Climate-friendly Air-Conditioning with Natural Refrigerants

Integrative concepts for non-residential buildings with data centres

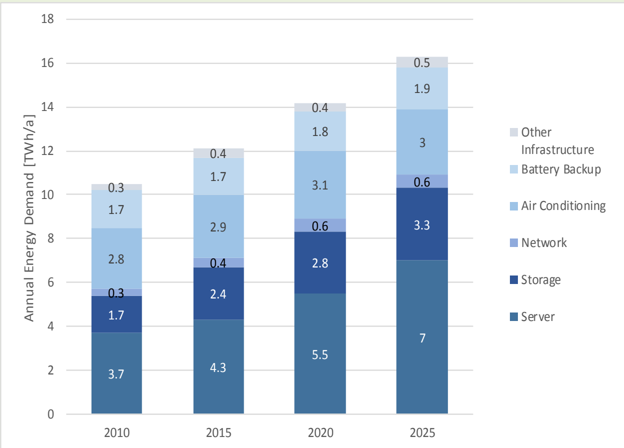
In contrast to heating, where a decrease of the specific final energy consumption over the past two years is noticeable, the trend in the case of air-conditioning of non-residential buildings is opposite. This is due to different aspects such as summerly heat island effects caused by accelerating urbanisation, increased demand for thermal comfort in summer and an increasing cooling load by utilisation of information and communication technologies. To reverse the trend and thus secure the long-term climate targets, a change from conventional air-conditioning towards climate-protective energy efficient solutions using natural refrigerants should be aspired. Suitable technical solutions are already available and proven. To overcome existing barriers, appropriate instruments need to be put in place.

Background

30.000 GWh/a of primary energy is required for the air-conditioning of buildings in Germany. The buildings containing server rooms and data centres are primarily offices, schools and universities, retail outlets and stand-alone data centres.

Over the last two years, a steeply increasing utilisation of information and communication technologies has been recorded in all sectors. This has led to an increase of energy demand, which is expected to grow further in the next couple of years.

Figure 1: Electrical energy demand of data centres in Germany and projections until 2025. (3)

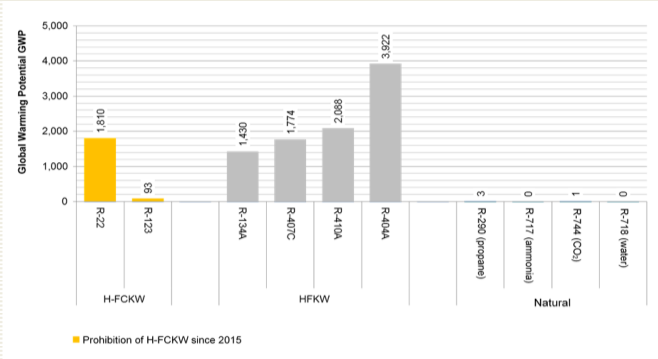


Most air-conditioning and cooling units as well as heat pumps today use HFC refrigerants. To achieve the long-term climate targets, a change towards natural refrigerants combined with improvements of the energy efficiency of the cooling systems is key.

Refrigerants & EU Phase Down:

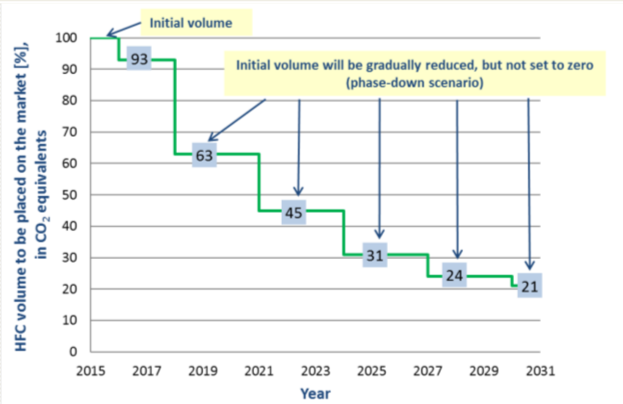
Hydrofluorocarbons (HFCs), the conventional synthetic refrigerants for air conditioning, have GWPs which are more than thousand times higher than CO_2.

Figure 2: Global warming potentials (GWPs) of refrigerants (10)



The EU F-Gas-Regulation (Regulation (EU) No 517/2014) aims to reduce fluorinated GHG emissions, which are mainly caused by refrigerant leakages. Its primary provisions gradually reduces the volume of HFCs to be placed on the EU market (Phase-Down-Scenario, see figure 3). The phase down's basis is the average of HFCs introduced into the EU from 2009 to 2012, calculated in CO_2 equivalents.

Figure 3: Cap and stepwise reduction of HFCs to be placed on the EU-market in the years 2015 to 2030 (5)



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Structure of data centres in Germany:

There are more than 50.000 data centres of different sizes in Germany. Most of those are racks and server rooms, mostly in office buildings. Although the number of big data centres is limited (70 in 2013), their contribution to the data centre's overall energy demand is relevant and has a share of about one third of all data centres in Germany. Nearly the same shares can be accounted for the category of small and medium sized data-centres and the single racks and server rooms. (8) (9)

Figure 4: Typology and number of data centres in Germany

Typ of data center	Number of server [-]	∅ Connected load IT [kW]	∅ Space requirement [m²]	Number of data centers in 2013 [-]	Number of servers in 2008 [-]
Server rack	3-10	1,5	5	30.500	160.000
Server room	<100	6	20	18.100	340.000
Small data center	<500	50	150	2.150	260.000
Medium-sized data center	<5000	240	600	280	220.000
Large data center	>5000	2.500	6.000	70	300.000
Total				**51.100**	**1.280.00**

Good Practice Examples

A variety of realised good practice examples show that techniques are available and proven that bring about a significant reduction in climate impact and thus contribute to ensure the attainment of the target corridor. The examples are simple and stable in operation and are applicable to the vast majority, i.e. can be multiplied.

Different good practice examples are available for all relevant size categories of data centres:

1. **Small server rooms** inside a non-residential building with around 0-10 kW of effective IT performance
2. **Structurally integrated medium-sized data centres:** Large server rooms and small to medium sized data centres inside non-residential buildings with 10-300 kW of effective IT performance
3. **Big data centres** with normally significantly over 300 kW of effective IT performance

Small Server Room

Administration Centre Fa. Pollmeier (6)

- Fan controlled free cooling of server room, when external temperature is less than 17 °C
- Simple and cost-effective system

Medium-sized Data Centre

Stadtwerke Lübbeke (4)

- Cold-water/brine system on the roof
- Refrigerant: R290 (propane)
- Suction gas heat exchanger increases efficiency
- Amortization time: one year

Big Data Centre

University Greifswald (7)

- Direct water cooling system based on an indirect, free cooling system with adiabatic spray humidification and air/air heat exchanger
- Excess heat partly heats two other buildings, while the surplus (~ 360 kW) is fed into low-temperature heat grid
- Power from PV system
- Water supply by rainwater utilization system

More examples and background information can be derived from (1)**.**

Best Practice Solutions

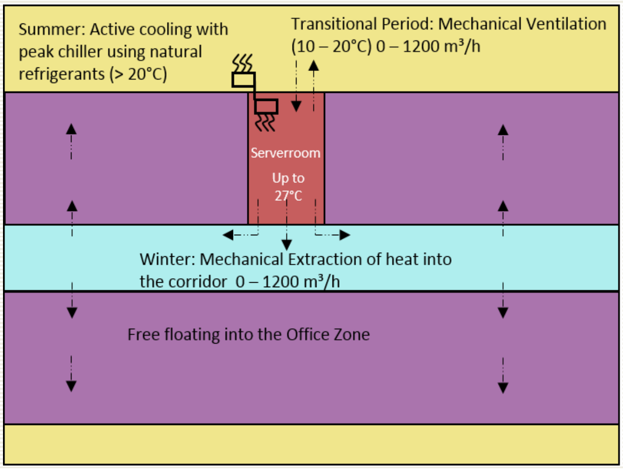
By appropriately combining the technologies applied in the good practice examples, and starting with typical reference buildings supplied by conventional HVAC systems with already high energy efficiency (nearly zero energy buildings based on a passive house standard), optimised concepts have been derived. These concepts have then been analysed in the context of numerical simulation calculations in terms of their energy efficiency and climate impact. Three building types have been considered: an office building with several small server rooms, an office building with an integrated medium-sized data centre, and a large stand-alone data centre.

Building with small server rooms

Specifications:

- Server rooms: 2 kW IT load each
- Variable air flow between 0 and 1.200 m³/h to lead away the constant heat load of 2 kW (6 kW in total)
- Max. allowed temperature in the server rooms is 27 °C
- Separate AC systems with natural refrigerant for server rooms (mobile units, as split AC with natural refrigerant are actually not available on German market)
- Outside temperature control:
  - Over 20 °C: Active cooling
  - 10 °C to 20 °C: Decentralized mechanical ventilation
  - Below 10 °C: Waste heat of server rooms is redirected into corridors
- Photovoltaic (PV) system with 50 kWp on roof produces solar power which can be used more than 80 % directly for air conditioning of the server rooms and the other consumers within the building

Figure 5: Best practice concept air conditioning of a small server room

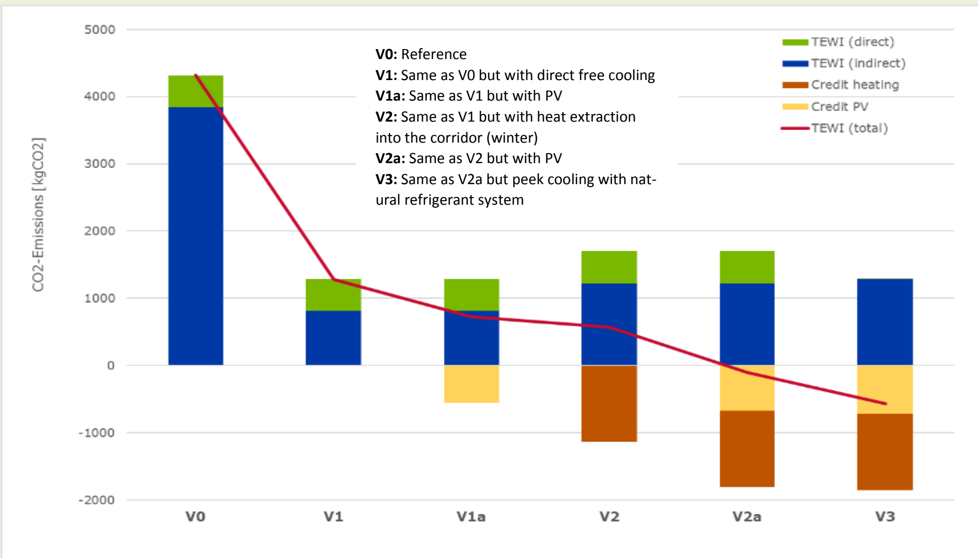


Results

The calculations show the effectiveness of different measures to improve the total equivalent warming impact (TEWI) value (sum of refrigerant (direct) and power related (indirect) GHG emissions). Starting with the standard reference variant (V0, see figure 6), the greatest reduction is achieved by the implementation of an efficient free cooling system (V1). More potentials may be leveraged by the use of waste heat (V2) and the implementation of a PV system on the roof (V1a, V2a and V3). Due to the avoidance of direct equivalent CO_2 emissions when using natural refrigerants (V3), the reduction of equivalent CO_2 emissions is comparable to that achieved by the waste heat-/PV-solution, despite the assumed significant lower efficiency of the mobile AC unit with natural refrigerants compared to the efficient split units (all other variants;). In purely mathematical terms, the implementation of all measures of the optimized practical concept even leads to a negative TEWI value. (1).

This results in operational cost savings at around 1.500 €/a for air conditioning and heating. It can be assumed that the system (V3) has an amortisation time of around 5 years.

Figure 6: Variants for small server rooms (2)

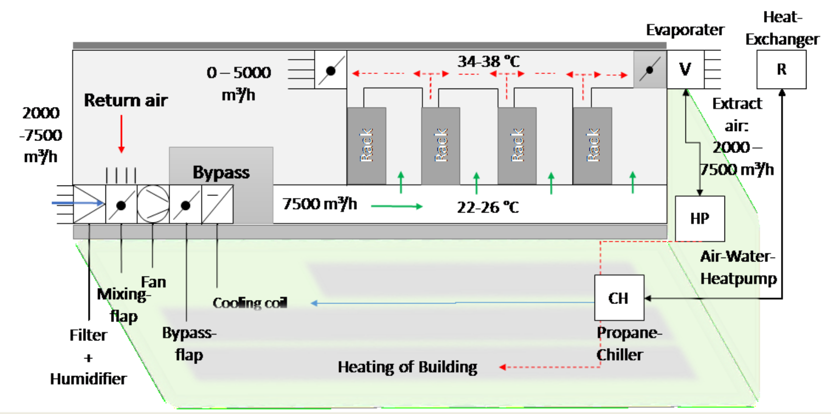


Building with air-cooled medium sized data centre

Specifications

- Data centre: 30 kW IT load
- Enclosure of supply/exhaust air system of air-cooled racks in data centre
- Air-conditioning of data centre
    - Through direct ventilation at external temperatures up to 26 °C
    - Through cooling system with natural refrigerant (e.g. propane) at external temperatures above 26 °C

Figure 7: Air-conditioning of medium-sized data centre



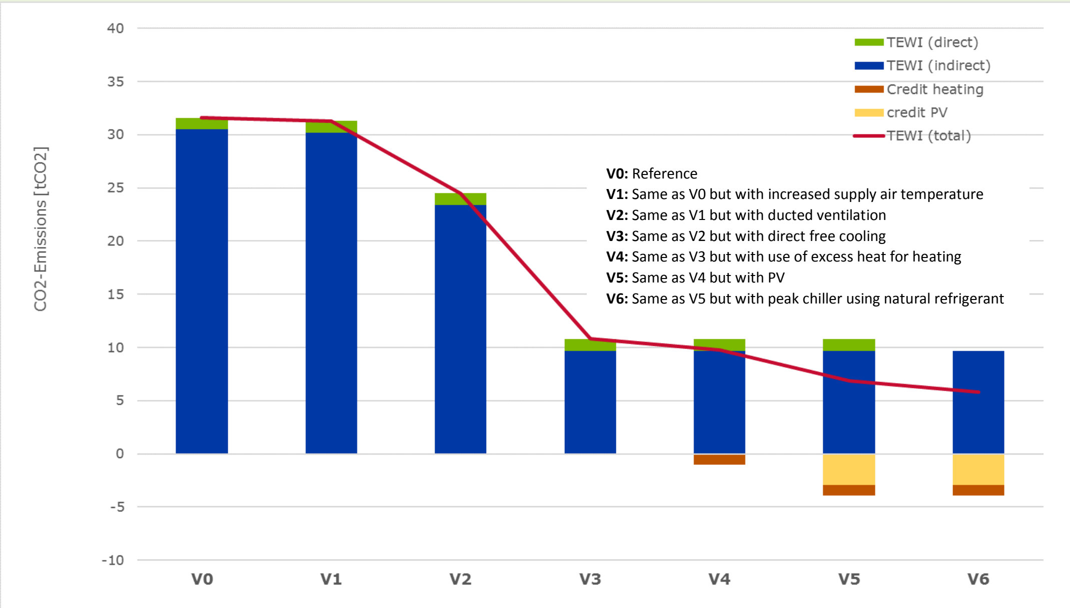
- Excess heat of data centre is used by an exhaust-air heat pump to cover the heating demand. This increases efficiency by a factor of 2 compared to conventional heat pumps using ambient air as a heat source
  <u>Alternative technique</u>: Use of convertible heat pump which serves as heating device for the office during winter and as cooling device for the data centre in summer
- PV-system with 50 kWp to reduce the power demand of air conditioning and systems technology

Results

The energetic improvements in air conditioning due to a simple increase of the temperature inside the data centre during summer are compensated through the higher energy need of the servers at higher temperatures and therefore only lead to a small overall reduction of CO_2 emissions (V1). The combination of a controlled temperature increase and a ducted airflow on the other hand, can reduce the TEWI-value by over 20% (V2). The biggest reduction step for improvement with over 50% is possible through the implementation of direct ventilation (V4). Further potential for a decrease of 10% and 30% is exploited by the use of waste heat (V4) and the implementation of a PV system (V5), respectively. A peak load cooling system without HFCs (V6) will decrease the TEWI value again by around 15%. Therefore, a total reduction of the TEWI value of more than 80% is possible, in comparison to the already efficient reference variant (1).

By applying these measures of V6 the operational costs can be reduced by up to 10,000 €/a even without considering the PV system. In this case amortisation time is around 10 years

Figure 8: Variants for medium-sized data centre

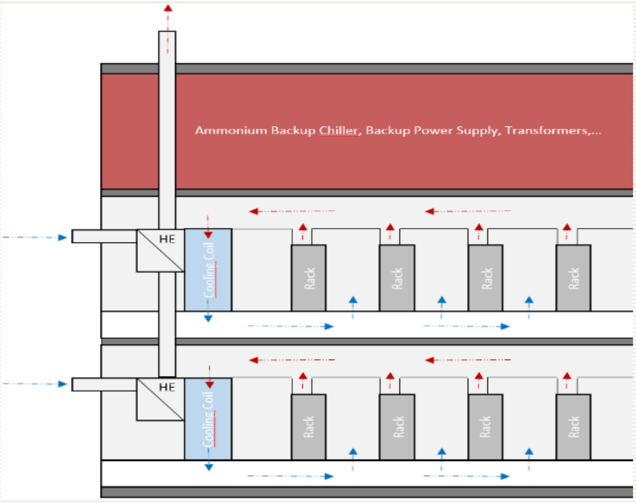


Air-cooled standalone data centre

Specifications

- Data centre: 9 MW IT load, 40 MW installed cooling capacity (Tier IV)
- Air cooling of racks with consistent separation of supply and exhaust air. Ducted airflow allows for supply air temperatures up to 30 °C (increase of energy demand of IT components at higher temperatures needs to be considered)
- Use of air to air heat exchangers
- Adiabatic cooling (humidification of outside air before it enters the heat exchanger); a cooling unit is not necessary
- Application of mechanical refrigeration plants with natural refrigerants (e.g. ammonia) as redundancy cooling system and safety mechanism in case of extreme climatic events (Tier IV requirement)

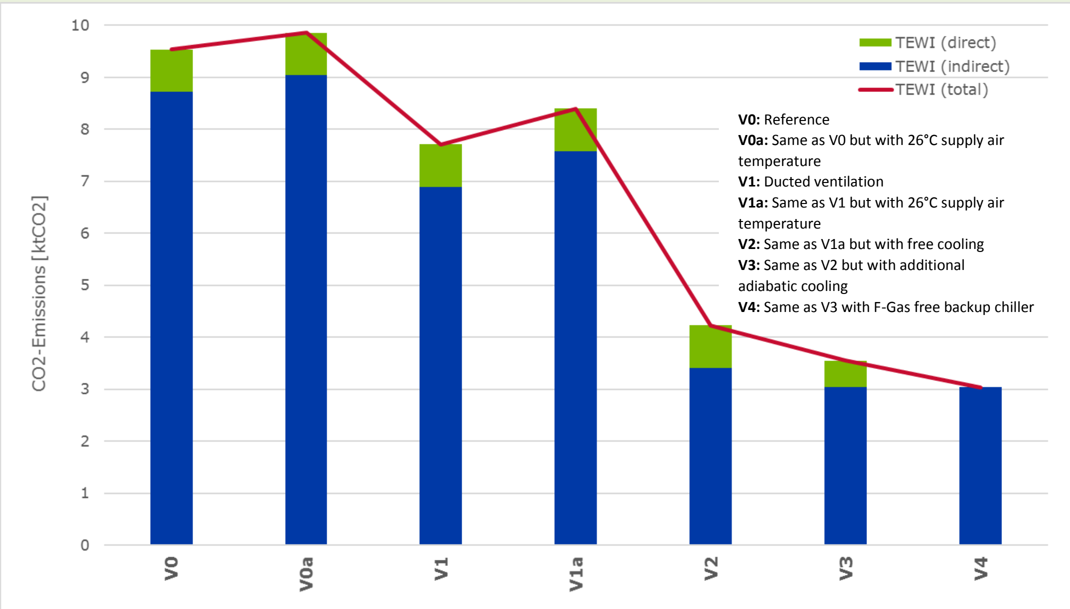
Figure 9: Best practice concept air-cooled standalone data centre



Results

The TEWI value can be reduced by up to 70% through the implementation of the described measures in comparison to the already efficient reference scenario (V0). (2) The biggest improvement is made by implementing the free cooling system with an efficient air/air heat exchanger in combination with a cold aisle containment (V2). A simple uncontrolled year-round increase of the temperature inside the IT rooms saves energy for air-conditioning but also leads to an increased energy demand of the IT components and may even cause a significantly increased energy consumption (V0a + V1a). **The specified improvement measures allow for savings in energy costs of more than 1,5 Mio €/a.** It can be assumed that, taking the increased space requirement into consideration, only very little additional costs arise, in comparison to a conventional cooling system.

Figure 10: Overview of CO_2-eq. emissions of different variants for standalone data centre



Conclusion

In comparison to the already highly efficient reference cases, TEWI value reductions of 80 % and 70 % for medium and large data centres, respectively, are possible. Arithmetically, small integrated server rooms with HFC free air conditioners can achieve even significant negative TEWI values. Moreover, it is possible also for the other size categories to reduce the TEWI values significantly by the implementation of air conditioners using natural refrigerants. For medium and large data centres, the reduction potential by using natural refrigerants is about 15 %. Considering that emission factors for electricity are likely to decrease with regard to the required parallel decarbonisation of the power sector, direct emissions from refrigerant leakages, accidents and disposal will become more important.

Therefore, the relative benefit of optimal practice concepts relying on F-gas free redundant cooling increases compared to solutions based on conventional HFC refrigerants.

In comparison to the reference concept with efficient conventional air-conditioning, all examined solution concepts indicate significantly reduced operating costs. Regarding investment costs, especially for small server rooms and structurally integrated medium-sized data centres significantly higher costs have to be considered. However, it can be assumed that those will be paid back in less than 10 years. The implementation of the optimized concept for the large stand-alone data centre is, if at all, associated only with slightly increased investment costs and a payback period of a few months. The results underpin, on the one hand, the achievability of the previously established GHG emission target corridor and provide, on the other hand, incentives for investors and planners to apply climate-friendly solutions.

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Editorial deadline: December 2016