Analysis of risk mitigation benefits for investments into energy efficient and renewable process heat technologies

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Abstract – **The European industrial process heat sector makes up for around 28% of the total European energy consumption and is still mainly run by conventional and carbon emitting fuel sources. The main reason for the lack of energy efficient and renewable process heat systems is of economic nature. This thesis will be analyzing how to properly address the economic problems of new and less carbon emitting process heat systems.**

A majority of up to 62% of European process heat is demanded at rather high temperature levels, though especially the chemicals sector has a large low and medium temperature demand, which can technically already be supplied by renewable energy systems. For energy efficiency measures, especially the iron and steel and the chemicals sector have a large potential.

Energy contracting schemes and risk mitigation measures have been used extensively in other sectors to decrease the risk perception of investors, one of the main economic issues. While applying these measures to the process heat sector, specifically to solar thermal process heat systems, a risk assessment model with a risk-adjusted discount rate was developed. The model considers the effects that energy contracting and other risk mitigation measures have on process heat investments.

An investment analysis, including the risk assessment model, was conducted for solar thermal process heat systems throughout Europe. Each location was assessed based on several risk factors with and without risk mitigation. The positive impacts of the risk mitigation measures were not displayed by the pay-back period and the IRR (internal rate of return) criteria. Solely the NPV (net present value) proved useful when showing how risk mitigation can positively influence the investment assessment of solar thermal process heat systems. Furthermore, risk mitigation measures yielded the highest impact in locations with high solar yield, e.g. Seville attained an additional NPV value of 73 €/m^2 through risk mitigation.

Index Terms – **Process heat; risk mitigation; energy contracting; net present value; internal rate of return; energy efficiency; renewable energy**

I. INTRODUCTION

Especially in the last decade increasing awareness was raised and policy makers in Europe and around the world introduced legislative changes to decarbonize several energy sectors, which were and still mostly are based on fossil fuels. The amounts of emitted CO_2 are supposed to be decreased, mainly through energy efficiency measures and renewable energy sources. Though, until now the main focus has been laid on the generation of electricity as a mean of decreasing carbon emissions.

A. Potential for Industrial Process Heat

In Europe, researchers from the German Aerospace Center conducted a recent study to estimate the process heat demand for the EU28 member states. Their calculations yielded a total demand of 7356 PJ. More than one-third of European heat demand stems from the industry, including heating for buildings and warm water [1].

B. Economic Drawbacks

Both energy efficiency and renewable energies yield relatively small annual cost savings in comparison to their large upfront investments. The main consequences that evolve from this are high pay-back periods and consequently low IRRs. Especially the use of the pay-back period as a financial criterion is critical, as it does not account for the time value of money and the total benefits of an investment into energy efficient or renewable heat technologies.

A further issue is the lack of investments for energy efficient or renewable process heat systems. Despite an increase of global investment into energy efficiency technologies from $710 million in 2005 to $1.1 billion in 2006 [2], these amounts still represent a rather small share of total investments into the global industrial sector of $1379 billion in 2005 [3].

Process heat generating technologies in the industry are largely neglected and clearly need additional investment that is allocated to their upgrade. Clearly, the lack of public funding is part of the problem. In 2014 there were around €500 million in public European funding for energy efficiency in the industry available. This represented only 9% of the amount available for the building sector.

C. Objectives

Firstly, this thesis will be analyzing which different process heat consuming sectors exist in Europe and what their future

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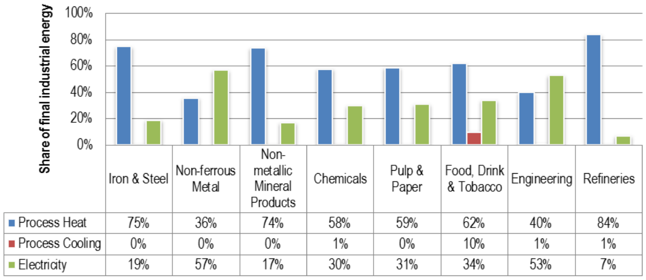
potential is estimated to be. A main focus though, will be on developing a risk assessment approach, which includes a risk-adjusted parameter into the investment analysis. The primary objective of this thesis work will be to analyze the impact and effect that different risk mitigation measures have on the investment assessment.

II. INDUSTRIAL PROCESS HEAT

In industry applications process heating and cooling are essential in a large variety of processes. The basic purpose of process heat systems is to generate heat and transfer it to the industry application.

A. *Market Potential of Process Heat*

Figure 1 confirms the high share of process heat in industry for several different industrial sectors. Refineries have the highest share of process heat with 84%, just followed by the iron and steel sector, in which 75% of its final energy demand stems from process heat. The second largest part of the total industrial energy use is from electric energy with 26%, process cooling only accounts for 1%.



	Iron & Steel	Non-ferrous Metal	Non-metallic Mineral Products	Chemicals	Pulp & Paper	Food, Drink & Tobacco	Engineering	Refineries
■ Process Heat	75%	36%	74%	58%	59%	62%	40%	84%
■ Process Cooling	0%	0%	0%	1%	0%	10%	1%	1%
■ Electricity	19%	57%	17%	30%	31%	34%	53%	7%

Fig. 1. Process heat share of final industrial energy in EU28, 2012 [4]

The total process heat only consumed by most energy-intensive sectors is around 80% and the share of high temperature energy is around 55% of the total industrial process heat.

The renewable share for process heating and cooling was still fairly low in 2012, with only biomass accounting for around 10% of the total process heat. The largest part, around 70%, is still provided by fossil fuel sources, mainly natural gas and coal. This share is supposed to decrease drastically up to 2050 [4].

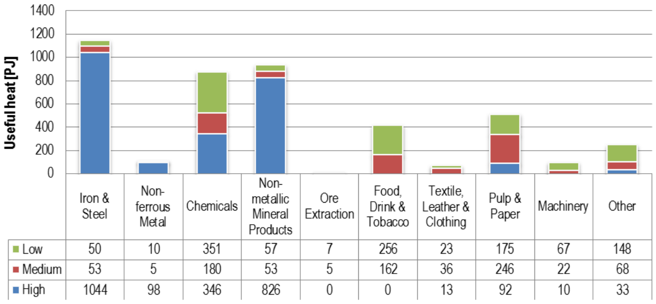
B. *Process Heat in Industrial Sectors*

Next to the division into different industrial sectors, heat processes are defined by their quality, hence their temperature levels. High temperature is defined to be over 400°C, medium temperature is from 100°C to 400°C and the low temperature level is below 100°C.

The most energy-intensive sectors especially consume energy at high temperature levels above 400°C. They are represented by the iron and steel, non-ferrous metals, chemicals, non-metallic mineral products and the pulp and paper sector (Figure 2) [5][6].

Though, in total around 45% of European industrial heat demand is for low to medium temperatures, which can already be provided by renewable energy process heat systems at better economic viability conditions than high temperature process heat.

The industrial sectors with the highest share of renewable energy generating systems are the food, drink and tobacco and the pulp and paper sector, with 18% and 32%, respectively.



	Iron & Steel	Non-ferrous Metal	Chemicals	Non-metallic Mineral Products	Ore Extraction	Food, Drink & Tobacco	Textile, Leather & Clothing	Pulp & Paper	Machinery	Other
■ Low	50	10	351	57	7	256	23	175	67	148
■ Medium	53	5	180	53	5	162	36	246	22	68
■ High	1044	98	346	826	0	0	13	92	10	33

Fig. 2. Industrial heat demand for EU27 in 2009 [6]

C. *Energy-Intensive Sectors*

There are five sectors considered as energy-intensive sectors, which are shown in Table I. All sectors, besides the non-ferrous metals sector, mostly have heat energy demands. This is confirmed by Figure 1. Especially, the iron and steel and the non-metallic mineral products have around 75% of their energy demand being for process heat. The chemical, pulp and paper and the non-ferrous metals sectors are especially suited for the capabilities of renewable process heat systems, which could provide them with low to medium temperature heat.

TABLE I
ENERGY-INTENSIVE INDUSTRY SECTORS [4][6][7][8][9]

Sector	**Products**	**Processes**	**Energy Driver**	**Temperatures**	**Specific Energy Demand**
Iron & Steel	Crude Steel	Blast Furnace Route, Recycling Route	75% Heat	800 – 2500°C	17 – 23 GJ/t 3 – 5 GJ/t
Non-metallic Mineral Products	Cement, Lime, Glass, Ceramics, Brick & Tiles	Melting, Sintering, Thermally Decomposing	74% Heat	800 – 1750°C	Glass: 7.7 – 10.1 GJ/t Brick Tiles: 2.31 – 8.1 GJ/t
Chemicals	Polymers, Petro-chemicals, Inorganic chemicals	Steam Cracking, Ammonia, Methanol, Chlorine Production	58% Heat	400 – 1000°C	Ammonia: 35 – 40.2 GJ/t Methanol: 10 – 12.4 GJ/t Chlorine: 1.2.3 GJ/t
Pulp & Paper	Paper	Mechanical, chemical or recovered paper production	59% Heat	Up to 400°C	Paper: 4 – 7 GJ/t
Non-ferrous Metals	Aluminum Copper Zinc	Aluminum: integrated or recycling route	36% Heat	300 – 1500°C	Aluminum: 3.8 – 76 GJ/t Copper: 14 – 20 GJ/t Zinc: 14 GJ/t

D. *Non-Energy-Intensive Sectors*

The remaining sectors are coined non-energy-intensive sectors. They are in charge of the remaining European process heat demand of 19% to 25% and displayed in Table II.

These sectors have maximum heat demands of up to 400°C and mainly have process heat demands as well. They are

TABLE II
NON-ENERGY-INTENSIVE INDUSTRY SECTORS [6][7][9][10]

Sector	Products	Processes	Energy Driver	Temper-atures	Specific Energy Demand
Food, Drink & Tobacco	Meat, Fish, Vegetables, Fruit, Wine, Beer, Soft Drinks, Cigarettes	Drying, Washing, Boiling, Sterilizing	62% Heat	0 - 400°C	Whey Dry: 11 GJ/t, Wheat Starch: 11.8 GJ/t, Carcass Poultry: 1.6 GJ/t
Textile, Leather & Clothing	Clothes, Bags, Tents, Nets, Umbrellas	Washing, Bleaching, Dyeing	45 – 52% Heat	30 - 160°C	Weaving: 11 – 65 GJ/t
Ore Extraction	Iron, Copper, Mercury	Froth Flotation, Reduction	N.A.	Up to 400°C	N.A.
Machinery	Aerospace, Automotive, Robotics	Cleaning, Drying	40% Heat	Up to 100°C	N.A.

already rather well suited to be supplied with more renewable technologies.

E. Energy Efficiency Strategies

Basically, there are two main energy efficiency strategies: heat recovery strategies and retrofitted systems. The former recovers and uses waste heat that otherwise is lost to the environment and would represent significant energetic losses. The latter consists of optimizing and retrofitting process heat systems.

In the recent past the progress of energy savings, through energy efficiency measures in the European industrial sectors, has slightly decreased, mainly due to the worldwide recession. From 2007 to 2013 the annual energy efficiency progress was down to 0.9%, in comparison to 1.9% from 2000 to 2007. Consequently, the annual energy savings decreased by around 60% after 2007 from an average of 6.3 Mtoe/year to around 2.5 Mtoe/year. One of the main reasons for this development is that many factories and companies had to decrease their production output and hence did not operate at full capacity, which then lead to less energy savings, as the total energy consumption decreased as well.

The firm ICF International conducted a study analyzing the energy efficiency potential of the European industrial sector. Their analysis is based upon a database of Energy Savings Opportunities (ESOs), which they grouped in regard to the respective industrial sectors. An ESO can either represent an energy efficiency measure through a heat recovery strategy or through a retrofitted system. The analysis is based on the energy consumption of a sector that will occur up to 2050 under usual and unchanging conditions, which is represented in the BAU (Business-as-Usual) consumption.

The machinery and food and beverage sectors reach the highest relative economic energy savings, with 13.3% and 14.5% of energy savings in 2050, respectively towards their BAU energy consumption. These savings are both in relation to relatively small total BAU energy consumptions and therefore solely present 2.5 Mtoe and 3.2 Mtoe of total saved energy, respectively. The highest total values of saved energy are attained in the iron and steel and the chemicals sector in 2050. The former is estimated to yield 6.8 Mtoe of saved energy and the latter around 7.4 Mtoe.

In detail heat recovery represents the recycling of heat. This can mean that a stream needs to be cooled down and hence the heat of this formerly hot stream is used elsewhere, e.g. to heat up a cold stream that needs to be warmed up. As well, this can entail the usage of waste heat to generate mechanical power or even electricity in the follow-up step [11].

The largest ESO of the heat recovery measures in terms of total quantity is the “low temperature heat recovery”, which has a large potential especially in the chemicals sector. In terms of relative energy savings potential per sector, the “exhaust gas” and “low temperature heat recovery” within the non-metallic minerals products have the largest potential with each around 13% to 14% of savings up to 2030 and 2050, respectively. The “exhaust gas heat recovery” is most applicable to different sectors, as it has a technical energy savings potential in six different sectors.

Next to the above presented heat recovery strategies, a large part of the ESOs involve retrofitting and changing the process heat generating systems. The largest technical energy savings potential is reached through an “integrated control system” in the iron and steel and the chemicals sectors, just as through the usage of “improved catalysts” in the chemicals sector with around 1500 to 1900 ktoe per year. The largest relative energy savings per sector are as well attained through an “integrated control system”, with around 14% to 15%, in each the pulp and paper, non-metallic mineral products and the machinery sectors. “Integrated control systems” and “flue-gas monitoring” systems are the most applicable to the overall industry, as they stand for energy savings in seven different industrial sectors.

F. Renewable Heat

Next to ESOs there are several renewable heat technologies that generate process heat. The increased deployment of these technologies mitigates emissions of carbon containing fossil fuel sources as well.

A study on the long-term potential of renewables in the global industry up to 2050 concluded that around 50 EJ/year of the final industrial energy consumption could be of renewable origin, representing around 21% of the total global industry share. 37 EJ/year (16%) standing for biomass feedstock and process energy and 10 EJ/year (4%) for process heat from solar thermal systems and heat pumps [5].

These three technologies are the most applicable for process heat generation in the industrial sector. The main focus in this thesis will be on solar thermal energy and biomass systems though, as these are direct renewable energy sources. Heat pumps basically depend on the power mix of the national electricity grid, as they are furnished with electricity. The investment analysis will only be conducted for solar thermal energy.

As for the moment biomass is mainly used in the food, drink and tobacco and the pulp and paper sectors, just as in the wood industry [12]. The further sectors, like the iron and steel, non-metallic mineral products, chemicals, non-ferrous metals, machinery and the textile, leather and clothes sectors use almost no process heat from biomass. In 2015 around 77% of global heat generated from biomass stemmed from solid biomass, 18% from municipal solid waste, 4% from biogas and 1% from biofuels [12].

Different biomass types are available and already commercialized. They are separated depending on their state of aggregation:

- Liquid biofuels: ethanol is produced through the fermentation of sugar and biodiesel through transesterification of vegetable oils
- Solid bioenergy: charcoal and pellets are made from wood and could both replace coal as a fossil fuel source
- Gaseous biofuels: biogas is obtained from anaerobic fermentation and producer or synthetic gas (syngas) from biomass gasification

The main solar collector technologies for low temperature levels (below 80°C) are unglazed flat plate, glazed flat plate and evacuated tube collectors. Flat plate collectors are made of plastic or copper tubing that is laid through an insulated and weather-proof box with a dark flat plate absorber on its top surface and insulated material on its backside.

For temperatures up to 200°C new technologies like ultra-high vacuum flat plate collectors or evacuated tube collectors with concentrators placed behind the tubes have been developed. The concentrators are called compound parabolic concentrators. Temperature levels up to 400°C can be generated by solar concentrators, such as parabolic dish and parabolic through collectors or linear Fresnel collectors.

By the end of 2015 the total global installed capacity of solar thermal systems reached around 435 GW, which provided a total energy output of 357 TWh [12]. Hence, the current installed capacity is around four times the capacity of 10 years ago, in 2005. The majority of these systems though are used for domestic hot water and space heating and very small amounts are used on an industrial scale. In fact only around 3% of the new installed capacity of solar thermal systems in the EU and Switzerland in 2015 was for district heating, process heat or cooling processes [12].

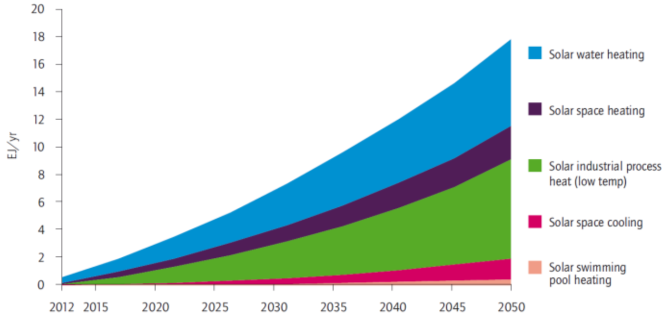


Fig. 3. Solar heating and cooling roadmap vision up to 2050 [14]

The key industrial sectors that should be addressed by solar thermal process heating technologies are the food, drink and tobacco; the transport equipment; the textile, leather and clothing; the machinery and the pulp and paper sectors. Around 60% of the heating need in these sectors is at temperatures below 250°C [13]. In regard to future installations of solar thermal systems the International Energy Agency (IEA) estimates that up to 2050 especially solar process heat technologies are going to gain a larger share of the total installed capacity of solar thermal systems, reaching up to around 7.2 EJ of newly installed capacity in 2050 (Figure 3).

III. INVESTMENT ANALYSIS AND THIRD-PARTY FUNDING

This chapter will present the main parameters that are needed for a thorough investment assessment. As well, a risk assessment model will be developed. Furthermore, it will present different risk mitigation measures and their influence on risk perception.

A. *Investment Analysis Parameters*

Investment analyses can be used to assess either a portfolio consisting of bonds and stocks, or an investment into a new business idea or even large corporate projects. In this thesis it is used to assess the profitability of an investment into more energy efficient and renewable process heat generating systems, exemplified by a solar thermal system. The use of the analysis results is supposed to be beneficial especially for third-party investors in helping them to compare such an investment to other options.

The main values that are generally used to assess the profitability of energy projects are the LCOE (levelized cost of energy) or in this case the LCOH (levelized cost of heat), the pay-pack period, the NPV (net present value) and the IRR (internal rate of return) [15]. In this case only the strictly financial parameters, the pay-back period, the NPV and the IRR will be assessed.

An issue regarding the pay-back period criterion is that it does not differentiate between different investment lifetimes and does not consider the time value of money. Both the IRR and the NPV take into consideration the time value of money and are therefore regarded as superior criteria towards the pay-back period criterion.

$$NPV = -I + \frac{\sum_{t=1}^{T_I} CF_t}{(1+i)^t} \qquad (1)$$

Equation (1) shows how NPV and IRR are calculated and it is defined by following values: investment I (CAPEX), investment lifetime T_I, discount rate i and the final cash flow CF.

If the NPV is positive the investment pays back more than it invested. In other words, if the sum of the discounted cash flows is larger than the initial investment, then the investment is profitable [16].

The IRR is equal to the discount rate i when the NPV is zero and hence is calculated through the same equation from above, setting the equation equal to zero. This can be done through a trial and error method, by trying to get the equation with the given investment and cash flows equal to zero. The IRR stands for the maximum discount rate at which the project remains profitable. If the discount rate is increased further the NPV becomes negative and hence the project is not profitable.

A relatively lower discount rate always increases the NPV, because the cash flows are discounted less.

$$CF_{Inv,t} = -I_t + RV_t \tag{2}$$

$$CF_{Op,t} = E_{R,t} * P_{C,t}(1-P) - I * OM * (1+Inf_t)^{t-1} \tag{3}$$

$$CF_{Fin,t} = Inc_t - FC_t \tag{4}$$

$$CF_{Fis,t} = -(CF_{Inv,t} + CF_{Op,t} + CF_{Fin,t} - Dep_t) * Tax \tag{5}$$

The final cash flow from Equation (1) is the sum of the four different cash flows presented in Equation (2), (3), (4) and (5). The equations are defined by the following values, presented in Table III.

TABLE III
INPUT PARAMETERS FOR CASH FLOW CALCULATION

Symbol	Description	Unit
RV	Residual value	€/m^2
E_R	Energy produced by renewable system	kWh
P_C	Conventional energy price	€/kWh
P	Premium for end user	%
OM	Operation & maintenance cost	%
Inf	Inflation	%
Inc	Financial incentive	€/m^2
FC	Financial cost (credit repayments and interest rate payments)	€/m^2
Dep	Depreciation	€/m^2
Tax	Tax rate	%
CF_{Inv}	Investment cash flow	€/m^2
CF_{Op}	Operational cash flow	€/m^2
CF_{Fin}	Financial cash flow	€/m^2
CF_{Fis}	Fiscal cash flow	€/m^2

B. *Risk Assessment and Mitigation Measures*

This chapter will focus on developing a risk assessment approach for process heat investments and on laying out different risk mitigation measures. The measures aim at securitizing investments into energy efficient and more renewable process heat technologies. They try to change the risk perception of investors, towards this kind of investments, through mitigating risk. This will be applicable to process heat investment into energy efficiency and renewable technologies, though the focus here will lay on solar thermal process heat systems.

1) *Risk-Adjusted Discount Rate*

There are different ways of how to include a risk analysis into assessing investment options. For investments into energy efficient and renewable process heat generation the risk-adjusted discount rate (RADR) technique has been analyzed to be the most appropriate and will therefore be presented and used to assess risk and the impact of risk mitigation measures on the risk perception.

Most of the other available techniques only allow determining a probability, with which future cash flows might occur. Hence, they make it more difficult to include all the impacts from the different risk mitigation measures. Or they yield a risk premium that is mainly based on systemic market risk and therefore represents exposure to market risk, but not to project risk. Especially for new markets, such as energy efficiency and renewable energies, this is critical, as there is little data available on the systemic risk of these markets [17].

The discount rate is one of the most important factors regarding the economics of a project, especially in capital intensive energy projects [18]. The RADR technique accounts for risk through the discount rate, which is determined by using the risk-free discount rate (RFDR) plus a risk premium that is in relation to the volatility and risk of the investment [19]. When a project is riskier than normal, the risk premium increases by the amount of risk that has been assessed.

The mainly used discount rate to assess investments is the weighted average cost of capital (WACC), which is calculated from the cost of equity and the cost of debt. Both equity and debt are generally used to finance projects. Therefore, the risk premium needs to be applied to the risk-free values of cost of equity and of cost of debt.

The risk of a creditor is generally lower than for an equity investor, because interest rate payments and debt repayments are rather secure, especially in comparison to dividends that are paid to an equity investor. The interest rate payments and debt repayments are ensured through the credit agreement, dividend payments though only occur if a project or company is making a profit. Furthermore, interest rate payments bring along a tax benefit, as they reduce the amount of taxes that need to be paid. Hence, the cost of equity is generally higher than the cost of debt.

The risk-free rate for the cost of debt and equity was set equal to the average annual yield of a 10-year government bond [20]. The risk-adjusted cost of debt C_D and cost of equity C_E are calculated through following Equations (6) and (7). They are basically the risk-free rate r_{RF}, which is the 10-year government bond yield of the respective country, plus the risk premium of debt r_{RPD} and of equity r_{RPE}, respectively.

$$C_D = r_{RF} + r_{RPD} \tag{6}$$

$$C_E = r_{RF} + r_{RPE} \tag{7}$$

The final RADR, or to be exact the risk-adjusted after-tax WACC, is going to be calculated through the risk-adjusted cost of debt and cost of equity, the tax rate and the capital structure. The tax rate is included to correct and further decrease the cost of debt. The after-tax WACC is calculated after the following Equation (8), in which DR is the debt ratio and ER is the equity ratio.

$$WACC = C_D * (1 - Tax) * DR + C_E * ER \tag{8}$$

The way risk premiums are generally calculated in the financial industry is not applicable to the energy efficiency and renewable sectors, because it is calculated in reference to past stock performances within a certain country and industry. Instead of referring to the financial industry, in this case the idea of how to calculate the risk premium for investments into energy technologies was taken from the mineral industry and a paper by PARK ET AL. In their approach five different steps are used to calculate the risk premium [19]:

1. Identifying risks
2. Developing rating scales
3. Determining risk values
4. Calculating risk scores
5. Determining the risk premium

As first step, three main risk categories were identified in the process heat technology sector: technology, economic and political or policy risk [21][19]. As second step after Park Et Al., each probability and impact per risk factor needed to have a rating scale. These were defined as low, medium or high on a scale from 0 to 1. In steps three and four the total risk score TRS of an investment is calculated trough Equation (9), based on all the risk factors and their probability P_{rf} and impact I_{rf} [19].

$$TRS = \sum_{i=1}^{11} P_{rf,i} * I_{rf,i} \qquad (9)$$

The last and fifth step is to convert the total risk score into a risk premium that can be used to adjust the cost of debt and equity. To define the risk premium values for process heat investments, reference was made to an analysis for onshore wind by Noothout Et Al., who calculated risk-adjusted values for the cost of debt and equity for each European country in 2014 and validated them through interviews with equity providers, project developers and banks [22].

2) *Energy Contracting*

Energy contracting is the general term currently used for energy services that are offered based on certain risk mitigation measures. Generally a contractor offers different kinds of contract types to an end-user, to make his energy consumption more energy and cost efficient. An energy service company (ESCO) or another type of energy related company can be the contractor. This is mostly done by offering a full package of services including planning, construction, operations and maintenance, optimization and financing. Most of the contract types are based on performance based compensation and performance guarantees, which consequently means that the supplier often has technical and economic project risk transferred to him [23]. The main contracting types are the following:

- Energy performance contracting (EPC)
- Energy supply contracting (ESC)
- Energy operations contracting (EOC)
- Guarantee of solar results (GSR)

GSR is the contracting and guarantee scheme that this thesis will focus on to assess investments into solar thermal systems for process heat applications in the industry. It is chosen in reference to Ademe Et Al. and Medved Et Al. and basically is equal to the ESC scheme [24][25].

The technology risk is swapped from the contractor or third-party investor to the tech-supplier, who will take care of operations and maintenance (O&M) and guarantee that the system functions adequately.

3) *Risk Mitigation Measures*

Additionally and next to the above presented contracting types, the following risk mitigation measures are applied to a solar thermal investment to further positively influence the risk perception through decreasing the risk-adjusted discount rate (Table IV).

TABLE IV
Risk mitigation measures

Risk Mitigation Measures	**Description**
Financial structure	Ensures timely payments to creditors through payment priorities settled in regard of the risk and return expectations of the handed out tranches. Low-risk tranches have a high payment priority, high-risk tranches have a lower priority
Internal liquidity facility	Helps ensure on time payments to investors when short-term cash flow problems arise; through debt service accounts or excess spread accounts
Liquidity guarantee	Ensures that the borrower can refinance the credit through lengthening the lifetime of a credit with a second credit
Partial credit guarantee	Helps to cover part of a debt default by the borrower, regardless of the cause of default for a period of the debt term for a public investment

C. *Third-Party Funding*

The above described manifold of energy contracting schemes and risk mitigation measures are thought to attract third-party investors to fund increasing amounts of retro-fitted process heat systems. Next to risk mitigation, there are other things that can enhance additional investment into energy efficiency and renewable technologies for process heat applications. ESCOs, contractors and investment funds have created a diverse mixture of different platforms to facilitate the process of bringing together end-users, technology suppliers and potential third-party investors.

1) *ESCOs*

ESCOs have been increasing the deployment of energy efficiency measures and renewable technologies through service contracting in several sectors. An ESCO is defined as a "[…] natural or legal person who delivers energy services or energy efficiency improvement measures in a final customer's facility or premises", by the European Energy Efficiency Directive [26][27].

Basically, ESCOs represent the following three characteristics. They guarantee energy savings or provide the same level of energy services at a lower cost. The remuneration is directly tied to energy saved or supplied and they help in financing or arranging finance for the energy system.

2) *Investment Funds*

Funds for general energy efficiency measures or renewable energy technologies have been available for some years now. There are funds based on equity, debt or a combination of both. Mostly they are attractive to socially and environmentally responsible investors. Though, they have become more and more accepted and interesting for other investors too, due to their financial attractiveness. They can be an interesting catalyst for increased investment into new process heat technologies [28]. Most of the current funds are developed to finance either energy efficiency measures or renewable energy technologies for the power sector.

Especially institutional investors, such as pension funds, insurance companies, endowments and sovereign wealth funds can play an important role in scaling up investments into these technologies [21]. After an estimate from the OECD (Organization for Economic Co-operation and Development) there are around $2.8 trillion available annually for clean energy investments from pension funds and insurance companies [29].

IV. IMPACT OF RISK MITIGATION MEASURES ON INVESTMENT ANALYSIS

The investment analysis is going to be done in the following for solar thermal systems that can replace conventional energy sources in process heat applications at each four locations in Austria, Germany, Portugal and Spain.

A. Input Parameters

The constant input parameters that were needed to conduct the investment analysis are displayed in Table V. They were used to calculate the above mentioned cash flows and hence as well the key performance indicators (KPIs), such as the pay-back period, the IRR and the NPV. For the solar yield of the installed solar thermal systems, a different value for each of the 16 locations was obtained. The inflation and conventional energy prices were defined in three different scenarios. The cost of debt, that would define the financial costs, will be defined for basic and for securitized risk, just as the WACC, which will additionally be calculated for three debt-to-equity ratios. The O&M cost differs for the basic and securitized case, because the tech supplier, who takes over the technology risk, charges a higher fee for securitizing some of the risk. All the above mentioned values can be found in detail in the full version of this thesis.

TABLE V
CONSTANT INPUT PARAMETERS

Symbol	Country/Risk	Quantity	Unit
I		400	€/m^2
P		98	% of conventional energy price
Dep		4	years
T_I		20	years
T_C		10	years
T_P		25	years
RV		20	% of investment
Inc	Austria	44	% of investment
	Germany	50	
	Portugal	1.25	
	Spain	0	
Tax	Austria	25	% of taxable profit
	Germany	30	
	Portugal	21	
	Spain	25	
OM	Basic	1	% of investment
	Securitized	1.5	

T_C is the credit lifetime and $T_P$is the product lifetime

B. Basic and Securitized Risk Assessment

The assessment will be done through the RADR method specifically for solar thermal systems providing process heat in Austria, Germany, Portugal and Spain. The risk assessment is done for the basic and securitized scenario by defining the impact and probability of several risk factors. The basic risk assessment is done for the reference case in which the energy system is installed, run and maintained by a contractor over the whole investment lifetime. In the case of securitized risk the system maintenance is handed over to a tech-supplier, who provides an availability guarantee.

Through Equations (6), (7), (8) and (9) the following WACC results (Table VI) could be obtained. For Austria and Germany the WACC is decreased by around 2% through risk mitigation. In Portugal and Spain the reduction is even of around 3%.

TABLE VI
WACC RESULTS FROM BASIC AND SECURITIZED RISK ASSESSMENT

Symbol	Risk	Country	Quantity	Unit
$WACC$	Basic	Austria	6.04	% (average out of three debt-to-equity ratios)
		Germany	5.66	
		Portugal	9.51	
		Spain	8.33	
	Securitized	Austria	4.04	
		Germany	3.29	
		Portugal	6.52	
		Spain	5.39	

C. Results of Investment Analysis

With the obtained WACC values an investment calculation was conducted, which yielded the most important KPIs. They were calculated for all 16 chosen countries, for three macroeconomic scenarios, for the basic and securitized risk assessment and for three debt-to-equity ratios. The highest debt lever is represented by option 3 (Figure 4, 5 and 6). The scenario of high conventional energy prices and inflation clearly yielded the most favorable results and therefore the main KPIs for this scenario are presented in Figure 4, 5 and 6.

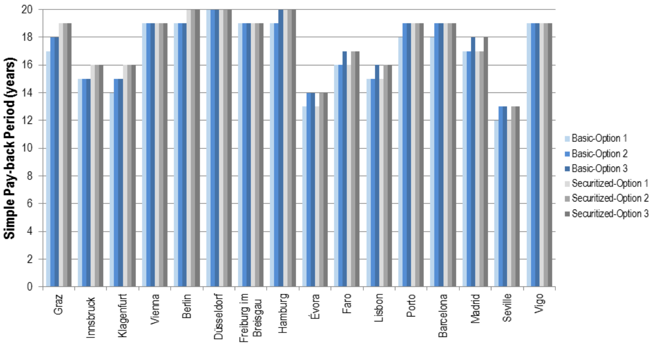


Fig. 4. High price scenario simple pay-back period results

Seville has the best pay-back values, which go down to 12 years. Évora, Innsbruck and Klagenfurt come close to that. The German locations yield the worst values, especially Düsseldorf has a pay-back period of 20 years in all scenarios, almost double that of Seville. In Austria and Germany the securitized pay-back periods are always at least higher than those from the basic assessment.

The majority of locations have positive IRRs, with the highest values at around 6% to 7% for Évora and Seville. Innsbruck and Klagenfurt come close to that and have IRRs of around 5%.

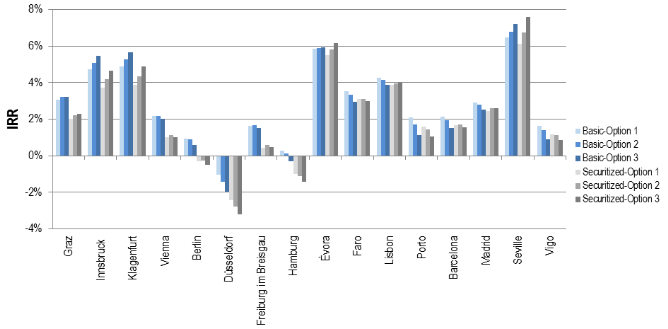


Fig. 5. High price scenario IRR results

Düsseldorf has negatives IRRs, just as Berlin and Hamburg with securitized risk. In Austria, besides in Vienna, option 3 always has a higher IRR than option 1 and 2.

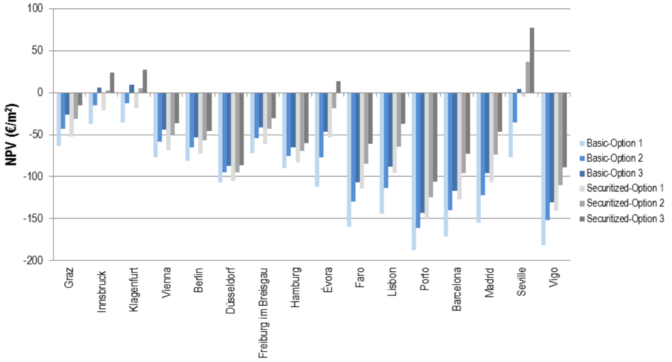


Fig. 6. High price scenario NPV results

Besides Innsbruck, Klagenfurt, Évora and Seville no location reaches financial viability under either of the scenarios after the NPV. The named locations are the only ones with positive NPVs. In all locations risk mitigation and higher debt leverage increase the NPV.

1) *Critical Input Parameters*

Through the different scenarios and options that were assessed, a kind of sensitivity analysis for important input values has already been conducted. Though, further input parameters are assumed to have a rather large influence on the KPIs as well. Therefore, an assessment of the impact of changing the incentives and the CAPEX (capital expenditure) will be done. The assessment will be done at high debt leverage. The question is which value would these two key input parameters have to have so that the investments would be financially viable at all locations. Financial viability is defined as having a positive NPV.

The results are presented in Table VII and are the average values from the three different scenarios. Their actual values are displayed for each country at basic and securitized risk and the difference towards the initial incentives and investment costs are shown as well. The initial values are displayed above in Table IV. In both cases Austria would attain viability conditions at the smallest decrease in investment cost of only around 40%. As well, Austria would only have to increase its incentives by 26% to be financially viable at all their locations. Germany would need to have the highest decrease of investment costs of around 54%, but would only need to increase its incentives by 33%, a lot less than Portugal and Spain.

TABLE VII
CRITICAL CAPEX AND INCENTIVES FOR FINANCIAL VIABILITY CONDITIONS (NPV > 0)

Symbol	Risk	Country	Quantity	Δ	Unit
I	Basic	Austria	235	- 41%	€/m^2 (average out of three energy price scenarios at high debt leverage option)
		Germany	175	- 56%	
		Portugal	188	- 53%	
		Spain	195	- 51%	
	Securitized	Austria	249	- 38%	
		Germany	190	- 53%	
		Portugal	218	- 45%	
		Spain	228	- 43%	
Inc	Basic	Austria	70	+ 26%	% of investment (average out of three energy price scenarios at high debt leverage option)
		Germany	82	+ 32%	
		Portugal	58	+ 56%	
		Spain	55	+ 55%	
	Securitized	Austria	70	+ 26%	
		Germany	84	+ 34%	
		Portugal	52	+ 51%	
		Spain	49	+ 49%	

2) *Analysis of Results*

The main question within this thesis is how far the risk mitigation measures can impact the assessment of an investment, so how far they influence the KPIs. Further questions that will be analyzed in the following are how changes of the debt-to-equity ratio, the CAPEX and the incentives impact the KPIs.

The main positive influence of a reduced WACC is a lower discounting effect on the final annual cash flows. The risk mitigation measures though have an effect on two other main parameters as well: the cost of debt and the O&M cost. The former is reduced through risk mitigation measures and hence reduces the costs that stem from interest rate payments, which directly reduce the financial cost. The latter is increased through risk mitigation measures, because the tech-supplier charges extra fees for providing an availability guarantee. An increase of O&M costs directly increases the operational cost (Figure 7).

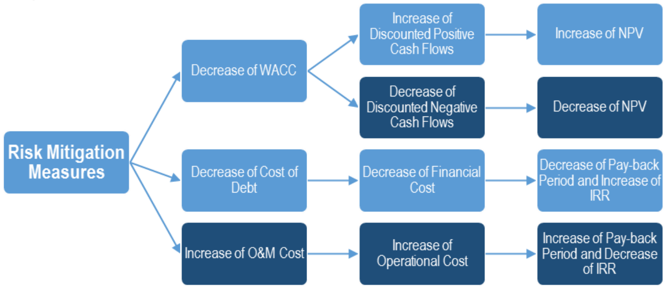


Fig. 7. Effects of risk mitigations measures through risk-adjusted discount rate method

The NPV clearly displays the advantages that risk mitigation, in form of energy contracting schemes and further risk mitigation measures, brings along. And most importantly it shows that the positive effects of the decreased WACC and cost of debt outweigh the increased O&M cost. Figure 8 confirms the positive impact of risk mitigation displayed through the NPV. It shows the Δ NPV from a basic to a securitized risk assessment. In other words, it shows the difference in €/m^2 from the NPV with basic risk to the NPV with securitized risk. It can be noted that in the locations with rather high solar yield risk mitigation has the most positive impact.

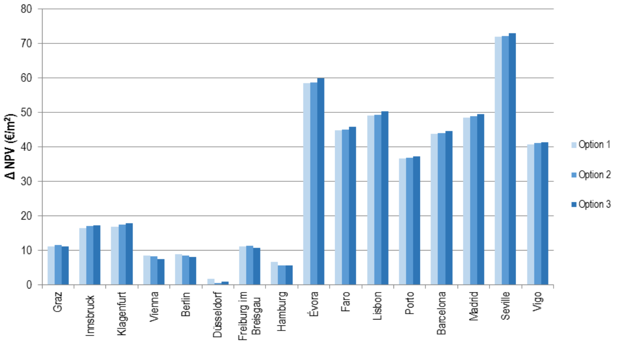


Fig. 8. High price scenario Δ NPV

A further analysis regarding the different three options of debt leverage shows that increasing the debt leverage has three direct consequences:

1. Initial CAPEX on the balance sheet is reduced
2. Financial cost is increased
3. WACC is decreased

The first two consequences generally lead to a higher pay-back period (Figure 4). The effect of a reduced CAPEX and an increased financial cost on the IRR depends on the final cash flows. In rather positive conditions, with positive final cash flows, the effect of higher debt leverage is a higher IRR. In the other, rather unfavorable, locations a counter effect of higher debt leverage takes place though. Especially the increase of the financial cost impacts the IRR negatively. Hence, smaller IRRs are obtained through higher debt leverage in rather unfavorable locations (Figure 5). As the NPV includes the positive impact of a decreased WACC, higher debt leverage generally leads to a higher NPV (Figure 6).

As for the critical CAPEX and incentives presented in Table VII, a first thought leads to the conclusion that more incentives to decrease the CAPEX by one unit should have the same financial effect as decreasing the CAPEX by one unit through improved manufacturing processes. Especially for Austria and Germany this is not entirely true. With basic risk they would have to have CAPEX decrease of 41% and 56%, respectively. And they would only need an incentive increase of 26% and 32%, respectively, to obtain financial viability. Similar results are obtained through the securitized risk assessment.

The reasons behind this are the incentives that are already in place in Austria and Germany. In Germany for example, decreasing the CAPEX by 10% only represents a decrease of 10% from the final CAPEX value, which is already deducted by the 50% incentive in Germany. At an initial CAPEX of 400 €/m^2 the final CAPEX value is 200 €/m^2, therefore a 10% decrease of the CAPEX stands for 20 €/m^2 instead of 40 €/m^2.

V. CONCLUSIONS AND FURTHER STEPS

The two most essential things within this thesis were, firstly, the development of the risk assessment model and its consequent application for basic and securitized risk and secondly, the investment analysis based on different energy price and inflation scenarios and for several locations in Europe.

Through the usage of the RADR method within the risk assessment, the WACC was able to be decreased through risk mitigation on average by 2.9%, under the least debt leveraged option. The highest impact of risk mitigation was analyzed in locations with high solar yield. Seville yielded an NPV that was 73 €/m^2 higher through risk mitigation (Figure 8). That means the NPV could be improved by this amount through using the GSR scheme and the other risk mitigation measures. The other two KPIs, the pay-back period and the IRR do not display the positive impact of risk mitigation, because they do not consider the discounted cash flows, which are positively influenced by the WACC. They are calculated from the undiscounted cash flows, which are slightly decreased through the increased O&M costs. The conclusion is that with the RADR method as risk assessment tool, the pay-back period and the IRR will yield less favorable results when using risk mitigation measures.

In regard to the capability of increasing the amount of investments into the process heat sector through risk mitigation and the RADR method, quite a paradigm shift would be necessary for an extensive increase of investments, because investors would need to start using solely the NPV as KPI and not consider the pay-back period and the IRR.

In regard to critical input parameters such as the technology cost, Seville proves the benefit of risk mitigation. Under a neutral energy price scenario with risk mitigation it would need a decrease of technology cost from 400 €/m^2 to 284 €/m^2. Though, with risk mitigation the technology cost decrease would only have to be decreased to 332 €/m^2, so that Seville reaches financial viability. This shows that risk mitigation tools render investments into solar thermal process heat systems more attractive under good solar irradiation.

The most critical input values for the evaluation of the effects of risk mitigation are the impact and probability of each risk factor under basic and securitized risk. For further validation of the developed risk assessment model these values would need to be verified through industry expert interviews. This would enable to see how accurate the values used in this thesis can be considered. Furthermore, industry experts could give feedback regarding the structure of the risk assessment model and how far they would consider only using the NPV as evaluation parameter.

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