Sustainable Hall Conditioning: Two-Stage Adiabatic Cooling

Operating principle and genuine unique selling points versus classic compression cooling and single-stage adiabatic cooling

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Executive Summary

Sustainable Hall Conditioning (SHC) replaces classic compression cooling with a two-stage, water-based cooling principle – no compressor, no refrigerant, no F-gases. The two overviews below summarize why SHC pays off both economically and technically compared with conventional compression cooling and with single-stage adiabatic cooling.

Advantages over classic compression cooling

- **Up to 95 %** lower operating costs and CO_2 emissions compared with compression cooling
- **Significantly** lower investment costs through the elimination of compressors, refrigerant circuits and heavy roof loads
- **0 % F-gases:** no climate-damaging, flammable or health-hazardous refrigerants – no regulatory or financial F-gas risk
- **100 % fresh air** instead of recirculated-air operation: noticeably better air quality, no drying-out of hall air
- **Proven in practice:** 250 t CO_2, 1.2 GWh of electricity and 250,000 m³ of water saved annually (BRP-Rotax reference project)

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Advantages over single-stage adiabatic cooling

- **Double effect:** resulting hall air condition 24.5 °C / 11.6 g/kg instead of 28.5 °C / 13.0 g/kg (example: 32 °C outside air temperature) – noticeably cooler AND drier at the same time
- **Standard-compliant comfort**: genuine comfort per EN-16798 / ASHRAE 55, instead of a humid, warm "tropical greenhouse climate"
- **Regulatory relief:** thanks to droplet-free contact evaporation, no mandatory inspection under 42. BImSchV / VDI 2047 (German cooling-tower regulations)
- **Intelligent control technology**: dew-point monitoring, humidity limiting and automatic free cooling for maximum efficiency in every season

1. Operating Principle: Two-Stage Adiabatic Cooling

Adiabatic cooling makes use of the natural evaporative cooling effect of water: as water evaporates, it draws heat from the surrounding air without the need for external electrical refrigeration. Single-stage systems carry out this process in a single step – the air is humidified directly and cooled in the process.

The problem: air humidity rises so sharply that the result is a humid, warm, uncomfortable climate rather than genuine comfort cooling.

INFRANORM® consistently relies on a two-stage process:

Stage	Operating principle	Effect on supply air
Stage 1 – indirect	Cold circulating water pre-cools the air "dry" via a heat exchanger, without direct air contact	Temperature drops noticeably, absolute humidity remains unchanged
Stage 2 – direct	Subsequent direct adiabatic cooling at the patented cooling pad	Further temperature reduction with only moderate humidity increase

The Mollier diagram (psychrometric chart) shows the difference clearly: while a single-stage system cools outside air along a single, steep line towards higher humidity, the two-stage process runs in two steps – first almost horizontally (temperature reduction with no change in humidity in stage 1), and only then the adiabatic cooling of stage 2. The end point is therefore at a lower temperature AND a lower absolute humidity than with the single-stage process – a result that cannot be achieved physically with a single evaporation step.

***Technical example – compact cooler**: 14,000 m³/h air volume flow, approx. 150 m³ water consumption per year, 800 W electrical power draw for cold generation. Cooling capacity: 91 kW at 38 °C / 21 % rel. humidity (18.6 °C supply air); 49 kW at 28 °C / 43 % rel. humidity (17.7 °C supply air). Design coverage: up to approx. 150 m².*

2. Compared with Classic Compression Cooling

Compression cooling (chiller/heat pump) is the established standard in hall air conditioning – but it is expensive to purchase and operate, maintenance-intensive, heavy (roof structural load), and dependent on climate-damaging, sometimes flammable or toxic refrigerants. SHC delivers comparable cooling capacity with a fraction of the energy and resource input, completely without refrigerants.

2.1 Decision criteria in direct comparison

The following criteria matrix comes from a real investment decision (evaluation of an existing system) and is used by INFRANORM® in initial discussions against classic compression-cooling suppliers:

Criterion	Compression cooling (2 suppliers)	SHC – 2-stage adiabatic
Refrigerant	F-gases / synthetic refrigerants	none – cooling medium is water
Electricity consumption	Reference	up to 95 % lower
CO_2 emissions	Reference	up to 95 % lower
Noise emission	high	low
Redundancy	limited	high (modular system)
Investment cost	high	lower
Operating cost	high	up to 95 % lower
Roof structural optimization	hardly possible	possible (lighter units)
Regulatory inspection obligations	more extensive	lower
Complexity of media distribution network	high	lower
Project timing	longer	shorter
Disruption to operations during implementation	lower	can be higher
System resilience	lower	high
Use of existing waste-heat sources	possible	possible
Stable hall temperature/humidity	possible	possible
Long-term system track record (market maturity)	high	lower than established compression cooling

SHC performs clearly better in 12 of 16 criteria. *For the remaining four – existing waste-heat use, temperature stability, operational disruption during implementation and market maturity – the picture is more nuanced: these points can be actively managed in project engineering but should be communicated openly.*

2.2 Economics: investment and operating costs

The economic advantage of SHC arises on two levels. **On investment cost**, the cost-intensive components of classic compression cooling are eliminated: compressors, refrigerant circuits, refrigerant management and the extensive roof structural work required for heavy chillers. SHC units are significantly lighter, modular in design, and require no refrigeration-specific engineering under pressure equipment directives.

On operating cost, the electrical power demand is the key factor: while a compression cooling unit must drive a compressor with high power draw to deliver the same cooling capacity, two-stage adiabatic cooling consumes electrical power only for fans and circulation pumps.

In practice this results in **up to 95 % lower operating costs** and **up to a 95 % smaller CO_2 footprint** compared with classic compression cooling – figures that are consistently confirmed in the range of 67 to 90 % savings across INFRANORM®'s best-practice projects (see 2.5). Because SHC also operates entirely without F-gases, it also eliminates the risk of future cost increases from the progressive phase-down and rising cost of fluorinated refrigerants under the EU F-Gas Regulation.

2.3 Air quality: 100 % fresh air instead of recirculated-air operation

A difference often underestimated in practice concerns **air quality.** Classic compression cooling systems predominantly cool hall air in recirculated-air operation: the same air is drawn in again and again, passed over cold evaporator surfaces, and blown back. Moisture condenses on the cold surfaces in the process – room air noticeably dries out over time, which can lead to dry mucous membranes, increased dust exposure, and an unpleasant indoor climate for employees. At the same time, CO_2 and odors from production accumulate in the recirculated air, since hardly any outside air is introduced.

Sustainable Hall Conditioning, by contrast, cools with 100 % fresh air: outside air is continuously drawn in, cooled adiabatically, and introduced into the hall, while spent hall air is continuously exhausted. In practice this means multiple air changes per hour with filtered, oxygen-rich outside air instead of endlessly recirculated room air.

The result is a drastically improved air quality: no artificial drying-out of room air, noticeably lower concentrations of pollutants, dust and odors, and a healthier, more productivity-supporting working climate – an advantage rarely captured in classic economic analyses, but one that weighs heavily for employee health and employer attractiveness.

2.4 Water use in comparison

A common objection to adiabatic systems is: "water consumption is bad for the environment." A direct comparison for the same cooling capacity (90 kW sensible) puts this objection into perspective:

	Power draw	Power-plant cooling water	On-site evaporation	Total water demand
Compression cooling	30 kW/h	300 L/h	–	300 L/h
SHC (2-stage)	1 kW/h	10 L/h	90 L/h	approx. 100 L/h

Despite local evaporation, SHC's total, cross-regional water demand is **around three times lower**, because a compression cooling unit's 30-fold higher power draw indirectly requires far more cooling water at power plants than is saved on site.

2.5 Practical example: BRP-Rotax reference project

Project data, phase 1: *14,100 m² of cooled floor area, 20 exhaust-air fans, 12 ventilation units, 30 adiabatic coolers, maximum fresh-air volume of 450,000 m³/h for 100,000 m³ of room volume. Average power draw for the entire production facility (cooling, ventilation, heating) approx. 51 kW.*

Annual savings compared with the previously used groundwater heat pump: 250 t of CO_2, 1.2 GWh of electricity, and 250,000 m³ of groundwater. The parallel switch from gas boiler heating to district heating saved a further 1,500 t of CO_2 annually.

3. Compared with Single-Stage Adiabatic Cooling

Not all adiabatic cooling is equal. Single-stage systems do cool the air, but at the same time raise humidity so sharply that the result is a humid, warm "tropical greenhouse climate" rather than genuine comfort. INFRANORM® therefore consistently relies on a two-stage process that controls temperature and humidity together, rather than working against each other.

3.1 Hall air condition in comparison

The resulting hall air condition (not the raw supply-air temperature at the unit, but the actual climate inside the hall) makes the difference clear – shown here using real climate data at 32 °C outside temperature:

	Outside air	Single-stage adiabatic	SHC – 2-stage adiabatic
Hall air temperature	32 °C / 25 % rh	28.5 °C	24.5 °C
Absolute humidity (hall air)	–	13.0 g/kg	11.6 g/kg
Rating (EN-16798 / ASHRAE 55)	–	uncomfortable	comfortable

The advantage also holds true for the actual supply-air temperature directly at the unit: across the entire tested outside-humidity range (10–60 % rh), two-stage adiabatic cooling consistently achieves lower supply-air temperatures at lower humidity than a single-stage unit – at low outside humidity, supply-air temperatures of 15–20 °C are achievable even at 40 °C outside temperature. The advantage grows even further as outside humidity increases.

3.2 Physical background: the Mollier diagram

Using real climate data (Vienna, approx. 36 °C / 7 g/kg outside air), the difference can be traced exactly on the Mollier diagram (psychrometric chart):

Process step	Temperature	Absolute humidity
Starting point: outside air	approx. 36 °C	approx. 7 g/kg
Single-stage – direct adiabatic cooling (only step)	approx. 22 °C	approx. 13 g/kg
2-stage – stage 1: indirect "dry" cooling	approx. 27 °C	approx. 7 g/kg (unchanged)
2-stage – stage 2: direct adiabatic cooling	approx. 17 °C	approx. 11 g/kg

Single-stage cooling follows a single, steep line towards higher humidity. The two-stage process first cools with almost no change in humidity (stage 1) and only then cools adiabatically (stage 2) – the end point is at a lower temperature and comparable or lower humidity. A result that is physically unachievable with a single evaporation step.

3.3 Control technology

Single-stage units are usually simple in design and offer little scope for intelligent operation. INFRANORM®'s two-stage adiabatic cooling is controlled via modular, decentralized control units each with its own CPU per module control center, ensuring reliable, efficient operation all year round:

Function	Benefit
Sliding setpoint control	Automatic adaptation to outside conditions for maximum efficiency
Humidity limiting	Prevents exceeding the maximum permissible humidity in the hall
Dew-point monitoring	Active prevention of condensation and corrosion on components
Free cooling with night setback	Use of cool night air for additional energy savings
Modular decentralized control units	Own CPU per module control center, fail-safe operation
Remote access & trend logging	Remote monitoring, operating-data analysis, predictive maintenance

3.4 Hygiene concept

In addition, cooling operates pressure-free, exclusively via contact evaporation at a patented cooling pad – no trickling, no droplets or aerosols in the airstream, unlike many single-stage or spray-based systems, which fall under 42. BImSchV and VDI 2047 (German cooling-tower regulations):

Measure	Effect
Aluminum cooling pad with antibacterial coating	No breeding ground for microorganisms, service life up to 5 years
Daily full drying ("bio-shock")	At least once every 24h
Permanent conductivity monitoring	Continuous water-quality monitoring
No trickling/spraying (contact evaporation)	Not applicable: 42. BImSchV, VDI 2047
Compliance with VDI 6022, VDI 3803, SWKI VA104-01	Recognized engineering standards fulfilled
Optional UVC disinfection	For the food industry and the highest hygiene requirements

3.5 Further performance metrics

Metric	Value
Energy savings vs. classic air conditioning	up to 90 %
Temperature advantage vs. single-stage direct adiabatic cooling	up to 7 °C lower
Reduction in humidity input vs. single-stage adiabatic cooling	up to 70 % lower
Water savings vs. reference systems	up to 30 % less
Wet-bulb efficiency (combined)	up to 114 %

4. Why INFRANORM® – Your Single-Source Partner

The technological advantages of two-stage adiabatic cooling are clear – but what determines project success is who reliably turns this technology into a working overall system. INFRANORM® combines technical depth, **holistic system understanding** and **proven implementation competence** in a combination that cannot be replicated by engaging several specialized individual suppliers.

Four reasons for INFRANORM® as your single-source partner

- **Systems integrator, not component supplier:** a single point of contact for engineering, implementation and service across the entire system lifecycle – no interface losses between trades
- **THINK INFRANOMIC® engineering:** holistic planning starting from the customer's value-creation process rather than isolated individual trades – uncovers synergy potential that single-discipline suppliers miss
- **Unique combination of competencies:** we are the only provider on the market combining Sustainable Hall Conditioning AND production infrastructure (extraction, explosion protection, process cooling, waste-heat use) under one roof
- **Proven implementation competence:** more than 20 years of project experience, numerous reference projects in demanding industries, repeatedly recognized for innovation

4.1 Systems integrator, not component supplier

Most market competitors act as suppliers of individual components – a chiller, a ventilation unit, an extraction system. INFRANORM®, by contrast, **acts as a systems integrator with overall responsibility:** from engineering through implementation to after-sales support across the entire system lifecycle. For the customer this means a single point of contact, consistent warranty coverage, and no interface losses between trades – a coordination burden that, with multiple individual suppliers, typically falls back on the customer.

4.2 THINK INFRANOMIC® engineering: holistic instead of trade-by-trade

Conventional providers plan cooling, ventilation, heating and the building envelope as separate trades – with corresponding interface losses and unused synergies. INFRANORM® consistently thinks from the **customer's value-creation process outward** ("inside out"): production requirements, infrastructure and the building are planned in an integrated way. This uncovers savings potential that remains invisible when individual trades are considered in isolation, and is a key reason why INFRANORM® projects typically pay for themselves within 6 months to 3 years.

4.3 A unique combination of two fields of expertise

No other provider on the market combines both of the following fields of expertise under one roof: **Sustainable Hall Conditioning** (two-stage adiabatic cooling, heating, ventilation, hall air purification, heat recovery, precision climate control) AND **production infrastructure** (extraction and filtration technology, fire and explosion protection, process cooling, waste-heat use, employee protection).

Especially at complex production sites with high internal heat loads, these areas interact directly – for example when waste heat from an extraction system feeds into the heat recovery of the hall conditioning system, or when explosion-protection requirements determine the design of the ventilation technology.

Anyone who does not plan these interdependencies from a single source gives up synergy potential or risks technical conflicts at the interfaces.

Aspect	Typical single-supplier approach	INFRANORM® single-source approach
Responsibility	Multiple points of contact, interface risk	One point of contact, overall responsibility
Planning approach	Trades planned separately	Holistically integrated (THINK INFRANOMIC®)
Cooling technology + infrastructure	Cooling technology separate from production infrastructure	SHC and production infrastructure from a single source
Use of synergies	Unused due to isolated consideration	Actively used (e.g. waste heat → heat recovery)
After-sales support	Warranty handled separately per trade	Consistent responsibility across the lifecycle

4.4 Proven implementation competence, not just a technology promise

The technical superiority of two-stage adiabatic cooling is undisputed – what matters is whether a provider can also implement it reliably in complex industrial environments. INFRANORM® can demonstrate this through **more than 20 years of project experience** and **a broad reference list** across demanding industries: from automotive (BRP-Rotax, MAGNA) to aerospace and precision manufacturing (voestalpine BÖHLER), the food industry (Adelholzener, Gmundner Molkerei) and metal processing (Andritz, Benteler, Teufelberger).

Repeatedly recognized for its innovative strength – including the Energy Globe Award and the 2025 Pegasus Business Award – this track record confirms: INFRANORM® delivers not just a technology promise, but demonstrable results.

Conclusion of this chapter: *In combining technological depth (patented two-stage adiabatic cooling), holistic system understanding (THINK INFRANOMIC® engineering) and proven implementation competence, INFRANORM® is uniquely positioned in the market in this form – making us the single-source partner that guarantees you both the technology and its reliable implementation from a single hand.*

5. Conclusion

Two-stage adiabatic cooling solves two independent technical problems at once: it replaces compressor-based refrigeration technology with a water-based system that has a fraction of the energy, cost and CO_2 footprint and noticeably better air quality through continuous fresh-air operation – and it overcomes the physical weakness of single-stage evaporative cooling, which buys comfort at the price of excessive humidity gain.

The fact that INFRANORM® does not merely supply this technology, but reliably implements it as **a systems integrator** with **holistic system understanding** and more than **20 years of project experience**, is what makes the difference between a technology promise and a demonstrable result – documented by real reference projects and **repeatedly recognized for its innovative strength.**