Thames Water: “Energy accounts for 85% of the total costs”
If we get more specific, what are the figures like within wastewater pumping? The potential for savings is as great as in other systems. And its not just Grundfos saying that. For example, Thames Water conducted an independent survey to identify the real cost of operating their pump systems over the systems’ total lifetime. They came up with the results shown to the right.

Why bother with LCC?
Why bother about the life cycle costs of pumping systems? Well, if you’re at all concerned about reducing energy consumption, it’s an excellent place to start:

Nearly 20% of the world’s electrical energy is used for pump systems
And no less than 30% to 50% of the energy consumed by pump systems could be saved! For details, visit the Grundfos website, the Energy Project initiative (www.energyproject.com) or contact us directly.

Choosing efficiency pays for itself
We can derive a very simple conclusion from Thames Water’s analysis:
The smart money focuses on the total Cost of Ownership over time – not just on the initial purchase price of the pumping equipment. As this graph shows, the decision to buy a more efficient pump will soon pay for itself – and continue to yield real profits.

Note that SmartTrim is a Grundfos-specific feature – more detail is included in the section about impeller clearance and its impact on overall costs.
How can I cut long-term costs?
Simply put, the Life Cycle Cost approach overall aims to save on energy consumption, maintenance and service. It pays in the long run. But how can this be achieved?
The three main objectives of this presentation are:

• To give an overview of the impact of pump efficiency and maintenance on the total life cycle costs
• To give concrete proof of how you can use Grundfos wastewater pumps to reduce total operation costs
• To introduce you to equations you can use to carry out your own LCC assessments

The elements of Life Cycle Costs
When you look at the total life cycle cost of owning and operating a wastewater pump, these are the elements you need to consider. Many leave out some of the elements – or omit to consider them altogether. But it is well worth making the effort to consider them all. And, of course, to get them all right instead of going on assumptions. The elements are:

- Cic = initial cost, purchase price
- Cin = installation and commissioning
- Ce = energy costs
- Co = operating costs
- Cm = maintenance costs
- Cs = downtime costs
- Cenv = environmental costs
- Cd = decommissioning and disposal

The evaluation period is typically 10 years

When should I carry out a LCC analysis?
There are two obvious stages where an LCC analysis makes good business sense: when you plan/design a system and when you are buying the pumps to go in them. Here, knowing the exact LCC of your different alternatives will help you answer questions like the ones below.

Planning and design stage
- Which of my investment alternatives is best?
- Should I replace old pumps with new? And what are the best replacements?
- What are the best pumps for my system design? What, for that matter, is the best system design?

Purchasing stage
- Which is the best reply to my tender?

Topics
There are many things worth considering when you want to reduce your total life cycle costs. This presentation looks at the following topics:

• Pumping system design
• Pump size and price
• Cost distribution
• Specific energy
• Reduced pump efficiency
• Leakage losses
• Pump LCC analysis
• Impact of increased impeller clearance
• Present life cycle cost value
The potential pitfalls of LCC analysis
A life cycle cost analysis is an excellent tool for comparing pump tenders with the end-user’s benefits in mind. It helps you focus on the total cost of ownership instead of just the initial purchase price.

It is, however, important to get the facts right. If the figures used for energy and maintenance costs are based on assumptions, the result of the analysis is not entirely certain. So get the facts right!

With that in mind, let us take a closer look at the planning and design stage – and what we need to consider there.

Pumping system design
When you design a pumping system, the cost of your equipment and operation costs both relate directly to the size of the rising main.

A reduced rising main diameter means
- Lower piping procurement costs
- Higher pump investment
- Higher energy costs

Rising main is selected on the basis of the following factors:
- Economy
- Required internal diameter for the application
- Required lowest flow
- Velocity of the application

Pumping system design
So what should you choose? The optimum rising main diameter depends on whether the pumping station will operate all the time or only intermittently.

- Stations with relatively few operating hours can be connected to smaller rising mains. This is because higher friction is acceptable; you will face greater energy consumption to compensate for the higher friction, but the total energy costs are not necessarily excessive.
- Stations with many operating hours must be connected to larger rising mains to reduce the friction, thereby also reducing the energy consumption arising from each hour of operation.

Energy consumption vs. maintenance ...
For smaller wastewater pumps (10kW or lower), energy consumption is not necessarily the main point you should consider.

The number of operating hours per year is often low
And the purchase price of efficient equipment can seem high
This is where you should take a look at the maintenance costs associated with different types of equipment.
Conclusions
So to sum up, a number of issues should be considered during the planning and design phase.

- For large stations, high pump efficiency is much more important than the initial purchase price— if you want to save money in the long run.
- For small pumping stations and/or intermittent operation, reliable, trouble-free operation is more important than energy efficiency. Here, maintenance costs are the most important.

Now, let’s move on to consider specific issues in greater detail. And do some calculations.

Avoid calculation pitfalls
Very frequently, calculations of energy consumption make assumptions that prevent the results from being accurate. Here’s how you avoid the most frequent pitfalls:

- Never assume the pumps’ efficiency remains unchanged— you need to consider the influence of possible air intake. But most people don’t.
- Don’t forget the influence of wear— testing standards must always be considered.
- Don’t just calculate for a single pump operating at a fixed duty point— it is important to include the influence of parallel operation and varying duty points.

Specific Energy: The cost of moving water
So let’s get calculating. One useful figure to know is the “specific energy” of your system. The principle is simple: A pump system is designed to move a certain volume of wastewater from point A to point B.

- The “specific energy” tells us the cost of moving that volume in Watt hours per pumped m³.

Calculating specific energy
The specific energy is a function of rate of flow. Pgr is the absorbed power by the unit.

\[
E_s = \frac{P_{gr}}{V} = \frac{P_{gr}}{Q} \times \frac{Q \times H \times \rho \times g}{\eta_{p}}
\]

It follows, then that the specific energy measured in kWh/1000 m³ is:

\[
E_s = \frac{H \times g}{\eta_e \times 3.6} \text{ kWh/1000 m}^3
\]

The density \( \rho \) 1000 kg/m³

Calculating specific energy
An example:
- Pump capacity: 1000 l/s
- Pump head: 11.8 m
- Overall efficiency: 76%
- Input power: 152 kW

\[
E_s = \frac{11.8 \times 9.81}{76 \times 3.6} = 0.42 \text{ kWh/1000 l}
\]

Leakage losses
Another key issue that many forget is the problem of leakage losses arising between the discharge flange of the pump and auto-coupling— in conventional pumps, leaks are especially bad where metal meets metal.

The leakage area is

\[
A = \frac{\pi D t}{2}
\]

And the leakage flow is

\[
Q = \mu A \sqrt{2gH} \text{ m}^3/\text{s}
\]

Leakage losses, metal-to-metal discharge connection
Or the flow Q is then

\[
Q = \mu A \sqrt{2gH} \times 10^3 \text{ l/s}
\]

Where

\[
\mu = 0.6 \text{ is a flow coefficient}
\]

\[
g = 9.81 \text{ m/s}^2
\]

\[
D = \text{mm}
\]

\[
t = \text{mm}
\]

\[
H = \text{m}
\]

Reduced pump efficiency
These leakage losses lead to reduced pump efficiency.

An example:
- Pump discharge flange: DN350
- Auto-coupling: DN350
- Leakage opening: 3 mm
- Pump head: 45 m

\[
0.0042 \times 350 \times 3 \times \sqrt{45} = 30 \text{ l/s}
\]
Avoid leakage losses with SmartSeal

Grundfos has developed a solution that prevents such leakage losses: A profiled rubber seal between the discharge of the pump and the auto-coupling stops the leak.

Auto coupling in DN65 – DN500

Other reasons for leakage losses

Leakage reduces pump efficiency – and leakage losses can occur for several reasons:

- Internal leakage losses can be the result of differential pressure across the impeller clearance.
- Abrasives such as sand and gravel in sewage and rainwater can cause wear in the clearance.
- Leakages commonly occur in the discharge connection

Experience shows that pump efficiency drops by 1-3% points per year in wastewater applications.

The impeller clearance and pump efficiency losses

Efficiency drops can be caused by an increase in impeller clearance

In this example, the curve describes a 200 kW pump with a two-channel impeller and how it is affected by a growing impeller clearance.

When delivered from the factory, the impeller clearance is 1mm, but it does not stay there. And as the impeller clearance increases, the efficiency decreases.

This curve shows the difference in performance and efficiency caused by an increase of the impeller clearance to 3mm and 6mm.

Efficiency drops of different pump types

In practice, sewage pumps that have been in operation for some time become less efficient than when they were new. However, having an adjustable clearance option can help a lot. On average, the efficiency of the different impeller types drops as indicated here:

- Semi-open impeller without adjustable clearance: - 5%
- Semi-open impeller with adjustable clearance: - 3%
- Closed impeller without adjustable suction clearance: - 3 % (radial clearance)
- Closed impeller with adjustable suction clearance: - 1.5% (axial clearance)
Restoring pump efficiency
Fortunately, Grundfos pumps can be restored to the full efficiency they had when they left the factory – thanks to the SmartTrim feature.

Grundfos SmartTrim
SmartTrim is an adjustable impeller clearance system which allows the impeller clearance to be adjusted without disconnecting or dismantling the pump. Traditional sewage pumps need to be disconnected from the pipe work and dismantled, making SmartTrim a much faster, easier road to renewed efficiency.

In the following you will find formulae that will let you calculate how much the impeller clearance affects your pump’s efficiency.

Impeller clearance affected by wear
Wear and tear increases the impeller clearance, which reduces pump efficiency. Unless the factory setting is restored, the efficiency will continue to drop as illustrated below.

In the following you will find formulae that will let you calculate how much the impeller clearance affects your pump’s efficiency.

Calculating the effect of an increasing impeller clearance
The impeller inlet diameter is

\[ d_i = \frac{4 * Q}{\pi * v_i} \]

At around the best efficiency point, the inlet velocity is 4.5m/s.

The area of the suction clearance is

\[ A_s = s * \pi * d_0 \]

Calculating the pressure drop
The pressure outside the clearance is approx. half the pump head (H/2)

\[ \Delta Q = 0.6 * A_s * \sqrt{\frac{2 * g * H}{2}} \]

Based on the above, we can calculate the leakage flow:

\[ \Delta Q = 0.6 * A_s * \sqrt{\frac{2 * g * H}{2}} \]

The relative value for the efficiency drop is:

\[ \eta = \frac{0.6 * A_s * \sqrt{2 * g * H}}{Q} \]

\[ \eta = 0.8 * \frac{Q * \pi}{H} \approx \Delta H \]
Calculating the effect of an increasing impeller clearance

When the clearance gap increases, \( H \) must be substituted by

\[
(1 - \Delta \eta) \cdot H
\]

The leakage flow increases and consequently the vortex velocity between the pump casing and the impeller accelerates, reducing the pressure outside the suction clearance. Real-life measurements show that this factor will approximately double the pressure decrease, which means that \( H \) can be replaced by

\[
(1 - 2 \cdot \Delta \eta) \cdot H
\]

We see, then, that the increasing impeller clearance causes a drop in efficiency of 11%.

Present Life Cycle Cost value

The present LCC value is the present value of the total life cycle costs. It can be very instructive to get an idea of what you save today by spending a little more.

\[
C_p = \frac{C_n}{[1 + (i - p)]^n}
\]

\( C_p \) = Cost element
\( n \) = number of years
\( i \) = interest rate
\( p \) = expected average annual inflation
\( i - p \) = real net rate

Another useful formula tells you the current value of minimising the total life cycle costs. It can be very instructive to get an idea of what you save today by spending a little more.

\[
\sum \frac{c}{[1 + (i - p)]^n}
\]

\( c \) = Cost element considered over a period of 10 years
\( i \) = interest rate
\( p \) = expected average annual inflation

Definition: Routine maintenance

For the purposes of this calculation, “routine maintenance” comprises the following:

1. Annual check and re-setting of impeller clearance
2. Oil check
3. Visual inspection of pump / pumping station

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