Energy Efficiency Analyses and Low- and Medium-Invest Measures: Identification of Saving Potentials

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Energy Efficiency
Energy Efficiency Measures
## Typical Measurements for Different Branches

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<tr>
<th></th>
<th>Chemical Industry</th>
<th>Food Industry</th>
<th>Paper Industry</th>
<th>Office Buildings</th>
<th>Public Transportation</th>
<th>Hospital</th>
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<td>✗</td>
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</table>
Savings in heating systems including hot water

Saving potentials in three areas:

- Optimisation of the heating system
  - Renovation of the heating system
  - Insulation of heating pipes
  - Optimisation of heating pumps
- Improvement of thermal insulation
- More efficient use of energy
The heating technology is constantly evolving, new heating systems are becoming more economical.

A modern heating system can save up to about 30% compared to a 25 years old heating system.

The estimate of the saving potentials will be based on the consumption of the current system.

Values for the savings from the modernisation of heat production:

- Standard boiler (25 years) → condensing boiler  saving potential: 30%
- Standard boiler (15 years) → condensing boiler  saving potential: 20%
- Low temperature boiler (10 years) → condensing boiler  saving potential: 10%

In the process of further consideration, the consumption of a new plant can be calculated fairly accurately on the determination of the heat demand.
The insulation of the heating cables significantly reduces the energy losses:

The achievable savings in energy consumption are between 4% and 10%.

No insulation $\rightarrow$ high cost

With an existing (bad) insulation, the cost will be less.
There are three different types of heating circuits:

**Unregulated pumps:**
Constant speed and thus a constant power consumption. The only way to save energy is to turn off the pumps in the summer.

**Variable pumps:**
Operation with fixed adjustable power levels. Savings of 33% to 75% possible.

**Pressure-controlled pumps:**
Adapt their performance to the current needs. Savings of up to 75% possible.

The prerequisite for this is a hydraulic-matched heating circuit.
Poor thermal insulation:

The greatest heat losses occur by transmission

By improving thermal insulation, the energy consumption for heating are significantly reduced.

The efficiency of thermal protection is poor, amortization periods are expected to be 20 to 30 years.

The amortization periods can be improved through state funding programs.

For renewal of e.g. windows or coverings for other reasons, it is highly recommended to pay attention to a good thermal insulation. The additional costs usually can be presented commercially.
• Areas with different demands on the room temperature are in one hall

• Saving energy by separation of the areas

• Zones with different temperatures are possible with dark radiators
If areas with high ceilings (> 4 Meter) are heated by hot air, switching to a heating with radiant heating can save 30-50% of heating energy.

Advantages of radiant heating:
• No formation of air cushions under the ceiling
• Heating according to use
• Less ventilation losses

The estimated savings can be expected of around 40%.
Heating

- Lowering the room temperature
- Lowering the supply temperature
- Lowering the water temperature
- Summer shutdown of the heating
- Heat recovery
Cooling

Opportunities for energy savings:

- Exchange individual systems with composite plant
- Exchange step control with frequency control
- Optimizing the heat exchanger geometry
- Optimization of the defrosting
- Reduction in solar heat gain
- Heat recovery
- Air Coolers
Individual plants can not be controlled harmonically.

Impact:

- Compressor runs between 60% and 70% of operating time not at the optimum operating point

Disadvantages of single unit:

- Increased energy consumption of the compressors
- Increased icing

The conversion to compound causes a reduction of approx. 20% to 25%.
Goal: keep refrigeration in a low swinging state.

One compressor of the cooling compound must be rotation speed controllable.

Savings of approx. 15% can be achieved.
The heat exchangers in the refrigeration facilities are often too large.

The adjustment results in a saving of about 7-10%.

Recognition of this is very difficult, one needs a very significant expertise and a "trained eye".

Such saving potentials can be detected usually only by refrigeration specialists.
Cooling

Control of defrosting:
Steering of defrosting on demand according to the degree of icing

Savings lie between 8 % and 12 %
Important!

Reduction of the air exchange also leads to savings in heating energy and climate cooling.

Rule of thumb for heating of mechanically ventilated areas:

- 50% of heating caused by ventilation losses and 50% by transmission losses.
- Reduction of air exchange by 50% resulting in a saving of heating energy by 25% by halving the ventilation losses.

Rule of thumb for cold climate of mechanically ventilated areas:

- 50% of the energy consumed for the production of climate cooling caused by the entry of warm air and 50% of the heat input on the building envelope.
- From the reduction of air exchange by 50% results in a saving of climate cooling by 25%.
Optimization of operating hours

Optimization of switching levels

Optimization of the room air temperatures (for heating / cooling)

Optimization of the flap control

The optimization of the settings in the control usually requires no investment.
Ventilation

- Operating hours
- Operating intensity
- Holidays
- Flap control
- Exceptions for level schemes
Ventilation

- Demand-control
- Frequency converter
- Rotary heat exchanger
- Modernization of the plant components
Variable speed control of the ventilation systems rather than a rigid step scheme:

- Double air quantity = four times performance
- It is extremely inefficient to switch the ventilation to level 2 if only a little more air is needed, as the level 1 provides.

<table>
<thead>
<tr>
<th></th>
<th>Classical Level Scheme</th>
<th>Variable Speed Control with Frequency Converter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance at Level 1</td>
<td>20 kW</td>
<td>Same air flow at 20 kW</td>
</tr>
<tr>
<td>Performance at Level 2</td>
<td>80 kW</td>
<td>Same amount of air at 80 kW</td>
</tr>
<tr>
<td>Required Volume of Air</td>
<td>1.05 x Step 1</td>
<td>1.05 x Step 1</td>
</tr>
<tr>
<td>Power at the Required Air Volume</td>
<td>80 kW</td>
<td>21 kW</td>
</tr>
<tr>
<td>Saving of Energy Per Hour</td>
<td>0 kWh</td>
<td>59 kWh</td>
</tr>
<tr>
<td>Savings in %</td>
<td>0</td>
<td>74</td>
</tr>
</tbody>
</table>

To illustrate the mode of operation, this example represents the maximum power savings. With frequency converters average savings of 20-30% can be achieved.
Ventilation

**Advantage:**

The adjustment of the air exchange to the actual demand

Controlled variable:

- CO$_2$-sensor, Customer counting device, etc.

Saving potentials up to 80% possible

**Negative-indication:**

- MAK-values (maximum workplace concentrations of hazardous substances)

This is especially true for carcinogens!

Decoupling of ventilation:

If areas, in which MAK-values or explosive gases (such as the battery room of the UPS) play a crucial role, are served by the same ventilation, a demand-control of the other areas can be realized by a decoupling of air conditioning.
Savings in heating energy and climate cooling

- Temperature differences of up to 10 K between room air and outside air can be balanced

- Rotary heat exchanger can be installed only if supply and return air duct are next to each other

Today, in modern large ventilation systems a rotary heat exchanger is standard.
Besides the optimization of existing technology, it can also be economical to replace parts of the plant.

Since the effort for this is very different, the assessment should be carried out by a specialized company.

Possibilities:

- Modern air engines consume about 10% and 20% less energy
- Optimization of canal system
- etc.
Examination of the set programs, especially switching times and switching stages
Examination of the flap control
Testing of the sensors
Adjustment of the holidays
Replacing the filters
Cleaning the air outlets

Depending on the system, a regular filter exchange saves between 5% and 10% of energy.
Compressed Air

Potential energy savings in compressed air systems:

- Pressure reduction
- Reduce standby losses
- Reduce leakage losses

The savings to be achieved during operation of a compressed air system can be determined very precisely by measurements and simulations.

Without such studies the savings potential must be estimated.

The estimation of the savings potential of a compressed air system is based on the energy consumption. If there is no reliable data for the power consumption of the compressors, it can be calculated.
Air operated systems often require a minimum operating pressure of 6 bar.

For a trouble-free operation, a pressure level of 6.5 bar is generally sufficient.

Often due to an individual consumer the pressure of the entire compressed air system is higher.

- Solution: Booster

- Pressure reduction to 1 bar = 7% less energy consumption
Standby losses occur when a compressor is in operation, without producing compressed air.

Two ways to reduce standby losses:

- Cascade control
- Speed control (will save more energy)

Determination of standby losses by measuring the operating data of the compressed air system.

This is not possible in the context of the general energy efficiency analysis. It has to be carried out by a compressed air specialist (Nationwide contact details available on request from Envidatec).

Rough estimates of the expected savings:

Systems without control: 10% standby losses
With cascade control: 5% standby losses
With speed control: 0% (theoretically)
Compressed Air

- There is no pressure pipeline network without leaks
- The question is how high the level of leakage losses is
- Assessment by pressure discharge measurement
- Search the leaks with ultrasonic detector
- Rule of thumb: 10% of total consumption is caused by leakage

In old systems with long pipeline networks, the losses due to leaks can be even larger.
Basic measures for optimization:

- A more efficient operation through the installation of new control and safety techniques
- A reduction in consumption, for example, by installing a new burner or heat recovery measures
- The reduction of wear by adjusting parameters and precise adjustment of the boiler
- Eliminating of pipeline leakages
- Examination of the pipeline insulation
- Examination of the pipeline sizing
- A fuel conversion, e.g. of oil to gas; natural gas burns cleaner and requires no storage tank
- Load optimization in combination with the performance component of the gas supply contracts
More efficient Operation through Installation of new Control and Safety Techniques

The optimization of the boiler controls and safety technology enables a more energy-efficient driving style of the boiler.

- Outdated rules are often disadvantageous with respect to energy efficiency
- Evaluation is often difficult even for a power engineer

Rough guide:

By a renewal of the controls for the boiler sequence control in multi-boiler systems savings of approximately 10% can be realised.
Prevention of Wear, by Adapting and precise Setting of the Boiler Parameters

Too fast up and down regulation of the burner:

Too fast load change rates in the burner control can have adverse effects on the durability of the boiler walls.

Parallel operation of multiple boilers, even though the current heat is too low:

Impact:

"Chopping" of boilers

Remedy by regulating the operation to the steam demand.

Systems with more than 2 boilers → automated sequence control

The amount of the savings potential can be 10-50%. Precise statements are made only by further analysis.
Examination of the Pipeline Insulation

Lack of pipeline insulation leads to thermal losses, resulting in significant additional costs.

As a benchmark:

1 meter missing insulation at 20 cm pipe diameter (DN200), leads to about 300 € per year at gas prices to market standard.

The insulation per meter DN200 costs about 90 €. Therefore, such a measure pays for itself in 0.3 years.

(Prices: west-European standard)
Undersized Pipelines

The pipeline sizing often fails to meet the requirements.

Impact:

The steam system must be operated at a higher pressure.

Savings:

Pressure reduction of 1 bar leads to 6% energy reduction.

The amortization period of such measure depends largely on the plant-specific conditions.
Oversized Pipelines

If the pipeline network has a too large capacity, it comes to considerable energy losses through the sometimes long transport distances for the process steam.

By adjustment of the pipeline network, the distribution losses can be reduced.

It is not possible to predict the savings potential.

Evidence can be obtained via temperature loss, building of condensation and mass flow.
The share of electricity consumption in the lighting is very different:

- In an industrial organisation it may be less than 5%
- In a supermarket it can be more than 50%

Three types of measures:

- Modifications of existing lighting
  - Exchange of lamp types / ballast to more efficient ones

- Re-installation
  - Complete exchange to more energy efficient systems
  - Installation of parental lighting control

- Organizational measures
  - Optimise / reduce switching times
  - Use of daylight / different light intensities
  - Sensitisation and training of staff
Just as an automobile's fuel efficiency is measured in kilometers per liter, light bulb efficiency is measured in terms of lumen per watt – the amount of light produced for each watt of electricity consumed.

**Most important types:**

- 100W light bulb 17 L/W
- T3 halogen 20 L/W
- LED compact 50 L/W
- 32W T8 fluorescent 90 L/W
Manifold options from water-saving operations in sinks or flush-hold buttons in toilets to the optimisation of processes that require much water.

Significant water savings by:
- Use of water
- Water treatment plants

High savings from a condensate return:
- For example, 100 °C hot condensate and 140 °C hot superheated steam led back to the boiler, contain a remarkable amount of energy.

- The additional energy compared with cold tap water is:

  \[
  \text{Energy in 1 m}^3 \text{ of condensate, } 100 \degree \mathrm{C} = 1.162 \text{ kWh/m}^3 \times \Delta 90 \degree \mathrm{C} = 104.6 \text{ kWh} \\
  \text{Energy in 1 ton of superheated steam, } 140 \degree \mathrm{C} = 1.870 \text{ kWh/ton} \times \Delta 40 \degree \mathrm{C} = 74.8 \text{ kWh} \\
  \text{Evaporation enthalpy } 2257 \text{ kJ/kg} = 2257 / 3600 \times 1000 \text{ kWh/ton} = 626.9 \text{ kWh}
  \]

- This results in an additional energy of 806.3 kWh per ton compared to fresh water.
There are significant savings obtained by the detection of leaks. At about 10% of the properties examined by Envidatec a water leak was found.

- In a practical example, these were 3 m³ / h, which flowed undetected in the ground. At a price of 4 € / m³ significant costs arise in one year:

\[
3 \text{ m}^3/\text{h} \times 24 \text{ h} \times 365 \text{ days} \times 4 \text{ €/m}^3 = 105,000 \text{ €}
\]

If more water is used a leak easily stays undetected.

Manual detection:

Select period in which usually no water use takes place during operation (e.g. at night or Sunday). Now you only have to manually read out the appropriate counters at the beginning and the end of this period. If the counter reading didn't change, a leak is ruled out.

In a continuous data collection:

Meters via pulse outputs or reed contacts are connected to a recording device. With the resulting data, the consumption will be analysed closely.
Waste Heat

In principle, the use of waste heat is suitable whenever heat is wasted and released into the environment and if there is a demand for heat. This is the case in nearly all commercial or industrial objects.

The amount of usable waste heat depends primarily on two factors:

- The amount of waste heat
- The possibilities for the use / heat demand

As the heat energy can be saved only with a very great expense to any significant extent, waste heat and heat demand have to occur at the same time.
Waste Heat

**Compressed Air**

Rule of thumb:

75% of the energy consumption of the compressed air system can be used as waste heat.

**Cold**

Rule of thumb:

75% of the energy consumption of the refrigeration system can be used as waste heat.
Flow Rates

There is a waste heat potential in all flow rates, which leave a plant as exhaust air or waste water. The amount of the potential is calculated on the mass flow, temperature and heat capacity.

If the flow rates have a high temperature, the heat can be used directly, at lower temperatures a heat pump is necessary.

Example calculation:

Exhaust air with an average temperature of 45 °C from a production hall

<table>
<thead>
<tr>
<th>ΔT</th>
<th>25 K</th>
</tr>
</thead>
<tbody>
<tr>
<td>cp</td>
<td>1.005 kJ/kgK</td>
</tr>
<tr>
<td>Air density ρ (40°C;1013hPa)</td>
<td>1.148 kg/m³</td>
</tr>
<tr>
<td>Conversion factor</td>
<td>3,600 J/kWh</td>
</tr>
<tr>
<td>Exhaust air flow</td>
<td>40,000 m³/h</td>
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<tr>
<td>Operating hours exhaust air</td>
<td>4,000 h/a</td>
</tr>
<tr>
<td>Waste heat potential</td>
<td>= 1,281,933 kWh/a</td>
</tr>
</tbody>
</table>
On this point, the following options for saving energy in the operation of electric motors are considered:

- High energy-efficient motors (EFF1)
- Optimization of the transmission
- Optimization of power
- Speed control by frequency converter

For all motors:
Optimization of the transmission

Motors with variable speed:
Speed variation by frequency converter

Constant speed engines (several levels):
Optimization of power
Electric Drives – High energy-efficient Motors (EFF1)

Classification of electric motors in three efficiency classes:

- EFF 1
- EFF 2
- EFF 3

With additional investment costs of 20-30% EFF 1 motors have an up to 6% higher efficiency than conventional electric motors.

Other benefits:

- Increased reliability
- Reduced downtime and maintenance costs
- Increased tolerance to heat stress
- Improved tolerance to overload
- etc.

Amortization periods of 30 to 40 years in exchange.

Additional costs are amortized generally faster than 10 years.
Electric Drives – Transmission

- Power transmission by flat ribbon belt:
  The conversion of the power transmission from v-belts to flat ribbon belts leads to a saving of around 4%.

- Direct Transmission:
  The conversion of the power transmission from v-belts to direct transmission leads to a saving of approximately 8%.
The optimization of the power supply is achieved by an intelligent control system. All following data refer to "integra" from powerboss.

- Suitable for all constant speed motors with one or more operational levels
- The savings are obtained by adjusting the electricity supply to the current load
- Adaptation 100 times / sec

The savings potential is given by the manufacturer at 20 – 40%.
Suitable for motors that can be operated at variable speed.

- E.g. ventilation systems, pumps, compressors, blowers

Principle: the performance is adjusted to the needs via the variable speed.
Load Management

The principle:

A load management system turns off electrical loads, or limit them in their performance when the power threatens to exceed a threshold.

Since electricity supply contracts typically include a demand charge, the identification of this potential cost reduction is prudent. This also applies to the gas consumption.

In our experience, the peak power can be reduced very often by 10 to 20%, the profitability for such measures is generally very good.

The amount of reducible power can be estimated by the analyst from the 15 minutes load profile.

In general, the amortization period is less than three years.
Objectives of Load Management

- Reduction of peak loads
  - Reducing power consumption of individual processes by influencing the control electronics
  - Temporary closure of suitable consumers
  - Switching on auto-producers (e.g. CHP, emergency generator)
  - Fuel switching
    ⇒ Homogenization of the working cot,
    Reduction in power costs
- Limit the instantaneous power
  - Reduced load of lines
    ⇒ Avoidance of investments for strengthening the connection (transformer stations)
Principle of Load Management

Distribution of peak load

Time

kW
Analysis of the Resources Structure

Controllable load = resources, that
- can be disabled temporarily without markedly disturbing the production process
- processes which can be reduced in consumption within their tolerance range
- are in operation during high power consumption
- can be integrated technically useful
Example for Control of Consumers by Load Management

Storage cooling 1 without Load Management

Storage cooling 2

Sum

Storage cooling 1 with Load Management

Storage cooling 2

Sum
Examples for Controllable Consumers

Technical heat consumers as
- Dryers
- Hot water tank
- Ovens
- Melting and hardening systems
- Form Heaters
- Electroplating baths
- Heat exchanger

Technical cold consumers as
- Climate control
- Refrigerators
- Storage cooling
- Band and spiral freezers

as well as
- Ventilation
- Compressed air with pressure tank
- Fermentation interrupter (cold/heat)
Energy Efficiency
Energy Efficiency Analysis
Energy Efficiency Analysis

Check List

DIAGNOSTIC AUDIT

ENERGY EFFICIENCY – SPECIAL ANALYSIS

- Heating Cooling
- Compressed Air
- Thermal Regulation
- Thermography
- Electric
- Water
- Energy Purchasing
- Compl. Energy Concept

Report

CONCEPTIONING / PLANNING PHASE

IMPLEMENTATION / CONTROL OF SUCCESS / ISO 50001
### Energy Efficiency Analysis: Check List

**Check List**

- Customer will receive a check list prior to the on-site analysis
- Has to be filled out in advance by the customer and should be available 2 weeks before the date of the analysis.

**Aim of the check list:**

- Easier assessment of time frame and effort for analysis
  - Easier to create a good and reasonable offer
- To help the inspector for preparation
  - The inspector knows in advance which process energies play the major role
- Check list as basis for ISO 50001
Energy Efficiency Analysis: Diagnostic Audit

**On-site-analysis**

- Visit of the relevant energy-intensive installations
- Development of a concept draft

**Results**

- First estimation of energy saving potentials
- Identification of organisational and investment measures to reduce energy costs
- Identification of process energies to conduct special analyses
Generally, for the main process energies more specialised analyses are recommended.

Results

- A detailed, certified report is made including appropriate measures to achieve the reported energy savings.
- Besides the analysis of energy consumption also an estimation of the \( \text{CO}_2 \)-emissions and the expected savings can be created.
Creation of a concept for the efficient use of energy

Results

- Investment plan for energy cost reducing measures
- Amortization calculations for energy cost reducing measures
Energy Efficiency Analysis: Implementation

- Installation of (temporary) measurement to verify the saving potentials
- Realisation of concept for the implementation of all measures
- Planning of the technical implementation of all measures
- Implementation of all measures
- Project management
- Bringing into service
- Technical solutions, e.g. load management system, energy and operating data controlling for permanent cost savings
At the organisational level

- Carrying out regular project meetings
- Regular status reports

Of an energy and operating data controlling

- Continuous monitoring of energy and operating data, e.g. by connecting to the portal "My-JEVis"
- Maximum transparency of operational processes
- Consumption peaks are immediately alerted and can be removed prior to high cost

EnMS

- ISO 50001
Questions?
Suggestions?
Thank you for your attention