NTNU – Trondheim
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Interrelationships of LNG cargo containment systems and machinery configurations on LNG carrier - design and operational factors with economic assessment

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Master's thesis

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The task of the candidate is to determine and evaluate the energy balance and efficiency, as well as economic interrelations between the layout of the vessel's cargo containment system, (i.e., tank type and it's volume and weight, insulation system, alternative boil-off gas handling systems (high/low pressure system, re-liquefaction plant)) and machinery configurations (2-stroke DF, 2-stroke diesel) on a vessel to carry LNG.

The cargo containment to be analysed can include an IMO Independent Tank Type A with various insulation configurations. An existing ship design can, if desirable, be used as basis in the analysis, and it is expected that the physical parameters of the ship is fixed. Irrelevant ship design tasks related to the problem above, such as stability and hull strength calculations, will not be expected from the candidate.

A model in Excel or similar is expected to be developed for calculations. Economic performance should be expressed and compared through ROI, PV and IRR calculations. The energy efficiency should be evaluated and expressed by IMO's Energy Efficiency Design Index (EEDI) or similar.

The candidate is assumed to cooperate with LNG New Technology AS (LNT), where the contact person is Kjetil Sjølie Strand. As demanded by LNT, the thesis will be marked "Confidential" and not made available to students, teachers or general public for a period of 5 years. A version stripped of all confidential information may however be used in research or teaching.

The assignment to be attached and the thesis produced in accordance with the rules of the Department of marine Technology. The thesis to be submitted not later than 10th of June, 2012.

Department of Marine Technology________2012

Preface

This report is a master thesis in ship technology, conducted spring 2012, and is the closure of the author's Master of Science degree at Division of Marine Systems at Department of Marine Technology at Faculty of Engineering Science and Technology at Norwegian University of Science and Technology (NTNU).

The thesis has been carried out in cooperation with LNG New Technologies AS (LNT), a naval architect company engaged in new LNG carrier designs. The author has mainly been located at LNT's head office in Tønsberg during the project work. Professor Bjørn Egil Asbjørnslett has been the author's supervisor from NTNU, while Kjetil Sjøli Strand, Managing Director of LNT, has been the supervisor from LNT.

The objective of the thesis have been to design a vessel for LNG transport between Port Moresby in Papua New Guinea and Singapore, with a cargo capacity corresponding to a total freight work within the range of 800,000-1000,000 m3 annually. The main focus area in the design process have been to evaluate and optimize various cargo handling configurations, including cargo containment systems, boil-off handling alternatives, as well as ME engine alternatives, against ship profitability and efficiency. The task has been extremely interesting as well as instructive, and has given the author a lot of insight into LNG carrier designs.

The main restrictive factor has been the time scale. As a consequence, only a few ship design configurations have been looked into and technical-economic evaluations have mainly been performed without sensitivity analysis.

I would like to thank my supervisors Professor Bjørn Egil Asbjørnslett and Kjetil Sjøli Strand for their valuable guidance throughout the project. Furthermore, I whould like to thank Jørn Jonas at Rondane LNG and Per Ivar Nikolaisen and Bjørn Are Olsberg at Marine Gas Insulation for their assistance and consultation, which has been very helpful.

Tønsberg 10/6 – 2012

Andreas Norberg

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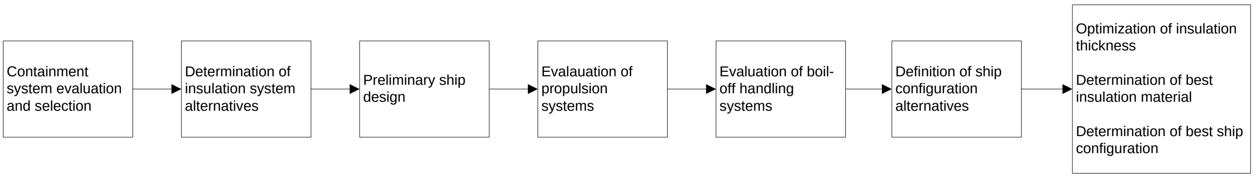
Executive Summary

The main objective of this project has been to design a ship for LNG trade between Port Moresby and Singapore, with a cargo capacity corresponding to a total freight work in the range of 1.000,000 - 800,000m3 annually. The main design emphases have been on propulsion- and cargo handling systems.

The project is divided in to three parts. The first part gives a thorough investigation into design theory and design optimization methods. The second part gives description of current state of the art within LNG carrier designs and technical interrelationships in ship design. The third part contains the ship design process, following the systematic approach illustrated below.



Based on a qualitative analysis of the most promising containment systems offered in the market, LNT A-BOX was found favourable. The LNT A-BOX consists of an independent tank type A as primary barrier, with liquid tight thermal insulation connected to the hull compartment as secondary barrier, resulting in a fabrication friendly and cost effective design with access to both primary and secondary barrier for ease of inspection and repairs.

The insulation system is built up by two layers of insulation and can either consist solely of polyurethane foam, polyurethane panels or expanded polystyrene panels or a combination of these. No obvious benefits of each insulation material were clear, so six different insulation systems were determined for further investigations.

Based on the given trade rout, a cargo capacity within the range of 35,500-49.000m3, divided in three equal sized cargo tanks, were found necessary to meet required annual freight work as well as damage stability requirements. The physical parameters of each cargo tank were furthermore determined by dimension ratios from previously built IMO A tanks in combination of with free board evaluations on existing gas carriers. A maximum allowable insulation thickness of 1040mm was set as constraint when determining required cargo hull compartment size. The cargo compartment size was furthermore used as basis in the ship design process.

In order to determine ship dimensions and hull form, ship statistics and empirical formulas was used. DWT was initially determined from comparison ships with cargo capacities within the same range, and was further used to set initial ship dimensions. Based on initial dimensions, LWT was determined from recommended empirical formulas and coefficients. An idea of required installed power for propulsion was early set by statistics, and weight of machinery systems was determined by weight coefficients. Some ship dimension iterations were performed before final dimensions where set.

Hull form was furthermore determined by empirical formulas and suggestions given in various literatures. Some minor changes where later on changes after determination of main engine alternatives, and during general arrangement modelling in Autocad.

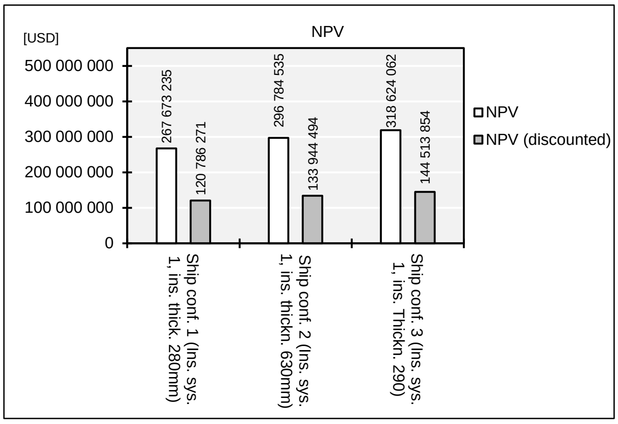
In order to select the best propulsion system for the vessel, evaluation of propulsion systems currently in use on LNG carriers were performed. Thermal efficiency, propulsion efficiency and fuel efficiency was decisive factors in the evaluation process. Slow speed duel fuel and diesel engines with direct drive and fixed propeller were found beneficial and MAN engines were selected.

Required engine output was determined by resistance calculations.

Boil-off handling systems for each propulsion systems have been selected based on recommendations given by engine supplier. In order to determine cost and power consumption of each system, statistics of previously built systems was gathered. Based on engine and boil-off handling evaluation the following ship configurations where determined as favourable for the vessel

Ship configuration	1	2	3
Propulsion system	MAN B&W 6S50MEB9 1 set. SMCR: 10680kW at 117RPM Direct drive, FPP	MAN B&W 6S50ME-GI-B9 1 set. SMCR: 10680kW at 117RPM Direct drive, FPP	
Boil-off handling system	Re-liquefaction plant + GCU	Gas supply system alt. 1 3 stg. HP compressor HP fuel pump LNG vaporizer + GCU	Gas supply system alt 2 HP fuel pump LNG vaporizer Re-liquefaction plant +GCU

To determine most cost efficient ship configuration a cash-flow model was used and NPV was selected as economic evaluation criteria. Optimal insulation thickness of each insulation material was first identified by using a direct search optimization approach, and optimal insulation thickness was identified from NPV graphs given as function of insulation thickness. Insulation system 1 was identified as the best insulation material for all insulation thicknesses. In order to determine the best ship configuration, ship profitability for each configuration with optimal insulation thickness was estimated and the result is presented in the bar chart below.



1 Introduction

Natural gas has been one of the fastest growing energy sources in the world the past two decades. Natural gas provides today 24% of the world's primary energy [1] and according to IEA, annual growth in natural gas usage will be about 1.7% from 2009 to 2030, [2].

A significant amount of discovered gas reserves are stranded. In order to commercialize stranded gas, the gas can be liquefied (LNG) for ease of storage or transport. According to IEA, LNG production is expected to play a key role to meet growing gas demand, and it is expected that LNG trade will grow with an annual rate of 7% in average from 2009 to 2030, [1].

At the end of 2010 there were 94 liquefaction plants in operation globally, representing a total liquefaction capacity of 270.9mmtpa, and during 2006-2010 liquefaction capacity increased with an annual rate of 10%. Considering the enormous gas resources and increasing LNG production as well as liquefaction capacity, the LNG price is expected to develop reasonably compared to other fuels, [2]. From an environmental point of view, natural gas is undoubtedly the cleanest fossil fuel. It is said that with an increasing awareness and focus on emissions, natural will play a key role bridging the use of traditional fossil fuels to renewable fuels in the future, [3].

The industry has typically only been about large scale production and transports. 3-4 train LNG liquefaction facility with production capacities in the range of 10-15mmtpa is typical, and transport is normally arranged on long term contracts on massive carriers with LNG capacities often in the range of 140,000-250,000m3. But due to an emerging natural gas demand, the LNG industry is getting more and more liquid and diverse. Small-scale LNG distribution is a new flourishing LNG market segment [4], and involves transport of LNG from large terminals or hubs to small terminals, in order to facilitate LNG supply to costumers in remote areas.

In Papua New Guinea, an interesting project to commercialize gas discoveries in the southern and western highlands of the country is currently under development. The project includes gas production, processing, liquefaction of 1mmtpa LNG, with an expected start up is 2015. The project is based around a one-train LNG liquefaction facility near Port Moresby and has an expected life span of 30 years, [5]. The gas buyer is however uncertain, but it is likely that the LNG will be re-distributed from a proposed LNG hub in Singapore. To bring the project alive, two dedicated and highly cost efficient carriers is expected to be requested for soon. The Papua New Guinea LNG project differs from most other projects going on, due to the relatively low annual production rate and comparatively small intermediate storage facilities compared to typical terminals in for instance Qatar, Kenai and Australia, which requires a non-existing LNG carrier size to perform the distribution job.

1.1 Objective

The objective is to propose a LNG carrier design for the given LNG trade between Port Moresby and Singapore, with a cargo capacity corresponding to a total freight work in the range of 1.000,000 - 800,000m3 annually, with emphases on propulsion- and cargo handling systems

1.2 Scope

- LNG cargo containment systems evaluation
- Optimization of cargo containment insulation thickness, and determination of favorable insulation materials
- Evaluation of propulsion systems i.e., main engines and power transmission systems
- Evaluation and determination of boil-off handling methods
- Determination of optimal cargo handling configurations
- Economic assessment of optimal ship configurations

1.3 Structure

The report is divided into three parts:

Part 1: Design Theory
Part 2: LNG Carrier Characteristics and Interrelationships in Design.
Part 3: Ship Design and Analysis

The first part gives a thorough investigation into design theory and design optimization methods. The second part gives description of current state of the art within LNG carrier designs and technical interrelationships in LNG carrier designs. The third part includes ship design, selection of favourable cargo containment systems and propulsion system alternatives, insulation thickness optimization and insulation material determination, and economic assessment of ship configurations as well as evaluation of energy efficiency.

Part 1 – Design theory

2 Ship design theory

Ship design brings together the needs and ideas of many functions from the ship operator, ship-owner, planner, procurer and producer, [6]. In other words, designing can be characterized as a process of converting information that characterizes the need and requirements for a product into knowledge about the product [7] and can be considered as a mapping of functional descriptions of a product into a physical description, [8].

Ship design requires the involvement of a wide range of engineering disciplines. Ship design is not an exact science but embraces a mixture of theoretical analysis and empirical data accumulated from previous successful designs. Due to the complex interrelationships between features of the technical design, and the construction of the ship and its operation, the final design will often represent a compromise between conflicting ship requirements, [9].

The goal of the ship design process is to determine the ship characteristics, and in order to achieve that, design has to be regarded as a decision making process. The selection of design parameters is a decision, and with any decision there is always some level of uncertainty, [6]. In order to reduce uncertainty, the designer has to use knowledge to reduce this uncertainty [6] such as knowledge about previous successful designs.

The vessel must be regarded both as a mean of transport that shall satisfy operational requirements, and in addition have the best possible constructive design. Thus, the design includes the selection of ship dimensions, hull form, power demand and type, cargo capacity and systems, preliminary arrangement of hull and machinery, and major structural layout. Proper selections assure the attainment of mission requirements such as good sea keeping performance, maneuverability, the desired speed, endurance, cargo capacity etc. Furthermore it includes checks and modifications for achievement of required cargo handling capabilities, quarters, hotel services, subdivisions and stability standard, freeboard and tonnage measurement; all while considering the ship as part of a profitable transportation, industrial or service system, [10]. This requires a balancing of technical, economic, environmental, social and legal factors. Consequently, design of ships requires considerable theoretical insight and professional experience, [11].

The most common way to describe ship design is by a spiral model, sometimes called set based design [6] capturing the sequential and iterative nature of the process. This model easily locks the naval architect to his first assumption and will patch and repair this single design concept rather than generate alternative solutions, [12]. Consequently, this traditional empirical design process is no longer sufficient. Today's design methods are characterized of improved integration between various professions, and comprehensive use of data processing, [11].

2.1 Preliminary ship design

Preliminary ship design compromises the activities from the design project in initiated to a contract specification is delivered. This corresponds to three first stage of the design model of [13], that is clarification of task, conceptual design and embodiment design. Each activity is bounded in time by a set of events and deliverables. Though the content of these activities and events will vary with respect to both the actual design problem and to differences in design practice, some similarities can be found that together can be used to form a prototypical preliminary ship process, [14].

Taking life cycle considerations into account increases the emphasis on the early stages of project initiation. This is because major design decisions are generally made in the preliminary design phase, and the main part of life cycle costs are consequence of decisions made in this phase. Usually, these decisions are based on predominance of soft information and can have far-reaching effects on the system being designed. Conceptually, it is evident from any perspective that as a design process progresses and decisions are made, the freedom to make changes as one proceeds is reduced and the knowledge about the project of design increases. At the same time, there is a transformation in the character of the information from soft to hard. The goal of modern design methods is to “drag” the knowledge curve to the left, and thereby increase the ratio of hard to soft information that is available in early stages of the design. The relative improvement in the quality of information should lead to designs that are completed in less time and less cost than those designed using a traditional sequential process, [7].

Furthermore, the number of assumptions made in the preliminary design phase is often astounding when one counts them thoroughly. To obtain a successful design it is especially important to have a clear understanding of these assumptions. It is important that assumptions are as unrestrictive as possible. A correct design method should include sensitivity tests on these assumptions and making a final choice based on the range of design parameters that may considered optimum as a result of the sensitivity analysis, [15].

2.2 Design structuring

Design has evolved from mainly being a one-man invention process into a multi-person/multi-team core activity in the industrial organization. In processes where the designer before could rely on skills and experience in organizing and carrying out the design tasks, it is now common that a large number of people with different backgrounds, sometimes located at geographically distant places work closely together on the same design in parallel. From this follows a requirement for both a systematization and common taxonomy of design, design process, manufacturing and estimating, [14]. In addition, a systematization of the project is an absolute condition to utilize all the advantages of data processing, [16]. To systemize the design process and manufacturing, it is common to use some sort of technical chart of accounts or a breakdown structure. A common system for technical chart of accounts in shipbuilding in Norway is the SFI group system, while a breakdown structure can be either a work breakdown structure (WBS), product breakdown structure (PBS), organization breakdown structure (OBS) or cost break down structure (CBS). To develop a breakdown structure, comprise splitting up or breakdown of the project into elements in a logic and systematic way. Furthermore, these elements can be divided into minor elements, [16].

2.3 Design objectives

Ship-owners operate ships to make a satisfactory profit on their investment. The evolution of technical design can therefore be considered as a component of an overall economic model. In evolving a ship design is therefore necessary to assess the operating requirements and the environment in which the vessel is to operate, to evolve the feasible technical design and to economically justify the viability of the proposal. In an overall final design process the design objectives have to be clearly identified and constraints in the process incorporated, [9]. The following are some examples of alternative objectives:

- Design for functionability or capability
- Design for efficiency and economy
- Design for production
- Design for maintenance
- Design for the environment
- Design for disposal or scrap

Each objective is important in each own way. Achievement of all the objectives is desirable, but difficult and resource-intensive, so a weighting is often important, [9].

2.4 Design models

The principal role of a ship designer is as mentioned to make decisions. The challenge is often how to make the right decision in an efficient way. During the last decades of the nineteenth century, there was a development towards a “science of design”. The notion of a design science was first put forth by Simon in his book “The science of the Artificial” in 1969, [17]. Following this, the design community has put considerable effort in developing a theoretical foundation on which such a science can be built. A good survey of the current status of design science was given by [18]. Particular research areas comprise the formulation of a design taxonomy [19] [20], the identification of fundamental design axioms and invariants [21] [7], the development of procedures for hypothesis formation and testing in design [22], and the establishment of a theory for understanding design process [12] [23].

2.4.1 Descriptive design models

The purpose of descriptive models is both to describe how design is performed within a practical setting, and to identify the general characteristics of real-world design processes. Often these descriptive models are based on protocol studies of individual designers or design groups, where data such as sketches, calculations, verbal communication et al. are systematically gathered and evaluated. Naturally it is difficult to validate the design models evolving from such studies, since design to a large extent is a mental process where there are few visible records. Still, descriptive models serve as an important input in the development of prescriptive models, as guidelines for humans designers, and for methods to be implemented in a computer system, [14].

2.4.2 Prescriptive design models

There has been several design frameworks proposed, aiming at serving an integrating role between the different design models. However, there are no neutral representations the way we choose to represent both the design object and the design process will necessarily presuppose a particular model. According to [14] different prescriptive design models can be grouped into five main categories:

1. Design as a systematic decomposition and synthesis
2. Design as a sequential, iterative process
3. Design as mathematical optimization problem
4. Design as a creative activity
5. Knowledge-based design and artificial intelligence approaches

Design as a systematic decomposition and synthesis

Design as a systematic decomposition and synthesis is a method that has been developed by the German design community and is often called the VDI model. The model was originally developed by Pahl and Beitz [13] and has later on been adopted as a part of the German national standard for design of technical products. This model offers a problem oriented strategy where the emphasis is placed on a detailed analysis and structured procedure to identify a solution. The first step is to identify the main function of the design object from a problem description where all functions are seen as a conversion of energy, material and or signal. The transformation from a hierarchy of function to a hierarchy of solution elements is by means of design catalogues, relating elementary functions with alternative physical effect solutions. These solutions are then synthesized into a complete design, and further improved in the embodiment design phase, [14].

Design as a sequential, iterative process

Design as a sequential, iterative process is the most common design method. This process can be illustrated by the spiral model. It is a descriptive model that captures the sequential and iterative nature of practical ship design, both as the different aspects of the solutions are calculated and checked, and as the process changes from broad investigation in the beginning towards detailed design as the center of the spiral. This process can be regarded as a “design-evaluate-redesign” cycle, [14]

Design as mathematical optimization problem

Design as mathematical optimization problem is a design method where a decision on how to improve a design is determined by various mathematical algorithms. In other words the conflict of a decision situation is resolved in such a way that the variables under the control of the decision-maker take their best possible value. The optimum value is achieved when the working area of the optimization problem is satisfied. In such an optimization, the value of all design variables is determined simultaneously, [14]. Numbers of methods for ship design as a mathematical optimization problem are available but will not be further examined here.

Design as a creative activity

In the previously mentioned generic models of design, the spiral model and the mathematical optimization method, the basic inference process is based on operations upon knowledge already existing within the design system. In real-world design situations and preliminary design in particular, this is not always the case. Specific design problems often require that the designer is able to look beyond the limits of the existing knowledge base, or to rearrange existing knowledge, in order to find a satisfactory solution. Designers mastering this skill are often describes as creative. Creativity could as well be described as the ability to recognize problems in an existing design, but also to see new possibilities to improve a product, [12]. To what degree creativity is required is dependent on the character of the design problem. Three main design problems have been identified by [13]; original, adaptive and variant design. Original design applies a new solution principle to a particular design problem; adaptive design tailor a known system to a different task, keeping the solution principle intact, while in variant design the size and/or arrangement of certain aspects of the solution is varied.

Knowledge-based design and artificial intelligence approaches

The common denominator in knowledge-based design is the way design knowledge is represented and used. In most conventional computer programs the knowledge is represented in the form of procedural algorithms. The problem with this representation is that it holds certain anticipations on how this knowledge will be used and that factual knowledge is only implicitly represented within the procedures of the program. Contrary to this, the general rule in knowledge-based system is a declarative representation of knowledge, where all factual knowledge is given a formal and explicit existence. The representation should, to the extent possible be independent of the way this knowledge is applied and processed, [14].

2.5 Design optimization

Optimization means finding the best solution from a limited or unlimited number of choices. Even if the number of choices is finite, it is often so large that it is impossible to evaluate each possible solution and then determine the best choice. There are in principle two methods of approaching optimization problems, those are as follows, [24]:

- Direct search approach (DSA)
- Steepness approach (SA)

DSA means that solutions are generated by varying parameters either systematically in certain steps or randomly. The best of these solutions is then taken as the estimated optimum. Systematic variation soon becomes prohibitively time consuming as the number of variables increase. Random searches are then employed, but these are still inefficient for problems with many design variables, [25].

SA means that the solutions are generated using some information on the local steepness (in various directions) of the functions to be optimized. When the steepness in all directions is (nearly zero), the estimate for the optimum is found. This approach is more efficient in many cases. However, if several local optima exist, the method will “get stuck” at the nearest local optimum, instead of finding the global optimum that is the best of all possible solutions. Additionally, discontinuities are problematic; even functions that vary steeply in one direction, but very little in another direction make they approach slow and often unreliable, [6]

A problem often encountered in optimization has to use unknown or uncertain values, e.g. future prices. Where assumptions are highly uncertain, it is common to optimize for several assumptions which is called sensitivity study. If a variation in certain input values only slightly affects the result, these may be assumed rather arbitrarily. The main difficulty in most optimization problems does not lie in the mathematics or methods involved, i.e. whether a certain algorithm is more efficient or robust than others. The main difficulty lies in formulating the objective and all the constraints, [25].

If the human is not clear about his objective, the computer cannot perform the optimization. The designer has to first decide what he really wants and this is often not easy for complex problems. Often the designer will list many objectives which a designer will achieve and this is referred to in the literature as “multi-criteria optimization.” Optimization is only possible for one criterion, e.g. it is nonsense to ask for the best and cheapest solution, since the best solution will not come cheaply, and the cheapest solution will not be so good, [25].

There are two ways to handle “multi criteria problems,” both leading to one-criterion optimization:

1. One criterion is selected and the other criteria are formulated as constraints.
2. A weighted sum of all criteria forms the optimization objective. This abstract criterion can be interpreted as an “optimum compromise,” [24]

The starting point of an optimization process is either called “basis design” or zero variant”. The optimization process generated alternatives or variants differing for example in main dimensions, form parameters, displacements, main propulsion power, cargo compartment, fuel consumption and initial cost. The constraints influence, usually, the result of the optimization, [24].

2.5.1 Economic basis for design optimization – economic evaluation criteria

In order to optimize a ship design or evaluated design alternatives against each other economic evaluation criteria. The most common economic evaluation criteria for ship investment are listed up below:

- Required freight rate (RFR)
- Net present value (NPV)
- Internal rate of return (IRR)

For the purpose of optimization the above listed evaluation criteria’s should be calculated for various alternatives. During a vessels lifetime and in order to calculate RFR, NPV and IRR, all payments should be discounted, which means that all payments are converted by taking account of the interest to the time when the vessel is commissioned. The rate of interest used in discounting is usually the market rate for long term loans, [24]. Discounting decreases the value of future payments and increases the value of past payments. A discounted value can be given by the following formulae:

$$K_{pv} = K(\frac{1}{(1+i)^l})$$

Where:

K_{pv}= discounted value
K= individual payment
l= years
i= interest rate

The above formulae assume payment of interest at the end of each year, which is the norm in economic calculations. However, other payment cycles can easily be converted to this form. For costs incurred at greater intervals than years, or on a highly irregular basis, e.g. large scale repair work, an annual average can be used. Where changes in costs are anticipated, future costs should be entered at the average annual level as expected. Evaluation of individual costs is based on present values which may be corrected if recognizable longer-terms exist. Problems in in discounting future payments can be that cost can change during the ships life. As an example, after the oil crisis of 1973, fuel cost rose dramatically. [24]

All expenditures and income in a ships life can be discounted to a total “net present value”. Yield is the interest rate i that gives zero NPV for a given cash flow. Yield is also called “internal rate of return” (IRR). It allows comparisons of different alternatives. NPV and IRR should be used as the economic criterion to evaluate various ship alternatives or configurations against each other []. They are used widely when benchmarking investment alternatives of all kinds. Unfortunately, NPV and IRR depend on uncertain quantities like future freight rates and future operating costs. It requires also that building cost, running cost and income must be estimated. Other economic criteria which consider the time value of money include required freight rate (RFR), i.e. the freight rate that gives zero NPV, which is discussed in more detail in [25] [6] [24].

Part 2 - LNG Carrier Design Theory

3 LNG carrier design and operation

3.1 Introduction

In October 2014, the LNG shipping industry will celebrate its 50th anniversary of the first delivered LNG cargo. This celebration will mark the transition to a new era for LNG carriers. Containment system designs has achieved significant performance gains, cargo containment boil-off rate has become less provoking in order to search for new and more efficient propulsion systems and boil-off handling systems has become more efficient than ever before. This chapter will carry out a brief introduction to the historical evolution of LNG carriers, and will give an overview of current stat of the art within LNG carrier designs and technologies.

3.2 Historical evolution in brief

On January 25th 1959, the 5,000m3 Methane Pioneer, a converted World War II freighter, carried the world’s first LNG cargo, [26]. The cargo containment system on Methane Pioneer consisted of five aluminium self-supporting prismatic cargo tanks, with balsa insulation panels and a secondary barrier for protection in the event of an LNG leak. This prototype vessel was a joint effort by a company called Constock International Methane, a partnership of Conoco and Union Stock Yards, and was funded by the British Gas Counsil. In 1959, the owning company became Conch International Methane Limited, and the partners were Conoco (40%), Union Stock Yards (20%) and Shell (40%), [27].

A second prototype ship, called the Beauvais, which was also a conversion, was undertaken by a group of French companies led by Gas de France a few years later. This vessel had a capacity of 640m3 and contained three different tank and insulation designs. Each tank was built by a different yard, testing slightly different technologies. The third experimental ship, the Phytagore, was built in 1965 with 610m3 capacity and used the *Technigaz* membrane cargo containment system. This system was actually first developed by DNV, but later on sold to Technigaz in the late 1950s, [27].

The Methane Pioneer, and the later prototype vessels, demonstrated that the transportation of large quantities of LNG safely across the ocean was possible, and in 1964 the two first commercial LNG carriers were built. They were the two sister ships Methane Princess and Methane Progress built by the British shipyards Vickers Armstrong and Harland & Wolff respectively. These vessels were owned by Conch International Methane. Each vessel had nine prismatic cargo tanks of the Conch design with a total capacity of 27,400m3 per vessel. They served the Algeria-to-Canvey Island LNG trade on behalf of British Gas, and between them made around 1,000 voyages before they were scrapped. Methane Progress enjoyed a service life of 22 years, while the Methane Princess operated for 28 years, for further info, see [27] [26].

The Jules Verne was a 25,840 m3 LNG carrier with a cylindrical cargo containment system built at the Ateliers et Chantiers de la Seine Maritime. She began operating in 1965, serving the Algeria-to-France trade, and later operated between Algeria and Spain until 2004 under the name Cinderella, [27].

In 1965 Phillips Petroleum contacted the Coast Guard concerning a proposal that the energy company had made to Tokyo Gas for shipping LNG from Alaska. The shipments were to be made in tanks that were designed by Worms and Co., Paris, France. This design later became known as the Gaz Transport design. At first, the LNG carriers were envisioned as being 34,000m3, but eventually the design called for 71,500 m3 vessels that became the Artic Tokyo and Polar Alaska, built at the Kockums yard in Sweden, [27].

At the 2nd LNG Congress in Paris in 1970 Kværner Moss presented "The design of an 88,000cbm LNG carrier with spherical cargo tanks and no secondary barrier". Leif Höegh and Louis Dreyfus became the first owners of a LNG carrier with spherical tanks – the Moss type. Norman Lady was delivered in November 1973, from the Rosenberg shipyard in Norway. The vessel was the prototype of the Moss spherical cargo containment system. DNV and Leif Höegh took an active role in the development of this system. During the 1970s the LNG tanker technology and size underwent considerable development, and an increasing number of shipyards began building LNG carriers, [27] [28] [26].

In 1994, Technigas merged with Gaz Transport, which had also patented a competing membrane containment system. Gaz Transport & Technigaz (GTT) is still the major player in this field of cargo containment technology for LNG carriers, [1].

In 1995, the Kenai LNG project (Alaska to Tokyo trade) replaced the original Swedish built ships with two somewhat larger capacity ships (89,990 m3) built by IHI in Japan. These vessels, named the Polar Eagle and Arctic Sun, were the first and so far only ships with the IHI′s free standing prismatic cargo tanks, the so called SPB design, [1].

During the last decade the LNG industry has developed significantly with the massive orders by Qatargas for so-called Q-Flex and Q-Max vessels of 216,000 m3 and 266,000 m3 respectively. The industry have also seen smaller vessels being developed and built, as well as vessels with on board re-gasification equipment, so-called FSRUs or SRVs. In few years' time, we will also have floating LNG production vessels in operation, [29].

At the end of 2010, the world LNG fleet consisted of 360 ships, with a combined capacity of 53 million m3, up from 195 ships at end-2005. Over the last decade the fleet has been growing at a rapid pace: during the 1980s and 1990s, the LNG shipping industry delivered an average of four new LNG carriers each year. By contrast, the industry delivered an average of 35 new LNG carriers over the past five years (2006-2010), hitting an all-time high of 47 LNG ships delivered in 2008.The average size of LNG carriers has also increased in recent years due to the commissioning of large carriers. As of the end of 2010, the fleet included 31 Q-Flex (210,000-217,000 m3 each) and 14 Q-Max (>260,000 m3) vessels.

The size of LNG carriers ranges significantly. The smallest cross-border LNG vessels, typically ~18,000 m3 - 40,000 m3, are mostly used to transport LNG from Southeast Asia to smaller terminals in Japan, whereas Qatar operates a fleet of large ships with capacities of 210,000 m3 to 266,000 m3. There are also much smaller carriers, 7,500 m3 and below, which are used in domestic and coastal trades, facilitating delivery of LNG to remote areas. LNG carriers with a capacity larger than 135,000 m3 accounted for 75% (270 carriers) of the global fleet by the end of 2010, a share which has continued to rise. Since 1969, the average capacity of the world's LNG fleet has more than doubled; between 2000 and 2010, total average capacity increased by 22%. As of end 2010, the average capacity per vessel was 146,700 m3 while the average capacity of all vessels on order was 157,654 m3.

3.3 LNG carrier design characteristics

The overall layout of LNG carriers is similar to that of the conventional oil tankers from which it evolved. The cargo containment and its incorporation into the hull of the LNG carriers, however, is very different due to the need to carry its cargo under pressure or in refrigerated semi-refrigerated condition. LNG carriers designed for pressurized cargoes can usually be readily identified by their cylindrical or spherical tanks. LNG carrier designs to carry cargo at atmospheric pressure in prismatic configuration tanks are not easily distinguishable from oil tankers other than that the freeboard is significantly greater because of the low density of LNG, [6].

To examine the design of LNG carriers in greater detail, it is convenient to consult the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (The IGC code) which has been incorporated in the 1974 Safety of Life at Sea (SOLAS) Convention, [30]. The rules of the major classification societies have been rewritten to incorporate all the requirements of the IGC code.

3.3.1 General arrangement

LNG carriers has typically propulsion machinery and crew accommodation arranged aft on the ship, in order to separate the deckhouse from gas dangerous zones for obvious safety reasons, [6]. Cargo tanks are furthermore arranged forward of propulsion machinery space and deckhouse.

Cargo tank capacity is determined by the required quantity of cargo to be transported and the number of cargo tanks is normally determined in relation with the damage stability criteria required by the IGC code. [30]

In general, the capacity of each tank is designed about equal, mainly because the cargo pumps of same size are installed in each tank, which means that unloading of all tanks is started and finished at the same period.

Another consideration which restricts tank size, is how to restrict the free liquid surface to avoid excessive sloshing phenomena which may cause cargo containment damages, [6]. Sloshing phenomena may restrict the length and/or breadth of the cargo tanks, or it may require swash bulkheads in the tanks to reduce the free surface of the liquid, [31] [6]. In some LNG carriers, the excessive sloshing phenomena are avoided by limiting LNG cargo in tank to only full or empty condition, [32]. Some containment system designs have dedicated tanks that are designed for partial loading of LNG, [33]. LNG tanks of any types; prismatic, cylindrical, spherical, membrane or bi-lube are required to be accommodated in the hull, keeping the necessary distance from the side shell and bottom shell of hull from the view point of collision and grounding, [34]. All insulated tanks are either installed below deck or above deck covering to protect the insulation form humidity, [35].

Almost all LNG carriers have double bottom below the cargo tanks, except from a few small scale LNG carriers with cylindrical pressure vessels, [36]. In general, double bottom and hull structure at the sides of LNG carriers is required to double skin, [30]. Transverse bulk heads in the cargo hull on LNG carriers are normally double and are usually arranged as water ballast tanks or fuel oil tanks [36] [37] [19]. The requirement to have double skin hull around cargo tanks is a result of the old concept that the cargo tanks should be capable of being completely surrounded by flooded tanks and cofferdams, to protect the hull from exposure to low temperature in case of cargo leaks, [19].

Cargo piping is arranged on the weather deck and led into the cargo tanks directly from the weather deck. It is not allowed to be pipe penetrations into the cargo tanks in the surrounding hold space, [28]. In most cases the dome extrudes partially through the weather deck for pipe penetrations, [36]. The location of the dome is normally either located at the center or at the aft and of each cargo tanks for cargo handling convenience, such as trim during loading/discharge and cargo piping length, [38]. The special feature of the piping arrangement on LNG carriers, compared to for instance oil tankers, is that there are two main cargo lines into each cargo tank, i.e., liquid line and a vapor line, which further described in [6] [39] [40] [41].

The cargo manifold on conventional LNG carriers is typically arranged about amidships on the weather deck for ship to shore connection for loading and discharge operation. There are some examples where cargo manifold is arranged at aft or fore and of the ship. These arrangements are determined to suit the terminal facility. In most cases for LNG carriers, the manifold arrangement should satisfy SIGTTO and OCIMF recommendations, including size and location of flanges, height above deck, spaces between liquid or vapor manifold etc., [38] [42].

Cargo pumps on LNG carriers are generally of the deep well type or the submerged type and installed in each cargo tank near the bottom to discharge close to all cargo, if necessary, in only that tank, [31]. This is because that the tank is independent from hull in most cases and it is not permitted to connect tanks with pipes at the bottom part in the holds from a safety point of view, [31].

Deckhouse for cargo machinery is arranged on upper deck. The deckhouse may contain a re-liquefaction plant or a gas supply system, dependent on main engine configuration. The driving motors of the machinery are required to be in an adjacent space separated by a gas tight bulkhead, [30].

On LNG carriers there are gas dangerous zones. The gas dangerous zone is the zone where is it considered that gas potentially exists. The IGC code defines the gas dangerous zone, which the arrangement of gas carriers has to satisfy in such a way to install only intrinsically safe machines in gas dangerous zone, [34]. That is the equipment must be designed so that it does not have sufficient electrical power to produce a spark. That means that explosion proof electrical equipment, designed and tested to extinguish internal ignition is permitted in gas dangerous zones. For further info about gas dangerous zones see [34] [31].

Discharge form safety relief valves of cargo tanks are led to vent riser through vent line on deck. According to the IGC code, the location of vent riser has to be at least 25 meters from the accommodation, [30].

Some LNG carriers have bow-thruster(s) to improve maneuverability in port or at an offshore mooring. The location of the side thruster is similar to other ships.

3.3.2 Hull structure and cargo containment system

The hull structure of a LNG carrier is completely dependent on the cargo containment system and the required cargo containment system, or the alternatives in which the LNG can be carried in, are dependent on the condition of the cargo during carriage. Since the vapor pressure of LNG is extremely high at ambient temperatures, see Appendix 2, LNG can only be transported semi-pressurized or in a fully refrigerated condition.

A cargo containment system is the total arrangement for containing the cargo during carriage. It contains, a primary barrier (the cargo tank), partial or secondary barrier, if required, thermal insulation, any intervening spaces and adjacent structure, if necessary for the support of these elements, [31].

A cargo containment system has to serve several important functions. It has to seal the LNG in a gas tight compartment to ensure no mixture with air, insulate the LNG from heat influx and thus minimizing boil-off (and consecutive operating cost) and to prevent the very low temperature of LNG from reaching the vessel′s hull, where it would cause steel brittleness, [40] [31]. In order to ensure the above, the insulation material used on each containment systems, should possess the following main characteristics:

- Low thermal conductivity
- Non-flammable or self-extinguishing
- Ability to bear load
- Material should not be affected by cargo or vapour.

In determining the insulation thickness, attention has to be paid to the minimum allowable temperature for the hull structure and the amount of acceptable boil-off in association with, if installed, the re-liquefaction plant capacity or fuel consumption, if boil-off gas is used as fuel.

The choice of cargo tank material in LNG cargo tanks is dictated by the minimum service temperature, which may vary in the range of -165-155°C for LNG, dependent on composition. For LNG carriers, 9% Ni steel, SUS304L stainless steel or A5083 aluminium alloy is normally used, [42] [30].

3.3.3 Cargo containment systems

The IGC code categorizes cargo containment systems for gas carriers as follows, [30]:

- Integral tanks
- Membrane tanks
- Semi-membrane tanks
- Independent tanks
    - Independent type A

   - Independent type B
   - Independent type C
- Internal insulation tanks

Integral insulation tanks form a structural part of the ship's hull, and are normally not allowed for the carriage of liquefied gas if the cargo temperature is below -10°C. Certain tanks on a limited number of Japanese-built LPG carriers for dedicated carriage of fully refrigerated butane have been built with integral insulation tanks, [43].

Semi-membrane concept is a variation of the membrane tank system, where the primary barrier is much thicker than on the membrane systems. Although this concept was originally developed for carriage of LNG, no LNG carriers have been built with this design. [43].

Internal insulated cargo tanks are similar to integral tanks, but they utilize insulation material to contain the cargo. Such tanks have been incorporated in a very limited number of fully refrigerated LPG carriers, but to date the concept is not proved satisfactory in service, [37]. As mentioned, these three tank types have only been applied on a limited number of ship and no LNG carriers so far.

As partly described in the foregoing, a few experimental designs for cargo containment systems were worked on in the early years of LNG shipping. A few of them are still around, but the market is today dominated by membrane systems and spherical tanks. Cylindrical tanks are typically used for small vessels, which are design as per classical principles for semi refrigerated gas carriers.

Membrane tanks

Membrane containment system is based on a very thin primary barrier, called membrane, which is supported through the insulation by adjacent hull structure. Such tanks are not self-supporting like independent tanks, and the inner hull forms the load bearing structure. Membrane containment systems must always be provided with a secondary barrier to ensure the integrity of the total system in the event of a primary barrier leakage. The membrane is designed in such a way that the thermal expansion or contraction is compensated without over-stressing the membrane itself, [27].

The design vapour pressure of membrane containment systems should normally not exceed 0.25 barg, [30]. If, however, the hull scantlings are increase accordingly and consideration is given, where appropriate, strengthening of the supporting insulation, allowable pressure may be increased to a higher value, but less than 0.7 barg, [30].

Over two thirds of the LNG vessels currently in service use a membrane containment system, and the majority of the vessels scheduled for delivery in the coming years will use membrane containment systems as well, [44]. Technigas and Gaz Transport (GTT), is currently completely dominating this market and has developed three types of membrane containment system, which is as follows [33]:

- Technigaz MARK III

- Gaz Transport NO96
- GTT CS1

Technigaz MARK III is a containment system using stainless steel as primary barrier, which is called “waffles” i.e. a steel plate corrugated both longitudinally and transversely to absorb thermal expansion and contraction. The inner and outer membranes are different. The Mark I system used a balsa wood held between two plywood layers for insulation, while the Mark III uses reinforced plastic foam with a secondary barrier made from Triplex, which is a composite aluminium-glass fibre, [33].

Gaz Transport NO96 is a system consisting of a liner with two identical separate membranes. The membranes act as dual barriers that protect the hull of the vessel from the LNG and are made in lengths of a 36% nickel-steel alloy, known as “Invar,” that is chosen for its very low thermal contraction coefficient. The insulation consists of perlite-filled plywood boxes, internally strengthened, and equipped with detectors to monitor for leaks, [33].

Both systems described above are now merged in the “Combined System 1” (CS1) which uses reinforced polyurethane foam insulation, a primary membrane made from 0.7 mm thick Invar and a Triplex secondary membrane. The system has been rationalised to make assembling easier. It is highly prefabricated allowing for quicker assembly on-board, [33].

Independent tanks

Independent tanks are completely self-supporting and does not form part of the ship′s hull structure, in contrast to membrane tanks. Moreover, they do not contribute to the hull strength of a ship. As already mentioned, and defined by the IGC code there are three different types of independent tanks for gas carriers; known as Type A, B and C.

Independent tank A

An independent tank type A is a tank which is designed primarily using classical ship-structural analysis procedure in accordance with the requirements of a Recognized Organization. Such tanks are primarily constructed of plane surfaces and the design vapor pressure has to be less than 0.7 barg, [30]. For cargo temperature below -10°C, a complete secondary barrier is required and the secondary barrier has to be capable of containing any envisaged leakage of liquid cargo for a period of 15 days, [30].

Type A tanks has traditionally been used on fully refrigerated LPG carriers, and is so far not adopted on LNG carriers, mainly due to the secondary barrier requirement, [31]. For a fully refrigerated LPG carrier the secondary barrier must be a complete barrier capable of containing the whole tank volume. On such ships (which will not carry cargoes below -55°C [40]) this is solved by constructing the inner hull in low temperature steel, [42].

LNG New Technologies (LNT) a Norwegian based naval architecture company are currently in the process of developing a new LNG containment system, called LNT A-BOX, based on an independent tank type A.

The containment system consists of an IMO independent tank type A as primary barrier with liquid tight thermal insulation connected to the hull compartment as secondary barrier. The concept is unique in that the LNG tank is placed in a cold box like hold space with access to any part of the tank barriers and is the only concept in the marked where there is access for repairs to any part of the containment in case of failure. The LNT A-BOX is a novel containment system for LNG based on robust technologies, but in a totally new configuration, [37].

The primary barrier of the LNT A-BOX is to be constructed in stainless steel, 9% nickel and will have a MARVS of 0.7barg. The tank will furthermore be supported to the hull structure by conventional wood supports. In order to avoid LNG leakage through minor gaps between the supports and the thermal insulation, in case of primary barrier collapse, a liquid tight seals are installed between the supports and the insulations system. Furthermore, the insulation system will be built up by two layers of insulation, either polyurethane foam/panels or EPS panels, and anchored to the hull compartment by stud bolts, [45].

The LNT A-BOX concept provides a number of unique features. It offers two truly independent barriers which are advantages with regard to inspection and periodic maintenance, since both primary and secondary barriers are accessible. The cargo tank is furthermore prismatic in shape, meaning the containment system provides excellent volume utilization as well as a flat deck layout.

The tank is intendant to be subdivide into four sections by a liquid tight bulkhead in order to eliminate sloshing. The LNT A-BOX concept is additionally construction friendly and cost-effective due to the utilization of a construction friendly independent tank type A and insulation system not exposed for sloshing.

Independent type B

An independent tank type B is a tank constructed of either flat surfaces or they may be spherical. This type of containment system is subject to much more detailed stress analysis compared to independent tank type A, [46]. These analyses must include an investigation of fatigue life and crack propagation characteristics, [42]. Where such tanks are primarily constructed of plane surfaces the design vapor pressure should be less than 0.7 barg. If the cargo temperature at atmospheric pressure is below -10°C, a partial secondary barrier with a leak protection system is required which is a so-called drip tray, [34]. Two types of containment systems based on an independent tank type B are available, and those are:

- Moss spherical
- IHI SPB

The Moss spherical system has large spherical tanks that suspend inside the hull. The tanks are completely self-supporting and do not form part of the hull structure. Spherical tanks bear the thermal expansion and extraction loads on the supporting members. The tanks are made either from aluminum alloy or 9% nickel steel, and insulated on the external surface, [26]. Since the tanks are spherical, vessels utilizing them have somewhat reduced forward visibility and make inefficient use of the ship′s hull space. They require therefor higher deckhouses and larger hulls compared to prismatic shaped tanks, [37]. From a technical perspective the spherical tanks have a few benefits. The geometric definition provides minimum surface for a given volume, which is favorable considering both material consumption and insulation. The center of gravity will always lie at the centerline of a sphere, which is beneficial considering stability. Furthermore, the spheres eliminate sloshing problems. The Moss design was released in the 1970s and has together with the membranes been the dominating tank containment system for LNG carriers since, [31].

The IHI SPG containment is based on a prismatic shaped independent tank type B who consists of a stiffened plate structure of either thick aluminum or 9% nickel steel. The tank rest on reinforced plywood supports, which allow them to expand or contract freely, [26]. The maximum design vapor pressure is limited to 0.7 barg, [30]. The prismatic SPB tanks have the benefit of maximizing ship-hull volumetric efficiency and having the entire cargo tanks placed beneath the main deck. A flat main deck gives advantages such as easier maintenance of piping and equipment on deck, good visibility and small windage area. The tanks is subdivide in sections, similar to LNT A-BOX, meaning that sloshing is not an issue, which allows the cargo tank to be partial loading, [31]. The tank insulation, unlike the membrane system, does not need to bear liquid pressure on the tank and so the best insulating material can be chosen to minimize boil-off, [45]. The SPB design was completed in 1985, but so far only two vessels, the Polar Eagle and Arctic Sun, have been built to this design, [44]. According to [47], IHI SPB has a 30% higher cost than Moss spherical, since it is far less construction friendly.

Independent type C

Type C tanks are normally cylindrical or bi-lobe pressure vessels having design pressures higher than 2 barg. The design basis for type C tanks is based on conventional pressure vessel criteria modified to include fracture mechanics and crack propagation criteria, [46]. The minimum design pressure is intended to ensure that the dynamic stress is sufficiently low so that an initial surface flaw will not propagate more than half the thickness of the shell during the lifetime of the tank. For this reason no secondary barrier is required for a type C tank. This type of containment system is always used on semi refrigerated and fully pressurized gas carriers, and during the last decade also used for small LNG carriers, [31].

Hamworthy and TGE, both cargo system EPCS contractors, are promoting, designing and building type C tanks for various smaller gas carriers. Type C tanks can however, be designed and built by a number of companies around the world that have experience with pressure vessel manufacturing, [37].

Type C tanks are a good alternative for gas carriers with a cargo capacity in the range of 500m3–20,000m3, but the volume utilization as well as the minimum design pressure is a challenge when the vessel sizes are getting bigger, [37]. The reason for this is that the fatigue strength of the tank is built into the formula for minimum design pressure which will increase with large tank sizes, and lead to very thick plate dimensions, [42].

3.4 Propulsion systems

Most propulsion systems introduced and in use in marine application can be used on LNG carriers, but there is one unique feature to be considered determining propulsion system and that is: Disposal of boil-off gas from cargo tanks. Boil-off gas is unavoidable and has to be treated properly and safely. Boil of gas can either be used as fuel in the propulsion machinery, or be re-liquefied and sent back to the cargo tanks for sale. Disposal of boil-off gas to the atmosphere is banned by regulations, [46], so in case of emergency situations, a unit capable of burning the boil-off gas has to be installed, [48].

Steam turbine propulsion has been the propulsion machinery for LNG carriers since the beginning. Steam turbine propulsion system employs two main boilers, which can burn both heavy fuel oil and boil-off gas. The boilers generate superheated steam to turbines for propulsion or electric power supply, [49]. Two steam turbo generators are normally installed for electric power generation with one conventional four stroke diesel generator on standby. Disposal of boil-off gas is carried out by burning it in the boilers and surplus steam is dumped into a sea water cooled condenser. A gas compressor is used to supply the boil-off gas from the cargo tanks, and it is equipped with inlet vane and an electric motor with variable speed to control the amount of gas supply, [50].

Steam turbines are acknowledged as a well proven and reliable system since first installed on LNG carriers, except for a few problems with high-speed reduction gear box, [50]. It considered as well-proven, reliable and infrequent and low cost maintenance machinery. The drawback is manly its thermal efficiency which is approximately 30%, [51]. In order to enhance plant efficiency for steam turbines propulsion systems, a recently developed concept called Ultra Steam Turbine has been introduced and it is expected that this system will enhance the efficiency of steam ships with about 15%, [1].

Since 2003, about 25 LNG carriers, including re-gasification vessels, have been built with medium speed (four stroke) dual fuel diesel electrical propulsion systems, [44], clearly indicating a shift in propulsion planet trend. DF engine adopted the lean-burn concept of Otto cycle requires a small amount of pilot fuel, about 1% of total energy input, in order to ignite the fuel in the combustion chamber, [52]. The boil-off gas as fuel is led to a charge air supply port at each cylinder and the gas fuel charge air mixture is compressed in the chamber until it is ignited by the pilot fuel. This mechanism enables the engine to run at relatively low gas pressures, about 5 bar, [52]. Gas fuel and liquid fuel can be used alternatively in DF engines. Since diesel engines are used as prime movers, a thermal efficiency of about 45% easily achievable, which is a definite advantage compared with steam turbine propulsion, [51]. The engines can as well dispose boil-off gas from cargo tanks through a two-stage compressor with constant speed as safely as steam boilers do, [52]. Each pair of DF engines has a separated gas fuel supply line branched from main line on the deck and electric power generator by alternators is fed to switchboard for distribution, transformers for voltage regulation, frequency converter for RPM adjustment, electric propulsion motors, RPM reduction gearing and finally to propeller for propulsion.

As a backup in case of emergency, and for use during gas freeing before docking a Gas Combustion Unit (GCU) has to be installed, [50].

There are several technical issues related to DF engines. Because the temperature of air-gas fuel mixture in combustion chamber is increased typically in excess of 540°C during the compression cycle, the methane number has to be high enough not to cause knocking phenomena by pre-ignition, [53]. For DF engines an minimum methane number of 80% is required at 100% engine load, [52] [50]. In case natural boil-off is used as fuel, which to a large extend is the case on LNG carriers [36], the methane number is not a problem for the reason the evaporating temperature of methane is much lower than heavier hydrocarbons, [31]. If natural boil-of rate is lower than required fuel consumption, forced boil-off gas is required which may result in a high probability of relatively higher content of heavy hydrocarbon in the gas fuel. This can however be avoided, by heating the LNG with temperatures below -100°C in order to not evaporate heavy hydrocarbons, [50]. A mist separator has to be installed in order to return liquid gas consisting of heavy hydrocarbons back to cargo tanks, [42]. Generally the operating window between misfiring and knocking becomes narrow as the engine load goes up along with mean effective pressure of the cylinders, [54], in that regard accurate electronic control of every single cylinder is necessary to ensure optimal air/fuel ratio on four stroke DF engines, [50].

High nitrogen content in the boil-off gas can as well be an issue since it can lower the calorific value of the gas fuel and result in limited engine output due to lack of energy in the fuel. In order to compensate for lowered calorific value the supply amount of gas fuel has to increase to get same engine output as for gas fuel with no nitrogen content, [50]. This can be attained by longer opening time of gas admission valve or by higher gas fuel supply pressure, [50] [52]. This measure is however limited both physically and practically on engines, [52]. Maximum nitrogen content of 20% of the gas fuel is acceptable for DF four stroke engines running on 100% engine load, [52]. DF four stroke engines uses quality diesel oil as pilot fuel, but it have been raised questions by the maritime industry in which use of heavy fuel oil can be used as backup fuel in case of high LNG prices, [52].

DF four stroke mechanical propulsion has been investigated in on several LNG carriers, and the first vessel with such an engine configuration is to be completed in 2012, [55]. The main advantage of such a configuration is the high transmission efficiency, since electrical transmission loss is eliminated. This propulsion system consist of one or more DF engines with same or variable RPM, reduction gear box with clutch device, shaft and controllable pitch propeller. Shaft generators (Power Take Out (PTO)) can be provided for electrical power generation for power supply on board, and PTO generators can be used as a Power Take In (PTI) from diesel generators for boosting propulsion in case of emergency. This system is highly redundant and is similar as for other four stroke medium speed propulsion systems, except that DF engines burn gas as fuel. Gas supply system and safety systems are in line with the DF four stroke electric propulsion system, [50].

Slow speed diesel two stroke propulsion system with re-liquefaction plant for boil of handling is another propulsion system in use on LNG carriers today, typically for long distance trading vessels with a large boil-off rate. The main advantage of slow speed engines is the thermal efficiency of the engine and the possibility of having direct drive, without reduction gear box, and fixed propeller, ensuring the best propulsion efficiency of all other engine configurations, [54] [51]. An additional benefit is that all LNG cargo is delivered to the costumer because the prime mover(s) do not consume gas fuel at all. All boil-off is re-liquefied by a re-liquefaction plant on deck and sent back to the cargo tanks. This propulsion system is identical to those used on most of the merchant ships. Two stroke diesel engines are installed on tank top in the engine room and the shaft is as mentioned directly coupled to the engine for propulsion. Four stroke diesel auxiliary generators have to be provided for electrical power generation. The drawback of such propulsion configuration system is that the re-liquefaction plant requires considerable electrical power, which might counterbalance the high efficiency of the engine by much more power consumption compared to other alternatives, [56] [53].

Slow speed diesel two stroke propulsion with gas injection is another alternative now ready for the market [53]. No vessels have jet been order with this type of engine, [56], but several conversions are planned for, [37]. Such engines inject gas directly into the combustion chamber rather than admission of gas-air mixture into the chamber. In order to be able to carry out gas fuel injection into the compressed scavenging air, gas fuel pressure up to about 250-300bars is required dependent on engine load and inlet temperature has to be about 45°C, [53]. The high pressure requires a high pressure, multistage gas compressor of piston type, [50], typically a Buchardt Compressor, [42]. This type of compressor has not yet been used in marine application, but has a long track record in LNG terminals. Electrical power consumption of high pressure piston type gas compressors is according to [50] half of a re-liquefaction plant. All related gas supply systems must naturally be design to permit the high gas pressure.

The advantage with gas injection is the high efficiency and fuel flexibility. It can easily burn all kind of marine fuels, [53]. Comparing with a lean burn four stroke DF engine that use gas fuel and liquid fuel alternatively, the gas injection two stroke diesel engines can burn gas fuel and heavy fuel oil at the same time with adjustable mixing ratio, meaning that the engine has a great fuel flexibility. The minimum engine load in gas mode is about 30% for stable combustion, [53] [50]. The engine requires about 8% pilot fuel, and the pilot fuel can be cheap heavy fuel oil. The gas supply system providing the engine with required gas fuel can be viewed on as relatively complex. It consists of bypass pressure control valves, buffer units and intercoolers, flow and temperature control etc. For further info about necessary facilities and required auxiliary systems, see [50]. In case of emergency boil-off gas disposal, a gas combustion unit is required, as for all other engine configuration alternatives mentioned, except from steam turbine plant, [50].

Combined gas turbine electric propulsion has been used on LNG carriers for decades. Combined gas turbine is capable of burning both diesel and gas and is highly reliability [57], and has a high power density, [54]. A lot of improvements of gas turbines throughout the years have resulted in large improvements in thermal efficiency. Thermal efficiency up to 40% at maximum load is to day achievable and is therefore today considered as a good option for LNG carriers, [48].

A combined gas turbine electric and steam system (COGES) is made up of one big gas turbine with an associated heat recovery steam generator and steam turbo generator and a small gas turbine generator as a standby. Due to the system redundancy in case of failure of the main turbine, a conventional diesel engine or a standby duct burner should be considered. Another COGES package consists of two identical gas turbine generators associated with heat recovery steam systems, which provides better redundancy but it is a more expensive solution, [50]. The reliability of a gas turbine is as high as 99% and more [58]. The gas supply fuel system of COGES is similar as for other gas burning propulsion alternatives, but the gas pressure is up to 40 bars depending on the type of gas turbine. A compressor of the screw type is normally used to compress and supply boil-off gas to gas turbines. A gas turbine package is often delivered self-contained, which includes all necessary instrumentation within the container, e.g. gas turbine, gas valves, local firefighting equipment, gas detecting sensors, ventilation fans and dampers, interlocking device at entrance door, control systems etc. Cooling water systems is not necessary for gas turbines; because it is cooled by air induced by the compressor section of the turbine. A gas turbine can burn any ratio of gas fuel and fuel oil, and the governor follows up rotating speed and control the fuel amount injected into combustors. The power turbine is connected to electrical generators via reduction gearing, [50] [57].

3.5 Boil-off handling

Whether the cargo compartment is outrageously well insulated, a heat flow vector towards the LNG cargo will continuously occur, as long as the ambient temperature remains above cargo temperature. Although some containment systems allows the LNG to be transported under pressure the ambient temperature will always be greater than the temperature of LNG , leading to a continuous heat ingress into the cargo tank increasing temperature and pressure of the cargo. In order to remain or lower the temperature/pressure of the cargo, boil-off gas has to be handled. On board LNG carriers, three ways of boil-off handling , to control tank pressure and temperature of LNG is possible, those are:

- Use boil-off as fuel in main/auxiliary engine(s).
- Boil-off gas re-liquefaction
- Boil-off combustion in a gas combustion unit (GCU)

Utilizing boil-off gas as fuel in the main engine(s) has been done for decades as mentioned, and has proven to be an excellent way of handling boil-off gas. On the other side, new energy efficient re-liquefaction plant technology, adjusted for marine use, have recently entered the market and proven to be cost efficient on several small scale LNG ships. Another advantage is that all cargo is delivered to costumer.

In the next sections a brief introduction to the various boil-off handling methods will be given. It has to be noted that numerous solutions for boil-off re-liquefaction and gas supply exist, and within the existing ones, several configurations is possible. It is not expedient to do a thoroughly analysis of all alternatives here, so only the most common systems will be described. Three different LNG re-liquefaction systems are currently in use on LNG carriers, and those are:

- Sintef Mini LNG (referred to as the “mini LNG” concept)
- Cryostar EcoRel
- Moss RS™

Small-scale natural gas liquefaction units have been challenged to be cost and energy efficient, so the keyword during the development of the mini LNG concept have been simplicity, efficiency and highest possible production capacity with lowest possible power consumption within the limited existing standard available components in the market, [59]. The concept has achieved a low cost and high efficiency by using standard refrigeration components in combination with advanced refrigeration techniques. The main components of the mini-LNG liquefaction unit are cobber brazed plate heat exchanges, a liquid-vapor separator, a lubricant injection screw compressor, cryogenic valves and tubing. In order to obtain high-energy efficiency, a mixed component refrigerant in combination with a lubricant injected screw compressor is used. Process losses are reduced to a minimum by optimizing the refrigerant combination to the operating conditions. The mixed component refrigerant enables small temperature differences in the heat exchangers by adapting the temperature glides of the two streams. An energy efficient concept is thereby obtained without using more sophisticated system layouts used for large scale plants such as Cryostar EcoRel and Moss RS™, [59]. For a full process description, that are beyond the author's field of study, see [59]. The Mini LNG system is currently installed on 6 small scale LNG carriers, [44]

The Cryostar EcoRel boil-off gas re-liquefaction system has recently been selected to equip the largest ever built LNG carriers i.e. the Q-Max series, utilizing two stroke MAN diesel engines for propulsion. It can perform full re-liquefaction of the boil-off gas on such vessels and can be designed with much higher capacities than the mini LNG plant, [42]. The EcoRel system relies on the principle of a closed nitrogen reverse Brayton cycle to produce the cold power needed to condense the boil-off gas. The amount of cold production is proportional to the amount of boil-off gas to be re-liquefied and is adapted by modifying the mass circulation in the nitrogen loop. The cycle includes 3 warm compression stages with intercoolers and after coolers and one cryogenic expansion turbine combined in a single machine called a “commander”. The cycle also includes a counter current heat exchanger and the condensing part in which the cold power is exchanges with the boil-off gas. On the boil-off gas side, two-stage compressor with intercooler is fitted, for a full description of the Cryostar EcoRel, see [60]

The Moss RS™ system is quite similar as EcoRel, and have been installed on totally 31 vessels, i.e. large and ultra large LNG carriers, [60] [36].

4 Interrelationships in LNG carrier design

4.1 Main dimensions

Main dimensions decide many of the ships characteristics, e.g. stability, cargo cold capacity, power requirements and economic efficiency. Therefore determining the man dimensions and ratios forms a particularly important phase in the overall design. The length L, width B, draught T, depth D, free board F and block coefficient C_B should be determined first, [25]. Graphs in Appendix 3, indicates typical dimensions of LNG carriers as function of cargo capacity for LNG carriers. The criteria for selecting main dimensions will be dealt with in subsequent chapters and principal factors influencing these dimensions will be given. The length is determined as a function of displacement, speed and, if necessary, of number of days at sea per annum and other factors affecting economic efficiency. The block coefficient is determined as a function of the Freude number and those factors influencing the length. Width, draught and depth should be related such that the, stability, statutory freeboard, spatial requirements et al. requirements are satisfied, [25]. In the subsequent sections, interrelationships between the various parameters mentioned will be presented.

4.1.1 Displacement

When the notation displacement is used, it is usually referring to weight displacement. Weight displacement is the weight of the water the hull displaces and can be derived from the following formulae:

$$\Delta = C_B \rho L_{WL} B T$$

where:
C_B = Block coefficient [-]
ρ = Density of seawater [ton/m3]
L_{WL} = Length of waterline [m]
B = Breadth [m]
T = Draught [m]

Weight displacement can be converted to volume displacement with the following formulae:

$$\nabla = \Delta / \rho$$

Block coefficient (C_B)

When the displacement is known, the block coefficient can be bound from the following formula:

$$C_B = \frac{\Delta}{(\rho L_{WL} B T)}$$

Ship-owners requirements can be met using a wide variety of C_B values. If C_B is decreased, breadth (B) must be increased to maintain stability, [25]. These changes have opposite effects on resistance in waves. With lower C_B, power reduction in heavy seas becomes less necessary. Recommendations for the choice of C_B

normally draw on statistics of built ships, such as Tefler's, Alexander's and Jenses's formulas, as listed below.

Tefler's formula:

$$C_B = 1 - \left(\frac{3}{8}\right)\left(\frac{B}{L} + 1\right)\left(\frac{V_{KNOTS}}{\sqrt{L}}\right)$$

Alexander's formula:

$$C_B = 1.04 - \left(\frac{V_{KNOTS}}{2\sqrt{L}}\right)$$

Jenses's formula:

$C_B = -4.22 + 27.8\sqrt{F_N} - 39.1F_N + 46.6{F_N}^3$ (valid for ships with 0.15<FN<0.32)

Mid-ship section area coefficient (C_M)

The mid-ship section area coefficient is given by the following formula:

$$C_M = \frac{A_M}{BT}$$

where:

A_M = Submerged area of mid-ship section [m2]

C_M is rarely known in advance by the designer. The choice is aided by the following criteria:

1. Effects on resistance
2. Effect on plate curvature
3. Effect on cargo hull
4. Effect on roll-damping

C_M's effect on resistance is small, normally a few percentage for variations within normal limits. High C_M and associated small bilge radius mean that the curved part of the outer shell area is smaller both in area of mid-ship section and the parallel mid body. The amount of frame-bending necessary is also reduced. Especially in containerships, the size and shape of the mid-ship area are often adapted where possible facilitate the stowage of cargo units. Due to the smaller rolling resistance of ships body and the smaller radius of the path swept out by the bilge keel, ships with small C_M tend to experience grater rolling motions in heavy seas than those with large $C_{M,}$ [38]. The following formulas represents C_M values as function of C_B recommended for ships without rise of floor, [25].

$$C_M = 0.9 + 0.1C_B$$

$$C_M = 1/(1 + (1 - C_B)^{3.5})$$

$$C_M = 1.006 - \ 0.0056 C_B^{-3.56}$$

Prismatic coefficient (C_P)

The prismatic coefficient C_P can be determined using largely the same criteria as for the clock coefficient and can be expressed as follows:

$$C_P = \frac{\Delta}{\rho L_{WL} A_M} = \frac{\Delta}{\rho L_{WL} B T C_M} = \frac{C_B}{C_M}$$

Water plane coefficient (C_W)

The water-plane area coefficient C_W influences resistance and stability considerably and is geometrically closely related to the shape of cross-sections. The formula for water-plane area coefficient is as follows:

$$C_W = \frac{A_M}{LB}$$

Where:
A_M = Water plane area [m2]

Some relevant approximate formulas for C_W as function of C_P are listed below and are in accordance with, [25].

U section form, no projecting stern form:

$$C_W = 0.95 C_P + 0.17 \sqrt[3]{1 - C_P}$$

$C_P > 0.85$:

$$C_W = 0.6 C_P + 0.4$$

Volumetric coefficient

The volumetric coefficient is also an expression for the plumpness of the hull. Vessels with volumetric coefficient close to 1 are classified as slender and can typically be frigates- While vessels with value near 15 are called plump. Examples of such lump vessels can typically be trawlers. The formula for volumetric coefficient is as follows:

$$C_V = \frac{\nabla}{\left(\frac{L}{10}\right)^3}$$

Dimensionless ratios

In addition to hull form coefficients, it is usual to apply dimensionless ratios between main dimensions to compare different ships and get some hints on how these parameters should interrelate. Example of such ratios are L_{PP}/B, B/T, D/T, L_{PP}/T and L_{PP}/D. Dimensionless ratios between main dimensions as function of cargo capacity are given in Appendix 7.

4.1.2 Cargo hull dimensions

On board LNG carriers with independent cargo tanks, either A, B or C, SOLAS sets requirements for void-space size in order to facilitate easy inspection of cargo containment system during operation. According to [42] those requirements are as follows:

- 0.5m clearance between cargo tanks and ship hull (sides and tank top/bottom)
- 0.8m clearance between cargo tanks and ship hull (tank ends)

Exact cargo hull dimensions are hard to predict accurately in an early design stage, since it normally requires several iterative design steps. Based analysis of existing ships with various cargo containment systems, the following formulas for cargo hull dimensions will be used further:

$$B_C = B - 6$$
$$H_C = T - 3$$
$$L_C = 0.6L_{PP}/n_C$$
$$A_C = 2B_C H_C + 2B_C L_C + 2H_C L_C$$
$$V_C = B_C L_C H_C$$

where:
B_C = Breadth cargo hull
H_C = Height cargo hull
L_C = Length cargo hull
n_C = number of cargo tanks
A_C = Area cargo hull
V_C = Volume cargo hull

Cargo tank dimension

Cargo capacity and hull dimensions are highly interrelated due to the previously mentioned void space requirements for LNG carriers. The following formulas describes interlinks between cargo tank volume as function of cargo hull dimensions an variable insulation thickness for a LNG ship utilizing a prismatic cargo tank.

$$B_T = B_C - (2t_{INS} + 1)$$
$$H_T = H_C - (2t_{INS} + 1)$$
$$L_T = L_C - (2t_{INS} + 1.6)$$
$$V_T = B_T H_T L_T$$

where:

B_T= Breadth cargo tank
H_T= Height cargo tank
L_T = Length cargo tank
V_T = Volume cargo tank

4.2 Weights

In early design phases, a ships weight displacement is required in order to determine ship parameters. Weight calculations will however be based on several assumptions since precise weight calculations are seldom available before building process is complete. Weight displacement equals a ships total weight, and the total weight is normally divided into two main groups. That is deadweight (DWT) (e.g. weight of cargo, supplies, bunker and water) and lightweight (LWT) (e.g. weight of ship without cargo, supplies, bunker and water). Weight displacement is therefore given by the following formula [25]:

$$\Delta = LWT + DWT$$

Also for weights, statistics and dimensionless ratios can be used in early design work, [12]. Ratios such as LWT/Δ and DWT/Δ are often used. Graphs given in Appendix 3, illustrates typical LWT/Δ and DWT/Δ ratios as function of displacement. The accuracy of using coefficients in the design work depends heavily on the quality and amount of data for existing ships used in the derivation of the empirical weight formulas, [12].

4.2.1 Steel weight

Harvald and Juncher Jensen (H&J) have developed a method for steel and weight estimation. H&J method divides a vessels displacement into the following components, [61]:

$$\Delta = W_S + W_O + W_M + DWT$$

Where:

W_S = Steel weight [ton]
W_O = Weight of outfitting [ton]
W_M = Machinery weight [ton]

To calculate the steel weight H&J propose to use a cubic number defined as follows:

$$K = LBD + GV$$

where:
L = Ship length [m]
B = Ship breadth [m]
D = Ship depth to upper deck [m]

GV = Gross volume [m3]

Furthermore, a steel weight coefficient is defined as follows:

$$C_S = \frac{W_S}{K}$$

Consequently, the steel weight WS can be found if cubic number K and the steel weight coefficient C_S are known. The steel weight coefficient can be derived from statistics or the following analytic expression:

$$C_S(\Delta) = C_{SO} + 0.064e^{[-(0.5u+0.1u^{2.45})]}$$

where:
C_{SO} = Coefficient dependent on ship type [ton/m3]

And "u" is derived from the following formula:

$$u = log_{10}\left(\frac{\Delta}{100}\right)$$

Proposed values for C_{SO} on bulk carriers are 0.7, and is probably valid for LNG carriers when weight of cargo containment system is excluded.

4.2.2 Outfitting weight

Detail of a ship's lightweight and its subdivision are rarely published and there are few common methods to determine a ships outfitting weight. What proportion of the ships lightweight is made up by outfitting depends on several factors such as ship type and type and amount of ship equipment installed on the respective ship which can vary allot from ship to ship. Schneekluth & Bertram have based on ship statistics, from ships built until 1998, developed coefficients for ship outfitting weight for various ship types. S&B suggest that outfitting weight can be estimated from the following formula:

$$W_O = KLB$$

where:
L = Ship length [m]
B = Ship breadth [m]
K = coefficient dependent on ship type

Proposed value for bulk carriers with length of around 250m is 0.17-0.18 ton/m2. Excluding cargo containment system and cargo handling equipment from the proposed value, a usable initial outfitting weight can probably be derived.

4.2.3 Machinery weight

When it comes to weight for machinery weight [54] suggest a 2-stroke machinery weight of 17-60 [kg/kW] and [43] suggest a machinery system weight of 0.11 [ton/kW]. Medium speed engines included generator has according to [56] a unit weight in the range of 0.08[ton/kW].

4.2.4 Cargo containment weight

Specific cargo containment weight depends on type of cargo tank and insulation system.

4.3 Resistance

As the resistance for s full-scale ship cannot be measured directly, our knowledge about the resistance of ships comes from model tests. The measured calm-water resistance is usually decomposed into various components, although all these components usually interact and most of them cannot be measured individually. The concept of resistance decomposition helps in designing the hull form as the designer can focus on how to influence individual resistance components, [62]. The total calm-water resistance (R_T) of a new ship hull can be decomposed as:

$$R_T = R_V + R_R + R_{AA} + R_{APP}$$

where:
R_V = Viscous resistance based on form factor k_0
R_R = Residual resistance
R_{AA} = Air resistance
R_{APP} = Appendix resistance

For calculation purposes the total calm-water resistance can be expressed as follows:

$$R_T = C_T(\frac{\rho}{2})V^2S$$

where:
C_T = Total resistance coefficient [-]
ρ = Density of water [ton/m3]
V = Vessels speed [m/s]
S = Wetted surface area [m2]

The total resistance coefficient is composed of various resistance coefficients As the formula above indicates, the vetted surface area, S, is an important parameter for the total resistance. Wetted surface area is usually taken at calm water conditions and estimated with empirical formulas. Examples of such empirical formulas can according to [25] be expressed as follows:

Cargo ship and ferries:

$S = \nabla^{\frac{1}{3}}(3.4\nabla^{\frac{1}{3}} + 0.5L_{WL})$

All types of vessels:

$S = kL(B + 2T)$ (k is a coefficient obtained from statistical coefficients

Among the most important parameters of the ship with respect to resistance is also the prismatic coefficient (C_P), Freude number (F_N) and hull slenderness:

Froude number

Freude number (F_N) is defined as follows:

$$F_N = (0.5144 * V_{KNOTS})/\sqrt{gL_{PP}}$$

Where:
V_{KNOTS} = Speed in knots
g = gravity force [m/s2]

Slenderness ratio

Slenderness ratio is defined as follows:

$$Slenderness\ ratio = L_{PP}/\nabla^{1/3}$$

4.3.1 Hollenbach 98 method

Hollenbach 98 calm-water resistance calculation method is based on regression analysis of approximately 430 ships. Hollenbach gives formulae for the “best-fit” curve, but also a curve describing the lower envelope, i.e. the minimum a designer may hope to achieve after extensive optimization of ship lines if its design is not subject to restrictions. Total resistance is as mentioned composed of a total resistance coefficient which can be expressed as follows [62]:

$$C_T = C_V + C_R + C_{AA} + C_{APP}$$

Where:
C_V = Viscous resistance coefficient
C_R = Residual resistance coefficient
C_{AA} = Air resistance coefficient
C_A = Appendix resistance coefficient
C_{APP} = Correlation coefficient

Viscous resistance coefficient C_V is estimated from the following formula:

$$C_V = (1 + k_0)(C_F + \Delta C_F$$

$C_F = 0.075/(\log(R_N - 2))^2$

$\Delta C_F = [110{,}3(HV)^{0.21} - 403.33]C_F^2$

where:

H = roughness factor

$R_N = VL/\nu$

Where:

ν = viscosity

$k_0 = 0.6\varphi + 145\varphi^{3.5}$

$\varphi = (C_B/L_{WL})(\sqrt{B(T_A + T_F)}$

Estimation of viscous resistance coefficient is independent of which resistance procedure that is applied. When it comes to the residual resistance coefficient a non-dimensional coefficient $C_{R\_HOLLENBACK}$ can be expressed as follows:

$$C_{R_{HOLLENBACH}} = C_{R,STANDARD} C_{R,FNKRIT} k_L \left(\frac{T}{B}\right)^{b1} \left(\frac{B}{L}\right)^{b2} \left(\frac{L_{OS}}{L_{WL}}\right)^{b3} \left(\frac{L_{WL}}{L}\right)^{b4} \left(1 + \frac{T_A - T_F}{L}\right)^{b5} \left(\frac{D_P}{T_A}\right)^{b6} (1 + N_{RUDD})^{b7} (1 + N_{BRAC})^{b8} (1 + N_{BOSS})^{b9} (1 + N_{THRUSTER})^{b10}$$

$$C_{R,STANDARD} = c_{11} + c_{12}F_N + c_{13}F_N^2 + C_B(c_{21} + c_{22}F_N + c_{23}F_N^2) + C_B^2(c_{31} + c_{32}F_N + c_{33}F_N^2)$$

$$C_{R\_FNKRIT} = \max(1.0 \left(\frac{F_N}{F_{N.KRIT}}\right)^{f1}$$

$$F_{N.KRIT} = d_1 + d_2 C_B + d_3 C_B^2$$

$$k_L = e_1 L^{e2}$$

The various coefficients given in the formulas above can be found in Appendix XX. Residual resistance coefficient can furthermore be estimated with the formula below:

$$C_R = C_{R_{HOLLENBACH}} B(\frac{T}{S})$$

Air resistance is an important contributor to the overall resistance on ships with large lateral area above the water level, e.g. container vessels and ferries. A simple estimate for air resistance coefficient for cargo ships is:

$$C_{AA} = 0.001(\frac{A_T}{S})$$

Where:

A_T = projected area above waterline.

Appendix resistance is resistance caused by bilge keels, brackets, shafts, bossings and rudder(s). This resistance coefficient is relatively complicated to estimate directly and will probably be a rather small contributor to the total resistance and will be excluded here.

4.4 Stability

Stability of a vessel can be divided into intact and damage stability. The transverse intact stability is crucial and strong influenced by the main dimensions and center of gravity of a ship. Damage stability is mostly dependent of the water tight areas and also very important. However, if the intact stability is not satisfactory it is impossible to fulfill the damage stability requirements. In order to reduce scope, stability calculations have been decided to be out of scope in this thesis. Stability calculations of the author's preliminary ship design will therefore not be performed, meaning that the preliminary ship design is assumed satisfactory in accordance with regulatory stability requirements.

4.5 Freeboard

Freeboard is the height of the freeboard deck above the load line measured at the deck edge at the mid-length between the perpendiculars. The freeboard is usually the uppermost continuous deck, although depending on structural requirements. Freeboard influences the following ship characteristics:

- Dryness of deck
- Reserve buoyancy in damage condition
- Intact stability
- Damage stability

Freeboard requirements are laid down in the International Load Line Convention of 1966 (ICLL 66), which has been recognized by nearly every seafarers nation. Freeboard calculation procedure can be found []. In order to reduce scope, freeboard of the authors preliminary design will be decided based on LNG vessel statistics.

4.6 Ship propulsion

Any propulsion system interacts with the ship hull. The flow field is changed by the upstream located hull. The propulsion system changes, in turn, the flow field at the ship hull. These effects and the open water efficiency of the propeller determine the propulsive efficiency η_D. The formula for propulsive efficiency is given below and is in accordance with [25].

$$\eta_D = \eta_H \eta_0 \eta_R = R_T V_S / P_D$$

Where:
η_H = Hull efficiency [-]

η_0 = Open-water propeller efficiency [-]

η_R = Relative rotative efficiency [-]

P_D = Delivered power at propeller [W]

R_T = Total calm-water resistance [N]

V_S = Ship speed [m/2]

The hull efficiency η_H combines the influence of hull-propeller interaction, and is given by:

$$\eta_H = \frac{1-t}{1-w}$$

Where:
t = thrust deduction factor
w = wake fraction

The thrust deduction factor, t, couples thrust and resistance and is defined as follows:

$$t = \frac{T-R_T}{T}$$

Where:
T = Thrust

The thrust, T, is measured in a propulsion test and is higher than the resistance R_T measured in a resistance test (without propeller), i.e. the propeller induces an additional resistance due to the following:

- The propeller increases the flow velocities in the aft-body of the ship which increases frictional resistance.
- The propeller decreases the pressure in the aft-body, this increasing the inviscid resistance.

The thrust deduction fraction is usually assumed to be the same for model and ship, although the friction component introduces a certain scale effect. A well-used empirical formula for t, for single screw cargo ships are as follows:

$t = 0.5C_B - 0.15$ [63]

An empirical coupling between t and wake fraction, w, are as follows:

$1 - t = (1-w)^{0.4-0.8}$ [63]

In general, in early design stage it cannot be determined which t will give the best hull efficiency η_H. t can be estimated only roughly in the design stage and all of the above formulae have a large uncertainty margin.

Open water propeller efficiency η_0 can be determined by model tests in either a cavitation tunnel or a towing tank. Mathematically, η_0 can be expressed as follows according to [63]:

$$\eta_0 = \frac{P_T}{P_D} = \frac{TV_A}{2\pi nQ} = \frac{J_A}{2\pi}\frac{K_T}{K_Q}$$

P_T = Thrust power delivered to by the propeller to water

P_D = power delivered to propeller

T = Thrust [N]

V_A= Speed [m/s]

n = propeller RPM [1/s]

Q = Torque [Nm]

J_A = Fremgangstall for the propeller

K_T = thrust-coefficient

K_Q = Moment-coefficient

Where K_T and K_Q are defined as follows:

$$K_T = \frac{T}{\rho n^2 D^4}$$

$$K_Q = \frac{T}{\rho n^2 D^5}$$

where:

D = Diameter of propeller

K_T and K_Q can be calculated for a given J-value for a given propeller geometry. If an estimate of propeller efficiency and propeller geometry is desirable, results from model tests with variable propeller geometry, propeller blade area and propeller blade number can be used. Such variation can give what is called a propeller-series witch can be used to determine the propeller efficiency. Values of propeller efficiency vary normally within the range of 0.5-0.7, [63].

Relative rotative efficiency η_R accounts for the differences between the open-water test and the inhomogeneous three-dimensional propeller inflow encountered in a propeller test. In reality, the propeller efficiency behind the ship cannot be measured and all effects not included in the hull efficiency, i.e. wake and thrust deduction fractions are included in η_R. In addition, the partial recovery of rotational energy by the rudder contributes to η_R. This mixture of effects makes it difficult to express η_R as a function of a few defined parameters, [25]. According to [25] relative rotative efficiency for single screw ships can be calculated by the following empirical formula:

$$\eta_R = 0.9922 - 0.05908\left(\frac{A_E}{A_0}\right) + 0.07424(C_P - 0.0225 L_{CB})$$

where:

$\frac{A_E}{A_0}$ = Blade area ratio of the propeller

L_{CB} = Longitudinal centre of buoyancy taken from $L_{WL}/2$

According to [64] relative efficiency vary normally in the range of 0.97 – 1.075.

Based on the propulsive efficiency an estimate of power requirements can be calculated. In addition to the propulsive efficiency an additional efficiency loss has to be overcome due to shaft and bearing. Shaft efficiency η_S is typically in the range of 0.98-0.985, [25]. Required installed power i.e. brake power of main engine, can further be expressed as follows:

$$P_B = \frac{P_E}{\eta_D \eta_S} = \frac{R_T V_S}{\eta_D \eta_S}$$

4.7 Cargo containment heat transmission

This section presents a brief overview of physics involved in heat transmission calculations which will be used as basis in boil-off rate prediction for the selected cargo containment system. LNG boil-off is caused by heat added to the LNG cargo tanks during operation. Heat can both leak into the LNG though the cargo containment system during transportation and through hoses et al. during loading, in order to not complicate, heat transmission theory through cargo containment insulation system will be the focus. Uncontrolled boil-off handling can cause excessive tank pressure buildup during operation, and if boil-off is not handled properly exceedance of allowable cargo tank pressure as well as emissions of natural gas to the atmosphere can occur, which is undesirable. Heat transfer may occur by one or more of three basic mechanisms of heat transfer which is as follows [65]:

- Conduction
- Convection
- Radiation

In conduction, heat can be conducted through solid, liquids and gasses. The heat is conducted by the transfer of the energy of motion between adjacent molecules. In a gas the “hotter” molecules, which have greater energy and motions, impart energy to the adjacent molecules at lower energy levels. This type of heat transfer is present in all solids, gases or liquids in which a temperature gradient exists. In conduction, energy can also be transferred by “free” electrons which is quite important in metallic solids, [65].

Transfer of heat by convection implies the transfer of heat by bulk transport and mixing of microscopic elements of warmer portions with cooler portions of a gas or liquid. It also often refers to the energy exchange between a solid surface and a fluid. A distinction must be made between forced-convection heat transfer, where a fluid is forced to flow past a solid surface by a pump, fan or other mechanical means, and natural or free convection, where warmer or cooler fluid next to the solid surface causes a circulation because of a density difference resulting from the temperature difference in the fluid, [65].

Radiation differs from heat transfer by conduction and convection in that no physical medium is needed for its propagation. Radiation is the transfer of energy through space by means of electromagnetic waves in much the same way as electromagnetic light waves transfer light. The same law that governs the transfer of light governs the radiant transfer of heat. Solids and liquids tend to absorb the radiation being transferred through them, so that radiation is important primarily in transfer through space and gases, [65].

The realistic boundary condition for heat transfer analysis of cargo containment systems are steady state heat transfer through natural and forced convection. Radiation is considered to have miniscule effect on the overall heat balance, although it might have some effect on ambient temperature above deck and weather shield. The following equations describe the general and specific thermal solution for one dimensional heat flow for a flat, spherical and cylindrical section.

Flat section

1) $\frac{\partial^2 T}{\partial x^2} = 0 \rightarrow q = \frac{T_0 - T_i}{\left(\frac{1}{h_i}\right) + \left(\frac{1}{h_0}\right) + \sum_j \frac{t_j}{K_j}}$ (divided from [63])

Where:

q = Heat flow rate [W/m2]

T_0, T_i = Surface temperature, outside, inside the section [K]

h_0, h_i = Film coefficient, outside and inside section, temperature dependent [W/m2K]

t_i = Thickness of material through the section [mm]

K_i = Thermal conductivity for different insulation material – temp dependent [W/mK]

Cylindrical section

2) $\frac{1}{r}\left(\frac{\partial}{\partial r}\right)\left(r\left(\frac{\partial T}{\partial r}\right)\right) = 0 \rightarrow Q = \frac{T_0 - T_i}{\left(\frac{1}{2\pi r_0 h_0}\right) + \left(\frac{1}{2\pi r_i h_i}\right) + \frac{\ln\left(\frac{r_0}{r_i}\right)}{2\pi K}}$ (divided from [63])

Where:

Q = Heat flow rate per unit length [W/m]

r_0, r_i = radius of insulation outside, inside respectively [m]

Spherical section

For the special case of a spherical geometry with one layer of insulation with constant conductivity, the following applies:

3) $\frac{1}{r}\left(\frac{\partial}{\partial r}\right)\left(r\left(\frac{\partial T}{\partial r}\right)\right) = 0 \rightarrow q = \frac{T_0 - T_i}{\left(\frac{1}{4\pi r^2 h_0}\right) + \left(\frac{1}{4\pi r^2 h_i}\right) + \frac{\left(\frac{1}{r_i}\right) - \left(\frac{1}{r_O}\right)}{4\pi K}}$ (divided from [63])

Where:

q = Heat flow rate [W]

The value of K can for some cases, if several layers of insulation are used, represents a combined effect of conduction, convection and radiation internal in the insulation system. The film coefficient h can be presented as follows:

4) $h = Nu\,(\frac{\lambda}{L})$

Where some empirical terms of Nu are:

5) $Nu = 0.140(Gr(T)\,\mathrm{Pr}(T))^{\frac{1}{3}}$ (Lower surf cooled or upper surf. heated)

6) $Nu = 0.27(Gr(T)\,\mathrm{Pr}(T))^{\frac{1}{4}}$ (Lower surf heated/upper surf. cooled)

7) $Nu = 0.1(Gr(T)\,\mathrm{Pr}(T))^{\frac{1}{3}}$ (Vertical plat)

Where:

λ = conductivity for fluid
L Plate length
Gr = Grashofs number – dependent on flow pattern, geometry and temp
Pr = Prandtls number – Physical constant for fluid – temp dependent

Re-arranging and substituting with material and temperature dependent properties in the expressions above gives the option of expressing the heat transfer relationship in the following manner:

8) $q_{conv} = h\Delta T = (C_1 \Delta T^{\frac{1}{n}})\Delta T$

Where C_1 and ΔT is defined from equation 4 and 5. ΔT is realistically a dynamic part Finite Element analysis, given by $T_{Surface}$ from the analysis and $T_{Ambient}$ from user input. The general temperature dependant terms for calculation of coefficients are expressed below:

$$q = h\Delta T$$

$$h = Nu\left(\frac{\lambda}{L}\right)$$

$$Nu = k_1(GrPr)^n$$

$$Gr = \frac{g\beta\Delta T L^3}{\nu^2}$$

$$\mathrm{Pr} = \frac{C\mu}{\lambda}$$

$$q = \left[k_1\left(\frac{g\beta\Delta T L^3 C\mu}{\nu^2\lambda}\right)^n\left(\frac{\lambda}{L}\right)\right]\Delta T$$

Where $n = \frac{1}{3}$ for turbulent flow, and according to [] L can be cancelled. q can then be expressed as follows:

$$q = \left[k_1 \left(\frac{g\beta\Delta T C\mu}{\nu^2\lambda} \right)^{\frac{1}{3}} \left(\frac{\lambda}{L} \right) \right] \Delta T^{\frac{1}{3}} \Delta T \ \rightarrow C_1 \Delta T^{\frac{1}{3}} \Delta T \ \rightarrow \ C_1 \Delta T^{\frac{1}{3}}$$

In cases where there is heat exchange between faces that li close to each other, the following relations apply:

$$q_{conv} = h\Delta T$$

$$h = Nu \left(\frac{\lambda}{L} \right)$$

For vertical parallel plates of height L and turbulent flow condition, Nu can be expressed as follows:

$$Nu = 0.05(f(\text{Pr})Gr(T)\,\text{Pr}(T))^{\frac{1}{3}}$$

Where $f(\text{Pr})$ is expresses as:

$$f(\text{Pr}) = \left[1 + \left(\frac{0.5}{\text{Pr}} \right)^{\frac{9}{16}} \right]^{-16/9}$$

Re-arranging and substituting with material and temperature dependent properties in the expression above give us the option of expressing the heat transfer relationship in the following manner, similar as in equation 8.

$q_{conv} = h\Delta T = (C_2 \Delta T^{\frac{1}{3}})\Delta T$, where $\Delta T = T_{surf.1} - T_{surf.2}$ which is the temperature difference between the opposing surfaces. The general temperature dependant terms for calculation of coefficients are shown below:

$$q = h\Delta T$$

$$h = Nu \left(\frac{\lambda}{L} \right)$$

$$Nu = k_2(GrPrf(\text{Pr}))^n$$

$$Gr = \frac{g\beta\Delta T L^3}{\nu^2}$$

$$\text{Pr} = \frac{C\mu}{\lambda}$$

$$f(\text{Pr}) = \left[1 + \left(\frac{0.5}{\text{Pr}} \right)^{\frac{9}{16}} \right]^{-16/9}$$

$$q = \left[k_2 \left(\frac{g\beta \Delta T L^3 C\mu}{\nu^2 \lambda} \left[1 + \left(\frac{0.5}{\mathrm{Pr}} \right)^{\frac{9}{16}} \right]^{-\frac{16}{9}} \right)^n \left(\frac{\lambda}{L} \right) \right] \Delta T$$

Where $n = \frac{1}{3}$ for turbulent flow

$$q = \left[k_2 \left(\frac{g\beta L^3 C\mu}{\nu^2 \lambda} \left[1 + \left(\frac{0.5\lambda}{C\mu} \right)^{\frac{9}{16}} \right]^{-\frac{16}{9}} \right)^{\frac{1}{3}} \left(\frac{\lambda}{L} \right)^3 \right]^{\frac{1}{3}} \Delta T^{\frac{1}{3}} \Delta T \; = \; K_1 \, \Delta T^{\frac{1}{3}} \Delta T \; \rightarrow h = \; K_1 \, \Delta T^{\frac{1}{3}}$$

General term of heat transfer coefficient for radiation from surrounding fluid outside the ship's hull is considered to be small, and will therefore be ignored later on. The general term is anyway as follows:

$$h_{rad} = 4\varepsilon\sigma T_{mean}^3$$

Where:

ε = Emissivity of insulation surface

σ = Boltzmanns constant

T_{mean} = Mean temperature which equals $(T_{insul.surface} + T_{anbient\ fluid})/2$

4.8 Boil of rate

Boil-off rate can be calculated by the formula below, returning the percentage of cargo that boils off during 24 hours, given the total heat ingress and total amount of cargo.

$$Boil - off\ rate = \frac{q(24 * 3600 * 100)}{\rho_{LNG} V_{LNG} h_{fg\ LNG}}$$

Where:

q = Heat flow rate [W]

ρ_{LNG} = density of LNG [kg/m3]

V_{LNG} Volume of LNG

$h_{fg\ LNG}$ Latent heat of evaporation of LNG

4.9 LNG fuel supply power

It has been stated that if a DF engine is installed for propulsion, gas supply can be supplied in two different ways. Boil-off gas can be supplied directly by a gas compressor in two or three stages, dependent on required injection pressure, or it can be supplied by a LNG fuel pump. In the following, equations for required power consumption for both alternatives will be expressed.

LNG fuel pump

Specific work of a LNG fuel pump, working with an incompressible fluid can be expressed as:

$W = \frac{p_2 - p_1}{\rho}$ [66]

Where:

W = specific work [Nm/kg]

p = pressure [N/m2]

ρ = density [kg/m3]

Pumps working with an incompressible fluid have typically an efficiency η of about 0.7, [].

Gas compressor

Specific compression work with compressible fluids and the specific work for an isentropic compressor process can be expressed with the help of:

$p_1 V_1^{\kappa} = p_2 V_2^{\kappa}$

where:

V = volume [m3]

$K = \frac{c_p}{c_v}$ = ratio of specific heats [J/kgK]

For an ideal gas the internal energy is a function of temperature and the change in internal energy, and can be expressed as follows:

$du = c_v dT$

Where:

du = change in inernal energy

c_v = specific heat for the gas in a constant volume process

dT = change in temperature

C_V varies with temperature, but within a moderate temperature change the heat capacity can be regarded as constant. For an ideal gas the enthalpy is function of temperature and the change in enthalpy can be expressed as follows:

$$dh = c_p dT$$

Where:
dh = change in enthalpy
c_p = specific heat for the gas in a constant pressure process
C_p can within a moderate temperature change be regarded as constant

Specific work is further given by:

$$W = \frac{\kappa}{\kappa - 1} RT[\left(\frac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}} - 1]$$ [66]

where:
R = individual gas constant [J/kgK] ($R_{METHANE}$=518J/kgK)
T = Absolute temperature [K]

Gas compressors have typically an efficiency η of about 0.7, [66].

Two or three stage gas compression power requirement is assumed to be expressed as follows:

$$W = (\frac{\kappa}{\kappa - 1} RT\left[\left(\frac{p_2}{p_1}\right)^{\frac{\kappa-1}{\kappa}} - 1\right])/n$$

Where:
n = number of compression stages

4.10 LNG carrier costs

4.10.1 Building cost

The price of LNG carriers depends mainly on the size of the vessel, operational demands, such as speed etc., and amount and type of equipment installed. The major factor affecting the building cost are the material and production cost. The payment terms, financing and currency are also of major importance, [67]. The price of cargo vessels are often compared based on deadweight, but vessels of different types should be compared based on tonnage, [37]. The building cost is often compared based on lightweight in shipyards, [12]. The material and equipment the shipyard purchase for shipbuilding can be divided into groups based on price per weight. Steel plates and profiles for the hull is the major part of the ship lightweight but the price per weight is very low. Fabricated steel in sections, hatches or doors is about 2-3 times more expensive than the price of steel. The price of machinery components and equipment is 10 times higher than the price for steel [68].

The hull form influence both building cost and operating cost of a vessel. In general, building cost of the ship hull decreases when the block coefficient increases while the power demand for propulsion increases, [69]. In other words, a short and wide vessel gives a light and cheap hull, but it requires higher power for propulsion resulting in higher fuel cost, if same freight work is required over time.

Material cost is as mentioned one of the major contributor to building cost. Choice of material is therefore important to consider, and can have a large effect on building cost. Choice of material influences the weight of the vessel, which again influences the ship efficiency. The materials of relevance for LNG carrier hull are mild steel or high tensile steel, where the difference is that high tensile steel can resist higher stresses [42] meaning that total steel weight can be reduced. It is however worth mentioning that high tensile steel normally will increase maintenance cost, since it is more sensitive for corrosion [42] and it has a higher initial cost per ton, [38].

Market forces and currencies, as well as location of the yard, have additionally one of the most fundamental influences on the building prize. Large variations in cost can occur due to market fluctuations [67] and can be often be regarded as an large risk for the final cost of the ship. This invariability is linked to the freight market, [67].

Fluctuations in currency may also have a large effect on building cost, [36] and is something that cannot be influenced by anyone. Building cost with regards to yard locations then it comes to both materials an component price as well as labor cost, [36].

The main building cost factors in ship building are material and component cost, labor plus overhead and design cost as well as financing cost, broker fees and profit to the yard and subcontractor, [12]. Various sophisticated estimation techniques are available for detailed building cost estimation, and several methods is described in [69] [70].

Running cost

The cost of running a LNG carrier depends on a combination of tree factors. First, the ship sets the framework for running cost through fuel consumption, the number of crew required to operate it and its physical condition. Secondly, inflation on cost of bought items, particularly bunkers, consumables, crew wages and the interest rates, which are subjected to economic trends outside the ship-owner’s control. Third, cost depends on how efficiently the ship-owner manages the vessel, including administrative overhead and operational efficiency, [67]. The shipping industry has no standard classification of running cost, which often leads to confusion over terminology. But one approach presented in [67] classifies running cost into four categories:

- Operating cost
- Periodic maintenance cost
- Voyage cost
- Capital cost

Operating cost are the ongoing expenses connected with day-to-day running of the vessel (excluding fuel, which is included in voyage costs), together with an allowance for day-to-day repairs and maintenance (but not major dry docking which are dealt with separately). The principle components of operating cost are: manning cost, stores, routine repair and maintenance, insurance and administration. The operating cost depends on the size and nationality of the crew, maintenance policy and the age and insured value of the ship and the administrative efficiency of the owner, [67].

Periodic maintenance is a provision set aside to cover the cost of interim dry-docking and special surveys. Docking of LNG vessels is normally every fifth year for LNG carriers [36] where all machinery is inspected and the thickness of steel in certain areas of the hull is measured and compared with acceptable standards, in order to approve the vessels seaworthiness, [42]. All defects must be remedied before a certificate of seaworthiness can be issued. In old ships these surveys often necessitate considerably expense, for example in replacing steelwork that is exposed of corrosion, [67].

Voyage cost can be defined as the variable costs incurred in undertaking a particular voyage. The main items are fuel costs, port dues, cargo handling costs, tugs and pilotage as well as canal charges. Voyage cost is strongly dominated by fuel costs and can vary allot in relation with fuel cost fluctuations.

Compared to operating cost, periodic maintenance cost and voyage cost, capital cost behaves differently. Capital cost may appear in the cash flow in three ways. First there is the initial purchase cost, secondly the cash payment to banks or equity investors who raise capital to purchase the vessel and thirdly cash received from a possible sale of the vessel, [67]. There is a wide variety of financing arrangements available for buyers, and it could be said that there are as many different financing packages as there are deals done. However, all these fall into one or more of just three main types of funding according to [71]; Loan, equity and leasing. Loans for shipping are typical serial loans, which mean that the term installments are constant while the interest costs will diminish with the time. Many deals are done on the basis of straightforward term loan, under which a sum of money is borrowed, to be repaid over a certain length of time. More sophisticated deals might include a fixed interest rate, or hedged against interest and exchange rate movements. Other mechanisms may be employed which, although it will make the loan more expensive in total, assist the owner in making repayment at particular times. The lender may grant a moratorium on capital repayment, or allow a ballon payment at the end of the term. A revolving loan, while being in force for a set time, allows the borrower to draw on funds, which have been repaired, [71]. The amount which a lender is prepared to provide against the security of a first mortgage on the vessel being acquired may well be insufficient to cover the cost of that vessel, even allowing for a propulsion being met by the owners own resources. In such cases, the buyer may be able to arrange a subordinate loan, also called mezzanine loans, to fill the gap. Lacking the security of a first mortgage, such finance will normally be more expensive, and may also involve the provision of some sort of equity options, [71]. Equity investment in a particular vessel comes either as a result of such an option or the assumption of a partnership or joint venture between a number of owners or individuals in that vessel. Equity funding is more usually a feature of corporate funding, and may be raised by an existing company, through the insurance of commercial paper, either bonds or debentures, or through an IPO or private placement of capital in a new investment vehicle or existing company aiming to broaden its capital base, [71]. Leasing, in which the lessor buys the vessel and effectively charters it to the lessee, allows the operator of the vessel to transfer the full capital cost of a vessel acquisition to cash-rich company or institution, in return of regular and equal payments. This may have implications for the balance sheet of the lessee, and allows access to tonnage without having to find the necessary capital to put down as a deposit on a new-building or secondhand acquisition. Leasing has become a favored option for those very few vessels owned with high credit rating, such as oil majors, [71]

Income/revenue

Ship revenue is dependent on several factors, such as cargo capacity, ship productivity and/or freight rates. There are several ways a ship-owner can gain revenue, each of which brings a different distribution of risk between the ship owner and the charterer and a different apportionment of cost. The risks are shipping market risk, which concerns the availability of cargo and the freight rate paid and operational risk arising from the ability of ship to perform the transport. The costs are those described in the preceding section. Each revenue arrangements deal with these items differently. A vessel can be engaged in three types of charter parties, which is:

- Voyage charter
- Time charter
- Bareboat charter

Voyage charter is a system which is used in the voyage carter market. The freight rate is paid per unit of cargo transported. Under this arrangement, the ship-owner generally pays all the costs, except possibly cargo handling, and is responsible both for managing the running of the ship and for planning and execution of the voyage. The ship-owner takes both the operational and the shipping market risk. If no cargo is available, the ship breaks down or it has to wait for cargo. Time charter is a system where the charterer hires a vessel at a specific fixed daily or monthly cost. Under this arrangement, the owner still takes the operational risk, since if the ship breaks down the ship-owner does not get paid. The charter pays fuel, port charges, cargo handling cost and other cargo related costs, which means that the charter takes the market risk. Bareboat charter is essentially a financial arrangement in which the charter hire only covers the financial cost of the ship. The owner finances the vessel and receives a charter payment to cover expenses. All operating costs, both voyage costs and cargo related costs are covered by the charterer who takes both operational and the shipping market risk, [67].

4.11 Energy Efficiency Design Index

The Energy Efficiency Design Index (EEDI) for new ships is the most important technical measure to promoting the use of more energy efficient equipment and engines on ships. Implementation of EEDI is currently under development by IMO. The EEDI requires a minimum energy efficiency level per cargo capacity nautical for different ship type and size segments, [72]. The most recent version of EEDI Guidelines presented in MEPC. 1/ Circ. 681 "Interim Guidelines on the Method of Calculation of the Energy Efficiency Design Index for New Ships" suggest that EEDI can be calculated with the following formulae:

$$EEDI = \left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} C_{FME(i)} SFC_{ME(i)}\right) + \left(P_{AE} C_{FAE} SFC_{AF}\right) + \left(\left(\prod_{j=1}^{M} f_j \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} P_{AE_{eff(i)}}\right) C_{FAE} SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} P_{eff(i)} C_{FME} SFC_{ME}\right)$$

Where:

P_{ME} = Power of main engine(s)

C_{FME} = Main engine composite fuel factor for CO_2 emissions

SFC_{ME} = Specific fuel oil consumption main engine

P_{AE} = Combined installed power of auxiliary engines

C_{FAE} = Auxiliary engine fuel factor

SFC_{AE} = Auxiliary engine fuel consumption

P_{PTI} = Power of individual shaft motors divided by the efficiency of shaft generators

f_{eff} = Availability factor of individual energy efficiency technologies (=1.0 if readily available)

P_{AEeff} = Auxiliary engine power reduction due to individual technologies for electrical energy efficiency

C_{FAE} = Auxiliary engine fuel factor for CO_2 emissions

SFC_{AE} = Specific fuel consumption auxiliary engine

Part 3

Analysis

5 Introduction

5.1 Design objective

5.2 Design approach

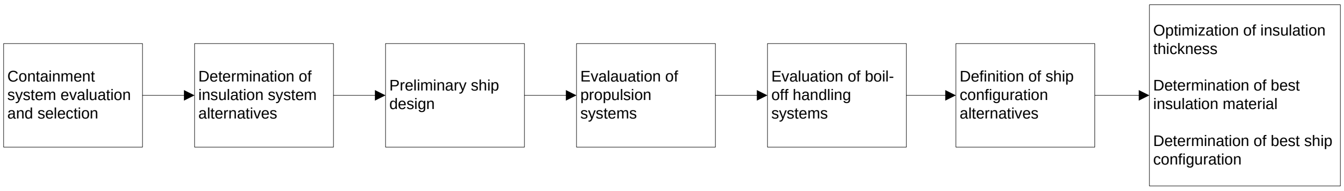


Figure 5-1: Design approach

6 LNG carrier design

6.1 Cargo containment system evaluation

Over the past 30 years, the technology used to build LNG carrier containment systems has changed very little. Indeed, many of the technologies in use today are the same as in the 1970s. The only “new” development implemented during the last decade was the GTT CS1 – which is a combination of GTT’s existing systems (Mark III and NO96).

The different containment systems have different characteristics, which must be considered when selecting containment system and designing a LNG carrier. The size class, trade and commercial circumstances attendant upon time of ordering may be the determining factors in the selection of a design. Both initial cost (newbuilding price) and operational costs, or even better the life cycle cost, should be considered, in addition to safety and reliability and it has to be beard in mind that what is advantageous for the shipbuilder may not necessarily be advantages for the owner and vice-versa.

As already mentioned, the membrane systems are dominating the market today and have been applied to a wide range of size classes. The Moss system has also a fair share of the existing fleet, but has been losing market share during the last decade. The Moss system has been implemented from around 20.000m3 and up to around 170.000m3 so far.

The type C tanks are the containment system of choice for small scale vessels, but not economical to scale up to larger vessel sizes. The size where the type C tanks do not make any sense depends on a number of factors, but seems to be in the range of 20.000m3 according to [37]. The IHI SPB has so far only been applied to two vessels, which are approx. 90.000m3 and it is known in the market that its cost is about 30% more than Moss, [47]. The concept can be scaled up and down, but considering the limited application since it was introduced 20 years ago, it seems difficult for this concept to compete with the membranes and Moss.

In the following, a qualitative comparison and evaluation of existing LNG containment systems is given. Only existing systems implemented in the market today are included.

LNG containment system comparison							
Category	Integrated tanks			Independent self-supporting tanks			
Classification	Membranes			Type A	Type B		Type C
Design criteria	Full secondary barrier			Full secondary barrier	Partial secondary barrier, “drip tray”		No secondary barrier
Design pressure, p_0	≤ 0,25 bar g			≤ 0,7 bar g	≤ 0,7 bar g		>0,7 bar g
Cont. name	Mark III	NO96	CS1	LNT A-BOX	Moss	IHI SPB	Type C
Provider	GTT	GTT	GTT	LNT	Moss M.	IHI	TGE, etc
Material (primary)	St.steel	Invar (36%Ni alloy)	Invar (36%Ni alloy)	St.steel	Aluminium	Aluminium	St.steel or 9% Ni steel
Material (secondary)	Triplex (laminated composite)	Invar (36%Ni alloy)	Triplex (laminated composite)	Alu.sheet / Plywood	NA	NA	NA
Insulation material	PU panels	Perlite panels	PU panels	PU panels	PU panels	PU panels	PU panels or PU foam
Geometric definition	Prismatic / trapezoidal	Prismatic / trapezoidal	Prismatic / trapezoidal	Prismatic / trapezoidal	Spherical	Prismatic / trapezoidal	Cylindrical / bi-lobe
Complexity	High	High	High	Medium	High	High	Low
Sloshing risk	Critical	Critical	Critical	Mitigated	No exposure	Mitigated	Mitigated
Volume efficiency	Good	Good	Good	Good	Poor	Good	Medium

Table 6:1: LNG containment comparison 1

Containment system			Pros	Cons
Integrated tanks	Membranes	GTT Mark III	• Good volume utilization • Long track record • Flat deck layout possible • Low weight and fast cool down	• Vulnerable to sloshing • Filling limitations • Specialized and labour intensive fabrication • Critical quality control • Accessibility for inspections and repairs • Small pressure tolerance
		GTT NO 96	• Good volume utilization • Long track record • Flat deck layout possible • Low weight and fast cool down	• Vulnerable to sloshing • Filling limitations • Specialized and labour intensive fabrication • Critical quality control • Accessibility for inspections and repairs • Small pressure tolerance
		GTT CS1	• Good volume utilization • Based on Mark III and NO96 with long track record • Flat deck layout possible • Low weight and fast cool down	• Vulnerable to sloshing • Filling limitations • Specialized and labour intensive fabrication • Critical quality control • Accessibility for inspections and repairs • Small pressure tolerance
Independent tanks	Type A	LNT A-BOX	• Simple design and fabrication • Independent tank fabrication • Good volume utilization • Flat deck layout • Sloshing eliminated • No filling restrictions • Full access to both primary and secondary barriers for inspections and repairs	• New entrance, no track record • Prone to structural fatigue
	Type B	Moss	• Not affected by sloshing • No filling limitations • No internal stiffeners • Excellent track record • Minimum surface relative to volume • Good fatigue properties	• Poor volume utilization • Complex design, construction and quality control • Highly specialized fabrication • Wind-age • Flat deck not possible
		IHI SPB	• Good volume utilization • Flat deck • Sloshing eliminated • No filling restrictions	• Complex design, construction and quality control • Extensive internal structural stiffeners • Prone to structural fatigue • Only two vessels built so far
	Type C	Type C	• No secondary barrier required Independent tank fabrication • No filling limitations • Sloshing eliminated • Simple and efficient system for small scale vessels • High pressure tolerance	• Poor volume utilization for bigger vessels • High p0 and thick steel plates for big tank sizes • Not suitable for medium or large scale vessels • Possibility for boil-off accumulation

Table 6:2: LNG containment comparison 2

6.2 Containment system selection

From a technical perspective the spherical tanks have a few benefits. The geometric definition provides minimum surface for a given volume, which is favorable considering both material consumption and insulation. The center of gravity will always lie at the centerline of a sphere, which is beneficial considering stability. Furthermore, the spheres eliminate sloshing problems. On the other hand, fabrication is fairly difficult, and only a few ship yards in the world are capable building such tanks and same is for the membrane systems. IHI SPB has a 30% higher cost than Moss spherical, since it is far less construction friendly and is in that regard not favorable.

Based on the table above the LNT A-BOX, seems very promising. The concept provides a number of unique features. It offers two truly independent barriers which are advantages with regard to inspection and periodic maintenance, since both primary and secondary barriers are accessible. The cargo tank is furthermore prismatic in shape, meaning the containment system provides excellent volume utilization as well as a flat deck layout. A flat main deck gives advantages such as easier maintenance of piping and equipment on deck, good visibility and small wind age area.

Based on the pros and cons of each containment system, given in Table 6:2, LNT A-BOX is determined to be the best option for the vessel.

6.3 Insulation system evaluation

The insulation system of LNT A-BOX is built up by two layer of cryogenic insulation with equal thickness. It has been mentioned that the insulation material can be polyurethane foam, rigid polyurethane boards/panels or expanded polystyrene or combinations of these. Between each layer of insulation, plywood boards of 20mm will be installed. Thermal conductivity and density of each material are listed in Table 6-3.

Insulation material			Thermal Conductivity	Density
ID.	Name	Abbreviation	k[W/mK]	ρ[kg/m3]
1	Polyurethane foam	PUF	0.016	50
2	Rigid polyurethane board/panel	PU	0.019	50
3	Expanded polystyrene	EPS	0.029	25
4	Plywood	PW	0.115	450

Table 6:3: Thermal conductivity and density of insulation materials

The thermal conductivity of each insulation material is to some degree temperature dependent [45], but the largest variations occurs at temperatures above -120°C. As can be seen from the table, EPS has less density then the PUF and PU but PUF and PU has definitely the lowest thermal conductivity.

Figure 6-1 shows U-values of all insulation materials given as function of insulation thickness. It is evident that that FUP has the best thermal insulation capability, and should in that regard be favorable

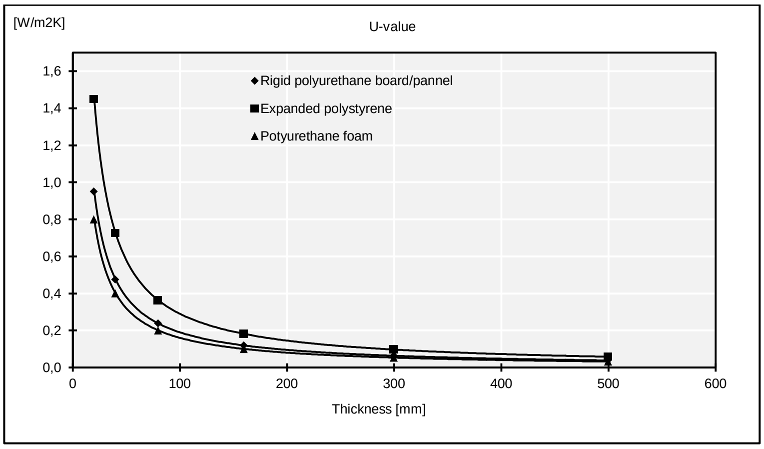


Figure 6-1: U-Value of insulation materials

The insulation systems listed has on the other hand major cost differences, both material and labour cost, see Table XX and XX. In that regard, it is at this point hard to determine favourable insulation material from an economical point of view.

6.4 Insulation system selection

Based on the above, 6 insulation systems have been selected for further evaluation, see Table 6.4 below.

	Insulation system 1	Insulation system 2	Insulation system 3	Insulation system 4	Insulation system 5	Insulation system 6
Layer 1	PU foam	PU foam	PU foam	PU panels	PU panels	EPS panels
Layer 2	Plywood (20mm)	Plywood (20mm)	Plywood (20mm)	Plywood (20mm)	Plywood (20mm)	Plywood (20mm)
Layer 3	PU foam	PU panels	EPS panels	PU panels	EPS panels	EPS panels
Layer 4	Plywood (20mm)	Plywood (20mm)	Plywood (20mm)	Plywood (20mm)	Plywood (20mm)	Plywood (20mm)

Table 6:4: Insulation systems

7 Basis design

In the following, the author's proposed LNG carrier design for small scale LNG trade between Papa New Guinea and in Singapore will be presented. Principle dimensions and hull form are summarized in Table 7.1 and 7.2. It must be noticed that the physical parameters of the basic design is expected to undergo minor changes, during additional and required design loops, later on.

7.1 Design approach

The design work has been carried out by combining ship statistics, knowledge from existing LNG carriers and empirical formulas suggested in various ship design literature. As starting point, existing LNG carriers were carefully analyzed in order to establish useful initial estimates for ship dimensions and characteristics. In order to decide required cargo capacity, a service speed of 15 knots was selected, based on statistics, for the given trade.

By evaluating trade rout distance in correspondence with service speed, a required cargo capacity within the range of 37,500-49.000m3 was found necessary to achieve required annual freight work as stated in Ch. 1. Required cargo capacity was further used to determine cargo containment dimensions, by using the formulas given in in Ch. 4. Number of required cargo was determined by evaluating existing LNG carriers with cargo capacities in the same range. The volume of each cargo hull compartment was further set equal.

In order to estimate LWT, a WBS structure was established, see Appendix 13, and the weight of each item in the break down structure was estimated by use of coefficients suggested by Harvald and Juncher Jensen , System based Ship Design, and exact coefficients from existing LNG ships, see Ch. 4.

As basis for the weight calculations, the vessel was first divided into spaces, and a thorough space allocation and gross volume was found. Volume estimations where performed by evaluating GA plans of various LNG and LPC carriers. In order to estimate main engine weight in an early design stage, required power was initially set to 10,000kW based on statistics, and weight coefficient for slow speed (two stroke) engines was used. Weight of cargo tanks were determined by assuming a fixed cargo capacity of 45,000m3. Insulation weight was furthermore determined by assuming an insulation thickness of 300mm PU insulation.

DWT was further found by comparing fuel and lube storage capacity, as well as required number of crew, on existing LNG carriers of about same size with both DF and conventional engines. A fixed cargo capacity of 45.000m3 was used as basis for DWT estimation. The indication of the total displacement of the vessel was further used to determine preliminary main dimensions of the vessel by using LNG carrier statistics given in Appendix 3.

When estimates of DWT, LWT, cargo capacity and GV were established, preliminary ship dimensions were set. The dimensions was furthermore checked against empirical formulas given in [25] for bulk carriers. Deviations were found to be surprisingly small, which indicated that the preliminary parameters were good. Some changes were later on done, during ship modeling in Autocad.

7.2 Physical parameters

The ship dimensions of the basic design are given in the table below:

Length overall	205 m
Length waterline	198 m
Length, between pp.	192 m
Breadth, molded	32 m
Depth	18 m
Draught	8.5 m

Table 7:1: Ship dimensions

7.3 Hull form

In Ch. 4, empirical formulas for hull form were presented. In order to determine suitable block coefficient for the vessel, Alexander's formula was used. The formulae suggested a block coefficient of 0.73, which is in accordance with existing LNG carriers with about same cargo capacity. Prismatic coefficient was furthermore set to 0.75, based on suggestion given in [12]. Water plane area and mid-ship section area coefficient was initially determined by Schneekluth&bertram98 formulas, given in Ch. 4, but slightly changed later on in parallel with ship modeling in Autocad. Determined hull form coefficients are given Table 7:2 below.

Block coefficient	0.73
Prismatic coefficient	0.75
Water plane area coefficient	0.85
Mid-ship section coefficient	0.97
Slenderness ratio	6.06

Table 7:2: Hull form

7.4 Cargo compartment

Cargo compartment dimensions were determined by evaluating the space required for each cargo tank with a total capacity corresponding to a cargo capacity in the range of 37,500-49.000m3. Determination of dimensions has been quite iterative. It was initially necessary to have a clue of insulation thickness range in order to determine required dimensions of the compartment system. Based on initial boil-off calculations and evaluations of boil-off handling power consumption, it was decided that the dimensions of each cargo compartment had to be large enough to carry a minimum cargo volume of 16.000m3, with insulation thicknesses up to 1000mm. L/B – ratio and L/H - ratio was determined based on cargo tank dimension ratios gathered from existing IMO independent tank type A used on LPG carriers. The cargo compartment dimensions determined are given in Table 6:5.

Length	45m
Breadth	27 m
Height	16 m

Table 7:3: Cargo compartment dimensions

7.5 GA plan

A GA plan of the ship is given in Figure 7-1.

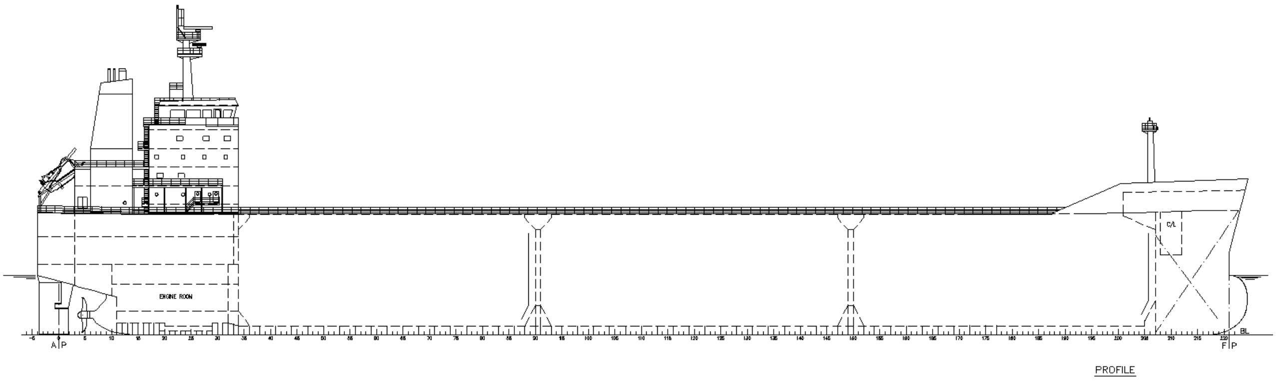


Figure 7-1: GA plan

7.6 Design evaluation

The ship design presented will further be used as basis in the next sections and ship dimensions will be regarded as fixed. Since cargo insulation and cargo tank weights were set fixed in LWT determinations, some minor edits of ship parameters is assumed to be required later on, after optimal insulation thickness, material and cargo tank size are determined, due to a change in displacement. In addition, weight of propulsion plant will additionally change slightly after determination of exact power requirement.

In the next chapters potential propulsion systems and corresponding boil-off handling systems will be evaluated and determined. Afterwards, determination of ship configurations will be carried out.

8 Propulsion system

8.1 Propulsion system evaluation

In this chapter, evaluation of propulsion systems will be performed in order to determine favorable propulsion systems for the vessel. The evaluation is performed by first evaluating pros and cons of existing engines and afterwards evaluation of corresponding power transmission systems. Notice that the information given can vary slightly in the literature. In Ch. 3.4, all different types of propulsion systems used in the current LNG carrier fleet were described. Main engines in use are as mentioned, steam turbine, slow speed (two stroke) conventional and DF, medium speed (four stroke) conventional and DF and gas turbine. In Table 8:1 evaluation of the various engines in use are presented.

Propulsion system	Pros	Cons
Steam turbine	• Proven system • Easy maintenance • Fuel redundancy – any combination of HFO and BOG • Low maintenance cost • Easy handling of boil-off gas	• Low thermal efficiency ($\eta \approx 0.30$) • Loss of cargo • Large engine room • Complicated steam system • Lack of qualified manning
Slow speed (two stroke) DF	• High redundancy • High thermal efficiency ($\eta \approx 0.50$) • Low emissions (Depends on engine load) • HFO as pilot fuel	• Loss of cargo • High pressure gas supply system • 5-8% pilot fuel in gas mode
Slow speed (two stroke) conventional	• Proven system • High redundancy • No loss of cargo • High thermal efficiency ($\eta \approx 0.50$) • Low emissions (Depends on engine load) • Qualified manning	• Re-liquefaction plant
Medium speed (four stroke) DF	• Proven system • High redundancy • High thermal efficiency ($\eta \approx 0.47$) • Small engine room • Reduced emissions • Low pressure gas supply system • Only 1.5% pilot fuel	• High initial cost • Loss of cargo • High maintenance cost • MDO as pilot fuel
Medium speed (four stroke) conventional	• Proven system • High redundancy • High thermal efficiency ($\eta \approx 0.47$) • No loss of cargo • Qualified manning	• Complex system • Re-liquefaction plant
Gas turbine	• High power density • Low weight	• Low thermal efficiency ($\eta \approx 0.30$) • High investment cost • High maintenance cost • Loss of cargo

Table 8:1: ME evaluation table, [51] [73] [53] [54] [74]

As can be seen from the table, it's a large variation in thermal efficiency between the systems. Slow speed two stroke engines have the largest thermal efficiency off all the engines, while gas and steam turbine engines have definitely the lowest. On the other side, slow speed engines requires more complex and costly as well as fuel consuming boil-off handling systems. Gas injection pressure on a steam turbine is only about 5 bars (gas turbine about 40 bars), requiring far less compression power than slow speed (two stroke) DF engines, which has an injection pressure in the range of 250-300 bars. Based on initial calculations, the additional fuel consumption required for gas supply to engines or re-liquefaction is far less than the additional required fuel for propulsion for stream- and gas turbines. It has been demonstrated that internal combustion engines can result in far less running costs, due to the relatively low fuel consumption, compared to steam- and gas turbines. However, steam- and gas turbines can be advantages, when it comes to reliability and boil-off handling simplicity, and low maintenance cost.

Table 8:2 below, illustrates propulsion efficiencies for existing power transmission systems. Combining the propulsion power transmission configurations on the left side of the table with the engines listed above, total fuel efficiency of potential propulsion systems can be determined. Notices that the efficiencies given can vary slightly from system to system, the values listed are average values gathered from various literature. Hull efficiency is neglected in the table, due to value uncertainty. According to [63] values of hull efficiency for cargo ships can vary within the range of 0.95-1.04.

<table>
<tr><td colspan="11">Propulsion efficiency</td></tr>
<tr><td rowspan="2">Power transmission configuration</td><td colspan="6">Transmission efficiency</td><td>Hull efficiency</td><td>Rel. rot. efficiency</td><td>Propeller efficiency</td><td>Propulsion efficiency</td></tr>
<tr><td colspan="6">η_S</td><td>η_H</td><td>η_R</td><td>η_O</td><td>η_p</td></tr>
<tr><td rowspan="2">Electric propulsion, FPP</td><td>Generator</td><td>Switchboard</td><td colspan="2">Transformer</td><td>Frequency converter</td><td>Electric motor</td><td rowspan="2">NA</td><td rowspan="2">0.97</td><td rowspan="2">0.75</td><td rowspan="2">0.674</td></tr>
<tr><td>0.974</td><td>0.999</td><td colspan="2">0.985</td><td>0.986</td><td>0.98</td></tr>
<tr><td rowspan="2">Direct drive, FPP</td><td colspan="6">Shaft</td><td rowspan="2">NA</td><td rowspan="2">0.97</td><td rowspan="2">0.75</td><td rowspan="2">0.717</td></tr>
<tr><td colspan="6">0.985</td></tr>
<tr><td rowspan="2">Direct drive, CPP</td><td colspan="3">Reduction gearbox</td><td colspan="3">Shaft</td><td rowspan="2">NA</td><td rowspan="2">0.97</td><td rowspan="2">0.73</td><td rowspan="2">0.684</td></tr>
<tr><td colspan="3">0.98</td><td colspan="3">0.985</td></tr>
</table>

Table 8:2: Propulsion efficiency [63] [54]

As stated in Ch. 3.2, propulsion systems utilizing steam of gas turbine(s) have typically electrical transmission. Some attempts for direct drive have been tried but have failed. Slow speed (two stroke) engines have typically direct drive fixed propeller without reduction gear box, while medium speed (four stroke) can both have electrical transmission with fixed propeller, or direct drive with reduction gear box and controllable pitch propeller. As can be seen from the table, there are quite large differences in propulsion efficiency for the various configurations. Direct drive with fixed propeller has the highest efficiency, about 3% higher than direct drive controllable pitch propeller and 5% higher than electrical propulsion with fixed propeller.

Fuel efficiency of each possible propulsion system can be expressed by multiplying propulsive efficiency with thermal efficiency. Figure 8-1 illustrates the fuel efficiency of each possible propulsion system alternative.

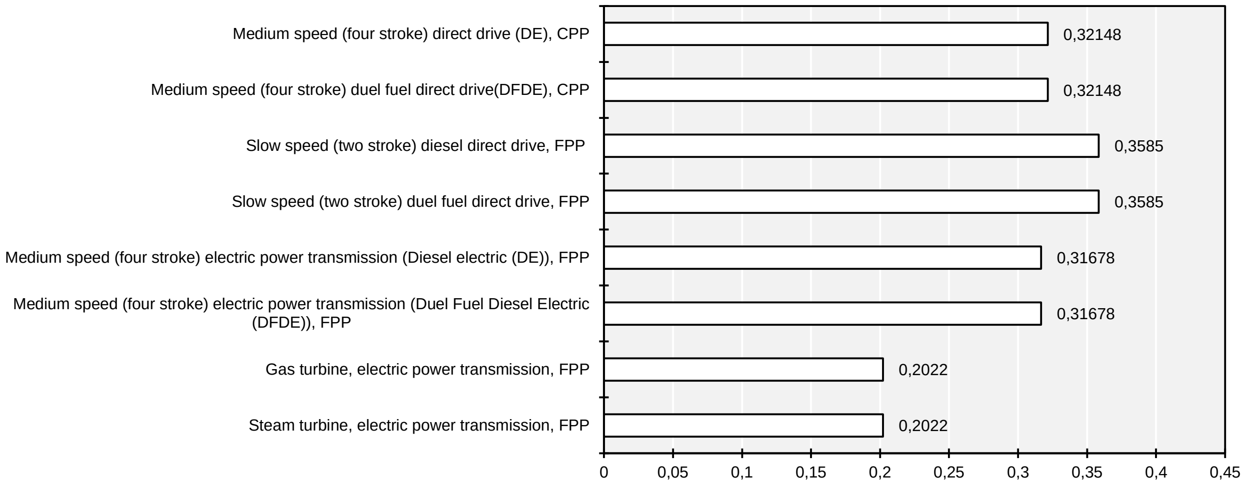


Figure 8-1: Propulsion system fuel efficiency

Evaluating the various systems from a fuel consuming perspective, it is evident that slow speed (two stroke) dual fuel/diesel direct drive with FPP is the most fuel efficient propulsion system. With an increased focus on fuel economy and emissions due to high fuel prizes and upcoming emission to air regulations, the most fuel efficient system is very favorable. Although direct drive offers the best propulsion efficiency, several advantages can be stated for electrical propulsion. Electrical propulsion may offer improved reliability due to greater engine redundancy, and prime movers can be located basically anywhere which can lead to increased available hull volume for cargo.

Based on above, it is obvious that gas- and steam turbine plants as well as the medium speed engine propulsion systems will require far more fuel for propulsion during the ships operation period. Assuming that a gas – or steam turbine plant consume 10,000tons of LNG per year (which should be quite realistic on the given trade route based in initial calculations), a medium speed (four stroke) DF direct drive configuration will consume about 6350 tons per year, corresponding to an annual fuel cost reduction of about 1.8mUSD annually assuming a LNG price of 500USD/ton (as of Henry Hub February 2012). Excluding present value considerations, this fuel cost reduction corresponds to operational cost saving of 54mUSD during the ship's lifetime assuming 30 years of operation.

Assuming that a the medium speed engine consume 10.000tons of HFO per year, the slow speed engine will only consume 8979 tons of HFO per year. With a HFO cost of 900USD/ton, an annual fuel cost reduction using slow speed engine compared to medium speed engine is about 1 mUSD. Based on the above it is realistic to assume that although the investment cost of medium speed configurations is far less than the slow speed engine configurations, the additional investment cost will pay off in the long run.

It is however at this stage very uncertain in which a two stroke DF of diesel engine should be selected. DF engines have historically proved to offer lower fuel cost than diesel engines, mainly due to the low price of LNG. However, diesel engines offer several advantages: A diesel engine results in increased cargo quantity delivered to costumer compared to DF engines, since DF engines use boil of gas as fuel, and should in that result in a higher freight rate. In addition, current state of the art within re-liquefaction plant technology offers energy efficient boil-off re-liquefaction and some claims that LNG re-liquefaction may be economically advantageous. Based on this, slow speed (two stroke) DF and diesel propulsion systems configurations will be evaluated further.

8.2 Propulsion system alternatives

ME alt.1	ME alt. 2
Slow speed (two stroke) diesel, direct drive, FPP	Slow speed (two stroke) DF, direct drive, FPP

Table 8:3: Propulsion system alternatives

8.3 MAN B&W slow speed engines

Two-stroke slow speed engines used in the worlds merchant fleet is predominantly dominated by MAN B&W engines. MAN B&W is additionally far ahead in development of slow speed dual fuel engines, compared to their competitors. MAN B&W offers to different slow speed engines.

- ME HFO burning engines (conventional)
- ME-GI dual fuel burning engines

Technically, there are few differences between the alternatives, but the GI engine provides optimal fuel flexibility. The two stroke slow speed high-pressure gas injection engine was originally a mechanical controlled engine (MC-GI) where it aimed at the stationary power plant marked as an alternative to steam turbines. ME-GI engine is a recently developed engine and is electronically controlled ensuring that the process of mixture formation, ignition and combustion is optimized at various engine loads.ME-GI engine is developed as a duel fuel engine and is able to operate 100% engine load (SMCR) on either gas, MDO or HFO without loss in thermal efficiency and offers thereby full fuel flexibility. To ensure efficient gas injection, ME-GI engines requires gas supply at a pressure in the range form 250-300bars, depending on engine load, and at a temperature of about 45°C. In order to deliver boil-off gas to the engine at such high pressures, a gas supply system with a capacity corresponding to the fuel consumption of the engine has be designed. Several gas supply systems for ME-GI exist, with large similarities and for the interested readers see [53].

8.4 Main engine size determination

Required break power of the basic design has been calculated in order to determine required power for propulsion to achieve a service speed of 15 knots. Hollenbach 98 method, as described in Ch. 4.3.1 has been used to predict the effective towing power of the vessel at various speeds. Curves of required towing power and brake power as function of ship speed is given in Figure 8-3. Required break power includes a sea margin of 15%. Resistance calculations can be found in Appendix 5.

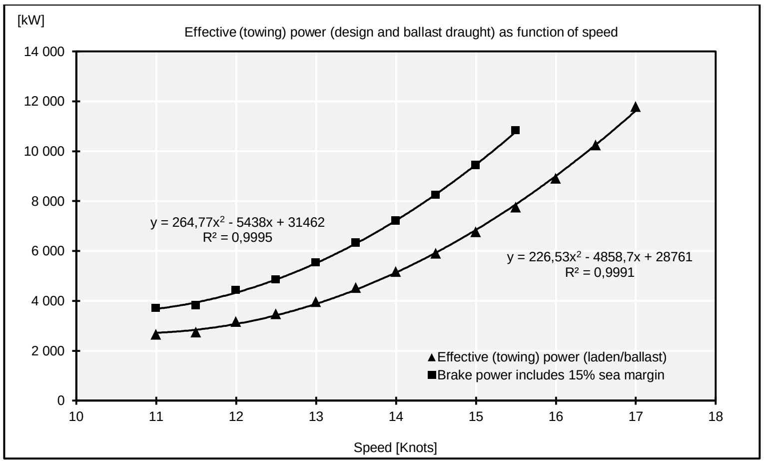


Figure 8-2: Ship resistance

As can be seen form the break power curve, a required ME power of about 10.000kW is required to achieve a service speed of 15 knots. Based on this the following ME alternatives have been selected.

8.5 Main engine selection

ME alt. 1	ME alt. 2
MAN B&W 6S50MEB9 1 set. SMCR: 10680kW at 117RPM	MAN B&W 6S50ME-GI-B9 1 set. SMCR: 10680kW at 117RPM

Table 8:4: Main engine selection

8.6 Aux generator selection

Based on LNG carrier statistics, it has been determined that two or three aux generators normally are installed on wessesl with approximately same cargo capacity. Typical installed power on LNG carriers with capacities within the range of 20.000-60.000m3 are typically in the rage of 2-4000kW. On new LNG vessels, DF aux generators have become more and more normal, but in this project, diesel generators will be selected. As basis for further evaluations 2 aux generators of type MAN B&W 6L27/38 SMCR: 1980kW with corresponding generator power of 1900kW will be used.

9 Boil-off handling systems

9.1 Boil off handling system evaluation

The following boil of handling systems is selected based evaluation of existing systems in use on existing vessels. In order enable calculation of power consumption, the systems are simplified. Only the main components consuming most power are included. For supplementary info about the systems see, [53] [50] [60].

9.1.1 Boil-off handling alternative 1 – Re-liquefaction plant

Boil-off handling alternative 1 consists solely of a re-liquefaction plant. Boil-off is taken out from the top of each cargo tank (1), and re-liquefied in a re-liquefaction plant on deck and sent back (2) to cargo tank. A simplified illustration of boil-off handling alternative 1 is given in Figure 9-1. In Ch. 3.5, descriptions of re-liquefaction plants were given, and it is obvious that re-liquefaction plants are complex systems, including a multiple number of power consuming items. In that regard, this paper will further treat re-liquefaction plant as one power consuming system. To enable that, statistics of power consumption of the various systems as function of capacity is gathered, given in Appendix 3.

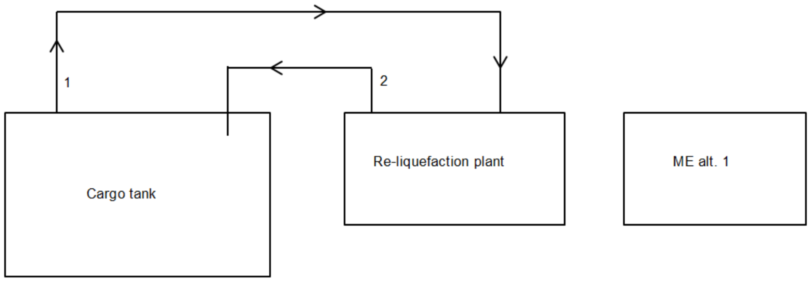


Figure 9-1: Boil-off handling alternative 1

9.1.2 Boil-off handling alternative 2 – Gas supply system alt. 1

Boil-off handling alternative 2 is determined by existing and purposed systems. In contrast to a re-liquefaction plant, these systems has far less power consuming items. It consists of a three stage HP Burchardt compressor (2), a LNG fuel pump (3), a HP piston pump (4) and HP vaporizer. The compressor compresses boil-off gas to required pressure, while fuel pump and HP piston pump adds additional fuel to engine if boil-off rate is insufficient. An illustration of the system is given in Figure 9.2.

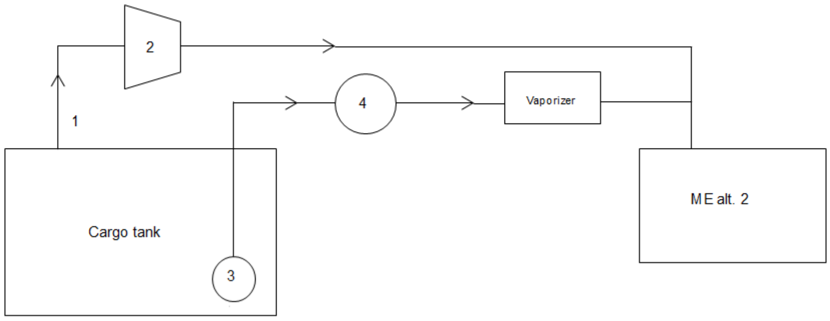


Figure 9-2: Boil-off handling alternative 2 - Gas supply system alt. 1

To ensure redundancy, the above illustrated system has normally additional compressors and pumps available in case of failure.

9.1.3 Boil-off handling alternative 3 – Gas supply system alt. 2

Boil-off handling alternative 3 is a combined configuration of the two other ones. Due to an improved efficiency, and reduced cost of re-liquefaction plant recant years, introductory calculations of required boil-off compressor power, has indicated that a combination LNG fuel supply and boil-off re-liquefaction may be favorable. The system is illustrated below in Figure 8-6. It consist of a re-liquefaction plant for boil-off gas re-liquefaction, and a simplified gas supply system consisting of a LNG fuel pump (3), a HP piston pump (4) and HP vaporizer.

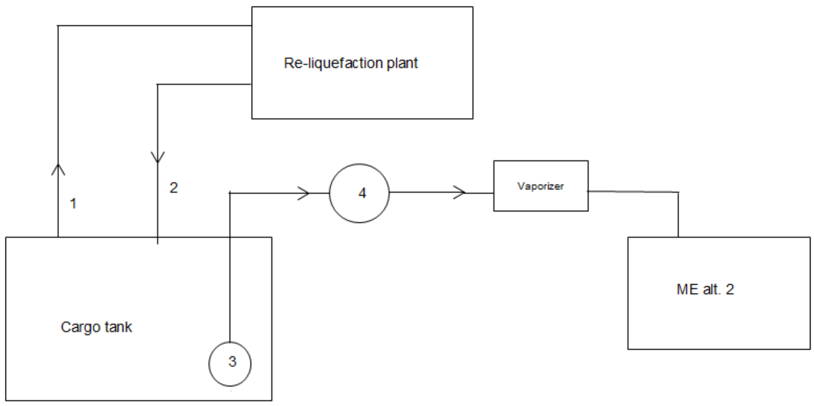


Figure 9-3: Boil-off handling alternative 3 - Gas supply system alt. 2

10 Technical-economic interrelationships

10.1 Building cost affecting interrelationships

10.1.1 Aux power

Pump- and compressor-work formulas given in Ch. 4.9 indicates that compressor and pump work will increase linearly with regard to capacity. In order to handle the boil-off rate, the capacity of boil-off handling systems must at least equal maximum boil-off rates occurring during operation. Since the main power consuming items in boil-off handling system 1-3 are compressors and pumps, it is likely to assume that required aux power installed will increase linearly with regard to boil of rate, meaning that required power installed is dependent on boil-off rate, and therefor also the cost.

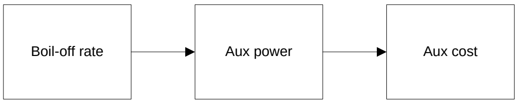


Figure 10-1: Aux cost affecting interrelationship

10.1.2 ME alternative

The main engine alternatives varies obviously with regard to ME alternative installed.

10.1.3 Insulation system

Insulation cost varies directly with regard to type of material and linearly with regard to insulation thickness, based on cost information given in Ch. 10.

10.2 Running cost affecting interrelationships

10.2.1 Fuel consumption

The fuel cost, assuming fixed cost of fuel, will vary linearly with regard to fuel consumption. The fuel consumption is however dependent on both ME alternative and onboard power consumption. Based on Sec. 12.1.1, it should be obvious that boil of rate will effect fuel consumption.

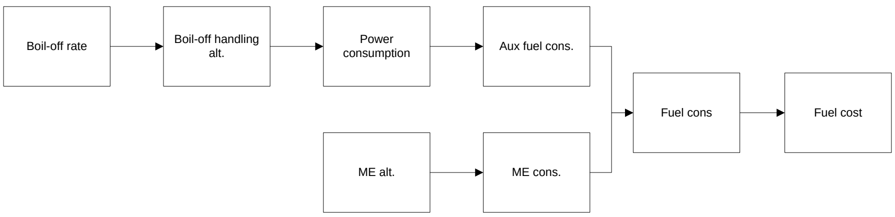


Figure 10-2: Fuel cost affecting interrelationship

10.3 Charter rate affecting interrelationships

10.3.1 Cargo volume

By increasing the insulation thickness, cargo tank size will decrease and the transport efficiency will be reduced. When ME is running on gas, less cargo will additionally be delivered to costumer. Charter rate is generally set by cargo quantity delivered to costumer, so both cargo volume and ME alternative will affect charter rate.

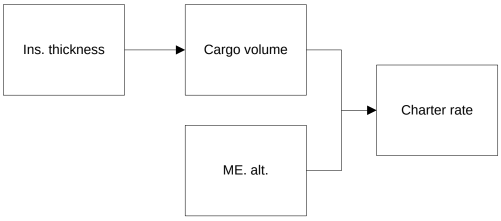


Figure 10-3: Charter rate affecting interrelationships

10.4 Boil-off rate

The boil of rate is as indicated above a major indirect cost contributor. Boil-rate rate will vary directly with regard to two parameters, assuming fixed LNG density and heat of evaporation, that is; heat flow rate into the cargo containment and volume of cargo in cargo tanks. Heat flow rate is dependent on the property of insulation material (thermal conductivity), insulation thickness, temperature difference between inner and out insulation surface and total, heat transfer area, which is determined by cargo tank size, and film coefficient. Technical interrelationships affecting boil-off rate is given in Figure 10-4 below:

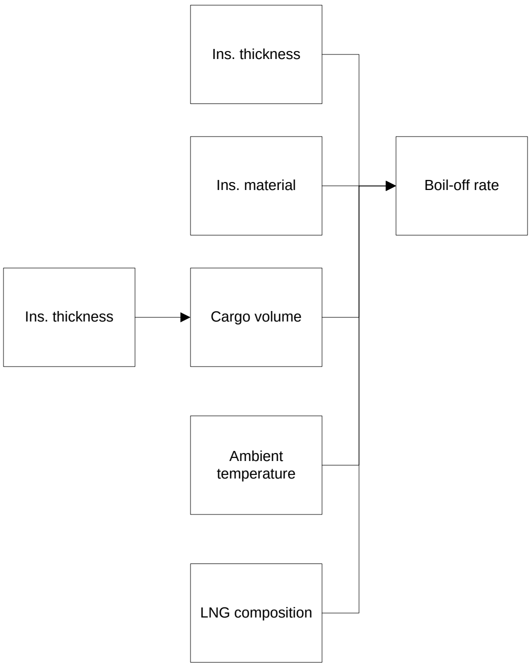


Figure 10-4: Technical interrelationships affecting boil-off rate

11 Boil-off rate determination

11.1 Heat flow rate

11.1.1 Influence of variation of heat transfer coefficients

For cryogenic insulation the relatively complex calculations outlined in Ch. 4.7 can be simplified and maintaining acceptable accuracy. To illustrate this, an example with realistic physical properties will be presented in the following. Refer again to equation 1 in Ch. 4.7.

$$q = \frac{T_0 - T_i}{\left(\frac{1}{h_i}\right) + \left(\frac{1}{h_0}\right) + \sum_j \frac{t_j}{K_j}}$$

Typical conservative values for natural convection will according to [45] be in the order of 3-7 W/m2K. Based on experience from LNG vessels a mean value of 5 W/m2K will typically be conservative for insulation surfaces exposed to natural convection. Thermal conductivity of the insulation materials is, as mentioned in the range of 0.016-0.029 W/mK. Assuming an insulation thickness in the range of 100-300mm and a temperature difference of 160K, the following examples will give a picture of the influence of the three “resistance” terms in the heat transfer equation relatively to each other:

$$q = \frac{160K}{\left(\frac{1}{5\frac{W}{m2K}} + \frac{1}{5\frac{W}{m2K}} + \frac{0.1m}{\frac{0.02W}{mK}}\right)} = \frac{160}{0.2 + 0.2 + 5}$$

$$q = \frac{160K}{\left(\frac{1}{5\frac{W}{m2K}} + \frac{1}{5\frac{W}{m2K}} + \frac{0.3m}{\frac{0.02W}{mK}}\right)} = \frac{160}{0.2 + 0.2 + 15}$$

It is easy to verify through these examples that the accurate values of the heat transfer coefficients for the cargo containment insulation system can be ignored for large insulation thicknesses, since it has a small effect on the total heat flow rate compared to the thermal conductance. The graph below gives a similar graphical presentation of the heat flux as function of heat transfer coefficient when PU foam is used as insulation.

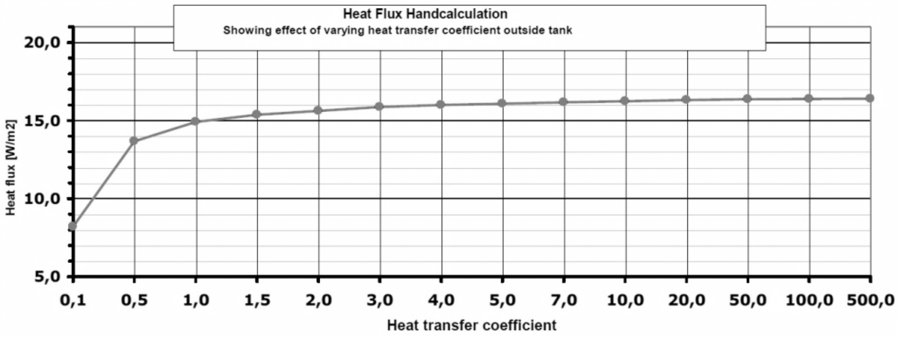


Figure 11-1: Heat flux as function of heat transfer coefficient, [45].

As the graph show, the total heat flux flattens out with heat transfer coefficients above 0.5, indicates that the heat transfer coefficient can be ignored in heat flow rate calculations, without effecting results significantly.

The heat flow rate calculations presented in this paper treat a steady stat situation, and is calculated in accordance with the following formula:

$$q = \frac{T_0 - T_i}{\left(\frac{1}{h_i}\right) + \left(\frac{1}{h_0}\right) + \sum_j \frac{t_j}{K_j}} = \frac{T_0 - T_i}{0 + 0 + \sum_j \frac{t_j}{K_j}} \text{ [W/m2]}$$

And as can be seen, the film coefficients have been set to zero, since its effect on heat flow rate is identified small. The temperatures used as input for the outer surface of the insulation, the insulation which is attached to the hull have been set to be 30°C, and should according to [45] reflect a typical operating condition on the set trading rout. The temperature at the inner insulation surface has been set to be 165°C, which is about 2% higher than the exact LNG temperature during normal operation, and is in accordance with recommendations from [45]. The insulation systems is, as mentioned divided into two insulation layers, and tow plywood layers, and a total thermal conductivity coefficient have been calculated for each insulation system and used. The heat transfer area in each cargo containment system have been calculated in accordance with the formulas given in Ch. 4.7, and a mean value of inner and outer insulation system area have been used in the total heat flow rate calculations.

11.1.2 Insulation system surface area and insulation volume

The following formulas have been used to calculated insulation system surface area and volume and are derived from geometrical consideration of each cargo compartment.

$$A_{TOP/BOT} = 2B_C L_C$$
$$A_{SIDES} = 2(H_C - 2t_{INS})\, L_C$$
$$A_{FRONT/END} = 2(B_C - 2t_{INS})\,(H_C - 2t_{INS})$$
$$A_{INS} = A_{TOP/BOT} + A_{SIDES} + A_{ENDS}$$
$$A_{INS}(t_{INS}) = 8t_{INS}^2 - \left(4t_{INS}(B_C + H_C + L_C)\right) + 2(B_C L_C + B_C H_C + H_C L_C)$$
$$V_{INS}(t_{INS}) = A_{INS}(t_{INS})\, t_{INS}$$

$$V_{INS\_L1} = (A_{INS}(t_{INS_{L1}}))\,(t_{INS_{L1}})$$
$$V_{INS\_L2} = A_{INS}(t_{INS_{L1+L2}})\,(t_{INS_{L1+L2}}) - V_{INS\_L1}$$
$$V_{INS\_L3} = A_{INS}\left(t_{INS_{L1+L2+L3}}\right)(t_{INS_{L1+L2+L3}}) - (V_{INS_{L1}} + V_{INS_{L2}})$$
$$V_{INS\_L4} = A_{INS}\left(t_{INS_{L1+L2+L3+L4}}\right)(t_{INS_{L1+L2+L3+L4}}) - (V_{INS_{L1}} + V_{INS_{L2}} + V_{INS_{L3}})$$

where:

$A_{TOP/BOT}$ = Insulation area above and below cargo tank

A_{SIDES} = Insulation area on beside cargo tank

$A_{FRONT/END}$ = Insulation area tank front and tank end

$A_{INS}(t_{INS})$ = Insulation area as function of insulation thickness

$V_{INS}(t_{INS})$ = Insulation volume as function of insulation thickness

t_{INS} = Total insulation thickness

$t_{INS_{L1}}$ = Insulation thickness (layer 1)

$t_{INS_{L1+L2}}$ = Total insulation thickness (layer 1 and layer 2)

$A_{INS}(t_{INS_{L1}})$ = Panel/foam insulation area (layer 1)

$A_{INS}(t_{INS_{L1+L2}})$ = Panel/foam insulation area (layer 2)

V_{INS_L1} = Volume insulation layer 1

Average insulation area as function of insulation thickness has been determined by the following derived formula:

$$A_{INS\_AVERAGE} = (A_C + A_I)/2$$

$$A_I(t_{INS}) = 2(B_C - 2t_{INS})(L_C - 2t_{INS}) + 2(B_C - 2t_{INS})(H_C - 2t_{INS}) + 2(L_C - 2t_{INS})(H_C - 2t_{INS})$$

$$= 24t_{INS} - 8t_{INS}(L_C + H_C + B_C) + 2(B_C L_C + B_C H_C + L_C H_C)$$

Where:

$A_I(t_{INS})$ = Inner insulation area as function of insulation thickness

11.1.3 Heat flow rate

The total heat flow rate of each insulation system as function of insulation thickness is given in Figure 13-2 below for laden voyage. The heat flow rates illustrated is for all three cargo containment systems.

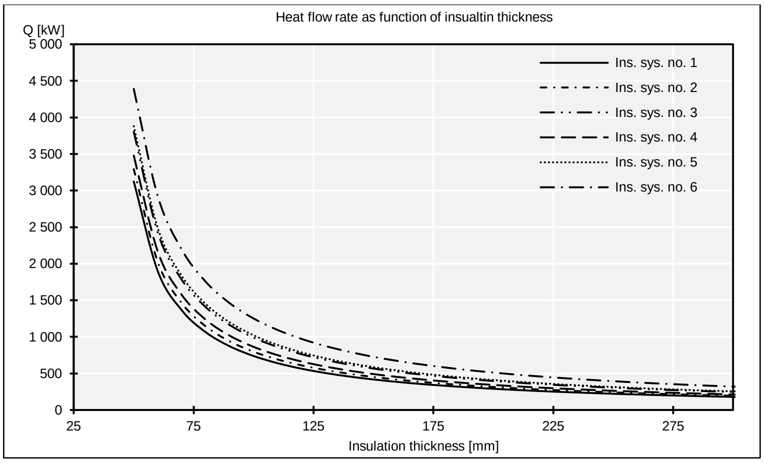


Figure 11-2: Heat flow rate as function of insulation thickness

11.1.4 Boil-off rate

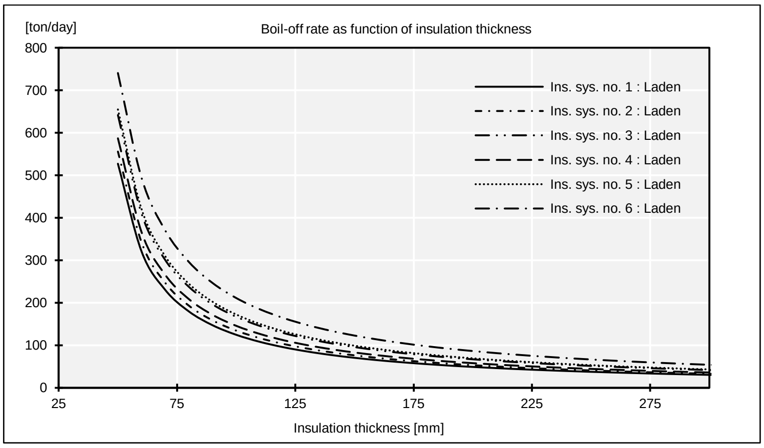


Figure 11-3: Boil-off rate as function of insulation thickness

11.1.5 Cargo containment system weight

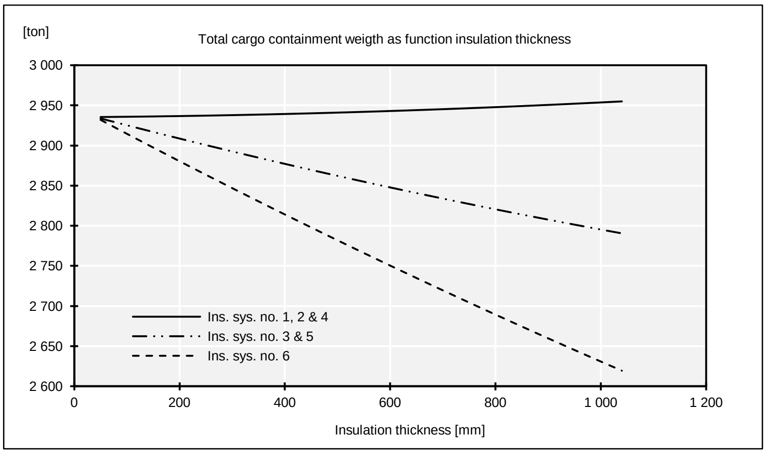


Figure 11-4: Containment system weight as function of insulation thickness

12 Charter rate

The charter rate of the vessel is expected to depend on the unit of cargo transported and delivered to costumer. Total cargo delivered to costumer varies, as shown in Figure 11-3, with cargo capacity and ME alternative, as described in Ch. 12.3. In this project, expected charter rates, as function of total delivered cargo to costumer is established. The charter rate is determined by current T/C-rates (as of Feb. 2012) for various LNG carriers with different cargo capacities, and a regression curve of T/C-rates as function of LNG volume delivered to costumer was drawn, see Appendix 7. The optimisation model includes fuel cost, and in that regard, the T/C – rates gathered have been increased with 30%, since fuel cost corresponds to about 30% of running cost on conventional ships, according to [67]. Figure 12-1 shows the regression curve for V/C – rate used in V/C – rate estimations.

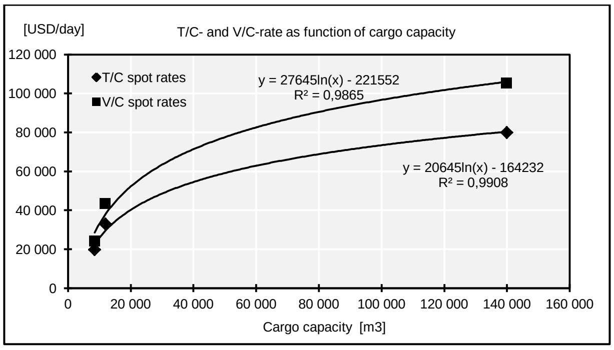


Figure 12-1: T/C – and V/C – rate as function cargo capacity

In Figure 12-1: Cargo capacity as function of insulation thickness is given. As seen, the cargo capacity decreases slightly by increasing insulation thickness. The cargo capacity difference between defined minimum and maximum insulation thickness corresponds to a cargo capacity drop of about 25%.

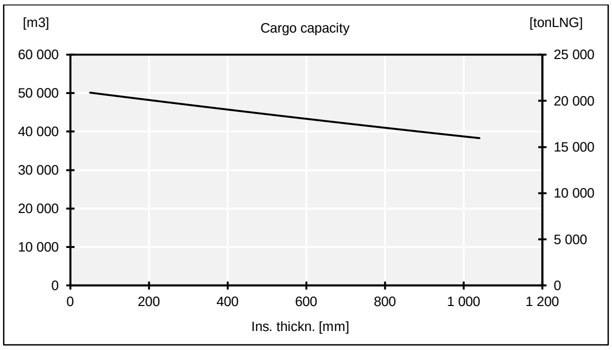


Figure 12-2: Cargo capacity as function of insulation thickness

In the Figure 12-2, Annual V/C – rate within actual cargo capacity range is given. As seen, small insulation thicknesses are very favourable with regard to V/C - rate.

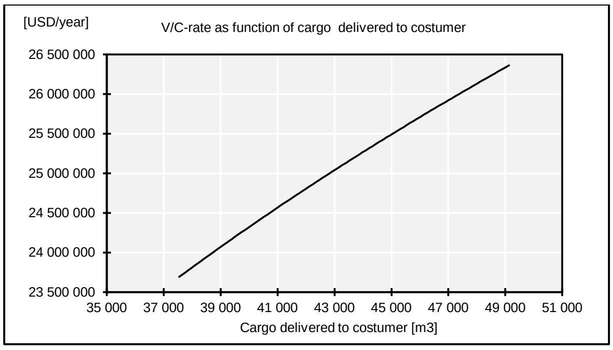


Figure 12-3: V/C – rate as function cargo capacity in relevant cargo capacity range

In Appendix 8, total gas consumption for ME alt. 2 given. As seen, gas consumption equals 246 ton on each leg, corresponding to a reduction in cargo delivery of 491 ton per roundtrip, since heel for ballast voyage is require. A reduction in unit cargo transported to costumer for ship configuration 2 and 3 is set to 1000m3, for safety reasons. Figure 12-5 below illustrates the difference in V/C rate for both ME configurations.

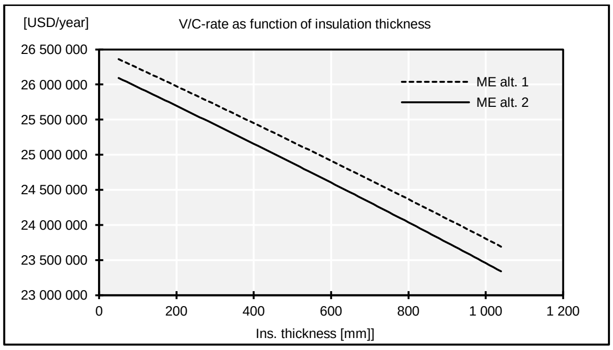


Figure 12-4: V/C rate as function of insulation thickness

13 Building cost

Due to the construction simplicity of LNT A-Box containment system, it is in this project assumed that the ship will be built in China. Cost coefficients and data for building costs are mainly obtained from statistics published in various literatures, experience data, statistical coefficients, and by consultants with experts. Data from suppliers and shipbuilders, and to some extent assumptions based on common sense have additionally been used.

As mentioned in Part 1, it is necessary to know the connection between technical and economic aspects, in order structure the building cost estimation process. In order to systemize costs estimation, a WBS and a CBS have been developed, see Appendix 13. The WBS is based on the main groups in the SFI group. A CBS has been developed for economic breakdown and can also be found in Appendix 13. The building cost is as seen divided into fixed and variable; administration and design cost, material and component cost and labor cost.

13.1 CBS 1.1 - Fixed building cost

13.1.1 CBS 1.1.1 – Fixed material and component cost

Material and component costs are to some degree dependent of where the vessel is to be built, but Chinese prices do not differ noteworthy, compared to labor cost [43]. In the next sections, cost coefficients and estimation of fixed building cost will be presented.

WBS 1 – Ship general

Ship general cost is assumed to be 150USD/LWT, which is a conservative estimate according to [43]. This cost group compromises details and costs that cannot be charged of any specific function onboard the vessel. The LWT used in the estimation excludes insulation and cargo tank weight, since insulation and cargo tank costs is estimated separately in CBS 1.1.2.

WBS 2 – Hull

Hull cost is calculated based on cost per ton steel. The group compromises hull structure and deckhouse of the ship. Various sources give relatively varying cost coefficients for steel, but 800USD/ton seems, with current steel price in china, to be a good estimate. Hull structure and deckhouse weight is calculated based on their inner volume and coefficients in accordance with Ch. 4.2.

WBS 3 – Cargo related

Cargo related cost is a wide cost block covering cost of WBS 3.1 - Cargo tanks, WBS 3.2 - Insulation system, WBS 3.3 – Boil off handling system, WBS 3.4 - Cargo instrumentation, WBS – 3.5 - Electrical system for cargo control, WBS 3.6 - PSA plant, WBS 3.7 - Piping, WBS 3.8 - Cargo pumps etc. WBS 3.4-3.8 cost have been assumed independent of boil-off rate, and have been estimated based on cost coefficients obtained from a 10,000m3 LNG carrier, Norgas Innovation [36].

WBS 4 – Ship equipment

Ship equipment costs have been calculated based on a coefficient suggested by [43], assuming that ship equipment costs is related to gross volume. A cost coefficient of 7USD/m3 has been used. Ship equipment compromises navigation equipment, maneuvering machinery, anchoring equipment etc.

WBS 5 – Equipment for crew

Equipment cost for crew is according to [12] assumed to be 35,000USD/crew. This cost group covers equipment which severs the crew such as furniture, catering, sanitary systems etc.

WBS 6 – Machinery

Machinery cost is divided into cost of WBS 6.1 - Main engine and WBS 6.2 – Aux generator. Main engine cost is fixed and independent of boil-off rate, since it does not produce electrical power for boil-off handling. Main engine cost for both ME alternatives is estimated by experience data from [36], which is respectively 427USD/SMCR for ME alt. 1 and 555USD/SMCR for ME alt. 2. ME system cost have been assumed to be 10USD/SMCR and 30USD/SMCR for both engine alternatives respectively.

WBS 7 – Ship common systems

Ship common system cost has roughly been estimated to 200USD/SMCR which is according to [12] recommendation. Ship common systems cost compromise cost of ballast and bilge systems, firefighting, systems for electrical distribution etc.

13.1.2 CBS 1.1.1 – Fixed material and component cost summary

An overview of total fixed building cost for each ME alternatives, is given in Figure 13-1. Fixed material and component cost for ship configuration with ME alt. 2 is slightly higher, about 2mUDS, due to the additional cost of the engine and corresponding machinery systems. The costs have been calculated in an Excel sheet and given in Appendix 9.

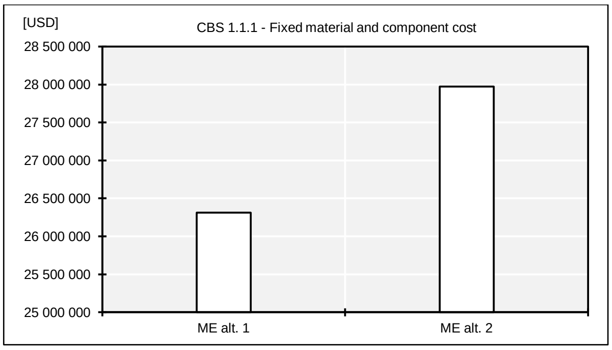


Figure 13-1: Fixed building cost

13.1.3 CBS 1.1.2 – Fixed labor hour cost

Labor cost is strongly dependent on geographical location of the shipyard. According to [43] labor consumption in northern Europe is typically 40 hours per ton steel, while price estimates for Chinese yards provided by [75] suggest 100 hours per ton steel. Cost of labor hours differs from 40USD per labor hour to 5.3 USD per labor hour in price estimates suggested according to [75]. Based on above, it is assumed that labor hour cost in China is 15USD/hour for general work. Furthermore, coefficients for labor consumption have been assumed to be somewhat higher than values proposed form European yards. In the next sections, used labor consumption for each WBS-group will be presented. The coefficients are mainly based on recommendations from [75] [37].

WBS 1 – Ship general

Labor consumption for WBS 1 has been assumed to be 10 hours/LWT. The value of LWT used, excludes cargo containment weight, since the labor cost of building the cargo containment system have been calculated separately since the cost of cargo containment system is dependent on insulation thickness and material.

WBS 2 – Hull

Considering the relatively high block coefficient of the LNG vessel, see [6], it has been assumed that 25hours/ton steel is required for WBS 2.

WBS 3 – Cargo related

Determination of required labor hours for fixed WBS 3 items have been difficult to predict from coefficients due to lack of data. A fixed price of 100,000USD have therefore been used for both ME alternatives.

WBS 4 – Ship equipment

Required labor hours for WBS 4 is assumed to be 0.5USD/GV which is a coefficient suggested by [12]

WBS 5 – Equipment for crew

Labor consumption for WBS 5 is related to the total number of crew and has been assumed to be 800hours/crew.

WBS 6 – Machinery

Labor consumption for WBS 6.1 – Main engine is estimated to 3hours/SMCR for ME alt. 1 and 5 hours/SMCR for ME alt 2. Required labor hours for ME alt. 2 has been assumed to be 30% higher based on recommendations form .

WBS 7 – Ship common systems

Labor consumption for WBS 6 has been assumed to be 2.5hours/SMCR for both ME alternatives and is taken from [36].

13.1.4 CBS 1.1.2 – Fixed labor hour cost summary

Labor cost of ME alt. 2 is as can be seen from Figure 15-2 somewhat higher than for ME alt. 1. This is due to a higher required number of hours for installation of engine and corresponding engine systems.

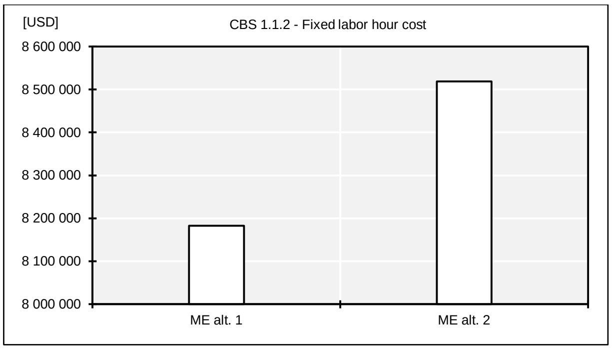


Figure 13-2: Fixed labour hour cost

13.1.5 CBS 1.1.3 – Fixed administration and design cost

Administration of ship design and manufacturing are cost contributors to the total newbuilding price. Although the vessel is assumed to be built in China, is likely to expect that much of the design work will be performed in Europe. According to [], a good coefficient for labor consumption for ship design in Europe is 15 hours/LWT according to []. Furthermore, the price of labor in Western Europe is approximately 30 USD/hour. In addition to design cost comes, building time finance, profit to shipyard and designers, financing payment and broker fees. The above mentioned cost components have been calculated as percentage of production cost and have been assumed to be 8%, 5%, 3% and 1% respectively of Material and component cost plus Labor cost plus Design cost. Containment system design cost has been assumed fixed and independent of insulation material selection and insulation thickness, see Appendix 9.

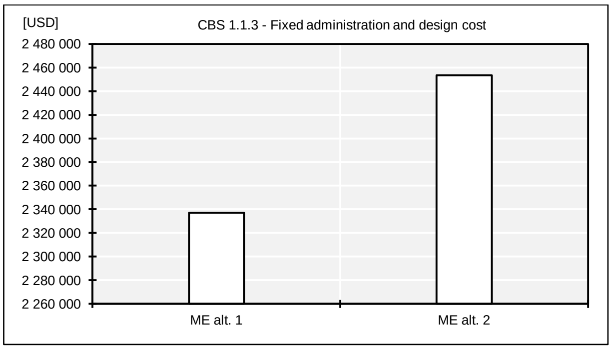


Figure 13-3: Fixed administration and design cost

13.1.6 Fixed building cost summary

Total fixed building costs can be found in Appendix 9, and as can be seen the main contributor to the higher cost of ME alt. 2 compared to ME alt. 1, is the higher initial cost of the engine. For further investigations into the cost estimation, the reader is recommended to look closer into calculations given in the attached Excel Doc. It must be noticed that there are some cost uncertainty due to several assumption. More advanced estimation techniques is required in order to predict fixed building costs more accurately. In addition, material and component cost as well as administration, design and labor costs, can vary extensively due to market fluctuations, as discussed in Ch. 4.10.

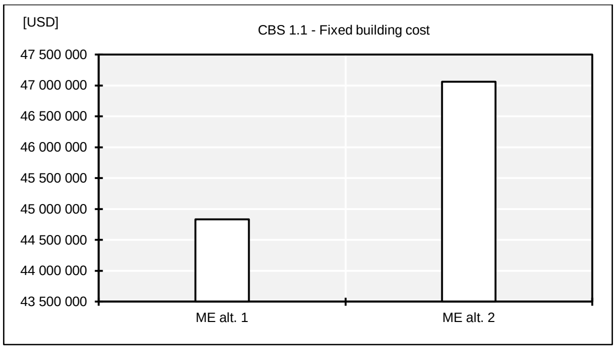


Figure 13-4: Fixed building cost

All fixed building costs for ME alt. 1 and ME alt. 2 are summarized in the pie charts below.

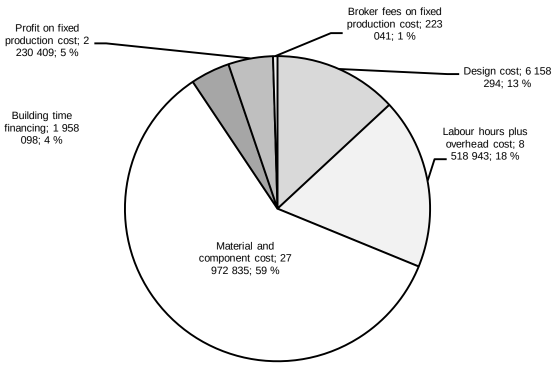


Figure 13-6: Fixed building cost division ME alt.1

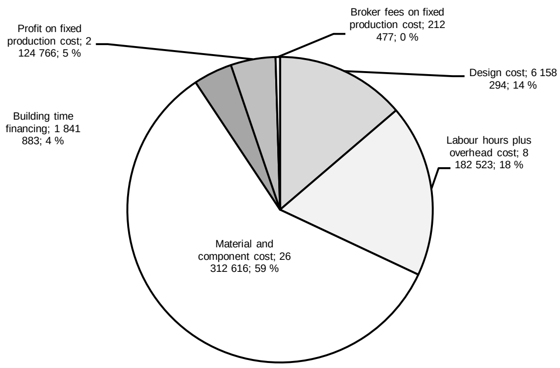


Figure 13-5: Fixed building cost division ME alt.2

13.2 CBS 1.2 - Variable building costs

Several cost items for both ME alternatives are as mentioned directly or indirectly dependent on insulation thickness and material and/or boil-off rate. Those cost items are:

- Cargo tank cost
- Insulation system cost
- Boil off handling system cost
- Aux. generator cost

Due to SOLAS void space requirements, see Ch. 4.1, and the fixed cargo hull volume of basis design, the cargo tank size, and weight, will vary as function of insulation thickness. Since cargo tank cost is dependent on cargo tank weight, cargo tank cost is directly dependent on insulation thickness. Insulation system cost is on the other directly dependent on insulation system thickness and type of insulation material. Several boil-off handling alternatives have been selected, see Ch. 9, and their cost varies with regard to capacity which as mentioned are determined by the boil-off rate. Since boil-off handling requires power, and since the power required for boil-off handling is dependent on the boil-off rate, necessary installed power on board, for electrical power production, is determined by boil-off handling power requirements. That means, number of aux generators and total aux. related building costs, is indirectly dependent on boil-off rate. In the next sections, variable cost interrelationships will be presented.

13.2.1 CBS 1.2.1 Cargo tank cost

WBS 3.1 – Cargo tank

CBS 1.2.1 & CBS 1.2.2– Variable material and component cost & labor hour cost

Total cargo tank capacity will as mentioned vary linearly as function of insulation thickness. Increased thickness will, as described, lead to decreased cargo tank capacity. Based on cargo tank weight statistics from existing LPG and LNG carriers obtained from [37] (i.e., 0.053 ton/m3, see Appendix 9) total cargo tank weight as function of cargo tank capacity and insulation thickness have been estimated. Cargo tank material cost has further been calculated based on current cost of stainless steel in Kina, which is 6.000 RMB per ton stainless steel (as of Feb 2012). The coefficient used in the material cost calculations is 1.000 USD per ton stainless steel, which should be conservative with regard to current exchange rate. Required labor hours for building of the tanks, have after consultations with [75], been set to 30 hours/ton steel. Figure 15-8 shows the material and labor cost for all three cargo tanks, as function of insulation thickness. Figure 15-7 shows the material and labor costs separately as function of the total weight of all three cargo tanks.

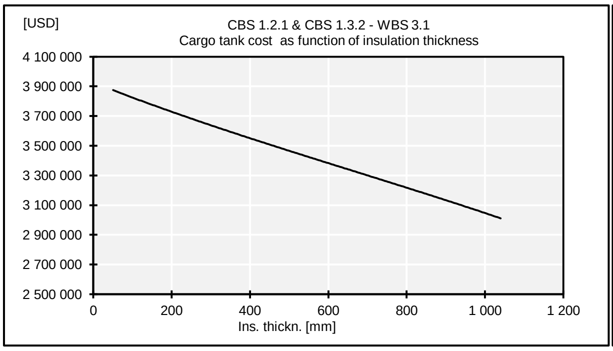


Figure 13-7: Total cargo tank cost

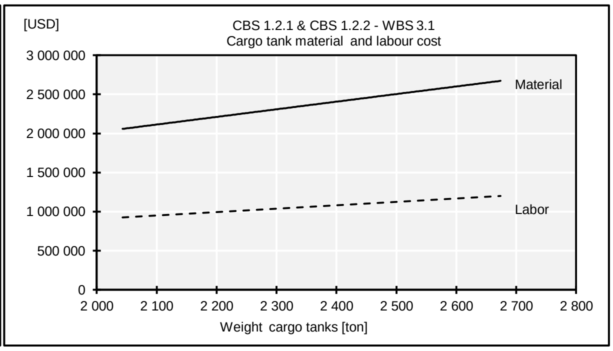


Figure 13-8: Total cargo tank labour & material cost

13.2.2 CBS 1.2 - Insulation system cost

WBS 3.2 – Insulation system

CBS – 1.2.1 Insulation system material cost

Insulation system material cost is based on ballpark numbers recommended from [76]. The costs are given in USD per cubic meter insulation and are summarized in Table 13.1. As can be seen from the table, polyurethane foam and expanded polystyrene panels has the same cost, while polyurethane panel cost is somewhat higher.

Insulation material cost	
Insulation material	[USD/m3]
Polyurethane foam	700
Polyurethane panel	1,000
Expanded polystyrene panel	700
Plywood	1,500

Table 13:1: Insulation material cost

Total insulation system material cost is summarized in Figure 14-2, as function of insulation thickness. The graphs shows that Insulation system 1, 3 and 6, have the lowest, and similar material cost, while Insulation system 4 obviously has the highest material cost.

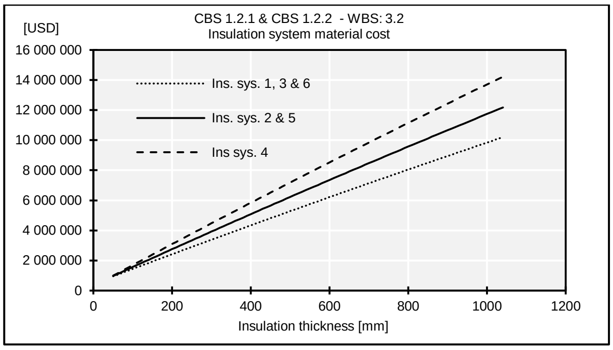


Figure 13-9: Insulation system material cost

CBS 1.2.2 Insulation system labor hour cost

Labor hour cost for each insulation system is based on coefficients given from [76], which defines required man hours per area installed insulation. The coefficients reflect insulation jobs recently performed in Kina and they are listed up in Table 13-2 below:

Insulation material inst. labour hours	
Insulation material	[hours/m2]
Polyurethane foam	3.0
Polyurethane panel	2.0
Expanded polystyrene panel	1.5
Plywood	1.5

Table 13:2: Insulation material required labour hours

Insulation foaming requires somewhat more man-hours per square meter than panel lying, as shown in the table, since foaming has to be performed slowly and carefully. Polyurethane foaming requires experienced workers, and it is according to [76] of major importance that the foaming is performed slowly in order to achieve best possible thermal conductivity. Expanded polystyrene panels, has about half the weight of polyurethane foam and panels, and is in that regard easier to handle during installation, and requires consequently a bit lower installation time. The best insulation installation specialist in the world comes from South Korea, having typically 15 USD/hour in salary, [76] which has been used in labor cost estimation. Figure 13-10 shows the man-hour cost of insulation installation.

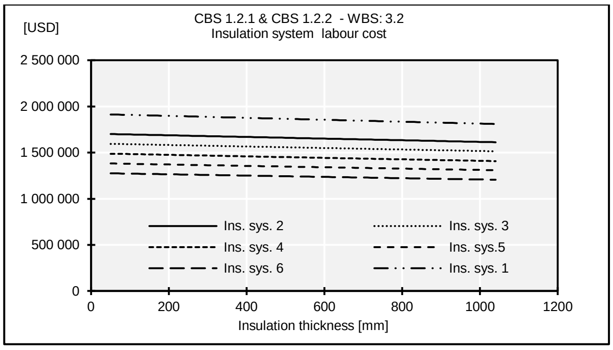


Figure 13-10: Insulation system labour cost

As can be seen from the graphs above, insulation system 1 has the highest labor cost, while insulation system 6 has the lowest, approx. 750 thousand USD cheaper regardless of insulation thickness. It might be confusing that the insulation thickness decreases with increased insulation thickness, but the reason is that total insulation system area is reduced with increasing insulation thickness, as shown from the formulas in Ch. 12.4. It should be mentioned that the author wonders in which the labor cost is trustworthy, since from a practical point of view it is likely that increases insulation thickness requires effort, However, the labor cost profile shown, will be used for now, but is assumed to be changed later on.

13.2.3 CBS 1.2 - Total insulation system cost

Summarizing the material and labor hour cost, total insulation system cost is obtained for all six insulation systems. Administration and design cost have been calculated from the total variable building cost, and will be described later on. As can be seen from the graphs in Figure 13-11, the cheapest insulation system is insulation system 6, consisting of two layers of EPS panels.

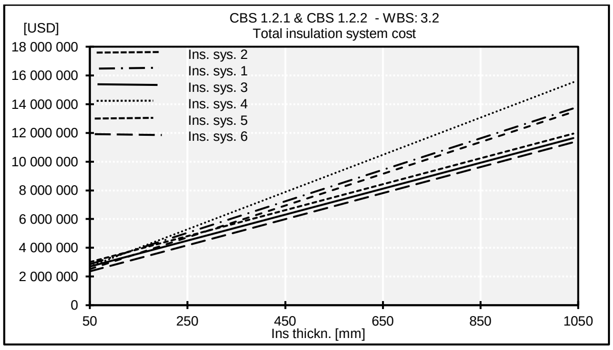


Figure 13-11: Total insulation system cost

13.2.4 Boil of handling system cost

WBS 3.3 – Boil of handling system cost

As previously described, three different boil-off handling alternatives have been selected, see Ch. 9.

Each of the boil-off handling alternatives have different cost profiles, and costs have been estimated based on turnkey cost statistics gathered from previously built ships as well as onshore boil-off handling plants obtained from [36] [1]. Statistics have been used for cost estimation due to boil-off handling system complexity and estimation difficulty that involves. Cost statistics can be found in Appendix 3, and turnkey cost of each boil-off handling system as function of their capacity have been drawn by using regression curve function in Excel. The boil-off handling system cost is directly dependant on the boil-off rate, since the boil-off handling system I required to have a capacity equal the boil-off rate, or more. In this paper, the boil-off handling capacity is set to equal boil-off rate.

Boil of handling system 1
WBS 3.3.1 – Re-liquefaction plant

Several types of LNG boil-off gas re-liquefaction plants exist. The mini LNG plant fitted on Norgas Carriers multi-gas carriers may be designed with capacities in the range of 10-50 tons/day, while Saacke systems may, if necessary, be designed with “unlimited” capacities. Due to difficulty obtaining cost data from Cryostar and Moss systems, re-liquefaction-plant cost as function of boil-off re-liquefaction capacity is drawn based on only three data points, and cost profile should in that regard be treated with caution. The graph in Figure 15-12 illustrates the regression curve drawn from turnkey cost statistics of re-liquefaction plant as function of boil-off gas re-liquefaction capacity.

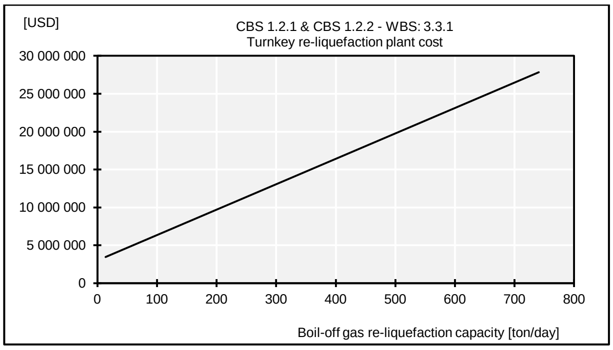


Figure 13-12: Turnkey re-liquefaction plant cost as function capacity

Re-liquefaction plans have normally a specific capacity range, dependent on components included in the plant, meaning that the graph in reality should not have been linear, but rather unsmooth for specific capacity intervals.

Boil of handling system 2
WBS 3.3.2 – Gas supply system
WBS 3.3.2.1 – Gas supply system alt. 1

The main factor determining the required capacity of boil of handling system 2 is the maximum ME gas consumption that may occur during ship-operation. The dimensioning capacity have been set to equal ME gas consumption at service speed during laden/ballast which is 32.5 tons of LNG per day, ref. Appendix 8. The cost of gas supply system 1 is determined by cost statistics gathered from similar systems with various capacities; see Appendix 4.

Since gas combustion is only to be performed in case of emergency the determining factor for minimum insulation thickness has also been the ME consumption for ship configuration 2. During slow laden/ballast, gas consumption is lower than during laden/ballast. This means that some boil-off accumulation will occur, but since MARVS of LNT A-BOX is 0.7barg, that should be no problem for short term slow speed operation.

Boil-off handling system 2, is as indicated in Figure 15-13 independent from boil-off rate, since the required capacity is determined by gas maximum gas consumption.

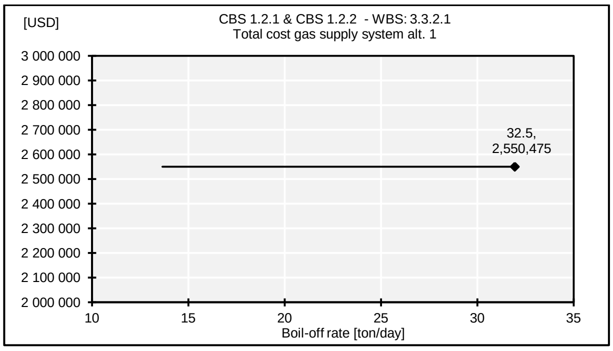


Figure 13-13: Cost boil of handling system 2

Boil of handling system 2

WBS 3.3.2 – Gas supply system

WBS 3.3.2.1 – Gas supply system alt. 2

The total cost of gas supply system alt. 2 is given in Figure 15-15 and includes two cost items as shown in Figure 15-14. The cost profile of the re-liquefaction plant associated with the gas supply system equals the cost of the re-liquefaction for boil-off handling alternative 1. The gas supply system cost compromises LNG fuel pump, and associated systems, as described in Ch 9. and the cost has been determined by statistics gathered from similar systems, see Appendix 4. The capacity if the gas supply system is determined by maximum gas consumption.

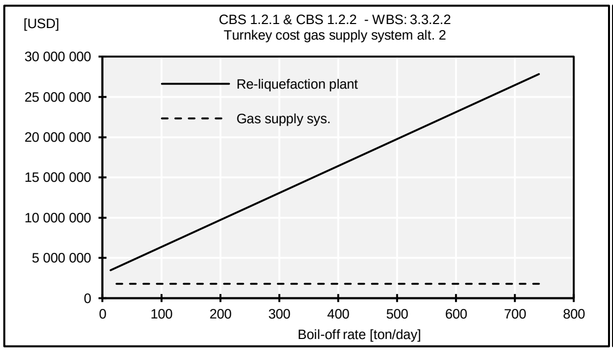


Figure 13-14: Turnkey costs gas supply sys. 2

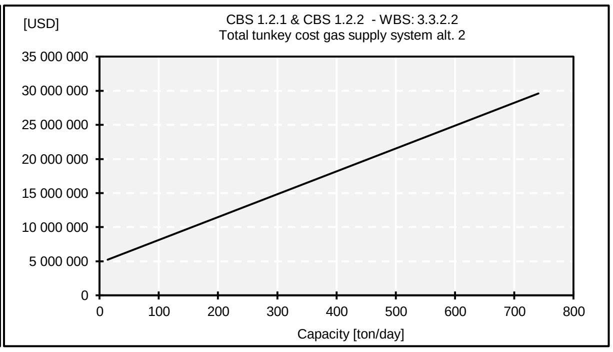


Figure 13-15: Total turnkey cost gas supply sys. 2

13.2.5 AUX generator cost

WBS 6.2 – AUX generator

Aux generator costs have been divided into three cost items i.e., cost of the aux generator (WBS 6.2.1), cost of corresponding systems (WBS 6.2.2), (e.g. systems for cooling, fuel supply, control etc.) and labor hour cost. The cost of aux generator and corresponding systems is estimated from total installed power for each ship configuration, and has been calculated using cost coefficients of 500 and 50 USD per installed kW respectively, which is in accordance with recommendation from [36]. The aux generator costs are directly dependent on the power requirements on board. Since only one type of aux generators is intended to be used onboard, see Ch. 8.6, the number of installed aux generators will naturally vary with regard to required power. The minimum amount of aux generators have been set to be two units, for redundancy purposes. In the next sections, aux generator cost for ship configuration will be presented.

Ship configuration 1

The total aux generator cost for the ship configuration 1 is shown in Figure 13-16. The graph shows that the aux generator cost stays constant for boil-off rates below approx. 80 tons per day, but increase rabidly when the boil-off rate increases, due to additional power requirement. For exact costs for each cost item, see Appendix 9.

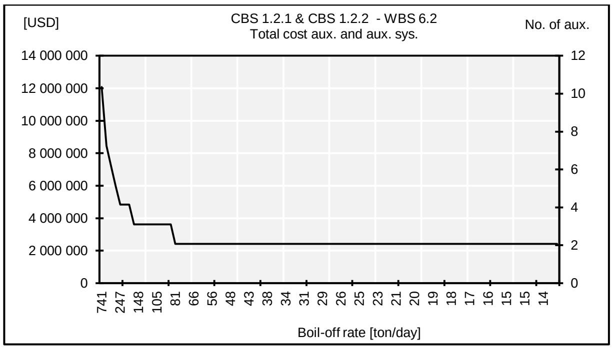


Figure 13-16: Aux generator cost as function of boil of rate ship configuration 1

Figure 13-17 illustrates total aux generator cost as function of insulation thickness for all 6 insulation system alternatives. It can be seen from the graphs that the the insulation systems with the highes total thermal conductivity, see Ch. 6.3, will have the lowest aux generator cost for insulation thicknesses below 200 mm. For insulatiuon thiknesses above 200 mm, only 2 generator sets is required for all insulation systems.

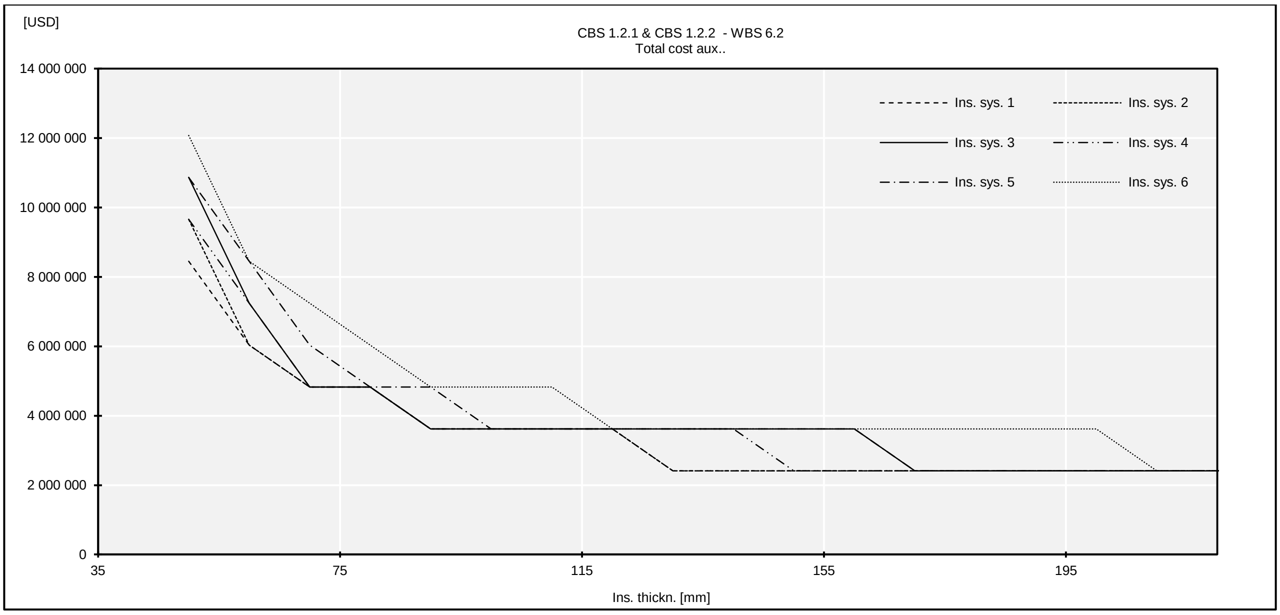


Figure 13-17: Aux generator cost as function of insulation thickness ship configuration 1

Ship configuration 2

The total aux generator cost for ship configuration 2 (i.e., boil-off rate is used as fuel), is given in Figure 13-18. Due to the extensive power requirement for HP gas compressor, 4 aux generators is required at boil-off rates equivalent to ME engine fuel consumption at service speed, meaning that aux cost constitutes a major cost for relatively small boil-off rates.

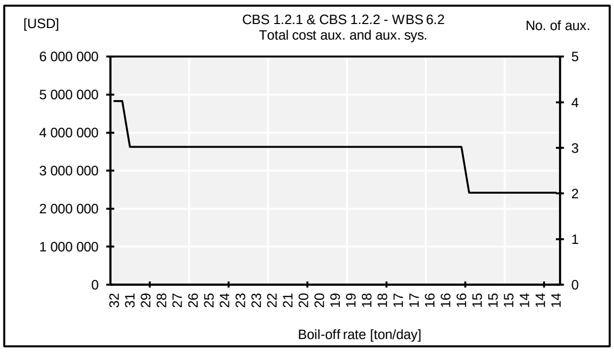


Figure 13-18: Aux generator cost as function of boil of rate ship configuration 2

Figure 13-19 below indicates that insulation thicknesses in the range of 550 - 950 mm are required to reduce the amount of necessary aux generators to two sets. An insulation thickness of 550 mm corresponds to a loss in cargo capacity of 3,000 m3, compared to an insulation thickness of 300 mm, this loss is according to Figure 10-3 equivalent with a loss in V/C-rate of approx. 2000 USD/day, which corresponds to an annual income loss of 685,000 USD.

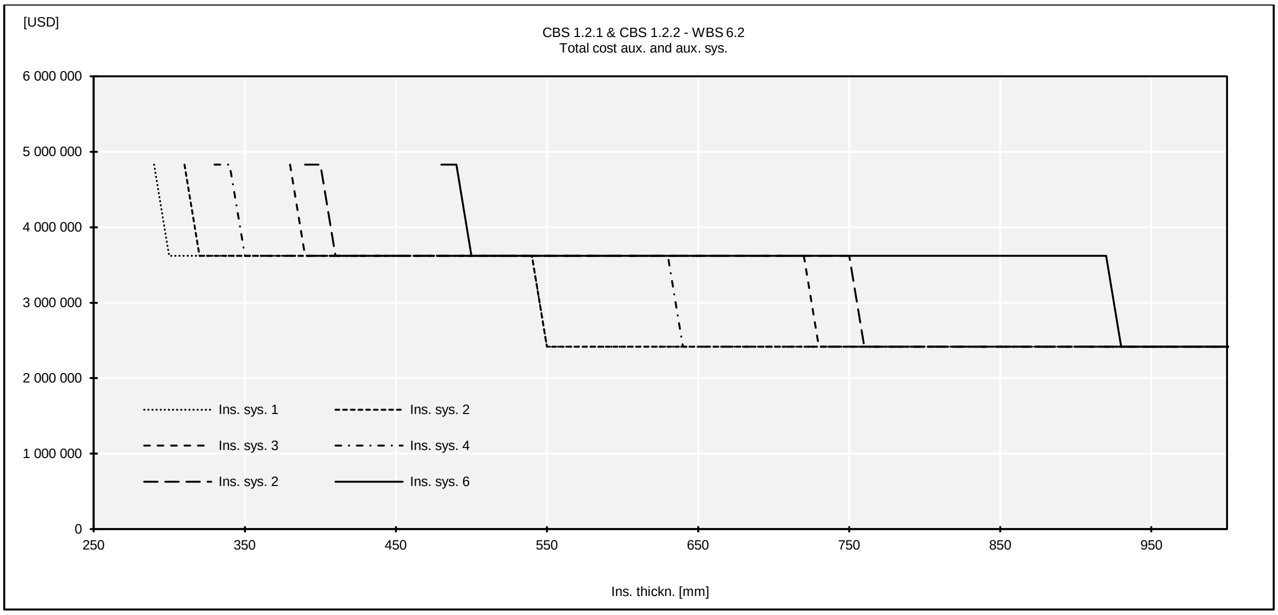


Figure 13-19: Aux generator cost as function of insulation thickness ship configuration 2

Ship configuration 3

The total aux generator cost for the ship configuration 3 is illustrated in Figure 13-20, as function of boil-off rate. The graph shows that 3 aux sets is required with boil off rates higher than about 34 tons/day which is slightly less than for the ship configuration with re-liquefaction plant only. The reason is that the related gas supply system for gas supply system. alt 2 requires additional power for LNG supply.

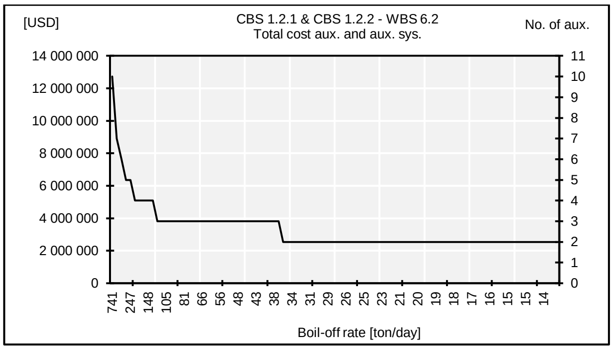


Figure 13-20: Aux generator cost as function of boil of rate ship configuration 3

Figure 13-21 shows as well total aux generator cost as sunction of insulation thickness for all the various insulation systems. As can be seen, the required insulation thickness is a bit right-shifted compared to ship configuration 1 meening that higher insulation thicknesses is required to allow the ship configuration to only have two aux sets installed.

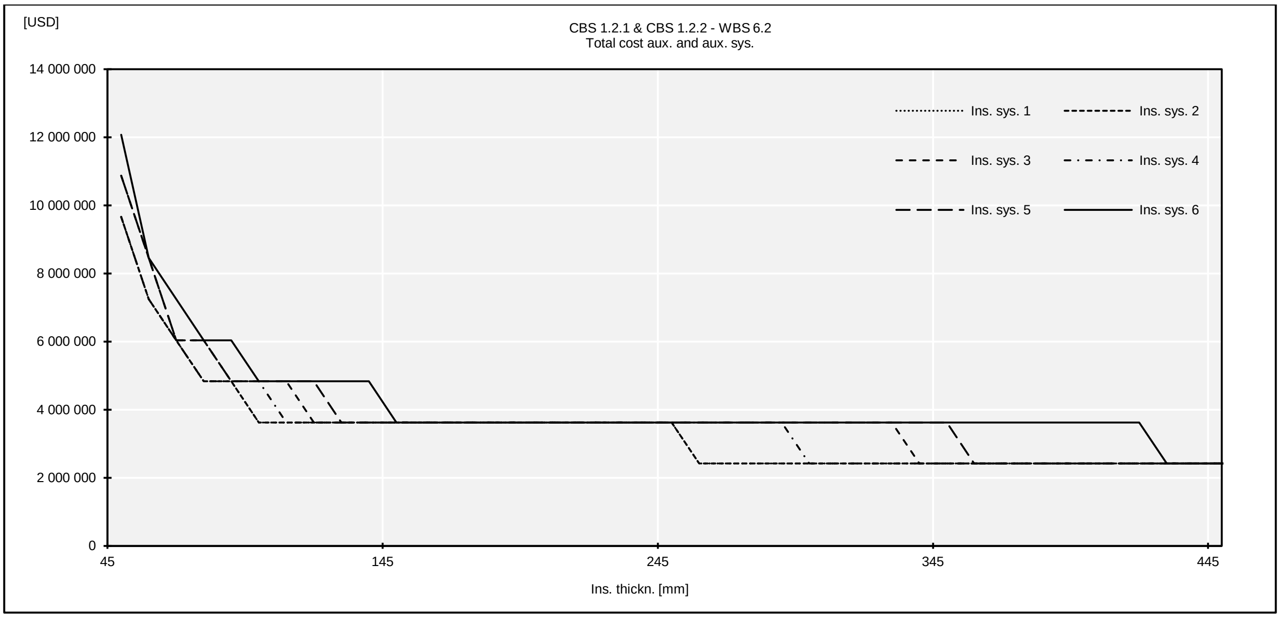


Figure 13-21: Aux generator cost as function of insulation thickness ship configuration 3

13.2.6 AUX generator cost summary

The graph in Figure 13-16 to 13-21 shows that boil-off rates may have an extensivly effect on buiding cost. In order to reduce required aux power the cargo tanks has to be insulated properly in order to reduce boil-off rate.

13.2.7 Gas combustion unit cost

WBS 3.3.3 Gas combustion unit

Cost of gas combustion unit is shown in Figure 13-22 as function of capacity. The cost curve compromise regressing curve, with highest R^2-value drawn based on statistics, see Appendix 3. GCU's has also normally a specific capacity range, dependent on components included in the plant, meaning that the graph in reality should not have been linear, but rather unsmooth for specific capacity intervals.

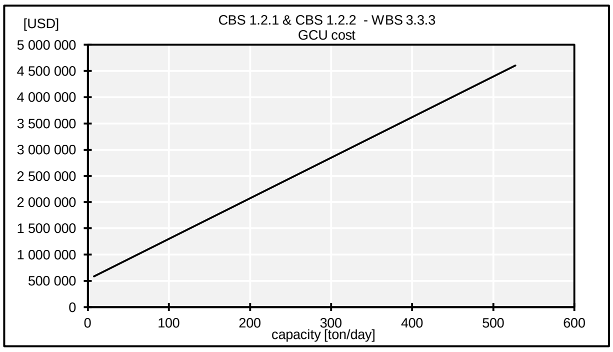


Figure 13-22: Turnkey GCU cost

13.3 Total building cost

All variable production cost have now been given, as function of either boil-off rate or insulation thickness, including material and labor hour cost of all insulation systems, cargo tanks and aux generators as well as turnkey boil-off handling system cost for all ship configurations. In the next sections total building cost will be presented. Administration of ship design and manufacturing are also cost contributors to the total variable building cost. In addition comes building time finance, profit to ship yard and designers, financing payment and broker fees, same as for fixed building cost, and have been calculated as percentage, 8%, 5%, 3% and 1% respectively, of total variable production cost. Total variable building cost includes total variable production cost and variable administration and design cost.

13.3.1 Ship configuration 1

Total variable production for ship 1, is illustrated in Figure 13-23 and Figure 13-24 below, for all insulation system alternatives. The cost profiles for insulation system 1-6 shows that the variable production costs falls drastically for insulation thicknesses in the range of 50-150 mm, i.e., abt. 30mUSD. The graphs curve out slightly with insulation thicknesses in the range of 150-300 mm, with some irregularities at insulation thicknesses below 200, which corresponds to aux generator cost variations as shown in Figure 13-17.

The lowest possible variable production cost is achieved with insulation system 1, but for insulation thicknesses above 500mm, insulation system 6 has the lowest variable building cost, which is understandable by interpreting Figure 13-16 and Table 13:1 & 13:2, in relation to each other.

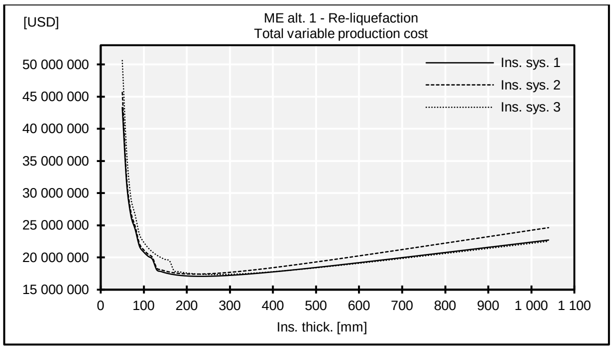


Figure 13-24: Variable prod. cost ship conf. 1 ins. sys. 1-3

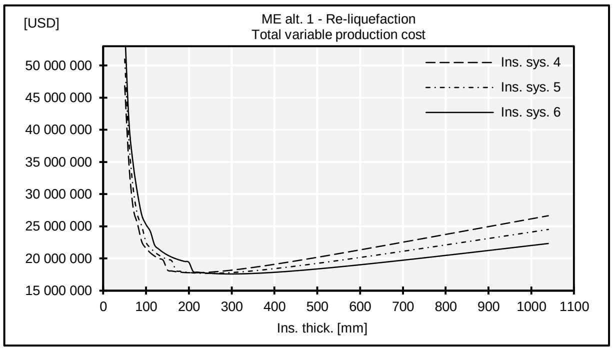


Figure 13-23: Variable prod. cost ship conf. 1 ins. sys. 4-6

Variable administration and design cost (CBS 1.3.2) is as mentioned calculated as percentage of total variable production cost, and is illustrated in Figure 13-26 and Figure 13-25 and has in that regard the same shape as the total variable production cost graphs. Total variable building cost equals the sum of total variable administration cost and total variable production cost.

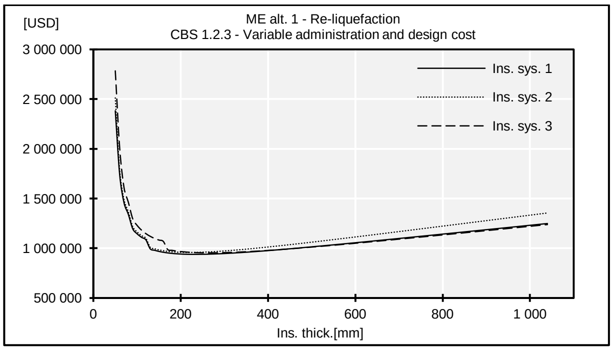


Figure 13-26: Var. admin and design cost ins. sys. 1-3

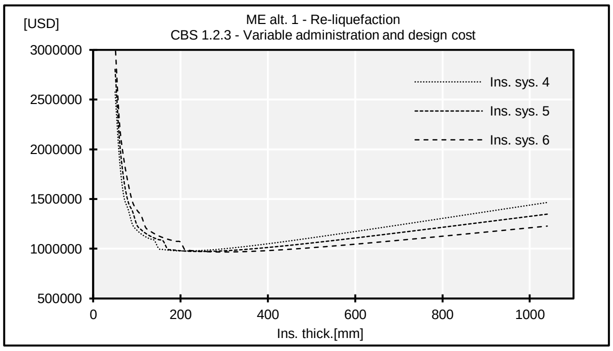


Figure 13-25: Var. admin and design cost ins. sys. 4-6

Total building cost as function of insulation thickness is illustrated in Figure 13-27 and Figure 13-28

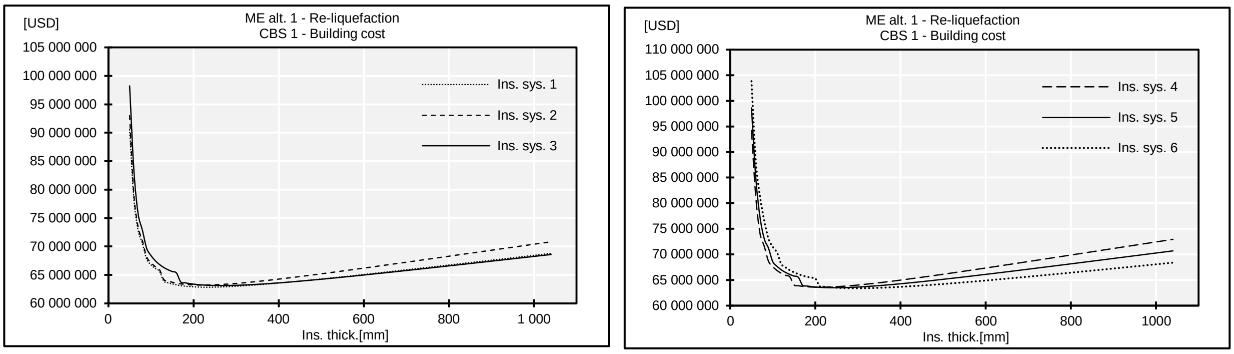


Figure 13-27: Total building cost ship configuration 1

13.3.2 Ship configuration 2

Total variable production cost for ship configuration 3

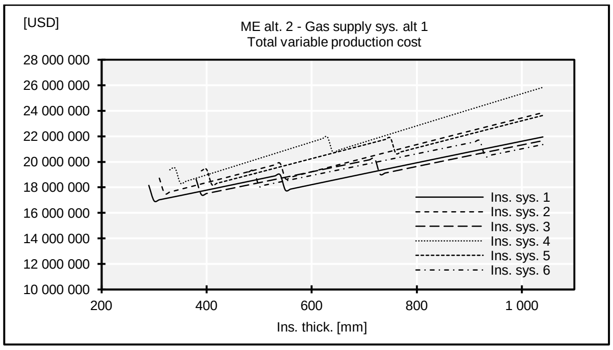


Figure 13-28: Total variable production cost ship configuration 2

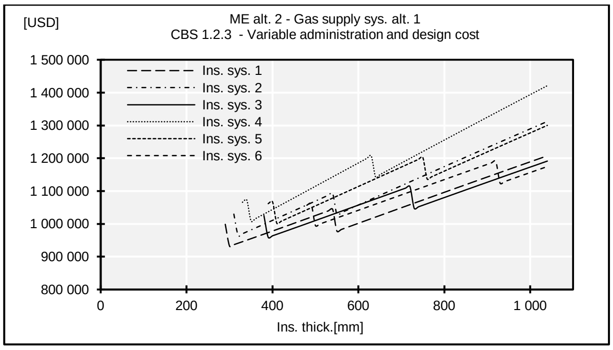


Figure 13-29: Total variable administration cost ship configuration 2

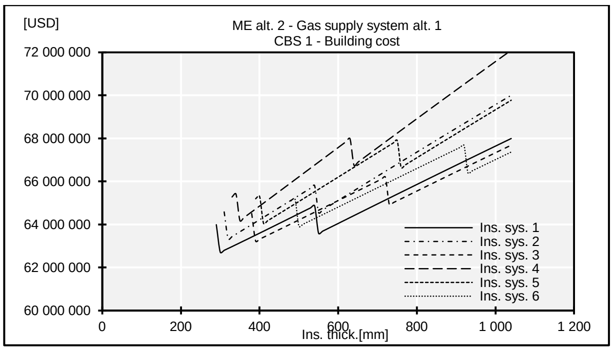


Figure 13-30: Total building cost ship configuration 2

Ship configuration 3 - ME alt. 2 - Gas supply system alt 2

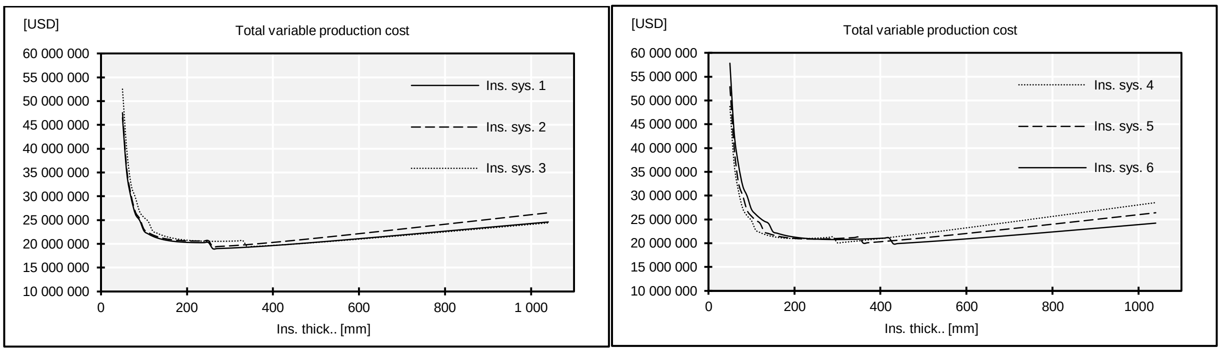


Figure 13-31: Total variable building cost ship configuration 3

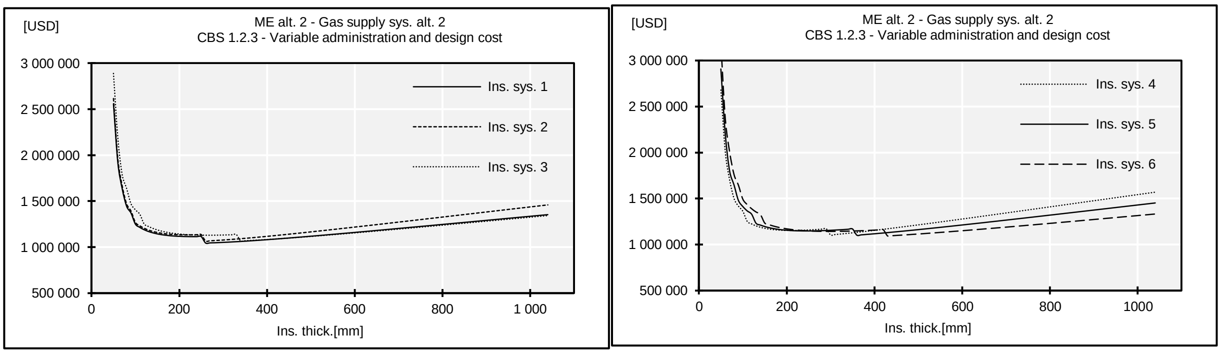


Figure 13-32: Variable administration and design cost ship configuration 3

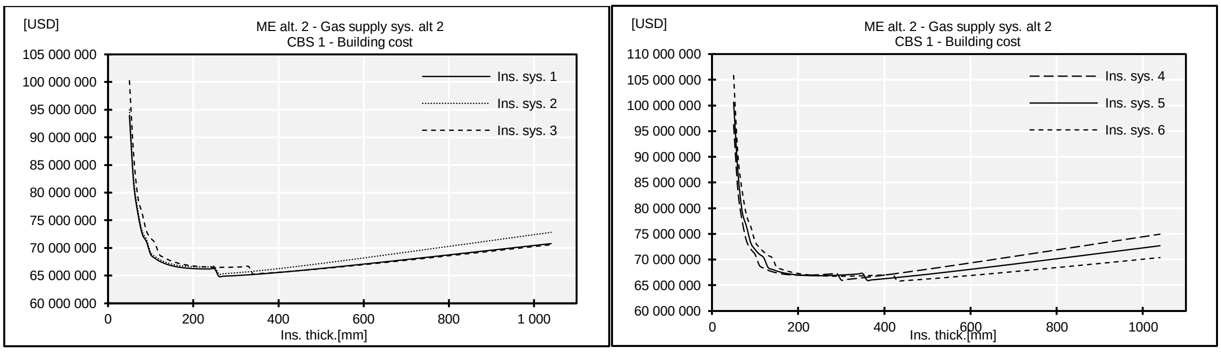


Figure 13-33: Total building cost ship configuration 3

14 Running cost

Prediction of running cost of a vessel on voyage charter with high degree of accuracy several years ahead is nearly impossible. This is mainly due to continuous fluctuations in fuel cost, which is a major running cost item. Also other running cost items can vary substantially with time. In order to evaluate each ship configuration it is however necessary to estimate these cost several years ahead since all configurations are varying with regards to running cost differently. The reason for the different running costs relates to the varying amount of fuel required for ship operation and type of fuel. The running cost is divided into four items as shown in the CBS in in Appendix 13.

14.1.1 CBS 2.1 Operating cost

Operating costs are basically obtained from statistics provided from [67] [36]. Cost coefficients for Manning (CBS 2.1.1) have been chosen according to [67] and are divided into Crew Wages (CBS 2.1.1.1), Victualing (CBS 2.1.1.2) and Travel insurance (CBS 2.1.1.3). Crew wages have been calculated with a coefficient of 27.520 USD/year/crew, victualing with a coefficient of 240 USD/crew/year and Travel insurance with a coefficient of 3400 USD/crew/year. The crew wage cost coefficient is based on crew wages standard for Singaporean registered vessel, while the coefficients for victualing and travel and insurance are according to [36] suggestions.

Coefficient for represents stores (CBS 2.1.2) is assumed to be 10 USD per installed SMCR of ME. Routine repair and maintenance (CBS 2.1.3) is divided into Maintenance (CBS 2.1.3.1) and Spare (CBS 2.1.3.2), where CBS 2.1.3.1 represents maintenance cost of the ship and machinery and CBS 2.1.3.2 represents cost of required spare parts to be available on board. CBS 2.1.3.1 have been assumed to be 7 USD per SMCR of ME per year, and the same coefficient has been used for CBS 2.1.3.2. Insurance cost (WBS 2.1.4) has been divided into insurance cost of Hull and Machinery (CBS 2.1.4.1) and P&I (CBS 2.1.4.2). The insurance cost items have been set to 500,000 USD/year each in accordance with [36] recommendations. The last cost item in CBS 2.1 is General cost (CBS 2.1.5) which is divided into Flag state registration cost (CBS 2.1.5.1), Port fees (CBS 2.1.5.2) and Management fee (CBS 2.1.5.3). CBS 2.1.5.1 is estimated by a coefficient of 0.3 USD/GT/year according to [67] ,CBS 2.1.5.2 by a coefficient of 3.7 USD/GT/year and CBS 2.1.5.3 has been assumed to be 200.000 USD/year for both ME alternatives.

Notice that CBS 2.1 has been assumed to be independent of ME alternative and cargo capacity. Running cost calculations can be found in Appendix 10 and total operating cost has been estimated to be just below 2.25mUSD/year for all ship configurations.

14.1.2 CBS 2.2 Periodic maintenance cost

Periodic maintenance cost is divided into maintenance cost of Machinery (CBS 2.2.1) and maintenance cost of Hull (CBS 2.2.2). CBS 2.2.1 has been calculated with a coefficient of 11 USD per SMCR of ME per 5th year, which is a coefficient, derived from cost data on a 10,000m3 LNG carrier. CBS 2.2.2 is calculated with a coefficient of 13 USD/GT per 5th year. Total annual maintenance cost is estimated to be 1.3mUSD/year for all ship configurations.

14.1.3 CBS 2.3 Voyage cost

CBS 2.3.1 Fixed voyage cost

Fixed voyage cost is divided into Pilotage cost (CBS 2.3.1.1), ME fuel cost (CBS 2.3.1.2) and Fixed aux generator fuel cost (CBS 2.3.1.3). CBS 2.3.1.1 has been estimated by a coefficient of 10.000 USD/roundtrips/year which is a coefficient suggested by [36]. ME fuel cost is further divided into HFO cost, LO cost and LNG cost. Fixed aux generator fuel cost is divided into MDO and LO cost and compromises aux fuel cost in harbor. As mentioned, cost of the various types of fuel is continuously varying, and the price is also to some extent dependent on where the fuel is bought. However, prices of HFO, MDO and LO have been obtained from www.bunkerworld.com as of Feb. 2012. Fixed voyage cost for both ME alternatives is illustrated in Figure 1-1 below.

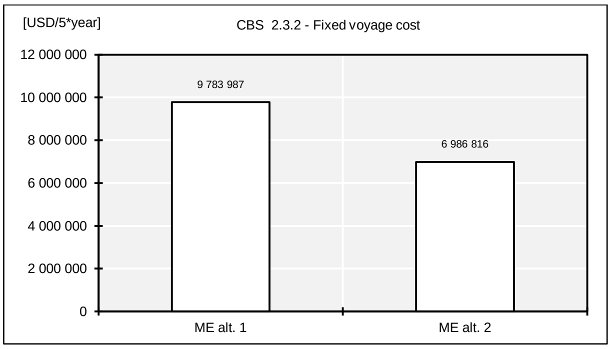
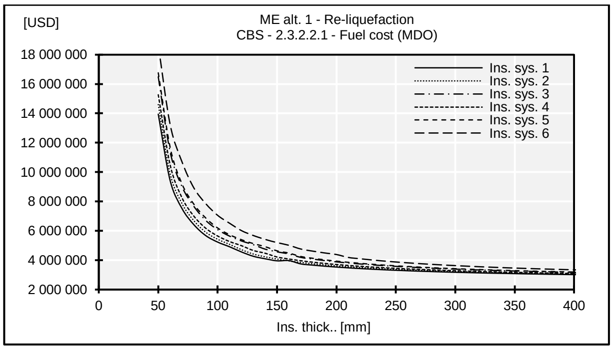


Figure 14-1: Fixed voyage cost

CBS 2.3.2 Variable voyage cost

Ship configuration 1



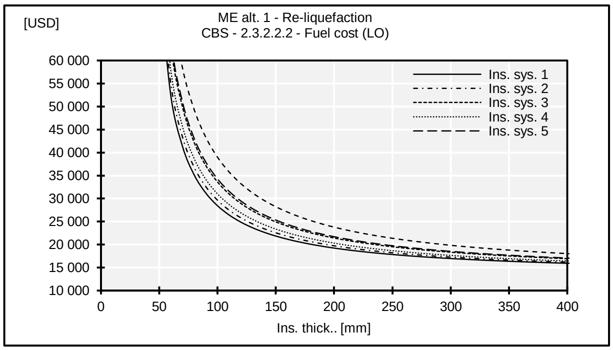


Figure 14-2: Variable voyage cost ship configuration 1

Ship configuration 2

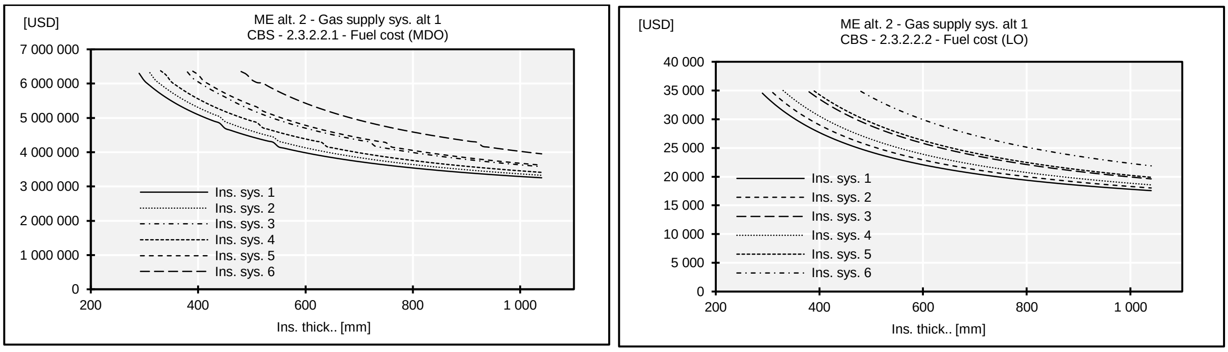


Figure 14-3: Variable voyage cost ship configuration 2

Ship configuration 3

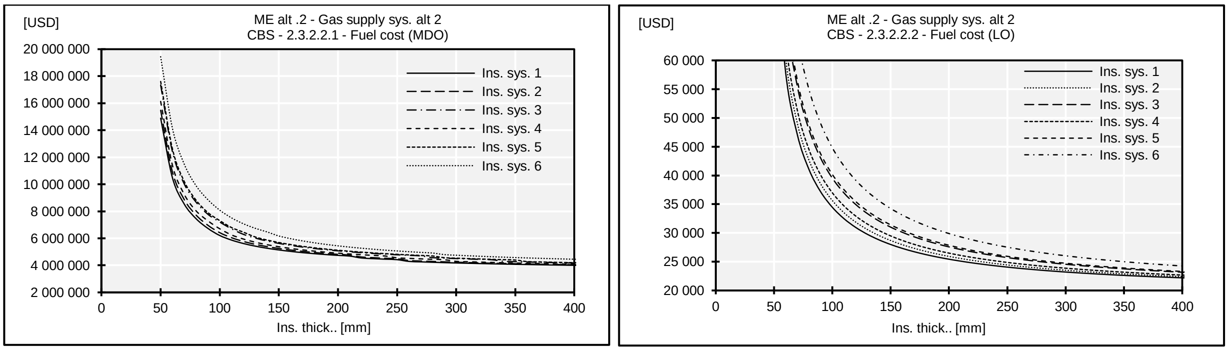


Figure 14-4: Variable voyage cost ship configuration 3

15 Economic assessment

In this chapter an economic assessment of the various ship configurations will be performed. For insulation thickness optimisation the illustrated direct search approach in Figure 15-1 have been used.

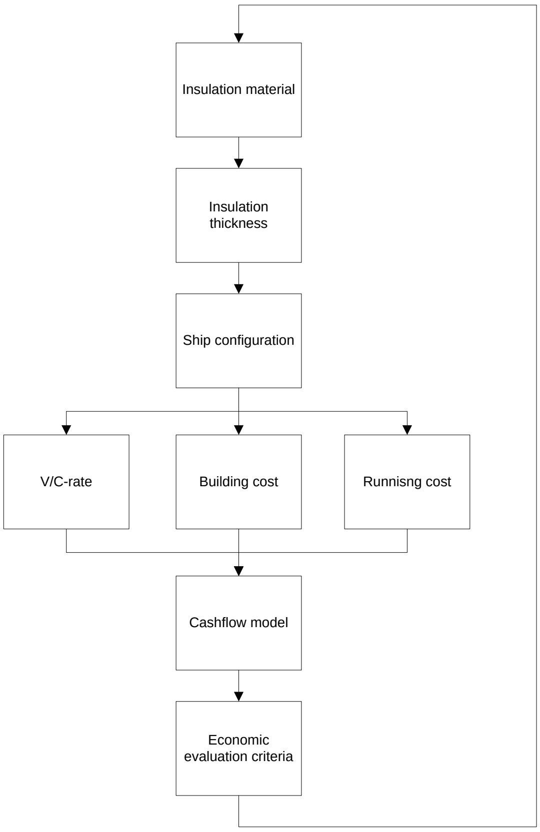


Figure 15-1: Direct search approach for

Presented V/C – rate,- building cost- and running cost- graphs as function of insulation thickness have been used as basis in optimal insulation thickness determination. The cashflow model in Appendix 11 has been used, and hundreds of cashflow replications have been performed, for each ship configuration, in order to identify ship profitability as function of insulation thickness. NPV have been used as economic evaluation criteria. The output from cashflow replications, are NPV graphs, for all insulation systems, as function of insulation thickness.

15.1 Results

15.1.1 Ship configuration 1

Curves for ship profitability for all insulation systems as function insulation thickness is given in Figure 15-2. The extremal values are furthermore illustrated in Figure 14-3.

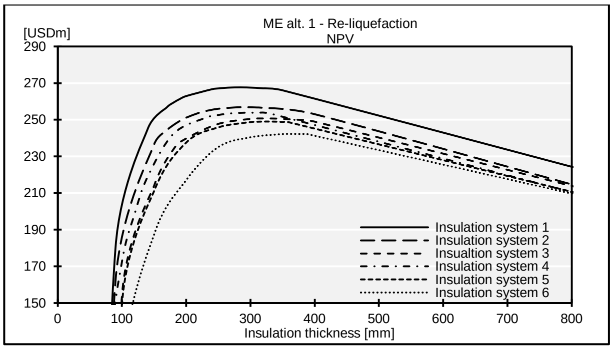


Figure 15-2: NPV as function of insulation thickness ship configuration 1

As can be seen form the graphs above, insulation system 1 offers the highest NPV of all the insulation systems.

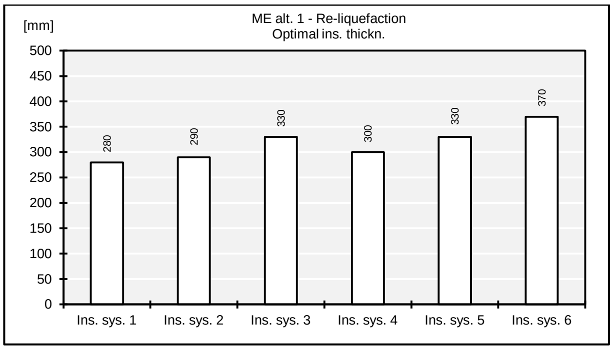


Figure 15-3: Optimal insulation thickness ship configuration 1

From the figures above it is evident that optimal insulation thickness varies slightly with regard to insulation system. Optimal insulation thickness of insulation system 1 is slightly lower than insulation system 2 and 3, while optimal insulation thickness for insulation system 3 and 5 is equal. Optimal insulation for insulation system 6 is significant higher than for the other ones.

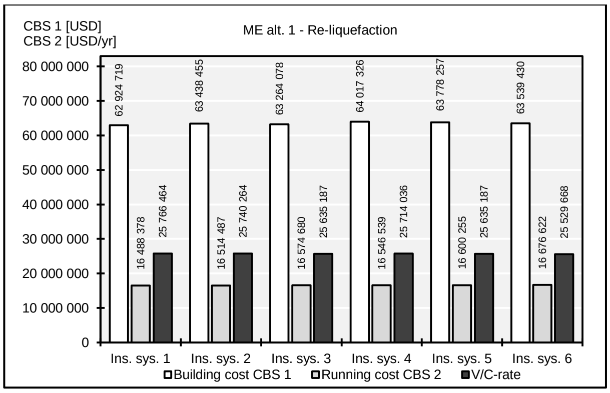


Figure 15-4: V/C – rate, building cost, & running cost ship configuration 1

Building cost, running cost and V/C-rate in correspondence with optimal insulation thickness is illustrated in Figure 15-4, above. As seen, insulation thickness 1 has the lowest building cost followed by Insulation system 2 and 3. It is however interesting to see that insulation system 6 is slightly lower than insulation system 4 and 5. But due to the large insulation thickness, insulation system 6 results definitely in the lowest V/C rate. The differences in running cost are as seen minor.

The energy efficiency at optimal insulation thickness is given in Figure 15-5 below. The EEDI is calculated based on the EEDI formulae in Ch. 4.11. Fuel factor for both ME and aux engines have set to 3.17, which is in accordance with IMO's recommendation. Calculation of EEDI is attached in Appendix 12.

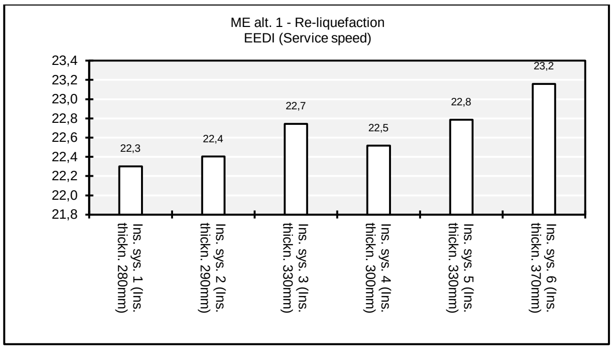


Figure 15-5: Optimal energy efficiency ship configuration 1

As seen from the bar graphs above, a configuration with insulation thickness 1 offers the best EEDI of all the insulation systems. The reason for this is the low optimal insulation thickness compared to the other insulation systems, resulting in the highest cargo capacity. The differences in fuel consumption between the insulation systems at optimal insulation thickness are very small, see Appendix 12, and have therefor a very small effect on EEDI.

15.1.2 Ship configuration 2

Figure 15-6 illustrates curves for ship profitability for all insulation systems as function insulation thickness for ship configuration 2. An interesting, but expected, observation is that the extremal values are reached at much higher insulation thicknesses than for ship configuration 2, due to the high power consumption of the boil-off handling system. The unsmooth parts of the graphs are caused by shift in required number of aux as shown in Figure 13-19.

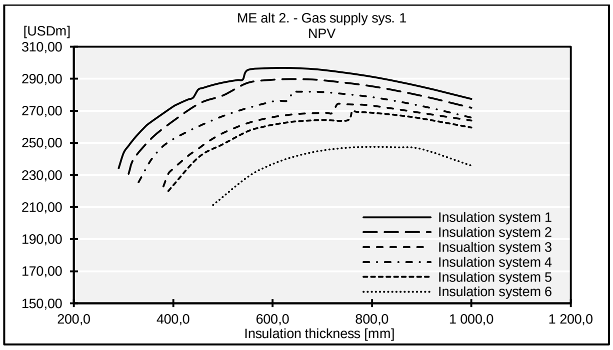


Figure 15-6: NPV as function of insulation thickness ship configuration 2

The optimal insulation thickness for each insulation system is presented in Figure 15-7. As seen, optimal insulation thickness 3 and 5 differs significantly in contrast the insulation thickness 3 and 5 in figure 16-3.

The reason for this is that the requirement for 3 aux generators for power generators occurs at insulation thicknesses slightly below 800 mm.

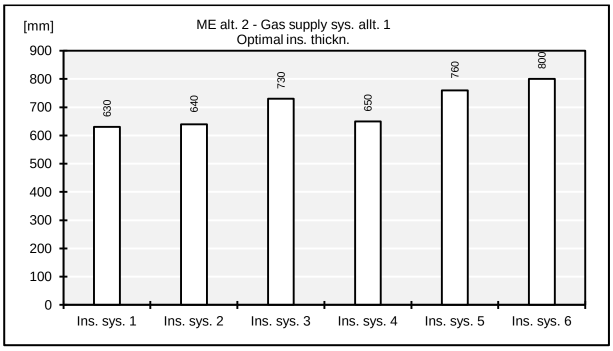


Figure 15-7: Optimal insulation thickness ship configuration 2

Figure 15-9 below illustrates V/C – rate, building cost and running cost for ship configuration 2 of all insulation materials. The large building cost difference between insulation thickness 6 and the other ones is the requirement of one additional aux generator, as can be seen from Figure 13-19 in Ch. 13

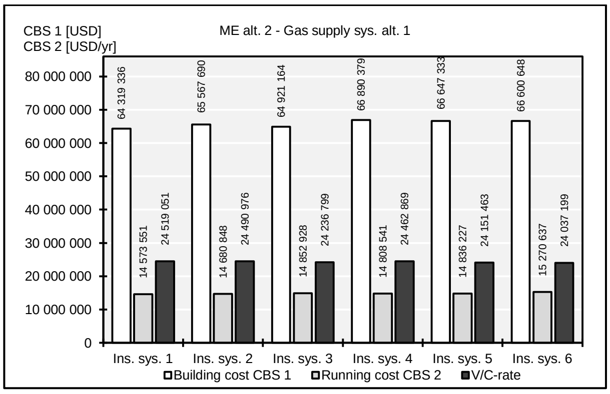


Figure 15-8: V/C – rate, building cost, & running cost ship configuration 2

In the figure below, the best EEDI for all insulation systems are given. As shown, insulation thickness 1 results in a much higher EEDI than the other ones due to the above. Fuel factor for CO_2 emissions have been set to 3.17 for HFO and MDO consumption, and 30% lower for LNG consumption, since LNG combustion results in 30% less CO_2 emissions compared to HFO and MDO consumption, [77].

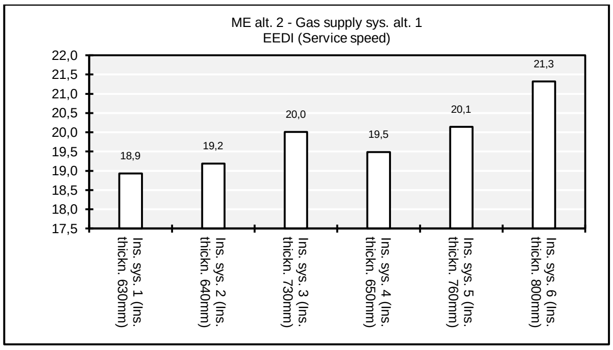


Figure 15-9: Optimal energy efficiency ship configuration 2

15.1.3 Ship configuration 3

Figure 15-11 illustrates curves for ship profitability for all insulation systems as function insulation thickness for ship configuration 3. The unsmooth parts of the curves at insulation thickness in the range of 250-350 mm can be related to Figure 13-21. Insulation system 1 offers not surprisingly the highest NPV also here, slightly followed by insulation system 2.

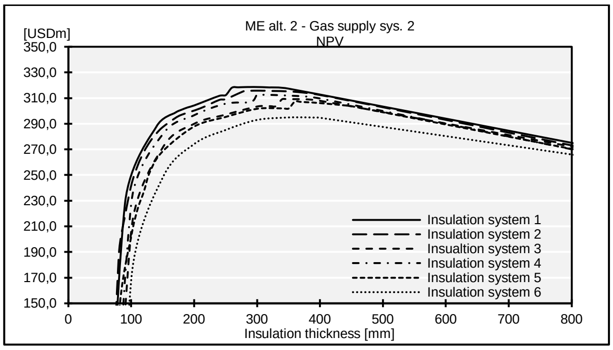


Figure 15-10: NPV as function of insulation thickness ship configuration 3

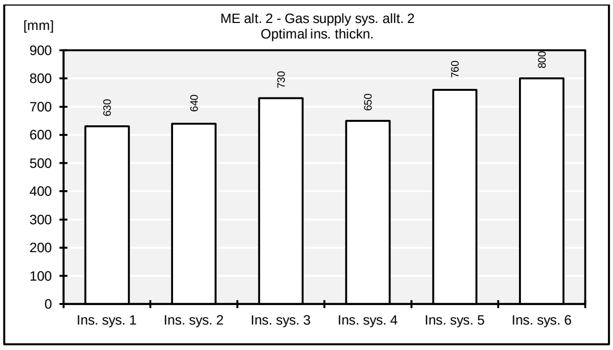


Figure 15-11: Optimal ship configuration insulation thickness 3

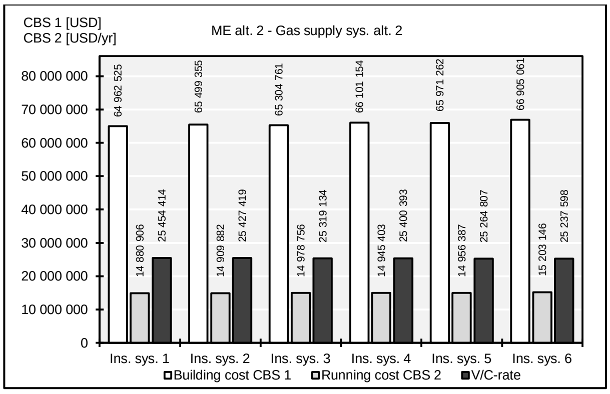


Figure 15-12: V/C – rate, building cost, & running cost ship configuration 3

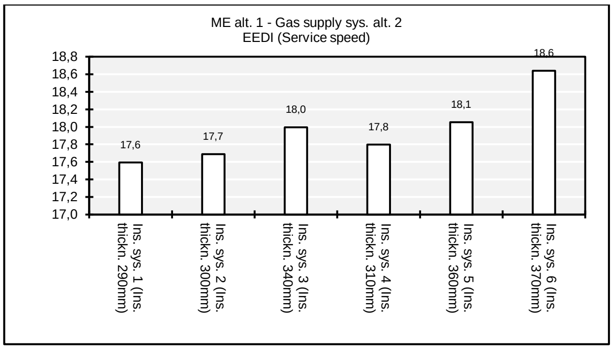
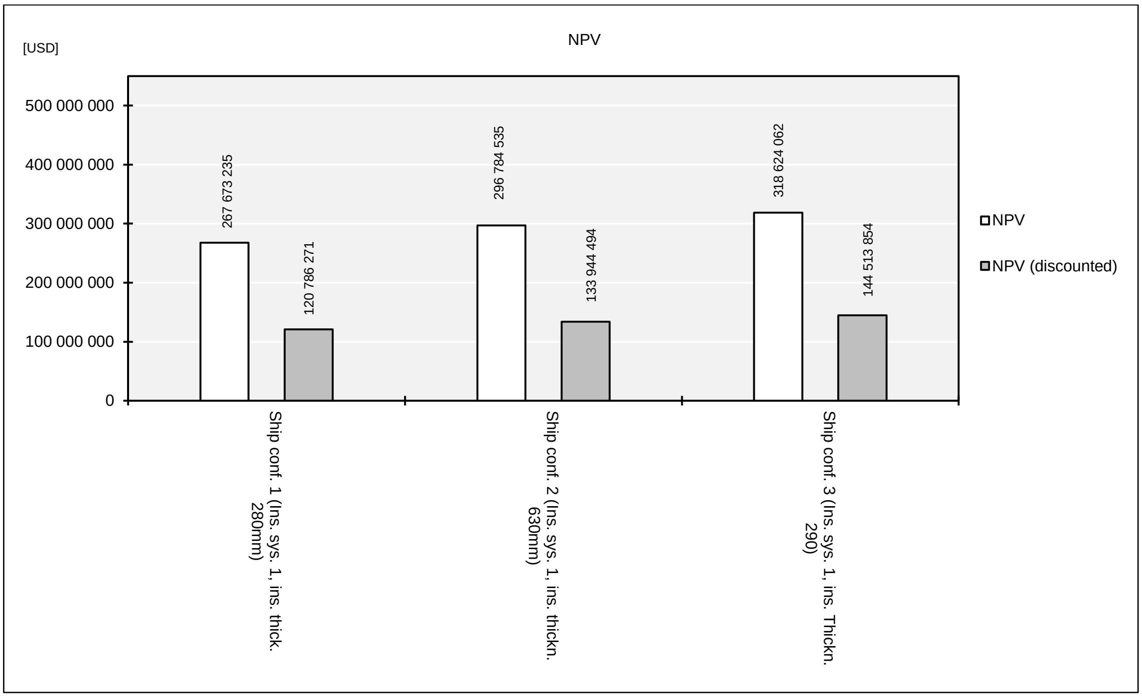
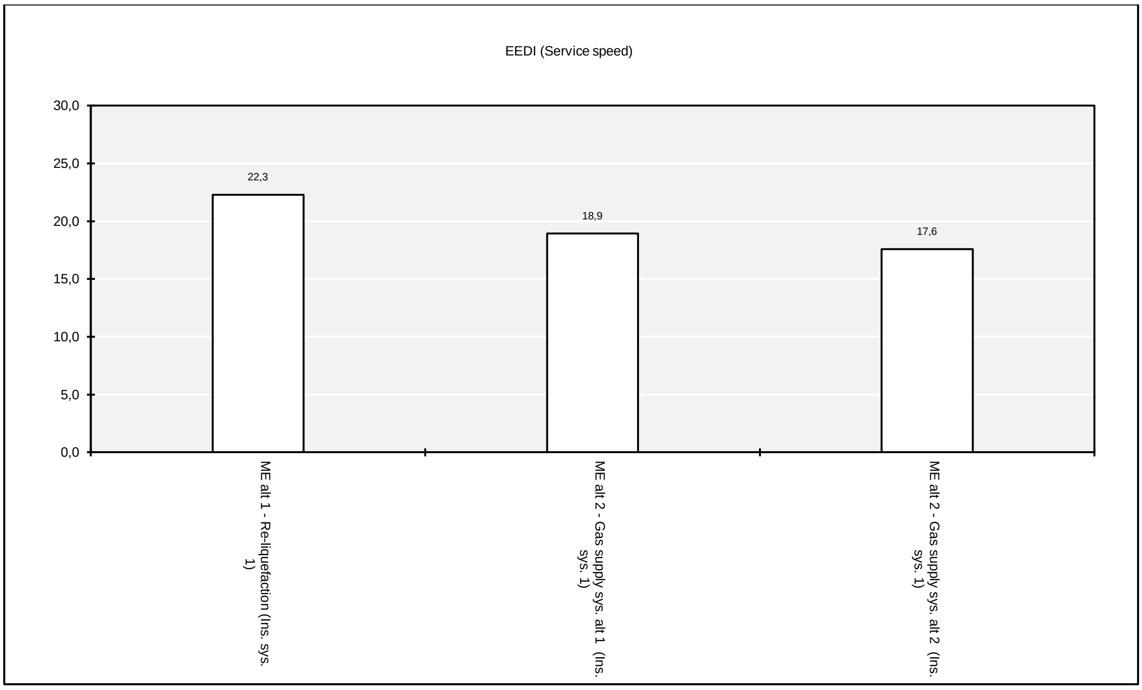


Figure 15-13: Optimal energy efficiency ship configuration 3

16 Conclusion

The economic assessment has indicated that ship configuration 3 is the most economically preferable choice for the LNG carrier on the given trade. The main constraint in the analysis is the fixed fuel prize used for each main engine alternatives. In that regards, a sensitivity analysis, with variable fuel prizes, should ideally have been performed, in order to identify how much fuel prize affect ship profitability. The figures below summarize the most important findings.





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Appendix

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Appendix 1

Mission

Mission			
Route: Port Moresby (Papua New Guinea) - Singapore			
Voyage charter (paid per m3 delivered LNG)			
Required freight work	abt.	1,000,000	[m3/yr]

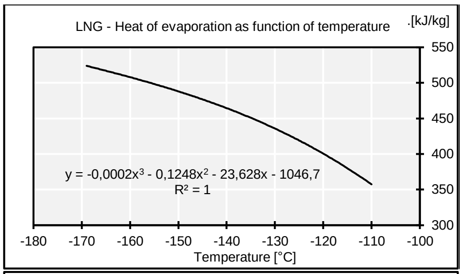
Operational assumption

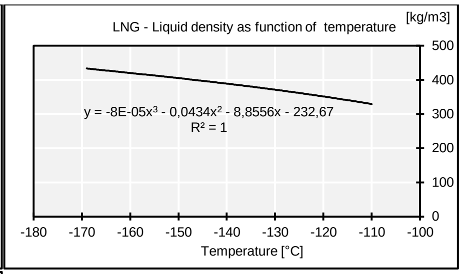
Operational assumption		
Transit distance	2,700	[nm]
Manoeuvring distance	40	[nm]
Speed laden/ballast	15	[kn]
Speed slow laden/ballast	11	[kn]
Loading/discharge time (incl. mooring)	20	[h]
Roundtrips per year	21.5	[-]

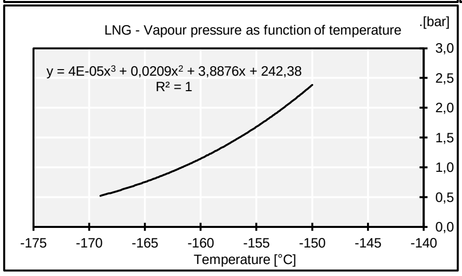
Appendix 2

LNG – Saturated properties

Temp.		Pressure		Specific volume		Enthalpy			Entropy		Density	
T [°C]	T [K]	P[Bar]	P[kPa]	v l [dm 3 /kg]	v g [m 3 /kg]	h l[kJ/kg]	h g[kJ/kg]	hlg[kJ/kg]	s l[kJ/(kg K]	s g [kJ/(kg K)]	ρl[kg/m3]	ρg[kg/m3]
-169	104	0.5	0.5	2.3	1.0	134	657	523	0.4	5.4	433	1.0
-168	105	0.6	0.6	2.3	0.9	137	659	522	0.5	5.4	432	1.1
-167	106	0.6	0.6	2.3	0.9	140	661	520	0.5	5.4	430	1.2
-166	107	0.7	0.7	2.3	0.8	144	662	519	0.5	5.4	429	1.3
-165	108	0.8	0.8	2.3	0.7	147	664	517	0.5	5.3	428	1.4
-164	109	0.8	0.8	2.3	0.7	151	666	515	0.6	5.3	426	1.5
-163	110	0.9	0.9	2.4	0.6	154	668	513	0.6	5.3	425	1.6
-162	111	1.0	1.0	2.4	0.6	158	669	512	0.6	5.2	423	1.8
-161	112	1.1	1.1	2.4	0.5	161	671	510	0.7	5.2	422	1.9
-160	113	1.15	1.2	2.4	0.5	165	673	508	0.7	5.2	420	2.0
-159	114	1.2	1.3	2.4	0.5	168	674	506	0.7	5.2	419	2.2
-158	115	1.3	1.4	2.4	0.4	172	676	504	0.8	5.1	417	2.3
-157	116	1.4	1.5	2.4	0.4	175	677	502	0.8	5.1	416	2.5
-156	117	1.6	1.6	2.4	0.4	179	679	500	0.8	5.1	414	2.7
-155	118	1.680	1.7	2.4	0.3	182	681	498	0.9	5.1	413	2.9
-154	119	1.8	1.8	2.4	0.3	186	682	496	0.9	5.0	411	3.1
-153	120	1.9	2.0	2.4	0.3	189	684	494	0.9	5.0	410	3.3
-152	121	2.1	2.1	2.4	0.3	193	685	492	0.9	5.0	408	3.5
-151	122	2.2	2.3	2.5	0.3	196	687	490	1.0	5.0	407	3.8
-150	123	2.4	2.4	2.5	0.3	200	688	488	1.0	5.0	405	4.0
-149	124	2.5	2.6	2.5	0.2	204	689	486	1.0	4.9	404	4.2
-148	125	2.7	2.8	2.5	0.2	207	691	484	1.1	4.9	402	4.5
-147	126	2.9	2.9	2.5	0.2	211	692	481	1.1	4.9	401	4.8
-146	127	3.1	3.1	2.5	0.2	215	694	479	1.1	4.9	399	5.1
-145	128	3.3	3.3	2.5	0.2	218	695	477	1.1	4.9	397	5.4
-144	129	3.5	3.5	2.5	0.2	222	696	474	1.2	4.8	396	5.7
-143	130	3.7	3.8	2.5	0.2	226	697	472	1.2	4.8	394	6.0
-142	131	3.9	4.0	2.5	0.2	229	699	469	1.2	4.8	392	6.4
-141	132	4.2	4.2	2.6	0.1	233	700	467	1.3	4.8	391	6.7
-140	133	4.4	4.5	2.6	0.1	237	701	464	1.3	4.8	389	7.1
-139	134	4.7	4.7	2.6	0.1	240	702	462	1.3	4.8	387	7.5
-138	135	5.0	5.0	2.6	0.1	244	703	459	1.3	4.7	386	7.9
-137	136	5.2	5.3	2.6	0.1	248	704	456	1.4	4.7	384	8.4
-136	137	5.5	5.6	2.6	0.1	252	705	453	1.4	4.7	382	8.8
-135	138	5.8	5.9	2.6	0.1	256	706	451	1.4	4.7	380	9.3
-134	139	6.1	6.2	2.6	0.1	259	707	448	1.4	4.7	379	9.7
-133	140	6.5	6.6	2.7	0.1	263	708	445	1.5	4.6	377	10.2
-132	141	6.8	6.9	2.7	0.1	267	709	442	1.5	4.6	375	10.8
-131	142	7.2	7.3	2.7	0.1	271	710	439	1.5	4.6	373	11.3
-130	143	7.5	7.6	2.7	0.1	275	711	436	1.6	4.6	371	11.9
-129	144	7.9	8.0	2.7	0.1	279	711	432	1.6	4.6	370	12.4
-128	145	8.3	8.4	2.7	0.1	283	712	429	1.6	4.6	368	13.0
-127	146	8.7	8.8	2.7	0.1	287	713	426	1.6	4.5	366	13.7
-126	147	9.1	9.3	2.7	0.1	291	713	423	1.7	4.5	364	14.3
-125	148	9.6	9.7	2.8	0.1	295	714	419	1.7	4.5	362	15.0
-124	149	10.0	10.2	2.8	0.1	299	714	416	1.7	4.5	360	15.7
-123	150	10.5	10.6	2.8	0.1	303	715	412	1.7	4.5	358	16.5
-122	151	11.0	11.1	2.8	0.1	307	715	408	1.8	4.5	356	17.2
-121	152	11.5	11.6	2.8	0.1	311	716	405	1.8	4.5	354	18.0
-120	153	12.0	12.1	2.8	0.1	315	716	401	1.8	4.4	352	18.8
-119	154	12.5	12.7	2.9	0.1	319	716	397	1.8	4.4	350	19.7
-118	155	13.0	13.2	2.9	0.0	324	716	393	1.9	4.4	347	20.6
-117	156	13.6	13.8	2.9	0.0	328	717	389	1.9	4.4	345	21.5
-116	157	14.2	14.4	2.9	0.0	332	717	384	1.9	4.4	343	22.5
-115	158	14.8	15.0	2.9	0.0	337	717	380	1.9	4.4	341	23.5
-114	159	15.4	15.6	3.0	0.0	341	717	376	2.0	4.3	339	24.5
-113	160	16.0	16.2	3.0	0.0	345	717	371	2.0	4.3	336	25.6
-112	161	16.7	16.9	3.0	0.0	350	716	367	2.0	4.3	334	26.7
-111	162	17.4	17.6	3.0	0.0	354	716	362	2.1	4.3	331	27.9
-110	163	18.0	18.3	3.0	0.0	359	716	357	2.1	4.3	329	29.1


LNG - Heat of evaporation as function of temperature
.[kJ/kg]
550
500
450
400
350
300
y = -0,0002x³ - 0,1248x² - 23,628x - 1046,7
R² = 1
-180 -170 -160 -150 -140 -130 -120 -110 -100
Temperature [°C]

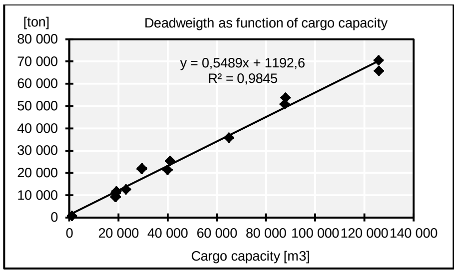

LNG - Liquid density as function of temperature
[kg/m3]
500
400
300
200
100
0
y = -8E-05x³ - 0,0434x² - 8,8556x - 232,67
R² = 1
-180 -170 -160 -150 -140 -130 -120 -110 -100
Temperature [°C]

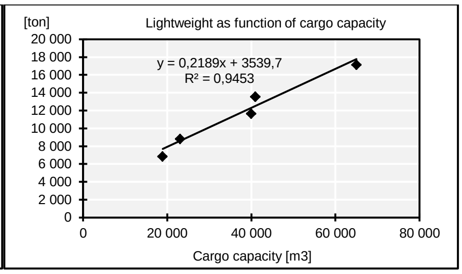

LNG - Vapour pressure as function of temperature
.[bar]
3,0
2,5
2,0
1,5
1,0
0,5
0,0
y = 4E-05x³ + 0,0209x² + 3,8876x + 242,38
R² = 1
-175 -170 -165 -160 -155 -150 -145 -140
Temperature [°C]

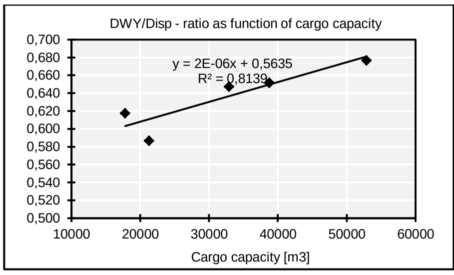
Appendix 3

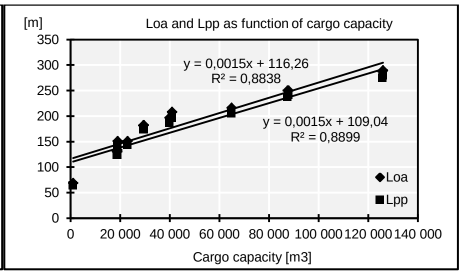
Ship statistics

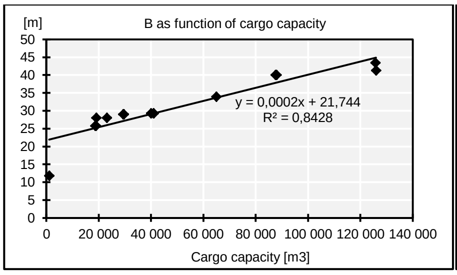
Name	Ship data													Coefficients						
LNG carrier	Cap.	DWT	LWT	Disp	GT	GV	Loa	Lpp	B	D	T	P	Speed	Lpp/B	B/T	B/D	T/D	Lpp/T	Lpp/D	Fn
	[m3]	[ton]	[ton]	[-]	[-]	[m3]	[m]	[m]	[m]	[m]	[m]	[kW]	[kn]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
TBN Knutsen	1,100	640			1,500		69	63	12	6	3	1,800	14.0	5.4	3.6	2.1	0.6	19.2	11.5	0.3
Aman Bintulu	18,800	9,100			16,500		130	124	26	17	7	7,500	15.0	4.8	4.0	1.5	0.4	19.1	7.5	0.2
Aman Sendai	18,800	9,220			16,336		130	124	26	17	7	5,516	15.0	4.8	4.0	1.5	0.4	19.1	7.5	0.2
Aman Bintulu	18,928	11,001	6,817	17818	16,399	55757	133	125	26	17	7	5516	15	4.9						
Aman Hakata	18,942	9,214			16,336		130	124	26	17	7	5,516	15.0	4.8	4.0	1.5	0.4	19.1	7.5	0.2
Surya Aki	19,100	11,612			20,524		151	140	28	16	8	8,826	18.5	5.0	3.7	1.8	0.5	18.4	8.8	0.3
Surya Satsuma	23,096	12,493	8,805	21,298	20,017	68058	151	144	28	16	7	7,798	17	5.1	4.0	1.8	0.4	20.3	9.0	0.2
Havfru	29,388	21,693			26,097		182	173	29	17	9	14,941	19.5	6.0	3.1	1.8	0.6	18.4	10.5	0.2
Century	29,588	22,036			26,097		182	174	29	17	9	12,365	18.0	6.0	3.1	1.8	0.6	18.5	10.5	0.2
Tellier	40,000	21,301	11,615	32,916	26,857	91314	196.8	185.8	29.2	17	8.1	12,504	18	6.4	3.6	1.7	0.5	22.9	10.9	0.2
LNG Elba	41,000	25,235	13,515	38750	29,264	99498	208	196	29	18	9.2	11,033	18	6.7	3.2	1.6	0.5	21.4	10.6	0.2
LNG Palmaria	41,000	25,235	13,515	38,750	29,264	99498	208	196	29	18	9	11,033	18	6.7	3.2	1.6	0.5	21.4	10.6	0.2
LNG Lerici	65,000	35,761	17,099	52,860	46,555	158287	216	205	34	21	10	12,500	17	6.0	3.6	1.6	0.4	21.5	9.6	0.2
Høegh Galleon	87,600	50,746			71,804		250	237	40		11	22,059	19.5	5.9	3.8			22.4		0.2
Norman Lady	87,994	53,624			71,469		250	241	40	23	11		19.0	6.0	3.8	1.7	0.5	22.7	10.5	0.2
Høegh Gandria	125,800	70,498			96,011		288	274	43	25	12		19.3	6.3	3.8	1.7	0.5	23.8	11.0	0.2
Matthew	126,000	65,674			88,919		289	279	41	26	12			6.8	3.5	1.6	0.5	23.4	10.8	

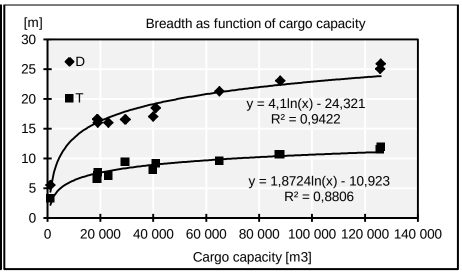

[ton]
Deadweigth as function of cargo capacity
y = 0,5489x + 1192,6
R² = 0,9845
Cargo capacity [m3]

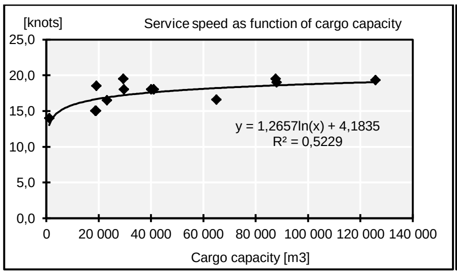

[ton]
Lightweight as function of cargo capacity
y = 0,2189x + 3539,7
R² = 0,9453
Cargo capacity [m3]

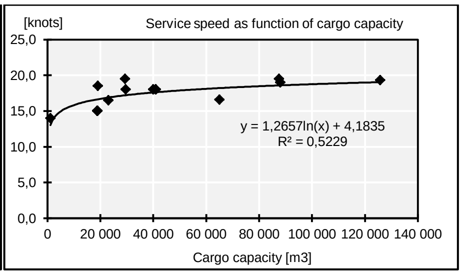

DWY/Disp - ratio as function of cargo capacity
y = 2E-06x + 0,5635
R² = 0,8139
Cargo capacity [m3]

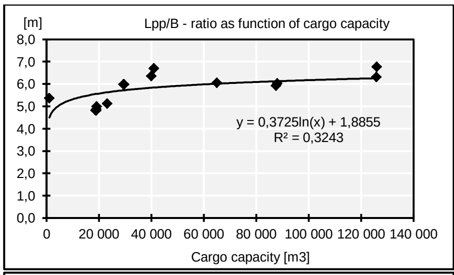

[m]
Loa and Lpp as function of cargo capacity
y = 0,0015x + 116,26
R² = 0,8838
y = 0,0015x + 109,04
R² = 0,8899
Loa
Lpp
Cargo capacity [m3]

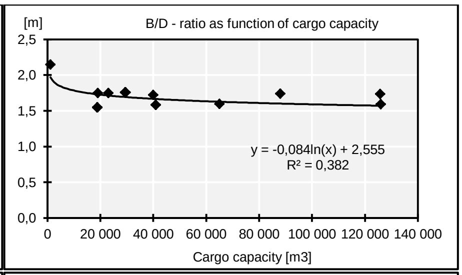

[m]
B as function of cargo capacity
y = 0,0002x + 21,744
R² = 0,8428
Cargo capacity [m3]

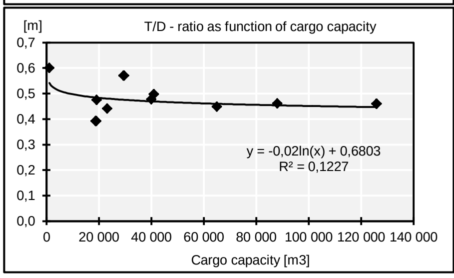

[m]
Breadth as function of cargo capacity
D
T
y = 4,1ln(x) - 24,321
R² = 0,9422
y = 1,8724ln(x) - 10,923
R² = 0,8806
Cargo capacity [m3]

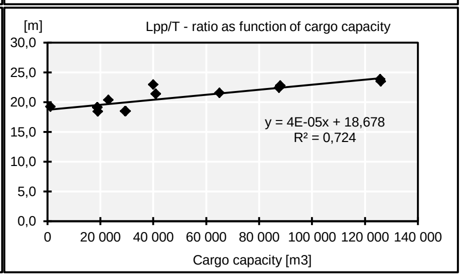

[knots]
Service speed as function of cargo capacity
y = 1,2657ln(x) + 4,1835
R² = 0,5229
Cargo capacity [m3]

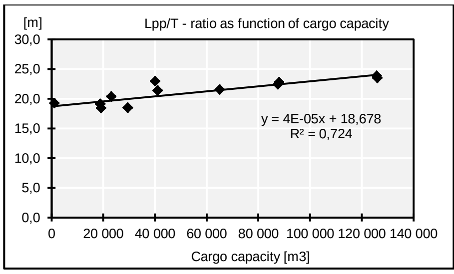

[knots]
Service speed as function of cargo capacity
y = 1,2657ln(x) + 4,1835
R² = 0,5229
Cargo capacity [m3]

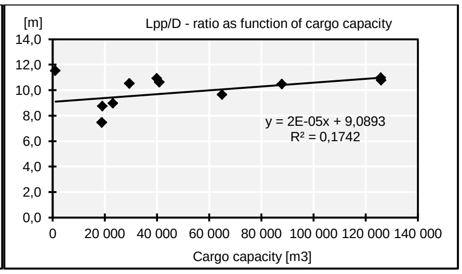

[m]
Lpp/B - ratio as function of cargo capacity
y = 0,3725ln(x) + 1,8855
R² = 0,3243
Cargo capacity [m3]

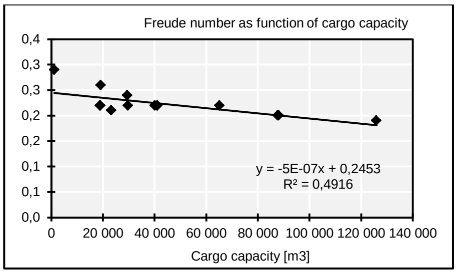

[m]
B/D - ratio as function of cargo capacity
y = -0,084ln(x) + 2,555
R² = 0,382
Cargo capacity [m3]


[m]
T/D - ratio as function of cargo capacity
y = -0,02ln(x) + 0,6803
R² = 0,1227
Cargo capacity [m3]


[m]
Lpp/T - ratio as function of cargo capacity
y = 4E-05x + 18,678
R² = 0,724
Cargo capacity [m3]


[m]
Lpp/T - ratio as function of cargo capacity
y = 4E-05x + 18,678
R² = 0,724
Cargo capacity [m3]


[m]
Lpp/D - ratio as function of cargo capacity
y = 2E-05x + 9,0893
R² = 0,1742
Cargo capacity [m3]

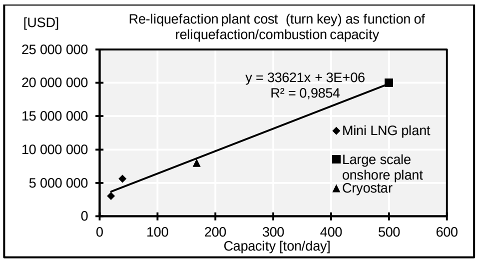


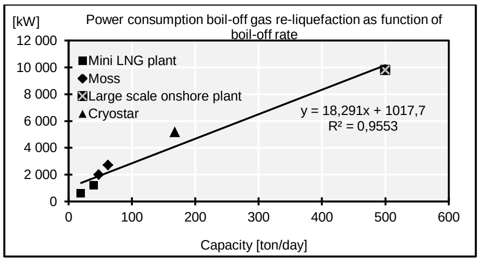
Freude number as function of cargo capacity
0,4
0,3
0,3
0,2
0,2
0,1
0,1
0,0
0
20 000
40 000
60 000
80 000
100 000
120 000
140 000
y = -5E-07x + 0,2453
R² = 0,4916
Cargo capacity [m3]

Boil-off handling system statistics

Re-liquefaction plant

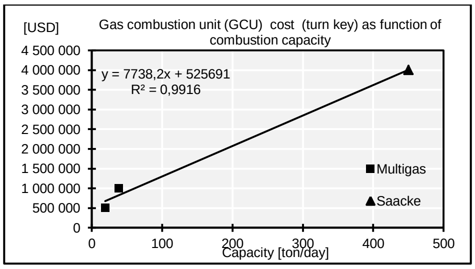
Re-liquefaction plant							
Plant type	Capacity			Energy cons.		Power	Cost
	[kg/h]	[ton/day]	[ton/h]	[kWh/kg]	[kWh/ton]	[kW]	[USD]
Mini LNG plant		20	1	1	700	583	3,000,000
		40	2	1	700	1,167	5,600,000
Moss	2000	48				2000	
	2600	62.4				2700	
Large scale onshore plant		500	21	0.4	470	9,792	20,000,000
Cryostar	7000	168				5200	8000000

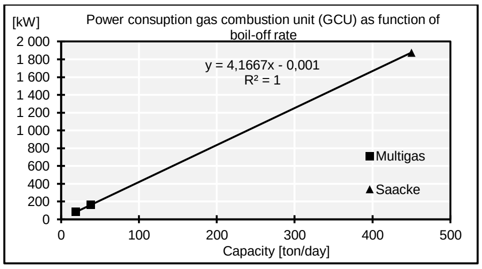




Gas combustion unit

Gas combustion unit					
Type	Capacity			Power	Cost
	[kg/h]	[ton/h]	[ton/day]	[kW]	[USD]
Multigas	800	1	19	80	505,000
	1,600	2	38	160	1,000,000
Saacke	18,750	19	450	1,875	4,000,000

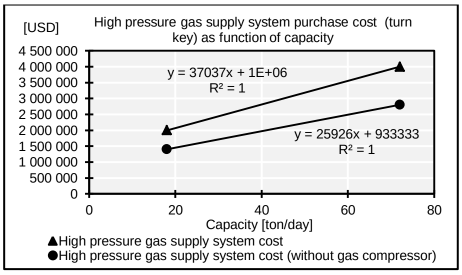




Gas supply system

High pressure gas supply system cost (without gas compressor)		
NB: Values based on assumptions		
Capacity		Cost
[kg/s]	[ton/day]	[USD]
5	18	2,000,000
20	72	4,000,000

High pressure gas supply system cost		
NB: Values based on assumptions		
Capacity		Cost
[kg/s]	[ton/day]	[USD]
5	18	1,400,000
20	72	2,800,000



Appendix 4

Ship design

Space allocation

Cargo related spaces	No.	H	A	V
Name:	[-]	[m]	[m2]	[m3]
Hull compartment	3	16	3645	58320
Total cargo related spaces			3645	58320

Crew Facilities	No.	Size	H	A	V
Cabins:	[-]	[m2]	[m]	[m2]	[m3]
Captain/Chief	2	40	2.8	80	224
Senior	2	25	2.8	50	140
Junior	6	10	2.8	60	168
Petty/ratings/pilot	15	10	2.8	150	420
Cabin corridors, wall lining			2.8	136	380.8
Total cabin area				476	1332.8
Public spaces:	Seats	[m2/seat]			
Mess	40	3	2.8	120	336
Gymnasium			2.8	30	84
Conference	20	2.5	2.8	50	140
Change room			2.8	15	42
Recreation	20	2.5	2.8	50	140
Stores			2.8	18	50
Total public spaces				283	792
Sanitary:					
Hospital			2.8	15	42
Public toilet			2.8	20	56
Total sanitary spaces				35	98
Service spaces:		[m2/crew]			
Galley			2.8	50	140
Pantries			2.8	10	28
Provision			2.8	20	56
Garbage handling		0.2	2.8	5	14
Laundry		0.2	2.8	4	11
Drying room		0.1	2.8	3	7
Total service spaces				91	256
Passage spaces:					
Stairway, corridors			2.8	164	458
Total passage spaces				164	458
Total crew facilities				1049	2936.5

Control spaces		Height	A	V
Name:	[m3/kW]	[m]	[m2]	[m3]
Wheelhouse		3.5	209	731.5
Engine control room	0.02	2.8	71	200
Fire station		2.8	18	50
Engine office		2.8	18	50
Cargo office		2.8	18	50
Total cargo spaces			334	1081.5

Technical Spaces				
		Height	A	V
Name:	[m3/kW]	[m]	[m2]	[m3]
Engine- and pump room	0.25	3.5	714	2500
Steering gear	0.03	3.5	86	300
Workshop and stores	0.01	3.5	29	100
Emergency generator, battery room	0.002	3.5	6	20
Engine casing and funnel	0.02			200
Total technical spaces			834	3120

Tanks and void spaces		
	V [m3]	
Name:	ME Alt 2.	ME Alt. 1
HFO	0	1800
MDO	220	220
LO	100	100
Fresh water	250	250
Ballast water	23000	23000
Voids	12700	10900
Total tanks and void spaces	36270	36270

Space allocation summary				
			Area	Volume
			[m3]	[m3]
Hull compartment				
Cargo related spaces			3,645	58,320
	[m2/crew]	[m3/crew]		
Cabins:	24	67	476	1,333
Public spaces:	14	40	283	792
Sanitary:	2	5	35	98
Service spaces:	5	13	91	256
Passage spaces:	8	23	164	458
Crew Facilities	52	147	1,049	2,937
Control spaces			334	1,082
	[m2/crew]	[m3/crew]		
Technical Spaces	42	156	834	3,120
Tanks and void spaces			36,270	36,270
Gross volume				101,728
Gross tonnage				30,534

Deadweight and lightweight

Lightweight								
		Unit	Value		Unit	Coeff	Weight [ton]	
WBS	Weight group:		Alt. 1	Alt 2.		[ton/unit]	Alt. 1	Alt 2.
1	Ship general							
2	Hull							
2.1	Hull structure	Hull volume	97,710	97,710	[m3]	0.07	6,337	6,337
2.2	Deckhouse	Deck house volume	4,018	4,018	[m3]	0.13	502	502
3	Cargo related							
3.1	Cargo tank	Cargo tank volume	Variable:	45,000	[m3]	0.05	2,400	2,400
3.2	Insulation system	Insulation weight average					900	900
3.(3-12)	Cargo systems	Variable with boil-off handling sys. Cargo system weight assumed fixed					2,150	2,150
4	Outfitting	GV	101,728	101,728	[m3]	0.005	509	509
5	Equipment for crew							
6	Machinery and piping's	Power ME	10,680	10,680	[kW]	0.11	1,208	1,208
7	Ship common systems	Gross volume	101,728	101,728	[m3]	0.006	610	610
	Total	GV	101,728				14,617	14,617
	Reserve	%	1				146	146
	Lightweight						14,763	14,763

Deadweight							
		Value				Weight [ton]	
Item:	Unit	Alt. 1	Alt 2.	Unit	Coeff.	Alt. 1	Alt 2.
LNG Cargo	Capacity	Variable:	45,000	[m3]	0.5	22,500	22,500
Crew	Persons	20	20	[-]	0.1	2	2
Provision and stores	Persons	20	20	[-]	0.1	2	2
HFO	Capacity	1,800	0	[m3]	1.0	1,800	0
MDO	Capacity	220	220	[m3]	1.0	220	220
LO	Capacity	100	100	[m3]	1.0	100	100
Fresh water	Capacity	250	250	[m3]	1.0	250	250
Ballast water	Capacity	0	0	[m3]	1.0	0	0
Deadweight						24,874	23,074

Displacement		39,637	37,837
	DWT/Displacement	0.63	0.61

Ship design basis

Principal dimensions	Value	Unit
Length, overall abt. (Loa)	205	[m]
Length waterline (Lwl)	198	[m]
Length, between pp (Lpp)	192	[m]
Breadth, moulded (B)	30	[m]
Depth (D)	18	[m]
Draught (T)	8.5	[m]
Draught aft (Ta)	8.5	[m]
Draught forward (Tf)	8.5	[m]

Weight and volumes	Value (average)	Unit
Deadweight (DWT)	23,974	[ton]
Lightweight [LWT)	14,763	[ton]
Displacement (Disp)	38,737	[ton]
DWT/Disp -ratio	0.62	[-]
Gross tonnage	30,534	[-]
Gross Volume	101,728	[m3]

Cargo comp. Date	Value	Unit
Cargo comp. length	45	[m]
Cargo comp. breadth	27	[m]
Cargo comp. height	16	[m]
Cargo comp.t volume	19440	[m3]
Number of cargo comp.	3	[-]
Total cargo comp. volume	58320	[m3]
Number of cargo tanks	3	[-]

Hull form	Value	Formula:
Block coefficient (Cb)	0.73	Alexanders formula
Prismatic coefficient (Cp)	0.75	SBSD
Waterline area coefficient (Cw)	0.85	Schneekluth&bertram98
Miship section coefficient (Cm)	0.97	Schneekluth&bertram98
Slenderness ratio	6.06	
Freude number (Fn)	0.18	

Operation	Value	Unit
Route: Port Moresby (Papua New Guinea) - Singapore		
Service speed	15	[kn]
Slow laden/ballast	11	[kn]
Total distance	2,740	[nm]
Roundtrip time	17	[days]

Appendix 5

Hollenback 98 method

Input values

Input values			
Name:	Abbr.	Value	Unit
Length waterline	Lwl	197.8	[m]
Length over surface	Los	205.0	[m]
Length, between pp	Lpp	192	[m]
Breadth, moulded	B	30	[m]
Depth	D	18	[m]
Draught	T	8.5	[m]
Draught aft	Ta	8.5	[m]
Draught forward	Tf	8.5	[m]
T/B	[-]	0.3	[-]
B/L	[-]	0.16	[-]
Los/Lwl	[-]	1.04	[-]
Lwl/Lpp	[-]	1.03	[-]
Dp/Ta	[-]	0.71	[-]
B/D	[-]	1.7	[-]
B/T	[-]	3.5	[-]
T/D	[-]	0.5	[-]
Lpp/T	[-]	22.6	[-]
Lpp/D	[-]	10.7	[-]
Lpp/B	[-]	6.4	[-]
Block coefficient	Cb	0.73	[-]
Wetted surface design draught	S	6309.6	[m2]
Wetted surface ballast draught	Sb	5969.9	[m2]
Displacement	Disp	39636.9	[ton]
Number of propellers	[-]	1.0	[-]
Propeller diameter	Dp	6.0	[m]
Propeller rounds per minute	Rpm	100.0	[1/s]
Propeller blade number	[-]	4.0	[-]
Service speed	Ss	16.0	[kn]
Number of rudders	NoR	1.0	[-]
Number of brackets	NoBr	1.0	[-]
Number of bossing's	NoBo	1.0	[-]

Physical Properties			
Name:	Abbr.	Value	Unit
Sea water density	ρS	1025	[kg/m3]
Dynamic viscosity	μ	1.03E-03	[Ns/m2]
Kinematic viscosity	ν	1.00E-06	[m^2*s^-1]
Roughness	k	150	[-]
Form factor	k	0.075	[-]
Form factor value	ϕ	0.084	[-]
Roughness factor	H	150	[-]
Frontal projected area	A_F	659.76	[-]
Propulsive efficiency	ηD	0.85	[-]
Shaft efficiency	ηS	0.97	
Total efficiency	ηT	0.8245	
Sea margin		25%	

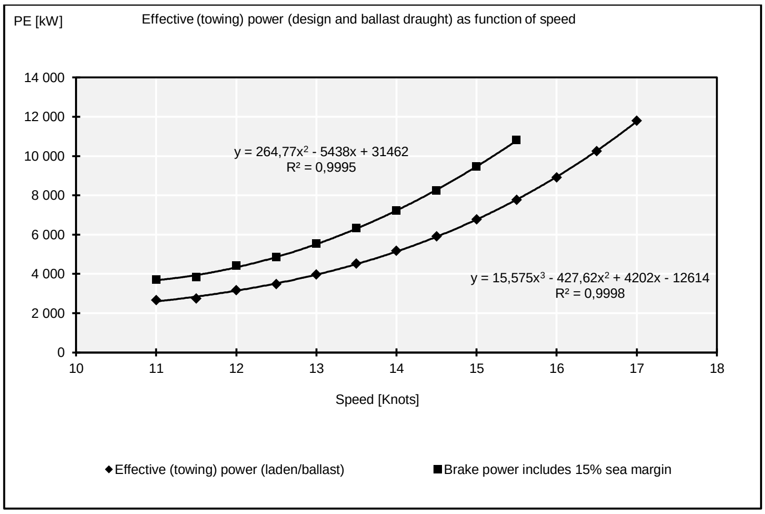
Coefficients for wetted surface Hollenbach98		
Coeff:	Design	Ballast
a0	-0.6837	-0.8037
a1	0.2771	0.2726
a2	0.6542	0.7133
a3	0.6422	0.6699
a4	0.0075	0.0243
a5	0.0275	0.0265
a6	-0.0045	-0.0061
a7	-0.4798	0.2349
a8	0.0376	0.0131
k	0.699197	0.661557

Wetted surface		
	Design	Ballast
Formula and deviation	[m2]	[m2]
Lap 1954 formula	7324	
Hollenback98 formula	6310	5970
Deviation	13.9%	

Range of validity Hollenbach98		
Fn,min	0.1434837	[-]
Fn,max	0.257312	[-]
Vmin	12.694917	[kn]
Vmax	22.76604	[kn]

Coefficients for resistance calculations Hollenbach98 method		
Coeff:	Design	Ballast
b1	-0.3382	-0.7139
b2	0.8086	0.2558
b3	-6.0258	-1.1606
b4	-3.5632	0.4534
b5	9.4405	11.222
b6	0.0146	0.4524
b7	0	0
b8	0	0
b9	0	0
b10	0	0
c11	-0.5742	-1.50162
c12	13.3893	12.9678
c13	90.596	-36.7985
c21	4.6614	5.55536
c22	-39.721	-45.8815
c23	-351.483	121.82
c31	-1.14215	-4.33571
c32	-12.3296	36.0782
c33	459.254	-85.3741
d1	0.854	0.032
d2	-1.228	0.803
d3	0.497	-0.739
e1	2.1701	1.9994
e2	-0.1602	-0.1446

Speed		Viscous resistance (CV)				Residual resistance (CR)							Total R. coeff	Towing	Effective
V	V	R_N	C_F	ΔC_F	C_V	Fn	$C_{R\_STANDARD}$	F_{N_KRIT}	k_L	f1	$C_{R\_FN\_KRIT}$	C_R	C_T	R_T	P_E
[kn]	[m/s]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[kN]	[kW]
8	4	8.E+08	0.002	0.000	0.002								0.002	95	393
9	5	9.E+08	0.002	0.000	0.002								0.002	121	560
10	5	1.E+09	0.002	0.000	0.002	Not Valid for Fn<14.7							0.002	149	768
11	6	1.E+09	0.002	0.000	0.002								0.005	470	2,659
12	6	1.E+09	0.002	0.000	0.002								0.004	464	2,746
12	6	1.E+09	0.001	0.000	0.002								0.004	514	3,173
13	6	1.E+09	0.001	0.000	0.002	0.1	0.01	0.2	0.9	0.6	0.8	0.002	0.004	541	3,480
13	7	1.E+09	0.001	0.000	0.002	0.1	0.01	0.2	0.9	0.7	0.8	0.002	0.004	593	3,967
14	7	1.E+09	0.001	0.000	0.002	0.2	0.01	0.2	0.9	0.7	0.8	0.002	0.004	652	4,526
14	7	1.E+09	0.001	0.000	0.002	0.2	0.01	0.2	0.9	0.7	0.8	0.003	0.004	718	5,169
15	7	1.E+09	0.001	0.000	0.002	0.2	0.01	0.2	0.9	0.8	0.8	0.003	0.004	792	5,910
15	8	2.E+09	0.001	0.000	0.002	0.2	0.01	0.2	0.9	0.8	0.8	0.003	0.005	877	6,767
16	8	2.E+09	0.001	0.000	0.002	0.2	0.02	0.2	0.9	0.8	0.8	0.003	0.005	973	7,759
16	8	2.E+09	0.001	0.000	0.002	0.2	0.02	0.2	0.9	0.8	0.9	0.003	0.005	1,082	8,909
17	8	2.E+09	0.001	0.000	0.002	0.2	0.02	0.2	0.9	0.9	0.9	0.003	0.005	1,207	10,243
17	9	2.E+09	0.001	0.000	0.002	0.2	0.02	0.2	0.9	0.9	0.9	0.004	0.005	1,348	11,792
18	9	2.E+09	0.001	0.000	0.002	0.2	0.02	0.2	0.9	0.9	0.9	0.004	0.006	1,693	15,677
19	10	2.E+09	0.001	0.000	0.002	0.2	0.02	0.2	0.9	1.0	1.0	0.005	0.007	2,139	20,907



Appendix 6

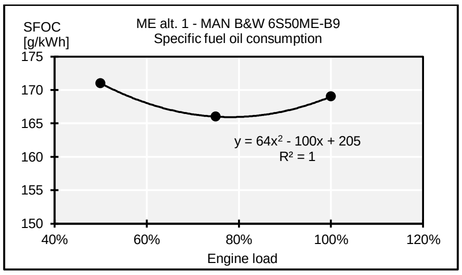
Main engine alternatives

ME alt. 1

ME alt. 1			
Two Stroke Conventional			
Main engine type:	MAN B&W 6S50ME-B9		1 set
SMCR:	10680	[kW]	at 117 RPM

Specific fuel consumption (SFOC):			
MCR	50%	75%	100%
SFOC [g/kWh]	171	166	169

Specific lube oil consumption (SLOC)		
SLOC:	0.1	[g/kWh]



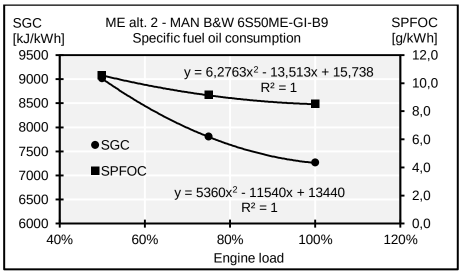
ME alt. 2

Main engine alternative 2 (ME alt. 2)			
Two Stroke Dual fuel (DF)			
Main engine type:	MAN B&W 6S50ME-GI-B9		1 set
SMCR:	10680	[kW]	at 117 RPM

Specific gas consumption (SGC):			
MCR	50%	75%	100%
SGC [kJ/kWh]	9010	7800	7260

Specific pilot fuel oil consumption (SPFOC)			
MCR	50%	75%	100%
SPFOC [kJ/kWh]	450.5	390	363
SPFOC [g/kWh]	10.6	9.1	8.5
Lower kalorific value (HFO)		42700	[kJ/kg]

Specific lube oil consumption (SLOC)	
SLOC [g/kWh]	0.1

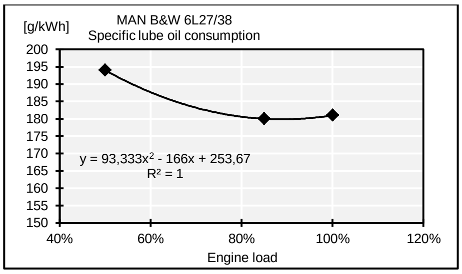


Aux. engine

Auxiliary engine			
Four stroke conventional			
Auxiliary type:	MAN B&W 6L27/38		
SMCR:		1980	kW
Corresponding generator power:		1900	kW

Specific fuel consumption (SFOC):			
MCR	50%	85%	100%
SPOC [g/kWh]	194	180	181

Specific lube oil consumption (SLOC)	
SLOC [g/kWh]	1



Appendix 6

Insulation properties

ID.	Insulation			Thermal Conductivity k[W/m•K]		Density	Material cost	Material cost
	Name	Abbr.	Type/description	Low	High	ρ[kg/m3]	[USD/m3]	[USD/ton]
1	Polyurethane foam	PUF	Sprayed foam	0.016	0.019	50	400	8000
2	Polyurethane	PU	Rigid PU-foam board/panel	0.019	0.022	50	300	6000
3	Expanded polystyrene	EPS	Rigid board/panel	0.036	0.04	25	150	6000
4	Plywood	PW		0.115	[-]	450	200	444

Insulation ID: 1

Thickness t[mm]	Thermal Conductivity k[W/m•K]	Heat transfer coeff. U[W/m2K]	Thermal Resistance R[m2K/W]	Weigth W[kg/m2]
20	0.016	0.8	1.3	1
40	0.016	0.4	3	2
80	0.016	0.2	5	4
160	0.016	0.1	10	8
300	0.016	0.1	19	15
500	0.016	0.0	31	25

Insulation ID: 2

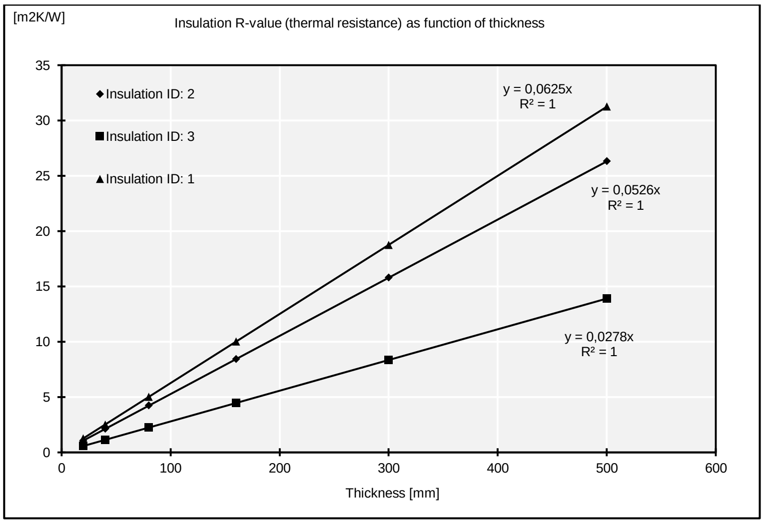
Thickness t[mm]	Thermal Conductivity k[W/m•K]	Heat transfer coeff. U[W/m2K]	Thermal Resistance R[m2K/W]	Weigth W[kg/m2]
20	0.019	1.0	1	1
40	0.019	0.5	2	2
80	0.019	0.2	4	4
160	0.019	0.1	8	8
300	0.019	0.1	16	15
500	0.019	0.0	26	25

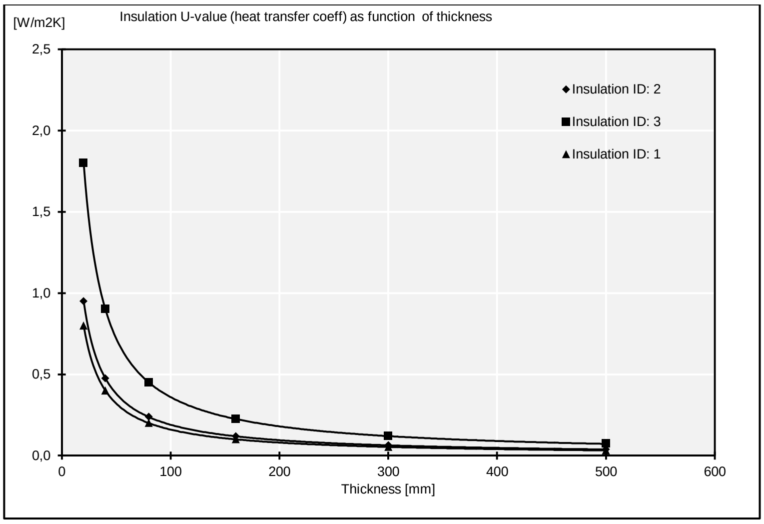
Insulation ID: 3

Thickness t[mm]	Thermal Conductivity k[W/m•K]	Heat transfer coeff. U[W/m2K]	Thermal Resistance R[m2K/W]	Weigth W[kg/m2]
20	0.036	1.8	1	0.5
40	0.036	0.9	1	1
80	0.036	0.5	2	2
160	0.036	0.2	4	4
300	0.036	0.1	8	7.5
500	0.036	0.1	14	12.5

Insulation ID: 4

Thickness t[mm]	Thermal Conductivity k[W/m•K]	Heat transfer coeff. U[W/m2K]	Thermal Resistance R[m2K/W]	Weigth W[kg/m2]
20	0.12	5.8	0.17	9





[W/m2K]
Insulation U-value (heat transfer coeff) as function of thickness
2,5
2,0
1,5
1,0
0,5
0,0
0
100
200
300
400
500
600
Thickness [mm]
Insulation ID: 2
Insulation ID: 3
Insulation ID: 1

Insulation system characteristics

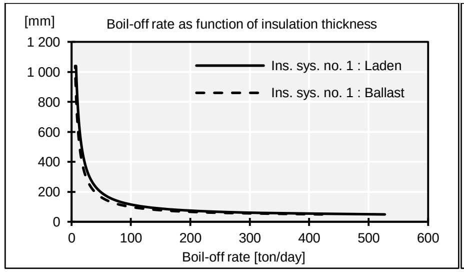
Insulation system 1

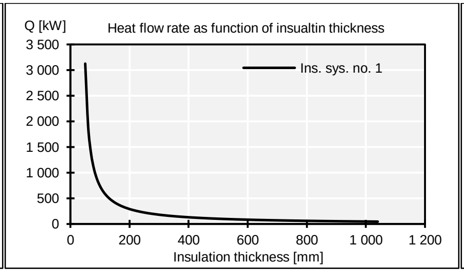
Table type:	Ins. sys. no:	Description:
Insulation sys. characteristics	1	Boil-off rate, insulation sys.- and containment weight

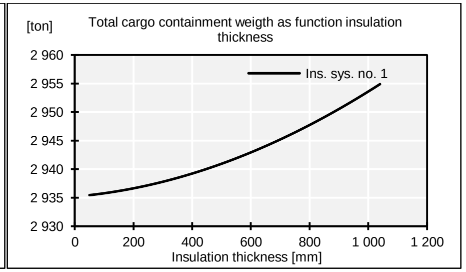
Ins. thick.	R value, U value and therm. conductance (for one containment)							Heat flow rate			Boil-off rate				Insulation system weight						Cont. weight	
t_{INS_TOT}	R_{L1}	R_{L2}	R_{L3}	R_{L4}	R_{INS_TOT}	U_{INS_TOT}	C_{INS_TOT}	Q_{INS}	Q_{SUP}	Q_{TOT}	BOR_{LAD}	BOR_{LAD}	BOR_{BALL}	BOR_{BALL}	W_{L1}	W_{L2}	W_{L3}	W_{L4}	W_{INS}	W_{INS_TOT}	W_C	W_{C_TOT}
[mm]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[W/m2K]	[W/K]	[kW]	[kW]	[kW]	[%/24h]	[ton/day]	[%/24h]	[ton/day]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]
50	0.3	0.2	0.3	0.2	1.0	1.0E+00	4,855	947	95	3,124	2.53%	528	42%	422	1	43	1	42	87	262	979	2,936
60	0.6	0.2	0.6	0.2	1.6	6.3E-01	2,952	576	58	1,900	1.54%	321	26%	257	2	43	2	42	90	269	979	2,936
70	0.9	0.2	0.9	0.2	2.2	4.5E-01	2,120	413	41	1,364	1.11%	230	18%	184	4	42	4	42	92	276	979	2,936
80	1.3	0.2	1.3	0.2	2.8	3.5E-01	1,653	322	32	1,064	0.87%	180	14%	144	5	42	5	42	94	283	979	2,936
90	1.6	0.2	1.6	0.2	3.5	2.9E-01	1,355	264	26	872	0.71%	147	12%	118	6	42	6	42	97	290	979	2,936
100	1.9	0.2	1.9	0.2	4.1	2.4E-01	1,147	224	22	738	0.61%	125	10%	100	7	42	7	42	99	297	979	2,936
110	2.2	0.2	2.2	0.2	4.7	2.1E-01	994	194	19	640	0.53%	108	9%	87	8	42	8	42	101	304	979	2,936
120	2.5	0.2	2.5	0.2	5.3	1.9E-01	878	171	17	565	0.47%	95	8%	76	9	42	9	42	103	310	979	2,936
130	2.8	0.2	2.8	0.2	6.0	1.7E-01	785	153	15	505	0.42%	85	7%	68	11	42	11	42	106	317	979	2,936
140	3.1	0.2	3.1	0.2	6.6	1.5E-01	710	138	14	457	0.38%	77	6%	62	12	42	12	42	108	324	979	2,936
150	3.4	0.2	3.4	0.2	7.2	1.4E-01	648	126	13	417	0.35%	70	6%	56	13	42	13	42	110	331	979	2,936
160	3.8	0.2	3.8	0.2	7.8	1.3E-01	596	116	12	384	0.32%	65	5%	52	14	42	14	42	113	338	979	2,936
170	4.1	0.2	4.1	0.2	8.5	1.2E-01	552	108	11	355	0.30%	60	5%	48	15	42	15	42	115	345	979	2,936
180	4.4	0.2	4.4	0.2	9.1	1.1E-01	514	100	10	330	0.28%	56	4%	45	16	42	16	42	117	352	979	2,937
190	4.7	0.2	4.7	0.2	9.7	1.0E-01	480	94	9	309	0.26%	52	4%	42	18	42	18	42	119	358	979	2,937
200	5.0	0.2	5.0	0.2	10.3	9.7E-02	451	88	9	290	0.24%	49	4%	39	19	42	19	42	122	365	979	2,937
210	5.3	0.2	5.3	0.2	11.0	9.1E-02	425	83	8	273	0.23%	46	4%	37	20	42	20	42	124	372	979	2,937
220	5.6	0.2	5.6	0.2	11.6	8.6E-02	402	78	8	258	0.22%	44	3%	35	21	42	21	42	126	379	979	2,937
230	5.9	0.2	5.9	0.2	12.2	8.2E-02	381	74	7	245	0.21%	41	3%	33	22	42	22	42	129	386	979	2,937
240	6.3	0.2	6.3	0.2	12.8	7.8E-02	362	71	7	233	0.20%	39	3%	31	23	42	23	42	131	393	979	2,937
250	6.6	0.2	6.6	0.2	13.5	7.4E-02	345	67	7	222	0.19%	37	3%	30	25	42	24	42	133	399	979	2,937
260	6.9	0.2	6.9	0.2	14.1	7.1E-02	329	64	6	212	0.18%	36	3%	29	26	42	26	42	135	406	979	2,937
270	7.2	0.2	7.2	0.2	14.7	6.8E-02	315	61	6	203	0.17%	34	3%	27	27	42	27	42	138	413	979	2,938
280	7.5	0.2	7.5	0.2	15.3	6.5E-02	302	59	6	194	0.17%	33	3%	26	28	42	28	42	140	420	979	2,938
290	7.8	0.2	7.8	0.2	16.0	6.3E-02	290	57	6	187	0.16%	32	3%	25	29	42	29	42	142	426	979	2,938
300	8.1	0.2	8.1	0.2	16.6	6.0E-02	279	54	5	180	0.16%	30	2%	24	30	42	30	42	144	433	979	2,938
310	8.4	0.2	8.4	0.2	17.2	5.8E-02	269	52	5	173	0.15%	29	2%	23	32	42	31	42	147	440	979	2,938
320	8.8	0.2	8.8	0.2	17.8	5.6E-02	259	51	5	167	0.14%	28	2%	23	33	42	32	42	149	447	979	2,938
330	9.1	0.2	9.1	0.2	18.5	5.4E-02	250	49	5	161	0.14%	27	2%	22	34	42	34	42	151	453	979	2,938
340	9.4	0.2	9.4	0.2	19.1	5.2E-02	242	47	5	156	0.14%	26	2%	21	35	42	35	42	153	460	979	2,938
350	9.7	0.2	9.7	0.2	19.7	5.1E-02	234	46	5	150	0.13%	25	2%	20	36	42	36	42	156	467	980	2,939
360	10.0	0.2	10.0	0.2	20.3	4.9E-02	227	44	4	146	0.13%	25	2%	20	37	42	37	41	158	474	980	2,939
370	10.3	0.2	10.3	0.2	21.0	4.8E-02	220	43	4	141	0.12%	24	2%	19	39	42	38	41	160	480	980	2,939
380	10.6	0.2	10.6	0.2	21.6	4.6E-02	213	42	4	137	0.12%	23	2%	19	40	42	39	41	162	487	980	2,939
390	10.9	0.2	10.9	0.2	22.2	4.5E-02	207	40	4	133	0.12%	22	2%	18	41	42	40	41	165	494	980	2,939
400	11.3	0.2	11.3	0.2	22.8	4.4E-02	201	39	4	129	0.11%	22	2%	18	42	42	41	41	167	500	980	2,939
410	11.6	0.2	11.6	0.2	23.5	4.3E-02	196	38	4	126	0.11%	21	2%	17	43	42	43	41	169	507	980	2,940

420	11.9	0.2	11.9	0.2	24.1	4.1E-02	190	37	4	123	0.11%	21	2%	17	44	42	44	41	171	514	980	2,940
430	12.2	0.2	12.2	0.2	24.7	4.0E-02	185	36	4	119	0.11%	20	2%	16	45	42	45	41	173	520	980	2,940
440	12.5	0.2	12.5	0.2	25.3	3.9E-02	181	35	4	116	0.10%	20	2%	16	47	42	46	41	176	527	980	2,940
450	12.8	0.2	12.8	0.2	26.0	3.9E-02	176	34	3	113	0.10%	19	2%	15	48	42	47	41	178	534	980	2,940
460	13.1	0.2	13.1	0.2	26.6	3.8E-02	172	34	3	111	0.10%	19	1%	15	49	42	48	41	180	540	980	2,940
470	13.4	0.2	13.4	0.2	27.2	3.7E-02	168	33	3	108	0.10%	18	1%	15	50	42	49	41	182	547	980	2,941
480	13.8	0.2	13.8	0.2	27.8	3.6E-02	164	32	3	106	0.10%	18	1%	14	51	42	50	41	184	553	980	2,941
490	14.1	0.2	14.1	0.2	28.5	3.5E-02	160	31	3	103	0.09%	17	1%	14	52	42	51	41	187	560	980	2,941
500	14.4	0.2	14.4	0.2	29.1	3.4E-02	157	31	3	101	0.09%	17	1%	14	54	42	53	41	189	567	980	2,941
510	14.7	0.2	14.7	0.2	29.7	3.4E-02	153	30	3	99	0.09%	17	1%	13	55	42	54	41	191	573	980	2,941
520	15.0	0.2	15.0	0.2	30.3	3.3E-02	150	29	3	97	0.09%	16	1%	13	56	42	55	41	193	580	980	2,941
530	15.3	0.2	15.3	0.2	31.0	3.2E-02	147	29	3	95	0.09%	16	1%	13	57	42	56	41	195	586	981	2,942
540	15.6	0.2	15.6	0.2	31.6	3.2E-02	144	28	3	93	0.09%	16	1%	13	58	42	57	41	198	593	981	2,942
550	15.9	0.2	15.9	0.2	32.2	3.1E-02	141	27	3	91	0.08%	15	1%	12	59	42	58	41	200	600	981	2,942
560	16.3	0.2	16.3	0.2	32.8	3.0E-02	138	27	3	89	0.08%	15	1%	12	60	42	59	41	202	606	981	2,942
570	16.6	0.2	16.6	0.2	33.5	3.0E-02	136	26	3	87	0.08%	15	1%	12	61	42	60	41	204	613	981	2,942
580	16.9	0.2	16.9	0.2	34.1	2.9E-02	133	26	3	86	0.08%	14	1%	12	63	42	61	41	206	619	981	2,943
590	17.2	0.2	17.2	0.2	34.7	2.9E-02	130	25	3	84	0.08%	14	1%	11	64	42	62	41	209	626	981	2,943
600	17.5	0.2	17.5	0.2	35.3	2.8E-02	128	25	2	82	0.08%	14	1%	11	65	42	63	41	211	632	981	2,943
610	17.8	0.2	17.8	0.2	36.0	2.8E-02	126	25	2	81	0.08%	14	1%	11	66	42	65	41	213	639	981	2,943
620	18.1	0.2	18.1	0.2	36.6	2.7E-02	124	24	2	79	0.07%	13	1%	11	67	42	66	41	215	645	981	2,943
630	18.4	0.2	18.4	0.2	37.2	2.7E-02	121	24	2	78	0.07%	13	1%	11	68	42	67	41	217	652	981	2,944
640	18.8	0.2	18.8	0.2	37.8	2.6E-02	119	23	2	77	0.07%	13	1%	10	69	42	68	41	219	658	981	2,944
650	19.1	0.2	19.1	0.2	38.5	2.6E-02	117	23	2	75	0.07%	13	1%	10	71	42	69	41	222	665	981	2,944
660	19.4	0.2	19.4	0.2	39.1	2.6E-02	115	22	2	74	0.07%	13	1%	10	72	42	70	41	224	671	981	2,944
670	19.7	0.2	19.7	0.2	39.7	2.5E-02	113	22	2	73	0.07%	12	1%	10	73	42	71	41	226	678	982	2,945
680	20.0	0.2	20.0	0.2	40.3	2.5E-02	112	22	2	72	0.07%	12	1%	10	74	42	72	40	228	684	982	2,945
690	20.3	0.2	20.3	0.2	41.0	2.4E-02	110	21	2	71	0.07%	12	1%	10	75	42	73	40	230	691	982	2,945
700	20.6	0.2	20.6	0.2	41.6	2.4E-02	108	21	2	70	0.07%	12	1%	9	76	42	74	40	232	697	982	2,945
710	20.9	0.2	20.9	0.2	42.2	2.4E-02	106	21	2	68	0.07%	12	1%	9	77	41	75	40	235	704	982	2,946
720	21.3	0.2	21.3	0.2	42.8	2.3E-02	105	20	2	67	0.07%	11	1%	9	78	41	76	40	237	710	982	2,946
730	21.6	0.2	21.6	0.2	43.5	2.3E-02	103	20	2	66	0.06%	11	1%	9	80	41	77	40	239	716	982	2,946
740	21.9	0.2	21.9	0.2	44.1	2.3E-02	102	20	2	65	0.06%	11	1%	9	81	41	78	40	241	723	982	2,946
750	22.2	0.2	22.2	0.2	44.7	2.2E-02	100	20	2	64	0.06%	11	1%	9	82	41	80	40	243	729	982	2,947
760	22.5	0.2	22.5	0.2	45.3	2.2E-02	99	19	2	63	0.06%	11	1%	9	83	41	81	40	245	736	982	2,947
770	22.8	0.2	22.8	0.2	46.0	2.2E-02	97	19	2	63	0.06%	11	1%	8	84	41	82	40	247	742	982	2,947
780	23.1	0.2	23.1	0.2	46.6	2.1E-02	96	19	2	62	0.06%	10	1%	8	85	41	83	40	249	748	982	2,947
790	23.4	0.2	23.4	0.2	47.2	2.1E-02	95	18	2	61	0.06%	10	1%	8	86	41	84	40	252	755	983	2,948
800	23.8	0.2	23.8	0.2	47.8	2.1E-02	93	18	2	60	0.06%	10	1%	8	87	41	85	40	254	761	983	2,948
810	24.1	0.2	24.1	0.2	48.5	2.1E-02	92	18	2	59	0.06%	10	1%	8	89	41	86	40	256	768	983	2,948
820	24.4	0.2	24.4	0.2	49.1	2.0E-02	91	18	2	58	0.06%	10	1%	8	90	41	87	40	258	774	983	2,948
830	24.7	0.2	24.7	0.2	49.7	2.0E-02	90	17	2	58	0.06%	10	1%	8	91	41	88	40	260	780	983	2,949
840	25.0	0.2	25.0	0.2	50.3	2.0E-02	88	17	2	57	0.06%	10	1%	8	92	41	89	40	262	787	983	2,949
850	25.3	0.2	25.3	0.2	51.0	2.0E-02	87	17	2	56	0.06%	9	1%	8	93	41	90	40	264	793	983	2,949
860	25.6	0.2	25.6	0.2	51.6	1.9E-02	86	17	2	55	0.06%	9	1%	7	94	41	91	40	266	799	983	2,950

870	25.9	0.2	25.9	0.2	52.2	1.9E-02	85	17	2	55	0.06%	9	1%	7	95	41	92	40	269	806	983	2,950
880	26.3	0.2	26.3	0.2	52.8	1.9E-02	84	16	2	54	0.05%	9	1%	7	96	41	93	40	271	812	983	2,950
890	26.6	0.2	26.6	0.2	53.5	1.9E-02	83	16	2	53	0.05%	9	1%	7	97	41	94	40	273	818	983	2,950
900	26.9	0.2	26.9	0.2	54.1	1.8E-02	82	16	2	53	0.05%	9	1%	7	99	41	95	40	275	824	984	2,951
910	27.2	0.2	27.2	0.2	54.7	1.8E-02	81	16	2	52	0.05%	9	1%	7	100	41	96	40	277	831	984	2,951
920	27.5	0.2	27.5	0.2	55.3	1.8E-02	80	16	2	51	0.05%	9	1%	7	101	41	97	40	279	837	984	2,951
930	27.8	0.2	27.8	0.2	56.0	1.8E-02	79	15	2	51	0.05%	9	1%	7	102	41	98	40	281	843	984	2,952
940	28.1	0.2	28.1	0.2	56.6	1.8E-02	78	15	2	50	0.05%	8	1%	7	103	41	99	40	283	850	984	2,952
950	28.4	0.2	28.4	0.2	57.2	1.7E-02	77	15	2	50	0.05%	8	1%	7	104	41	100	40	285	856	984	2,952
960	28.8	0.2	28.8	0.2	57.8	1.7E-02	76	15	1	49	0.05%	8	1%	7	105	41	101	40	287	862	984	2,952
970	29.1	0.2	29.1	0.2	58.5	1.7E-02	75	15	1	48	0.05%	8	1%	7	106	41	102	40	289	868	984	2,953
980	29.4	0.2	29.4	0.2	59.1	1.7E-02	74	15	1	48	0.05%	8	1%	6	107	41	103	40	292	875	984	2,953
990	29.7	0.2	29.7	0.2	59.7	1.7E-02	74	14	1	47	0.05%	8	1%	6	109	41	105	40	294	881	984	2,953
1,000	30.0	0.2	30.0	0.2	60.3	1.7E-02	73	14	1	47	0.05%	8	1%	6	110	41	106	40	296	887	985	2,954
1,010	30.3	0.2	30.3	0.2	61.0	1.6E-02	72	14	1	46	0.05%	8	1%	6	111	41	107	39	298	893	985	2,954
1,020	30.6	0.2	30.6	0.2	61.6	1.6E-02	71	14	1	46	0.05%	8	1%	6	112	41	108	39	300	899	985	2,954
1,030	30.9	0.2	30.9	0.2	62.2	1.6E-02	70	14	1	45	0.05%	8	1%	6	113	41	109	39	302	906	985	2,955
1,040	31.3	0.2	31.3	0.2	62.8	1.6E-02	70	14	1	45	0.05%	8	1%	6	114	41	110	39	304	912	985	2,955





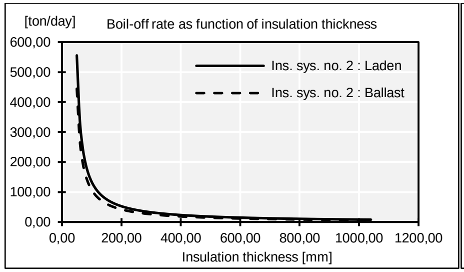


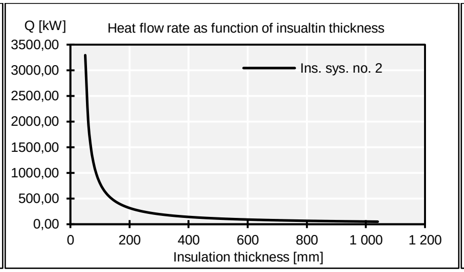
Insulation system 2

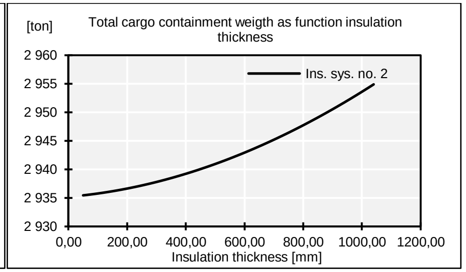
Table type:		Ins. sys. no:	Description:																			
Insulation characteristics		2	Boil-off rate, insulation sys.- and containment weight																			
Ins. thick.	R value, U value and therm. conductance (for one containment)							Heat flow rate			Boil-off rate				Insulation system weight						Cont. weight	
t_{INS_TOT}	R_{L1}	R_{L2}	R_{L3}	R_{L4}	R_{INS_TOT}	U_{INS_TOT}	C_{INS_TOT}	Q_{INS}	Q_{SUP}	Q_{TOT}	BOR_{LAD}	BOR_{LAD}	BOR_{BALL}	BOR_{BALL}	W_{L1}	W_{L2}	W_{L3}	W_{L4}	W_{INS}	W_{INS_TOT}	W_C	W_{C_TOT}
[mm]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[W/m2K]	[W/K]	[kW]	[kW]	[kW]	[%/24h]	[ton/day]	[%/24h]	[ton/day]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]
50.00	0.31	0.17	0.26	0.17	0.92	1.09	5118.76	998.16	99.82	3293.93	0.03	555.85	0.44	444.86	1.18	42.53	1.18	42.45	87.34	262.02	978.48	2,935
60.00	0.63	0.17	0.53	0.17	1.50	0.67	3149.51	614.15	61.42	2026.71	0.02	342.01	0.27	273.72	2.37	42.51	2.36	42.42	89.65	268.96	978.50	2,935
70.00	0.94	0.17	0.79	0.17	2.07	0.48	2273.54	443.34	44.33	1463.03	0.01	246.89	0.20	197.59	3.55	42.50	3.54	42.38	91.96	275.89	978.52	2,936
80.00	1.25	0.17	1.05	0.17	2.65	0.38	1778.23	346.76	34.68	1144.29	0.01	193.10	0.15	154.54	4.73	42.48	4.71	42.35	94.27	282.82	978.54	2,936
90.00	1.56	0.17	1.31	0.17	3.22	0.31	1459.74	284.65	28.46	939.34	0.01	158.51	0.13	126.86	5.91	42.46	5.89	42.32	96.58	289.73	978.56	2,936
100.00	1.88	0.17	1.58	0.17	3.80	0.26	1237.73	241.36	24.14	796.48	0.01	134.41	0.11	107.57	7.09	42.45	7.06	42.29	98.88	296.65	978.59	2,936
110.00	2.19	0.17	1.84	0.17	4.37	0.23	1074.12	209.45	20.95	691.20	0.01	116.64	0.09	93.35	8.26	42.43	8.23	42.26	101.18	303.55	978.61	2,936
120.00	2.50	0.17	2.10	0.17	4.95	0.20	948.56	184.97	18.50	610.40	0.01	103.00	0.08	82.44	9.44	42.42	9.40	42.23	103.48	310.44	978.64	2,936
130.00	2.81	0.17	2.36	0.17	5.52	0.18	849.14	165.58	16.56	546.42	0.00	92.21	0.07	73.80	10.62	42.40	10.56	42.20	105.78	317.33	978.66	2,936
140.00	3.13	0.17	2.63	0.17	6.10	0.16	768.48	149.85	14.99	494.52	0.00	83.45	0.07	66.79	11.79	42.38	11.73	42.16	108.07	324.21	978.69	2,936
150.00	3.44	0.17	2.89	0.17	6.67	0.15	701.72	136.84	13.68	451.56	0.00	76.20	0.06	60.98	12.97	42.37	12.89	42.13	110.36	331.08	978.72	2,936
160.00	3.75	0.17	3.15	0.17	7.25	0.14	645.56	125.88	12.59	415.42	0.00	70.10	0.06	56.10	14.14	42.35	14.05	42.10	112.65	337.94	978.75	2,936
170.00	4.06	0.17	3.41	0.17	7.82	0.13	597.66	116.54	11.65	384.59	0.00	64.90	0.05	51.94	15.31	42.34	15.21	42.07	114.93	344.80	978.78	2,936
180.00	4.38	0.17	3.68	0.17	8.40	0.12	556.31	108.48	10.85	357.99	0.00	60.41	0.05	48.35	16.48	42.32	16.37	42.04	117.22	351.65	978.81	2,936
190.00	4.69	0.17	3.94	0.17	8.97	0.11	520.27	101.45	10.15	334.79	0.00	56.50	0.05	45.22	17.65	42.31	17.53	42.01	119.50	358.49	978.84	2,937
200.00	5.00	0.17	4.20	0.17	9.55	0.10	488.57	95.27	9.53	314.39	0.00	53.05	0.04	42.46	18.82	42.29	18.68	41.98	121.77	365.32	978.88	2,937
210.00	5.31	0.17	4.46	0.17	10.12	0.10	460.47	89.79	8.98	296.31	0.00	50.00	0.04	40.02	19.99	42.27	19.84	41.94	124.05	372.14	978.91	2,937
220.00	5.63	0.17	4.73	0.17	10.70	0.09	435.39	84.90	8.49	280.18	0.00	47.28	0.04	37.84	21.16	42.26	20.99	41.91	126.32	378.96	978.94	2,937
230.00	5.94	0.17	4.99	0.17	11.27	0.09	412.87	80.51	8.05	265.68	0.00	44.83	0.04	35.88	22.33	42.24	22.14	41.88	128.59	385.77	978.98	2,937
240.00	6.25	0.17	5.25	0.17	11.85	0.08	392.54	76.55	7.65	252.60	0.00	42.63	0.03	34.11	23.49	42.23	23.28	41.85	130.86	392.57	979.02	2,937
250.00	6.56	0.17	5.51	0.17	12.42	0.08	374.09	72.95	7.29	240.73	0.00	40.62	0.03	32.51	24.66	42.21	24.43	41.82	133.12	399.36	979.06	2,937
260.00	6.88	0.17	5.78	0.17	13.00	0.08	357.28	69.67	6.97	229.91	0.00	38.80	0.03	31.05	25.82	42.20	25.57	41.79	135.38	406.15	979.09	2,937
270.00	7.19	0.17	6.04	0.17	13.57	0.07	341.88	66.67	6.67	220.00	0.00	37.13	0.03	29.71	26.99	42.18	26.72	41.76	137.64	412.92	979.13	2,937
280.00	7.50	0.17	6.30	0.17	14.15	0.07	327.74	63.91	6.39	210.90	0.00	35.59	0.03	28.48	28.15	42.16	27.86	41.72	139.90	419.69	979.17	2,938
290.00	7.81	0.17	6.56	0.17	14.72	0.07	314.71	61.37	6.14	202.51	0.00	34.17	0.03	27.35	29.31	42.15	29.00	41.69	142.15	426.46	979.22	2,938
300.00	8.13	0.17	6.83	0.17	15.30	0.07	302.65	59.02	5.90	194.76	0.00	32.87	0.03	26.30	30.47	42.13	30.13	41.66	144.40	433.21	979.26	2,938
310.00	8.44	0.17	7.09	0.17	15.87	0.06	291.47	56.84	5.68	187.56	0.00	31.65	0.03	25.33	31.63	42.12	31.27	41.63	146.65	439.96	979.30	2,938
320.00	8.75	0.17	7.35	0.17	16.45	0.06	281.07	54.81	5.48	180.87	0.00	30.52	0.02	24.43	32.79	42.10	32.40	41.60	148.90	446.70	979.35	2,938
330.00	9.06	0.17	7.61	0.17	17.02	0.06	271.37	52.92	5.29	174.63	0.00	29.47	0.02	23.58	33.95	42.09	33.54	41.57	151.14	453.43	979.39	2,938
340.00	9.38	0.17	7.88	0.17	17.60	0.06	262.31	51.15	5.12	168.80	0.00	28.48	0.02	22.80	35.11	42.07	34.67	41.54	153.38	460.15	979.44	2,938
350.00	9.69	0.17	8.14	0.17	18.17	0.06	253.82	49.49	4.95	163.33	0.00	27.56	0.02	22.06	36.27	42.05	35.80	41.51	155.62	466.87	979.49	2,938
360.00	10.00	0.17	8.40	0.17	18.75	0.05	245.85	47.94	4.79	158.21	0.00	26.70	0.02	21.37	37.42	42.04	36.92	41.47	157.86	473.57	979.54	2,939
370.00	10.31	0.17	8.66	0.17	19.32	0.05	238.36	46.48	4.65	153.38	0.00	25.88	0.02	20.72	38.58	42.02	38.05	41.44	160.09	480.27	979.58	2,939
380.00	10.63	0.17	8.93	0.17	19.90	0.05	231.30	45.10	4.51	148.84	0.00	25.12	0.02	20.10	39.73	42.01	39.17	41.41	162.32	486.97	979.63	2,939
390.00	10.94	0.17	9.19	0.17	20.47	0.05	224.63	43.80	4.38	144.55	0.00	24.39	0.02	19.52	40.89	41.99	40.29	41.38	164.55	493.65	979.69	2,939
400.00	11.25	0.17	9.45	0.17	21.05	0.05	218.33	42.57	4.26	140.50	0.00	23.71	0.02	18.97	42.04	41.98	41.41	41.35	166.78	500.33	979.74	2,939
410.00	11.56	0.17	9.71	0.17	21.62	0.05	212.37	41.41	4.14	136.66	0.00	23.06	0.02	18.46	43.19	41.96	42.53	41.32	169.00	507.00	979.79	2,939
420.00	11.88	0.17	9.98	0.17	22.20	0.05	206.71	40.31	4.03	133.02	0.00	22.45	0.02	17.96	44.34	41.94	43.65	41.29	171.22	513.66	979.84	2,940

430.00	12.19	0.17	10.24	0.17	22.77	0.04	201.34	39.26	3.93	129.56	0.00	21.86	0.02	17.50	45.49	41.93	44.76	41.26	173.44	520.31	979.90	2,940
440.00	12.50	0.17	10.50	0.17	23.35	0.04	196.24	38.27	3.83	126.28	0.00	21.31	0.02	17.05	46.64	41.91	45.88	41.23	175.65	526.96	979.96	2,940
450.00	12.81	0.17	10.76	0.17	23.92	0.04	191.38	37.32	3.73	123.15	0.00	20.78	0.02	16.63	47.79	41.90	46.99	41.19	177.87	533.60	980.01	2,940
460.00	13.13	0.17	11.03	0.17	24.50	0.04	186.75	36.42	3.64	120.17	0.00	20.28	0.02	16.23	48.93	41.88	48.10	41.16	180.08	540.23	980.07	2,940
470.00	13.44	0.17	11.29	0.17	25.07	0.04	182.33	35.55	3.56	117.33	0.00	19.80	0.02	15.85	50.08	41.87	49.21	41.13	182.28	546.85	980.13	2,940
480.00	13.75	0.17	11.55	0.17	25.65	0.04	178.11	34.73	3.47	114.61	0.00	19.34	0.02	15.48	51.23	41.85	50.31	41.10	184.49	553.47	980.19	2,941
490.00	14.06	0.17	11.81	0.17	26.22	0.04	174.07	33.94	3.39	112.02	0.00	18.90	0.02	15.13	52.37	41.83	51.42	41.07	186.69	560.08	980.25	2,941
500.00	14.38	0.17	12.08	0.17	26.80	0.04	170.21	33.19	3.32	109.53	0.00	18.48	0.01	14.79	53.51	41.82	52.52	41.04	188.89	566.68	980.31	2,941
510.00	14.69	0.17	12.34	0.17	27.37	0.04	166.51	32.47	3.25	107.15	0.00	18.08	0.01	14.47	54.66	41.80	53.62	41.01	191.09	573.27	980.37	2,941
520.00	15.00	0.17	12.60	0.17	27.95	0.04	162.96	31.78	3.18	104.87	0.00	17.70	0.01	14.16	55.80	41.79	54.72	40.98	193.29	579.86	980.44	2,941
530.00	15.31	0.17	12.86	0.17	28.52	0.04	159.56	31.11	3.11	102.68	0.00	17.33	0.01	13.87	56.94	41.77	55.82	40.95	195.48	586.43	980.50	2,941
540.00	15.63	0.17	13.13	0.17	29.10	0.03	156.29	30.48	3.05	100.57	0.00	16.97	0.01	13.58	58.08	41.76	56.91	40.92	197.67	593.00	980.56	2,942
550.00	15.94	0.17	13.39	0.17	29.67	0.03	153.15	29.86	2.99	98.55	0.00	16.63	0.01	13.31	59.22	41.74	58.01	40.89	199.85	599.56	980.63	2,942
560.00	16.25	0.17	13.65	0.17	30.25	0.03	150.12	29.27	2.93	96.60	0.00	16.30	0.01	13.05	60.36	41.72	59.10	40.85	202.04	606.12	980.70	2,942
570.00	16.56	0.17	13.91	0.17	30.82	0.03	147.21	28.71	2.87	94.73	0.00	15.99	0.01	12.79	61.50	41.71	60.19	40.82	204.22	612.67	980.76	2,942
580.00	16.88	0.17	14.18	0.17	31.40	0.03	144.41	28.16	2.82	92.93	0.00	15.68	0.01	12.55	62.63	41.69	61.28	40.79	206.40	619.21	980.83	2,943
590.00	17.19	0.17	14.44	0.17	31.97	0.03	141.70	27.63	2.76	91.19	0.00	15.39	0.01	12.32	63.77	41.68	62.37	40.76	208.58	625.74	980.90	2,943
600.00	17.50	0.17	14.70	0.17	32.55	0.03	139.10	27.12	2.71	89.51	0.00	15.10	0.01	12.09	64.90	41.66	63.46	40.73	210.75	632.26	980.97	2,943
610.00	17.81	0.17	14.96	0.17	33.12	0.03	136.58	26.63	2.66	87.89	0.00	14.83	0.01	11.87	66.04	41.65	64.54	40.70	212.93	638.78	981.05	2,943
620.00	18.13	0.17	15.23	0.17	33.70	0.03	134.15	26.16	2.62	86.33	0.00	14.57	0.01	11.66	67.17	41.63	65.62	40.67	215.10	645.29	981.12	2,943
630.00	18.44	0.17	15.49	0.17	34.27	0.03	131.80	25.70	2.57	84.81	0.00	14.31	0.01	11.45	68.31	41.62	66.70	40.64	217.26	651.79	981.19	2,944
640.00	18.75	0.17	15.75	0.17	34.85	0.03	129.53	25.26	2.53	83.35	0.00	14.07	0.01	11.26	69.44	41.60	67.78	40.61	219.43	658.28	981.26	2,944
650.00	19.06	0.17	16.01	0.17	35.42	0.03	127.33	24.83	2.48	81.94	0.00	13.83	0.01	11.07	70.57	41.58	68.86	40.58	221.59	664.77	981.34	2,944
660.00	19.38	0.17	16.28	0.17	36.00	0.03	125.20	24.41	2.44	80.57	0.00	13.60	0.01	10.88	71.70	41.57	69.94	40.55	223.75	671.25	981.42	2,944
670.00	19.69	0.17	16.54	0.17	36.57	0.03	123.14	24.01	2.40	79.24	0.00	13.37	0.01	10.70	72.83	41.55	71.01	40.52	225.91	677.72	981.49	2,944
680.00	20.00	0.17	16.80	0.17	37.15	0.03	121.15	23.62	2.36	77.96	0.00	13.16	0.01	10.53	73.95	41.54	72.08	40.49	228.06	684.18	981.57	2,945
690.00	20.31	0.17	17.06	0.17	37.72	0.03	119.21	23.25	2.32	76.71	0.00	12.95	0.01	10.36	75.08	41.52	73.15	40.45	230.21	690.63	981.65	2,945
700.00	20.63	0.17	17.33	0.17	38.30	0.03	117.33	22.88	2.29	75.50	0.00	12.74	0.01	10.20	76.21	41.51	74.22	40.42	232.36	697.08	981.73	2,945
710.00	20.94	0.17	17.59	0.17	38.87	0.03	115.51	22.52	2.25	74.33	0.00	12.54	0.01	10.04	77.33	41.49	75.29	40.39	234.51	703.52	981.81	2,945
720.00	21.25	0.17	17.85	0.17	39.45	0.03	113.74	22.18	2.22	73.19	0.00	12.35	0.01	9.89	78.46	41.47	76.36	40.36	236.65	709.96	981.89	2,946
730.00	21.56	0.17	18.11	0.17	40.02	0.02	112.03	21.85	2.18	72.09	0.00	12.16	0.01	9.74	79.58	41.46	77.42	40.33	238.79	716.38	981.97	2,946
740.00	21.88	0.17	18.38	0.17	40.60	0.02	110.36	21.52	2.15	71.01	0.00	11.98	0.01	9.59	80.71	41.44	78.48	40.30	240.93	722.80	982.06	2,946
750.00	22.19	0.17	18.64	0.17	41.17	0.02	108.73	21.20	2.12	69.97	0.00	11.81	0.01	9.45	81.83	41.43	79.54	40.27	243.07	729.21	982.14	2,946
760.00	22.50	0.17	18.90	0.17	41.75	0.02	107.16	20.90	2.09	68.96	0.00	11.64	0.01	9.31	82.95	41.41	80.60	40.24	245.20	735.61	982.22	2,947
770.00	22.81	0.17	19.16	0.17	42.32	0.02	105.62	20.60	2.06	67.97	0.00	11.47	0.01	9.18	84.07	41.40	81.66	40.21	247.34	742.01	982.31	2,947
780.00	23.13	0.17	19.43	0.17	42.90	0.02	104.13	20.31	2.03	67.01	0.00	11.31	0.01	9.05	85.19	41.38	82.72	40.18	249.47	748.40	982.40	2,947
790.00	23.44	0.17	19.69	0.17	43.47	0.02	102.67	20.02	2.00	66.07	0.00	11.15	0.01	8.92	86.31	41.37	83.77	40.15	251.59	754.78	982.49	2,947
800.00	23.75	0.17	19.95	0.17	44.05	0.02	101.26	19.75	1.97	65.16	0.00	11.00	0.01	8.80	87.43	41.35	84.82	40.12	253.72	761.15	982.57	2,948
810.00	24.06	0.17	20.21	0.17	44.62	0.02	99.88	19.48	1.95	64.27	0.00	10.85	0.01	8.68	88.54	41.33	85.87	40.09	255.84	767.51	982.66	2,948
820.00	24.38	0.17	20.48	0.17	45.20	0.02	98.54	19.21	1.92	63.41	0.00	10.70	0.01	8.56	89.66	41.32	86.92	40.06	257.96	773.87	982.75	2,948
830.00	24.69	0.17	20.74	0.17	45.77	0.02	97.22	18.96	1.90	62.56	0.00	10.56	0.01	8.45	90.78	41.30	87.97	40.03	260.07	780.22	982.84	2,949
840.00	25.00	0.17	21.00	0.17	46.35	0.02	95.95	18.71	1.87	61.74	0.00	10.42	0.01	8.34	91.89	41.29	89.01	40.00	262.19	786.56	982.94	2,949
850.00	25.31	0.17	21.26	0.17	46.92	0.02	94.70	18.47	1.85	60.94	0.00	10.28	0.01	8.23	93.00	41.27	90.06	39.97	264.30	792.90	983.03	2,949
860.00	25.63	0.17	21.53	0.17	47.50	0.02	93.48	18.23	1.82	60.16	0.00	10.15	0.01	8.12	94.12	41.26	91.10	39.93	266.41	799.23	983.12	2,949
870.00	25.94	0.17	21.79	0.17	48.07	0.02	92.30	18.00	1.80	59.39	0.00	10.02	0.01	8.02	95.23	41.24	92.14	39.90	268.52	805.55	983.22	2,950

880.00	26.25	0.17	22.05	0.17	48.65	0.02	91.14	17.77	1.78	58.65	0.00	9.90	0.01	7.92	96.34	41.23	93.18	39.87	270.62	811.86	983.31	2,950
890.00	26.56	0.17	22.31	0.17	49.22	0.02	90.01	17.55	1.76	57.92	0.00	9.77	0.01	7.82	97.45	41.21	94.22	39.84	272.72	818.17	983.41	2,950
900.00	26.88	0.17	22.58	0.17	49.80	0.02	88.90	17.34	1.73	57.21	0.00	9.65	0.01	7.73	98.56	41.19	95.25	39.81	274.82	824.46	983.51	2,951
910.00	27.19	0.17	22.84	0.17	50.37	0.02	87.82	17.12	1.71	56.51	0.00	9.54	0.01	7.63	99.67	41.18	96.29	39.78	276.92	830.75	983.61	2,951
920.00	27.50	0.17	23.10	0.17	50.95	0.02	86.76	16.92	1.69	55.83	0.00	9.42	0.01	7.54	100.77	41.16	97.32	39.75	279.01	837.04	983.70	2,951
930.00	27.81	0.17	23.36	0.17	51.52	0.02	85.73	16.72	1.67	55.17	0.00	9.31	0.01	7.45	101.88	41.15	98.35	39.72	281.10	843.31	983.80	2,951
940.00	28.13	0.17	23.63	0.17	52.10	0.02	84.72	16.52	1.65	54.52	0.00	9.20	0.01	7.36	102.99	41.13	99.38	39.69	283.19	849.58	983.91	2,952
950.00	28.44	0.17	23.89	0.17	52.67	0.02	83.73	16.33	1.63	53.88	0.00	9.09	0.01	7.28	104.09	41.12	100.41	39.66	285.28	855.84	984.01	2,952
960.00	28.75	0.17	24.15	0.17	53.25	0.02	82.77	16.14	1.61	53.26	0.00	8.99	0.01	7.19	105.20	41.10	101.43	39.63	287.36	862.09	984.11	2,952
970.00	29.06	0.17	24.41	0.17	53.82	0.02	81.82	15.96	1.60	52.65	0.00	8.89	0.01	7.11	106.30	41.09	102.46	39.60	289.45	868.34	984.21	2,953
980.00	29.38	0.17	24.68	0.17	54.40	0.02	80.90	15.78	1.58	52.06	0.00	8.78	0.01	7.03	107.40	41.07	103.48	39.57	291.53	874.58	984.32	2,953
990.00	29.69	0.17	24.94	0.17	54.97	0.02	79.99	15.60	1.56	51.47	0.00	8.69	0.01	6.95	108.50	41.06	104.50	39.54	293.60	880.81	984.42	2,953
1000.00	30.00	0.17	25.20	0.17	55.55	0.02	79.11	15.43	1.54	50.90	0.00	8.59	0.01	6.87	109.61	41.04	105.52	39.51	295.68	887.03	984.53	2,954
1010.00	30.31	0.17	25.46	0.17	56.12	0.02	78.24	15.26	1.53	50.34	0.00	8.50	0.01	6.80	110.71	41.02	106.54	39.48	297.75	893.25	984.64	2,954
1020.00	30.63	0.17	25.73	0.17	56.70	0.02	77.38	15.09	1.51	49.80	0.00	8.40	0.01	6.73	111.80	41.01	107.56	39.45	299.82	899.45	984.74	2,954
1030.00	30.94	0.17	25.99	0.17	57.27	0.02	76.55	14.93	1.49	49.26	0.00	8.31	0.01	6.65	112.90	40.99	108.57	39.42	301.88	905.65	984.85	2,955
1040.00	31.25	0.17	26.25	0.17	57.85	0.02	75.73	14.77	1.48	48.73	0.00	8.22	0.01	6.58	114.00	40.98	109.58	39.39	303.95	911.85	984.96	2,955





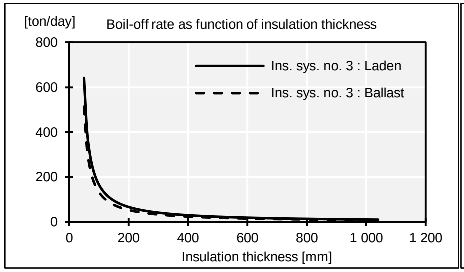


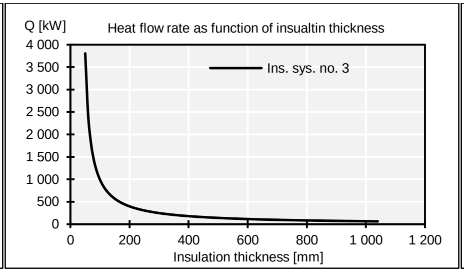
Insulation system 3

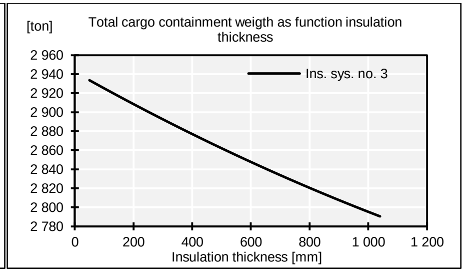
Table type:	Ins. sys. no:	Description:																				
Insulation characteristics	3	Boil-off rate, insulation sys.- and containment weight																				
Ins. thick.	R value, U value and therm. conductance (for one containment)							Heat flow rate			Boil-off rate				Insulation system weight						Cont. weight	
t_{INS_TOT}	R_{L1}	R_{L2}	R_{L3}	R_{L4}	R_{INS_TOT}	U_{INS_TOT}	C_{INS_TOT}	Q_{INS}	Q_{SUP}	Q_{TOT}	BOR_{LAD}	BOR_{LAD}	BOR_{BALL}	BOR_{BALL}	W_{L1}	W_{L2}	W_{L3}	W_{L4}	W_{INS}	W_{INS_TOT}	W_{C}	W_{C_TOT}
[mm]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[W/m2K]	[W/K]	[kW]	[kW]	[kW]	[%/24h]	[ton/day]	[%/24h]	[ton/day]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]
50	0.31	0.17	0.14	0.17	0.8	1.3E+00	5,911	1,153	115	3,804	3.07%	642	51%	514	1	43	1	42	87	260	978	2,934
60	0.63	0.17	0.28	0.17	1.2	8.0E-01	3,772	736	74	2,427	1.97%	410	33%	328	2	43	1	42	88	265	977	2,932
70	0.94	0.17	0.42	0.17	1.7	5.9E-01	2,769	540	54	1,782	1.45%	301	24%	241	4	42	2	42	90	271	977	2,930
80	1.25	0.17	0.56	0.17	2.2	4.6E-01	2,186	426	43	1,407	1.15%	237	19%	190	5	42	2	42	92	276	976	2,929
90	1.56	0.17	0.70	0.17	2.6	3.8E-01	1,806	352	35	1,162	0.95%	196	16%	157	6	42	3	42	94	281	976	2,927
100	1.88	0.17	0.83	0.17	3.1	3.3E-01	1,538	300	30	990	0.81%	167	13%	134	7	42	4	42	95	286	975	2,925
110	2.19	0.17	0.97	0.17	3.5	2.9E-01	1,339	261	26	862	0.71%	145	12%	116	8	42	4	42	97	291	974	2,923
120	2.50	0.17	1.11	0.17	4.0	2.5E-01	1,185	231	23	763	0.63%	129	10%	103	9	42	5	42	99	296	974	2,922
130	2.81	0.17	1.25	0.17	4.4	2.3E-01	1,063	207	21	684	0.56%	115	9%	92	11	42	5	42	100	301	973	2,920
140	3.13	0.17	1.39	0.17	4.9	2.1E-01	964	188	19	620	0.51%	105	8%	84	12	42	6	42	102	307	973	2,918
150	3.44	0.17	1.53	0.17	5.3	1.9E-01	881	172	17	567	0.47%	96	8%	77	13	42	6	42	104	312	972	2,917
160	3.75	0.17	1.67	0.17	5.8	1.7E-01	812	158	16	522	0.43%	88	7%	71	14	42	7	42	106	317	972	2,915
170	4.06	0.17	1.81	0.17	6.2	1.6E-01	752	147	15	484	0.40%	82	7%	65	15	42	8	42	107	322	971	2,914
180	4.38	0.17	1.95	0.17	6.7	1.5E-01	701	137	14	451	0.38%	76	6%	61	16	42	8	42	109	327	971	2,912
190	4.69	0.17	2.09	0.17	7.1	1.4E-01	656	128	13	422	0.35%	71	6%	57	18	42	9	42	111	332	970	2,910
200	5.00	0.17	2.22	0.17	7.6	1.3E-01	616	120	12	396	0.33%	67	5%	54	19	42	9	42	112	337	970	2,909
210	5.31	0.17	2.36	0.17	8.0	1.2E-01	581	113	11	374	0.31%	63	5%	50	20	42	10	42	114	342	969	2,907
220	5.63	0.17	2.50	0.17	8.5	1.2E-01	550	107	11	354	0.30%	60	5%	48	21	42	10	42	116	347	968	2,905
230	5.94	0.17	2.64	0.17	8.9	1.1E-01	521	102	10	336	0.28%	57	5%	45	22	42	11	42	118	353	968	2,904
240	6.25	0.17	2.78	0.17	9.4	1.1E-01	496	97	10	319	0.27%	54	4%	43	23	42	12	42	119	358	967	2,902
250	6.56	0.17	2.92	0.17	9.8	1.0E-01	473	92	9	304	0.26%	51	4%	41	25	42	12	42	121	363	967	2,901
260	6.88	0.17	3.06	0.17	10.3	9.7E-02	452	88	9	291	0.25%	49	4%	39	26	42	13	42	123	368	966	2,899
270	7.19	0.17	3.20	0.17	10.7	9.3E-02	432	84	8	278	0.24%	47	4%	38	27	42	13	42	124	373	966	2,897
280	7.50	0.17	3.34	0.17	11.2	8.9E-02	415	81	8	267	0.23%	45	4%	36	28	42	14	42	126	378	965	2,896
290	7.81	0.17	3.48	0.17	11.6	8.6E-02	398	78	8	256	0.22%	43	3%	35	29	42	14	42	128	383	965	2,894
300	8.13	0.17	3.61	0.17	12.1	8.3E-02	383	75	7	247	0.21%	42	3%	33	30	42	15	42	129	388	964	2,893
310	8.44	0.17	3.75	0.17	12.5	8.0E-02	369	72	7	237	0.21%	40	3%	32	32	42	16	42	131	393	964	2,891
320	8.75	0.17	3.89	0.17	13.0	7.7E-02	356	69	7	229	0.20%	39	3%	31	33	42	16	42	133	398	963	2,889
330	9.06	0.17	4.03	0.17	13.4	7.4E-02	344	67	7	221	0.19%	37	3%	30	34	42	17	42	134	403	963	2,888
340	9.38	0.17	4.17	0.17	13.9	7.2E-02	332	65	6	214	0.19%	36	3%	29	35	42	17	42	136	408	962	2,886
350	9.69	0.17	4.31	0.17	14.3	7.0E-02	322	63	6	207	0.18%	35	3%	28	36	42	18	42	138	413	962	2,885
360	10.00	0.17	4.45	0.17	14.8	6.8E-02	312	61	6	200	0.18%	34	3%	27	37	42	18	41	139	418	961	2,883
370	10.31	0.17	4.59	0.17	15.2	6.6E-02	302	59	6	194	0.17%	33	3%	26	39	42	19	41	141	423	961	2,882
380	10.63	0.17	4.73	0.17	15.7	6.4E-02	293	57	6	189	0.17%	32	3%	25	40	42	20	41	143	428	960	2,880
390	10.94	0.17	4.87	0.17	16.1	6.2E-02	285	56	6	183	0.16%	31	2%	25	41	42	20	41	144	433	960	2,879
400	11.25	0.17	5.00	0.17	16.6	6.0E-02	277	54	5	178	0.16%	30	2%	24	42	42	21	41	146	438	959	2,877
410	11.56	0.17	5.14	0.17	17.1	5.9E-02	269	53	5	173	0.15%	29	2%	23	43	42	21	41	148	443	959	2,876
420	11.88	0.17	5.28	0.17	17.5	5.7E-02	262	51	5	169	0.15%	28	2%	23	44	42	22	41	149	448	958	2,874

430	12.19	0.17	5.42	0.17	18.0	5.6E-02	255	50	5	164	0.15%	28	2%	22	45	42	22	41	151	453	958	2,873
440	12.50	0.17	5.56	0.17	18.4	5.4E-02	249	49	5	160	0.14%	27	2%	22	47	42	23	41	153	458	957	2,871
450	12.81	0.17	5.70	0.17	18.9	5.3E-02	243	47	5	156	0.14%	26	2%	21	48	42	23	41	154	463	957	2,870
460	13.13	0.17	5.84	0.17	19.3	5.2E-02	237	46	5	152	0.14%	26	2%	21	49	42	24	41	156	468	956	2,868
470	13.44	0.17	5.98	0.17	19.8	5.1E-02	231	45	5	149	0.13%	25	2%	20	50	42	25	41	158	473	956	2,867
480	13.75	0.17	6.12	0.17	20.2	4.9E-02	226	44	4	145	0.13%	25	2%	20	51	42	25	41	159	478	955	2,865
490	14.06	0.17	6.26	0.17	20.7	4.8E-02	221	43	4	142	0.13%	24	2%	19	52	42	26	41	161	483	955	2,864
500	14.38	0.17	6.39	0.17	21.1	4.7E-02	216	42	4	139	0.13%	23	2%	19	54	42	26	41	163	488	954	2,862
510	14.69	0.17	6.53	0.17	21.6	4.6E-02	211	41	4	136	0.12%	23	2%	18	55	42	27	41	164	493	954	2,861
520	15.00	0.17	6.67	0.17	22.0	4.5E-02	207	40	4	133	0.12%	22	2%	18	56	42	27	41	166	498	953	2,859
530	15.31	0.17	6.81	0.17	22.5	4.5E-02	203	39	4	130	0.12%	22	2%	18	57	42	28	41	168	503	953	2,858
540	15.63	0.17	6.95	0.17	22.9	4.4E-02	198	39	4	128	0.12%	22	2%	17	58	42	28	41	169	508	952	2,856
550	15.94	0.17	7.09	0.17	23.4	4.3E-02	194	38	4	125	0.12%	21	2%	17	59	42	29	41	171	513	952	2,855
560	16.25	0.17	7.23	0.17	23.8	4.2E-02	191	37	4	123	0.11%	21	2%	17	60	42	30	41	172	517	951	2,853
570	16.56	0.17	7.37	0.17	24.3	4.1E-02	187	36	4	120	0.11%	20	2%	16	61	42	30	41	174	522	951	2,852
580	16.88	0.17	7.51	0.17	24.7	4.0E-02	183	36	4	118	0.11%	20	2%	16	63	42	31	41	176	527	950	2,851
590	17.19	0.17	7.65	0.17	25.2	4.0E-02	180	35	4	116	0.11%	20	2%	16	64	42	31	41	177	532	950	2,849
600	17.50	0.17	7.78	0.17	25.6	3.9E-02	177	34	3	114	0.11%	19	2%	15	65	42	32	41	179	537	949	2,848
610	17.81	0.17	7.92	0.17	26.1	3.8E-02	173	34	3	112	0.10%	19	2%	15	66	42	32	41	181	542	949	2,846
620	18.13	0.17	8.06	0.17	26.5	3.8E-02	170	33	3	110	0.10%	19	1%	15	67	42	33	41	182	547	948	2,845
630	18.44	0.17	8.20	0.17	27.0	3.7E-02	167	33	3	108	0.10%	18	1%	15	68	42	33	41	184	552	948	2,844
640	18.75	0.17	8.34	0.17	27.4	3.6E-02	165	32	3	106	0.10%	18	1%	14	69	42	34	41	186	557	947	2,842
650	19.06	0.17	8.48	0.17	27.9	3.6E-02	162	32	3	104	0.10%	18	1%	14	71	42	34	41	187	561	947	2,841
660	19.38	0.17	8.62	0.17	28.3	3.5E-02	159	31	3	102	0.10%	17	1%	14	72	42	35	41	189	566	946	2,839
670	19.69	0.17	8.76	0.17	28.8	3.5E-02	156	31	3	101	0.10%	17	1%	14	73	42	36	41	190	571	946	2,838
680	20.00	0.17	8.90	0.17	29.2	3.4E-02	154	30	3	99	0.09%	17	1%	13	74	42	36	40	192	576	946	2,837
690	20.31	0.17	9.04	0.17	29.7	3.4E-02	151	30	3	97	0.09%	16	1%	13	75	42	37	40	194	581	945	2,835
700	20.63	0.17	9.17	0.17	30.1	3.3E-02	149	29	3	96	0.09%	16	1%	13	76	42	37	40	195	586	945	2,834
710	20.94	0.17	9.31	0.17	30.6	3.3E-02	147	29	3	94	0.09%	16	1%	13	77	41	38	40	197	591	944	2,832
720	21.25	0.17	9.45	0.17	31.0	3.2E-02	145	28	3	93	0.09%	16	1%	13	78	41	38	40	198	595	944	2,831
730	21.56	0.17	9.59	0.17	31.5	3.2E-02	142	28	3	92	0.09%	15	1%	12	80	41	39	40	200	600	943	2,830
740	21.88	0.17	9.73	0.17	32.0	3.1E-02	140	27	3	90	0.09%	15	1%	12	81	41	39	40	202	605	943	2,828
750	22.19	0.17	9.87	0.17	32.4	3.1E-02	138	27	3	89	0.09%	15	1%	12	82	41	40	40	203	610	942	2,827
760	22.50	0.17	10.01	0.17	32.9	3.0E-02	136	27	3	88	0.09%	15	1%	12	83	41	40	40	205	615	942	2,826
770	22.81	0.17	10.15	0.17	33.3	3.0E-02	134	26	3	86	0.08%	15	1%	12	84	41	41	40	207	620	941	2,824
780	23.13	0.17	10.29	0.17	33.8	3.0E-02	132	26	3	85	0.08%	14	1%	11	85	41	41	40	208	624	941	2,823
790	23.44	0.17	10.43	0.17	34.2	2.9E-02	130	25	3	84	0.08%	14	1%	11	86	41	42	40	210	629	941	2,822
800	23.75	0.17	10.56	0.17	34.7	2.9E-02	129	25	3	83	0.08%	14	1%	11	87	41	42	40	211	634	940	2,820
810	24.06	0.17	10.70	0.17	35.1	2.8E-02	127	25	2	82	0.08%	14	1%	11	89	41	43	40	213	639	940	2,819
820	24.38	0.17	10.84	0.17	35.6	2.8E-02	125	24	2	81	0.08%	14	1%	11	90	41	43	40	214	643	939	2,818
830	24.69	0.17	10.98	0.17	36.0	2.8E-02	124	24	2	80	0.08%	13	1%	11	91	41	44	40	216	648	939	2,817
840	25.00	0.17	11.12	0.17	36.5	2.7E-02	122	24	2	78	0.08%	13	1%	11	92	41	45	40	218	653	938	2,815
850	25.31	0.17	11.26	0.17	36.9	2.7E-02	120	23	2	77	0.08%	13	1%	10	93	41	45	40	219	658	938	2,814
860	25.63	0.17	11.40	0.17	37.4	2.7E-02	119	23	2	76	0.08%	13	1%	10	94	41	46	40	221	663	938	2,813
870	25.94	0.17	11.54	0.17	37.8	2.6E-02	117	23	2	75	0.08%	13	1%	10	95	41	46	40	222	667	937	2,811

880	26.25	0.17	11.68	0.17	38.3	2.6E-02	116	23	2	75	0.08%	13	1%	10	96	41	47	40	224	672	937	2,810
890	26.56	0.17	11.82	0.17	38.7	2.6E-02	114	22	2	74	0.07%	12	1%	10	97	41	47	40	226	677	936	2,809
900	26.88	0.17	11.95	0.17	39.2	2.6E-02	113	22	2	73	0.07%	12	1%	10	99	41	48	40	227	682	936	2,808
910	27.19	0.17	12.09	0.17	39.6	2.5E-02	112	22	2	72	0.07%	12	1%	10	100	41	48	40	229	686	935	2,806
920	27.50	0.17	12.23	0.17	40.1	2.5E-02	110	22	2	71	0.07%	12	1%	10	101	41	49	40	230	691	935	2,805
930	27.81	0.17	12.37	0.17	40.5	2.5E-02	109	21	2	70	0.07%	12	1%	9	102	41	49	40	232	696	935	2,804
940	28.13	0.17	12.51	0.17	41.0	2.4E-02	108	21	2	69	0.07%	12	1%	9	103	41	50	40	234	701	934	2,803
950	28.44	0.17	12.65	0.17	41.4	2.4E-02	106	21	2	68	0.07%	12	1%	9	104	41	50	40	235	705	934	2,801
960	28.75	0.17	12.79	0.17	41.9	2.4E-02	105	21	2	68	0.07%	11	1%	9	105	41	51	40	237	710	933	2,800
970	29.06	0.17	12.93	0.17	42.3	2.4E-02	104	20	2	67	0.07%	11	1%	9	106	41	51	40	238	715	933	2,799
980	29.38	0.17	13.07	0.17	42.8	2.3E-02	103	20	2	66	0.07%	11	1%	9	107	41	52	40	240	719	933	2,798
990	29.69	0.17	13.21	0.17	43.2	2.3E-02	102	20	2	65	0.07%	11	1%	9	109	41	52	40	241	724	932	2,797
1,000	30.00	0.17	13.34	0.17	43.7	2.3E-02	101	20	2	65	0.07%	11	1%	9	110	41	53	40	243	729	932	2,795
1,010	30.31	0.17	13.48	0.17	44.1	2.3E-02	99	19	2	64	0.07%	11	1%	9	111	41	53	39	244	733	931	2,794
1,020	30.63	0.17	13.62	0.17	44.6	2.2E-02	98	19	2	63	0.07%	11	1%	9	112	41	54	39	246	738	931	2,793
1,030	30.94	0.17	13.76	0.17	45.0	2.2E-02	97	19	2	63	0.07%	11	1%	8	113	41	54	39	248	743	931	2,792
1,040	31.25	0.17	13.90	0.17	45.5	2.2E-02	96	19	2	62	0.07%	10	1%	8	114	41	55	39	249	747	930	2,791





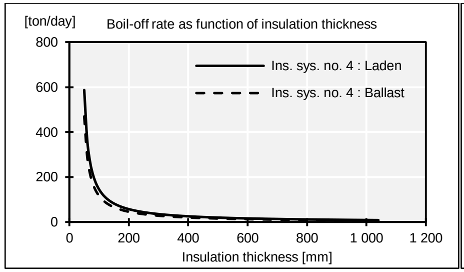


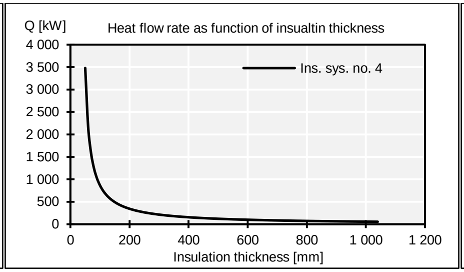
Insulation system 4

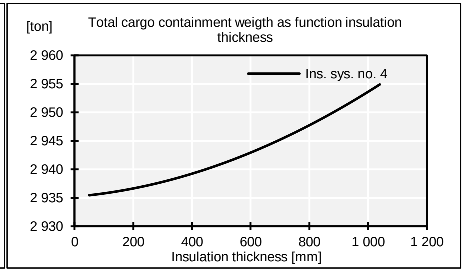
Table type:		Ins. sys. no:	Description:																			
Insulation characteristics		4	Boil-off rate, insulation sys.- and containment weight																			
Ins. thick.	R value, U value and therm. conductance (for one containment)							Heat flow rate			Boil-off rate				Insulation system weight						Cont. weight	
t_{INS_TOT}	R_{L1}	R_{L2}	R_{L3}	R_{L4}	R_{INS_TOT}	U_{INS_TOT}	C_{INS_TOT}	Q_{INS}	Q_{SUP}	Q_{TOT}	BOR_{LAD}	BOR_{LAD}	BOR_{BALL}	BOR_{BALL}	W_{L1}	W_{L2}	W_{L3}	W_{L4}	W_{INS}	W_{INS_TOT}	W_C	W_{C_TOT}
[mm]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[W/m2K]	[W/K]	[kW]	[kW]	[kW]	[%/24h]	[ton/day]	[%/24h]	[ton/day]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]
50	0.26	0.17	0.26	0.17	0.9	1.1E+00	5,406	1,054	105	3,479	2.81%	587	47%	470	1	43	1	42	87	262	978	2,935
60	0.53	0.17	0.53	0.17	1.4	7.2E-01	3,370	657	66	2,169	1.76%	366	29%	293	2	43	2	42	90	269	978	2,935
70	0.79	0.17	0.79	0.17	1.9	5.2E-01	2,447	477	48	1,575	1.28%	266	21%	213	4	42	4	42	92	276	979	2,936
80	1.05	0.17	1.05	0.17	2.5	4.1E-01	1,920	374	37	1,236	1.01%	209	17%	167	5	42	5	42	94	283	979	2,936
90	1.32	0.17	1.32	0.17	3.0	3.4E-01	1,580	308	31	1,017	0.83%	172	14%	137	6	42	6	42	97	290	979	2,936
100	1.58	0.17	1.58	0.17	3.5	2.9E-01	1,342	262	26	863	0.71%	146	12%	117	7	42	7	42	99	297	979	2,936
110	1.84	0.17	1.84	0.17	4.0	2.5E-01	1,166	227	23	750	0.62%	127	10%	101	8	42	8	42	101	304	979	2,936
120	2.10	0.17	2.10	0.17	4.6	2.2E-01	1,030	201	20	663	0.55%	112	9%	90	9	42	9	42	103	310	979	2,936
130	2.37	0.17	2.37	0.17	5.1	2.0E-01	923	180	18	594	0.49%	100	8%	80	11	42	11	42	106	317	979	2,936
140	2.63	0.17	2.63	0.17	5.6	1.8E-01	836	163	16	538	0.44%	91	7%	73	12	42	12	42	108	324	979	2,936
150	2.89	0.17	2.89	0.17	6.1	1.6E-01	763	149	15	491	0.41%	83	7%	66	13	42	13	42	110	331	979	2,936
160	3.16	0.17	3.16	0.17	6.7	1.5E-01	703	137	14	452	0.38%	76	6%	61	14	42	14	42	113	338	979	2,936
170	3.42	0.17	3.42	0.17	7.2	1.4E-01	651	127	13	419	0.35%	71	6%	57	15	42	15	42	115	345	979	2,936
180	3.68	0.17	3.68	0.17	7.7	1.3E-01	606	118	12	390	0.33%	66	5%	53	16	42	16	42	117	352	979	2,936
190	3.95	0.17	3.95	0.17	8.2	1.2E-01	567	111	11	365	0.31%	62	5%	49	18	42	18	42	119	358	979	2,937
200	4.21	0.17	4.21	0.17	8.8	1.1E-01	532	104	10	343	0.29%	58	5%	46	19	42	19	42	122	365	979	2,937
210	4.47	0.17	4.47	0.17	9.3	1.1E-01	502	98	10	323	0.27%	54	4%	44	20	42	20	42	124	372	979	2,937
220	4.73	0.17	4.73	0.17	9.8	1.0E-01	475	93	9	305	0.26%	52	4%	41	21	42	21	42	126	379	979	2,937
230	5.00	0.17	5.00	0.17	10.3	9.7E-02	450	88	9	290	0.25%	49	4%	39	22	42	22	42	129	386	979	2,937
240	5.26	0.17	5.26	0.17	10.9	9.2E-02	428	83	8	275	0.23%	46	4%	37	23	42	23	42	131	393	979	2,937
250	5.52	0.17	5.52	0.17	11.4	8.8E-02	408	80	8	262	0.22%	44	4%	35	25	42	24	42	133	399	979	2,937
260	5.79	0.17	5.79	0.17	11.9	8.4E-02	390	76	8	251	0.21%	42	3%	34	26	42	26	42	135	406	979	2,937
270	6.05	0.17	6.05	0.17	12.4	8.0E-02	373	73	7	240	0.21%	40	3%	32	27	42	27	42	138	413	979	2,937
280	6.31	0.17	6.31	0.17	13.0	7.7E-02	357	70	7	230	0.20%	39	3%	31	28	42	28	42	140	420	979	2,938
290	6.58	0.17	6.58	0.17	13.5	7.4E-02	343	67	7	221	0.19%	37	3%	30	29	42	29	42	142	426	979	2,938
300	6.84	0.17	6.84	0.17	14.0	7.1E-02	330	64	6	212	0.18%	36	3%	29	30	42	30	42	144	433	979	2,938
310	7.10	0.17	7.10	0.17	14.5	6.9E-02	318	62	6	205	0.18%	35	3%	28	32	42	31	42	147	440	979	2,938
320	7.36	0.17	7.36	0.17	15.1	6.6E-02	307	60	6	197	0.17%	33	3%	27	33	42	32	42	149	447	979	2,938
330	7.63	0.17	7.63	0.17	15.6	6.4E-02	296	58	6	191	0.17%	32	3%	26	34	42	34	42	151	453	979	2,938
340	7.89	0.17	7.89	0.17	16.1	6.2E-02	286	56	6	184	0.16%	31	2%	25	35	42	35	42	153	460	979	2,938
350	8.15	0.17	8.15	0.17	16.7	6.0E-02	277	54	5	178	0.16%	30	2%	24	36	42	36	42	156	467	979	2,938
360	8.42	0.17	8.42	0.17	17.2	5.8E-02	268	52	5	173	0.15%	29	2%	23	37	42	37	41	158	474	980	2,939
370	8.68	0.17	8.68	0.17	17.7	5.6E-02	260	51	5	167	0.15%	28	2%	23	39	42	38	41	160	480	980	2,939
380	8.94	0.17	8.94	0.17	18.2	5.5E-02	252	49	5	162	0.14%	27	2%	22	40	42	39	41	162	487	980	2,939
390	9.21	0.17	9.21	0.17	18.8	5.3E-02	245	48	5	158	0.14%	27	2%	21	41	42	40	41	165	494	980	2,939
400	9.47	0.17	9.47	0.17	19.3	5.2E-02	238	46	5	153	0.14%	26	2%	21	42	42	41	41	167	500	980	2,939
410	9.73	0.17	9.73	0.17	19.8	5.0E-02	232	45	5	149	0.13%	25	2%	20	43	42	43	41	169	507	980	2,939
420	9.99	0.17	9.99	0.17	20.3	4.9E-02	226	44	4	145	0.13%	25	2%	20	44	42	44	41	171	514	980	2,940

430	10.26	0.17	10.26	0.17	20.9	4.8E-02	220	43	4	141	0.13%	24	2%	19	45	42	45	41	173	520	980	2,940
440	10.52	0.17	10.52	0.17	21.4	4.7E-02	214	42	4	138	0.12%	23	2%	19	47	42	46	41	176	527	980	2,940
450	10.78	0.17	10.78	0.17	21.9	4.6E-02	209	41	4	134	0.12%	23	2%	18	48	42	47	41	178	534	980	2,940
460	11.05	0.17	11.05	0.17	22.4	4.5E-02	204	40	4	131	0.12%	22	2%	18	49	42	48	41	180	540	980	2,940
470	11.31	0.17	11.31	0.17	23.0	4.4E-02	199	39	4	128	0.12%	22	2%	17	50	42	49	41	182	547	980	2,940
480	11.57	0.17	11.57	0.17	23.5	4.3E-02	194	38	4	125	0.11%	21	2%	17	51	42	50	41	184	553	980	2,941
490	11.84	0.17	11.84	0.17	24.0	4.2E-02	190	37	4	122	0.11%	21	2%	17	52	42	51	41	187	560	980	2,941
500	12.10	0.17	12.10	0.17	24.5	4.1E-02	186	36	4	120	0.11%	20	2%	16	54	42	53	41	189	567	980	2,941
510	12.36	0.17	12.36	0.17	25.1	4.0E-02	182	35	4	117	0.11%	20	2%	16	55	42	54	41	191	573	980	2,941
520	12.62	0.17	12.62	0.17	25.6	3.9E-02	178	35	3	115	0.10%	19	2%	15	56	42	55	41	193	580	980	2,941
530	12.89	0.17	12.89	0.17	26.1	3.8E-02	174	34	3	112	0.10%	19	2%	15	57	42	56	41	195	586	980	2,941
540	13.15	0.17	13.15	0.17	26.6	3.8E-02	171	33	3	110	0.10%	19	1%	15	58	42	57	41	198	593	981	2,942
550	13.41	0.17	13.41	0.17	27.2	3.7E-02	167	33	3	108	0.10%	18	1%	15	59	42	58	41	200	600	981	2,942
560	13.68	0.17	13.68	0.17	27.7	3.6E-02	164	32	3	105	0.10%	18	1%	14	60	42	59	41	202	606	981	2,942
570	13.94	0.17	13.94	0.17	28.2	3.5E-02	161	31	3	103	0.10%	17	1%	14	61	42	60	41	204	613	981	2,942
580	14.20	0.17	14.20	0.17	28.8	3.5E-02	158	31	3	101	0.09%	17	1%	14	63	42	61	41	206	619	981	2,943
590	14.47	0.17	14.47	0.17	29.3	3.4E-02	155	30	3	100	0.09%	17	1%	13	64	42	62	41	209	626	981	2,943
600	14.73	0.17	14.73	0.17	29.8	3.4E-02	152	30	3	98	0.09%	16	1%	13	65	42	63	41	211	632	981	2,943
610	14.99	0.17	14.99	0.17	30.3	3.3E-02	149	29	3	96	0.09%	16	1%	13	66	42	65	41	213	639	981	2,943
620	15.25	0.17	15.25	0.17	30.9	3.2E-02	147	29	3	94	0.09%	16	1%	13	67	42	66	41	215	645	981	2,943
630	15.52	0.17	15.52	0.17	31.4	3.2E-02	144	28	3	93	0.09%	16	1%	13	68	42	67	41	217	652	981	2,944
640	15.78	0.17	15.78	0.17	31.9	3.1E-02	141	28	3	91	0.09%	15	1%	12	69	42	68	41	219	658	981	2,944
650	16.04	0.17	16.04	0.17	32.4	3.1E-02	139	27	3	89	0.08%	15	1%	12	71	42	69	41	222	665	981	2,944
660	16.31	0.17	16.31	0.17	33.0	3.0E-02	137	27	3	88	0.08%	15	1%	12	72	42	70	41	224	671	981	2,944
670	16.57	0.17	16.57	0.17	33.5	3.0E-02	134	26	3	87	0.08%	15	1%	12	73	42	71	41	226	678	981	2,944
680	16.83	0.17	16.83	0.17	34.0	2.9E-02	132	26	3	85	0.08%	14	1%	11	74	42	72	40	228	684	982	2,945
690	17.10	0.17	17.10	0.17	34.5	2.9E-02	130	25	3	84	0.08%	14	1%	11	75	42	73	40	230	691	982	2,945
700	17.36	0.17	17.36	0.17	35.1	2.9E-02	128	25	2	82	0.08%	14	1%	11	76	42	74	40	232	697	982	2,945
710	17.62	0.17	17.62	0.17	35.6	2.8E-02	126	25	2	81	0.08%	14	1%	11	77	41	75	40	235	704	982	2,945
720	17.88	0.17	17.88	0.17	36.1	2.8E-02	124	24	2	80	0.08%	13	1%	11	78	41	76	40	237	710	982	2,946
730	18.15	0.17	18.15	0.17	36.6	2.7E-02	122	24	2	79	0.08%	13	1%	11	80	41	77	40	239	716	982	2,946
740	18.41	0.17	18.41	0.17	37.2	2.7E-02	121	24	2	78	0.08%	13	1%	10	81	41	78	40	241	723	982	2,946
750	18.67	0.17	18.67	0.17	37.7	2.7E-02	119	23	2	76	0.07%	13	1%	10	82	41	80	40	243	729	982	2,946
760	18.94	0.17	18.94	0.17	38.2	2.6E-02	117	23	2	75	0.07%	13	1%	10	83	41	81	40	245	736	982	2,947
770	19.20	0.17	19.20	0.17	38.7	2.6E-02	115	22	2	74	0.07%	13	1%	10	84	41	82	40	247	742	982	2,947
780	19.46	0.17	19.46	0.17	39.3	2.5E-02	114	22	2	73	0.07%	12	1%	10	85	41	83	40	249	748	982	2,947
790	19.73	0.17	19.73	0.17	39.8	2.5E-02	112	22	2	72	0.07%	12	1%	10	86	41	84	40	252	755	982	2,947
800	19.99	0.17	19.99	0.17	40.3	2.5E-02	111	22	2	71	0.07%	12	1%	10	87	41	85	40	254	761	983	2,948
810	20.25	0.17	20.25	0.17	40.8	2.4E-02	109	21	2	70	0.07%	12	1%	9	89	41	86	40	256	768	983	2,948
820	20.51	0.17	20.51	0.17	41.4	2.4E-02	108	21	2	69	0.07%	12	1%	9	90	41	87	40	258	774	983	2,948
830	20.78	0.17	20.78	0.17	41.9	2.4E-02	106	21	2	68	0.07%	12	1%	9	91	41	88	40	260	780	983	2,949
840	21.04	0.17	21.04	0.17	42.4	2.4E-02	105	20	2	67	0.07%	11	1%	9	92	41	89	40	262	787	983	2,949
850	21.30	0.17	21.30	0.17	43.0	2.3E-02	103	20	2	67	0.07%	11	1%	9	93	41	90	40	264	793	983	2,949
860	21.57	0.17	21.57	0.17	43.5	2.3E-02	102	20	2	66	0.07%	11	1%	9	94	41	91	40	266	799	983	2,949
870	21.83	0.17	21.83	0.17	44.0	2.3E-02	101	20	2	65	0.07%	11	1%	9	95	41	92	40	269	806	983	2,950

880	22.09	0.17	22.09	0.17	44.5	2.2E-02	100	19	2	64	0.06%	11	1%	9	96	41	93	40	271	812	983	2,950
890	22.36	0.17	22.36	0.17	45.1	2.2E-02	98	19	2	63	0.06%	11	1%	9	97	41	94	40	273	818	983	2,950
900	22.62	0.17	22.62	0.17	45.6	2.2E-02	97	19	2	62	0.06%	11	1%	8	99	41	95	40	275	824	984	2,951
910	22.88	0.17	22.88	0.17	46.1	2.2E-02	96	19	2	62	0.06%	10	1%	8	100	41	96	40	277	831	984	2,951
920	23.14	0.17	23.14	0.17	46.6	2.1E-02	95	18	2	61	0.06%	10	1%	8	101	41	97	40	279	837	984	2,951
930	23.41	0.17	23.41	0.17	47.2	2.1E-02	94	18	2	60	0.06%	10	1%	8	102	41	98	40	281	843	984	2,951
940	23.67	0.17	23.67	0.17	47.7	2.1E-02	93	18	2	60	0.06%	10	1%	8	103	41	99	40	283	850	984	2,952
950	23.93	0.17	23.93	0.17	48.2	2.1E-02	91	18	2	59	0.06%	10	1%	8	104	41	100	40	285	856	984	2,952
960	24.20	0.17	24.20	0.17	48.7	2.1E-02	90	18	2	58	0.06%	10	1%	8	105	41	101	40	287	862	984	2,952
970	24.46	0.17	24.46	0.17	49.3	2.0E-02	89	17	2	58	0.06%	10	1%	8	106	41	102	40	289	868	984	2,953
980	24.72	0.17	24.72	0.17	49.8	2.0E-02	88	17	2	57	0.06%	10	1%	8	107	41	103	40	292	875	984	2,953
990	24.99	0.17	24.99	0.17	50.3	2.0E-02	87	17	2	56	0.06%	9	1%	8	109	41	105	40	294	881	984	2,953
1,000	25.25	0.17	25.25	0.17	50.8	2.0E-02	86	17	2	56	0.06%	9	1%	8	110	41	106	40	296	887	985	2,954
1,010	25.51	0.17	25.51	0.17	51.4	1.9E-02	85	17	2	55	0.06%	9	1%	7	111	41	107	39	298	893	985	2,954
1,020	25.77	0.17	25.77	0.17	51.9	1.9E-02	85	16	2	54	0.06%	9	1%	7	112	41	108	39	300	899	985	2,954
1,030	26.04	0.17	26.04	0.17	52.4	1.9E-02	84	16	2	54	0.06%	9	1%	7	113	41	109	39	302	906	985	2,955
1,040	26.30	0.17	26.30	0.17	52.9	1.9E-02	83	16	2	53	0.06%	9	1%	7	114	41	110	39	304	912	985	2,955







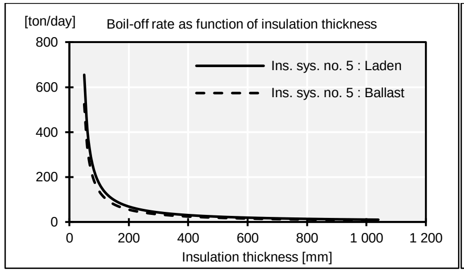
Insulation system 5

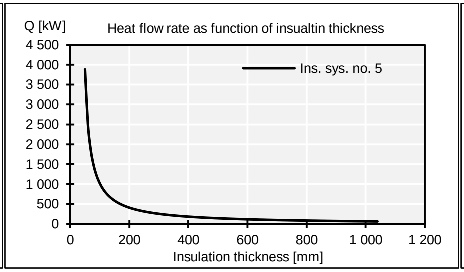
Table type:	Ins. sys. no:	Description:
Insulation characteristics	5	Boil-off rate, insulation sys.- and containment weight

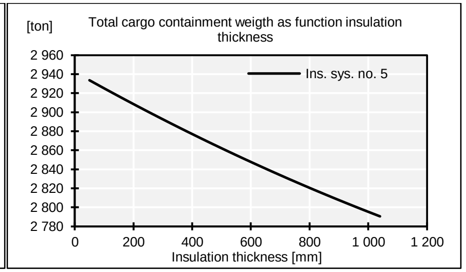
Ins. thick.	R value, U value and therm. conductance (for one containment)							Heat flow rate			Boil-off rate				Insulation system weight						Cont. weight	
t_{INS_TOT}	R_{L1}	R_{L2}	R_{L3}	R_{L4}	R_{INS_TOT}	U_{INS_TOT}	C_{INS_TOT}	Q_{INS}	Q_{SUP}	Q_{TOT}	BOR_{LAD}	BOR_{LAD}	BOR_{BALL}	BOR_{BALL}	W_{L1}	W_{L2}	W_{L3}	W_{L4}	W_{INS}	W_{INS_TOT}	W_C	W_{C_TOT}
[mm]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[W/m2K]	[W/K]	[kW]	[kW]	[kW]	[%/24h]	[ton/day]	[%/24h]	[ton/day]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]
50	0.26	0.17	0.17	0.17	0.8	1.3E+00	6,032	1,176	118	3,882	3.14%	655	52%	524	1	43	1	42	87	260	978	2,934
60	0.53	0.17	0.35	0.17	1.2	8.2E-01	3,871	755	75	2,491	2.02%	420	34%	336	2	43	1	42	88	265	977	2,932
70	0.79	0.17	0.52	0.17	1.7	6.0E-01	2,849	556	56	1,833	1.49%	309	25%	248	4	42	2	42	90	271	977	2,930
80	1.05	0.17	0.69	0.17	2.1	4.8E-01	2,253	439	44	1,450	1.18%	245	20%	196	5	42	2	42	92	276	976	2,929
90	1.32	0.17	0.86	0.17	2.5	4.0E-01	1,863	363	36	1,199	0.98%	202	16%	162	6	42	3	42	94	281	976	2,927
100	1.58	0.17	1.04	0.17	3.0	3.4E-01	1,588	310	31	1,022	0.84%	172	14%	138	7	42	4	42	95	286	975	2,925
110	1.84	0.17	1.21	0.17	3.4	2.9E-01	1,383	270	27	890	0.73%	150	12%	120	8	42	4	42	97	291	974	2,923
120	2.10	0.17	1.38	0.17	3.8	2.6E-01	1,225	239	24	788	0.65%	133	11%	106	9	42	5	42	99	296	974	2,922
130	2.37	0.17	1.55	0.17	4.3	2.3E-01	1,099	214	21	707	0.58%	119	10%	96	11	42	5	42	100	301	973	2,920
140	2.63	0.17	1.73	0.17	4.7	2.1E-01	997	194	19	641	0.53%	108	9%	87	12	42	6	42	102	307	973	2,918
150	2.89	0.17	1.90	0.17	5.1	1.9E-01	911	178	18	586	0.49%	99	8%	79	13	42	6	42	104	312	972	2,917
160	3.16	0.17	2.07	0.17	5.6	1.8E-01	839	164	16	540	0.45%	91	7%	73	14	42	7	42	106	317	972	2,915
170	3.42	0.17	2.24	0.17	6.0	1.7E-01	778	152	15	501	0.42%	84	7%	68	15	42	8	42	107	322	971	2,914
180	3.68	0.17	2.42	0.17	6.4	1.6E-01	725	141	14	466	0.39%	79	6%	63	16	42	8	42	109	327	971	2,912
190	3.95	0.17	2.59	0.17	6.9	1.5E-01	679	132	13	437	0.37%	74	6%	59	18	42	9	42	111	332	970	2,910
200	4.21	0.17	2.76	0.17	7.3	1.4E-01	638	124	12	410	0.34%	69	6%	55	19	42	9	42	112	337	970	2,909
210	4.47	0.17	2.93	0.17	7.7	1.3E-01	601	117	12	387	0.33%	65	5%	52	20	42	10	42	114	342	969	2,907
220	4.73	0.17	3.11	0.17	8.2	1.2E-01	569	111	11	366	0.31%	62	5%	49	21	42	10	42	116	347	968	2,905
230	5.00	0.17	3.28	0.17	8.6	1.2E-01	540	105	11	347	0.29%	59	5%	47	22	42	11	42	118	353	968	2,904
240	5.26	0.17	3.45	0.17	9.1	1.1E-01	513	100	10	330	0.28%	56	4%	45	23	42	12	42	119	358	967	2,902
250	5.52	0.17	3.62	0.17	9.5	1.1E-01	490	95	10	315	0.27%	53	4%	43	25	42	12	42	121	363	967	2,901
260	5.79	0.17	3.80	0.17	9.9	1.0E-01	468	91	9	301	0.26%	51	4%	41	26	42	13	42	123	368	966	2,899
270	6.05	0.17	3.97	0.17	10.4	9.6E-02	448	87	9	288	0.25%	49	4%	39	27	42	13	42	124	373	966	2,897
280	6.31	0.17	4.14	0.17	10.8	9.3E-02	429	84	8	276	0.24%	47	4%	37	28	42	14	42	126	378	965	2,896
290	6.58	0.17	4.31	0.17	11.2	8.9E-02	412	80	8	265	0.23%	45	4%	36	29	42	14	42	128	383	965	2,894
300	6.84	0.17	4.49	0.17	11.7	8.6E-02	397	77	8	255	0.22%	43	3%	34	30	42	15	42	129	388	964	2,893
310	7.10	0.17	4.66	0.17	12.1	8.3E-02	382	75	7	246	0.21%	41	3%	33	32	42	16	42	131	393	964	2,891
320	7.36	0.17	4.83	0.17	12.5	8.0E-02	369	72	7	237	0.21%	40	3%	32	33	42	16	42	133	398	963	2,889
330	7.63	0.17	5.00	0.17	13.0	7.7E-02	356	69	7	229	0.20%	39	3%	31	34	42	17	42	134	403	963	2,888
340	7.89	0.17	5.18	0.17	13.4	7.5E-02	344	67	7	221	0.19%	37	3%	30	35	42	17	42	136	408	962	2,886
350	8.15	0.17	5.35	0.17	13.8	7.2E-02	333	65	6	214	0.19%	36	3%	29	36	42	18	42	138	413	962	2,885
360	8.42	0.17	5.52	0.17	14.3	7.0E-02	323	63	6	208	0.18%	35	3%	28	37	42	18	41	139	418	961	2,883
370	8.68	0.17	5.69	0.17	14.7	6.8E-02	313	61	6	201	0.18%	34	3%	27	39	42	19	41	141	423	961	2,882
380	8.94	0.17	5.87	0.17	15.2	6.6E-02	304	59	6	195	0.17%	33	3%	26	40	42	20	41	143	428	960	2,880
390	9.21	0.17	6.04	0.17	15.6	6.4E-02	295	58	6	190	0.17%	32	3%	26	41	42	20	41	144	433	960	2,879
400	9.47	0.17	6.21	0.17	16.0	6.2E-02	287	56	6	185	0.16%	31	2%	25	42	42	21	41	146	438	959	2,877
410	9.73	0.17	6.38	0.17	16.5	6.1E-02	279	54	5	180	0.16%	30	2%	24	43	42	21	41	148	443	959	2,876
420	9.99	0.17	6.56	0.17	16.9	5.9E-02	272	53	5	175	0.16%	29	2%	24	44	42	22	41	149	448	958	2,874

430	10.26	0.17	6.73	0.17	17.3	5.8E-02	265	52	5	170	0.15%	29	2%	23	45	42	22	41	151	453	958	2,873
440	10.52	0.17	6.90	0.17	17.8	5.6E-02	258	50	5	166	0.15%	28	2%	22	47	42	23	41	153	458	957	2,871
450	10.78	0.17	7.07	0.17	18.2	5.5E-02	252	49	5	162	0.15%	27	2%	22	48	42	23	41	154	463	957	2,870
460	11.05	0.17	7.25	0.17	18.6	5.4E-02	245	48	5	158	0.14%	27	2%	21	49	42	24	41	156	468	956	2,868
470	11.31	0.17	7.42	0.17	19.1	5.2E-02	240	47	5	154	0.14%	26	2%	21	50	42	25	41	158	473	956	2,867
480	11.57	0.17	7.59	0.17	19.5	5.1E-02	234	46	5	151	0.14%	25	2%	20	51	42	25	41	159	478	955	2,865
490	11.84	0.17	7.76	0.17	19.9	5.0E-02	229	45	4	147	0.13%	25	2%	20	52	42	26	41	161	483	955	2,864
500	12.10	0.17	7.94	0.17	20.4	4.9E-02	224	44	4	144	0.13%	24	2%	19	54	42	26	41	163	488	954	2,862
510	12.36	0.17	8.11	0.17	20.8	4.8E-02	219	43	4	141	0.13%	24	2%	19	55	42	27	41	164	493	954	2,861
520	12.62	0.17	8.28	0.17	21.3	4.7E-02	214	42	4	138	0.13%	23	2%	19	56	42	27	41	166	498	953	2,859
530	12.89	0.17	8.45	0.17	21.7	4.6E-02	210	41	4	135	0.12%	23	2%	18	57	42	28	41	168	503	953	2,858
540	13.15	0.17	8.63	0.17	22.1	4.5E-02	206	40	4	132	0.12%	22	2%	18	58	42	28	41	169	508	952	2,856
550	13.41	0.17	8.80	0.17	22.6	4.4E-02	201	39	4	130	0.12%	22	2%	18	59	42	29	41	171	513	952	2,855
560	13.68	0.17	8.97	0.17	23.0	4.3E-02	197	39	4	127	0.12%	21	2%	17	60	42	30	41	172	517	951	2,853
570	13.94	0.17	9.14	0.17	23.4	4.3E-02	194	38	4	125	0.12%	21	2%	17	61	42	30	41	174	522	951	2,852
580	14.20	0.17	9.32	0.17	23.9	4.2E-02	190	37	4	122	0.11%	21	2%	17	63	42	31	41	176	527	950	2,851
590	14.47	0.17	9.49	0.17	24.3	4.1E-02	186	36	4	120	0.11%	20	2%	16	64	42	31	41	177	532	950	2,849
600	14.73	0.17	9.66	0.17	24.7	4.0E-02	183	36	4	118	0.11%	20	2%	16	65	42	32	41	179	537	949	2,848
610	14.99	0.17	9.83	0.17	25.2	4.0E-02	180	35	4	116	0.11%	20	2%	16	66	42	32	41	181	542	949	2,846
620	15.25	0.17	10.01	0.17	25.6	3.9E-02	177	34	3	114	0.11%	19	2%	15	67	42	33	41	182	547	948	2,845
630	15.52	0.17	10.18	0.17	26.0	3.8E-02	173	34	3	112	0.11%	19	2%	15	68	42	33	41	184	552	948	2,844
640	15.78	0.17	10.35	0.17	26.5	3.8E-02	170	33	3	110	0.10%	19	1%	15	69	42	34	41	186	557	947	2,842
650	16.04	0.17	10.52	0.17	26.9	3.7E-02	168	33	3	108	0.10%	18	1%	15	71	42	34	41	187	561	947	2,841
660	16.31	0.17	10.70	0.17	27.3	3.7E-02	165	32	3	106	0.10%	18	1%	14	72	42	35	41	189	566	946	2,839
670	16.57	0.17	10.87	0.17	27.8	3.6E-02	162	32	3	104	0.10%	18	1%	14	73	42	36	41	190	571	946	2,838
680	16.83	0.17	11.04	0.17	28.2	3.5E-02	159	31	3	103	0.10%	17	1%	14	74	42	36	40	192	576	946	2,837
690	17.10	0.17	11.21	0.17	28.7	3.5E-02	157	31	3	101	0.10%	17	1%	14	75	42	37	40	194	581	945	2,835
700	17.36	0.17	11.39	0.17	29.1	3.4E-02	154	30	3	99	0.10%	17	1%	13	76	42	37	40	195	586	945	2,834
710	17.62	0.17	11.56	0.17	29.5	3.4E-02	152	30	3	98	0.09%	17	1%	13	77	41	38	40	197	591	944	2,832
720	17.88	0.17	11.73	0.17	30.0	3.3E-02	150	29	3	96	0.09%	16	1%	13	78	41	38	40	198	595	944	2,831
730	18.15	0.17	11.90	0.17	30.4	3.3E-02	148	29	3	95	0.09%	16	1%	13	80	41	39	40	200	600	943	2,830
740	18.41	0.17	12.08	0.17	30.8	3.2E-02	145	28	3	94	0.09%	16	1%	13	81	41	39	40	202	605	943	2,828
750	18.67	0.17	12.25	0.17	31.3	3.2E-02	143	28	3	92	0.09%	16	1%	12	82	41	40	40	203	610	942	2,827
760	18.94	0.17	12.42	0.17	31.7	3.2E-02	141	28	3	91	0.09%	15	1%	12	83	41	40	40	205	615	942	2,826
770	19.20	0.17	12.59	0.17	32.1	3.1E-02	139	27	3	90	0.09%	15	1%	12	84	41	41	40	207	620	941	2,824
780	19.46	0.17	12.77	0.17	32.6	3.1E-02	137	27	3	88	0.09%	15	1%	12	85	41	41	40	208	624	941	2,823
790	19.73	0.17	12.94	0.17	33.0	3.0E-02	135	26	3	87	0.09%	15	1%	12	86	41	42	40	210	629	941	2,822
800	19.99	0.17	13.11	0.17	33.4	3.0E-02	133	26	3	86	0.08%	14	1%	12	87	41	42	40	211	634	940	2,820
810	20.25	0.17	13.28	0.17	33.9	3.0E-02	132	26	3	85	0.08%	14	1%	11	89	41	43	40	213	639	940	2,819
820	20.51	0.17	13.46	0.17	34.3	2.9E-02	130	25	3	84	0.08%	14	1%	11	90	41	43	40	214	643	939	2,818
830	20.78	0.17	13.63	0.17	34.8	2.9E-02	128	25	2	82	0.08%	14	1%	11	91	41	44	40	216	648	939	2,817
840	21.04	0.17	13.80	0.17	35.2	2.8E-02	126	25	2	81	0.08%	14	1%	11	92	41	45	40	218	653	938	2,815
850	21.30	0.17	13.97	0.17	35.6	2.8E-02	125	24	2	80	0.08%	14	1%	11	93	41	45	40	219	658	938	2,814
860	21.57	0.17	14.15	0.17	36.1	2.8E-02	123	24	2	79	0.08%	13	1%	11	94	41	46	40	221	663	938	2,813
870	21.83	0.17	14.32	0.17	36.5	2.7E-02	122	24	2	78	0.08%	13	1%	11	95	41	46	40	222	667	937	2,811

880	22.09	0.17	14.49	0.17	36.9	2.7E-02	120	23	2	77	0.08%	13	1%	10	96	41	47	40	224	672	937	2,810
890	22.36	0.17	14.66	0.17	37.4	2.7E-02	119	23	2	76	0.08%	13	1%	10	97	41	47	40	226	677	936	2,809
900	22.62	0.17	14.84	0.17	37.8	2.6E-02	117	23	2	75	0.08%	13	1%	10	99	41	48	40	227	682	936	2,808
910	22.88	0.17	15.01	0.17	38.2	2.6E-02	116	23	2	74	0.08%	13	1%	10	100	41	48	40	229	686	935	2,806
920	23.14	0.17	15.18	0.17	38.7	2.6E-02	114	22	2	74	0.08%	12	1%	10	101	41	49	40	230	691	935	2,805
930	23.41	0.17	15.35	0.17	39.1	2.6E-02	113	22	2	73	0.07%	12	1%	10	102	41	49	40	232	696	935	2,804
940	23.67	0.17	15.53	0.17	39.5	2.5E-02	112	22	2	72	0.07%	12	1%	10	103	41	50	40	234	701	934	2,803
950	23.93	0.17	15.70	0.17	40.0	2.5E-02	110	22	2	71	0.07%	12	1%	10	104	41	50	40	235	705	934	2,801
960	24.20	0.17	15.87	0.17	40.4	2.5E-02	109	21	2	70	0.07%	12	1%	9	105	41	51	40	237	710	933	2,800
970	24.46	0.17	16.04	0.17	40.8	2.4E-02	108	21	2	69	0.07%	12	1%	9	106	41	51	40	238	715	933	2,799
980	24.72	0.17	16.22	0.17	41.3	2.4E-02	107	21	2	69	0.07%	12	1%	9	107	41	52	40	240	719	933	2,798
990	24.99	0.17	16.39	0.17	41.7	2.4E-02	105	21	2	68	0.07%	11	1%	9	109	41	52	40	241	724	932	2,797
1,000	25.25	0.17	16.56	0.17	42.2	2.4E-02	104	20	2	67	0.07%	11	1%	9	110	41	53	40	243	729	932	2,795
1,010	25.51	0.17	16.73	0.17	42.6	2.3E-02	103	20	2	66	0.07%	11	1%	9	111	41	53	39	244	733	931	2,794
1,020	25.77	0.17	16.91	0.17	43.0	2.3E-02	102	20	2	66	0.07%	11	1%	9	112	41	54	39	246	738	931	2,793
1,030	26.04	0.17	17.08	0.17	43.5	2.3E-02	101	20	2	65	0.07%	11	1%	9	113	41	54	39	248	743	931	2,792
1,040	26.30	0.17	17.25	0.17	43.9	2.3E-02	100	19	2	64	0.07%	11	1%	9	114	41	55	39	249	747	930	2,791





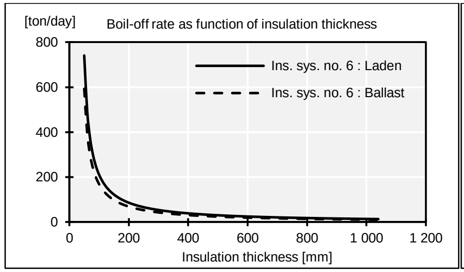


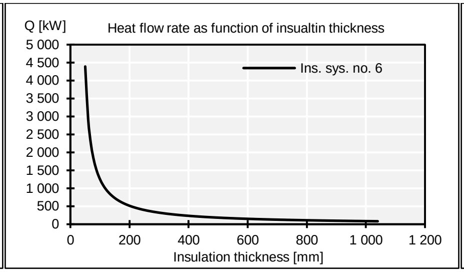
Insulation system 6

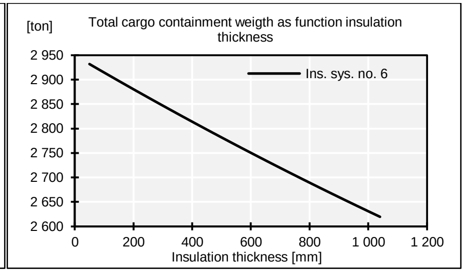
Table type:		Ins. sys. no:	Description:																			
Insulation characteristics		6	Boil-off rate, insulation sys.- and containment weight																			
Ins. thick.	R value, U value and therm. conductance (for one containment)							Heat flow rate			Boil-off rate				Insulation system weight						Cont. weight	
t_{INS_TOT}	R_{L1}	R_{L2}	R_{L3}	R_{L4}	R_{INS_TOT}	U_{INS_TOT}	C_{INS_TOT}	Q_{INS}	Q_{SUP}	Q_{TOT}	BOR_{LAD}	BOR_{LAD}	BOR_{BALL}	BOR_{BALL}	W_{L1}	W_{L2}	W_{L3}	W_{L4}	W_{INS}	W_{INS_TOT}	W_C	W_{C_TOT}
[mm]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[m2K/W]	[W/m2K]	[W/K]	[kW]	[kW]	[kW]	[%/24h]	[ton/day]	[%/24h]	[ton/day]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]	[ton]
50	0.17	0.17	0.17	0.17	0.7	1.4E+00	6,822	1,330	133	4,390	3.55%	741	59%	593	1	43	1	42	86	258	977	2,932
60	0.35	0.17	0.35	0.17	1.0	9.6E-01	4,547	887	89	2,926	2.37%	494	40%	395	1	43	1	42	87	262	976	2,928
70	0.52	0.17	0.52	0.17	1.4	7.2E-01	3,409	665	66	2,194	1.78%	370	30%	296	2	42	2	42	88	265	975	2,925
80	0.69	0.17	0.69	0.17	1.7	5.8E-01	2,726	532	53	1,754	1.43%	296	24%	237	2	42	2	42	90	269	974	2,921
90	0.86	0.17	0.86	0.17	2.1	4.8E-01	2,270	443	44	1,461	1.19%	247	20%	197	3	42	3	42	91	272	973	2,918
100	1.04	0.17	1.04	0.17	2.4	4.1E-01	1,945	379	38	1,251	1.02%	211	17%	169	4	42	4	42	92	275	972	2,915
110	1.21	0.17	1.21	0.17	2.8	3.6E-01	1,700	332	33	1,094	0.90%	185	15%	148	4	42	4	42	93	279	970	2,911
120	1.38	0.17	1.38	0.17	3.1	3.2E-01	1,510	295	29	972	0.80%	164	13%	131	5	42	5	42	94	282	969	2,908
130	1.55	0.17	1.55	0.17	3.5	2.9E-01	1,358	265	26	874	0.72%	148	12%	118	5	42	5	42	95	286	968	2,904
140	1.73	0.17	1.73	0.17	3.8	2.6E-01	1,234	241	24	794	0.66%	134	11%	107	6	42	6	42	96	289	967	2,901
150	1.90	0.17	1.90	0.17	4.1	2.4E-01	1,130	220	22	727	0.60%	123	10%	98	6	42	6	42	97	292	966	2,897
160	2.07	0.17	2.07	0.17	4.5	2.2E-01	1,043	203	20	671	0.56%	113	9%	91	7	42	7	42	99	296	965	2,894
170	2.24	0.17	2.24	0.17	4.8	2.1E-01	968	189	19	623	0.52%	105	8%	84	8	42	8	42	100	299	964	2,891
180	2.42	0.17	2.42	0.17	5.2	1.9E-01	902	176	18	581	0.49%	98	8%	78	8	42	8	42	101	302	962	2,887
190	2.59	0.17	2.59	0.17	5.5	1.8E-01	845	165	16	544	0.46%	92	7%	73	9	42	9	42	102	306	961	2,884
200	2.76	0.17	2.76	0.17	5.9	1.7E-01	795	155	16	512	0.43%	86	7%	69	9	42	9	42	103	309	960	2,880
210	2.93	0.17	2.93	0.17	6.2	1.6E-01	750	146	15	483	0.41%	81	7%	65	10	42	10	42	104	312	959	2,877
220	3.11	0.17	3.11	0.17	6.6	1.5E-01	710	139	14	457	0.39%	77	6%	62	11	42	10	42	105	316	958	2,874
230	3.28	0.17	3.28	0.17	6.9	1.4E-01	674	131	13	434	0.37%	73	6%	59	11	42	11	42	106	319	957	2,870
240	3.45	0.17	3.45	0.17	7.2	1.4E-01	642	125	13	413	0.35%	70	6%	56	12	42	12	42	107	322	956	2,867
250	3.62	0.17	3.62	0.17	7.6	1.3E-01	612	119	12	394	0.34%	66	5%	53	12	42	12	42	109	326	955	2,864
260	3.80	0.17	3.80	0.17	7.9	1.3E-01	585	114	11	376	0.32%	64	5%	51	13	42	13	42	110	329	953	2,860
270	3.97	0.17	3.97	0.17	8.3	1.2E-01	560	109	11	361	0.31%	61	5%	49	13	42	13	42	111	332	952	2,857
280	4.14	0.17	4.14	0.17	8.6	1.2E-01	537	105	10	346	0.30%	58	5%	47	14	42	14	42	112	336	951	2,854
290	4.31	0.17	4.31	0.17	9.0	1.1E-01	516	101	10	332	0.29%	56	4%	45	15	42	14	42	113	339	950	2,850
300	4.49	0.17	4.49	0.17	9.3	1.1E-01	497	97	10	320	0.28%	54	4%	43	15	42	15	42	114	342	949	2,847
310	4.66	0.17	4.66	0.17	9.7	1.0E-01	479	93	9	308	0.27%	52	4%	42	16	42	16	42	115	346	948	2,844
320	4.83	0.17	4.83	0.17	10.0	1.0E-01	462	90	9	297	0.26%	50	4%	40	16	42	16	42	116	349	947	2,840
330	5.00	0.17	5.00	0.17	10.4	9.7E-02	446	87	9	287	0.25%	48	4%	39	17	42	17	42	117	352	946	2,837
340	5.18	0.17	5.18	0.17	10.7	9.3E-02	432	84	8	278	0.24%	47	4%	38	18	42	17	42	118	355	945	2,834
350	5.35	0.17	5.35	0.17	11.0	9.1E-02	418	81	8	269	0.23%	45	4%	36	18	42	18	42	120	359	943	2,830
360	5.52	0.17	5.52	0.17	11.4	8.8E-02	405	79	8	260	0.23%	44	4%	35	19	42	18	41	121	362	942	2,827
370	5.69	0.17	5.69	0.17	11.7	8.5E-02	393	77	8	253	0.22%	43	3%	34	19	42	19	41	122	365	941	2,824
380	5.87	0.17	5.87	0.17	12.1	8.3E-02	381	74	7	245	0.22%	41	3%	33	20	42	20	41	123	369	940	2,821
390	6.04	0.17	6.04	0.17	12.4	8.1E-02	370	72	7	238	0.21%	40	3%	32	20	42	20	41	124	372	939	2,817
400	6.21	0.17	6.21	0.17	12.8	7.8E-02	360	70	7	232	0.21%	39	3%	31	21	42	21	41	125	375	938	2,814
410	6.38	0.17	6.38	0.17	13.1	7.6E-02	350	68	7	225	0.20%	38	3%	30	22	42	21	41	126	378	937	2,811
420	6.56	0.17	6.56	0.17	13.5	7.4E-02	341	66	7	219	0.20%	37	3%	30	22	42	22	41	127	382	936	2,808

430	6.73	0.17	6.73	0.17	13.8	7.2E-02	332	65	6	214	0.19%	36	3%	29	23	42	22	41	128	385	935	2,804
440	6.90	0.17	6.90	0.17	14.1	7.1E-02	324	63	6	208	0.19%	35	3%	28	23	42	23	41	129	388	934	2,801
450	7.07	0.17	7.07	0.17	14.5	6.9E-02	316	62	6	203	0.18%	34	3%	27	24	42	23	41	130	391	933	2,798
460	7.25	0.17	7.25	0.17	14.8	6.7E-02	308	60	6	198	0.18%	33	3%	27	24	42	24	41	132	395	932	2,795
470	7.42	0.17	7.42	0.17	15.2	6.6E-02	301	59	6	194	0.17%	33	3%	26	25	42	25	41	133	398	930	2,791
480	7.59	0.17	7.59	0.17	15.5	6.4E-02	294	57	6	189	0.17%	32	3%	26	26	42	25	41	134	401	929	2,788
490	7.76	0.17	7.76	0.17	15.9	6.3E-02	288	56	6	185	0.17%	31	2%	25	26	42	26	41	135	404	928	2,785
500	7.94	0.17	7.94	0.17	16.2	6.2E-02	281	55	5	181	0.16%	31	2%	24	27	42	26	41	136	408	927	2,782
510	8.11	0.17	8.11	0.17	16.6	6.0E-02	275	54	5	177	0.16%	30	2%	24	27	42	27	41	137	411	926	2,779
520	8.28	0.17	8.28	0.17	16.9	5.9E-02	269	53	5	173	0.16%	29	2%	23	28	42	27	41	138	414	925	2,776
530	8.45	0.17	8.45	0.17	17.3	5.8E-02	264	51	5	170	0.16%	29	2%	23	28	42	28	41	139	417	924	2,772
540	8.63	0.17	8.63	0.17	17.6	5.7E-02	258	50	5	166	0.15%	28	2%	22	29	42	28	41	140	421	923	2,769
550	8.80	0.17	8.80	0.17	17.9	5.6E-02	253	49	5	163	0.15%	28	2%	22	30	42	29	41	141	424	922	2,766
560	8.97	0.17	8.97	0.17	18.3	5.5E-02	248	48	5	160	0.15%	27	2%	22	30	42	30	41	142	427	921	2,763
570	9.14	0.17	9.14	0.17	18.6	5.4E-02	244	47	5	157	0.15%	26	2%	21	31	42	30	41	143	430	920	2,760
580	9.32	0.17	9.32	0.17	19.0	5.3E-02	239	47	5	154	0.14%	26	2%	21	31	42	31	41	144	433	919	2,757
590	9.49	0.17	9.49	0.17	19.3	5.2E-02	234	46	5	151	0.14%	25	2%	20	32	42	31	41	146	437	918	2,754
600	9.66	0.17	9.66	0.17	19.7	5.1E-02	230	45	4	148	0.14%	25	2%	20	32	42	32	41	147	440	917	2,750
610	9.83	0.17	9.83	0.17	20.0	5.0E-02	226	44	4	145	0.14%	25	2%	20	33	42	32	41	148	443	916	2,747
620	10.01	0.17	10.01	0.17	20.4	4.9E-02	222	43	4	143	0.13%	24	2%	19	34	42	33	41	149	446	915	2,744
630	10.18	0.17	10.18	0.17	20.7	4.8E-02	218	43	4	140	0.13%	24	2%	19	34	42	33	41	150	449	914	2,741
640	10.35	0.17	10.35	0.17	21.0	4.8E-02	214	42	4	138	0.13%	23	2%	19	35	42	34	41	151	452	913	2,738
650	10.52	0.17	10.52	0.17	21.4	4.7E-02	211	41	4	136	0.13%	23	2%	18	35	42	34	41	152	456	912	2,735
660	10.70	0.17	10.70	0.17	21.7	4.6E-02	207	40	4	133	0.13%	23	2%	18	36	42	35	41	153	459	911	2,732
670	10.87	0.17	10.87	0.17	22.1	4.5E-02	204	40	4	131	0.13%	22	2%	18	36	42	36	41	154	462	910	2,729
680	11.04	0.17	11.04	0.17	22.4	4.5E-02	201	39	4	129	0.12%	22	2%	17	37	42	36	40	155	465	909	2,726
690	11.21	0.17	11.21	0.17	22.8	4.4E-02	197	39	4	127	0.12%	21	2%	17	38	42	37	40	156	468	908	2,723
700	11.39	0.17	11.39	0.17	23.1	4.3E-02	194	38	4	125	0.12%	21	2%	17	38	42	37	40	157	471	907	2,720
710	11.56	0.17	11.56	0.17	23.5	4.3E-02	191	37	4	123	0.12%	21	2%	17	39	41	38	40	158	475	905	2,716
720	11.73	0.17	11.73	0.17	23.8	4.2E-02	188	37	4	121	0.12%	20	2%	16	39	41	38	40	159	478	904	2,713
730	11.90	0.17	11.90	0.17	24.2	4.1E-02	186	36	4	119	0.12%	20	2%	16	40	41	39	40	160	481	903	2,710
740	12.08	0.17	12.08	0.17	24.5	4.1E-02	183	36	4	118	0.11%	20	2%	16	40	41	39	40	161	484	902	2,707
750	12.25	0.17	12.25	0.17	24.8	4.0E-02	180	35	4	116	0.11%	20	2%	16	41	41	40	40	162	487	901	2,704
760	12.42	0.17	12.42	0.17	25.2	4.0E-02	178	35	3	114	0.11%	19	2%	15	41	41	40	40	163	490	900	2,701
770	12.59	0.17	12.59	0.17	25.5	3.9E-02	175	34	3	113	0.11%	19	2%	15	42	41	41	40	164	493	899	2,698
780	12.77	0.17	12.77	0.17	25.9	3.9E-02	173	34	3	111	0.11%	19	2%	15	43	41	41	40	166	497	898	2,695
790	12.94	0.17	12.94	0.17	26.2	3.8E-02	170	33	3	110	0.11%	18	1%	15	43	41	42	40	167	500	897	2,692
800	13.11	0.17	13.11	0.17	26.6	3.8E-02	168	33	3	108	0.11%	18	1%	15	44	41	42	40	168	503	896	2,689
810	13.28	0.17	13.28	0.17	26.9	3.7E-02	166	32	3	107	0.11%	18	1%	14	44	41	43	40	169	506	895	2,686
820	13.46	0.17	13.46	0.17	27.3	3.7E-02	163	32	3	105	0.10%	18	1%	14	45	41	43	40	170	509	894	2,683
830	13.63	0.17	13.63	0.17	27.6	3.6E-02	161	31	3	104	0.10%	18	1%	14	45	41	44	40	171	512	893	2,680
840	13.80	0.17	13.80	0.17	27.9	3.6E-02	159	31	3	102	0.10%	17	1%	14	46	41	45	40	172	515	892	2,677
850	13.97	0.17	13.97	0.17	28.3	3.5E-02	157	31	3	101	0.10%	17	1%	14	47	41	45	40	173	518	891	2,674
860	14.15	0.17	14.15	0.17	28.6	3.5E-02	155	30	3	100	0.10%	17	1%	13	47	41	46	40	174	521	891	2,672
870	14.32	0.17	14.32	0.17	29.0	3.5E-02	153	30	3	99	0.10%	17	1%	13	48	41	46	40	175	524	890	2,669

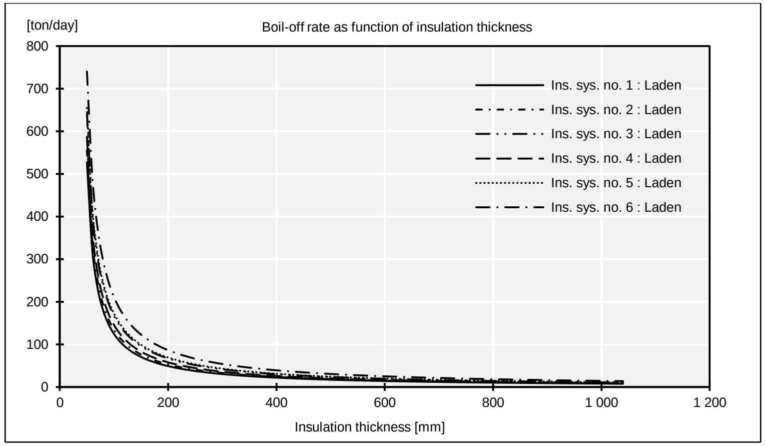
880	14.49	0.17	14.49	0.17	29.3	3.4E-02	151	29	3	97	0.10%	16	1%	13	48	41	47	40	176	528	889	2,666
890	14.66	0.17	14.66	0.17	29.7	3.4E-02	149	29	3	96	0.10%	16	1%	13	49	41	47	40	177	531	888	2,663
900	14.84	0.17	14.84	0.17	30.0	3.3E-02	147	29	3	95	0.10%	16	1%	13	49	41	48	40	178	534	887	2,660
910	15.01	0.17	15.01	0.17	30.4	3.3E-02	146	28	3	94	0.10%	16	1%	13	50	41	48	40	179	537	886	2,657
920	15.18	0.17	15.18	0.17	30.7	3.3E-02	144	28	3	93	0.09%	16	1%	13	50	41	49	40	180	540	885	2,654
930	15.35	0.17	15.35	0.17	31.1	3.2E-02	142	28	3	92	0.09%	15	1%	12	51	41	49	40	181	543	884	2,651
940	15.53	0.17	15.53	0.17	31.4	3.2E-02	141	27	3	90	0.09%	15	1%	12	51	41	50	40	182	546	883	2,648
950	15.70	0.17	15.70	0.17	31.7	3.2E-02	139	27	3	89	0.09%	15	1%	12	52	41	50	40	183	549	882	2,645
960	15.87	0.17	15.87	0.17	32.1	3.1E-02	137	27	3	88	0.09%	15	1%	12	53	41	51	40	184	552	881	2,642
970	16.04	0.17	16.04	0.17	32.4	3.1E-02	136	26	3	87	0.09%	15	1%	12	53	41	51	40	185	555	880	2,640
980	16.22	0.17	16.22	0.17	32.8	3.1E-02	134	26	3	86	0.09%	15	1%	12	54	41	52	40	186	558	879	2,637
990	16.39	0.17	16.39	0.17	33.1	3.0E-02	133	26	3	85	0.09%	14	1%	12	54	41	52	40	187	561	878	2,634
1,000	16.56	0.17	16.56	0.17	33.5	3.0E-02	131	26	3	84	0.09%	14	1%	11	55	41	53	40	188	564	877	2,631
1,010	16.73	0.17	16.73	0.17	33.8	3.0E-02	130	25	3	84	0.09%	14	1%	11	55	41	53	39	189	567	876	2,628
1,020	16.91	0.17	16.91	0.17	34.2	2.9E-02	128	25	3	83	0.09%	14	1%	11	56	41	54	39	190	570	875	2,625
1,030	17.08	0.17	17.08	0.17	34.5	2.9E-02	127	25	2	82	0.09%	14	1%	11	56	41	54	39	191	573	874	2,622
1,040	17.25	0.17	17.25	0.17	34.8	2.9E-02	126	25	2	81	0.09%	14	1%	11	57	41	55	39	192	576	873	2,620

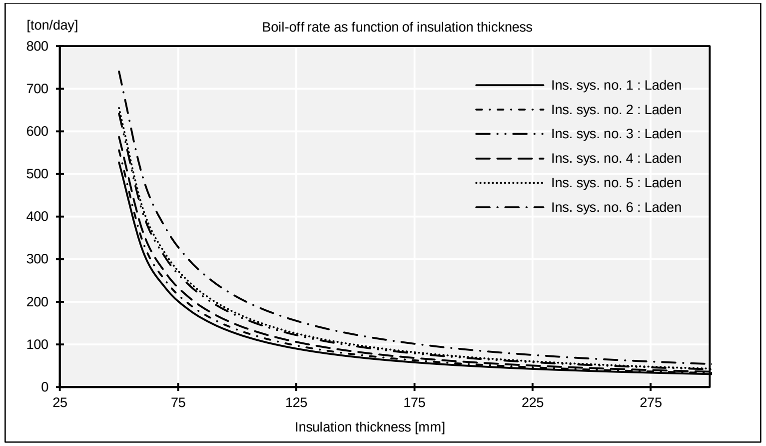


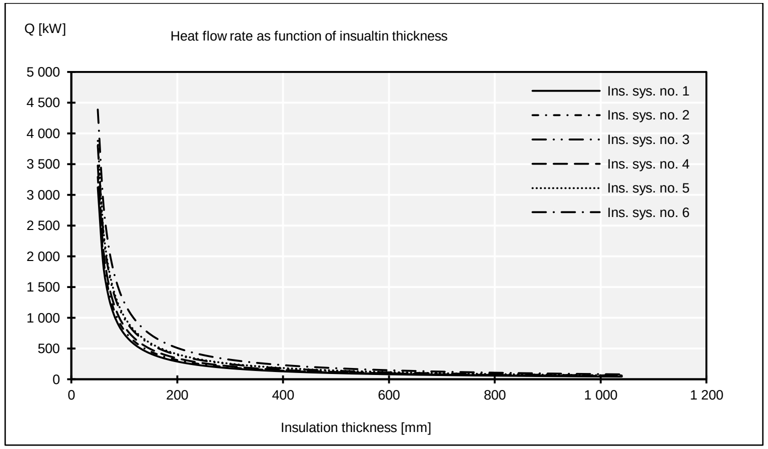


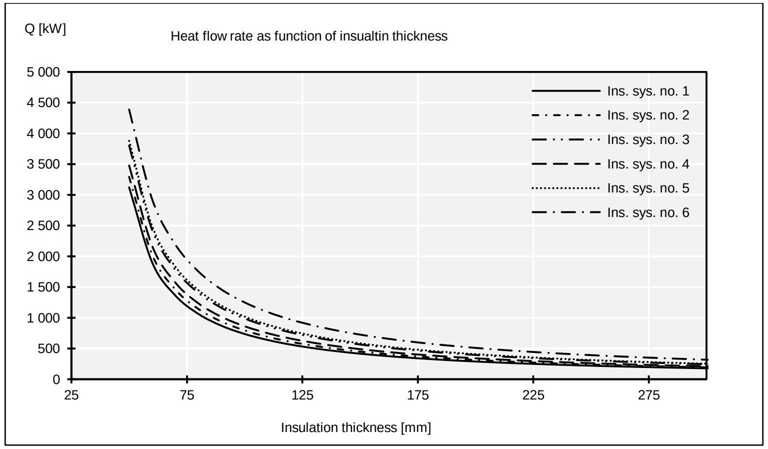


Insulation system comparison

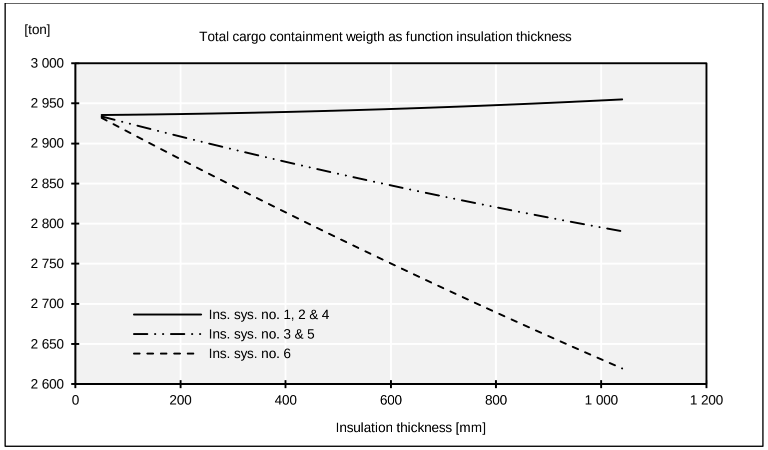








Containment system weight comparison



Appendix 7

Voyage rate

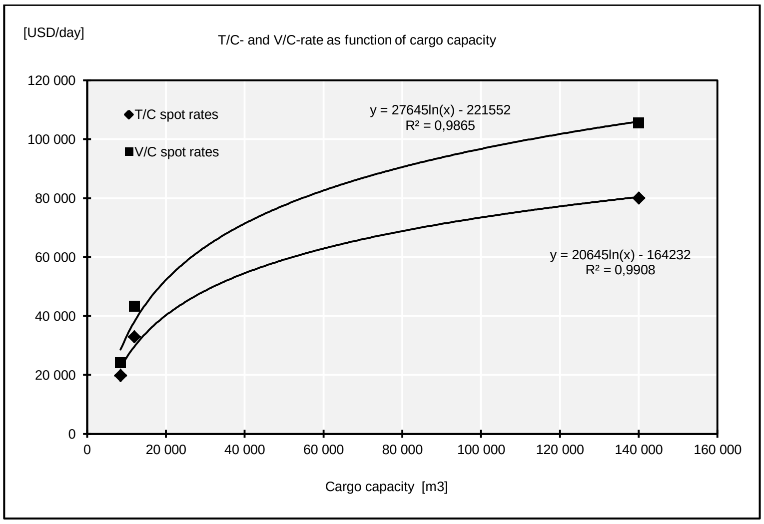
T/C spot rate input

T/C spot rates		
[m3]	[USD/month]	[USD/day]
8,500	600,000	19,737
12,000	1,000,000	32,895
140,000	2,432,000	80,000

V/C spot rate output

V/C spot rates		
[m3]	[USD/month]	[USD/day]
8,500	720,000	24,000
12,000	1,300,000	43,333
140,000	3,161,600	105,387

T/C-rate and V/C-rate as function of cargo capacity

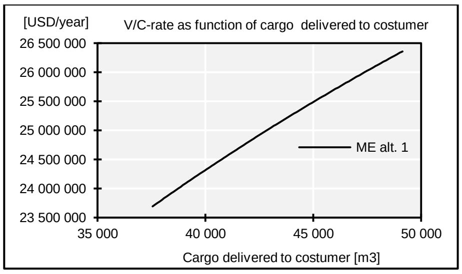


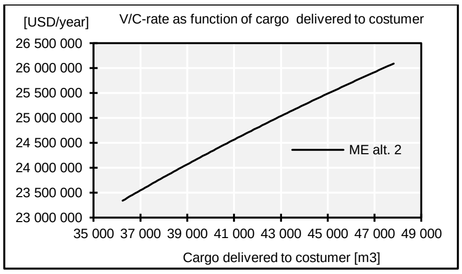
Freight work and V/C-rate as function of ins. thickness.

Insulation thickness	ME alt. 1			ME alt. 2		
t_{INS_TOT}	Cargo delivered to costumer	V/C rate	V/C rate	Cargo delivered to costumer	V/C rate	V/C rate
[mm]	[m3]	[USD/day]	[USD/year]	[m3]	[USD/day]	[USD/year]
50	49,127	72,224	26,361,657	47,817	71,489	26,093,389
60	49,001	72,154	26,336,069	47,691	71,417	26,067,099
70	48,874	72,083	26,310,456	47,564	71,345	26,040,782
80	48,748	72,013	26,284,816	47,438	71,272	26,014,435
90	48,622	71,943	26,259,151	47,313	71,200	25,988,060
100	48,497	71,872	26,233,459	47,187	71,128	25,961,656
110	48,371	71,802	26,207,741	47,061	71,055	25,935,223
120	48,246	71,731	26,181,997	46,936	70,983	25,908,761
130	48,121	71,661	26,156,226	46,811	70,910	25,882,270
140	47,996	71,590	26,130,429	46,686	70,838	25,855,751
150	47,871	71,519	26,104,606	46,561	70,765	25,829,202
160	47,747	71,449	26,078,756	46,437	70,692	25,802,623
170	47,622	71,378	26,052,879	46,313	70,619	25,776,016
180	47,498	71,307	26,026,976	46,188	70,546	25,749,379
190	47,374	71,236	26,001,046	46,065	70,473	25,722,713
200	47,251	71,165	25,975,089	45,941	70,400	25,696,017
210	47,127	71,093	25,949,106	45,817	70,327	25,669,292
220	47,004	71,022	25,923,095	45,694	70,254	25,642,537
230	46,881	70,951	25,897,058	45,571	70,180	25,615,752
240	46,758	70,879	25,870,994	45,448	70,107	25,588,937
250	46,635	70,808	25,844,902	45,325	70,033	25,562,093
260	46,513	70,736	25,818,783	45,203	69,960	25,535,218
270	46,390	70,665	25,792,638	45,080	69,886	25,508,314
280	46,268	70,593	25,766,464	44,958	69,812	25,481,379

290	46,146	70,521	25,740,264	44,836	69,738	25,454,414
300	46,024	70,449	25,714,036	44,714	69,664	25,427,419
310	45,903	70,377	25,687,781	44,593	69,590	25,400,393
320	45,781	70,305	25,661,498	44,471	69,516	25,373,337
330	45,660	70,233	25,635,187	44,350	69,442	25,346,251
340	45,539	70,161	25,608,849	44,229	69,367	25,319,134
350	45,418	70,089	25,582,483	44,108	69,293	25,291,986
360	45,298	70,017	25,556,090	43,988	69,219	25,264,807
370	45,177	69,944	25,529,668	43,867	69,144	25,237,598
380	45,057	69,872	25,503,219	43,747	69,069	25,210,358
390	44,937	69,799	25,476,741	43,627	68,995	25,183,086
400	44,817	69,727	25,450,236	43,507	68,920	25,155,784
410	44,698	69,654	25,423,702	43,388	68,845	25,128,450
420	44,578	69,581	25,397,140	43,268	68,770	25,101,085
430	44,459	69,508	25,370,550	43,149	68,695	25,073,689
440	44,340	69,435	25,343,931	43,030	68,620	25,046,261
450	44,221	69,362	25,317,285	42,911	68,545	25,018,802
460	44,102	69,289	25,290,609	42,792	68,469	24,991,311
470	43,984	69,216	25,263,905	42,674	68,394	24,963,789
480	43,866	69,143	25,237,173	42,556	68,318	24,936,235
490	43,748	69,070	25,210,412	42,438	68,243	24,908,649
500	43,630	68,996	25,183,622	42,320	68,167	24,881,031
510	43,512	68,923	25,156,803	42,202	68,091	24,853,381
520	43,394	68,849	25,129,955	42,084	68,016	24,825,698
530	43,277	68,776	25,103,079	41,967	67,940	24,797,984
540	43,160	68,702	25,076,173	41,850	67,864	24,770,238
550	43,043	68,628	25,049,238	41,733	67,788	24,742,459
560	42,926	68,554	25,022,274	41,616	67,711	24,714,647
570	42,810	68,480	24,995,281	41,500	67,635	24,686,803
580	42,693	68,406	24,968,259	41,383	67,559	24,658,927
590	42,577	68,332	24,941,207	41,267	67,482	24,631,017
600	42,461	68,258	24,914,126	41,151	67,406	24,603,075
610	42,345	68,184	24,887,015	41,035	67,329	24,575,100
620	42,230	68,109	24,859,874	40,920	67,252	24,547,092
630	42,114	68,035	24,832,704	40,804	67,175	24,519,051
640	41,999	67,960	24,805,504	40,689	67,099	24,490,976
650	41,884	67,886	24,778,274	40,574	67,022	24,462,869
660	41,769	67,811	24,751,015	40,459	66,944	24,434,728
670	41,654	67,736	24,723,725	40,344	66,867	24,406,554
680	41,540	67,661	24,696,406	40,230	66,790	24,378,346
690	41,426	67,586	24,669,056	40,116	66,713	24,350,104
700	41,311	67,511	24,641,676	40,002	66,635	24,321,829
710	41,198	67,436	24,614,265	39,888	66,558	24,293,520
720	41,084	67,361	24,586,825	39,774	66,480	24,265,176
730	40,970	67,286	24,559,354	39,660	66,402	24,236,799
740	40,857	67,211	24,531,852	39,547	66,324	24,208,388
750	40,744	67,135	24,504,320	39,434	66,246	24,179,943
760	40,631	67,060	24,476,757	39,321	66,168	24,151,463
770	40,518	66,984	24,449,164	39,208	66,090	24,122,949
780	40,405	66,908	24,421,539	39,096	66,012	24,094,400
790	40,293	66,833	24,393,884	38,983	65,934	24,065,817
800	40,181	66,757	24,366,198	38,871	65,855	24,037,199
810	40,069	66,681	24,338,480	38,759	65,777	24,008,546
820	39,957	66,605	24,310,732	38,647	65,698	23,979,859
830	39,845	66,529	24,282,952	38,535	65,620	23,951,136
840	39,734	66,452	24,255,141	38,424	65,541	23,922,379
850	39,622	66,376	24,227,299	38,313	65,462	23,893,586
860	39,511	66,300	24,199,425	38,201	65,383	23,864,758
870	39,400	66,223	24,171,520	38,091	65,304	23,835,894
880	39,290	66,147	24,143,583	37,980	65,225	23,806,995
890	39,179	66,070	24,115,614	37,869	65,145	23,778,060
900	39,069	65,993	24,087,614	37,759	65,066	23,749,090
910	38,959	65,917	24,059,581	37,649	64,987	23,720,084
920	38,849	65,840	24,031,517	37,539	64,907	23,691,042
930	38,739	65,763	24,003,421	37,429	64,827	23,661,963

940	38,629	65,686	23,975,293	37,319	64,748	23,632,849
950	38,520	65,609	23,947,132	37,210	64,668	23,603,699
960	38,411	65,531	23,918,939	37,101	64,588	23,574,512
970	38,301	65,454	23,890,714	36,992	64,508	23,545,289
980	38,193	65,377	23,862,456	36,883	64,427	23,516,029
990	38,084	65,299	23,834,166	36,774	64,347	23,486,733
1,000	37,975	65,221	23,805,843	36,665	64,267	23,457,400
1,010	37,867	65,144	23,777,488	36,557	64,186	23,428,029
1,020	37,759	65,066	23,749,099	36,449	64,106	23,398,622
1,030	37,651	64,988	23,720,678	36,341	64,025	23,369,178
1,040	37,543	64,910	23,692,224	36,233	63,944	23,339,697





Appendix 8

ME fuel consumption

ME operation profile

Operation mode	Operating time	Sailing speed
	[days/yr]	[kn]
Slow laden/ballast	7	11
Laden/ballast	323	15
Loading	18	0
Unloading	18	0

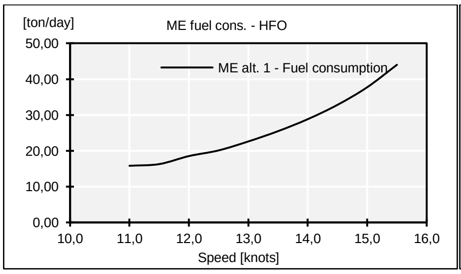
ME fuel consumption - ME alt. 1

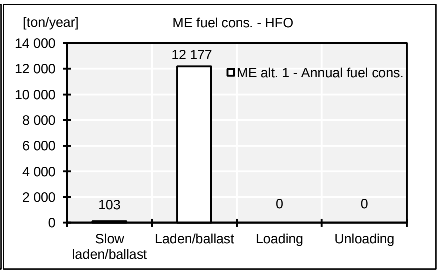
ME alt. 1 - Fuel consumption as function of speed

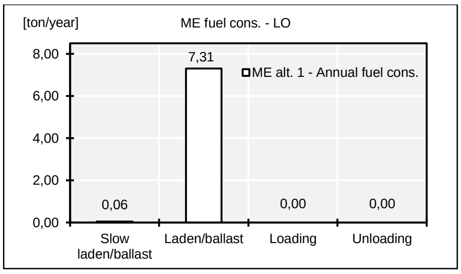
Speed	Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SFOC	FOC (HFO)	SLOC	LOC
[kn]	P_E [kW]	η_T [%]	P_B [kW]	[%]	P_{B_SM} [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]
11.0	2,658.9	0.8	3,224.8	0.2	3,709	35%	178.0	15.84	0.1	0.009
11.5	2,746.2	0.8	3,330.8	0.2	3,830	36%	177.4	16.31	0.1	0.009
12.0	3,173.4	0.8	3,848.9	0.2	4,426	41%	174.5	18.54	0.1	0.011
12.5	3,480.2	0.8	4,221.0	0.2	4,854	45%	172.8	20.13	0.1	0.012
13.0	3,967.5	0.8	4,812.0	0.2	5,534	52%	170.4	22.63	0.1	0.013
13.5	4,526.3	0.8	5,489.8	0.2	6,313	59%	168.3	25.49	0.1	0.015
14.0	5,169.1	0.8	6,269.4	0.2	7,210	68%	166.7	28.84	0.1	0.017
14.5	5,910.4	0.8	7,168.5	0.2	8,244	77%	165.9	32.83	0.1	0.020
15.0	6,767.3	0.8	8,207.7	0.2	9,439	88%	166.6	37.74	0.1	0.023
15.5	7,759.3	0.8	9,410.9	0.2	10,822	101%	169.4	44.00	0.1	0.026

ME alt. 1 - Annual fuel consumption

Operation mode	HFO	LO
	[ton/year]	[ton/year]
Slow laden/ballast	103	0.06
Laden/ballast	12,177	7.31
Loading	0	0.00
Unloading	0	0.00
Total	12,280	7



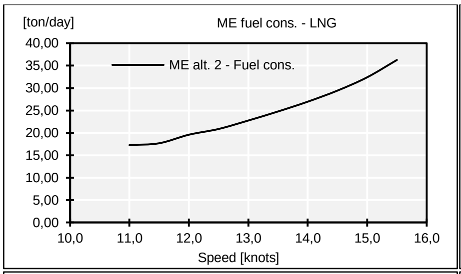


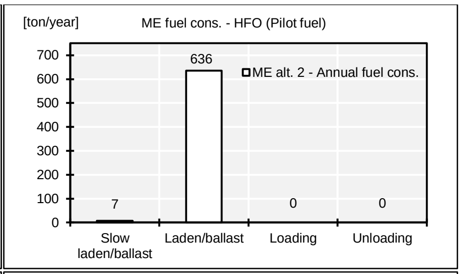


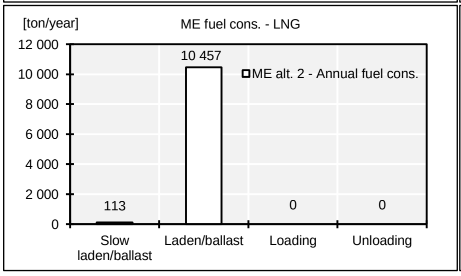
ME fuel consumption ME alt. 2

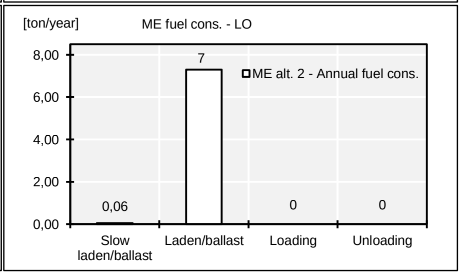
ME alt. 2 - Fuel consumption as function of speed													
Speed	Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC	GC	GC	SPFOC	PFOC (HFO)	SLOC	LOC
[kn]	P_E [kW]	η_T [%]	P_B [kW]	[%]	P_{B_SM} [kW]	[%]	[kJ/kWh]	[kWh/h]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]
11.0	2,658.9	0.8	3,224.8	0.2	3,709	35%	10,079	10,383	17.28	11.8	1.1	0.1	0.009
11.5	2,746.2	0.8	3,330.8	0.2	3,830	36%	9,991	10,630	17.69	11.7	1.1	0.1	0.009
12.0	3,173.4	0.8	3,848.9	0.2	4,426	41%	9,578	11,776	19.60	11.2	1.2	0.1	0.011
12.5	3,480.2	0.8	4,221.0	0.2	4,854	45%	9,302	12,543	20.88	10.9	1.3	0.1	0.012
13.0	3,967.5	0.8	4,812.0	0.2	5,534	52%	8,900	13,680	22.77	10.4	1.4	0.1	0.013
13.5	4,526.3	0.8	5,489.8	0.2	6,313	59%	8,491	14,891	24.78	9.9	1.5	0.1	0.015
14.0	5,169.1	0.8	6,269.4	0.2	7,210	68%	8,092	16,207	26.97	9.5	1.6	0.1	0.017
14.5	5,910.4	0.8	7,168.5	0.2	8,244	77%	7,726	17,692	29.45	9.0	1.8	0.1	0.020
15.0	6,767.3	0.8	8,207.7	0.2	9,439	88%	7,428	19,475	32.41	8.7	2.0	0.1	0.023
15.5	7,759.3	0.8	9,410.9	0.2	10,822	101%	7,250	21,795	36.28	8.5	2.2	0.1	0.026

ME alt. 2 – Annual fuel consumption			
Operation mode	LNG	PFOC (HFO)	LO
	[ton/year]	[ton/year]	[ton/year]
Slow laden/ballast	113	7	0.06
Laden/ballast	10,457	636	7
Loading	0	0	0
Unloading	0	0	0
Total	10,570	643	7









Aux. fuel consumption

Aux. operation profile

Operation mode:	Condition	Load [kW]		Operating time [days/year]
Slow laden/ballast	Boil-off handling	Base-load:	776*	
		Boil-off handling load – Slow laden	Variable	7
		Boil-off handling load – Slow ballast	Variable	7
Laden/ballast	Boil-off handling	Base-load:	776	323
		Boil-off handling load - Laden	Variable	161
		Boil-off handling load - Ballast	Variable	161
Unloading	Vapour return line to shore tank → no on-board boil-off handling		971*	18
Loading	Vapour return line to shore tank → no on-board boil-off handling		371*	18

*Derived from comparison ship.

Aux. fuel consumption

Fixed aux. fuel cons.

Aux. fuel cons.						
Operation mode	No. of employed aux.	Aux. load	Sp. cons.	Energy cons.	MDO cons.	LO cons.
	[-]	[%]	[g/kWh]	[kW]	[ton/day]	[ton/day]
Unloading	1	51%	193	971	5	0.02
Loading	1	20%	225	371	2	0.02

Variable aux. fuel cons.

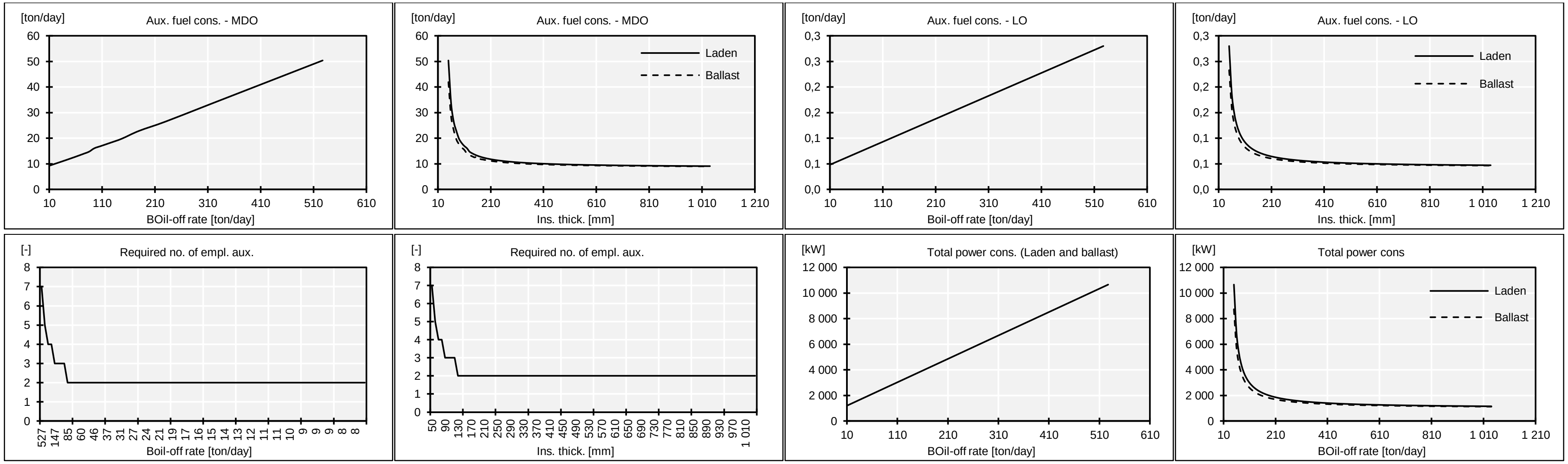
Insulation system 1

Boil-off handling – Re-liquefaction

Table type:	Ins. sys. no:	ME alt. 1	Boil-off handling:		Description:									
Aux. fuel cons.	1	1	Re-liquefaction											
					Oper. mode: Laden/slow laden					Oper. mode: Ballast/slow ballast				
			Total power				Fuel cons.					Fuel cons.		
Insulation thickness	Boil of rate		WBS 3.3.1		No. of empl. aux.	Aux load incl. baseload	Sp. MDO cons.	MDO cons.	LO cons.	No. of empl. aux.	Aux load incl. baseload	Sp. MDO cons.	MDO cons.	LO cons.
	BOR_{LAD}	BOR_{BAL}	$P_{RELIQU\_LAD\_TOT}$	$P_{RELIQUE\_BAL\_TOT}$										
[mm]	[ton/day]	[ton/day]	[kW]	[kW]	[-]	[-]	[g/kWh]	[ton/day]	[ton/day]	[-]	[-]	[g/kWh]	[ton/day]	[ton/day]
50	528	422	10,668	8,745	7	88%	180	50	0.3	6	85%	180	42	0.2
60	321	257	6,886	5,716	5	82%	180	34	0.2	4	87%	180	29	0.2
70	230	184	5,232	4,392	4	81%	180	27	0.1	4	69%	183	23	0.1
80	180	144	4,304	3,649	4	68%	184	23	0.1	3	79%	181	20	0.1
90	147	118	3,710	3,174	3	80%	181	20	0.1	3	71%	183	18	0.1
100	125	100	3,298	2,843	3	73%	182	18	0.1	3	65%	185	16	0.1
110	108	87	2,994	2,600	3	67%	184	17	0.1	3	60%	187	15	0.1
120	95	76	2,762	2,414	3	63%	186	16	0.1	2	86%	180	14	0.1
130	85	68	2,578	2,267	2	90%	180	15	0.1	2	82%	180	13	0.1
140	77	62	2,429	2,148	2	86%	180	14	0.1	2	79%	181	13	0.1
150	70	56	2,306	2,049	2	83%	180	14	0.1	2	76%	181	13	0.1
160	65	52	2,203	1,967	2	80%	181	13	0.1	2	74%	182	12	0.1
170	60	48	2,114	1,896	2	78%	181	13	0.1	2	72%	183	12	0.1
180	56	45	2,038	1,835	2	76%	182	13	0.1	2	70%	183	12	0.1
190	52	42	1,972	1,782	2	74%	182	12	0.1	2	69%	184	12	0.1
200	49	39	1,914	1,735	2	72%	182	12	0.1	2	67%	184	11	0.1
210	46	37	1,862	1,694	2	71%	183	12	0.1	2	66%	185	11	0.1
220	44	35	1,816	1,657	2	70%	183	12	0.1	2	65%	185	11	0.1
230	41	33	1,775	1,624	2	68%	184	11	0.1	2	64%	185	11	0.1
240	39	31	1,737	1,594	2	67%	184	11	0.1	2	64%	186	11	0.1
250	37	30	1,703	1,567	2	67%	185	11	0.1	2	63%	186	11	0.1
260	36	29	1,672	1,542	2	66%	185	11	0.1	2	62%	187	11	0.1
270	34	27	1,644	1,519	2	65%	185	11	0.1	2	62%	187	11	0.1
280	33	26	1,618	1,499	2	64%	186	11	0.1	2	61%	187	10	0.1
290	32	25	1,594	1,479	2	64%	186	11	0.1	2	61%	187	10	0.1
300	30	24	1,572	1,462	2	63%	186	11	0.1	2	60%	188	10	0.1
310	29	23	1,552	1,445	2	63%	186	11	0.1	2	60%	188	10	0.1
320	28	23	1,533	1,430	2	62%	187	11	0.1	2	59%	188	10	0.1
330	27	22	1,515	1,416	2	62%	187	10	0.1	2	59%	188	10	0.1
340	26	21	1,498	1,402	2	61%	187	10	0.1	2	58%	189	10	0.1
350	25	20	1,483	1,390	2	61%	187	10	0.1	2	58%	189	10	0.1
360	25	20	1,468	1,378	2	60%	188	10	0.1	2	58%	189	10	0.1
370	24	19	1,454	1,367	2	60%	188	10	0.1	2	58%	189	10	0.1
380	23	19	1,441	1,357	2	60%	188	10	0.1	2	57%	189	10	0.1

390	22	18	1,429	1,347	2	59%	188	10	0.1	2	57%	189	10	0.1
400	22	18	1,417	1,338	2	59%	188	10	0.1	2	57%	190	10	0.1
410	21	17	1,407	1,329	2	59%	188	10	0.1	2	57%	190	10	0.1
420	21	17	1,396	1,321	2	58%	189	10	0.1	2	56%	190	10	0.1
430	20	16	1,386	1,313	2	58%	189	10	0.1	2	56%	190	10	0.1
440	20	16	1,377	1,305	2	58%	189	10	0.1	2	56%	190	10	0.1
450	19	15	1,368	1,298	2	58%	189	10	0.1	2	56%	190	10	0.1
460	19	15	1,360	1,291	2	57%	189	10	0.1	2	56%	190	10	0.1
470	18	15	1,351	1,285	2	57%	189	10	0.1	2	55%	190	10	0.1
480	18	14	1,344	1,279	2	57%	189	10	0.1	2	55%	190	10	0.1
490	17	14	1,336	1,273	2	57%	190	10	0.1	2	55%	191	10	0.1
500	17	14	1,329	1,267	2	57%	190	10	0.1	2	55%	191	10	0.1
510	17	13	1,322	1,262	2	56%	190	10	0.1	2	55%	191	10	0.0
520	16	13	1,316	1,257	2	56%	190	10	0.1	2	55%	191	10	0.0
530	16	13	1,310	1,252	2	56%	190	10	0.1	2	54%	191	9	0.0
540	16	13	1,304	1,247	2	56%	190	10	0.1	2	54%	191	9	0.0
550	15	12	1,298	1,242	2	56%	190	10	0.1	2	54%	191	9	0.0
560	15	12	1,292	1,238	2	56%	190	10	0.1	2	54%	191	9	0.0
570	15	12	1,287	1,233	2	55%	190	10	0.1	2	54%	191	9	0.0
580	14	12	1,282	1,229	2	55%	190	10	0.1	2	54%	191	9	0.0
590	14	11	1,277	1,225	2	55%	191	10	0.1	2	54%	191	9	0.0
600	14	11	1,272	1,222	2	55%	191	10	0.1	2	54%	191	9	0.0
610	14	11	1,268	1,218	2	55%	191	10	0.1	2	54%	192	9	0.0
620	13	11	1,263	1,214	2	55%	191	10	0.0	2	53%	192	9	0.0
630	13	11	1,259	1,211	2	55%	191	10	0.0	2	53%	192	9	0.0
640	13	10	1,255	1,208	2	55%	191	9	0.0	2	53%	192	9	0.0
650	13	10	1,251	1,204	2	54%	191	9	0.0	2	53%	192	9	0.0
660	13	10	1,247	1,201	2	54%	191	9	0.0	2	53%	192	9	0.0
670	12	10	1,243	1,198	2	54%	191	9	0.0	2	53%	192	9	0.0
680	12	10	1,239	1,195	2	54%	191	9	0.0	2	53%	192	9	0.0
690	12	10	1,236	1,192	2	54%	191	9	0.0	2	53%	192	9	0.0
700	12	9	1,232	1,190	2	54%	191	9	0.0	2	53%	192	9	0.0
710	12	9	1,229	1,187	2	54%	191	9	0.0	2	53%	192	9	0.0
720	11	9	1,226	1,184	2	54%	191	9	0.0	2	53%	192	9	0.0
730	11	9	1,223	1,182	2	54%	191	9	0.0	2	53%	192	9	0.0
740	11	9	1,220	1,179	2	54%	192	9	0.0	2	53%	192	9	0.0
750	11	9	1,217	1,177	2	54%	192	9	0.0	2	52%	192	9	0.0
760	11	9	1,214	1,175	2	53%	192	9	0.0	2	52%	192	9	0.0
770	11	8	1,211	1,172	2	53%	192	9	0.0	2	52%	192	9	0.0
780	10	8	1,208	1,170	2	53%	192	9	0.0	2	52%	192	9	0.0
790	10	8	1,206	1,168	2	53%	192	9	0.0	2	52%	192	9	0.0
800	10	8	1,203	1,166	2	53%	192	9	0.0	2	52%	192	9	0.0
810	10	8	1,200	1,164	2	53%	192	9	0.0	2	52%	193	9	0.0
820	10	8	1,198	1,162	2	53%	192	9	0.0	2	52%	193	9	0.0
830	10	8	1,196	1,160	2	53%	192	9	0.0	2	52%	193	9	0.0

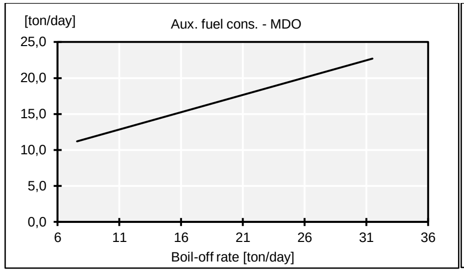
840	10	8	1,193	1,158	2	53%	192	9	0.0	2	52%	193	9	0.0
850	9	8	1,191	1,156	2	53%	192	9	0.0	2	52%	193	9	0.0
860	9	7	1,189	1,155	2	53%	192	9	0.0	2	52%	193	9	0.0
870	9	7	1,187	1,153	2	53%	192	9	0.0	2	52%	193	9	0.0
880	9	7	1,184	1,151	2	53%	192	9	0.0	2	52%	193	9	0.0
890	9	7	1,182	1,150	2	53%	192	9	0.0	2	52%	193	9	0.0
900	9	7	1,180	1,148	2	53%	192	9	0.0	2	52%	193	9	0.0
910	9	7	1,178	1,146	2	52%	192	9	0.0	2	52%	193	9	0.0
920	9	7	1,176	1,145	2	52%	192	9	0.0	2	52%	193	9	0.0
930	9	7	1,175	1,143	2	52%	192	9	0.0	2	52%	193	9	0.0
940	8	7	1,173	1,142	2	52%	192	9	0.0	2	51%	193	9	0.0
950	8	7	1,171	1,140	2	52%	192	9	0.0	2	51%	193	9	0.0
960	8	7	1,169	1,139	2	52%	192	9	0.0	2	51%	193	9	0.0
970	8	7	1,167	1,138	2	52%	192	9	0.0	2	51%	193	9	0.0
980	8	6	1,166	1,136	2	52%	192	9	0.0	2	51%	193	9	0.0
990	8	6	1,164	1,135	2	52%	193	9	0.0	2	51%	193	9	0.0
1,000	8	6	1,162	1,134	2	52%	193	9	0.0	2	51%	193	9	0.0
1,010	8	6	1,161	1,132	2	52%	193	9	0.0	2	51%	193	9	0.0
1,020	8	6	1,159	1,131	2	52%	193	9	0.0	2	51%	193	9	0.0
1,030	8	6	1,158	1,130	2	52%	193	9	0.0	2	51%	193	9	0.0
1,040	8	6	1,156	1,129	2	52%	193	9	0.0	2	51%	193	9	0.0

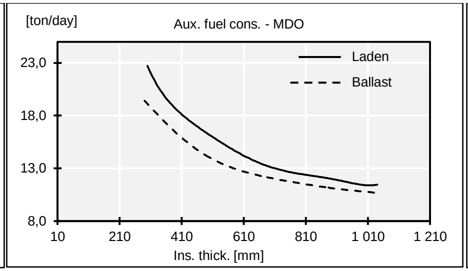


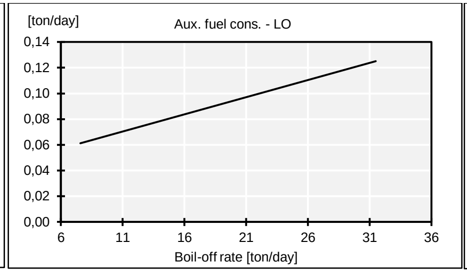
Boil-off handling – Gas supply system alt. 1

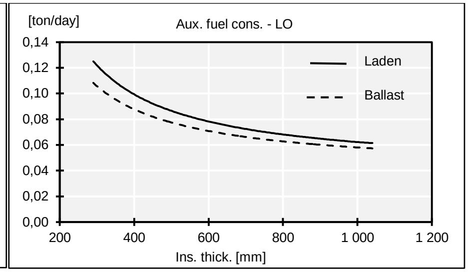
Table type:	Ins. sys. no:	ME alt. 1	Boil-off handling:		Description:																	
Aux. fuel cons.	1	2	Gas supply alt. 1																			
			WBS 3.3.2.1										Oper. mode: Laden/slow laden					Oper. mode: Ballast/slow ballast				
			HP pump				3 st. compressor				Total power				Fuel cons.					Fuel cons.		
Insulation thickness	Boil-off rate		Intake flow rate		Power		Intake flow rate		Power		WBS 3.3.2.1		No. of empl. aux.	Aux. load incl. baseload	Sp. MDO cons.	MDO cons.	LO cons.	No. of empl. aux.	Aux. load incl. baseload	Sp. MDO cons.	MDO cons.	LO cons.
	BOR_{LAD}	BOR_{BAL}	Q_{LAD}	Q_{BAL}	P_{LAD}	P_{BAL}	Q_{LAD}	Q_{BAL}	P_{LAD}	P_{BAL}	P_{LAD/SLW_LAD_TOT}	P_{BAL/SLW_BALL_TOT}										
[mm]	[ton/day]	[ton/day]	[kg/s]	[kg/s]	[W]	[W]	[kg/s]	[kg/s]	[kW]	[kW]	[kW]	[kW]	[-]	[-]	[g/kWh]	[ton/day]	[ton/day]	[-]	[-]	[g/kWh]	[ton/day]	[ton/day]
290	32	25	0	2	25	200	9	7	4,305	3,447	4,330	3,648	4	69%	184	23	0.13	3	79%	181	20	0.11
300	30	24	1	2	59	227	8.4	7	4,140	3,315	4,199	3,543	3	89%	180	22	0.12	3	77%	181	19	0.11
310	29	23	1	3	90	252	8	6	3,987	3,192	4,077	3,445	3	87%	180	21	0.12	3	76%	182	19	0.10
320	28	23	1	3	119	276	8	6	3,844	3,078	3,964	3,354	3	85%	180	21	0.12	3	74%	182	18	0.10
330	27	22	1	3	146	298	8	6	3,712	2,972	3,858	3,270	3	83%	180	20	0.11	3	72%	182	18	0.10
340	26	21	2	3	172	318	7	6	3,587	2,873	3,759	3,190	3	81%	180	20	0.11	3	71%	183	18	0.10
350	25	20	2	3	195	337	7	6	3,471	2,779	3,667	3,116	3	80%	181	20	0.11	3	70%	183	17	0.10
360	25	20	2	4	218	355	7	5	3,362	2,692	3,580	3,047	3	78%	181	19	0.11	3	68%	184	17	0.09
370	24	19	2	4	239	372	7	5	3,259	2,610	3,498	2,982	3	77%	181	19	0.10	3	67%	184	17	0.09
380	23	19	3	4	259	387	6	5	3,163	2,532	3,421	2,920	3	75%	182	19	0.10	3	66%	185	17	0.09
390	22	18	3	4	277	402	6	5	3,072	2,459	3,349	2,862	3	74%	182	18	0.10	3	65%	185	16	0.09
400	22	18	3	4	295	417	6	5	2,985	2,390	3,280	2,807	3	73%	182	18	0.10	3	64%	186	16	0.09
410	21	17	3	4	312	430	6	5	2,904	2,325	3,215	2,755	3	71%	183	18	0.10	3	63%	186	16	0.09
420	21	17	3	4	327	443	6	5	2,826	2,263	3,154	2,706	3	70%	183	18	0.10	3	62%	186	16	0.09
430	20	16	3	5	342	455	6	4	2,753	2,204	3,095	2,659	3	69%	183	17	0.09	3	61%	187	16	0.08
440	20	16	4	5	357	466	5	4	2,683	2,148	3,040	2,614	3	68%	184	17	0.09	3	61%	187	16	0.08
450	19	15	4	5	370	477	5	4	2,616	2,095	2,987	2,572	3	67%	184	17	0.09	2	90%	180	15	0.08
460	19	15	4	5	383	487	5	4	2,553	2,044	2,936	2,531	3	66%	185	17	0.09	2	89%	180	15	0.08
470	18	15	4	5	396	497	5	4	2,492	1,996	2,888	2,493	3	66%	185	17	0.09	2	88%	180	14	0.08
480	18	14	4	5	407	507	5	4	2,435	1,949	2,842	2,456	3	65%	185	16	0.09	2	87%	180	14	0.08
490	17	14	4	5	419	516	5	4	2,379	1,905	2,798	2,421	3	64%	186	16	0.09	2	86%	180	14	0.08
500	17	14	4	5	430	524	5	4	2,327	1,863	2,756	2,387	3	63%	186	16	0.09	2	85%	180	14	0.08
510	17	13	4	5	440	533	5	4	2,276	1,822	2,716	2,355	3	63%	186	16	0.09	2	84%	180	14	0.08
520	16	13	4	5	450	541	5	4	2,227	1,784	2,677	2,324	3	62%	187	16	0.08	2	83%	180	14	0.08
530	16	13	5	5	459	548	4	4	2,181	1,746	2,640	2,294	3	61%	187	16	0.08	2	82%	180	14	0.08
540	16	13	5	6	469	556	4	3	2,136	1,710	2,605	2,266	3	61%	187	16	0.08	2	82%	180	13	0.07
550	15	12	5	6	477	563	4	3	2,093	1,676	2,570	2,239	2	90%	180	15	0.08	2	81%	180	13	0.07
560	15	12	5	6	486	569	4	3	2,052	1,643	2,538	2,212	2	89%	180	15	0.08	2	80%	181	13	0.07
570	15	12	5	6	494	576	4	3	2,012	1,611	2,506	2,187	2	88%	180	14	0.08	2	80%	181	13	0.07
580	14	12	5	6	502	582	4	3	1,974	1,580	2,475	2,162	2	87%	180	14	0.08	2	79%	181	13	0.07
590	14	11	5	6	509	588	4	3	1,937	1,551	2,446	2,139	2	87%	180	14	0.08	2	78%	181	13	0.07
600	14	11	5	6	517	594	4	3	1,901	1,522	2,418	2,116	2	86%	180	14	0.08	2	78%	181	13	0.07
610	14	11	5	6	524	600	4	3	1,867	1,495	2,390	2,094	2	85%	180	14	0.08	2	77%	181	13	0.07
620	13	11	5	6	530	605	4	3	1,833	1,468	2,364	2,073	2	84%	180	14	0.08	2	77%	181	13	0.07
630	13	11	5	6	537	610	4	3	1,801	1,442	2,338	2,053	2	84%	180	14	0.08	2	76%	181	13	0.07
640	13	10	5	6	543	615	4	3	1,770	1,417	2,313	2,033	2	83%	180	14	0.08	2	75%	182	12	0.07
650	13	10	5	6	549	620	4	3	1,740	1,393	2,290	2,014	2	82%	180	14	0.08	2	75%	182	12	0.07

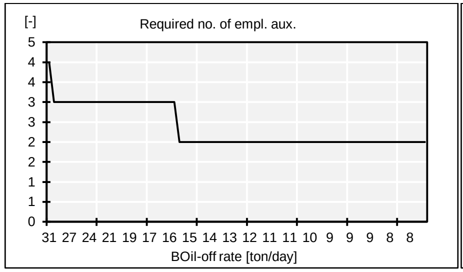
660	13	10	6	6	555	625	3	3	1,711	1,370	2,266	1,995	2	82%	180	13	0.07	2	74%	182	12	0.07
670	12	10	6	6	561	630	3	3	1,683	1,347	2,244	1,977	2	81%	180	13	0.07	2	74%	182	12	0.07
680	12	10	6	6	567	634	3	3	1,655	1,326	2,222	1,960	2	81%	181	13	0.07	2	73%	182	12	0.07
690	12	10	6	6	572	639	3	3	1,629	1,304	2,201	1,943	2	80%	181	13	0.07	2	73%	182	12	0.07
700	12	9	6	6	577	643	3	3	1,603	1,284	2,181	1,927	2	79%	181	13	0.07	2	73%	182	12	0.07
710	12	9	6	6	583	647	3	3	1,578	1,264	2,161	1,911	2	79%	181	13	0.07	2	72%	182	12	0.07
720	11	9	6	6	587	651	3	3	1,554	1,245	2,142	1,895	2	78%	181	13	0.07	2	72%	183	12	0.07
730	11	9	6	7	592	655	3	2	1,531	1,226	2,123	1,880	2	78%	181	13	0.07	2	71%	183	12	0.07
740	11	9	6	7	597	658	3	2	1,508	1,207	2,105	1,866	2	77%	181	13	0.07	2	71%	183	12	0.06
750	11	9	6	7	602	662	3	2	1,486	1,190	2,087	1,852	2	77%	181	13	0.07	2	71%	183	12	0.06
760	11	9	6	7	606	666	3	2	1,464	1,172	2,070	1,838	2	76%	181	13	0.07	2	70%	183	12	0.06
770	11	8	6	7	610	669	3	2	1,443	1,156	2,053	1,825	2	76%	181	13	0.07	2	70%	183	12	0.06
780	10	8	6	7	614	672	3	2	1,423	1,139	2,037	1,812	2	76%	182	13	0.07	2	69%	183	12	0.06
790	10	8	6	7	618	676	3	2	1,403	1,123	2,021	1,799	2	75%	182	12	0.07	2	69%	184	12	0.06
800	10	8	6	7	622	679	3	2	1,384	1,108	2,006	1,787	2	75%	182	12	0.07	2	69%	184	12	0.06
810	10	8	6	7	626	682	3	2	1,365	1,093	1,991	1,775	2	74%	182	12	0.07	2	68%	184	11	0.06
820	10	8	6	7	630	685	3	2	1,346	1,078	1,976	1,763	2	74%	182	12	0.07	2	68%	184	11	0.06
830	10	8	6	7	634	688	3	2	1,328	1,064	1,962	1,751	2	74%	182	12	0.07	2	68%	184	11	0.06
840	10	8	6	7	637	691	3	2	1,311	1,050	1,948	1,740	2	73%	182	12	0.07	2	68%	184	11	0.06
850	9	8	6	7	641	693	3	2	1,294	1,036	1,935	1,730	2	73%	182	12	0.07	2	67%	184	11	0.06
860	9	7	6	7	644	696	3	2	1,277	1,023	1,921	1,719	2	72%	182	12	0.07	2	67%	184	11	0.06
870	9	7	6	7	647	699	3	2	1,261	1,010	1,908	1,709	2	72%	183	12	0.07	2	67%	184	11	0.06
880	9	7	6	7	651	701	3	2	1,245	997	1,896	1,698	2	72%	183	12	0.07	2	66%	185	11	0.06
890	9	7	7	7	654	704	3	2	1,230	985	1,884	1,689	2	71%	183	12	0.07	2	66%	185	11	0.06
900	9	7	7	7	657	706	2	2	1,215	973	1,872	1,679	2	71%	183	12	0.06	2	66%	185	11	0.06
910	9	7	7	7	660	709	2	2	1,200	961	1,860	1,670	2	71%	183	12	0.06	2	66%	185	11	0.06
920	9	7	7	7	663	711	2	2	1,185	949	1,848	1,660	2	70%	183	12	0.06	2	65%	185	11	0.06
930	9	7	7	7	666	714	2	2	1,171	938	1,837	1,651	2	70%	183	12	0.06	2	65%	185	11	0.06
940	8	7	7	7	669	716	2	2	1,157	927	1,826	1,643	2	70%	183	12	0.06	2	65%	185	11	0.06
950	8	7	7	7	671	718	2	2	1,144	916	1,815	1,634	2	70%	183	12	0.06	2	65%	185	11	0.06
960	8	7	7	7	674	720	2	2	1,131	905	1,805	1,626	2	69%	183	12	0.06	2	64%	185	11	0.06
970	8	7	7	7	677	722	2	2	1,118	895	1,795	1,617	2	69%	184	12	0.06	2	64%	186	11	0.06
980	8	6	7	7	679	724	2	2	1,105	885	1,785	1,609	2	69%	184	12	0.06	2	64%	186	11	0.06
990	8	6	7	7	682	726	2	2	1,093	875	1,775	1,601	2	68%	184	11	0.06	2	64%	186	11	0.06
1,000	8	6	7	7	684	728	2	2	1,081	865	1,765	1,594	2	68%	184	11	0.06	2	64%	186	11	0.06
1,010	8	6	7	7	687	730	2	2	1,069	856	1,756	1,586	2	68%	184	11	0.06	2	63%	186	11	0.06
1,020	8	6	7	7	689	732	2	2	1,057	847	1,746	1,579	2	68%	184	11	0.06	2	63%	186	11	0.06
1,030	8	6	7	7	691	734	2	2	1,046	837	1,737	1,571	2	67%	184	11	0.06	2	63%	186	11	0.06
1,040	8	6	7	7	694	736	2	2	1,035	828	1,728	1,564	2	67%	184	11	0.06	2	63%	186	11	0.06

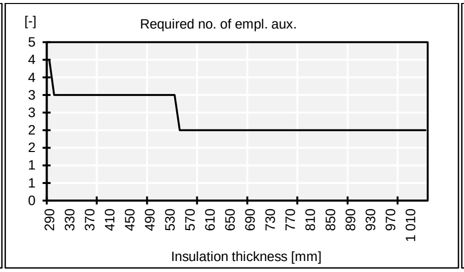

[ton/day]
Aux. fuel cons. - MDO
Boil-off rate [ton/day]

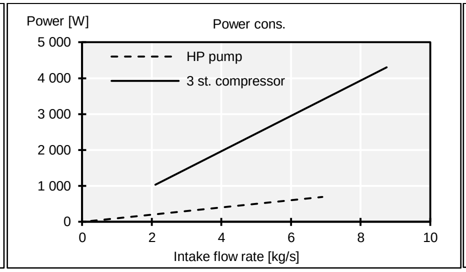

[ton/day]
Aux. fuel cons. - MDO
Laden
Ballast
Ins. thick. [mm]

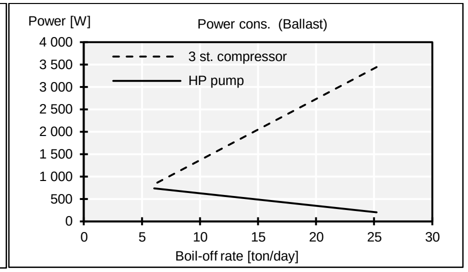

[ton/day]
Aux. fuel cons. - LO
Boil-off rate [ton/day]

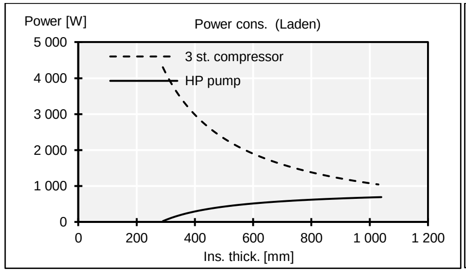

[ton/day]
Aux. fuel cons. - LO
Laden
Ballast
Ins. thick. [mm]

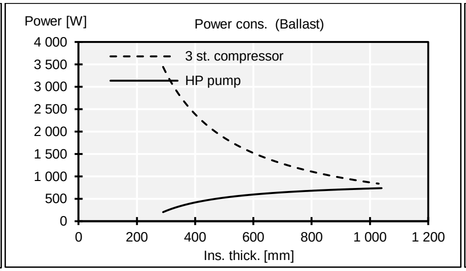

[-]
Required no. of empl. aux.
BOil-off rate [ton/day]

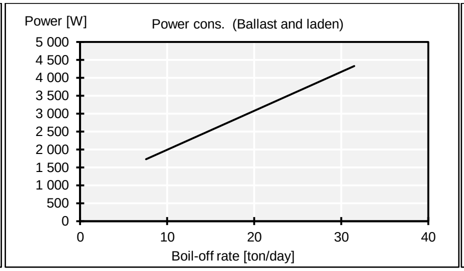

[-]
Required no. of empl. aux.
Insulation thickness [mm]

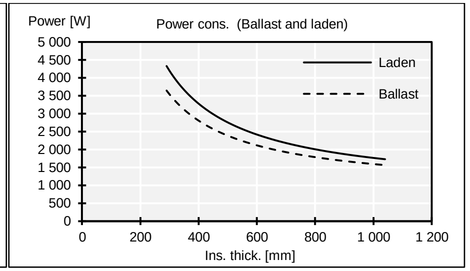

Power [W]
Power cons.
HP pump
3 st. compressor
Intake flow rate [kg/s]


Power [W]
Power cons. (Ballast)
3 st. compressor
HP pump
Boil-off rate [ton/day]


Power [W]
Power cons. (Laden)
3 st. compressor
HP pump
Ins. thick. [mm]


Power [W]
Power cons. (Ballast)
3 st. compressor
HP pump
Ins. thick. [mm]


Power [W]
Power cons. (Ballast and laden)
Boil-off rate [ton/day]

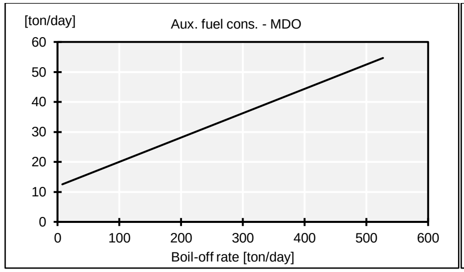

Power [W]
Power cons. (Ballast and laden)
Laden
Ballast
Ins. thick. [mm]

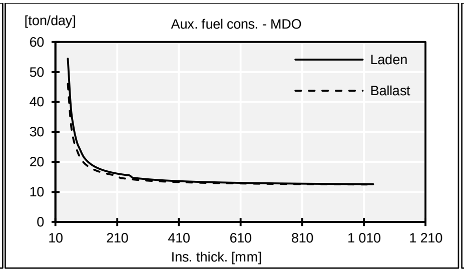
Boil-off handling – Gas supply system alt. 2

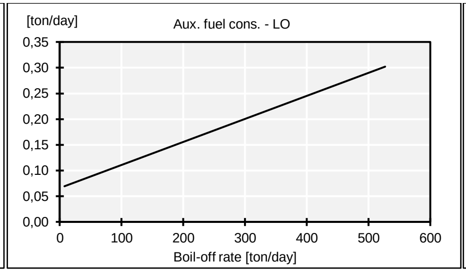
Table type:	Ins. sys. no:	ME alt. 1	Boil-off handling:		Description:												
Aux. fuel cons.	1	2	Gas supply alt. 2														
								Oper. mode: Laden/slow laden					Oper. mode: Ballast/slow ballast				
			Power			Total power				Fuel cons.					Fuel cons.		
Insulation thickness	Boil-of rate		WBS 3.3.2.2.2		WBS 3.3.2.2.1	WBS 3.3.2.2		No. of empl. aux.	Aux. load incl. baseload	Sp. MDO cons.	MDO cons.	LO cons.	No. of employed aux.	Aux load incl. baseload	Sp. MDO cons.	MDO cons.	LO cons.
	BOR_{LAD}	BOR_{BAL}	P_{RELIQU_LAD}	$P_{RELIQUE\_BAL}$	P_{HP_PUMP}	P_{LAD/SLW_LAD_TOT}	P_{BAL/SLW_BALL_TOT}										
[mm]	[ton/day]	[ton/day]	[kW]	[kW]	[kW]	[kW]	[kW]	[-]	[-]	[g/kWh]	[ton/day]	[ton/day]	[-]	[-]	[g/kWh]	[ton/day]	[ton/day]
50	528	422	10,668	8,745	905	11,574	9,650	8	83%	180	54	0.30	7	80%	181	46	0.26
60	321	257	6,886	5,716	905	7,791	6,622	6	77%	181	38	0.21	5	79%	181	33	0.18
70	230	184	5,232	4,392	905	6,137	5,297	5	74%	182	31	0.17	4	82%	180	27	0.15
80	180	144	4,304	3,649	905	5,209	4,554	4	80%	181	26	0.15	4	72%	183	24	0.13
90	147	118	3,710	3,174	905	4,616	4,079	4	72%	182	24	0.13	3	87%	180	21	0.12
100	125	100	3,298	2,843	905	4,203	3,749	3	89%	180	22	0.12	3	81%	180	20	0.11
110	108	87	2,994	2,600	905	3,900	3,506	3	84%	180	21	0.11	3	77%	181	19	0.10
120	95	76	2,762	2,414	905	3,667	3,320	3	80%	181	20	0.11	3	73%	182	18	0.10
130	85	68	2,578	2,267	905	3,484	3,173	3	76%	181	19	0.10	3	71%	183	18	0.10
140	77	62	2,429	2,148	905	3,335	3,053	3	74%	182	18	0.10	3	69%	184	17	0.09
150	70	56	2,306	2,049	905	3,212	2,955	3	71%	183	18	0.10	3	67%	184	17	0.09
160	65	52	2,203	1,967	905	3,108	2,872	3	70%	183	17	0.10	3	65%	185	17	0.09
170	60	48	2,114	1,896	905	3,020	2,801	3	68%	184	17	0.09	3	64%	186	16	0.09
180	56	45	2,038	1,835	905	2,944	2,740	3	67%	185	17	0.09	3	63%	186	16	0.09
190	52	42	1,972	1,782	905	2,877	2,687	3	65%	185	17	0.09	3	62%	187	16	0.08
200	49	39	1,914	1,735	905	2,819	2,640	3	64%	185	16	0.09	3	61%	187	16	0.08
210	46	37	1,862	1,694	905	2,767	2,599	3	63%	186	16	0.09	3	60%	187	15	0.08
220	44	35	1,816	1,657	905	2,721	2,562	3	63%	186	16	0.09	2	90%	180	15	0.08
230	41	33	1,775	1,624	905	2,680	2,529	3	62%	187	16	0.08	2	89%	180	15	0.08
240	39	31	1,737	1,594	905	2,643	2,499	3	61%	187	16	0.08	2	88%	180	14	0.08
250	37	30	1,703	1,567	905	2,609	2,472	3	61%	187	16	0.08	2	87%	180	14	0.08
260	36	29	1,672	1,542	905	2,578	2,447	2	90%	180	15	0.08	2	87%	180	14	0.08
270	34	27	1,644	1,519	905	2,549	2,425	2	89%	180	15	0.08	2	86%	180	14	0.08
280	33	26	1,618	1,499	905	2,524	2,404	2	89%	180	15	0.08	2	85%	180	14	0.08
290	32	25	1,594	1,479	905	2,500	2,385	2	88%	180	14	0.08	2	85%	180	14	0.08
300	30	24	1,572	1,462	905	2,477	2,367	2	87%	180	14	0.08	2	84%	180	14	0.08
310	29	23	1,552	1,445	905	2,457	2,351	2	87%	180	14	0.08	2	84%	180	14	0.08
320	28	23	1,533	1,430	905	2,438	2,335	2	86%	180	14	0.08	2	84%	180	14	0.08
330	27	22	1,515	1,416	905	2,420	2,321	2	86%	180	14	0.08	2	83%	180	14	0.08
340	26	21	1,498	1,402	905	2,403	2,308	2	85%	180	14	0.08	2	83%	180	14	0.08
350	25	20	1,483	1,390	905	2,388	2,295	2	85%	180	14	0.08	2	82%	180	14	0.08
360	25	20	1,468	1,378	905	2,373	2,284	2	85%	180	14	0.08	2	82%	180	14	0.07
370	24	19	1,454	1,367	905	2,360	2,273	2	84%	180	14	0.08	2	82%	180	13	0.07
380	23	19	1,441	1,357	905	2,347	2,262	2	84%	180	14	0.08	2	82%	180	13	0.07
390	22	18	1,429	1,347	905	2,334	2,252	2	84%	180	14	0.08	2	81%	180	13	0.07
400	22	18	1,417	1,338	905	2,323	2,243	2	83%	180	14	0.08	2	81%	180	13	0.07
410	21	17	1,407	1,329	905	2,312	2,234	2	83%	180	14	0.08	2	81%	180	13	0.07

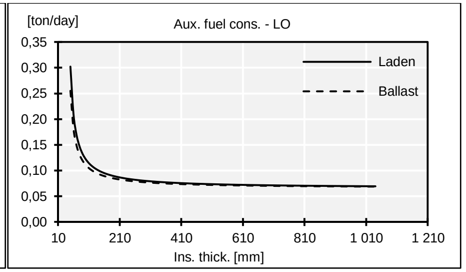
420	21	17	1,396	1,321	905	2,302	2,226	2	83%	180	14	0.08	2	81%	181	13	0.07
430	20	16	1,386	1,313	905	2,292	2,218	2	82%	180	14	0.08	2	80%	181	13	0.07
440	20	16	1,377	1,305	905	2,282	2,211	2	82%	180	14	0.07	2	80%	181	13	0.07
450	19	15	1,368	1,298	905	2,273	2,204	2	82%	180	13	0.07	2	80%	181	13	0.07
460	19	15	1,360	1,291	905	2,265	2,197	2	82%	180	13	0.07	2	80%	181	13	0.07
470	18	15	1,351	1,285	905	2,257	2,190	2	81%	180	13	0.07	2	80%	181	13	0.07
480	18	14	1,344	1,279	905	2,249	2,184	2	81%	180	13	0.07	2	79%	181	13	0.07
490	17	14	1,336	1,273	905	2,242	2,178	2	81%	180	13	0.07	2	79%	181	13	0.07
500	17	14	1,329	1,267	905	2,235	2,173	2	81%	180	13	0.07	2	79%	181	13	0.07
510	17	13	1,322	1,262	905	2,228	2,167	2	81%	180	13	0.07	2	79%	181	13	0.07
520	16	13	1,316	1,257	905	2,221	2,162	2	80%	181	13	0.07	2	79%	181	13	0.07
530	16	13	1,310	1,252	905	2,215	2,157	2	80%	181	13	0.07	2	79%	181	13	0.07
540	16	13	1,304	1,247	905	2,209	2,152	2	80%	181	13	0.07	2	79%	181	13	0.07
550	15	12	1,298	1,242	905	2,203	2,147	2	80%	181	13	0.07	2	79%	181	13	0.07
560	15	12	1,292	1,238	905	2,198	2,143	2	80%	181	13	0.07	2	78%	181	13	0.07
570	15	12	1,287	1,233	905	2,192	2,139	2	80%	181	13	0.07	2	78%	181	13	0.07
580	14	12	1,282	1,229	905	2,187	2,135	2	80%	181	13	0.07	2	78%	181	13	0.07
590	14	11	1,277	1,225	905	2,182	2,131	2	79%	181	13	0.07	2	78%	181	13	0.07
600	14	11	1,272	1,222	905	2,178	2,127	2	79%	181	13	0.07	2	78%	181	13	0.07
610	14	11	1,268	1,218	905	2,173	2,123	2	79%	181	13	0.07	2	78%	181	13	0.07
620	13	11	1,263	1,214	905	2,169	2,120	2	79%	181	13	0.07	2	78%	181	13	0.07
630	13	11	1,259	1,211	905	2,164	2,116	2	79%	181	13	0.07	2	78%	181	13	0.07
640	13	10	1,255	1,208	905	2,160	2,113	2	79%	181	13	0.07	2	78%	181	13	0.07
650	13	10	1,251	1,204	905	2,156	2,110	2	79%	181	13	0.07	2	77%	181	13	0.07
660	13	10	1,247	1,201	905	2,152	2,107	2	79%	181	13	0.07	2	77%	181	13	0.07
670	12	10	1,243	1,198	905	2,148	2,103	2	79%	181	13	0.07	2	77%	181	13	0.07
680	12	10	1,239	1,195	905	2,145	2,101	2	78%	181	13	0.07	2	77%	181	13	0.07
690	12	10	1,236	1,192	905	2,141	2,098	2	78%	181	13	0.07	2	77%	181	13	0.07
700	12	9	1,232	1,190	905	2,138	2,095	2	78%	181	13	0.07	2	77%	181	13	0.07
710	12	9	1,229	1,187	905	2,134	2,092	2	78%	181	13	0.07	2	77%	181	13	0.07
720	11	9	1,226	1,184	905	2,131	2,090	2	78%	181	13	0.07	2	77%	181	13	0.07
730	11	9	1,223	1,182	905	2,128	2,087	2	78%	181	13	0.07	2	77%	181	13	0.07
740	11	9	1,220	1,179	905	2,125	2,085	2	78%	181	13	0.07	2	77%	181	13	0.07
750	11	9	1,217	1,177	905	2,122	2,082	2	78%	181	13	0.07	2	77%	181	13	0.07
760	11	9	1,214	1,175	905	2,119	2,080	2	78%	181	13	0.07	2	77%	181	13	0.07
770	11	8	1,211	1,172	905	2,116	2,078	2	78%	181	13	0.07	2	77%	181	13	0.07
780	10	8	1,208	1,170	905	2,114	2,076	2	78%	181	13	0.07	2	77%	181	13	0.07
790	10	8	1,206	1,168	905	2,111	2,073	2	78%	181	13	0.07	2	77%	181	13	0.07
800	10	8	1,203	1,166	905	2,108	2,071	2	77%	181	13	0.07	2	76%	181	13	0.07
810	10	8	1,200	1,164	905	2,106	2,069	2	77%	181	13	0.07	2	76%	181	13	0.07
820	10	8	1,198	1,162	905	2,103	2,067	2	77%	181	13	0.07	2	76%	181	13	0.07
830	10	8	1,196	1,160	905	2,101	2,065	2	77%	181	13	0.07	2	76%	181	13	0.07
840	10	8	1,193	1,158	905	2,099	2,064	2	77%	181	13	0.07	2	76%	181	13	0.07
850	9	8	1,191	1,156	905	2,096	2,062	2	77%	181	13	0.07	2	76%	181	13	0.07
860	9	7	1,189	1,155	905	2,094	2,060	2	77%	181	13	0.07	2	76%	181	13	0.07

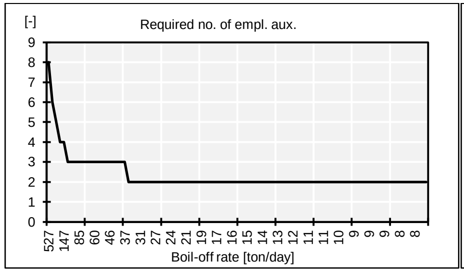
870	9	7	1,187	1,153	905	2,092	2,058	2	77%	181	13	0.07	2	76%	181	13	0.07
880	9	7	1,184	1,151	905	2,090	2,057	2	77%	181	13	0.07	2	76%	181	13	0.07
890	9	7	1,182	1,150	905	2,088	2,055	2	77%	181	13	0.07	2	76%	181	13	0.07
900	9	7	1,180	1,148	905	2,086	2,053	2	77%	181	13	0.07	2	76%	181	13	0.07
910	9	7	1,178	1,146	905	2,084	2,052	2	77%	181	13	0.07	2	76%	181	13	0.07
920	9	7	1,176	1,145	905	2,082	2,050	2	77%	181	13	0.07	2	76%	181	13	0.07
930	9	7	1,175	1,143	905	2,080	2,049	2	77%	181	13	0.07	2	76%	181	13	0.07
940	8	7	1,173	1,142	905	2,078	2,047	2	77%	181	13	0.07	2	76%	181	13	0.07
950	8	7	1,171	1,140	905	2,076	2,046	2	77%	181	13	0.07	2	76%	181	13	0.07
960	8	7	1,169	1,139	905	2,074	2,044	2	77%	181	13	0.07	2	76%	181	13	0.07
970	8	7	1,167	1,138	905	2,073	2,043	2	76%	181	13	0.07	2	76%	181	13	0.07
980	8	6	1,166	1,136	905	2,071	2,042	2	76%	181	13	0.07	2	76%	182	13	0.07
990	8	6	1,164	1,135	905	2,069	2,040	2	76%	181	13	0.07	2	76%	182	13	0.07
1,000	8	6	1,162	1,134	905	2,068	2,039	2	76%	181	13	0.07	2	76%	182	13	0.07
1,010	8	6	1,161	1,132	905	2,066	2,038	2	76%	181	13	0.07	2	76%	182	13	0.07
1,020	8	6	1,159	1,131	905	2,065	2,036	2	76%	181	13	0.07	2	76%	182	13	0.07
1,030	8	6	1,158	1,130	905	2,063	2,035	2	76%	181	13	0.07	2	75%	182	12	0.07
1,040	8	6	1,156	1,129	905	2,062	2,034	2	76%	181	13	0.07	2	75%	182	12	0.07

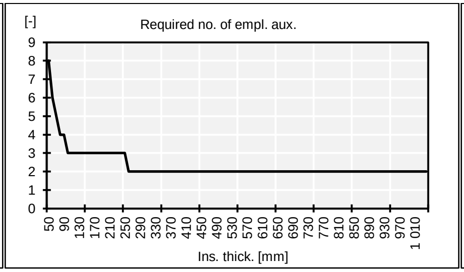


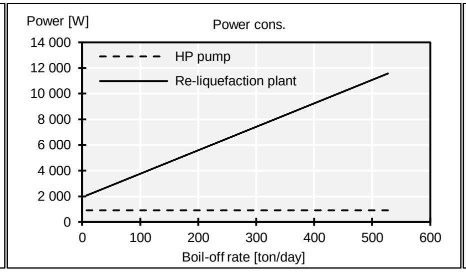


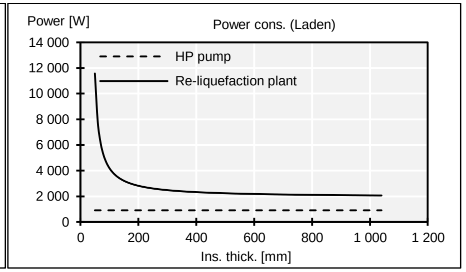


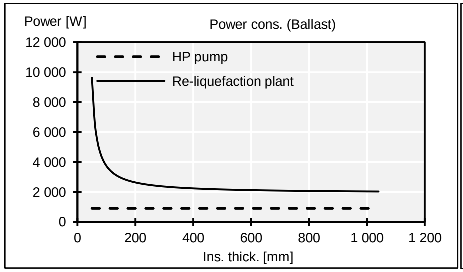


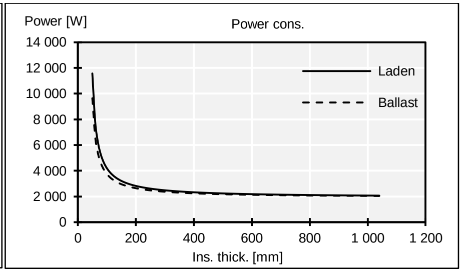






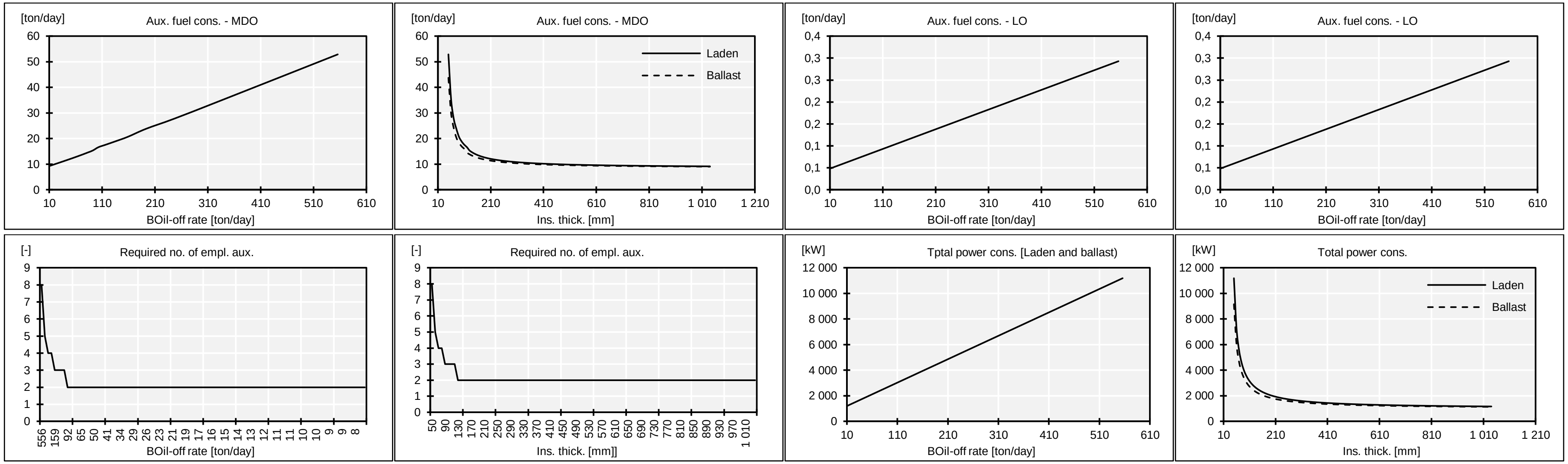




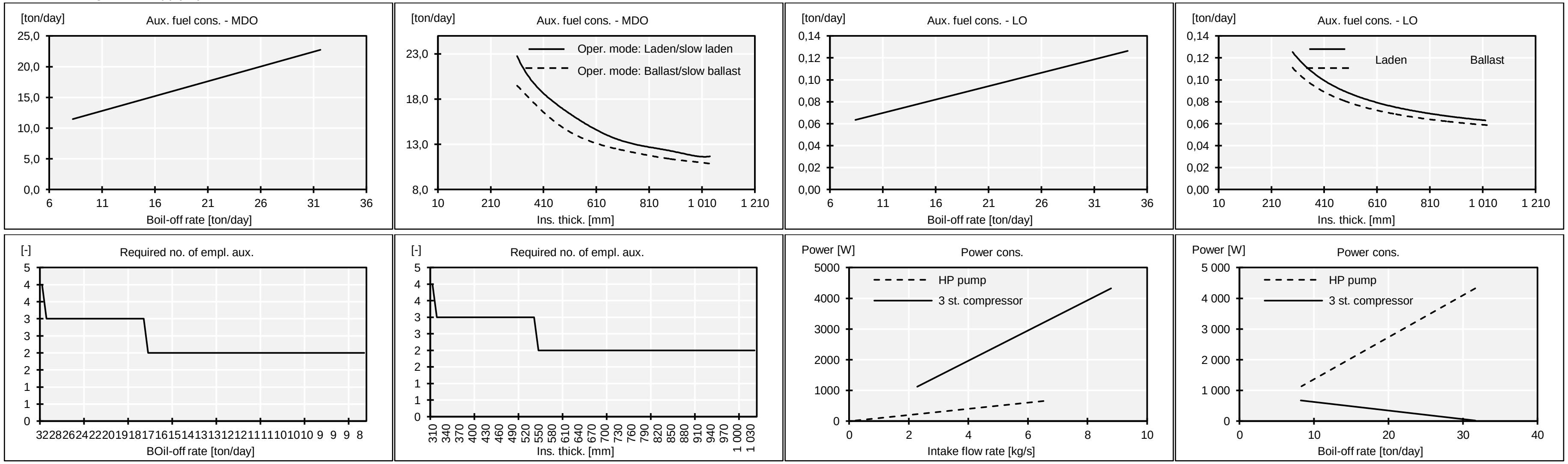


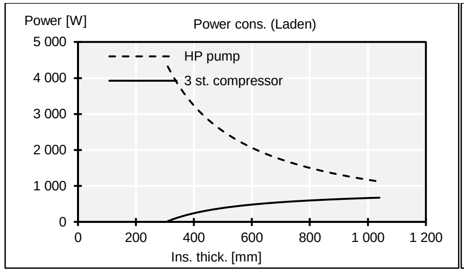
Insulation system 2

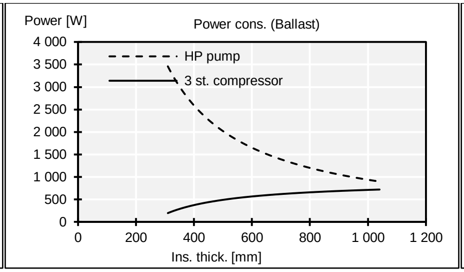
Boil-off handling – Re-liquefaction

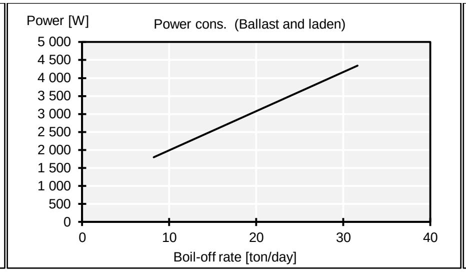


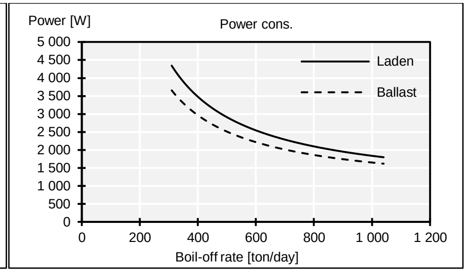
Boil-off handling – Gas supply system alt. 1



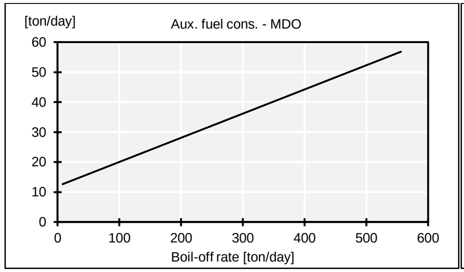

Power [W]
Power cons. (Laden)
HP pump
3 st. compressor
Ins. thick. [mm]

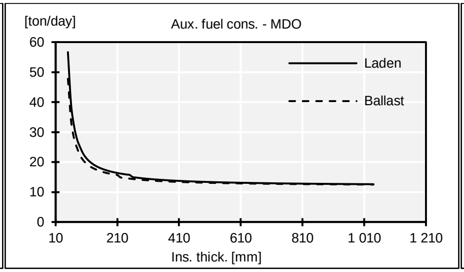

Power [W]
Power cons. (Ballast)
HP pump
3 st. compressor
Ins. thick. [mm]

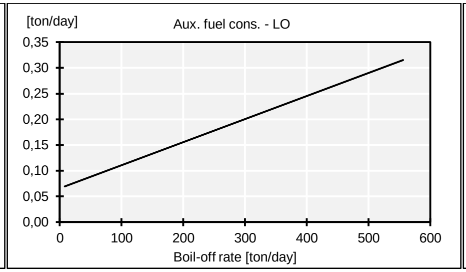

Power [W]
Power cons. (Ballast and laden)
Boil-off rate [ton/day]

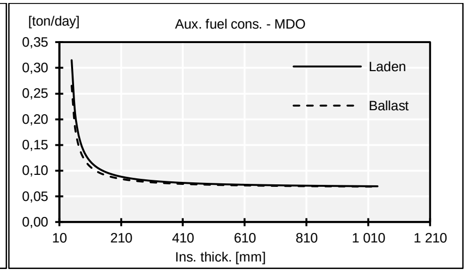

Power [W]
Power cons.
Laden
Ballast
Boil-off rate [ton/day]

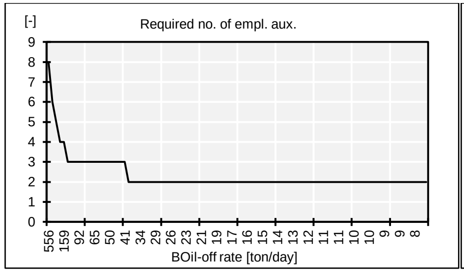
Boil-off handling – Gas supply system alt. 2

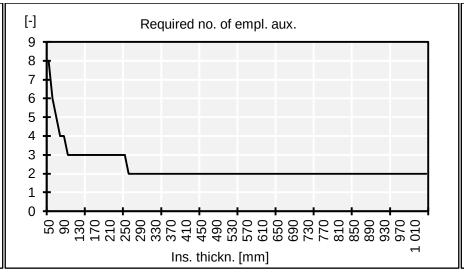


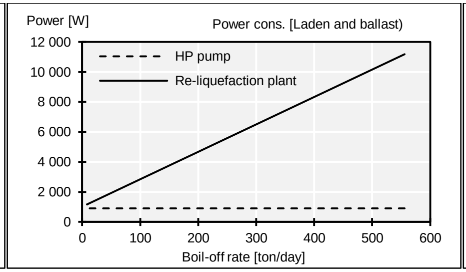


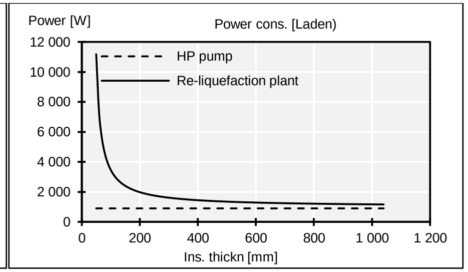


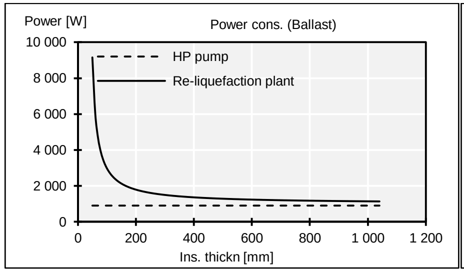


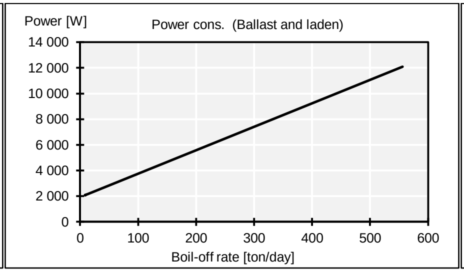


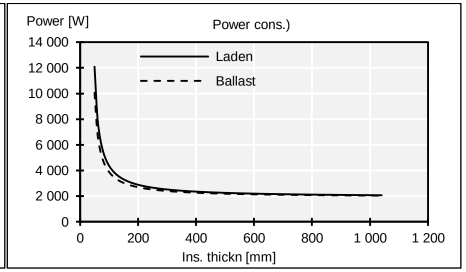






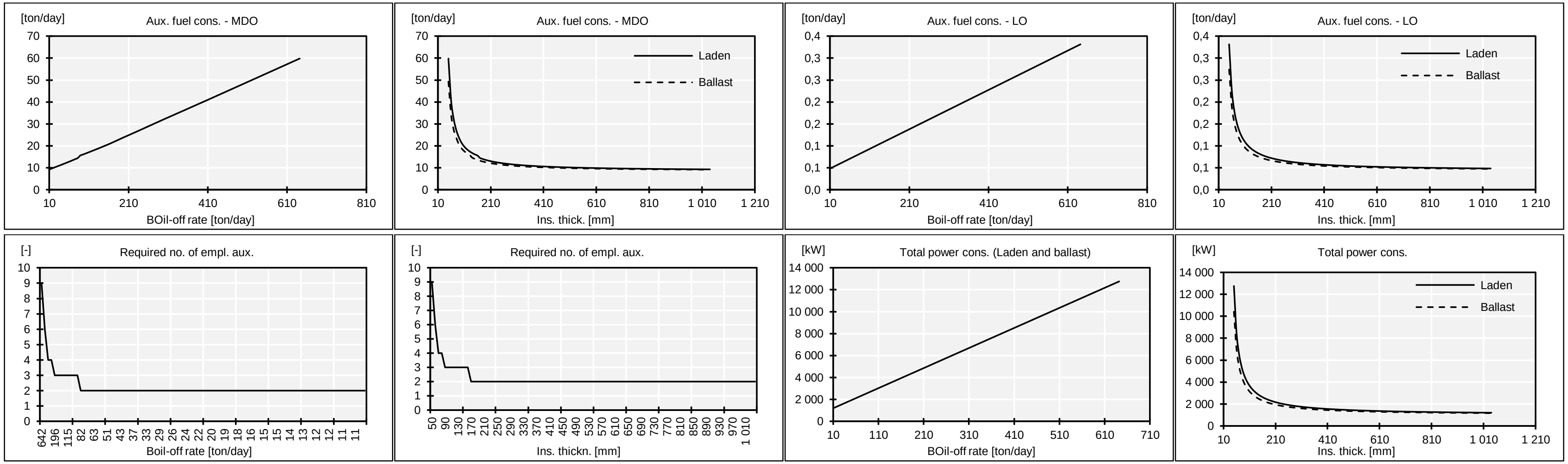




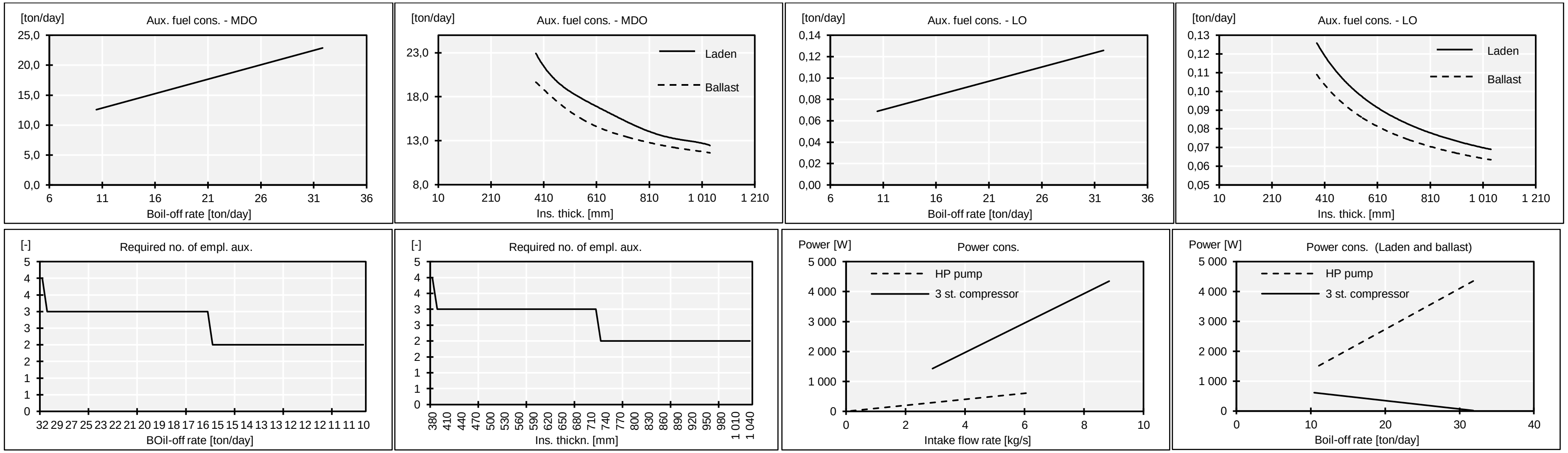


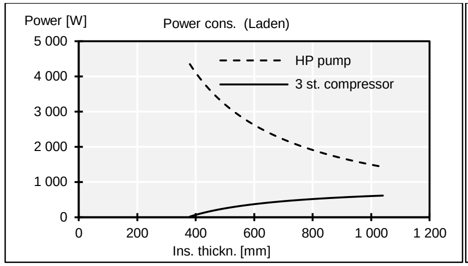
Insulation system 3

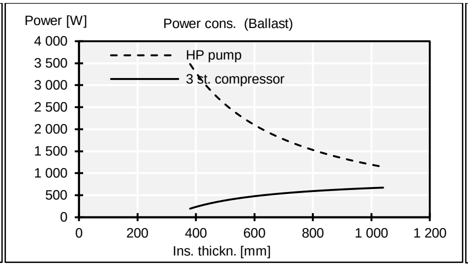
Boil off handling -– Re-liquefaction

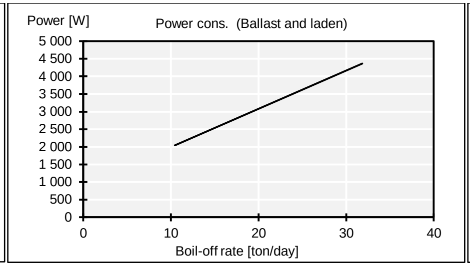


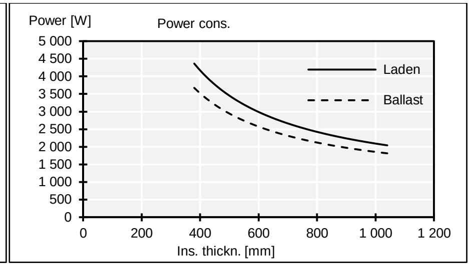
Boil-off handling – Gas supply system alt. 1



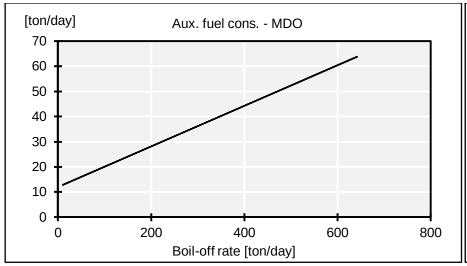


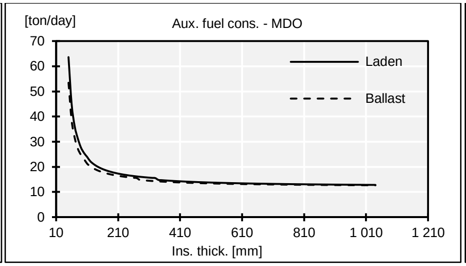


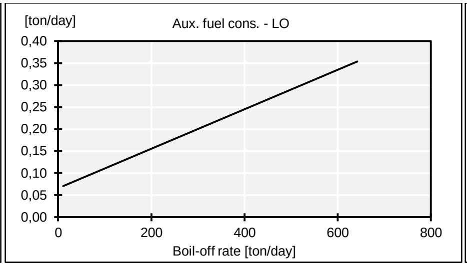


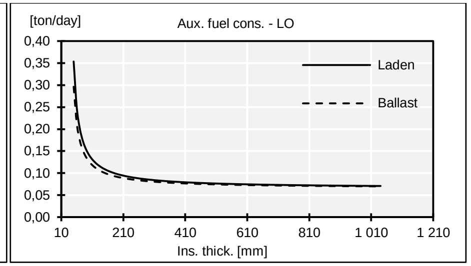


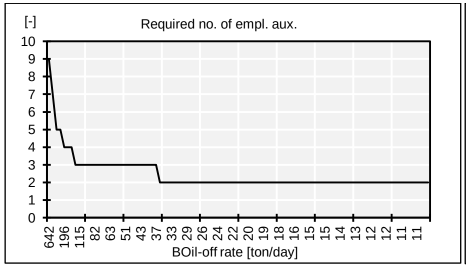
Boil-off handling – Gas supply system alt. 2

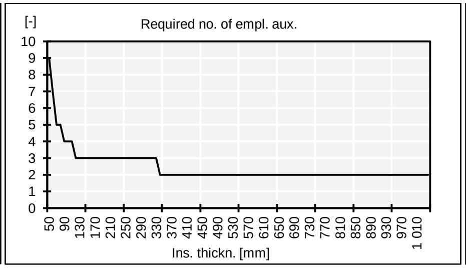


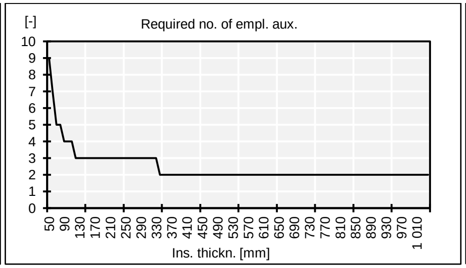


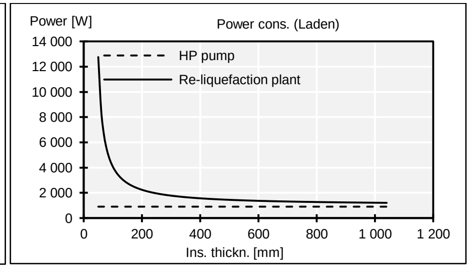


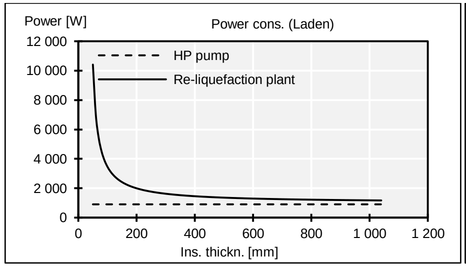


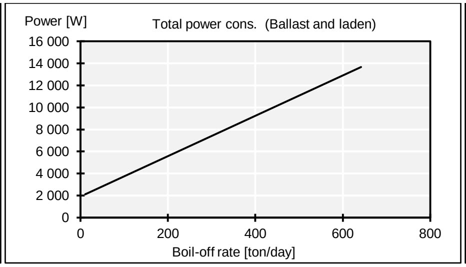


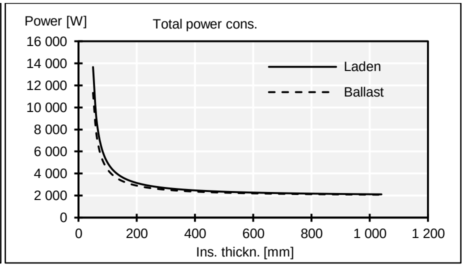






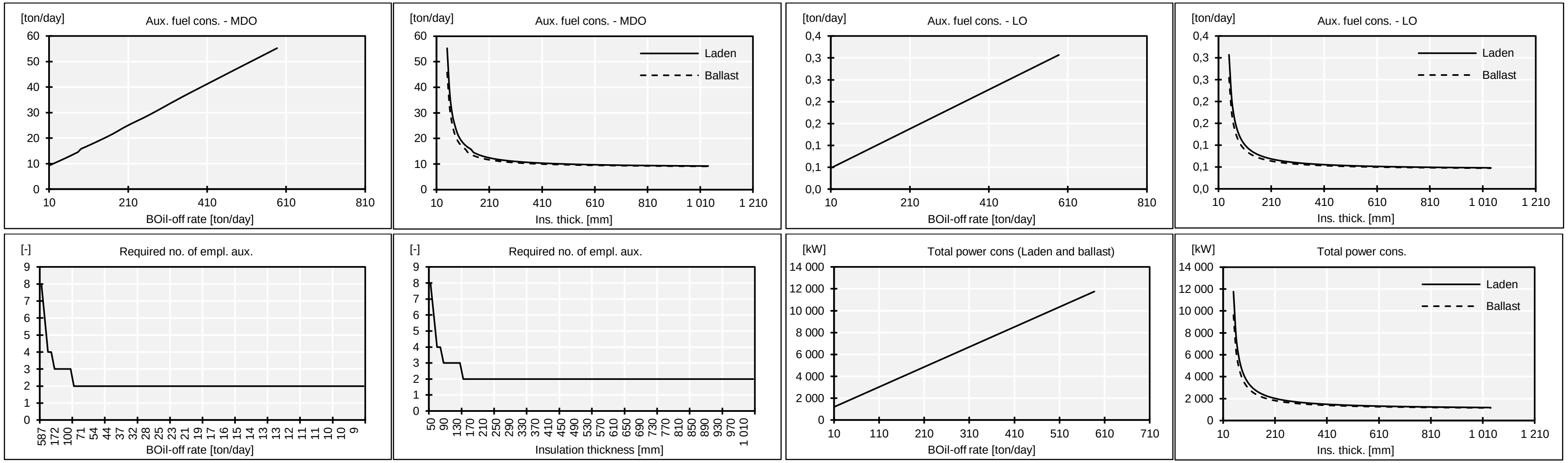




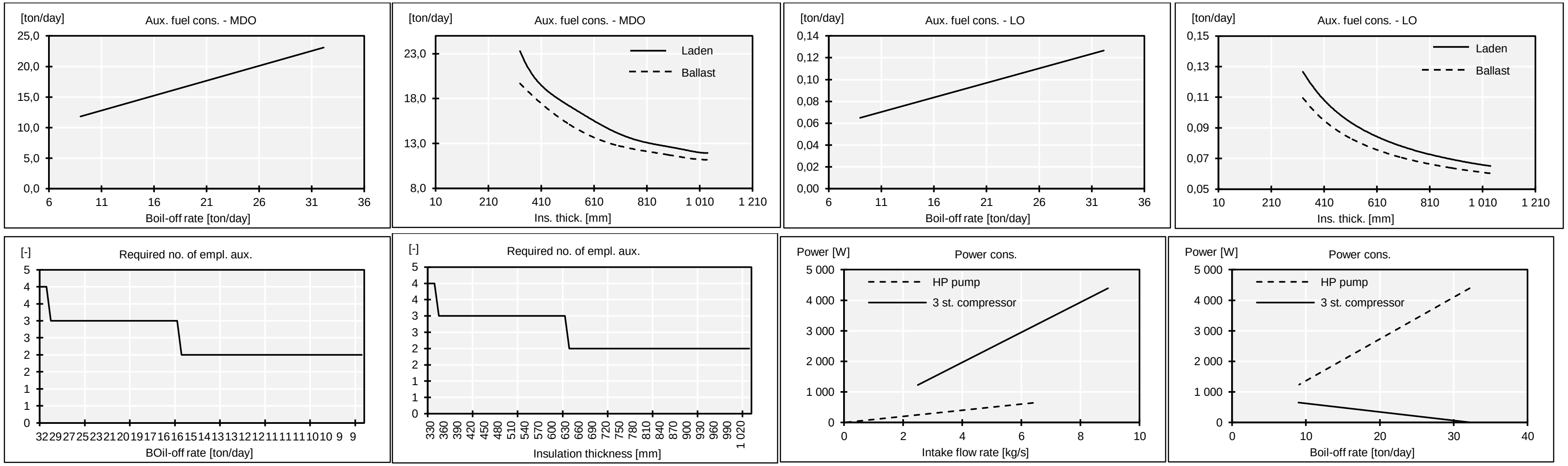


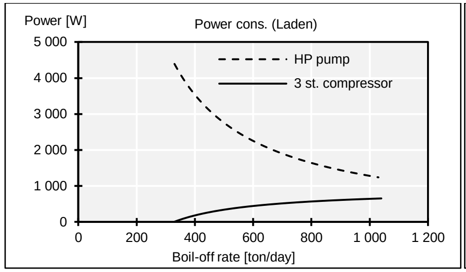
Insulation system 4

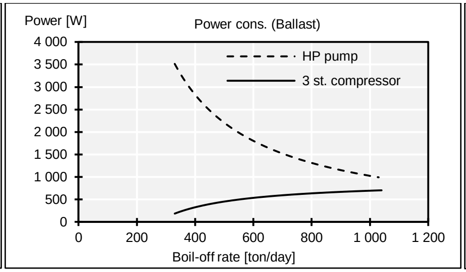
Boil off handling -– Re-liquefaction

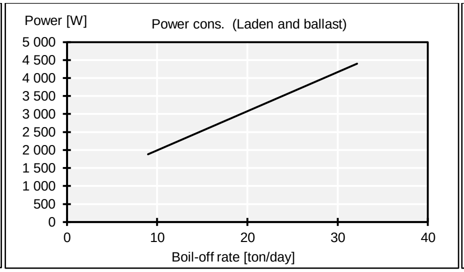


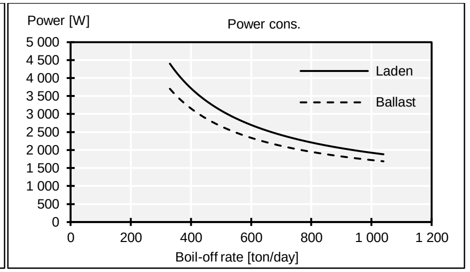
Boil-off handling – Gas supply system alt. 1



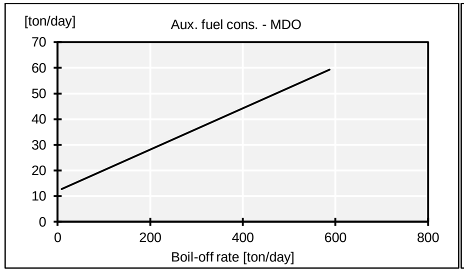


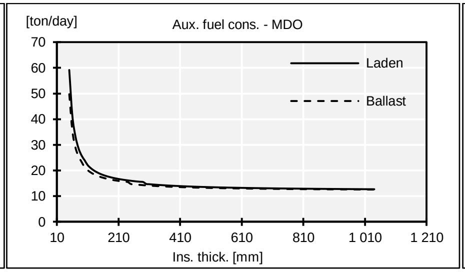


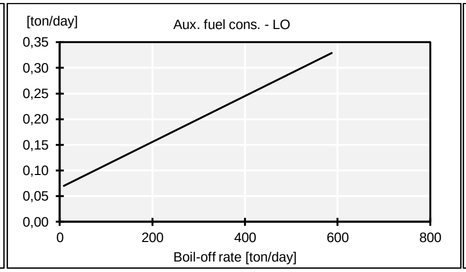


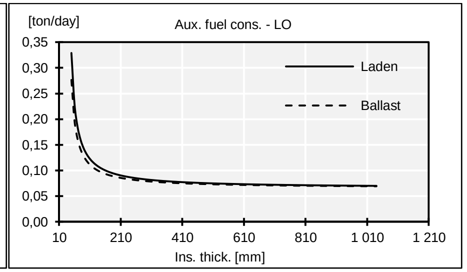


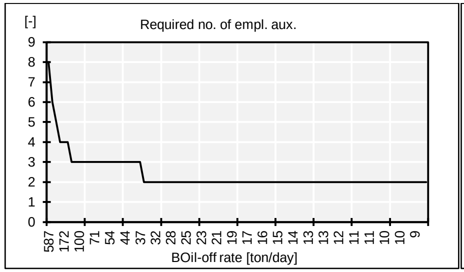
Boil-off handling – Gas supply system alt. 2

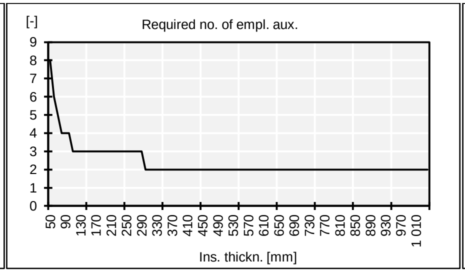


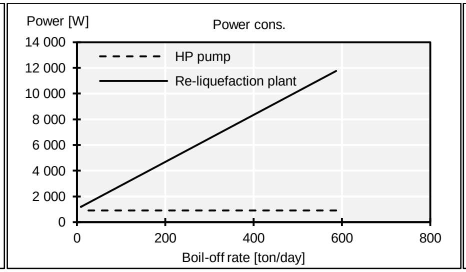


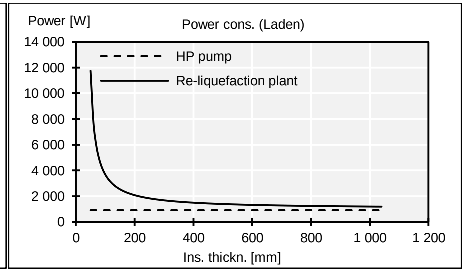


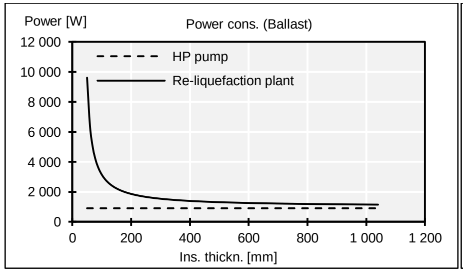


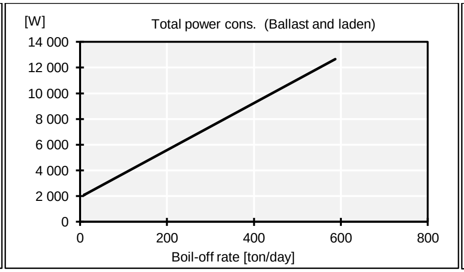


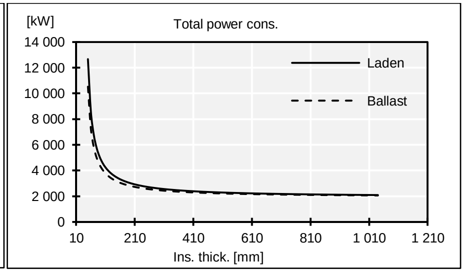






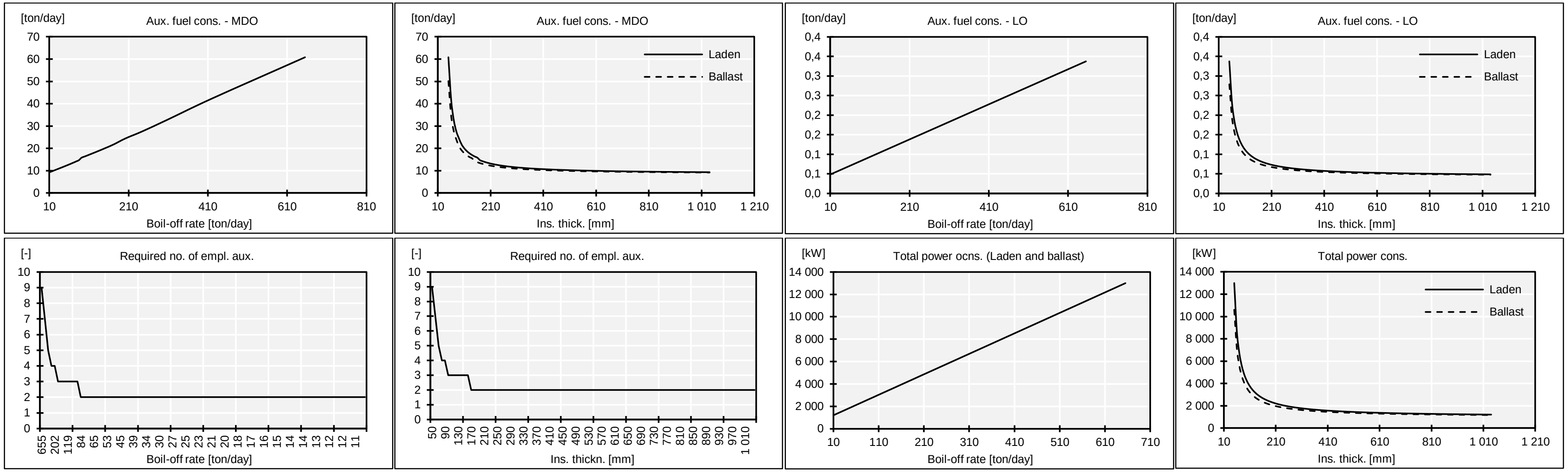




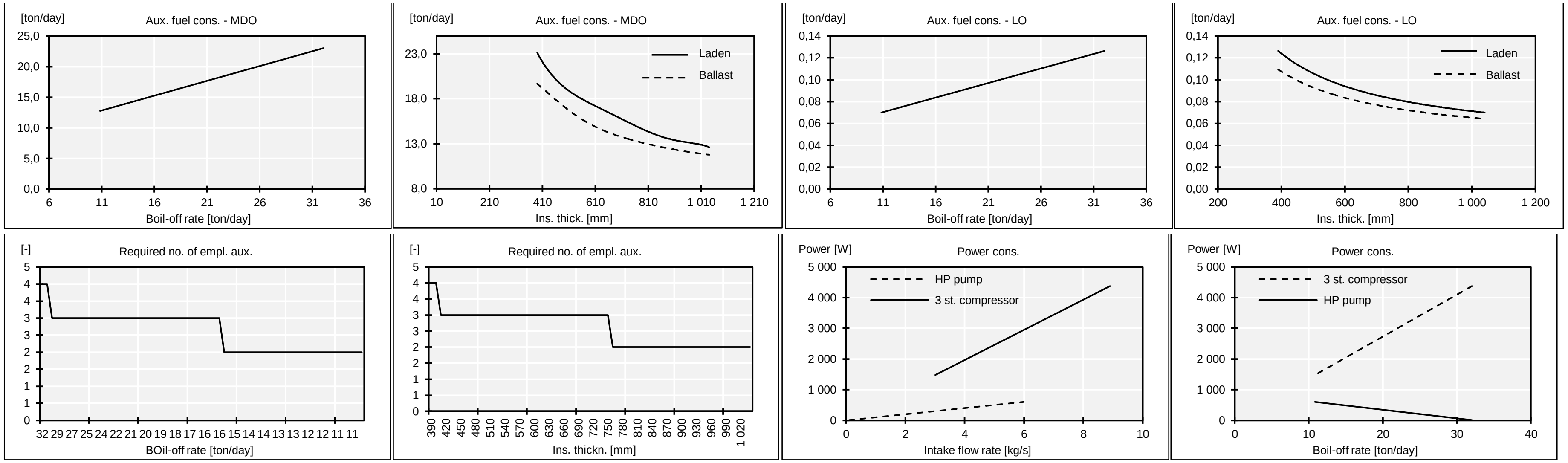


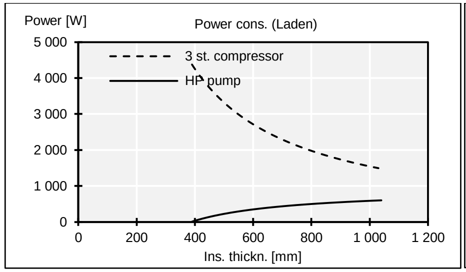
Insulation system 5

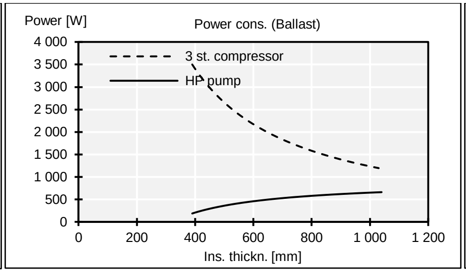
Boil off handling -– Re-liquefaction

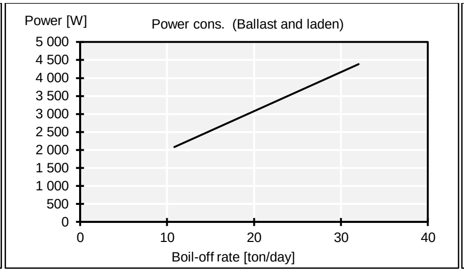


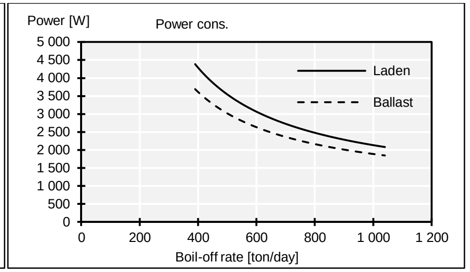
Boil-off handling – Gas supply system alt. 1



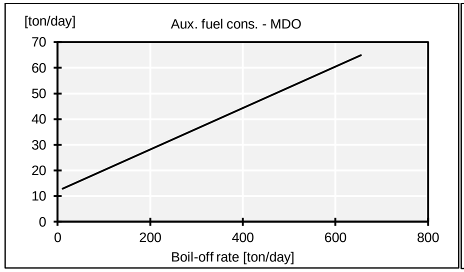


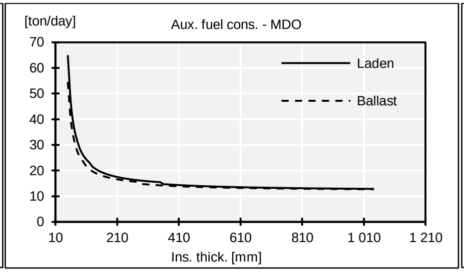


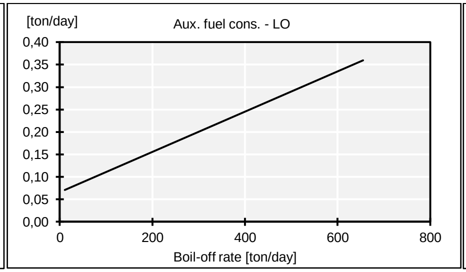


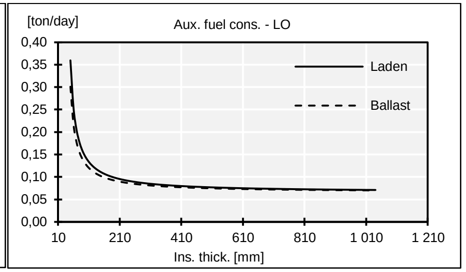


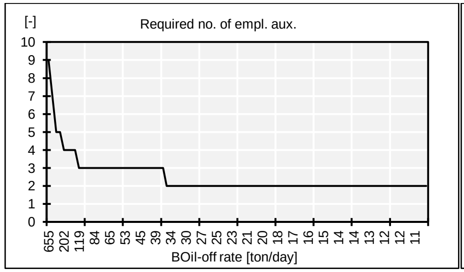
Boil-off handling – Gas supply system alt. 2

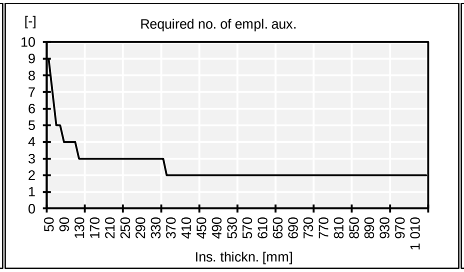


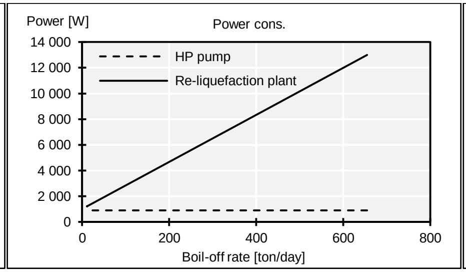


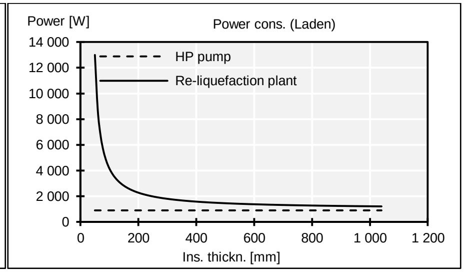


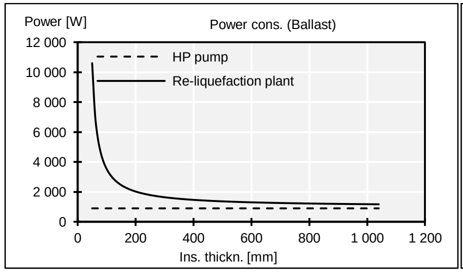


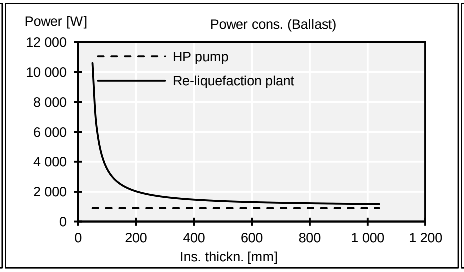


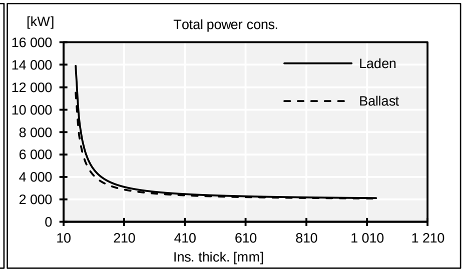






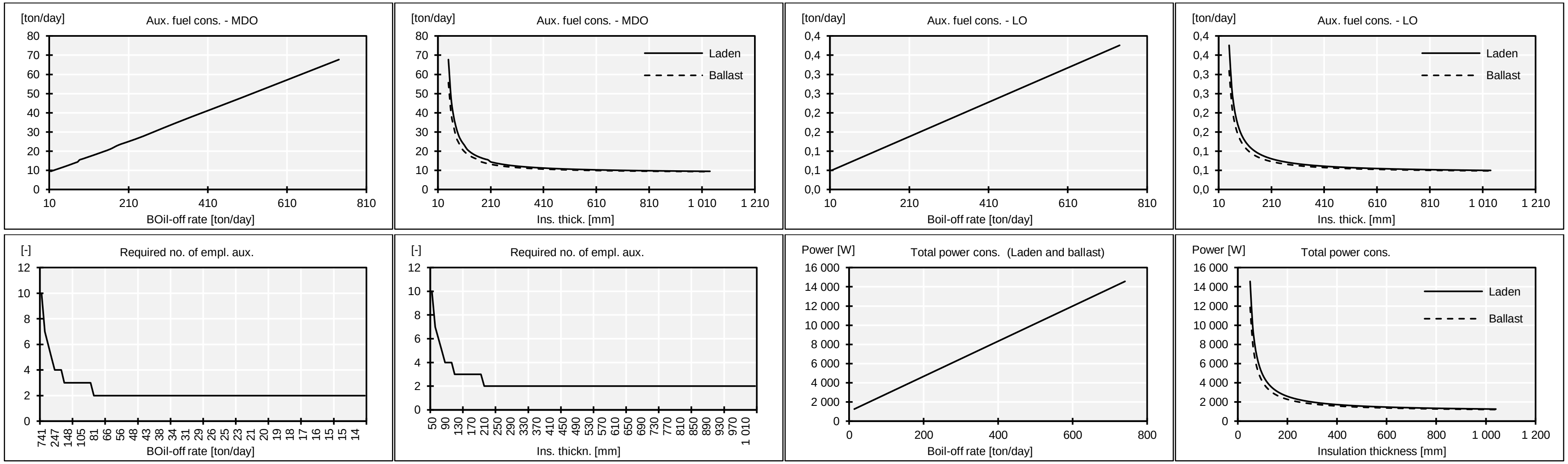




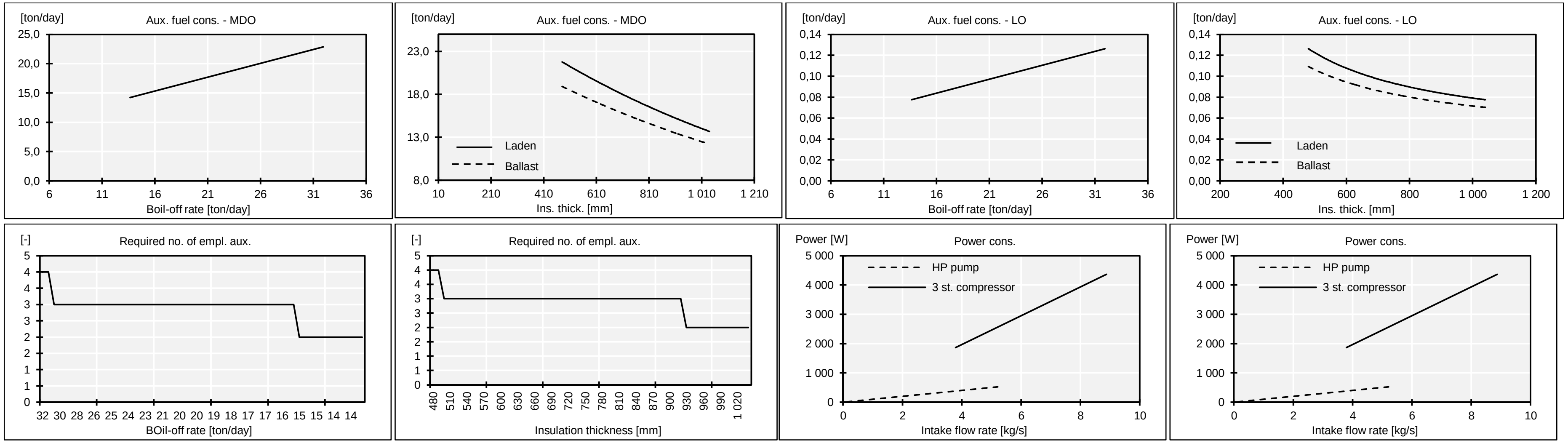


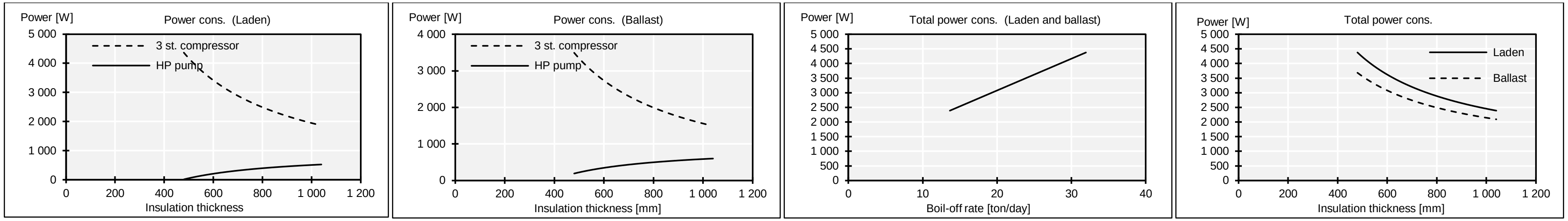
Insulation system 6

Boil off handling – Re-liquefaction

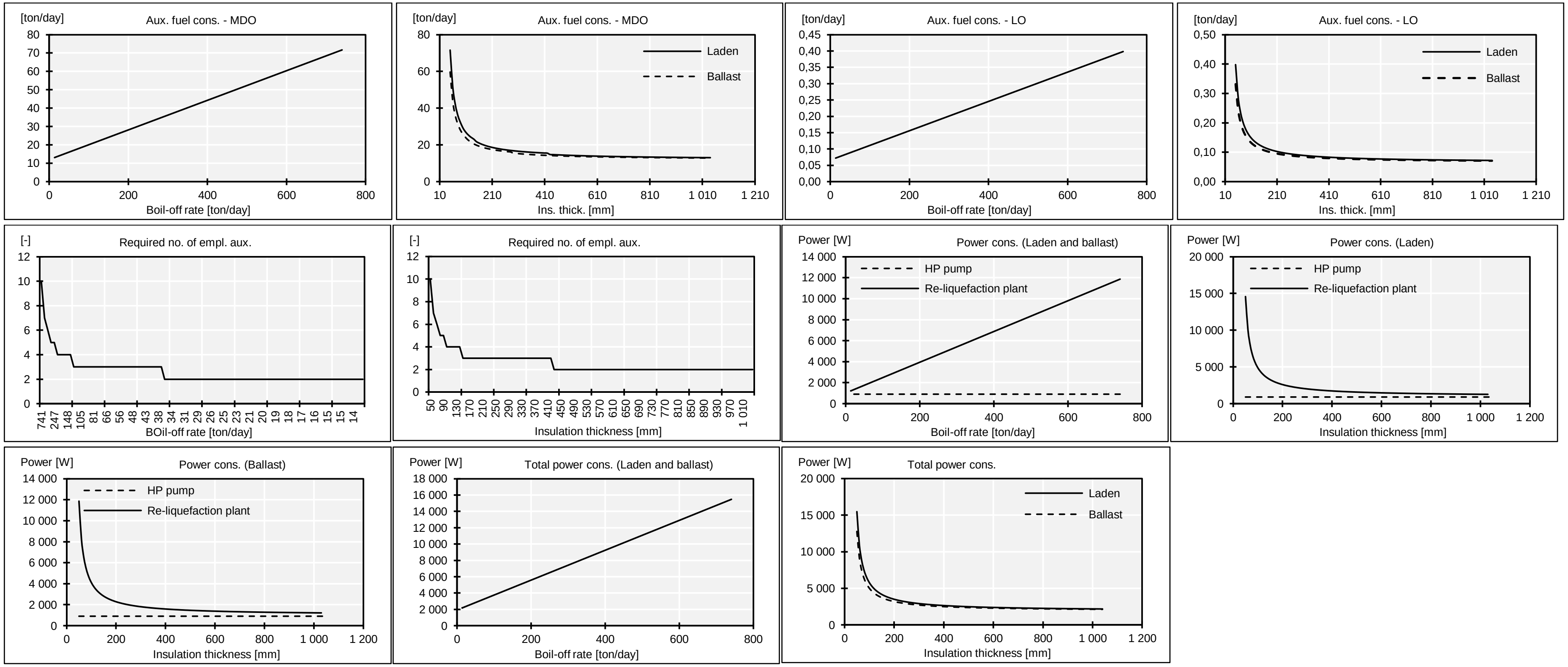


Boil-off handling – Gas supply system alt. 1





Boil-off handling – Gas supply system alt. 2



Appendix 9

Building cost – CBS 1

Fixed building cost – CBS 1.1

CBS 1.1.1 – Fixed material and component cost				Value		Coeff. [USD/unit]		Cost [USD]	
WBS	Cost group	Unit		Alt 1.	Alt 2.	Alt 1.	Alt 2.	Alt 1.	Alt. 2
1	Ship general	Lightweight - excl. insulation and tank weight)	[ton]	11,463	11,463	150	150	1,719,431	1,719,431
2	Hull	Steel weight hull	[ton]	6,840	6,840	800	800	5,471,760	5,471,760
3	Cargo related								
3.4	Cargo instrumentation	Cargo capacity	[m3]	45,000	45,000	27	27	1,210,347	1,210,347
3.5	Electrical systems (cargo control)	Cargo capacity	[m3]	45,000	45,000	38	38	1,724,996	1,724,996
3.6	PSA plant (nitrogen)	Cargo capacity	[m3]	45,000	45,000	40	40	1,781,250	1,781,250
3.7	Gas piping	Cargo capacity	[m3]	45,000	45,000	63	63	2,822,468	2,822,468
3.8	Deep well cargo pumps inc. sys	Pump capacity	[m3/h]	2,499	2,499	501	501	1,251,950	1,251,950
3.9	Miscellaneous cargo equipment	Cargo capacity	[m3]					100,000	100,000
4	Ship equipment	Gross volume	[m3]	101,728	101,728	7	7	712,096	712,096
5	Equipment for crew	Number of crew	[-]	20	20	35,000	35,000	700,000	700,000
6	Machinery								
6.1	Main engine								
6.1.1	Main engine	SMCR ME	[kW]	10,680	10,680	427	555	4,558,537	5,926,098
6.1.2	Main engine systems	SMCR ME	[kW]	10,680	10,680	10	30	106,800	320,400
6.3	Miscellaneous machinery systems	Propulsion power	[kW]					100,000	100,000
7	Ship common systems	Total power	[kW]	14,000	14,000	200	200	2,800,000	2,800,000
	Total fixed material and component cost							25,059,635	26,640,796
	Reserve	Percentage of total fixed cost					5%	1,252,982	1,332,040
	Total variable material and component cost							26,312,616	27,972,835

CBS 1.1.2 - Fixed labour hours				Value		Coeff. [hours/unit]		Labour hours	
WBS	Cost group	Unit		Alt 1.	Alt 2.	Alt 1.	Alt 2.	Alt 1.	Alt. 2
1	Ship general	Lightweight - excl. insulation and tank weight)	[ton]	11,463	11,463	10	10	114,629	114,629
2	Hull	Steel weight	[ton]	6,840	6,840	25	25	170,993	170,993
3	Cargo related	Cargo capacity	[m3]					100,000	100,000
4	Ship equipment	Gross volume	[m3]	101,728	101,728	1	1	50,864	50,864
5	Equipment for crew	Number of crew	[-]	20	20	800	800	16,000	16,000
6.1	Machinery	SMCR ME	[kW]	10,680	10,680	3	5	32,040	53,400
7	Ship common systems	Propulsion power	[kW]	14,000	14,000	3	3	35,000	35,000
	Total fixed labour							519,525	540,885
	Reserve	Percentage of total fixed labour hours					5%	25,976	27,044
	Total fixed labour hours consumption							545,502	567,930

CBS 1.1.3 - Fixed administration and design cost			Value		Coeff. [USD/unit]		Cost [USD]	
Cost group	Unit/comment		Alt 1.	Alt 2.	Alt 1.	Alt 2.	Alt 1.	Alt. 2
Design cost (excl. containment system design cost)	NB! (LWT exclude cargo- and ins. weight)	15 [hours/LWT]	11,463	11,463	30	30	5,158,294	5,158,294
Containment system related design cost	Assumed fixed and independent from cargo tank size and insulation thickness						1,000,000	1,000,000
Total fixed design cost							6,158,294	6,158,294
Fixed labour hours plus overhead cost	Labour hours	[hours]	545,502	567,930	15	15	8,182,523	8,518,943
Fixed material and component cost							26,312,616	27,972,835
Total fixed production cost							34,495,139	36,491,778
Fixed building time financing	Assumed 7% of fixed material and component cost					7%	1,841,883	1,958,098
Total fixed production cost							42,495,316	44,608,170
Profit on fixed production cost	Percentage of total fixed production cost					5%	2,124,766	2,230,409
Broker fees on fixed production cost	Percentage of total fixed production cost					1%	212,477	223,041
Total fixed administration and design cost							2,337,242	2,453,449

Total fixed building cost	44,832,558	47,061,620

Variable building cost – CBS 1.2

Variable building cost									
CBS 1.2.1 - Variable material and component cost				Value		Coeff. [USD/unit]		Cost [USD]	
WBS	Cost group	Unit		Alt 1.	Alt 2.	Alt 1.	Alt 2.	Alt 1.	Alt. 2
3	Cargo related								
3.1	Cargo tank	Weight all cargo tanks	[ton]	Variable	Variable	1000	1000	Variable	Variable
3.2	Insulation system								
3.2.1	Insulation layer 1	Insulation volume	[m3]	Variable				Variable	
3.2.2	Insulation layer 2	Insulation volume	[m3]	Variable		Variable with regard to insulation thickness and type		Variable	
3.2.3	Insulation layer 3	Insulation volume	[m3]	Variable				Variable	
3.2.4	Insulation layer 4	Insulation volume	[m3]	Variable				Variable	
3.3	Boil-off handling system								
3.3.1	Re-liquefaction plant	Boil-off rate	[ton/day]	Variable				Variable	
3.3.2	Gas supply system								
3.3.2.1	Alt 1: Conv. gas supply system	Boil-off rate and fuel cons.	[ton/day]		Variable	Variable with regard to capacity			Variable
3.3.2.2	Alt 2: Comb. gas supply system								
3.3.2.2.1	Simpl. gas supply system	Fuel consumption	[ton/day]		Variable				Variable
3.3.2.2.2	Re-liquefaction	Boil-off rate	[ton/day]		Variable				Variable
3.3.3	GCU	Boil-off rate	[ton/day]	Variable	Variable			Variable	Variable
6	Machinery								
6.2	Aux generator								
6.2.1	Auxiliary engine & generator	Installed aux. power	[kW]	Variable	Variable	500	500	Variable	Variable
6.2.2	Auxiliary generator systems	Installed aux. power	[kW]	Variable	Variable	50	50	Variable	Variable
	Total variable material and component cost								
	Reserve	Percentage of total fixed cost					5%		
	Total material and component cost							Variable	Variable

CBS 1.2.2 - Variable labour hours				Value		Coeff. [hours/unit]		Labour hours	
WBS	Cost group	Unit		Alt 1.	Alt 2.	Alt 1.	Alt 2.	Alt 1.	Alt. 2
3	Cargo related								
3.1	Cargo tank	Weight all cargo tanks	[ton]	Variable		30	30	Variable	
3.2	Insulation material								
3.2.1	Insulation layer 1	Area to be insulated	[m2]	Variable				Variable	
3.2.2	Insulation layer 2	Area to be insulated	[m2]	Variable		Variable with regard to insulation system and insulation thickness		Variable	
3.2.3	Insulation layer 3	Area to be insulated	[m2]	Variable				Variable	
3.2.4	Insulation layer 4	Area to be insulated	[m2]	Variable				Variable	
3.3.1	Re-liquefaction plant								
3.3.2	Gas supply system	Included in material and component cost (turnkey)							
3.3.3	GCU								
6	Machinery								
6.2	Auxiliary generator related	Installed aux. power	[kW]	Variable	Variable	4		Variable	Variable
	Total variable labour							Variable	Variable
	Reserve	Percentage of total fixed labour hours					5%	Variable	Variable
	Total variable labour hours consumption							Variable	Variable

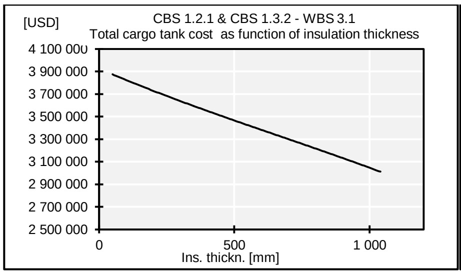
CBS 1.3.2 - Variable administration and design cost			Value		Coeff. [USD/unit]		Cost [USD]	
Cost group	Unit/comment		Alt 1.	Alt 2.	Alt 1.	Alt 2.	Alt 1.	Alt. 2
Variable labour hours plus overhead	Labour hours	[hours]	Variable		15	15	Variable	Variable
Variable material and component cost			Variable		Variable	Variable	Variable	Variable
Variable production cost							Variable	Variable
Variable building time financing	Assumed 7% of fixed material and component cost					7%	Variable	Variable
Total variable production cost							Variable	Variable
Profit on variable production cost	Percentage of total fixed production cost					5%	Variable	Variable
Broker fees on variable production cost	Percentage of total fixed production cost					1%	Variable	Variable
Total variable administration and design cost							Variable	Variable

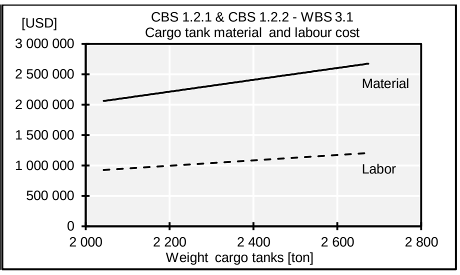
Total variable building cost	Variable	Variable

Cargo tank building cost – WBS 3.1

Table type:		Ins. sys. no:	ME alt:	Description:	
Cargo tank building cost		All	Both	Cargo tank cost as function of ins. thick.	
Insulation thickness	Total cargo tank weight	CBS 1.2.1 WBS 3.1	CBS 1.2.2 WBS 3.1	CBS 1.3.2 WBS 3.1	CBS 1.2.1 & CBS 1.3.2 WBS 3.1
t_{INS_TOT} [mm]	W_T [ton]	C_{T_MAT} [USD]	$T_{T\_LAB\_TOT}$ [hours]	C_{T_LAB} [USD]	C_{T_TOT} [USD]
50	2,674	2,673,584	80,208	1,203,113	3,876,697
60	2,667	2,666,702	80,001	1,200,016	3,866,717
70	2,660	2,659,830	79,795	1,196,923	3,856,753
80	2,653	2,652,968	79,589	1,193,836	3,846,804
90	2,646	2,646,118	79,384	1,190,753	3,836,871
100	2,639	2,639,278	79,178	1,187,675	3,826,953
110	2,632	2,632,449	78,973	1,184,602	3,817,051
120	2,626	2,625,631	78,769	1,181,534	3,807,164
130	2,619	2,618,823	78,565	1,178,470	3,797,293
140	2,612	2,612,026	78,361	1,175,412	3,787,438
150	2,605	2,605,240	78,157	1,172,358	3,777,598
160	2,598	2,598,464	77,954	1,169,309	3,767,773
170	2,592	2,591,699	77,751	1,166,265	3,757,964
180	2,585	2,584,945	77,548	1,163,225	3,748,171
190	2,578	2,578,202	77,346	1,160,191	3,738,392
200	2,571	2,571,469	77,144	1,157,161	3,728,630
210	2,565	2,564,747	76,942	1,154,136	3,718,883
220	2,558	2,558,035	76,741	1,151,116	3,709,151
230	2,551	2,551,334	76,540	1,148,100	3,699,434
240	2,545	2,544,644	76,339	1,145,090	3,689,733
250	2,538	2,537,964	76,139	1,142,084	3,680,048
260	2,531	2,531,295	75,939	1,139,083	3,670,378
270	2,525	2,524,636	75,739	1,136,086	3,660,723
280	2,518	2,517,989	75,540	1,133,095	3,651,083
290	2,511	2,511,351	75,341	1,130,108	3,641,459
300	2,505	2,504,724	75,142	1,127,126	3,631,850
310	2,498	2,498,108	74,943	1,124,149	3,622,257
320	2,492	2,491,503	74,745	1,121,176	3,612,679
330	2,485	2,484,908	74,547	1,118,208	3,603,116
340	2,478	2,478,323	74,350	1,115,245	3,593,569
350	2,472	2,471,749	74,152	1,112,287	3,584,036
360	2,465	2,465,186	73,956	1,109,334	3,574,520
370	2,459	2,458,633	73,759	1,106,385	3,565,018
380	2,452	2,452,091	73,563	1,103,441	3,555,531
390	2,446	2,445,559	73,367	1,100,501	3,546,060
400	2,439	2,439,037	73,171	1,097,567	3,536,604
410	2,433	2,432,527	72,976	1,094,637	3,527,164
420	2,426	2,426,026	72,781	1,091,712	3,517,738
430	2,420	2,419,536	72,586	1,088,791	3,508,328
440	2,413	2,413,057	72,392	1,085,876	3,498,933
450	2,407	2,406,588	72,198	1,082,965	3,489,553
460	2,400	2,400,130	72,004	1,080,058	3,480,188
470	2,394	2,393,681	71,810	1,077,157	3,470,838
480	2,387	2,387,244	71,617	1,074,260	3,461,504
490	2,381	2,380,817	71,425	1,071,368	3,452,184
500	2,374	2,374,400	71,232	1,068,480	3,442,880
510	2,368	2,367,994	71,040	1,065,597	3,433,591
520	2,362	2,361,598	70,848	1,062,719	3,424,317
530	2,355	2,355,212	70,656	1,059,846	3,415,058
540	2,349	2,348,837	70,465	1,056,977	3,405,814
550	2,342	2,342,472	70,274	1,054,113	3,396,585
560	2,336	2,336,118	70,084	1,051,253	3,387,371
570	2,330	2,329,774	69,893	1,048,398	3,378,173
580	2,323	2,323,441	69,703	1,045,548	3,368,989
590	2,317	2,317,117	69,514	1,042,703	3,359,820

600	2,311	2,310,804	69,324	1,039,862	3,350,666
610	2,305	2,304,502	69,135	1,037,026	3,341,528
620	2,298	2,298,210	68,946	1,034,194	3,332,404
630	2,292	2,291,928	68,758	1,031,368	3,323,295
640	2,286	2,285,656	68,570	1,028,545	3,314,202
650	2,279	2,279,395	68,382	1,025,728	3,305,123
660	2,273	2,273,144	68,194	1,022,915	3,296,059
670	2,267	2,266,903	68,007	1,020,107	3,287,010
680	2,261	2,260,673	67,820	1,017,303	3,277,976
690	2,254	2,254,453	67,634	1,014,504	3,268,957
700	2,248	2,248,243	67,447	1,011,709	3,259,953
710	2,242	2,242,044	67,261	1,008,920	3,250,963
720	2,236	2,235,854	67,076	1,006,134	3,241,989
730	2,230	2,229,675	66,890	1,003,354	3,233,029
740	2,224	2,223,507	66,705	1,000,578	3,224,085
750	2,217	2,217,348	66,520	997,807	3,215,155
760	2,211	2,211,200	66,336	995,040	3,206,240
770	2,205	2,205,062	66,152	992,278	3,197,339
780	2,199	2,198,934	65,968	989,520	3,188,454
790	2,193	2,192,816	65,784	986,767	3,179,583
800	2,187	2,186,708	65,601	984,019	3,170,727
810	2,181	2,180,611	65,418	981,275	3,161,886
820	2,175	2,174,524	65,236	978,536	3,153,060
830	2,168	2,168,447	65,053	975,801	3,144,248
840	2,162	2,162,380	64,871	973,071	3,135,451
850	2,156	2,156,324	64,690	970,346	3,126,669
860	2,150	2,150,277	64,508	967,625	3,117,902
870	2,144	2,144,241	64,327	964,908	3,109,149
880	2,138	2,138,215	64,146	962,197	3,100,411
890	2,132	2,132,199	63,966	959,489	3,091,688
900	2,126	2,126,193	63,786	956,787	3,082,979
910	2,120	2,120,197	63,606	954,089	3,074,285
920	2,114	2,114,211	63,426	951,395	3,065,606
930	2,108	2,108,235	63,247	948,706	3,056,941
940	2,102	2,102,270	63,068	946,021	3,048,291
950	2,096	2,096,314	62,889	943,341	3,039,656
960	2,090	2,090,369	62,711	940,666	3,031,035
970	2,084	2,084,434	62,533	937,995	3,022,429
980	2,079	2,078,508	62,355	935,329	3,013,837
990	2,073	2,072,593	62,178	932,667	3,005,260
1,000	2,067	2,066,688	62,001	930,010	2,996,698
1,010	2,061	2,060,793	61,824	927,357	2,988,150
1,020	2,055	2,054,908	61,647	924,708	2,979,616
1,030	2,049	2,049,033	61,471	922,065	2,971,097
1,040	2,043	2,043,168	61,295	919,425	2,962,593



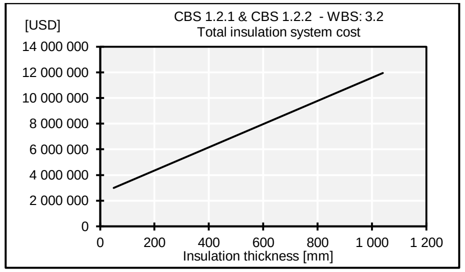


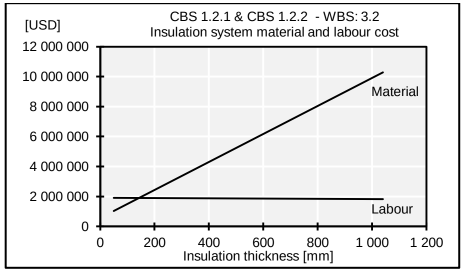
Insulation system cost – WBS 3.2
Insulation system 1

Table type:		Ins. sys. no:	ME alt:	Description:							
Insulation system cost		1	Both	Cost and required labour hours listed is for all containment systems							
Insulation thickness	Boil-off rate	CBS 1.2.1 WBS 3.2.1	CBS 1.2.1 WBS 3.2.2	CBS 1.2.1 WBS 3.2.3	CBS 1.2.1 WBS 3.2.4	CBS 1.2.1 WBS 3.2	CBS 1.2.2 WBS 3.2.1	CBS 1.2.2 WBS 3.2.2	CBS 1.2.2 WBS 3.2.3	CBS 1.2.2 WBS 3.2.4	CBS 1.2.2 WBS 3.2	CBS 1.2.2 WBS 3.2	CBS 1.2.1 & CBS 1.2.2 WBS 3.2
t_{INS_TOT} [mm]	BOR_{TOT} [ton/day]	$C_{INS\_MAT\_L1}$ [USD]	$C_{INS\_MAT\_L2}$ [USD]	$C_{INS\_MAT\_L3}$ [USD]	$C_{INS\_MAT\_L4}$ [USD]	C_{INS_MAT} [USD]	$T_{INS\_LAB\_L1}$ [hours]	$T_{INS\_LAB\_L2}$ [hours]	$T_{INS\_LAB\_L3}$ [hours]	$T_{INS\_LAB\_L4}$ [hours]	T_{INS_LAB} [hours]	C_{INS_LAB} [USD]	C_{INS_TOT} [USD]
50	528	49,689	425,268	49,596	424,478	949,031	42,590	21,263	42,511	21,224	127,588	1,913,827	2,862,858
60	321	99,340	425,110	99,119	424,162	1,047,731	42,574	21,256	42,479	21,208	127,517	1,912,760	2,960,491
70	230	148,955	424,952	148,567	423,846	1,146,320	42,558	21,248	42,448	21,192	127,446	1,911,693	3,058,013
80	180	198,532	424,794	197,942	423,530	1,244,799	42,543	21,240	42,416	21,177	127,375	1,910,626	3,155,425
90	147	248,073	424,636	247,243	423,215	1,343,167	42,527	21,232	42,385	21,161	127,304	1,909,559	3,252,727
100	125	297,577	424,478	296,471	422,899	1,441,425	42,511	21,224	42,353	21,145	127,233	1,908,493	3,349,919
110	108	347,044	424,320	345,625	422,584	1,539,573	42,495	21,216	42,321	21,129	127,162	1,907,428	3,447,001
120	95	396,474	424,162	394,706	422,269	1,637,611	42,479	21,208	42,290	21,113	127,091	1,906,363	3,543,973
130	85	445,868	424,004	443,713	421,954	1,735,538	42,464	21,200	42,258	21,098	127,020	1,905,298	3,640,836
140	77	495,224	423,846	492,647	421,639	1,833,356	42,448	21,192	42,227	21,082	126,949	1,904,233	3,737,589
150	70	544,544	423,688	541,507	421,324	1,931,063	42,432	21,184	42,195	21,066	126,878	1,903,170	3,834,233
160	65	593,827	423,530	590,294	421,010	2,028,661	42,416	21,177	42,164	21,050	126,807	1,902,106	3,930,767
170	60	643,072	423,372	639,008	420,695	2,126,148	42,400	21,169	42,132	21,035	126,736	1,901,043	4,027,191
180	56	692,282	423,215	687,649	420,381	2,223,526	42,385	21,161	42,101	21,019	126,665	1,899,980	4,123,506
190	52	741,454	423,057	736,217	420,067	2,320,794	42,369	21,153	42,070	21,003	126,595	1,898,918	4,219,712
200	49	790,590	422,899	784,711	419,753	2,417,953	42,353	21,145	42,038	20,988	126,524	1,897,856	4,315,808
210	46	839,689	422,742	833,132	419,439	2,515,002	42,337	21,137	42,007	20,972	126,453	1,896,794	4,411,796
220	44	888,751	422,584	881,481	419,125	2,611,941	42,321	21,129	41,975	20,956	126,382	1,895,733	4,507,674
230	41	937,776	422,426	929,756	418,812	2,708,770	42,306	21,121	41,944	20,941	126,311	1,894,672	4,603,443
240	39	986,765	422,269	977,959	418,498	2,805,491	42,290	21,113	41,913	20,925	126,241	1,893,612	4,699,103
250	37	1,035,717	422,111	1,026,089	418,185	2,902,102	42,274	21,106	41,881	20,909	126,170	1,892,552	4,794,654
260	36	1,084,632	421,954	1,074,146	417,872	2,998,603	42,258	21,098	41,850	20,894	126,100	1,891,493	4,890,096
270	34	1,133,511	421,796	1,122,130	417,559	3,094,996	42,243	21,090	41,819	20,878	126,029	1,890,433	4,985,429
280	33	1,182,353	421,639	1,170,041	417,246	3,191,279	42,227	21,082	41,787	20,862	125,958	1,889,375	5,080,653
290	32	1,231,158	421,482	1,217,880	416,933	3,287,453	42,211	21,074	41,756	20,847	125,888	1,888,316	5,175,769
300	30	1,279,926	421,324	1,265,646	416,621	3,383,518	42,195	21,066	41,725	20,831	125,817	1,887,258	5,270,776
310	29	1,328,658	421,167	1,313,340	416,308	3,479,474	42,180	21,058	41,693	20,815	125,747	1,886,201	5,365,675
320	28	1,377,354	421,010	1,360,961	415,996	3,575,321	42,164	21,050	41,662	20,800	125,676	1,885,144	5,460,465
330	27	1,426,013	420,852	1,408,510	415,684	3,671,059	42,148	21,043	41,631	20,784	125,606	1,884,087	5,555,146
340	26	1,474,635	420,695	1,455,986	415,372	3,766,688	42,132	21,035	41,600	20,769	125,535	1,883,031	5,649,719
350	25	1,523,220	420,538	1,503,390	415,060	3,862,209	42,117	21,027	41,568	20,753	125,465	1,881,975	5,744,184
360	25	1,571,769	420,381	1,550,722	414,749	3,957,621	42,101	21,019	41,537	20,737	125,395	1,880,920	5,838,541
370	24	1,620,282	420,224	1,597,982	414,437	4,052,924	42,085	21,011	41,506	20,722	125,324	1,879,865	5,932,789
380	23	1,668,758	420,067	1,645,169	414,126	4,148,119	42,070	21,003	41,475	20,706	125,254	1,878,810	6,026,929
390	22	1,717,197	419,910	1,692,284	413,814	4,243,205	42,054	20,995	41,444	20,691	125,184	1,877,756	6,120,961

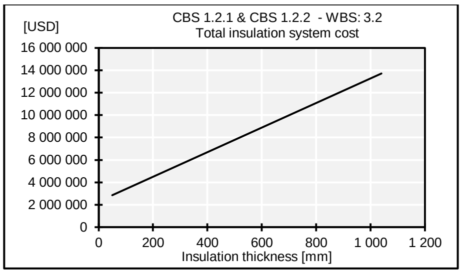
400	22	1,765,600	419,753	1,739,327	413,503	4,338,183	42,038	20,988	41,413	20,675	125,113	1,876,702	6,214,885
410	21	1,813,966	419,596	1,786,298	413,192	4,433,053	42,022	20,980	41,381	20,660	125,043	1,875,648	6,308,701
420	21	1,862,296	419,439	1,833,198	412,881	4,527,814	42,007	20,972	41,350	20,644	124,973	1,874,595	6,402,409
430	20	1,910,589	419,282	1,880,025	412,571	4,622,467	41,991	20,964	41,319	20,629	124,903	1,873,543	6,496,010
440	20	1,958,846	419,125	1,926,780	412,260	4,717,012	41,975	20,956	41,288	20,613	124,833	1,872,490	6,589,502
450	19	2,007,067	418,968	1,973,463	411,950	4,811,448	41,960	20,948	41,257	20,597	124,763	1,871,439	6,682,887
460	19	2,055,251	418,812	2,020,075	411,640	4,905,777	41,944	20,941	41,226	20,582	124,692	1,870,387	6,776,164
470	18	2,103,398	418,655	2,066,615	411,329	4,999,998	41,928	20,933	41,195	20,566	124,622	1,869,336	6,869,334
480	18	2,151,510	418,498	2,113,083	411,019	5,094,110	41,913	20,925	41,164	20,551	124,552	1,868,286	6,962,396
490	17	2,199,584	418,342	2,159,480	410,710	5,188,115	41,897	20,917	41,133	20,535	124,482	1,867,235	7,055,351
500	17	2,247,623	418,185	2,205,805	410,400	5,282,012	41,881	20,909	41,102	20,520	124,412	1,866,186	7,148,198
510	17	2,295,625	418,028	2,252,058	410,090	5,375,802	41,865	20,901	41,071	20,505	124,342	1,865,136	7,240,938
520	16	2,343,590	417,872	2,298,240	409,781	5,469,483	41,850	20,894	41,040	20,489	124,272	1,864,087	7,333,570
530	16	2,391,520	417,715	2,344,351	409,472	5,563,057	41,834	20,886	41,009	20,474	124,203	1,863,039	7,426,096
540	16	2,439,413	417,559	2,390,390	409,163	5,656,524	41,819	20,878	40,978	20,458	124,133	1,861,990	7,518,514
550	15	2,487,269	417,402	2,436,357	408,854	5,749,883	41,803	20,870	40,947	20,443	124,063	1,860,943	7,610,825
560	15	2,535,089	417,246	2,482,254	408,545	5,843,134	41,787	20,862	40,916	20,427	123,993	1,859,895	7,703,030
570	15	2,582,873	417,090	2,528,079	408,236	5,936,279	41,772	20,854	40,885	20,412	123,923	1,858,848	7,795,127
580	14	2,630,621	416,933	2,573,833	407,928	6,029,316	41,756	20,847	40,854	20,396	123,853	1,857,802	7,887,117
590	14	2,678,332	416,777	2,619,516	407,619	6,122,245	41,740	20,839	40,824	20,381	123,784	1,856,756	7,979,001
600	14	2,726,008	416,621	2,665,128	407,311	6,215,068	41,725	20,831	40,793	20,366	123,714	1,855,710	8,070,778
610	14	2,773,646	416,465	2,710,669	407,003	6,307,783	41,709	20,823	40,762	20,350	123,644	1,854,664	8,162,448
620	13	2,821,249	416,308	2,756,139	406,695	6,400,392	41,693	20,815	40,731	20,335	123,575	1,853,619	8,254,011
630	13	2,868,815	416,152	2,801,538	406,387	6,492,893	41,678	20,808	40,700	20,319	123,505	1,852,575	8,345,468
640	13	2,916,346	415,996	2,846,866	406,080	6,585,288	41,662	20,800	40,670	20,304	123,435	1,851,531	8,436,818
650	13	2,963,840	415,840	2,892,123	405,772	6,677,575	41,646	20,792	40,639	20,289	123,366	1,850,487	8,528,062
660	13	3,011,297	415,684	2,937,310	405,465	6,769,756	41,631	20,784	40,608	20,273	123,296	1,849,444	8,619,200
670	12	3,058,719	415,528	2,982,426	405,158	6,861,830	41,615	20,776	40,577	20,258	123,227	1,848,401	8,710,231
680	12	3,106,104	415,372	3,027,471	404,851	6,953,798	41,600	20,769	40,546	20,243	123,157	1,847,358	8,801,156
690	12	3,153,454	415,216	3,072,445	404,544	7,045,659	41,584	20,761	40,516	20,227	123,088	1,846,316	8,891,975
700	12	3,200,767	415,060	3,117,349	404,237	7,137,413	41,568	20,753	40,485	20,212	123,018	1,845,275	8,982,687
710	12	3,248,044	414,904	3,162,182	403,930	7,229,061	41,553	20,745	40,454	20,197	122,949	1,844,233	9,073,294
720	11	3,295,285	414,749	3,206,945	403,624	7,320,602	41,537	20,737	40,424	20,181	122,879	1,843,192	9,163,795
730	11	3,342,490	414,593	3,251,638	403,317	7,412,037	41,522	20,730	40,393	20,166	122,810	1,842,152	9,254,189
740	11	3,389,658	414,437	3,296,260	403,011	7,503,366	41,506	20,722	40,362	20,151	122,741	1,841,112	9,344,478
750	11	3,436,791	414,281	3,340,812	402,705	7,594,589	41,490	20,714	40,332	20,135	122,671	1,840,072	9,434,661
760	11	3,483,888	414,126	3,385,293	402,399	7,685,705	41,475	20,706	40,301	20,120	122,602	1,839,033	9,524,738
770	11	3,530,948	413,970	3,429,704	402,093	7,776,715	41,459	20,698	40,271	20,105	122,533	1,837,994	9,614,709
780	10	3,577,972	413,814	3,474,045	401,788	7,867,620	41,444	20,691	40,240	20,089	122,464	1,836,956	9,704,575
790	10	3,624,961	413,659	3,518,316	401,482	7,958,418	41,428	20,683	40,209	20,074	122,394	1,835,917	9,794,336
800	10	3,671,913	413,503	3,562,517	401,177	8,049,111	41,413	20,675	40,179	20,059	122,325	1,834,880	9,883,990
810	10	3,718,830	413,348	3,606,648	400,872	8,139,697	41,397	20,667	40,148	20,044	122,256	1,833,843	9,973,540
820	10	3,765,710	413,192	3,650,709	400,567	8,230,178	41,381	20,660	40,118	20,028	122,187	1,832,806	10,062,984
830	10	3,812,555	413,037	3,694,700	400,262	8,320,553	41,366	20,652	40,087	20,013	122,118	1,831,769	10,152,322

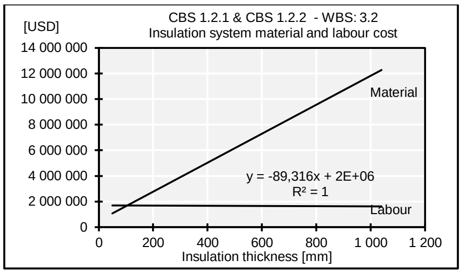
840	10	3,859,363	412,881	3,738,621	399,957	8,410,822	41,350	20,644	40,057	19,998	122,049	1,830,733	10,241,556
850	9	3,906,136	412,726	3,782,472	399,652	8,500,986	41,335	20,636	40,026	19,983	121,980	1,829,698	10,330,684
860	9	3,952,872	412,571	3,826,254	399,348	8,591,044	41,319	20,629	39,996	19,967	121,911	1,828,662	10,419,707
870	9	3,999,573	412,415	3,869,965	399,043	8,680,997	41,304	20,621	39,965	19,952	121,842	1,827,628	10,508,625
880	9	4,046,238	412,260	3,913,608	398,739	8,770,845	41,288	20,613	39,935	19,937	121,773	1,826,593	10,597,438
890	9	4,092,867	412,105	3,957,180	398,435	8,860,587	41,273	20,605	39,904	19,922	121,704	1,825,559	10,686,146
900	9	4,139,460	411,950	4,000,683	398,131	8,950,224	41,257	20,597	39,874	19,907	121,635	1,824,526	10,774,749
910	9	4,186,017	411,795	4,044,116	397,827	9,039,755	41,242	20,590	39,844	19,891	121,566	1,823,492	10,863,248
920	9	4,232,538	411,640	4,087,480	397,524	9,129,182	41,226	20,582	39,813	19,876	121,497	1,822,460	10,951,641
930	9	4,279,023	411,484	4,130,775	397,220	9,218,503	41,210	20,574	39,783	19,861	121,428	1,821,427	11,039,930
940	8	4,325,473	411,329	4,174,000	396,917	9,307,719	41,195	20,566	39,752	19,846	121,360	1,820,395	11,128,115
950	8	4,371,887	411,174	4,217,156	396,614	9,396,831	41,179	20,559	39,722	19,831	121,291	1,819,364	11,216,194
960	8	4,418,265	411,019	4,260,242	396,311	9,485,837	41,164	20,551	39,692	19,816	121,222	1,818,332	11,304,170
970	8	4,464,607	410,865	4,303,260	396,008	9,574,739	41,148	20,543	39,661	19,800	121,153	1,817,302	11,392,041
980	8	4,510,913	410,710	4,346,208	395,705	9,663,536	41,133	20,535	39,631	19,785	121,085	1,816,271	11,479,807
990	8	4,557,183	410,555	4,389,087	395,402	9,752,228	41,117	20,528	39,601	19,770	121,016	1,815,241	11,567,469
1,000	8	4,603,418	410,400	4,431,897	395,100	9,840,815	41,102	20,520	39,571	19,755	120,947	1,814,212	11,655,027
1,010	8	4,649,617	410,245	4,474,638	394,798	9,929,298	41,086	20,512	39,540	19,740	120,879	1,813,183	11,742,481
1,020	8	4,695,781	410,090	4,517,310	394,495	10,017,677	41,071	20,505	39,510	19,725	120,810	1,812,154	11,829,831
1,030	8	4,741,908	409,936	4,559,913	394,193	10,105,950	41,055	20,497	39,480	19,710	120,742	1,811,126	11,917,076
1,040	8	4,788,000	409,781	4,602,447	393,892	10,194,120	41,040	20,489	39,450	19,695	120,673	1,810,098	12,004,218





Insulation system 2





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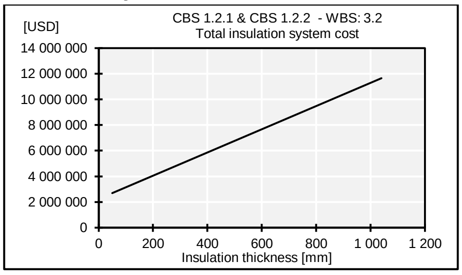
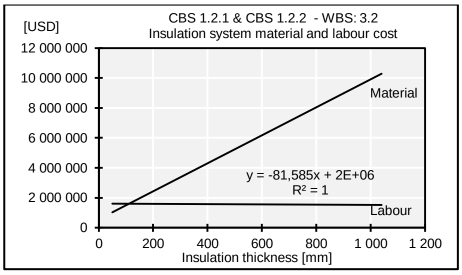
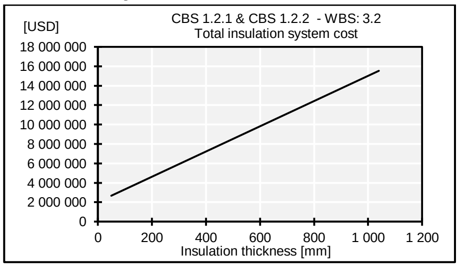
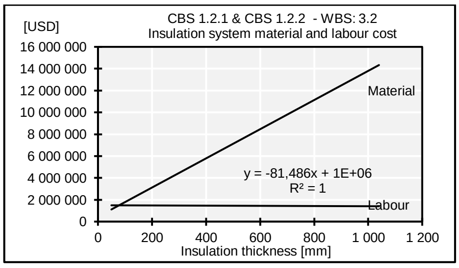


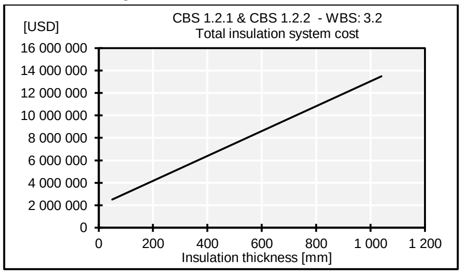


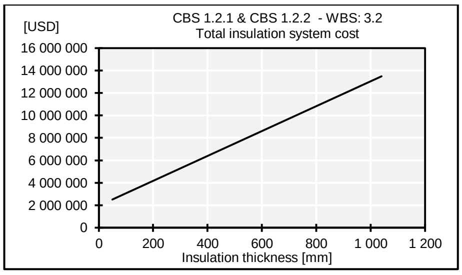
Insulation system 4



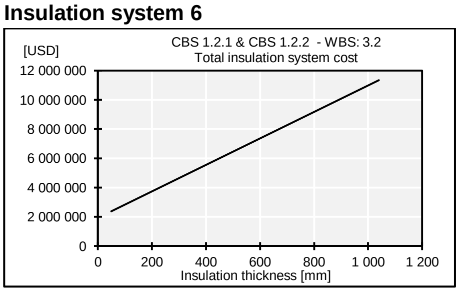


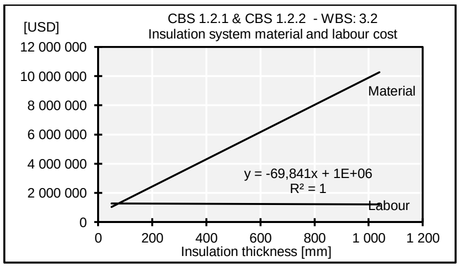
Insulation system 5





Insulation system 6

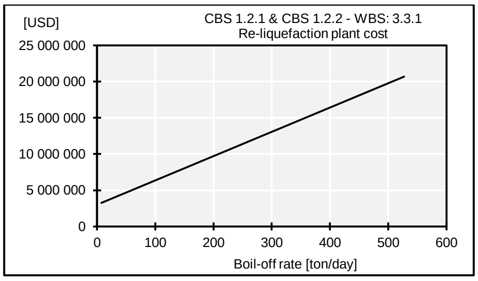




Boil-off handling system cost – WBS 3.3
Insulation system 1
Boil of handling – Re-liquefaction

Table type:	Ins. sys. no:	ME alt:	Boil-off handling:
Boil-off handl. sys. cost	1	1	Re-liquefaction
Insulation thickness	Boil-off rate	CBS 1.2.1 & CBS 1.2.2	
		WBS 3.3.1	WBS 3.3.3
t_{INS_TOT}	BOR_{LAD}	C_{RELIQ_TOT}	C_{GCU_TOT}
[mm]	[ton/day]	[USD]	[USD]
50	528	20,693,405	4,608,443
60	321	13,758,327	3,008,175
70	230	10,725,679	2,308,391
80	180	9,024,825	1,915,919
90	147	7,936,426	1,664,771
100	125	7,180,149	1,490,260
110	108	6,624,101	1,361,952
120	95	6,198,059	1,263,643
130	85	5,861,202	1,185,913
140	77	5,588,181	1,122,914
150	70	5,362,419	1,070,819
160	65	5,172,625	1,027,024
170	60	5,010,836	989,691
180	56	4,871,281	957,489
190	52	4,749,672	929,428
200	49	4,642,755	904,757
210	46	4,548,021	882,897
220	44	4,463,499	863,393
230	41	4,387,622	845,885
240	39	4,319,129	830,080
250	37	4,256,993	815,742
260	36	4,200,366	802,675
270	34	4,148,549	790,719
280	33	4,100,953	779,736
290	32	4,057,082	769,613
300	30	4,016,517	760,252
310	29	3,978,896	751,571
320	28	3,943,910	743,498
330	27	3,911,293	735,972
340	26	3,880,811	728,938
350	25	3,852,262	722,350
360	25	3,825,467	716,167
370	24	3,800,270	710,353
380	23	3,776,531	704,875
390	22	3,754,128	699,706
400	22	3,732,951	694,820
410	21	3,712,903	690,193
420	21	3,693,895	685,807
430	20	3,675,848	681,643
440	20	3,658,692	677,684
450	19	3,642,361	673,916
460	19	3,626,799	670,325
470	18	3,611,951	666,899
480	18	3,597,771	663,627
490	17	3,584,213	660,498
500	17	3,571,238	657,504
510	17	3,558,809	654,636
520	16	3,546,892	651,886
530	16	3,535,456	649,248
540	16	3,524,473	646,713
550	15	3,513,917	644,277
560	15	3,503,762	641,934
570	15	3,493,987	639,679
580	14	3,484,571	637,506
590	14	3,475,494	635,411

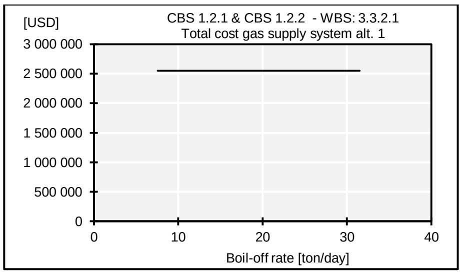
600	14	3,466,738	633,391
610	14	3,458,286	631,441
620	13	3,450,124	629,557
630	13	3,442,236	627,737
640	13	3,434,608	625,977
650	13	3,427,229	624,274
660	13	3,420,086	622,626
670	12	3,413,168	621,029
680	12	3,406,464	619,483
690	12	3,399,965	617,983
700	12	3,393,662	616,528
710	12	3,387,545	615,117
720	11	3,381,607	613,747
730	11	3,375,840	612,416
740	11	3,370,237	611,123
750	11	3,364,791	609,866
760	11	3,359,494	608,644
770	11	3,354,342	607,456
780	10	3,349,329	606,299
790	10	3,344,448	605,172
800	10	3,339,695	604,076
810	10	3,335,065	603,007
820	10	3,330,553	601,966
830	10	3,326,154	600,951
840	10	3,321,865	599,961
850	9	3,317,681	598,996
860	9	3,313,599	598,054
870	9	3,309,615	597,135
880	9	3,305,725	596,237
890	9	3,301,926	595,360
900	9	3,298,215	594,504
910	9	3,294,589	593,667
920	9	3,291,045	592,850
930	9	3,287,580	592,050
940	8	3,284,192	591,268
950	8	3,280,879	590,504
960	8	3,277,636	589,756
970	8	3,274,464	589,024
980	8	3,271,359	588,307
990	8	3,268,318	587,605
1,000	8	3,265,341	586,918
1,010	8	3,262,425	586,246
1,020	8	3,259,569	585,586
1,030	8	3,256,770	584,941
1,040	8	3,254,026	584,308

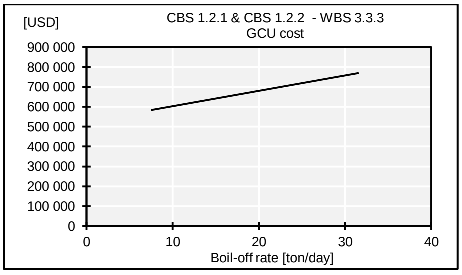


Boil of handling – Gas supply alt. 1

Table type:	Ins. sys. no:	ME alt:	Boil-off handling:	
Boil-off handl. sys. cost	1	2	Gas supply system alt. 1	
Insulation thickness	Boil-off rate	Conv. gas supply system capacity	CBS 1.2.1 WBS 3.3.2.1	CBS 1.2.1 WBS 3.3.3
t_{INS_TOT} [mm]	BOR_{LADEN} [ton/day]	$Q_{GAS\_SUPL\_MAX}$ [kg/s]	$C_{GAS\_SUPL\_ALT1}$ [USD]	C_{GCU_TOT} [USD]
290	32	9	2,550,475	769,613
300	30	9	2,550,475	760,252
310	29	9	2,550,475	751,571
320	28	9	2,550,475	743,498
330	27	9	2,550,475	735,972
340	26	9	2,550,475	728,938
350	25	9	2,550,475	722,350
360	25	9	2,550,475	716,167
370	24	9	2,550,475	710,353
380	23	9	2,550,475	704,875
390	22	9	2,550,475	699,706
400	22	9	2,550,475	694,820
410	21	9	2,550,475	690,193
420	21	9	2,550,475	685,807
430	20	9	2,550,475	681,643
440	20	9	2,550,475	677,684
450	19	9	2,550,475	673,916
460	19	9	2,550,475	670,325
470	18	9	2,550,475	666,899
480	18	9	2,550,475	663,627
490	17	9	2,550,475	660,498
500	17	9	2,550,475	657,504
510	17	9	2,550,475	654,636
520	16	9	2,550,475	651,886
530	16	9	2,550,475	649,248
540	16	9	2,550,475	646,713
550	15	9	2,550,475	644,277
560	15	9	2,550,475	641,934
570	15	9	2,550,475	639,679
580	14	9	2,550,475	637,506
590	14	9	2,550,475	635,411
600	14	9	2,550,475	633,391
610	14	9	2,550,475	631,441
620	13	9	2,550,475	629,557
630	13	9	2,550,475	627,737
640	13	9	2,550,475	625,977
650	13	9	2,550,475	624,274
660	13	9	2,550,475	622,626
670	12	9	2,550,475	621,029
680	12	9	2,550,475	619,483
690	12	9	2,550,475	617,983
700	12	9	2,550,475	616,528
710	12	9	2,550,475	615,117
720	11	9	2,550,475	613,747
730	11	9	2,550,475	612,416
740	11	9	2,550,475	611,123
750	11	9	2,550,475	609,866
760	11	9	2,550,475	608,644
770	11	9	2,550,475	607,456
780	10	9	2,550,475	606,299
790	10	9	2,550,475	605,172
800	10	9	2,550,475	604,076
810	10	9	2,550,475	603,007
820	10	9	2,550,475	601,966
830	10	9	2,550,475	600,951
840	10	9	2,550,475	599,961

850	9	9	2,550,475	598,996
860	9	9	2,550,475	598,054
870	9	9	2,550,475	597,135
880	9	9	2,550,475	596,237
890	9	9	2,550,475	595,360
900	9	9	2,550,475	594,504
910	9	9	2,550,475	593,667
920	9	9	2,550,475	592,850
930	9	9	2,550,475	592,050
940	8	9	2,550,475	591,268
950	8	9	2,550,475	590,504
960	8	9	2,550,475	589,756
970	8	9	2,550,475	589,024
980	8	9	2,550,475	588,307
990	8	9	2,550,475	587,605
1,000	8	9	2,550,475	586,918
1,010	8	9	2,550,475	586,246
1,020	8	9	2,550,475	585,586
1,030	8	9	2,550,475	584,941
1,040	8	9	2,550,475	584,308

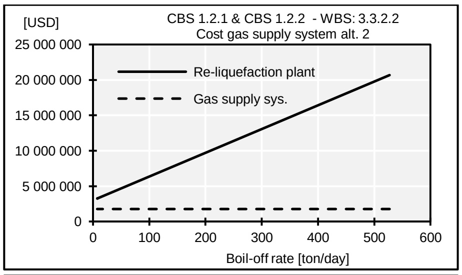


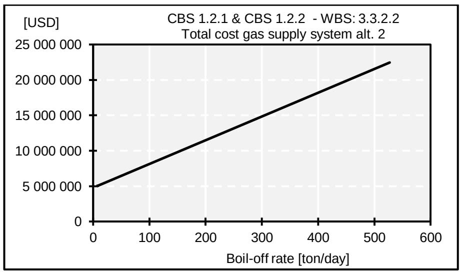


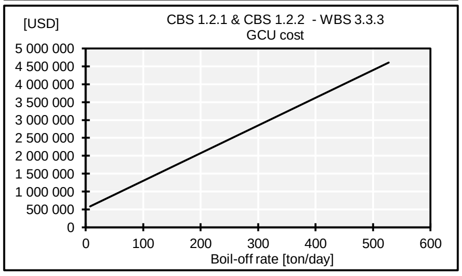
Boil of handling method – Gas supply alt. 2

Table type:	Ins. sys. no:	ME alt:	Boil-off handling:			
Boil-off handl. sys. cost	1	2	Gas supply system alt. 2			
Insulation thickness	Boil-off rate	Gas supply system capacity	CBS 1.2.1 WBS 3.3.2.2.1	CBS 1.2.1 WBS 3.3.2.2.2	CBS 1.2.1 WBS 3.3.2.2	CBS 1.2.1 WBS 3.3.3
t_{INS_TOT} [mm]	BOR_{LAD} [ton/day]	$Q_{GAS\_SUPL\_MAX}$ [kg/s]	$C_{SIMPL\_GAS\_SUPL}$ [USD]	C_{RELIQ} [USD]	$C_{GAS\_SUPL\_ALT2}$ [USD]	C_{GCU_TOT} [USD]
50	528	9	1,773,669	20,693,405	22,467,073	4,608,443
60	321	9	1,773,669	13,758,327	15,531,996	3,008,175
70	230	9	1,773,669	10,725,679	12,499,348	2,308,391
80	180	9	1,773,669	9,024,825	10,798,494	1,915,919
90	147	9	1,773,669	7,936,426	9,710,095	1,664,771
100	125	9	1,773,669	7,180,149	8,953,818	1,490,260
110	108	9	1,773,669	6,624,101	8,397,769	1,361,952
120	95	9	1,773,669	6,198,059	7,971,728	1,263,643
130	85	9	1,773,669	5,861,202	7,634,871	1,185,913
140	77	9	1,773,669	5,588,181	7,361,849	1,122,914
150	70	9	1,773,669	5,362,419	7,136,088	1,070,819
160	65	9	1,773,669	5,172,625	6,946,293	1,027,024
170	60	9	1,773,669	5,010,836	6,784,505	989,691
180	56	9	1,773,669	4,871,281	6,644,950	957,489
190	52	9	1,773,669	4,749,672	6,523,341	929,428
200	49	9	1,773,669	4,642,755	6,416,424	904,757
210	46	9	1,773,669	4,548,021	6,321,689	882,897
220	44	9	1,773,669	4,463,499	6,237,167	863,393
230	41	9	1,773,669	4,387,622	6,161,291	845,885
240	39	9	1,773,669	4,319,129	6,092,798	830,080
250	37	9	1,773,669	4,256,993	6,030,661	815,742
260	36	9	1,773,669	4,200,366	5,974,035	802,675
270	34	9	1,773,669	4,148,549	5,922,218	790,719
280	33	9	1,773,669	4,100,953	5,874,622	779,736
290	32	9	1,773,669	4,057,082	5,830,751	769,613
300	30	9	1,773,669	4,016,517	5,790,185	760,252
310	29	9	1,773,669	3,978,896	5,752,564	751,571
320	28	9	1,773,669	3,943,910	5,717,579	743,498
330	27	9	1,773,669	3,911,293	5,684,962	735,972
340	26	9	1,773,669	3,880,811	5,654,480	728,938
350	25	9	1,773,669	3,852,262	5,625,931	722,350
360	25	9	1,773,669	3,825,467	5,599,136	716,167
370	24	9	1,773,669	3,800,270	5,573,938	710,353
380	23	9	1,773,669	3,776,531	5,550,200	704,875
390	22	9	1,773,669	3,754,128	5,527,797	699,706
400	22	9	1,773,669	3,732,951	5,506,620	694,820
410	21	9	1,773,669	3,712,903	5,486,572	690,193
420	21	9	1,773,669	3,693,895	5,467,563	685,807
430	20	9	1,773,669	3,675,848	5,449,517	681,643
440	20	9	1,773,669	3,658,692	5,432,360	677,684
450	19	9	1,773,669	3,642,361	5,416,030	673,916
460	19	9	1,773,669	3,626,799	5,400,468	670,325
470	18	9	1,773,669	3,611,951	5,385,620	666,899
480	18	9	1,773,669	3,597,771	5,371,439	663,627
490	17	9	1,773,669	3,584,213	5,357,882	660,498
500	17	9	1,773,669	3,571,238	5,344,907	657,504
510	17	9	1,773,669	3,558,809	5,332,478	654,636
520	16	9	1,773,669	3,546,892	5,320,561	651,886
530	16	9	1,773,669	3,535,456	5,309,125	649,248
540	16	9	1,773,669	3,524,473	5,298,142	646,713
550	15	9	1,773,669	3,513,917	5,287,586	644,277
560	15	9	1,773,669	3,503,762	5,277,431	641,934
570	15	9	1,773,669	3,493,987	5,267,656	639,679
580	14	9	1,773,669	3,484,571	5,258,240	637,506
590	14	9	1,773,669	3,475,494	5,249,162	635,411
600	14	9	1,773,669	3,466,738	5,240,407	633,391
610	14	9	1,773,669	3,458,286	5,231,955	631,441

620	13	9	1,773,669	3,450,124	5,223,793	629,557
630	13	9	1,773,669	3,442,236	5,215,904	627,737
640	13	9	1,773,669	3,434,608	5,208,277	625,977
650	13	9	1,773,669	3,427,229	5,200,898	624,274
660	13	9	1,773,669	3,420,086	5,193,755	622,626
670	12	9	1,773,669	3,413,168	5,186,836	621,029
680	12	9	1,773,669	3,406,464	5,180,133	619,483
690	12	9	1,773,669	3,399,965	5,173,634	617,983
700	12	9	1,773,669	3,393,662	5,167,331	616,528
710	12	9	1,773,669	3,387,545	5,161,214	615,117
720	11	9	1,773,669	3,381,607	5,155,276	613,747
730	11	9	1,773,669	3,375,840	5,149,509	612,416
740	11	9	1,773,669	3,370,237	5,143,906	611,123
750	11	9	1,773,669	3,364,791	5,138,459	609,866
760	11	9	1,773,669	3,359,494	5,133,163	608,644
770	11	9	1,773,669	3,354,342	5,128,011	607,456
780	10	9	1,773,669	3,349,329	5,122,998	606,299
790	10	9	1,773,669	3,344,448	5,118,117	605,172
800	10	9	1,773,669	3,339,695	5,113,364	604,076
810	10	9	1,773,669	3,335,065	5,108,734	603,007
820	10	9	1,773,669	3,330,553	5,104,222	601,966
830	10	9	1,773,669	3,326,154	5,099,823	600,951
840	10	9	1,773,669	3,321,865	5,095,534	599,961
850	9	9	1,773,669	3,317,681	5,091,350	598,996
860	9	9	1,773,669	3,313,599	5,087,268	598,054
870	9	9	1,773,669	3,309,615	5,083,284	597,135
880	9	9	1,773,669	3,305,725	5,079,394	596,237
890	9	9	1,773,669	3,301,926	5,075,595	595,360
900	9	9	1,773,669	3,298,215	5,071,884	594,504
910	9	9	1,773,669	3,294,589	5,068,258	593,667
920	9	9	1,773,669	3,291,045	5,064,714	592,850
930	9	9	1,773,669	3,287,580	5,061,249	592,050
940	8	9	1,773,669	3,284,192	5,057,861	591,268
950	8	9	1,773,669	3,280,879	5,054,547	590,504
960	8	9	1,773,669	3,277,636	5,051,305	589,756
970	8	9	1,773,669	3,274,464	5,048,133	589,024
980	8	9	1,773,669	3,271,359	5,045,027	588,307
990	8	9	1,773,669	3,268,318	5,041,987	587,605
1,000	8	9	1,773,669	3,265,341	5,039,010	586,918
1,010	8	9	1,773,669	3,262,425	5,036,094	586,246
1,020	8	9	1,773,669	3,259,569	5,033,238	585,586
1,030	8	9	1,773,669	3,256,770	5,030,439	584,941
1,040	8	9	1,773,669	3,254,026	5,027,695	584,308

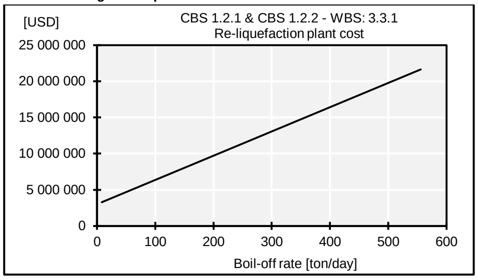




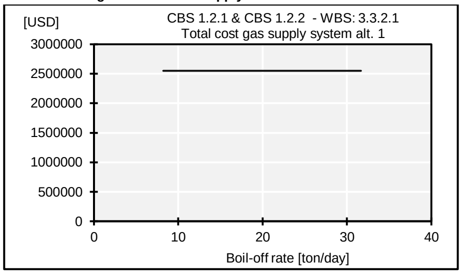


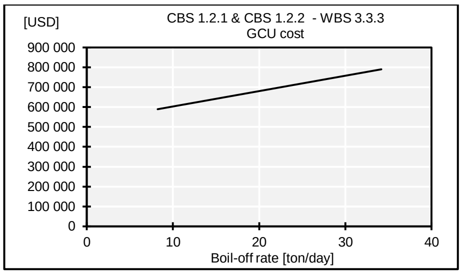
Insulation system 2

Boil of handling – Re-liquefaction

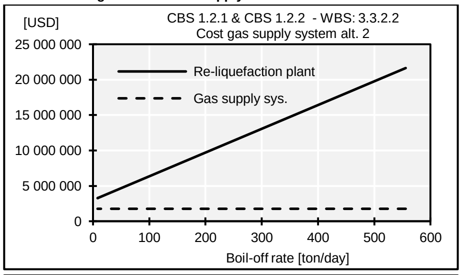


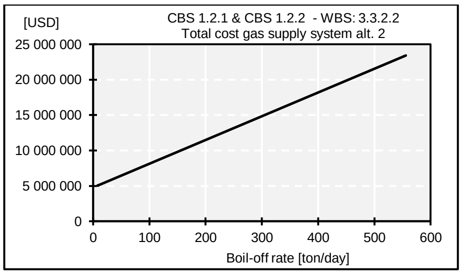
Boil of handling method – Gas supply alt. 1

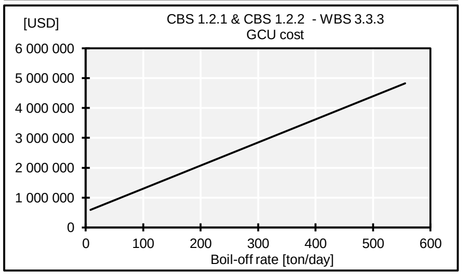




Boil of handling method – Gas supply alt. 2

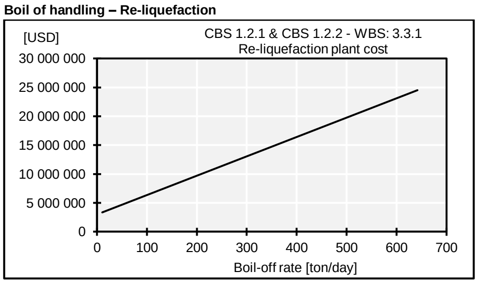




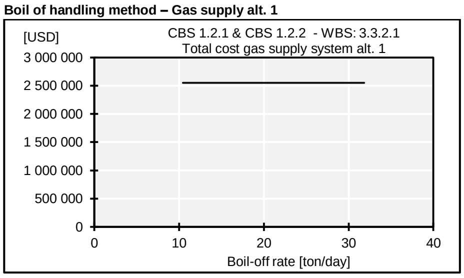


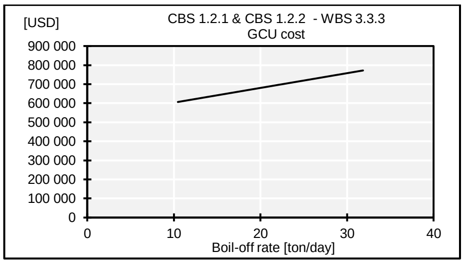
Insulation system 3

Boil of handling – Re-liquefaction

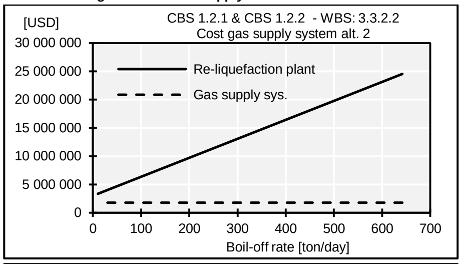


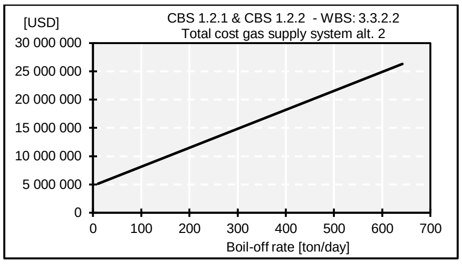
Boil of handling method – Gas supply alt. 1

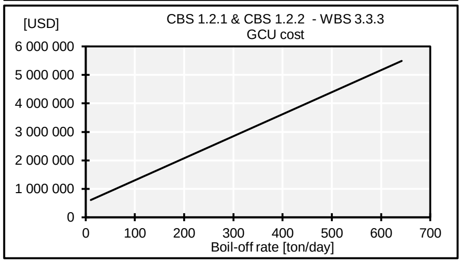




Boil of handling method – Gas supply alt. 2

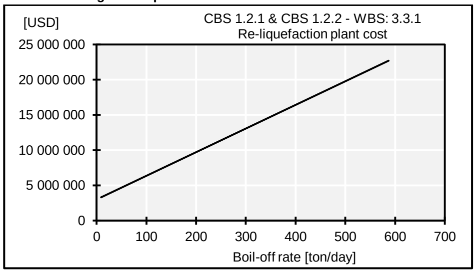




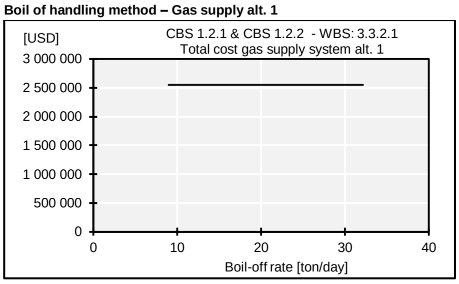


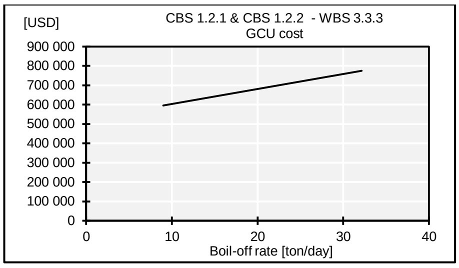
Insulation system 4

Boil of handling – Re-liquefaction

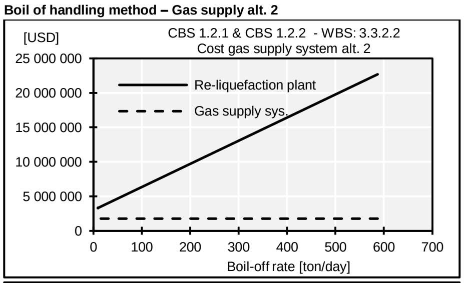


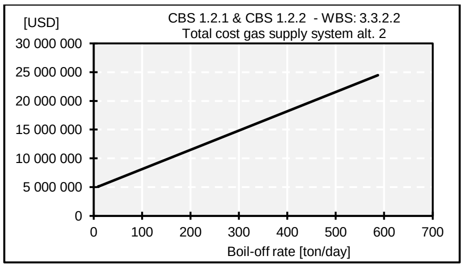
Boil of handling method – Gas supply alt. 1

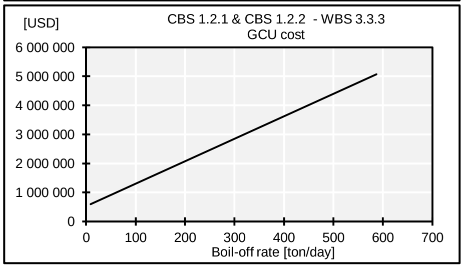




Boil of handling method – Gas supply alt. 2

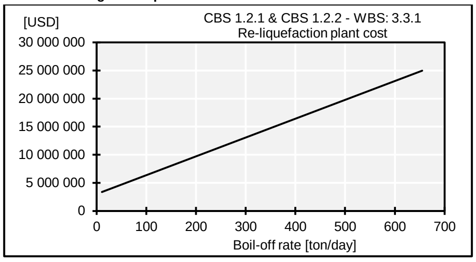




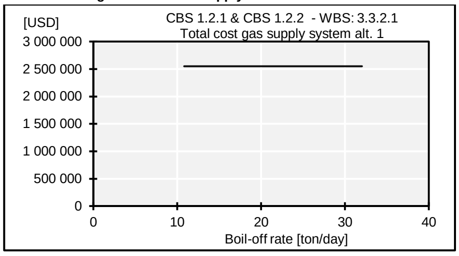


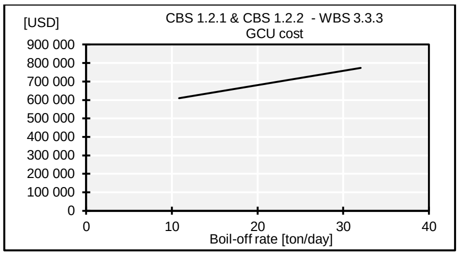
Insulation system 5

Boil of handling – Re-liquefaction

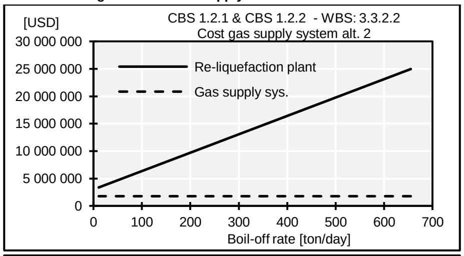


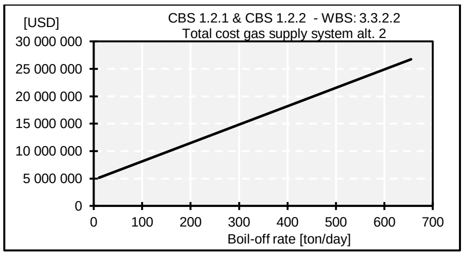
Boil of handling method – Gas supply alt. 1

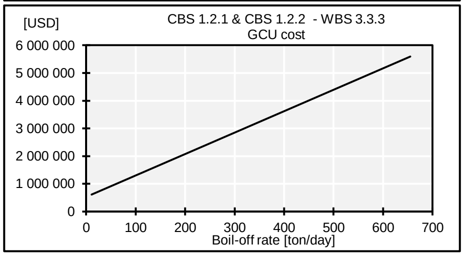




Boil of handling method – Gas supply alt. 2

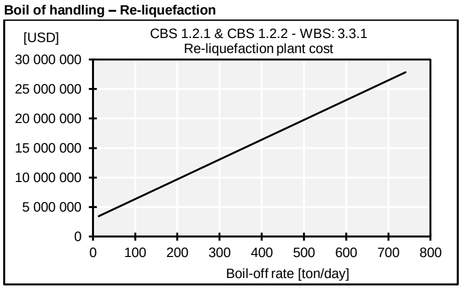




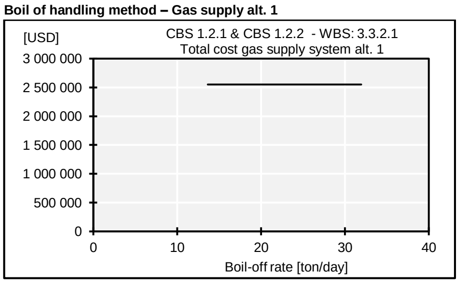


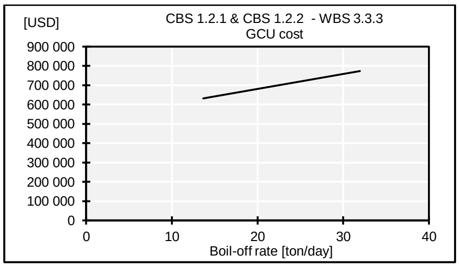
Insulation system 6

Boil of handling – Re-liquefaction

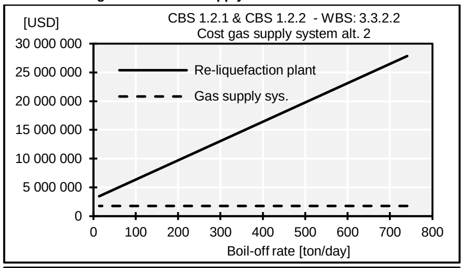


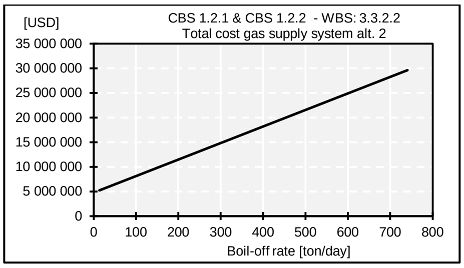
Boil of handling method – Gas supply alt. 1

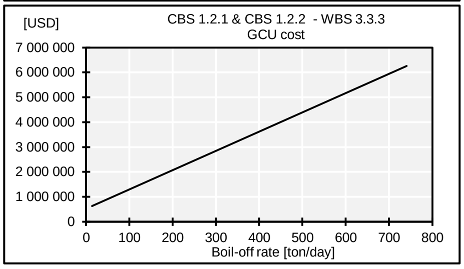




Boil of handling method – Gas supply alt. 2







Auxiliary generator cost – WBS 6.2
Insulation system 1
Boil of handling – Re-liquefaction

Table type:	Ins. sys. no:	ME alt:	Boil-off handling:	Description:					
Aux. incl. sys. cost	1	1	Re-liquefaction						
Insulation thickness	Boil-off rate	Re-liquefaction power	Number of Aux.	Total installed Aux. power	CBS 1.2.1 WBS 6.2.1	CBS 1.2.1 WBS 6.2.2	CBS 1.2.2 WBS 6.2.1	CBS 1.2.2 WBS 6.2.2	CBS 1.2.1 & CBS 1.2.2 WBS 6.2
t_{INS_TOT} [mm]	BOR_{LADEN} [ton/day]	P_{RELIQ_TOT} [kW]	No of aux. employed	Aux power [kW]	C_{AUX} [USD]	C_{AUX_SYS} [USD]	T_{AUX_LAB} [hours]	C_{AUX_LAB} [USD]	C_{AUX_TOT} [USD]
50	528	10,668	7	13,860	6,930,000	693,000	55,440	831,600	8,454,600
60	321	6,886	5	9,900	4,950,000	495,000	39,600	594,000	6,039,000
70	230	5,232	4	7,920	3,960,000	396,000	31,680	475,200	4,831,200
80	180	4,304	4	7,920	3,960,000	396,000	31,680	475,200	4,831,200
90	147	3,710	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
100	125	3,298	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
110	108	2,994	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
120	95	2,762	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
130	85	2,578	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
140	77	2,429	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
150	70	2,306	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
160	65	2,203	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
170	60	2,114	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
180	56	2,038	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
190	52	1,972	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
200	49	1,914	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
210	46	1,862	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
220	44	1,816	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
230	41	1,775	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
240	39	1,737	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
250	37	1,703	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
260	36	1,672	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
270	34	1,644	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
280	33	1,618	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
290	32	1,594	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
300	30	1,572	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
310	29	1,552	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
320	28	1,533	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
330	27	1,515	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
340	26	1,498	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
350	25	1,483	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
360	25	1,468	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
370	24	1,454	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
380	23	1,441	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
390	22	1,429	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
400	22	1,417	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
410	21	1,407	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
420	21	1,396	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
430	20	1,386	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
440	20	1,377	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
450	19	1,368	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
460	19	1,360	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
470	18	1,351	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
480	18	1,344	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
490	17	1,336	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
500	17	1,329	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
510	17	1,322	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
520	16	1,316	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
530	16	1,310	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
540	16	1,304	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
550	15	1,298	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
560	15	1,292	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
570	15	1,287	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
580	14	1,282	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
590	14	1,277	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600

600	14	1,272	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
610	14	1,268	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
620	13	1,263	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
630	13	1,259	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
640	13	1,255	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
650	13	1,251	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
660	13	1,247	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
670	12	1,243	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
680	12	1,239	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
690	12	1,236	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
700	12	1,232	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
710	12	1,229	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
720	11	1,226	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
730	11	1,223	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
740	11	1,220	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
750	11	1,217	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
760	11	1,214	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
770	11	1,211	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
780	10	1,208	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
790	10	1,206	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
800	10	1,203	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
810	10	1,200	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
820	10	1,198	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
830	10	1,196	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
840	10	1,193	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
850	9	1,191	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
860	9	1,189	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
870	9	1,187	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
880	9	1,184	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
890	9	1,182	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
900	9	1,180	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
910	9	1,178	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
920	9	1,176	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
930	9	1,175	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
940	8	1,173	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
950	8	1,171	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
960	8	1,169	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
970	8	1,167	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
980	8	1,166	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
990	8	1,164	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,000	8	1,162	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,010	8	1,161	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,020	8	1,159	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,030	8	1,158	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
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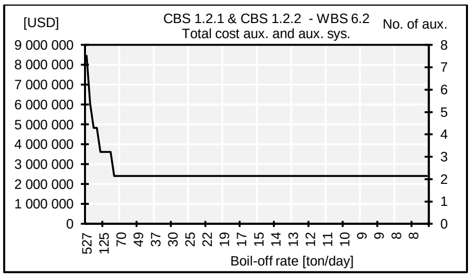
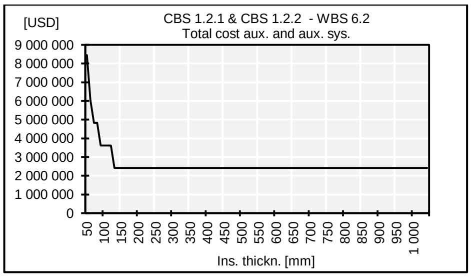
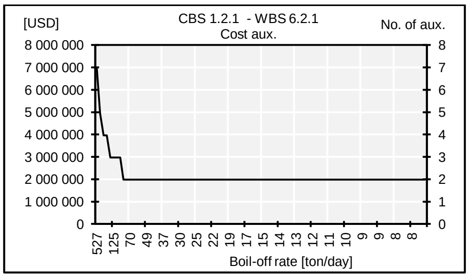
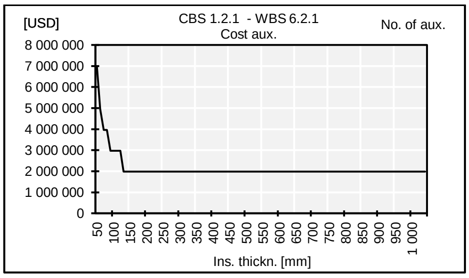
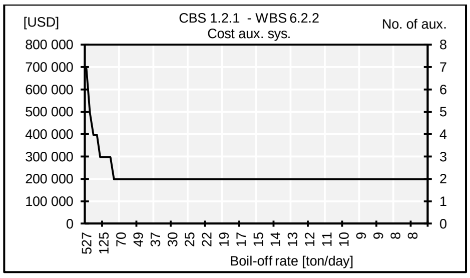
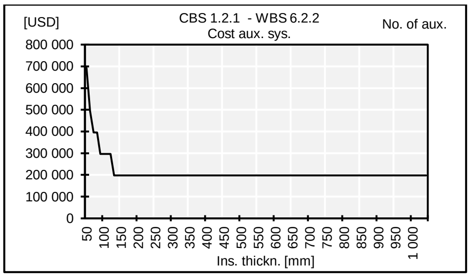


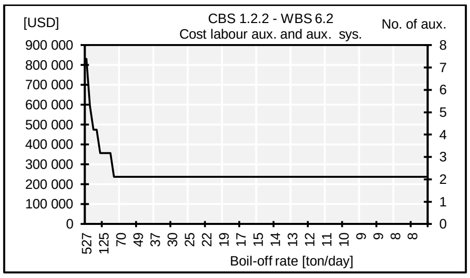


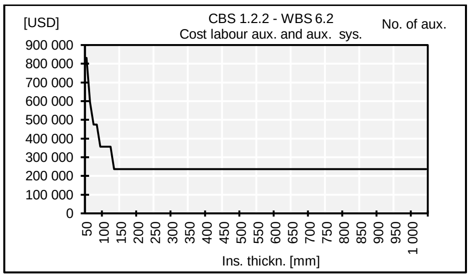





[USD]
CBS 1.2.1 - WBS 6.2.2
Cost aux. sys.
No. of aux.
Boil-off rate [ton/day]


[USD]
CBS 1.2.1 - WBS 6.2.2
Cost aux. sys.
No. of aux.
Ins. thickn. [mm]

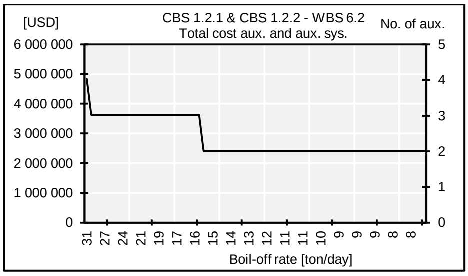

[USD]
CBS 1.2.2 - WBS 6.2
Cost labour aux. and aux. sys.
No. of aux.
Boil-off rate [ton/day]

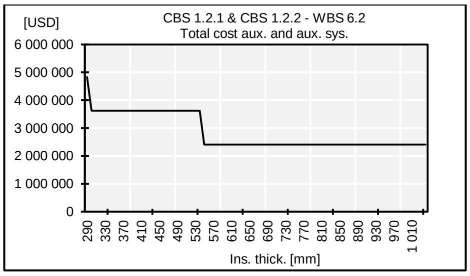

[USD]
CBS 1.2.2 - WBS 6.2
Cost labour aux. and aux. sys.
No. of aux.
Ins. thickn. [mm]

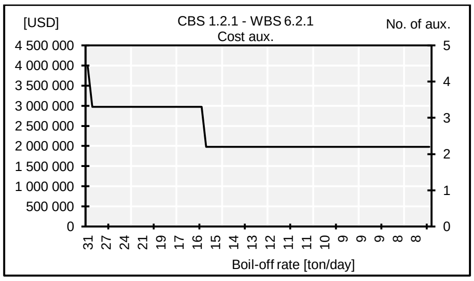
Boil of handling – Gas supply system alt. 1

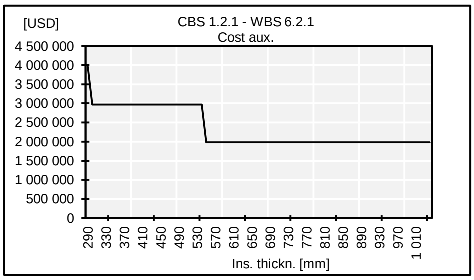
Table type:	Ins. sys. no:	ME alt:	Boil-off handling:		Description:				
Aux. incl. sys. cost	All	2	Gas supply system alt. 1						
Insulation thickness	Boil-off rate	Gas supply power	Number of Aux.	Total installed Aux. power	CBS 1.2.1 WBS 6.2.1	CBS 1.2.1 WBS 6.2.2	CBS 1.1.2 WBS 6.2.1	CBS 1.1.2 WBS 6.2.2	CBS 1.0.2 & CBS 1.1.2 WBS 6.2
t_{INS_TOT} [mm]	BOR_{LADEN} [ton/day]	$P_{GAS\_SUPL.}$ [kW]	No of Aux. [-]	Aux power [kW]	C_{AUX} [USD]	C_{AUX_SYS} [USD]	T_{AUX_LAB} [hours]	C_{AUX_LAB} [USD]	C_{AUX_TOT} [USD]
290	32	4,330	4	7,920	3,960,000	396,000	31,680	475,200	4,831,200
300	30	4,199	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
310	29	4,077	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
320	28	3,964	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
330	27	3,858	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
340	26	3,759	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
350	25	3,667	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
360	25	3,580	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
370	24	3,498	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
380	23	3,421	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
390	22	3,349	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
400	22	3,280	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
410	21	3,215	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
420	21	3,154	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
430	20	3,095	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
440	20	3,040	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
450	19	2,987	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
460	19	2,936	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
470	18	2,888	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
480	18	2,842	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
490	17	2,798	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
500	17	2,756	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
510	17	2,716	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
520	16	2,677	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
530	16	2,640	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
540	16	2,605	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
550	15	2,570	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
560	15	2,538	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
570	15	2,506	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
580	14	2,475	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
590	14	2,446	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
600	14	2,418	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
610	14	2,390	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
620	13	2,364	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
630	13	2,338	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
640	13	2,313	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
650	13	2,290	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
660	13	2,266	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
670	12	2,244	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
680	12	2,222	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
690	12	2,201	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
700	12	2,181	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
710	12	2,161	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
720	11	2,142	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
730	11	2,123	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
740	11	2,105	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
750	11	2,087	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
760	11	2,070	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
770	11	2,053	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
780	10	2,037	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
790	10	2,021	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
800	10	2,006	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
810	10	1,991	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
820	10	1,976	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
830	10	1,962	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
840	10	1,948	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
850	9	1,935	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600

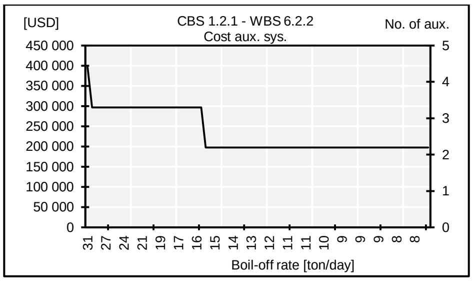
860	9	1,921	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
870	9	1,908	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
880	9	1,896	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
890	9	1,884	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
900	9	1,872	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
910	9	1,860	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
920	9	1,848	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
930	9	1,837	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
940	8	1,826	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
950	8	1,815	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
960	8	1,805	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
970	8	1,795	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
980	8	1,785	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
990	8	1,775	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,000	8	1,765	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,010	8	1,756	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,020	8	1,746	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,030	8	1,737	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,040	8	1,728	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600

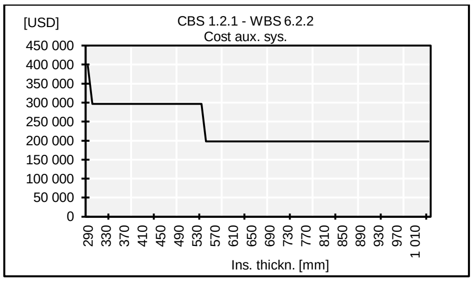


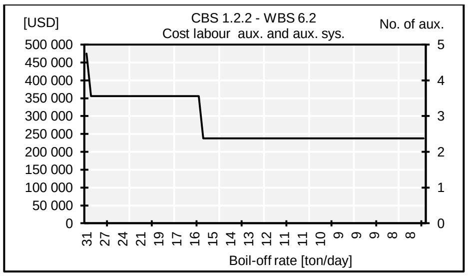


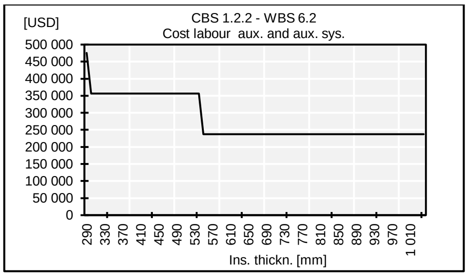












Boil of handling – Gas supply system alt. 2

Table type:	Ins. sys. no:	ME alt:	Boil-off handling:		Description:				
Aux. incl. sys. cost	All	2	Gas supply system alt. 2						
Insulation thickness	Boil-off rate	Gas supply power	Number of Aux.	Total installed Aux. power	CBS 1.0.2 WBS 6.2.1	CBS 1.0.2 WBS 6.2.2	CBS 1.1.2 WBS 6.2.1	CBS 1.1.2 WBS 6.2.2	CBS 1.0.2 & CBS 1.1.2 WBS 6.2
t_{INS_TOT} [mm]	BOR_{LADEN} [ton/day]	[kW]	No of Aux. [-]	Aux power [kW]	C_{AUX} [USD]	C_{AUX_SYS} [USD]	T_{AUX_LAB} [hours]	C_{AUX_LAB} [USD]	C_{AUX_TOT} [USD]
50	528	11,574	8	15,840	7,920,000	792,000	63,360	950,400	9,662,400
60	321	7,791	6	11,880	5,940,000	594,000	47,520	712,800	7,246,800
70	230	6,137	5	9,900	4,950,000	495,000	39,600	594,000	6,039,000
80	180	5,209	4	7,920	3,960,000	396,000	31,680	475,200	4,831,200
90	147	4,616	4	7,920	3,960,000	396,000	31,680	475,200	4,831,200
100	125	4,203	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
110	108	3,900	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
120	95	3,667	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
130	85	3,484	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
140	77	3,335	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
150	70	3,212	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
160	65	3,108	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
170	60	3,020	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
180	56	2,944	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
190	52	2,877	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
200	49	2,819	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
210	46	2,767	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
220	44	2,721	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
230	41	2,680	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
240	39	2,643	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
250	37	2,609	3	5,940	2,970,000	297,000	23,760	356,400	3,623,400
260	36	2,578	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
270	34	2,549	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
280	33	2,524	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
290	32	2,500	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
300	30	2,477	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
310	29	2,457	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
320	28	2,438	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
330	27	2,420	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
340	26	2,403	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
350	25	2,388	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
360	25	2,373	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
370	24	2,360	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
380	23	2,347	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
390	22	2,334	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
400	22	2,323	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
410	21	2,312	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
420	21	2,302	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
430	20	2,292	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
440	20	2,282	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
450	19	2,273	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
460	19	2,265	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
470	18	2,257	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
480	18	2,249	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
490	17	2,242	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
500	17	2,235	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
510	17	2,228	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
520	16	2,221	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
530	16	2,215	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
540	16	2,209	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
550	15	2,203	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
560	15	2,198	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
570	15	2,192	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
580	14	2,187	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
590	14	2,182	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
600	14	2,178	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
610	14	2,173	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600

620	13	2,169	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
630	13	2,164	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
640	13	2,160	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
650	13	2,156	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
660	13	2,152	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
670	12	2,148	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
680	12	2,145	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
690	12	2,141	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
700	12	2,138	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
710	12	2,134	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
720	11	2,131	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
730	11	2,128	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
740	11	2,125	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
750	11	2,122	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
760	11	2,119	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
770	11	2,116	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
780	10	2,114	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
790	10	2,111	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
800	10	2,108	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
810	10	2,106	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
820	10	2,103	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
830	10	2,101	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
840	10	2,099	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
850	9	2,096	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
860	9	2,094	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
870	9	2,092	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
880	9	2,090	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
890	9	2,088	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
900	9	2,086	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
910	9	2,084	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
920	9	2,082	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
930	9	2,080	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
940	8	2,078	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
950	8	2,076	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
960	8	2,074	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
970	8	2,073	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
980	8	2,071	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
990	8	2,069	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,000	8	2,068	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,010	8	2,066	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,020	8	2,065	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
1,030	8	2,063	2	3,960	1,980,000	198,000	15,840	237,600	2,415,600
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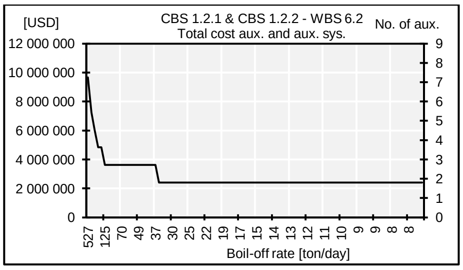
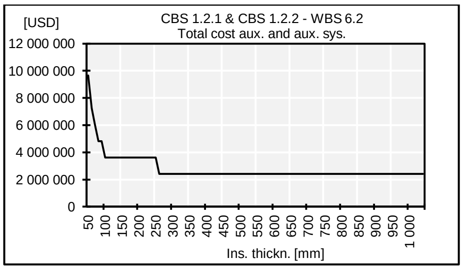
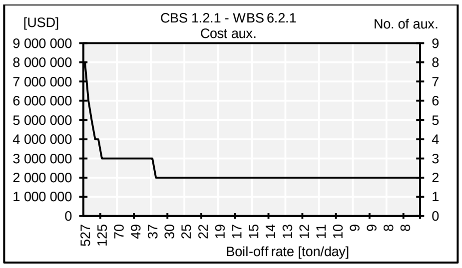
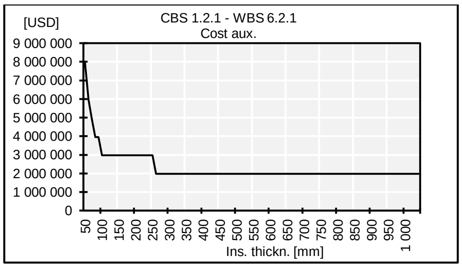
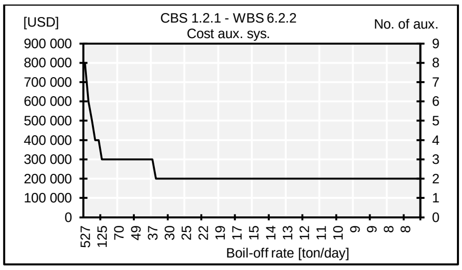
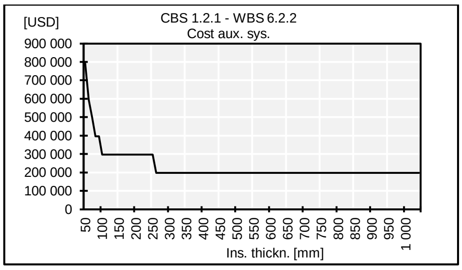


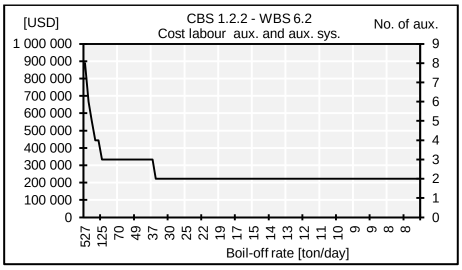


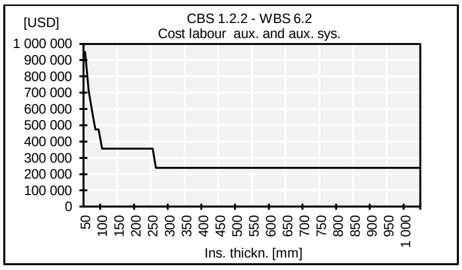






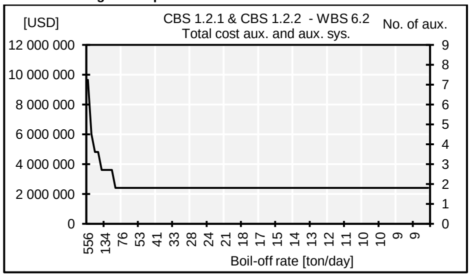


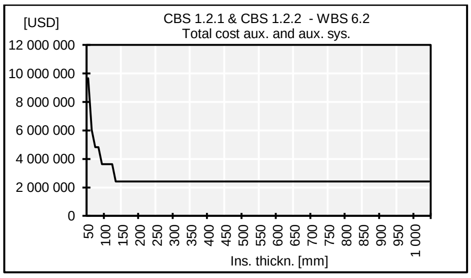


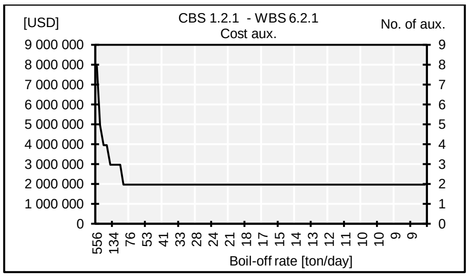


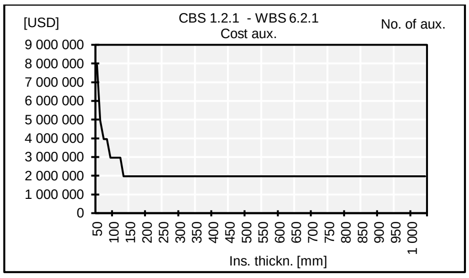
Insulation system 2

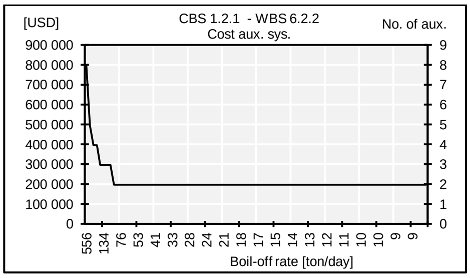
Boil of handling – Re-liquefaction

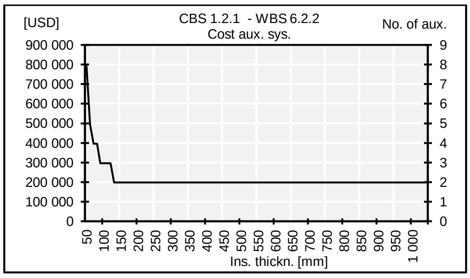


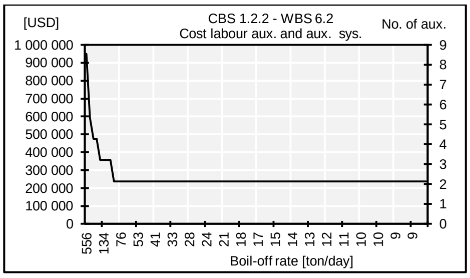


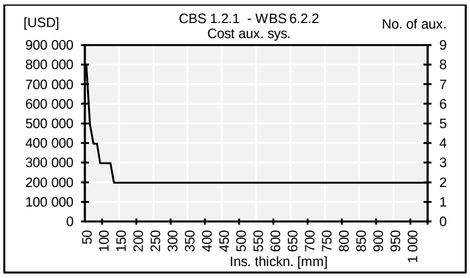




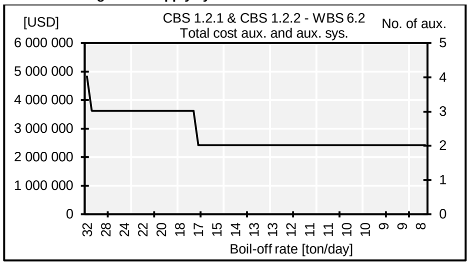


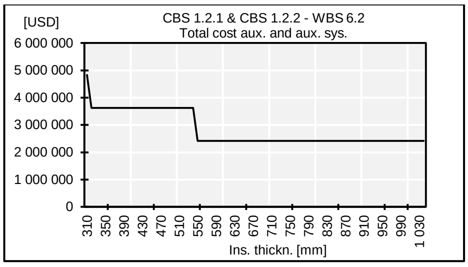


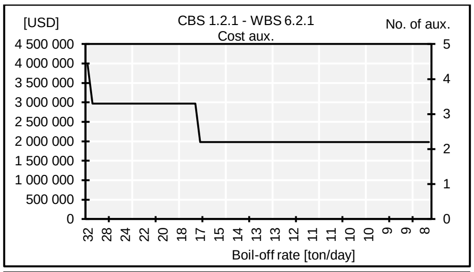


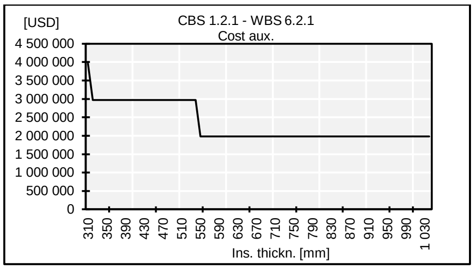


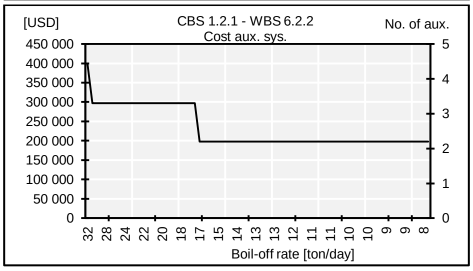
Boil of handling – Gas supply system alt. 1

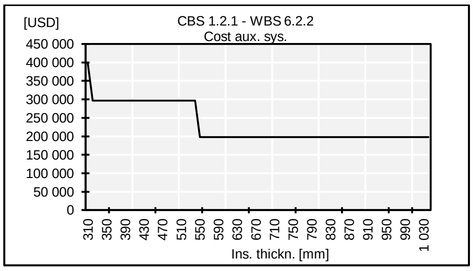


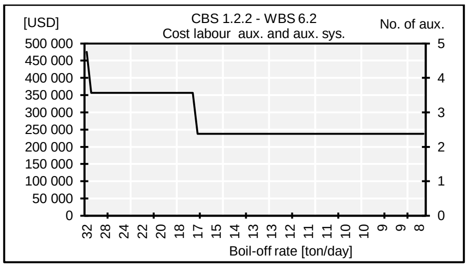


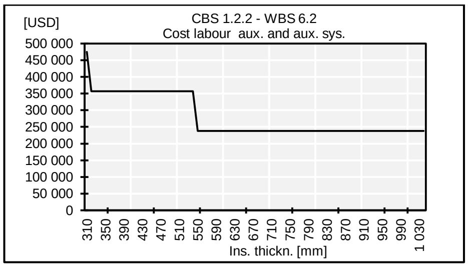




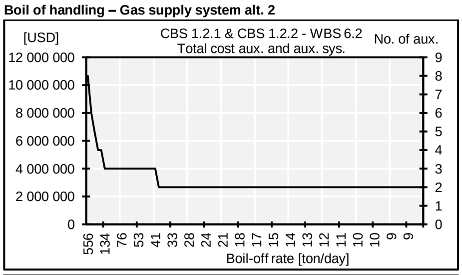


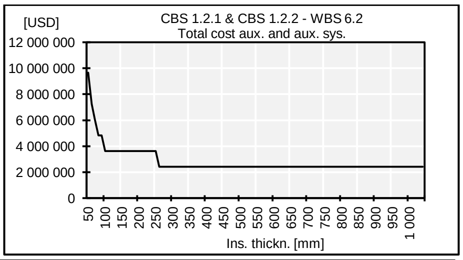


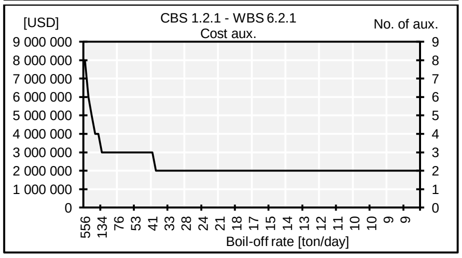


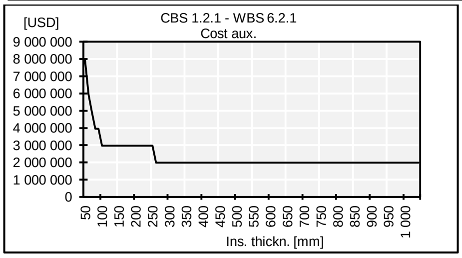


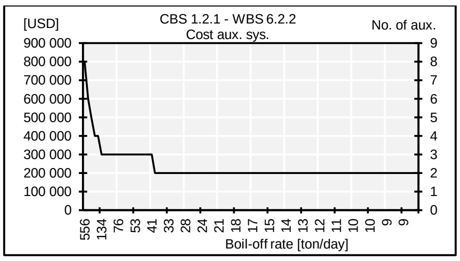
Boil of handling – Gas supply system alt. 2

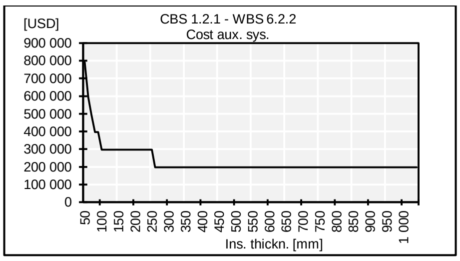


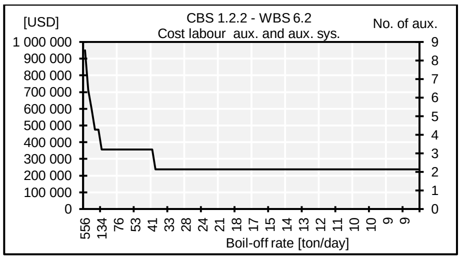


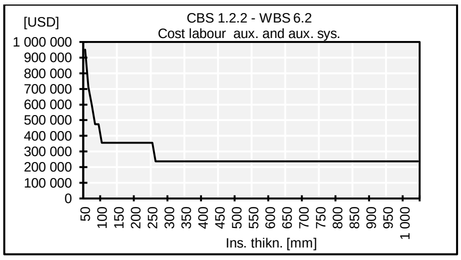






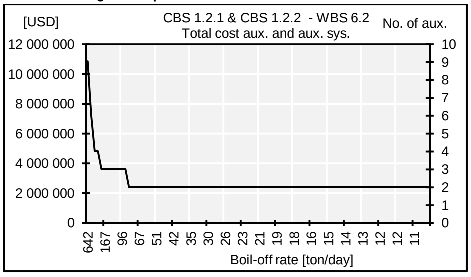


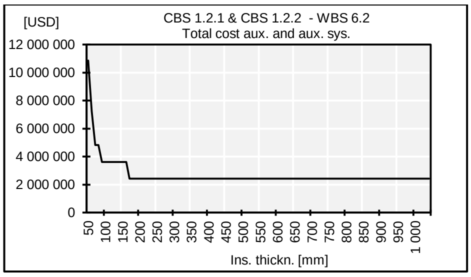


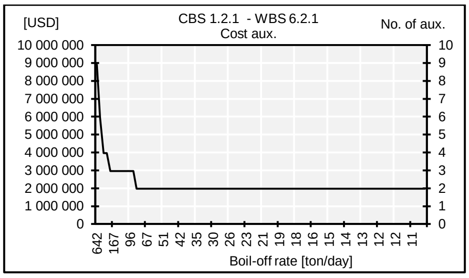


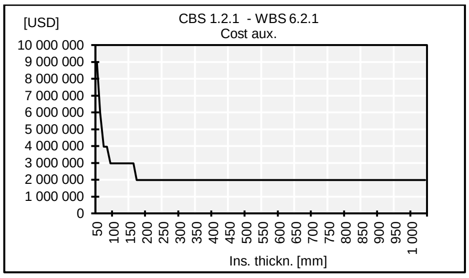
Insulation system 3

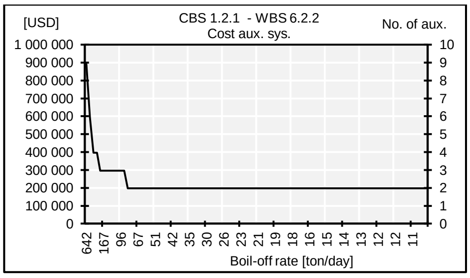
Boil of handling – Re-liquefaction

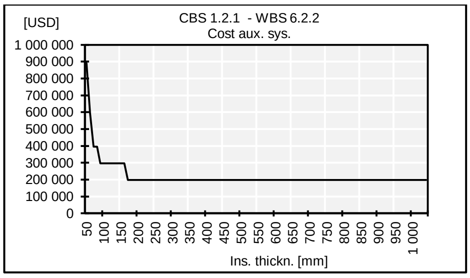


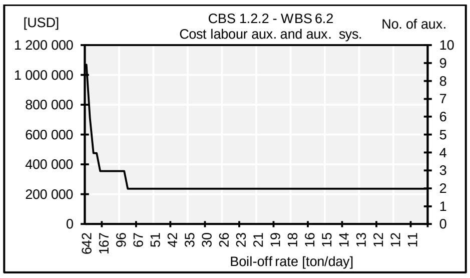


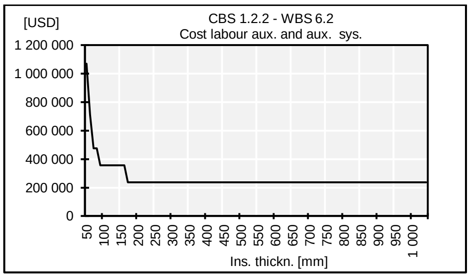




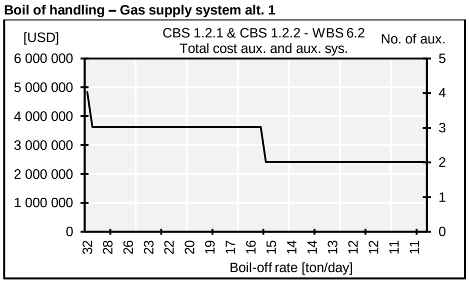


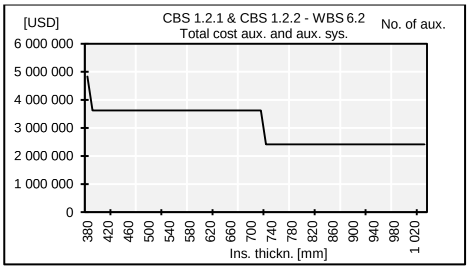


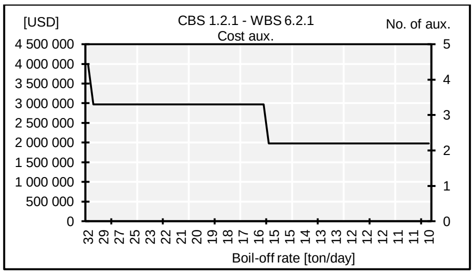


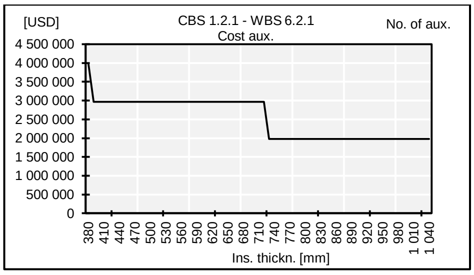


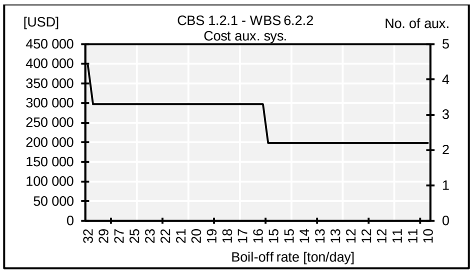
Boil of handling – Gas supply system alt. 1

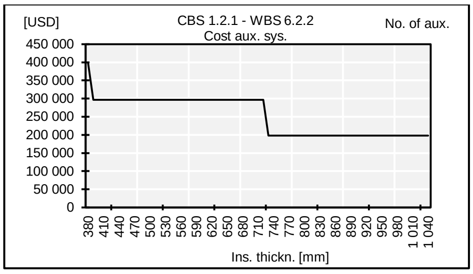


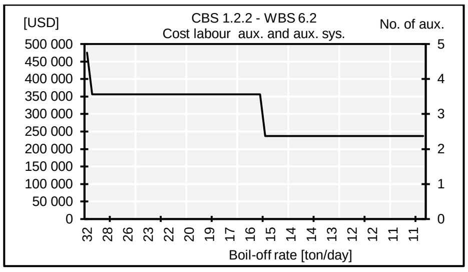


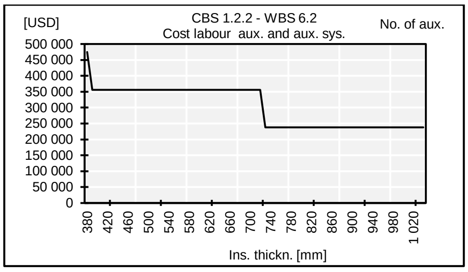




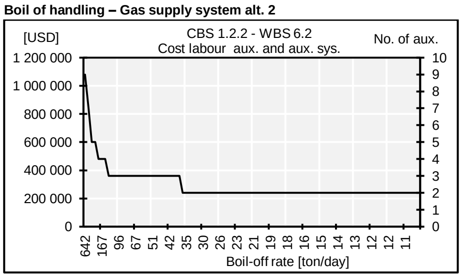


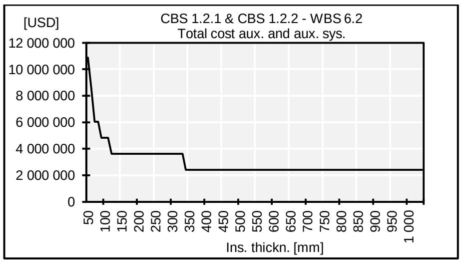


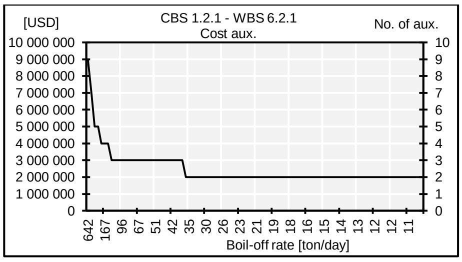


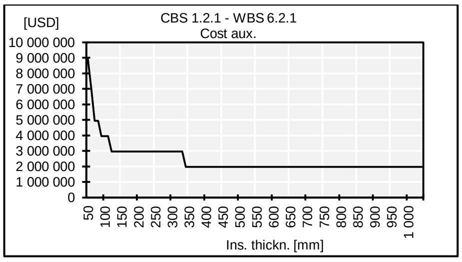


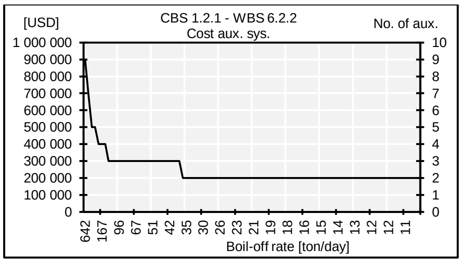
Boil of handling – Gas supply system alt. 2

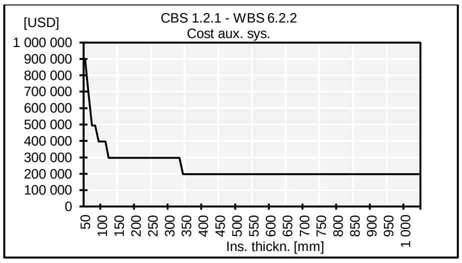


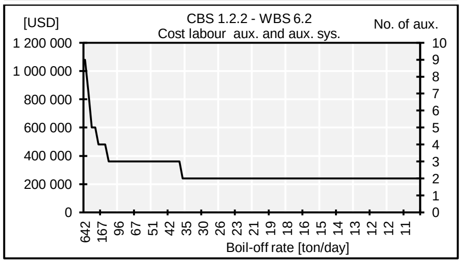


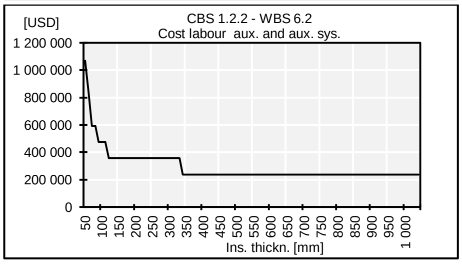






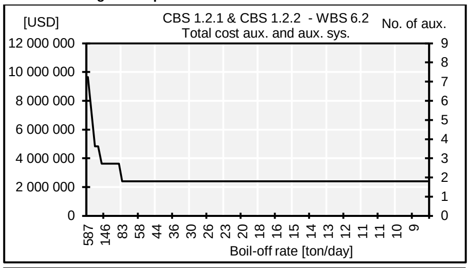


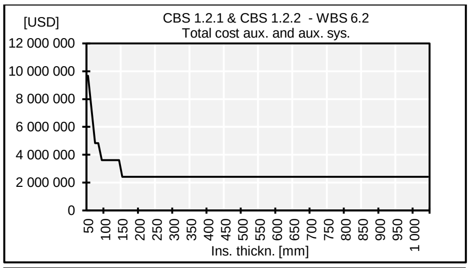


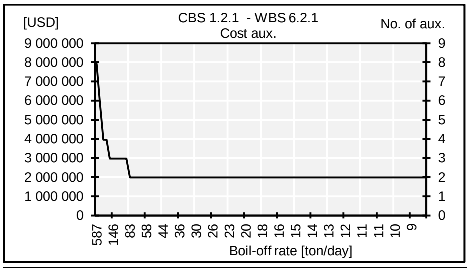


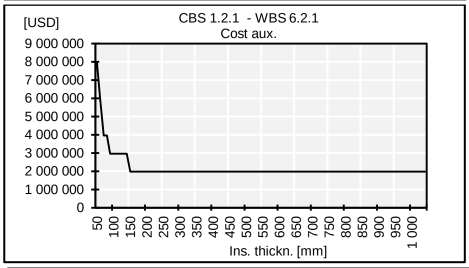
Insulation system 4

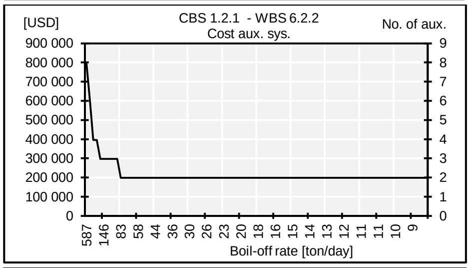
Boil of handling – Re-liquefaction

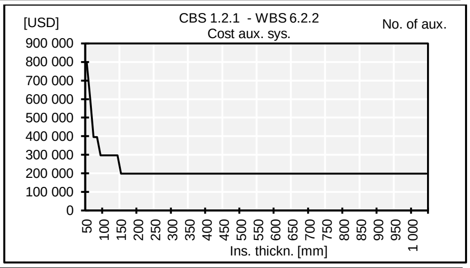


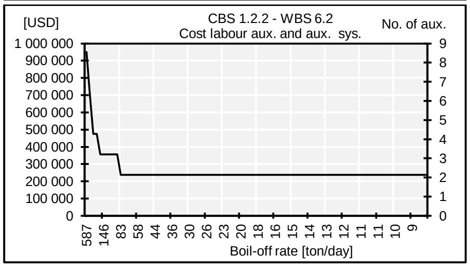


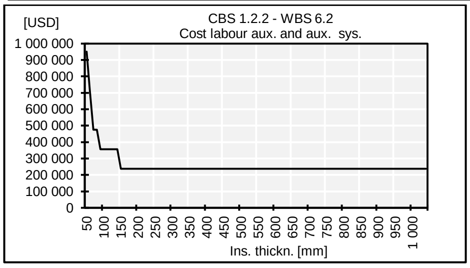




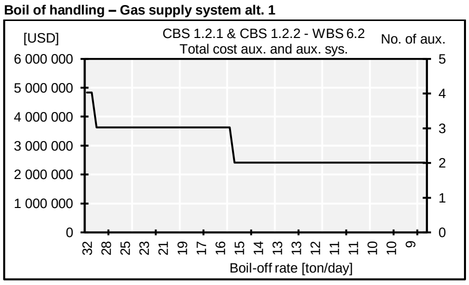


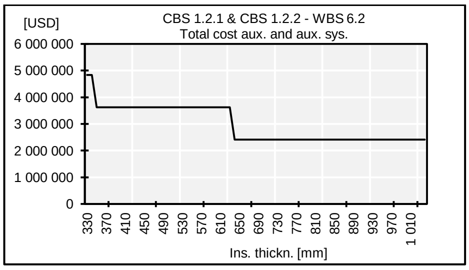


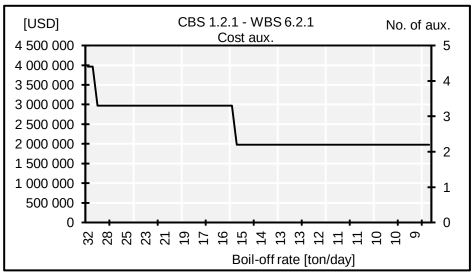


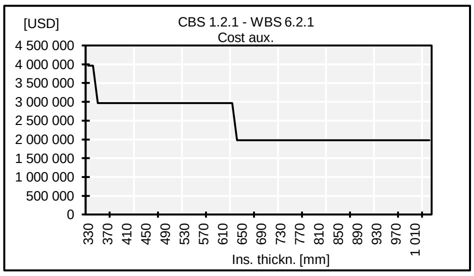


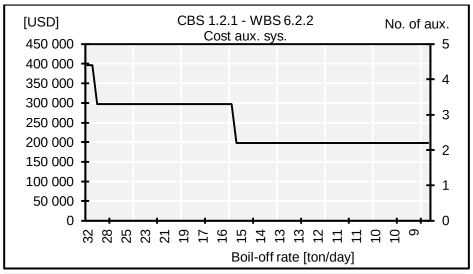
Boil of handling – Gas supply system alt. 1

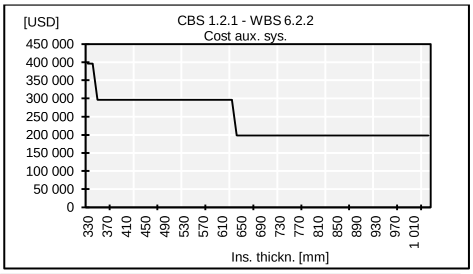


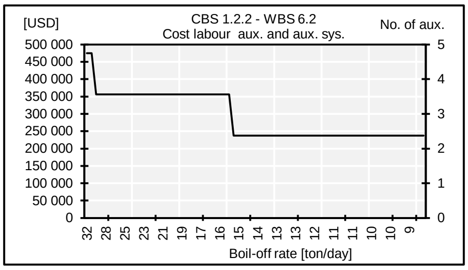


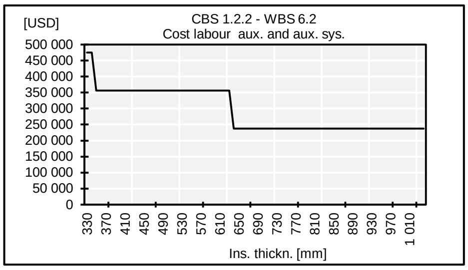




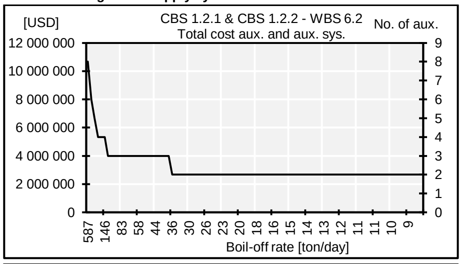


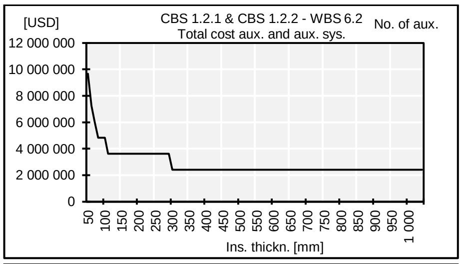


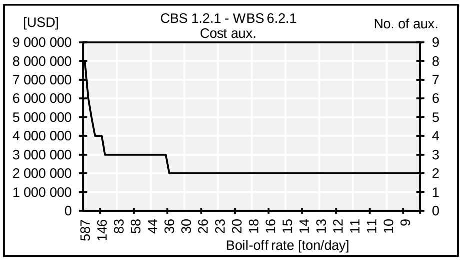


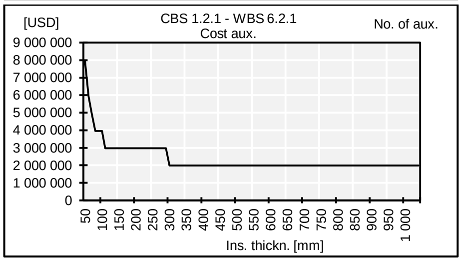


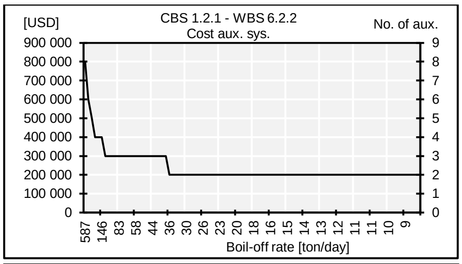
Boil of handling – Gas supply system alt. 2

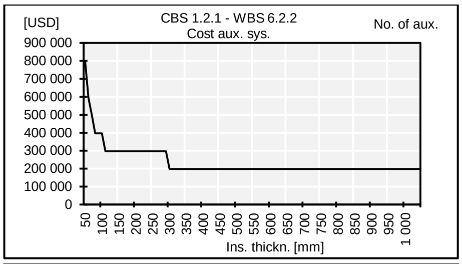


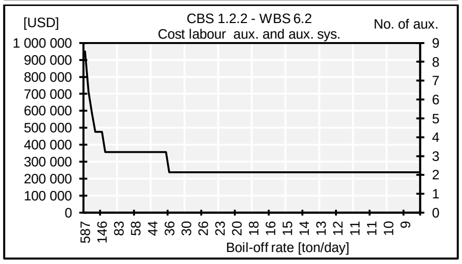


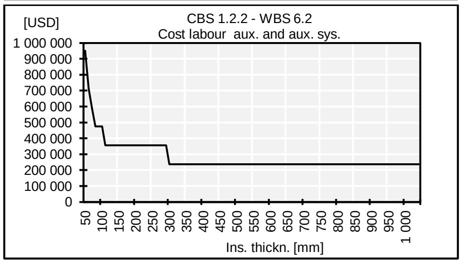






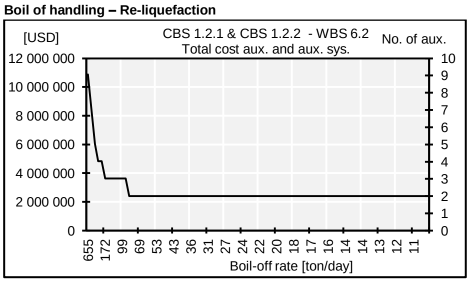


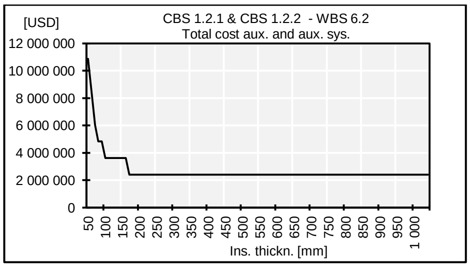


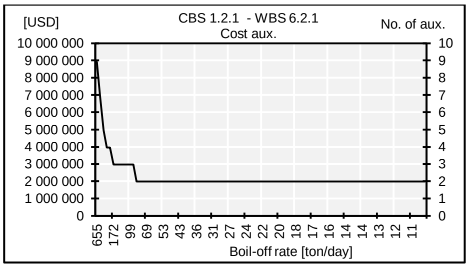


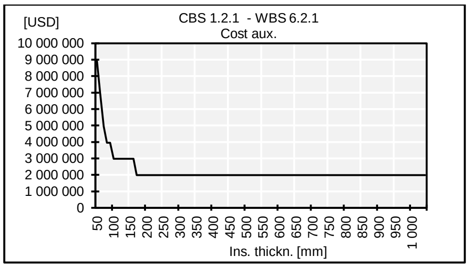
Insulation system 5

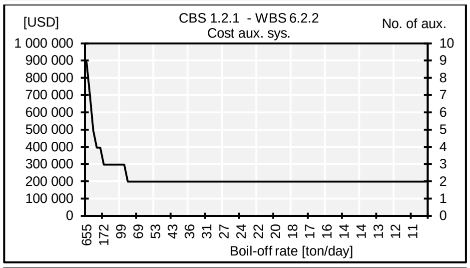
Boil of handling – Re-liquefaction

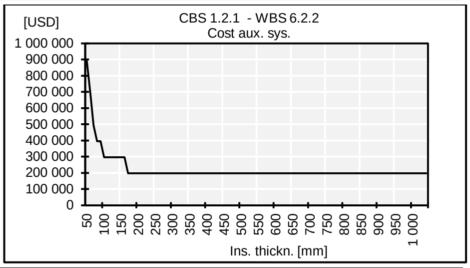


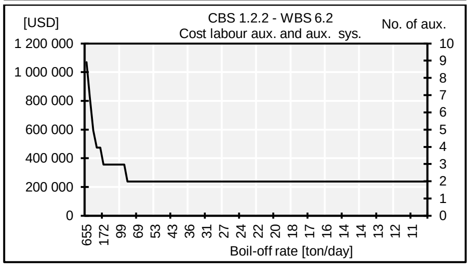


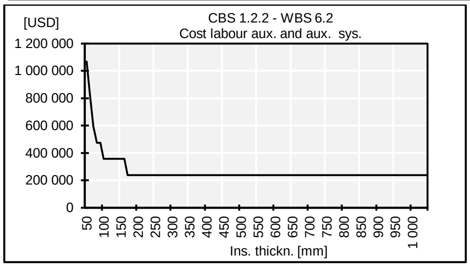




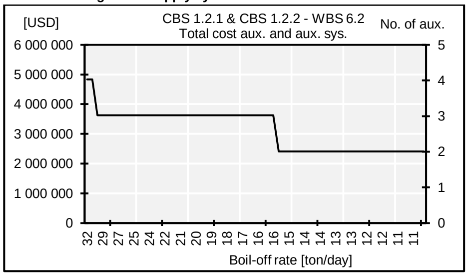


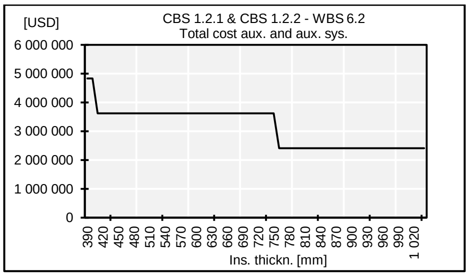


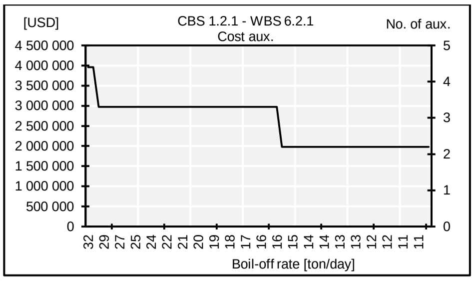


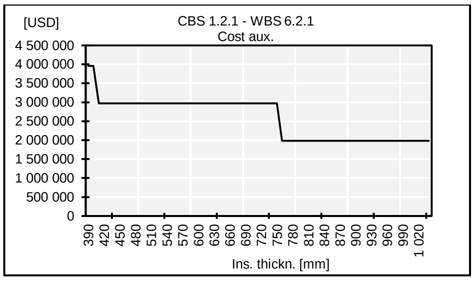


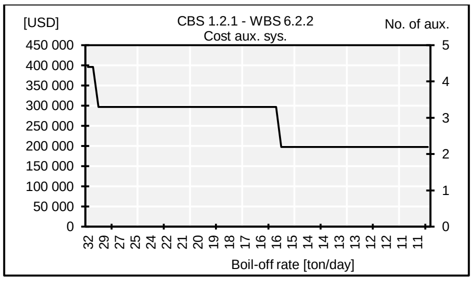
Boil of handling – Gas supply system alt. 1

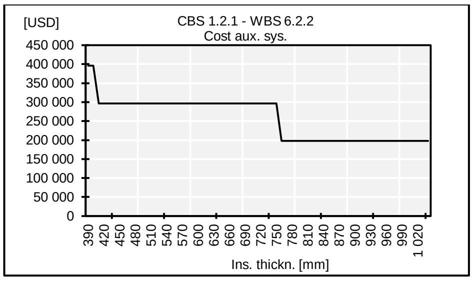


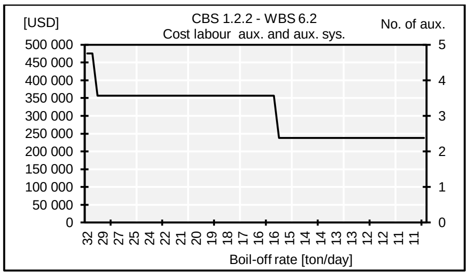


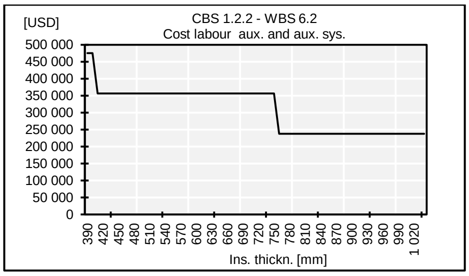




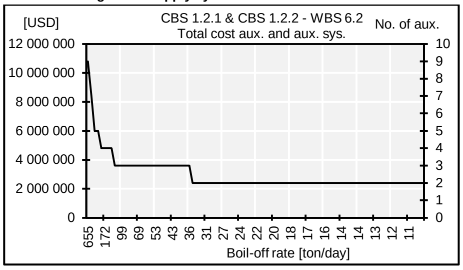


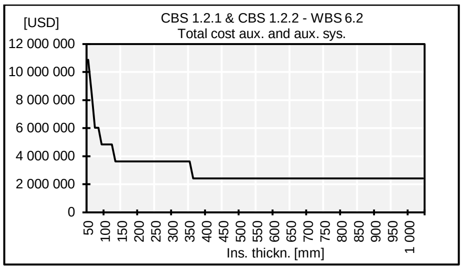


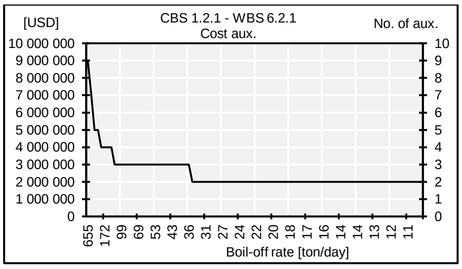


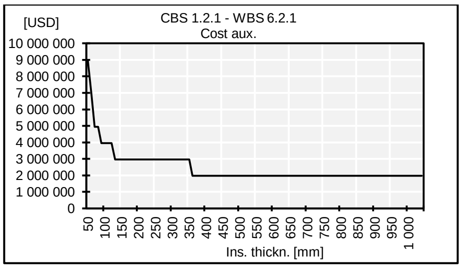


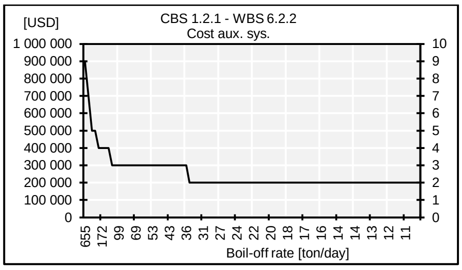
Boil of handling – Gas supply system alt. 2

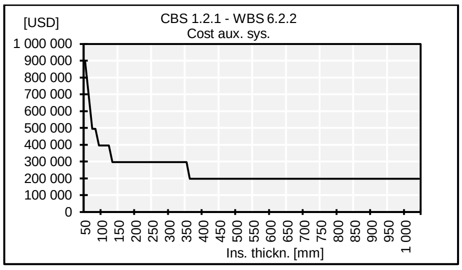


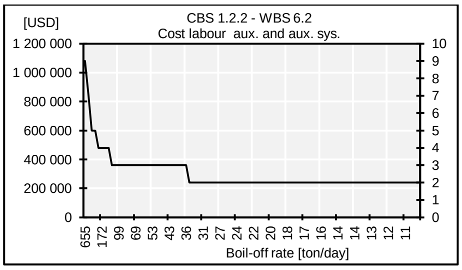


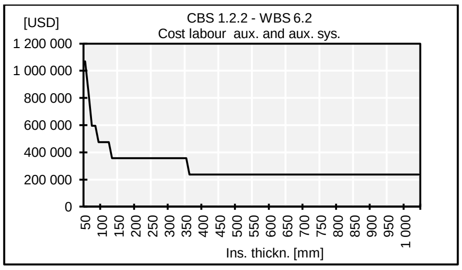






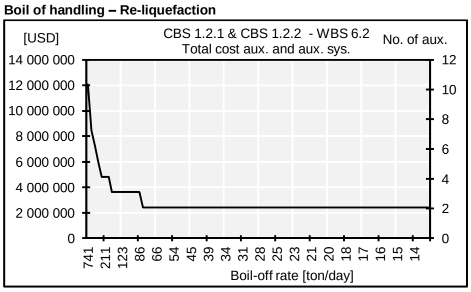


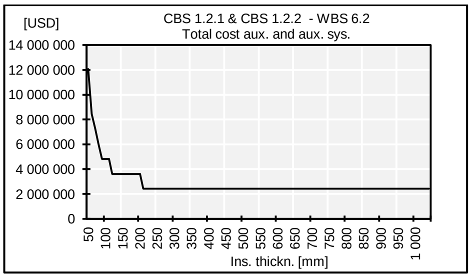


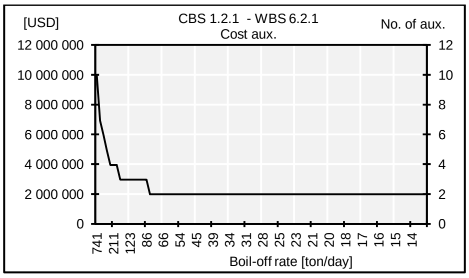


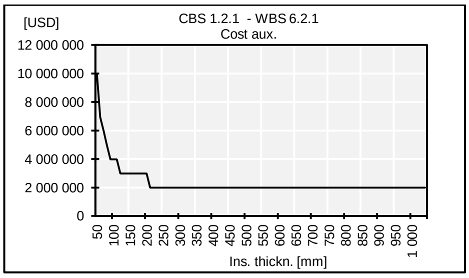
Insulation system 6

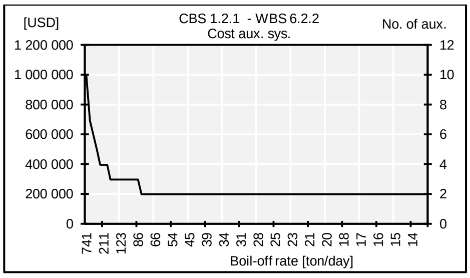
Boil of handling – Re-liquefaction

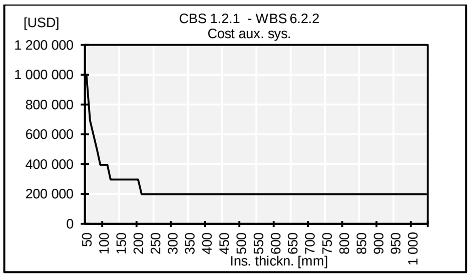


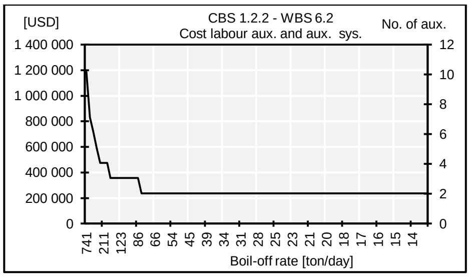


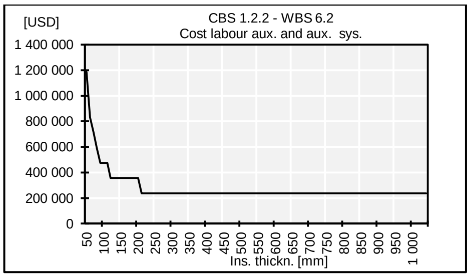




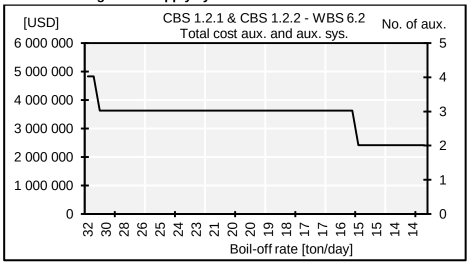


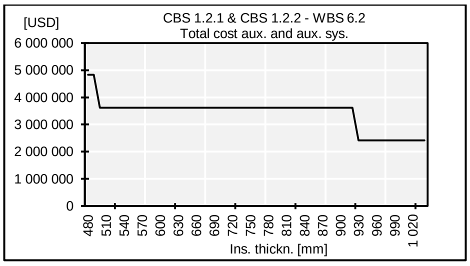


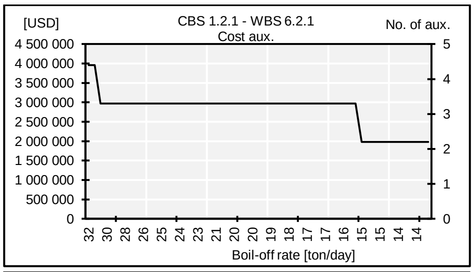


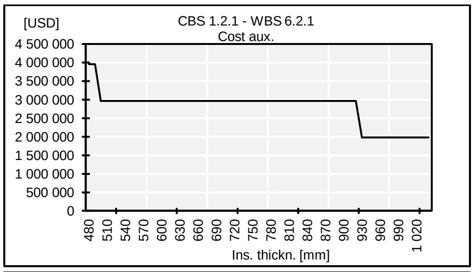


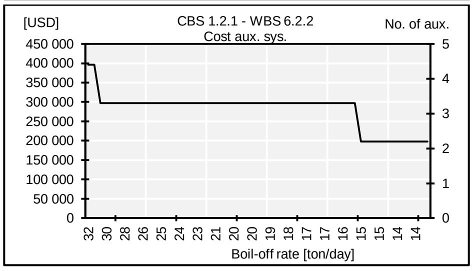
Boil of handling – Gas supply system alt. 1

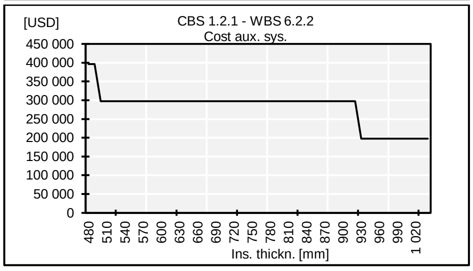


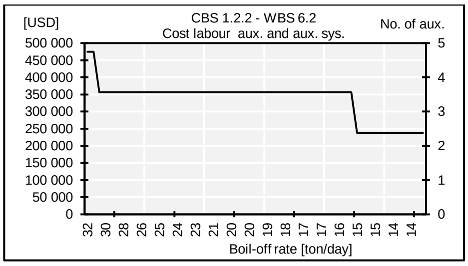


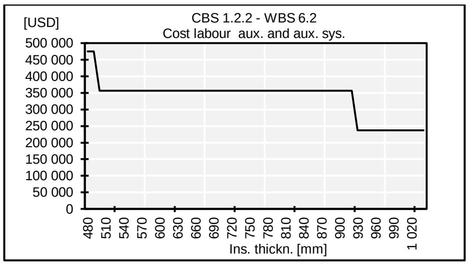




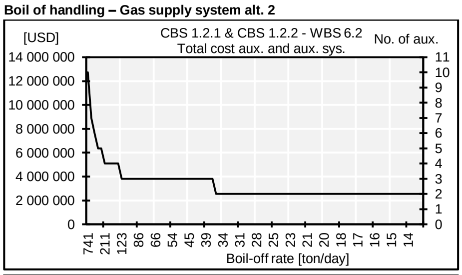


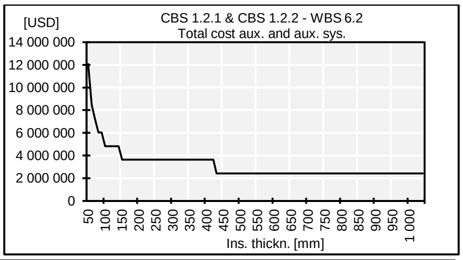


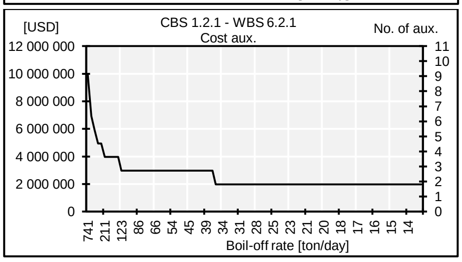


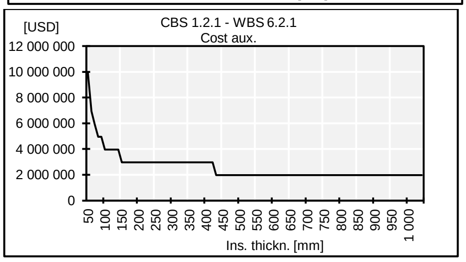


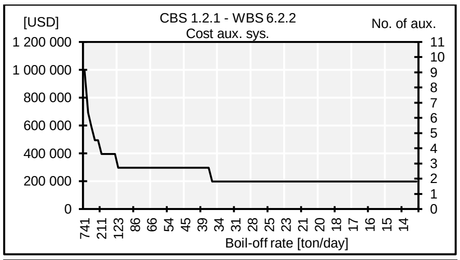
Boil of handling – Gas supply system alt. 2



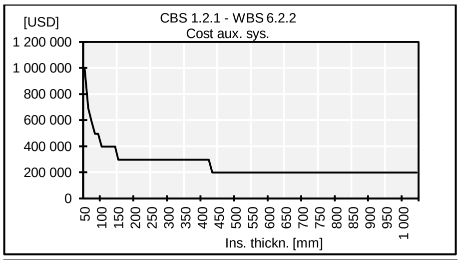




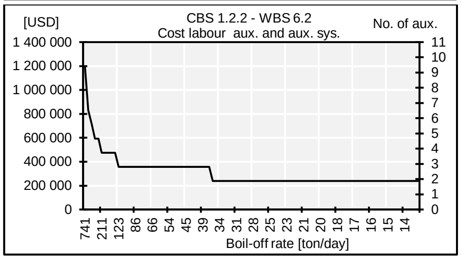




[USD]
CBS 1.2.1 - WBS 6.2.2
Cost aux. sys.
No. of aux.
1 200 000
1 000 000
800 000
600 000
400 000
200 000
0
741 211 123 86 66 54 45 39 34 31 28 25 23 21 20 18 17 16 15 14
Boil-off rate [ton/day]



[USD]
CBS 1.2.1 - WBS 6.2.2
Cost aux. sys.
1 200 000
1 000 000
800 000
600 000
400 000
200 000
0
50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1 000
Ins. thickn. [mm]



[USD]
CBS 1.2.2 - WBS 6.2
Cost labour aux. and aux. sys.
No. of aux.
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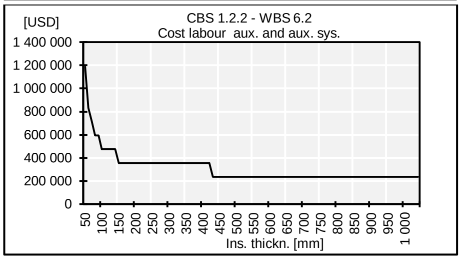
1 200 000
1 000 000
800 000
600 000
400 000
200 000
0
741 211 123 86 66 54 45 39 34 31 28 25 23 21 20 18 17 16 15 14
Boil-off rate [ton/day]



[USD]
CBS 1.2.2 - WBS 6.2
Cost labour aux. and aux. sys.
1 400 000
1 200 000
1 000 000
800 000
600 000
400 000
200 000
0
50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1 000
Ins. thickn. [mm]

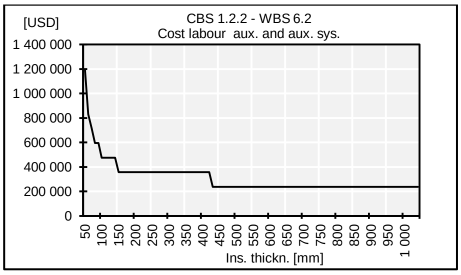
Variable admin. and design cost – CBS 3.2.3

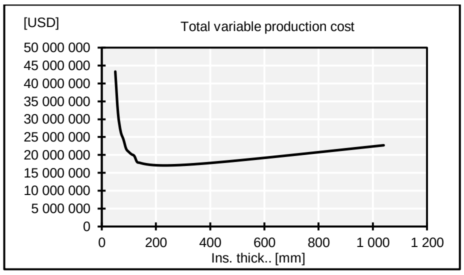
Insulation system 1

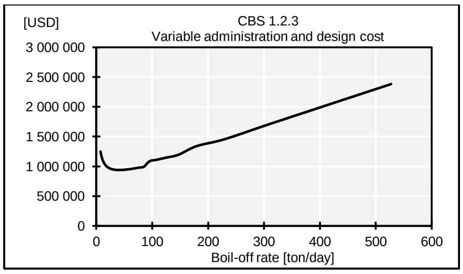
Boil of handling – Re-liquefaction

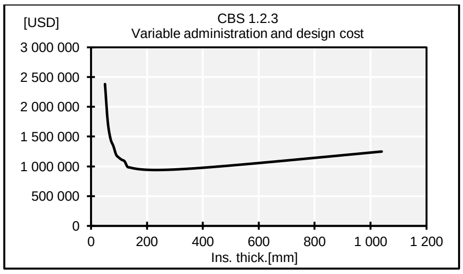
Table type:		Ins. sys. no:	ME alt:	Boil-off handling:	Description:		
Admin. and design cost		1	1	Re-liquefaction			
Insulation thickness	Boil-off rate	Variable production cost	Variable building finance cost	Variable production cost	Shipyard profit on total variable production cost	Broker fee on total variable production cost	CBS 1.3.2
t_{INS_TOT}	BOR_{TOT}	$C_{VAR\_PROD\_COST}$	$C_{VAR\_BUILD\_FINANCE\_TOT}$	$C_{VAR\_PROD\_COST\_TOT}$	C_{VAR_PROFIT}	C_{VAR_BROKER}	C_{VAR_ADMIN}
[mm]	[ton/day]	[USD]	[USD]	[USD]	[USD]	[USD]	[USD]
50	528	40,496,004	2,834,720	43,330,724	2,166,536	216,654	2,383,190
60	321	29,632,710	2,074,290	31,707,000	1,585,350	158,535	1,743,885
70	230	24,780,036	1,734,603	26,514,638	1,325,732	132,573	1,458,305
80	180	22,774,173	1,594,192	24,368,365	1,218,418	121,842	1,340,260
90	147	20,314,194	1,421,994	21,736,188	1,086,809	108,681	1,195,490
100	125	19,470,682	1,362,948	20,833,629	1,041,681	104,168	1,145,850
110	108	18,873,505	1,321,145	20,194,650	1,009,733	100,973	1,110,706
120	95	18,436,240	1,290,537	19,726,777	986,339	98,634	1,084,973
130	85	16,900,845	1,183,059	18,083,904	904,195	90,420	994,615
140	77	16,651,721	1,165,620	17,817,342	890,867	89,087	979,954
150	70	16,460,669	1,152,247	17,612,916	880,646	88,065	968,710
160	65	16,313,789	1,141,965	17,455,754	872,788	87,279	960,066
170	60	16,201,283	1,134,090	17,335,373	866,769	86,677	953,446
180	56	16,116,047	1,128,123	17,244,171	862,209	86,221	948,429
190	52	16,052,804	1,123,696	17,176,500	858,825	85,883	944,708
200	49	16,007,550	1,120,529	17,128,079	856,404	85,640	942,044
210	46	15,977,196	1,118,404	17,095,599	854,780	85,478	940,258
220	44	15,959,316	1,117,152	17,076,468	853,823	85,382	939,206
230	41	15,951,984	1,116,639	17,068,623	853,431	85,343	938,774
240	39	15,953,645	1,116,755	17,070,401	853,520	85,352	938,872
250	37	15,963,036	1,117,413	17,080,448	854,022	85,402	939,425
260	36	15,979,115	1,118,538	17,097,653	854,883	85,488	940,371
270	34	16,001,019	1,120,071	17,121,091	856,055	85,605	941,660
280	33	16,028,025	1,121,962	17,149,987	857,499	85,750	943,249
290	32	16,059,523	1,124,167	17,183,690	859,185	85,918	945,103
300	30	16,094,995	1,126,650	17,221,645	861,082	86,108	947,190
310	29	16,133,999	1,129,380	17,263,379	863,169	86,317	949,486
320	28	16,176,152	1,132,331	17,308,483	865,424	86,542	951,967
330	27	16,221,127	1,135,479	17,356,606	867,830	86,783	954,613
340	26	16,268,637	1,138,805	17,407,442	870,372	87,037	957,409
350	25	16,318,433	1,142,290	17,460,723	873,036	87,304	960,340
360	25	16,370,295	1,145,921	17,516,215	875,811	87,581	963,392
370	24	16,424,029	1,149,682	17,573,712	878,686	87,869	966,554
380	23	16,479,467	1,153,563	17,633,030	881,651	88,165	969,817
390	22	16,536,455	1,157,552	17,694,007	884,700	88,470	973,170
400	22	16,594,860	1,161,640	17,756,500	887,825	88,783	976,608
410	21	16,654,561	1,165,819	17,820,380	891,019	89,102	980,121
420	21	16,715,449	1,170,081	17,885,531	894,277	89,428	983,704
430	20	16,777,428	1,174,420	17,951,848	897,592	89,759	987,352
440	20	16,840,410	1,178,829	18,019,239	900,962	90,096	991,058
450	19	16,904,317	1,183,302	18,087,619	904,381	90,438	994,819
460	19	16,969,076	1,187,835	18,156,911	907,846	90,785	998,630
470	18	17,034,622	1,192,424	18,227,046	911,352	91,135	1,002,488
480	18	17,100,897	1,197,063	18,297,960	914,898	91,490	1,006,388
490	17	17,167,846	1,201,749	18,369,595	918,480	91,848	1,010,328
500	17	17,235,420	1,206,479	18,441,899	922,095	92,209	1,014,304
510	17	17,303,573	1,211,250	18,514,824	925,741	92,574	1,018,315
520	16	17,372,265	1,216,059	18,588,324	929,416	92,942	1,022,358
530	16	17,441,458	1,220,902	18,662,360	933,118	93,312	1,026,430
540	16	17,511,115	1,225,778	18,736,893	936,845	93,684	1,030,529
550	15	17,581,205	1,230,684	18,811,889	940,594	94,059	1,034,654
560	15	17,651,697	1,235,619	18,887,316	944,366	94,437	1,038,802
570	15	17,722,565	1,240,580	18,963,145	948,157	94,816	1,042,973
580	14	17,793,783	1,245,565	19,039,348	951,967	95,197	1,047,164
590	14	17,865,326	1,250,573	19,115,899	955,795	95,579	1,051,374

600	14	17,937,173	1,255,602	19,192,775	959,639	95,964	1,055,603
610	14	18,009,302	1,260,651	19,269,954	963,498	96,350	1,059,847
620	13	18,081,696	1,265,719	19,347,415	967,371	96,737	1,064,108
630	13	18,154,336	1,270,804	19,425,140	971,257	97,126	1,068,383
640	13	18,227,205	1,275,904	19,503,110	975,155	97,516	1,072,671
650	13	18,300,288	1,281,020	19,581,308	979,065	97,907	1,076,972
660	13	18,373,570	1,286,150	19,659,720	982,986	98,299	1,081,285
670	12	18,447,038	1,291,293	19,738,331	986,917	98,692	1,085,608
680	12	18,520,679	1,296,448	19,817,126	990,856	99,086	1,089,942
690	12	18,594,480	1,301,614	19,896,093	994,805	99,480	1,094,285
700	12	18,668,430	1,306,790	19,975,220	998,761	99,876	1,098,637
710	12	18,742,520	1,311,976	20,054,496	1,002,725	100,272	1,102,997
720	11	18,816,738	1,317,172	20,133,909	1,006,695	100,670	1,107,365
730	11	18,891,075	1,322,375	20,213,450	1,010,673	101,067	1,111,740
740	11	18,965,523	1,327,587	20,293,109	1,014,655	101,466	1,116,121
750	11	19,040,072	1,332,805	20,372,877	1,018,644	101,864	1,120,508
760	11	19,114,716	1,338,030	20,452,746	1,022,637	102,264	1,124,901
770	11	19,189,447	1,343,261	20,532,708	1,026,635	102,664	1,129,299
780	10	19,264,257	1,348,498	20,612,755	1,030,638	103,064	1,133,702
790	10	19,339,139	1,353,740	20,692,879	1,034,644	103,464	1,138,108
800	10	19,414,089	1,358,986	20,773,075	1,038,654	103,865	1,142,519
810	10	19,489,098	1,364,237	20,853,335	1,042,667	104,267	1,146,933
820	10	19,564,162	1,369,491	20,933,654	1,046,683	104,668	1,151,351
830	10	19,639,276	1,374,749	21,014,025	1,050,701	105,070	1,155,771
840	10	19,714,434	1,380,010	21,094,444	1,054,722	105,472	1,160,194
850	9	19,789,631	1,385,274	21,174,905	1,058,745	105,875	1,164,620
860	9	19,864,862	1,390,540	21,255,402	1,062,770	106,277	1,169,047
870	9	19,940,124	1,395,809	21,335,932	1,066,797	106,680	1,173,476
880	9	20,015,411	1,401,079	21,416,490	1,070,824	107,082	1,177,907
890	9	20,090,720	1,406,350	21,497,071	1,074,854	107,485	1,182,339
900	9	20,166,048	1,411,623	21,577,671	1,078,884	107,888	1,186,772
910	9	20,241,389	1,416,897	21,658,287	1,082,914	108,291	1,191,206
920	9	20,316,742	1,422,172	21,738,914	1,086,946	108,695	1,195,640
930	9	20,392,102	1,427,447	21,819,549	1,090,977	109,098	1,200,075
940	8	20,467,467	1,432,723	21,900,189	1,095,009	109,501	1,204,510
950	8	20,542,832	1,437,998	21,980,831	1,099,042	109,904	1,208,946
960	8	20,618,197	1,443,274	22,061,471	1,103,074	110,307	1,213,381
970	8	20,693,557	1,448,549	22,142,106	1,107,105	110,711	1,217,816
980	8	20,768,910	1,453,824	22,222,733	1,111,137	111,114	1,222,250
990	8	20,844,253	1,459,098	22,303,351	1,115,168	111,517	1,226,684
1,000	8	20,919,584	1,464,371	22,383,955	1,119,198	111,920	1,231,118
1,010	8	20,994,902	1,469,643	22,464,545	1,123,227	112,323	1,235,550
1,020	8	21,070,202	1,474,914	22,545,116	1,127,256	112,726	1,239,981
1,030	8	21,145,484	1,480,184	22,625,668	1,131,283	113,128	1,244,412
1,040	8	21,220,745	1,485,452	22,706,197	1,135,310	113,531	1,248,841





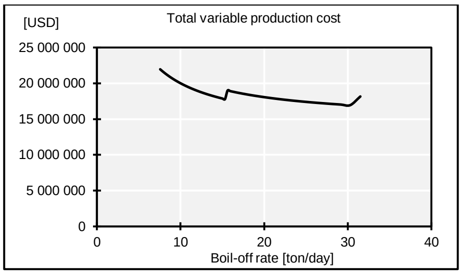


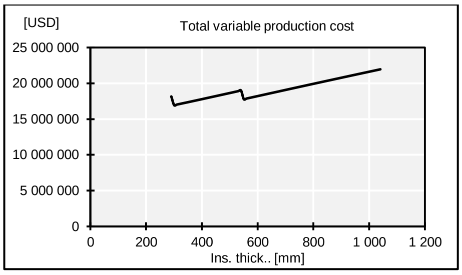


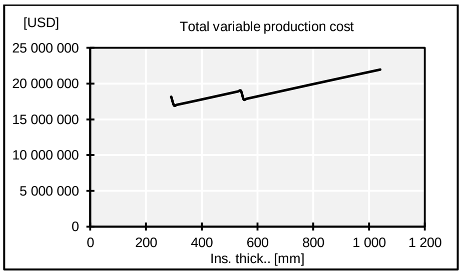
Boil of handling – Gas supply system alt. 1

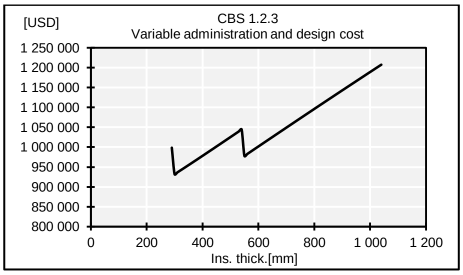
Table type:		Ins. sys. no:	ME alt:	Boil-off handling:	Description:		
Admin. and design cost		1	2	Gas supply system alt 1			
Insulation thickness	Boil-off rate	Variable production cost	Variable building finance cost	Variable production cost	Shipyard profit on total variable production cost	Broker fee on total variable production cost	CBS 1.3.2
t_{INS_TOT}	BOR_{TOT}	$C_{VAR\_PROD\_COST}$	$C_{VAR\_BUILD\_FINANCE\_TOT}$	$C_{VAR\_PROD\_COST\_TOT}$	C_{VAR_PROFIT}	C_{VAR_BROKER}	C_{VAR_ADMIN}
[mm]	[ton/day]	[USD]	[USD]	[USD]	[USD]	[USD]	[USD]
290	32	14,457,165	1,012,002	15,469,167	773,458	77,346	850,804
300	30	13,332,029	933,242	14,265,272	713,264	71,326	784,590
310	29	13,415,270	939,069	14,354,339	717,717	71,772	789,489
320	28	13,499,014	944,931	14,443,945	722,197	72,220	794,417
330	27	13,583,202	950,824	14,534,026	726,701	72,670	799,371
340	26	13,667,778	956,744	14,624,522	731,226	73,123	804,349
350	25	13,752,697	962,689	14,715,385	735,769	73,577	809,346
360	25	13,837,917	968,654	14,806,571	740,329	74,033	814,361
370	24	13,923,402	974,638	14,898,040	744,902	74,490	819,392
380	23	14,009,120	980,638	14,989,759	749,488	74,949	824,437
390	22	14,095,044	986,653	15,081,697	754,085	75,408	829,493
400	22	14,181,146	992,680	15,173,827	758,691	75,869	834,560
410	21	14,267,406	998,718	15,266,125	763,306	76,331	839,637
420	21	14,353,803	1,004,766	15,358,570	767,928	76,793	844,721
430	20	14,440,319	1,010,822	15,451,141	772,557	77,256	849,813
440	20	14,526,937	1,016,886	15,543,822	777,191	77,719	854,910
450	19	14,613,643	1,022,955	15,636,597	781,830	78,183	860,013
460	19	14,700,422	1,029,030	15,729,452	786,473	78,647	865,120
470	18	14,787,264	1,035,109	15,822,373	791,119	79,112	870,231
480	18	14,874,157	1,041,191	15,915,348	795,767	79,577	875,344
490	17	14,961,091	1,047,276	16,008,368	800,418	80,042	880,460
500	17	15,048,057	1,053,364	16,101,421	805,071	80,507	885,578
510	17	15,135,046	1,059,453	16,194,499	809,725	80,972	890,697
520	16	15,222,051	1,065,544	16,287,594	814,380	81,438	895,818
530	16	15,309,064	1,071,634	16,380,698	819,035	81,903	900,938
540	16	15,396,079	1,077,726	16,473,805	823,690	82,369	906,059
550	15	14,275,290	999,270	15,274,561	763,728	76,373	840,101
560	15	14,362,292	1,005,360	15,367,652	768,383	76,838	845,221
570	15	14,449,279	1,011,450	15,460,728	773,036	77,304	850,340
580	14	14,536,246	1,017,537	15,553,784	777,689	77,769	855,458
590	14	14,623,190	1,023,623	15,646,813	782,341	78,234	860,575
600	14	14,710,105	1,029,707	15,739,813	786,991	78,699	865,690
610	14	14,796,989	1,035,789	15,832,778	791,639	79,164	870,803
620	13	14,883,838	1,041,869	15,925,706	796,285	79,629	875,914
630	13	14,970,648	1,047,945	16,018,593	800,930	80,093	881,023
640	13	15,057,416	1,054,019	16,111,435	805,572	80,557	886,129
650	13	15,144,139	1,060,090	16,204,229	810,211	81,021	891,233
660	13	15,230,816	1,066,157	16,296,973	814,849	81,485	896,333
670	12	15,317,442	1,072,221	16,389,663	819,483	81,948	901,431
680	12	15,404,017	1,078,281	16,482,298	824,115	82,411	906,526
690	12	15,490,537	1,084,338	16,574,874	828,744	82,874	911,618
700	12	15,577,000	1,090,390	16,667,390	833,370	83,337	916,706
710	12	15,663,406	1,096,438	16,759,844	837,992	83,799	921,791
720	11	15,749,751	1,102,483	16,852,234	842,612	84,261	926,873
730	11	15,836,034	1,108,522	16,944,557	847,228	84,723	931,951
740	11	15,922,254	1,114,558	17,036,812	851,841	85,184	937,025
750	11	16,008,409	1,120,589	17,128,998	856,450	85,645	942,095
760	11	16,094,497	1,126,615	17,221,112	861,056	86,106	947,161
770	11	16,180,518	1,132,636	17,313,154	865,658	86,566	952,223
780	10	16,266,469	1,138,653	17,405,122	870,256	87,026	957,282
790	10	16,352,350	1,144,665	17,497,015	874,851	87,485	962,336
800	10	16,438,160	1,150,671	17,588,831	879,442	87,944	967,386
810	10	16,523,897	1,156,673	17,680,570	884,028	88,403	972,431
820	10	16,609,561	1,162,669	17,772,230	888,611	88,861	977,473
830	10	16,695,150	1,168,660	17,863,810	893,191	89,319	982,510
840	10	16,780,663	1,174,646	17,955,310	897,765	89,777	987,542
850	9	16,866,101	1,180,627	18,046,728	902,336	90,234	992,570

860	9	16,951,461	1,186,602	18,138,063	906,903	90,690	997,593
870	9	17,036,743	1,192,572	18,229,315	911,466	91,147	1,002,612
880	9	17,121,947	1,198,536	18,320,483	916,024	91,602	1,007,627
890	9	17,207,071	1,204,495	18,411,566	920,578	92,058	1,012,636
900	9	17,292,115	1,210,448	18,502,563	925,128	92,513	1,017,641
910	9	17,377,079	1,216,396	18,593,474	929,674	92,967	1,022,641
920	9	17,461,961	1,222,337	18,684,298	934,215	93,421	1,027,636
930	9	17,546,761	1,228,273	18,775,035	938,752	93,875	1,032,627
940	8	17,631,479	1,234,204	18,865,683	943,284	94,328	1,037,613
950	8	17,716,115	1,240,128	18,956,243	947,812	94,781	1,042,593
960	8	17,800,666	1,246,047	19,046,713	952,336	95,234	1,047,569
970	8	17,885,134	1,251,959	19,137,094	956,855	95,685	1,052,540
980	8	17,969,518	1,257,866	19,227,384	961,369	96,137	1,057,506
990	8	18,053,817	1,263,767	19,317,584	965,879	96,588	1,062,467
1,000	8	18,138,030	1,269,662	19,407,692	970,385	97,038	1,067,423
1,010	8	18,222,158	1,275,551	19,497,709	974,885	97,489	1,072,374
1,020	8	18,306,201	1,281,434	19,587,635	979,382	97,938	1,077,320
1,030	8	18,390,156	1,287,311	19,677,467	983,873	98,387	1,082,261
1,040	8	18,474,026	1,293,182	19,767,208	988,360	98,836	1,087,196





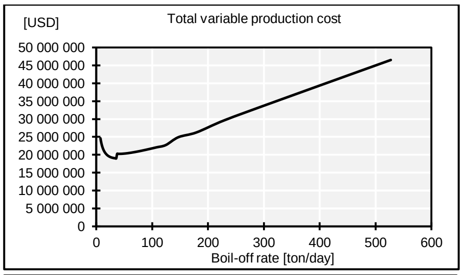


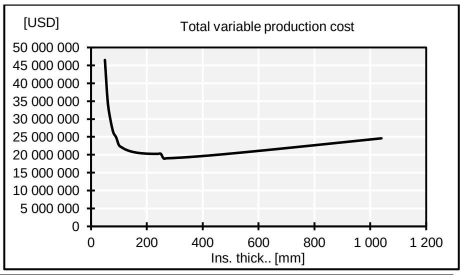


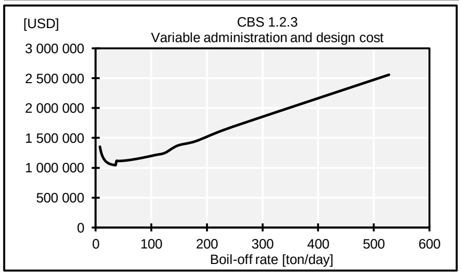
Boil of handling – Gas supply system alt. 2

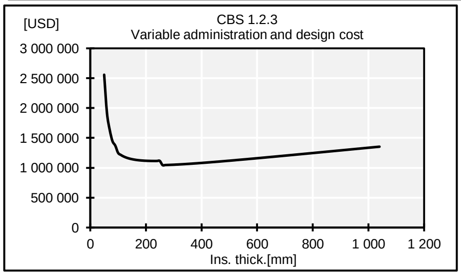
Table type:		Ins. sys. no:	ME alt:	Boil-off handling:	Description:		
Admin. and design cost		1	2	Gas supply system alt 2			
Insulation thickness	Boil-off rate	Variable production cost	Variable building finance cost	Variable production cost	Shipyard profit on total variable production cost	Broker fee on total variable production cost	CBS 1.3.2
t_{INS_TOT}	BOR_{TOT}	$C_{VAR\_PROD\_COST}$	$C_{VAR\_BUILD\_FINANCE\_TOT}$	$C_{VAR\_PROD\_COST\_TOT}$	C_{VAR_PROFIT}	C_{VAR_BROKER}	C_{VAR_ADMIN}
[mm]	[ton/day]	[USD]	[USD]	[USD]	[USD]	[USD]	[USD]
50	528	43,477,473	3,043,423	46,520,896	2,326,045	232,604	2,558,649
60	321	32,614,179	2,282,993	34,897,171	1,744,859	174,486	1,919,344
70	230	27,761,505	1,943,305	29,704,810	1,485,240	148,524	1,633,765
80	180	24,547,842	1,718,349	26,266,191	1,313,310	131,331	1,444,640
90	147	23,295,663	1,630,696	24,926,360	1,246,318	124,632	1,370,950
100	125	21,244,351	1,487,105	22,731,455	1,136,573	113,657	1,250,230
110	108	20,647,174	1,445,302	22,092,476	1,104,624	110,462	1,215,086
120	95	20,209,909	1,414,694	21,624,602	1,081,230	108,123	1,189,353
130	85	19,882,314	1,391,762	21,274,076	1,063,704	106,370	1,170,074
140	77	19,633,190	1,374,323	21,007,513	1,050,376	105,038	1,155,413
150	70	19,442,138	1,360,950	20,803,087	1,040,154	104,015	1,144,170
160	65	19,295,257	1,350,668	20,645,925	1,032,296	103,230	1,135,526
170	60	19,182,752	1,342,793	20,525,545	1,026,277	102,628	1,128,905
180	56	19,097,516	1,336,826	20,434,342	1,021,717	102,172	1,123,889
190	52	19,034,273	1,332,399	20,366,672	1,018,334	101,833	1,120,167
200	49	18,989,019	1,329,231	20,318,250	1,015,913	101,591	1,117,504
210	46	18,958,664	1,327,107	20,285,771	1,014,289	101,429	1,115,717
220	44	18,940,785	1,325,855	20,266,640	1,013,332	101,333	1,114,665
230	41	18,933,453	1,325,342	20,258,794	1,012,940	101,294	1,114,234
240	39	18,935,114	1,325,458	20,260,572	1,013,029	101,303	1,114,331
250	37	18,944,505	1,326,115	20,270,620	1,013,531	101,353	1,114,884
260	36	17,752,784	1,242,695	18,995,479	949,774	94,977	1,044,751
270	34	17,774,688	1,244,228	19,018,916	950,946	95,095	1,046,040
280	33	17,801,694	1,246,119	19,047,813	952,391	95,239	1,047,630
290	32	17,833,192	1,248,323	19,081,516	954,076	95,408	1,049,483
300	30	17,868,664	1,250,806	19,119,471	955,974	95,597	1,051,571
310	29	17,907,667	1,253,537	19,161,204	958,060	95,806	1,053,866
320	28	17,949,821	1,256,487	19,206,309	960,315	96,032	1,056,347
330	27	17,994,796	1,259,636	19,254,432	962,722	96,272	1,058,994
340	26	18,042,306	1,262,961	19,305,268	965,263	96,526	1,061,790
350	25	18,092,102	1,266,447	19,358,549	967,927	96,793	1,064,720
360	25	18,143,963	1,270,077	19,414,041	970,702	97,070	1,067,772
370	24	18,197,698	1,273,839	19,471,537	973,577	97,358	1,070,935
380	23	18,253,136	1,277,719	19,530,855	976,543	97,654	1,074,197
390	22	18,310,124	1,281,709	19,591,833	979,592	97,959	1,077,551
400	22	18,368,529	1,285,797	19,654,326	982,716	98,272	1,080,988
410	21	18,428,230	1,289,976	19,718,206	985,910	98,591	1,084,501
420	21	18,489,118	1,294,238	19,783,356	989,168	98,917	1,088,085
430	20	18,551,097	1,298,577	19,849,674	992,484	99,248	1,091,732
440	20	18,614,079	1,302,986	19,917,065	995,853	99,585	1,095,439
450	19	18,677,986	1,307,459	19,985,445	999,272	99,927	1,099,199
460	19	18,742,744	1,311,992	20,054,737	1,002,737	100,274	1,103,011
470	18	18,808,291	1,316,580	20,124,871	1,006,244	100,624	1,106,868
480	18	18,874,566	1,321,220	20,195,785	1,009,789	100,979	1,110,768
490	17	18,941,515	1,325,906	20,267,421	1,013,371	101,337	1,114,708
500	17	19,009,088	1,330,636	20,339,725	1,016,986	101,699	1,118,685
510	17	19,077,242	1,335,407	20,412,649	1,020,632	102,063	1,122,696
520	16	19,145,934	1,340,215	20,486,150	1,024,307	102,431	1,126,738
530	16	19,215,126	1,345,059	20,560,185	1,028,009	102,801	1,130,810
540	16	19,284,784	1,349,935	20,634,718	1,031,736	103,174	1,134,910
550	15	19,354,874	1,354,841	20,709,715	1,035,486	103,549	1,139,034
560	15	19,425,366	1,359,776	20,785,142	1,039,257	103,926	1,143,183
570	15	19,496,234	1,364,736	20,860,971	1,043,049	104,305	1,147,353
580	14	19,567,452	1,369,722	20,937,173	1,046,859	104,686	1,151,545
590	14	19,638,995	1,374,730	21,013,724	1,050,686	105,069	1,155,755
600	14	19,710,841	1,379,759	21,090,600	1,054,530	105,453	1,159,983
610	14	19,782,971	1,384,808	21,167,779	1,058,389	105,839	1,164,228

620	13	19,855,365	1,389,876	21,245,241	1,062,262	106,226	1,168,488
630	13	19,928,005	1,394,960	21,322,965	1,066,148	106,615	1,172,763
640	13	20,000,874	1,400,061	21,400,935	1,070,047	107,005	1,177,051
650	13	20,073,957	1,405,177	21,479,134	1,073,957	107,396	1,181,352
660	13	20,147,239	1,410,307	21,557,546	1,077,877	107,788	1,185,665
670	12	20,220,707	1,415,449	21,636,156	1,081,808	108,181	1,189,989
680	12	20,294,347	1,420,604	21,714,952	1,085,748	108,575	1,194,322
690	12	20,368,149	1,425,770	21,793,919	1,089,696	108,970	1,198,666
700	12	20,442,099	1,430,947	21,873,046	1,093,652	109,365	1,203,018
710	12	20,516,188	1,436,133	21,952,322	1,097,616	109,762	1,207,378
720	11	20,590,406	1,441,328	22,031,735	1,101,587	110,159	1,211,745
730	11	20,664,744	1,446,532	22,111,276	1,105,564	110,556	1,216,120
740	11	20,739,191	1,451,743	22,190,935	1,109,547	110,955	1,220,501
750	11	20,813,741	1,456,962	22,270,703	1,113,535	111,354	1,224,889
760	11	20,888,385	1,462,187	22,350,572	1,117,529	111,753	1,229,281
770	11	20,963,115	1,467,418	22,430,534	1,121,527	112,153	1,233,679
780	10	21,037,925	1,472,655	22,510,580	1,125,529	112,553	1,238,082
790	10	21,112,808	1,477,897	22,590,705	1,129,535	112,954	1,242,489
800	10	21,187,757	1,483,143	22,670,900	1,133,545	113,355	1,246,900
810	10	21,262,767	1,488,394	22,751,161	1,137,558	113,756	1,251,314
820	10	21,337,831	1,493,648	22,831,479	1,141,574	114,157	1,255,731
830	10	21,412,945	1,498,906	22,911,851	1,145,593	114,559	1,260,152
840	10	21,488,102	1,504,167	22,992,270	1,149,613	114,961	1,264,575
850	9	21,563,299	1,509,431	23,072,730	1,153,637	115,364	1,269,000
860	9	21,638,531	1,514,697	23,153,228	1,157,661	115,766	1,273,428
870	9	21,713,792	1,519,965	23,233,758	1,161,688	116,169	1,277,857
880	9	21,789,080	1,525,236	23,314,315	1,165,716	116,572	1,282,287
890	9	21,864,389	1,530,507	23,394,896	1,169,745	116,974	1,286,719
900	9	21,939,716	1,535,780	23,475,497	1,173,775	117,377	1,291,152
910	9	22,015,058	1,541,054	23,556,112	1,177,806	117,781	1,295,586
920	9	22,090,411	1,546,329	23,636,739	1,181,837	118,184	1,300,021
930	9	22,165,771	1,551,604	23,717,375	1,185,869	118,587	1,304,456
940	8	22,241,135	1,556,879	23,798,015	1,189,901	118,990	1,308,891
950	8	22,316,501	1,562,155	23,878,656	1,193,933	119,393	1,313,326
960	8	22,391,866	1,567,431	23,959,296	1,197,965	119,796	1,317,761
970	8	22,467,226	1,572,706	24,039,931	1,201,997	120,200	1,322,196
980	8	22,542,578	1,577,980	24,120,559	1,206,028	120,603	1,326,631
990	8	22,617,922	1,583,255	24,201,176	1,210,059	121,006	1,331,065
1,000	8	22,693,253	1,588,528	24,281,781	1,214,089	121,409	1,335,498
1,010	8	22,768,570	1,593,800	24,362,370	1,218,119	121,812	1,339,930
1,020	8	22,843,871	1,599,071	24,442,942	1,222,147	122,215	1,344,362
1,030	8	22,919,153	1,604,341	24,523,493	1,226,175	122,617	1,348,792
1,040	8	22,994,414	1,609,609	24,604,022	1,230,201	123,020	1,353,221



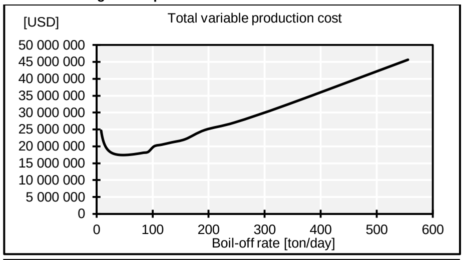


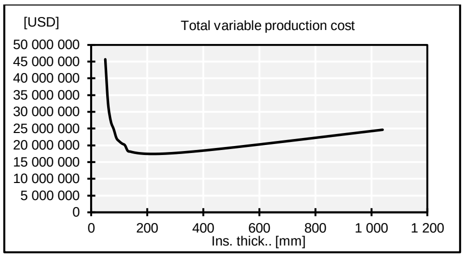


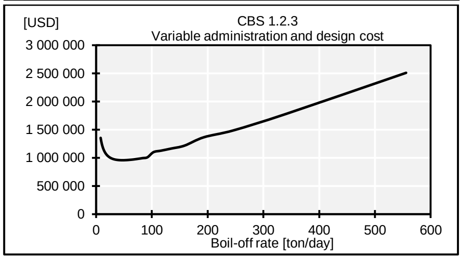


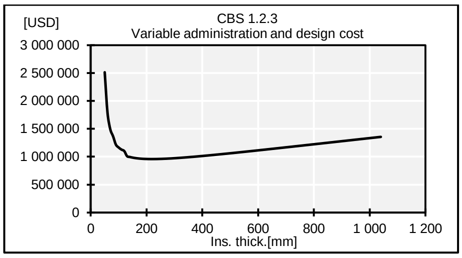
Insulation system 2

Boil of handling – Re-liquefaction

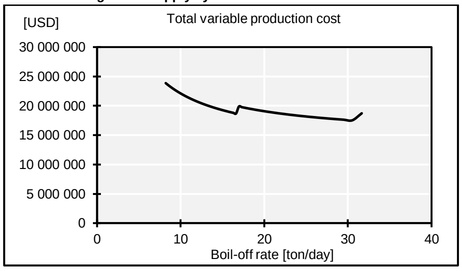


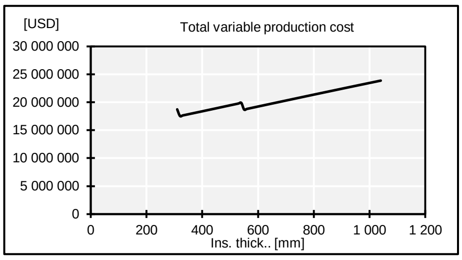


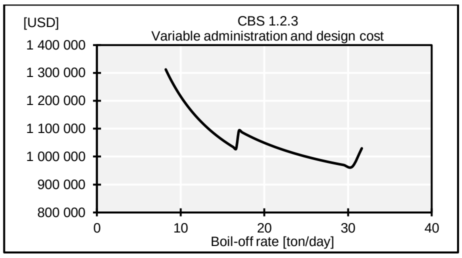


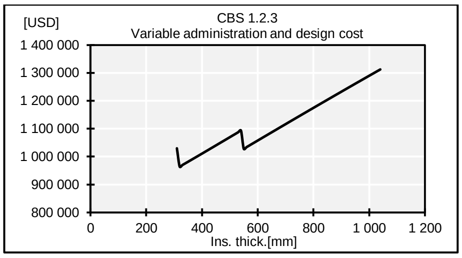


Boil of handling – Gas supply system alt. 1

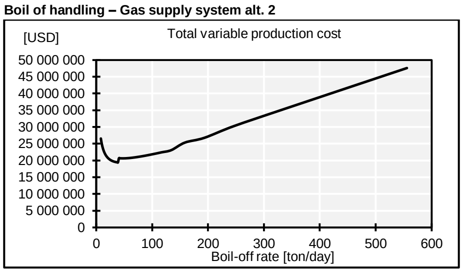


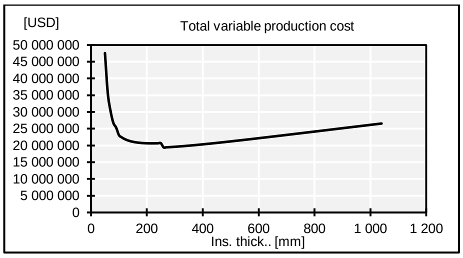


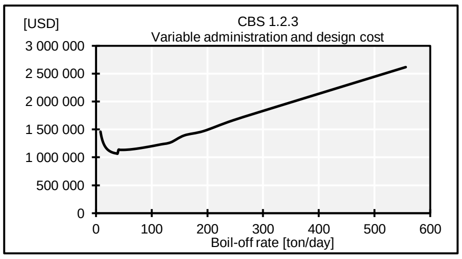


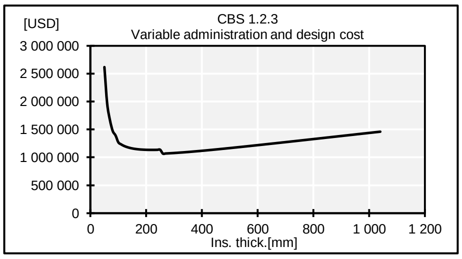


Boil of handling – Gas supply system alt. 2



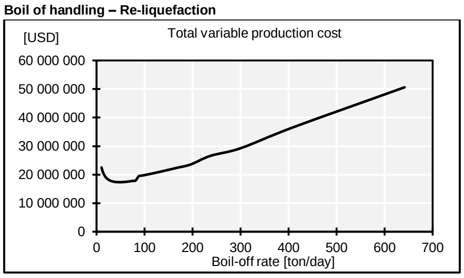


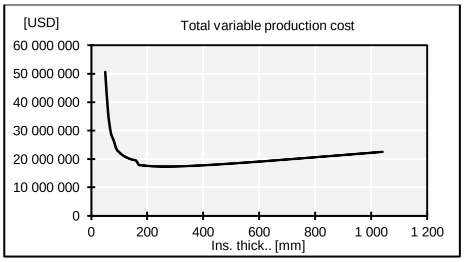


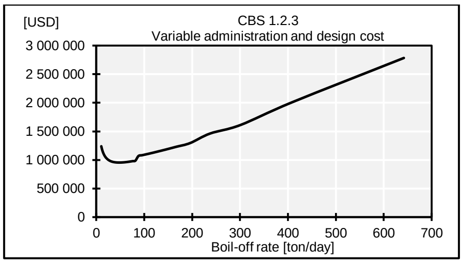


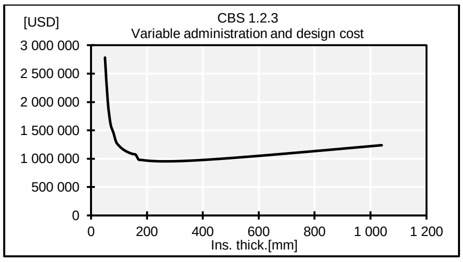
Insulation system 3

Boil of handling – Re-liquefaction

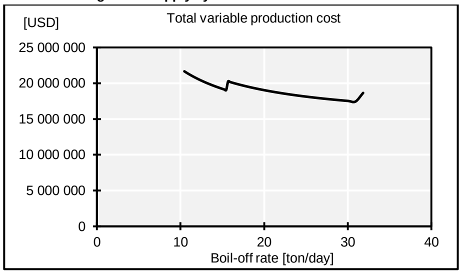


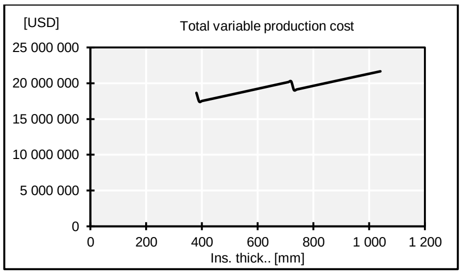


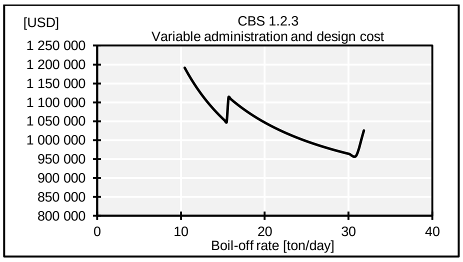


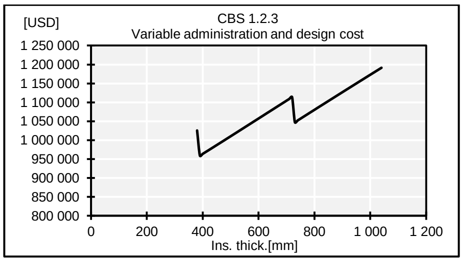


Boil of handling – Gas supply system alt. 1

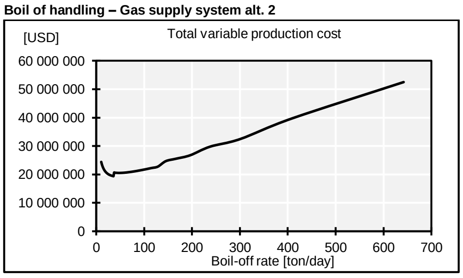


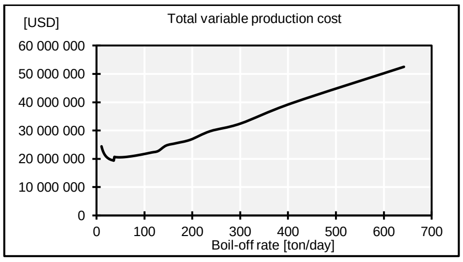


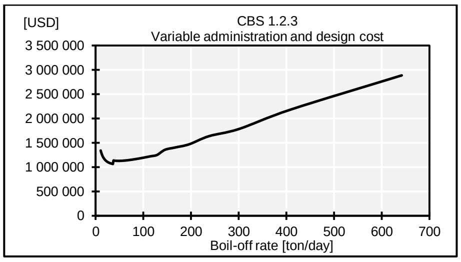


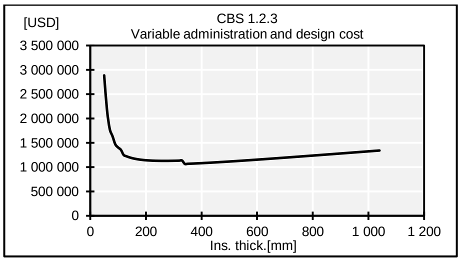


Boil of handling – Gas supply system alt. 2



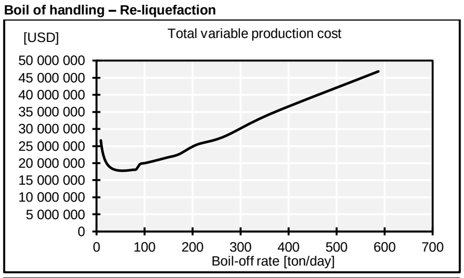


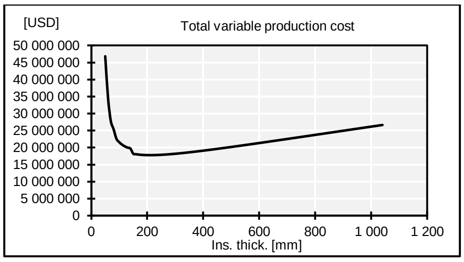


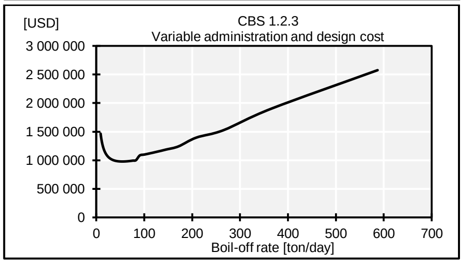


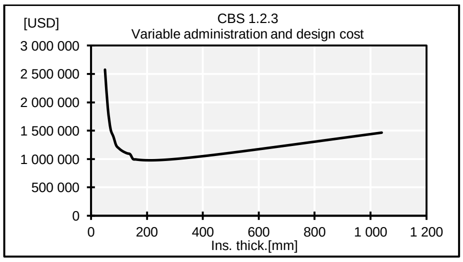
Insulation system 4

Boil of handling – Re-liquefaction

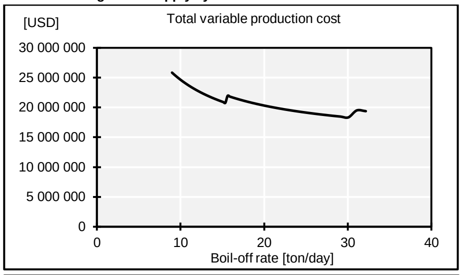


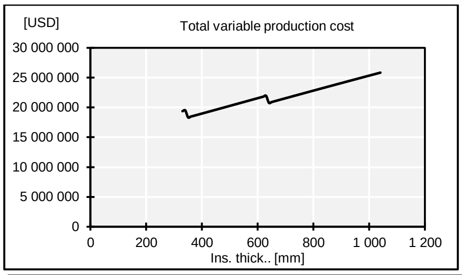


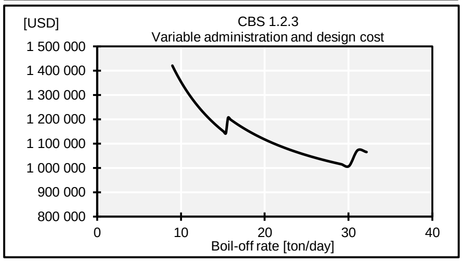


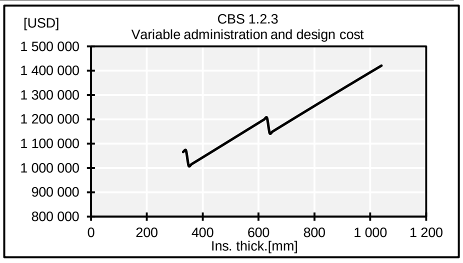


Boil of handling – Gas supply system alt. 1

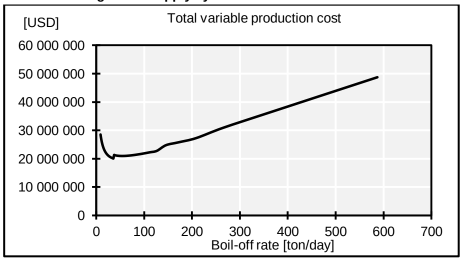


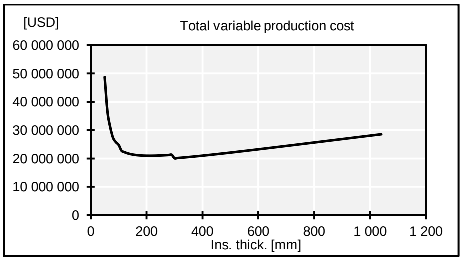


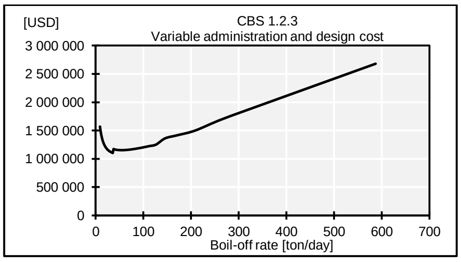


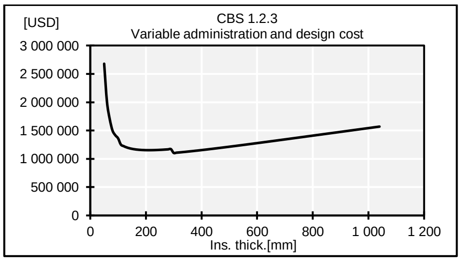


Boil of handling – Gas supply system alt. 2



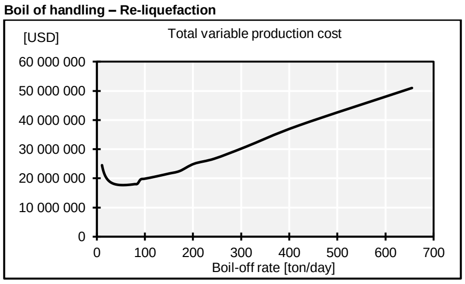


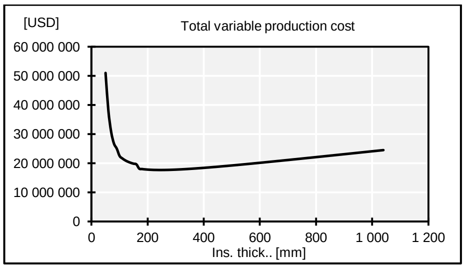


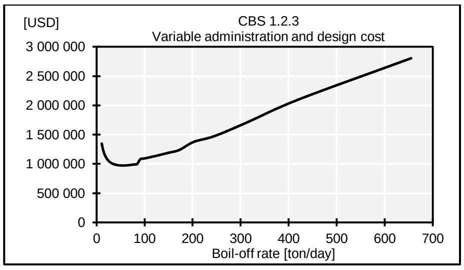


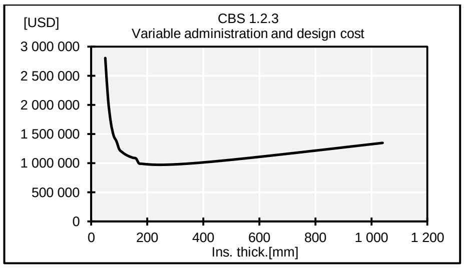
Insulation system 5

Boil of handling – Re-liquefaction

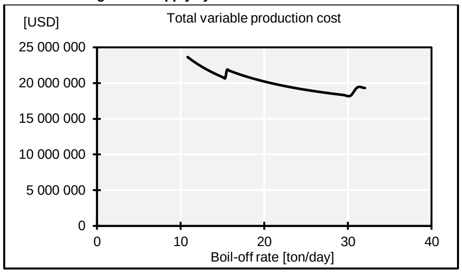


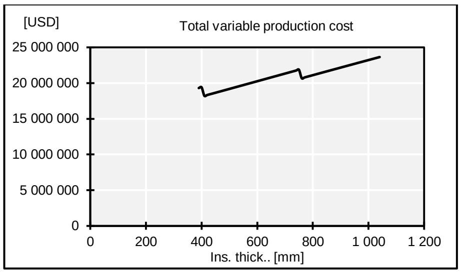


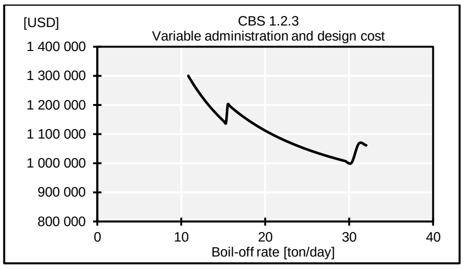


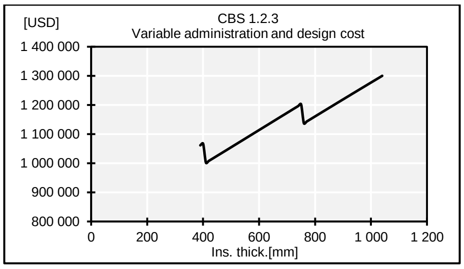


Boil of handling – Gas supply system alt. 1

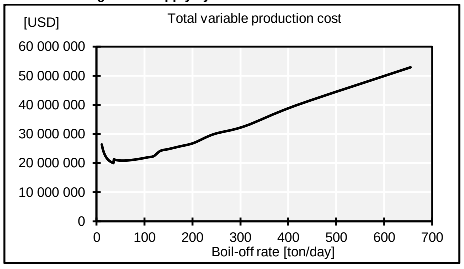


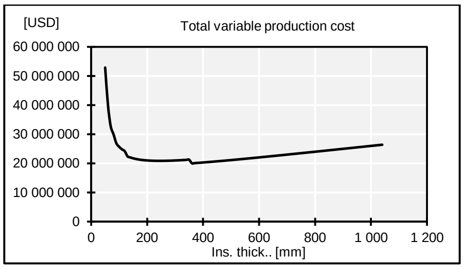


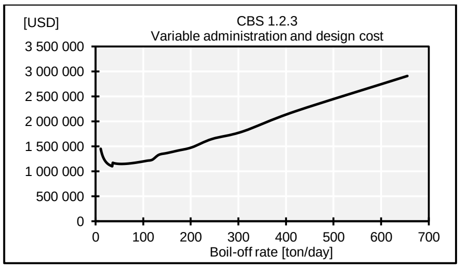


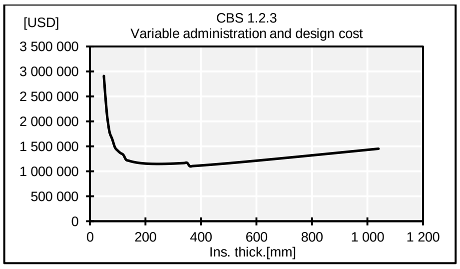


Boil of handling – Gas supply system alt. 2



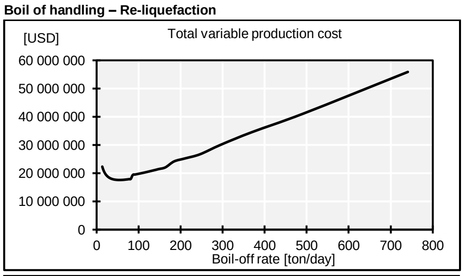


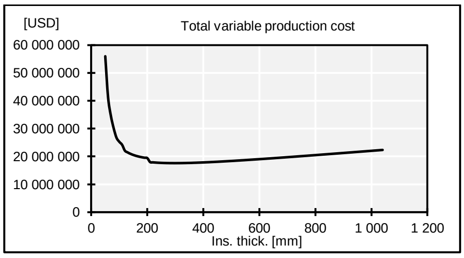


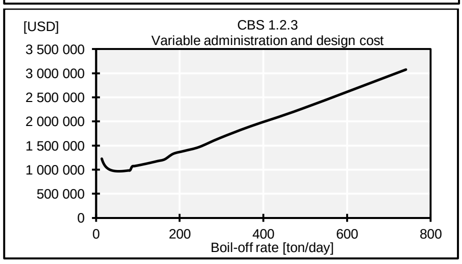


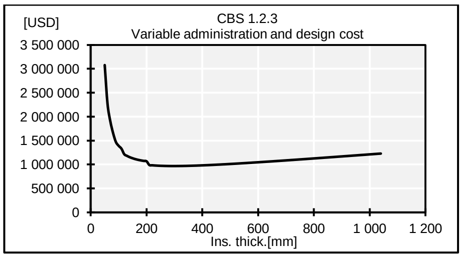
Insulation system 6

Boil of handling – Re-liquefaction

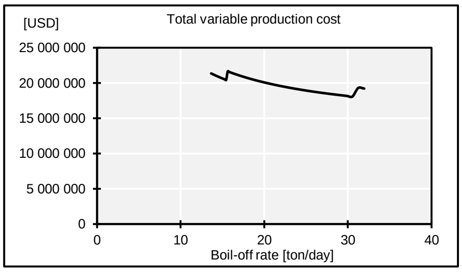


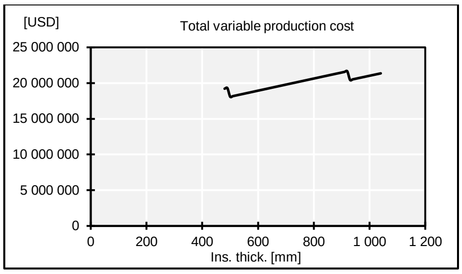


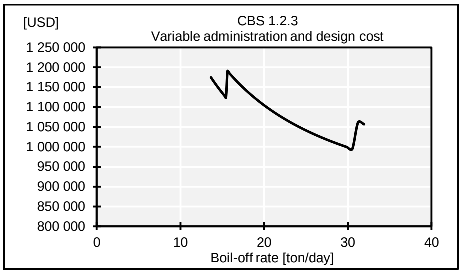


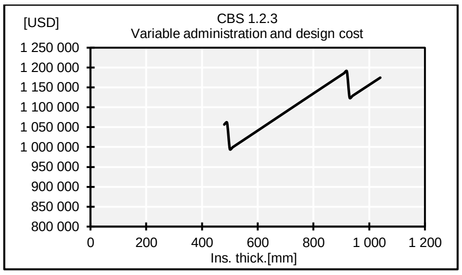


Boil of handling – Gas supply system alt. 1

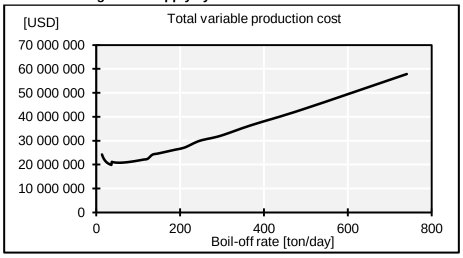


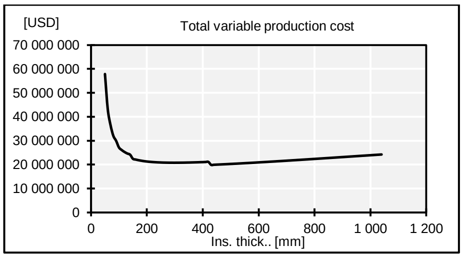


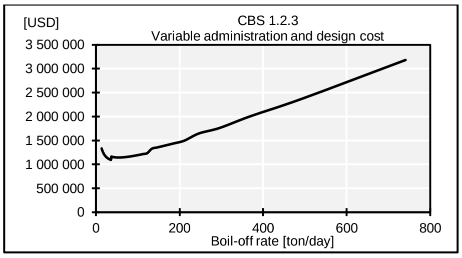


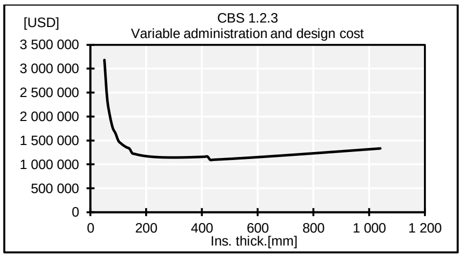


Boil of handling – Gas supply system alt. 2



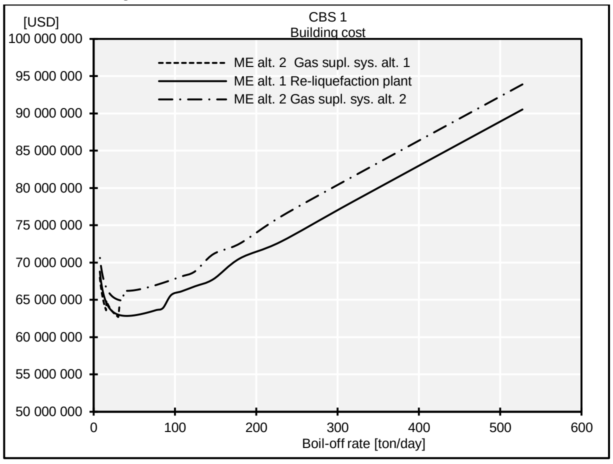


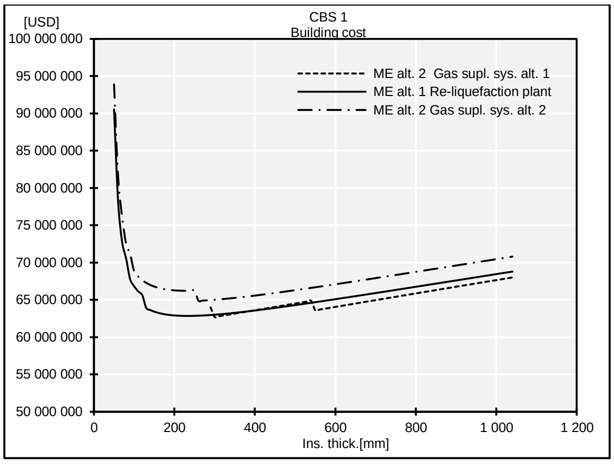




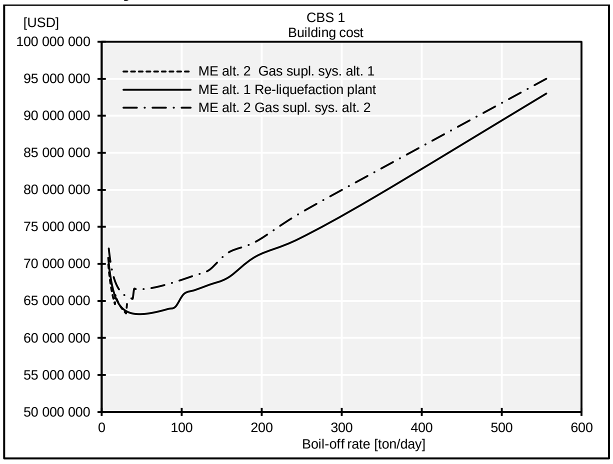
Building cost – CBS 1

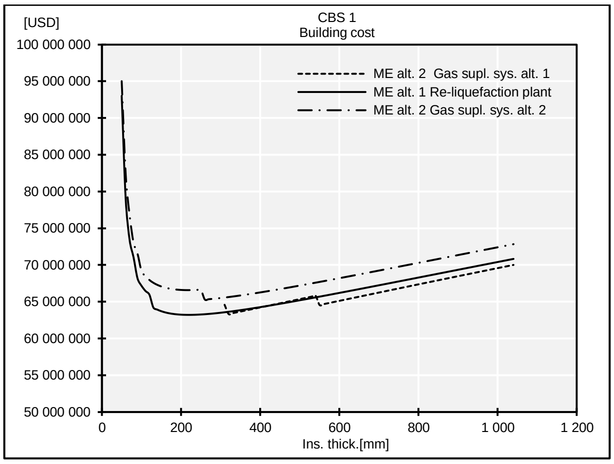
Insulation system 1



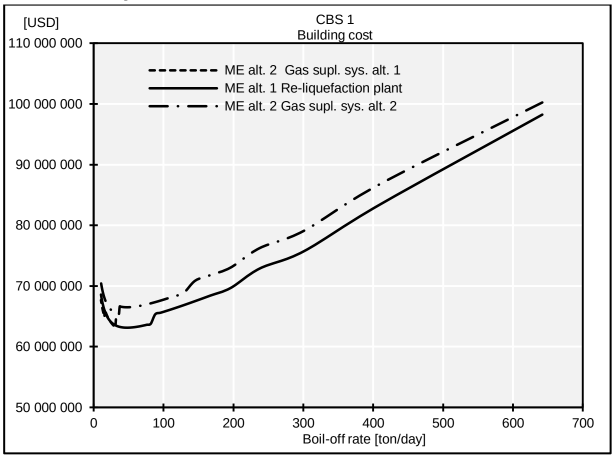


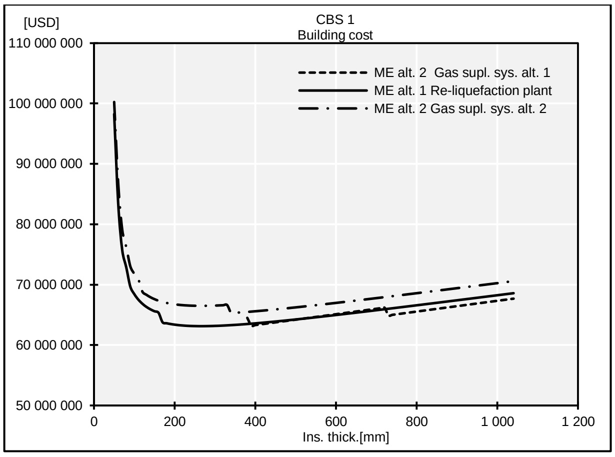
Insulation system 2



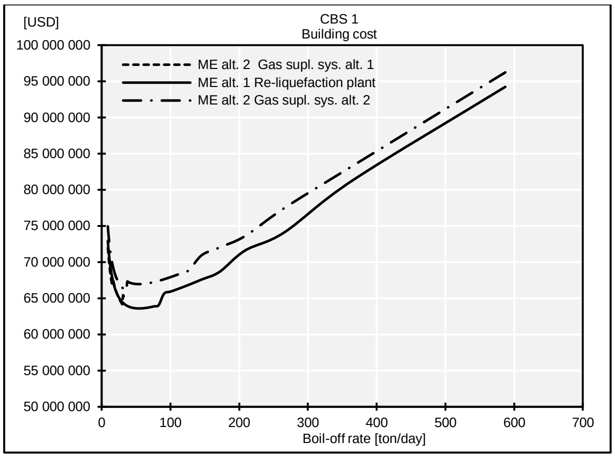


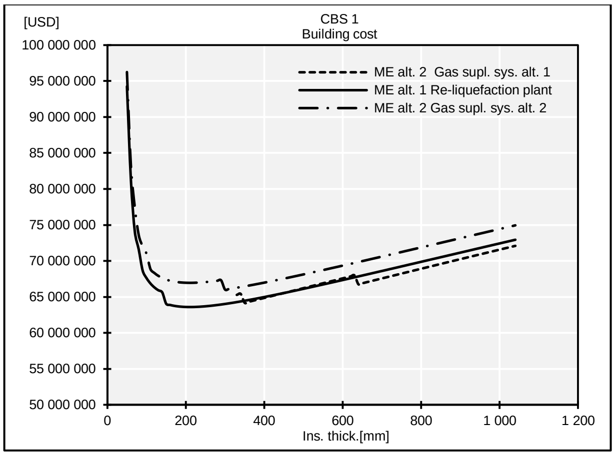
Insulation system 3



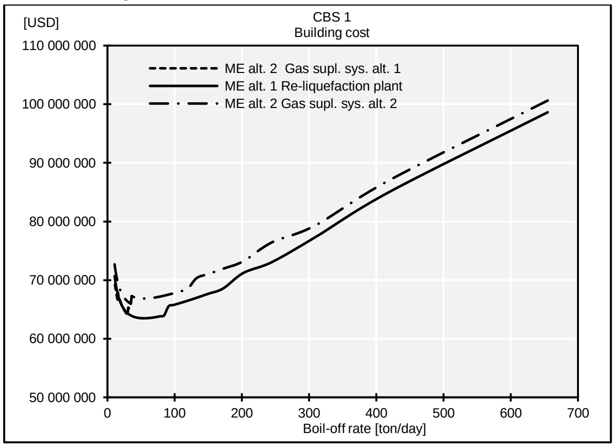


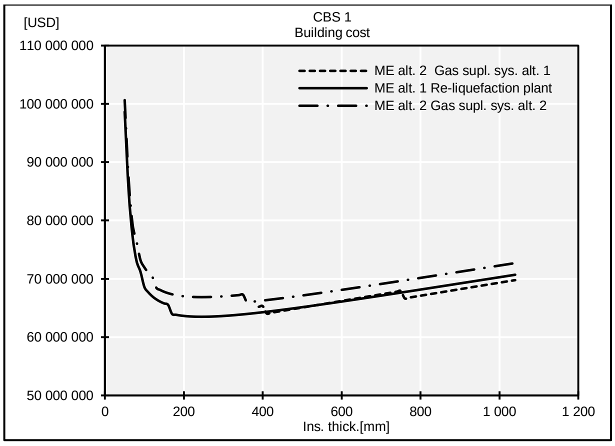
Insulation system 4



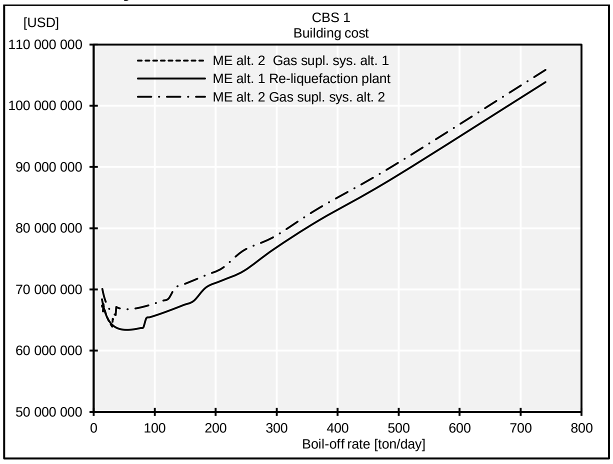


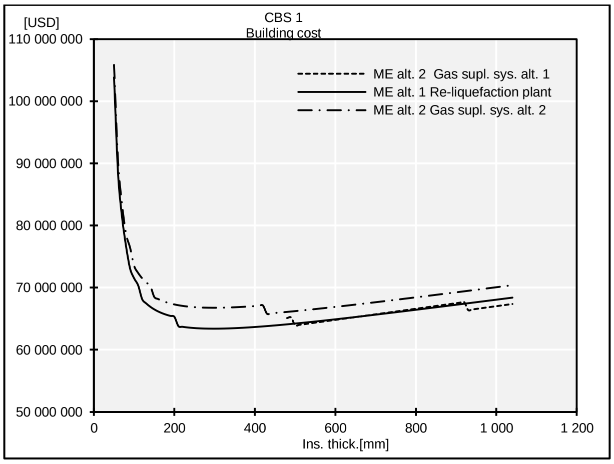
Insulation system 5





Insulation system 6





Appendix 10

Running cost – CBS 2

Operating cost – CBS 2.1

CBS 2.1 - Operating Cost					
				Alt 1.	Alt 2.
CBS	Cost type:	Units	Coeff.	[USD/year]	[USD/year]
2.1.1	Manning cost				
2.1.1.1	Crew wages	[USD/crew/year]	27520	550,400	550,400
2.1.1.2	Victualing	[USD/crew/year]	2400	48,000	48,000
2.1.1.3	Travel, insurance etc.	[USD/crew/year]	3400	68,000	68,000
2.1.2	Represents stores				
2.1.2.1	General store	[USD/kW/year]	10	102,053	102,053
2.1.3	Routine repair and maintenance				
2.1.3.1	Maintenance	[USD/kW*year]	7	79,111	79,111
2.1.3.2	Spares	[USD/kW*year]	7	79,111	79,111
2.1.4	Insurance				0
2.1.4.1	Hull & machinery			500,000	500,000
2.1.4.2	P&I			500,000	500,000
2.1.5	General cost				
2.1.5.1	Flag state registration cost	[USD/GT/year]	0.3	9,615	9,615
2.1.5.2	Port fees	[USD/GT/year]	4	113,112	113,112
2.1.5.3	Management fee			200,000	200,000
	Total operating cost	[USD/year]		2,049,402	2,249,402

Periodic maintenance cost – CBS 2.2

CBS 2.2 - Periodic maintenance (docking)					
				Alt 1.	Alt 2.
CBS	Cost type:	Units	Coeff.	[USD/year]	[USD/year]
2.2.1	Maintenance ME and Aux.	[USD/kW/5thyear]	11	118,667	118,667
2.2.2	Hull etc.	[USD/GV/5thyear]	13	1,302,363	1,302,363
	Total annual periodic maintenance cost	[USD/5thyear]		1,421,030	1,421,030

Voyage cost – CBS 2.3

Fixed voyage cost – CBS 2.3.1

CBS 2.3.1 - Fixed voyage cost					
				Alt 1.	Alt 2.
CBS	Cost type:	Units	Coeff.	[USD/year]	[USD/year]
2.3.1.1	Port charges	[USD/roundtrip/year]	40000	860,357	860,357
2.3.1.2	Pilotage	[USD/roundtrip/year]	10000	215,089	215,089
2.3.1.3	Main engine fuel cost				
2.3.1.3.1	HFO	[USD/ton]	700	8,596,262	449,775
2.3.1.3.2	LO	[USD/ton]	900	6,630	6,630
2.3.1.3.3	LNG	[USD/ton]	500	0	5,285,062
2.3.1.4	Diesel generator fuel cost (fixed)				
2.3.1.4.1	MDO	[USD/ton]	900	104,874	104,874
2.3.1.4.2	LO	[USD/ton]	900	774	774
	Total annual fixed voyage cost			9,783,987	6,922,562

Variable voyage cost – CBS 2.3.2

CBS 2.3.2 - Variable voyage cost					
				Alt 1.	Alt 2.
CBS	Cost type:	Units		[USD/year]	[USD/year]
2.3.2.1	Aux.fuel cost				
2.3.2.2.1	MDO	[USD/ton]	900	Variable	Variable
2.3.2.2.2	LO	[USD/ton]	900	Variable	Variable
	Total annual variable operating cost			Variable	Variable

Capital cost – CBS 2.4

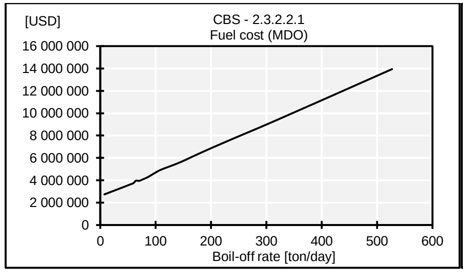
CBS 2.4 - Capital cost					
				Alt 1.	Alt 2.
CBS	Cost type:	Units	Unit	[USD/year]	[USD/year]
2.4.1	Repayment	[USD/years]		Variable	Variable
2.4.2	Interest	[USD/years]		Variable	Variable
	Total annual capital expenses			Variable	Variable

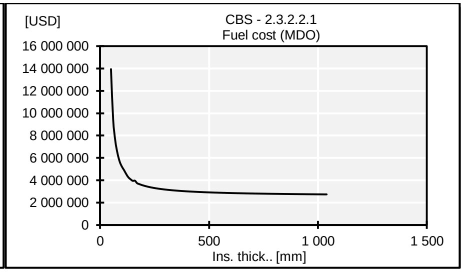
Variable voyage cost – CBS 2.3.2
Insulation system 1
Boil-off handling – Re-liquefaction

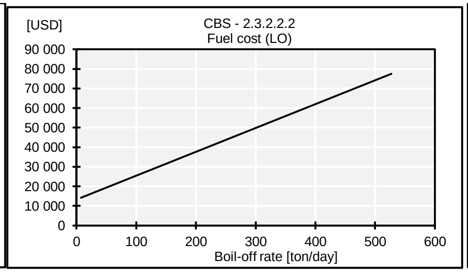
Table type:		Ins. sys. no:	ME alt:	Description:									
Variable voyage cost		1	1										
			Oper. mode										
Insulation thickness	Boil-off rate		Laden		Slow laden		Ballast		Slow ballast		Yearly MDO and LO cons.		Variable var. voy. cost
			CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2
t_{INS_TOT}	BOR_{LAD}	BOR_{BALL}	C_{MDO_LAD}	C_{LO_LAD}	$C_{MDO\_SLW\_LAD}$	$C_{LO\_SLW\_LAD}$	C_{MDO_BALL}	C_{LO_BALL}	$C_{MDO\_SLW\_BALL}$	$C_{LO\_SLW\_BALL}$	C_{MDO_TOT}	C_{LO_TOT}	C_{VAR_VOY}
[mm]	[ton/day]	[ton/day]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]
50	528	422	7,319,001	40,690	295,717	1,644	6,092,969	33,852	246,181	1,368	13,953,868	77,554	14,031,422
60	321	257	4,910,740	27,241	198,414	1,101	4,152,390	23,083	167,773	933	9,429,317	52,357	9,481,674
70	230	184	3,855,387	21,360	155,773	863	3,370,240	18,374	136,171	742	7,517,572	41,339	7,558,911
80	180	144	3,320,902	18,061	134,178	730	2,843,555	15,733	114,891	636	6,413,525	35,160	6,448,685
90	147	118	2,879,912	15,951	116,360	644	2,569,247	14,043	103,808	567	5,669,327	31,205	5,700,533
100	125	100	2,639,684	14,484	106,654	585	2,384,469	12,868	96,342	520	5,227,149	28,457	5,255,607
110	108	87	2,468,586	13,406	99,741	542	2,250,107	12,005	90,913	485	4,909,348	26,437	4,935,785
120	95	76	2,339,407	12,579	94,521	508	2,041,329	11,343	82,478	458	4,557,736	24,889	4,582,625
130	85	68	2,145,154	11,926	86,673	482	1,951,373	10,820	78,843	437	4,262,044	23,665	4,285,709
140	77	62	2,050,647	11,397	82,854	460	1,880,390	10,396	75,975	420	4,089,867	22,673	4,112,540
150	70	56	1,974,919	10,959	79,795	443	1,822,809	10,046	73,649	406	3,951,171	21,853	3,973,024
160	65	52	1,912,739	10,591	77,282	428	1,775,073	9,751	71,720	394	3,836,815	21,164	3,857,978
170	60	48	1,860,677	10,277	75,179	415	1,734,802	9,500	70,093	384	3,740,750	20,576	3,761,326
180	56	45	1,816,386	10,006	73,389	404	1,700,333	9,283	68,700	375	3,658,809	20,069	3,678,877
190	52	42	1,778,204	9,770	71,847	395	1,670,474	9,094	67,494	367	3,588,018	19,627	3,607,645
200	49	39	1,744,918	9,563	70,502	386	1,644,339	8,928	66,438	361	3,526,197	19,238	3,545,436
210	46	37	1,715,623	9,379	69,318	379	1,621,263	8,781	65,506	355	3,471,709	18,894	3,490,603
220	44	35	1,689,625	9,215	68,268	372	1,600,728	8,650	64,676	349	3,423,297	18,587	3,441,884
230	41	33	1,666,387	9,068	67,329	366	1,582,332	8,532	63,933	345	3,379,980	18,311	3,398,291
240	39	31	1,645,482	8,935	66,484	361	1,565,752	8,426	63,263	340	3,340,981	18,063	3,359,044
250	37	30	1,626,571	8,815	65,720	356	1,550,729	8,329	62,656	337	3,305,676	17,837	3,323,512
260	36	29	1,609,376	8,705	65,025	352	1,537,050	8,241	62,103	333	3,273,555	17,631	3,291,186
270	34	27	1,593,671	8,605	64,391	348	1,524,542	8,161	61,598	330	3,244,201	17,443	3,261,644
280	33	26	1,579,266	8,512	63,809	344	1,513,058	8,087	61,134	327	3,217,266	17,270	3,234,536
290	32	25	1,566,005	8,427	63,273	340	1,502,477	8,019	60,706	324	3,192,461	17,111	3,209,571
300	30	24	1,553,754	8,349	62,778	337	1,492,695	7,956	60,311	321	3,169,538	16,963	3,186,501
310	29	23	1,542,402	8,276	62,319	334	1,483,625	7,897	59,944	319	3,148,291	16,826	3,165,117
320	28	23	1,531,852	8,208	61,893	332	1,475,190	7,843	59,604	317	3,128,539	16,699	3,145,238
330	27	22	1,522,020	8,145	61,496	329	1,467,327	7,792	59,286	315	3,110,129	16,581	3,126,709
340	26	21	1,512,836	8,085	61,125	327	1,459,977	7,745	58,989	313	3,092,927	16,470	3,109,397
350	25	20	1,504,236	8,030	60,777	324	1,453,093	7,701	58,711	311	3,076,818	16,366	3,093,184
360	25	20	1,496,167	7,978	60,451	322	1,446,631	7,659	58,450	309	3,061,699	16,269	3,077,968
370	24	19	1,488,579	7,929	60,145	320	1,440,554	7,620	58,204	308	3,047,482	16,177	3,063,659
380	23	19	1,481,431	7,883	59,856	319	1,434,827	7,583	57,973	306	3,034,087	16,091	3,050,179
390	22	18	1,474,686	7,840	59,583	317	1,429,422	7,548	57,754	305	3,021,446	16,010	3,037,455

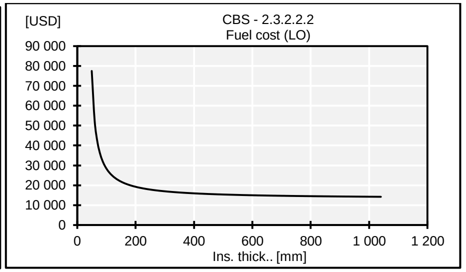
400	22	18	1,468,310	7,799	59,326	315	1,424,311	7,515	57,548	304	3,009,495	15,933	3,025,428
410	21	17	1,462,273	7,760	59,082	314	1,419,472	7,484	57,352	302	2,998,179	15,860	3,014,039
420	21	17	1,456,549	7,723	58,850	312	1,414,882	7,455	57,167	301	2,987,449	15,791	3,003,240
430	20	16	1,451,115	7,688	58,631	311	1,410,524	7,427	56,991	300	2,977,260	15,725	2,992,986
440	20	16	1,445,947	7,655	58,422	309	1,406,380	7,400	56,823	299	2,967,572	15,663	2,983,235
450	19	15	1,441,028	7,623	58,223	308	1,402,434	7,375	56,664	298	2,958,349	15,604	2,973,953
460	19	15	1,436,340	7,593	58,034	307	1,398,673	7,351	56,512	297	2,949,558	15,547	2,965,106
470	18	15	1,431,866	7,564	57,853	306	1,395,084	7,328	56,367	296	2,941,170	15,493	2,956,663
480	18	14	1,427,592	7,537	57,680	305	1,391,655	7,306	56,228	295	2,933,156	15,442	2,948,598
490	17	14	1,423,506	7,510	57,515	303	1,388,376	7,284	56,096	294	2,925,493	15,392	2,940,885
500	17	14	1,419,594	7,485	57,357	302	1,385,237	7,264	55,969	294	2,918,158	15,345	2,933,503
510	17	13	1,415,846	7,461	57,206	301	1,382,230	7,245	55,848	293	2,911,130	15,300	2,926,430
520	16	13	1,412,252	7,438	57,061	301	1,379,346	7,227	55,731	292	2,904,390	15,257	2,919,647
530	16	13	1,408,803	7,416	56,921	300	1,376,577	7,209	55,619	291	2,897,921	15,215	2,913,136
540	16	13	1,405,489	7,394	56,787	299	1,373,918	7,192	55,512	291	2,891,707	15,175	2,906,882
550	15	12	1,402,304	7,374	56,659	298	1,371,361	7,175	55,409	290	2,885,732	15,137	2,900,870
560	15	12	1,399,239	7,354	56,535	297	1,368,902	7,160	55,309	289	2,879,985	15,100	2,895,085
570	15	12	1,396,288	7,335	56,416	296	1,366,533	7,144	55,213	289	2,874,450	15,065	2,889,515
580	14	12	1,393,445	7,317	56,301	296	1,364,251	7,130	55,121	288	2,869,118	15,030	2,884,148
590	14	11	1,390,704	7,299	56,190	295	1,362,051	7,116	55,032	288	2,863,977	14,997	2,878,974
600	14	11	1,388,059	7,282	56,083	294	1,359,928	7,102	54,947	287	2,859,016	14,966	2,873,982
610	14	11	1,385,506	7,266	55,980	294	1,357,878	7,089	54,864	286	2,854,228	14,935	2,869,163
620	13	11	1,383,039	7,250	55,880	293	1,355,899	7,076	54,784	286	2,849,602	14,905	2,864,507
630	13	11	1,380,655	7,235	55,784	292	1,353,985	7,064	54,706	285	2,845,131	14,877	2,860,007
640	13	10	1,378,349	7,220	55,691	292	1,352,134	7,052	54,632	285	2,840,806	14,849	2,855,655
650	13	10	1,376,118	7,206	55,601	291	1,350,343	7,041	54,559	284	2,836,622	14,822	2,851,444
660	13	10	1,373,958	7,192	55,513	291	1,348,610	7,030	54,489	284	2,832,570	14,796	2,847,367
670	12	10	1,371,866	7,179	55,429	290	1,346,930	7,019	54,421	284	2,828,646	14,771	2,843,417
680	12	10	1,369,838	7,166	55,347	290	1,345,302	7,008	54,356	283	2,824,843	14,747	2,839,589
690	12	10	1,367,871	7,153	55,268	289	1,343,724	6,998	54,292	283	2,821,155	14,723	2,835,878
700	12	9	1,365,964	7,141	55,190	289	1,342,193	6,989	54,230	282	2,817,577	14,700	2,832,277
710	12	9	1,364,113	7,129	55,116	288	1,340,707	6,979	54,170	282	2,814,105	14,678	2,828,783
720	11	9	1,362,315	7,117	55,043	288	1,339,264	6,970	54,112	282	2,810,734	14,656	2,825,390
730	11	9	1,360,569	7,106	54,972	287	1,337,862	6,961	54,055	281	2,807,459	14,635	2,822,094
740	11	9	1,358,872	7,095	54,904	287	1,336,500	6,952	54,000	281	2,804,276	14,615	2,818,891
750	11	9	1,357,222	7,085	54,837	286	1,335,176	6,944	53,947	281	2,801,183	14,595	2,815,778
760	11	9	1,355,618	7,074	54,772	286	1,333,889	6,936	53,894	280	2,798,174	14,576	2,812,750
770	11	8	1,354,057	7,064	54,709	285	1,332,636	6,928	53,844	280	2,795,246	14,557	2,809,804
780	10	8	1,352,538	7,055	54,648	285	1,331,416	6,920	53,795	280	2,792,397	14,539	2,806,936
790	10	8	1,351,059	7,045	54,588	285	1,330,229	6,912	53,747	279	2,789,623	14,521	2,804,144
800	10	8	1,349,618	7,036	54,530	284	1,329,073	6,905	53,700	279	2,786,921	14,504	2,801,425
810	10	8	1,348,214	7,027	54,473	284	1,327,946	6,898	53,654	279	2,784,288	14,487	2,798,776
820	10	8	1,346,846	7,018	54,418	284	1,326,848	6,891	53,610	278	2,781,723	14,471	2,796,193
830	10	8	1,345,512	7,010	54,364	283	1,325,778	6,884	53,567	278	2,779,221	14,455	2,793,676
840	10	8	1,344,211	7,001	54,312	283	1,324,734	6,877	53,525	278	2,776,781	14,439	2,791,221

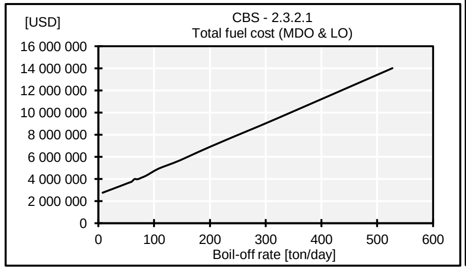
850	9	8	1,342,942	6,993	54,260	283	1,323,715	6,871	53,483	278	2,774,401	14,424	2,788,825
860	9	7	1,341,704	6,985	54,210	282	1,322,721	6,864	53,443	277	2,772,079	14,409	2,786,488
870	9	7	1,340,495	6,978	54,161	282	1,321,751	6,858	53,404	277	2,769,811	14,395	2,784,206
880	9	7	1,339,314	6,970	54,114	282	1,320,804	6,852	53,366	277	2,767,598	14,381	2,781,978
890	9	7	1,338,161	6,963	54,067	281	1,319,878	6,846	53,328	277	2,765,435	14,367	2,779,802
900	9	7	1,337,035	6,956	54,022	281	1,318,974	6,840	53,292	276	2,763,323	14,353	2,777,676
910	9	7	1,335,934	6,949	53,977	281	1,318,091	6,835	53,256	276	2,761,258	14,340	2,775,599
920	9	7	1,334,858	6,942	53,934	280	1,317,227	6,829	53,221	276	2,759,241	14,327	2,773,568
930	9	7	1,333,806	6,935	53,891	280	1,316,383	6,824	53,187	276	2,757,268	14,315	2,771,582
940	8	7	1,332,777	6,928	53,850	280	1,315,557	6,819	53,154	275	2,755,338	14,302	2,769,640
950	8	7	1,331,771	6,922	53,809	280	1,314,750	6,813	53,121	275	2,753,450	14,290	2,767,741
960	8	7	1,330,786	6,916	53,769	279	1,313,959	6,808	53,089	275	2,751,604	14,279	2,765,882
970	8	7	1,329,822	6,910	53,730	279	1,313,186	6,803	53,058	275	2,749,796	14,267	2,764,063
980	8	6	1,328,878	6,904	53,692	279	1,312,429	6,799	53,027	275	2,748,027	14,256	2,762,283
990	8	6	1,327,955	6,898	53,655	279	1,311,688	6,794	52,997	275	2,746,294	14,245	2,760,539
1,000	8	6	1,327,050	6,892	53,618	278	1,310,962	6,789	52,968	274	2,744,598	14,234	2,758,832
1,010	8	6	1,326,163	6,886	53,582	278	1,310,250	6,785	52,939	274	2,742,936	14,223	2,757,159
1,020	8	6	1,325,295	6,881	53,547	278	1,309,554	6,780	52,911	274	2,741,307	14,213	2,755,520
1,030	8	6	1,324,444	6,875	53,513	278	1,308,871	6,776	52,884	274	2,739,712	14,203	2,753,914
1,040	8	6	1,323,610	6,870	53,479	278	1,308,202	6,772	52,857	274	2,738,148	14,193	2,752,340

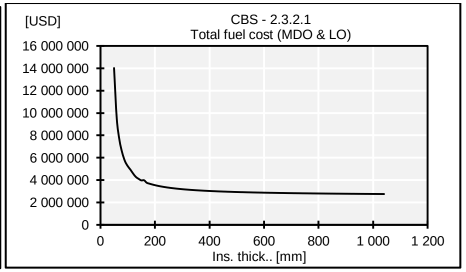








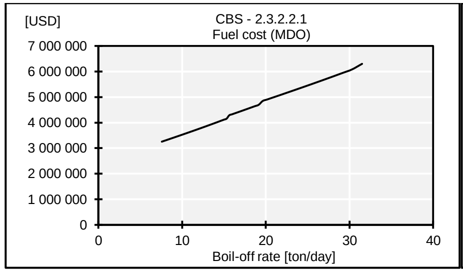


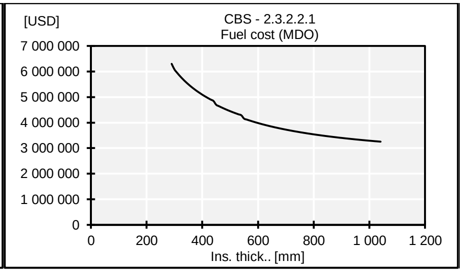


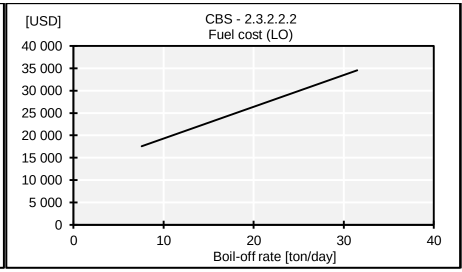
Boil-off handling – Gas supply system alt. 1

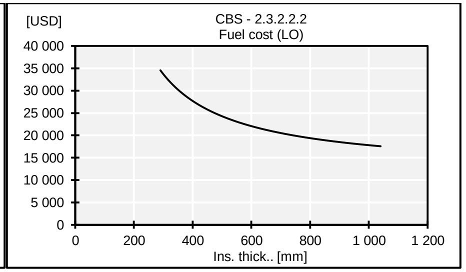
Table type:		Ins. sys. no:	ME alt:	Description:									
Variable voyage cost		1	2										
			Oper. mode										
Insulation thickness	Boil-off rate		Laden		Slow laden		Ballast		Slow ballast		Yearly MDO and LO cons.		Variable var. voy. cost
			CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2
t_{INS_TOT}	BOR_{LAD}	BOR_{BALL}	C_{MDO_LAD}	C_{LO_LAD}	$C_{MDO\_SLW\_LAD}$	$C_{LO\_SLW\_LAD}$	C_{MDO_BALL}	C_{LO_BALL}	$C_{MDO\_SLW\_BALL}$	$C_{LO\_SLW\_BALL}$	C_{MDO_TOT}	C_{LO_TOT}	C_{VAR_VOY}
[mm]	[ton/day]	[ton/day]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]
290	32	25	3,335,740	18,155	67,389	367	2,842,854	15,729	57,431	318	6,303,415	34,569	6,337,983
300	30	24	3,181,377	17,688	64,270	357	2,780,988	15,354	56,182	310	6,082,817	33,710	6,116,527
310	29	23	3,104,103	17,255	62,709	349	2,724,250	15,007	55,035	303	5,946,098	32,914	5,979,012
320	28	23	3,033,556	16,852	61,284	340	2,671,985	14,685	53,979	297	5,820,804	32,173	5,852,977
330	27	22	2,968,840	16,476	59,977	333	2,623,645	14,384	53,003	291	5,705,465	31,483	5,736,948
340	26	21	2,909,215	16,125	58,772	326	2,578,774	14,103	52,096	285	5,598,857	30,838	5,629,695
350	25	20	2,854,061	15,796	57,658	319	2,536,986	13,839	51,252	280	5,499,957	30,234	5,530,191
360	25	20	2,802,859	15,487	56,623	313	2,497,950	13,592	50,464	275	5,407,897	29,667	5,437,563
370	24	19	2,755,169	15,197	55,660	307	2,461,387	13,360	49,725	270	5,321,940	29,134	5,351,074
380	23	19	2,710,615	14,923	54,760	301	2,427,051	13,141	49,031	265	5,241,457	28,631	5,270,088
390	22	18	2,668,875	14,665	53,917	296	2,394,733	12,934	48,378	261	5,165,903	28,157	5,194,060
400	22	18	2,629,671	14,421	53,125	291	2,364,249	12,739	47,763	257	5,094,807	27,709	5,122,516
410	21	17	2,592,762	14,190	52,379	287	2,335,437	12,554	47,181	254	5,027,759	27,285	5,055,043
420	21	17	2,557,938	13,972	51,676	282	2,308,155	12,378	46,629	250	4,964,398	26,882	4,991,280
430	20	16	2,525,014	13,764	51,010	278	2,282,278	12,212	46,107	247	4,904,408	26,500	4,930,909
440	20	16	2,493,827	13,566	50,380	274	2,257,693	12,054	45,610	244	4,847,510	26,137	4,873,648
450	19	15	2,464,234	13,378	49,783	270	2,140,990	11,903	43,252	240	4,698,259	25,792	4,724,051
460	19	15	2,436,108	13,199	49,214	267	2,115,068	11,760	42,729	238	4,643,119	25,462	4,668,582
470	18	15	2,409,335	13,028	48,673	263	2,090,577	11,623	42,234	235	4,590,820	25,148	4,615,968
480	18	14	2,383,813	12,864	48,158	260	2,067,397	11,492	41,766	232	4,541,134	24,848	4,565,982
490	17	14	2,359,450	12,708	47,666	257	2,045,422	11,367	41,322	230	4,493,859	24,561	4,518,420
500	17	14	2,336,165	12,558	47,195	254	2,024,555	11,247	40,900	227	4,448,816	24,286	4,473,103
510	17	13	2,313,884	12,415	46,745	251	2,004,713	11,132	40,499	225	4,405,841	24,023	4,429,864
520	16	13	2,292,538	12,278	46,314	248	1,985,818	11,022	40,118	223	4,364,787	23,771	4,388,558
530	16	13	2,272,067	12,146	45,900	245	1,967,801	10,917	39,754	221	4,325,521	23,529	4,349,050
540	16	13	2,252,415	12,020	45,503	243	1,950,600	10,816	39,406	218	4,287,923	23,297	4,311,220
550	15	12	2,140,089	11,898	43,234	240	1,934,158	10,718	39,074	217	4,156,555	23,073	4,179,628
560	15	12	2,118,953	11,781	42,807	238	1,918,424	10,625	38,756	215	4,118,940	22,858	4,141,799
570	15	12	2,098,769	11,669	42,399	236	1,903,352	10,534	38,452	213	4,082,972	22,652	4,105,624
580	14	12	2,079,472	11,560	42,010	234	1,888,899	10,448	38,160	211	4,048,540	22,452	4,070,993
590	14	11	2,061,003	11,456	41,636	231	1,875,026	10,364	37,879	209	4,015,544	22,260	4,037,804
600	14	11	2,043,306	11,355	41,279	229	1,861,697	10,283	37,610	208	3,983,892	22,075	4,005,967
610	14	11	2,026,333	11,257	40,936	227	1,848,880	10,205	37,351	206	3,953,500	21,896	3,975,396
620	13	11	2,010,038	11,163	40,607	226	1,836,544	10,130	37,102	205	3,924,291	21,723	3,946,014
630	13	11	1,994,380	11,072	40,290	224	1,824,662	10,057	36,862	203	3,896,194	21,556	3,917,751
640	13	10	1,979,320	10,985	39,986	222	1,813,209	9,987	36,630	202	3,869,145	21,395	3,890,540
650	13	10	1,964,823	10,900	39,693	220	1,802,160	9,919	36,407	200	3,843,084	21,239	3,864,323

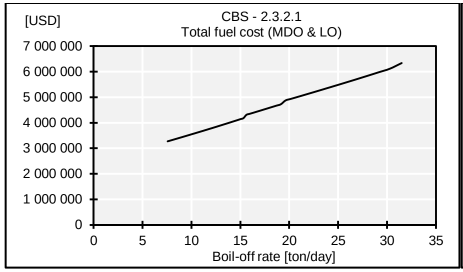
660	13	10	1,950,858	10,817	39,411	219	1,791,494	9,853	36,192	199	3,817,955	21,088	3,839,042
670	12	10	1,937,393	10,738	39,139	217	1,781,190	9,789	35,984	198	3,793,707	20,941	3,814,648
680	12	10	1,924,402	10,660	38,877	215	1,771,230	9,727	35,782	197	3,770,292	20,799	3,791,091
690	12	10	1,911,859	10,585	38,623	214	1,761,597	9,667	35,588	195	3,747,667	20,662	3,768,329
700	12	9	1,899,741	10,513	38,379	212	1,752,272	9,609	35,399	194	3,725,791	20,528	3,746,319
710	12	9	1,888,024	10,442	38,142	211	1,743,243	9,553	35,217	193	3,704,625	20,399	3,725,024
720	11	9	1,876,688	10,374	37,913	210	1,734,493	9,498	35,040	192	3,684,135	20,273	3,704,408
730	11	9	1,865,716	10,308	37,691	208	1,726,011	9,445	34,869	191	3,664,287	20,151	3,684,438
740	11	9	1,855,087	10,243	37,477	207	1,717,783	9,393	34,703	190	3,645,050	20,033	3,665,083
750	11	9	1,844,787	10,180	37,268	206	1,709,798	9,343	34,541	189	3,626,395	19,917	3,646,313
760	11	9	1,834,799	10,119	37,067	204	1,702,045	9,294	34,385	188	3,608,296	19,805	3,628,102
770	11	8	1,825,109	10,060	36,871	203	1,694,514	9,246	34,233	187	3,590,727	19,696	3,610,423
780	10	8	1,815,704	10,002	36,681	202	1,687,195	9,200	34,085	186	3,573,664	19,590	3,593,254
790	10	8	1,806,569	9,946	36,496	201	1,680,078	9,155	33,941	185	3,557,085	19,487	3,576,572
800	10	8	1,797,694	9,891	36,317	200	1,673,156	9,111	33,801	184	3,540,968	19,386	3,560,355
810	10	8	1,789,067	9,838	36,143	199	1,666,420	9,069	33,665	183	3,525,295	19,288	3,544,583
820	10	8	1,780,677	9,786	35,973	198	1,659,863	9,027	33,533	182	3,510,046	19,193	3,529,239
830	10	8	1,772,515	9,735	35,808	197	1,653,477	8,986	33,404	182	3,495,204	19,100	3,514,303
840	10	8	1,764,570	9,686	35,648	196	1,647,256	8,947	33,278	181	3,480,752	19,009	3,499,761
850	9	8	1,756,835	9,638	35,492	195	1,641,192	8,908	33,155	180	3,466,674	18,920	3,485,594
860	9	7	1,749,299	9,590	35,339	194	1,635,281	8,871	33,036	179	3,452,956	18,834	3,471,790
870	9	7	1,741,957	9,545	35,191	193	1,629,516	8,834	32,920	178	3,439,584	18,750	3,458,333
880	9	7	1,734,799	9,500	35,046	192	1,623,892	8,798	32,806	178	3,426,543	18,667	3,445,211
890	9	7	1,727,820	9,456	34,905	191	1,618,403	8,763	32,695	177	3,413,823	18,587	3,432,410
900	9	7	1,721,011	9,413	34,768	190	1,613,044	8,729	32,587	176	3,401,410	18,508	3,419,918
910	9	7	1,714,367	9,371	34,634	189	1,607,812	8,695	32,481	176	3,389,293	18,432	3,407,725
920	9	7	1,707,881	9,331	34,503	188	1,602,701	8,662	32,378	175	3,377,462	18,357	3,395,819
930	9	7	1,701,549	9,291	34,375	188	1,597,706	8,631	32,277	174	3,365,907	18,283	3,384,190
940	8	7	1,695,363	9,252	34,250	187	1,592,825	8,599	32,178	174	3,354,616	18,212	3,372,828
950	8	7	1,689,320	9,214	34,128	186	1,588,053	8,569	32,082	173	3,343,582	18,141	3,361,724
960	8	7	1,683,413	9,176	34,008	185	1,583,386	8,539	31,988	173	3,332,795	18,073	3,350,868
970	8	7	1,677,639	9,140	33,892	185	1,578,822	8,510	31,895	172	3,322,248	18,006	3,340,253
980	8	6	1,671,992	9,104	33,778	184	1,574,355	8,481	31,805	171	3,311,930	17,940	3,329,870
990	8	6	1,666,469	9,069	33,666	183	1,569,984	8,453	31,717	171	3,301,837	17,876	3,319,712
1,000	8	6	1,661,066	9,035	33,557	183	1,565,706	8,425	31,630	170	3,291,958	17,813	3,309,771
1,010	8	6	1,655,777	9,001	33,450	182	1,561,516	8,398	31,546	170	3,282,289	17,751	3,300,040
1,020	8	6	1,650,600	8,968	33,345	181	1,557,413	8,372	31,463	169	3,272,822	17,690	3,290,512
1,030	8	6	1,645,531	8,936	33,243	181	1,553,394	8,346	31,382	169	3,263,550	17,631	3,281,181
1,040	8	6	1,640,567	8,904	33,143	180	1,549,456	8,321	31,302	168	3,254,468	17,573	3,272,041

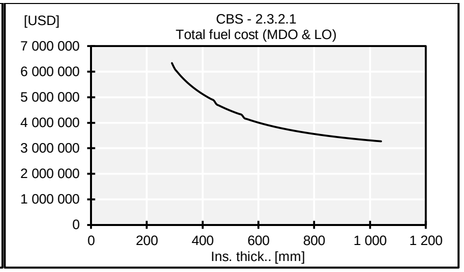

[USD]
CBS - 2.3.2.2.1
Fuel cost (MDO)
7 000 000
6 000 000
5 000 000
4 000 000
3 000 000
2 000 000
1 000 000
0
0
10
20
30
40
Boil-off rate [ton/day]


[USD]
CBS - 2.3.2.2.1
Fuel cost (MDO)
7 000 000
6 000 000
5 000 000
4 000 000
3 000 000
2 000 000
1 000 000
0
0
200
400
600
800
1 000
1 200
Ins. thick.. [mm]


[USD]
CBS - 2.3.2.2.2
Fuel cost (LO)
40 000
35 000
30 000
25 000
20 000
15 000
10 000
5 000
0
0
10
20
30
40
Boil-off rate [ton/day]


[USD]
CBS - 2.3.2.2.2
Fuel cost (LO)
40 000
35 000
30 000
25 000
20 000
15 000
10 000
5 000
0
0
200
400
600
800
1 000
1 200
Ins. thick.. [mm]


[USD]
CBS - 2.3.2.1
Total fuel cost (MDO & LO)
7 000 000
6 000 000
5 000 000
4 000 000
3 000 000
2 000 000
1 000 000
0
0
5
10
15
20
25
30
35
Boil-off rate [ton/day]

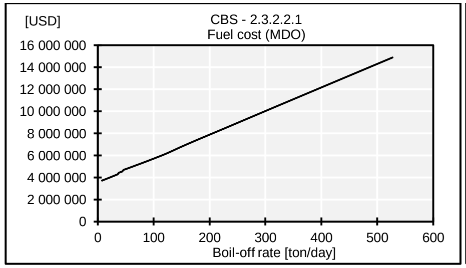

[USD]
CBS - 2.3.2.1
Total fuel cost (MDO & LO)
7 000 000
6 000 000
5 000 000
4 000 000
3 000 000
2 000 000
1 000 000
0
0
200
400
600
800
1 000
1 200
Ins. thick.. [mm]

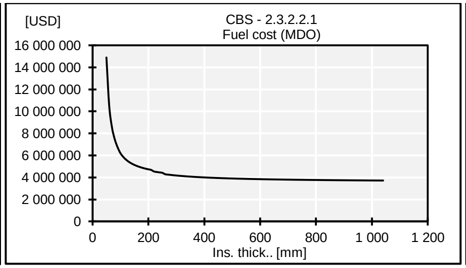
Boil-off handling – Gas supply system alt. 2

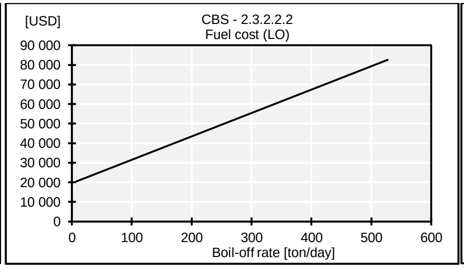
Table type:		Ins. sys. no:	ME alt:	Description:									
Variable voyage cost		1	2										
			Oper. mode										
Insulation thickness	Boil-off rate		Laden		Slow laden		Ballast		Slow ballast		Yearly MDO and LO cons.		Variable var. voy. cost
			CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2.2.1	CBS 2.3.2.2.2	CBS 2.3.2
t_{INS_TOT}	BOR_{LAD}	BOR_{BALL}	C_{MDO_LAD}	C_{LO_LAD}	$C_{MDO\_SLW\_LAD}$	$C_{LO\_SLW\_LAD}$	C_{MDO_BALL}	C_{LO_BALL}	$C_{MDO\_SLW\_BALL}$	$C_{LO\_SLW\_BALL}$	C_{MDO_TOT}	C_{LO_TOT}	C_{VAR_VOY}
[mm]	[ton/day]	[ton/day]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]	[USD/year]
50	528	422	7,912,358	43,909	159,846	887	6,695,221	37,071	135,257	749	14,902,681	82,616	14,985,297
60	321	257	5,521,154	30,460	111,538	615	4,752,708	26,302	96,014	531	10,481,415	57,909	10,539,324
70	230	184	4,470,138	24,579	90,306	497	3,894,700	21,593	78,681	436	8,533,825	47,104	8,580,929
80	180	144	3,842,044	21,280	77,617	430	3,461,988	18,952	69,939	383	7,451,588	41,045	7,492,633
90	147	118	3,496,771	19,170	70,642	387	3,105,337	17,262	62,734	349	6,735,484	37,167	6,772,651
100	125	100	3,184,035	17,703	64,324	358	2,902,903	16,087	58,644	325	6,209,906	34,473	6,244,379
110	108	87	2,994,314	16,625	60,491	336	2,759,579	15,224	55,749	308	5,870,133	32,492	5,902,625
120	95	76	2,854,461	15,798	57,666	319	2,652,284	14,562	53,581	294	5,617,992	30,974	5,648,966
130	85	68	2,746,684	15,145	55,489	306	2,568,695	14,039	51,893	284	5,422,760	29,774	5,452,534
140	77	62	2,660,847	14,616	53,754	295	2,501,601	13,615	50,537	275	5,266,741	28,801	5,295,542
150	70	56	2,590,732	14,178	52,338	286	2,446,481	13,265	49,424	268	5,138,975	27,997	5,166,972
160	65	52	2,532,298	13,810	51,158	279	2,400,346	12,970	48,492	262	5,032,293	27,321	5,059,614
170	60	48	2,482,798	13,496	50,158	273	2,361,136	12,719	47,700	257	4,941,791	26,744	4,968,536
180	56	45	2,440,296	13,225	49,299	267	2,327,383	12,502	47,018	253	4,863,996	26,247	4,890,243
190	52	42	2,403,383	12,989	48,553	262	2,298,011	12,313	46,424	249	4,796,371	25,814	4,822,185
200	49	39	2,371,009	12,782	47,899	258	2,272,210	12,147	45,903	245	4,737,021	25,433	4,762,454
210	46	37	2,342,376	12,598	47,321	255	2,249,361	12,000	45,442	242	4,684,500	25,095	4,709,595
220	44	35	2,316,863	12,434	46,805	251	2,134,779	11,869	43,127	240	4,541,574	24,794	4,566,369
230	41	33	2,293,981	12,287	46,343	248	2,113,535	11,751	42,698	237	4,496,557	24,524	4,521,081
240	39	31	2,273,340	12,154	45,926	246	2,094,507	11,645	42,313	235	4,456,087	24,280	4,480,367
250	37	30	2,254,623	12,034	45,548	243	2,077,364	11,548	41,967	233	4,419,502	24,059	4,443,560
260	36	29	2,144,813	11,924	43,330	241	2,061,837	11,460	41,653	232	4,291,633	23,857	4,315,490
270	34	27	2,126,613	11,824	42,962	239	2,047,707	11,380	41,368	230	4,258,649	23,672	4,282,321
280	33	26	2,110,008	11,731	42,626	237	2,034,792	11,306	41,107	228	4,228,533	23,503	4,252,036
290	32	25	2,094,797	11,646	42,319	235	2,022,941	11,238	40,867	227	4,200,924	23,346	4,224,271
300	30	24	2,080,809	11,568	42,037	234	2,012,028	11,175	40,647	226	4,175,521	23,202	4,198,723
310	29	23	2,067,903	11,495	41,776	232	2,001,945	11,116	40,443	225	4,152,067	23,068	4,175,135
320	28	23	2,055,957	11,427	41,534	231	1,992,600	11,062	40,255	223	4,130,346	22,943	4,153,289
330	27	22	2,044,866	11,364	41,310	230	1,983,915	11,011	40,079	222	4,110,171	22,827	4,132,998
340	26	21	2,034,542	11,304	41,102	228	1,975,822	10,964	39,916	221	4,091,382	22,718	4,114,100
350	25	20	2,024,908	11,249	40,907	227	1,968,262	10,920	39,763	221	4,073,841	22,617	4,096,457
360	25	20	2,015,896	11,197	40,725	226	1,961,185	10,878	39,620	220	4,057,426	22,521	4,079,947
370	24	19	2,007,448	11,148	40,555	225	1,954,544	10,839	39,486	219	4,042,032	22,431	4,064,464
380	23	19	1,999,512	11,102	40,394	224	1,948,302	10,802	39,360	218	4,027,567	22,347	4,049,914
390	22	18	1,992,042	11,059	40,243	223	1,942,422	10,767	39,241	218	4,013,949	22,267	4,036,216
400	22	18	1,985,000	11,018	40,101	223	1,936,875	10,734	39,129	217	4,001,104	22,192	4,023,296
410	21	17	1,978,348	10,979	39,967	222	1,931,632	10,703	39,023	216	3,988,969	22,120	4,011,090

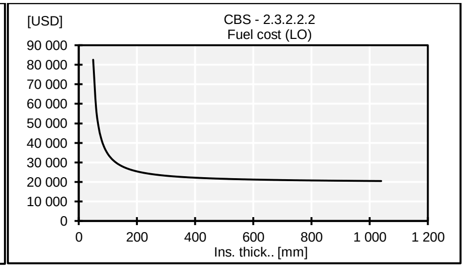
420	21	17	1,972,055	10,942	39,839	221	1,926,670	10,674	38,923	216	3,977,487	22,052	3,999,539
430	20	16	1,966,093	10,907	39,719	220	1,921,966	10,646	38,828	215	3,966,605	21,988	3,988,593
440	20	16	1,960,436	10,874	39,605	220	1,917,500	10,619	38,737	215	3,956,278	21,927	3,978,205
450	19	15	1,955,062	10,842	39,496	219	1,913,255	10,594	38,652	214	3,946,465	21,869	3,968,334
460	19	15	1,949,949	10,812	39,393	218	1,909,215	10,570	38,570	214	3,937,127	21,813	3,958,941
470	18	15	1,945,079	10,783	39,295	218	1,905,366	10,547	38,492	213	3,928,232	21,760	3,949,992
480	18	14	1,940,435	10,756	39,201	217	1,901,693	10,525	38,418	213	3,919,747	21,710	3,941,457
490	17	14	1,936,002	10,729	39,111	217	1,898,186	10,503	38,347	212	3,911,646	21,662	3,933,308
500	17	14	1,931,765	10,704	39,026	216	1,894,833	10,483	38,279	212	3,903,903	21,615	3,925,518
510	17	13	1,927,712	10,680	38,944	216	1,891,625	10,464	38,215	211	3,896,494	21,571	3,918,066
520	16	13	1,923,830	10,657	38,865	215	1,888,551	10,446	38,153	211	3,889,399	21,529	3,910,928
530	16	13	1,920,110	10,635	38,790	215	1,885,604	10,428	38,093	211	3,882,598	21,488	3,904,086
540	16	13	1,916,542	10,613	38,718	214	1,882,777	10,411	38,036	210	3,876,072	21,449	3,897,521
550	15	12	1,913,115	10,593	38,649	214	1,880,061	10,394	37,981	210	3,869,806	21,411	3,891,218
560	15	12	1,909,823	10,573	38,582	214	1,877,451	10,379	37,928	210	3,863,785	21,375	3,885,160
570	15	12	1,906,657	10,554	38,518	213	1,874,940	10,363	37,878	209	3,857,993	21,340	3,879,333
580	14	12	1,903,610	10,536	38,457	213	1,872,523	10,349	37,829	209	3,852,419	21,307	3,873,726
590	14	11	1,900,675	10,518	38,397	212	1,870,195	10,335	37,782	209	3,847,050	21,274	3,868,324
600	14	11	1,897,847	10,501	38,340	212	1,867,951	10,321	37,736	209	3,841,875	21,243	3,863,118
610	14	11	1,895,120	10,485	38,285	212	1,865,786	10,308	37,693	208	3,836,884	21,213	3,858,097
620	13	11	1,892,488	10,469	38,232	211	1,863,697	10,295	37,650	208	3,832,067	21,184	3,853,251
630	13	11	1,889,946	10,454	38,181	211	1,861,679	10,283	37,610	208	3,827,415	21,156	3,848,571
640	13	10	1,887,490	10,439	38,131	211	1,859,728	10,271	37,570	207	3,822,920	21,129	3,844,048
650	13	10	1,885,116	10,425	38,083	211	1,857,842	10,260	37,532	207	3,818,574	21,102	3,839,676
660	13	10	1,882,819	10,411	38,037	210	1,856,018	10,249	37,495	207	3,814,369	21,077	3,835,446
670	12	10	1,880,596	10,398	37,992	210	1,854,252	10,238	37,460	207	3,810,300	21,052	3,831,352
680	12	10	1,878,444	10,385	37,948	210	1,852,541	10,227	37,425	207	3,806,359	21,028	3,827,387
690	12	10	1,876,359	10,372	37,906	210	1,850,884	10,217	37,392	206	3,802,540	21,005	3,823,545
700	12	9	1,874,337	10,360	37,865	209	1,849,277	10,208	37,359	206	3,798,839	20,983	3,819,821
710	12	9	1,872,377	10,348	37,826	209	1,847,718	10,198	37,328	206	3,795,248	20,961	3,816,209
720	11	9	1,870,475	10,336	37,787	209	1,846,206	10,189	37,297	206	3,791,765	20,940	3,812,705
730	11	9	1,868,628	10,325	37,750	209	1,844,738	10,180	37,267	206	3,788,384	20,919	3,809,303
740	11	9	1,866,836	10,314	37,714	208	1,843,312	10,171	37,239	205	3,785,100	20,899	3,805,999
750	11	9	1,865,094	10,304	37,679	208	1,841,926	10,163	37,211	205	3,781,909	20,880	3,802,789
760	11	9	1,863,401	10,293	37,644	208	1,840,579	10,155	37,183	205	3,778,808	20,861	3,799,669
770	11	8	1,861,755	10,283	37,611	208	1,839,269	10,147	37,157	205	3,775,792	20,843	3,796,635
780	10	8	1,860,153	10,274	37,579	208	1,837,995	10,139	37,131	205	3,772,859	20,825	3,793,684
790	10	8	1,858,596	10,264	37,547	207	1,836,756	10,131	37,106	205	3,770,005	20,807	3,790,812
800	10	8	1,857,079	10,255	37,517	207	1,835,549	10,124	37,082	205	3,767,226	20,791	3,788,017
810	10	8	1,855,602	10,246	37,487	207	1,834,373	10,117	37,058	204	3,764,520	20,774	3,785,294
820	10	8	1,854,164	10,237	37,458	207	1,833,228	10,110	37,035	204	3,761,884	20,758	3,782,642
830	10	8	1,852,762	10,229	37,430	207	1,832,112	10,103	37,012	204	3,759,316	20,742	3,780,058
840	10	8	1,851,396	10,220	37,402	206	1,831,024	10,096	36,990	204	3,756,812	20,727	3,777,539
850	9	8	1,850,063	10,212	37,375	206	1,829,963	10,090	36,969	204	3,754,371	20,712	3,775,083
860	9	7	1,848,764	10,204	37,349	206	1,828,928	10,083	36,948	204	3,751,989	20,698	3,772,687

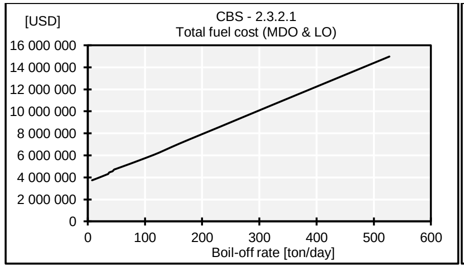
870	9	7	1,847,496	10,197	37,323	206	1,827,919	10,077	36,928	204	3,749,666	20,683	3,770,349
880	9	7	1,846,259	10,189	37,298	206	1,826,933	10,071	36,908	203	3,747,398	20,670	3,768,067
890	9	7	1,845,051	10,182	37,274	206	1,825,971	10,065	36,888	203	3,745,184	20,656	3,765,840
900	9	7	1,843,871	10,175	37,250	206	1,825,031	10,059	36,869	203	3,743,022	20,643	3,763,664
910	9	7	1,842,719	10,168	37,227	205	1,824,113	10,054	36,851	203	3,740,910	20,630	3,761,539
920	9	7	1,841,593	10,161	37,204	205	1,823,216	10,048	36,833	203	3,738,846	20,617	3,759,463
930	9	7	1,840,493	10,154	37,182	205	1,822,340	10,043	36,815	203	3,736,829	20,605	3,757,434
940	8	7	1,839,417	10,147	37,160	205	1,821,483	10,038	36,798	203	3,734,857	20,593	3,755,450
950	8	7	1,838,365	10,141	37,139	205	1,820,644	10,032	36,781	203	3,732,929	20,581	3,753,510
960	8	7	1,837,337	10,135	37,118	205	1,819,825	10,027	36,764	203	3,731,043	20,569	3,751,613
970	8	7	1,836,330	10,129	37,098	205	1,819,022	10,022	36,748	202	3,729,198	20,558	3,749,756
980	8	6	1,835,345	10,123	37,078	204	1,818,238	10,018	36,732	202	3,727,393	20,547	3,747,940
990	8	6	1,834,382	10,117	37,058	204	1,817,469	10,013	36,717	202	3,725,626	20,536	3,746,162
1,000	8	6	1,833,438	10,111	37,039	204	1,816,717	10,008	36,701	202	3,723,896	20,526	3,744,421
1,010	8	6	1,832,514	10,105	37,020	204	1,815,980	10,004	36,686	202	3,722,201	20,515	3,742,717
1,020	8	6	1,831,609	10,100	37,002	204	1,815,259	9,999	36,672	202	3,720,542	20,505	3,741,047
1,030	8	6	1,830,722	10,094	36,984	204	1,814,552	9,995	36,658	202	3,718,917	20,495	3,739,412
1,040	8	6	1,829,854	10,089	36,967	204	1,813,860	9,991	36,644	202	3,717,324	20,485	3,737,809

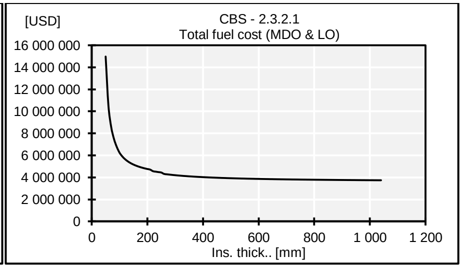






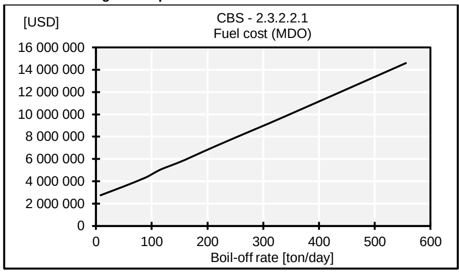


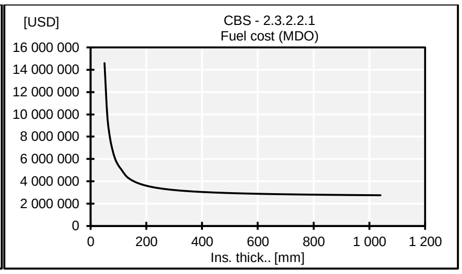


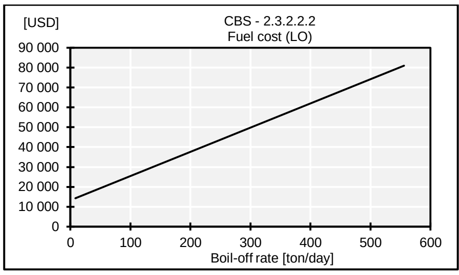


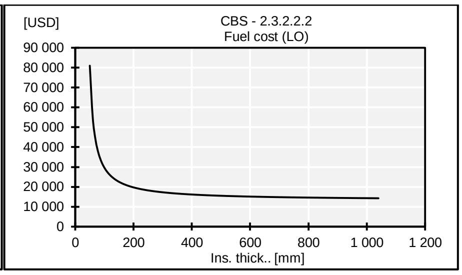
Insulation system 2

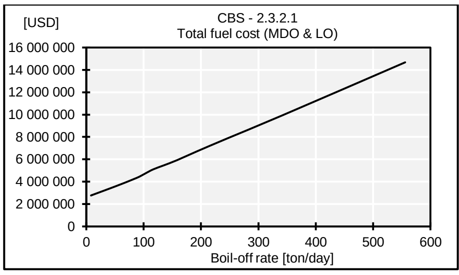
Boil-off handling – Re-liquefaction

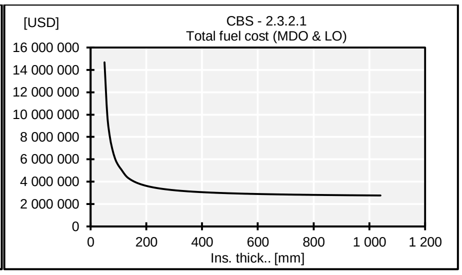




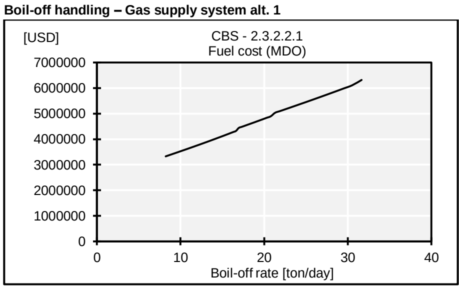


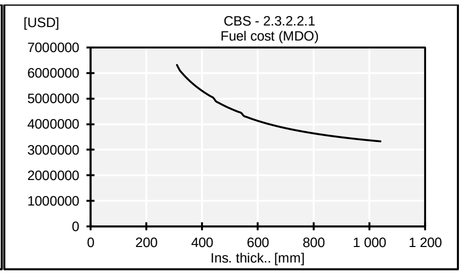


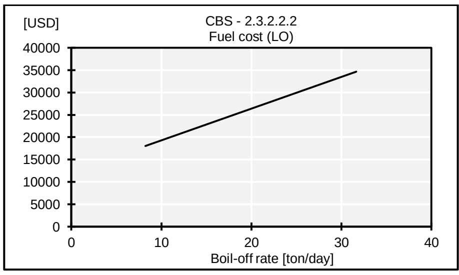


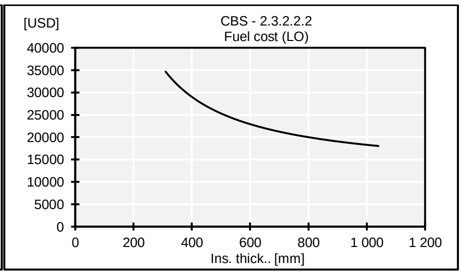


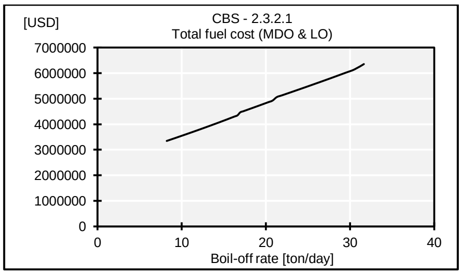
Boil-off handling – Gas supply system alt. 1

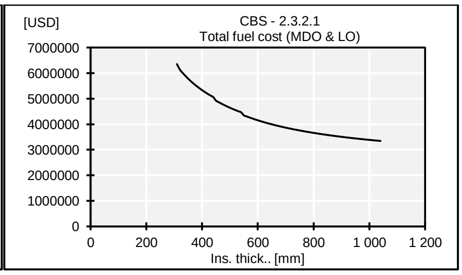




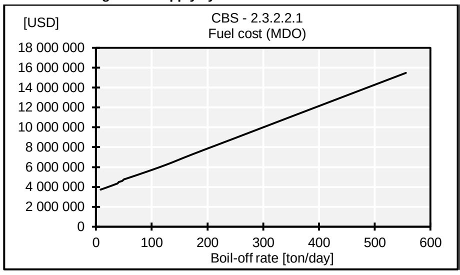


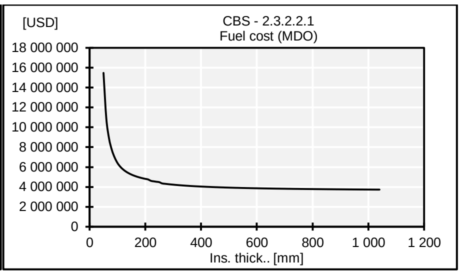


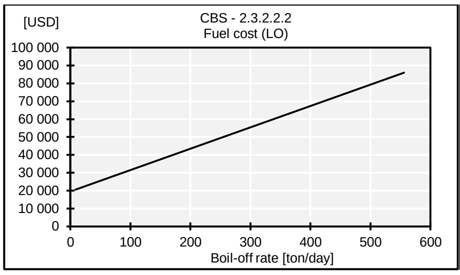


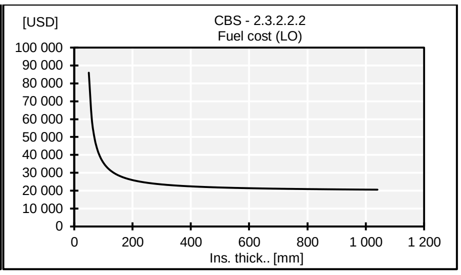


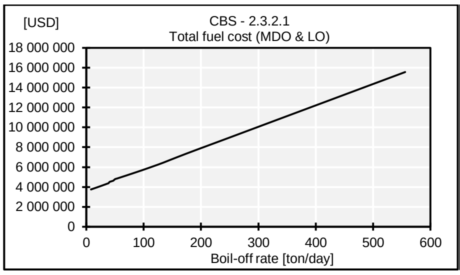
Boil-off handling – Gas supply system alt. 2

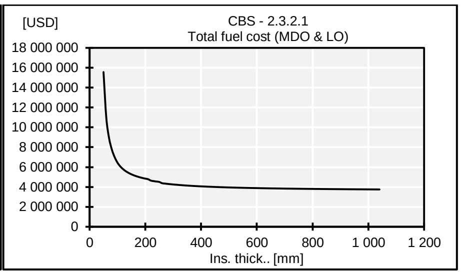






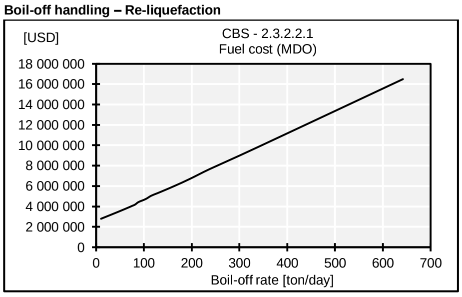


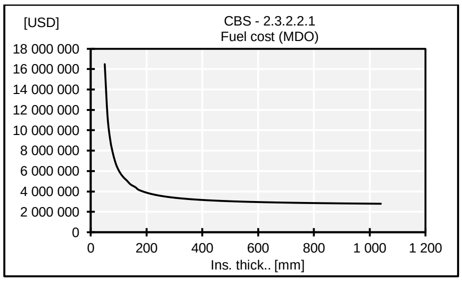


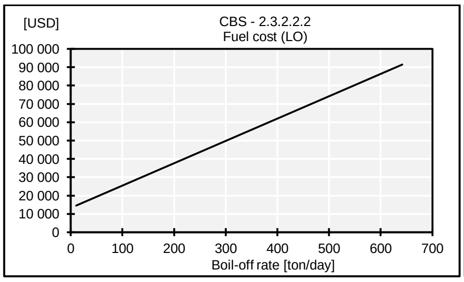


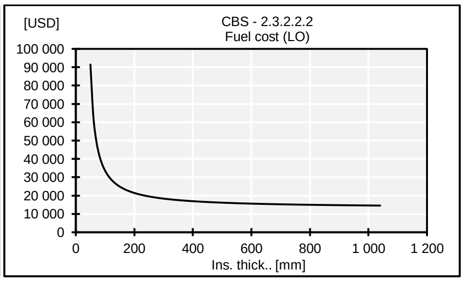
Insulation system 3

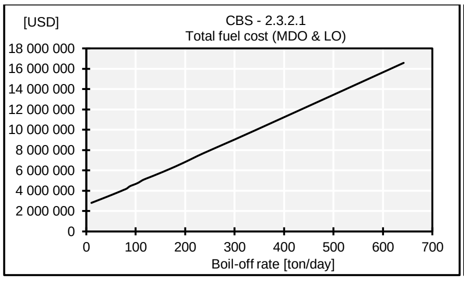
Boil-off handling – Re-liquefaction

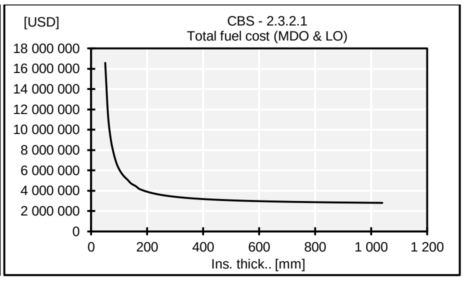




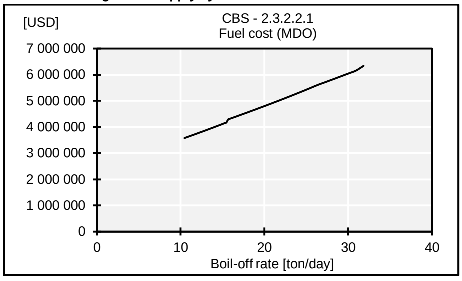


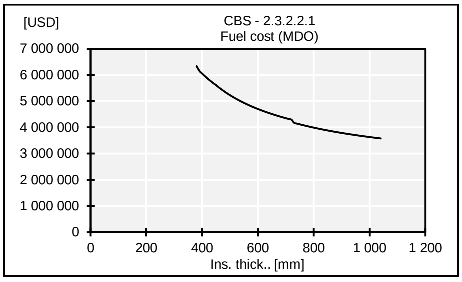


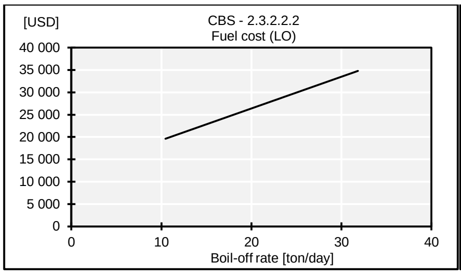


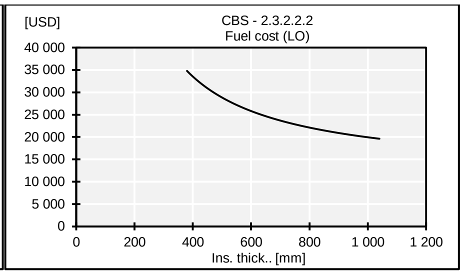


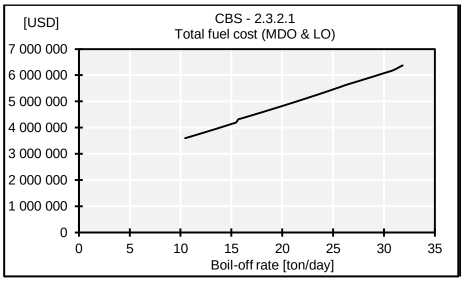
Boil-off handling – Gas supply system alt. 1

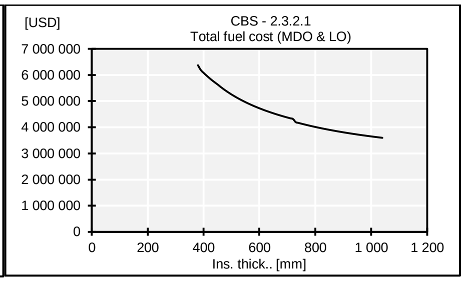




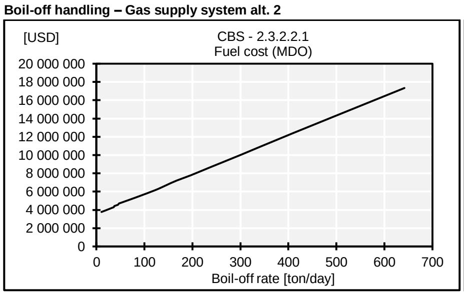


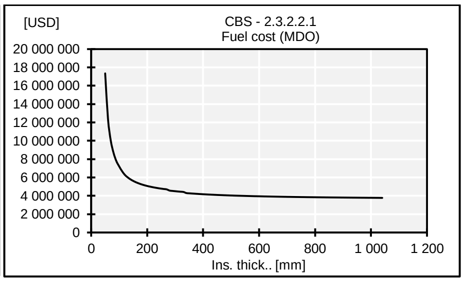


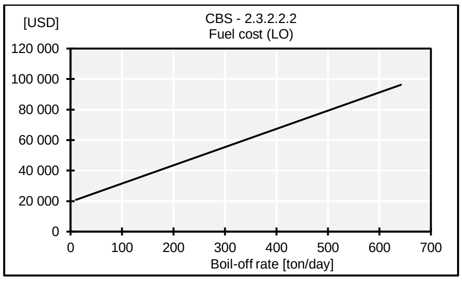


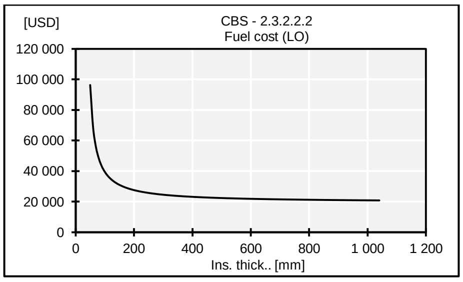


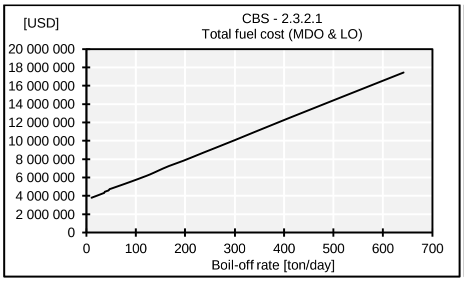
Boil-off handling – Gas supply system alt. 2

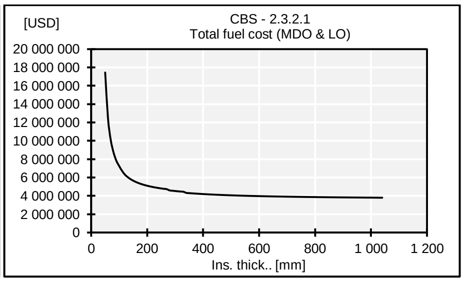






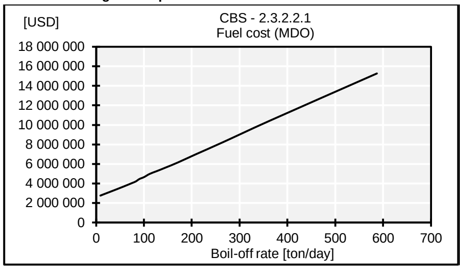


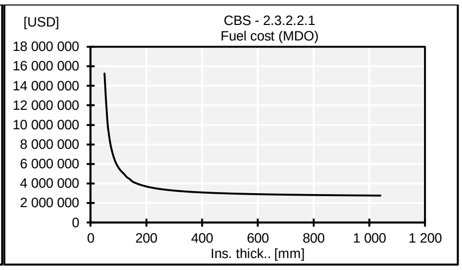


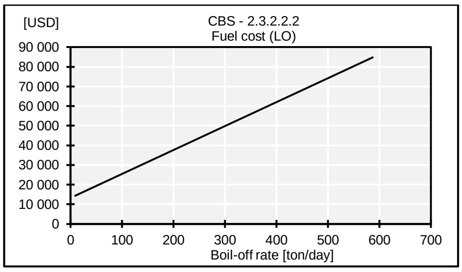


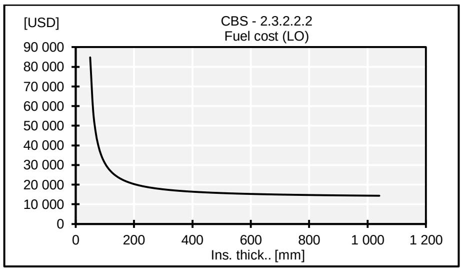
Insulation system 4

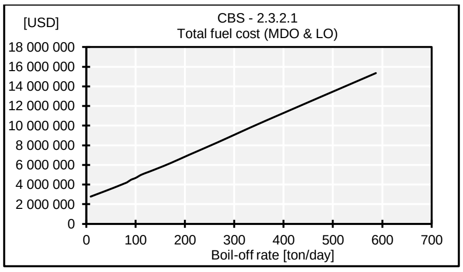
Boil-off handling – Re-liquefaction

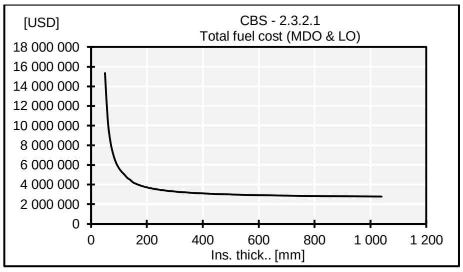




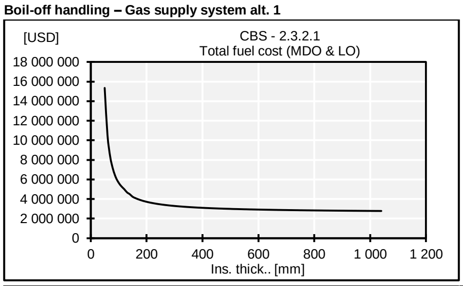


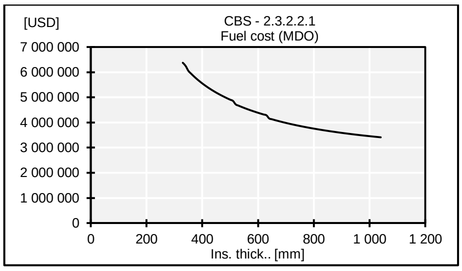


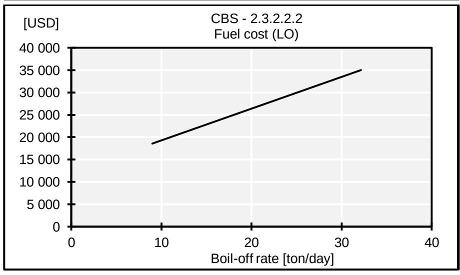


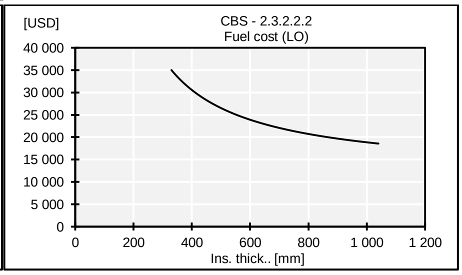


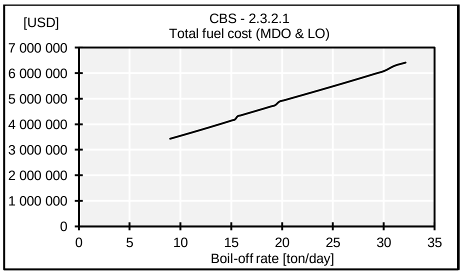
Boil-off handling – Gas supply system alt. 1

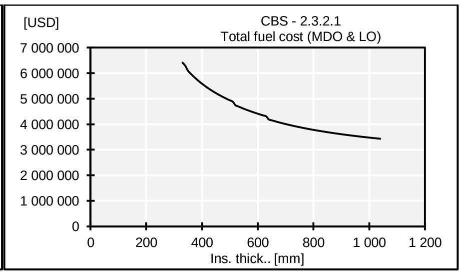




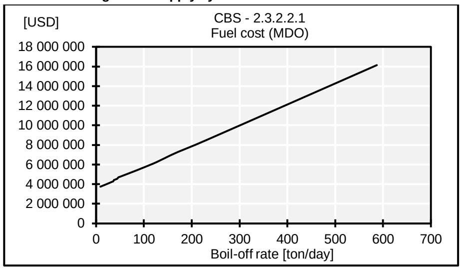


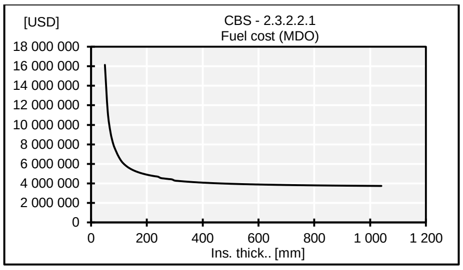


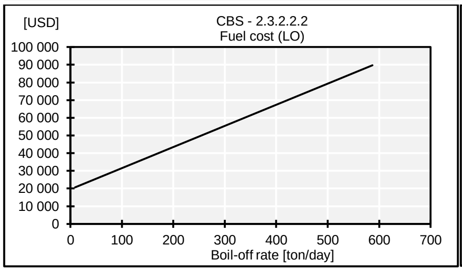


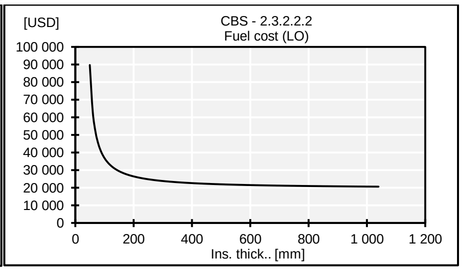


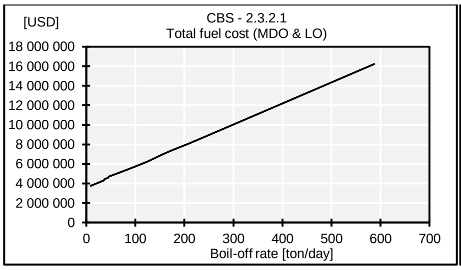
Boil-off handling – Gas supply system alt. 2

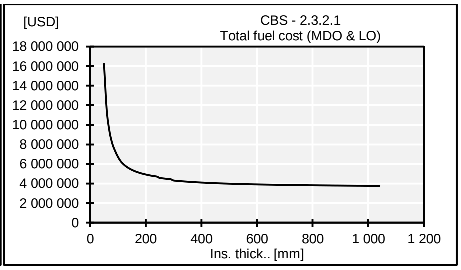






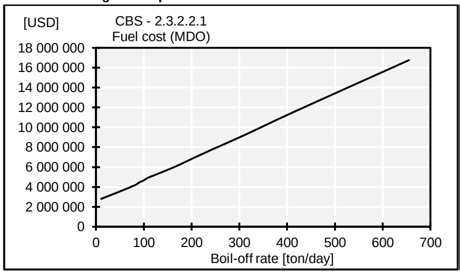


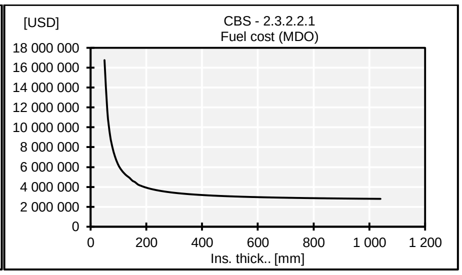


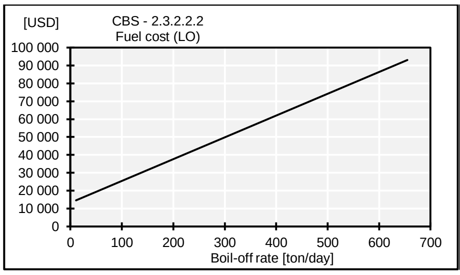


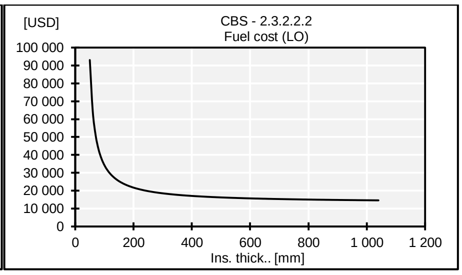
Insulation system 5

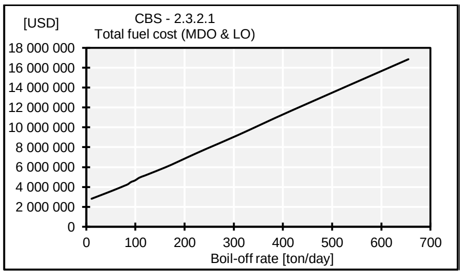
Boil-off handling – Re-liquefaction

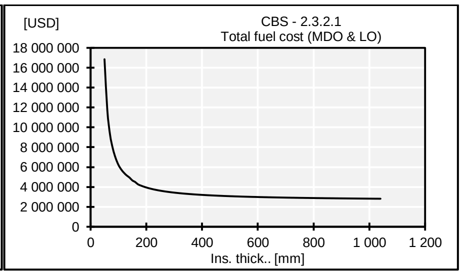




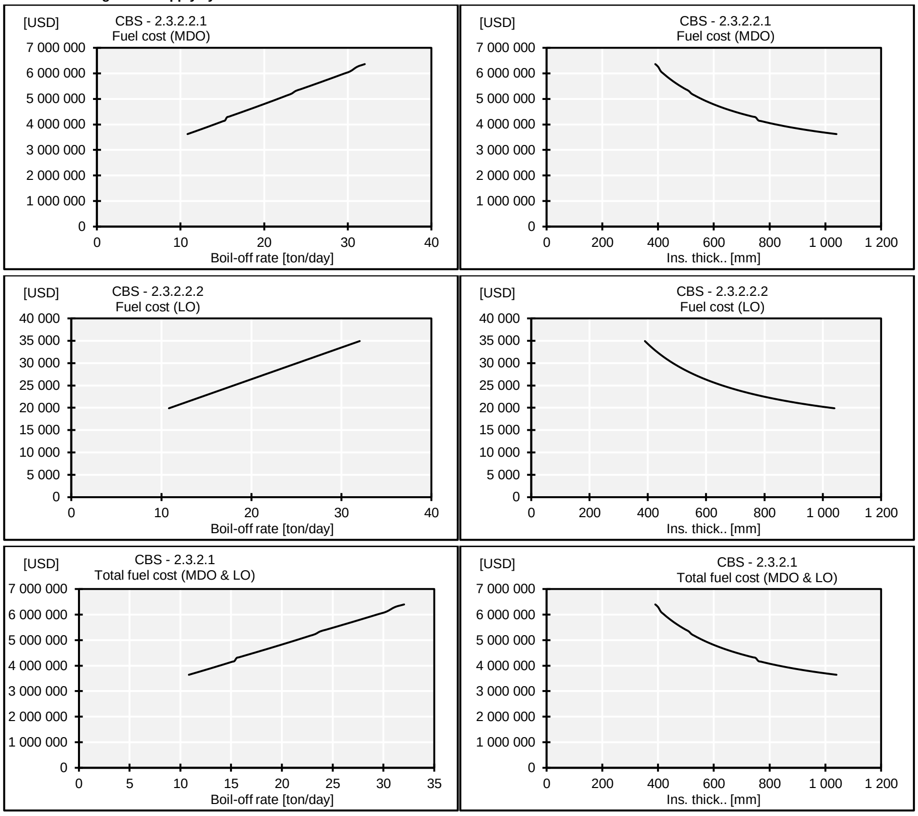




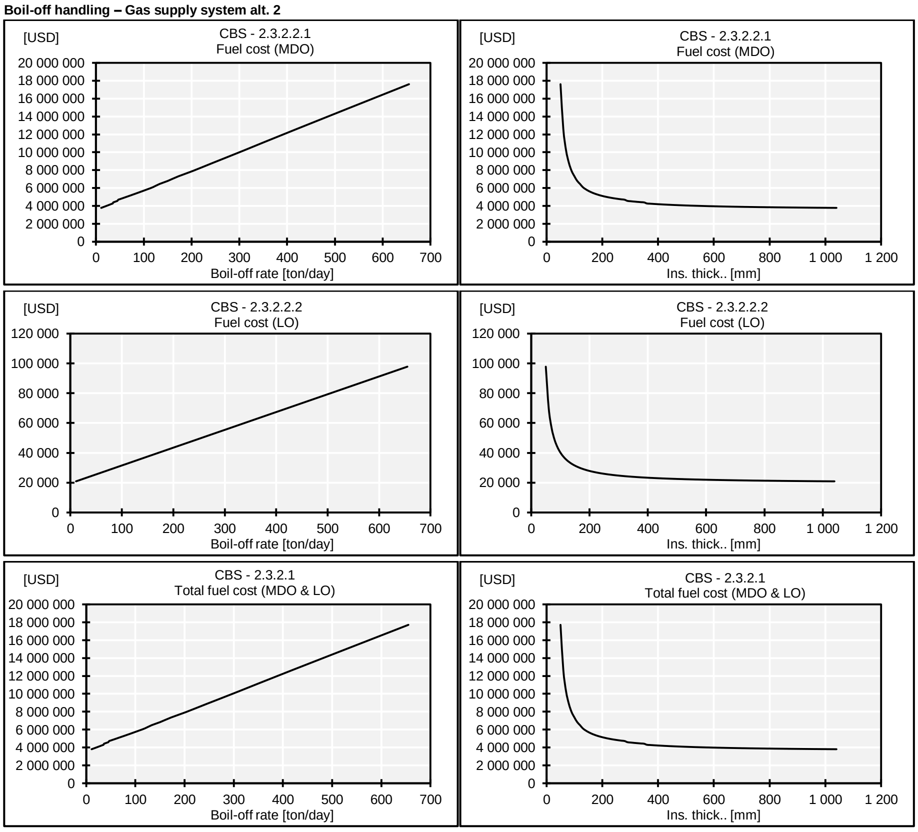




Boil-off handling – Gas supply system alt. 1

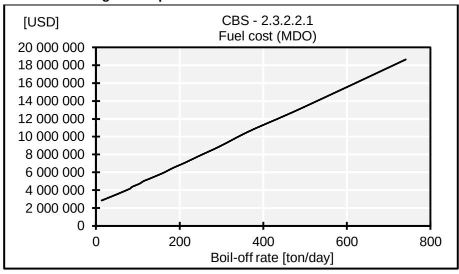


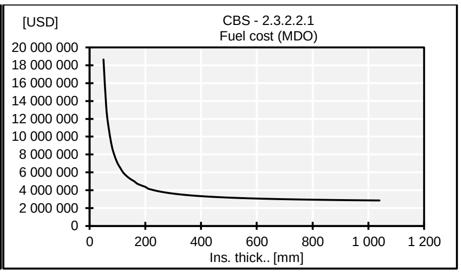
Boil-off handling – Gas supply system alt. 2

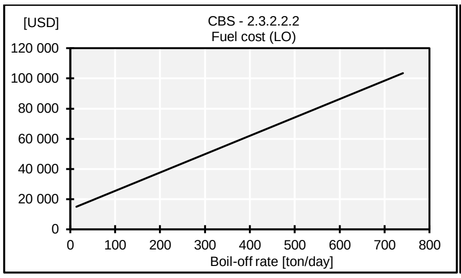


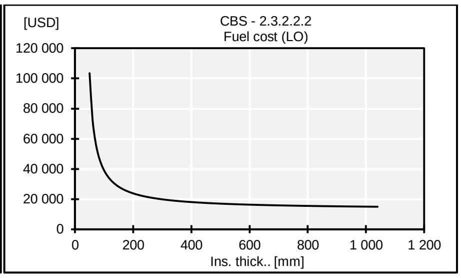
Insulation system 6

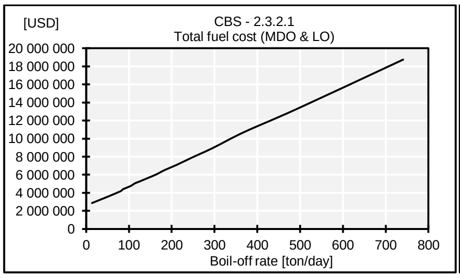
Boil-off handling – Re-liquefaction

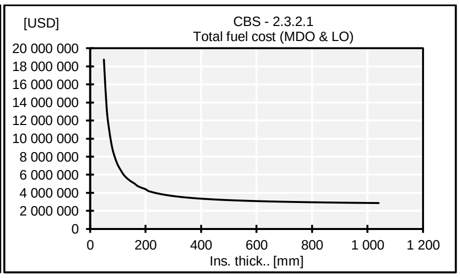




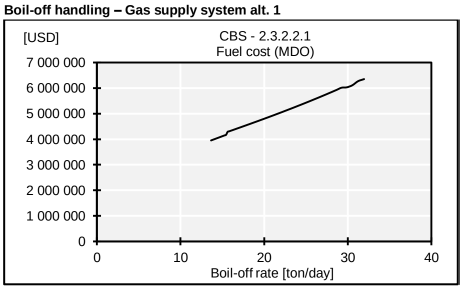


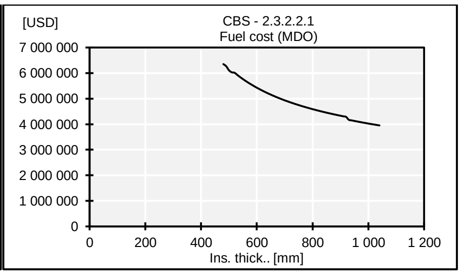


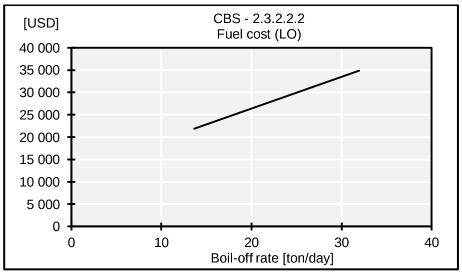


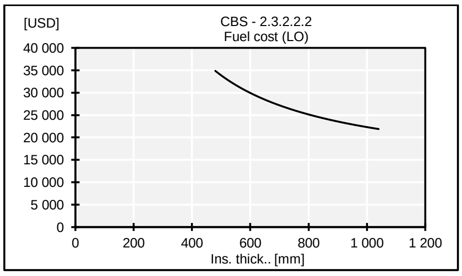


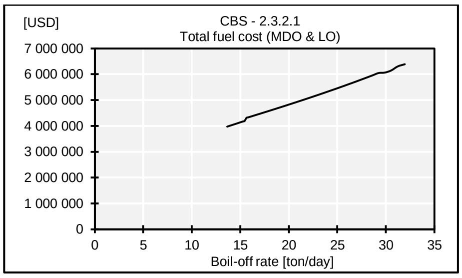
Boil-off handling – Gas supply system alt. 1

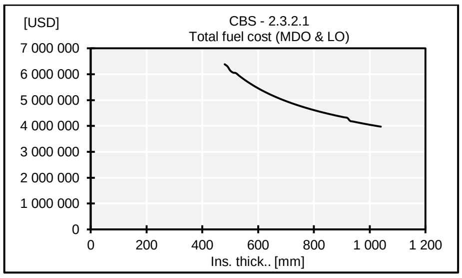




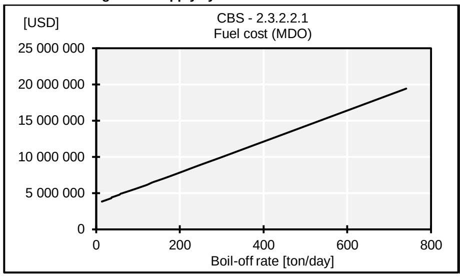


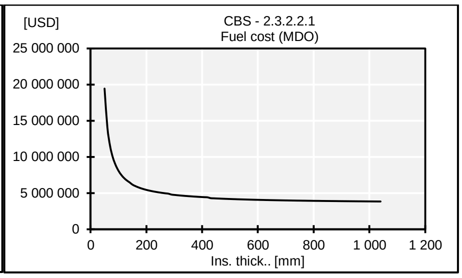


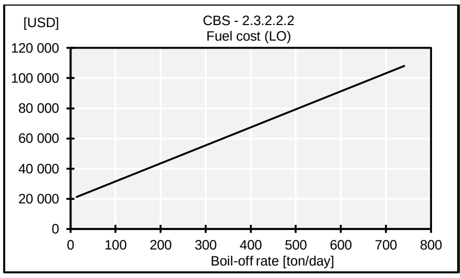


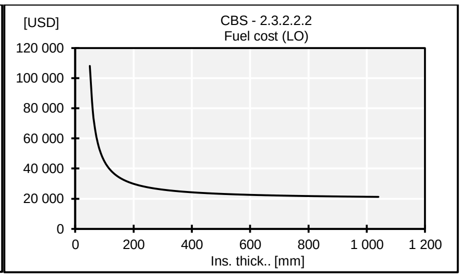


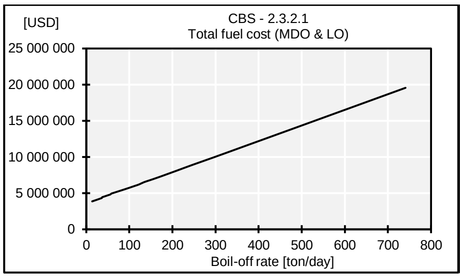
Boil-off handling – Gas supply system alt. 2

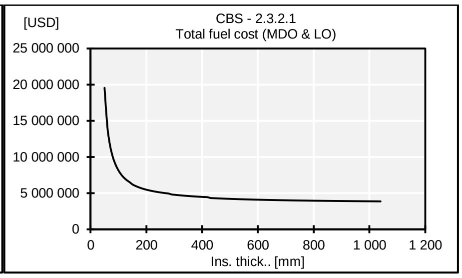












Appendix 11

Cash flow model

Operational assumptions

Operational assumptions	
Operational period in years	30
Sale basis percentage scrap value of building cost	15%
Inflation on costs	2%
Income escalation	2%
Depreciation to scrap	30
Loan facility	80%
Loan period in years	20
Interest rate	5%

Cost input

Fixed cost input

Fixed cost input	ME alt 1	ME alt 2
	[USD]	[USD]
CBS 2.1 - Operating Cost	2,049,402	2,249,402
CBS 2.2 - Periodic maintenance (docking)	1,421,030	1,421,030
CBS 2.3.1 - Fixed voyage cost	9,783,987	6,922,562

Variable cost input

Variable cost input		
	[USD]	[USD/year]
V/C-rate		25,000,000
CBS 1 - Building cost	100,000,000	
CBS 2.3.2 - Variable voyage cost		5,000,000

Financial output

Financial output			
IRR	NPV (discounted)	NPV	ROI
5%	69,679,814	196,647,110	11%

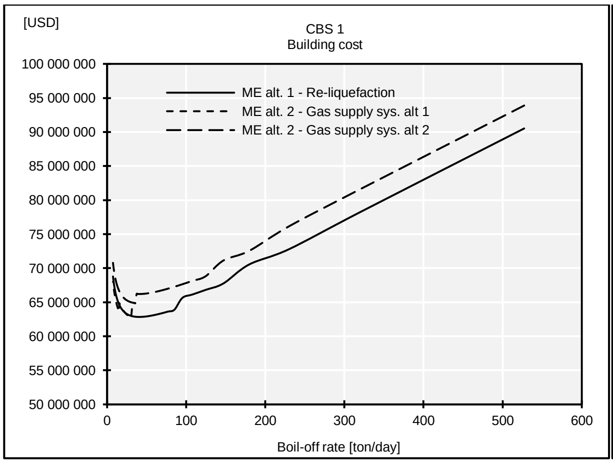
Cash-flow model

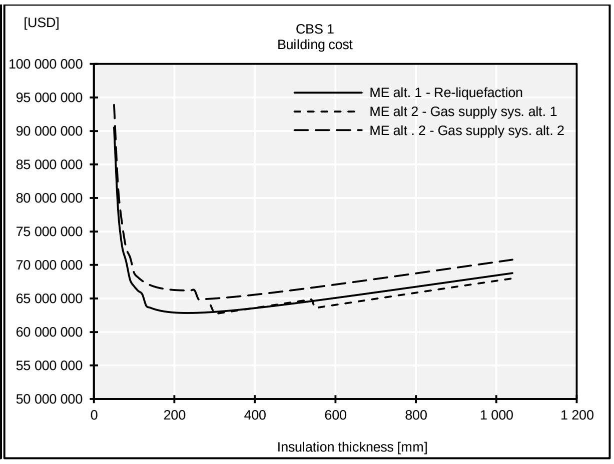
Detailed cash flow:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Expl. Years		2,013	2,014	2,015	2,016	2,017	2,018	2,019	2,020	2,021	2,022	2,023	2,024	2,025	2,026	2,027	2,028	2,029	2,030	2,031	2,032	2,033	2,034	2,035	2,036	2,037	2,038	2,039	2,040	2,041	2,042	
Income																																
V/C-rate		25,000,000	25,500,000	26,010,000	26,530,200	27,060,804	27,602,020	28,154,060	28,717,142	29,291,485	29,877,314	30,474,860	31,084,358	31,706,045	32,340,166	32,986,969	33,646,708	34,319,643	35,006,035	35,706,156	36,420,279	37,148,685	37,891,659	38,649,492	39,422,482	40,210,931	41,015,150	41,835,453	42,672,162	43,525,605	44,396,117	1,014,201,980
CBS 2.0 - Running cost																																
CBS 2.1 - Operating Cost		2,049,402	2,090,390	2,132,198	2,174,842	2,218,339	2,262,706	2,307,960	2,354,119	2,401,202	2,449,226	2,498,210	2,548,174	2,599,138	2,651,121	2,704,143	2,758,226	2,813,390	2,869,658	2,927,051	2,985,592	3,045,304	3,106,210	3,168,334	3,231,701	3,296,335	3,362,262	3,429,507	3,498,097	3,568,059	3,639,420	
CBS 2.2 - Periodic maintenance (docking)						1,568,932					1,732,228					1,912,519					2,111,576					2,331,351						
CBS 2.3.1 - Fixed voyage cost		9,783,987	9,979,666	10,179,260	10,382,845	10,590,502	10,802,312	11,018,358	11,238,725	11,463,500	11,692,770	11,926,625	12,165,158	12,408,461	12,656,630	12,909,763	13,167,958	13,431,317	13,699,943	13,973,942	14,253,421	14,538,490	14,829,259	15,125,845	15,428,361	15,736,929	16,051,667	16,372,701	16,700,155	17,034,158	17,374,841	
CBS 2.3.2 - Variable voyage cost		5,000,000	5,100,000	5,202,000	5,306,040	5,412,161	5,520,404	5,630,812	5,743,428	5,858,297	5,975,463	6,094,972	6,216,872	6,341,209	6,468,033	6,597,394	6,729,342	6,863,929	7,001,207	7,141,231	7,284,056	7,429,737	7,578,332	7,729,898	7,884,496	8,042,186	8,203,030	8,367,091	8,534,432	8,705,121	8,879,223	
Total running cost		16,833,389	17,170,057	17,513,458	17,863,727	19,789,934	18,585,422	18,957,130	19,336,273	19,722,998	21,849,686	20,519,807	20,930,204	21,348,808	21,775,784	24,123,819	22,655,525	23,108,636	23,570,809	24,042,225	26,634,645	25,013,531	25,513,801	26,024,077	26,544,559	29,406,801	27,616,959	28,169,298	28,732,684	29,307,338	29,893,485	692,554,870
CBS 2.4 - Capital cost																																
Bank loan	80,000,000	76,000,000	72,000,000	68,000,000	64,000,000	60,000,000	56,000,000	52,000,000	48,000,000	44,000,000	40,000,000	36,000,000	32,000,000	28,000,000	24,000,000	20,000,000	16,000,000	12,000,000	8,000,000	4,000,000	0											
CBS 2.4.1 - Repayment		4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000											
CBS 2.4.2 - Interest		3,900,000	3,700,000	3,500,000	3,300,000	3,100,000	2,900,000	2,700,000	2,500,000	2,300,000	2,100,000	1,900,000	1,700,000	1,500,000	1,300,000	1,100,000	900,000	700,000	500,000	300,000	100,000	0										
Total capital cost		7,900,000	7,700,000	7,500,000	7,300,000	7,100,000	6,900,000	6,700,000	6,500,000	6,300,000	6,100,000	5,900,000	5,700,000	5,500,000	5,300,000	5,100,000	4,900,000	4,700,000	4,500,000	4,300,000	4,100,000	0										120,000,000
																																201,647,110
Operational cashflow																																
Operational cash flow	-20,000,000	266,611	629,943	996,542	1,366,473	170,870	2,116,598	2,496,930	2,880,869	3,268,486	1,927,628	4,055,053	4,454,154	4,857,237	5,264,382	3,763,150	6,091,183	6,511,007	6,935,227	7,363,931	5,685,634	12,135,154	12,377,857	12,625,414	12,877,923	10,804,131	13,398,191	13,666,155	13,939,478	14,218,267	14,502,633	15,000,000
Discount factor	1.00	1.05	1.10	1.16	1.22	1.28	1.34	1.41	1.48	1.55	1.63	1.71	1.80	1.89	1.98	2.08	2.18	2.29	2.41	2.53	2.65	2.79	2.93	3.07	3.23	3.39	3.56	3.73	3.92	4.12	4.32	
Discounted cashflow	-20,000,000	253,915	571,377	860,850	1,124,201	133,881	1,579,438	1,774,522	1,949,885	2,106,895	1,183,396	2,370,906	2,480,240	2,575,897	2,658,871	1,810,140	2,790,441	2,840,731	2,881,730	2,914,158	2,142,856	4,355,821	4,231,369	4,110,473	3,993,031	3,190,490	3,768,117	3,660,457	3,555,872	3,454,276	3,355,582	15,000,000
Cummulative cash flow	-20,000,000	-19,733,389	-19,103,446	-18,106,904	-16,740,431	-16,569,561	-14,452,963	-11,956,033	-9,075,164	-5,806,678	-3,879,050	176,004	4,630,158	9,487,395	14,751,777	18,514,927	24,606,110	31,117,117	38,052,343	45,416,275	51,101,909	63,237,063	75,614,920	88,240,334	#########	111,922,387	125,320,578	138,986,733	152,926,210	167,144,478	181,647,110	
Cummulative discounted cash flow	-20,000,000	-19,746,085	-19,174,708	-18,313,858	-17,189,657	-17,055,776	-15,476,338	-13,701,816	-11,751,930	-9,645,035	-8,461,639	-6,090,733	-3,610,493	-1,034,597	1,624,274	3,434,413	6,224,854	9,065,585	11,947,315	14,861,473	17,004,328	21,360,149	25,591,518	29,701,991	33,695,021	36,885,511	40,653,628	44,314,085	47,869,957	51,324,232	54,679,814	15,000,000
		1.3%	*2.9%*	*4.3%*	*5.6%*	*0.7%*	*7.9%*	*8.9%*	*9.7%*	*10.5%*	*5.9%*	*11.9%*	*12.4%*	*12.9%*	*13.3%*	*9.1%*	*14.0%*	*14.2%*	*14.4%*	*14.6%*	*10.7%*	*21.8%*	*21.2%*	*20.6%*	*20.0%*	*16.0%*	*18.8%*	*18.3%*	*17.8%*	*17.3%*	*16.8%*	
Profit/loss account																																
Expl. Years		2,013	2,014	2,015	2,016	2,017	2,018	2,019	2,020	2,021	2,022	2,023	2,024	2,025	2,026	2,027	2,028	2,029	2,030	2,031	2,032	2,033	2,034	2,035	2,036	2,037	2,038	2,039	2,040	2,041	2,042	TOTAL
Income		25,000,000	25,500,000	26,010,000	26,530,200	27,060,804	27,602,020	28,154,060	28,717,142	29,291,485	29,877,314	30,474,860	31,084,358	31,706,045	32,340,166	32,986,969	33,646,708	34,319,643	35,006,035	35,706,156	36,420,279	37,148,685	37,891,659	38,649,492	39,422,482	40,210,931	41,015,150	41,835,453	42,672,162	43,525,605	44,396,117	800,757,493
Running cost		16,833,389	17,170,057	17,513,458	17,863,727	19,789,934	18,585,422	18,957,130	19,336,273	19,722,998	21,849,686	20,519,807	20,930,204	21,348,808	21,775,784	24,123,819	22,655,525	23,108,636	23,570,809	24,042,225	26,634,645	25,013,531	25,513,801	26,024,077	26,544,559	29,406,801	27,616,959	28,169,298	28,732,684	29,307,338	29,893,485	692,554,870
EBITDA		8,166,611	8,329,943	8,496,542	8,666,473	7,270,870	9,016,598	9,196,930	9,380,869	9,568,486	8,027,628	9,955,053	10,154,154	10,357,237	10,564,382	8,863,150	10,991,183	11,211,007	11,435,227	11,663,931	9,785,634	12,135,154	12,377,857	12,625,414	12,877,923	10,804,131	13,398,191	13,666,155	13,939,478	14,218,267	14,502,633	1,493,312,363
Interest		3,900,000	3,700,000	3,500,000	3,300,000	3,100,000	2,900,000	2,700,000	2,500,000	2,300,000	2,100,000	1,900,000	1,700,000	1,500,000	1,300,000	1,100,000	900,000	700,000	500,000	300,000	100,000											40,000,000
Depreciation		2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	2,166,667	65,000,000
Bookresult																																
Net result		14,233,278	14,196,610	14,163,209	14,133,139	12,537,537	14,083,265	14,063,597	14,047,536	14,035,153	12,294,295	14,021,720	14,020,821	14,023,904	14,031,049	12,129,817	14,057,850	14,077,673	14,101,893	14,130,598	12,052,301	14,301,821	14,544,524	14,792,081	15,044,589	12,970,797	15,564,857	15,832,821	16,106,144	16,384,934	16,669,299	1,598,312,363
ROI	92%	95%	95%	94%	94%	84%	94%	94%	94%	94%	82%	93%	93%	93%	94%	81%	94%	94%	94%	94%	80%	95%	97%	99%	100%	86%	104%	106%	107%	109%	111%	

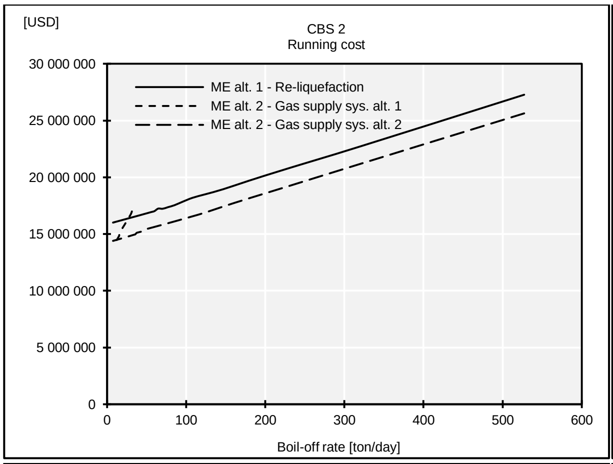
Variable cost input
Insulation system 1

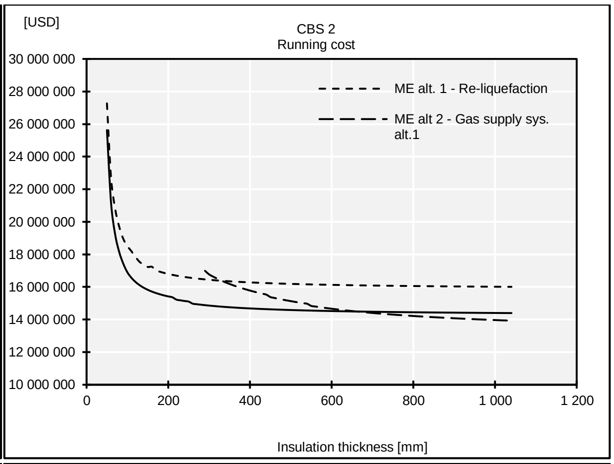
Insulation system 1											
	ME alt. 1				ME alt. 2						
Ins. thickness	Re-liquefaction					Gas supply alt. 1			Gas supply alt. 2		
	V/C-rate	CBS 1	CBS 2.3.2	CBS 2	V/C rate	CBS 1	CBS 2.3.2	CBS 2	CBS 1	CBS 2.3.2	CBS 2
t_{INS_TOT}		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$	$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$
[mm]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]
50	26,361,657	90,529,188	14,020,951	27,275,370	26,093,389				93,894,819	14,975,432	25,632,681
60	26,336,069	78,272,934	9,475,367	22,729,786	26,067,099				81,638,565	10,533,445	21,190,693
70	26,310,456	72,797,955	7,554,685	20,809,105	26,040,782				76,163,586	8,576,695	19,233,943
80	26,284,816	70,535,298	6,445,384	19,699,803	26,014,435				72,537,504	7,489,389	18,146,638
90	26,259,151	67,759,414	5,697,828	18,952,247	25,988,060				71,125,045	6,769,886	17,427,134
100	26,233,459	66,807,954	5,253,381	18,507,801	25,961,656				68,810,160	6,241,984	16,899,233
110	26,207,741	66,134,374	4,933,878	18,188,298	25,935,223				68,136,580	5,900,623	16,557,871
120	26,181,997	65,641,183	4,580,829	17,835,248	25,908,761				67,643,389	5,647,240	16,304,489
130	26,156,226	63,908,283	4,284,026	17,538,446	25,882,270				67,273,914	5,451,014	16,108,262
140	26,130,429	63,627,326	4,111,060	17,365,480	25,855,751				66,992,957	5,294,181	15,951,429
150	26,104,606	63,411,877	3,971,701	17,226,120	25,829,202				66,777,508	5,165,739	15,822,987
160	26,078,756	63,246,256	3,984,907	17,239,326	25,802,623				66,611,887	5,058,486	15,715,734
170	26,052,879	63,119,412	3,760,230	17,014,649	25,776,016				66,485,043	4,967,495	15,624,744
180	26,026,976	63,023,330	3,677,867	16,932,286	25,749,379				66,388,962	4,889,277	15,546,525
190	26,001,046	62,952,057	3,606,706	16,861,125	25,722,713				66,317,688	4,821,284	15,478,532
200	25,975,089	62,901,077	3,544,559	16,798,978	25,696,017				66,266,708	4,761,609	15,418,857
210	25,949,106	62,866,903	3,489,781	16,744,200	25,669,292				66,232,534	4,708,799	15,366,048
220	25,923,095	62,846,803	3,441,109	16,695,528	25,642,537				66,212,434	4,565,545	15,222,794
230	25,897,058	62,838,600	3,397,558	16,651,978	25,615,752				66,204,231	4,520,305	15,177,553
240	25,870,994	62,840,542	3,358,349	16,612,768	25,588,937				66,206,173	4,479,632	15,136,881
250	25,844,902	62,851,204	3,322,851	16,577,270	25,562,093				66,216,835	4,442,863	15,100,111
260	25,818,783	62,869,410	3,290,555	16,544,974	25,535,218				64,871,616	4,314,782	14,972,031
270	25,792,638	62,894,187	3,261,041	16,515,460	25,508,314				64,896,393	4,281,648	14,938,897
280	25,766,464	62,924,719	3,233,959	16,488,378	25,481,379				64,926,925	4,251,394	14,908,642
290	25,740,264	62,960,319	3,209,017	16,463,436	25,454,414	63,987,274	6,334,608	16,991,856	64,962,525	4,223,658	14,880,906
300	25,714,036	63,000,401	3,185,969	16,440,388	25,427,419	62,709,692	6,113,116	16,770,365	65,002,607	4,198,136	14,855,384
310	25,687,781	63,044,466	3,164,604	16,419,024	25,400,393	62,796,196	5,975,774	16,633,022	65,046,672	4,174,572	14,831,820
320	25,661,498	63,092,086	3,144,744	16,399,163	25,373,337	62,883,281	5,849,894	16,507,142	65,094,292	4,152,748	14,809,996
330	25,635,187	63,142,888	3,126,232	16,380,652	25,346,251	62,970,877	5,734,003	16,391,251	65,145,094	4,132,477	14,789,726
340	25,608,849	63,196,549	3,108,936	16,363,355	25,319,134	63,058,923	5,626,875	16,284,123	65,198,755	4,113,599	14,770,847
350	25,582,483	63,252,789	3,092,738	16,347,157	25,291,986	63,147,368	5,527,483	16,184,731	65,254,995	4,095,974	14,753,222
360	25,556,090	63,311,359	3,077,536	16,331,955	25,264,807	63,236,165	5,434,959	16,092,207	65,313,565	4,079,480	14,736,728
370	25,529,668	63,372,042	3,063,240	16,317,660	25,237,598	63,325,272	5,348,564	16,005,812	65,374,248	4,064,012	14,721,260
380	25,503,219	63,434,646	3,049,772	16,304,191	25,210,358	63,414,654	5,267,665	15,924,913	65,436,852	4,049,477	14,706,725
390	25,476,741	63,498,999	3,037,061	16,291,480	25,183,086	63,504,279	5,191,716	15,848,965	65,501,205	4,035,792	14,693,040
400	25,450,236	63,564,950	3,025,044	16,279,463	25,155,784	63,594,119	5,120,246	15,777,495	65,567,156	4,022,885	14,680,133
410	25,423,702	63,632,363	3,013,666	16,268,085	25,128,450	63,684,147	5,052,842	15,710,090	65,634,569	4,010,691	14,667,939
420	25,397,140	63,701,115	3,002,876	16,257,296	25,101,085	63,774,342	4,989,143	15,646,391	65,703,321	3,999,152	14,656,400
430	25,370,550	63,771,098	2,992,631	16,247,051	25,073,689	63,864,682	4,928,832	15,586,080	65,773,304	3,988,217	14,645,465
440	25,343,931	63,842,212	2,982,890	16,237,310	25,046,261	63,955,150	4,871,627	15,528,875	65,844,418	3,977,839	14,635,087
450	25,317,285	63,914,369	2,973,616	16,228,036	25,018,802	64,045,728	4,721,894	15,379,142	65,916,575	3,967,977	14,625,225
460	25,290,609	63,987,487	2,964,777	16,219,196	24,991,311	64,136,402	4,666,492	15,323,740	65,989,693	3,958,593	14,615,841
470	25,263,905	64,061,494	2,956,342	16,210,761	24,963,789	64,227,157	4,613,940	15,271,189	66,063,700	3,949,653	14,606,901
480	25,237,173	64,136,322	2,948,284	16,202,704	24,936,235	64,317,982	4,564,013	15,221,261	66,138,528	3,941,126	14,598,374
490	25,210,412	64,211,910	2,940,579	16,194,998	24,908,649	64,408,864	4,516,507	15,173,755	66,214,116	3,932,985	14,590,233
500	25,183,622	64,288,204	2,933,203	16,187,623	24,881,031	64,499,794	4,471,241	15,128,489	66,290,410	3,925,203	14,582,451
510	25,156,803	64,365,151	2,926,137	16,180,556	24,853,381	64,590,762	4,428,052	15,085,300	66,367,357	3,917,757	14,575,005
520	25,129,955	64,442,706	2,919,360	16,173,779	24,825,698	64,681,760	4,386,791	15,044,040	66,444,912	3,910,627	14,567,875
530	25,103,079	64,520,825	2,912,855	16,167,274	24,797,984	64,772,779	4,347,327	15,004,576	66,523,031	3,903,791	14,561,039
540	25,076,173	64,599,468	2,906,607	16,161,026	24,770,238	64,863,811	4,309,538	14,966,787	66,601,674	3,897,233	14,554,481
550	25,049,238	64,678,599	2,900,600	16,155,019	24,742,459	63,591,426	4,177,875	14,835,123	66,680,805	3,890,935	14,548,183
560	25,022,274	64,758,185	2,894,820	16,149,239	24,714,647	63,682,466	4,140,091	14,797,339	66,760,391	3,884,883	14,542,131
570	24,995,281	64,838,194	2,889,255	16,143,675	24,686,803	63,773,502	4,103,959	14,761,207	66,840,400	3,879,062	14,536,311
580	24,968,259	64,918,597	2,883,894	16,138,313	24,658,927	63,864,527	4,069,369	14,726,617	66,920,803	3,873,460	14,530,708
590	24,941,207	64,999,367	2,878,724	16,133,144	24,631,017	63,955,537	4,036,219	14,693,468	67,001,573	3,868,064	14,525,312
600	24,914,126	65,080,480	2,873,737	16,128,156	24,603,075	64,046,527	4,004,419	14,661,667	67,082,686	3,862,863	14,520,111
610	24,887,015	65,161,912	2,868,922	16,123,341	24,575,100	64,137,493	3,973,883	14,631,131	67,164,118	3,857,846	14,515,094

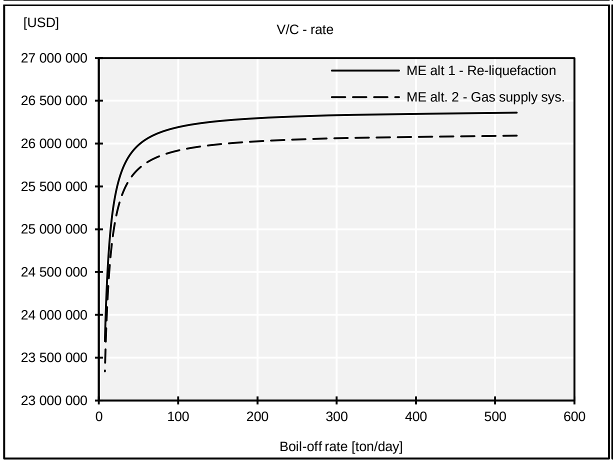
620	24,859,874	65,243,641	2,864,270	16,118,690	24,547,092	64,228,430	3,944,535	14,601,783	67,245,847	3,853,005	14,510,253
630	24,832,704	65,325,649	2,859,775	16,114,194	24,519,051	64,319,336	3,916,303	14,573,551	67,327,855	3,848,329	14,505,577
640	24,805,504	65,407,914	2,855,426	16,109,846	24,490,976	64,410,206	3,889,123	14,546,372	67,410,120	3,843,811	14,501,059
650	24,778,274	65,490,421	2,851,219	16,105,638	24,462,869	64,501,037	3,862,935	14,520,183	67,492,627	3,839,443	14,496,691
660	24,751,015	65,573,153	2,847,145	16,101,565	24,434,728	64,591,826	3,837,683	14,494,931	67,575,359	3,835,217	14,492,465
670	24,723,725	65,656,094	2,843,199	16,097,619	24,406,554	64,682,571	3,813,315	14,470,563	67,658,300	3,831,127	14,488,375
680	24,696,406	65,739,229	2,839,375	16,093,794	24,378,346	64,773,269	3,789,784	14,447,033	67,741,435	3,827,166	14,484,414
690	24,669,056	65,822,546	2,835,667	16,090,086	24,350,104	64,863,917	3,767,047	14,424,295	67,824,752	3,823,328	14,480,576
700	24,641,676	65,906,031	2,832,070	16,086,489	24,321,829	64,954,512	3,745,061	14,402,309	67,908,237	3,819,607	14,476,855
710	24,614,265	65,989,673	2,828,579	16,082,998	24,293,520	65,045,054	3,723,788	14,381,037	67,991,879	3,815,999	14,473,247
720	24,586,825	66,073,460	2,825,189	16,079,608	24,265,176	65,135,539	3,703,194	14,360,443	68,075,666	3,812,497	14,469,746
730	24,559,354	66,157,381	2,821,896	16,076,315	24,236,799	65,225,966	3,683,245	14,340,493	68,159,587	3,809,099	14,466,347
740	24,531,852	66,241,427	2,818,696	16,073,116	24,208,388	65,316,332	3,663,910	14,321,158	68,243,633	3,805,798	14,463,046
750	24,504,320	66,325,588	2,815,586	16,070,005	24,179,943	65,406,637	3,645,160	14,302,408	68,327,794	3,802,591	14,459,839
760	24,476,757	66,409,855	2,812,560	16,066,979	24,151,463	65,496,878	3,626,968	14,284,216	68,412,061	3,799,474	14,456,722
770	24,449,164	66,494,219	2,809,617	16,064,036	24,122,949	65,587,055	3,609,308	14,266,556	68,496,425	3,796,443	14,453,691
780	24,421,539	66,578,673	2,806,752	16,061,171	24,094,400	65,677,164	3,592,156	14,249,405	68,580,879	3,793,494	14,450,743
790	24,393,884	66,663,209	2,803,963	16,058,382	24,065,817	65,767,206	3,575,491	14,232,739	68,665,415	3,790,625	14,447,874
800	24,366,198	66,747,820	2,801,246	16,055,665	24,037,199	65,857,179	3,559,291	14,216,539	68,750,026	3,787,833	14,445,081
810	24,338,480	66,832,499	2,798,599	16,053,018	24,008,546	65,947,081	3,543,536	14,200,784	68,834,705	3,785,113	14,442,361
820	24,310,732	66,917,240	2,796,019	16,050,438	23,979,859	66,036,912	3,528,207	14,185,455	68,919,446	3,782,463	14,439,712
830	24,282,952	67,002,036	2,793,504	16,047,923	23,951,136	66,126,670	3,513,286	14,170,535	69,004,242	3,779,882	14,437,130
840	24,255,141	67,086,882	2,791,051	16,045,470	23,922,379	66,216,354	3,498,758	14,156,006	69,089,088	3,777,365	14,434,613
850	24,227,299	67,171,772	2,788,658	16,043,077	23,893,586	66,305,964	3,484,606	14,141,854	69,173,978	3,774,911	14,432,159
860	24,199,425	67,256,701	2,786,322	16,040,742	23,864,758	66,395,498	3,470,816	14,128,064	69,258,907	3,772,517	14,429,765
870	24,171,520	67,341,664	2,784,043	16,038,462	23,835,894	66,484,955	3,457,372	14,114,620	69,343,870	3,770,182	14,427,430
880	24,143,583	67,426,656	2,781,817	16,036,236	23,806,995	66,574,335	3,444,263	14,101,511	69,428,862	3,767,902	14,425,150
890	24,115,614	67,511,673	2,779,643	16,034,062	23,778,060	66,663,637	3,431,474	14,088,723	69,513,879	3,765,677	14,422,925
900	24,087,614	67,596,710	2,777,519	16,031,938	23,749,090	66,752,860	3,418,995	14,076,244	69,598,916	3,763,503	14,420,752
910	24,059,581	67,681,763	2,775,443	16,029,862	23,720,084	66,842,004	3,406,814	14,064,062	69,683,969	3,761,380	14,418,629
920	24,031,517	67,766,828	2,773,414	16,027,833	23,691,042	66,931,067	3,394,920	14,052,168	69,769,034	3,759,306	14,416,554
930	24,003,421	67,851,902	2,771,430	16,025,850	23,661,963	67,020,049	3,383,302	14,040,550	69,854,108	3,757,279	14,414,527
940	23,975,293	67,936,980	2,769,490	16,023,910	23,632,849	67,108,949	3,371,951	14,029,200	69,939,186	3,755,297	14,412,545
950	23,947,132	68,022,060	2,767,592	16,022,012	23,603,699	67,197,767	3,360,858	14,018,106	70,024,266	3,753,359	14,410,607
960	23,918,939	68,107,139	2,765,735	16,020,155	23,574,512	67,286,503	3,350,013	14,007,261	70,109,345	3,751,463	14,408,711
970	23,890,714	68,192,212	2,763,918	16,018,337	23,545,289	67,375,155	3,339,408	13,996,657	70,194,418	3,749,608	14,406,857
980	23,862,456	68,277,277	2,762,139	16,016,558	23,516,029	67,463,723	3,329,036	13,986,284	70,279,483	3,747,794	14,405,042
990	23,834,166	68,362,331	2,760,397	16,014,816	23,486,733	67,552,207	3,318,887	13,976,135	70,364,537	3,746,017	14,403,265
1,000	23,805,843	68,447,372	2,758,691	16,013,111	23,457,400	67,640,606	3,308,956	13,966,204	70,449,578	3,744,278	14,401,526
1,010	23,777,488	68,532,397	2,757,020	16,011,439	23,428,029	67,728,920	3,299,234	13,956,482	70,534,603	3,742,575	14,399,824
1,020	23,749,099	68,617,402	2,755,383	16,009,802	23,398,622	67,817,148	3,289,715	13,946,963	70,619,608	3,740,907	14,398,156
1,030	23,720,678	68,702,387	2,753,779	16,008,198	23,369,178	67,905,290	3,280,393	13,937,641	70,704,593	3,739,273	14,396,522
1,040	23,692,224	68,787,348	2,752,206	16,006,625	23,339,697	67,993,346	3,271,262	13,928,510	70,789,554	3,737,672	14,394,921

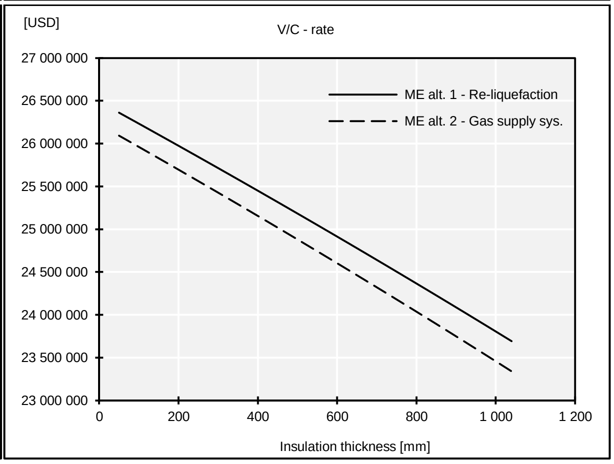





[USD]
CBS 2
Running cost
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys. alt. 1
ME alt. 2 - Gas supply sys. alt. 2
Boil-off rate [ton/day]


[USD]
CBS 2
Running cost
ME alt. 1 - Re-liquefaction
ME alt 2 - Gas supply sys. alt.1
Insulation thickness [mm]

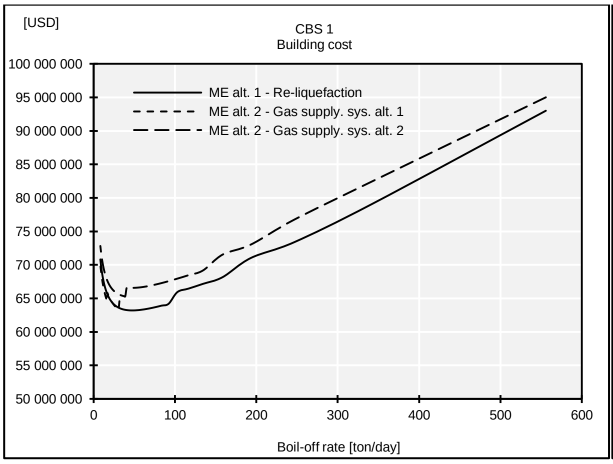

[USD]
V/C - rate
ME alt 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
Boil-off rate [ton/day]

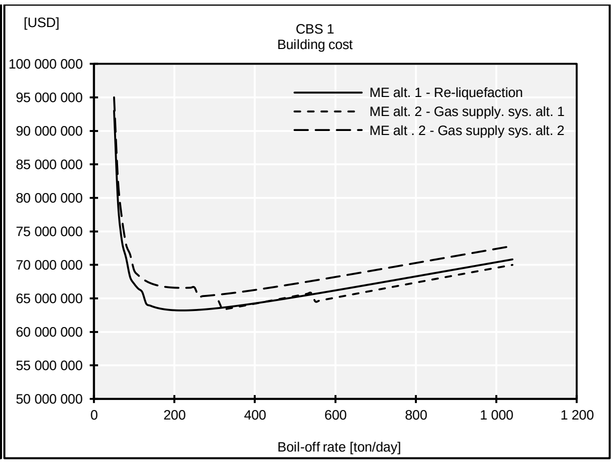

[USD]
V/C - rate
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
Insulation thickness [mm]

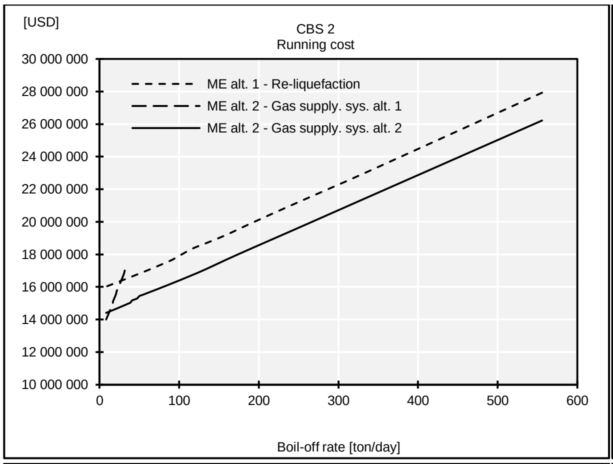
Insulation system 2

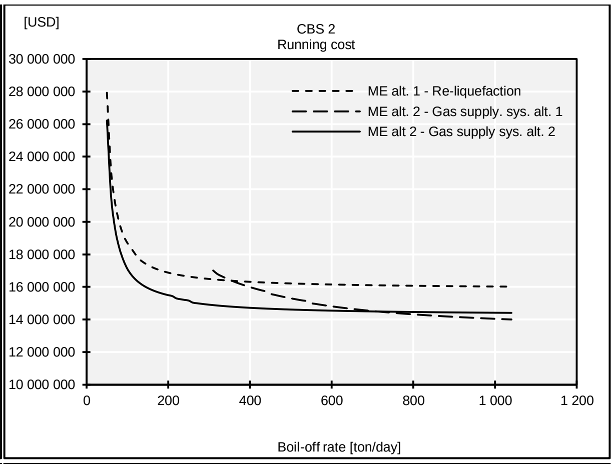
Insulation system 2												
Ins. thickness	ME alt. 1				ME alt. 2							
	Re-liquefaction					Gas supply alt. 1			Gas supply alt. 2			
	V/C-rate	CBS 1	CBS 2.3.2	CBS 2	V/C rate	CBS 1	CBS 2.3.2	CBS 2	CBS 1	CBS 2.3.2	CBS 2
t_{INS_TOT}		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$	$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$
[mm]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]
50	26,361,657	93,009,676	14,676,799	27,931,219	26,093,389				95,011,882	15,564,678	26,221,926
60	26,336,069	79,079,276	9,937,822	23,192,241	26,067,099				82,444,907	10,963,048	21,620,296
70	26,310,456	73,406,965	7,892,783	21,147,202	26,040,782				76,772,596	8,910,489	19,567,737
80	26,284,816	71,023,802	6,716,188	19,970,607	26,014,435				73,026,008	7,759,377	18,416,625
90	26,259,151	68,171,674	5,929,322	19,183,741	25,988,060				71,537,305	7,001,775	17,659,024
100	26,233,459	67,170,942	5,445,765	18,700,184	25,961,656				69,173,148	6,451,508	17,108,756
110	26,207,741	66,465,567	5,100,051	18,354,471	25,935,223				68,467,773	6,077,105	16,734,354
120	26,181,997	65,952,497	4,737,004	17,991,424	25,908,761				67,954,703	5,800,288	16,457,536
130	26,156,226	64,208,183	4,436,129	17,690,548	25,882,270				67,573,814	5,586,500	16,243,748
140	26,130,429	63,922,033	4,245,085	17,499,504	25,855,751				67,287,664	5,415,960	16,073,208
150	26,104,606	63,706,091	4,091,739	17,346,158	25,829,202				67,071,722	5,276,483	15,933,731
160	26,078,756	63,543,608	3,965,658	17,220,077	25,802,623				66,909,239	5,160,128	15,817,376
170	26,052,879	63,422,764	3,859,978	17,114,397	25,776,016				66,788,395	5,061,486	15,718,734
180	26,026,976	63,334,975	3,769,994	17,024,413	25,749,379				66,700,606	4,976,732	15,633,980
190	26,001,046	63,273,858	3,692,364	16,946,783	25,722,713				66,639,489	4,903,083	15,560,332
200	25,975,089	63,234,568	3,624,649	16,879,068	25,696,017				66,600,199	4,838,462	15,495,711
210	25,949,106	63,213,362	3,565,020	16,819,439	25,669,292				66,578,993	4,781,285	15,438,533
220	25,923,095	63,207,299	3,512,080	16,766,499	25,642,537				66,572,930	4,639,400	15,296,648
230	25,897,058	63,214,042	3,464,741	16,719,160	25,615,752				66,579,673	4,590,121	15,247,369
240	25,870,994	63,231,704	3,422,143	16,676,562	25,588,937				66,597,335	4,545,836	15,203,084
250	25,844,902	63,258,751	3,383,595	16,638,014	25,562,093				66,624,382	4,505,814	15,163,062
260	25,818,783	63,293,917	3,348,536	16,602,955	25,535,218				65,296,123	4,380,361	15,037,609
270	25,792,638	63,336,153	3,316,506	16,570,925	25,508,314				65,338,359	4,344,054	15,001,302
280	25,766,464	63,384,579	3,287,123	16,541,542	25,481,379				65,386,785	4,310,921	14,968,169
290	25,740,264	63,438,455	3,260,068	16,514,487	25,454,414				65,440,661	4,280,559	14,937,807
300	25,714,036	63,497,149	3,235,070	16,489,490	25,427,419				65,499,355	4,252,633	14,909,882
310	25,687,781	63,560,123	3,211,903	16,466,322	25,400,393	64,581,351	6,352,060	17,009,309	65,562,329	4,226,860	14,884,109
320	25,661,498	63,626,913	3,190,368	16,444,787	25,373,337	63,327,468	6,141,659	16,798,907	65,629,119	4,202,999	14,860,247
330	25,635,187	63,697,118	3,170,298	16,424,717	25,346,251	63,437,536	6,012,174	16,669,423	65,699,324	4,180,843	14,838,091
340	25,608,849	63,770,390	3,151,547	16,405,966	25,319,134	63,548,065	5,892,828	16,550,076	65,772,596	4,160,215	14,817,463
350	25,582,483	63,846,425	3,133,988	16,388,407	25,291,986	63,658,998	5,782,394	16,439,642	65,848,631	4,140,962	14,798,210
360	25,556,090	63,924,955	3,117,509	16,371,928	25,264,807	63,770,285	5,679,840	16,337,088	65,927,161	4,122,949	14,780,197
370	25,529,668	64,005,746	3,102,013	16,356,433	25,237,598	63,881,883	5,584,292	16,241,541	66,007,952	4,106,060	14,763,308
380	25,503,219	64,088,588	3,087,415	16,341,834	25,210,358	63,993,751	5,495,006	16,152,254	66,090,794	4,090,193	14,747,441
390	25,476,741	64,173,299	3,073,637	16,328,056	25,183,086	64,105,856	5,411,340	16,068,588	66,175,505	4,075,258	14,732,506
400	25,450,236	64,259,712	3,060,612	16,315,032	25,155,784	64,218,167	5,332,741	15,989,989	66,261,918	4,061,173	14,718,421
410	25,423,702	64,347,682	3,048,280	16,302,699	25,128,450	64,330,656	5,258,730	15,915,978	66,349,888	4,047,869	14,705,117
420	25,397,140	64,437,076	3,036,586	16,291,005	25,101,085	64,443,299	5,188,888	15,846,136	66,439,282	4,035,282	14,692,530
430	25,370,550	64,527,776	3,025,482	16,279,901	25,073,689	64,556,074	5,122,846	15,780,095	66,529,982	4,023,355	14,680,603
440	25,343,931	64,619,676	3,014,924	16,269,343	25,046,261	64,668,960	5,060,282	15,717,531	66,621,882	4,012,038	14,669,286
450	25,317,285	64,712,678	3,004,872	16,259,291	25,018,802	64,781,939	4,920,759	15,578,007	66,714,884	4,001,284	14,658,532
460	25,290,609	64,806,696	2,995,291	16,249,710	24,991,311	64,894,996	4,859,281	15,516,529	66,808,902	3,991,053	14,648,301
470	25,263,905	64,901,650	2,986,148	16,240,568	24,963,789	65,008,116	4,801,052	15,458,300	66,903,856	3,981,307	14,638,556
480	25,237,173	64,997,469	2,977,414	16,231,834	24,936,235	65,121,284	4,745,806	15,403,054	66,999,675	3,972,013	14,629,262
490	25,210,412	65,094,085	2,969,062	16,223,481	24,908,649	65,234,489	4,693,306	15,350,554	67,096,291	3,963,140	14,620,388
500	25,183,622	65,191,439	2,961,067	16,215,487	24,881,031	65,347,720	4,643,342	15,300,591	67,193,645	3,954,659	14,611,907
510	25,156,803	65,289,475	2,953,407	16,207,826	24,853,381	65,460,966	4,595,724	15,252,973	67,291,681	3,946,546	14,603,794
520	25,129,955	65,388,144	2,946,061	16,200,480	24,825,698	65,574,217	4,550,282	15,207,530	67,390,350	3,938,776	14,596,024
530	25,103,079	65,487,398	2,939,010	16,193,429	24,797,984	65,687,466	4,506,860	15,164,108	67,489,604	3,931,328	14,588,577
540	25,076,173	65,587,195	2,932,236	16,186,656	24,770,238	65,800,704	4,465,321	15,122,569	67,589,401	3,924,183	14,581,432
550	25,049,238	65,687,495	2,925,724	16,180,144	24,742,459	64,550,499	4,345,360	15,002,609	67,689,701	3,917,323	14,574,571
560	25,022,274	65,788,261	2,919,459	16,173,878	24,714,647	64,663,693	4,303,082	14,960,330	67,790,467	3,910,731	14,567,979
570	24,995,281	65,889,460	2,913,426	16,167,845	24,686,803	64,776,857	4,262,701	14,919,950	67,891,666	3,904,391	14,561,639
580	24,968,259	65,991,061	2,907,613	16,162,033	24,658,927	64,889,984	4,224,089	14,881,337	67,993,267	3,898,289	14,555,537
590	24,941,207	66,093,034	2,902,009	16,156,428	24,631,017	65,003,068	4,187,127	14,844,375	68,095,240	3,892,412	14,549,660
600	24,914,126	66,195,353	2,896,601	16,151,021	24,603,075	65,116,104	4,151,707	14,808,956	68,197,559	3,886,748	14,543,996
610	24,887,015	66,297,992	2,891,381	16,145,800	24,575,100	65,229,089	4,117,731	14,774,979	68,300,198	3,881,285	14,538,533
620	24,859,874	66,400,928	2,886,338	16,140,757	24,547,092	65,342,018	4,085,108	14,742,357	68,403,134	3,876,013	14,533,261

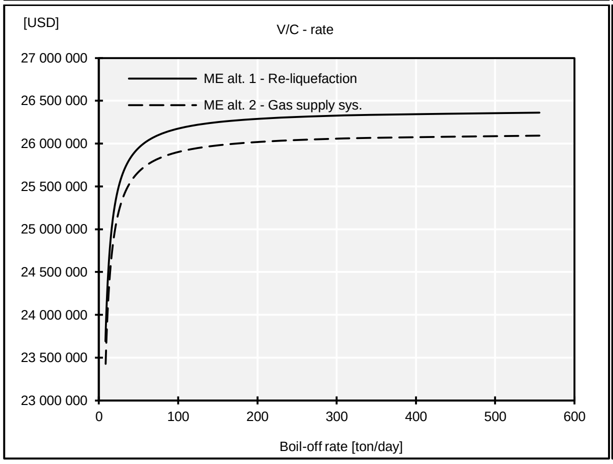
630	24,832,704	66,504,140	2,881,463	16,135,882	24,519,051	65,454,886	4,053,757	14,711,005	68,506,346	3,870,922	14,528,170
640	24,805,504	66,607,606	2,876,748	16,131,168	24,490,976	65,567,690	4,023,600	14,680,848	68,609,812	3,866,003	14,523,251
650	24,778,274	66,711,308	2,872,186	16,126,605	24,462,869	65,680,426	3,994,568	14,651,816	68,713,514	3,861,247	14,518,495
660	24,751,015	66,815,228	2,867,769	16,122,188	24,434,728	65,793,091	3,966,597	14,623,845	68,817,434	3,856,646	14,513,894
670	24,723,725	66,919,350	2,863,490	16,117,910	24,406,554	65,905,683	3,939,626	14,596,874	68,921,556	3,852,193	14,509,441
680	24,696,406	67,023,657	2,859,343	16,113,763	24,378,346	66,018,197	3,913,602	14,570,850	69,025,863	3,847,881	14,505,129
690	24,669,056	67,128,135	2,855,322	16,109,741	24,350,104	66,130,633	3,888,473	14,545,721	69,130,341	3,843,703	14,500,951
700	24,641,676	67,232,770	2,851,421	16,105,840	24,321,829	66,242,986	3,864,191	14,521,439	69,234,976	3,839,653	14,496,901
710	24,614,265	67,337,550	2,847,635	16,102,054	24,293,520	66,355,254	3,840,713	14,497,962	69,339,756	3,835,725	14,492,973
720	24,586,825	67,442,461	2,843,959	16,098,378	24,265,176	66,467,437	3,817,998	14,475,246	69,444,667	3,831,914	14,489,162
730	24,559,354	67,547,493	2,840,388	16,094,807	24,236,799	66,579,530	3,796,008	14,453,256	69,549,699	3,828,215	14,485,463
740	24,531,852	67,652,635	2,836,918	16,091,337	24,208,388	66,691,533	3,774,707	14,431,955	69,654,841	3,824,622	14,481,870
750	24,504,320	67,757,875	2,833,544	16,087,963	24,179,943	66,803,443	3,754,062	14,411,310	69,760,081	3,821,131	14,478,380
760	24,476,757	67,863,206	2,830,263	16,084,682	24,151,463	66,915,259	3,734,041	14,391,289	69,865,412	3,817,739	14,474,987
770	24,449,164	67,968,617	2,827,070	16,081,490	24,122,949	67,026,979	3,714,617	14,371,865	69,970,823	3,814,440	14,471,689
780	24,421,539	68,074,100	2,823,963	16,078,382	24,094,400	67,138,602	3,695,761	14,353,009	70,076,306	3,811,232	14,468,480
790	24,393,884	68,179,647	2,820,938	16,075,357	24,065,817	67,250,125	3,677,448	14,334,696	70,181,853	3,808,110	14,465,358
800	24,366,198	68,285,249	2,817,991	16,072,410	24,037,199	67,361,549	3,659,654	14,316,902	70,287,455	3,805,070	14,462,319
810	24,338,480	68,390,901	2,815,120	16,069,539	24,008,546	67,472,870	3,642,356	14,299,604	70,393,107	3,802,111	14,459,359
820	24,310,732	68,496,594	2,812,321	16,066,741	23,979,859	67,584,089	3,625,533	14,282,782	70,498,800	3,799,228	14,456,476
830	24,282,952	68,602,321	2,809,593	16,064,012	23,951,136	67,695,204	3,609,166	14,266,414	70,604,527	3,796,418	14,453,667
840	24,255,141	68,708,078	2,806,932	16,061,351	23,922,379	67,806,213	3,593,235	14,250,483	70,710,284	3,793,680	14,450,928
850	24,227,299	68,813,857	2,804,336	16,058,755	23,893,586	67,917,117	3,577,722	14,234,970	70,816,063	3,791,010	14,448,258
860	24,199,425	68,919,654	2,801,803	16,056,222	23,864,758	68,027,913	3,562,610	14,219,858	70,921,860	3,788,405	14,445,653
870	24,171,520	69,025,462	2,799,330	16,053,749	23,835,894	68,138,601	3,547,884	14,205,132	71,027,668	3,785,864	14,443,112
880	24,143,583	69,131,276	2,796,915	16,051,334	23,806,995	68,249,180	3,533,528	14,190,777	71,133,482	3,783,384	14,440,632
890	24,115,614	69,237,092	2,794,557	16,048,976	23,778,060	68,359,649	3,519,529	14,176,777	71,239,298	3,780,962	14,438,210
900	24,087,614	69,342,905	2,792,252	16,046,672	23,749,090	68,470,007	3,505,872	14,163,121	71,345,111	3,778,598	14,435,846
910	24,059,581	69,448,711	2,790,001	16,044,420	23,720,084	68,580,254	3,492,545	14,149,794	71,450,917	3,776,288	14,433,536
920	24,031,517	69,554,505	2,787,799	16,042,219	23,691,042	68,690,388	3,479,536	14,136,784	71,556,711	3,774,031	14,431,279
930	24,003,421	69,660,283	2,785,647	16,040,067	23,661,963	68,800,410	3,466,833	14,124,081	71,662,489	3,771,825	14,429,074
940	23,975,293	69,766,041	2,783,542	16,037,962	23,632,849	68,910,318	3,454,424	14,111,673	71,768,247	3,769,669	14,426,917
950	23,947,132	69,871,776	2,781,483	16,035,903	23,603,699	69,020,112	3,442,300	14,099,549	71,873,982	3,767,561	14,424,809
960	23,918,939	69,977,484	2,779,469	16,033,888	23,574,512	69,129,791	3,430,451	14,087,699	71,979,690	3,765,499	14,422,747
970	23,890,714	70,083,161	2,777,497	16,031,916	23,545,289	69,239,355	3,418,867	14,076,115	72,085,367	3,763,481	14,420,729
980	23,862,456	70,188,805	2,775,567	16,029,986	23,516,029	69,348,803	3,407,539	14,064,787	72,191,011	3,761,507	14,418,755
990	23,834,166	70,294,413	2,773,677	16,028,096	23,486,733	69,458,134	3,396,458	14,053,706	72,296,619	3,759,574	14,416,823
1,000	23,805,843	70,399,980	2,771,826	16,026,245	23,457,400	69,567,349	3,385,616	14,042,864	72,402,186	3,757,683	14,414,931
1,010	23,777,488	70,505,506	2,770,012	16,024,432	23,428,029	69,676,446	3,375,005	14,032,253	72,507,712	3,755,830	14,413,078
1,020	23,749,099	70,610,986	2,768,236	16,022,655	23,398,622	69,785,425	3,364,618	14,021,866	72,613,192	3,754,016	14,411,264
1,030	23,720,678	70,716,418	2,766,495	16,020,914	23,369,178	69,894,286	3,354,448	14,011,696	72,718,624	3,752,238	14,409,486
1,040	23,692,224	70,821,800	2,764,789	16,019,208	23,339,697	70,003,029	3,344,487	14,001,735	72,824,006	3,750,497	14,407,745

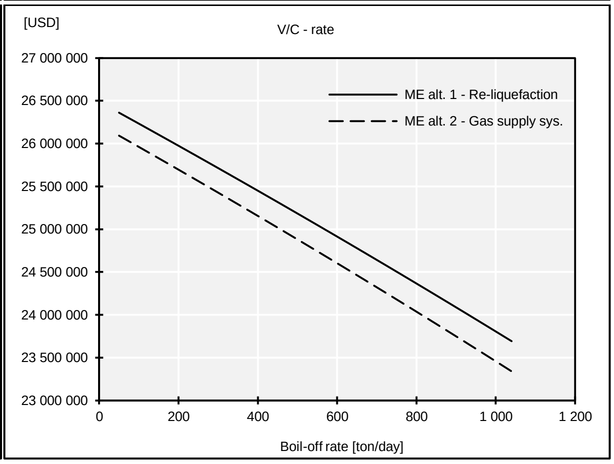





[USD]
CBS 2
Running cost
30 000 000
28 000 000
26 000 000
24 000 000
22 000 000
20 000 000
18 000 000
16 000 000
14 000 000
12 000 000
10 000 000
0
100
200
300
400
500
600
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply. sys. alt. 1
ME alt. 2 - Gas supply. sys. alt. 2
Boil-off rate [ton/day]


[USD]
CBS 2
Running cost
30 000 000
28 000 000
26 000 000
24 000 000
22 000 000
20 000 000
18 000 000
16 000 000
14 000 000
12 000 000
10 000 000
0
200
400
600
800
1 000
1 200
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply. sys. alt. 1
ME alt 2 - Gas supply sys. alt. 2
Boil-off rate [ton/day]

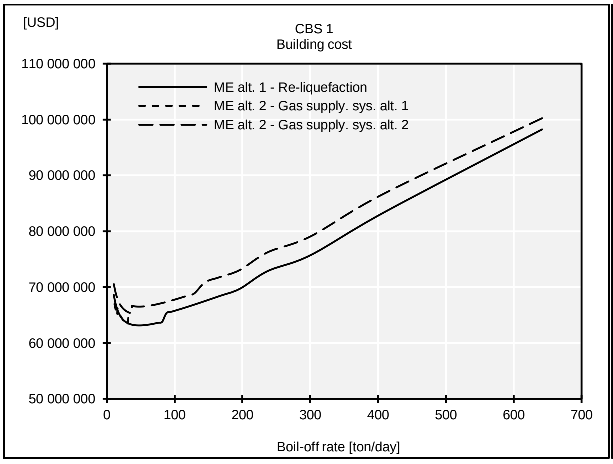

[USD]
V/C - rate
27 000 000
26 500 000
26 000 000
25 500 000
25 000 000
24 500 000
24 000 000
23 500 000
23 000 000
0
100
200
300
400
500
600
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
Boil-off rate [ton/day]

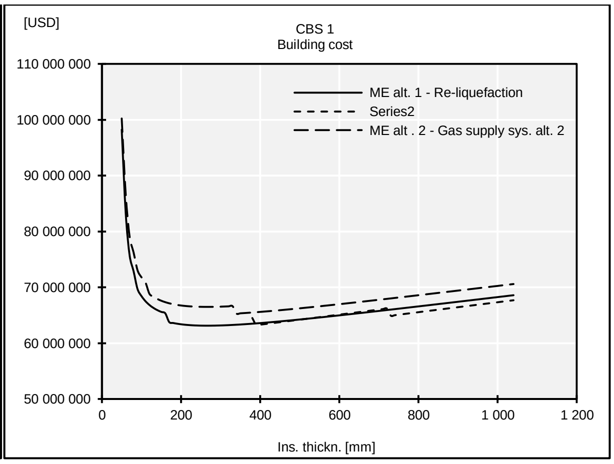

[USD]
V/C - rate
27 000 000
26 500 000
26 000 000
25 500 000
25 000 000
24 500 000
24 000 000
23 500 000
23 000 000
0
200
400
600
800
1 000
1 200
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
Boil-off rate [ton/day]

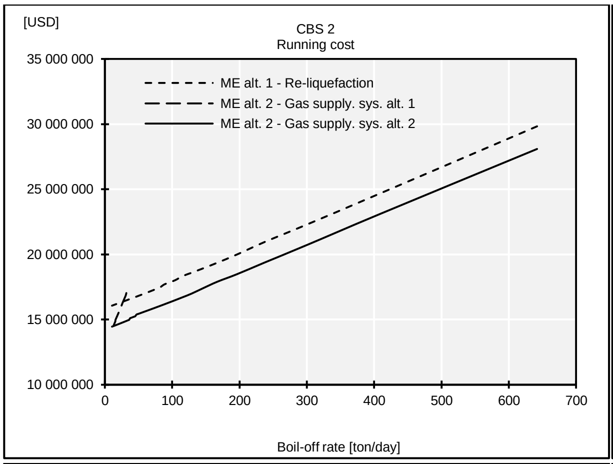
Insulation system 3

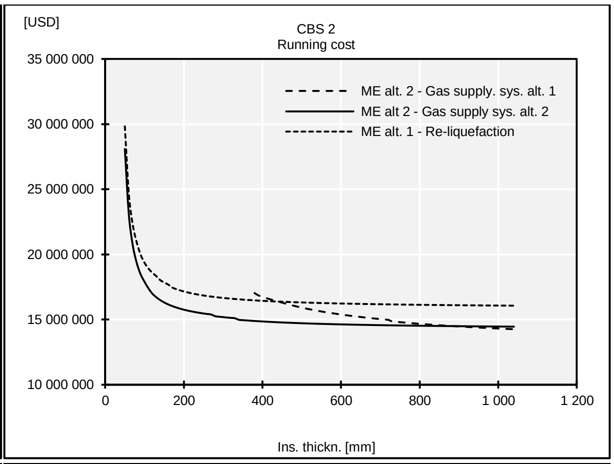
Insulation system 3											
	ME alt. 1				ME alt. 2						
Ins. thickness	Re-liquefaction					Gas supply alt. 1			Gas supply alt. 2		
	V/C-rate	CBS 1	CBS 2.3.2	CBS 2	V/C rate	CBS 1	CBS 2.3.2	CBS 2	CBS 1	CBS 2.3.2	CBS 2
t_{INS_TOT}		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$	$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$
[mm]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]
50	26,361,657	98,237,621	16,576,281	29,830,700	26,093,389				100,239,827	17,436,372	28,093,620
60	26,336,069	83,425,042	11,442,653	24,697,072	26,067,099				86,790,674	12,466,503	23,123,751
70	26,310,456	75,720,883	9,051,394	22,305,813	26,040,782				79,086,514	10,075,390	20,732,639
80	26,284,816	72,873,190	7,699,799	20,954,219	26,014,435				76,238,821	8,720,040	19,377,288
90	26,259,151	69,683,846	6,735,317	19,989,737	25,988,060				73,049,478	7,819,929	18,477,177
100	26,233,459	68,426,689	6,104,946	19,359,366	25,961,656				71,792,320	7,244,399	17,901,647
110	26,207,741	67,518,573	5,663,656	18,918,076	25,935,223				70,884,204	6,735,630	17,392,878
120	26,181,997	66,840,027	5,334,225	18,588,644	25,908,761				68,842,233	6,329,679	16,986,928
130	26,156,226	66,320,506	5,077,113	18,331,533	25,882,270				68,322,712	6,052,606	16,709,854
140	26,130,429	65,915,671	4,770,662	18,025,081	25,855,751				67,917,877	5,833,259	16,490,507
150	26,104,606	65,596,257	4,588,618	17,843,037	25,829,202				67,598,463	5,654,874	16,312,122
160	26,078,756	65,342,168	4,437,412	17,691,831	25,802,623				67,344,374	5,506,686	16,163,934
170	26,052,879	63,775,719	4,206,910	17,461,329	25,776,016				67,141,350	5,381,450	16,038,699
180	26,026,976	63,613,366	4,089,143	17,343,562	25,749,379				66,978,997	5,274,102	15,931,350
190	26,001,046	63,483,926	3,988,142	17,242,561	25,722,713				66,849,557	5,180,986	15,838,234
200	25,975,089	63,381,489	3,900,465	17,154,884	25,696,017				66,747,120	5,099,393	15,756,642
210	25,949,106	63,301,480	3,823,566	17,077,985	25,669,292				66,667,111	5,027,272	15,684,521
220	25,923,095	63,240,296	3,755,520	17,009,940	25,642,537				66,605,927	4,963,037	15,620,285
230	25,897,058	63,195,063	3,694,842	16,949,262	25,615,752				66,560,694	4,905,442	15,562,690
240	25,870,994	63,163,463	3,640,367	16,894,786	25,588,937				66,529,095	4,853,493	15,510,741
250	25,844,902	63,143,603	3,591,167	16,845,586	25,562,093				66,509,234	4,806,387	15,463,636
260	25,818,783	63,133,920	3,546,494	16,800,913	25,535,218				66,499,551	4,763,471	15,420,719
270	25,792,638	63,133,118	3,505,736	16,760,156	25,508,314				66,498,749	4,724,201	15,381,450
280	25,766,464	63,140,107	3,468,392	16,722,811	25,481,379				66,505,738	4,593,919	15,251,167
290	25,740,264	63,153,969	3,434,040	16,688,459	25,454,414				66,519,600	4,558,198	15,215,446
300	25,714,036	63,173,922	3,402,328	16,656,747	25,427,419				66,539,553	4,525,256	15,182,504
310	25,687,781	63,199,295	3,372,957	16,627,377	25,400,393				66,564,926	4,494,779	15,152,028
320	25,661,498	63,229,514	3,345,675	16,600,094	25,373,337				66,595,145	4,466,498	15,123,747
330	25,635,187	63,264,078	3,320,261	16,574,680	25,346,251				66,629,709	4,440,182	15,097,430
340	25,608,849	63,302,555	3,296,528	16,550,947	25,319,134				65,304,761	4,321,508	14,978,756
350	25,582,483	63,344,564	3,274,311	16,528,730	25,291,986				65,346,770	4,296,526	14,953,774
360	25,556,090	63,389,773	3,253,469	16,507,888	25,264,807				65,391,979	4,273,175	14,930,423
370	25,529,668	63,437,888	3,233,875	16,488,294	25,237,598				65,440,094	4,251,301	14,908,549
380	25,503,219	63,488,649	3,215,420	16,469,839	25,210,358	64,502,897	6,373,358	17,030,607	65,490,855	4,230,766	14,888,015
390	25,476,741	63,541,826	3,198,006	16,452,425	25,183,086	63,227,216	6,191,435	16,848,683	65,544,032	4,211,451	14,868,700
400	25,450,236	63,597,213	3,181,546	16,435,965	25,155,784	63,315,289	6,084,509	16,741,757	65,599,419	4,193,250	14,850,498
410	25,423,702	63,654,626	3,165,963	16,420,382	25,128,450	63,403,657	5,984,446	16,641,694	65,656,832	4,176,068	14,833,316
420	25,397,140	63,713,901	3,151,188	16,405,608	25,101,085	63,492,289	5,890,559	16,547,807	65,716,107	4,159,821	14,817,069
430	25,370,550	63,774,889	3,137,160	16,391,579	25,073,689	63,581,156	5,802,255	16,459,503	65,777,095	4,144,435	14,801,684
440	25,343,931	63,837,456	3,123,822	16,378,242	25,046,261	63,670,235	5,719,012	16,376,261	65,839,662	4,129,844	14,787,092
450	25,317,285	63,901,482	3,111,125	16,365,545	25,018,802	63,759,503	5,640,291	16,297,539	65,903,688	4,115,986	14,773,234
460	25,290,609	63,966,856	3,099,023	16,353,443	24,991,311	63,848,938	5,554,356	16,211,605	65,969,062	4,102,807	14,760,055
470	25,263,905	64,033,480	3,087,475	16,341,895	24,963,789	63,938,523	5,473,402	16,130,650	66,035,686	4,090,259	14,747,507
480	25,237,173	64,101,263	3,076,444	16,330,863	24,936,235	64,028,240	5,396,988	16,054,236	66,103,469	4,078,297	14,735,545
490	25,210,412	64,170,122	3,065,894	16,320,314	24,908,649	64,118,074	5,324,724	15,981,973	66,172,328	4,066,881	14,724,129
500	25,183,622	64,239,981	3,055,796	16,310,216	24,881,031	64,208,011	5,256,266	15,913,514	66,242,187	4,055,974	14,713,222
510	25,156,803	64,310,770	3,046,121	16,300,540	24,853,381	64,298,038	5,191,303	15,848,551	66,312,977	4,045,543	14,702,791
520	25,129,955	64,382,428	3,036,842	16,291,261	24,825,698	64,388,143	5,129,563	15,786,811	66,384,634	4,035,557	14,692,805
530	25,103,079	64,454,894	3,027,935	16,282,354	24,797,984	64,478,315	5,070,797	15,728,045	66,457,100	4,025,988	14,683,236
540	25,076,173	64,528,115	3,019,379	16,273,798	24,770,238	64,568,543	5,014,784	15,672,032	66,530,321	4,016,810	14,674,059
550	25,049,238	64,602,041	3,011,153	16,265,572	24,742,459	64,658,820	4,961,324	15,618,573	66,604,247	4,008,001	14,665,249
560	25,022,274	64,676,627	3,003,238	16,257,657	24,714,647	64,749,136	4,910,238	15,567,486	66,678,833	3,999,538	14,656,786
570	24,995,281	64,751,829	2,995,616	16,250,036	24,686,803	64,839,483	4,861,361	15,518,609	66,754,035	3,991,400	14,648,648
580	24,968,259	64,827,609	2,988,273	16,242,692	24,658,927	64,929,854	4,814,544	15,471,793	66,829,815	3,983,570	14,640,819
590	24,941,207	64,903,929	2,981,192	16,235,611	24,631,017	65,020,241	4,769,654	15,426,902	66,906,135	3,976,031	14,633,279
600	24,914,126	64,980,756	2,974,359	16,228,779	24,603,075	65,110,640	4,726,565	15,383,814	66,982,962	3,968,766	14,626,014
610	24,887,015	65,058,059	2,967,763	16,222,182	24,575,100	65,201,044	4,685,167	15,342,415	67,060,265	3,961,761	14,619,009

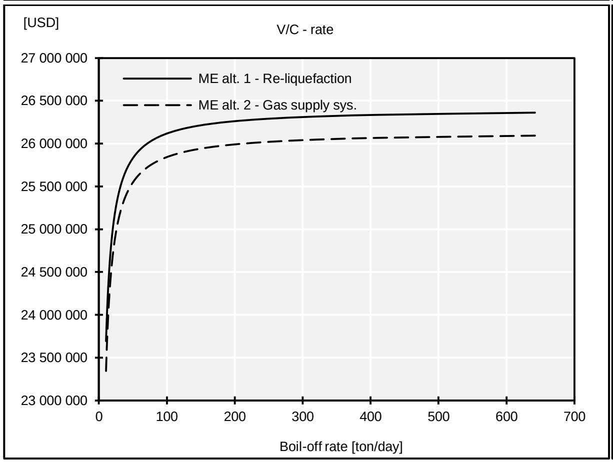
620	24,859,874	65,135,807	2,961,390	16,215,809	24,547,092	65,291,447	4,645,355	15,302,603	67,138,013	3,955,001	14,612,250
630	24,832,704	65,213,973	2,955,230	16,209,649	24,519,051	65,381,844	4,607,034	15,264,283	67,216,179	3,948,475	14,605,724
640	24,805,504	65,292,531	2,949,272	16,203,691	24,490,976	65,472,231	4,570,119	15,227,367	67,294,737	3,942,171	14,599,419
650	24,778,274	65,371,458	2,943,506	16,197,925	24,462,869	65,562,602	4,534,527	15,191,775	67,373,664	3,936,076	14,593,324
660	24,751,015	65,450,731	2,937,923	16,192,343	24,434,728	65,652,955	4,500,186	15,157,434	67,452,937	3,930,182	14,587,430
670	24,723,725	65,530,329	2,932,515	16,186,934	24,406,554	65,743,285	4,467,027	15,124,275	67,532,535	3,924,477	14,581,726
680	24,696,406	65,610,231	2,927,273	16,181,692	24,378,346	65,833,588	4,434,986	15,092,234	67,612,437	3,918,954	14,576,202
690	24,669,056	65,690,420	2,922,190	16,176,609	24,350,104	65,923,860	4,404,005	15,061,253	67,692,626	3,913,603	14,570,852
700	24,641,676	65,770,879	2,917,259	16,171,678	24,321,829	66,014,100	4,374,029	15,031,277	67,773,085	3,908,418	14,565,666
710	24,614,265	65,851,589	2,912,472	16,166,891	24,293,520	66,104,303	4,345,007	15,002,255	67,853,795	3,903,389	14,560,637
720	24,586,825	65,932,537	2,907,824	16,162,243	24,265,176	66,194,467	4,316,892	14,974,141	67,934,743	3,898,510	14,555,758
730	24,559,354	66,013,708	2,903,309	16,157,728	24,236,799	64,921,164	4,195,680	14,852,928	68,015,914	3,893,775	14,551,023
740	24,531,852	66,095,088	2,898,921	16,153,340	24,208,388	65,011,241	4,166,873	14,824,121	68,097,294	3,889,177	14,546,425
750	24,504,320	66,176,663	2,894,655	16,149,074	24,179,943	65,101,272	4,139,013	14,796,262	68,178,869	3,884,710	14,541,958
760	24,476,757	66,258,422	2,890,505	16,144,924	24,151,463	65,191,254	4,112,053	14,769,301	68,260,628	3,880,369	14,537,617
770	24,449,164	66,340,353	2,886,468	16,140,887	24,122,949	65,281,184	4,085,947	14,743,196	68,342,559	3,876,149	14,533,397
780	24,421,539	66,422,445	2,882,538	16,136,957	24,094,400	65,371,062	4,060,654	14,717,903	68,424,651	3,872,044	14,529,292
790	24,393,884	66,504,688	2,878,711	16,133,130	24,065,817	65,460,884	4,036,135	14,693,384	68,506,894	3,868,050	14,525,298
800	24,366,198	66,587,071	2,874,984	16,129,403	24,037,199	65,550,649	4,012,354	14,669,602	68,589,277	3,864,163	14,521,411
810	24,338,480	66,669,587	2,871,352	16,125,771	24,008,546	65,640,356	3,989,275	14,646,523	68,671,793	3,860,378	14,517,626
820	24,310,732	66,752,224	2,867,812	16,122,231	23,979,859	65,730,002	3,966,868	14,624,116	68,754,430	3,856,691	14,513,939
830	24,282,952	66,834,976	2,864,360	16,118,780	23,951,136	65,819,587	3,945,101	14,602,349	68,837,182	3,853,098	14,510,347
840	24,255,141	66,917,835	2,860,994	16,115,413	23,922,379	65,909,109	3,923,947	14,581,195	68,920,041	3,849,597	14,506,845
850	24,227,299	67,000,792	2,857,709	16,112,129	23,893,586	65,998,566	3,903,379	14,560,628	69,002,998	3,846,183	14,503,431
860	24,199,425	67,083,840	2,854,504	16,108,923	23,864,758	66,087,957	3,883,372	14,540,621	69,086,046	3,842,853	14,500,101
870	24,171,520	67,166,973	2,851,375	16,105,794	23,835,894	66,177,281	3,863,903	14,521,151	69,169,179	3,839,605	14,496,853
880	24,143,583	67,250,184	2,848,319	16,102,738	23,806,995	66,266,536	3,844,948	14,502,197	69,252,390	3,836,434	14,493,683
890	24,115,614	67,333,467	2,845,334	16,099,754	23,778,060	66,355,723	3,826,488	14,483,736	69,335,673	3,833,340	14,490,588
900	24,087,614	67,416,816	2,842,418	16,096,838	23,749,090	66,444,838	3,808,501	14,465,750	69,419,022	3,830,318	14,487,566
910	24,059,581	67,500,225	2,839,568	16,093,988	23,720,084	66,533,883	3,790,971	14,448,219	69,502,431	3,827,366	14,484,614
920	24,031,517	67,583,689	2,836,782	16,091,202	23,691,042	66,622,854	3,773,877	14,431,125	69,585,895	3,824,482	14,481,730
930	24,003,421	67,667,202	2,834,058	16,088,477	23,661,963	66,711,753	3,757,204	14,414,453	69,669,408	3,821,663	14,478,912
940	23,975,293	67,750,760	2,831,394	16,085,813	23,632,849	66,800,577	3,740,936	14,398,185	69,752,966	3,818,908	14,476,156
950	23,947,132	67,834,357	2,828,787	16,083,207	23,603,699	66,889,326	3,725,058	14,382,306	69,836,563	3,816,214	14,473,463
960	23,918,939	67,917,991	2,826,237	16,080,656	23,574,512	66,977,999	3,709,555	14,366,803	69,920,197	3,813,580	14,470,828
970	23,890,714	68,001,655	2,823,741	16,078,160	23,545,289	67,066,596	3,694,413	14,351,661	70,003,861	3,811,002	14,468,250
980	23,862,456	68,085,346	2,821,297	16,075,716	23,516,029	67,155,115	3,679,619	14,336,868	70,087,552	3,808,480	14,465,728
990	23,834,166	68,169,060	2,818,904	16,073,323	23,486,733	67,243,556	3,665,162	14,322,410	70,171,266	3,806,012	14,463,260
1,000	23,805,843	68,252,793	2,816,560	16,070,979	23,457,400	67,331,918	3,651,029	14,308,278	70,254,999	3,803,595	14,460,844
1,010	23,777,488	68,336,542	2,814,264	16,068,684	23,428,029	67,420,201	3,637,210	14,294,458	70,338,748	3,801,229	14,458,477
1,020	23,749,099	68,420,303	2,812,015	16,066,434	23,398,622	67,508,403	3,623,692	14,280,941	70,422,509	3,798,912	14,456,160
1,030	23,720,678	68,504,072	2,809,810	16,064,229	23,369,178	67,596,526	3,610,467	14,267,716	70,506,278	3,796,642	14,453,890
1,040	23,692,224	68,587,847	2,807,649	16,062,069	23,339,697	67,684,567	3,597,525	14,254,773	70,590,053	3,794,418	14,451,666

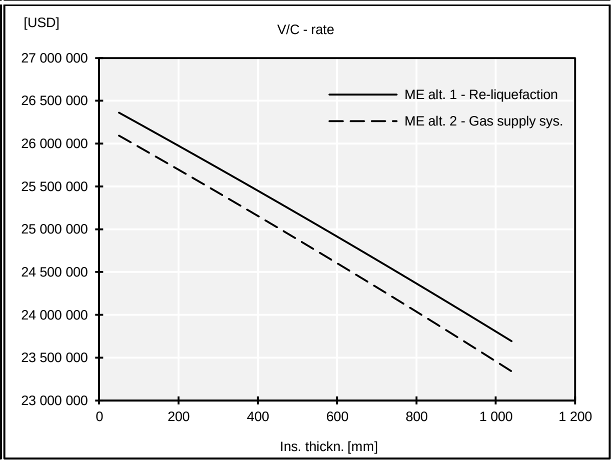





[USD]
CBS 2
Running cost
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply. sys. alt. 1
ME alt. 2 - Gas supply. sys. alt. 2
35 000 000
30 000 000
25 000 000
20 000 000
15 000 000
10 000 000
0
100
200
300
400
500
600
700
Boil-off rate [ton/day]


[USD]
CBS 2
Running cost
ME alt. 2 - Gas supply. sys. alt. 1
ME alt 2 - Gas supply sys. alt. 2
ME alt. 1 - Re-liquefaction
35 000 000
30 000 000
25 000 000
20 000 000
15 000 000
10 000 000
0
200
400
600
800
1 000
1 200
Ins. thickn. [mm]

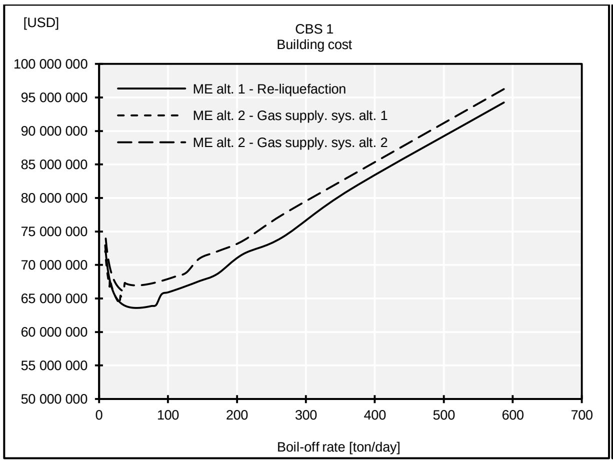

[USD]
V/C - rate
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
27 000 000
26 500 000
26 000 000
25 500 000
25 000 000
24 500 000
24 000 000
23 500 000
23 000 000
0
100
200
300
400
500
600
700
Boil-off rate [ton/day]

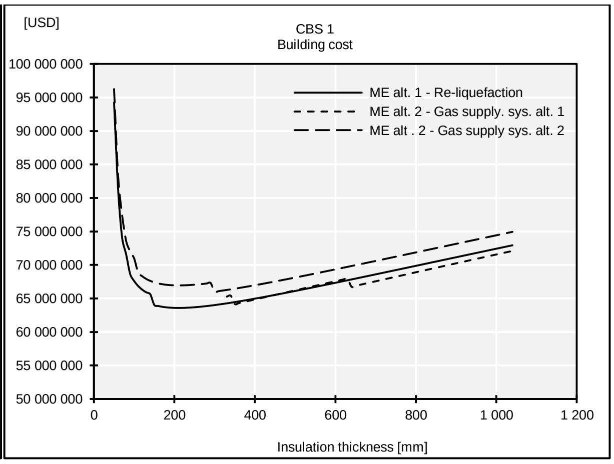

[USD]
V/C - rate
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
27 000 000
26 500 000
26 000 000
25 500 000
25 000 000
24 500 000
24 000 000
23 500 000
23 000 000
0
200
400
600
800
1 000
1 200
Ins. thickn. [mm]

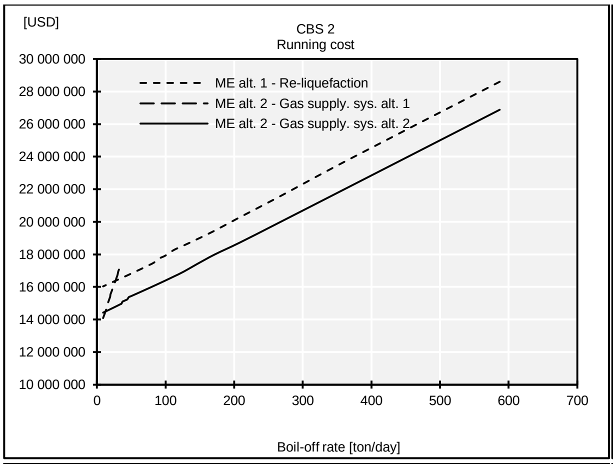
Insulation system 4

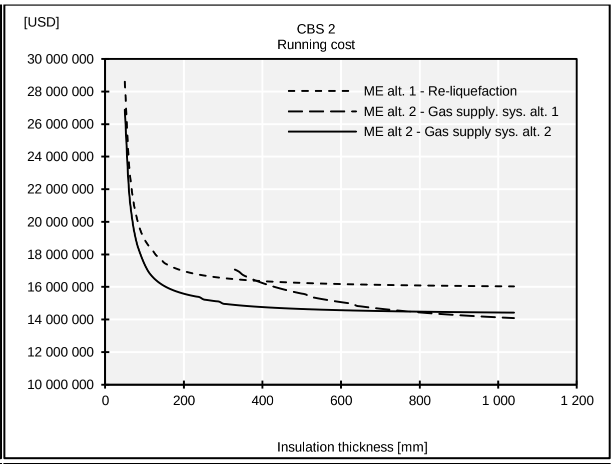
Insulation system 4											
Ins. thickness	ME alt. 1				ME alt. 2						
	Re-liquefaction					Gas supply alt. 1			Gas supply alt. 2		
	V/C-rate	CBS 1	CBS 2.3.2	CBS 2	V/C rate	CBS 1	CBS 2.3.2	CBS 2	CBS 1	CBS 2.3.2	CBS 2
t_{INS_TOT} [mm]	[USD/year]	$C_{BUILDING\_TOT}$ [USD]	C_{VOY_VAR} [USD/year]	$C_{RUNNING}$ [USD/year]	[USD/year]	$C_{BUILDING\_TOT}$ [USD]	C_{VOY_VAR} [USD/year]	$C_{RUNNING}$ [USD/year]	$C_{BUILDING\_TOT}$ [USD]	C_{VOY_VAR} [USD/year]	$C_{RUNNING}$ [USD/year]
50	26,361,657	94,247,921	15,349,688	28,604,107	26,093,389				96,250,127	16,226,726	26,883,974
60	26,336,069	81,367,155	10,548,295	23,802,714	26,067,099				83,369,361	11,456,627	22,113,875
70	26,310,456	74,117,480	8,285,925	21,540,345	26,040,782				77,483,111	9,297,597	19,954,845
80	26,284,816	71,599,352	7,031,244	20,285,663	26,014,435				73,601,558	8,073,706	18,730,954
90	26,259,151	68,659,580	6,200,687	19,455,106	25,988,060				72,025,211	7,333,130	17,990,378
100	26,233,459	67,600,624	5,669,563	18,923,982	25,961,656				70,966,255	6,741,551	17,398,799
110	26,207,741	66,856,325	5,292,450	18,546,869	25,935,223				68,858,531	6,284,299	16,941,547
120	26,181,997	66,317,605	5,008,255	18,262,674	25,908,761				68,319,811	5,979,325	16,636,573
130	26,156,226	65,920,561	4,680,160	17,934,579	25,882,270				67,922,767	5,744,590	16,401,838
140	26,130,429	65,625,272	4,489,568	17,743,988	25,855,751				67,627,478	5,557,797	16,215,045
150	26,104,606	64,042,087	4,233,273	17,487,692	25,829,202				67,407,718	5,405,297	16,062,545
160	26,078,756	63,879,920	4,093,660	17,348,079	25,802,623				67,245,551	5,278,244	15,935,492
170	26,052,879	63,762,660	3,976,976	17,231,395	25,776,016				67,128,291	5,170,633	15,827,881
180	26,026,976	63,681,083	3,877,852	17,132,271	25,749,379				67,046,714	5,078,239	15,735,487
190	26,001,046	63,628,324	3,792,498	17,046,917	25,722,713				66,993,955	4,997,992	15,655,240
200	25,975,089	63,599,164	3,718,159	16,972,578	25,696,017				66,964,795	4,927,608	15,584,856
210	25,949,106	63,589,566	3,652,779	16,907,198	25,669,292				66,955,197	4,865,348	15,522,597
220	25,923,095	63,596,360	3,594,793	16,849,212	25,642,537				66,961,991	4,809,865	15,467,113
230	25,897,058	63,617,021	3,542,986	16,797,406	25,615,752				66,982,652	4,760,096	15,417,344
240	25,870,994	63,649,511	3,496,400	16,750,820	25,588,937				67,015,142	4,715,191	15,372,439
250	25,844,902	63,692,170	3,454,268	16,708,688	25,562,093				67,057,801	4,579,228	15,236,476
260	25,818,783	63,743,630	3,415,969	16,670,388	25,535,218				67,109,261	4,539,422	15,196,670
270	25,792,638	63,802,757	3,380,992	16,635,412	25,508,314				67,168,388	4,503,114	15,160,362
280	25,766,464	63,868,597	3,348,918	16,603,337	25,481,379				67,234,228	4,469,859	15,127,107
290	25,740,264	63,940,348	3,319,392	16,573,812	25,454,414				67,305,979	4,439,283	15,096,532
300	25,714,036	64,017,326	3,292,120	16,546,539	25,427,419				66,019,532	4,316,544	14,973,792
310	25,687,781	64,098,948	3,266,848	16,521,267	25,400,393				66,101,154	4,288,155	14,945,403
320	25,661,498	64,184,710	3,243,362	16,497,781	25,373,337				66,186,916	4,261,883	14,919,131
330	25,635,187	64,274,179	3,221,477	16,475,896	25,346,251	65,276,408	6,410,099	17,067,347	66,276,385	4,237,498	14,894,747
340	25,608,849	64,366,976	3,201,032	16,455,451	25,319,134	65,409,783	6,286,404	16,943,652	66,369,182	4,214,804	14,872,052
350	25,582,483	64,462,771	3,181,888	16,436,307	25,291,986	64,180,166	6,086,721	16,743,969	66,464,977	4,193,628	14,850,876
360	25,556,090	64,561,274	3,163,924	16,418,343	25,264,807	64,314,354	5,971,435	16,628,683	66,563,480	4,173,823	14,831,072
370	25,529,668	64,662,229	3,147,033	16,401,452	25,237,598	64,448,874	5,864,320	16,521,569	66,664,435	4,155,260	14,812,508
380	25,503,219	64,765,412	3,131,121	16,385,540	25,210,358	64,583,684	5,764,478	16,421,726	66,767,618	4,137,824	14,795,072
390	25,476,741	64,870,620	3,116,104	16,370,523	25,183,086	64,718,745	5,671,139	16,328,387	66,872,826	4,121,415	14,778,663
400	25,450,236	64,977,677	3,101,908	16,356,327	25,155,784	64,854,025	5,583,643	16,240,891	66,979,883	4,105,945	14,763,193
410	25,423,702	65,086,422	3,088,467	16,342,886	25,128,450	64,989,493	5,501,417	16,158,665	67,088,628	4,091,335	14,748,583
420	25,397,140	65,196,711	3,075,722	16,330,141	25,101,085	65,125,123	5,423,965	16,081,213	67,198,917	4,077,515	14,734,763
430	25,370,550	65,308,417	3,063,620	16,318,039	25,073,689	65,260,892	5,350,852	16,008,100	67,310,623	4,064,423	14,721,671
440	25,343,931	65,421,423	3,052,113	16,306,533	25,046,261	65,396,776	5,281,696	15,938,944	67,423,629	4,052,001	14,709,250
450	25,317,285	65,535,625	3,041,159	16,295,578	25,018,802	65,532,757	5,216,162	15,873,410	67,537,831	4,040,201	14,697,449
460	25,290,609	65,650,927	3,030,717	16,285,136	24,991,311	65,668,817	5,153,952	15,811,200	67,653,133	4,028,975	14,686,223
470	25,263,905	65,767,243	3,020,753	16,275,172	24,963,789	65,804,940	5,094,800	15,752,049	67,769,449	4,018,284	14,675,532
480	25,237,173	65,884,495	3,011,235	16,265,654	24,936,235	65,941,111	5,038,472	15,695,720	67,886,701	4,008,089	14,665,337
490	25,210,412	66,002,610	3,002,132	16,256,551	24,908,649	66,077,316	4,984,755	15,642,004	68,004,816	3,998,356	14,655,605
500	25,183,622	66,121,524	2,993,419	16,247,838	24,881,031	66,213,544	4,933,461	15,590,709	68,123,730	3,989,056	14,646,304
510	25,156,803	66,241,176	2,985,070	16,239,489	24,853,381	66,349,783	4,884,416	15,541,665	68,243,382	3,980,159	14,637,407
520	25,129,955	66,361,512	2,977,064	16,231,483	24,825,698	66,486,024	4,743,594	15,400,842	68,363,718	3,971,640	14,628,889
530	25,103,079	66,482,480	2,969,378	16,223,798	24,797,984	66,622,256	4,695,288	15,352,537	68,484,686	3,963,476	14,620,724
540	25,076,173	66,604,034	2,961,996	16,216,415	24,770,238	66,758,471	4,649,131	15,306,379	68,606,240	3,955,643	14,612,892
550	25,049,238	66,726,131	2,954,898	16,209,317	24,742,459	66,894,661	4,604,973	15,262,221	68,728,337	3,948,124	14,605,372
560	25,022,274	66,848,731	2,948,069	16,202,488	24,714,647	67,030,819	4,562,680	15,219,928	68,850,937	3,940,898	14,598,146
570	24,995,281	66,971,798	2,941,493	16,195,912	24,686,803	67,166,937	4,522,131	15,179,379	68,974,004	3,933,950	14,591,198
580	24,968,259	67,095,297	2,935,157	16,189,576	24,658,927	67,303,010	4,483,212	15,140,461	69,097,503	3,927,263	14,584,511
590	24,941,207	67,219,197	2,929,048	16,183,467	24,631,017	67,439,032	4,445,824	15,103,072	69,221,403	3,920,823	14,578,072
600	24,914,126	67,343,468	2,923,153	16,177,573	24,603,075	67,574,997	4,409,871	15,067,119	69,345,674	3,914,617	14,571,865
610	24,887,015	67,468,083	2,917,463	16,171,882	24,575,100	67,710,900	4,375,268	15,032,517	69,470,289	3,908,632	14,565,880

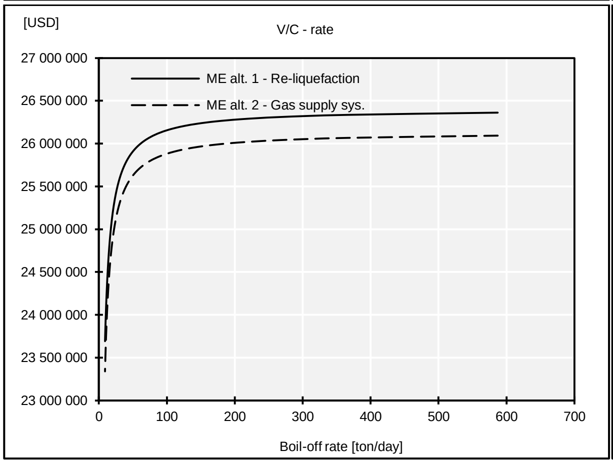
620	24,859,874	67,593,017	2,911,965	16,166,384	24,547,092	67,846,736	4,341,938	14,999,186	69,595,223	3,902,856	14,560,105
630	24,832,704	67,718,246	2,906,651	16,161,070	24,519,051	67,982,502	4,309,806	14,967,054	69,720,452	3,897,279	14,554,527
640	24,805,504	67,843,748	2,901,511	16,155,931	24,490,976	66,754,767	4,183,860	14,841,108	69,845,954	3,891,891	14,549,139
650	24,778,274	67,969,501	2,896,538	16,150,957	24,462,869	66,890,379	4,151,293	14,808,541	69,971,707	3,886,681	14,543,929
660	24,751,015	68,095,488	2,891,722	16,146,142	24,434,728	67,025,908	4,119,947	14,777,195	70,097,694	3,881,642	14,538,890
670	24,723,725	68,221,688	2,887,057	16,141,477	24,406,554	67,161,351	4,089,752	14,747,000	70,223,894	3,876,765	14,534,013
680	24,696,406	68,348,086	2,882,536	16,136,955	24,378,346	67,296,706	4,060,643	14,717,891	70,350,292	3,872,042	14,529,290
690	24,669,056	68,474,665	2,878,152	16,132,571	24,350,104	67,431,969	4,032,561	14,689,809	70,476,871	3,867,467	14,524,715
700	24,641,676	68,601,410	2,873,899	16,128,318	24,321,829	67,567,137	4,005,448	14,662,696	70,603,616	3,863,031	14,520,280
710	24,614,265	68,728,308	2,869,771	16,124,190	24,293,520	67,702,208	3,979,255	14,636,503	70,730,514	3,858,730	14,515,978
720	24,586,825	68,855,344	2,865,762	16,120,182	24,265,176	67,837,180	3,953,932	14,611,180	70,857,550	3,854,557	14,511,805
730	24,559,354	68,982,507	2,861,869	16,116,288	24,236,799	67,972,050	3,929,436	14,586,684	70,984,713	3,850,506	14,507,755
740	24,531,852	69,109,784	2,858,085	16,112,504	24,208,388	68,106,816	3,905,725	14,562,973	71,111,990	3,846,573	14,503,821
750	24,504,320	69,237,165	2,854,406	16,108,825	24,179,943	68,241,476	3,882,760	14,540,008	71,239,371	3,842,751	14,499,999
760	24,476,757	69,364,638	2,850,828	16,105,247	24,151,463	68,376,028	3,860,505	14,517,753	71,366,844	3,839,037	14,496,285
770	24,449,164	69,492,194	2,847,346	16,101,766	24,122,949	68,510,470	3,838,926	14,496,174	71,494,400	3,835,426	14,492,674
780	24,421,539	69,619,823	2,843,958	16,098,377	24,094,400	68,644,801	3,817,991	14,475,240	71,622,029	3,831,913	14,489,161
790	24,393,884	69,747,517	2,840,659	16,095,078	24,065,817	68,779,019	3,797,672	14,454,920	71,749,723	3,828,495	14,485,743
800	24,366,198	69,875,266	2,837,445	16,091,864	24,037,199	68,913,122	3,777,939	14,435,188	71,877,472	3,825,168	14,482,416
810	24,338,480	70,003,064	2,834,314	16,088,733	24,008,546	69,047,109	3,758,768	14,416,016	72,005,270	3,821,928	14,479,176
820	24,310,732	70,130,902	2,831,262	16,085,681	23,979,859	69,180,980	3,740,133	14,397,381	72,133,108	3,818,772	14,476,020
830	24,282,952	70,258,773	2,828,287	16,082,706	23,951,136	69,314,731	3,722,011	14,379,259	72,260,979	3,815,697	14,472,945
840	24,255,141	70,386,670	2,825,384	16,079,804	23,922,379	69,448,363	3,704,381	14,361,629	72,388,876	3,812,699	14,469,948
850	24,227,299	70,514,587	2,822,553	16,076,972	23,893,586	69,581,874	3,687,222	14,344,470	72,516,793	3,809,777	14,467,025
860	24,199,425	70,642,518	2,819,790	16,074,209	23,864,758	69,715,263	3,670,514	14,327,762	72,644,724	3,806,926	14,464,174
870	24,171,520	70,770,456	2,817,093	16,071,512	23,835,894	69,848,529	3,654,240	14,311,488	72,772,662	3,804,145	14,461,393
880	24,143,583	70,898,397	2,814,459	16,068,878	23,806,995	69,981,671	3,638,382	14,295,630	72,900,603	3,801,430	14,458,678
890	24,115,614	71,026,334	2,811,887	16,066,306	23,778,060	70,114,688	3,622,923	14,280,171	73,028,540	3,798,780	14,456,028
900	24,087,614	71,154,262	2,809,373	16,063,793	23,749,090	70,247,579	3,607,849	14,265,097	73,156,468	3,796,192	14,453,440
910	24,059,581	71,282,178	2,806,917	16,061,336	23,720,084	70,380,343	3,593,144	14,250,392	73,284,384	3,793,664	14,450,913
920	24,031,517	71,410,075	2,804,516	16,058,935	23,691,042	70,512,980	3,578,795	14,236,043	73,412,281	3,791,195	14,448,443
930	24,003,421	71,537,951	2,802,168	16,056,588	23,661,963	70,645,489	3,564,788	14,222,037	73,540,157	3,788,781	14,446,029
940	23,975,293	71,665,799	2,799,872	16,054,292	23,632,849	70,777,868	3,551,112	14,208,360	73,668,005	3,786,421	14,443,669
950	23,947,132	71,793,618	2,797,626	16,052,045	23,603,699	70,910,118	3,537,753	14,195,001	73,795,824	3,784,114	14,441,362
960	23,918,939	71,921,401	2,795,428	16,049,848	23,574,512	71,042,238	3,524,700	14,181,949	73,923,607	3,781,857	14,439,105
970	23,890,714	72,049,147	2,793,277	16,047,697	23,545,289	71,174,227	3,511,944	14,169,192	74,051,353	3,779,649	14,436,897
980	23,862,456	72,176,851	2,791,172	16,045,591	23,516,029	71,306,084	3,499,473	14,156,721	74,179,057	3,777,489	14,434,737
990	23,834,166	72,304,510	2,789,110	16,043,529	23,486,733	71,437,810	3,487,278	14,144,526	74,306,716	3,775,374	14,432,623
1,000	23,805,843	72,432,120	2,787,090	16,041,510	23,457,400	71,569,402	3,475,349	14,132,597	74,434,327	3,773,304	14,430,553
1,010	23,777,488	72,559,680	2,785,112	16,039,532	23,428,029	71,700,862	3,463,678	14,120,926	74,561,886	3,771,277	14,428,526
1,020	23,749,099	72,687,185	2,783,174	16,037,593	23,398,622	71,832,188	3,452,255	14,109,503	74,689,391	3,769,292	14,426,540
1,030	23,720,678	72,814,633	2,781,275	16,035,694	23,369,178	71,963,380	3,441,073	14,098,322	74,816,839	3,767,347	14,424,595
1,040	23,692,224	72,942,021	2,779,413	16,033,832	23,339,697	72,094,437	3,430,125	14,087,373	74,944,227	3,765,442	14,422,690

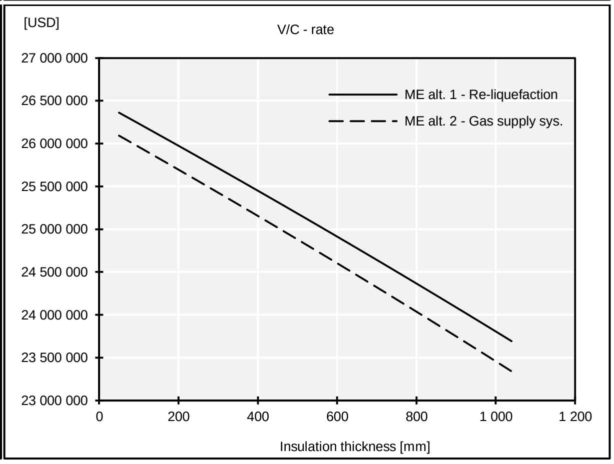





[USD]
CBS 2
Running cost
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply. sys. alt. 1
ME alt. 2 - Gas supply. sys. alt. 2
Boil-off rate [ton/day]


[USD]
CBS 2
Running cost
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply. sys. alt. 1
ME alt 2 - Gas supply sys. alt. 2
Insulation thickness [mm]

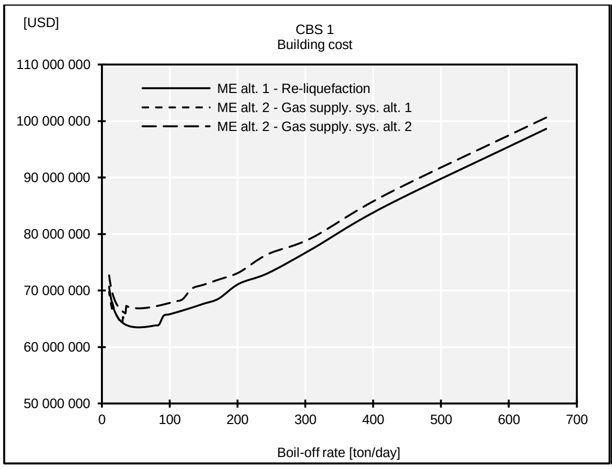

[USD]
V/C - rate
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
Boil-off rate [ton/day]

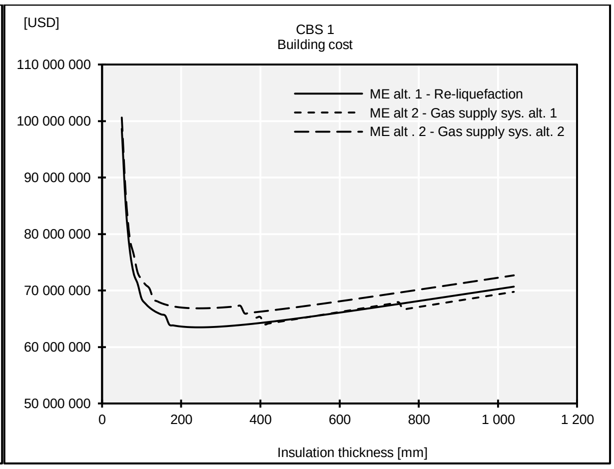

[USD]
V/C - rate
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
Insulation thickness [mm]

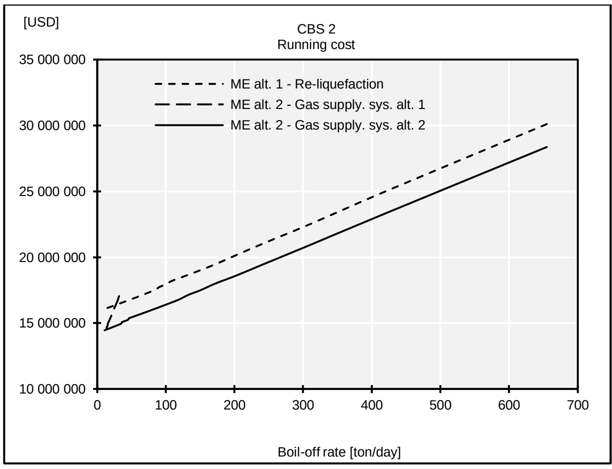
Insulation system 5

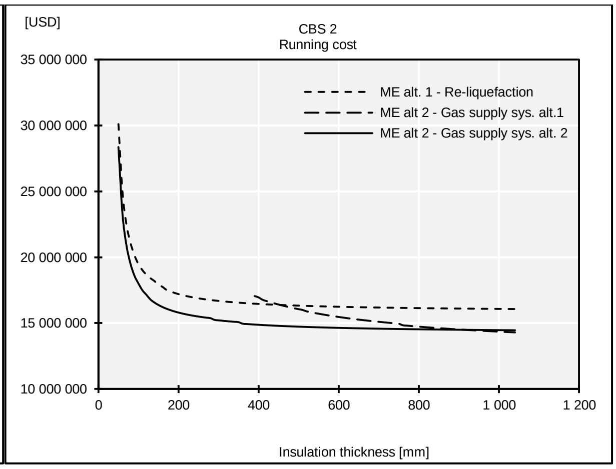
Insulation system 5											
Ins. thickness	ME alt. 1				ME alt. 2						
	Re-liquefaction					Gas supply alt. 1			Gas supply alt. 2		
	V/C-rate	CBS 1	CBS 2.3.2	CBS 2	V/C rate	CBS 1	CBS 2.3.2	CBS 2	CBS 1	CBS 2.3.2	CBS 2
t_{INS_TOT}		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$	$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$
[mm]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]
50	26,361,657	98,633,241	16,853,405	30,107,824	26,093,389				100,635,447	17,710,056	28,367,305
60	26,336,069	85,097,879	11,750,737	25,005,156	26,067,099				87,100,085	12,681,136	23,338,384
70	26,310,456	77,322,960	9,240,156	22,494,575	26,040,782				79,325,166	10,256,655	20,913,903
80	26,284,816	73,068,105	7,847,865	21,102,284	26,014,435				76,433,736	8,866,182	19,523,430
90	26,259,151	71,216,864	6,903,329	20,157,748	25,988,060				73,219,070	7,946,079	18,603,327
100	26,233,459	68,583,114	6,218,798	19,473,217	25,961,656				71,948,745	7,349,863	18,007,111
110	26,207,741	67,670,098	5,760,020	19,014,439	25,935,223				71,035,729	6,832,218	17,489,466
120	26,181,997	66,992,473	5,418,429	18,672,848	25,908,761				70,358,104	6,489,731	17,146,979
130	26,156,226	66,478,110	5,152,306	18,406,725	25,882,270				68,480,316	6,133,080	16,790,328
140	26,130,429	66,081,604	4,938,048	18,192,467	25,855,751				68,083,810	5,905,023	16,562,271
150	26,104,606	65,772,949	4,654,816	17,909,235	25,829,202				67,775,155	5,719,754	16,377,002
160	26,078,756	65,531,518	4,497,912	17,752,332	25,802,623				67,533,724	5,565,974	16,223,222
170	26,052,879	63,979,240	4,267,432	17,521,852	25,776,016				67,344,871	5,436,095	16,093,343
180	26,026,976	63,832,279	4,144,602	17,399,022	25,749,379				67,197,910	5,324,821	15,982,069
190	26,001,046	63,719,231	4,039,374	17,293,793	25,722,713				67,084,862	5,228,337	15,885,585
200	25,975,089	63,634,015	3,948,111	17,202,530	25,696,017				66,999,646	5,143,819	15,801,067
210	25,949,106	63,571,919	3,868,129	17,122,549	25,669,292				66,937,550	5,069,129	15,726,378
220	25,923,095	63,529,233	3,797,401	17,051,821	25,642,537				66,894,864	5,002,618	15,659,867
230	25,897,058	63,502,996	3,734,366	16,988,786	25,615,752				66,868,627	4,942,991	15,600,239
240	25,870,994	63,490,818	3,677,801	16,932,220	25,588,937				66,856,449	4,889,215	15,546,463
250	25,844,902	63,490,747	3,626,734	16,881,153	25,562,093				66,856,378	4,840,457	15,497,705
260	25,818,783	63,501,173	3,580,381	16,834,800	25,535,218				66,866,804	4,796,038	15,453,286
270	25,792,638	63,520,758	3,538,103	16,792,523	25,508,314				66,886,389	4,755,395	15,412,644
280	25,766,464	63,548,377	3,499,375	16,753,794	25,481,379				66,914,008	4,718,063	15,375,311
290	25,740,264	63,583,084	3,463,758	16,718,177	25,454,414				66,948,715	4,589,099	15,246,347
300	25,714,036	63,624,069	3,430,885	16,685,304	25,427,419				66,989,700	4,554,919	15,212,167
310	25,687,781	63,670,643	3,400,444	16,654,863	25,400,393				67,036,275	4,523,300	15,180,548
320	25,661,498	63,722,211	3,372,170	16,626,589	25,373,337				67,087,842	4,493,963	15,151,211
330	25,635,187	63,778,257	3,345,836	16,600,255	25,346,251				67,143,888	4,466,666	15,123,914
340	25,608,849	63,838,333	3,321,246	16,575,666	25,319,134				67,203,964	4,441,202	15,098,451
350	25,582,483	63,902,048	3,298,230	16,552,650	25,291,986				67,267,679	4,417,392	15,074,640
360	25,556,090	63,969,056	3,276,639	16,531,059	25,264,807				65,971,262	4,299,139	14,956,387
370	25,529,668	64,039,056	3,256,343	16,510,763	25,237,598				66,041,262	4,276,391	14,933,639
380	25,503,219	64,111,779	3,237,228	16,491,647	25,210,358				66,113,985	4,255,039	14,912,287
390	25,476,741	64,186,986	3,219,191	16,473,611	25,183,086	65,193,750	6,396,226	17,053,474	66,189,192	4,234,957	14,892,206
400	25,450,236	64,264,464	3,202,144	16,456,563	25,155,784	65,305,063	6,293,110	16,950,358	66,266,670	4,216,036	14,873,284
410	25,423,702	64,344,025	3,186,006	16,440,425	25,128,450	64,053,243	6,113,355	16,770,603	66,346,231	4,198,177	14,855,425
420	25,397,140	64,425,497	3,170,705	16,425,124	25,101,085	64,165,106	6,014,782	16,672,030	66,427,703	4,181,292	14,838,540
430	25,370,550	64,508,727	3,156,178	16,410,597	25,073,689	64,277,200	5,922,161	16,579,410	66,510,933	4,165,303	14,822,551
440	25,343,931	64,593,577	3,142,366	16,396,785	25,046,261	64,389,497	5,834,933	16,492,181	66,595,783	4,150,141	14,807,389
450	25,317,285	64,679,922	3,129,218	16,383,637	25,018,802	64,501,976	5,752,604	16,409,852	66,682,128	4,135,742	14,792,990
460	25,290,609	64,767,649	3,116,686	16,371,105	24,991,311	64,614,615	5,674,744	16,331,992	66,769,855	4,122,051	14,779,299
470	25,263,905	64,856,654	3,104,728	16,359,147	24,963,789	64,727,394	5,600,971	16,258,219	66,858,860	4,109,015	14,766,263
480	25,237,173	64,946,844	3,093,305	16,347,724	24,936,235	64,840,296	5,530,947	16,188,195	66,949,050	4,096,590	14,753,838
490	25,210,412	65,038,134	3,082,381	16,336,800	24,908,649	64,953,305	5,464,373	16,121,621	67,040,340	4,084,732	14,741,980
500	25,183,622	65,130,445	3,071,925	16,326,344	24,881,031	65,066,407	5,400,980	16,058,228	67,132,651	4,073,404	14,730,652
510	25,156,803	65,223,705	3,061,906	16,316,325	24,853,381	65,179,588	5,340,528	15,997,776	67,225,911	4,062,571	14,719,819
520	25,129,955	65,317,849	3,052,298	16,306,717	24,825,698	65,292,835	5,232,707	15,889,956	67,320,055	4,052,200	14,709,448
530	25,103,079	65,412,816	3,043,076	16,297,495	24,797,984	65,406,138	5,170,982	15,828,230	67,415,022	4,042,264	14,699,512
540	25,076,173	65,508,550	3,034,216	16,288,635	24,770,238	65,519,485	5,112,188	15,769,436	67,510,756	4,032,734	14,689,982
550	25,049,238	65,605,001	3,025,698	16,280,117	24,742,459	65,632,869	5,056,111	15,713,359	67,607,207	4,023,587	14,680,835
560	25,022,274	65,702,120	3,017,502	16,271,922	24,714,647	65,746,278	5,002,556	15,659,804	67,704,326	4,014,800	14,672,048
570	24,995,281	65,799,863	3,009,611	16,264,030	24,686,803	65,859,707	4,951,346	15,608,595	67,802,069	4,006,351	14,663,600
580	24,968,259	65,898,191	3,002,007	16,256,426	24,658,927	65,973,146	4,902,324	15,559,572	67,900,397	3,998,223	14,655,471
590	24,941,207	65,997,064	2,994,675	16,249,094	24,631,017	66,086,588	4,855,342	15,512,590	67,999,270	3,990,396	14,647,644
600	24,914,126	66,096,447	2,987,600	16,242,019	24,603,075	66,200,028	4,810,270	15,467,518	68,098,653	3,982,854	14,640,102
610	24,887,015	66,196,309	2,980,770	16,235,189	24,575,100	66,313,459	4,766,986	15,424,234	68,198,515	3,975,582	14,632,830

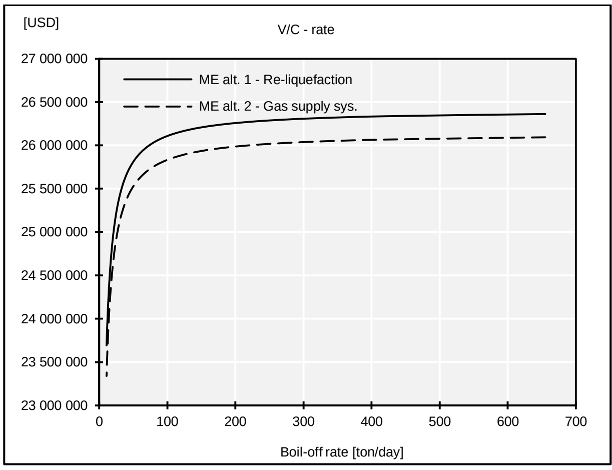
620	24,859,874	66,296,618	2,974,171	16,228,590	24,547,092	66,426,876	4,725,380	15,382,628	68,298,824	3,968,566	14,625,814
630	24,832,704	66,397,346	2,967,792	16,222,211	24,519,051	66,540,273	4,685,350	15,342,599	68,399,552	3,961,792	14,619,040
640	24,805,504	66,498,466	2,961,623	16,216,042	24,490,976	66,653,645	4,646,804	15,304,052	68,500,672	3,955,248	14,612,496
650	24,778,274	66,599,954	2,955,652	16,210,071	24,462,869	66,766,987	4,609,655	15,266,903	68,602,160	3,948,922	14,606,171
660	24,751,015	66,701,787	2,949,871	16,204,291	24,434,728	66,880,296	4,573,825	15,231,073	68,703,993	3,942,804	14,600,053
670	24,723,725	66,803,941	2,944,271	16,198,690	24,406,554	66,993,568	4,539,240	15,196,489	68,806,147	3,936,884	14,594,132
680	24,696,406	66,906,398	2,938,843	16,193,262	24,378,346	67,106,797	4,505,834	15,163,082	68,908,604	3,931,152	14,588,400
690	24,669,056	67,009,137	2,933,579	16,187,998	24,350,104	67,219,982	4,473,542	15,130,791	69,011,343	3,925,599	14,582,847
700	24,641,676	67,112,141	2,928,472	16,182,892	24,321,829	67,333,118	4,442,308	15,099,557	69,114,347	3,920,217	14,577,465
710	24,614,265	67,215,393	2,923,516	16,177,935	24,293,520	67,446,203	4,412,078	15,069,326	69,217,599	3,914,999	14,572,247
720	24,586,825	67,318,877	2,918,703	16,173,122	24,265,176	67,559,234	4,382,800	15,040,048	69,321,083	3,909,936	14,567,184
730	24,559,354	67,422,577	2,914,027	16,168,446	24,236,799	67,672,207	4,354,429	15,011,677	69,424,783	3,905,022	14,562,270
740	24,531,852	67,526,480	2,909,483	16,163,902	24,208,388	67,785,120	4,326,920	14,984,168	69,528,686	3,900,251	14,557,499
750	24,504,320	67,630,572	2,905,065	16,159,484	24,179,943	67,897,971	4,300,232	14,957,481	69,632,778	3,895,616	14,552,864
760	24,476,757	67,734,840	2,900,768	16,155,187	24,151,463	66,647,333	4,178,979	14,836,227	69,737,046	3,891,112	14,548,360
770	24,449,164	67,839,272	2,896,587	16,151,006	24,122,949	66,760,052	4,151,613	14,808,861	69,841,478	3,886,733	14,543,981
780	24,421,539	67,943,858	2,892,517	16,146,936	24,094,400	66,872,703	4,125,108	14,782,357	69,946,064	3,882,473	14,539,722
790	24,393,884	68,048,585	2,888,554	16,142,974	24,065,817	66,985,283	4,099,424	14,756,672	70,050,791	3,878,329	14,535,578
800	24,366,198	68,153,445	2,884,694	16,139,114	24,037,199	67,097,790	4,074,519	14,731,768	70,155,651	3,874,296	14,531,544
810	24,338,480	68,258,427	2,880,933	16,135,352	24,008,546	67,210,222	4,050,359	14,707,608	70,260,633	3,870,369	14,527,617
820	24,310,732	68,363,523	2,877,267	16,131,686	23,979,859	67,322,579	4,026,909	14,684,157	70,365,729	3,866,544	14,523,792
830	24,282,952	68,468,723	2,873,692	16,128,112	23,951,136	67,434,858	4,004,137	14,661,385	70,470,929	3,862,816	14,520,065
840	24,255,141	68,574,019	2,870,206	16,124,625	23,922,379	67,547,057	3,982,012	14,639,260	70,576,225	3,859,184	14,516,432
850	24,227,299	68,679,404	2,866,804	16,121,224	23,893,586	67,659,176	3,960,505	14,617,754	70,681,610	3,855,642	14,512,890
860	24,199,425	68,784,869	2,863,485	16,117,904	23,864,758	67,771,213	3,939,592	14,596,840	70,787,075	3,852,187	14,509,436
870	24,171,520	68,890,409	2,860,244	16,114,663	23,835,894	67,883,167	3,919,245	14,576,493	70,892,615	3,848,817	14,506,065
880	24,143,583	68,996,015	2,857,079	16,111,499	23,806,995	67,995,036	3,899,441	14,556,690	70,998,221	3,845,528	14,502,776
890	24,115,614	69,101,682	2,853,988	16,108,407	23,778,060	68,106,819	3,880,159	14,537,407	71,103,888	3,842,318	14,499,566
900	24,087,614	69,207,404	2,850,968	16,105,387	23,749,090	68,218,516	3,861,376	14,518,624	71,209,610	3,839,182	14,496,431
910	24,059,581	69,313,174	2,848,016	16,102,436	23,720,084	68,330,125	3,843,073	14,500,321	71,315,380	3,836,120	14,493,368
920	24,031,517	69,418,987	2,845,131	16,099,550	23,691,042	68,441,645	3,825,231	14,482,479	71,421,193	3,833,129	14,490,377
930	24,003,421	69,524,838	2,842,309	16,096,729	23,661,963	68,553,076	3,807,831	14,465,079	71,527,044	3,830,205	14,487,453
940	23,975,293	69,630,722	2,839,550	16,093,969	23,632,849	68,664,416	3,790,858	14,448,106	71,632,928	3,827,347	14,484,595
950	23,947,132	69,736,633	2,836,850	16,091,270	23,603,699	68,775,664	3,774,294	14,431,542	71,738,839	3,824,552	14,481,800
960	23,918,939	69,842,566	2,834,209	16,088,628	23,574,512	68,886,820	3,758,125	14,415,373	71,844,772	3,821,819	14,479,067
970	23,890,714	69,948,519	2,831,623	16,086,043	23,545,289	68,997,883	3,742,336	14,399,584	71,950,725	3,819,145	14,476,394
980	23,862,456	70,054,485	2,829,092	16,083,511	23,516,029	69,108,852	3,726,913	14,384,161	72,056,691	3,816,529	14,473,777
990	23,834,166	70,160,462	2,826,614	16,081,033	23,486,733	69,219,726	3,711,843	14,369,091	72,162,668	3,813,969	14,471,217
1,000	23,805,843	70,266,445	2,824,186	16,078,605	23,457,400	69,330,505	3,697,114	14,354,362	72,268,651	3,811,462	14,468,710
1,010	23,777,488	70,372,430	2,821,808	16,076,228	23,428,029	69,441,188	3,682,713	14,339,961	72,374,636	3,809,008	14,466,256
1,020	23,749,099	70,478,414	2,819,478	16,073,898	23,398,622	69,551,775	3,668,630	14,325,878	72,480,620	3,806,604	14,463,852
1,030	23,720,678	70,584,393	2,817,195	16,071,614	23,369,178	69,662,264	3,654,854	14,312,102	72,586,599	3,804,250	14,461,498
1,040	23,692,224	70,690,364	2,814,957	16,069,376	23,339,697	69,772,656	3,641,374	14,298,622	72,692,570	3,801,943	14,459,191

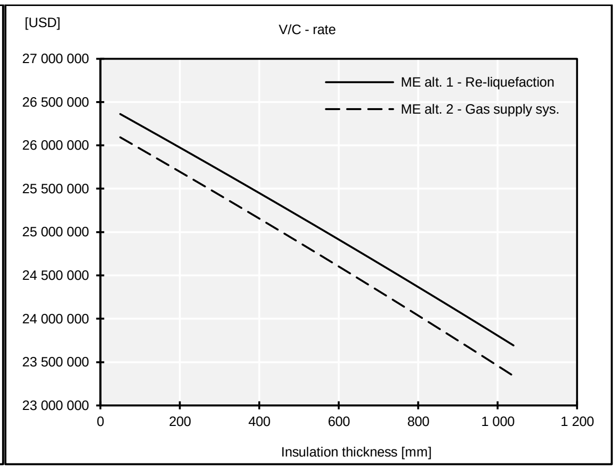





[USD]
CBS 2
Running cost
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply. sys. alt. 1
ME alt. 2 - Gas supply. sys. alt. 2
35 000 000
30 000 000
25 000 000
20 000 000
15 000 000
10 000 000
0
100
200
300
400
500
600
700
Boil-off rate [ton/day]


[USD]
CBS 2
Running cost
ME alt. 1 - Re-liquefaction
ME alt 2 - Gas supply sys. alt.1
ME alt 2 - Gas supply sys. alt. 2
35 000 000
30 000 000
25 000 000
20 000 000
15 000 000
10 000 000
0
200
400
600
800
1 000
1 200
Insulation thickness [mm]

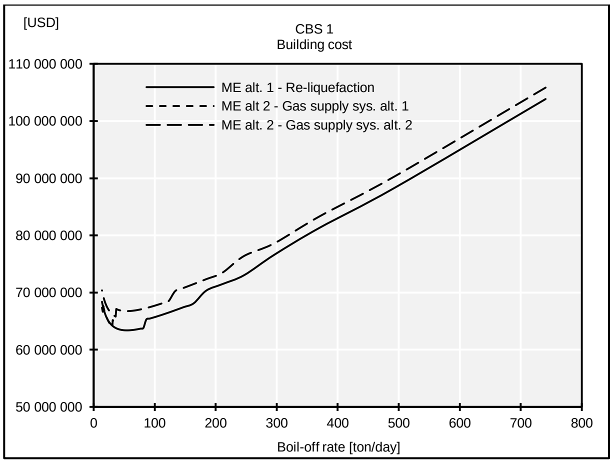

[USD]
V/C - rate
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
27 000 000
26 500 000
26 000 000
25 500 000
25 000 000
24 500 000
24 000 000
23 500 000
23 000 000
0
100
200
300
400
500
600
700
Boil-off rate [ton/day]

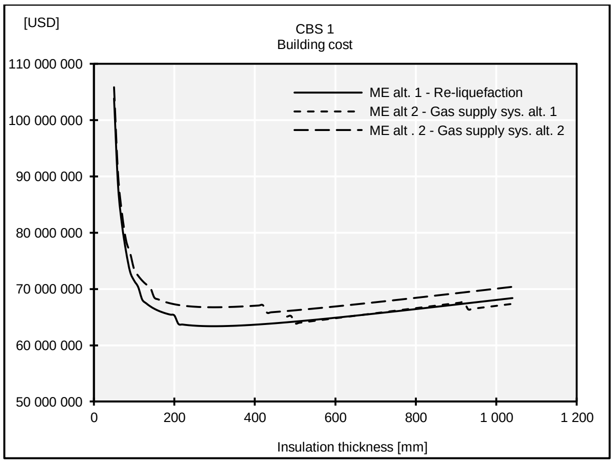

[USD]
V/C - rate
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
27 000 000
26 500 000
26 000 000
25 500 000
25 000 000
24 500 000
24 000 000
23 500 000
23 000 000
0
200
400
600
800
1 000
1 200
Insulation thickness [mm]

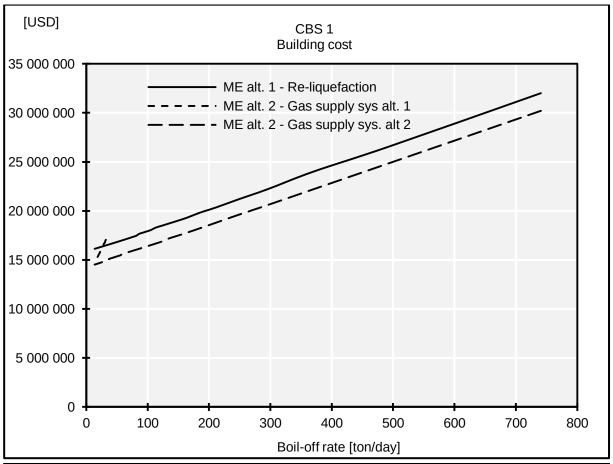
Insulation system 6

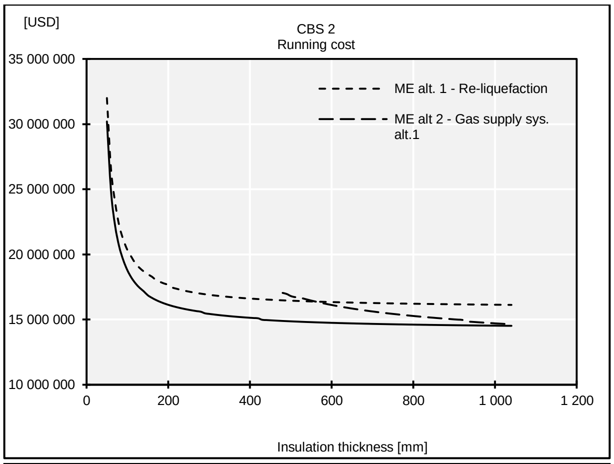
Insulation system 6											
Ins. thickness	ME alt. 1				ME alt. 2						
	Re-liquefaction					Gas supply alt. 1			Gas supply alt. 2		
	V/C-rate	CBS 1	CBS 2.3.2	CBS 2	V/C rate	CBS 1	CBS 2.3.2	CBS 2	CBS 1	CBS 2.3.2	CBS 2
t_{INS_TOT}		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$		$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$	$C_{BUILDING\_TOT}$	C_{VOY_VAR}	$C_{RUNNING}$
[mm]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]	[USD]	[USD/year]	[USD/year]
50	26,361,657	103,847,077	18,749,642	32,004,062	26,093,389				105,849,283	19,547,497	30,204,745
60	26,336,069	88,350,290	13,312,765	26,567,185	26,067,099				90,352,496	14,209,595	24,866,844
70	26,310,456	81,327,355	10,748,331	24,002,750	26,040,782				83,329,561	11,545,293	22,202,541
80	26,284,816	76,605,952	8,963,636	22,218,056	26,014,435				78,608,158	9,943,973	20,601,221
90	26,259,151	73,036,040	7,885,250	21,139,669	25,988,060				76,401,671	8,903,060	19,560,308
100	26,233,459	71,487,789	7,085,510	20,339,929	25,961,656				73,489,995	8,127,845	18,785,093
110	26,207,741	70,351,020	6,546,869	19,801,288	25,935,223				72,353,226	7,552,398	18,209,646
120	26,181,997	68,125,173	6,042,791	19,297,211	25,908,761				71,490,804	7,115,277	17,772,525
130	26,156,226	67,454,796	5,706,112	18,960,531	25,882,270				70,820,427	6,778,190	17,435,438
140	26,130,429	66,924,079	5,437,911	18,692,330	25,855,751				70,289,710	6,509,265	17,166,513
150	26,104,606	66,498,092	5,218,226	18,472,646	25,829,202				68,500,298	6,204,013	16,861,261
160	26,078,756	66,152,649	5,034,356	18,288,775	25,802,623				68,154,855	6,007,056	16,664,304
170	26,052,879	65,870,473	4,779,171	18,033,590	25,776,016				67,872,679	5,841,593	16,498,842
180	26,026,976	65,638,893	4,635,101	17,889,521	25,749,379				67,641,099	5,700,433	16,357,681
190	26,001,046	65,448,405	4,510,639	17,765,058	25,722,713				67,450,611	5,578,446	16,235,694
200	25,975,089	65,291,741	4,401,884	17,656,303	25,696,017				67,293,947	5,471,877	16,129,126
210	25,949,106	63,799,821	4,202,997	17,457,417	25,669,292				67,165,452	5,377,906	16,035,154
220	25,923,095	63,695,032	4,111,267	17,365,686	25,642,537				67,060,663	5,294,370	15,951,618
230	25,897,058	63,610,379	4,029,885	17,284,304	25,615,752				66,976,010	5,219,585	15,876,833
240	25,870,994	63,542,970	3,957,141	17,211,561	25,588,937				66,908,601	5,152,216	15,809,464
250	25,844,902	63,490,439	3,891,690	17,146,109	25,562,093				66,856,070	5,091,190	15,748,438
260	25,818,783	63,450,834	3,832,455	17,086,874	25,535,218				66,816,465	5,035,635	15,692,883
270	25,792,638	63,422,524	3,778,564	17,032,984	25,508,314				66,788,155	4,984,834	15,642,082
280	25,766,464	63,404,143	3,729,307	16,983,726	25,481,379				66,769,774	4,938,191	15,595,439
290	25,740,264	63,394,532	3,684,093	16,938,513	25,454,414				66,760,163	4,818,891	15,476,140
300	25,714,036	63,392,707	3,642,433	16,896,852	25,427,419				66,758,338	4,775,371	15,432,619
310	25,687,781	63,397,820	3,603,911	16,858,330	25,400,393				66,763,452	4,735,154	15,392,402
320	25,661,498	63,409,145	3,568,178	16,822,597	25,373,337				66,774,776	4,697,872	15,355,120
330	25,635,187	63,426,049	3,534,935	16,789,354	25,346,251				66,791,680	4,663,213	15,320,461
340	25,608,849	63,447,983	3,503,924	16,758,343	25,319,134				66,813,614	4,630,905	15,288,153
350	25,582,483	63,474,464	3,474,923	16,729,342	25,291,986				66,840,095	4,600,715	15,257,963
360	25,556,090	63,505,071	3,447,739	16,702,158	25,264,807				66,870,702	4,572,438	15,229,687
370	25,529,668	63,539,430	3,422,202	16,676,622	25,237,598				66,905,061	4,545,897	15,203,146
380	25,503,219	63,577,210	3,398,166	16,652,585	25,210,358				66,942,841	4,520,936	15,178,184
390	25,476,741	63,618,119	3,375,498	16,629,917	25,183,086				66,983,750	4,497,414	15,154,663
400	25,450,236	63,661,893	3,354,084	16,608,503	25,155,784				67,027,524	4,475,212	15,132,460
410	25,423,702	63,708,298	3,333,820	16,588,239	25,128,450				67,073,929	4,454,219	15,111,467
420	25,397,140	63,757,124	3,314,614	16,569,034	25,101,085				67,122,755	4,434,339	15,091,587
430	25,370,550	63,808,182	3,296,386	16,550,805	25,073,689				65,810,388	4,321,348	14,978,596
440	25,343,931	63,861,300	3,279,060	16,533,479	25,046,261				65,863,506	4,301,857	14,959,105
450	25,317,285	63,916,324	3,262,570	16,516,990	25,018,802				65,918,530	4,283,362	14,940,610
460	25,290,609	63,973,115	3,246,858	16,501,277	24,991,311				65,975,321	4,265,786	14,923,034
470	25,263,905	64,031,543	3,231,867	16,486,286	24,963,789				66,033,749	4,249,064	14,906,312
480	25,237,173	64,091,494	3,217,550	16,471,969	24,936,235	65,101,516	6,386,269	17,043,517	66,093,700	4,233,133	14,890,381
490	25,210,412	64,152,862	3,203,860	16,458,280	24,908,649	65,190,053	6,303,464	16,960,712	66,155,068	4,217,939	14,875,187
500	25,183,622	64,215,548	3,190,758	16,445,178	24,881,031	63,915,328	6,144,195	16,801,444	66,217,754	4,203,431	14,860,679
510	25,156,803	64,279,465	3,178,206	16,432,625	24,853,381	64,004,174	6,062,971	16,720,219	66,281,671	4,189,563	14,846,812
520	25,129,955	64,344,531	3,166,169	16,420,589	24,825,698	64,093,151	6,046,505	16,703,753	66,346,737	4,176,295	14,833,543
530	25,103,079	64,410,670	3,154,617	16,409,036	24,797,984	64,182,244	5,959,049	16,616,297	66,412,876	4,163,587	14,820,836
540	25,076,173	64,477,814	3,143,520	16,397,939	24,770,238	64,271,442	5,876,173	16,533,421	66,480,020	4,151,406	14,808,654
550	25,049,238	64,545,898	3,132,851	16,387,270	24,742,459	64,360,731	5,797,514	16,454,762	66,548,104	4,139,717	14,796,965
560	25,022,274	64,614,864	3,122,586	16,377,006	24,714,647	64,450,100	5,722,747	16,379,995	66,617,070	4,128,493	14,785,741
570	24,995,281	64,684,656	3,112,703	16,367,122	24,686,803	64,539,541	5,651,578	16,308,826	66,686,862	4,117,706	14,774,954
580	24,968,259	64,755,224	3,103,180	16,357,599	24,658,927	64,629,042	5,583,743	16,240,991	66,757,430	4,107,330	14,764,578
590	24,941,207	64,826,522	3,093,998	16,348,417	24,631,017	64,718,596	5,519,002	16,176,251	66,828,728	4,097,343	14,754,591
600	24,914,126	64,898,505	3,085,138	16,339,558	24,603,075	64,808,194	5,457,140	16,114,388	66,900,711	4,087,723	14,744,971
610	24,887,015	64,971,132	3,076,585	16,331,004	24,575,100	64,897,828	5,397,959	16,055,207	66,973,338	4,078,450	14,735,698
620	24,859,874	65,044,365	3,068,321	16,322,741	24,547,092	64,987,493	5,341,280	15,998,528	67,046,571	4,069,505	14,726,753

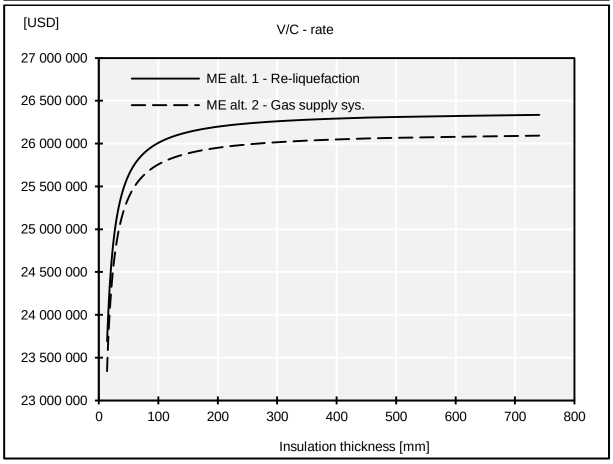
630	24,832,704	65,118,170	3,060,333	16,314,753	24,519,051	65,077,180	5,286,939	15,944,188	67,120,376	4,060,872	14,718,120
640	24,805,504	65,192,513	3,052,607	16,307,027	24,490,976	65,166,883	5,234,788	15,892,036	67,194,719	4,052,534	14,709,782
650	24,778,274	65,267,362	3,045,131	16,299,550	24,462,869	65,256,598	5,184,689	15,841,937	67,269,568	4,044,476	14,701,725
660	24,751,015	65,342,690	3,037,891	16,292,310	24,434,728	65,346,319	5,136,518	15,793,766	67,344,896	4,036,685	14,693,933
670	24,723,725	65,418,468	3,030,877	16,285,297	24,406,554	65,436,039	5,090,158	15,747,406	67,420,674	4,029,147	14,686,395
680	24,696,406	65,494,671	3,024,079	16,278,499	24,378,346	65,525,756	5,045,504	15,702,752	67,496,877	4,021,851	14,679,099
690	24,669,056	65,571,276	3,017,487	16,271,907	24,350,104	65,615,464	5,002,457	15,659,706	67,573,482	4,014,784	14,672,032
700	24,641,676	65,648,260	3,011,092	16,265,511	24,321,829	65,705,160	4,960,929	15,618,177	67,650,466	4,007,936	14,665,184
710	24,614,265	65,725,601	3,004,884	16,259,303	24,293,520	65,794,838	4,920,834	15,578,083	67,727,807	4,001,297	14,658,545
720	24,586,825	65,803,279	2,998,855	16,253,275	24,265,176	65,884,497	4,882,097	15,539,345	67,805,485	3,994,857	14,652,105
730	24,559,354	65,881,277	2,992,999	16,247,418	24,236,799	65,974,131	4,844,644	15,501,892	67,883,483	3,988,608	14,645,857
740	24,531,852	65,959,575	2,987,307	16,241,726	24,208,388	66,063,738	4,808,409	15,465,657	67,961,781	3,982,542	14,639,790
750	24,504,320	66,038,158	2,981,773	16,236,192	24,179,943	66,153,315	4,773,331	15,430,579	68,040,364	3,976,650	14,633,898
760	24,476,757	66,117,009	2,976,390	16,230,809	24,151,463	66,242,859	4,739,351	15,396,599	68,119,215	3,970,924	14,628,173
770	24,449,164	66,196,113	2,971,152	16,225,572	24,122,949	66,332,366	4,706,415	15,363,663	68,198,319	3,965,359	14,622,607
780	24,421,539	66,275,457	2,966,054	16,220,473	24,094,400	66,421,836	4,674,474	15,331,722	68,277,663	3,959,947	14,617,196
790	24,393,884	66,355,027	2,961,089	16,215,509	24,065,817	66,511,264	4,643,480	15,300,728	68,357,233	3,954,683	14,611,931
800	24,366,198	66,434,809	2,956,253	16,210,673	24,037,199	66,600,648	4,613,389	15,270,637	68,437,015	3,949,559	14,606,807
810	24,338,480	66,514,792	2,951,541	16,205,960	24,008,546	66,689,987	4,584,160	15,241,408	68,516,998	3,944,571	14,601,819
820	24,310,732	66,594,965	2,946,948	16,201,367	23,979,859	66,779,279	4,555,755	15,213,003	68,597,171	3,939,713	14,596,961
830	24,282,952	66,675,317	2,942,469	16,196,888	23,951,136	66,868,521	4,528,136	15,185,384	68,677,523	3,934,980	14,592,228
840	24,255,141	66,755,837	2,938,100	16,192,519	23,922,379	66,957,711	4,501,270	15,158,518	68,758,043	3,930,368	14,587,616
850	24,227,299	66,836,515	2,933,837	16,188,257	23,893,586	67,046,847	4,475,124	15,132,372	68,838,721	3,925,871	14,583,120
860	24,199,425	66,917,342	2,929,677	16,184,096	23,864,758	67,135,929	4,449,669	15,106,917	68,919,548	3,921,486	14,578,735
870	24,171,520	66,998,310	2,925,616	16,180,035	23,835,894	67,224,954	4,424,875	15,082,124	69,000,516	3,917,209	14,574,457
880	24,143,583	67,079,409	2,921,650	16,176,069	23,806,995	67,313,920	4,400,717	15,057,965	69,081,615	3,913,035	14,570,283
890	24,115,614	67,160,631	2,917,775	16,172,195	23,778,060	67,402,827	4,377,167	15,034,416	69,162,837	3,908,961	14,566,209
900	24,087,614	67,241,970	2,913,990	16,168,409	23,749,090	67,491,673	4,354,203	15,011,452	69,244,176	3,904,983	14,562,231
910	24,059,581	67,323,416	2,910,290	16,164,710	23,720,084	67,580,456	4,331,802	14,989,050	69,325,623	3,901,098	14,558,346
920	24,031,517	67,404,965	2,906,673	16,161,093	23,691,042	67,669,176	4,309,941	14,967,190	69,407,171	3,897,303	14,554,551
930	24,003,421	67,486,608	2,903,137	16,157,556	23,661,963	66,394,405	4,194,545	14,851,794	69,488,814	3,893,594	14,550,842
940	23,975,293	67,568,339	2,899,677	16,154,097	23,632,849	66,482,994	4,171,828	14,829,076	69,570,545	3,889,969	14,547,217
950	23,947,132	67,650,153	2,896,293	16,150,712	23,603,699	66,571,515	4,149,696	14,806,944	69,652,359	3,886,425	14,543,673
960	23,918,939	67,732,042	2,892,981	16,147,401	23,574,512	66,659,968	4,128,125	14,785,373	69,734,248	3,882,959	14,540,207
970	23,890,714	67,814,003	2,889,740	16,144,159	23,545,289	66,748,352	4,107,094	14,764,343	69,816,209	3,879,569	14,536,817
980	23,862,456	67,896,029	2,886,566	16,140,985	23,516,029	66,836,665	4,086,583	14,743,831	69,898,235	3,876,252	14,533,500
990	23,834,166	67,978,115	2,883,458	16,137,878	23,486,733	66,924,907	4,066,570	14,723,818	69,980,321	3,873,005	14,530,254
1,000	23,805,843	68,060,256	2,880,415	16,134,834	23,457,400	67,013,078	4,047,038	14,704,286	70,062,462	3,869,828	14,527,076
1,010	23,777,488	68,142,447	2,877,433	16,131,852	23,428,029	67,101,175	4,027,968	14,685,216	70,144,653	3,866,717	14,523,965
1,020	23,749,099	68,224,685	2,874,511	16,128,930	23,398,622	67,189,199	4,009,344	14,666,592	70,226,891	3,863,670	14,520,918
1,030	23,720,678	68,306,964	2,871,647	16,126,067	23,369,178	67,277,148	3,991,149	14,648,397	70,309,170	3,860,685	14,517,934
1,040	23,692,224	68,389,280	2,868,840	16,123,260	23,339,697	67,365,022	3,973,368	14,630,616	70,391,486	3,857,761	14,515,010

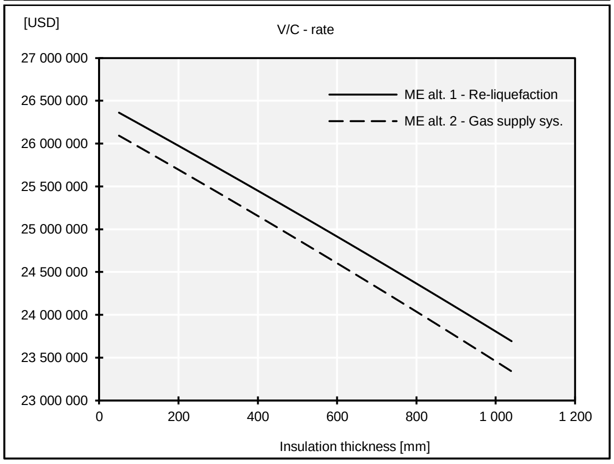




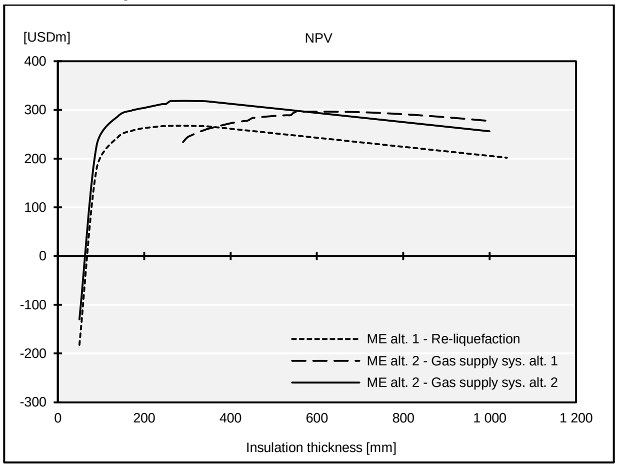

[USD]
CBS 1
Building cost
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys alt. 1
ME alt. 2 - Gas supply sys. alt 2
35 000 000
30 000 000
25 000 000
20 000 000
15 000 000
10 000 000
5 000 000
0
0
100
200
300
400
500
600
700
800
Boil-off rate [ton/day]


[USD]
CBS 2
Running cost
ME alt. 1 - Re-liquefaction
ME alt 2 - Gas supply sys. alt.1
35 000 000
30 000 000
25 000 000
20 000 000
15 000 000
10 000 000
0
200
400
600
800
1 000
1 200
Insulation thickness [mm]

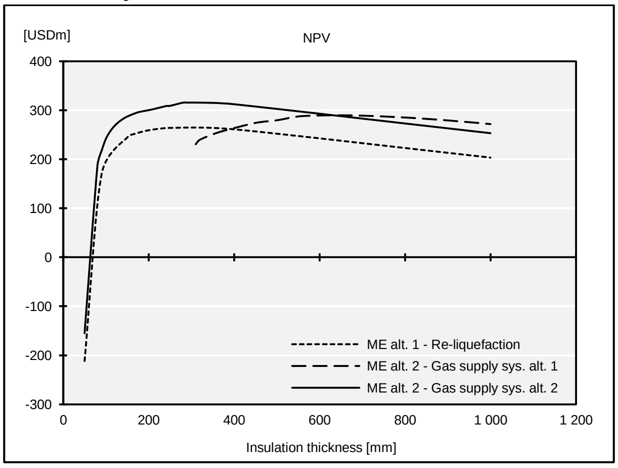

[USD]
V/C - rate
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
27 000 000
26 500 000
26 000 000
25 500 000
25 000 000
24 500 000
24 000 000
23 500 000
23 000 000
0
100
200
300
400
500
600
700
800
Insulation thickness [mm]


[USD]
V/C - rate
ME alt. 1 - Re-liquefaction
ME alt. 2 - Gas supply sys.
27 000 000
26 500 000
26 000 000
25 500 000
25 000 000
24 500 000
24 000 000
23 500 000
23 000 000
0
200
400
600
800
1 000
1 200
Insulation thickness [mm]

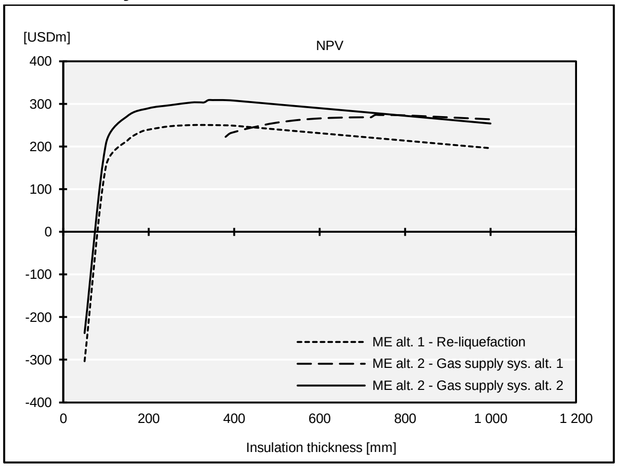
Economic evaluation
Evaluation of optimal insulation thickness
Insulation system 1



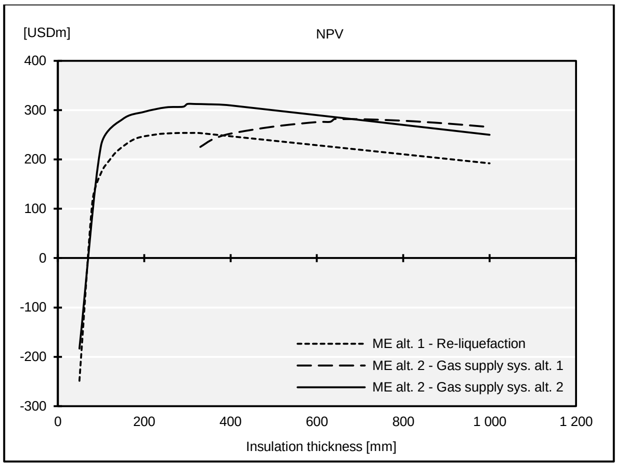
Insulation system 2



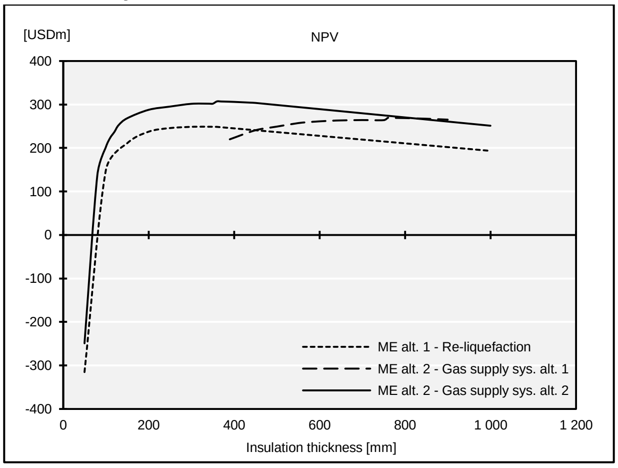
Insulation system 3



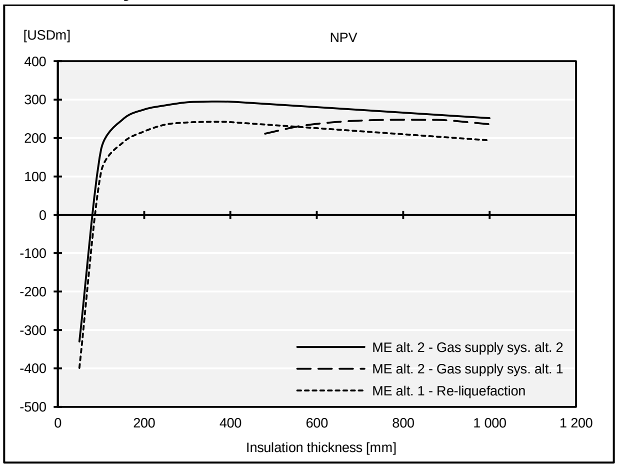
Insulation system 4



Insulation system 5



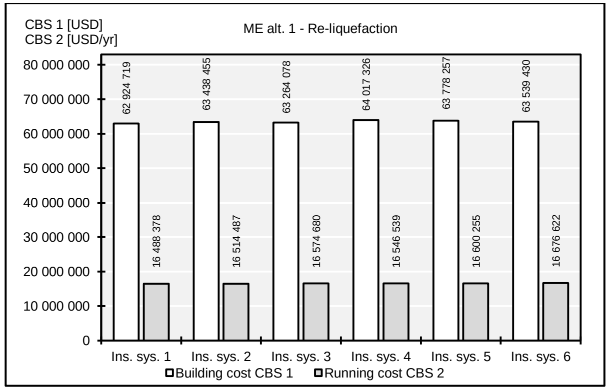
Insulation system 6

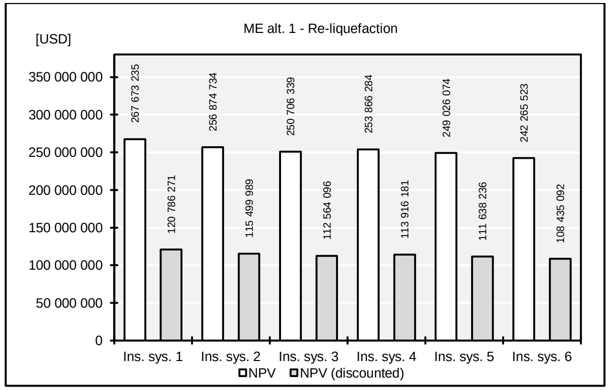


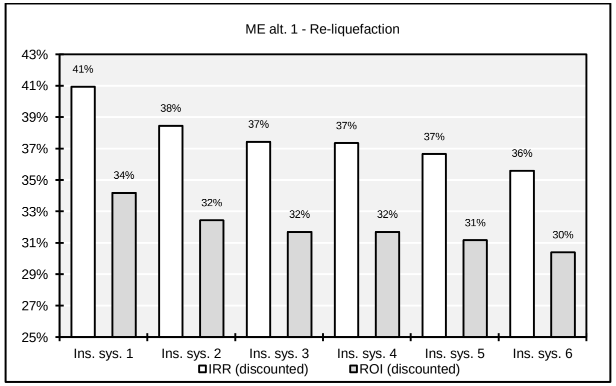
Economical evaluation

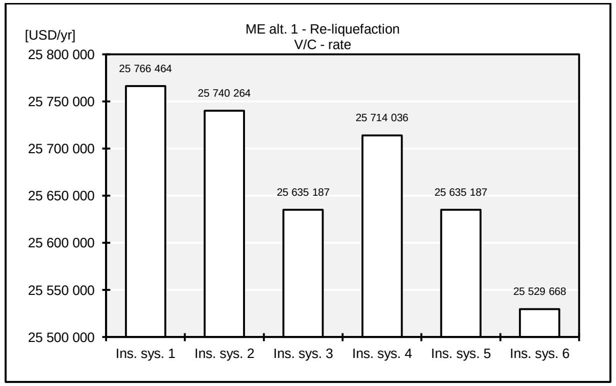
ME-alt .1 – Re-liquefaction

ME alt. 1 - Re-liquefaction													
					Building cost	Running cost	Fixed voy. cost	Var. voy. cost					
	Ins. thickn.	Cargo capacity	Boil-off rate	V/C-rate	CBS 1	CBS 2	CBS 2.3.1	CBS 2.3.2	NPV	NPV (discounted)	IRR (discounted)	ROI (discounted)	
Insulation system	[mm]	[m3]	[ton/day]	[USD/yr]	[USD]	[USD/yr]	[USD/yr]	[USD/yr]	[-]	[-]	[-]	[-]	
Ins. sys. 1	280	46,268	32.8	25,766,464	62,924,719	16,488,378	13,254,419	3,233,959	267,673,235	120,786,271	41%	34%	
Ins. sys. 2	290	46,146	34.2	25,740,264	63,438,455	16,514,487	13,254,419	3,260,068	256,874,734	115,499,989	38%	32%	
Ins. sys. 3	330	45,660	37.3	25,635,187	63,264,078	16,574,680	13,254,419	3,320,261	250,706,339	112,564,096	37%	32%	
Ins. sys. 4	300	46,024	35.9	25,714,036	64,017,326	16,546,539	13,254,419	3,292,120	253,866,284	113,916,181	37%	32%	
Ins. sys. 5	330	45,660	38.7	25,635,187	63,778,257	16,600,255	13,254,419	3,345,836	249,026,074	111,638,236	37%	31%	
Ins. sys. 6	370	45,177	42.6	25,529,668	63,539,430	16,676,622	13,254,419	3,422,202	242,265,523	108,435,092	36%	30%	



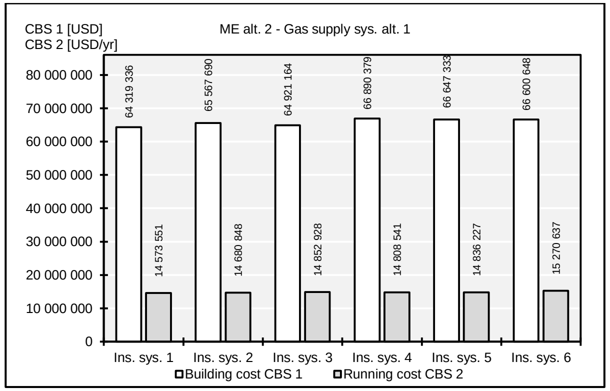


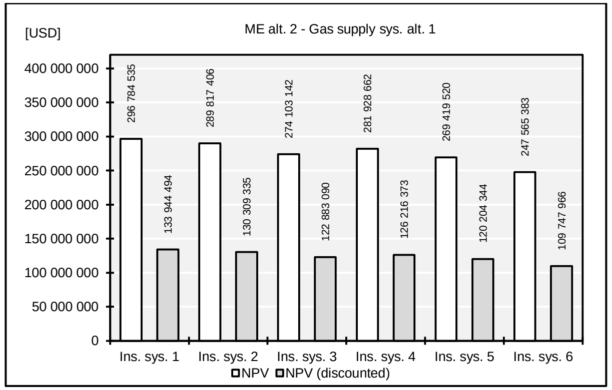


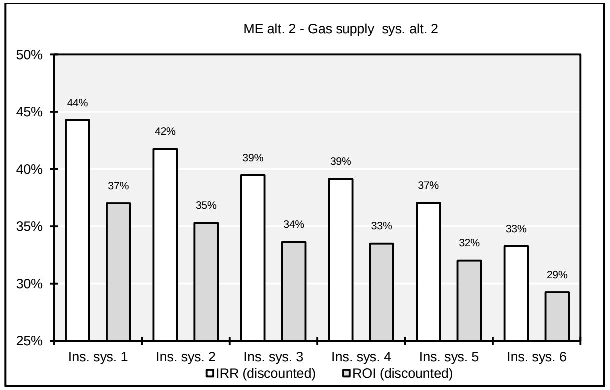


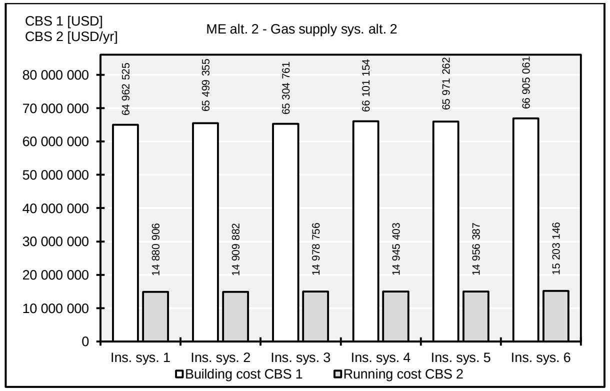
ME-alt .2 – Gas supply sys. alt. 1

ME alt. 2 - Gas supply sys. alt. 1												
					Building cost	Running cost	Fixed voy. cost	Var. voy. cost				
	Ins. thickn.	Cargo capacity	Boil-off rate	V/C-rate	CBS 1	CBS 2	CBS 2.3.1	CBS 2.3.2	NPV	NPV (discounted)	IRR (discounted)	ROI (discounted)
Insulation system	[mm]	[m3]	[ton/day]	[USD/yr]	[USD]	[USD/yr]	[USD/yr]	[USD/yr]	[-]	[-]	[-]	[-]
Ins. sys. 1	630	42,114	13.2	24,519,051	64,319,336	14,573,551	10,657,248	3,916,303	296,784,535	133,944,494	44%	37%
Ins. sys. 2	640	41,999	14.1	24,490,976	65,567,690	14,680,848	10,657,248	4,023,600	289,817,406	130,309,335	42%	35%
Ins. sys. 3	730	40,970	15.5	24,236,799	64,921,164	14,852,928	10,657,248	4,195,680	274,103,142	122,883,090	39%	34%
Ins. sys. 4	650	41,884	15.1	24,462,869	66,890,379	14,808,541	10,657,248	4,151,293	281,928,662	126,216,373	39%	33%
Ins. sys. 5	760	40,631	15.3	24,151,463	66,647,333	14,836,227	10,657,248	4,178,979	269,419,520	120,204,344	37%	32%
Ins. sys. 6	800	40,181	18.2	24,037,199	66,600,648	15,270,637	10,657,248	4,613,389	247,565,383	109,747,966	33%	29%



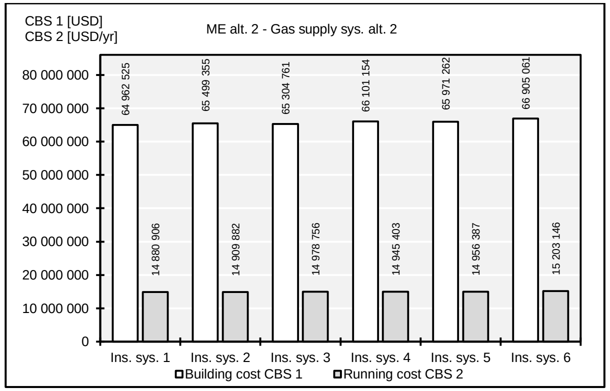


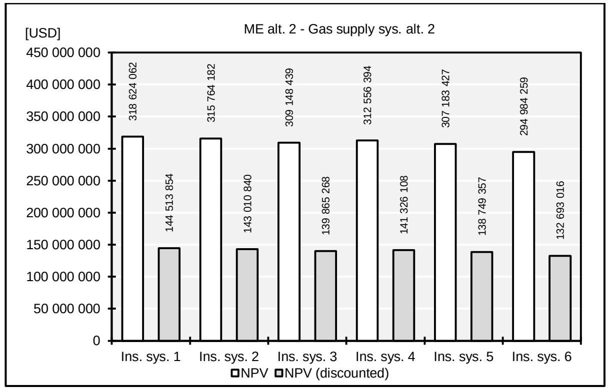


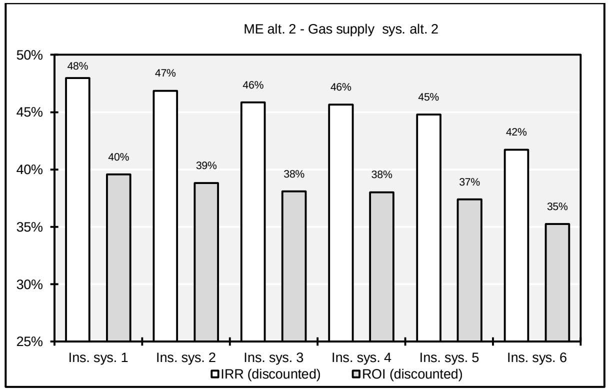


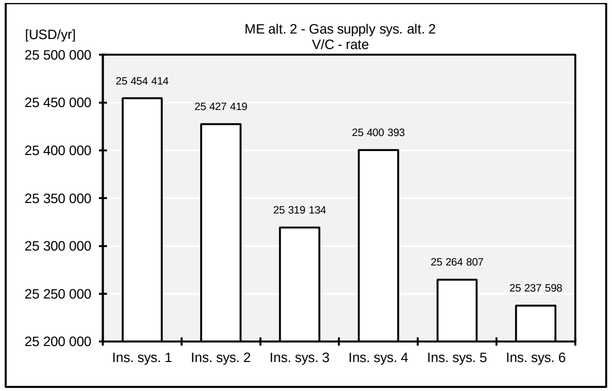
ME-alt .2 – Gas supply sys. alt. 2

ME alt. 2 - Gas supply sys. alt. 2												
					Building cost	Running cost	Fixed voy. cost	Var. voy. cost				
	Ins. thickn.	Cargo capacity	Boil-off rate	V/C-rate	CBS 1	CBS 2	CBS 2.3.1	CBS 2.3.2	NPV	NPV (discounted)	IRR (discounted)	ROI (discounted)
Insulation system	[mm]	[m3]	[ton/day]	[USD/yr]	[USD]	[USD/yr]	[USD/yr]	[USD/yr]	[-]	[-]	[-]	[-]
Ins. sys. 1	290	46,146	31.5	25,454,414	64,962,525	14,880,906	10,657,248	4,223,658	318,624,062	144,513,854	48%	40%
Ins. sys. 2	300	46,024	32.9	25,427,419	65,499,355	14,909,882	10,657,248	4,252,633	315,764,182	143,010,840	47%	39%
Ins. sys. 3	340	45,539	36.1	25,319,134	65,304,761	14,978,756	10,657,248	4,321,508	309,148,439	139,865,268	46%	38%
Ins. sys. 4	310	45,903	34.5	25,400,393	66,101,154	14,945,403	10,657,248	4,288,155	312,556,394	141,326,108	46%	38%
Ins. sys. 5	360	45,298	35.0	25,264,807	65,971,262	14,956,387	10,657,248	4,299,139	307,183,427	138,749,357	45%	37%
Ins. sys. 6	370	45,177	42.6	25,237,598	66,905,061	15,203,146	10,657,248	4,545,897	294,984,259	132,693,016	42%	35%

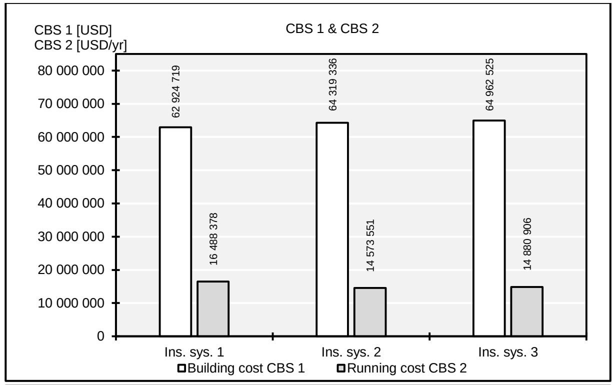


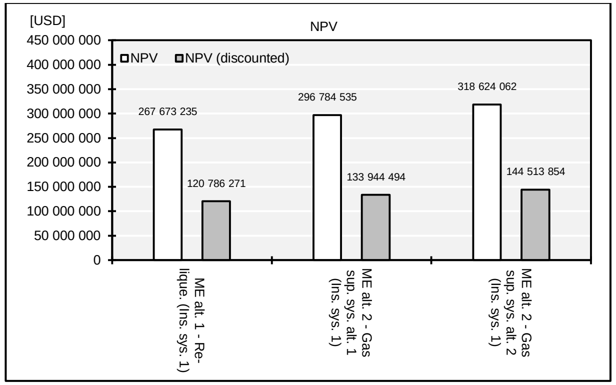


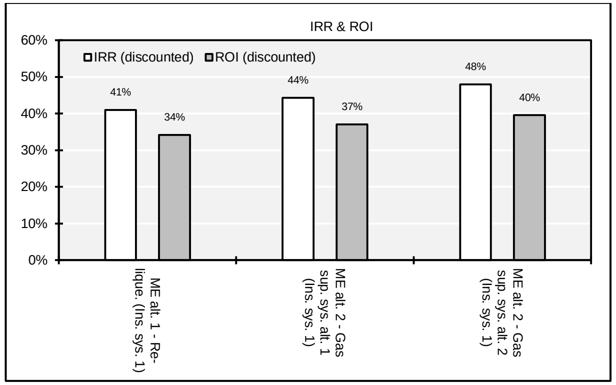


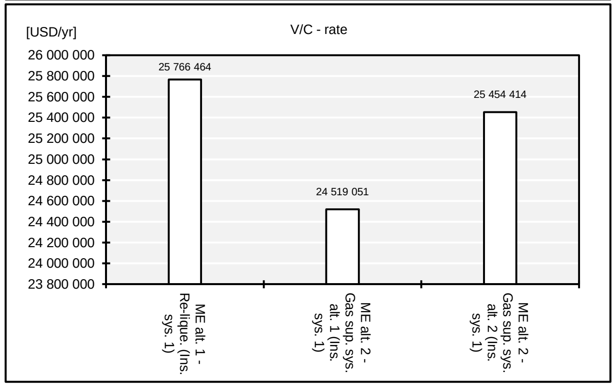


Economical evaluation of best alternatives









Appendix 12

Energy efficiency

ME alt. 1 – Re-liquefaction

EEDI as function of speed - ME alt. 1 - Ins. sys. 1 (Ins. thickn. 280mm)

			Fuel cons. ME										Fuel cons. Aux						Daily cons.	Trans. capacity	Trans.eff.	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SFOC	FOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	SLOC	LOC	(HFO, MDO & LO)	[ton*nm]/[day]	[g]/[ton*nm]	(HFO, MDO, LO)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	η_T [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[ton/day]				
11	46,268	19,664	2,659	1	3,225	15%	3,709	35%	178	16	0.1	0.009	2	64%	186	11	1	0.1	28	5,191,274	5	3.2	17
11.5	46,268	19,664	2,746	1	3,331	15%	3,830	36%	177	16	0.1	0.009	2	64%	187	11	1	0.1	28	5,427,241	5	3.2	17
12	46,268	19,664	3,173	1	3,849	15%	4,426	41%	175	19	0.1	0.011	2	64%	188	11	1	0.1	31	5,663,208	5	3.2	17
12.5	46,268	19,664	3,480	1	4,221	15%	4,854	45%	173	20	0.1	0.012	2	64%	189	11	1	0.1	32	5,899,175	5	3.2	17
13	46,268	19,664	3,967	1	4,812	15%	5,534	52%	170	23	0.1	0.013	2	64%	190	11	1	0.1	35	6,135,142	6	3.2	18
13.5	46,268	19,664	4,526	1	5,490	15%	6,313	59%	168	25	0.1	0.015	2	64%	191	11	1	0.1	38	6,371,109	6	3.2	19
14	46,268	19,664	5,169	1	6,269	15%	7,210	68%	167	29	0.1	0.017	2	64%	192	11	1	0.1	41	6,607,076	6	3.2	20
14.5	46,268	19,664	5,910	1	7,169	15%	8,244	77%	166	33	0.1	0.020	2	64%	193	11	1	0.1	45	6,843,043	7	3.2	21
15	46,268	19,664	6,767	1	8,208	15%	9,439	88%	167	38	0.1	0.023	2	64%	194	11	1	0.1	50	7,079,010	7	3.2	22
15.5	46,268	19,664	7,759	1	9,411	15%	10,822	101%	169	44	0.1	0.026	2	64%	195	11	1	0.1	56	7,314,977	8	3.2	24

EEDI as function of speed - ME alt. 1 - Ins. sys. 2 (Ins. thickn. 290mm)

			Fuel cons. ME										Fuel cons. Aux						Daily cons.	Trans. capacity	Trans.eff.	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SFOC	FOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	SLOC	LOC	(HFO, MDO & LO)	[ton*nm]/[day]	[g]/[ton*nm]	(HFO, MDO, LO)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	η_T [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[ton/day]				
11	46,146	19,612	2,659	1	3,225	15%	3,709	35%	178	16	0.1	0.009	2	65%	185	11	1	0.1	28	5,177,590	5	3.2	17
11.5	46,146	19,612	2,746	1	3,331	15%	3,830	36%	177	16	0.1	0.009	2	65%	185	11	1	0.1	28	5,412,935	5	3.2	17
12	46,146	19,612	3,173	1	3,849	15%	4,426	41%	175	19	0.1	0.011	2	65%	185	11	1	0.1	31	5,648,280	5	3.2	17
12.5	46,146	19,612	3,480	1	4,221	15%	4,854	45%	173	20	0.1	0.012	2	65%	185	11	1	0.1	32	5,883,625	5	3.2	17
13	46,146	19,612	3,967	1	4,812	15%	5,534	52%	170	23	0.1	0.013	2	65%	185	11	1	0.1	35	6,118,970	6	3.2	18
13.5	46,146	19,612	4,526	1	5,490	15%	6,313	59%	168	25	0.1	0.015	2	65%	185	11	1	0.1	38	6,354,315	6	3.2	19
14	46,146	19,612	5,169	1	6,269	15%	7,210	68%	167	29	0.1	0.017	2	65%	185	11	1	0.1	41	6,589,660	6	3.2	20
14.5	46,146	19,612	5,910	1	7,169	15%	8,244	77%	166	33	0.1	0.020	2	65%	185	11	1	0.1	45	6,825,005	7	3.2	21
15	46,146	19,612	6,767	1	8,208	15%	9,439	88%	167	38	0.1	0.023	2	65%	185	11	1	0.1	50	7,060,350	7	3.2	22
15.5	46,146	19,612	7,759	1	9,411	15%	10,822	101%	169	44	0.1	0.026	2	65%	185	11	1	0.1	56	7,295,695	8	3.2	24

EEDI as function of speed - ME alt. 1 - Ins. sys. 3 (Ins. thickn. 330mm)

			Fuel cons. ME										Fuel cons. Aux						Daily cons.	Trans. capacity	Trans.eff.	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SFOC	FOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	SLOC	LOC	(HFO, MDO & LO)	[ton*nm]/[day]	[g]/[ton*nm]	(HFO, MDO, LO)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	η_T [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[ton/day]				
11	45,660	19,406	2,659	1	3,225	15%	3,709	35%	178	16	0.1	0.009	2	66%	185	11	1	0.1	28	5,123,072	6	3.2	17
11.5	45,660	19,406	2,746	1	3,331	15%	3,830	36%	177	16	0.1	0.009	2	66%	185	11	1	0.1	29	5,355,939	5	3.2	17
12	45,660	19,406	3,173	1	3,849	15%	4,426	41%	175	19	0.1	0.011	2	66%	185	11	1	0.1	31	5,588,806	6	3.2	18
12.5	45,660	19,406	3,480	1	4,221	15%	4,854	45%	173	20	0.1	0.012	2	66%	185	11	1	0.1	32	5,821,673	6	3.2	18
13	45,660	19,406	3,967	1	4,812	15%	5,534	52%	170	23	0.1	0.013	2	66%	185	11	1	0.1	35	6,054,540	6	3.2	18
13.5	45,660	19,406	4,526	1	5,490	15%	6,313	59%	168	25	0.1	0.015	2	66%	185	11	1	0.1	38	6,287,407	6	3.2	19

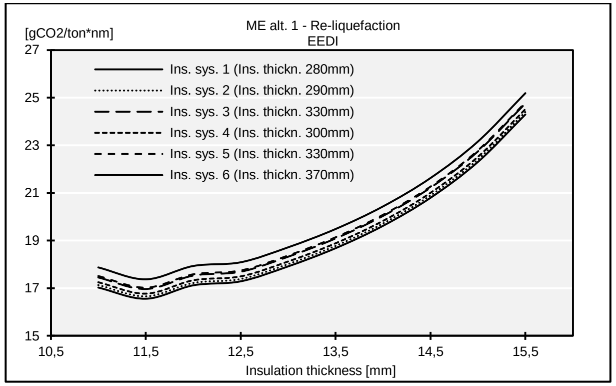
14	45,660	19,406	5,169	1	6,269	15%	7,210	68%	167	29	0.1	0.017	2	66%	185	11	1	0.1	41	6,520,274	6	3.2	20
14.5	45,660	19,406	5,910	1	7,169	15%	8,244	77%	166	33	0.1	0.020	2	66%	185	11	1	0.1	45	6,753,140	7	3.2	21
15	45,660	19,406	6,767	1	8,208	15%	9,439	88%	167	38	0.1	0.023	2	66%	185	11	1	0.1	50	6,986,007	7	3.2	23
15.5	45,660	19,406	7,759	1	9,411	15%	10,822	101%	169	44	0.1	0.026	2	66%	185	11	1	0.1	56	7,218,874	8	3.2	25

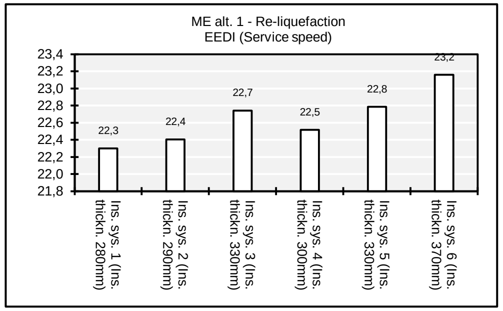
EEDI as function of speed - ME alt. 1 - Ins. sys. 4 (Ins. thickn. 300mm)																							
			Fuel cons. ME										Fuel cons. Aux						Daily cons.	Trans. capacity	Trans.eff.	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SFOC	FOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	SLOC	LOC	(HFO, MDO & LO)	[ton*nm]/[day]	[g]/[ton*nm]	(HFO, MDO, LO)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[ton/day]				
11	46,024	19,560	2,659	1	3,225	15%	3,709	35%	178	16	0.1	0.009	2	66%	185	11	1	0.1	28	5,163,928	5	3.2	17
11.5	46,024	19,560	2,746	1	3,331	15%	3,830	36%	177	16	0.1	0.009	2	66%	185	11	1	0.1	29	5,398,652	5	3.2	17
12	46,024	19,560	3,173	1	3,849	15%	4,426	41%	175	19	0.1	0.011	2	66%	185	11	1	0.1	31	5,633,376	5	3.2	17
12.5	46,024	19,560	3,480	1	4,221	15%	4,854	45%	173	20	0.1	0.012	2	66%	185	11	1	0.1	32	5,868,100	6	3.2	17
13	46,024	19,560	3,967	1	4,812	15%	5,534	52%	170	23	0.1	0.013	2	66%	185	11	1	0.1	35	6,102,824	6	3.2	18
13.5	46,024	19,560	4,526	1	5,490	15%	6,313	59%	168	25	0.1	0.015	2	66%	185	11	1	0.1	38	6,337,548	6	3.2	19
14	46,024	19,560	5,169	1	6,269	15%	7,210	68%	167	29	0.1	0.017	2	66%	185	11	1	0.1	41	6,572,272	6	3.2	20
14.5	46,024	19,560	5,910	1	7,169	15%	8,244	77%	166	33	0.1	0.020	2	66%	185	11	1	0.1	45	6,806,996	7	3.2	21
15	46,024	19,560	6,767	1	8,208	15%	9,439	88%	167	38	0.1	0.023	2	66%	185	11	1	0.1	50	7,041,720	7	3.2	23
15.5	46,024	19,560	7,759	1	9,411	15%	10,822	101%	169	44	0.1	0.026	2	66%	185	11	1	0.1	56	7,276,444	8	3.2	25

EEDI as function of speed - ME alt. 1 - Ins. sys. 5 (Ins. thickn. 330mm)																							
			Fuel cons. ME										Fuel cons. Aux						Daily cons.	Trans. capacity	Trans.eff.	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SFOC	FOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	SLOC	LOC	(HFO, MDO & LO)	[ton*nm]/[day]	[g]/[ton*nm]	(HFO, MDO, LO)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[ton/day]				
11	45,660	19,406	2,659	1	3,225	15%	3,709	35%	178	16	0.1	0.009	2	67%	184	11	1	0.1	28	5,123,072	6	3.2	18
11.5	45,660	19,406	2,746	1	3,331	15%	3,830	36%	177	16	0.1	0.009	2	67%	184	11	1	0.1	29	5,355,939	5	3.2	17
12	45,660	19,406	3,173	1	3,849	15%	4,426	41%	175	19	0.1	0.011	2	67%	184	11	1	0.1	31	5,588,806	6	3.2	18
12.5	45,660	19,406	3,480	1	4,221	15%	4,854	45%	173	20	0.1	0.012	2	67%	184	11	1	0.1	33	5,821,673	6	3.2	18
13	45,660	19,406	3,967	1	4,812	15%	5,534	52%	170	23	0.1	0.013	2	67%	184	11	1	0.1	35	6,054,540	6	3.2	18
13.5	45,660	19,406	4,526	1	5,490	15%	6,313	59%	168	25	0.1	0.015	2	67%	184	11	1	0.1	38	6,287,407	6	3.2	19
14	45,660	19,406	5,169	1	6,269	15%	7,210	68%	167	29	0.1	0.017	2	67%	184	11	1	0.1	41	6,520,274	6	3.2	20
14.5	45,660	19,406	5,910	1	7,169	15%	8,244	77%	166	33	0.1	0.020	2	67%	184	11	1	0.1	45	6,753,140	7	3.2	21
15	45,660	19,406	6,767	1	8,208	15%	9,439	88%	167	38	0.1	0.023	2	67%	184	11	1	0.1	50	6,986,007	7	3.2	23
15.5	45,660	19,406	7,759	1	9,411	15%	10,822	101%	169	44	0.1	0.026	2	67%	184	11	1	0.1	56	7,218,874	8	3.2	25

EEDI as function of speed - ME alt. 1 - Ins. sys. 6 (Ins. thickn. 370mm)																							
			Fuel cons. ME										Fuel cons. Aux						Daily cons.	Trans. capacity	Trans.eff.	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SFOC	FOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	SLOC	LOC	(HFO, MDO & LO)	[ton*nm]/[day]	[g]/[ton*nm]	(HFO, MDO, LO)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[ton/day]				
11	45,177	19,200	2,659	1	3,225	15%	3,709	35%	178	16	0.1	0.009	2	69%	184	12	1	0.1	29	5,068,902	6	3.2	18
11.5	45,177	19,200	2,746	1	3,331	15%	3,830	36%	177	16	0.1	0.009	2	69%	184	12	1	0.1	29	5,299,307	5	3.2	17

12	45,177	19,200	3,173	1	3,849	15%	4,426	41%	175	19	0.1	0.011	2	69%	184	12	1	0.1	31	5,529,711	6	3.2	18
12.5	45,177	19,200	3,480	1	4,221	15%	4,854	45%	173	20	0.1	0.012	2	69%	184	12	1	0.1	33	5,760,116	6	3.2	18
13	45,177	19,200	3,967	1	4,812	15%	5,534	52%	170	23	0.1	0.013	2	69%	184	12	1	0.1	35	5,990,521	6	3.2	19
13.5	45,177	19,200	4,526	1	5,490	15%	6,313	59%	168	25	0.1	0.015	2	69%	184	12	1	0.1	38	6,220,925	6	3.2	19
14	45,177	19,200	5,169	1	6,269	15%	7,210	68%	167	29	0.1	0.017	2	69%	184	12	1	0.1	42	6,451,330	6	3.2	20
14.5	45,177	19,200	5,910	1	7,169	15%	8,244	77%	166	33	0.1	0.020	2	69%	184	12	1	0.1	46	6,681,735	7	3.2	22
15	45,177	19,200	6,767	1	8,208	15%	9,439	88%	167	38	0.1	0.023	2	69%	184	12	1	0.1	50	6,912,139	7	3.2	23
15.5	45,177	19,200	7,759	1	9,411	15%	10,822	101%	169	44	0.1	0.026	2	69%	184	12	1	0.1	57	7,142,544	8	3.2	25





ME alt. 2 - Gas supply sys. alt. 1

EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 1 - Ins. sys. 1 (Ins. Thickn. 630 mm)

			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11.00	42114.17	17898.52	2658.86	0.82	3224.82	0.15	3708.54	0.35	10079.12	17.28	11.80	1.05	0.10	0.01	2.00	0.84	180.12	13.73	0.08	14.87	17.28	4725210.35	3.15	3.66	3.17	2.22	18.09
11.50	42115.17	17898.95	2746.20	0.82	3330.75	0.15	3830.36	0.36	9990.65	17.69	11.70	1.08	0.10	0.01	2.00	0.84	180.12	13.73	0.08	14.89	17.69	4940109.94	3.01	3.58	3.17	2.22	17.50
12.00	42116.17	17899.37	3173.44	0.82	3848.92	0.15	4426.26	0.41	9577.97	19.60	11.22	1.19	0.10	0.01	2.00	0.84	180.12	13.73	0.08	15.01	19.60	5155019.73	2.91	3.80	3.17	2.22	17.67
12.50	42117.17	17899.80	3480.21	0.82	4221.00	0.15	4854.14	0.45	9302.23	20.88	10.89	1.27	0.10	0.01	2.00	0.84	180.12	13.73	0.08	15.09	20.88	5369939.72	2.81	3.89	3.17	2.22	17.53
13.00	42118.17	17900.22	3967.49	0.82	4812.00	0.15	5533.80	0.52	8899.62	22.77	10.42	1.38	0.10	0.01	2.00	0.84	180.12	13.73	0.08	15.21	22.77	5584869.91	2.72	4.08	3.17	2.22	17.68
13.50	42119.17	17900.65	4526.31	0.82	5489.76	0.15	6313.23	0.59	8491.35	24.78	9.94	1.51	0.10	0.02	2.00	0.84	180.12	13.73	0.08	15.33	24.78	5799810.29	2.64	4.27	3.17	2.22	17.86
14.00	42120.17	17901.07	5169.11	0.82	6269.38	0.15	7209.79	0.68	8092.33	26.97	9.48	1.64	0.10	0.02	2.00	0.84	180.12	13.73	0.08	15.47	26.97	6014760.88	2.57	4.48	3.17	2.22	18.10
14.50	42121.17	17901.50	5910.45	0.82	7168.52	0.15	8243.80	0.77	7725.95	29.45	9.05	1.79	0.10	0.02	2.00	0.84	180.12	13.73	0.08	15.62	29.45	6229721.67	2.51	4.73	3.17	2.22	18.44
15.00	42122.17	17901.92	6767.27	0.82	8207.73	0.15	9438.89	0.88	7427.68	32.41	8.70	1.97	0.10	0.02	2.00	0.84	180.12	13.73	0.08	15.80	32.41	6444692.66	2.45	5.03	3.17	2.22	18.93
15.50	42123.17	17902.35	7759.26	0.82	9410.87	0.15	10822.50	1.01	7250.01	36.28	8.49	2.21	0.10	0.03	2.00	0.84	180.12	13.73	0.08	16.04	36.28	6659673.85	2.41	5.45	3.17	2.22	19.72

EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 1 - Ins. sys. 2 (Ins. Thickn. 640 mm)

			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	41,999	17,850	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1	0.1	0.009	2	86%	180	14	0.1	15	17	4,712,280	3.2	3.7	3.2	2.2	18.4
11.5	42,000	17,850	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1	0.1	0.009	2	86%	180	14	0.1	15	18	4,926,592	3.1	3.6	3.2	2.2	17.8
12	42,001	17,850	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1	0.1	0.011	2	86%	180	14	0.1	15	20	5,140,914	3.0	3.8	3.2	2.2	18.0
12.5	42,002	17,851	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1	0.1	0.012	2	86%	180	14	0.1	16	21	5,355,247	2.9	3.9	3.2	2.2	17.8
13	42,003	17,851	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1	0.1	0.013	2	86%	180	14	0.1	16	23	5,569,589	2.8	4.1	3.2	2.2	18.0
13.5	42,004	17,852	4,526	1	5,490	15%	6,313	59%	8,491	25	10	2	0.1	0.015	2	86%	180	14	0.1	16	25	5,783,942	2.7	4.3	3.2	2.2	18.1
14	42,005	17,852	5,169	1	6,269	15%	7,210	68%	8,092	27	9	2	0.1	0.017	2	86%	180	14	0.1	16	27	5,998,305	2.6	4.5	3.2	2.2	18.4
14.5	42,006	17,853	5,910	1	7,169	15%	8,244	77%	7,726	29	9	2	0.1	0.020	2	86%	180	14	0.1	16	29	6,212,678	2.6	4.7	3.2	2.2	18.7
15	42,007	17,853	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2	0.1	0.023	2	86%	180	14	0.1	16	32	6,427,061	2.5	5.0	3.2	2.2	19.2
15.5	42,008	17,853	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2	0.1	0.026	2	86%	180	14	0.1	16	36	6,641,454	2.5	5.5	3.2	2.2	20.0

EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 1 - Ins. sys. 3 (Ins. Thickn. 730 mm)

			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	40,970	17,412	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1	0.1	0.009	2	90%	180	15	0.1	16	17	4,596,866	3.5	3.8	3.2	2.2	19.3
11.5	40,971	17,413	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1	0.1	0.009	2	90%	180	15	0.1	16	18	4,805,932	3.3	3.7	3.2	2.2	18.7
12	40,972	17,413	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1	0.1	0.011	2	90%	180	15	0.1	16	20	5,015,008	3.2	3.9	3.2	2.2	18.8
12.5	40,973	17,414	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1	0.1	0.012	2	90%	180	15	0.1	16	21	5,224,094	3.1	4.0	3.2	2.2	18.7
13	40,974	17,414	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1	0.1	0.013	2	90%	180	15	0.1	16	23	5,433,190	3.0	4.2	3.2	2.2	18.8
13.5	40,975	17,414	4,526	1	5,490	15%	6,313	59%	8,491	25	10	2	0.1	0.015	2	90%	180	15	0.1	16	25	5,642,297	2.9	4.4	3.2	2.2	19.0
14	40,976	17,415	5,169	1	6,269	15%	7,210	68%	8,092	27	9	2	0.1	0.017	2	90%	180	15	0.1	17	27	5,851,413	2.8	4.6	3.2	2.2	19.2
14.5	40,977	17,415	5,910	1	7,169	15%	8,244	77%	7,726	29	9	2	0.1	0.020	2	90%	180	15	0.1	17	29	6,060,540	2.8	4.9	3.2	2.2	19.5
15	40,978	17,416	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2	0.1	0.023	2	90%	180	15	0.1	17	32	6,269,678	2.7	5.2	3.2	2.2	20.0
15.5	40,979	17,416	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2	0.1	0.026	2	90%	180	15	0.1	17	36	6,478,825	2.6	5.6	3.2	2.2	20.8

EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 1 - Ins. sys. 4 (Ins. Thickn. 650 mm)

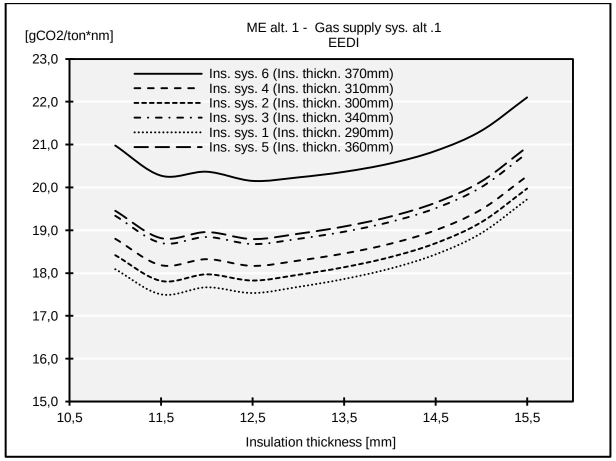
			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	41,884	17,801	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1	0.1	0.009	2	89%	180	15	0.1	16	17	4,699,372	3.4	3.7	3.2	2.2	18.8
11.5	41,885	17,801	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1	0.1	0.009	2	89%	180	15	0.1	16	18	4,913,097	3.2	3.6	3.2	2.2	18.2
12	41,886	17,802	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1	0.1	0.011	2	89%	180	15	0.1	16	20	5,126,832	3.1	3.8	3.2	2.2	18.3
12.5	41,887	17,802	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1	0.1	0.012	2	89%	180	15	0.1	16	21	5,340,578	3.0	3.9	3.2	2.2	18.2
13	41,888	17,802	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1	0.1	0.013	2	89%	180	15	0.1	16	23	5,554,333	2.9	4.1	3.2	2.2	18.3
13.5	41,889	17,803	4,526	1	5,490	15%	6,313	59%	8,491	25	10	2	0.1	0.015	2	89%	180	15	0.1	16	25	5,768,099	2.8	4.3	3.2	2.2	18.5
14	41,890	17,803	5,169	1	6,269	15%	7,210	68%	8,092	27	9	2	0.1	0.017	2	89%	180	15	0.1	16	27	5,981,875	2.7	4.5	3.2	2.2	18.7
14.5	41,891	17,804	5,910	1	7,169	15%	8,244	77%	7,726	29	9	2	0.1	0.020	2	89%	180	15	0.1	17	29	6,195,662	2.7	4.8	3.2	2.2	19.0
15	41,892	17,804	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2	0.1	0.023	2	89%	180	15	0.1	17	32	6,409,458	2.6	5.1	3.2	2.2	19.5
15.5	41,893	17,804	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2	0.1	0.026	2	89%	180	15	0.1	17	36	6,623,265	2.6	5.5	3.2	2.2	20.3

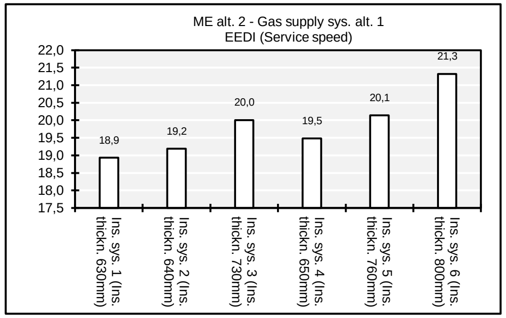
EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 1 - Ins. sys. 5 (Ins. Thickn. 760 mm)

			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	40,631	17,268	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1	0.1	0.009	2	90%	180	15	0.1	16	17	4,558,775	3.5	3.8	3.2	2.2	19.5
11.5	40,632	17,269	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1	0.1	0.009	2	90%	180	15	0.1	16	18	4,766,109	3.3	3.7	3.2	2.2	18.8
12	40,633	17,269	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1	0.1	0.011	2	90%	180	15	0.1	16	20	4,973,454	3.2	3.9	3.2	2.2	19.0
12.5	40,634	17,269	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1	0.1	0.012	2	90%	180	15	0.1	16	21	5,180,809	3.1	4.0	3.2	2.2	18.8
13	40,635	17,270	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1	0.1	0.013	2	90%	180	15	0.1	16	23	5,388,174	3.0	4.2	3.2	2.2	18.9
13.5	40,636	17,270	4,526	1	5,490	15%	6,313	59%	8,491	25	10	2	0.1	0.015	2	90%	180	15	0.1	16	25	5,595,549	2.9	4.4	3.2	2.2	19.1
14	40,637	17,271	5,169	1	6,269	15%	7,210	68%	8,092	27	9	2	0.1	0.017	2	90%	180	15	0.1	16	27	5,802,934	2.8	4.6	3.2	2.2	19.3
14.5	40,638	17,271	5,910	1	7,169	15%	8,244	77%	7,726	29	9	2	0.1	0.020	2	90%	180	15	0.1	17	29	6,010,330	2.8	4.9	3.2	2.2	19.6
15	40,639	17,271	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2	0.1	0.023	2	90%	180	15	0.1	17	32	6,217,735	2.7	5.2	3.2	2.2	20.1
15.5	40,640	17,272	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2	0.1	0.026	2	90%	180	15	0.1	17	36	6,425,151	2.7	5.6	3.2	2.2	20.9

EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 1 - Ins. sys. 6 (Ins. Thickn. 800 mm)

			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	40,181	17,077	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1	0.1	0.009	3	66%	185	17	0.1	18	17	4,508,282	3.9	3.8	3.2	2.2	21.0
11.5	40,182	17,077	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1	0.1	0.009	3	66%	185	17	0.1	18	18	4,713,321	3.8	3.8	3.2	2.2	20.3
12	40,183	17,078	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1	0.1	0.011	3	66%	185	17	0.1	18	20	4,918,371	3.6	4.0	3.2	2.2	20.4
12.5	40,184	17,078	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1	0.1	0.012	3	66%	185	17	0.1	18	21	5,123,430	3.5	4.1	3.2	2.2	20.2
13	40,185	17,079	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1	0.1	0.013	3	66%	185	17	0.1	18	23	5,328,500	3.4	4.3	3.2	2.2	20.2
13.5	40,186	17,079	4,526	1	5,490	15%	6,313	59%	8,491	25	10	2	0.1	0.015	3	66%	185	17	0.1	18	25	5,533,580	3.3	4.5	3.2	2.2	20.4
14	40,187	17,079	5,169	1	6,269	15%	7,210	68%	8,092	27	9	2	0.1	0.017	3	66%	185	17	0.1	18	27	5,738,671	3.2	4.7	3.2	2.2	20.6
14.5	40,188	17,080	5,910	1	7,169	15%	8,244	77%	7,726	29	9	2	0.1	0.020	3	66%	185	17	0.1	18	29	5,943,771	3.1	5.0	3.2	2.2	20.9
15	40,189	17,080	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2	0.1	0.023	3	66%	185	17	0.1	19	32	6,148,882	3.0	5.3	3.2	2.2	21.3
15.5	40,190	17,081	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2	0.1	0.026	3	66%	185	17	0.1	19	36	6,354,002	3.0	5.7	3.2	2.2	22.1


ME alt. 1 - Gas supply sys. alt .1
EEDI
[gCO2/ton*nm]
Ins. sys. 6 (Ins. thickn. 370mm)
Ins. sys. 4 (Ins. thickn. 310mm)
Ins. sys. 2 (Ins. thickn. 300mm)
Ins. sys. 3 (Ins. thickn. 340mm)
Ins. sys. 1 (Ins. thickn. 290mm)
Ins. sys. 5 (Ins. thickn. 360mm)
23,0
22,0
21,0
20,0
19,0
18,0
17,0
16,0
15,0
10,5
11,5
12,5
13,5
14,5
15,5
Insulation thickness [mm]


ME alt. 2 - Gas supply sys. alt. 1
EEDI (Service speed)
22,0
21,5
21,0
20,5
20,0
19,5
19,0
18,5
18,0
17,5
18,9
19,2
20,0
19,5
20,1
21,3
Ins. sys. 1 (Ins. thickn. 630mm)
Ins. sys. 2 (Ins. thickn. 640mm)
Ins. sys. 3 (Ins. thickn. 730mm)
Ins. sys. 4 (Ins. thickn. 650mm)
Ins. sys. 5 (Ins. thickn. 760mm)
Ins. sys. 6 (Ins. thickn. 800mm)

ME alt. 2 - Gas supply sys. alt. 2

EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 2 - Ins. sys. 1 (Ins. Thickn. 290 mm)

			Fuel cons. ME											Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	46,146	19,612	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1.1	0.1	0.009	2	88%	180	14	0.1	16	17	5,177,590	3.0	3.3	3.2	2.2	16.9
11.5	46,147	19,613	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1.1	0.1	0.009	2	88%	180	14	0.1	16	18	5,413,052	2.9	3.3	3.2	2.2	16.4
12	46,148	19,613	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1.2	0.1	0.011	2	88%	180	14	0.1	16	20	5,648,525	2.8	3.5	3.2	2.2	16.5
12.5	46,149	19,613	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1.3	0.1	0.012	2	88%	180	14	0.1	16	21	5,884,008	2.7	3.5	3.2	2.2	16.4
13	46,150	19,614	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1.4	0.1	0.013	2	88%	180	14	0.1	16	23	6,119,500	2.6	3.7	3.2	2.2	16.5
13.5	46,151	19,614	4,526	1	5,490	15%	6,313	59%	8,491	25	10	1.5	0.1	0.015	2	88%	180	14	0.1	16	25	6,355,004	2.5	3.9	3.2	2.2	16.6
14	46,152	19,615	5,169	1	6,269	15%	7,210	68%	8,092	27	9	1.6	0.1	0.017	2	88%	180	14	0.1	16	27	6,590,517	2.5	4.1	3.2	2.2	16.9
14.5	46,153	19,615	5,910	1	7,169	15%	8,244	77%	7,726	29	9	1.8	0.1	0.020	2	88%	180	14	0.1	16	29	6,826,040	2.4	4.3	3.2	2.2	17.1
15	46,154	19,615	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2.0	0.1	0.023	2	88%	180	14	0.1	16	32	7,061,574	2.3	4.6	3.2	2.2	17.6
15.5	46,155	19,616	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2.2	0.1	0.026	2	88%	180	14	0.1	17	36	7,297,118	2.3	5.0	3.2	2.2	18.3

EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 2 - Ins. sys. 2 (Ins. Thickn. 300 mm)

			Fuel cons. ME											Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	46,024	19,560	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1.1	0.1	0.009	2	89%	180	15	0.1	16	17	5,163,928	3.0	3.3	3.2	2.2	17.0
11.5	46,025	19,561	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1.1	0.1	0.009	2	89%	180	15	0.1	16	18	5,398,769	2.9	3.3	3.2	2.2	16.5
12	46,026	19,561	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1.2	0.1	0.011	2	89%	180	15	0.1	16	20	5,633,621	2.8	3.5	3.2	2.2	16.6
12.5	46,027	19,562	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1.3	0.1	0.012	2	89%	180	15	0.1	16	21	5,868,482	2.7	3.6	3.2	2.2	16.5
13	46,028	19,562	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1.4	0.1	0.013	2	89%	180	15	0.1	16	23	6,103,354	2.6	3.7	3.2	2.2	16.6
13.5	46,029	19,562	4,526	1	5,490	15%	6,313	59%	8,491	25	10	1.5	0.1	0.015	2	89%	180	15	0.1	16	25	6,338,236	2.5	3.9	3.2	2.2	16.7
14	46,030	19,563	5,169	1	6,269	15%	7,210	68%	8,092	27	9	1.6	0.1	0.017	2	89%	180	15	0.1	16	27	6,573,129	2.5	4.1	3.2	2.2	17.0
14.5	46,031	19,563	5,910	1	7,169	15%	8,244	77%	7,726	29	9	1.8	0.1	0.020	2	89%	180	15	0.1	16	29	6,808,031	2.4	4.3	3.2	2.2	17.2
15	46,032	19,564	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2.0	0.1	0.023	2	89%	180	15	0.1	17	32	7,042,944	2.4	4.6	3.2	2.2	17.7
15.5	46,033	19,564	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2.2	0.1	0.026	2	89%	180	15	0.1	17	36	7,277,867	2.3	5.0	3.2	2.2	18.4

EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 2 - Ins. sys. 3 (Ins. Thickn. 340 mm)

			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	45,539	19,354	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1.1	0.1	0.009	2	90%	180	15	0.1	16	17	5,109,497	3.1	3.4	3.2	2.2	17.4
11.5	45,540	19,355	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1.1	0.1	0.009	2	90%	180	15	0.1	16	18	5,341,864	3.0	3.3	3.2	2.2	16.8
12	45,541	19,355	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1.2	0.1	0.011	2	90%	180	15	0.1	16	20	5,574,242	2.9	3.5	3.2	2.2	16.9
12.5	45,542	19,355	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1.3	0.1	0.012	2	90%	180	15	0.1	16	21	5,806,629	2.8	3.6	3.2	2.2	16.8
13	45,543	19,356	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1.4	0.1	0.013	2	90%	180	15	0.1	16	23	6,039,027	2.7	3.8	3.2	2.2	16.9
13.5	45,544	19,356	4,526	1	5,490	15%	6,313	59%	8,491	25	10	1.5	0.1	0.015	2	90%	180	15	0.1	16	25	6,271,435	2.6	4.0	3.2	2.2	17.1
14	45,545	19,357	5,169	1	6,269	15%	7,210	68%	8,092	27	9	1.6	0.1	0.017	2	90%	180	15	0.1	17	27	6,503,853	2.5	4.1	3.2	2.2	17.3
14.5	45,546	19,357	5,910	1	7,169	15%	8,244	77%	7,726	29	9	1.8	0.1	0.020	2	90%	180	15	0.1	17	29	6,736,281	2.5	4.4	3.2	2.2	17.6
15	45,547	19,358	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2.0	0.1	0.023	2	90%	180	15	0.1	17	32	6,968,720	2.4	4.7	3.2	2.2	18.0
15.5	45,548	19,358	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2.2	0.1	0.026	2	90%	180	15	0.1	17	36	7,201,169	2.4	5.0	3.2	2.2	18.7

EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 2 - Ins. sys. 4 (Ins. Thickn. 310 mm)

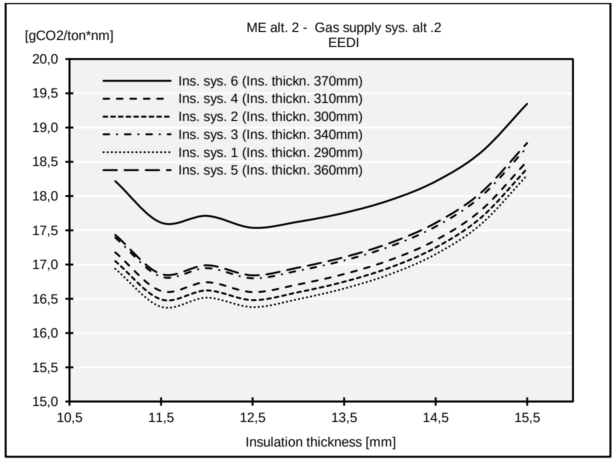
			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	45,903	19,509	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1.1	0.1	0.009	2	89%	180	15	0.1	16	17	5,150,287	3.1	3.4	3.2	2.2	17.2
11.5	45,904	19,509	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1.1	0.1	0.009	2	89%	180	15	0.1	16	18	5,384,509	2.9	3.3	3.2	2.2	16.6
12	45,905	19,510	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1.2	0.1	0.011	2	89%	180	15	0.1	16	20	5,618,740	2.8	3.5	3.2	2.2	16.7
12.5	45,906	19,510	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1.3	0.1	0.012	2	89%	180	15	0.1	16	21	5,852,982	2.7	3.6	3.2	2.2	16.6
13	45,907	19,510	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1.4	0.1	0.013	2	89%	180	15	0.1	16	23	6,087,234	2.7	3.7	3.2	2.2	16.7
13.5	45,908	19,511	4,526	1	5,490	15%	6,313	59%	8,491	25	10	1.5	0.1	0.015	2	89%	180	15	0.1	16	25	6,321,496	2.6	3.9	3.2	2.2	16.9
14	45,909	19,511	5,169	1	6,269	15%	7,210	68%	8,092	27	9	1.6	0.1	0.017	2	89%	180	15	0.1	16	27	6,555,768	2.5	4.1	3.2	2.2	17.1
14.5	45,910	19,512	5,910	1	7,169	15%	8,244	77%	7,726	29	9	1.8	0.1	0.020	2	89%	180	15	0.1	17	29	6,790,051	2.4	4.3	3.2	2.2	17.4
15	45,911	19,512	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2.0	0.1	0.023	2	89%	180	15	0.1	17	32	7,024,343	2.4	4.6	3.2	2.2	17.8
15.5	45,912	19,512	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2.2	0.1	0.026	2	89%	180	15	0.1	17	36	7,258,646	2.3	5.0	3.2	2.2	18.5

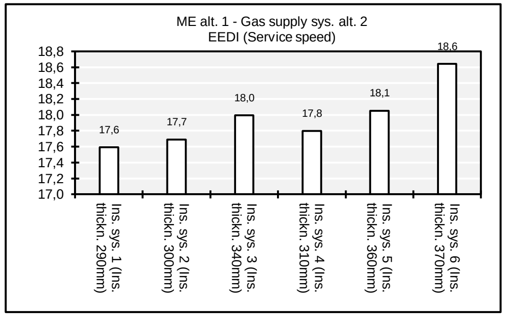
EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 2 - Ins. sys. 5 (Ins. Thickn. 360 mm)

			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	45,298	19,252	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1.1	0.1	0.009	2	90%	180	15	0.1	16	17	5,082,412	3.1	3.4	3.2	2.2	17.4
11.5	45,299	19,252	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1.1	0.1	0.009	2	90%	180	15	0.1	16	18	5,313,548	3.0	3.3	3.2	2.2	16.9
12	45,300	19,252	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1.2	0.1	0.011	2	90%	180	15	0.1	16	20	5,544,694	2.9	3.5	3.2	2.2	17.0
12.5	45,301	19,253	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1.3	0.1	0.012	2	90%	180	15	0.1	16	21	5,775,851	2.8	3.6	3.2	2.2	16.8
13	45,302	19,253	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1.4	0.1	0.013	2	90%	180	15	0.1	16	23	6,007,017	2.7	3.8	3.2	2.2	17.0
13.5	45,303	19,254	4,526	1	5,490	15%	6,313	59%	8,491	25	10	1.5	0.1	0.015	2	90%	180	15	0.1	16	25	6,238,194	2.6	4.0	3.2	2.2	17.1
14	45,304	19,254	5,169	1	6,269	15%	7,210	68%	8,092	27	9	1.6	0.1	0.017	2	90%	180	15	0.1	16	27	6,469,381	2.5	4.2	3.2	2.2	17.3
14.5	45,305	19,255	5,910	1	7,169	15%	8,244	77%	7,726	29	9	1.8	0.1	0.020	2	90%	180	15	0.1	17	29	6,700,579	2.5	4.4	3.2	2.2	17.6
15	45,306	19,255	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2.0	0.1	0.023	2	90%	180	15	0.1	17	32	6,931,786	2.4	4.7	3.2	2.2	18.1
15.5	45,307	19,255	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2.2	0.1	0.026	2	90%	180	15	0.1	17	36	7,163,004	2.4	5.1	3.2	2.2	18.8

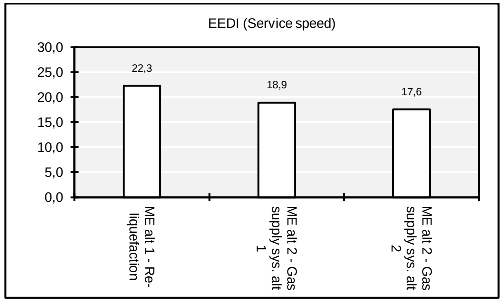
EEDI as function of speed - ME alt. 2 - Gas supply sys. alt. 2 - Ins. sys. 6 (Ins. Thickn. 370 mm)

			Fuel cons. ME												Fuel cons. Aux					Daily cons.	Daily cons.	Capacity	Trans.eff.		CO2 factor	CO2 factor	EEDI
Speed	Cargo cap.		Effective power	Efficiency	Brake power	Sea margin	Brake power	Engine load	SGC (LNG)	GC (LNG)	SPFOC	PFOC (HFO)	SLOC	LOC	No. of empl. aux.	Aux load	SFOC (MDO)	FOC (MDO)	LOC	(HFO, MDO & LO)	(LNG)	[ton*nm]/[day]	[g]/[ton*nm]		(HFO, MDO, LO)	(LNG)	[gCO2]/[ton*nm]
[kn]	[m3]	[ton]	PE [kW]	ηT [%]	PB [kW]	[%]	PB_SM [kW]	[%]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[g/kWh]	[ton/day]	[-]	[%]	[g/kWh]	[ton/day]	[ton/day]	[ton/day]	[ton/day]		(HFO, MDO & LO)	(LNG)			
11	45,177	19,200	2,659	1	3,225	15%	3,709	35%	10,079	17	12	1.1	0.1	0.009	3	62%	186	16	0.1	17	17	5,068,902	3.4	3.4	3.2	2.2	18.2
11.5	45,178	19,201	2,746	1	3,331	15%	3,830	36%	9,991	18	12	1.1	0.1	0.009	3	62%	186	16	0.1	17	18	5,299,424	3.2	3.3	3.2	2.2	17.6
12	45,179	19,201	3,173	1	3,849	15%	4,426	41%	9,578	20	11	1.2	0.1	0.011	3	62%	186	16	0.1	17	20	5,529,956	3.1	3.5	3.2	2.2	17.7
12.5	45,180	19,202	3,480	1	4,221	15%	4,854	45%	9,302	21	11	1.3	0.1	0.012	3	62%	186	16	0.1	17	21	5,760,499	3.0	3.6	3.2	2.2	17.5
13	45,181	19,202	3,967	1	4,812	15%	5,534	52%	8,900	23	10	1.4	0.1	0.013	3	62%	186	16	0.1	17	23	5,991,051	2.9	3.8	3.2	2.2	17.6
13.5	45,182	19,203	4,526	1	5,490	15%	6,313	59%	8,491	25	10	1.5	0.1	0.015	3	62%	186	16	0.1	17	25	6,221,614	2.8	4.0	3.2	2.2	17.8
14	45,183	19,203	5,169	1	6,269	15%	7,210	68%	8,092	27	9	1.6	0.1	0.017	3	62%	186	16	0.1	18	27	6,452,187	2.7	4.2	3.2	2.2	17.9
14.5	45,184	19,203	5,910	1	7,169	15%	8,244	77%	7,726	29	9	1.8	0.1	0.020	3	62%	186	16	0.1	18	29	6,682,770	2.7	4.4	3.2	2.2	18.2
15	45,185	19,204	6,767	1	8,208	15%	9,439	88%	7,428	32	9	2.0	0.1	0.023	3	62%	186	16	0.1	18	32	6,913,363	2.6	4.7	3.2	2.2	18.6
15.5	45,186	19,204	7,759	1	9,411	15%	10,822	101%	7,250	36	8	2.2	0.1	0.026	3	62%	186	16	0.1	18	36	7,143,967	2.5	5.1	3.2	2.2	19.3



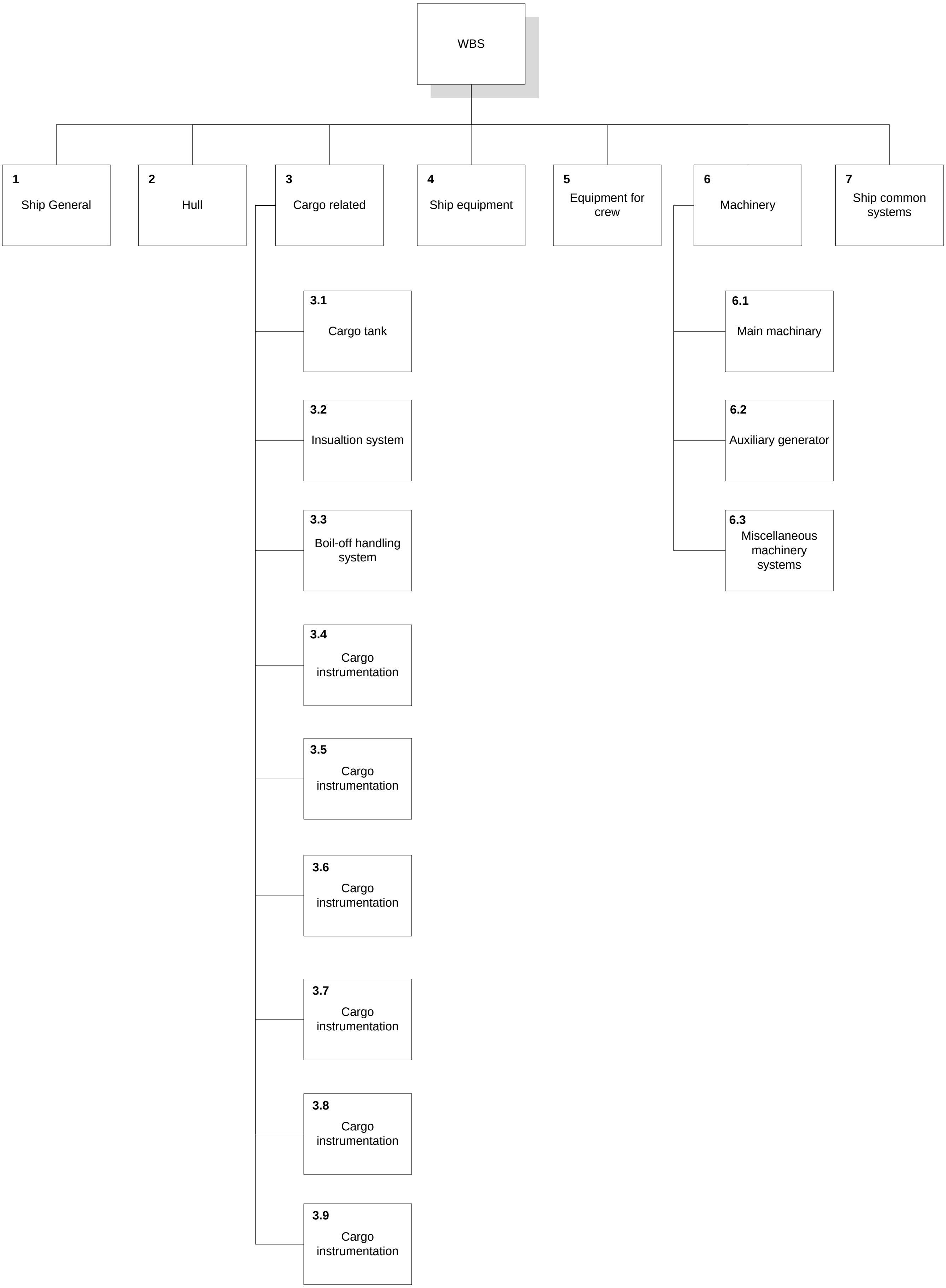


Evaluation of best alternatives



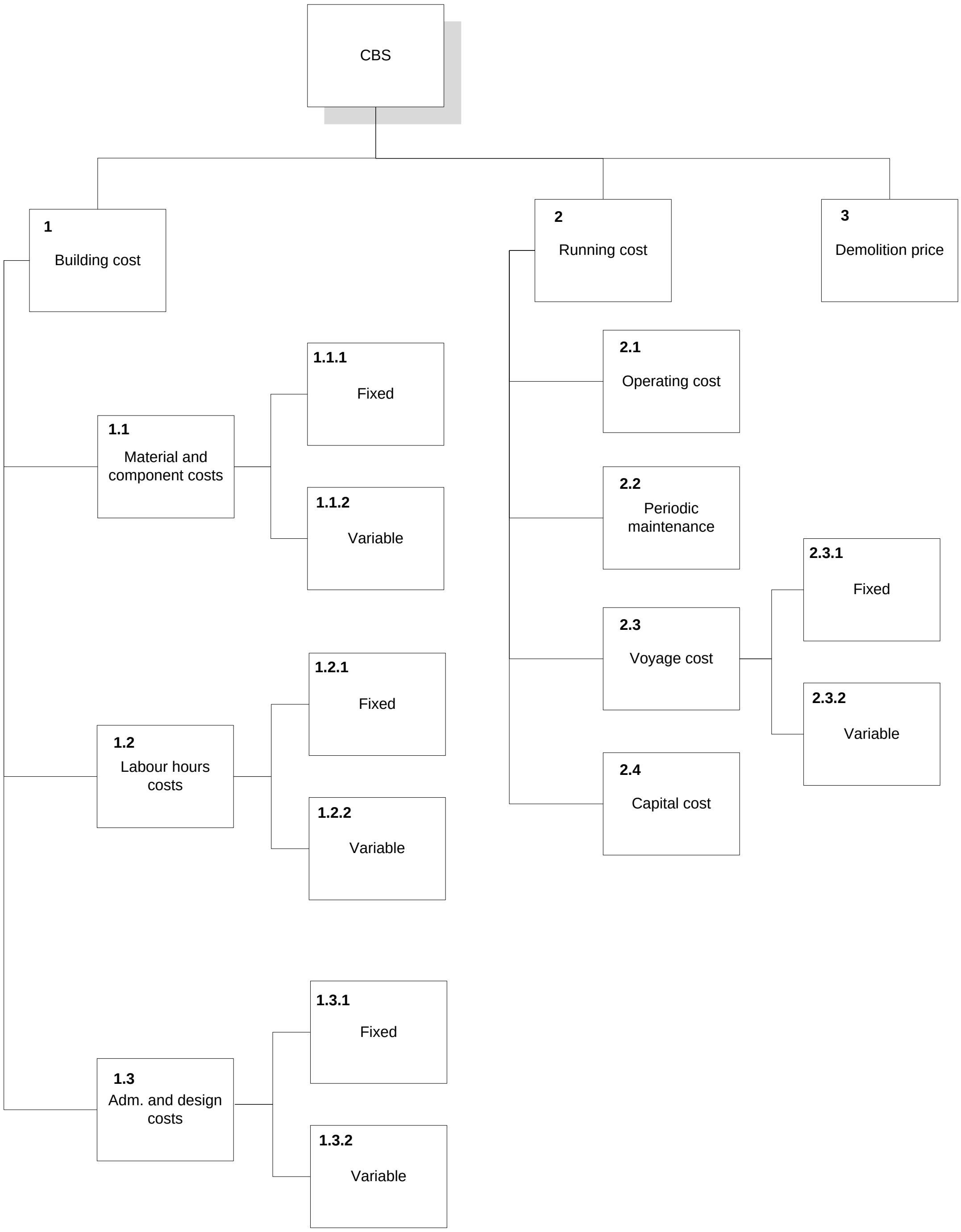
Appendix 13

WBS



WBS
1
Ship General
2
Hull
3
Cargo related
4
Ship equipment
5
Equipment for crew
6
Machinery
7
Ship common systems
3.1
Cargo tank
3.2
Insualtion system
3.3
Boil-off handling system
3.4
Cargo instrumentation
3.5
Cargo instrumentation
3.6
Cargo instrumentation
3.7
Cargo instrumentation
3.8
Cargo instrumentation
3.9
Cargo instrumentation
6.1
Main machinary
6.2
Auxiliary generator
6.3
Miscellaneous machinery systems

CBS


CBS
1
Building cost
2
Running cost
3
Demolition price
1.1
Material and component costs
1.1.1
Fixed
1.1.2
Variable
1.2
Labour hours costs
1.2.1
Fixed
1.2.2
Variable
1.3
Adm. and design costs
1.3.1
Fixed
1.3.2
Variable
2.1
Operating cost
2.2
Periodic maintenance
2.3
Voyage cost
2.3.1
Fixed
2.3.2
Variable
2.4
Capital cost