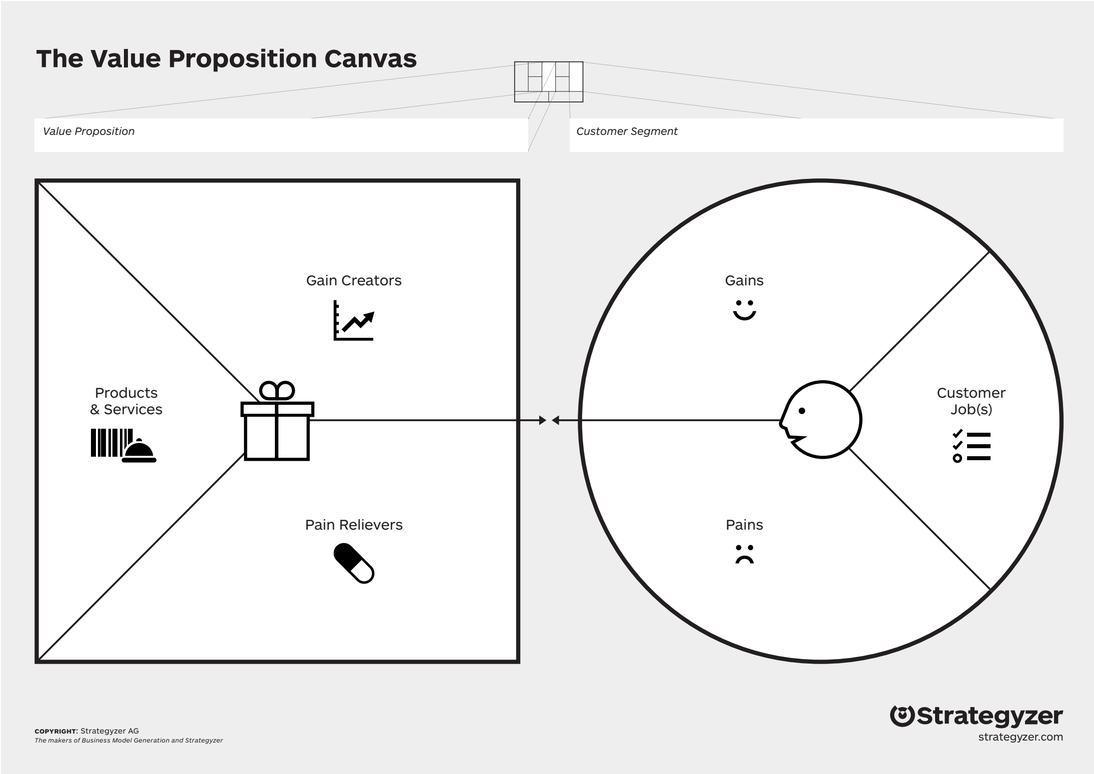


Figure 2. The Value Proposition Canvas – source:
http://businessmodelgeneration.com

2.1.2 Building blocks of the business model canvas

2.1.2.1 Customer Profile

The customer profile is defined by the customer jobs, pains and gains. In order to fully define the "customer profile" for a company it is necessary to analyse the different customers in the company, e.g. users and buyers. When investigating the jobs, pains and gains it important to anticipate the customers' point of view.

"Jobs" are things customers are trying to get done in their work or in their life. Customer jobs can be functional, like performing a task, can be social, like gain power or status or can be personal or emotional, like a specific emotional state or achieving the feeling of job security.

"Pains describe anything that annoys your customers before, during, and after trying to get a job done or simply prevents them from getting a job done." Pains can be broken down in "Undesired outcomes, problems, and characteristics", in "Obstacles" and in "Risks (undesired potential outcomes)". Pains are also mistakes the customer makes, e.g. in using a solution in the wrong way.

Gains on the other hand describe outcomes and benefits customers seek. Gains can be required, expected, desired and unexpected.

2.1.2.2 Value Proposition

“The Value Proposition Building Block describes the bundle of products and services that create value for a specific Customer Segment”. The Value Map of the Value Proposition Canvas breaks down this Building Block in Products & Services, Gain Creators and Pain Relievers.

“Products & Services” is the comprehensive list of offerings of a company. The bundle of products and services will support the respective customer segments to fulfil their “jobs”. The list can also include supporting products and services that will support the customer e.g. in its role as buyer in the process of comparing and deciding.

“Pain Relievers” describe how the offered products and services will ease the pain of customers. Focus is on extreme pains of the customer. 100% coverage of customer pains is not realistic.

“Gain Creators” describe how the products and services produce outcomes and benefits that customers expect, desire, or would be surprised by, including functional utility, social gains, positive emotions, and cost savings.

2.1.2.3 Channels

“The Channels Building Block describes how a company communicates with and reaches its Customer Segments to deliver a Value Proposition. Communication, distribution, and sales Channels comprise a company's interface with customers”. Osterwalder & Pigneur distinguish between five phases of interaction with the customer: awareness, evaluation, purchase, delivery and after sales. Furthermore, they distinguish if a channel is owned by the company itself or if the channel is partner owned, e.g. wholesalers or agencies and if it is a direct or indirect channel – see Figure 3

Channel Types			Channel Phases				
Own	Direct	*Sales force*	**1. Awareness** How do we raise awareness about our company's products and services?	**2. Evaluation** How do we help customers evaluate our organization's Value Proposition?	**3. Purchase** How do we allow customers to purchase specific products and services?	**4. Delivery** How do we deliver a Value Proposition to customers?	**5. After sales** How do we provide post-purchase customer support?
		Web sales					
	Indirect	*Own stores*					
Partner		*Partner stores*					
		Wholesaler					

Figure 3. Business Model Canvas Building Block Channels (Osterwalder & Pigneur, 2010)

2.1.2.4 Customer relationship

"The Customer Relationships Building Block describes the types of relationships a company establishes with specific Customer Segments. A company should clarify the type of relationship it wants to establish with each Customer Segment. Relationships can range from personal to automated."

2.1.2.5 Revenue Streams

Basis for the definition of the revenue streams from the customer segments should be the consideration for what value delivered the customer is willing to pay.

Two basic types of revenue streams can be defined: Transaction revenues resulting from one-time customer payments and Recurring revenues resulting from ongoing payments to either deliver a Value Proposition to customers or provide post-purchase customer support

2.1.2.6 Key Resources

"The Key Resources Building Block describes the most important assets required to make a business model work". The key resources are basis to create the value propositions, to address the customer segments and thus to earn revenue. "Key resources can be physical, financial, intellectual or human. Key resources can be owned or leased by the company or acquired from key partners.".

2.1.2.7 Key activities

"The Key Activities Building Block describes the most important things a company must do to make its business model work". Key activities can relate to production, problem solving or a platform/network.

2.1.2.8 Key partnerships

“The Key Partnerships Building Block describes the network of suppliers and partners that make the business model work”. It is necessary to define which services and products the company requires from its partners, what is the motivation for the partnership and what type of partnership is formed.

Following types of partnerships are distinguished:

- Strategic alliances between non-competitors
- Coopetition: strategic partnerships between competitors
- Joint ventures to develop new businesses
- Buyer-supplier relationships to assure reliable supplies

Motivation for partnerships can be: -) Optimization and economy of scale, -) Reduction of risk and uncertainty or -) Acquisition of particular resources and activities.

2.1.2.9 Cost Structure

Based on the results of the buildings blocks Key Resources, Key Activities and Key Partnerships the building block Cost Structure describes the most important costs incurred while operating under a particular business model.

2.1.3 Implementation of the methodology in this thesis

The business model canvas was used to develop the business model from scratch, based on the defined parameters to define a “contracting model” for “public office space” using “thermochemical heat storage”.

As the initial step the setting and technical boundaries were analysed. Following that, as the initial element of the business model canvas, the customer roles were analysed and the customer segment was defined. Based on the identified customer “jobs”, “pains” and “gains” alternative basic value propositions were drafted and pros and cons were considered. One of the basic value propositions was chosen and further building blocks of the business model canvas were defined.

According to the business model canvas methodology the business model was developed in an iterative approach using “post its” on a large print out to support the creative process by visualizing the full picture, while at the same limiting to key statements and key facts.

3 Key technologies and Energy Contracting

3.1 Solar thermal energy – technological overview, seasonal problem of solar radiation vs. heat demand

"Solar energy is the conversion of sunlight into usable energy forms" (IEA, 2016). While "Solar Photovoltaics" directly generates electricity utilizing conduction of electrons in semiconductors, "Solar thermal" utilizes the absorption by gaseous, liquid or solid materials to transform solar radiant energy in usable heat (IEA, 2011). This heat can then be used for water heating, space heating and cooling, but also as process heat in commercial and industrial processes as well as for generation of electricity.

Solar Thermal is a well-established and widespread technology. "By the end of 2014, an installed capacity of 410.2 GW_{th}, corresponding to a total of 586 million square meters of collector area was in operation worldwide" (Mauthner, Weiss, & Spörk-Dür, 2016) – see Figure 4

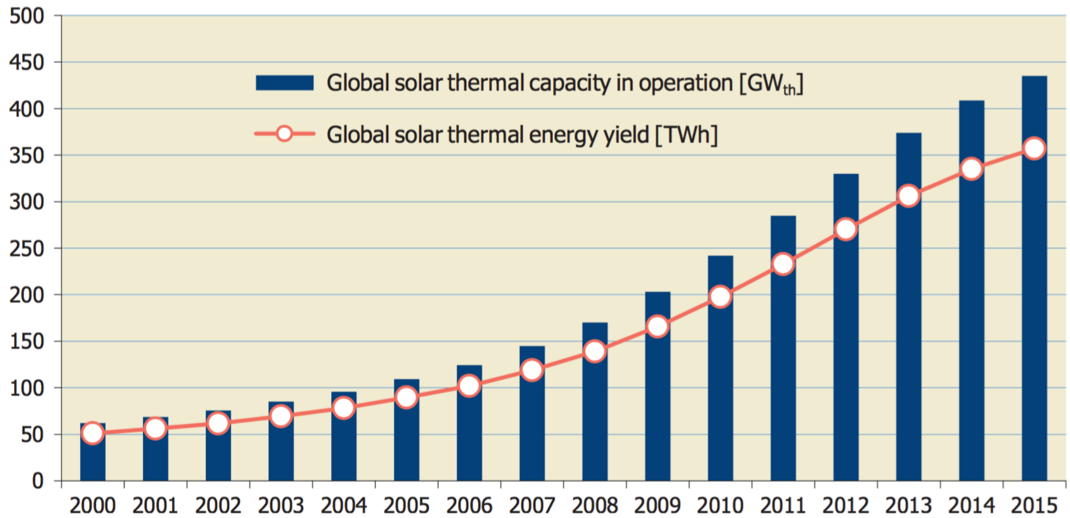


Figure 4. Global solar thermal capacity in operation and annual energy yields 2000 – 2015 (Mauthner, Weiss, & Spörk-Dür, 2016)

3.1.1 Solar collector

Key component of a solar thermal system is the solar collector. As basic types can be distinguished: unglazed collectors, flat plate collectors, evacuated tubular collectors and concentrating collectors. The different types of collectors achieve based on their design different working temperature and different efficiency values – see Figure 5 and Figure 6. The achieved working temperatures also define the predominant area of application.

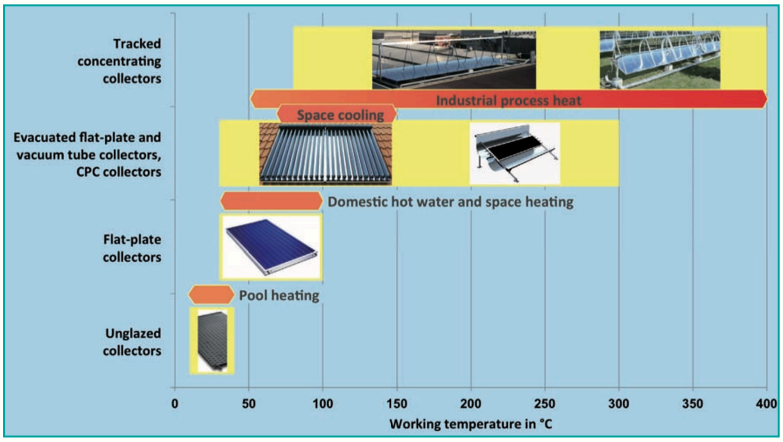


Figure 5. working temperature of different types of solar collectors (ETP RHC, 2012)

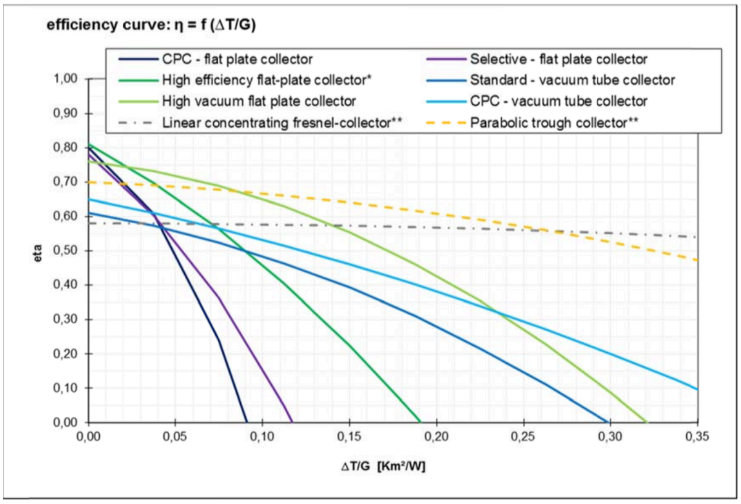


Figure 6. collector efficiency curves of different collector types (Weiss, 2015)

For space heating and domestic hot water (DHW) flat plate collectors and vacuum tube collectors are common, based on their working temperature. Vacuum tube collectors compared to standard flat plate collect have less losses as no convection and no heat losses by air conduction can occur, thus the efficiency is better - Figure 6. Vacuum tube collectors are often equipped with Compound Parabolic Concentrators (CPC), which concentrate solar radiation by 1-2 factors and at the same time accept most of the diffuse radiation. Furthermore, these concentrators can be stationary or only need seasonal tilt adjustments. Current prototypes of TCS

System utilize CPC vacuum tube collectors. To leverage on the advantage of vacuum insulation in recent years high vacuum flat-plate collector have been developed, this allowed to decrease heat loss and thus increase efficiency and working temperature, while maintaining the advantage of flat plate collectors to use both beam and diffuse solar radiation and thus do not require tracking of the sun. (Weiss, 2015)

3.1.2 Energy yield and solar fraction

Energy yield of the solar systems depends of different factors, like the type of the collector, mounting of the collectors (geographic direction and tilt), thermal losses of the system but most of all on available solar radiation at the location of the system.

3.1.2.1 Solar Radiation

Available solar radiation is dependent on the duration of the sunshine and its intensity, which again is dependent on the time of the year, weather conditions and geographical location. Given by the latitude of European cities there is a peak of radiation in summer months and rather low radiation in winter. This is, especially for central and northern European regions, fully anticyclical to space heating demand. – see Figure 7. In order to tackle this anticyclical demand and yield seasonal storage is needed to achieve space heating 100% based on solar thermal energy.

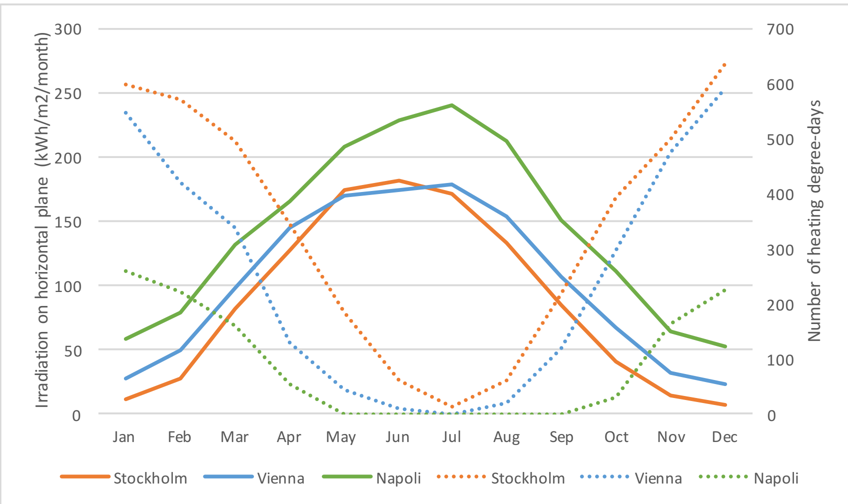


Figure 7. Average monthly values of global solar radiation (on horizontal surface) and number of heating degree-days for selected European cities (source: PVGIS http://re.jrc.ec.europa.eu/pvgis/)

3.1.2.2 Mounting of Solar Collectors

Depending on the geographical location there is an optimum orientation and inclination of solar collectors – general rules: “the collector should be facing the equator” and “the optimum angle of tilt is equal to the degree of latitude of the site” for use throughout the year (Weiss, 2015). However slight to moderate deviation from optimum orientation and tilt will not have extreme effect on the available solar radiation on the collectors – see Figure 8. This also allows to integrate collectors even in the façade of buildings – still achieving 80% of maximum yield in a south facing façade. This bandwidth of deviation from the optimal orientation is especially important for implementing solar thermal systems in building stock, where integration of solar collectors was not a requirement for planning and designing of the building.

Irrespective of orientation any shading from obstacles, like other buildings, trees or other collectors at any time of the year will have effect on available radiation and thus on yield.

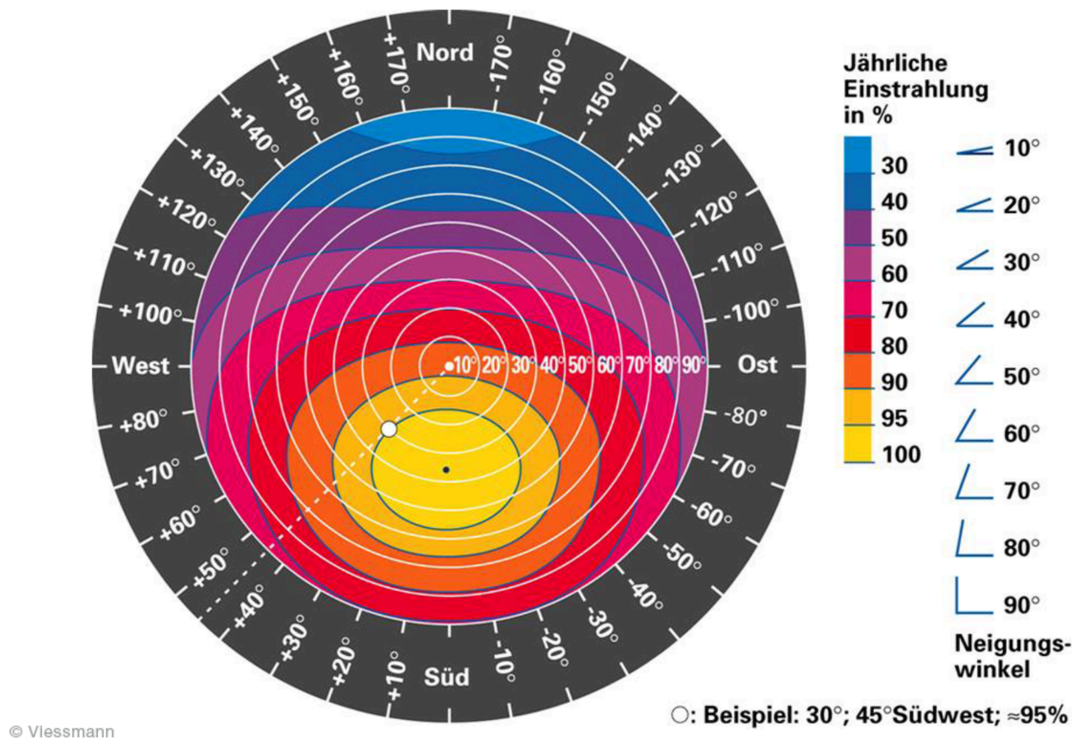


Figure 8. percentage of optimal solar radiation in variation of optimal orientation and inclination – source: https://www.zukunftsheizen.de/oelheizung/hybridheizung/oel-solar.html

3.1.2.3 Heat loss of the system

Heat losses will occur in any unit of the system, starting from the collectors, to piping and connections, valves and sensible heat storages (hot water storage). For every unit of the systems different measures to minimize heat loss can be taken, key measures are insulation (collectors, pipe, tubes, storage tanks), evacuation of collectors, limit distance of piping and high quality of connections.

3.1.2.4 Solar fraction

The factors mentioned above will define the annual yield achieved with a solar thermal system. "Depending on the dimensioning and the application, annual yields of 300 kWh/m^2 to 500 kWh/m^2 can be achieved with flat-plate collectors under central European weather conditions." (Weiss, 2015). Based however on the seasonal distribution of solar radiation and the anticyclical demand for space heating, yield in northern hemisphere will exceed the demand in summer and will be insufficient in winter. Without sufficient storage a solar thermal system will not cover the full heat demand and supplementing energy is needed. The ratio between energy provided from solar thermal system and total energy needed for DWH and space heating is defined as solar fraction (ESTIF, 2007).

Considering that in central Europe 300-500 kWh/m^2 of yield can be achieved with flat-plate collectors (Weiss, 2015) 15-20 m^2 of solar collectors would provide sufficient energy for heating demand of a low energy one family house of 150 m^2 (heating demand <50 kWh/m^2a). However, the solar fraction of a Combi-System (DHW & space heating, 10 to 15 m^2 flat plate collector and a 600 to 1000 litre hot water store) in a well-insulated one or two family house will only cover 25% of the overall building heat demand (ETP RHC, 2012).

3.2 Thermal energy storage systems – technological overview

To raise the solar fraction and in general to overcome the problem of demand for heat (time, location) versus availability of the according energy (solar radiation, electricity peaks due to renewable energy in the grid, cheap off peak tariffs, waste heat from industrial processes or CHPs) effective thermal energy storages are required. "Thermal energy storage (TES) systems can store heat or cold to be used later under varying conditions such as temperature, place or power. The main use of

TES is to overcome the mismatch between energy generation and energy use" (Cabeza & et al., 2015). This can be temporal mismatch – from short time: heat generation during day and demand at night to seasonal storage: exceeding heat generation in summer and heat demand in winter – but this can also be geographical mismatch – waste heat recovery in an industry plant and transport of heat with mobile storage.

Thermal Energy Storage Systems (TESS) have a wide range of potential applications. Some key applications are:

- "seasonal storage of solar energy,
- "waste heat" recovery in industrial processes,
- temperature control in buildings,
- improved efficiency in the operation of Smart Grids, district heating- and low-temperature distribution networks using (micro)cogeneration plants, solar thermal collector systems and heat pumps,
- thermal storage technologies that assist in the heat management of energy systems for hybrid and electric vehicles and transport systems. " (Rommel & et al., 2015) and
- smoothening the load curve during peak consumption (Cabeza & et al., 2015)

3.2.1 Types of Thermal Energy Storages

Three basic types of TESS can be differentiated: sensible heat storages, latent heat storages and thermochemical heat storages – see Figure 9

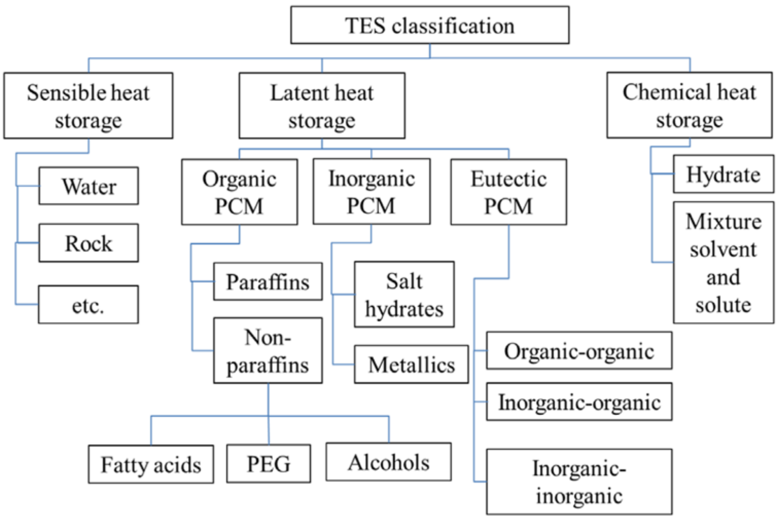


Figure 9. TESS classifications (Khadiran & et al., 2016).

3.2.1.1 Sensible Heat Storages

For storing energy, the temperature of the storage material itself is increased, no phase change of the material takes place. “Sensible heat storage utilizes the thermal storage capacity of solid or liquid (or even gaseous) materials (i.e., thermal mass). The storage capacity depends on the specific heat capacity of the material and the temperature difference” (Cabeza & et al., 2015). A wide range of material can be used for sensible heat storage, e.g. water, rock, concrete, metal or air. “The thermal efficiency is also influenced by the ratio of thermal use, thermal losses and is a function of the insulation, storage duration and other factors” (Cabeza & et al., 2015).

3.2.1.2 Latent Heat Storage

“Latent heat storage uses the phase transition of a material. Usually solid–liquid phase change is used, by melting and solidification of a material. Upon melting heat is transferred to the material, storing large amounts of heat at constant temperature; the heat is released when the material solidifies. Materials used for latent heat storage are called phase change materials (PCM)” (Cabeza & et al., 2015, S. 4).

3.2.1.3 Thermochemical Storage

“Thermochemical energy storage is produced when a chemical reaction with high energy involved in the reaction is used to store energy. The products of the reaction should be able to be stored and the heat stored separately during the reaction should be able to be retrieved when the reverse reaction takes place. Therefore, only reversible reactions can be used for this storage process” (Cabeza & et al., 2015).

TCS itself can be differentiated in chemical reaction systems and sorption systems. Chemical reactions used for storage are mainly hydration of salt hydrates (Rommel & et al., 2015). Sorption storage utilizes the reversible physico-chemical process of adsorption/absorption and desorption of water on porous solid or liquid sorbents ((Cabeza & et al., 2015) and (Rommel & et al., 2015)).

3.2.1.4 Differences of TESS – advantages and disadvantages

When comparing TESS usual criteria/requirements are: energy density of the storage material (storage capacity), heat transfer between the HTF (Heat Transfer Fluid) and the storage material, mechanical and chemical stability of the storage material, compatibility between the storage material and the container material, complete reversibility of a number of cycles, low thermal losses during the storage period and easy control (Cabeza & et al., 2015). Furthermore, the temperature needed for charging and the temperature provided when discharging.

Basically the mentioned criteria need to be evaluated for the single storage material, even for the single storage system. In general, though TCS materials operate at higher temperatures and have higher storage capacity (amount of energy stored per m^3 of storage material) than sensible or latent storages – see Figure 10. "Thermochemical energy storage has the potential to store heat energy ten times more than sensible and three times more than latent heat storage technologies" (Rommel & et al., 2015).

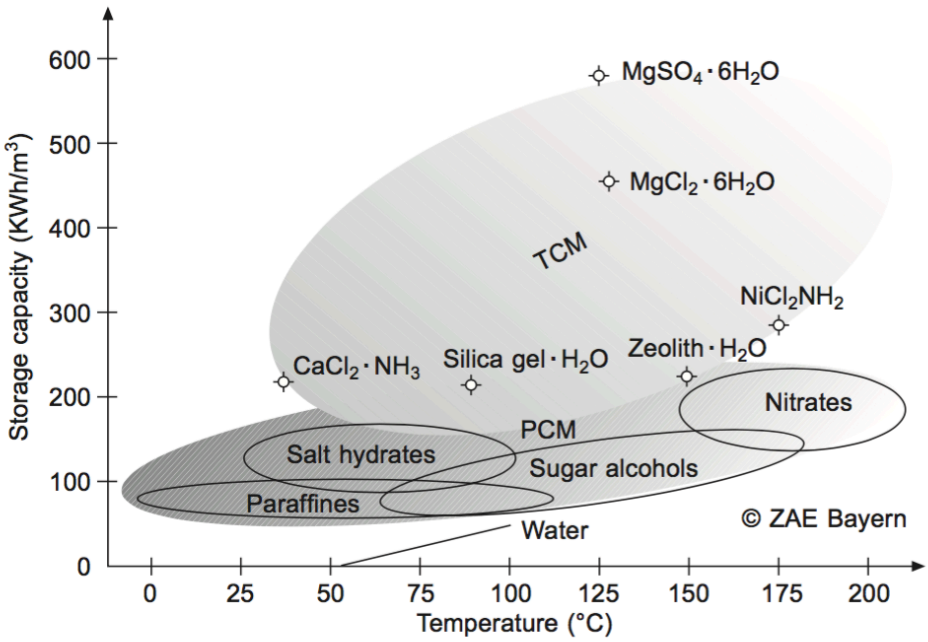


Figure 10. Storage capacities of PCM and TCM compared to water (Cabeza & et al., Final report Annex 25: Surplus Heat Management using Advanced TES for CO2 Mitigation, 2013)

In general, one of the main differences is that in TCS "in contrast to sensible or latent storage systems, thermal losses can not only be avoided by thermal insulation but also by suppressing the respective exothermic reaction. Depending on the reaction system, this can either be reached by kinetic limitations (e.g., absence of catalyst and/or low storage temperatures) or by thermodynamic limitations (e.g., physical separation of the reaction partners)" (Cabeza & et al., 2015). A scheme of the principle of TCS of heat is displayed in Figure 11. Based on this principle long-term storage of heat is possible.

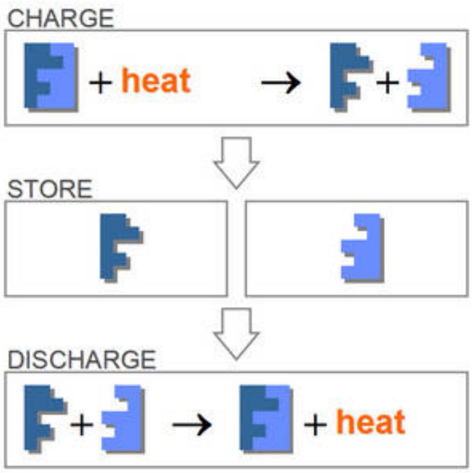


Figure 11. Principle of thermochemical storage of heat (ECN, 2009)

Based on these technological advantages - long time, compact storage of high temperatures - TCS systems have high potential for seasonal storage of heat for space heating and DHW applications. The business model developed in this thesis therefore considers TCS as the core technology for the heating system.

3.2.2 TCS – Potential, Status of Research & Development

TCS technology can be used for various applications, ranging from seasonal storage, to transport of heat and even household applications, where zeolite is already successfully used for years in dishwashers for highly efficient drying process. The mobile TCS by ZAE Bayern uses a sorption heat storage in a container to collect waste heat from waste incineration plant and transports it with trucks to an industry plant using the heat for drying process – 4,600 kWh per storage container (Hauer, 2016) and (Rommel & et al., 2015).

Based on the long term storage possibility and the high storage capacity TCS Systems have highest potential for seasonal heat storage in buildings. "With thermochemical materials, the entire heating demand of a low-energy house during winter can be met using a storage volume of 5–10 m^3, which is charged during summer by solar collectors" (Cabeza & et al., 2015).

TCS Systems at this point of time are not yet available on the market but are still in R&D phase. Prototypes of TCS Systems for seasonal storage with solar thermal energy have been installed and are in operation, e.g. EU funded COMTES project based on solid sorption solar seasonal storage (AEE INTEC, ITW, TH Wildau, Vaillant) – see Figure 12 – or EU funded MERITS project TCS demonstration system for space heating and DHW (TNO) (Rommel & et al., 2015).

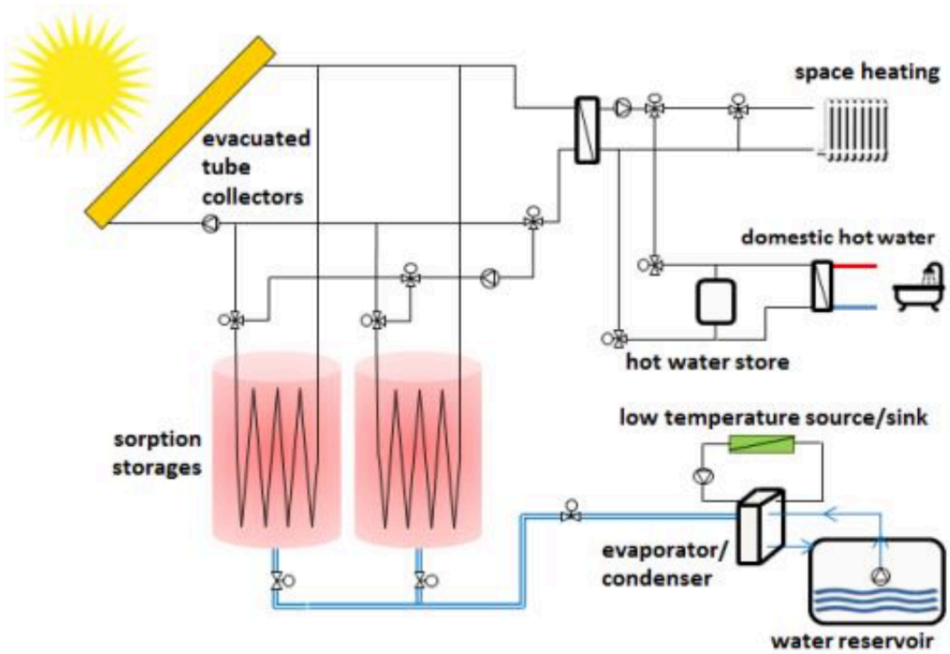


Figure 12. System Scheme COMTES project - solid sorption solar seasonal storage (AEE INTEC, ITW, TH Wildau, Vaillant) (Engel, AEE INTEC, 2016)

Further R&D is needed regarding materials, components and systems (Rommel & et al., 2015). EU is funding the development of compact heat storages and heat batteries e.g. in above mentioned programmes COMPTES and MERITS. The objective of MERITS is to develop, demonstrate and evaluate a compact seasonal storage system based on novel high-density materials that can supply required heating, cooling and DHW with up to 100% RES.

3.3 “Energy Contracting” – overview of the methodology, contracting types

3.3.1 Definitions

International Energy Agency (IEA) - Demand-Side Management Task 16: „Energy-Contracting - also labelled as ESCo or Energy Service - is a comprehensive energy service concept to execute energy efficiency projects in buildings or production facilities according to minimized project cycle cost.

An Energy Service Company (ESCo) implements a customized energy service package (consisting of planning, building, operation & maintenance, optimization, fuel purchase, (co-)financing, user behaviour ...). The ESCo provides guarantees for all-inclusive cost and results and takes over commercial, technical implementation and operation risks over the whole project term of typically 10 to 15 years” (Bleyl-Androschin, 2010, S. 14)

EU Directive 2012/27/EU on energy efficiency: “‘energy service’ means the physical benefit, utility or good derived from a combination of energy with energy-efficient technology or with action, which may include the operations, maintenance and control necessary to deliver the service, which is delivered on the basis of a contract and in normal circumstances has proven to result in verifiable and measurable or estimable energy efficiency improvement or primary energy savings”

3.3.2 Basic Business Modell of Energy Contracting

Initially two basic models of Energy Contracting (EC) have been described: Energy Supply Contracting (ESC) and Energy Performance Contracting (EPC). More recently, especially to overcome problems with measurement & verification of guaranteed energy savings, the Integrated Energy-Contracting Model (IEC) has been developed.

EC services are not about any particular technology or energy carrier. Instead EC is a flexible and modular “efficiency tool” to execute energy efficiency projects, according to the goals of the facility owner. It is an instrument to minimize life- or project cycle cost, including the operation phase of the building. (Bleyl-Androschin, 2011, S. 3) - Figure 13

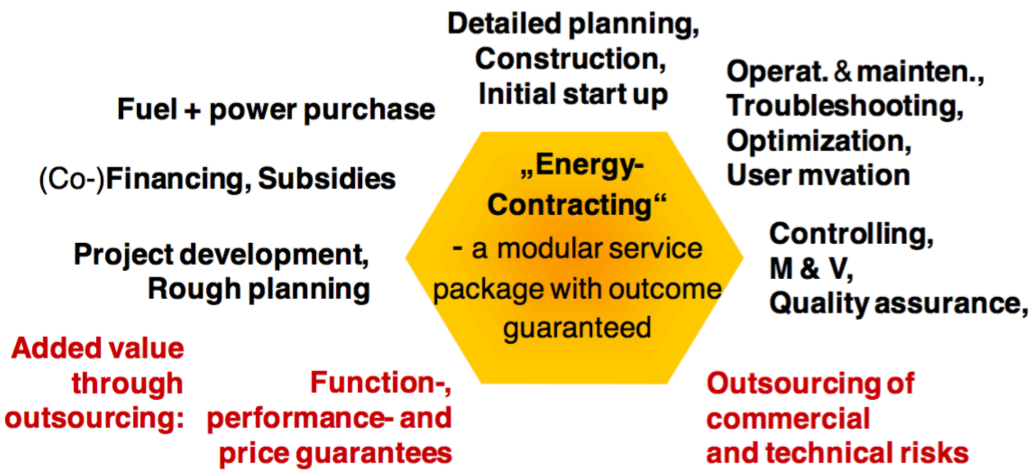


Figure 13. customized energy service packages (Bleyl-Androschin, 2011)

The basic characteristics of EC that the ESCo provides useful heat as a services to the customer, (co-)financing the initial investment and the risk free situation of the customer due to function-, performance- and price guarantee of the ESCo indicates that contracting models can be used to introduce new technologies to customers. Therefore contract models were chosen as basic concept for the business model developed in the thesis.

3.3.2.1 Energy Supply Contracting

"At Energy Supply Contracting (ESC) efficient supply of useful energy such as heat, steam or compressed air is contracted and measured in Megawatt hours (MWh) delivered. The business model usually includes purchasing of fuels and is comparable to district heating or cogeneration supply contracts." (Bleyl-Androschin, 2010).

Key advantage of the ESC model is in general the clear compensation model which is based on direct measurement of the useful energy consumed. Any increase in demand will result in increased billing – see Figure 14. This fact facilitates the ESCo to guarantee the price per MWh. Technical improvement and efficiency measures are however limited to use-full energy generation.

3.3.2.2 Energy Performance Contracting

"For Energy Performance Contracting (EPC), the focus is on reducing final energy consumption through demand side energy efficiency measures. The scope is extended to the entire building or enterprise including measures such as technical building equipment, user behaviour or the building envelope insulation. The business model is based on delivering savings compared to a predefined baseline, also labelled as Negawatt hours (NWh)." (Bleyl-Androschin, 2010).

Key problem of the EPC model is the measuring of Negawatt hours, especially regarding baseline for measurement of saving, changes compared to the baseline which cannot be controlled by ESCo such as changed climate conditions, energy prices, changes in utilization of the building etc. To compensate these issue high effort for measurement & verification of guaranteed energy savings is necessary – see Figure 14. Even though EPC provides higher saving potentials than ESC, market share lacks way behind ESC model. (Bleyl-Androschin, 2011)

3.3.2.3 Integrated Energy-Contracting

Integrated Energy-Contracting Model (IEC) seeks to combine the advantages of the ESC and EPC, by implementing demand side energy efficiency measures (EEM) and efficient supply of useful energy. To overcome the problems with measurement & verification of guaranteed energy savings, payment builds on base fees for services of energy supply and efficiency measures, while charging useful energy consumption by MWh. To evaluate the efficiency of implemented efficiency measures different individual quality assurance instruments (QAI) shall be defined. Such QAI might be one-time thermographic analyses, inspection of construction, proof of function processes – see Figure 14. This concept allows the building owner to define customized energy service packages and demand guarantees for the results of the measures taken by the ESCo. (Bleyl-Androschin, 2011)

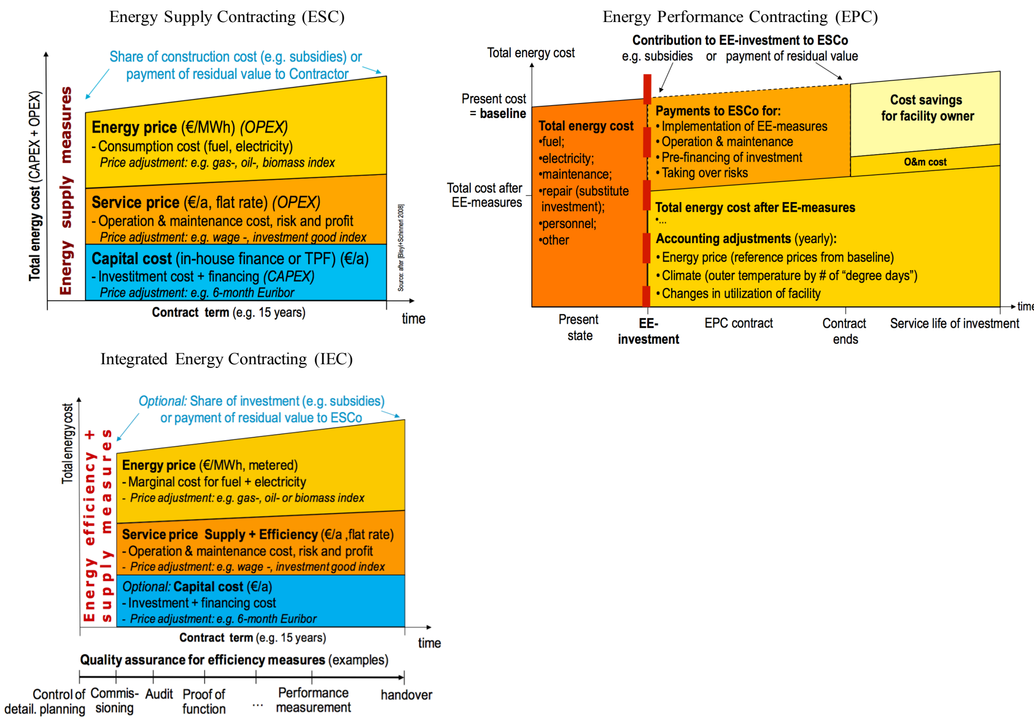


Figure 14. concepts of EC business models (Bleyl-Androschin & Schinnerl, 2008) (Bleyl-Androschin, 2011)

3.4 Assumptions & implications from applied technologies and contracting models for the Business Model developed

3.4.1 Energy Efficiency of Buildings

As stated in some detail above the yield of solar thermal systems is defined by different technical and geographical factors. General factors are geographical location, collector type and mounting of collectors (orientation and tilt). Specific ones for single buildings are the available area for collectors, shadings from other buildings or trees or static limitations.

Also the heat storage will have limitations. On one hand the amount of energy provided to system, e.g. by the solar thermal system, and on the other hand the available room in the building for installation of heat storage. In some of the existing buildings there will be some room that already was dedicated to “energy storage”, namely oil tanks, in other buildings a certain amount of space can be made available for heat storage components. In any way space for storage cannot be considered to be unlimited.

These limitations are specific for each single building and need to be assessed for each single project. In general though, given the limitations of yield and available space for collector area and storage it has to be assumed that EEM have to be applied to building stock to reduce heat demand in order to provide a high solar fraction with a system consisting of local solar thermal system and local heat storage – see evaluation in Table 1. Based on the assumption of 300 m^2 collector area, 500 kWh annual yield per m^2 of collector area and 100% solar fraction in buildings with energy classes B and better substantial space can be heated – 3.000 m^2 and more. On the other hand, especially in classes D and worse very limited space could be heated with the system. This evaluation does not even consider the space needed for the heat storage.

Table 1. Sample evaluation of space potentially heated by solar thermal system with storage achieving 100% solar fraction – own table

	assumed values	
collector area	300	m2
annual yield/m2	500	kWk
annual yield system	150000	kWh

Energy Class	annual heat demand ≤ kWh	heated space with annual yield >m2
A++	10	15000
A+	15	10000
A	25	6000
B	50	3000
C	100	1500
D	150	1000
E	200	750
F	250	600
G	>250	<600

The business model developed is focussed on highly efficient buildings – new or already retrofitted with sufficient EEM. Primary service of the business model is heat supply to the customer with an ESC Model. Also the case study is assessing the target price for the TCS for a newly build primary school.

EEM for buildings with lower energy efficiency are preceding services in an EPC or IEC. Once the EEM are implemented heat supply services are common to ESC. In a separate chapter of the thesis an overview of the implications of the EEM services on the business model is given.

3.4.2 Solar thermal collectors and thermochemical storage

In this thesis TCS systems are applied as storage system given the higher temperatures that can be stored, the higher storage capacity and thus lower volume demand of these systems and the technical possibility of loss free long-term storage.

TCS though are still in R&D phase and different storage materials are being developed and tested. The technical, chemical and physical design of TCS is not scope of this thesis. Therefore, technical details and specifications of the TCS systems will not be further discussed. For the case study the TCS system will only be defined by the amount of heat to be extracted in the heating season.

As in the ongoing prototype of COMTES project based on solid sorption solar seasonal storage (AEE INTEC, ITW, TH Wildau, Vaillant) CPC Vacuum Tube Collectors will be applied in the case study.

3.4.3 Scope of Services of the ESCo

The business model developed is based on the assumption that contracting services offered to customers is the sole product/service the ESCo offers. Therefore double interests of constructions companies, collector manufacturers or heat storage developers were not considered. Same is true for potential synergies in case any of the aforementioned businesses decide for contracting as an additional go to market approach. This assumption has especially impact on the building blocks "Key Partners", "Channels" and "Relationship". This assumption was taken considering that the ideas and results of the business model for EC services can also be applied and rather easily be adapted for a double interest approach, while a specific business model e.g. for heat storage developer will have less implications for other potential ESCo's.

Another key assumption of the thesis is that services are provided for public office space. Public office space was chosen, as the public sector is driven by international and European treaties to apply sustainable principles and to achieve climate targets. Thus the public sector is urged to apply heating solutions based on renewable energy. And the public sector is also already moving towards a more sustainable evaluation of building investment, e.g. for public buildings in the Region of Lower Austria lifecycle costs are basic economic evaluation criteria (Amt der NÖ Landesregierung, 2014). Based on the parameter of offering services for public office space, it considered that a formal public procurement process is to be applied.

4 Customer Segment/Profile

4.1 Key roles involved in the procurement process

The organizational set up of customers will be different for every building and for every project. Still common roles can be defined.

Following roles are usually involved in procurement process of space heating related services or are affected by these services:

- "End users": staff actually located in the building in scope
- "Tenants": management of organizational units located in the building, e.g. heads of local organizational units, court managers or school principals
- "Persons politically responsible": persons that have been assigned or elected as the formally representative of the public body that is owning the building, e.g. regional governors, ministers of infrastructure or city mayors
- "Representatives of the building owner": by legislation or assignment certain persons or organizations will be responsible for the actual property management of the building. These will act as formal representatives of the owner and will be responsible to manage and maintain the building in a way that legal requirements are fulfilled, property value is retained and operation is efficient. Who has this role will be strongly depending on the size of the organization owning the building. In a small village the elected mayor might be directly responsible for the municipal office or the primary school. Larger organizations like federal states or regions might have own organizational units dedicated to property management, e.g. in Austria Bundesimmobiliengesellschaft (~ferderal property company) being owned 100% by federal state of Austria being represented by ministry of economics.
- "Public procurement officer": this role will operate the formal public procurement process. Again it will be strongly depended on the size of the organization and on local legislation who takes the responsibility for this role. This might be once more the mayor of a village, it can be an employee of the property management organization or special public procurement units on regional of federal level might be responsible.

- "Technical consultant": in general, it can be assumed that neither the representative of the owner nor the public procurement officer will have the deep technical know-how on space heating to design a public tender, especially the technical requirements and specifications. Therefore, the formally responsible roles for the correct and efficient procurement process will in most cases involve a technical consultant. This can be an internal consultant or an external consultant.

For the design of the business model, it is important to understand which role will have actual influence on the procurement decision. The value proposition will have to support these roles in their jobs, ease their pains and provide gains for them.

Different roles will be affected by the services provided, like end users or tenants. In many cases these roles however will have no or only indirect influence on the procurement process. End users usually have no influence on the procurement decision. Tenants might have indirect influence as an opinion leader, in some cases even tenants might have direct influence, e.g. when a tenant is part of an evaluation committee.

The role of the political responsible person in the procurement process is difficult to assess. In larger organizational units the political responsible will not involve himself in property management and thus will not be involved in the procurement process. The political responsible will assign the task and targets to a representative. The targets will usually at least contain the efficient economic management, the retaining of property value and the compliance with legal requirements. These legal requirements will also include ecological targets, like reduction of emissions, especially CO_2. In smaller public bodies owning a property the political responsible person himself might have the task to manage the property and thus would be directly involved in the procurement, e.g. the mayor of a village.

The representative of the owner assigned with the task to manage the property will be the key role in the procurement process, driving the decisions: Starting from the key decision of the scope of the tender: make or buy, so to either buy a heating system and produce heat in own responsibility or to procure services and outsource the responsibility of heat production, to the decision on evaluation criteria and to the final evaluation of offers.

The procurement officer will also by deeply involved in the procurement process. If this person has only the role of "procurement officer" with the sole task of driving the formal procurement process, then this person will have a rather formal involvement. Decisions will be limited to formal and quantitative evaluations. Qualitative and technical evaluations will usually not be assigned to the procurement officer. Of course in several procurement processes there will not be a person with the sole role of procurement officer, but the same person might have the role of representative of the owner, e.g. again the mayor of a village or the administrative head of municipality.

Also the "technical consultant" will have an active role in the procurement process. He will influence the make or buy decision, he will help to assess requirements, provide the specifications, propose evaluation criteria and often he will also be actively involved in the evaluation of offers, either being part of the commission or by preparing a proposal for decision.

Considering the involvement in the procurement process the "representative of the owner", the "public procurement officer" and the "technical consultant" were identified as the key roles. In order for the business model to be successful the value propositions need to produce pain relievers and gain creators that match one or more of the jobs, pains, and gains that are important to these three roles.

4.2 Jobs, pains and gains of key customer roles

4.2.1 Representative of the owner

Owner of public buildings will be regularly public bodies, like regions, cities or chambers. These public bodies in a democracy will either be represented by single elected persons or usually by elected assemblies, like parliaments or city councils – the "politically responsible persons". These elected bodies will usually assign individual persons or specialized organizations to represent the owner with regard to property management. As mentioned above who is assigned as representative will be strongly dependant on the size of the public body owning the building and on the amount of buildings this public body owns. In small villages with no professional staff elected persons like the mayor or municipal councillors can be assigned with the task. Large public bodies with high number of properties will assign an organization with the task. This can be units within the structure of the public body, but it can also be private companies controlled by the public body.

These representative will be assigned by the politically responsible persons to secure the interests of the owner. In general, this will be the retention of the value of the property, the compliance with legal requirements and the efficient economic management of the property. It can be assumed that by the politically responsible person in many cases additional political targets will be defined, example could be a marketable “green” success story that would support the image of the politically responsible person.

In Figure 15 the identified jobs, pain and gains of the role “representative of the owner” are displayed.

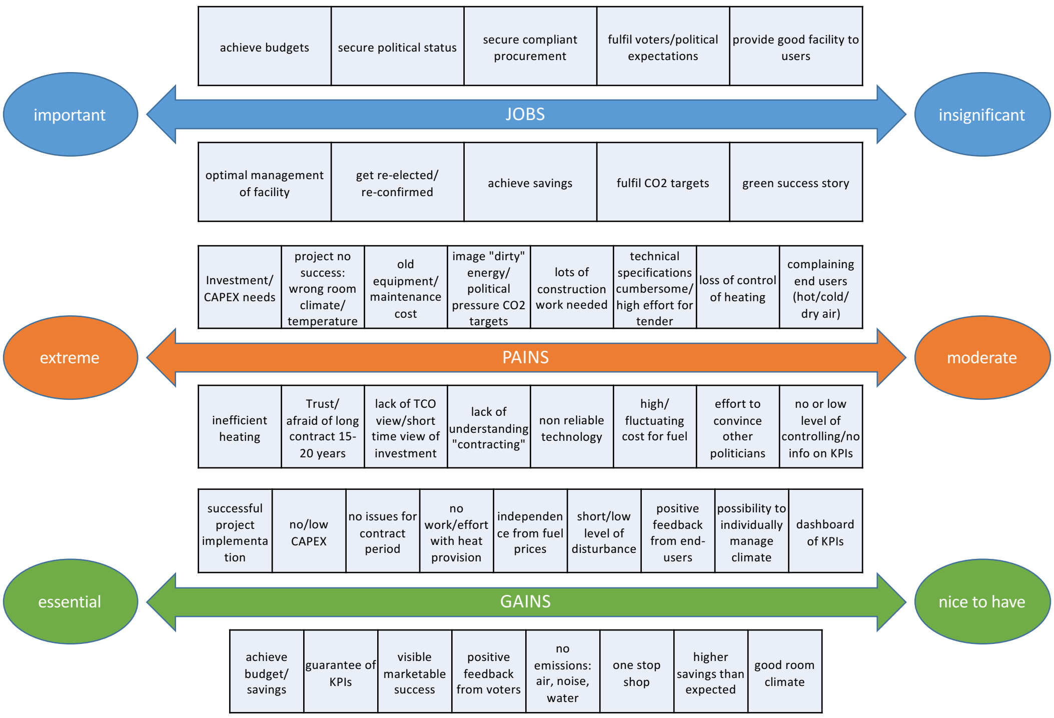


Figure 15. Jobs, pains and gains of the “representative of the owner” – own illustration

The jobs identified are functional jobs, derived from the general targets of property management, like achieving budgets or securing compliant procurement process. But on the other hand also social and emotional "jobs" were identified, like achieving additional savings or achieving CO_2 targets, which will secure the social "job" of securing the political status and to help to be re-elected or re-confirmed in the position.

The pains identified are related to commercial back ground, like CAPEX need or fuel cost, but are also related to the success of the project, the long contract periods and new technology. Other pains derive from lack of knowledge of new technologies, new business models, new way of procurement and with that the higher effort for changing standard or known processes and solutions.

The identified gains for the "representative of the owner" in large would support the social jobs identified, like a visible marketable success, positive feedback from end-users or directly voters in smaller villages. The success of the project and somebody taking responsibility for success and thus no negative impact or feedback for the representative are also key gain for the "representative".

4.2.2 Procurement officer

Based on the assumption that all public bodies that own buildings are in the factual scope of public procurement laws, the role of the "public procurement officer" has the key task to drive the formal process and to secure legal compliance of the process. In course of the procurement process a person needs to take that role, either as the sole role or on top of other roles. Larger organizations will often have own procurement units highly specialized, in smaller organizations again the representative of the owner might take that role on top. Or this role might even be outsourced to a lawyer or to public procurement companies, e.g. in Austria Bundesbeschaffung GmbH.

Given by the task of the role the involvement in the procurement is formal. Decisions taken by this role will be based on clear requirements by law, e.g. minimum qualification criteria, or defined in the tender, e.g. cheapest price according to predefined pricing sheet. This role will usually not make qualitative evaluations of the solution, of presentations or technical compliance.

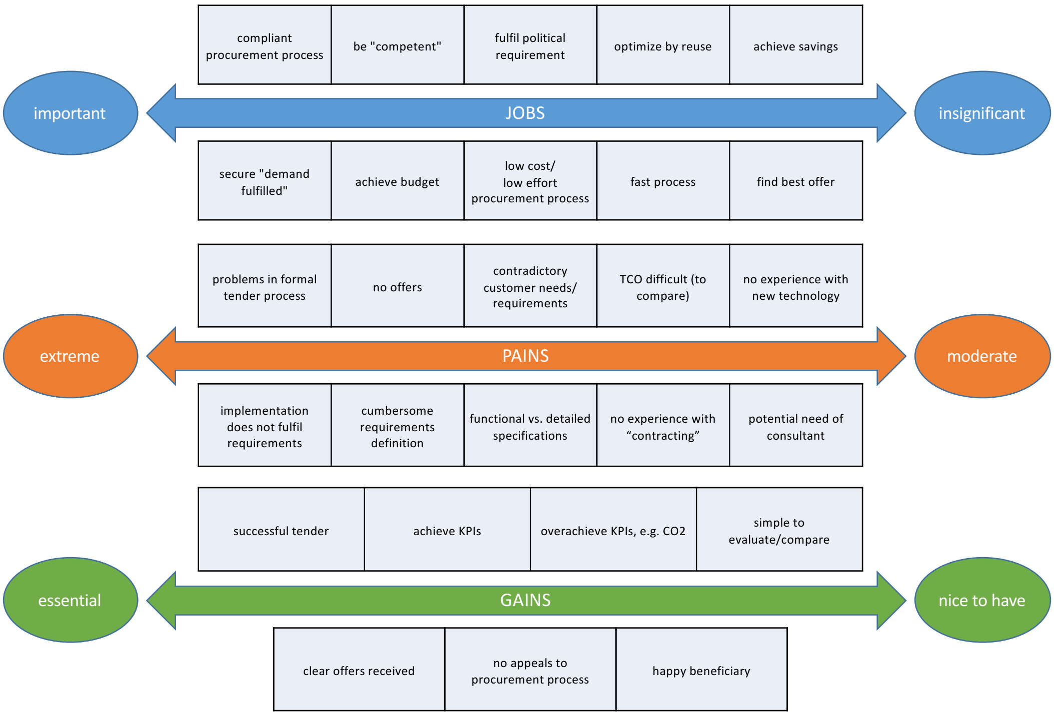


Figure 16. Jobs, pains and gains of the "procurement officer" – own illustration

Based on this formal position the jobs of the procurement officer are very much driven by the legal requirements of the public procurement law and by being competent and efficient in that role. Also the pains identified are related to the process of procurement itself. Issues that might slow down the process, increase the effort for the procurement officer or that might result in the need to repeat fully the procurement process. Same is true for the gains sought by the "procurement officer". See Figure 16

4.2.3 Technical consultant

Given the life cycle of a heating system in a building it can be assumed that in many cases the representative of the owner, being responsible for management of the building and the compliant procurement process, will not have everyday experience with procurement of heating systems. Still it is important to him to achieve reliable, efficient and sufficient space heating and hot water supply for the building for the next 20plus years. Therefore, the "representative of the owner" will involve a "technical consultant" to secure up-to-date knowledge and experience on heating systems. This "technical consultant" can be an external expert, e.g. involved as a facilitator (Bleyl-Androschin, 2010). But this role can also be assumed by an internal expert – large property management organization responsible for several dozens to several hundreds of buildings on regular basis are procuring heating systems or heating services.

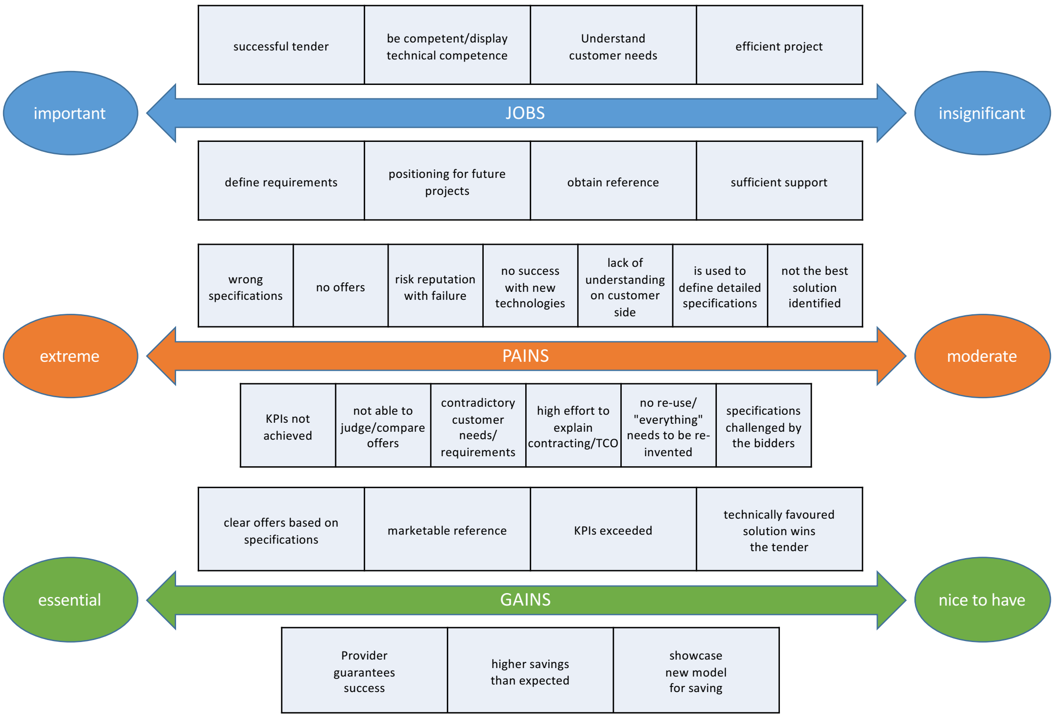


Figure 17. Jobs, pains and gains of the “technical consultant” – own illustration

The “technical consultant” of course also has as the main job to secure a “successful” tender but not only “successful” in the formal way of the procurement officer, but successful in the sense to actually secure sufficient and efficient heating for the building in scope. Especially for external consultants this is important for their own positioning on the market of technical consultants. The pains of the technical consultants are dominated by securing a technically valid tender, that will secure a successful procurement, a successful project implementation and finally heating that will cover the customer needs. Again especially for the external consultant exceeding effort for a single tender will be a “pain”, this exceeding effort can result from long discussions on requirements, from necessary explanation on certain technologies or from convincing the representative of the owner to outsource heat provision, to move to a contracting model. The gains for the “technical consultant” are majorly related to the future positioning of the consultant, by being able to manifest its competence, with a smooth tender procedure, exceeding KPIs (Key Performance Indicators) and savings.

4.3 Prototypes of business models based on customer profile

In course of the iterative process of devolving the business model canvas basic business models (prototypes) were sketched out based on the customer profile and implications from applied technologies – see 3.4.

Similar to usual batteries two basic modes were used as starting point: 1) buy pre-loaded batteries or 2) load rechargeable batteries - Figure 18

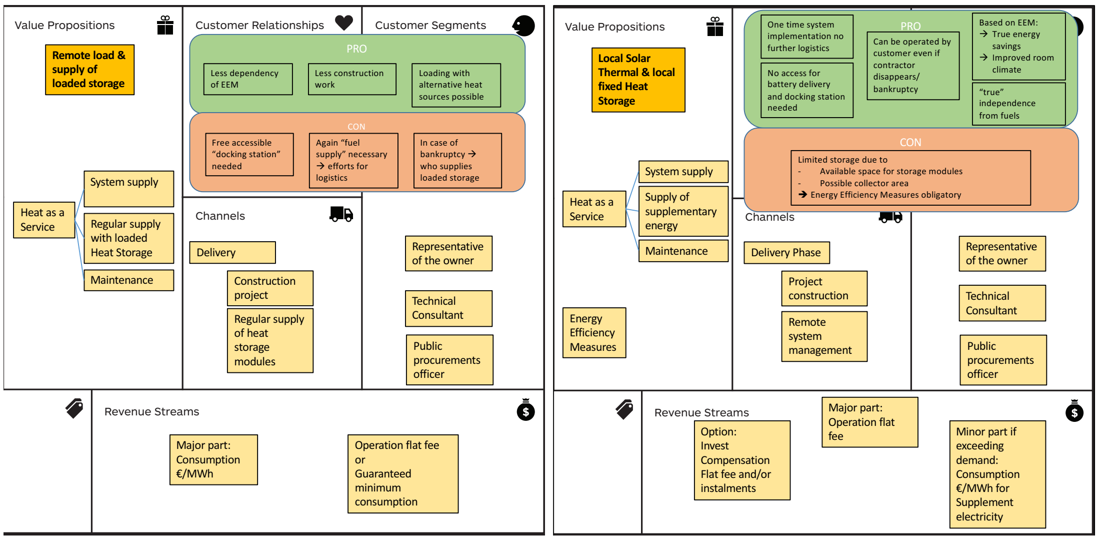


Figure 18. prototypes of potential business models – own illustration

Both basic business models do have Pros and Cons. The supply of heat storage modules to a customer, which are loaded remotely will allow to load the storage not only with solar thermal heat, but also with all other excess heat or energy, like off-heat from a CHP or industrial process or with balance energy. This approach would also bypass the problem of limited space in a building for storage and by that, sufficient energy in heat storage modules could also be supplied for buildings with lower efficiency class. This might reduce the need for extensive retrofit for better insulation. These positive effects would ease some important pains of the customer. However even more extreme pains would not be relieved: on regular basis a truck would have to provide loaded heat storages to the building to a free accessible "docking station". This would mean on customer premises an area for the docking station has to be reserved and again the customer is dependent on "fuel delivery". Also given the fact that different storage materials are possible, heat modules are not yet standardized and "docking stations" are not standardized the customer faces major issues if the supplier of heat modules closes down its business or files bankruptcy. The customer cannot be sure if an alternative supplier can supply exactly the required storage modules. So the customer needs to have highest trust in the ESCo and its technology partner and must believe that the partner will be providing services not only for the contract period of 10 or 15 years, but for the full life cycle of the heating system.

The basic business model of onsite loading of fixed heat storage devices on the other hand has the major downside of limited storage potential as mentioned under 3.4.1 resulting among other from limited space for storage modules, limited area of collectors, available solar radiation etc. This limitation of storage in most cases will result in the need of EEM that will have to be implemented in building stock in order to provide heat with thermochemical heat storage and 100% or at least close to 100% solar fraction. This need for EEM will then result in extended construction work and business interruption for the customer. So some of the identified pains of the customer will not be relieved. Still this model offers several pro arguments for the customer, all of them giving the customer a higher degree of independence from the supplier: After the one-time implementation no further heat battery/fuel supply is needed, the system will basically be self-sufficient. The risk of the supplier going out of business is to a large extend limited to the initial years when mistakes and weak points of the system will become evident. Furthermore, as a result from the EEM real energy savings will be achieved and no space on the outside premises has to be made available for the docking station and storage device and no further logistics are necessary.

Given this initial analysis the basic setup of loading the TCS on site with on-site solar thermal collectors was followed up to develop the full Business Model Canvas. AS already mentioned above, focus is on energy services for highly efficient buildings. Impacts of additional EEM on the business model are shortly sketched out in an excursus - 5.9

5 Results Business Model

5.1 Value proposition/Value Map

5.1.1 Products & Services

Based on the basic setup of loading the TCS on site with on-site solar thermal collectors and the assumed customer jobs, pains and gains the products and services of the ESCo were defined - Figure 19

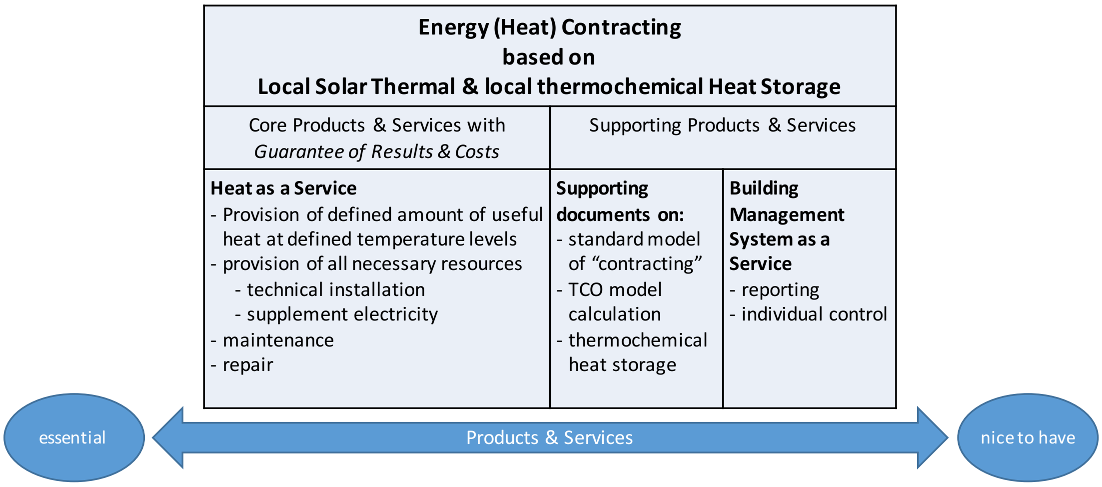


Figure 19. List of products & services – own illustration

The products & services can be split into core products, which are essential for providing heat contracting, and in supporting products, which are not pre-condition for delivery of contracting services, but will relieve some pains and create some gains for the customer – more details will be discussed below.

"Heat as a Service" is the core service in the business model. The service towards the customer is the supply of a defined amount of useful heat at a defined temperature level. This service contains the provision and installation of all necessary parts of the heating system, including among others solar collectors, plumbing work, heat exchangers, different storage modules and control units. For this full installation, maintenance and repair have to be provided. Also "supplement electricity" needed for operation of the system and possibly for heating if 100% solar fraction cannot be achieved is fully covered by "Heat as a Service".

For this core product the supplier has to give a guarantee for results and costs. The supplier has to secure that the Key Performance Indicators (KPI) defined in the tender are achieved. The risk of sufficient sizing of the system, quality of the system, reliability and all variables, like solar radiation (within defined limits), are to be borne by the ESCo.

As supporting products “supporting documents” and “Building Management System as a Service” have been identified. The “supporting documents” shall provide sufficient, specific and applicable information for all customer roles involved. Key topics for supporting documents will be contracting models, TCO/Life Cycle Cost and the technical systems to be implemented, especially on TCS. Given by the target role for a supporting document and the purpose the target role wants to use it for different documents with varying focus points and depth of information will have to be provided. There needs to be a supporting document to describe e.g. contracting models in a way that a “technical consultant” or a “representative of the owner” can use it to introduce the model to “political responsible persons”, e.g. city councils. But there also needs to be a document that describes contracting in a way that the “procurement officer” or the “technical consultant” can build their tender documentation on.

Finally, “Building Management System as a Service” has been identified as necessary service. In order to monitor, operate and manage the heating system of a building end to end the ESCo will need an according IT Solution – in this work referred to as Building Management System. This BMS is one of the key resources for the ESCo – see below 5.5. As a supporting services access can be granted to the customer. This can allow the customer to manage his building himself within contractually defined bandwidth, for example room temperature in building within a defined range, also the customer can use certain monitoring and reporting functionalities. The access of the customer of course needs to be limited to an extent, which does not interfere with the responsibility of the supplier.

5.1.2 Pain Relievers & Gain Creators and mapping to customers Pains & Gains

“Pain relievers and gain creators are explanations or characteristics that make the value creation of your products and services explicit.” (Osterwalder & et al, 2014, S. 1.2) Products & services will only create value for the customer if they relate to customer jobs, relieve some of their pains and create some gains they expect or even do not expect.

Based on the products and services defined some key pains relievers and gain creators common to all customer roles can be highlighted:

- the guarantee of results & costs, which will relate to all pains regarding doubts of achieving targeted KPIs, targeted savings or increasing cost for fuel or maintenance
- pain relievers resulting from the provision of the supporting documents, that will help to foster understanding of involved stakeholders, ease the work of the involved roles in defining the tender and comparing the offers
- pain relievers and gain creators resulting from the fact that energy generation is based on solar thermal, which will secure real reduction of CO_2, prevent emissions, secure independence from fuel or feedstock and reduced supplement electricity need compared to heat pump solutions

Due to the central role of the “representative of the owner” and its numerous jobs, pains and potential gains in the procurement of heating services the products and services defined offer the most pain relievers and gains creators for this role. In Figure 20 single pain relievers and gain creators are mapped to the pains & gains of the “representative of the owner”. Apart from the pain relievers and gains creators mentioned above especially the contracting model itself can offer value to the role of the “representative of the owner”. The pain of high CAPEX can be relieved and the contracting model with the guaranteed results and cots will provide for contract period (usually 10 years plus) a stable, no effort, low risk situation for the “representative of the owner”. Precondition for this value add though is the stable set-up of the supplier.

Even though the set-up of the ESCo is not a product or service as such, it is one of the main pain relievers and gain creators for the “representative of the owner”. Only an organization that is set-up in a way and can be trusted to exist for the long contract period can actually provide the security that the guarantee of results and costs is actually fulfilled. As mentioned this business model assumes that “contracting” is the sole product or service the ESCo offers. Based on this assumption the size of the ESCo will be limited and key assets/resources - as will be discussed later in detail 5.5 – are expertise and human resource. Therefore, in order to be able to secure the set-up that will create trust with the customer the partnering, especially with the TCS technology partner, is a key criteria for the business model – see 5.7.

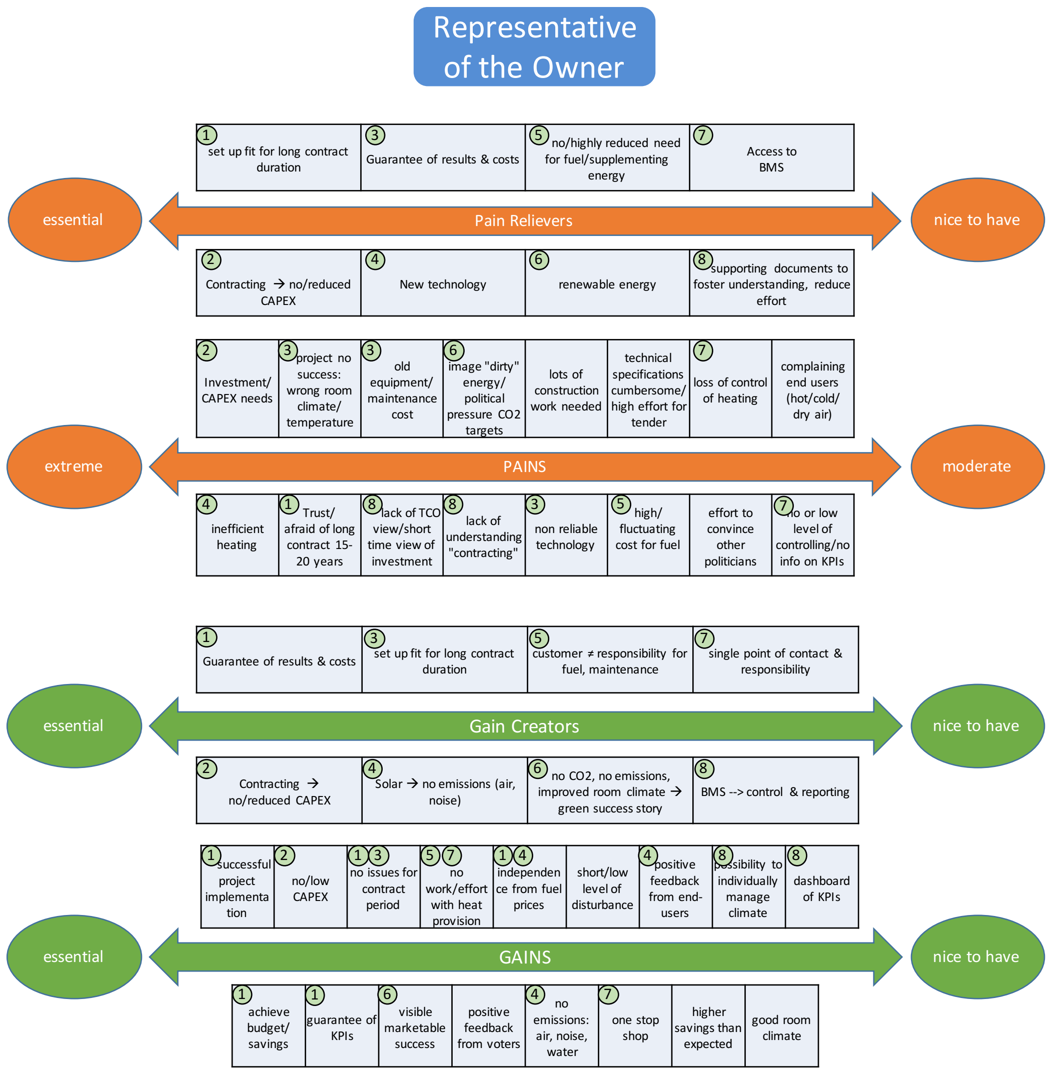


Figure 20. Mapping of pain relievers and gain creators to the pains and gains for the representative of the owner – own illustration

Detailed mapping of pain relievers and gain creators to the pains and gains of the customer roles involved are shown in, Appendix 1 and Appendix 2.

5.2 Channels

5.2.1 Awareness Phase

Given the circumstance that TCS are at this point of time still in R&D phase, this business model considers the situation that TCS are newly entering the market. Therefore, the awareness phase will be of utmost importance. The same is true for the model of EC. Even if EC is already established in some countries to a certain extend still in several other countries it is not yet a common model.

In order for a ESCo to be successful in offering EC services based on solar thermal energy and TCS the ESCo will have to invest in creating awareness for the technical solution and also for the EC model. Already in the value proposition above the according "supporting documentation" was highlighted as an important pain reliever for the customer. In the awareness phase the ESCo needs to deliver this value proposition to the different customer roles.

The awareness phase in this business model for public customers comprises the period from initial information in publications to create general awareness, to direct contact with interested stakeholders prior to tender definition up until the formal tender is published.

The channels in this awareness phase need to be individual for each of the roles defined in the Building Block "Customer Segments", especially the interaction in between the roles needs to be considered – see Figure 21.

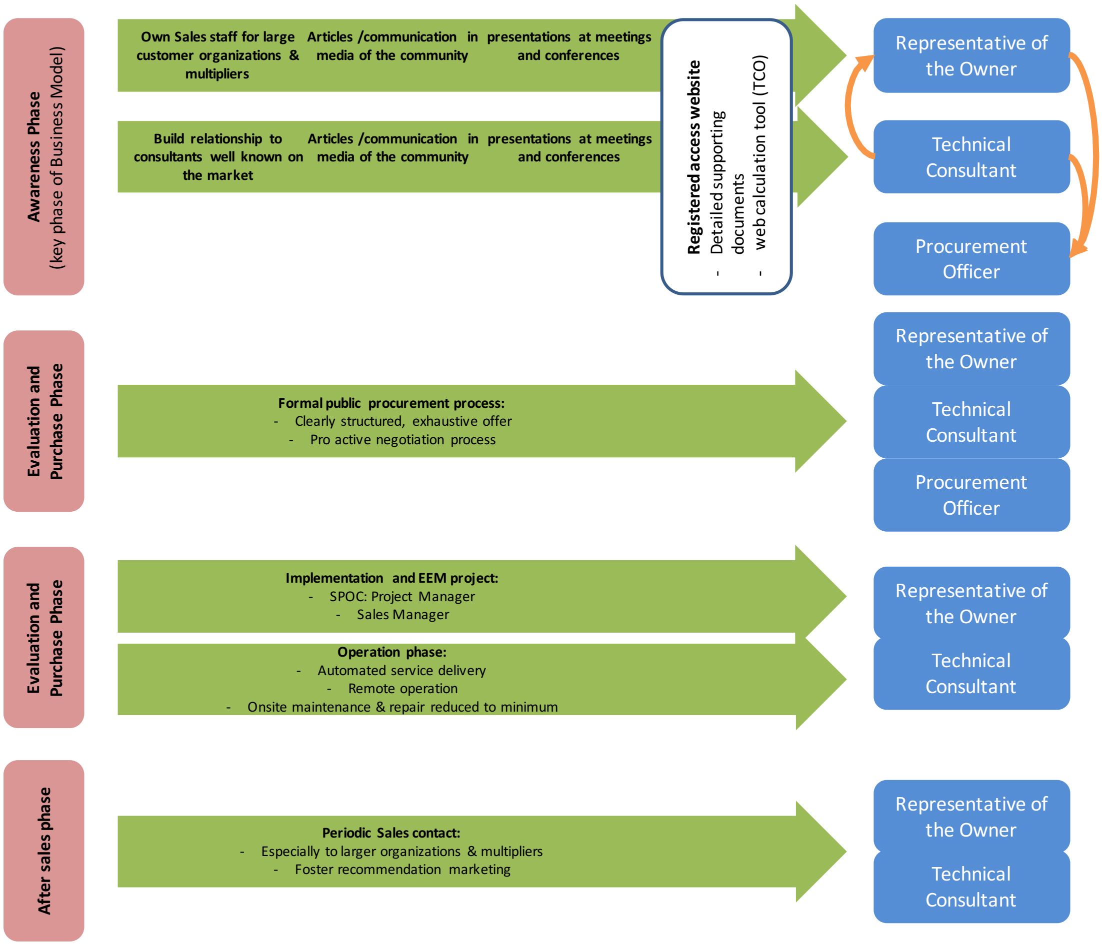


Figure 21. Building Block Channels – own illustration

5.2.1.1 Addressing "technical consultants"

The "technical consultant" might only be involved after a basic setup for the tender is defined, but often the "technical consultant" will be in contact and discussion with the "representative of the owner" and even with the "political responsible" even before the decision to start a tender was taken. So to create awareness with "technical consultants" will be crucial for the ESCo. The "technical consultant" has to be considered as a multiplier and as a channel itself.

The creation of awareness with "technical consultants" needs to be driven by different means. To create general awareness and interest in the community of technical consultants' articles and success stories of prototypes could be published in different media of the community, like magazines of chambers of civil engineers or community websites. Furthermore, presentations or speeches at summits, conferences, expos or specialized fairs can be considered to raise interest in the technical solution and the contracting model.

In addition to these general measures a direct sales relationship needs to be build up with established and well known "technical consultants" in the market, both internal and external technical consultants.

As an accompanying measures a well-designed website should be implemented which is communicated at each of the above mentioned interactions with "technical consultants". The website should have a public site with initial basic supporting documentation. More detailed supporting documentation needs to be limited to registered users respectively individual request. This will allow to identify interested "technical consultants" and if needed track their research on the website. Based on this information again direct sales contact can be established.

5.2.1.2 Addressing "representatives of the owner"

The creating of general awareness will be similar to the approach for "technical consultants" although communication and presentation will be in different media and at different meetings. In general it should be assumed that the information needs to be provided on a different level of technical detail and that information should be focusses more on commercial and political topics.

Given the large group of potential customers – nearly every village has some municipal office or school – direct sales contact with own sales force needs to be selective. Focus should be on one hand on large public property management organizations. On the other hand multipliers should be identified. This could be mayors that are active in associations of municipalities or that are also representatives in other political bodies like regional parliaments.

As for the "technical consultants", the "supporting documentation" should be provided to the interested "representatives of the owners" via the restricted area of a website or upon direct request.

5.2.1.3 Addressing "procurement officers"

If again assuming that "procurement officer" is a separate role in the procurement process limited to formal operation of the public procurement process, the interaction in the awareness phase will be limited.

The "procurement officer" will primarily be triggered by the roles "representative of the owner" and by the "technical consultant". Assessment of demand and requirement definition is usually not driven by the formal role "procurement officer", rather by the "technical consultant" or the "representative of the owner". By the requirement definition though the decision to either procure installation of a heating system or heat provision services, so to "make" heat or "buy" heat and thus outsource, is taken. Therefore, the roles of the "technical consultants" and the "representative of the owner" can be considered as channels towards the "Procurement officer". The role of the "procurement officer" will then have to secure compliant public procurement process. As mentioned above the supporting documentation on contracting and connected TCO calculation can be an important pain reliever for the procurement officer, to support him in defining the tender and evaluation criteria suitable for EC.

5.2.2 Evaluation and purchasing phase

The evaluation and purchasing phase starts with the formal publication of a tender and is very much formalized by the public procurement laws. Interaction with the customer are in general limited to formal Q&A sessions, documents and offers submitted and negotiations. Direct contact with the "procurement officer" and the "representative of the owner" are prohibited. Potential contact could still be an external "technical consultant" if he has no formal role in the procurement, e.g. member of the evaluation committee.

Any individual help for the customer to evaluate the value proposition needs to be provided in the awareness phase. In the evaluation and purchasing phase this support is limited to providing clearly structured, exhaustive offers, compliant with published requirements and price sheets. In the offers and negotiations, the ESCo needs to introduce all required tools and processes that will secure efficient project management, acceptance and finally guarantee of results. The key activities of the ESCo especially relate to this phase – see 5.2.2.

5.2.3 Delivery phase

The delivery of the core products of the ESCo is split into two phases or stages: First, the implementation project, when the heating system is installed and second, the operation phase, when actually heat is provided to the building.

After the public procurement process is finalized the involved customer roles will change. The "procurement officer" is not involved anymore. With regard to the "technical consultant" the further involvement in the delivery will be different per project. Internal technical consultants, e.g. experts of the property management company, will most probably be involved in the delivery phase, especially in the project phase. External consultants hired especially for the procurement process will pull out once the public procurement is formally finalized. In some projects, especially when buildings are owned by smaller public entities, the "representative of the owner" might extend the contract of the external supplier in order to secure his expertise in the project phase to control the ESCo and its performance. If the "technical consultants" stays involved in the delivery phase, he will still be a very important contact for the ESCo and a channel to the "representative of the owner".

The main interface for the ESCo will be the "representative of the owner". Often though the person having this role will change once the public procurement is finalized, e.g. a mayor of a village might strongly involve himself in the procurement process but might delegate the task of project manager on customer side to an employee of the municipality or in public property management organizations dedicated project managers might be assigned to manage projects on customer side.

5.2.3.1 Implementation project

The installation of the heating system is part of the core product of the ESCo. It is a precondition for the future provision of heat as a service. To be the single point of contact and responsibility is an important value proposition of the ESCo. Therefore, the delivery of the value proposition should be provided directly by the ESCo.

On one hand there needs to be a Project Manager responsible for execution of the project, for coordination of partners and project related communication with the customers' project manager. However, the Sales Manager should stay involved allowing the project manager to be consequent in executing the contract and in driving the customer were needed, while the sales manager can attend the position of the customer.

A crucial part of the implementation project is the acceptance phase.

5.2.3.2 Operation phase

Depending on the contracting model chosen the contractual term will last from 10 years up to 25 years (Bleyl-Androschin & Schinnerl, 2008).

In order to be competitive, operation and maintenance services to be provided will have to be automated as far as possible. Any manual system operation and controlling need to be executed via remote access to largest extend. Based on this predominant automated or remote service provision and having no need for any "fuel" delivery, personal interaction between the ESCo and the customer for delivering the value propositions will be very limited. Interaction regarding service provision will mostly be limited to the BMS, which should as mentioned above also provide a customer interface, to allow for individual settings and controlling.

Actual onsite service provision will be limited to periodic maintenance and, if any, possible repair work.

5.2.4 After Sales Phase

Given by the character of the services the after sales phase is overlapping with the operation phase. From sales perspective though the aftersales channel with personal interaction needs to be maintained, especially with larger public entities that represent or own further public buildings, but also with "smaller" customers to leverage on personal recommendations and references to create further awareness.

5.3 Customer relationship

The basic character of the business model is business to business project and service business. Standardization needs to be achieved in the processes of planning, modelling and operation, still as every building is unique every project is unique, therefore the customer relationship basically needs to be a personal relationship based on personal assistance to the customer. This is especially true for the awareness, the evaluation, the purchasing and the project delivery phase.

Certain supporting products, like the supporting documents, are standardized and thus can be offered in a self-service relationship via a website as mentioned above. Still when the customer needs more detailed information and documentation, it should be provided again with personal assistance as the technology of TCS and the contracting models are not standardized in a way that the customer could configure the product for the project in scope by himself.

5.4 Revenue streams

In general revenue streams of the different contracting models have been defined in literature - (Bleyl-Androschin & Schinnerl, 2008) (Bleyl-Androschin, 2011) – see also Figure 14. The revenue streams will basically be -) energy price for consumed energy, -) Service Price to cover services, operation, maintenance, risk and profit of the ESCo and -) capital cost to cover the investment and the interest.

5.4.1 Energy price for consumed energy

Based on the technology offered in addition to solar radiation only electricity is needed to operate supporting units, like pumps, evaporators and controls – assuming 100% solar fraction of the system. Thus the energy costs will be low. Operating pumps in the system usually have up to 100W power only (Weiss, 2015). For the operation of the storage system roughly 10% of the energy extracted for the storage needs to be supplied in electricity (Engel, electricity demand of thermochemical storage prototype, 2016). Based on this the ESCo could actually decide to refrain from a revenue stream for consumed energy. Energy consumption only needs to be invoiced if the heat consumption of the customer exceeds the amount defined in the Service Level Agreements (SLA) and thus the energy provided by the solar and storage system are not sufficient and heat has to be generated by supplementing energy, e.g. electricity or back-up gas firing systems.

Any need for supplementing energy due to insufficiency of the solar and storage system, e.g. based on technology issues, planning mistakes, etc. while the customer does not exceed consumption defined in the SLA, cannot be invoiced to the customer, as this is covered by the guarantee of costs and results by the ESCo. If, however KPIs defined in the SLA are not met supplementing energy demand needs to be invoiced to the customer. Such deviation could be:

- lower annual solar radiation than defined in the contract as minimum – the ESCo cannot bear the risk of changing climate or weather anomalies
- higher heat demand due to more heating degree-days again due changing climate or weather anomalies
- lower solar radiation due to new shadings on the collectors that have not existed at the time of planning the system, e.g. new or higher buildings or trees.

In order to be able to track and control sufficient monitoring and metering needs to be implemented in the solar and storage system and in the monitoring & operation system.

5.4.2 Service price

The service price needs to include all operation related cost, i.e. the cost for operation & maintenance, personal, insurance, management etc. of the energy supply infrastructure, the EEM as well as entrepreneurial risk. (Bleyl-Androschin, 2011)

As these costs are independent from the actual consumption of heat this service price should be defined as a flat fee.

5.4.3 Capital cost

Capital Cost need to cover the investment of the ESCo and the financing cost. The capital cost will be the largest part of the revenues streams from the customer as the full solar thermal system and the storage will have to be invested by the ESCo.

5.5 Key resources

Again referring to the assumption that the products defined above are the sole products of the company, the key resources of the company in this business model will be mostly intellectual and human.

The key resource of the ESCo will be persons knowledgeable on designing, planning and implementing of heating systems, solar thermal systems and TCS. Leveraging on the experts the ESCo will have to develop standard system designs, standard calculation models and a stable partner network, especially to the suppliers of the new technology of TCS systems. An exclusive partnership with the supplier of the TCS system would further emphasize this key asset.

Another key resources will be the sales staff of the ESCo. Based on the fact that TCS is a new technology the awareness phase will be key for the ESCo – as mentioned above. In this awareness phase the staff involved should have good connections with potential customers – with different roles of the customer discussed above: “political responsible”, “representatives of the owners” and “technical consultants”.

Key resources acquired from partners will be the TCS and the BMS. The TCS is the core technology of the business model that will allow to achieve 100% solar fraction. The TCS has to be fully reliable for the full life-cycle of the heating system – so for 20 years and more.

Another key resource especially for the operation phase will be the BMS. The BMS has to support operation of several buildings and heating systems. It needs to support customer access in order to secure the possibility for the customer to manage his heating system within the defined limits and have his own monitoring and reporting possibilities. As the BMS need to be in operation 24x7 the ESCo should consider to source the BMS as a service from the provider or outsource the operation of the BMS.

5.6 Key activities

Key activities of the ESCo will be related to the different phases discussed above in the building block channels - 5.2. In the awareness phase, it will be marketing and establishing the product and technical solution in the customer segment. Another key activity in the awareness phase will be the set-up of strategic partner ships regarding the core technologies – further details below 5.7.

The evaluation and purchasing phase will be most critical for the success of the individual projects. In this phase the key activities – all closely linked to the key human resources of the ESCo – will be the end-to-end design of the solution, the business case and the contracting model. This includes especially:

- the design and definition of assumptions and pre-conditions, e.g. minimum annual solar radiation, customers' obligation to prevent shading of collectors
- the definition of SLA, including clear KPIs for the services provided

Further key activities relevant for the evaluation and purchasing phase are the project planning and individual contracting with the partners.

Key activity in the implementation phase will be project management and in the operations phase the highly automated remote operation and maintenance.

5.7 Key partnerships

The definition of partnerships is again highly related to the assumption that contracting services are the sole offering of the ESCo. In Figure 22 the key partnerships identified and the type of relationships are shown.

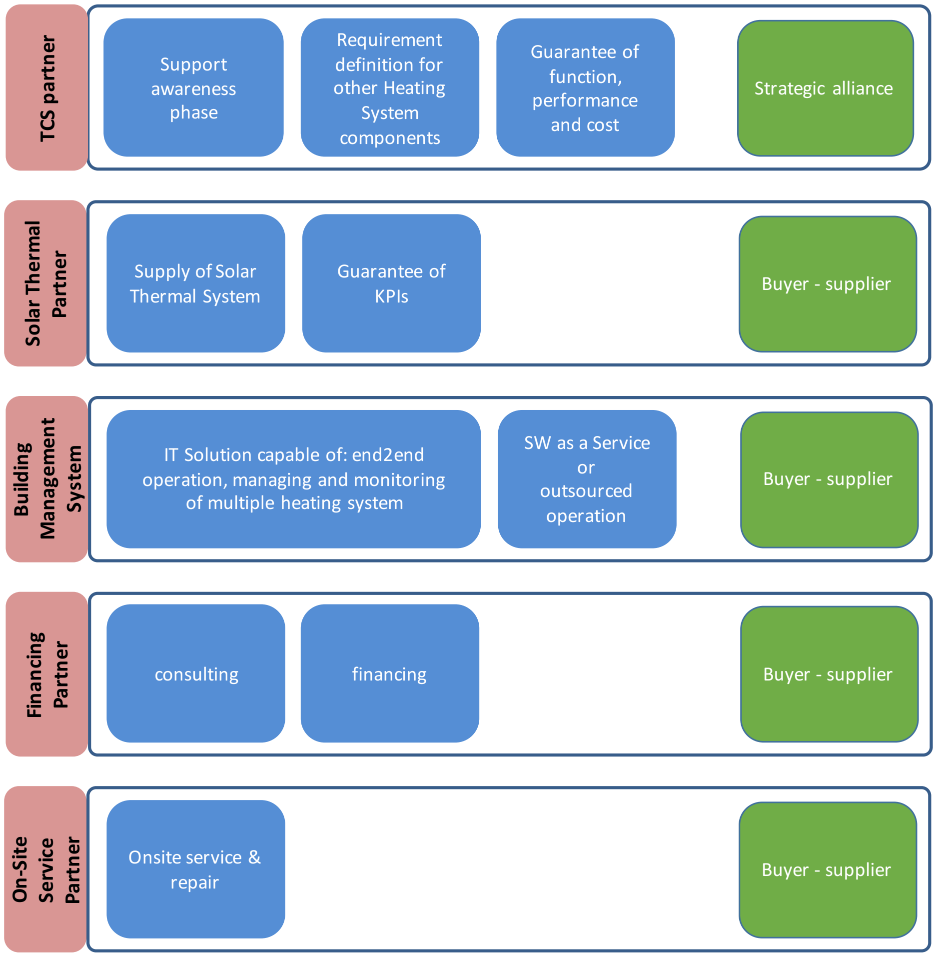


Figure 22. Partnerships of the business model – own illustration

5.7.1 Provider of thermochemical storage

The TCS will be the decisive and crucial element of the heating system to be able to provide with solar thermal technology full year space heating and domestic hot water supply with 100% or close to 100% solar fraction. Resulting from the fact that it is a new technology, no or low experiences from real life installations are available. Therefore, the trust in this new technology which is necessary to convince the customer to accept it for a 10-20 years contract needs to be secured by the trust in the company offering the technology. This trust can be provided by the ESCo, when it is clear that the ESCo has the set up and the financial power to cover technological short comings, e.g. by replacing the technology or by generating lacking heat with alternative energy sourcing. It can however be expected that a customer will have more trust in a new technology if a well-established, financially liable company develops, produces and offers TCS as a new and additional innovative product. This should be an important factor for the ESCo to consider when selecting a partner for provision the storage system.

Especially at market introduction of the technology storage providers will not easily be interchangeable – different loading and discharging temperature for each storage material, different mass flow of the heat transfer fluid, etc. Other units and elements of the solar thermal system are for more standardized already.

The partnering with the provider of the TCS will be crucial for the business model. It should be set up as a strategic alliance. In the awareness phase the TCS provider will have to provide marketing material, participate in consultant and customer community events, be ready for visits to prototype sites, etc. In the evaluation and purchasing phase the TCS provider needs to provide detailed input to the offer and detailed requirements regarding interfacing systems, like solar thermal system, heating installations (radiators, etc.) and control systems. For the operation phase the TCS partner has to provide the guarantee of performance of the storage for the full contract duration.

The set-up of the partnership not only has to create the trust of the customer, but it also needs to create sufficient security the ESCo to offer contracting based on this new technology instead of well-established technologies, like biomass boilers or heat pumps. To mitigate his risks, the ESCo therefore needs to secure sufficient instruments in the partnership to secure performance of the TCS System and the TCS technology partner. Such instruments should be:

- Clear definition of scope, requirements, performance KPIs, timeline and responsibility
- contractual guarantee of function, performance and price
- bank guarantee supporting the contractual guarantee
- liability clauses securing possibility for the ESCo to claim additional costs, e.g. exceeding supplementing energy in case solar fraction is not achieved

An alternative approach to these contractual instruments could also be to form a Joint Venture with the TCS technology partner. Of course also in the company agreement clear split of responsibility needs to be defined.

5.7.2 Solar Thermal System

Given the fact that solar thermal technology is already a widespread and well established technology, the partnership to the solar thermal system provider can be limited to a standard buyer-supplier relationship. Different suppliers for collectors and other units of a standard solar thermal system are on the market. The equipment manufacturer has to guarantee the KPIs of the solar thermal system according to specification in the back-to-back agreement with the ESCo. Having this buyer-supplier relationship for single projects will allow the ESCo to make use of competition among equipment manufacturers.

Alternatively, of course the ESCo can choose to have a strategic alliance with a single equipment manufacturer which will allow the ESCo to focus its time on other tasks. In this case the partnership agreement should include mechanisms to secure competitive prices for the solar thermal systems, e.g. periodic benchmarking processes.

5.7.3 Building Management System

As mentioned above this paper subsumes under Building Management System an IT-System that allows to operate, manage and monitor end-to-end the full heating system and room conditions. The ESCo will need such a system to monitor especially the charging status and discharge of the storage. Based on this information the ESCo will have to decide if supplementing energy for heat generation is needed and will have to plan energy consumption to reduce cost. The system will have to allow the ESCo to operate several heating systems in parallel.

Even though the choice of the BMS will be critical and important decision for the ESCo a standard buyer-supplier relationship should be sufficient. As the ESCo needs the BMS 24x7 the ESCo should consider to outsource operation or procure the BMS from the supplier as a Service with according SLA and penalty regulations.

5.7.4 Financing partners

As discussed above the ESCo will have to cover the investments for the heating system. In some projects the customer might cover parts or the full financing. “Financing can be provided by the building owner, the ESCo or a third financing partner, depending on who can offer the better conditions.” (Bleyl-Androschin, 2010). Considering above evaluations regarding the positioning and set-up of the storage partner (partial) financing could also be provided by this partner.

“Financing is not necessarily their (ESCo) core business. ESCo’s can be considered as a vehicle and facilitator for financing. In many cases including a financing institution (FI) as a third party to take over financing matters and risks makes good sense.” (Bleyl-Androschin & Schinnerl, 2010).

The contractual relationship will basically a buyer-supplier relationship. This will allow to achieve better conditions on the market.

5.7.5 Onsite Service Partner

For reasons of cost optimization, the basic target is to provide most of the operational service remote via the BMS. Still some periodic maintenance and potentially some repair work will be necessary on-site. The ESCo has to evaluate individually if a maintenance contract with the supplying partner for the full contracting period is cheaper or if the maintenance responsibility after a certain period will be taken over by the ESCo. The ESCo can have own staff for maintenance, this might be feasible if all buildings for which the ESCo provides contracting services are within a certain proximity. If the buildings in service are however distributed it can be more cost effective if the ESCo works with an onsite Service Partner.

5.8 Cost structure

The cost structure of the business model can be seen from two perspectives: on one hand the cost structure of the company as such and on the other hand, in the given business model even more important, since it is a project driven business model, the cost structure of the single contracting project. See Figure 23

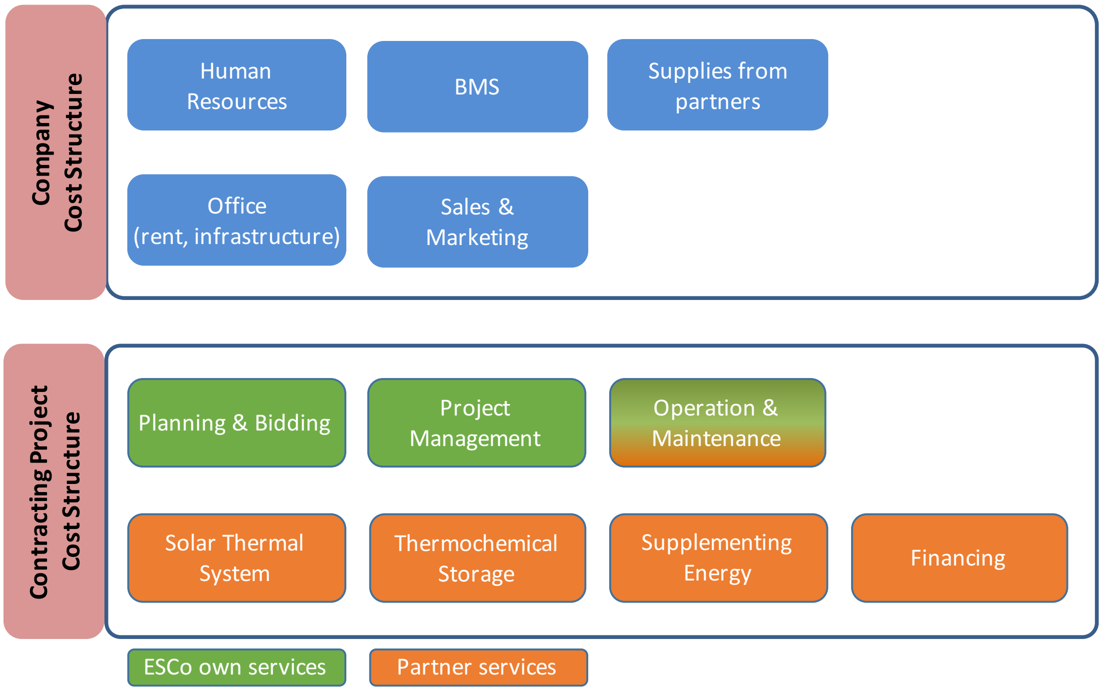


Figure 23. Cost Structure of the Business Model – own illustration

5.8.1 Company Cost Structure

The ESCo as such is a knowledge driven service company. Human resource is the key resource of the ESCo so personnel cost is a key cost item. The ESCo will not produce any physical products itself, so no costs for machinery or productions sites will be necessary. All physical products will be supplied by partners; therefore, the supply of partners is the second key cost item.

Another cost item will be the BMS, which was defined as another key resource and also as a service to the customer. As discussed above the ESCo should consider to outsource the operation or to procure the BMS as a service. When outsourcing option is chosen the investment in BMS licenses have to be considered in the company business plan. When BMS as a service is chosen only monthly services will occur.

Otherwise the ESCo will have rather unspecific cost items like cost for office space and office infrastructure (including Standard Software) and especially in the awareness phase cost for Sales & Marketing.

Optimization of the cost structure for the company will mainly be possible in the procurement from partners, especially from partner services were competition can be leveraged. Given the dependency on the experience and knowledge of involved human resources, optimization potential of personnel cost will be limited.

5.8.2 Project Cost Structure

As the business model is based on single projects or contracts that are independent from each other, the project cost structure will be of crucial importance for the company.

Cost items in the project can be divided in own services and partner supplies – see Figure 23. Planning and bidding (end-to-end design of the solution, the business case and the contracting model - 5.6) are the key activities in the evaluation and purchasing phase, project management is key activity in the delivery phase therefore these services should be provided by ESCo's own staff. Remote operation should be provided by ESCo's own staff, maintenance – as discussed above – can be provided by the system supplier, by the ESCo or by an onsite service partner. All other key cost items in the project will be partner supplies, like the solar thermal installation and the storage system.

Optimization of cost of partner supplies have to be achieved in the procurement process. For own services ongoing process optimization within single projects and across projects has to be achieved, based on increasing experience and knowledge and based on economy of scale and scope.

5.9 Excursus: Variation of the Business Model for Energy Performance Contracting or Integrated Energy Contracting

The focus of this Business Model and Thesis is ESC for highly energy efficient buildings. If the building in scope of EC is not highly energy efficient a heating system based on solar thermal and TCS is most probably not feasible – see 3.4.1. In order to apply this heating technology EEM will have to be implemented first to secure sufficient energy efficiency of the building. Instead of the ESC model EPC or IEC should be applied to cater for the specifics of implementation of EEM – 3.3.2.

The above developed Business Model would need to be enhanced to cover also the value proposition of “implementation of EEM”. In an excursus the main enhancements which have identified in course of the development of the Business Model for ESC, are given.

The product “Energy Efficiency Measures” contains all potential measures to decrease heat demand of a building, like insulation of the façade, the top floor or the basement, but also exchange of windows or heating controls. The product/service “Energy Efficiency Measures” contains all necessary planning, management and execution/implementation of the measures.

Regarding channels, the difference in the awareness phase is limited, as EEM are well known in the market and do not need special introduction. In the evaluation and purchasing phase special focus has to be on the scope of EEM in the offer and the according acceptance phase, including the respective definition of QAI – see 3.3.2.3. In the delivery phase of course, the initial implementation project will be much more extensive and the quality of the implementation of the EEM is crucial for achieving the planned energy efficiency and thus crucial for achieving the guaranteed heat supply with the planned heating system. The execution of the defined QAI is also part of the implementation project. The operation phase is not different to the Energy Supply Business Model.

In the cost building block, the capital cost block of the different revenue streams is more in focus. The investment in EEM will often exceed the cost of the heating system. Extensive EEM cannot fully be covered by energy cost savings, therefore the customer will have to cover some of the investment or to grant a building allowance for the EEM (Bleyl-Androschin & Schinnerl, 2008). Depending on the customers’ budget and financing situation it might also make economic sense if the customer partly or fully covers the financing.

Given the importance of sufficient and effective EEM for full contracting period another key resource for the ESCo will be a person in the team that has experience and knowledge regarding EEMs. Also the key activities in the business model need to be enhanced by designing, planning and execution of EEM.

The list of partners will have to be enhanced by one or more partners for EEM. Similar as for the solar thermal system the services for implementation of different EEM are introduced in the market and a high number of potential partners are on the market. Different models to realize EEM are possible; the ESCo can directly contract the single contractors for specific measures like façade works, exchange of windows, installation of new room heating system and act himself as general contractor for the EEM. Or, the ESCo signs a General Contractor to implement all EEM with sub-contractors.

A general preference cannot be stated in as this is highly dependent on the structure of the ESCo, on the experience of ESCo and its human resources and the extend of the EEM to be implemented. Same is true for the decision if simple buyer-supplier relationship for single projects should be contracted or if strategic partnerships should be established. A strategic partnership will allow to better leverage on sales contacts, references and relationship of construction companies established in the customer segment. On the other hand, single buyer-supplier relationship will secure more competition and thus betters prices.

The products and services provided by the contractors will depend on the role of the ESCo in the implementation of the EEM. If the ESCo takes the role of a General Contractor suppliers need to deliver according to specification. If a construction company takes the role of the General Contractor, this construction company will have to take responsibility to delivery according to defined performance requirements.

Another impact of enhancing the business model by EEM is the fact that the role financing partner will be more important, as the amounts to be financed will be much higher.

6 Case Study Primary School in Lower Austria

6.1 Selection of case study

In order to analyse under which circumstances the heating system based on solar thermal technology and TCS can be competitive in contracting models a case study was conducted. For the case study a fictional newly build primary school in Lower Austria, city of Baden bei Wien, was selected. By comparison of TCO for different heating systems (biomass heating system and a heat pump) and target price for the TCS was calculated.

A primary school was chosen based on the consideration that in nearly every village there are school buildings or kindergartens, which are similar regarding building and heating requirements. In many villages there is no district heating network and thus the school buildings have to be heated by heating systems installed on-site.

For the case study a newly build school has been chosen in order to have clear minimum requirements defined by local building regulations. Also it allows to neglect any limitations of the existing building regarding available room for storage (TCS or biomass) and limitations of installation of collectors (solar or ground collectors).

The city of Baden bei Wien is 25 km from the city borders of Vienna and located in the middle growing southern urban catchment of Vienna – political districts of Mödling, Baden bei Wien and Wiener Neustadt (source: Statistik Austria, www.statistik.at). Especially families with children move to villages of this southern catchment. In the region therefore additional schools or retrofit or extension of existing school will be necessary.

As already mentioned above TCS are yet in R&D phase and only initial prototypes for seasonal storage have been implemented. At this point of time no sufficient commercial data is available to define future cost of TCS systems (Engel, Dimensioning of thermochemical stroage systems, cost of components, 2016). A tool for the economic evaluation of thermal energy storages was developed by Rathgeber et al. This tool however compares in the top down approach the storage cost per kWh to the market price of energy. Cost of heating systems, like biomass boiler, heat pump or solar thermal collectors, are not considered. In the bottom up analysis of cost of thermal storages focus is on sensible and latent storage materials, which are already at a higher development stage or on the market. For TCS only one industrial mobile storage and household applications of TCS (e.g. dishwasher) have been analysed. (Rommel & et al., 2015).

As no sufficient data is available to estimate the cost of the TCS needed, the case study cannot compare the TCO of the full solar thermal and TCS system. In this case study only the TCO of a "conventional" solar thermal system is calculated and in comparison to calculated TCOs of the competitive heating systems a target price for the storage is derived.

6.2 Assumptions and limitations of case study

6.2.1 Legal parameters

The province of Lower Austria has adopted the "Pfichtenheft Energieeffzienz und Nachhaltigkeit für NÖ Landesgebäude 2014" (≈ "specifications for energy efficiency and sustainability for public buildings in Lower Austria 2014"), which regulates in detail all requirements and specifications for newly built or retrofitted public buildings.

Relevant regulations for heating of newly build public school buildings:

- Target value heat demand for schools (8.1.1): 10 kWh/m^2/a
- U-Values (8.3):
  - Outside air facing wall: 0,2 W/m^{2}K
  - Outside air facing ceiling: 0,15 W/m^{2}K
  - Outside air facing windows: 1,2 W/m^{2}K (wood & synthetic frames), 1,4 W/m^{2}K (metal frames)
- Use of highly efficient alternative energy heating systems (9.1.1)
- Minimum COP heat pump ground water (9.1.5.2): 3,8 at 35°C flow temperature heating circuit, 3 at 55°C
- Efficiency factor (η) bio mass heating system (9.1.2): ≥ 80%
- Room temperatures (9.3.1) a.o.:

    - Class rooms: 20°C
    - Corridors, secondary rooms: 15°C
    - Gym: 16°C

6.2.2 Assumptions and limitations of TCO and target price calculation

Based on the legal requirements only renewable heating systems will be compared: Biomass and heat pump. For the Biomass heating system pellets where chosen as fuel, to exclude manual effort for heating. The heat pump will use groundwater as heat source, which will allow higher power of the same heat pump system compared to air or ground (brine) as heat source.

The TCO analysis was done from ESCo point of view and from customer point of view.

As the case study is based on a new school building, no EEM have to be implemented, therefore an ESC model would apply. A contract term of 10 years is applied – 10 – 15 years is usual term (european association of energy service companies, 2010). The TCO analysis for the ESCo is limited to 10 years. The analysis for the customer though is done for 25 years, given the useful life of solar thermal collectors of more than 20 years (Viessmann GmbH, 2008). In this case study reinvestments in the assumed periods are not considered.

In order to focus on the cost of the heating system, all cost that are common to the different systems are not considered, e.g. plumbing or pumps – assuming they have similar cost. Only specific costs of the different systems are considered:

- Biomass:
    - Investment
        - Furnace
        - Pellets transportation system
    - Operating cost:
        - Pellets
        - Electricity
        - Maintenance & repair
- Heat pump:
    - Investment

        - Heat pump
        - Accessories
        - Tapping of groundwater heat source
    - Operation
        - Electricity
        - Maintenance & repair
- Solar Thermal
    - Investment
        - Solar thermal collectors & mounting
        - Short-term water storage
    - Operation
        - Electricity
        - Maintenance & repair

For all systems 100% debt financing was assumed and financing cost were considered in the 10 years' term of the Energy Supply contract. In the TCO calculation 3% interest rate for financing was assumed. For Net Present Value calculation, the investments for the ESCo was considered in year 0 as cash out and in the years 1-10 interest is included as cash out. In the NPV from customer perspective the investment and interest was included as monthly instalments in the initial 10 years. As WACC 4,5% were considered in the TCO calculations.

The additional cost of the ESCo invoiced to the customer, e.g. risk mark up, overhead and profit are not considered, again assuming that these cost will be similar for all heating systems.

As public customers cannot deduct VAT, all cost for the customer were increased by the Austria VAT rate of 20%.

6.2.3 Case study building - heat load and heat demand

The fictional school building of the case study is situated in the region of Baden bei Wien in Lower Austria. The school building has a floor space of 1.500 m^2 at a room height of 3 m on 2 floors and an attached gym of 450 m^2 with a room height of 5,5 m. Based on the legal requirements of maximum heat demand per m^2 of 10 kWh the annual heat demand of the school will be 19.500 kWh.

In order to calculate the necessary heat load of the heating system further climate data has to be considered. Geographical and climate data of Baden bei Wien is cited in Table 2.

Table 2. climate data Baden bei Wien, Austria and heat demand – sources: see footnotes of the table

Baden bei Wien, Austria		
ZIP Code:	2500	
Latitude:	48°0'7"	North
Longitude:	16°13'51"	East
Optimal inclination angle is:	35	deg.
standard outside temperature: 3)	-12	°C
Heat Demand School		
area (1500m² school + 450 m² gym)	1.950	m²
max head demand acc. Regulation*	10	kWh/m² /a
annual heat demand	**19.500**	**kWh**

Month	H_h	H_{opt}	monthly irradiation in kWh	avg. Monthly temp	avg. monthly low temp	avg. monthly high temp	HDD	monthly ratio of annual HDD	Heat Demand in kWh
Jan	918	1.420	44	0	-2,6	3,4	548	18,14%	3.537
Feb	1.750	2.540	71	1,2	-1,7	5,5	423	14,00%	2.730
Mar	3.120	4.000	124	5,3	1,7	10,3	341	11,29%	2.201
Apr	4.730	5.380	161	10,2	5,6	16,1	136	4,50%	878
May	5.380	5.460	169	15,2	10,2	20,9	47	1,56%	303
Jun	5.610	5.430	163	18,2	13,3	23,8	13	0,43%	84
Jul	5.640	5.600	174	20,4	15,3	26,4	2	0,07%	13
Aug	4.830	5.280	164	19,7	15	25,8	23	0,76%	148
Sep	3.480	4.250	128	15	11,2	20,7	121	4,01%	781
Oct	2.150	2.970	92	9,9	6,7	15	297	9,83%	1.917
Nov	1.080	1.630	49	4,6	2,2	8,1	477	15,79%	3.079
Dec	752	1.190	37	0,7	-1,6	3,7	593	19,63%	3.828
Year	3.290	3.770	1.375				3.021	100,00%	19.500

H_h : Irradiation on horizontal plane (Wh/m² /day) 1)

H_{opt} : Irradiation on optimally inclined plane (Wh/m² /day) 1)

HDD: Number of heating degree-days (-) 1)

avg. monthly temperatures (°C) 2)

1) PVGIS (c) European Communities, 2001-2012; http://re.jrc.ec.europa.eu/pvgis/

2) Zentralanstalt für Meteorologie und Geodynamik (ZAMG), climate data Austria 1981 - 2010, https://www.zamg.ac.at

3) source: http://www.ifea.tugraz.at/hp_old/heizlast/wertetab2.htm

Based on the climate data, the legal requirements of U-Values for the building and the building size, estimations of the required heat load of the heating system for building can be done. For the estimation the online tool of energieportal24.de was used and a combined heat load for the school and the attached gym of ~60kW was estimated – results see Figure 24

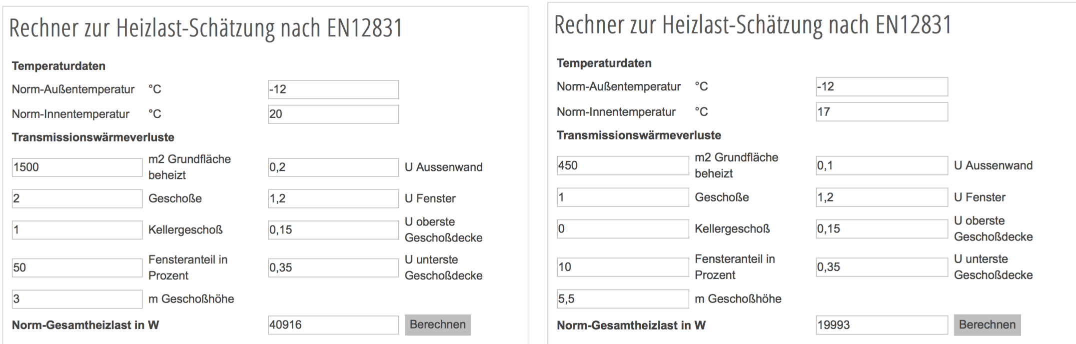


Figure 24. Heating load – school building and gym – source: http://www.energieportal24.de/cms1/wissensportale/heiztechnik/heizlast-berechnen/

6.2.4 Heating Systems – TCO calculations

6.2.4.1 Biomass

For the biomass heating system (pellet boiler and pellet feed system) an indicative offer was received from Windhager Zentralheizung GmbH. The BioWIN 600 pellet boiler with an 8 probe pellet feed system was chosen for the TCO calculation – Figure 25. From the defined annual heat demand and the boiler efficiency the annual pellet demand was derived. The annual cost of maintenance and the annual electricity demand is based on information by Windhager.

Prices for pellets is based on information from proPellets Austria (http://www.propellets.at) – 0,0455 €/kWh incl. VAT – Figure 26. Cost of electricity is based on information from e-control Austria – average annual cost of electricity including all cost for grid and taxes for business customers in lower Austria with 8.000 kWh is 1.400 €, resulting in 0,175 €/kWh incl. VAT - Figure 27.

The results of the TCO calculations for the biomass heating system from ESCo and customer point of view are shown in Table 3, the detailed calculations are attached as Appendix 3 and Appendix 4.

		BioWIN 350	BioWIN 450	BioWIN 600
Rated thermal output range	kW	10 – 35	13,5 – 45	18 – 60
Boiler efficiency at nominal load	%	91,2	90	90,1
Pellet fuel hopper	kg	135	135	135
Boiler weight – completely mounted	kg	700	700	700
Boiler part transport weight	kg	480	480	480
Installation dimensions W x D x H	mm	780 x 980 x 1.800		
Flue gas connection diameter	mm	150	150	150
Power consumption at nominal load	W	103	122	156
Power consumption at part load	W	43	53	63

Figure 25. technical data pellet boiler Windhager BioWIN 600 – source www.windhager.com

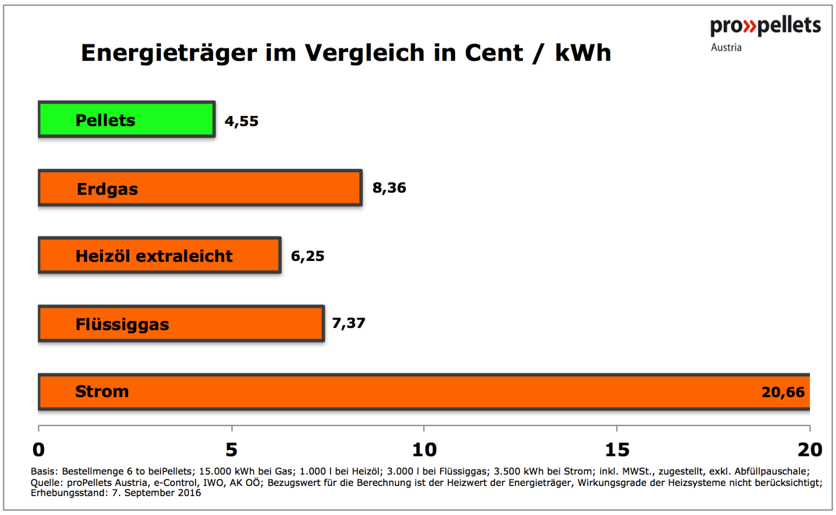


Figure 26. Pellet prices Austria September 2016 – source: www.propellets.at

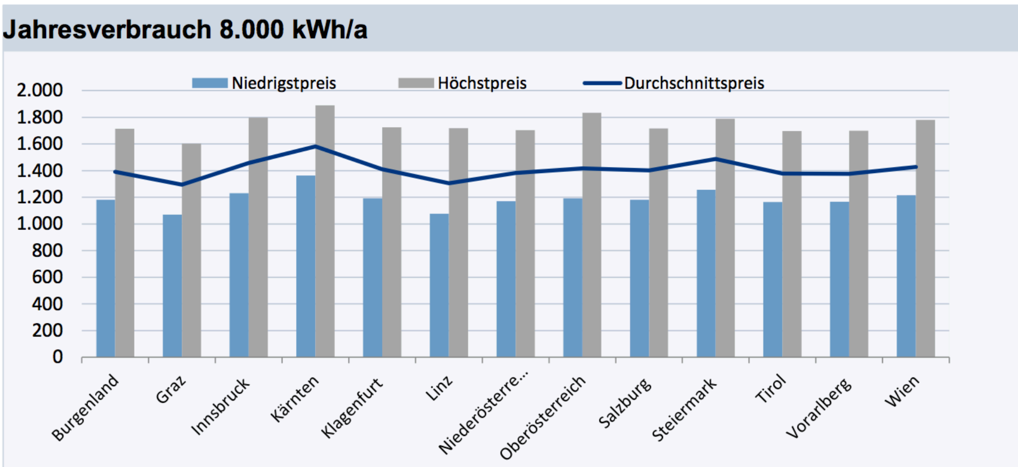


Figure 27. annual cost of electricity for business customers including all cost for grid and taxes – September 2016 – source: www.e-control.at

Table 3. case study TCO Biomass – input data & results – own table

ESCo Point of View				Customer Point of View			
	excl. 20% VAT	incl. 20% VAT			excl. 20% VAT	incl. 20% VAT	
Investment Costs	17.162,00	20.594,40	€	**Investment Costs**	17.162,00	20.594,40	€
Maintenance p.a.	250,00	300,00	€	**Maintenance p.a.**	250,00	300,00	€
Capacity biomass boiler	60		kW	**Capacity biomass boiler**	60		kW
Efficiency	90,00%			**Efficiency**	90,00%		
Annual heat demand	20.000,00		kWh	**Annual heat demand**	20.000,00		kWh
Biomass Input	22.222,22		kWh	**Biomass Input**	22.222,22		kWh
Biomass price	0,0379	0,0455	€/kWh	**Biomass price**	0,0379	0,0455	€/kWh
Electricity consumption p.a.	500,00		kWh	**Electricity consumption p.a.**	500,00		kWh
Electricity price	0,146	0,175	€/kWh	**Electricity price**	0,146	0,175	€/kWh
Annual price increase maintenance	1,00%			**Annual price increase maintenance**	1,00%		
Annual price increase Biomass	1,00%			**Annual price increase Biomass**	1,00%		
Annual price increase electricity	1,00%			**Annual price increase electricity**	1,00%		
Interest on financing	3,00%			**Interest on financing**	3,00%		
Financing period	10,00		years	**Financing period**	10,00		years
Monthly instalment	-165,72		€	**Monthly instalment**	-165,72	-198,86	€
Discount rate / cost of capital	4,50%			**Discount rate / cost of capital**	4,50%		
Investment Horizon	10,00		years	**Investment Horizon**	25		years
TCO Net Cash Flow	**-32.175,69**		€	**TCO Net Cash Flow**		**-63.674,86**	€
TCO Net Present Value	**-29.153,66**		€	**TCO Net Present Value**		**-41.971,41**	€

6.2.4.2 Heat pump

The heat pump system uses as heat source ground water. An indicative offer of Viessmann Gesellschaft m.b.H. for a Vitocal 300G 301.A45 heat pump system – data see Figure 28 –, necessary accessories and annual maintenance cost was obtained. The information on price ranges for tapping of groundwater heat source was found on the website of www.erdwaermepumpe.at - 4.000 € excluding VAT was assumed.

The results of the TCO calculations for the heat pump from ESCo and customer point of view are shown in Table 4, the detailed calculations are attached as Appendix 5 and Appendix 6

Vitocal 300-G single stage water/water heat pump*

Vitocal 300-G	Type	BW 301.A21	BW 301.A29	BW 301.A45
Output data (to EN 14511, W10/W35 °C, 5 K spread)				
Rated heating output	kW	28.1	37.1	58.9
Cooling capacity	kW	23.7	31.4	48.9
Power consumption	kW	4.73	6.2	10.7
Coefficient of performance ε in htg mode		5.94	6.0	5.5
Maximum flow temperature	°C	60	60	60
Dimensions				
Length (depth)	mm	1085	1085	1085
Width	mm	780	780	780
Height	mm	1267	1267	1267
Weight	kg	245	272	298
Energy efficiency class**		A++	A++	A++

Figure 28. Technical data heat pump – Viessmann Vitocal 300G 301.A45 – source: www.viessmann.at

Table 4. case study TCO Heat Pump – input data & results – own table

ESCo Point of View				Customer Point of View			
	excl. 20% VAT	incl. 20% VAT			excl. 20% VAT	incl. 20% VAT	
Groundwater heat pump	26.364,00	31.636,80	€	Groundwater heat pump	26.364,00	31.636,80	€
Groundwater well	4.000,00	4.800,00	€	Groundwater well	4.000,00	4.800,00	€
Investment Costs	30.364,00	36.436,80	€	Investment Costs	30.364,00	36.436,80	€
Maintenance p.a.	480,00	576,00	€	Maintenance p.a.	480,00	576,00	€
Capacity heat pump	58,90		kW	Capacity heat pump	58,90		kW
COP	5,50			COP	5,50		
Annual heat demand	20.000,00		kWh	Annual heat demand	20.000,00		kWh
Electricity consumption p.a.	3.636,36		kWh	Electricity consumption p.a.	3.636,36		kWh
Electricity price	0,146	0,175	€/kWh	Electricity price	0,146	0,175	€/kWh
Annual price increase maintenance	1,00%			Annual price increase maintenance	1,00%		
Annual price increase Biomass	1,00%			Annual price increase Biomass	1,00%		
Annual price increase electricity	1,00%			Annual price increase electricity	1,00%		
Interest on financing	3,00%			Interest on financing	3,00%		
Financing period	10,00		years	Financing period	10,00		years
Monthly instalment	-293,20		€	Monthly instalment	-293,20	-351,84	€
Discount rate / cost of capital	4,50%			Discount rate / cost of capital	4,50%		
Investment Horizon	10,00		years	Investment Horizon	25		years
TCO Net Cash Flow	**-40.989,49**		€	TCO Net Cash Flow		**-76.641,13**	€
TCO Net Present Value	**-38.741,39**		€	TCO Net Present Value		**-53.370,39**	€

6.2.4.3 Solar Thermal

The solar thermal system is based on simulations and an indicative price by GREENoneTEC Solarindustrie GmbH. GREENoneTEC used Vela Solaris Polysun simulation SW.

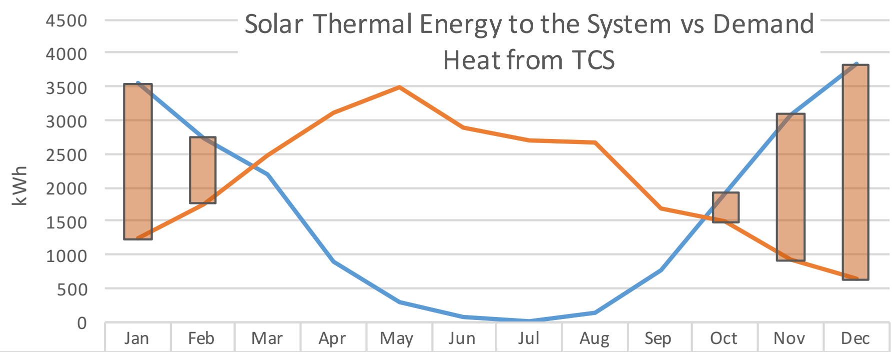
At this stage of TCS R&D there is no standard model for design and sizing of the thermochemical seasonal storage and the respective solar thermal system. Planning of prototypes is an iterative process of individual calculation of different configurations (Engel, Dimensioning of thermochemical stroage systems, cost of components, 2016). In this case study the TCS is therefore only defined by the amount of heat to be extracted, which is derived as delta of solar fraction of the solar thermal system and the calculated annual heat demand of the building. To assess the minimum size of the solar thermal system and the solar fraction two simulations were conducted. For the simulation and the TCO calculation GREENoneTEC VK 4250 CVC vacuum tube collectors have been applied – data of collectors Figure 29.

	VK4200	VK4250
Collector type	Roof-mounted collector	
Number of tubes	10	14
Overall area [m²]	1.84	2.57
Absorber area [m²]	1.69	2.36
Aperture area [m²]	1.60	2.23
L x W x H [mm]	1.120 x 1.647 x 107	1.560 x 1.647 x 107
Weight [kg]	31	42
Absorber capacity [l]	1.63	2.27
Housing	Al powder-coated	
Absorber sheet	Rolled Al-sheet	
Absorption [%]	96	
Emission [%]	6	
Ø manifold [mm]	18 (¾")	
Ø risers [mm]	8	
Connections	Coupling nut with flat seal	
Vacuum tubes	Borosilicate glass, high selective inside coating	
Reflection mirror	PVD-coated	
Insulation	Vacuum insulated	
Max. stagnation temperature	292 °C under test conditions	
Max. operating pressure	10 bar	
Heat transfer medium	Polypropylene glycol / water mixture	
Approved installation angle	min. 15°, max. 75°	
Packaging	customer specific	

Figure 29. Technical data solar thermal collectors – GREENoneTEC VK4000 Series – source: www.greenonetec.com

The first simulation, to assess the minimum size of the Solar thermal system, applied the largest standard water storage available in the Polysun simulation SW – 100.000 litres. This simulation allowed to reduce the stagnation days of the system to 3 days, as the storage is large enough to absorb all the heat generated by the collectors and thus full yield is used for heating or storage. In this simulation the water storage stores the heat, when having a TCS the heat would be used for respective chemical reaction of the storage material, e.g. desorption of Zeolite. The simulation showed that in Baden bei Wien ~50 m^2 of CPC vacuum tube collectors generate sufficient annual yield of ~25.000 kWh - Appendix 9

For the second simulation, the water storage was reduced to 5.000 litres, which is used as a short-term storage in combination with the TCS as seasonal storage. This second simulation showed a solar fraction of 61,4%. Based on this configuration 7.720 kWh of the assumed annual heat demand of 20.000 kWh will have to be extracted from the TCS - Appendix 10. In Figure 30 the monthly amount of solar thermal energy provided to the system based on the simulation is compared to the monthly heat demand of the school based on climatic data (Table 2), the delta in the months from October to February has to be covered by the TCS System.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Heat Demand	3.537	2.730	2.201	878	303	84	13	148	781	1.917	3.079	3.828
solar thermal energy provided to the system	1.227	1.758	2.476	3.117	3.485	2.900	2.704	2.668	1.692	1.492	918	624

Figure 30. Solar thermal energy provided to the system vs. heat demand – own table

For the TCO calculation, 20 collectors GREENoneTEC VK 4250 are considered based on the indicative quote of GREENoneTEC of 433 € excl. VAT. The price of mounting structures for the collectors is based on the price list of SEG Kioto GmbH (http://www.solarenergy.at), considering 2.050 € excl. VAT for mounting systems and 950 € excl. VAT for additional material needed. The price of the 5.000 litres water storage is based on the standard price list of Lorenz GmbH & Co KG (http://www.lorenz-behaelterbau.de) - 3.527 € excl. VAT for storage tank and 910+496 € excl. VAT for heat exchangers.

Electricity demand of the heating system has two components: first the pumps of the solar thermal system and secondly the pumps and the evaporator/condenser of the TCS. Electricity consumption of the solar thermal system is considered at a ratio of 1:50 compared to kWh produced by the solar thermal system (Viessmann GmbH, 2008). Electricity consumption of the TCS is assumed at 10% of heat extracted from the storage, based on experience with the current prototype of COMTES project in Gleisdorf (AEE INTEC, ITW, TH Wildau, Vaillant) (Engel, electricity demand of thermochemical storage prototype, 2016).

Maintenance of the solar thermal system is considered annually at 1,5% of the investment (Viessmann GmbH, 2008).

The results of the TCO calculations for the solar thermal system without TCS from ESCo and customer point of view are shown in Table 5, the detailed calculations are attached as Appendix 7 and Appendix 8

Table 5. case study TCO solar thermal w/o TCS – input data & results – own table

ESCo Point of View				Customer Point of View			
	excl. 20% VAT	incl. 20% VAT			excl. 20% VAT	incl. 20% VAT	
Price per collector	433,33	520,00	€	Price per collector	433,33	520,00	€
Number of Collectors	20,00			Number of Collectors	20,00		
Solarthermal heating system	8.666,67	10.400,00	€	Solarthermal heating system	8.666,67	10.400,00	€
5000l Waterstorage	4.933,00	5.919,60	€	5000l Waterstorage	4.933,00	5.919,60	€
Mounting structure	3.000,00	3.600,00	€	mounting	3.000,00	3.600,00	€
Investment Costs	**16.599,67**	**19.919,60**	**€**	Investment Costs	**16.599,67**	**19.919,60**	€
Maintenance p.a. assumed 1,5%	249,00	298,79	€	Maintenance p.a. assumed 1,5%	249,00	298,79	€
Absorber area	2,57		m^2	Absorber area	2,57		m^2
Collector area	51,40		m^2	Collector area	51,40		m^2
Annual heat production	25.000,00		kWh	Annual heat production	25.000,00		kWh
ratio electricticy consuption solar	2%			ratio electricticy consuption solar	2%		
Electricity consumption solar th.	500,00		kWh	Electricity consumption solar th. Sys.	500,00		kWh
Annual heat demand	20.000,00		kWh	Annual heat demand	20.000,00		kWh
solar fraction without storage	12.280,00		kWh	solar fraction without storage	12.280,00		kWh
heat extraction from storage	7.720,00		kWh	heat extraction from storage	7.720,00		kWh
ratio electricticy consuption TCS	10%			ratio electricticy consuption TCS	10%		
Electricity consumption TCS p.a.	772,00		kWh	Electricity consumption TCS p.a.	772,00		kWh
Electricity price	0,146	0,175	€/kWh	Electricity price	0,146	0,175	€/kWh
Annual price increase maintenance	1,00%			Annual price increase maintenance	1,00%		
Annual price increase Biomass	1,00%			Annual price increase Biomass	1,00%		
Annual price increase electricity	1,00%			Annual price increase electricity	1,00%		
Interest on financing	3,00%			Interest on financing	3,00%		
Financing period	10,00		years	Financing period	10,00		years
Monthly instalment	-160,29		€	Monthly instalment	-160,29	-192,35	€
Discount rate / cost of capital	4,50%			Discount rate / cost of capital	4,50%		
Investment Horizon	10,00		years	Investment Horizon	25		years
TCO Net Cash Flow	**-21.164,85**		€	TCO Net Cash Flow		**-37.870,12**	€
TCO Net Present Value	**-20.198,97**		€	TCO Net Present Value		**-26.840,51**	€

6.2.5 Target price for Thermochemical Storage

When comparing the investment costs of the above mentioned systems the solar thermal system without TCS is the cheapest. But the investment for the biomass heating system just 560 € more expensive. So when evaluating only the initial investment for the heating systems potential price for the TCS would be just 560 € which can never be sufficient for a TCS that needs to provide 7.720 kWh per heating season. Compared to the heat pump system that has the highest investment costs of the case study the target price for the TCS would be ~13.800 €. So based on comparison of initial investment only the solar thermal/TCS heating system cannot be competitive to Biomass heating system.

Assuming however a public tender that defines the TCO as evaluation criteria, the TCO from customer perspective is relevant for the target price analysis. The initial investment, respectively the contracting period of 10 years, might be more expensive for the customer but the long-term view of TCO is relevant for the customer. Therefore, the TCO of the ESCo is of limited importance for TCS target price analysis, as the higher price in the contracting period would be paid by the customer.

Comparing the Net Present Value of the TCO calculations from customer point of view of the alternative heating systems under the above-mentioned assumptions the solar thermal heating system without TCS is the cheapest, followed by the Biomass Heating System and most expensive is the Heat Pump System – 0. Also shown in 0 is the target price calculation for the TCS System based on the NPV of TCO to be competitive with the alternative systems. In order to be competitive with the Biomass System the TCS can have investment cost of ~13.000€ including 20% VAT, so ~10.800 € net. To compete against the heat pump system, the TCS investment can be up to ~22.800 € including 20% VAT or ~19.000 € net.

Based on the case study configuration of the solar thermal system, the TCS has to provide 7.720 kWh per season. This results in a target price of ~1,4 €/kWh to be provided from the storage system vs. biomass and ~2,5 €/kWh vs heat pump. These values though cannot be translated as price per kWh storage capacity as the simulation done for this business case cannot consider any intermediate loading periods during the heating season.

Table 6. Comparison TCO and Target prices TCS customer point of view – own table

Customer Point of View						
	Biomass	Heatpump	Solar Thermal	Solar Thermal TCS vs. Biomass	Solar Thermal TCS vs. Heatpump	
Investment core system	20.594,40	31.636,80	10.400,00	10.400,00	10.400,00	€
Investment related		4.800,00	9.519,60	9.519,60	9.519,60	€
target price TCS				***13.015,07***	***22.820,08***	€
Investment total	**20.594,40**	**36.436,80**	**19.919,60**	**32.934,67**	**42.739,68**	€
Maintenance	300,00	576,00	298,79	494,02	641,10	€
COP		5,50				
Number of Collectors			20	20	20	
Biomass Input	22.222,22					kWh
Biomass price	0,0455					€/kWh
Electricity consumption p.a.	500,00	3.636,36	1.272,00	1.272,00	1.272,00	kWh
Electricity price	0,175	0,175	0,175	0,175	0,175	€/kWh
Annual price increase maintenance	1,00%	1,00%	1,00%	1,00%	1,00%	
Annual price increase Biomass	1,00%	1,00%	1,00%	1,00%	1,00%	
Annual price increase electricity	1,00%	1,00%	1,00%	1,00%	1,00%	
Interest on financing	3,00%	3,00%	3,00%	3,00%	3,00%	
Financing period	10	10	10	10	10	years
Monthly instalment	-198,86	-351,84	-192,35	-318,02	-412,70	€
Discount rate / cost of capital	4,50%	4,50%	4,50%	4,50%	4,50%	
Investment Horizon	25	25	25	25	25	years
TCO Net Cash Flow	**-63.674,86**	**-76.641,13**	**-37.870,12**	**-58.464,87**	**-73.980,09**	€
TCO Net Present Value	**-41.971,41**	**-53.370,39**	**-26.840,51**	**-41.971,41**	**-53.370,39**	€

all prices incl. 20% VAT

In 0 the TCO of the ESCo is shown for the different systems, for solar thermal without the TCS and also including the TCS based on the target prices evaluated above. In the 10 years' period of the TCO calculation of the ESCo the solar thermal solution considering the target price for TCS versus biomass cannot compete against the biomass heating system. But as mentioned above, the TCO of the customer will be decisive to the evaluation of the offers.

Table 7. Comparison TCO ESCo point of view – own table

ESCo Point of View						
	Biomass	**Heatpump**	**Solar Thermal**	**Solar Thermal TCS vs. Biomass**	**Solar Thermal TCS vs. Heatpump**	
Investment core system	17.162,00	26.364,00	8.666,67	8.666,67	8.666,67	€
Investment related		4.000,00	7.933,00	7.933,00	7.933,00	€
target price TCS				***10.845,89***	***19.016,73***	€
Investment total	**17.162,00**	**30.364,00**	**16.599,67**	**27.445,56**	**42.739,68**	€
Maintenance	250,00	480,00	249,00	411,68	534,25	€
COP		5,50				
Number of Collectors			20	20	20	
Biomass Input	22.222,22					kWh
Biomass price	0,0379					€/kWh
Electricity consumption p.a.	500,00	3.636,36	1.272,00	1.272,00	1.272,00	kWh
Electricity price	0,146	0,146	0,146	0,146	0,146	€/kWh
Annual price increase maintenance	1,00%	1,00%	1,00%	1,00%	1,00%	
Annual price increase Biomass	1,00%	1,00%	1,00%	1,00%	1,00%	
Annual price increase electricity	1,00%	1,00%	1,00%	1,00%	1,00%	
Interest on financing	3,00%	3,00%	3,00%	3,00%	3,00%	
Financing period	10	10	10	10	10	years
Discount rate / cost of capital	4,50%	4,50%	4,50%	4,50%	4,50%	
Investment Horizon	10	10	10	10	10	years
TCO Net Cash Flow	**-32.175,69**	**-40.989,49**	**-37.870,12**	**-33.712,83**	**-43.165,94**	€
TCO Net Present Value	**-29.153,66**	**-38.741,39**	**-26.840,51**	**-32.386,82**	**-41.568,64**	€

all prices incl. 20% VAT

TCS systems are so far only in prototype phase, system tests are expected in the years to follow (Rommel & et al., 2015). A market introduction will therefore still take several years. Based on learning curve and economies of scale price decreases of the heating systems until market introduction can be assumed. Biomass boiler technology is well established and large industrial producers are in the market. Kalt and Kranzl assume only ~5% price reduction of biomass heating systems from 2010 until 2030 (Kalt & Kranzl, 2009). Boiler efficiency is already higher than 90%. For the other heating systems assessed, IEA sees relevant price decreases in the same period and for heat pump also improved COPs - Figure 31.

	2030		2050	
Active solar thermal				
Installed cost	-50% to -75%		-50% to -75%	
Maintenance cost	0% to -40%		0% to -40%	
Delivered energy cost	-50% to -60%		-50% to -65%	
Thermal energy storage	PCM, thermal-chemical and centralised		PCM, thermal-chemical and centralised	
Installed cost	-50% to -75%		-65% to -85%	
Delivered energy cost	Depends on cycle regime		Depends on cycle regime	
Heat pumps	Space/water heating	Cooling	Space/water heating	Cooling
Installed cost	-20% to -30%	-5% to -15%	-30% to -40%	-5% to -20%
Coefficient of performance	30% to 50% improvement	20% to 40% improvement	40%to 60% improvement	30% to 50% improvement
Delivered energy cost	-20% to -30%	-10% to -20%	-30% to -40%	-15% to -25%

Figure 31. Cost and performance goals for heating and cooling technologies, 2030 and 2050 (IEA International Energy Agency, 2011, S. 25)

In 0 TCO are shown considering 5% price reduction for pellet boilers, 10% price reduction and 15% improved COP for heat pumps and 25% price reduction for solar thermal. In this TCO calculation not the full price reduction and efficiency increase forecasted until 2030 were considered as a market introduction of TCS earlier than 2030 is assumed. Based on these TCOs the target price for the TCS System is ~14.800 € incl. VAT, ~12.300 € net to be competitive against the Biomass Heating System and ~21.750 € incl. VAT, ~18.125 € net to be competitive against the Heat Pump System.

Table 8. TCO and Target price TCS considering price reductions and efficiency increase until potential TCS market introduction – own table

Customer Point of View						
	Biomass 5% price decrease	**Heatpump 10% price decrease & 15% improved COP**	**Solar Thermal 25% price decrease**	**Solar Thermal TCS vs. Biomass**	**Solar Thermal TCS vs. Heatpump**	
Investment core system	19.564,68	28.473,12	7.800,00	7.800,00	7.800,00	€
Investment related		4.800,00	9.519,60	9.519,60	9.519,60	€
target price TCS				***14.802,97***	***21.743,85***	€
Investment total	**19.564,68**	**33.273,12**	**17.319,60**	**32.122,57**	**39.063,45**	€
Maintenance	300,00	576,00	259,79	481,84	585,95	€
COP		5,50				
Number of Collectors			20	20	20	
Biomass Input	22.222,22					kWh
Biomass price	0,0455					€/kWh
Electricity consumption p.a.	500,00	3.162,06	1.272,00	1.272,00	1.272,00	kWh
Electricity price	0,175	0,175	0,175	0,175	0,175	€/kWh
Annual price increase maintenance	1,00%	1,00%	1,00%	1,00%	1,00%	
Annual price increase Biomass	1,00%	1,00%	1,00%	1,00%	1,00%	
Annual price increase electricity	1,00%	1,00%	1,00%	1,00%	1,00%	
Interest on financing	3,00%	3,00%	3,00%	3,00%	3,00%	
Financing period	10	10	10	10	10	years
Monthly instalment	-188,92	-321,29	-167,24	-310,18	-377,20	€
Discount rate / cost of capital	4,50%	4,50%	4,50%	4,50%	4,50%	
Investment Horizon	25	25	25	25	25	years
TCO Net Cash Flow	**-62.481,70**	**-70.607,54**	**-33.755,94**	**-57.179,82**	**-68.162,90**	€
TCO Net Present Value	**-41.027,29**	**-49.096,52**	**-23.817,83**	**-41.027,29**	**-49.096,52**	€

all prices incl. 20% VAT

7 CONCLUSIONS

TCS Systems are still in R&D phase. However, based on the current status of R&D, these systems will allow to store heat at higher temperatures for long-term without loss and will have higher storage capacity than thermal storage systems currently on the market. Different funded projects are ongoing to develop compact thermal storage to be used in combination with solar thermal energy for space heating.

The assessment of the technology however showed, that the solution of Solar Thermal and TCS cannot be applied to all buildings. Given by usual restrictions of space, both for solar thermal collectors and storage modules in the building, the building will have to achieve a rather high level of energy efficiency. Therefore, this technology in large part can only be applied for new buildings or buildings recently retrofitted with sufficient EEM.

The fact that TCS is a fully new technology has also major influence on the contracting business model developed. Many of the identified jobs, pains and gains of the key roles in the procurement for heating services in public buildings – the representative of the owner, the public procurement officer and the technical consultant – relate to the success of the project, the security of heat supply and trust. The value proposition of the EC business model can relate to these needs of the customer, by providing a guarantee of function, performance and costs.

This value proposition however needs to be supported by a sufficient back ground and set-up of the ESCo to create the trust of the customer. This back ground and set-up can be based on the economic size and market position of the ESCo itself, but also by the partner set-up. Especially the TCS technology partner is of key importance to create trust in the new technology. The customer needs to be secure that the ESCo in cooperation with the TCS technology has the economic and technical potential to secure full functioning of the heating system.

The partnering with the TCS technology partner is also the core mechanism for the ESCo to manage the risk of the new technology for himself. The ESCo will have to obtain from the TCS technology partner the same guarantees as the ESCo gives to the customer. An option to secure the sharing of risk could be a joint venture of the ESCo and the TCS technology partner.

The EC business model will also address economic pains and gains of the customer, especially of the representative of the owner. The financing component of the contracting model will allow to reduce CAPEX of the customer. It will secure defined costs for the contractual term and based on the solar thermal/TCS system low operation cost after the contracting period.

Based on the need to create trust of the customer in the new technology, in the contracting model and the ESCo himself, the awareness phase prior to the actual procurement phase, is most important for the success of the business model. In this awareness phase the ESCo in cooperation with the TCS technology partner has to specifically address the representatives of building owners and technical consultants.

Another key factor for the success of the business model is of course the competitive pricing of the technical solution of the solar thermal system in combination with the TCS. Due to the fact that TCS is only in R&D phase and only initial prototypes for seasonal storage are yet implemented, an assessment of the competitive situation in comparison with other renewable heating system is not possible yet, but target prices can be derived in comparison with alternative heating systems.

Based on the case study conducted it is evident that the solar thermal/TCS system can only be competitive when TCO/Life Cycle Cost is evaluated. Looking only at the initial investment costs of the different heating systems, less than 1.000 € in comparison to the biomass heating system would be available for the TCS System, which has to supply ~8.000 kWh per heating season in the assessed case study. But when considering the full lifetime of a solar thermal collector (25 years) and the respective Net Present Value of TCO, the solar thermal solution without TCS is ~11.000 € cheaper than Biomass. So these ~11.000 € can be invested in the TCS to still be competitive against the biomass heating system. In comparison to the heat pump driven heating system, which has the highest investment costs, the target price for the TCS would be ~13.500 € based on investment point of view and even ~19.000 € based on TCO point of view.

Concluding can be said, that if the target prices of the TCS Systems based on TCO can be achieved, a contracting business model would be valid means to implement solar thermal/TCS heating system in public office space. Public sector has clear targets to implement renewable energy heating systems, public sector can apply and partially already applies economic evaluation based on TCO and the contracting models provide the public customers with sufficient security and trust to accept also heating systems based on new technology.

List of References

Amt der NÖ Landesregierung. (2014). Pfichtenheft Energieeffizienz und Nachhaltigkeit für NÖ Landesgebäude.

Bleyl-Androschin, J. (2010). *Competitive Energy Services (Energy-Contracting, ESCo Services) - Final Task Report (Phase 1: 2006 – 2009).* IEA DSM Task 16.

Bleyl-Androschin, J. (2011). *Conservation First! The New Integrated Energy-Contracting Model to Combine Energy Efficiency and Renewable Supply in Large Buildings and Industry.* IEA DSM Task 16. Retrieved 08 16, 2016, from http://www.ieadsm.org/wp/files/Bleyl_Integrated-Energy-Contracting_ECEEE-paper-1-485_1106.pdf

Bleyl-Androschin, J., & Schinnerl, D. (2008). "Energy-Contracting" to Achieve Energy Efficiency and Renewables using Comprehensive Refurbishment of Buildings as an Example. In P. Droege, *Urban Energy Transition.* Elsevier.

Bleyl-Androschin, J., & Schinnerl, D. (2010). *Financing Options for Energy-Contracting Projects – Comparison and Evaluation.* International Energy Agency IA Demand Side Management (DSM) Task XVI.

Cabeza, L., & et al. (2013). *Final report Annex 25: Surplus Heat Management using Advanced TES for CO2 Mitigation.* ECES IA – IEA.

Cabeza, L., & et al. (2015). *Advances in thermal energy storage systems: Methods and applications.* Woodhead Publishing Series in Energy.

ECN. (2009). *Energieonderzoek Centrum Nederland (ECN).* Retrieved 08 11, 2016, from https://www.ecn.nl/nl/nieuws/newsletter-en/2009/june-2009/seasonal-storage/

Engel, G. (2016). *AEE INTEC.* Retrieved 08 11, 2016, from http://www.aee-intec.at/0uploads/dateien1162.pdf

Engel, G. (2016, September 29). Dimensioning of thermochemical stroage systems, cost of components. *phone call*.

Engel, G. (2016, October 03). electricity demand of thermochemical storage prototype. *e-mail*.

ESTIF. (2007). *Objective methodology for simple calculation of the energy delivery of (small) Solar Thermal systems.* European Solar Thermal Industry Federation.

ETP RHC. (2012). *Strategic Research Priorities for Solar Thermal Technology.* European Technology Platform on Renewable Heating and Cooling.

ETP RHC. (2013). *Strategic Research and Innovation Agenda for Renewable Heating & Cooling.* The European Technology Platform on Renewable Heating and Cooling (RHC-Platform).

european association of energy service companies. (2010). Energy Contracting - Successful energy services business models.

Hauer, A. (2016, September 14). Überblick zu internationalen F&E Aktivitäten und Anwendungsfällen für kompakte thermische Energiespeicher. *2. Tagung „Kompakte thermische Energiespeicher"*. Vienna.

IEA. (2011). *Solar Energy Perspectives.* IEA - International Energy Agency.

IEA. (2016). *IEA International Energy Agency*. Retrieved 08 17, 2016, from https://www.iea.org/topics/renewables/subtopics/solar/

IEA International Energy Agency. (2011). *Technology Roadmap Energy-efficient Buildings: Heating and Cooling Equipment.*

Kalt, G., & Kranzl, L. (2009). Bioenergieketten: Ein dynamischer Vergleich von Effizienzen, Kosten und Treibhausgaseinsparungen. *6. Internationale Energiewirtschaftstagung an der TU Wien, 11. - 13. Februar 2009.*

Khadiran, T., & et al. (2016). Advanced energy storage materials for building applications and their thermal performance characterization: A review. *Renewable and Sustainable Energy Reviews, 57*, pp. 916-928.

Mauthner, F., Weiss, W., & Spörk-Dür, M. (2016). *Solar Heat Worldwide - Markets and Contribution to the Energy Supply 2014.* IEA Solar Heating & Cooling Programme.

Osterwalder, A., & et al. (2014). *Value Proposition Design - How to create products and services customers want.* John Wiley & Sons.

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers.* John Wiley & Sons.

Rommel, M., & et al. (2015). *Compact Thermal Energy Storage IEA SHC Position Paper.* IEA SHC Task 42 / ECES Annex 29. Elsevier Ltd.

Viessmann GmbH. (2008). *Viessmann - Technical guide Solar thermal systems.* (www.viessmann.co.uk, Ed.)

Weiss, W. (2015). Solar Energy – Solar Heating & Cooling. *scipt of lecture: Basics of solar thermal energy use; TU Vienna MSc Program Renewable Energy in Central and Eastern Europe*.

List of abbreviations

BMS	Building Management System
CAPEX	Capital Expenditures
CHP	Combined Heat and Power
COP	Coefficient of Performance
CPC	Compound Parabolic Concentrators
DHW	Domestic Hot Water
EC	Energy Contracting
EEM	Energy Efficiency Measures
EPC	Energy Performance Contracting
ESC	Energy Supply Contracting
ESCo	Energy Service Company
HTF	Heat Transfer Fluid
IEA	International Energy Agency
IEC	Integrated Energy-Contracting
KPI	Key Performance Indicators
PCM	Phase Change Materials
Q&A	Questions & Answers
QAI	Quality Assurance Instruments
R&D	Research and Development
SLA	Service Level Agreement
TCO	Total Cost of Ownership
TCS	Thermochemical Storage
TESS	Thermal Energy Storage Systems
VAT	Value Added Tax

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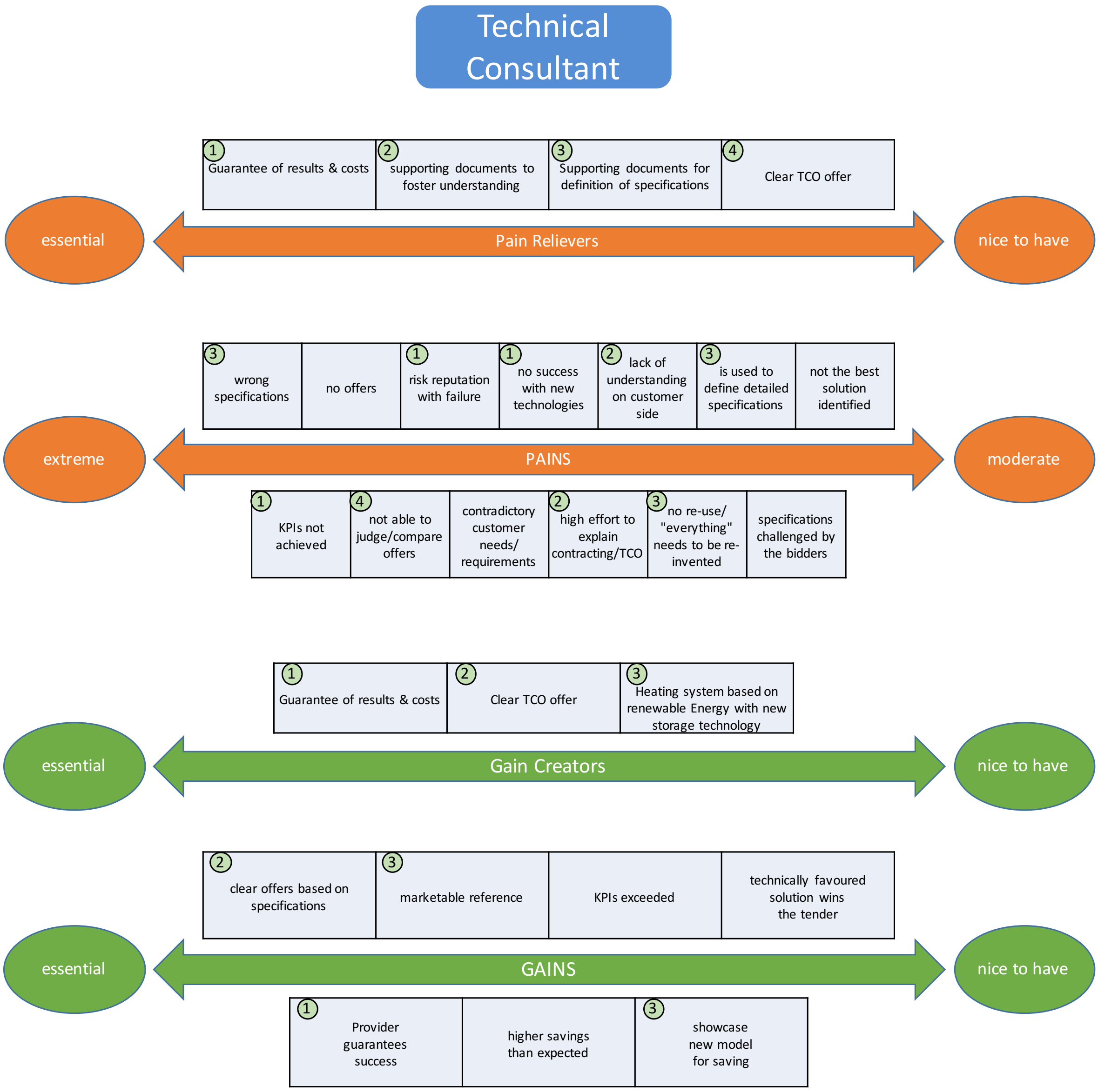
APPENDICES

Appendix 1. Mapping of Gain Creators & Pain Relievers to Pains & Gains of the Technical Consultant



Appendix 2. Mapping of Gain Creators & Pain Relievers to Pains & Gains of the Representative of the Owner

Appendix 3. TCO biomass ESCo point of view

ESCo Point of View			
	excl. 20% VAT	incl. 20% VAT	
Investment Costs	17.162,00	20.594,40	€
Maintenance p.a.	250,00	300,00	€
Capacity biomass boiler	60		kW
Efficiency	90,00%		
Annual heat demand	20.000,00		kWh
Biomass Input	22.222,22		kWh
Biomass price	0,0379	0,0455	€/kWh
Electricity consumption p.a.	500,00		kWh
Electricity price	0,146	0,175	€/kWh
Annual price increase maintenance	1,00%		
Annual price increase Biomass	1,00%		
Annual price increase electricity	1,00%		
Interest on financing	3,00%		
Financing period	10,00		years
Monthly instalment	-165,72		€
Discount rate / cost of capital	4,50%		
Investment Horizon	10,00		years
TCO Net Cash Flow	**-32.175,69**		€
TCO Net Present Value	**-29.153,66**		€

Year	**discounted CF**	**nominal CF**	**Investment**	**financing cost**	**Maintenance p.a.**	**Electricity price/kWh**	**Electricity p.a.**	**Biomass price/kWh**	**Biomass p.a.**
t	DCF	NCF	C_{inv}	C_{fin}	C_m		C_{ele}		C_{BM}
	$\frac{NCF}{(1+r)^t}$	ΣC							
0	-17.162,00	-17.162,00	-17.162,00			-0,146		-0,0379	
1	-1.597,22	-1.669,09		-494,43	-250,00	-0,147	-73,65	-0,0383	-851,02
2	-1.497,58	-1.635,39		-448,98	-252,50	-0,149	-74,38	-0,0387	-859,53
3	-1.402,45	-1.600,42		-402,15	-255,03	-0,150	-75,13	-0,0391	-868,12
4	-1.311,64	-1.564,15		-353,90	-257,58	-0,152	-75,88	-0,0395	-876,81
5	-1.224,97	-1.526,53		-304,17	-260,15	-0,153	-76,64	-0,0399	-885,57
6	-1.142,26	-1.487,52		-252,94	-262,75	-0,155	-77,40	-0,0402	-894,43
7	-1.063,35	-1.447,08		-200,15	-265,38	-0,156	-78,18	-0,0407	-903,37
8	-988,08	-1.405,15		-145,75	-268,03	-0,158	-78,96	-0,0411	-912,41
9	-916,29	-1.361,69		-89,70	-270,71	-0,159	-79,75	-0,0415	-921,53
10	-847,83	-1.316,65		-31,94	-273,42	-0,161	-80,55	-0,0419	-930,75
	-29.153,66	-32.175,69	-17.162,00	-2.724,11	-2.615,55		-770,50		-8.903,54

Appendix 4. TCO biomass Customer point of view

Customer Point of View			
	excl. 20% VAT	incl. 20% VAT	
Investment Costs	17.162,00	20.594,40	€
Maintenance p.a.	250,00	300,00	€
Capacity biomass boiler	60		kW
Efficiency	90,00%		
Annual heat demand	20.000,00		kWh
Biomass Input	22.222,22		kWh
Biomass price	0,0379	0,0455	€/kWh
Electricity consumption p.a.	500,00		kWh
Electricity price	0,146	0,175	€/kWh
Annual price increase maintenance	1,00%		
Annual price increase Biomass	1,00%		
Annual price increase electricity	1,00%		
Interest on financing	3,00%		
Financing period	10,00		years
Monthly instalment	-165,72	-198,86	€
Discount rate / cost of capital	4,50%		
Investment Horizon	25		years
TCO Net Cash Flow		**-63.674,86**	€
TCO Net Present Value		**-41.971,41**	€

Year	**discounted CF**	**nominal CF**	**monthly installments including VAT**	**Maintenance p.a.**	**Electricity price/kWh**	**Electricity p.a.**	**Biomass price/kWh**	**Biomass p.a.**
t	DCF	NCF	C_{inv}	C_m		C_{ele}		C_{BM}
	$\frac{NCF}{(1+r)^t}$	ΣC						
0	0,00	0,00			-0,175		-0,0455	
1	-3.632,47	-3.795,93	-2.386,33	-300,00	-0,177	-88,38	-0,0460	-1.021,22
2	-3.488,95	-3.810,03	-2.386,33	-303,00	-0,179	-89,26	-0,0464	-1.031,43
3	-3.351,19	-3.824,26	-2.386,33	-306,03	-0,180	-90,15	-0,0469	-1.041,75
4	-3.218,94	-3.838,64	-2.386,33	-309,09	-0,182	-91,05	-0,0473	-1.052,17
5	-3.091,98	-3.853,17	-2.386,33	-312,18	-0,184	-91,96	-0,0478	-1.062,69
6	-2.970,09	-3.867,83	-2.386,33	-315,30	-0,186	-92,88	-0,0483	-1.073,31
7	-2.853,08	-3.882,65	-2.386,33	-318,46	-0,188	-93,81	-0,0488	-1.084,05
8	-2.740,74	-3.897,61	-2.386,33	-321,64	-0,189	-94,75	-0,0493	-1.094,89
9	-2.632,89	-3.912,72	-2.386,33	-324,86	-0,191	-95,70	-0,0498	-1.105,84
10	-2.529,34	-3.927,99	-2.386,33	-328,11	-0,193	-96,65	-0,0503	-1.116,90
11	-959,47	-1.557,07		-331,39	-0,195	-97,62	-0,0508	-1.128,06
12	-927,33	-1.572,64		-334,70	-0,197	-98,60	-0,0513	-1.139,35
13	-896,27	-1.588,37		-338,05	-0,199	-99,58	-0,0518	-1.150,74
14	-866,25	-1.604,25		-341,43	-0,201	-100,58	-0,0523	-1.162,25
15	-837,24	-1.620,30		-344,84	-0,203	-101,58	-0,0528	-1.173,87
16	-809,20	-1.636,50		-348,29	-0,205	-102,60	-0,0534	-1.185,61
17	-782,10	-1.652,86		-351,77	-0,207	-103,63	-0,0539	-1.197,46
18	-755,90	-1.669,39		-355,29	-0,209	-104,66	-0,0544	-1.209,44
19	-730,58	-1.686,09		-358,84	-0,211	-105,71	-0,0550	-1.221,53
20	-706,11	-1.702,95		-362,43	-0,214	-106,77	-0,0555	-1.233,75
21	-682,47	-1.719,98		-366,06	-0,216	-107,83	-0,0561	-1.246,09
22	-659,61	-1.737,18		-369,72	-0,218	-108,91	-0,0566	-1.258,55
23	-637,52	-1.754,55		-373,41	-0,220	-110,00	-0,0572	-1.271,13
24	-616,16	-1.772,09		-377,15	-0,222	-111,10	-0,0578	-1.283,84
25	-595,53	-1.789,81		-380,92	-0,224	-112,21	-0,0584	-1.296,68
	-41.971,41	**-63.674,86**	-23.863,33	-8.472,96		-2.495,99		-28.842,58

Appendix 5. TCO heat pump ESCo point of view

ESCo Point of View			
	excl. 20% VAT	incl. 20% VAT	
Groundwater heat pump	26.364,00	31.636,80	€
Groundwater well	4.000,00	4.800,00	€
Investment Costs	30.364,00	36.436,80	€
Maintenance p.a.	480,00	576,00	€
Capacity heat pump	58,90		kW
COP	5,50		
Annual heat demand	20.000,00		kWh
Electricity consumption p.a.	3.636,36		kWh
Electricity price	0,146	0,175	€/kWh
Annual price increase maintenance	1,00%		
Annual price increase Biomass	1,00%		
Annual price increase electricity	1,00%		
Interest on financing	3,00%		
Financing period	10,00		years
Monthly instalment	-293,20		€
Discount rate / cost of capital	4,50%		
Investment Horizon	10,00		years
TCO Net Cash Flow	**-40.989,49**		€
TCO Net Present Value	**-38.741,39**		€

Year	**discounted CF**	**nominal CF**	**Investment**	**financing cost**	**Maintenance p.a.**	**Electricity price/kWh**	**Electricity p.a.**
t	DCF	NCF	C_{inv}	C_{fin}	C_m		C_{ele}
	$\frac{NCF}{(1+r)^t}$	ΣC					
0	-30.364,00	-30.364,00	-30.364,00			-0,146	
1	-971,87	-1.015,61		-874,77	-480,00	-0,147	-535,61
2	-939,32	-1.025,76		-794,36	-484,80	-0,149	-540,96
3	-907,86	-1.036,02		-711,51	-489,65	-0,150	-546,37
4	-877,45	-1.046,38		-626,13	-494,54	-0,152	-551,84
5	-848,07	-1.056,84		-538,16	-499,49	-0,153	-557,35
6	-819,66	-1.067,41		-447,52	-504,48	-0,155	-562,93
7	-792,21	-1.078,09		-354,11	-509,53	-0,156	-568,56
8	-765,68	-1.088,87		-257,87	-514,62	-0,158	-574,24
9	-740,03	-1.099,76		-158,70	-519,77	-0,159	-579,98
10	-715,24	-1.110,75		-56,51	-524,97	-0,161	-585,78
	-38.741,39	-40.989,49	-30.364,00	-4.819,65	-5.021,86		-5.603,62

Appendix 6. TCO heat pump Customer point of view

Customer Point of View			
	excl. 20% VAT	incl. 20% VAT	
Groundwater heat pump	26.364,00	31.636,80	€
Groundwater well	4.000,00	4.800,00	€
Investment Costs	30.364,00	36.436,80	€
Maintenance p.a.	480,00	576,00	€
Capacity heat pump	58,90		kW
COP	5,50		
Annual heat demand	20.000,00		kWh
Electricity consumption p.a.	3.636,36		kWh
Electricity price	0,146	0,175	€/kWh
Annual price increase maintenance	1,00%		
Annual price increase Biomass	1,00%		
Annual price increase electricity	1,00%		
Interest on financing	3,00%		
Financing period	10,00		years
Monthly instalment	-293,20	-351,84	€
Discount rate / cost of capital	4,50%		
Investment Horizon	25		years
TCO Net Cash Flow		**-76.641,13**	€
TCO Net Present Value		**-53.370,39**	€

Year	discounted CF	nominal CF	Investment	Maintenance p.a.	Electricity price/kWh	Electricity p.a.
t	DCF	NCF	C_{inv}	C_m		C_{ele}
	$\frac{NCF}{(1+r)^t}$	ΣC				
0	0,00	0,00			-0,175	
1	-5.206,47	-5.440,76	-4.222,04	-576,00	-0,177	-642,73
2	-4.993,43	-5.452,95	-4.222,04	-581,76	-0,179	-649,15
3	-4.789,19	-5.465,26	-4.222,04	-587,58	-0,180	-655,65
4	-4.593,38	-5.477,69	-4.222,04	-593,45	-0,182	-662,20
5	-4.405,66	-5.490,25	-4.222,04	-599,39	-0,184	-668,82
6	-4.225,68	-5.502,93	-4.222,04	-605,38	-0,186	-675,51
7	-4.053,12	-5.515,74	-4.222,04	-611,44	-0,188	-682,27
8	-3.887,68	-5.528,68	-4.222,04	-617,55	-0,189	-689,09
9	-3.729,06	-5.541,74	-4.222,04	-623,73	-0,191	-695,98
10	-3.576,98	-5.554,94	-4.222,04	-629,96	-0,193	-702,94
11	-829,55	-1.346,23		-636,26	-0,195	-709,97
12	-801,76	-1.359,70		-642,62	-0,197	-717,07
13	-774,91	-1.373,29		-649,05	-0,199	-724,24
14	-748,96	-1.387,03		-655,54	-0,201	-731,48
15	-723,87	-1.400,90		-662,10	-0,203	-738,80
16	-699,63	-1.414,90		-668,72	-0,205	-746,19
17	-676,19	-1.429,05		-675,41	-0,207	-753,65
18	-653,55	-1.443,34		-682,16	-0,209	-761,18
19	-631,66	-1.457,78		-688,98	-0,211	-768,80
20	-610,50	-1.472,36		-695,87	-0,214	-776,48
21	-590,05	-1.487,08		-702,83	-0,216	-784,25
22	-570,29	-1.501,95		-709,86	-0,218	-792,09
23	-551,19	-1.516,97		-716,96	-0,220	-800,01
24	-532,73	-1.532,14		-724,13	-0,222	-808,01
25	-514,89	-1.547,46		-731,37	-0,224	-816,09
	-53.370,39	**-76.641,13**	**-42.220,37**	**-16.268,08**		**-18.152,67**

Appendix 7. TCO solar thermal without TCS ESCo point of view

ESCo Point of View			
	excl. 20% VAT	incl. 20% VAT	
Price per collector	433,33	520,00	€
Number of Collectors	20,00		
Solarthermal heating system	8.666,67	10.400,00	€
5000l Waterstorage	4.933,00	5.919,60	€
Mounting structure	3.000,00	3.600,00	€
Investment Costs	**16.599,67**	**19.919,60**	**€**
Maintenance p.a. assumed 1,5%	249,00	298,79	€
Absorber area	2,57		m^2
Collector area	51,40		m^2
Annual heat production	25.000,00		kWh
ratio electricticy consuption solar	2%		
Electricity consumption solar th.	500,00		kWh
Annual heat demand	20.000,00		kWh
solar fraction without storage	12.280,00		kWh
heat extraction from storage	7.720,00		kWh
ratio electricticy consuption TCS	10%		
Electricity consumption TCS p.a.	772,00		kWh
Electricity price	0,146	0,175	€/kWh
Annual price increase maintenance	1,00%		
Annual price increase Biomass	1,00%		
Annual price increase electricity	1,00%		
Interest on financing	3,00%		
Financing period	10,00		years
Monthly instalment	-160,29		€
Discount rate / cost of capital	4,50%		
Investment Horizon	10,00		years
TCO Net Cash Flow	**-21.164,85**		€
TCO Net Present Value	**-20.198,97**		€

Year	**discounted CF**	**nominal CF**	**Investment**	**financing cost**	**Maintenance p.a. assumed 1,5%**	**Electricity price/kWh**	**Electricity p.a.**
t	DCF	NCF	C_{inv}	C_{fin}	C_m		C_{ele}
	$\frac{NCF}{(1+r)^t}$	ΣC					
0	-16.599,67	-16.599,67	-16.599,67			-0,146	
1	-417,56	-436,35		-874,77	-249,00	-0,147	-187,36
2	-403,57	-440,71		-434,27	-251,48	-0,149	-189,23
3	-390,06	-445,12		-388,97	-254,00	-0,150	-191,12
4	-376,99	-449,57		-342,30	-256,54	-0,152	-193,03
5	-364,37	-454,07		-294,21	-259,11	-0,153	-194,96
6	-352,16	-458,61		-244,65	-261,70	-0,155	-196,91
7	-340,37	-463,19		-193,59	-264,31	-0,156	-198,88
8	-328,97	-467,83		-140,98	-266,96	-0,158	-200,87
9	-317,95	-472,50		-86,76	-269,63	-0,159	-202,88
10	-307,30	-477,23		-30,89	-272,32	-0,161	-204,91
	-20.198,97	-21.164,85	-16.599,67	-3.031,39	-2.605,04		-1.960,15

Appendix 8. TCO solar thermal without TCS Customer point of view

Customer Point of View			
	excl. 20% VAT	incl. 20% VAT	
Price per collector	433,33	520,00	€
Number of Collectors	20,00		
Solarthermal heating system	8.666,67	10.400,00	€
5000l Waterstorage	4.933,00	5.919,60	€
mounting	3.000,00	3.600,00	€
Investment Costs	**16.599,67**	**19.919,60**	€
Maintenance p.a. assumed 1,5%	249,00	298,79	€
Absorber area	2,57		m^2
Collector area	51,40		m^2
Annual heat production	25.000,00		kWh
ratio electricticy consuption solar	2%		
Electricity consumption solar th. Sys.	500,00		kWh
Annual heat demand	20.000,00		kWh
solar fraction without storage	12.280,00		kWh
heat extraction from storage	7.720,00		kWh
ratio electricticy consuption TCS	10%		
Electricity consumption TCS p.a.	772,00		kWh
Electricity price	0,146	0,175	€/kWh
Annual price increase maintenance	1,00%		
Annual price increase Biomass	1,00%		
Annual price increase electricity	1,00%		
Interest on financing	3,00%		
Financing period	10,00		years
Monthly instalment	-160,29	-192,35	€
Discount rate / cost of capital	4,50%		
Investment Horizon	25		years
TCO Net Cash Flow		**-37.870,12**	€
TCO Net Present Value		**-26.840,51**	€

Year	**discounted CF**	**nominal CF**	**Investment**	**Maintenance p.a. assumed 1,5%**	**Electricity price/kWh**	**Electricity p.a.**
t	DCF	NCF	C_{inv}	C_m		C_{ele}
	$\frac{NCF}{(1+r)^t}$	ΣC				
0	0,00	0,00			0,175	
1	-2.709,82	-2.831,76	-2.308,14	-298,79	0,177	-224,83
2	-2.597,92	-2.837,00	-2.308,14	-301,78	0,179	-227,07
3	-2.490,69	-2.842,29	-2.308,14	-304,80	0,180	-229,35
4	-2.387,91	-2.847,63	-2.308,14	-307,85	0,182	-231,64
5	-2.289,41	-2.853,02	-2.308,14	-310,93	0,184	-233,95
6	-2.195,01	-2.858,47	-2.308,14	-314,04	0,186	-236,29
7	-2.104,53	-2.863,97	-2.308,14	-317,18	0,188	-238,66
8	-2.017,81	-2.869,53	-2.308,14	-320,35	0,189	-241,04
9	-1.934,70	-2.875,15	-2.308,14	-323,55	0,191	-243,45
10	-1.855,04	-2.880,82	-2.308,14	-326,79	0,193	-245,89
11	-356,41	-578,40		-330,05	0,195	-248,35
12	-344,47	-584,19		-333,36	0,197	-250,83
13	-332,94	-590,03		-336,69	0,199	-253,34
14	-321,79	-595,93		-340,06	0,201	-255,87
15	-311,01	-601,89		-343,46	0,203	-258,43
16	-300,59	-607,91		-346,89	0,205	-261,02
17	-290,52	-613,99		-350,36	0,207	-263,63
18	-280,79	-620,13		-353,86	0,209	-266,26
19	-271,39	-626,33		-357,40	0,211	-268,93
20	-262,30	-632,59		-360,98	0,214	-271,61
21	-253,51	-638,92		-364,59	0,216	-274,33
22	-245,02	-645,31		-368,23	0,218	-277,07
23	-236,82	-651,76		-371,91	0,220	-279,84
24	-228,88	-658,28		-375,63	0,222	-282,64
25	-221,22	-664,86		-379,39	0,224	-285,47
	-26.840,51	-37.870,12	-23.081,42	-8.438,90		-6.349,81

Appendix 9. Simulation solar thermal system with 100.000 litre storage

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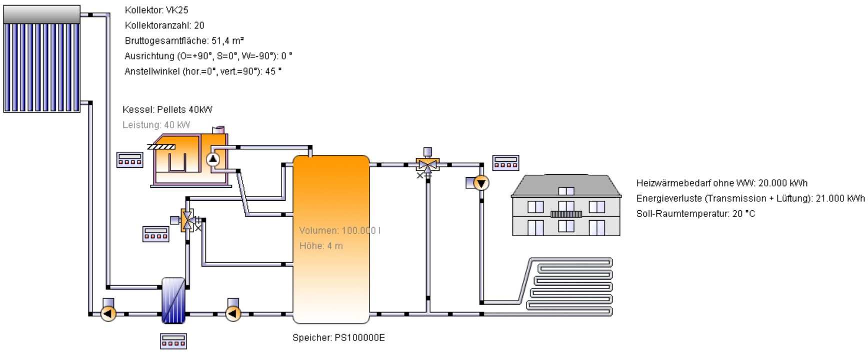
Projekt — **13b2: Raumheizung (Solarthermie)**



Dieser Report wurde erstellt durch:	Standort der Anlage
Koschier Günter	
Georg Ziegler	Baden
Industriepark St. Veit	Längengrad: 16,233°
9300 St. Veit	Breitengrad: 48,005°
	Höhe ü.M.: 224 m

Systemübersicht (Jahreswerte)

Gesamter Brennstoff- und Strom-Verbrauch des Systems [Etot]	8.911,8 kWh
Komfortanforderungen	Energiebedarf ist gedeckt
Anlagenaufwandszahl	0,46

Übersicht Solarthermie (Jahreswerte)

Kollektorfläche	51,4 m²
Solarer Deckungsgrad gesamt	78,3%
Gesamter Kollektorfeldertrag	25.059,7 kWh
Kollektorfeldertrag bzgl. Bruttofläche	487,5 kWh/m²/Jahr
Kollektorfeldertrag bzgl. Aperturfläche	564,4 kWh/m²/Jahr
Max. Brennstoffeinsparung (VDI 6002)	6.112,1 kg: [Pellets]
Max. Energieeinsparung (VDI 6002)	30.560,6 kWh
Max. vermiedene CO2-Emission	1.540,3 kg

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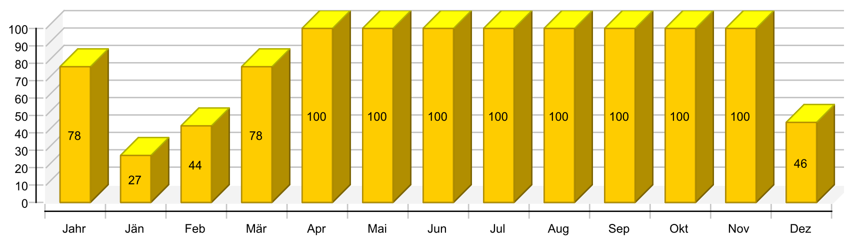
Meteodaten-Übersicht

Mittlere Aussentemperatur	10,6 °C
Globalstrahlung, Jahressumme	1.161,9 kWh/m²
Diffusstrahlung, Jahressumme	573 kWh/m²

Komponentenübersicht (Jahreswerte)

Kessel	**Pellets 40kW**	
Leistung	kW	40
Gesamtnutzungsgrad	%	80,1
Brennstoff- und Strom-Verbrauch [Eaux]	kWh	8.686,9
Kollektor	**VK25**	
Bruttogesamtfläche	m²	51,4
Gesamte Aperturfläche	m²	44,4
Anstellwinkel (hor.=0°, vert.=90°)	°	45
Ausrichtung (O=+90°, S=0°, W=-90°)	°	0
Kollektorfeldertrag [Qsol]	kWh	25.059,7
Einstrahlung in Kollektorebene [Esol]	kWh	58.501,8
Gebäude	**-**	
Soll-Raumtemperatur	°C	20
Heizwärmebedarf ohne WW [Qdem]	kWh	20.000
Heiz-/Kühlelement	**Fussbodenheizung**	
Nettoenergie von/zu den Heiz-/Kühlmodulen	kWh	19.535,9

Solarer Deckungsgrad: Anteil Solarenergie an das System [SFn] **%**



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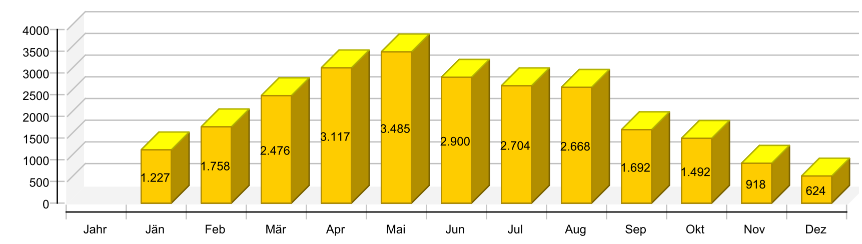
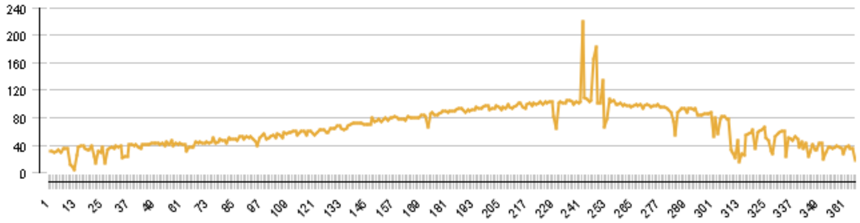
Solarthermische Energie an das System [Qsol] **kWh**



Kollektor

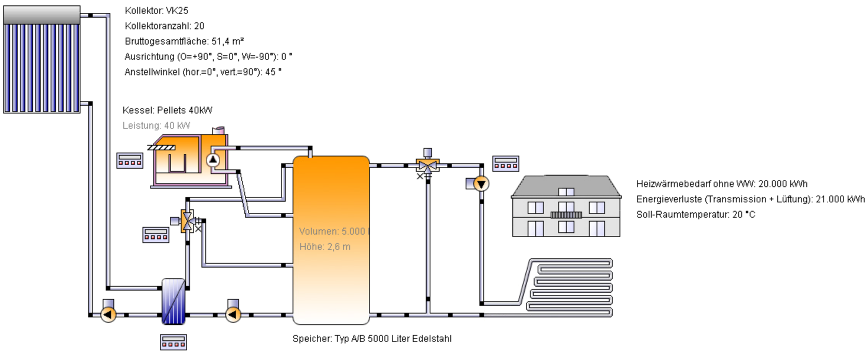
Tägliche Maximaltemperatur [°C]



Appendix 10. Simulation solar thermal system with 5.000 litre storage

Kurz-Report

Projekt | **13b: Raumheizung (Solarthermie)**



Dieser Report wurde erstellt durch:	Standort der Anlage
Koschier Günter	
Georg Ziegler	Baden
Industriepark St. Veit	Längengrad: 16,233°
9300 St. Veit	Breitengrad: 48,005°
	Höhe ü.M.: 224 m

Systemübersicht (Jahreswerte)

Gesamter Brennstoff- und Strom-Verbrauch des Systems [Etot]	12.064,8 kWh
Komfortanforderungen	Energiebedarf ist gedeckt
Anlagenaufwandszahl	0,62

Übersicht Solarthermie (Jahreswerte)

Kollektorfläche	51,4 m²
Solarer Deckungsgrad gesamt	61,4%
Gesamter Kollektorfeldertrag	14.266 kWh
Kollektorfeldertrag bzgl. Bruttofläche	277,5 kWh/m²/Jahr
Kollektorfeldertrag bzgl. Aperturfläche	321,3 kWh/m²/Jahr
Max. Brennstoffeinsparung (VDI 6002)	3.479,5 kg: [Pellets]
Max. Energieeinsparung (VDI 6002)	17.397,5 kWh
Max. vermiedene CO2-Emission	876,8 kg

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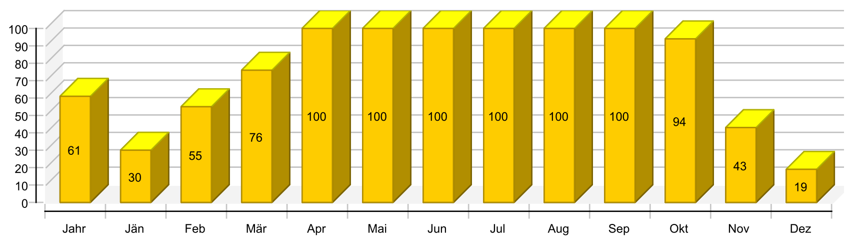
Meteodaten-Übersicht	
Mittlere Aussentemperatur	10,6 °C
Globalstrahlung, Jahressumme	1.161,9 kWh/m²
Diffusstrahlung, Jahressumme	573 kWh/m²

Komponentenübersicht (Jahreswerte)

Kessel	**Pellets 40kW**	
Leistung	kW	40
Gesamtnutzungsgrad	%	75,6
Brennstoff- und Strom-Verbrauch [Eaux]	kWh	11.869,2
Kollektor	**VK25**	
Bruttogesamtfläche	m²	51,4
Gesamte Aperturfläche	m²	44,4
Anstellwinkel (hor.=0°, vert.=90°)	°	45
Ausrichtung (O=+90°, S=0°, W=-90°)	°	0
Kollektorfeldertrag [Qsol]	kWh	14.266
Einstrahlung in Kollektorebene [Esol]	kWh	58.501,8
Gebäude	**-**	
Soll-Raumtemperatur	°C	20
Heizwärmebedarf ohne WW [Qdem]	kWh	20.000
Heiz-/Kühlelement	**Fussbodenheizung**	
Nettoenergie von/zu den Heiz-/Kühlmodulen	kWh	19.521,8

Solarer Deckungsgrad: Anteil Solarenergie an das System [SFn] %



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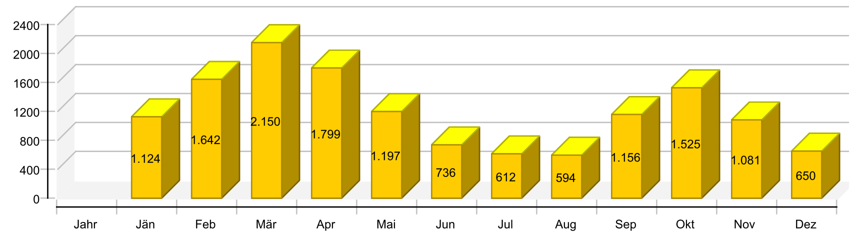
Solarthermische Energie an das System [Qsol] **kWh**



Kollektor

Tägliche Maximaltemperatur [°C]