

Energy Efficiency of Refrigerating Systems – Information No. 2

Basic Principles

Guidelines for Planning Refrigerating Systems



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The Guidelines for Planning Refrigerating Systems support you in questions that are important for running an economical, reliable and energy-efficient refrigerating system.

This document contains all the information you need.



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1 Clarifying the cooling demand

In existing systems, the requirements for the refrigerating system will usually have changed since it was created. A renewal is therefore the perfect time to work with the customer to analyze his current requirements for the refrigerating system.

This provides the basis for an appropriate design for the entire refrigerating system.

In new systems, the key is not to block off opportunities.
Plan the refrigerating system as an entire system.

Clarification includes the following points:

Cooling demand/load profile of the heat source

- Clarify the dimensions of the system
- Record the freezing capacity, goods turnover or load
- Take further extensions and modifications into account
- Maximum refrigeration capacity in summer
- Minimum partial load

Temperatures/temperature profile of the heat sink

- Define the current process temperatures
- Define specific requirements of the processes
- Record the temperature requirements in the operation area
- Maximum and minimum outside temperatures

Reduction/change in the refrigeration demand

What needs to be done?

- Discuss construction measures (shading, insulation, construction features)
- Check the insulation of new or existing rooms and pipes
- Take components procured by the operator himself (e.g. refrigerated display cabinet) into account
- Reduce the demand through correct user operation
- Train staff (see optimization tool, information sheets for staff)

Taken into account in planning.



Note

For the refrigerating system to comply with the VDMA recommendations, all ten points from the guidelines need to be taken into account in planning. Deviations from the recommendations may be necessary in Section 3 (Proper planning of the system) in specific cases (e.g. in refrigerating systems for specific processes). In such cases, the contractor/planner can give reasons for the points not fulfilled in the “Comments on the guidelines” box.

2 Heat recovery

Heat recovery can make a valuable contribution to reducing the energy costs for building heating, warm water or process heat, without impairing the efficiency of the refrigerating system.

Examining the options

The Guidelines for Planning Refrigerating Systems specifies that the refrigeration expert must work with the customer and the other trades to examine the suitability of heat recovery from the refrigerating system. This examination includes the following steps as a minimum:

Heat recovery?

Discuss the following:

- Is there an option for using the waste heat in the immediate vicinity?
Which temperature level is needed for this?
- When, in which season and in what quantity is the waste heat needed?

Define the most efficient source of waste heat

If there is a demand for heat, it is important to examine which sources of waste heat (refrigerating system, compressed air system, waste process heat e.g. from ovens, melting processes...) are available in the plant and which are best suited to each use:

- Temperature levels of the waste heat sources
- When does the waste heat arise (schedule)?
- How much heat can be delivered in each case?

Requirement for heat recovery

If the refrigerating system meets the requirements of the heat user, heat recovery must be examined in detail.

The condensation temperature of the refrigerating system to be controlled is especially important here.

Note for planners and contractors

(See also VDMA Specification 24019 “Heat recovery in refrigerating systems”)

Options for heat recovery

Passive waste heat

- No change to the condensation temperature (for the use of de-heating heat/oil cooler heat).

There are no additional operating costs for this waste heat (heating price zero per kWh).

Conditioned waste heat

- With increase in condensation temperature (in order to use all waste heat). The operating costs of the refrigerating system increase.

In this case, the waste heat is not free.

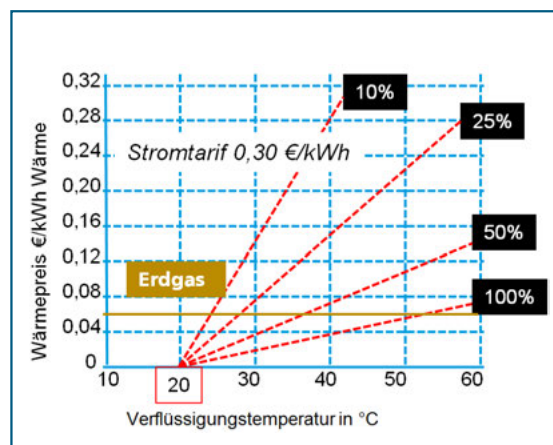
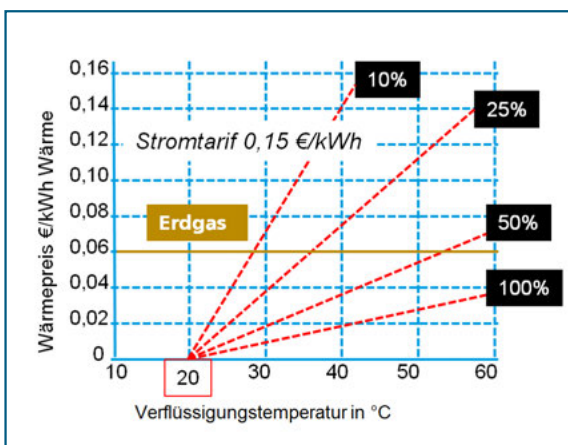
The costs for waste heat are lowest when all the waste heat is used.

The control must be designed in such a way that the condensation temperature is only raised during the the period in which waste heat is used.

Economic evaluation

A simple economic evaluation (investment costs, operating costs) is useful. As well as the investment, the price of the waste heat must also be taken into account in the economic evaluation (see graph below).

Heat price for heat recovery



Graphs apply to piston compressors,
 $Q_o = 98 \text{ kW}$, R134a, $-10/+20 \dots 60 \text{ }^\circ\text{C}$;
 The heat price (waste heat) can be seen from the red line.
 Source: Derived from SSP Kälteplaner, Switzerland

Taken into account in planning.



3 Planning the system properly

The planning phase decides whether the refrigerating system will be able to work in a reliable, economical, energy-efficient and environmentally-friendly way. Planning should always be based on the latest technology.

Sizing principles

- The requirements, framework conditions and size of the system should be discussed and defined in detail together with the customer.
- Depending on the load profile, number and performance of the refrigeration units, the use of several compressors or separate system components may be an advantage.
- The predominant operating conditions (normal operation), potential extreme operating conditions and maximum cooling load must be determined.
- Preventing multiple consumers from having their peak cooling loads at the same time enables a reduction in the cooling capacity to be installed.
- Reserves and redundant capacity must be planned.
- Heat exchangers must be sized in such a way that the temperature differences are as small as possible.
- Where possible, free cooling for air conditioning applications (water cooling) should be planned.

Requirements for control

- The compressor control adapts the cooling capacity to the cooling demand. The control that uses the least energy of the available options should be chosen for each individual case.
- The condensation temperature should be based on the outside temperature. Limits of use for compressors and the operation ranges of expansion valves can impair this objective.
- Auxiliary drives (e.g. pumps, fans, heater) may be operated if possible, depending on demand.
- The interdependency between the input power for pumps or fans (fluid transport effort for cooling water or cooling air) and modification of the input power for the compressor must be assessed in accordance with VDMA Specification 24247-2 “Energy Efficiency of Refrigerating Systems, Part 2: Requirements of the system design and components”.
- Mixing cooling water of different temperatures is only acceptable if the alternatives (e.g. using multiple individual systems) are less energy efficient.

Requirements for the individual components

- Temperature differences in accordance with VDMA 24247-8 “Energy Efficiency of Refrigerating Systems, Part 8: Component heat exchangers” are the target for heat exchangers.
- For dry evaporation, electronic injection valves should be preferred in order to achieve the smallest possible temperature differences.
- In a group of multiple condensers, at least one compressor should have energy-efficient, continuous partial load control, e.g. steady control of the rotational frequency.
- In the secondary refrigerant system (e.g. cold water systems), the pump must be controlled according to need.
- The interdependency between the temperature difference in the secondary refrigerant and the recirculation pump performance (fluid transport effort) should be assessed in accordance with VDMA Specification 24247-2 “Energy Efficiency of Refrigerating Systems, Part 2: Requirements of the system design and components”.
- Fans and pumps should have speed-controlled EC motors.
- Motors of efficiency class IE3 or IE4 should be used.

EC energy class	IEC code	EFF code	NEMA
Super premium efficiency	IE4		
Premium efficiency	IE3		NEMA premium
High efficiency	IE2	EFF1	EPAct
Standard efficiency	IE1	EFF2	
Below standard efficiency		EFF3	

Table: Overview of the IEC energy classes and various efficiency codes

Requirements for defrosting

The type of defrosting should be determined based on the following system:

In coolers installed in rooms with a room temperature higher than 4°C, circulation defrosting must be preferred to other versions. If the room temperature is lower than 4°C or circulation defrosting is not possible for other reasons, it is important to examine whether heat recovery is possible, e.g. warm glycol defrosting or, if this is not possible, hot gas defrosting or combined hot gas/electric defrosting. In other cases, electric defrosting must be chosen. The defrosting process must always be conducted according to demand (defrost on demand).

Note

VDMA Specifications can be ordered from Beuth Verlag, 10772 Berlin, phone: 030/2601-2260, fax: 030/2601-1260.

4 Thermal insulation

Cold pipings and valves must be provided with suitable vapor-tight thermal insulation in order to prevent heat input and condensation formation, and have a leak-proof design.

The thickness of the insulation is determined using the following process:

- Determination of the required insulation thickness for condensation prevention
- Determination of the required insulation thickness in order to minimize the heat input (“waste cooling”) based on the fluid temperature, the pipe diameter and the ambient conditions

Taken into account in planning.



5 Monitoring and remote monitoring of refrigerating systems

For safe operation, for preventative maintenance and to minimize the operating costs, it should be possible for a specialist company and/or the operator to monitor the refrigerating system remotely via a data connection. This allows to take action in time and, for example, observe the energy consumption and temperature of the cooling locations. To reach this state, the refrigerating system needs to be equipped with suitable sensors.

Minimum requirements

As a minimum for monitoring, collection of operation data and optimizing the operation of the refrigerating system, following meters are necessary:

- Separate electricity meter for the entire refrigerating system (incl. auxiliary drives)
- Operating hours and switch-on frequency meters for each compressor

Recommendation

Further separate electricity or operating hours meters for auxiliary drives (pumps, fans, defrost heater etc.)

Systems with secondary loop (e.g. chiller)

In addition, the following components must be installed:

- Temperature sensors at the inlet and outlet of the condenser's secondary circuit.
- If a heat meter is not yet installed, an adapter should be provided for later installation.

The measuring data recorded enable the coefficients of energy efficiency and the level of energy efficiency of the refrigerating system to be determined in detail (see VDMA Specification 24247-2 "Energy efficiency of refrigerating systems, Part 2: Requirements for system design and components").

The efficiency tool (calculation model for the implementation of the energy efficiency criteria of refrigerating systems developed in VDMA 24247) of the Forschungsrat Kältetechnik e.V. (Research Council for Refrigeration Technology, www.fkt.com) can be used for calculation.

Taken into account in planning.



Note

VDMA Specifications can be ordered from Beuth Verlag, 10772 Berlin, phone: 030/2601-2260, fax: 030/2601-1260.

6 Choosing a refrigerant

The refrigerant affects the environmental impact (global warming), electricity consumption and economic feasibility of the refrigerating system.

Natural refrigerants: Why?

Although natural refrigerants are usually the right choice when it comes to the environmental impact and economic feasibility, they cannot be used in every case, as the components needed for the cooling circuit are only available at greater expense or increased safety requirements have to be met.

The past has shown that chemical substances repeatedly had to be replaced due to their global impact on the environment.

- The use of R11 and R12, for example, was banned in the Montreal Protocol.
- The use of HCFC (e.g. R22) for service purposes has been banned since 2015.
- The EU F-Gas Regulation (EU) No. 517/2014 defines GWP upper limits that limit or even ban the refilling and use of refrigerants.

Choosing the refrigerant carefully and with an eye on the long term protects the operator from expensive conversions in the future.

The specifications of the German Chemicals and Climate Protection Ordinance (Chemikalien-Klimaschutz-Verordnung) and the German Chemicals and Ozone Layer Ordinance (Chemikalien-Ozonschicht-Verordnung) must be adhered to when the refrigerant is chosen.

A suitable refrigerant must be chosen for each application. The best choice is a refrigerant with low global warming potential (GWP), ideally a natural refrigerant such as R744, R717 or R290.

The following aspects are important in this context:

- Environmental impact, especially the global warming potential of the refrigerant
- Occupational health and safety, safety requirements
- Service and training requirements
- Availability and costs

Conversion and/or expansion of existing refrigerating systems

In a system that still uses refrigerants containing fluorine (CFC/HCFC/HFC), it is important to clarify whether the existing refrigerant can be replaced.

- Is conversion technically possible (e.g. pressures, oil)?
- What would be the cost of conversion?

As an alternative to conversion and/or expansion, new construction should be assessed as part of an overall feasibility study.

This would enable the entire system, including heat recovery, to be redesigned and optimized under aspects of energy efficiency.

Taken into account in planning.



7 Greenhouse gas emissions

Planning refrigerating systems should include calculation of the total equivalent warming impact (TEWI).

The TEWI value shows the greenhouse gas emissions a refrigerating system causes over its expected life time. This consideration enables different types of system to be assessed for their environmental efficiency.

The greenhouse gas emissions of a refrigerating system comprise the direct CO₂ emissions (refrigerant loss during operation and recovery of the refrigerant) and indirect CO₂ emissions (energy consumption).

Calculating the TEWI

In order to calculate the TEWI, leaks during operation, recycling leaks and electricity consumption need to be determined.

The standardized calculation helps the customer to assess the environmental impact of different systems.

Calculation of the TEWI is shown in EN 378-1; see also www.energieschweiz.ch.

The calculation of the TEWI of the various system concepts and refrigerants is attached to the planning documents for the refrigerating system and has been explained to the customer.



8 Electricity consumption

Depending on the type of system, the electricity costs can account for up to 90% of the total costs over the entire life cycle of a refrigerating system. Investment in a more expensive yet more efficient refrigerating system can therefore pay off quickly.

When planning refrigerating systems, it therefore makes sense to calculate the electricity consumption of the refrigerating system (compressor and auxiliary drives) so that the influences of the season and goods turnover on the refrigeration demand and electricity consumption can be taken into account.

The planning documents should include a calculation of the seasonal energy efficiency.

To do this, the following assumptions should be made as realistically as possible:

- Cooling load characteristics, e.g. depending on the outside temperature (kWh/a)
- Location-dependent seasonal outside temperature characteristics for the condenser/recooler

The Forschungsrat Kältetechnik e.V. 's (Research Council for Refrigeration Technology) efficiency tool should be used to calculate the seasonal energy efficiency.

Determining the electricity consumption (using the efficiency tool, www.fkt.com)

The efficiency tool enables an estimate of the electricity consumption for the planned refrigerating system, taking into account the seasonal cooling load demand depending on the outside temperature.

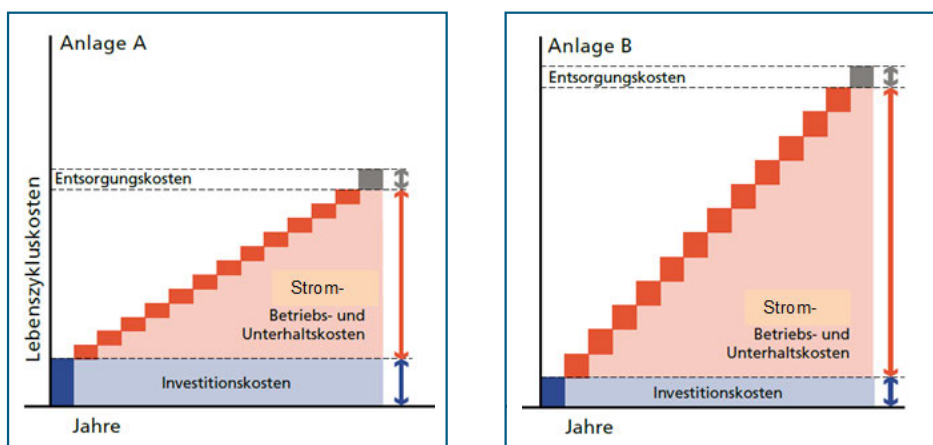


Fig. 1: System A, with slightly higher investment costs but lower seasonal electricity costs, has much lower life cycle costs than System B, which has a lower purchase price but higher seasonal electricity costs.

The planning documents should include a calculation of the seasonal energy efficiency for various system concepts.



9 Economic Evaluation

A refrigerating system incurs investment, maintenance and operating costs – e.g. for electricity and water – of various amounts. The planning documents should take these cost items into account in a feasibility study over the entire life span.

The investment costs and the annual operating costs of the refrigerating system can be estimated for every possible system configuration. The Forschungsrat Kältetechnik e.V.'s (Research Council for Refrigeration Technology) efficiency tool can be used to do this.

Here it is important to define the framework conditions so that the operating costs of various system configurations can be compared.

Among other factors, the annual amortization depends on the planned usage period.

Life time of the system

The life time of the refrigerating system must be estimated in consultation with the operator.

In Switzerland, for example, the following average life spans are assumed for specific applications:

- Supermarket 12 years
- Industrial refrigeration 20 years
- Commercial refrigeration 15 years
- Air conditioning refrigeration 15 years

(Source: “Kampagne effiziente Kältetechnik”, Switzerland)

Electricity costs

The electricity costs (see also section 7 in this document) are calculated based on the consumption and the current electricity price.

Where different daily and weekly rates for electricity apply, a mixed rate is calculated based on the assumed operating times. Predicted changes in the electricity price are not taken into account.

Maintenance costs

A figure of 3% of the investment costs are assumed for this (see DIN 31051).

Interest on capital

Interest on capital is not taken into account in the calculation. Depreciation on the investment is not taken in account.

Calculating the annual costs

The annual costs of the refrigerating system are calculated as follows:

$$\text{costs} = \frac{\text{investment costs}}{\text{life time}} + \text{electricity costs} + \text{maintenance}$$

The Forschungsrat Kältetechnik e.V.'s (Research Council for Refrigeration Technology) efficiency tool can be used to calculate the annual electricity costs.

**For a detailed feasibility study, changeable capital costs and predicted changes in the electricity price must also be taken into account.
The planning documents include a feasibility study.**



10 Commissioning, optimization, operating manual

Refrigerating systems that are properly planned, adjusted correctly during commissioning and optimized run in a reliable, economical and environmentally-friendly way. Commissioning must therefore be conducted by an expert.

Proper commissioning

In addition to the usual commissioning process, the following points must be taken into account for adjustment:

- Set the highest possible demanded evaporation temperatures.
- Set the lowest possible demanded liquefaction temperatures.
- If expansion valves are used, overheating must be set as well as possible.
On air coolers, expansion valves should be set in such a way that the total overheating corresponds to 0.65 times the air entry temperature difference as far as possible. Overheating must be checked during operation. Smaller overheating values can usually be set on electronic injection valves.
- Defrosting as needed must be set.
- In air conditioning refrigeration, the release value for refrigeration (refrigeration threshold) must be set as high as possible.
- Ensure that it is not possible to operate heating and air conditioning in the same room at the same time.
- On the air conditioning control, the refrigeration curve must be set to adapt automatically to the different outside temperatures in summer and winter.
- Remixing of the cold water must be prevented (air conditioning refrigeration, recooling).
- Ensure that the consumers are only in operation when they are needed.
- A system protocol, e.g. in accordance with EN 378, must be compiled as documentation.

Optimizing the system

After the refrigerating system is commissioned, optimization should take action. This must include checking, and adjusting if necessary, all values regarding the function and minimum energy consumption set during commissioning.

Operating manual for the operator

The planning documents include a relevant operating manual (see also EN 378).

It provides information on the following:

- Structure and function of the refrigerating system
- Refrigerant: control cycles for leak checks
- Behavior in case of leakage
- Safety equipment
- Behavior in case of disturbances
- Options for checking and improving the energy efficiency of the system
- Options for the operator and individual users to reduce electricity consumption
- Operation optimization, running times, temperature level
- Regular maintenance work (cleaning of heat exchangers, recoolers, fans etc.)

**The Guidelines for Planning Refrigerating Systems specify proper commissioning and optimization that includes the points listed above.
The operator is informed as necessary.**



11 Servicing during operation

Correct operation and continuous maintenance ensure the energy efficiency of the refrigerating system. Well-maintained refrigerating systems need noticeably less electricity and have a lower environmental impact.

Maintenance measures may only be conducted by specialist staff qualified to do so (see EN 13313).

The annual refrigeration check

The annual refrigeration check allows the refrigerating system's current level to be checked in relation to the planning and initial commissioning.

Checklists are provided for this (see VDMA 24186-3: 2002-09 “Program of services for the maintenance of air-handling and other technical equipment in buildings – Part 3: Refrigerating devices and systems for cooling and heating purposes”). These checklists must be discussed with the operator.

The guidelines for planning the refrigerating system should show the servicing needed for the new refrigerating system.

If it is not yet clear at the time of planning who will operate the system in the future, this section must be transferred to the operator for maintenance before commissioning.

Servicing is included in the Guidelines for Planning Refrigerating Systems  and adapted to the specific demands of the customer.

Note

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You will find more information on energy and cost efficiency at www.kwt.vdma.org/Energieeffizienz.

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- is based on the form and content of the SVK document “Grundlagendokument zur Leistungsgarantie Kälteanlagen”.
- leads systematically to the relevant issues for planning and operating an energy-efficient refrigerating system.
- increase awareness of planners, installers and operators of refrigerating systems for the topic of energy efficiency and helps them to enhance their skills.
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