Energy Efficient HVAC Design in Energy Saving projects at Novo Nordisk's Aseptic Filling plants

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Agenda

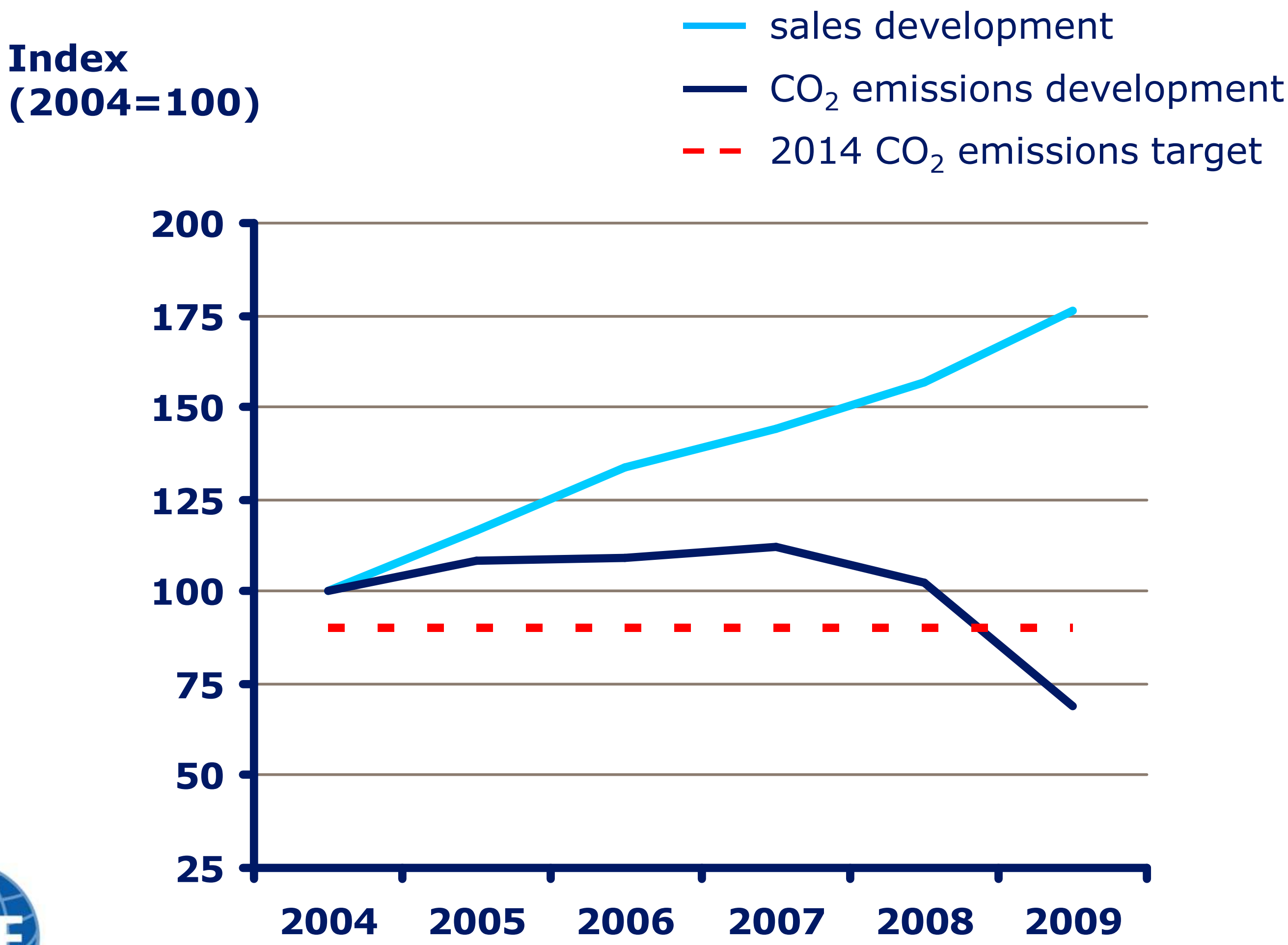
- A company strategy on Climate Change
- Saving energy at design stage – a case story for a new aseptic filling facility
- Comparing three different HVAC set-up’s
- Saving energy at facilities in operation
- Discussion

The Novo Nordisk Climate Strategy

Why is Climate Change *our business ?*

- The biggest global challenge of our times
- An act of corporate responsibility
- Critical risk mitigation
- -10% GHG reduction commitment by 2014 compared to 2004
- Novo Nordisk is part of the (WWF) Climate Savers global network

Breaking the curve - sales up, CO2 down



Achieving target through three levers

1. Increase overall productivity through cLEAN®
2. Identify and implement energy saving projects
3. Secure a greener energy supply

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Sustainable Design at Tanjin

- New Greenfield filling facility in China
- -20% energy reduction target compared with existing plant
- HVAC was targeted because HVAC with subsystems is by far the facility’s largest energy consumer.
- Focus areas
    - HVAC system design
    - Component efficiencies

Some of the results of energy efficient design on a new aseptic filling facility

- Predicted electricity consumption for fans came down from 13mill kWh/year to 6.5mill kWh/year

- Installed cooling capacity for the plant was reduced more than 4MW and investment on cooling compressors was reduced by more than 3mill Euro.

- Overall the absolute energy consumption for the plant is expected to be 20% lower than at a similar plant – despite larger footprint, larger production volume and a more challenging climate. The largest savings have been achieved by targeting HVAC.

Energy, one of 4 key HVAC issues

Most important design requirements for HVAC installation at filling facility:

1. **Functionality** – all GMP requirements are adhered to
2. **Installation cost** is not excessively high
3. **Test and maintenance** can be done smoothly with no or little disruption to production
4. The **energy cost and climate impact** is reasonable

Saving energy on HVAC at design stage

Technical issues

- Optimal system design is chosen
- Best available components are chosen, heat recovery applied and subsystems for heating and cooling optimized
- Demands for max pressure drops laid down

Other tools

- Independent energy screening of design is carried out
- "Long list" with energy saving ideas is developed and maintained throughout the design process

Energy savings and investment
- hand in hand

It is not unusual that pay back time is negative. Some examples:

- When **improving fan efficiency or reducing pressure losses in the system** the cooling compressor, the cables for fan installation, the VSDs, the transformer etc can all be reduced.

- When **increasing interval for temperature and humidity** cooling compressor and boiler size can be reduced.

In terms of investment savings the cooling capacity is the most interesting target because the cost pr KW of cooling compressors is much higher than for other utility systems.

Component efficiency requirements

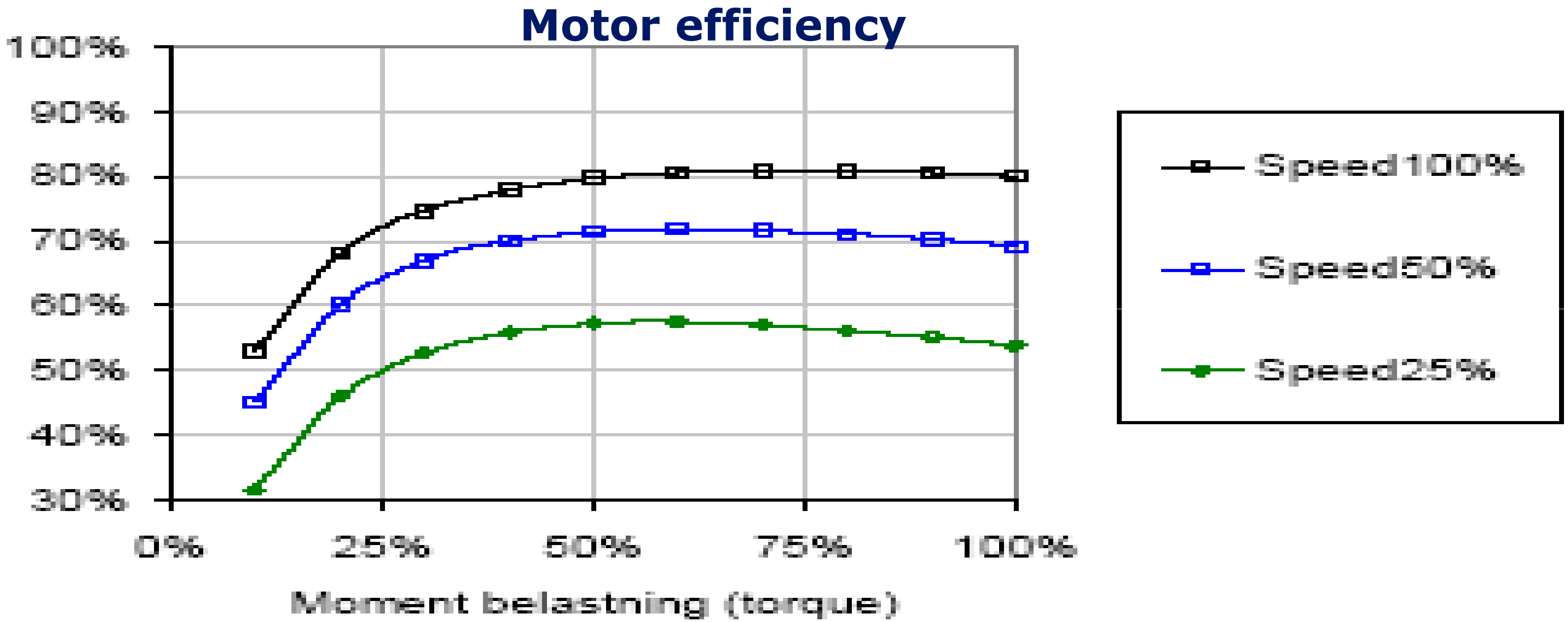
Component	Demand
Belts and pulleys	98% efficiency or better
Variable Speed Drives (VSD's)	98% efficiency or better
Motors	EFF1 or better
Fans	82% efficiency build in (in total for fan, motor, (belts) and drives: 65 – 70%)
Filters	Max start pressure drops: F7= 100, F9=125 , HEPA / ULPA =125Pa
Ducts	Max pressure drops = 0.75Pa/meter
Cooling, heating and recovery surfaces	Maximum pressure drops: Cooling coil=150, Heating coil=35, Heat recovery coil=130, reheating coil=30

The VSD pitfall

VSD's are a benefit to the installation – in terms of energy and in terms of good control. Note however:

- With direct drive efficiency benefit can be offset if the motor is running at frequencies far form 50Hz
- If possible make sure that the VSD delivers a frequency not far from 50Hz
- The coward factor: too large fans and motors leads to lower efficiency

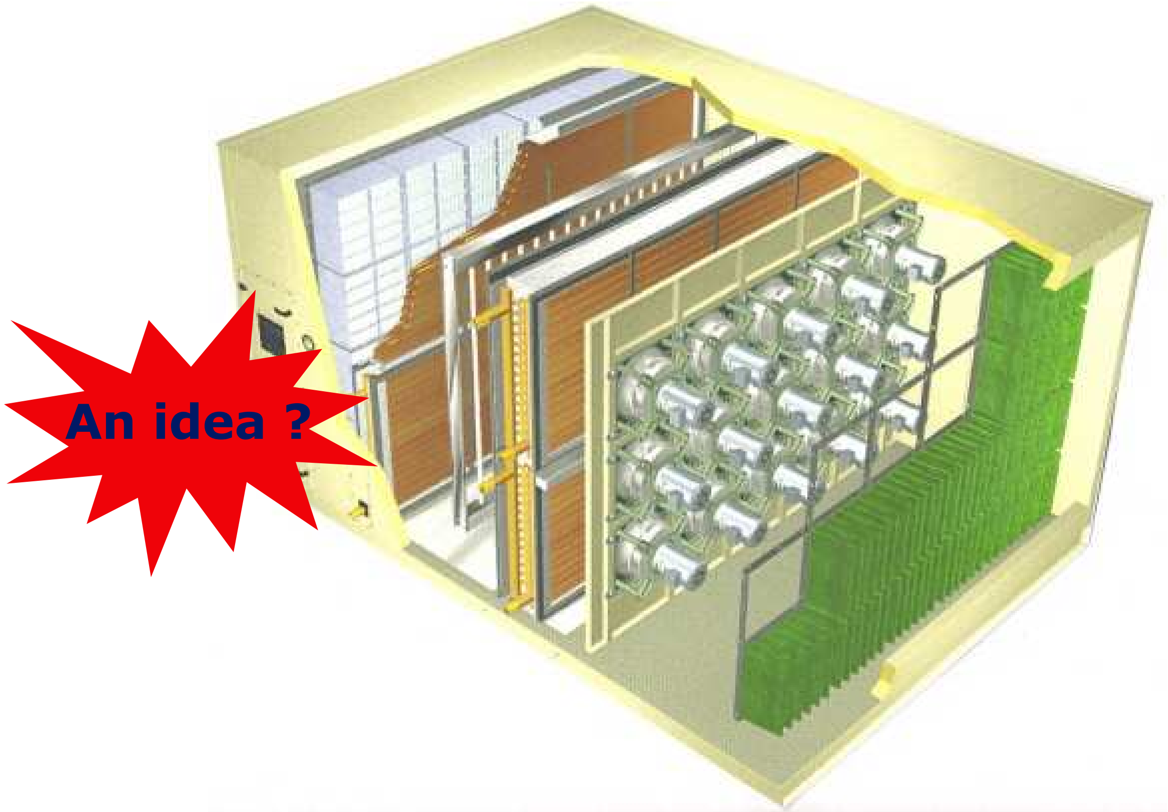
The VSD pitfall
– reduced motor efficiency at part load (torque/ speed)



The load/ efficiency issue is understated by experts and often disregarded by practicians

High safety factors on fans and motor capacity comes at cost – higher energy consumption.

Replacing the big fan with "a wall of fans" - ensuring optimal running conditions



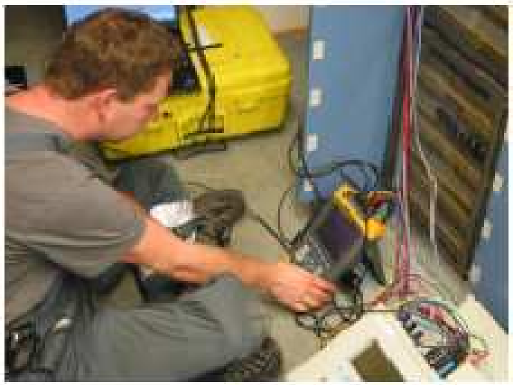
If multiple fans are installed and only some of them are necessary both the "coward factor" and the energy considerations are satisfied

– and there is fan redundancy, lower noise and lower footprint

* Fan wall technology: CES Group, USA

Permanent magnet motors - what are they ?

- Permanent magnet motors have synchronous rotation (no ‘slip’ as the standard motor)
- they used to be very expensive and only used where the precise speed of rotation was needed
- Today they can be acquired at a small extra cost



Permanent magnet motors - a Novo test

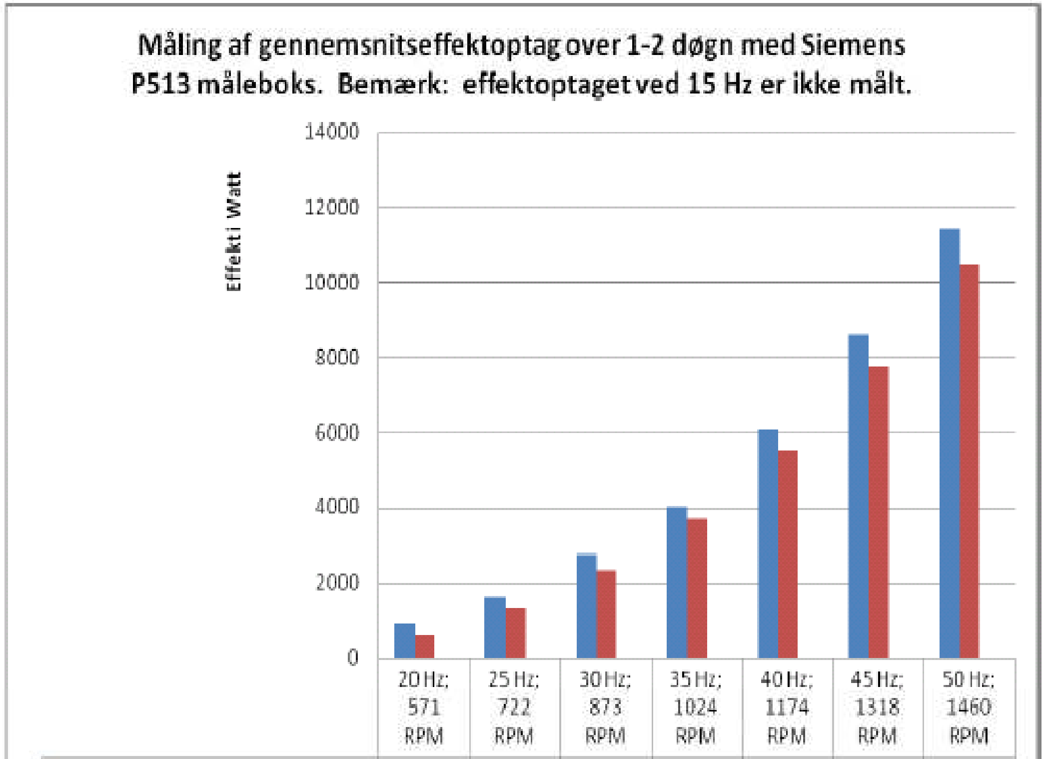
Comparison of Leroy Somer permanent magnet motor (PM motor) and Emerson drive **RED**

with

ABB standard motor and Danfoss drive **BLUE**

The test was carried out on existing AHU over a 14 day period.

In the range 25 to 50hz the PM motor setup used 8 to 17% less electricity



	20 Hz; 571 RPM	25 Hz; 722 RPM	30 Hz; 873 RPM	35 Hz; 1024 RPM	40 Hz; 1174 RPM	45 Hz; 1318 RPM	50 Hz; 1460 RPM
ABB + Danfoss VLT, P 513 måling, Gennemsnitseffekt over 1-2 døgn.	906	1593	2756	4038	6114	8605	11450
Leroy Somer + Unidrive, P 513 måling, Gennemsnitseffekt over 1-2 døgn.	635	1350	2288	3698	5507	7777	10472
Procentuel besparelse	29,91	15,25	16,98	8,42	9,93	9,62	8,54

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Design affects consumption
- comparison of three different HVAC set-up's

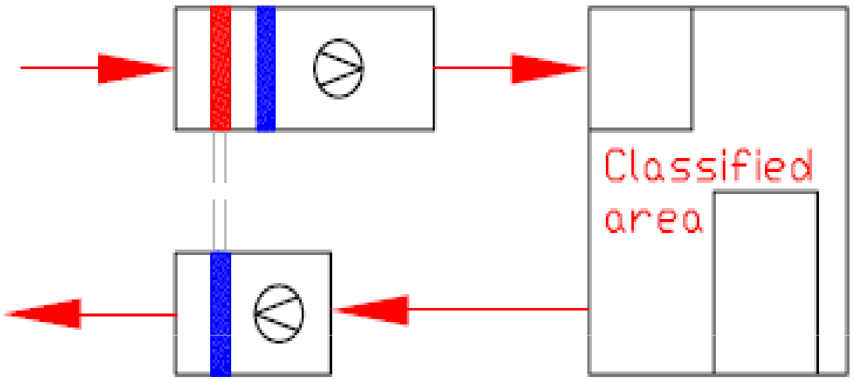
System 1: Existing "Once through" ventilation with heat recovery.

System 2: First basic design for a new facility. Recirculation with passive pre-conditioner unit - a large pressure drop on main flow is used to control fresh air and exhaust airflows.

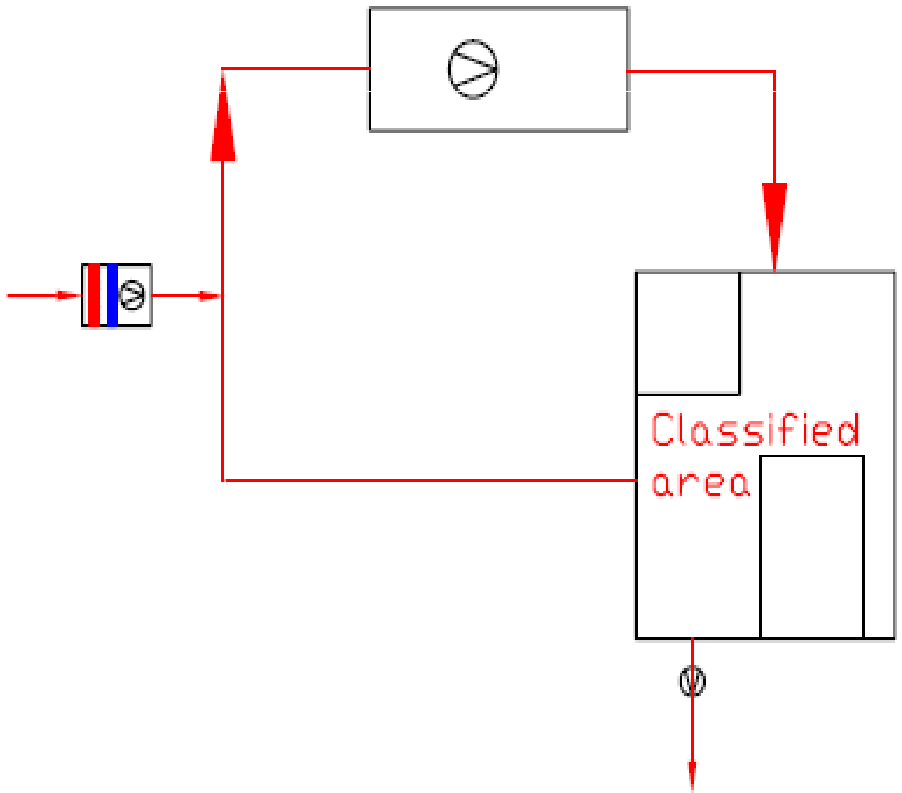
System 3: Current design of the new facility. Recirculation with active pre-con unit

Comparing three different set-up's

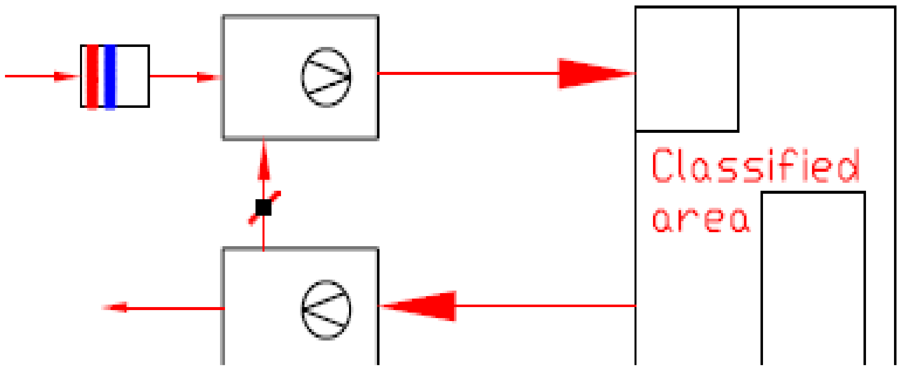
1. "Once through" with heat recovery



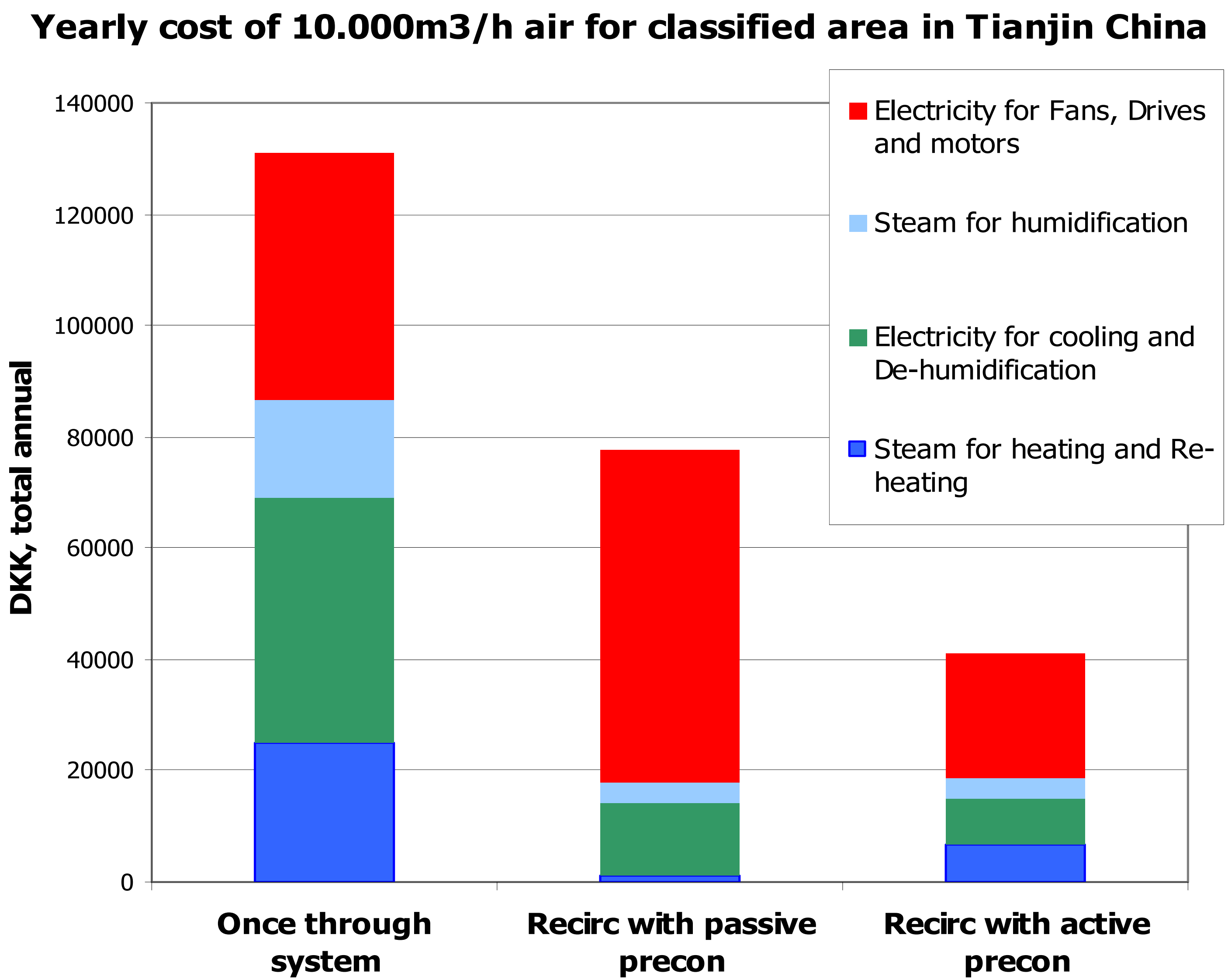
3. Recirc with active pre-conditioning



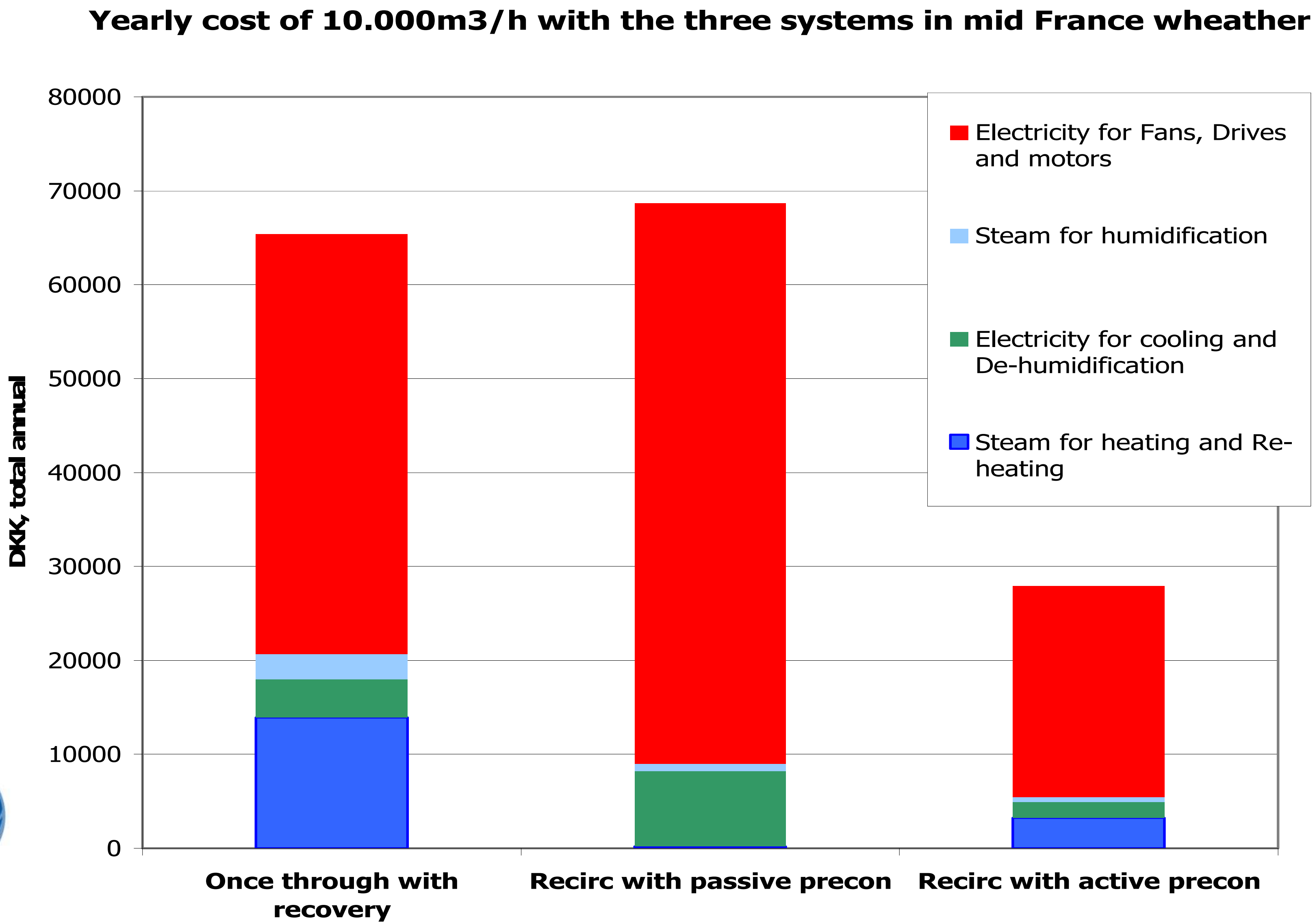
2. Recirc with passive pre-conditioning



Comparing three different set-up’s



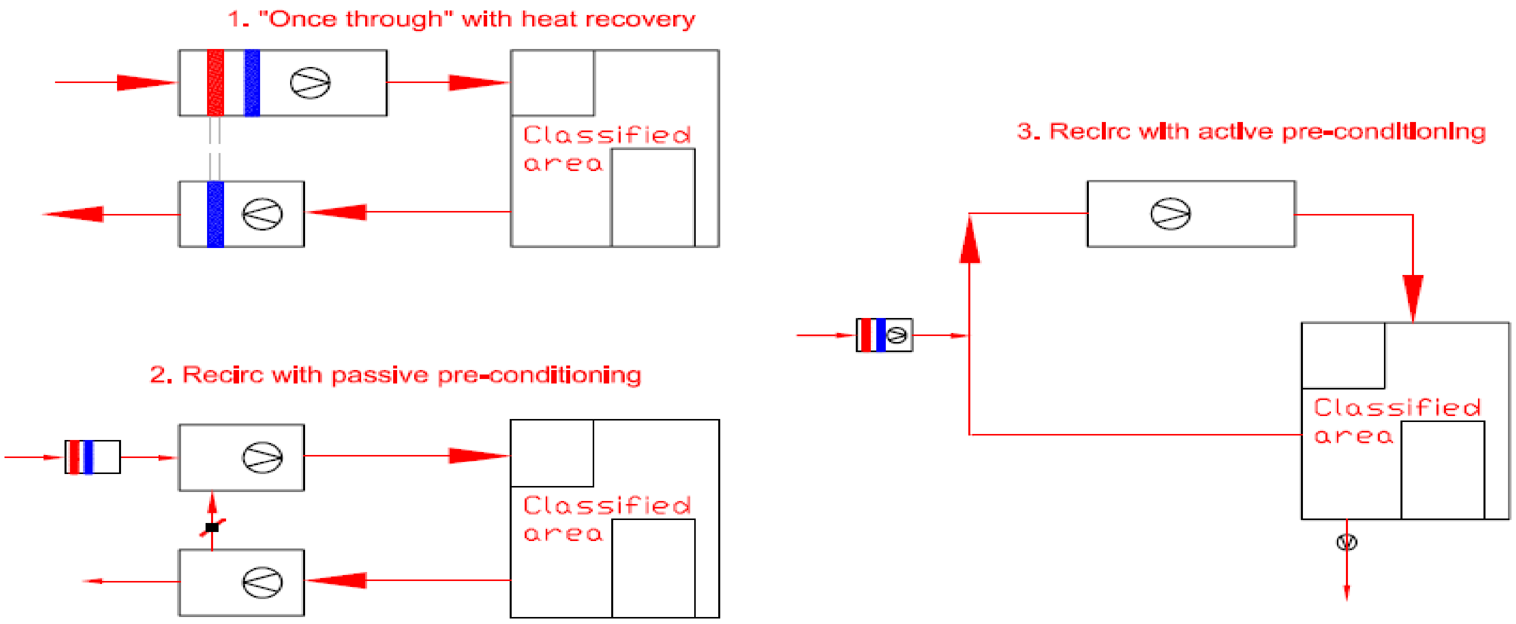
Comparing three different set-up's



Conclusion to system design principles

In terms of energy cost (and carbon footprint) the relation between the three different set ups is ~3:2:1 for the Northern Chinese climate.

For a less adverse climate the relation changes – only actual 8760h/y calculations of climate impact gives the right picture.



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Energy savings in existing plants

- Opportunities
  - Historical data
  - Operation costs
  - Immediate benefit from impelmented savings

- Challenges
  - Replacing equipment during operation of facility
  - New equipment equals new investments to replace functional system
  - Infrastructure/building/utilities ”as is”
  - Validation

Saving energy on GMP facilities in operation – Possibilities and limitations

Some of the possibilities	Have we done it ?	Some of the limitations
Fine tune airbalance	Yes system pressure drops were reduced up to 250Pa (it was just unnecessarily high in relation to the needed capacity for filter pressure drops)	If the pressure is high due to component pressure drops this cannot easily be changed.
Fine tune media (hot and cold water) pressure and temperature	Yes, cold media temperature has been increased	Size of coils limits the potential change. Multiple users fed off same system can have different requirements.

Saving energy on GMP facilities in operation – Possibilities and limitations

Some of the possibilities	Have we done it ?	Some of the limitations
Improve filter configuration	Yes, F5-F7-F9-H14-H14 was reduced to F7-F9-H14 with increased filter media area.	The length and width of the AHUs set limits to the reduction in filter dP
Improve fan, motor and drive configuration	No, we have not identified potential for direct change, only for replacement (with smaller motors) when maintenance requires change. Possibly "fan wall" technology or permanent magnet motors could be a beneficial upgrade for some (older) units	These are quite time consuming and risky activities.

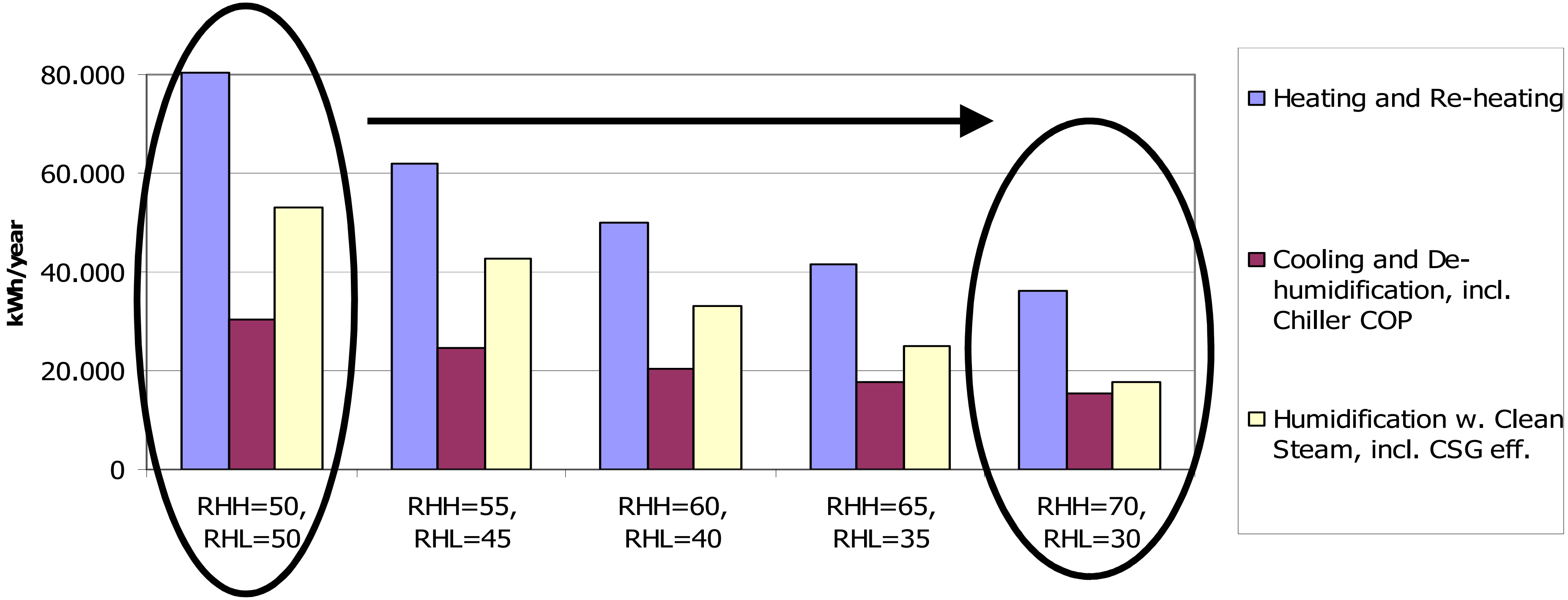
Saving energy on GMP facilities in operation – Possibilities and limitations

Some of the possibilities	Have we done it ?	Some of the limitations
Reduce airchange rate generally generally, airchange after hours, demand for cooling, (de) humidification and heating	Yes, air change rates have been reduced in a grade B area after new operating procedures with fewer operators. Air velocity in grade A areas have been reduced to fit actual operational needs	The room sizes are fairly fixed. The UDF (grade A device) might not be fit to local adjustment of velocities
Reduce airchange rate after hours	No, the silent hours have been too few because most facilities run day and night.	The limitations here are mostly GMP **interpretations**
Reduce the need for cooling, heating and humidification	YES !! This is the number 1 saving initiative that has brought large savings in our aseptic filling facilities	Some BMS programs does not have the “interval” facility for temp and humdity.

Humidity and temperature intervals

From 50%rH to 30 – 70%rH:

- 55% reduction in heating costs
- 47% reduction in cooling and dehumidification cost
- 66% reduction in humidification cost

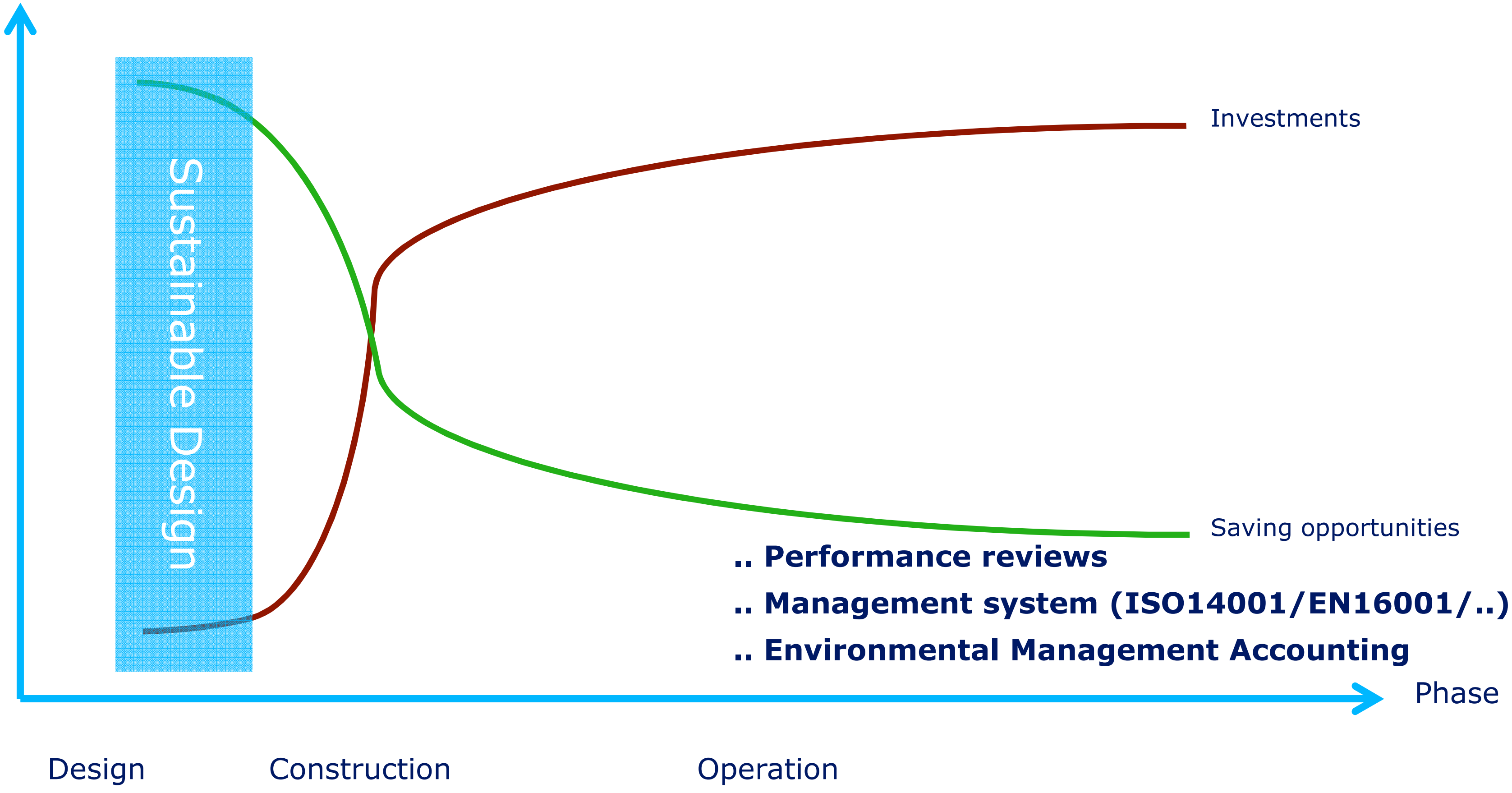


Figures for northern China weather conditions

A nice story worth ¼ mill €/y

- Existing filling site from '90 with 682 employees
- 20000m² of classified clean spaces in grade A, B and C.
- Changed humidity control 50% RH → 50% ±10%
- Results
  - GHG emissions reduced by 670 tonnes CO_2/year
  - Water consumption reduced by 2500 m³/year (humidification and cooling towers)
  - Gas consumption reduced by 2800 MWh/year (clean steam and re-heating of the air)
  - Electricity consumption reduced by 1700 MWh/year (chillers and cooling towers)

A Lifetime of Opportunities



Conclusions

- It is possible to save energy in most existing facilities
- The potential savings are much larger at design stage – *and it is cheaper to modify paper than steel !!*
- The choice of basic system set up determines *a very large part* of the future energy consumption
- Designing with energy efficiency in mind can reduce investment
- Watch out for new technical advances like PM motors and Fan Wall technology
- Never, never fixed set-point for temperature and humidity - unless the process requires it!

Who to blame ??

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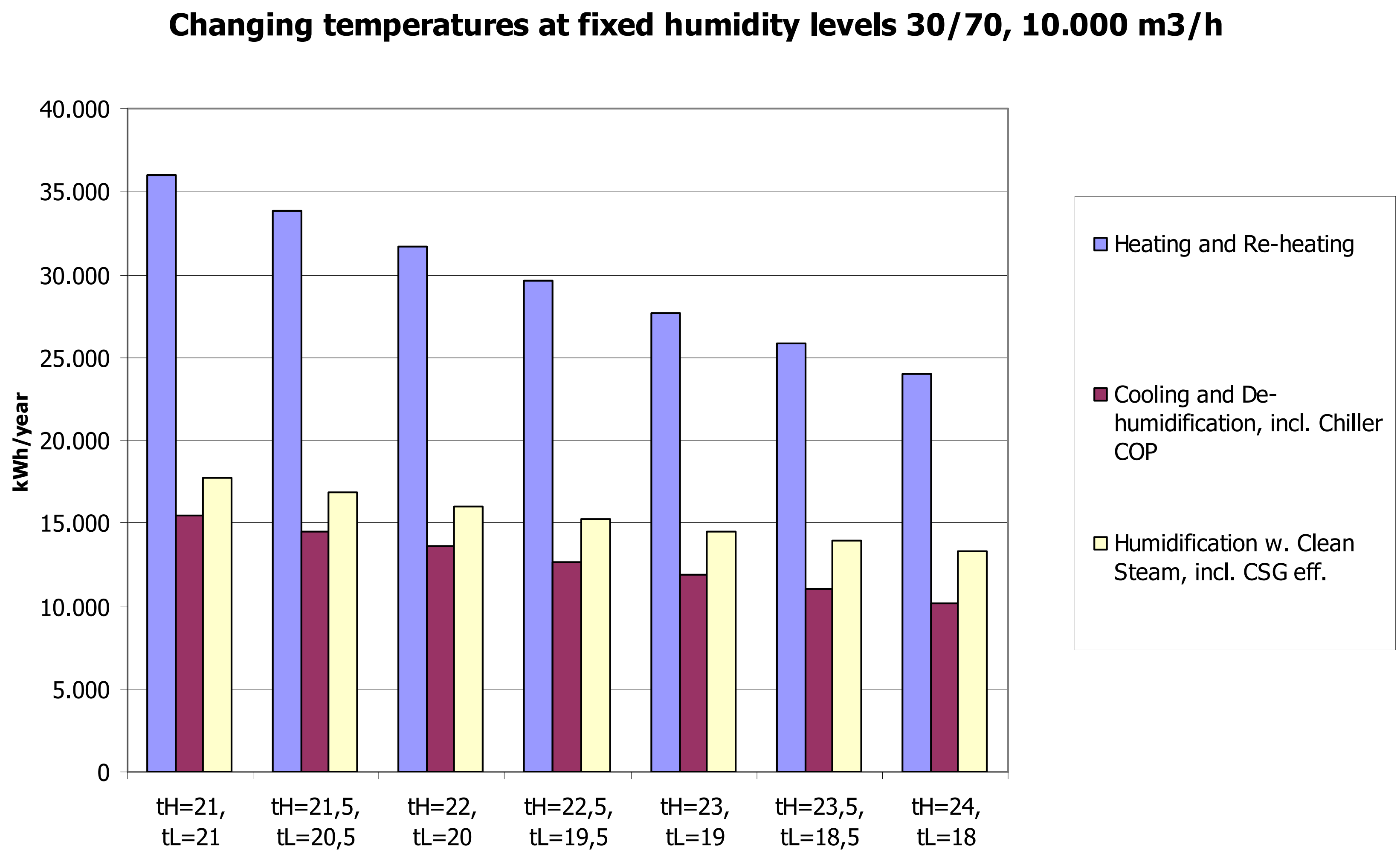
Jens Frederik Studstrup, Novo Nordisk Dept. for External Environment
Carsten Tonn Petersen, cTOPconsult
Lars Møller Kristensen, ALECTIA

Backup slides

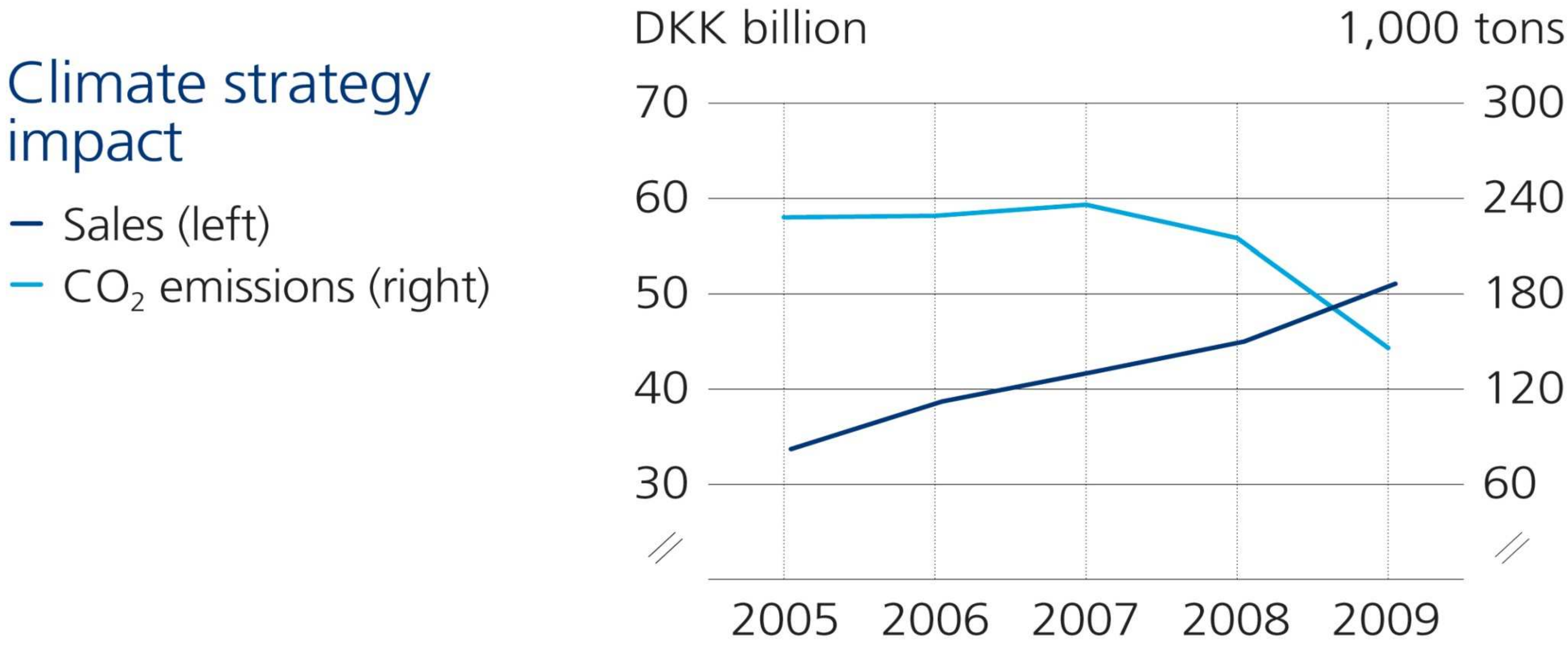
Humidity and temperature intervals



Notes

- All climate calculations are based on hourly calculations (8760 hours pr year) with either reference data (Design reference year) or real data registered at nearest airport.
- The temperature and humidity variation graphs are based on 81% recirc with no internal heat loads or losses – only the heat loads from the fans.

Breaking the curve – absolute figures



Discussion, misc

- **10% being added** at every turn in design is something often seen: 10% extra fan capacity, 10% extra electrical power, fan capacity calculated from full pressure drop on all filters, fan efficiency underestimated etc etc. The result is that often the VSD is running at 30Hz and the motors are nearly twice the needed size

- **Reduce UDF airflow overall** – large UDF modules can also be sectioned to meet the specific needs at different locations. Estimated savings 20 – 40% of energy consumption

Discussion, the challenge of complexity

Some choices to avoid complexity

- No change in exhaust due to changing heat loads in classified areas

- No changes in fresh air input to classified areas to reduce mechanical cooling when it is cold outside

- No heat recovery in classified area – this would not add much complexity, but since there is high degree of recirc (=fan heat input) the estimated benefit is marginal

Discussion, cooling storage

The daytime cooling use can be reduced through cooling down the building structures (or separate storage tanks).

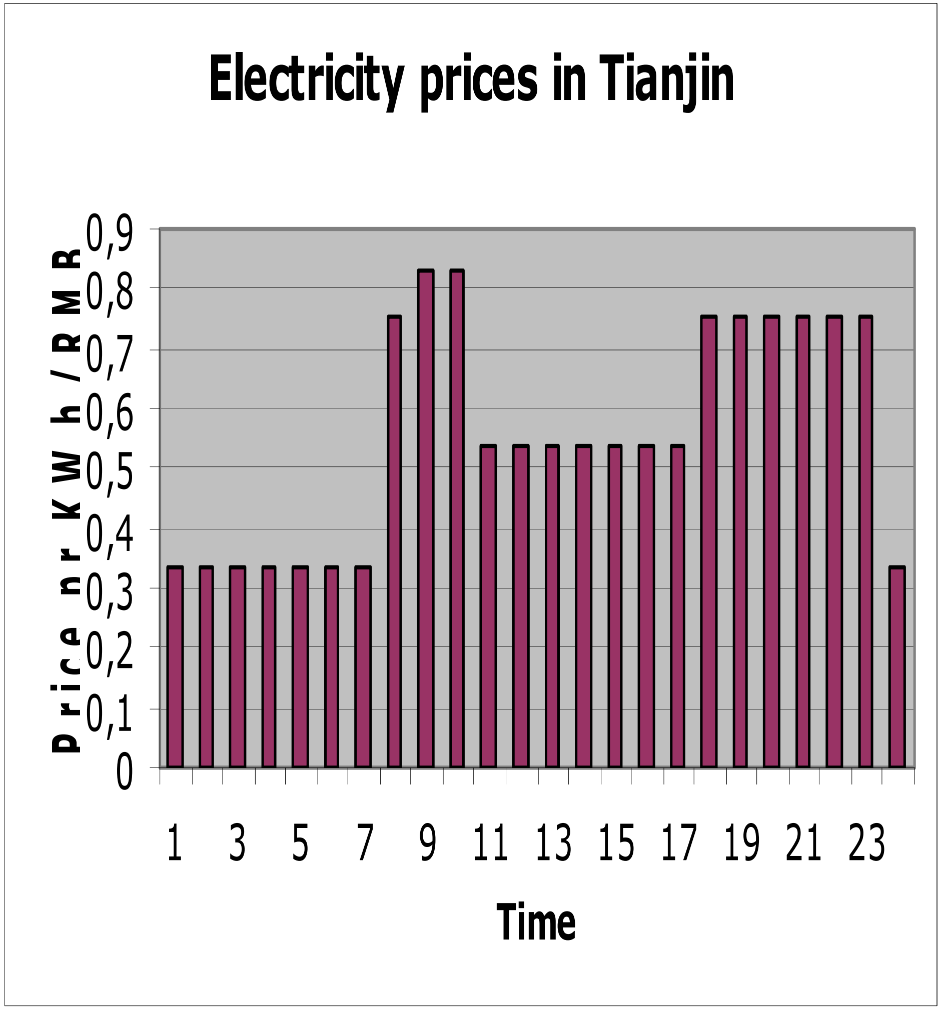
+Lower energy cost

+Reduce peak consumption

+Utilise higher COP at night

- A small loss due to storage

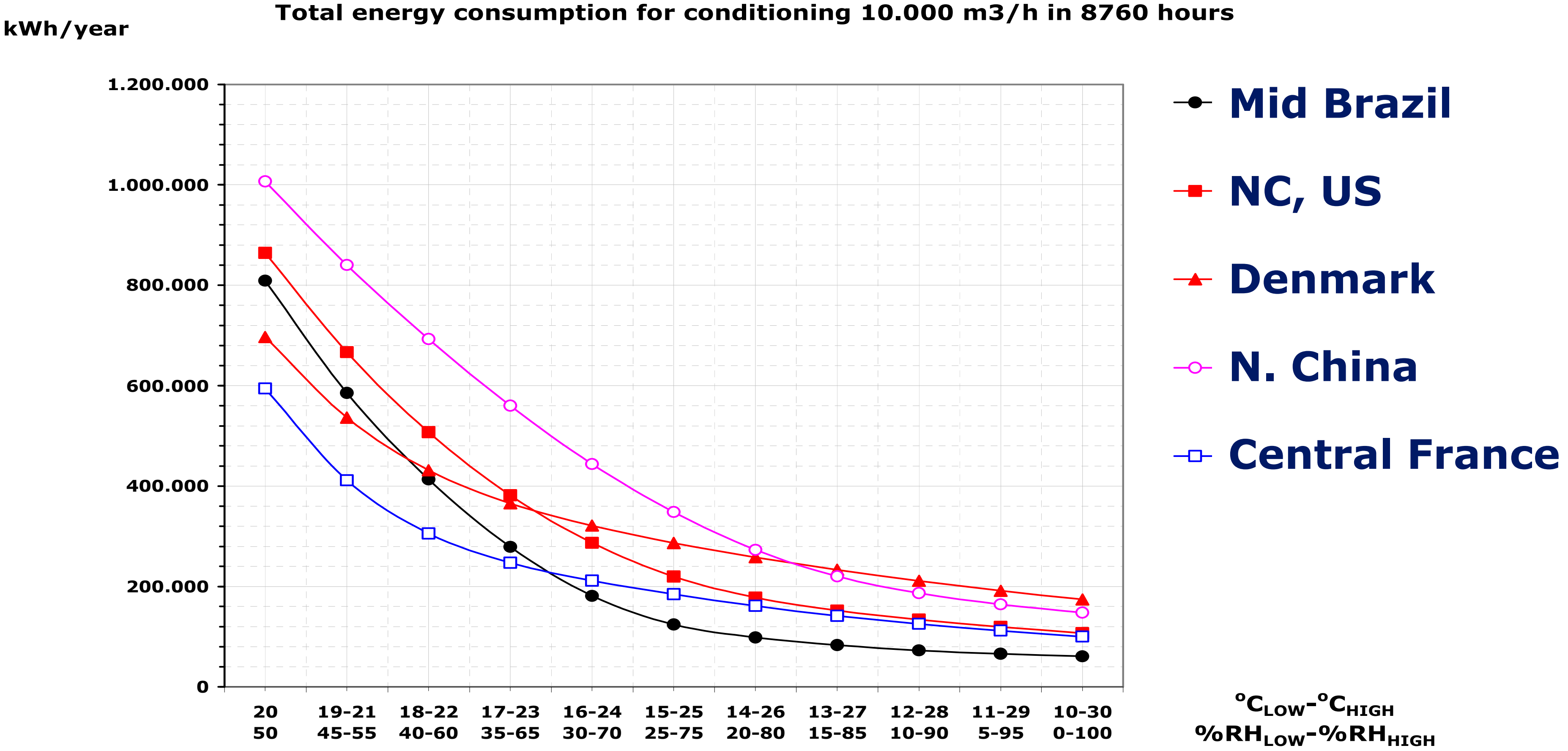
Cooling storage is especially interesting where wind turbines or nuclear power cover a large part of the electrical supply



Design features that should be outlawed

- Electrical zone heating (except for very small volumes)
- Fixed set points for temperature and humidity – the programs should **always** accommodate intervals
- Small face area on filters / high volume pr filter
- Programming that results in unnecessary cooling and subsequent heating or visa versa

The effect of temperature and humidity – different climates, once through



The diagram shows the total net energy consumption for conditioning 10,000 m3/h in 8760 hours, going from singular to split temperature- and humidity-limits. Note that fan-power, room load and efficiency parameters are NOT included, and that the air-flow is once through (not re-circulated).

A few figures
- electricity used at the company and at home

Electrical energy consumption for all of Novo Nordisk	~250 million Kwh / year
Electrical energy consumption for all of Novo Nordisk	~10.000 Kwh / year / employee
Electrical energy consumption of my household	~1.000 Kwh / year / member

It should be obvious that our chance of influencing the global climate through an effort at work could be much larger than through an effort at home

The role of the (non HVAC) professional

1. Realise that many of the professional decisions you make influence the climate
2. If in doubt concerning the magnitude of climate impact of your decisions make sure it is clarified and make your decisions on the basis of facts
3. If there is high climate impact make sure all alternatives are thoroughly analysed
4. Consider and suggest energy savings within your field of work

Notes on heat recovery

- Use “heat wheels” for direct recovery in non classified areas with low load of contaminants and proximity of inlet and exhaust air
- Use coil to coil systems when the recovery is from one area to another or when exhaust and inlet are far apart or there is risk of cross contamination
- Consider using energy recovery from one area to another.
- Don’t apply heat recovery indiscriminately – high degree of air recirc could make the recovery redundant; low volumes of air could make it too costly
- Where only smaller savings are gained on air temperature this benefit can be offset by pressure drop over the recovery device

65 - 70% Fan efficiency

Component efficiency for fan, motor, pulley and VSD:

- **Fan:** 82% efficiency build in
- **Motor:** EFF1 or better
- **Belt and pulley:** 98%
- **VSD:** 98%

Total efficiency for the lot: 65 – 70%

These efficiency requirements are based on a combination of documentation review and measurement of 5 existing air handling units that all showed efficiency of at least 70%

Low pressure drops on filters

Filters

- F7 start: max 100 (change at 200) Pa
- F9 start: max 125 (change at 250) Pa
- H14 start: max 125 (change at 250) Pa

These are lower than nominal pressure drop indicated in supplier information, remember:

- 50% increase in filter media area => twice service span (reduction of downtime and reduction of man hours spent on service)
- Lower flow = increased filtering efficiency = longer life for subsequent filters and cleaner air to rooms

Duct pressure – optimize the index run

For Air Handling Units serving several rooms nothing is gained through "over optimizing" the short runs.

Well balanced duct runs with equal pressure drops from AHU to point of use will increase robustness of the system

Therefore the effort of reducing pressure drop should focus on the longest most complicated duct run
– the **index run**

- Straight ducts: maximum 0.75 Pa pr meter for the ***index run***