energy technology services

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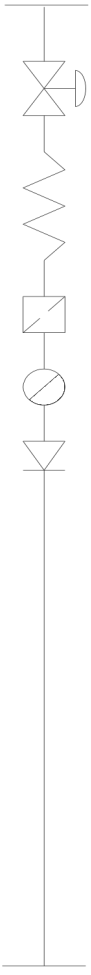
Bench mark analysis
on industrial steam systems
as part of an internship project ETS.



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1. Introduction and summary

1.1 Introduction

Energy Technology Services (ETS) is a technical consultancy company with its expertise in steam related issues. In 2019, we started an internship project where we analyzed different steam systems. As a result, we have a benchmark for steam systems based on a number of different steam systems.

In this project, we used a mathematical model that we made and so have an identical procedure for every steam system analyzed. The companies that participated have each filled their system in a data file. We processed this data in the model.

Each participating company has received an individual report with the results and conclusions of the analysis. The important part of those conclusions are the possibilities of improving the performance of the system and thus lower the costs.

The report was made with emphasis on:

- Total Cost of Ownership (TCO)
- TCO per ton of steam
- Splitting TCO into fuel, other recourses, maintenance, supervision, depreciation and loss of interest.
- Thermal efficiency of the system
- Energy losses

This report anonymously expresses the summary of these analysis.

ETS has decided to continue this project in 2020. If your company would like to compare your steam system with others, you can participate. Contact the author for more information.

1.2 Summary and recommendation

The report can be summarized as follows:

1. The steam systems are often too large, in capacity in comparison to the steam demand. This results in a lower efficiency.
2. Most of the systems still lack in thermal efficiency. This can be improved by adding more heat recovery. Sometimes it is even possible to replace the boiler itself (participant no. 5).
3. More attention is needed to the isolation of condensate and steam pipes.
4. A lot of companies do not have enough insight in their data and the consequences of the lack of supervision.
5. There are a lot of errors in the recorded data. Having good data on the steam system is vital to the maintenance and efficiency of a system. More attention needs to be given to the data recording of the system.

2. Participating companies

There is a lot of variation between the companies, and thus the results of the analysis differs a lot. However all required a full continuous steam supply.

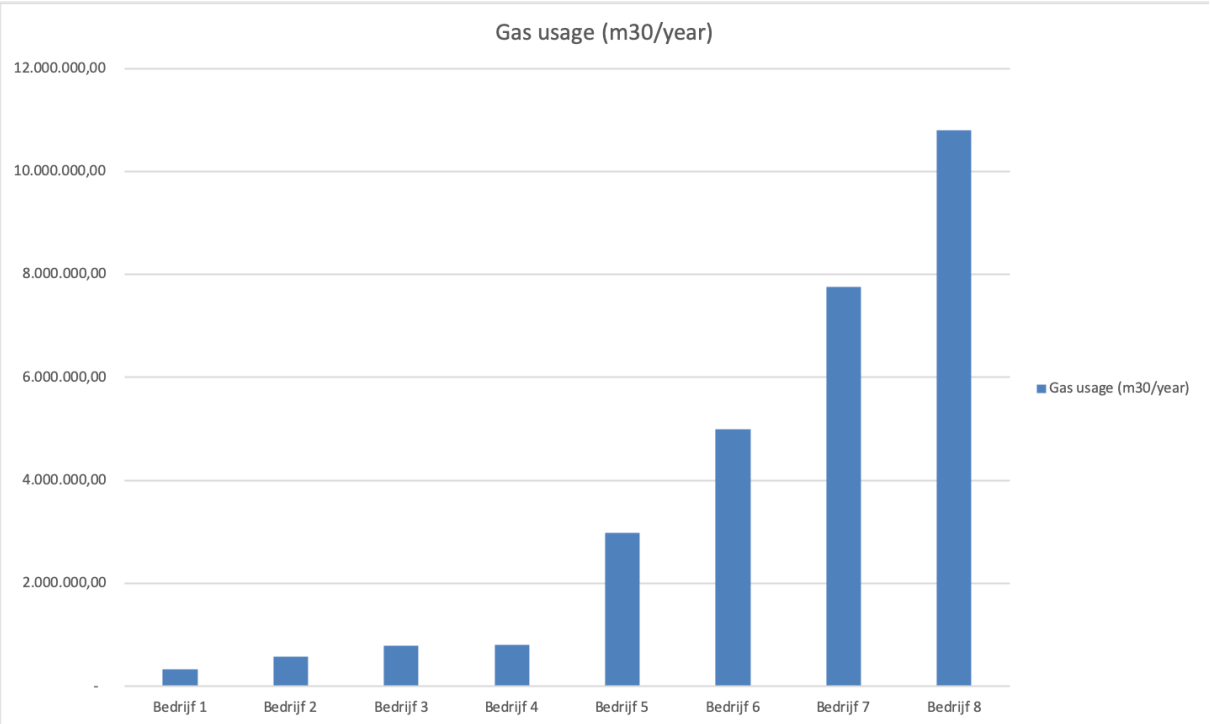
These are the main characteristics of all the participants:

- All the steam systems are cylindrical steam boilers and produce saturated steam.
- **Company 1**
  - Industry: Health
  - Total capacity boiler: 3,5 ton/h
  - Gas consumption: 295.000 m^3_0
  - Production hours: 8760 h/year
- **Company 2**
  - Industry: Health
  - Total capacity boiler: 3,5 ton/h
  - Gas consumption: 530.00 m^3_0
  - Production hours: 8760 h/year
- **Company 3**
  - Industry: Recycling
  - Total capacity boiler: 2,0 ton/h
  - Gas consumption: 800.000 m^3_0
  - Production hours: 8400 h/year
- **Company 4**
  - Industry: Recycling
  - Total capacity boiler: 2,0 ton/h
  - Gas consumption: 792.000 m^3_0
  - Production hours: 8400 h/year
- **Company 5**
  - Industry: Food
  - Total capacity boiler: 16 ton/h
  - Gas consumption: 3.000.000 m^3_0
  - Production hours: 8500 h/year
- **Company 6**
  - Industry: Food
  - Total capacity boiler: 30 ton/h
  - Gas consumption: 5.000.000 m^3_0
  - Production hours: 8500 h/year
- **Company 7**
  - Industry: Paper
  - Total capacity boiler: 21 ton/h
  - Gas consumption: 7.750.000 m^3_0
  - Production hours: 8500 h/year
- **Company 8**
  - Industry: Building materials
  - Total capacity boiler: 30 ton/h
  - Gas consumption: 10.800.000 m^3_0
  - Production hours: 8500 h/year

3. Supplied data

To be able to compare the calculated data of each company we made graphical representations of some of the supplied data:

3.1 Gas consumpotion in m^3_0/year



There are big differences between the yearly gas usage of the participants. This is a result of the industries size and the variance in demand over the year for company 1 and 2. There is practically no difference between production hours, so that is not one of the causes for this difference.

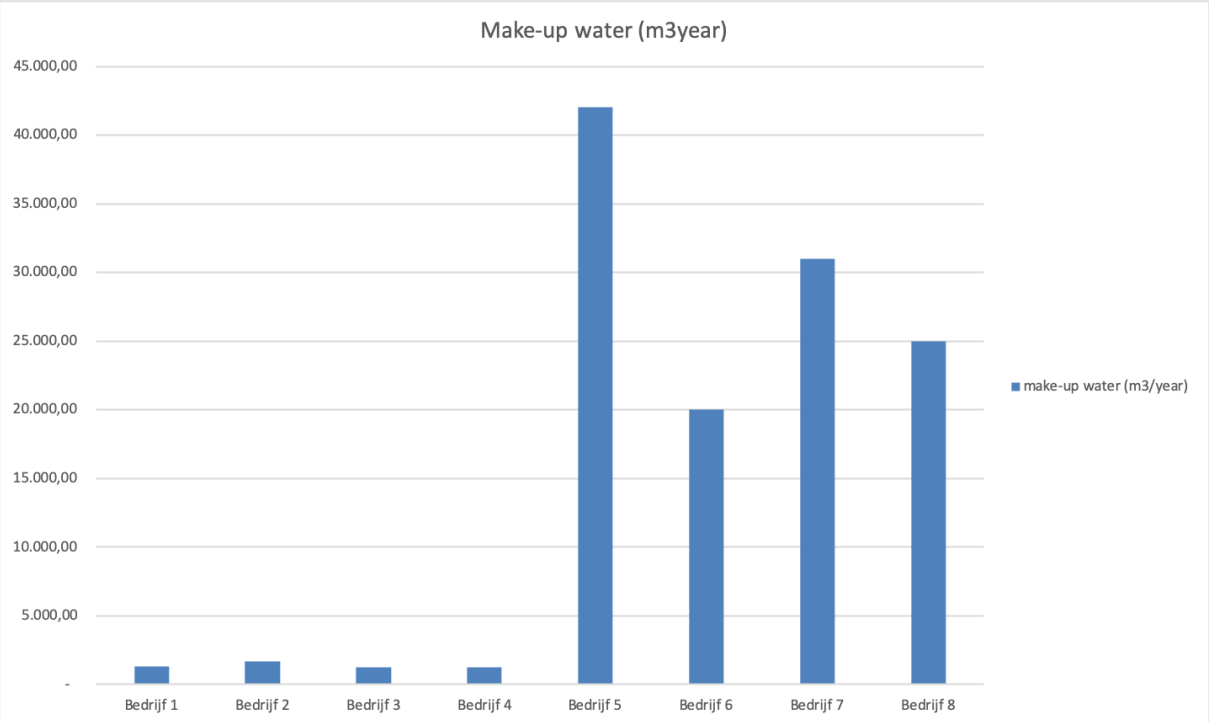
3.2 Gas prices in €/m30

Between the companies there is a fairly big difference in gas price per m^3_0. This can be best explained by the big difference in demand. “bigger consumers gets their gas cheaper”.

3.3 Production hours

The amount of production hours has a lot of influence on the results of the analysis but because it is the practically the same for all the participants (8200-8740), we decided a graph was not needed.

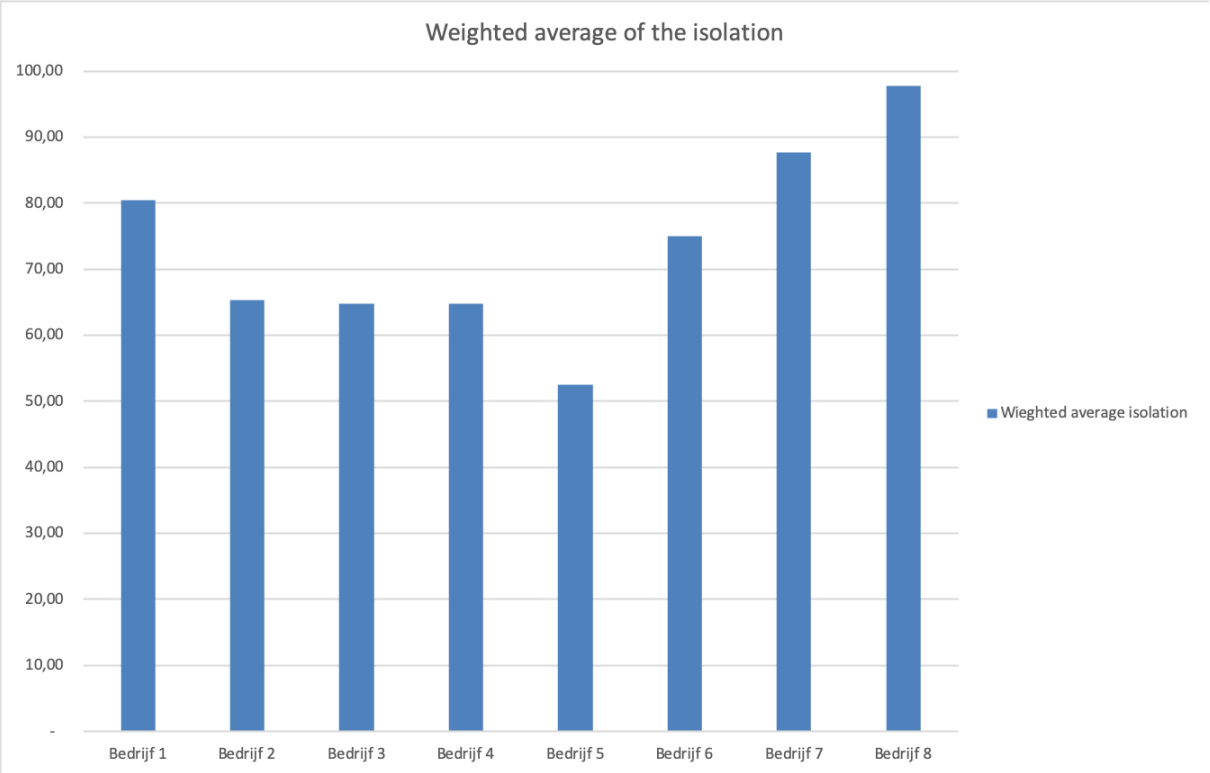
3.4 Make-up water usage



Most companies did not track their make-up water usage. Tracing and trending should be common practice, because these values are very important to study the possibilities to improve on the efficiency of the boiler. The amount of return condensate and blow-down water are instrumental to add heat recovery systems and to judge if they are economically viable.

This gives thought to the knowledge and insight of those who deal with the (energy) management of the steam system.

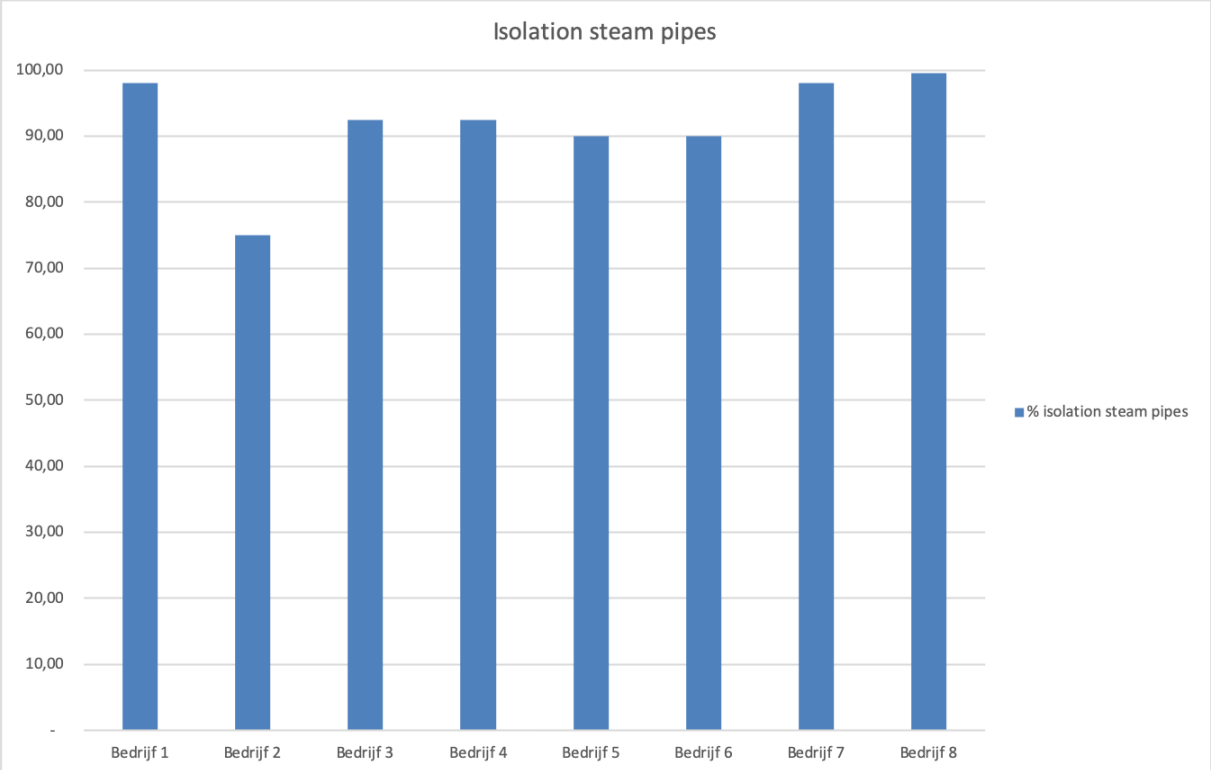
3.5 Percentage isolation steam system



Steam systems are very hot and should always be insulated to reduce heat loss and prevent injury from touching hot surfaces. Steam lines and components are hotter that condensate lines and their components should have a high priority on insulation.

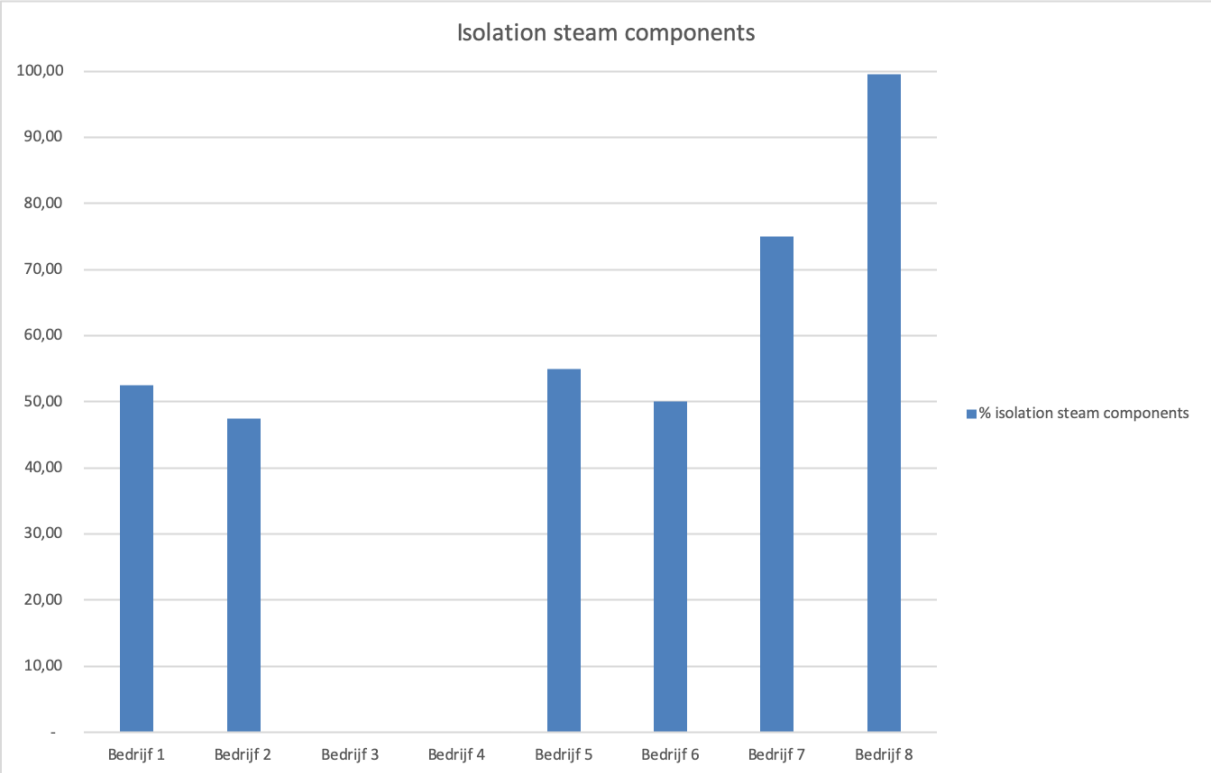
The shown percentages are averages and not the exact percentages. Surprising is that insulation is not yet a priority with every participant.

3.5.1 Steam lines



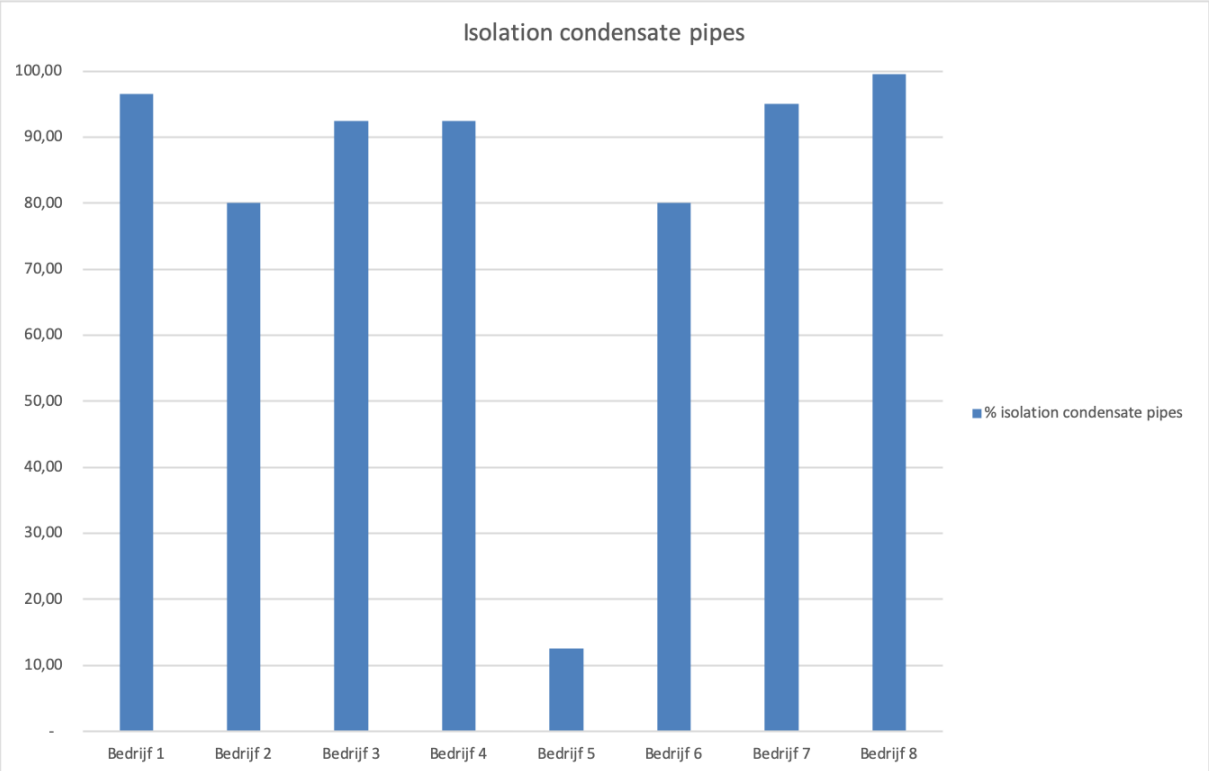
Due to the high temperatures and the low costs for insulation, the cladding of lines are economically very viable and can pay for itself very quickly (SPOT 1-2 years). The percentage of lines that should be insulated should be above 95%. None of the participants reach this value.

3.5.2 Steam components and flanges



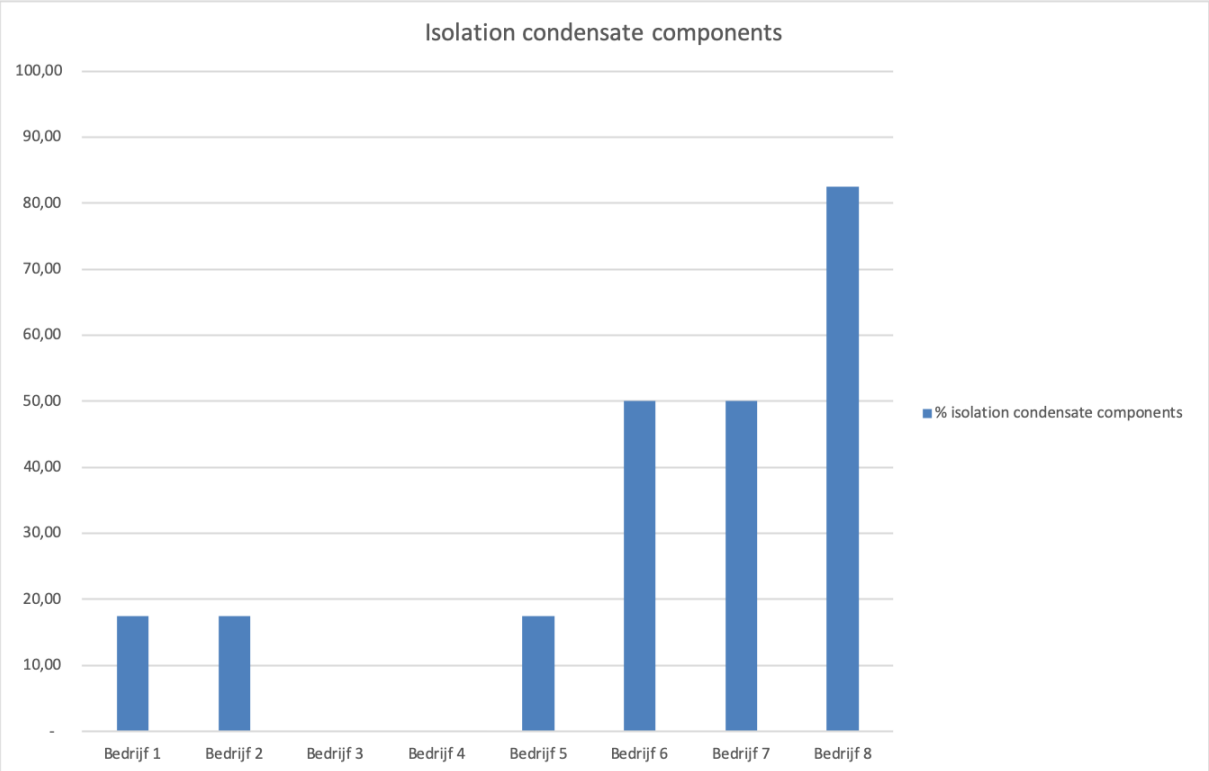
Relative to the costs of insulating steam lines, insulating components and flanges is more expensive. If a system is running continuous (all of the participants), all the components of DN80 or larger should be isolated (SPOT 2-3 years). This is not the case with most of the participants. The percentage should be 80-90%.

3.5.3 Condensate lines



The condensate pipes are not as hot as the steam lines so the losses are lower if they are not insulated. This doesn't mean that it is not worth it to isolate them (SPOT 2-4 years). Improvements can still be made at most companies. Percentages should be over 80-90%.

3.5.4 Condensate components

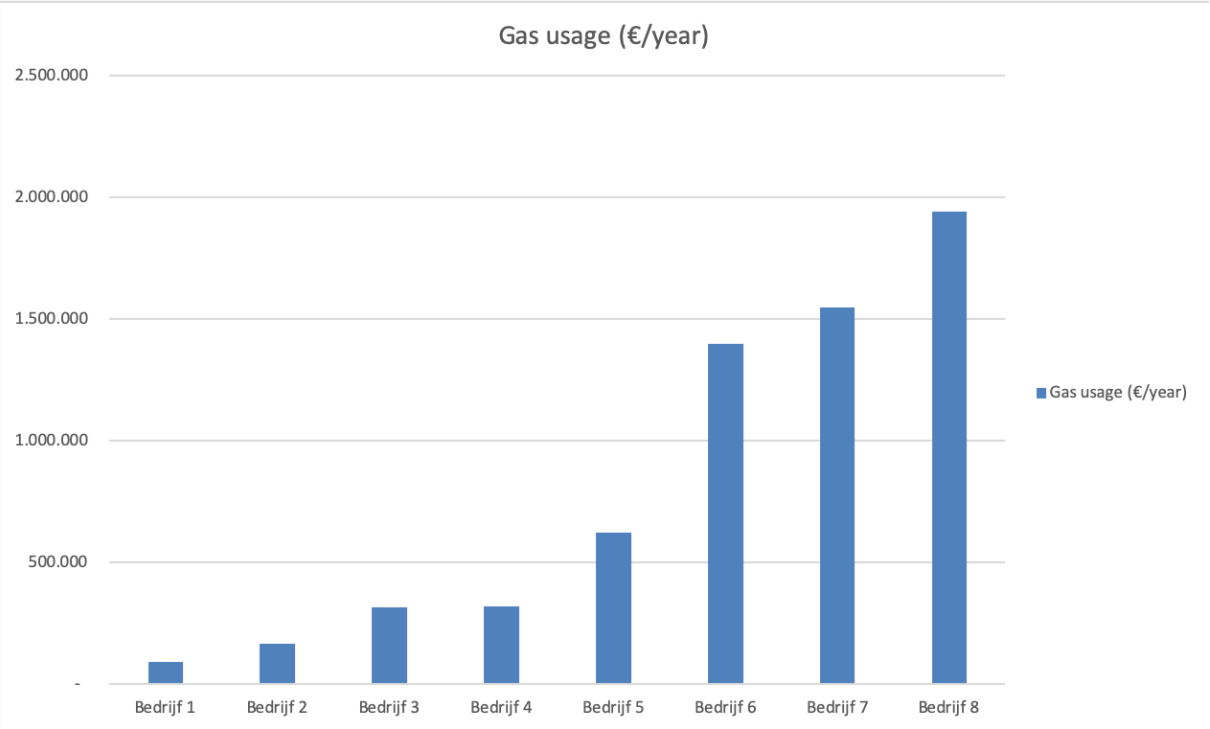


Just like steam components, condensate components are more expensive to insulate and thus have a higher payback time (SPOT 3-5 years). With a fully continuous system, condensate components should still be mostly isolated (DN80 or higher).

4. Calculated data

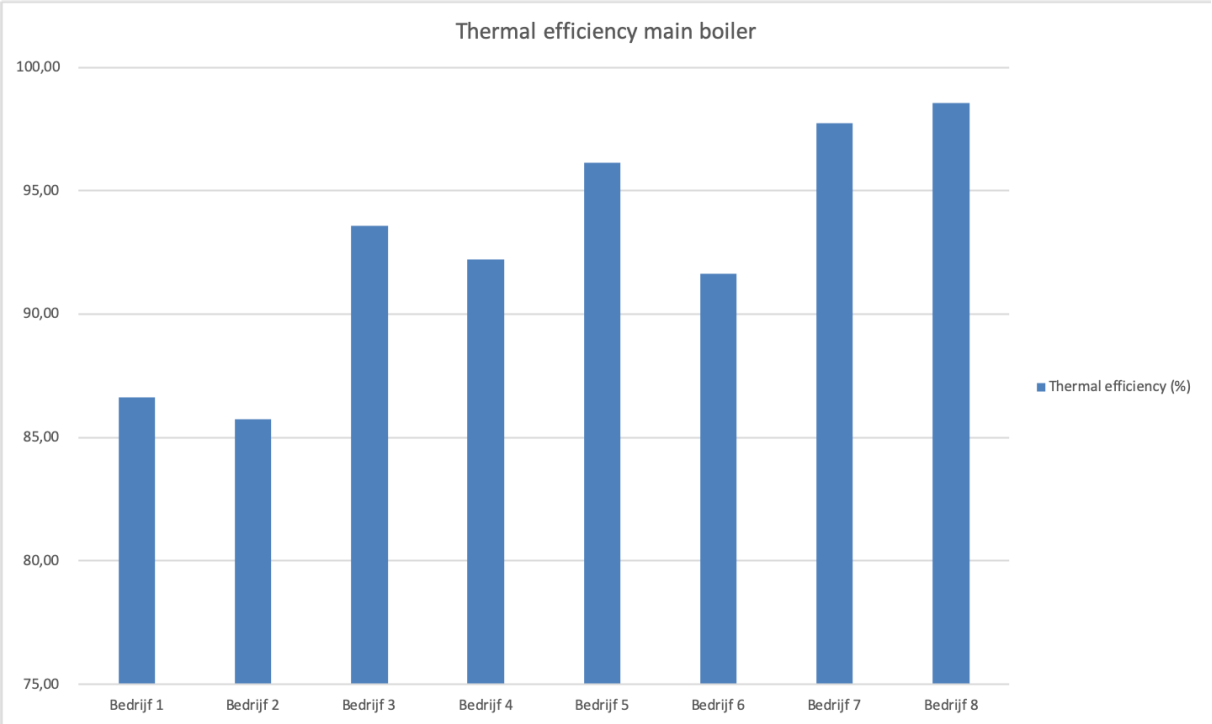
The supplied data has been processed in our model and with those results we calculated a number of values that are essential to know if you want good insight into your steam boiler. We again put the results into a graphical form:

4.1 Gas consumption in € /year



Gas consumption has the largest share in the costs of a steam system. Given the large differences in steam demand, the large difference in annual gas costs makes sense.

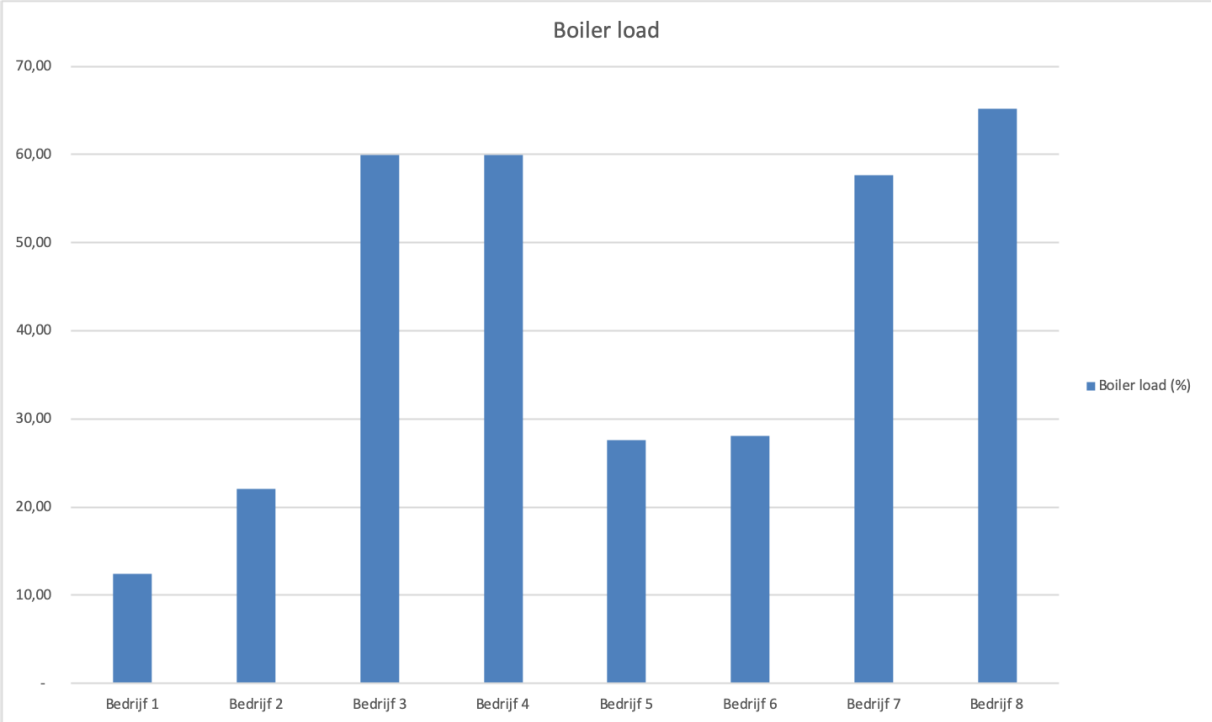
4.2 Thermal efficiency of the boiler in $\%_{ow}$



The gas consumption of an installation is determined by the steam demand of the production processes and the efficiency of their steam boilers.
The boiler efficiency determined by us is the total efficiency, including all heat recovery.
Technically, every steam boiler installation can have a thermal efficiency of 98%, based on the lower heating value. With high make-up water percentages (80-100%) this percentage can even rise to 107%.

The economic viability of achieving the highest efficiency is strongly dependent on production hours and gas consumption on yearly basis. Companies 1, 2, 3, 4 and 6 had a thermal efficiency that was too low and should consider upgrading this value.

4.3 Boiler load as % on yearly basis



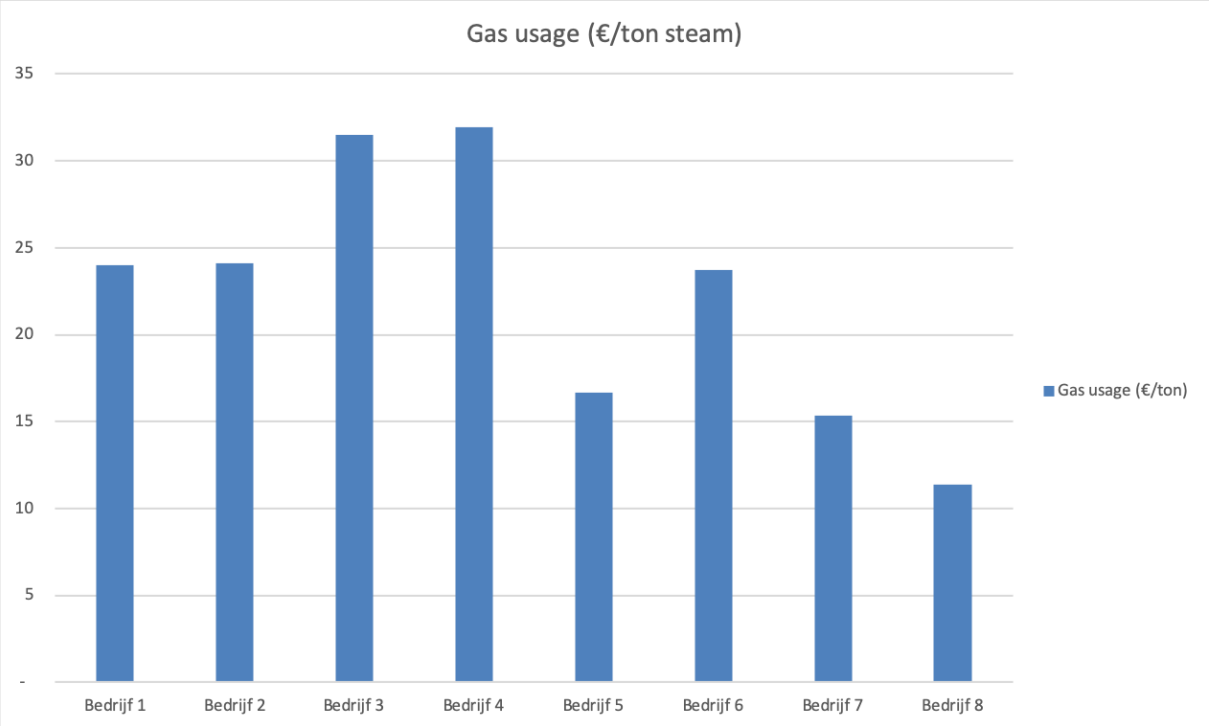
Most of the boilers in the Netherlands are oversized, with the following results:

- Too large means a more expensive boilers
- Heat recovery costs more
- Relatively high radiation losses because of the bigger size of the boiler
- High fixed duty rates for natural gas

Flattening the variance of steam demand and lowering the steam demand itself means lower investments, but also has a positive effect on the efficiency.

Of the participating companies, only no. 8 had a load higher than 60%.

4.4 Gas consumption in €/ton steam

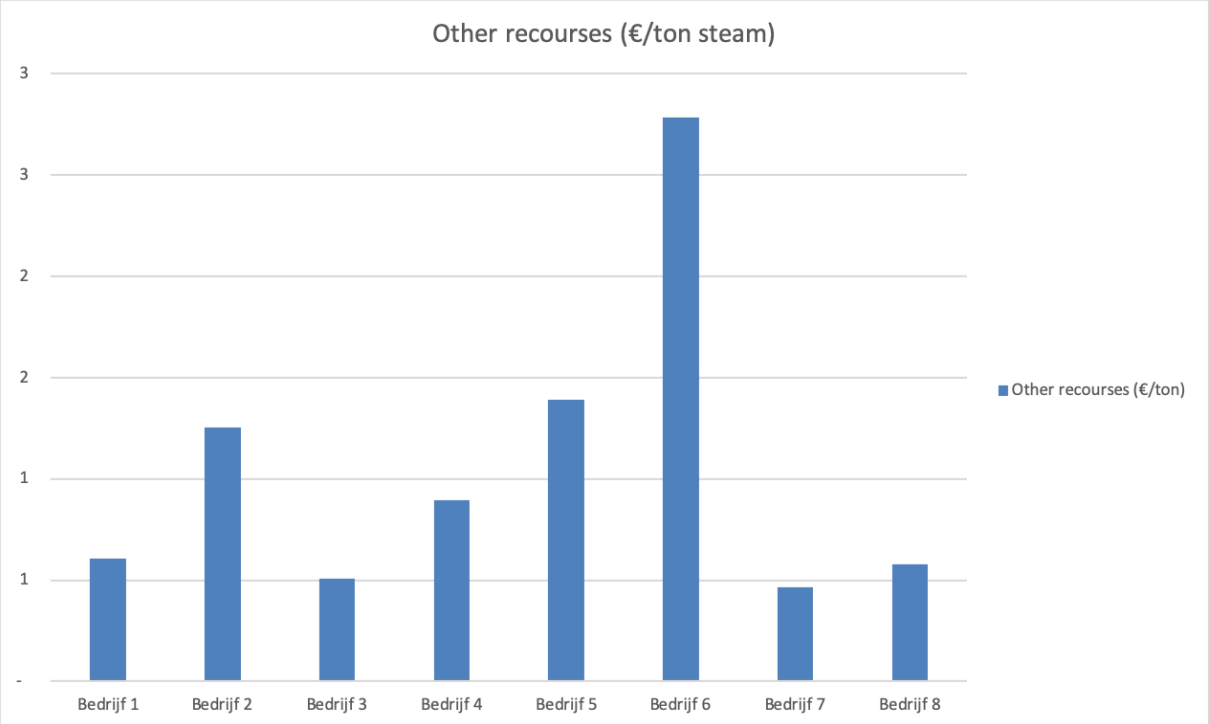


The costs for gas is the biggest part of the TCO per ton of steam produced. This depends mostly on the gas price and the efficiency of the boilers.

Companies 7 and 8 are favored here because of their high efficiency and lower gas prices.
Companies 1 and 2 have a low efficiency but due to the limited capacity and high variance of steam demand, improving is difficult.

Companies 3, 4 and 6 Should be able to make big improvements to their efficiency. The required investments would be economically viable.

4.5 Other resourses in €/ton steam

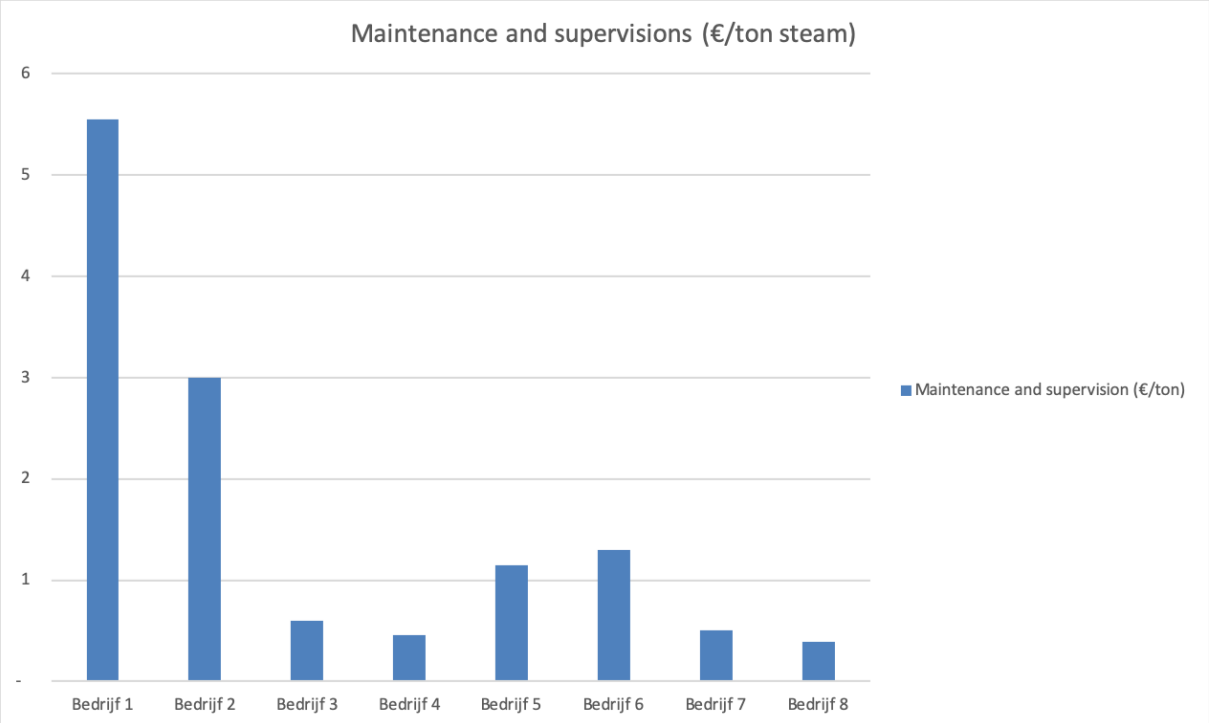


The other recourses used in a steam system are:

- Water
- Chemicals for water treatment, including costs for watersoftening
- Costs for electricity used in the system
- The blowdown losses

These costs are relatively low compared to the costs for gas. Even then, it is still possible to lower these costs with a good water treatment, minimalize blowdown losses and increase retour condensate. All participants could save, to lower the costs, except participants no. 1, 3, 7 and 8.

4.6 Maintenance and supervision in €/ton steam

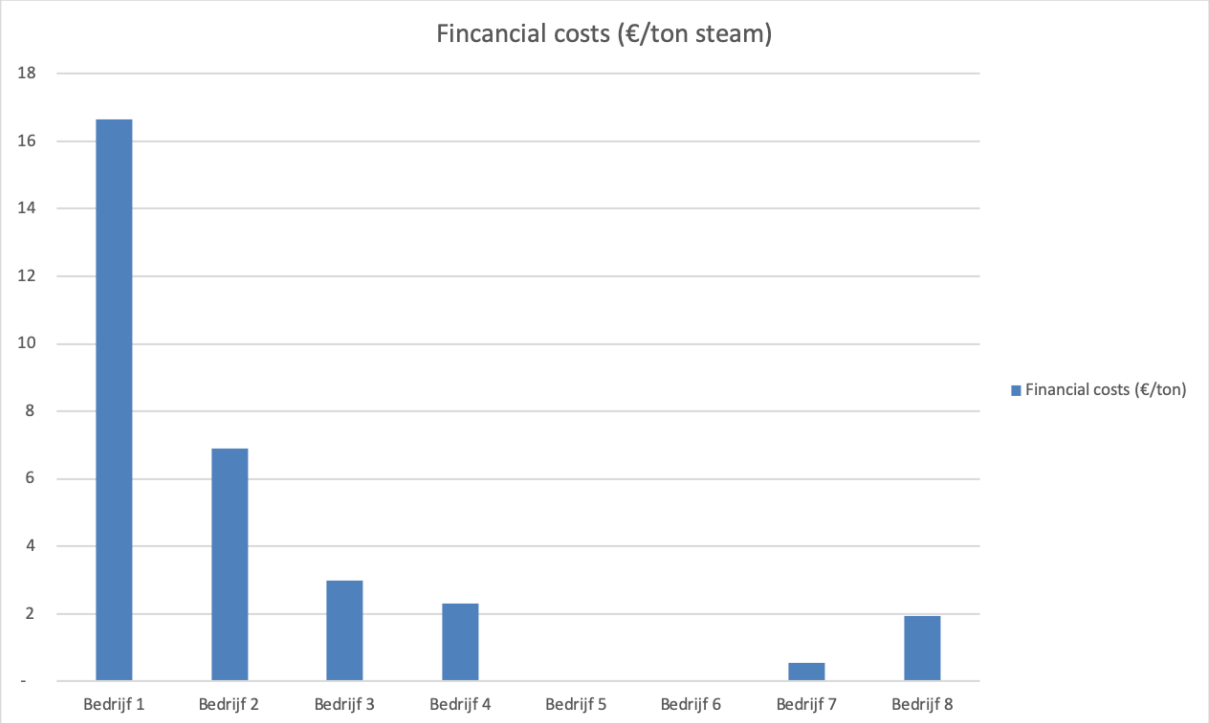


From our experience and the results of the analysis we can conclude that maintenance by external parties and the costs for supervision are relatively low.

Too low? Because of far-reaching savings on maintenance and supervision, we see more cases of large damages in the last 10 years.

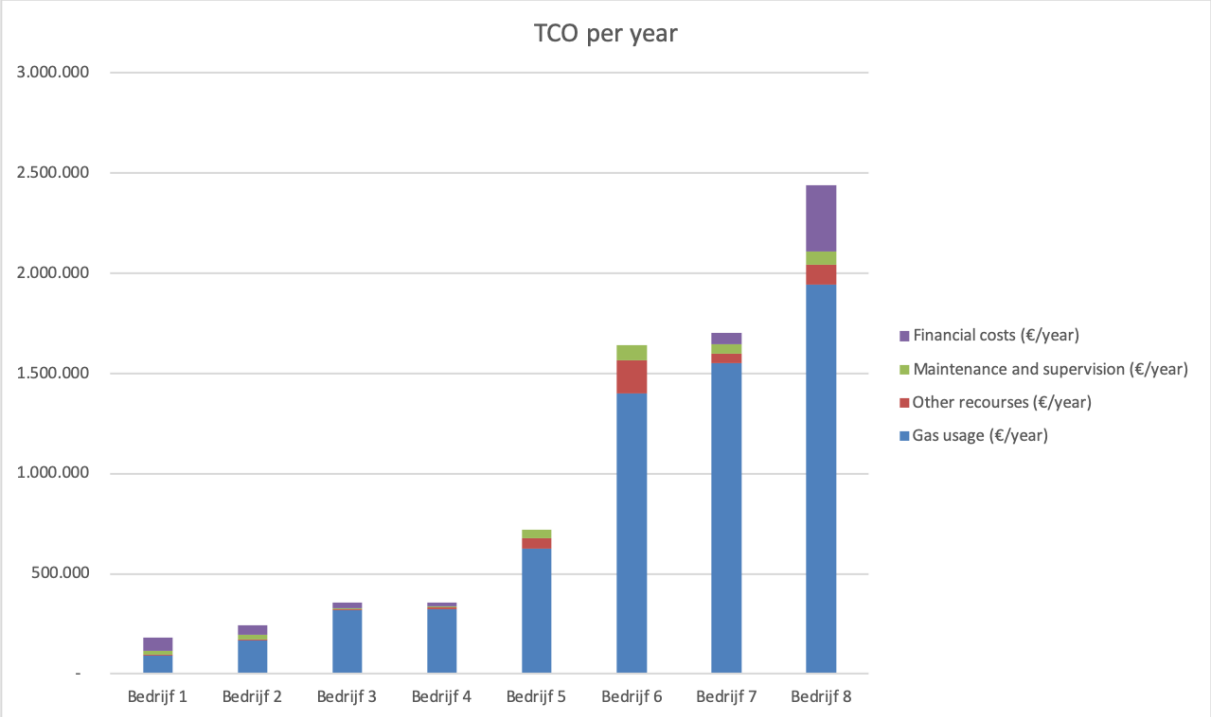
Saving more is not advised. Thorough maintenance management is to be adviced.

4.7 Financial costs in €/ton steam



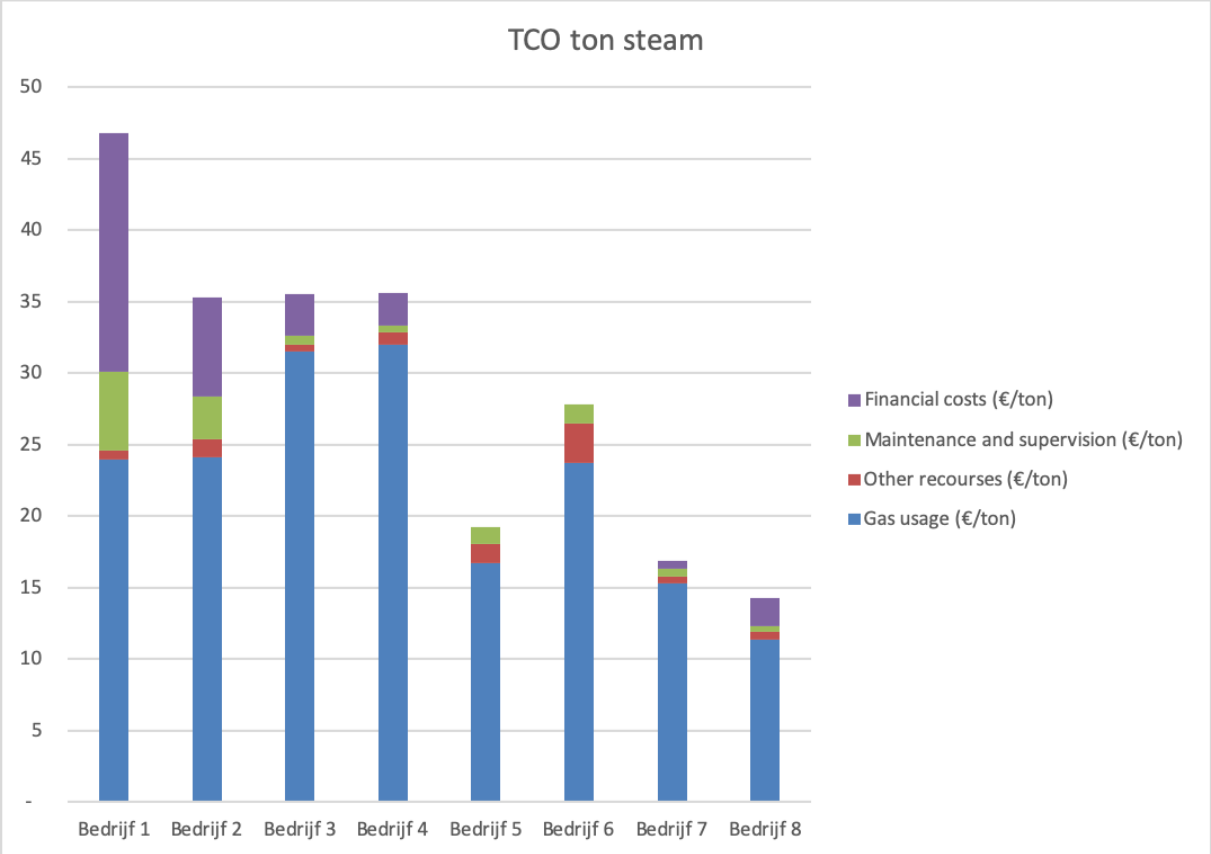
The loss of interest and depreciation (this what we consider financial costs) are results of an installation that is relatively new and still in the legal depreciation period. A number of installations is older and thus do not have these costs.

4.8 Total Cost of Ownership in €/year



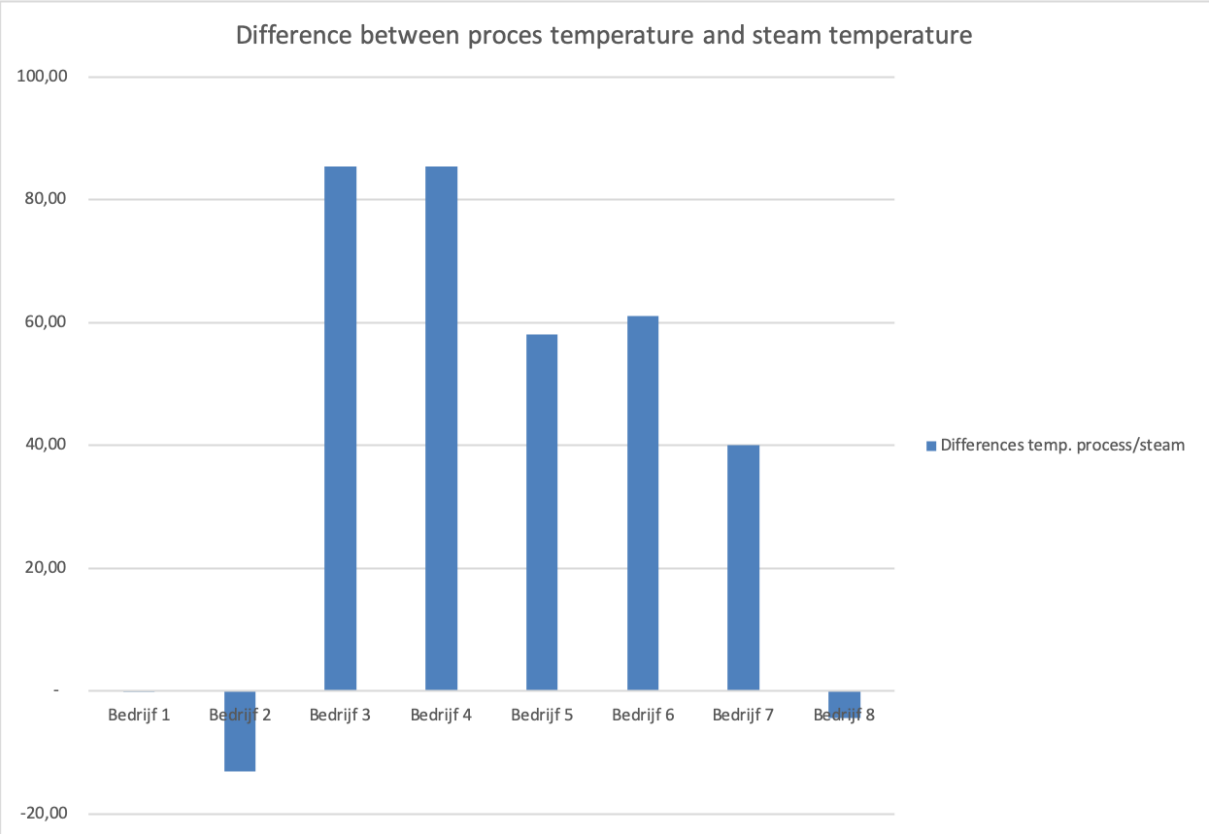
The total costs are heavily dependent on the gas costs, which is clearly visible from the individual pasts of this graph.

4.9 Total Cost of ownership in €/ton steam



If the total costs of the steam system (the costs from Graph 4.8) are divided by the annual tonnage of steam produced we come to the TCO/ton. It now becomes clear that companies with a “large” installation, a high hourly load and a high boiler efficiency have a low TCO.
Flattening the variation in steam demand offers good opportunities, especially for new projects: smaller boilers, higher hourly load, lower TCO.

4.10 Steam temperature vs highest process temperature



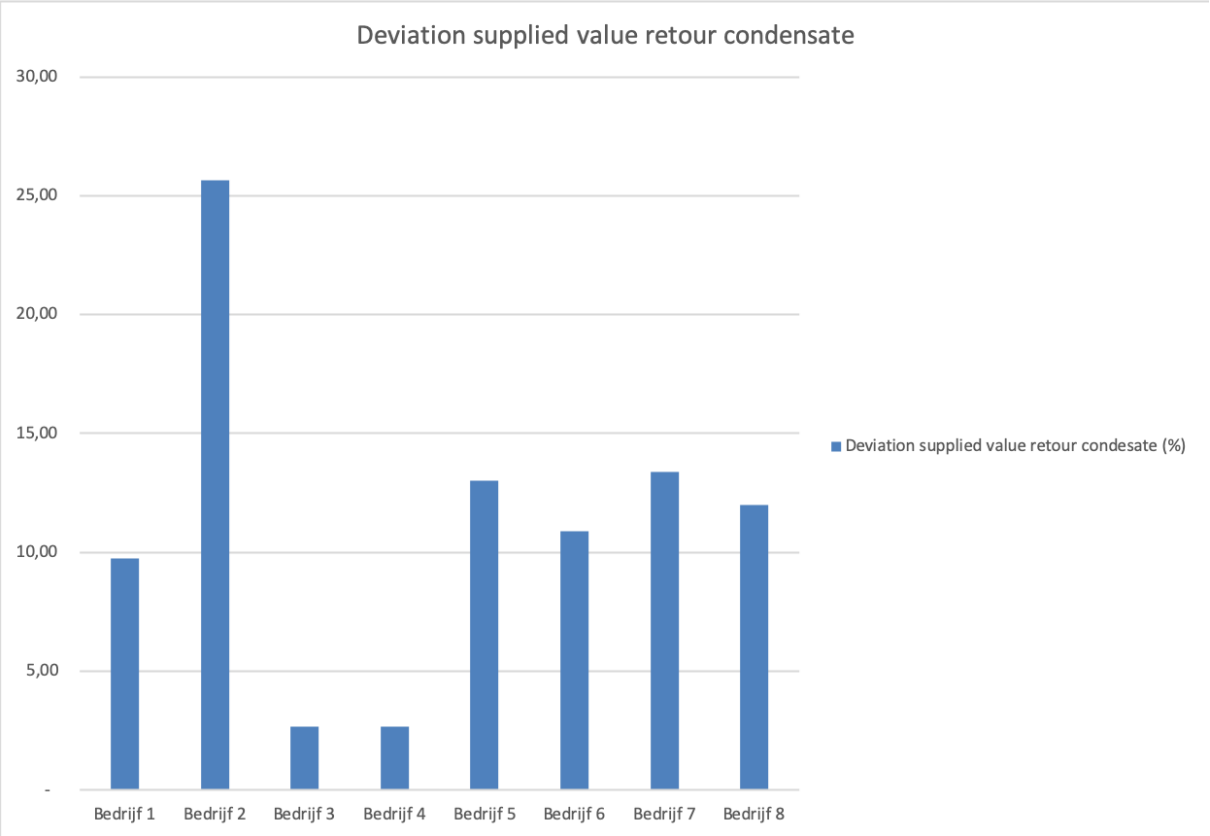
Steam has an extremely good heat transfer in heat exchangers. This means that the steam temperature of saturated steam only needs to be 10-20 °C above the desired process temperature.
Various companies have quoted values that were well above that and these companies could theoretically work with a lower boiler pressure. This will reduce the stack loss and the total radiation losses.

Companies 3, and 4 could even buy a new boiler on the basis of this, in combination with the possible increase in boiler efficiency.

Companies 2 and 8 have a steam temperature lower than that required for the processes. This could be due to a bad measurement of the steam pressure or that the process temperature is not properly anticipated.

4.11 Return condensate: flow vs chemistry

Graph:



The percentage of return condensate can be determined in two ways: on the basis of the water treatment results or on the basis of the flow meters of gas, steam and water. These percentages should theoretically be the same (+/- 10%).
These values were too far apart in company 2. This indicates insufficiently accurate values of the water treatment and/or the flow measurements.

5. Analysis

Based on the supplied and calculated data, we draw the following conclusions:

- The TCO per ton of steam is approximately inversely proportional to the annual TCO. This is of course due to the fact that “large” installations:
  - are cheaper in investment per ton of steam
  - consume more gas and thereby negotiate a lower gas tariff
  - their heat recovery is also cheaper per kW
- Natural gas consumption has by far the greatest impact on TCO per ton and per year. The steam demand, the natural gas tariff and the efficiency of the boilers have an influence on this
- Maintenance & supervision has a relatively minor impact on the TCO
- Other raw materials (water, electricity and chemicals) have a minor impact on the TCO
- Even the internal interest rate and the depreciation period have a relatively small impact (approx. 10%) because the minimum depreciation period is determined by the Tax Administration and the internal interest rate for the various companies varied only a few percent.
- The load on the boilers was relatively low for relatively many companies. This is at the expense of the fixed maintenance costs and the thermal efficiency
- The TCO is as low as possible if:
  - The gas price is low
  - The installation has a high load
  - The steam demand has been minimized
  - The steam demand is relatively stable (no large fluctuations)
  - Maximum responsible heat recovery has been applied
  - At maximum condensate return percentage

We also noticed that practically no company has a good level of thermal insulation. Only companies 1, 7 and 8 have insulated more than 95% of the piping and components. The others still have a lot to improve

Many companies (3, 4, 5 & 7) had a relatively large difference between the steam temperature and the highest process temperature. This means that the steam pressure is actually too high and can theoretically be reduced. Too high a steam pressure is unfavorable for the boiler efficiency and the radiation losses of the system

Company 4, 5 & 6 have too low boiler efficiencies. Extra investment in heat recovery has a payback time of <5 years at these companies. These investments should be made to save energy

The above analysis shows that companies no. 7 and 8 are well-organized and have relatively few opportunities for improvement. We have also experienced that these are companies with people with knowledge and experience. These companies work with boiler operators with a VPS certificate.

Based on the analysis, company 5 can purchase a new steam boiler installation with a SPOT of <5 years