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IFMA BENCHMARKING
// CHEMISTRY, PHARMA, LIFE SCIENCE

IFMA Benchmarking®
Good Operating Practice

Whitepaper
CO_2 - und energy reduced operation of lab-buildings

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1 Preface

1.1 Work group IFMA-Benchmarking

The research results presented below are the result of several years of work by the IFMA-Benchmarking® Chemistry, Pharma & Life Science working group. When the work group was established in 2004, the participating companies pursued the goal of using benchmarking to identify the most successful concepts and solutions for the construction and operation of research buildings. Currently, 13 leading companies in the chemical and pharmaceutical industry, often with several sites, are taking part in the benchmarking process.
The benchmarking methodology used provides the participating companies with insights into the potential for improving quality and optimizing costs in facility management. The benchmarking itself, which is carried out continuously in anonymized form in compliance with the principles of competition law, serves the participants to determine their own position in the field of comparable companies.
The focus of the joint work is on best practice workshops in which the participants discuss their experiences and optimization concepts. This structured exchange of experience provides all participants with continuous inspiration and identifies potential for improvement. Approaches to solutions that achieve a broad consensus are generally processed as so-called Good Operating Practices (GoP). They serve as guidelines for the participants to develop company-specific solutions.
This GoP was prepared by a working group consisting of Thomas Herweg (Bayer), Kai Uwe Thorn (Covestro), Thilo Brockschmidt (Merck) and Dr. Stefan Krause and Nikolai Schütz (both Sanofi).
Jörg Petri and Hermann Josef Rottkemper are the spokespersons of the Best Practice Group. Andreas Kühne, BAUAKADEMIE Performance Management GmbH (BPM), is responsible for scientific management and moderation. BPM specializes in industry-specific roundtable benchmarking and assumes the neutral function of benchmarking coordinator. In this role, it provides organization, technical support, data management including reporting, and moderation of all working sessions. BPM holds a special antitrust certificate and is certified according to DIN ISO 9001 (quality management) and DIN ISO 27001 (information security). With this qualification, BAUAKADEMIE Performance Management GmbH assumes responsibility for compliance with the principles of competition law and ensures the confidential handling of data. Additionally, the following companies participated in the IFMA Benchmarking® Best Practice Group this year, represented by:

BASF SE	Udo Armin Winnewisser Thomas Wall
Bayer AG - Berlin	Jörg Petri
Bayer AG - Monheim	Martin Ritterbach Christian Schmitz
Bayer AG - Wuppertal	Stephan Schmidt
Boehringer Ingelheim Pharma GmbH & Co. KG	Dieter Butz Hermann-Josef Rottkemper
Covestro Deutschland AG	Kai-Uwe Thorn Markus Hauser
CURRENTA GmbH & Co. OHG	Toni Buettgen

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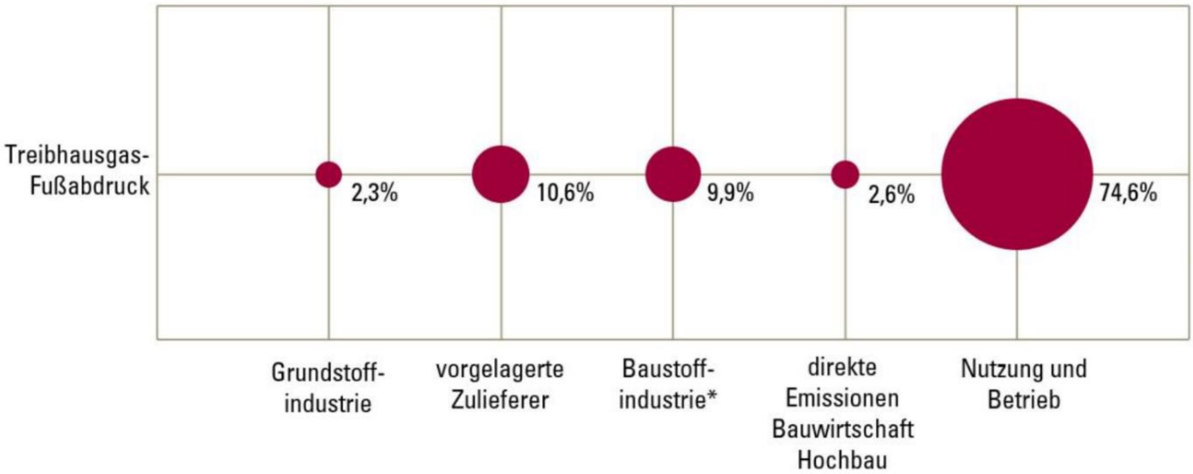
Roche Real Estate Services Mannheim GmbH	Martin Flörchinger Christoph Zeller
Roche Diagnostics GmbH, Penzberg	Klaus Retschy Sven Schuldt
Sanofi Aventis Deutschland GmbH	Dr. Stefan Krause Lars Pfannenschmidt

1.2 Energy & CO_2-footprint

Like all commodities, real estate goes through a life cycle, beginning with construction and ending with demolition. However, the focus is usually only on the longest phase of the lifecycle, operations.
Accordingly, this white paper focuses on operational CO2 emissions, also known as operational carbon.
When the term CO2 is used in the following, it always refers to CO2 equivalent or greenhouse gas.
However, when considering the entire lifecycle of a property, other emissions also play a role and are referred to as "grey emissions".
These are the CO2 emissions caused by the manufacturing process of building materials and components, as well as the construction of the final product, the building. While emissions from the operation of a building are proportional to its use and the duration of its life cycle, embodied emissions are released into the environment within a short period of time (during production) or are partially stored in the building itself in the long term (relevant for emissions during demolition).
Roughly speaking, embodied carbon accounts for 25% of lifecycle emissions, with operational carbon[1] accounting for the remaining 75%.With this in mind, before demolishing a building, careful consideration should be given to whether it makes more sense to keep it in use.

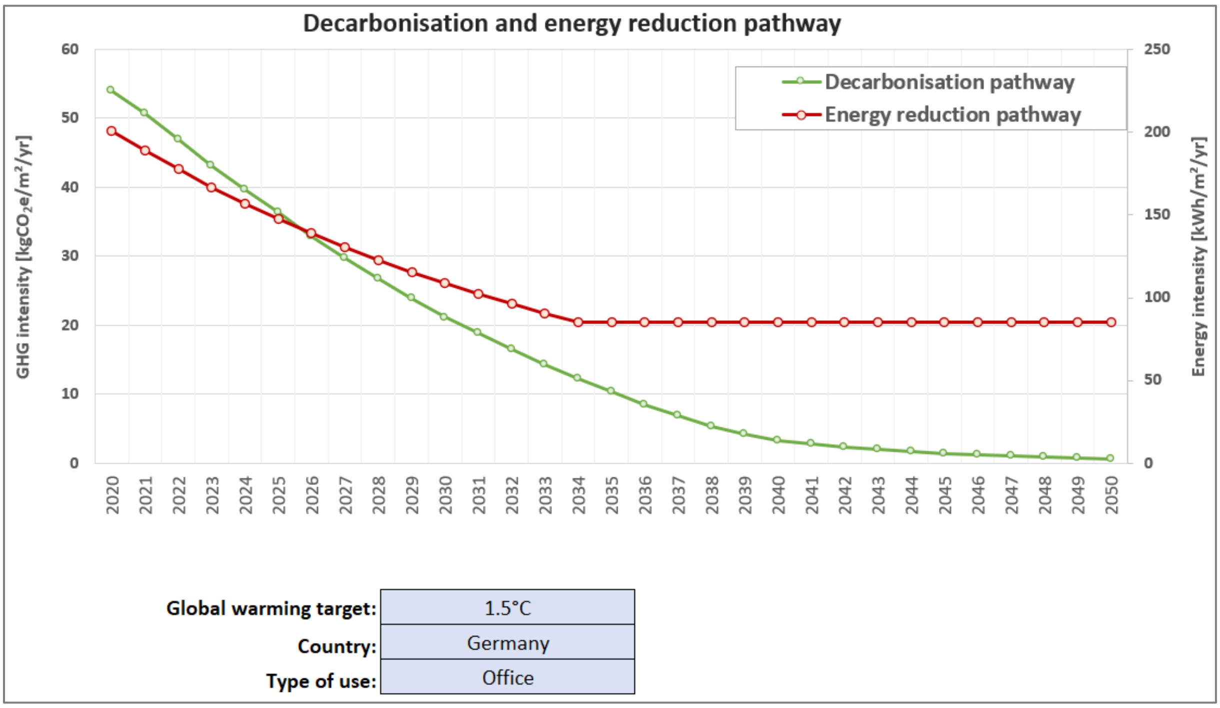


CO2-Footprint of the action field „erection and utilization of surface constructions"
(*Construction materials industry and direct suppliers)

[1] BBSR -Online-Publikation Nr. 17/2020 Umweltfußabdruck von Gebäuden in Deutschland

1.3 Decarbonisation and reduction of energy

The Carbon Risk Real Estate Monitor (CRREM), which shows the necessary reduction in energy consumption and the corresponding CO2 emissions by the year in which the real estate portfolio in the EU is to be carbon neutral, gives an idea of the future challenges. The CRREM does not yet include reduction paths for laboratory real estate. However, the chart below shows the trend using office buildings as an example.[2]



[2] CRREM CARBON RISK REAL ESTATE MONITOR v2.03 – EU (18.04.2023)

2 Initial situation & question

The basis for global climate protection efforts is the United Nations Framework Convention on Climate Change of 1992, supplemented and specified by the Kyoto Protocol of 1997, which for the first time legally established the obligation to limit and reduce greenhouse gases.
The German Climate Protection Act of 2019, updated in 2021, is a response to the Paris Agreement of 2015, which entered into force in November 2016 and commits all parties to the agreement, at that time 195 states and the European Union, to take the necessary measures to limit global warming to "well below" two degrees compared to pre-industrial times and to make efforts to limit it to 1.5 degrees.
In the current German Climate Protection Act, the targets for CO2 emissions have been tightened once again in view of the new European climate target for 2030. In the Climate Protection Amendment of June 24, 2021, the stages for reducing CO2 emissions were redefined in terms of both time and quantity until climate neutrality is achieved in 2045. These regulations will primarily affect the main emitters: industry, transportation, buildings and agriculture.

The law currently sets the following targets for greenhouse gas emissions
- By 2030: 65% less CO2 than in 1990 (2016 target: 55%)
- By 2040: 88% less CO2 than in 1990
- **By 2045: climate neutrality (2016 target: 2050)**

While realisable concepts for achieving these goals are available for residential buildings in particular, but also for office properties, these are still lacking for many energy-intensive industrial sectors. However, it is precisely in these sectors that such measures urgently need to be developed due to the considerable lead time for planning, financing and implementation and also in view of the often long service life of technical systems.
These guidelines provide information on how to reduce CO2 emissions on the way to climate neutrality in the operation of laboratory buildings.

Questions in detail:

1. How energy consumption in the operation of laboratory buildings can be reduced?
2. Which options for local energy generation contribute to further CO_2 reduction?
   a) Energy generation at the property
   b) Energy supply from the neighbourhood

3 Principles and scope

In particular, these guidelines address laboratory specific requirements (e.g., air exchange, handling of hazardous materials). It does not address issues that apply to buildings in general (e.g. external shading, PV, heat recovery, geothermal solutions).

3.1 Preliminary notes

In the interplay of building / room layout, technical trades system design, (laboratory) equipment layout, intelligent laboratory use, etc., the goal should be to operate the building as precisely as possible according to actual requirements and thus in a cost and energy efficient manner. The basis for this is already created during the planning of the building, starting with the size or area of the laboratories and the level of detail of the technical building systems. The corresponding measures are outlined below.

3.2 Criticism of current laboratory utilization system

This guideline is based on the assumption that it is possible to drastically reduce energy consumption of laboratory buildings by fundamentally rethinking the way they operate. Almost all existing laboratories reflect a concept that has remained unchanged for decades. It is therefore strongly recommended that the basic concept of the laboratory be discussed in detail before any new project is undertaken.

Currently, almost all laboratories have an air exchange rate of at least 25 $m^3/m^2/h$, which is considered safe according to the lab guidelines. The existing option to optimize the air exchange rate according to the needs based on a risk assessment is not used sufficiently. In many cases, the air exchange rate implemented to protect workers is misused to dissipate heat/temperature loads from energy-intensive laboratory equipment.

This often eliminates the possibility of reducing the air change rate (to zero), even outside of working hours.

There is an urgent need to change habits in the implementation of laws and laboratory guidelines and to justify every air change, starting from zero, and to end the temperature control of (energy-intensive) laboratory equipment via the general room air conditioning. This is one of the biggest levers for CO2 and energy savings.

3.3 Scope of application

This white paper is intended for those responsible for infrastructure management and occupational safety in the laboratory environment, planners and suppliers of technical equipment for laboratory buildings, engineering and technical departments, and employees in laboratories and pilot plants.

All measures described here are recommendations and suggestions. Each individual measure must be agreed upon with those responsible for the operation, i.e. the plant manager and the laboratory manager, and analysed by means of a risk assessment/safety analysis before it is implemented. Relevant regulations and technical rules for planning and operation remain unaffected. When implementing the measures described here, personal, technical and organizational safety precautions must always be taken for employees in laboratories and pilot plants. Responsibility remains with the above-mentioned management functions. The protection of people, the environment and property must be taken into account in all considerations.

4 Basic design requirements with respect to existing lab buildings

4.1 State of the art

The main energy consumer in a laboratory building is the ventilation system (50-70% of the total energy demand). The required air exchange rate is determined by occupational health and safety (handling of hazardous substances). In addition, many laboratory instruments are cooled by the general room ventilation. This is one reason why ventilation cannot be completely shut off outside working hours. Since the efficiency of exhaust and cooling systems decreases at partial load, even in setback mode, the overall energy savings are small.

4.2 Consequences for energy-optimization of laboratory buildings

When operating an energy-optimized laboratory building, the focus must primarily be on direct and indirect energy consumption for ventilation, including temperature control of the laboratories and technical systems.

Necessary air changes should therefore be reserved for work and product protection; cooling of laboratory equipment (especially in 24/7 operation) should be avoided.

The specification of the laboratory guideline of 25 m³/m²/h fresh air (approx. 8-fold air change) does not usually require any further risk analysis and is therefore usually implemented for practical reasons. In reality, however, air changes on this scale should be an exception.

A concept must be drawn up for the laboratory building as to how laboratory operation can be ensured with < 25 m³/m²/h fresh air (down to 0). This is possible in accordance with the laboratory guideline (TRGS 526, Chapter 6.2.5 Para. 1) on the basis of a risk and hazard assessment and has already been successfully implemented.
The procedure should be selected in such a way that the smallest unit of use (e.g. fume cupboard, laboratory room, possibly an entire room or floor) is considered and then evaluated. The HSE, user, operating engineer and, if necessary, other responsible parties should be consulted.
Two time ranges should be taken into account:

a) Night, public holiday and weekend operation
b) Regular operation during normal working hours

In both periods, organizational and technical options (e.g., frequency converters / ventilation control dampers, etc.) should be used to meet the respective usage requirements of laboratory areas and equipment (e.g., fume hoods, extracted enclosures/workstations) quickly and without involving third parties (technical personnel).

It should be noted that the open handling of hazardous substances has decreased significantly over the last 20 years and is now mainly done in closed systems or fume cupboards.
The Laboratory Guidelines[3] does not yet address this development.
One possible approach to implementation is the zoning of a laboratory building into (large) areas with complete shutdown outside working hours (special procedures may remain in place) and 24/7 operation of other (smaller) areas.

[3] The "Guidelines for Laboratories" (DGUV Information 213-851 (previously BGI/GUV-I 850-0e, BGR/GUV-R 120e, ZH 1/119 and GUV 16.17)

4.3 Building layout

4.3.1 Building design / Layout

The building layout is of fundamental importance, as only with the right planning the operation will remain flexible to take advantage of future energy saving opportunities.
Based on the assumption that there is an optimal building size (building volume) in terms of usability and energy efficiency, it is proposed to define "modular basic laboratory units" (with a fixed area of x * y m²). These should have the following characteristics

- Optimal ventilation connection
- Sufficient size for individual operation, e.g. on weekends (controllability)
- Optimized infrastructure (technical building equipment, logistics, supply and disposal, bundling of critical areas) for the spatial connection of the individual units.

The "modular basic laboratory unit" should be planned as often as necessary in the optimal building volume.
Limiting or required parameters of the individual units can be essential for the planning and should therefore be defined at an early stage in order to meet the requirements of a) research and b) climate neutrality:

- Max. required surface load
- Door and window geometry
  Clear room height/ceiling height or floor height (influence on possible ventilation duct cross-sections)
- Max. Loads and dimensions for the freight elevator
- Logistics parameters (e.g., forklift and truck traffic, ramp, floor assembly openings)
- Other parameters, if applicable

The laboratory building consists of the following types of laboratory units:

1. 12/5 standard laboratory (standard laboratory with 12-hour working time, 5 days a week, outside working time all room ventilation is switched off, except for special exhaust air)
2. Documentation areas (typing/writing areas with very little or no forced ventilation)
3. 24/7 laboratory ("night laboratory")
4. Support laboratory areas for shared equipment
5. Support laboratory areas for high heat emitting equipment (e.g. MS equipment, low temperature cabinets, cold rooms).

This approach is based on "normal" laboratory use (= wet chemical/biological/physical laboratory); larger machines and systems should be planned in separate usage units along similar lines wherever possible.

It should be considered whether an optimal size of basic laboratory units (with xy m²) can be aimed for, because it can be operated efficiently.
Possible factors:

- Usage units that are too small => higher investment costs & higher control costs
- Units of service that are too large => lower savings if not fully utilized ("switched on" even if only one person is working)

4.3.2 Operational concept

Together with the users (= research functions), the optimum in terms of (laboratory) space utilization and energy consumption should be sought, depending on the use of the building. Equipment and space should be shared rather than procured and operated "individually" for each research function.

In this context, the "shared lab concept" is a convincing method for reducing space and thus energy requirements and should be introduced and implemented on a broad basis. Existing or implemented concepts should be regularly reviewed, validated and, if necessary, adapted/optimized.

4.3.3 12/5-Standard-Lab

Outside working hours (generally 6 p.m. to 6 a.m. on weekdays, holidays and weekends, to be defined individually for each property), the ventilation system is shut down completely or reduced to the minimum technically possible. The following must be ensured

- No backflow from the exhaust ducts
- Special exhaust air for safety cabinets, if necessary
- No freezing of the heating coil when restarting
- No unacceptable cooling or heating of the building
- No risk to guard personnel (night/weekend security)

4.3.4 Write-up areas (Non-Lab areas)

Write-up areas and other laboratory-related areas that are not subject to ventilation requirements should be isolated to prevent unnecessary air changes.
This can be done in two ways:

A. Writing-areas should be closely adjacent to laboratories (an appropriate zone concept for overflow should be developed). Compared to B), this solution has a less efficient energy balance for the same lab/desk configuration.

or

B. Writing areas are bundled and completely separated from laboratory areas. Writing areas are connected to the laboratory units only via sluice-like connections (more favourable energy balance, as unnecessary overflows and associated pressure losses are avoided).

4.3.5 24/7- Lab („nightlab“)

In a laboratory building that operates primarily on day shifts, some 24/7 ventilation areas ("night rooms") will need to be provided, where systems that also operate at night or on weekends will be grouped together. Depending on the research project, it may be necessary to replace equipment or processes in consultation with HSE or the plant engineer/laboratory manager.
Organizational (agreement between research functions or e.g. "booking system") and technical precautions (e.g. coupling of drying oven - ventilation) must be taken in order to use the 24/7 rooms as required.

4.3.6 Support-Lab space for commonly used devices

In laboratory areas, a lot of redundant equipment is kept, maintained, checked, inventoried, repaired if necessary, etc.. In most cases, each laboratory or laboratory unit has a "complete set" of equipment and systems, e.g. dishwasher, balance, stirrer, etc. This form of organization requires a corresponding amount of space and ultimately ventilation volume for each individual operational laboratory unit.

This shortcoming can be remedied by developing a "shared equipment" concept and implementing it for as many laboratory units as possible.

A theoretical example is the introduction of a "central" weighing area: where previously there were ten scales in the relevant laboratory area, now only five are needed if the scales are brought together in one central weighing area and are technically supervised by a dedicated person. All researchers in the area are free to use the scales, but it may be necessary to coordinate the times of use.

4.3.7 Support-Lab space for devices with high heat load to the room

For example MS equipment, low temperature cabinets, cold rooms

The concept should be very similar to the example in chapter 4.3.6.

Here it should be possible to regulate the heat dissipation in order to be able to react to higher or lower requirements (e.g. due to devices being switched on/off and depending on the season) with regard to heat dissipation.

5 Building construction

5.1 Structural design

During the design and construction phase, it is important to ensure that all structural elements of the building - columns, floors, beams, walls, joists, or similar structures - are selected with an eye toward optimizing CO2 reduction. This is beyond the scope of this white paper.

5.2 Technical building equipment

In general, during the planning and construction phase, care should be taken to ensure that all elements of the technical building equipment (e.g. energy-optimized motors, fans, pumps, etc.) are selected in a CO2-optimized manner.
A detailed analysis is beyond the scope of this white paper.

At present, the central question is how the building can be operated exclusively with energy from renewable sources and suitable technical building equipment (e.g. heat recovery, heat pumps, low-temperature cooling and heating elements, etc.).

5.3 Power generation and -storage on site

This topic is not covered in the white paper as it is not related to building operations.

Possible measures (informative keyword collection):

- Photovoltaic system (roof/facade/facade modules)
- Hot water collectors (roof/facade/facade modules)
- Free cooling
- Roof insulation, exterior insulation, window replacement (glazing)
- Solar shading

6 Building automation and operations control

Laboratory automation is becoming increasingly important in the context of energy optimization and sustainability. Communication between devices and system components via the building management system is an important aspect of demand-driven regulation of energy consumption and operating costs.
To ensure a high level of automation, building monitoring should be carried out in accordance with VDI 6041.

6.1 IT-infrastructure and data transfer for building control

Possible measures (informative keywords):

- Demand-oriented and real-time controllability of the indoor climate and (automatic) monitoring of the associated parameters and characteristics is only possible with an appropriately designed IT infrastructure. Therefore, the associated information transmission technology (network) must be planned from the beginning due to the foreseeable high requirements and must have a very high density and quality as well as sufficient reserves.
- If there are servers or server rooms in a (laboratory) building, these must be considered separately in terms of energy.
- Water cooling and recirculating air cooling technology should be considered as energy-efficient technical solutions, but are not further evaluated in this whitepaper.
- Protection against external attackers (“hackers”) is a particularly relevant topic, but is not part of this white paper.

6.2 User-oriented control of lab operation

Laboratory users should be able to switch the lab on and off (compressed air, vacuum system, lighting, ventilation) easily and independently (using buttons/switches or by a phone call). An operating indicator should be clearly visible in the laboratory.
This does not apply to emergency and rescue systems, which must be operational at all times.

Other possible measures (informative keywords)

- Miniaturization of experiments to reduce ventilation requirements and conserve resources
- Simulation of tests
- Selection and use of equipment optimized for heat dissipation
- Bundling of laboratory areas with the same hazard potential or the same requirements (clean rooms, forced standard climate).

6.3 Ventilation

In general, semi-automated operation (startup and shutdown of laboratories) requires a much higher degree of automation than conventional operation, especially for the ventilation and heating components.
The automation requirements indicate in two directions:
On the one hand, the systems should react in a highly automated manner to the known influencing variables (temperature, humidity, individual requirements of machines/devices); on the other hand, the user should be able to "turn on" and "turn off" selected areas as easily as possible, or to regulate them within certain limits.

The use of hazardous material sensors is helpful in controlling air volumes. This requires a risk assessment in consultation with the HSE.

In the future, artificial intelligence could also link climatic and occupancy data, for example, to the building management system. This would allow demand-driven regulation to be determined in advance and all system components to be controlled in tune .

The use of energy-efficient filters is recommended to reduce differential pressure losses. Differential pressure measurement can help optimize filter life.
Leaks and losses must be avoided at all costs. The tightness of the ductwork must be continuously checked.
Humidification and dehumidification in ventilation systems should only be provided where absolutely necessary. It must be possible to control the system as required (night setback, weekend operation). If possible and necessary, the air should not be humidified with steam, but with demineralized water.

See also chapter 3.2.

6.4 Heating and cooling

Production and distribution of heating and cooling costs a lot of energy in building operation a. To effectively reduce these costs, it makes sense to look at the entire building and ask "Where is heating/cooling absolutely necessary?
The CO_2 potential of the refrigerant must also be analysed.

Part of the thermal energy can be saved by heat recovery. On the other hand, the use of outside air in certain weather conditions can reduce the amount of technical cooling required. Other technical options (e.g. ice or buffer storage) can help to stabilize the cooling supply and compensate for fluctuations in demand.
A standard measure is hydraulic balancing, which ensures an even distribution and temperature spread of heating and cooling water throughout the building, potentially reducing energy consumption.

6.5 Water supply

In general, the number of hot water taps (both drinking water and service water) should be reduced as far as possible. Hot water supply is only provided in justified individual cases, for example in showers.

- Hand basins are not generally equipped with hot water, but only where required by law.

- The supply network (circulation pipes) for hot water must be limited.
- Decentralized hot water supply as a basic concept, circulation systems only for special requirements.

6.6 Pressure air and vacuum

Compressed air and vacuum networks are generally susceptible to leaks, often resulting in undetected energy losses. The following measures should be considered

- Network structure (lines, shut-off options, flow sensors, automated pressure monitoring, use of bypass gauges)
- Review pressure level requirements (determine requirements and adjust if necessary, review standards to achieve lowest possible pressure level, e.g. 6 bar). If unavoidable, local generation of compressed air > 6 bar from 6 bar building network.

6.7 Storage

A central stock of relevant consumables should be established for research operations. This will streamline ordering, reduce transportation, and maximize storage space. Storage areas should be located outside the laboratory area (costs/air exchange).

7 CO_2-neutral energy production and -storage in the building

In principle, it is possible to meet the energy needs of new and existing buildings in a CO2-neutral way. The following solutions are currently known

- Use/purchase of (certified) green electricity
- Photovoltaics on roofs, facades, open spaces
- Solar thermal energy
- Wind energy
- Geothermal energy
- Hydroelectric power
- Hydrogen
- Battery Storage
- Hot water/cold water/ice storage
- Thermal Energy Storage
- Building component activation
- Heat from wastewater or river water

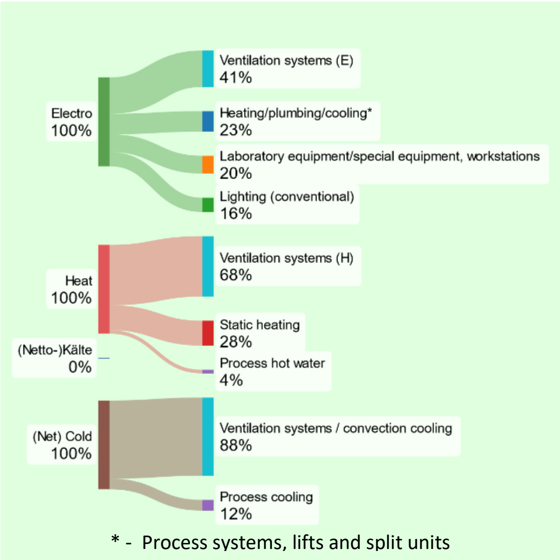
All technologies should be evaluated for cost-effectiveness and feasibility on a case-by-case basis.

8 Case studies

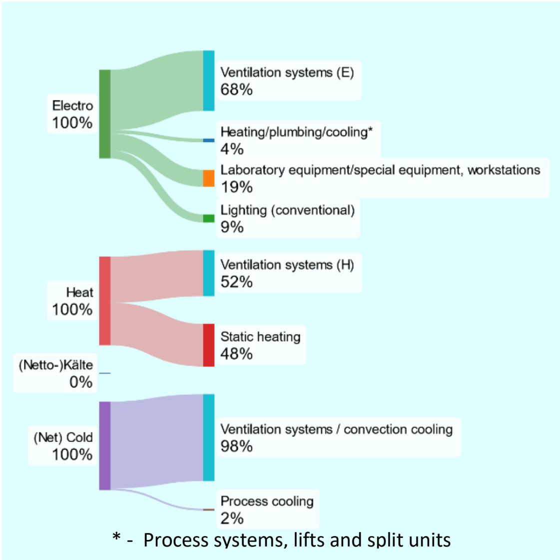
8.1 Estimation of the relative energy consumption of a model lab building

A Sankey energy flow diagram was created for a sample laboratory building based on the values of the IFMA benchmark to assess the effectiveness of the measures described and generally as a basis for our own planning.

Two companies provided corresponding energy flow diagrams as input for the averaged Sankey diagram. The left side of the Sankey diagrams is specified by the data available in the IFMA: electricity, heating, cooling energy quantities.
The categories on the right side of the diagram were initially structured differently for the two companies, but could be converted to a consistent set of categories. Percentages are derived from measured or estimated values averaged across multiple buildings.

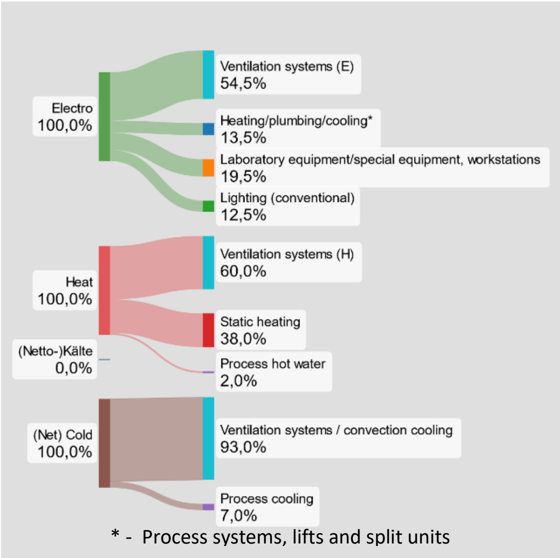


Energy flow, company 1



Energy flow, company 2

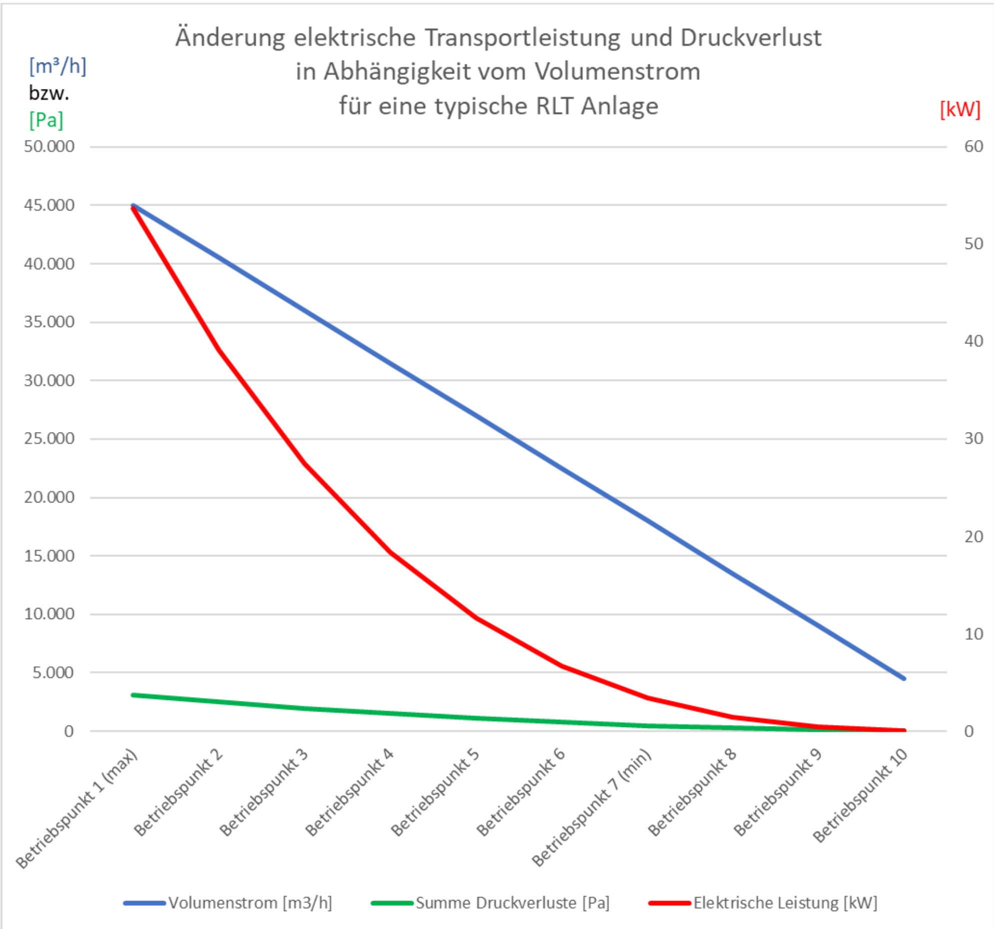
The averaged energy flows in the model laboratory building are as follows:



With the exception of electric energy for single AC split units, no cooling energy is included in the electrical energy flow. In the cooling flow, only the (net) cooling is considered, i.e. the pure cooling energy used in the building, (and not the amount of electricity required to generate it. The total cooling production is therefore not taken into account.

These energy flow diagrams can be used to estimate the results of measures even if the building data is not available at the required level of detail.
Other assumptions used in the estimate are

- LEDs use approximately 40% of the energy of conventional lighting (T5/T8 tubes).
- The potential solar gain on the roof surfaces is assumed to be 180kWh/m²/a.
- Each degree of temperature reduction in the winter season results in heat savings of approximately 5-6%.
- Volume flow (increase/decrease) is included cubically in the electrical power requirement.Pressure (decrease/increase) is included in the electrical power requirement as a square, see diagram below.
  Savings can easily be derived from this:
  - Existing systems: Reduction
  - New systems



8.2 Consumption in selected energy saving scenarios on the basis of an average laboratory building

In collaboration with a laboratory and a technical building services planner (engineering office), one participant calculated / simulated several energy-saving scenarios for a laboratory building. The main objective was the mathematical determination of possible refurbishment/upgrade procedures to achieve CO2 neutrality while maximizing long-term energy savings. The key tasks in the scenarios were to

- to calculate the savings potential of the selected model compared to the current state (unrenovated) and
- to evaluate how the upgrade variants compare with a virtual new build to the current energy standard.

The results can be used to derive the next steps for own buildings based on the respective status.

8.2.1 Base line and validation

The starting point (Scenario 0 "Unrenovated Old Building") is a real laboratory building (or part of it) with consumption according to the existing energy meters.
This building was mapped with its relevant consumers (e.g. heating, ventilation) in a standard building simulation program, taking into account its energy gains and losses (e.g. solar, convection, electrical losses/gains). The result was compared with the corresponding IFMA values and thus validated (see line "IFMA range").

8.2.2 Selected Energy Saving Scenarios

According to the abvious options, four energy saving scenarios were defined and simulated employing the a.m. software:

No.	building	Technical building equipment
0.1	Old building (status quo) thermically unrefurbished	Heating: steam 3,7 bar (abs)/(status quo) Ventilation technology: unrefurbished, standard setting (acc. guidelines) Cooling: WNC 6/12°C
0.2	Old building (status quo) thermically unrefurbished	Heating: steam 3,7 bar (abs)/(status quo) Ventilation technology: unrefurbished, reduced ACR 6 (with risk assessment) Cooling: WNC 6/12°C
1	Old building (status quo) thermically unrefurbished	Heating: high temp. Heat pumpe/ (refurbished) Ventilation technology: new, reduced ACR 6 (with risk assessment) Cooling: geothermal free cooling
2	Old building thermically refurbished	Heating: steam 3,7 bar (abs)/(status quo) Ventilation technology: standard setting (acc. guidelines) Cooling: WNC 6/12°C+ photovoltaics
3	Old building thermically refurbished (New building standard)	Heating: geothermal/low temp heat pump Ventilation technology: new, reduced ACR 6 (with risk assessment) Cooling: geothermal + photovoltaics
4	New building	Technical building equipment: completely new acc. recent standard Cooling: geothermal, thermal concrete core activation in offices & social spaces + photovoltaics

The results of the following table are explained below. Subject areas are labeled as follows:

Yellow:	Technical design details
Red:	Heating: Thermal data (results)
Light blue:	Cooling: Thermal data (results)
Dark blue:	Electric related data (results)
Green:	Area related data (results)
Purplet:	Note on results validation (reference: IFMA data)
Blue:	CO_2 reduction

8.2.3 Results and findings

Remark:
Due to the complexity of the analyses and the large number of influencing factors, only a holistic view can be taken. It is not possible to transfer the results to a specific building with its detailed situation, but it is possible to classify them in principle and to make a relatively accurate assessment of the possibilities for energy optimization.
Individual findings should be highlighted here, as they may be particularly important for your own approach, depending on the initial situation.
All figures must be evaluated with tolerances, as they were calculated with a simulation program based on assumptions, known values and proven calculation methods.
The costs include only the operation of the building, not the costs of conversion to new systems and operation (e.g. geothermal energy).

Findings:
A) Validation
- Scenario 0.1 and 2: Validation of heat demand, cell D28/32 and cell G28/32.
  The calculated value is well within the range of the IFMA average values.
- Scenario 0.1 and 2: Validation of cooling demand, cell D37/38 and cell G37/38
  The calculated value is well within the range of IFMA averages.

B) Energy savings
- Scenario 0.2:
  Building and building services unrenovated, reduction of LW to 6 times
  - Steam demand is reduced by 49% (cell E33), electricity demand by 15% (cell E50).
  - Total primary energy demand is reduced by 34% (cell E67).
  - Costs decrease by 39%.

=> This measure alone is not sufficient in the long term for cost reasons. Transitional use should be examined on the basis of cost efficiency.

- Scenario 1:
  Building: unrenovated; TGA: renovated + geothermal energy
  - Steam demand decreases to 0% (cell F33), electricity demand decreases by 19% (cell E50).
  - Total primary energy demand decreases by 62% (cell F67).
  - Costs decrease by 41%.

=> This measure alone is not sufficient in the long run for cost reasons.

- Scenario 2:
  Building: renovated (insulation + windows); Building services: unrenovated + photovoltaics
  - Steam demand decreases by 40% (cell G33), electricity demand by 0% (cell G42).
  - Costs decrease by 19%.

=> This measure alone is not sufficient.

- Scenario 3 (= combination of scenarios 1 & 2)
  Building: renovated (insulation + windows); building services: renovated (geothermal, photovoltaic, etc.)

- Steam consumption drops to 0 (cell H33), electricity demand drops by 33% (cell H50).
- Costs decrease by 61%.

=> This measure may be sufficient.

- Scenario 4:
  Building: new construction; TGA: new (geothermal, photovoltaic, etc.)
  - Steam consumption decreases to 0 (cell I33), electricity demand decreases by 36% (I50).
  - Costs decrease by 63%.

=> This measure may be sufficient.

Conclusion:

- The renovation of the outer skin (insulation, roof and windows) and the renewal of the technical building equipment each provide very strong support, but are not sufficient, especially in the long term.
- Reducing the air exchange rate (and thus the overall energy consumption) can be an interim solution worth considering.
- If the existing building is retained, a combination of envelope renovation and building services upgrades + geothermal + photovoltaics + conversion to green electricity may be the solution.
- New construction: This measure may be sufficient, but must be weighed against Scenario 3 in terms of cost, given the limited benefit.
- A prerequisite for all solutions is the availability of sufficient and cheap CO2-neutral electricity. Without this, the costs can rise immensely.

Table of results

	A	B	C	D	E
1	Energiewerte		Variante	0.1	0.2
2	Untersuchung	Gebäude	Modellgebäude	Altbau unsaniert (Status Quo)	Altbau unsaniert, RLT reduzierte Lüftung, 6-fach tags, nachts und WE 20%)
3	Bedarf/Primär	Wärme/Kälte	Konzept	Dampf 4 bar/6-12	Dampf 4 bar/6-12
4	* Strom für Geräte wird separiert behandelt	Gerätestrom ist in Bilanz Strom enthalten	Annahmen		Nachtragsvariante
5	* Strom für RLT wird separiert behandelt	Luftörderung ist in Blianz Strom enthalten	Fassade opak	Ungedämmt, U-Werte (W/m²/K) Betonfassade 3, Paneele 5,6	Ungedämmt, U-Werte (W/m²/K) Betonfassade 3, Paneele 5,7
6	Farbcodierung:		Dach	Dach Ist-Zustand, U-Wert ca. 0,62 (W/m²/K)	Dach Ist-Zustand, U-Wert ca. 0,62 (W/m²/K)
7	Technische Auslegung		Fassade transparent	2-fach Iso-Glas, U=2.8 W/m²/K	2-fach Iso-Glas, U=2.8 W/m²/K
8	Heizenergie		Fensteranteil	35%, kein Sonnenschutz	35%, kein Sonnenschutz
9	Kühlenergie		Lüftung Labor	8 facher LW (WRG 35%), DP 2000 Pa	6 facher LW (WRG 35%), DP 2000 Pa
10	Strom (mit RLT und Labortechnik)		Regelung	Kein reduzierter Betrieb	reduzierter Betrieb
11	Primärenergie		Lüftung Büro	Büro 3-fach LW	2-fach LW im Büro
12	CO_2-Bilanz		Innere Wärmelast Tags, (Nacht+WoE)	20, (8) W/m²	20, (8) W/m²
13	IFMA-Range		Sollwert Heizen/Kühlen (ArbStRichlinen-gerecht)	21 °C, 23 °C	21 °C, 23 °C
14	Genauigkeit	Alle Angaben sind mit einem Fehlerbalken von ca. +-10% behaftet	Umrechnungsfaktoren Energiebedarf -> Endenergie	Aufwandszahl Wärme aus Verbrauch COP Kälte aus Verbrauch	Aufwandszahl Wärme aus Verbrauch COP Kälte aus Verbrauch
15					
16	Bedarf Raumheizung	Heizenergiebedarf (Simulation)	kWh/m²/a	280	142
17	Heizwärme	Faktor Wärme	1/COP oder Aufwandszahl	1,5	1,5
18	Quelle			Dampf	Dampf
19	Endenergie Heizwärmeerzeugung	Heizenergiebedarf x Aufwandszahl	kWh/m²/a	420	214
20	IFMA-Range		kWh/m²/a	250 - 550	250 - 550
21	Prozentuale Einsparung	Heizenergie	%	0%	49%
22					
23	Bedarf Raumkühlung	Kühlenergiebedarf (Simulation)	kWh/m²/a	55	41
24	Zusatzbedarf (aus Lastkurve Kälte 2022)	Rückkühlung für Kühlschrankräume (derzeit ganzjährig über Turbo-Kältem.)	kWh/m²/a	70	70
25		Summe	kWh/m²/a	125	111
26	IFMA-Range		kWh/m²/a	ca. 100 - 150	ca. 100 - 150
27	Quelle			Kältmaschinen/Strom	Kältmaschinen/Strom
28	Kühlen	Faktor Kälte	1/COP	0,40	0,40
29	Strom Kälte	Faktor Kälte x Bedarf kühlung	kWh/m²/a	50,2	44,4
30	Prozentuale Einsparung	Strom für Kälte (Gebäude ohne Rückkühlung Kühlschränke)	%	11%	22%
31					
32	Strombedarf	Strom Wärme und Kälte	kWh/m²/a	50	44
33		Strom für Luftförderung (RLT)	kWh/m²/a	93	58
34		Strom für Geräte/Ausstattung	kWh/m²/a	139	139
35		Rückkühlung für Kühlschrankräume (derzeit ganzjährig über Turbo-Kältem.)	kWh/m²/a	28	28
36					
37		Summe	kWh/m²/a	310	269
38	Prozentuale Einsparung		%	2%	15%
39					
40	Einsparung		%	0%	39%
41					
42	Primärenergie	Faktor Strom (ca. EnEV)		2,0	2,0
43	Dampfheizung		kWh/m²/a	420	214
44	Strom Kälte/Wärme Gebäude + RK Kühlschränke	Strom x Faktor Strom	kWh/m²/a	100	89
45	Strom Luftförderung	Strom x Faktor Strom	kWh/m²/a	186	116
46	Strom Geräte in der Fläche	Strom x Faktor Strom	kWh/m²/a	139	139
47	Summe	Dampf/Strom	kWh/m²/a	846	557
48	Primärenergie	prozentuale Einsparung	%	0%	34%
49					
50	CO_2-Bilanz	Endenergieart	CO_2-Faktoren [g/kWh]		
51	Quelle: IWU Stand 2020	Erdgas für Dampferzeugung	230		
52	Stand: 2022, nach Reaktivierung der Kohlekraftwerke	Strom aus D-Kraftwerksmix (kein reiner Ökostrom)	420		
53	Dampferzeugung	Dampf mit Primärenergiefaktor	kWh/a	420	214
54	Stromverbrauch	Strom ohne PV	kWh/a	310	269
55	CO_2-Emissionen		kg/m²/a	227	162
56	Einsparung		%	0%	28%
57					

	F	G	H	I
1	**Altbau unsaniert, RLT-neu (reduzierte Lüftung, nachts und WE 5%)**	**Altbau baulich saniert**	**Altbau, saniert (Neubaustandard), RLT neu (reduzierte Lüftung)**	**Neubau, mit thermischer Betonkernaktierung im Bürobereich und in Sozialräumen**
2	**Hochtemperatur-WP/freie Kühlung/Geothermie**	**Dampf 4 bar/6-12**	**Niedertemperatur-WP/Geothermie**	**Niedertemperatur-WP/Geothermie**
3				
4	Ungedämmt, U-Werte (W/m²/K) Betonfassade 3, Paneele 5,6	Altbau baulich saniert, U-Wert Fassade 0,23 W/m²/K	Altbau baulich saniert, U-Wert Fassade 0,23 W/m²/K	Neubau, U-Wert Fassade 0,23 W/m²/K
5	Dach Ist-Zustand, U-Wert ca. 0,62 (W/m²/K)	Dach 20 cm Dämmung, U-Wert 0,08 W/m²/K	Dach 20 cm Dämmung, U-Wert 0,08 W/m²/K	Dach 20 cm Dämmung, U-Wert 0,08 W/m²/K
6	2-fach Iso-Glas, U=2.8 W/m²/K	3-fach WSV-Glas, U=1.1	3-fach WSV-Glas, U=1.1	3-fach WSV-Glas, U=1.1
7	35%, kein Sonnenschutz	40%, kein Sonnenschutz	40%, kein Sonnenschutz	40%, außenliegender Sonnenschutz
8	6 facher LW (WRG 73%), DP 2000 Pa	8 facher LW (WRG 35%), DP 2000 Pa	6 facher LW (WRG 73%), DP 2000 Pa	6 facher LW (WRG 73%)
9	reduzierter Betrieb	Kein reduzierter Betrieb	reduzierter Betrieb	reduzierter Betrieb
10	2-fach LW im Büro	Büro 3-fach LW	2-fach LW im Büro	2-fach LW im Büro
11	20, (8) W/m²	20, (8) W/m²	20, (8) W/m²	20, (8) W/m²
12	21 °C, 23 °C	21 °C, 23 °C	22 °C (Mo-Fr 7-19), 24-26°C (nach Aussenluft)	22 °C (Mo-Fr 7-19), 24-26°C (nach Aussenluft)
13	COP Wärme 2.5 , Kälte 20	Aufwandszahl Wärme aus Verbrauch COP Kälte aus Verbrauch	COP Wärme 3.5 , Kälte 30 (freie Kühlung)	COP Wärme 3.7 , Kälte 30 (freie Kühlung)
14				
15	117	169	80	56
16	0,4	1,5	0,29	0,27
17	Wärmepumpe/Strom	Dampf	Wärmepumpe/Strom	Wärmepumpe/Strom
18	47	253	23	15
19		250 - 550		
20	89%	40%	95%	96%
21				
22	**47**	**71**	**70**	**55**
23	**70**	**70**	**21**	**21**
24	**117**	**141**	**91**	**76**
25		ca. 100 - 150		
26	Geothermie/Strom	Kältemaschinen/Strom	Geothermie/Strom	Geothermie/Strom
27	0,05	0,4	0,03	0,03
28	5,8	56,6	3,0	2,5
29	90%	0%	95%	96%
30				
31	53	57	26	18
32	38	93	38	38
33	139	139	139	139
34	28	28	8,4	8,4
35			vom System abhängig, das künftig für Rückkühlung zuständig sein soll; Annahme: Red. auf 30%	vom System abhängig, das künftig für Rückkühlung zuständig sein soll; Annahme: Red. auf 30%
36				
37	258	317	211	203
38	19%	0%	33%	36%
39				
40	41%	19%	61%	63%
41				
42	2,0	2,0	2,0	2,0
43		253		
44	105	113	52	36
45	77	186	77	77
46	139	139	139	139
47	**321**	**691**	**267**	**251**
48	**62%**	**18%**	**68%**	**70%**
49				
50				
51				
52				
53	**0**	**253**	**0**	**0**
54	**258**	**277**	**171**	**163**
55	**108**	**174**	**72**	**69**
56	**52%**	**23%**	**68%**	**70%**
57				

8.3 Air exchange in work areas where hazardous substances are in use (example of a participant's document)

To determine the required airflow, complete the following room data sheet for each work area and classify it according to the hazardous substances listed (risk assessment process).

Raumdatenblatt

Erstelldatum:

Ausfüllhinweise:
n.z. = nicht zutreffend   x = Pkt. trifft zu   Labor-/Produktionsleiter: Betriebsingenieur /Betreiber der RLT /TPL/TPV/TPK   Site Safety

Labor-/Produktionsleiter:	

Allgemeine Raumdaten und Anforderungen

Raum				Arbeitszeit (falls abweichend zu Regelarbeitszeit-Roche)									Raumkonditionen (falls abweichend von ASR3.5)							
Gebäude:		Raumnummer:			Mo	Di	Mi	Do	Fr	Sa	So		Temperatur:		bis		°C	±		K
Raumbezeichnung:		Raumtyp:		von	6:00	6:00	6:00	6:00	6:00	6:00	6:00	Uhr	Feuchte:		bis		% r.F.	±		% r.F.
Raumfläche:		Raumhöhe:	Volumen:	bis	20:00	20:00	20:00	20:00	20:00	20:00	20:00	Uhr								

Anlagen- und Gerätedaten (entspricht Messzustand)

Lüftungsgeräte			
R&I DVS-Nr.:		Luftausfallüberwachung:	
Sonstiges:			

Geräte und Einrichtungen im Mess- und Beurteilungszustand (bei komplexen Schaltungen separates Dokument)

	Anlagenzustand technisch sichergestellt (keine Eintragung in Zeile 15-20 erforderlich)	Detailbeschreibung:		Betriebsanweisung:	

		Laborabzug	Objekt/Behälter -absaugung	Sicherheits-werkbank	Zytostatika-werkbank	Isolator	Säure-/Lauge-schrank	Lösemittel-schrank	Umluftkühl-anlage	Sonstiges
Normalbetrieb	Anzahl									
	Zustand									
Absenkbetrieb	Anzahl									
	Zustand									

Gefahrstoffnutzung (Lagerort, Arbeitsweise, Umgang nur im Abzug)

Tatigkeiten bzw. Arbeitprozesse gemäß		Ablageort	Dokumenten-Nr.	Quelldokument
	Gefahrstoffverzeichnis	SAP DVS		

	Art	Einsatzort/ Beschreibung		Art	Einsatzort/ Beschreibung
	KMR			erstickende Gase	
	brennbare Stoffe/Gase			Dampf	
	Biologische Gefahrstoffe			Gifte	
	Säuren/ Laugen			Desinfektionsmittel	
				Sprühdesinfektion	
				Wischdesinfektion	

Tätigkeitseinstufung auf Basis der Gefahren in Zeile 22 bis 32 und Rationalen gemäß Kapitel 3 IQS _SOP_PZ_12419_DOK_D im Normalbetrieb während der Arbeitszeit?	**gelb**
Tätigkeitseinstufung auf Basis der Gefahren in Zeile 22 bis 32 und Rationalen gemäß Kapitel 3 IQS _SOP_PZ_12419_DOK_D im Absenkbetrieb außerhalb der Arbeitszeit?	**gelb**

Weitere Gefahrenquellen und Anforderungen

Tatigkeiten bzw. Arbeitprozesse gem.:			Ablageort	Dokumenten-Nr.	Dokumentenbezeichnung	Volumenstromanforderung Normal	Volumenstromanforderung Abgesenkt	
	Schutzstufe Labor (z.B. GenTG, BioStoffV, IfSG, TierSEV)	Schutzstufe:			Gefährdungsbeurteilung BioStoffV / RA nach GenTG			m³/h
	Chemisches Labor		SAP DVS		Gefährdungsbeurteilung			m³/h
	Isotopenlabor (Radionuklidlabor, StrlSchV)	Gefahrengruppe:	SAP DVS		Gefährdungsbeurteilung			m³/h
	BetriebssicherheitsV (BetrSichV)	EX-Zone (Gas/ Dämpfe):	SAP DVS		Explosionsschutzdokument			m³/h
		EX-Zone (Staub):						m³/h
n.z.	K16 Kataster		SAP DVS		K16-Kataster			m³/h
	SONSTIGE:							m³/h
	SONSTIGE:							m³/h

SHE-Lüftungsanforderungen

Mindest-Volumenstromanforderungen auf Grund weiterer Gefahrenquellen gemäß Zeile 24 bis 32 im Normalbetrieb?		m³/h
Mindest-Volumenstromanforderungen auf Grund weiterer Gefahrenquellen gemäß Zeile 24 bis 32 im Absenkbetrieb?		m³/h
Volumenstrom aufgrund weiterer Gefahrenquellen 40 bis 47 im Normalbetrieb		m³/h
Volumenstrom aufgrund weiterer Gefahrenquellen Zeilen 40 bis 47 im Absenkbetrieb		m³/h

	entspricht Luftwechsel		entspricht flächenbezogenem Volumenstrom		**Volumenstrom** (gerundet)		
Nachzuweisender SHE-Volumenstrom im Normalbetrieb		1/h		m³/(h*m²)			**m³/h**
Nachzuweisender SHE-Volumenstrom im Absenkbetrieb		1/h		m³/(h*m²)			**m³/h**

Anrechenbarer Volumenstrom muss den Kriterien gemäß IQS_SOP_PZ_12419_DOK_D entsprechen und frei von Schadstoffen sein!
Nachweis des Volumenstrom erfolgt durch   Zuluft   oder   Abluft

Weitere Lüftungs-Anforderungen - Nachweis über separate Messung, ggf. Abgleich erforderlich

Tatigkeiten bzw. Arbeitprozesse gem.:		Ablageort	Dokumenten-Nr.	Quelldokument
	Thermische Lasten werden über RLT abgeführt	SAP DVS		Heizlast/Kühlalstberechnung
	Anforderungen Reinraum (IQS_SOP_PZ_04319_DOK_D oder Bereichsspez.)	SAP DVS		Zonenplan/Filterplan/Testspezifikation
	SONSTIGE:			

Überströmungen aufgrund SHE-Anforderungen

	Es bestehen Anforderungen an Überströmungen	Anforderungen resultieren aus Zeile:	
Überströmung von		Überströmung nach	

Sonstige Angaben

entfällt bei DVS Workflow

Name			
Datum/Unterschrift			
	(Labor-/Produktionsleiter)	(Site Safety)	(Betriebsingenieur/Betreiber der RLT /TPL/TPV/TPK)

History

Datum	Wer	Was	Wo
		Erstellung, Eingabe Grunddaten	Lüftung, Sicherheit, Allg. Raumdaten, Gefährliche Stoffe

8.4 Evaluation of the IFMA Benchmarking information on the topic of building services systems

			Proportion of "yes" responses	
Technical building equipment			Office	Lab
Duration of standby mode	Mon-ths (m)	1 Lab: 12 m; 1 Lab: 3m; 4 Labs: 1m; 5 Büros: 1m		
Mainly 24h operation	y/n		21%	68%
Does the building have automated ventilation and temperature control based on demand?	y/n		35%	68%
Reasons why the ventilation systems in this building are not completely shut off during off-hours:				
Frequent on/off cycling increases mechanical wear and shortens the life of machinery and equipment.	y/n		11%	21%
Interruption too short (stable operation cannot be restored quickly enough)	y/n		7%	11%
Nighttime operation (e.g. emergency service, rounds, shift work)	y/n		7%	34%
Product protection (e.g. open handling of materials)	y/n		3%	42%
Explosion protection (due to lack of dilution)	y/n		5%	37%
Animal welfare (keeping of animals)	y/n		0%	12%
Protect against infection (indoor airborne pathogens)	y/n		3%	7%
Waste heat from appliances running at night (room temperature gets too high)	y/n		20%	60%
No separate dedicated exhaust (general exhaust also vents hazardous materials or safety cabinets)	y/n		30%	40%
Room air control cannot be (simply) changed	y/n		7%	24%
Not legally permissible (e.g. pressure maintenance according to approval notice, regulations)	y/n		8%	26%
Not permitted internally (HSE rules)	y/n		10%	33%
Does not correspond to the culture, not desired	y/n		3%	9%
Too complex to implement organizationally	y/n		5%	21%
Damage to building (e.g. frost protection)	y/n		21%	24%
Not yet considered	y/n		3%	9%
Temperature change at night and weekend (static heating)	y/n		84%	71%
Temperature change at night and weekend (ventilation)	y/n		50%	55%
Night-time reduction of air volumes	%	office: 21x100%; 70%; 60%; 2x50%; 30%; 10% lab: 2x100%; 70%; 65%; 4x60%; 14x50%; 3x30%;20%; 8x10%; 6%		
Air flow volume detection available	j/n		25%	49%
Air volume meter present in each line	j/n		10%	18%
Individual room or room group control available	j/n		70%	89%

(Year of occupation 2022)

9 Sources

1	Bewertungssystem Nachhaltiges Bauen (BNB) Laborgebäude BNB_LN 4.1.7 / Bundesministerium des Innern, für Bau und Heimat
2	VDI 6041: Facility-Management - Technisches Monitoring von Gebäuden und gebäudetechnischen Anlagen (2017-07)
3	VDMA 15391-1: Wirtschaftliche und sichere Druckluftverteilung – Teil 1: Planung und Neubau (2020-05)

10 Imprint

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