Chapter 4 Economy

4.1 Economy

4.1.1 Costs for compressed air production

4.1.1.1 General

Electrical energy is the dominant energy type with virtually all industrial compressed air production. In many compressed air installations there are often significant and unutilised energy-saving possibilities through, e.g. energy recovery, pressure lowering, leakage reduction and by optimising operations through the choice of the control and regulation system.

It is profitable to look to the future as far as possible and try to assess the affects of new situations and demands that might apply to the installation when planning a new investment. Typical examples are environmental demands, energy saving demands, increased quality requirements from production and future production investments.

Optimised compressor operations are becoming more important, especially for larger, compressed air dependent industries. Production changes over time in a developing industry and thereby the conditions for compressor operations. It is therefore important that the compressed air supply is based both on the actual requirement and on plans for the future. Experience shows that an extensive and unbiased analysis of the operating situation results, on nearly every occasion, in improved overall economy.

Energy costs are clearly the dominating factor for the installation's overall economy. It is therefore important to concentrate on finding solutions that comply with demands of performance and quality as well as demands on efficient energy utilisation. The added cost involved with acquiring compressors and other equipment that comply with both of these demands will been seen in time as a good investment.

As energy consumption often represents approx. 80% of the overall cost you should exercise care when selecting the regulation system. The difference in regulation systems overshadows the difference

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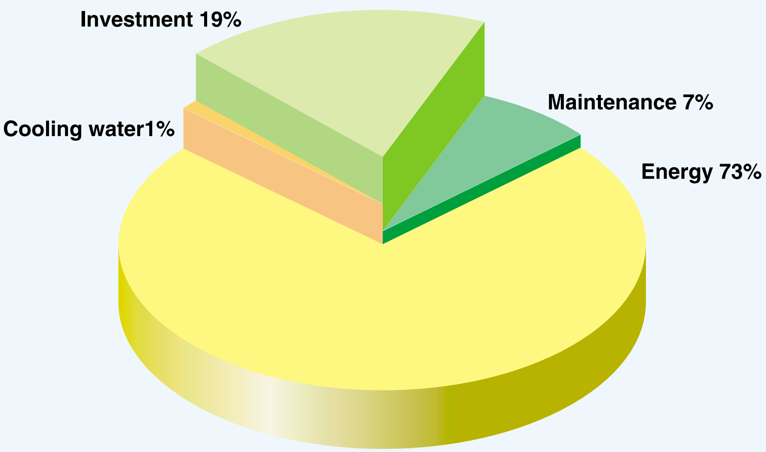
When analysing different expenses for the production of compressed air you will find a breakdown similar to the one in the diagram. However, the apportionment between different types of costs change with the number of operating hours/year, the equipment included in the calculation, the types of machine and the selected cooling system, etc.



between types of compressor. The ideal situation is when the compressor's full capacity is adapted exactly to balanced consumption, something frequently applied in process applications. Most types of compressors are supplied with their own control and regulation system, but the addition of equipment for co-control with other compressors in the installation can further improve the operating economy.

Speed regulation is becoming a popular regulation method, due to the power requirement being virtually proportional to the speed, drawn capacity. To think carefully and allow the requirement govern the selection of regulation equipment gives good results.

If a small amount of compressed air is required during the night and weekends, it can be profitable to install a small compressor adapted to this requirement. If, for some reason, you need another working pressure, the requirement should be analysed to discover whether the entire production can take place from a compressor centre or whether the network should be divided up for different pressure levels. Sectioning of the compressed air network can also come into question, in order to shutdown certain sections during the night and at weekends, to reduce air consumption or when you wish to apportion costs internally based on flow measurements.

4.1.1.2 Apportioning costs

Investment costs are a fixed cost made up of the purchasing price, building costs, installation and insurance. The cost of the investment as a part of the overall cost is connected partly with the selection of the quality of the compressed air and partly with the amortisation period and the cal-

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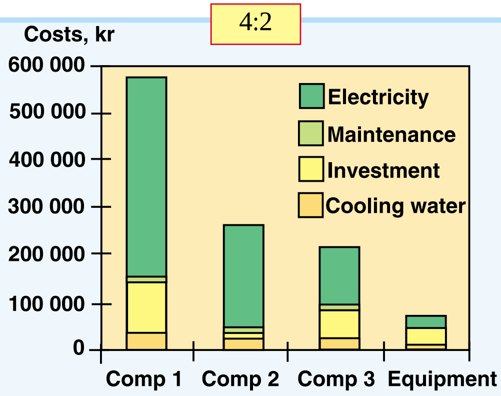

This is how costs can be divided between 3 compressors and auxiliary equipment. The large differences can be due to how the included machines are valued, that the capital value for an older machine may be higher than for a newly purchased machine, that the selected level of safety can affect the accounted maintenance costs, etc.

culation's interest rate. The size of energy costs are linked to the operating time per year, degree of utilisation and the energy price, etc. Some acquisition costs, for example, equipment for energy recovery give a direct pay off in the form of reduced operating and maintenance costs.

4.2 Opportunities for saving

4.2.1 Power requirement

When performing calculations it is important to bear in mind the overall power requirement. All energy consumers that belong to machines, should be observed, for example, intake filters, fans and pumps.

With comparisons between different investment options particular importance must be placed on the use of comparable values. Therefore you must be assured that the values are stated in accordance with

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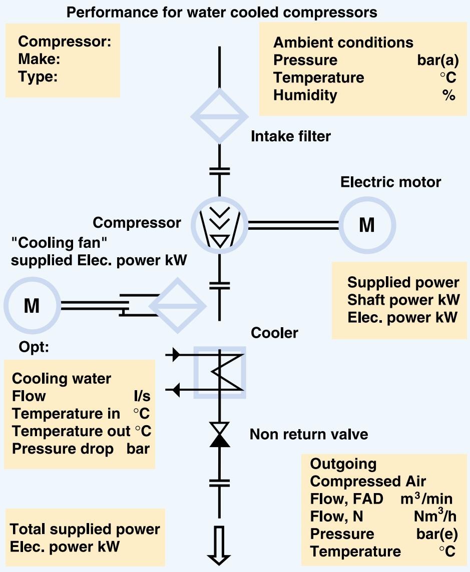

The figure shows a simple, but extremely useful model that can be used to give a true picture of a compressor's electrical energy requirement.

internationally agreed regulations, for example, as set out in ISO 1217. Ed3, supplement C-1996.

4.2.2 Working pressure

The working pressure directly affects the power requirement. High pressure means higher energy consumption. To increase the working pressure to compensate for pressure drop always results in impaired operating economy.

Despite this it is a common method, for example, with pressure drop caused by a too small pipe system or blocked filters. As an example , an increase in the working pressure by 1 bar, brings about an increase in the power requirement by approx. 6% . In an installation with several filters, especially if they have been operational for a long period of time without being replaced, the pressure drop can be significantly higher and therefore very costly.

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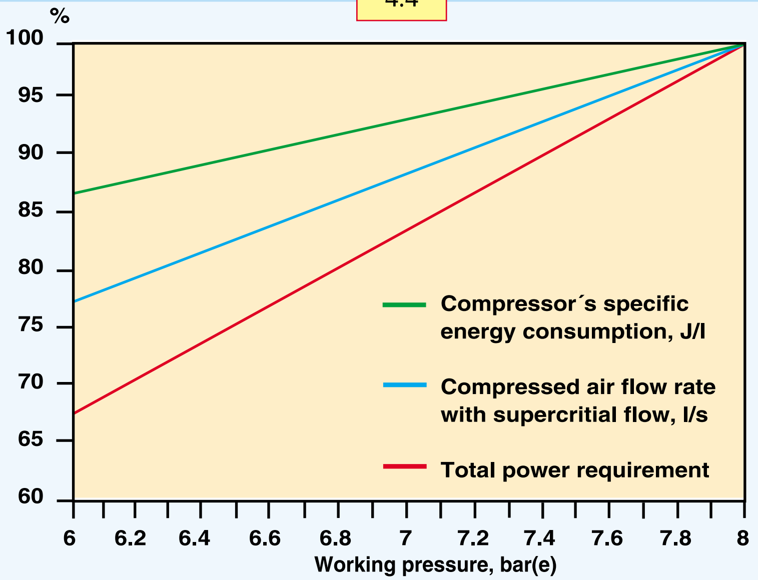

The relation between pressure and electrical energy consumption. For a compressor of 15 m³/min a reduction of the working pressure from 7 to 6 bar means that the power requirement decreases from 91 to 85 kW. With a running time of 4000 hours/year this represents 24,000 kWh/year.

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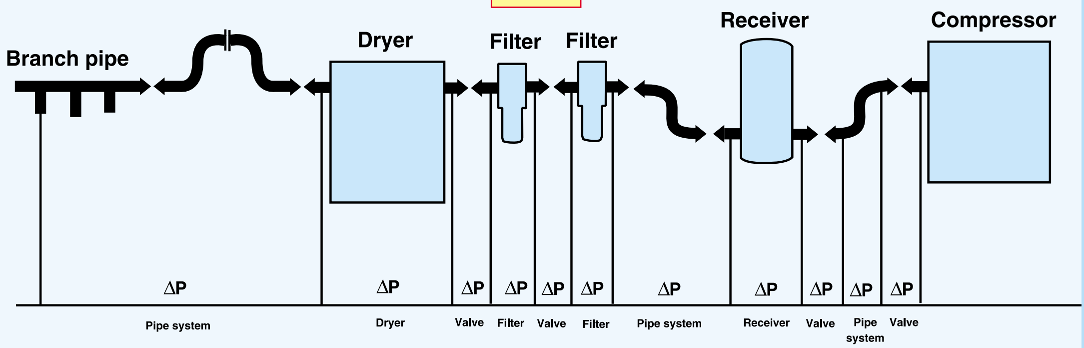

This is how the pressure drop across different components in the network affects the requisite working pressure.

In many installations it is not possible to implement large pressure reductions, but using modern regulation equipment it is frequently fully realistic to lower the pressure by 0.5 bar. This means a saving of perhaps a few per cent, which may seem to be low, but if you consider that the total efficiency of the installation is increased to an equivalent degree it becomes more evident what the pressure reduction means.

4.2.3 Air consumption

By analysing routines and the use of compressed air, you can find solutions that give a more equal load on the compressed air system. The need of increased air production can thereby be kept low, which reduces operating costs.

Unprofitable consumption, which usually depends on leakage, worn equipment, processes that have not been adap-

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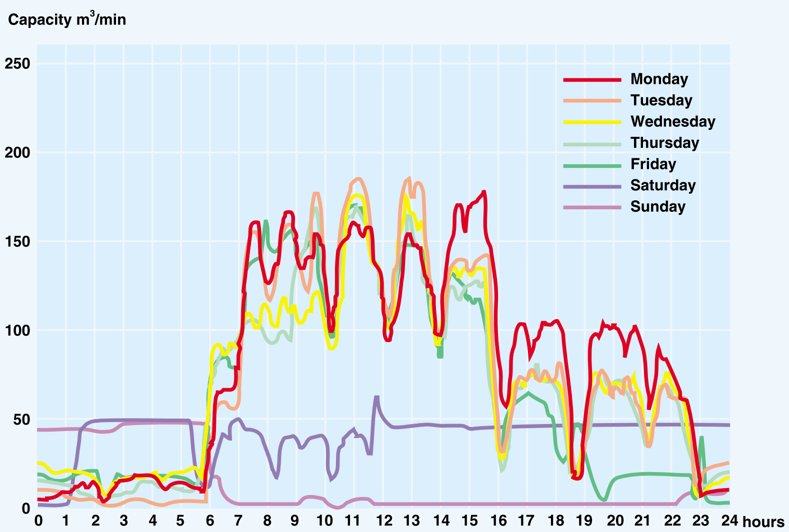

The diagram shows how consumption can be spread during a week and 24 hours per day. Consumption is low during the night shift, high during the day shift, it drops during breaks, but is constant during the weekends (leakage or production).

ted or the incorrect use of compressed air is best rectified by increasing general awareness. Dividing the compressed air system into sections, that can be separated using valves, can be a method of reducing consumption during the night and at weekends. In most installations there is some leakage, which is a pure loss that must therefore be minimised. Frequently leakage claims 10-15% of the produced compressed air sometimes even more. Leakage is proportional to the working pressure, which is why one method of reducing leakage is to repair leaking equipment and lower the working pressure, e.g. at night.

A lowering of the pressure by only 0.3 bar reduces leakage by 4%. If the leakage in an installation of 100 m^3/min is 12% and the pressure is reduced by 0.3 bar, this represents a saving of approx. 3 kWh/hour, which is equivalent to the electricity consumption in a normal electrically heated home. Even the air consumption for machines and equipment increases with an increased working pressure.

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Hole diameter		Output flow at 7 bar working pressure	Power requirement for the compressor
Size	mm	l/s	kW
	1	1.2	0.4
	3	11.1	4.0
	5	31	10.8
	10	124	43

The table shows the relation between leakage and power consumption for some different (small) holes at a system pressure of 7 bar.

4.2.4 Regulation method

Using a modern, master control system the compressor central can be run optimally for different operating situations at the same time as safety and availability increase.

Selecting the right regulation method allows the supplied quantity of energy to be reduced through a lower system pressure and the degree of utilisation is optimised for each machine in the installation. At the same time availability increases, which reduces the risk of unplanned downtime. Besides, central control allows programming for automatic pressure reduction in the entire system, e.g. during operations at night and weekends.

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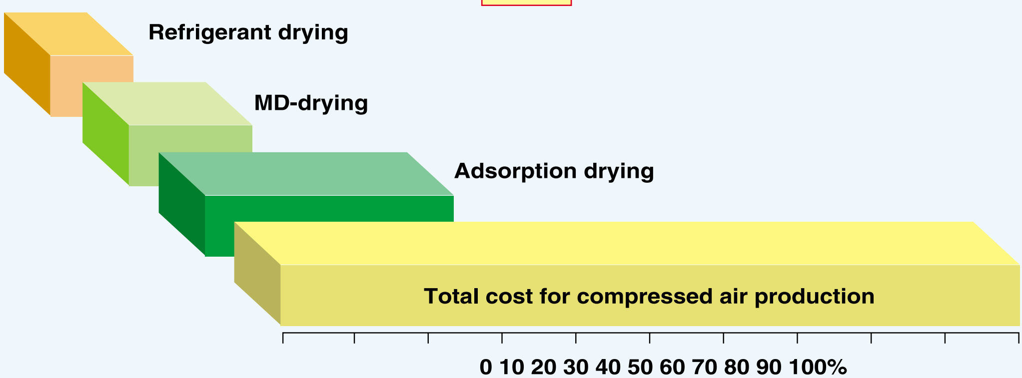

A cost comparison between different drying methods.

As compressed air consumption is seldom constant, the compressor installation should have a flexible design, for example, through the use of compressors with different capacities and speed controlled motors. Compressors with a prudent design can be run with speed control and screw compressors are especially suited for this, as their capacity and power requirement are virtually proportional to the speed.

4.2.5 Air quality

High quality compressed air reduces the need of maintenance, increases operating reliability of the pneumatic system, control system and instrumentation at the same time as wear to the air-powered machines is reduced.

If the compressed air system is adapted for dry compressed air from the outset the installation will be less expensive and simpler, as the pipe system does not need to be fitted with a water separator and so-called, swan-necks. When the air is dry it is not necessary to discharge air to the atmosphere to remove condensation. Condensation drainage on the pipe system is also not required, which means lower costs for installation and maintenance. The best economy can be gained by installing a central compressed air dryer. Decentralising air treatment, with several smaller units placed in the system, is more expensive and makes the system harder to maintain.

It is normally calculated that the reduced installation and maintenance costs for a system with dry compressed air cover the cost of the drying equipment. Profitability is very good, even when it is a question of supplementing existing installations with drying equipment.

Oil-free compressors do not need an oil separator or cleaning equipment for condensation. At the same time filters are not needed and therefore the cost for filter replacement is avoided. Consequently, there is no need to compensate for the pressure drop in the filter so compressor's working pressure can be lowered, which improves the installation's economy yet further.

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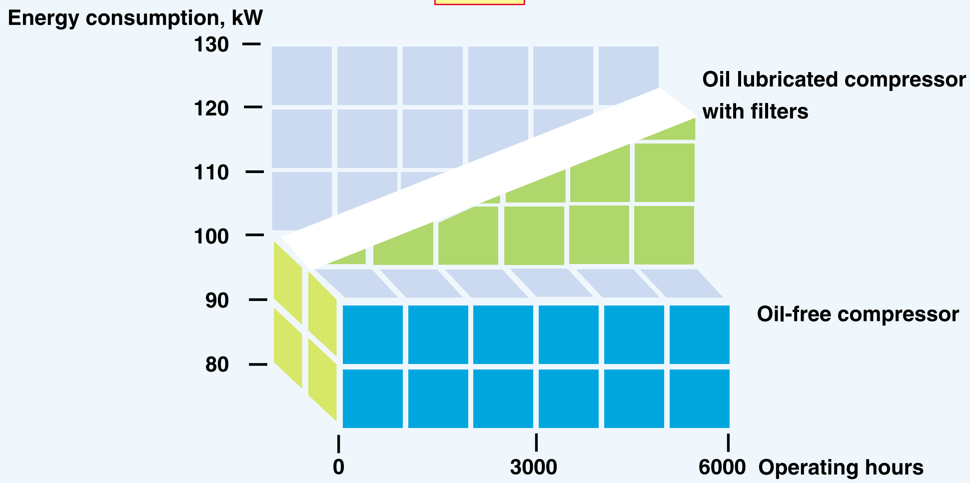

An oil-free compressor gives constant compressed air quality to a fixed energy cost.

4.2.6 Energy recovery

If you use electricity, gas or oil for any form of heating within the production facilities or in the process, there is good reason to investigate the possibilities of fully or partly replacing the energy with surplus energy from the compressor installation. The decisive factors are the alternative value in SEK/kWh for the surplus energy, degree of utilisation and the amount of additional investment necessary. A well planned investment in energy recovery often gives a repayment time of only 1–3 years. Over 90% of the power supplied to the compressor can be recovered in the form of highly valuable heat. The temperature level of the recovered energy determines the possible application areas and thereby the value.

The highest degree of efficiency is generally obtained from water cooled installations, when the compressor installation's outgoing cooling water can be connected directly to a continuous heating requirement, for example, the heating boiler's return circuit. Surplus energy can then be effectively utilised all year round. Different compressor designs give different prerequisites. In situations requiring a large heat flow, long transporting distances to the point of utilisation, a generally lower requirement or a requirement that varies during the year, it can be of interest to look at the possibilities of selling the recovered energy.

4.2.7 Maintenance

As all other equipment, even a compressor

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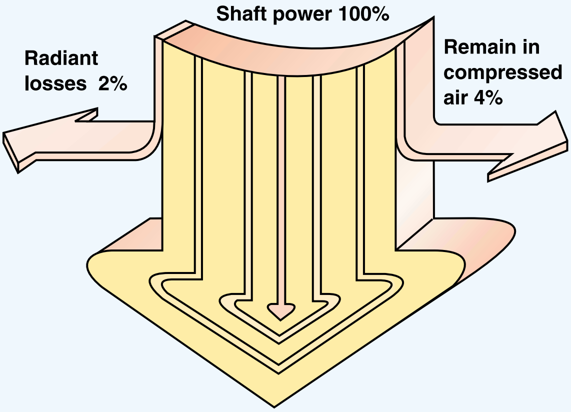

Recovered energy kWh/year:

$W = [(K_1 \times Q_1) + (K_2 \times Q_2)] \times T_R$

Saving/year: $W \times e_p/\eta$

Saved oil m³/year: $W/6800 \times \eta$

W = Recovered energy (kWh/year)
T_R = Time per year when there is a need of power recovery (hours/year)
K_1 = Part of T_R with loaded compressor
K_2 = Part of T_R with off-loaded compressor
Q_1 = Available power in coolant with loaded compressor (kW)
Q_2 = Available power in coolant with off-loaded compressor (kW)
e_p = Energy price
η = Normal heat source's efficiency.

At the same time as the compressor produces compressed air, it also converts the supplied energy to heat, which is transferred to the coolant, air or water. Only a small part follows with the compressed air and is emitted as radiation from the machine and pipes. An air cooled compressor involves the simplest recovery system, while a water cooled compressor involves more efficient and more flexible recovery possibilities.

installation requires some form of maintenance. However, maintenance is low in relation to other costs, but can be reduced further through planning measures. The choice of the level of maintenance is determined by the installation's reliability and performance.

Maintenance makes up the smallest part of the installation's total cost. This is connected to a high degree on how the installation has been planned in general and the choice of compressor and the auxiliary equipment.

You can reduce costs by combining monitoring with other functions when using equipment for fully automatic operations and monitoring of the compressor central. The total budget for maintenance is affected by:

- **Type of compressors**
- **Auxiliary equipment (dryers, filters, control and regulation equipment)**
- **Operating situation**
- **Installation conditions**
- **Media quality**
- **Maintenance planning**
- **Choice of safety level**
- **Energy recovery/cooling system**
- **Degree of utilisation**

The annual cost usually lies between 5–10% of the machine's investment value.

4.2.7.1 Maintenance planning

Well planned maintenance means that you can anticipate costs and extend the service life of the machine and auxiliary equipment. At the same time costs for repair of small faults decrease and downtime becomes shorter.

By utilising advanced electronics to a greater degree machines are equipped with instruments for diagnostic examination. This means that component parts can be utilised optimally and replacement takes place only when there is a need. The

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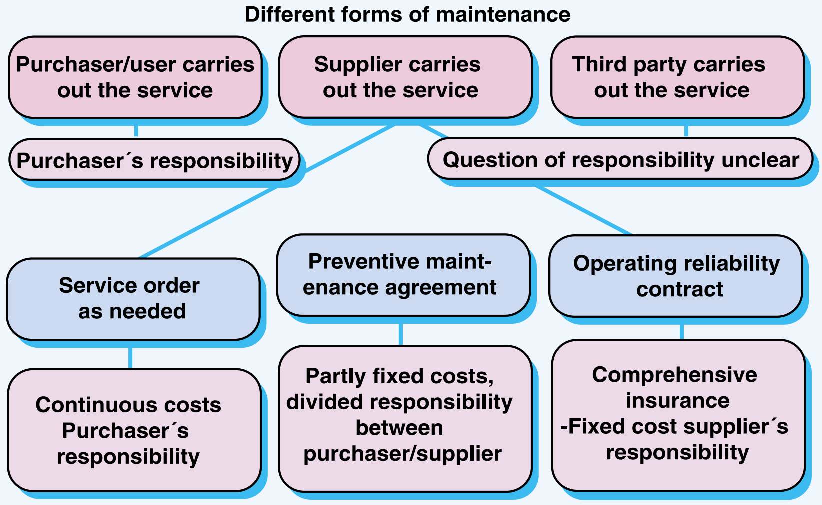

The highest possible degree of utilisation reduces the cost of service and maintenance, counted in SEK/operating hour. It is realistic to plan for 100% utilisation and at least 98% availability.

need of reconditioning can be discovered at an early stage before becoming immense, thus avoiding subsequent damage and unnecessary downtime.

By utilising the supplier's service staff and original spare parts, you can expect the machine to have a high technical standard and you have the possibility of adopting modifications based on the latest findings during the machine's service life. The assessment of the maintenance requirement is made by specially trained technicians, who also answer for the training of in-house maintenance staff. You should always have you own skilled staff to take care of daily inspection, as ears and eyes can hear and see things that monitoring equipment cannot.

4.2.7.2 Auxiliary equipment

It is easy to expand an installation with numerous pieces of auxiliary equipment to, for example, increase the air quality or monitor the system. However, even auxiliary equipment needs service and brings about costs for maintenance, e.g. in the form of filter replacement, drying agent replacement, adaptation to other equipment and the training of staff.

In addition there are secondary maintenance costs, for example, the distribution network and production machines, which are affected by the quality of the compressed air and deposit costs for oil and filter cartridges. All of these costs must be evaluated in the calculation that forms the basis of an investment.

4.3 Other economic factors

4.3.1 General

You can describe and analyse a product, a material or service in a systematic way (yet simplified), with the help of a life cycle analysis, LCA. The LCA analyses all the stages in the product's live cycle. This means everything, from the selection of the raw material to the final waste depositing are included in the study.

The analysis is often used as a comparison between different options, for example, products with an equivalent function. The result is often used to provide guidance in issues concerning processes or product design. LCA can also be used by companies in communication with subcontractors, customers or the authorities to describe their product's characteristics.

The results from an LCA primarily act to form the basis for making decisions in the work minimise a product's effect on the environment. LCA does not give the answer to every question, which is why other aspects such as quality and the available technology must be examined to provide comprehensive background material.

4.3.2 LCC

LCC calculations (LCC = Life Cycle Cost) are used more and more as a tool to evaluate the different investment options. Included in the LCC calculation are the product's combined costs during a specific period, thus the capital cost, operating cost and the service cost.

The LCC calculation is often implemented based on a planned installation or a working installation and with this as a basis, defines the requirement level for the new installation. However, it is right to point out that a LCC calculation is often only a qualified guess with regard to future costs and is limited as it is based on today's knowledge of an installation's condition and energy price changes.

Neither does it bear in mind "soft" values that can be just as important, for example, production safety and subsequent costs.

To make an LCC calculation requires knowledge and preferably experience of compressed air installations. For the best result it should be made in consultation between the purchaser and the salesman. Central issues are, e.g. how different investment options affect factors such as production quality, production safety, the need of subsequent investment, maintenance of production machines and the distribution network, environment, the quality of the final product, risk assessment for downtime and rejections. An expression that must not be forgotten in this context is LCP, Life Cycle Profit, i.e. the earnings that can be made through, e.g. energy recovery and reduced rejections.

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Example of a compressor calculation

Input data						
Price of electricity	SEK/kWh	0.45				
Calculation interest	%	12				
Depreciation period	years	10				
Operating time	hours/year	6 000				
		Comp 1	**Comp 2**	**Comp 3**	**Dryers**	**TOTAL**
Annual consumption						
Electricity	MWh/year	1 200	555	406	133	2 294
Water (circulation system)	m^3/year	-	-	-	-	-
Divided operating costs						
Electricity	kSEK/year	540	250	183	60	1 033
Water	kSEK/year	6	4	2	0	12
Annual costs without energy recovery	**kSEK/year**	**760**	**383**	**197**	**114**	**1 454**
Operating costs	kSEK/year	547	254	185	60	1 046
Capital cost	kSEK	167	99	2	44	312
Service and maintenance	kSEK/year	45	30	11	11	97
Air production, total	**Mm^3/year**	**12 600**	**5 760**	**3 670**	**-**	**22 030**
Energy recovery						
Energy price (for the alternative use)	SEK/kWh	0.4	0.4	0.4	-	-
Recovery period	months/year	10	10	8	-	-
Degree of recovery	%	94	94	94	-	-
Quantity of recovered energy	MWh/year	893	395	233	-	1 521
Annual cost with energy recovery	**kSEK/year**	**413**	**234**	**109**	**114**	**870**
Saving with energy recovery	**kSEK/year**	**347**	**149**	**88**		**584**
Specific air costs 1, without energy recovery	öre/m^3	6.0	6.6	5.4	0.5	6.6
Specific air costs 2, with energy recovery	öre/m^3	3.3	4.1	3.0		3.9

Note:values have been rounded off.

When assessing service and maintenance costs you must also consider the equipment's expected condition after the calculation period has passed, that is whether it should be seen as consumed or be restored to its original condition.

Furthermore, the calculation model must be adapted to the type of compressor. The example below can serve as a model for the economic evaluation of a compressor installation, with or without energy recovery.

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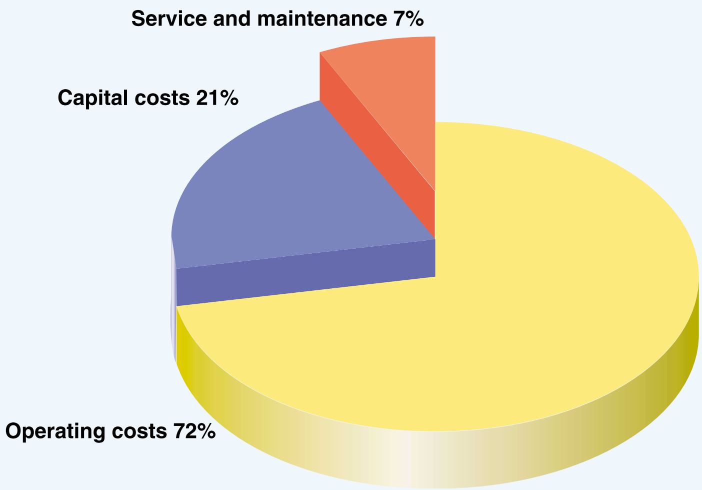

This is how costs are divided without energy recovery.

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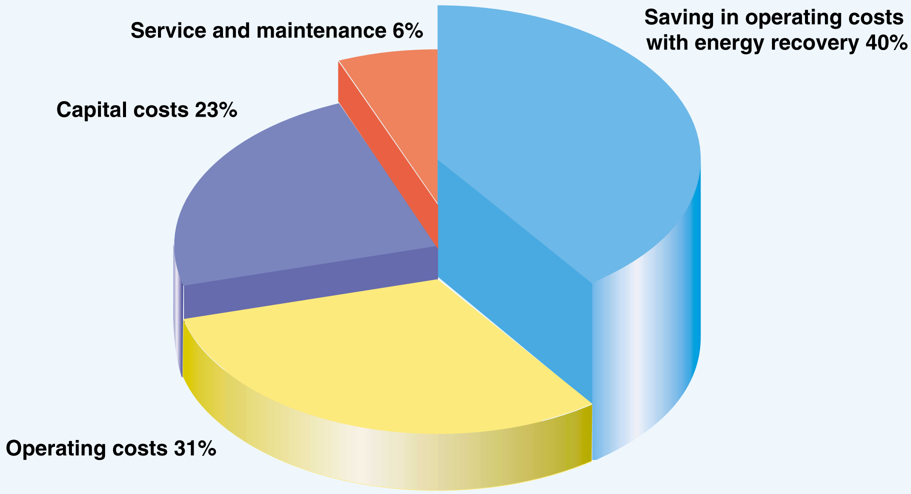

This is how costs are divided with energy recovery.