

***Reduction of air production***



## Reduce compressed air production

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# Heineken®

Project sponsor:

Martin van Nuus

- [martin.vannuus@heineken.nl](mailto:martin.vannuus@heineken.nl)

-+31 6 13625040

Rietveldenweg 25, 's-Hertogenbosch

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Group Heineken/AVANS

Francesco Montaquila - 2217879

- [f.montaquila@student.avans.nl](mailto:f.montaquila@student.avans.nl)

Sandor Lazzeri - 2200952

- [Sp.lazzeri@student.avans.nl](mailto:Sp.lazzeri@student.avans.nl)

Pablo Martin Cuesta - 2243801

-

[mp.martincuesta@student.avans.nl](mailto:mp.martincuesta@student.avans.nl)

Núria Rojas Soteras - 2245030

- [n.rojassoteras@student.avans.nl](mailto:n.rojassoteras@student.avans.nl)

## Executive Summary

Heineken aims to become CO<sub>2</sub> neutral by 2027. In line with this objective, this project focuses on reducing unnecessary energy consumption and CO<sub>2</sub> emissions related to compressed air usage at the Heineken brewery in 's-Hertogenbosch. Compressed air accounts for approximately 7% of the site's total electricity consumption and therefore represents a significant opportunity for improvement.

Using the DMAIC methodology, the project investigated abnormal compressed air consumption during non-production hours, particularly during weekends. Data analysis, site inspections, interviews, and technical drawings revealed that although air leakage exists, it is not the main cause of the observed consumption fluctuations.

The analysis shows that the primary causes are structural and operational issues within the compressed air system, such as uncontrolled or intermittent air consumers, insufficient isolation of production lines during non-production hours, and the compressor control strategy amplifying demand fluctuations. The packaging department was identified as the largest contributor to unnecessary air consumption.

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## Chapter 1: introduction

Heineken aims to become CO<sub>2</sub> neutral by 2027, making energy efficiency a key priority across its production sites. Compressed air systems are among the most energy-intensive utilities in industrial environments and therefore offer significant potential for energy and emission reduction.

This project was conducted at the Heineken brewery in 's-Hertogenbosch and focuses on reducing unnecessary compressed air consumption, particularly during non-production hours. Using the DMAIC methodology, the project analyzes system behavior, identifies inefficiencies, and develops practical recommendations to reduce energy use, CO<sub>2</sub> emissions, and operating costs.

## Chapter 2: Theoretical framework

### 2.1 Study design

The study was structured following the Lean maintenance philosophy, which emphasizes the identification and elimination of waste in maintenance processes, aiming to improve efficiency, reliability, and overall equipment performance. In this context, the project focused on the cleaning process of critical production machinery at BAF Valves, given its direct impact on machine reliability and product quality.

To systematically approach the analysis, the DMAIC methodology (de Mast & Lokkerbol, 2012) was employed. This methodology allowed for a structured progression through the phases of Define, Measure, Analyze, Improve, and Control, ensuring that each step was guided by data and evidence. The study design included a combination of on-site observations, data collection from machine sensors, maintenance records, and direct collaboration with the maintenance team. These methods provided a comprehensive view of current practices and allowed for the identification of inefficiencies affecting machine performance and resource consumption.

### 2.2 Exclusion principle

A central element of the study design was the application of the exclusion principle. This principle involves systematically discarding variables that do not demonstrate a significant effect on the identified inefficiencies, while retaining those factors that are most relevant for further analysis. By applying this principle, the study was able to focus resources and efforts on areas with the highest potential impact, avoiding unnecessary analysis of factors with minimal influence.

The exclusion principle also played a critical role in ensuring the transition from the measurement phase to the root cause analysis. By prioritizing relevant variables, the methodology ensures a data-driven, evidence-based approach, maintaining focus on operational improvements that would yield measurable results.

Detailed diagrams illustrating the evaluated variables, measurement plans, and their subsequent analysis are presented in the following sections. These visual representations provide clarity on how the study was structured and how key inefficiencies were identified and addressed.

## Chapter 3: DEFINE

In this chapter the problem at Heineken will be defined. To gather the information we used an advanced Gemba walk to get as much information as possible. During this Gemba walk, not only was a physical walkthrough conducted, but also interviews to get a clear image of the problem.

### 3.1 Background / Context

To have a general background, Heineken is a beer company created in 1864 in Amsterdam, Netherlands, by Gerard Adriaan Heineken. Starting as a small local brewery it expanded really quick thanks to the quality of its beer and an aggressive exportation strategy, being nowadays one of the most relatable and largest beer brands in the world.

Currently it is installed in more than 190 countries and possesses more than 300 brands such as Amstel and Birra Moretti. Its strategy goes from strong investment in global marketing (one of the biggest football and Formula1 sponsors) to betting on sustainability by supporting renewable energy, CO2 reduction etc.

One of the main goals of the company is to become 100% green by 2027, which might seem really optimistic, but they have actually been approaching that goal during the last years.

For the specific case of Heineken's brewery at 's-Hertogenbosch, it is one of the largest factories in the Netherlands, producing more than 94 different types of beer on its facilities. But one of the critical issues it faces has to do with compressed air installation. Observations on several diagrams show that there is an inconsistent amount of compressed air used at some particular point of the installation, going from maximum to minimum pressure and probably provoking leakages, going on peaks instead of the regular consumption it is supposed to.

That is where we enter as a team: for the next months we need to get to know the factory and the different parts that form the compressed air installation and study what are the possible reasons for its unusual behavior, finding a practical and doable solution to the problem by working on site, interviewing workers and applying different methodologies.

## 3.2 Reason for the project

100% sustainable co2 neutral by 2027 Heineken 2030.

## 3.3 Problem exploration

This project is about reducing CO<sub>2</sub> emissions in the production area of the Heineken Brewery in 's-Hertogenbosch. To understand the problem better, an exploration analysis was made using the 5W1H and 5 Whys methods.

According to the first information and what was mentioned at Heineken, we believe that CO<sub>2</sub> emissions in the brewery may mostly affect production. The main actors are probably the operators, the maintenance team, the process engineers and the sustainability department. We think the problem happens in the 's-Hertogenbosch plant, in processes like fermentation, water heating, pasteurization and packaging.

It may be stronger during production peaks and when machines start running. The main cause could be related to some inefficiencies in energy recovery. This would lead to high annual CO<sub>2</sub> emissions, with economic and environmental impact, and pressure to achieve

### 3.3.1 Elaboration of the problem

Heineken sees the compressor as the problem because it cannot easily adapt to changes of air usage. Therefore they want to change the compressor to a newer version. But this doesn't take away the production waste part.

Heineken produces a significant amount of CO<sub>2</sub> during the production process. These emissions may have economic, environmental, and regulatory consequences, and they contribute to the company's pressure to meet sustainability goals. Preliminary observations suggest that emissions may be linked to energy use, efficiency of equipment, and the current level of renewable energy. This problem affects different areas like operators, maintenance staff, engineers, and the sustainability of the department. It's important to know that if no solution appears this issue will increase. This leads to an increase in costs not only by wasted energy but even in maintenance cost. When the compressor runs more than necessary there will be more frequent maintenance required. However, this problem has existed for years, as energy-intensive processes have been running in the same way, but it has not yet been fully investigated or addressed.

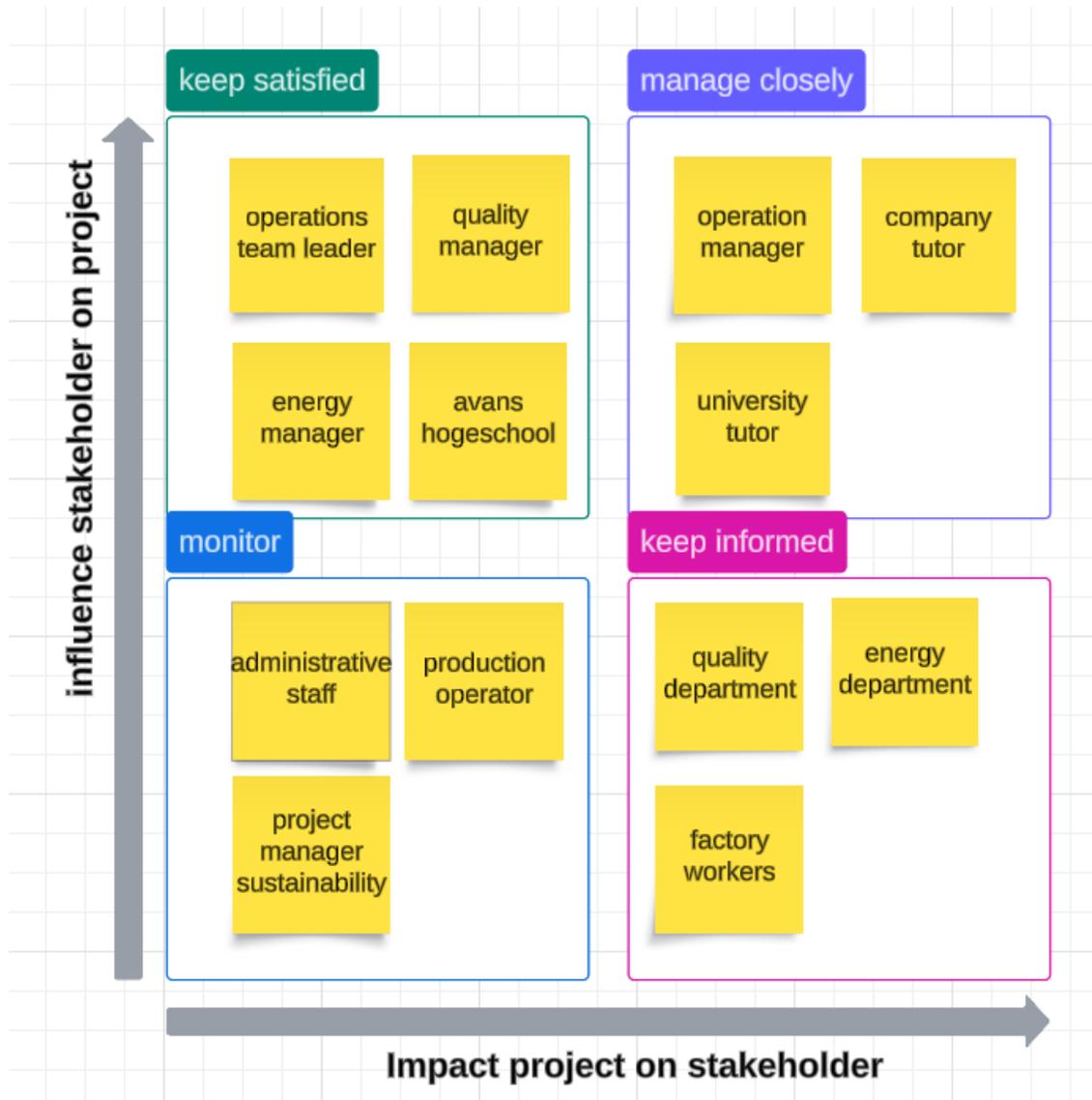
It is important for this project to get rid of the wasted air when there are no production hours. Now there is often fluctuating consumption during weekend days when production is at a standstill, especially in the packaging department there is a strong fluctuation. So, there is direct waste here. By preventing this waste, work, faulty machines and leaks can be detected. By pinpointing these on production-free days, heineken can apply these solutions as well on production hours.

### 3.3.2 Problem definition

High CO<sub>2</sub> emissions in the production process at Heineken may result in increased operational costs, environmental impact, and difficulty in sustainability goals too. The causes of these emissions are not fully known, and more information is required to identify the main factors contributing to the issue.

### 3.4 Mission reconnaissance

#### 3.4.1 Stakeholder analysis:



### 3.4.2 Scoping of the project

The problem takes place within the production environment of Heineken in Den Bosch. The focus is on the entire beer production environment. The challenge is to come up with a solution for unnecessary energy consumption caused by air compressors that supply compressed air to the whole environment. This means A solution must be advised to Heineken before the end of the 20-week project period. This includes mapping out during which process steps compressed air is consumed. In this context, one could look at an SOE and gamba walk.

### 3.4.3 Project objective

Provide advice within 20 weeks on how to reduce unnecessary air consumption by air compressors during non-production hours.

Need to haves      Nice to haves

Reduce air waste    6.2 bars 6.4 advise run on 4 bar

Get rid of high consumers

## 3.5 Main question

How can the ETP Avans project group for Heineken eliminate unnecessary energy consumption by air compressors during non-production hours?

### 3.6 Study design

The following diagram shows the development of the research during the measure phase, starting from the main problem identified in the define phase: wasted air. The purpose of this schematic representation is to visualize how the study evolved from a general problem into specific variables, measurement methods, and validated results.

The research was structured around four main areas: production technology, manual labor, leak detection, system structure, and outputs. Each area represents a potential source of wasted air and was analyzed using specific measurement tools and different methods.

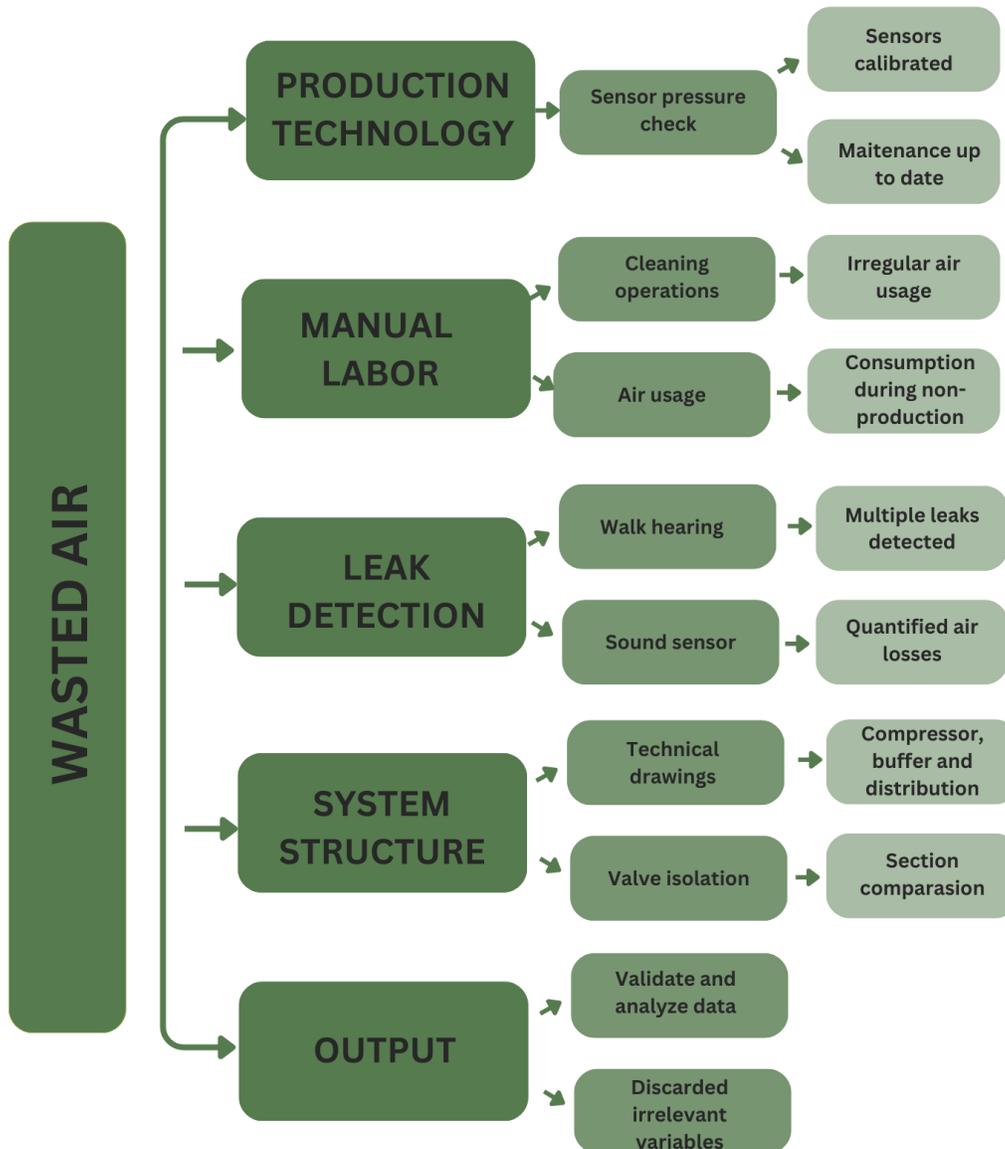
The first variable is production technology, which refers to the quality of production tools. Two indicators were used: sensor pressure checks and maintenance records. These were reviewed to verify the reliability of the measurement system. The results showed that sensors were correctly calibrated, and maintenance was up to date, allowing this variable to be considered low relevance and excluded from further analysis. The measurement plan used for these indicators included tools and methodologies such as 5S, TPM Scan, OEE, CMM and Gamba Walk.

After evaluating production technology, the next variable studied was manual labor. This was studied through the observation of cleaning operations and the analysis of air usage data. This analysis identified irregular air usage during cleaning activities and significant consumption during non-production periods, indicating a relevant contribution to wasted air. The measurement plan for these two indicators are FMEA, Statistic process control, energy audits, ishikawa, processflow and interviews.

After evaluating manual labor, leak detection was addressed using walk hearing and ultrasound sound sensors. These methods allowed the identification of multiple leaks and the quantification of air losses, confirming leakages as one of the main contributors to the issue. The measurement plan for this variable consisted of on-site observations and notes during inspections to systematically record leak locations and air loss magnitudes.

Finally, the system structure was analyzed using technical drawings and valve isolation techniques. This approach made it possible to understand the layout of the compressor, buffer, and distribution system, and to compare different sections of the installation, supporting the identification of inefficient areas. The measurement plan for this variable consisted of detailed analysis of technical drawings combined with on-site inspections, systematically recording system configurations, and operational behaviors.

Following the exclusion principle, variables that did not show a significant impact on wasted air were discarded, while relevant causes were retained for the analyze phase. This structured, data-driven approach ensured a clear and methodical transition from the measurement phase to the root cause analysis, reinforcing the reliability and focus of the study.



## Chapter 4: MEASURE

### 4.1. Objective of the Measure Phase

The following step to be taken in the DMAIC methodology is Measure, where we take all the necessary measurements on several items and conditions after defining the main goals of the project and the way to approach them through different methodologies.

This phase is started right after the Define Phase, so it is really important to contemplate at the very beginning of the project all the possible causes that may lead us to the root of the problem, by defining previously the list of items to study.

We began this measuring phase at the first weeks of the program once we contemplated the methods to approach the items and how to discard later the ones that provide no relevant information on the Analyze phase.

This was done following the exclusion method, mentioned earlier in the Study Design, where if one of the measured variables is irrelevant to the final studied result (compressed air/electricity consumption) it is eliminated from the list of causes of the problem.

### 4.2. Items studied during the Measure Phase

Hereby we present a list of items that were measured in order to have a global insight of all possible problems that may cause the production of air to be ineffective or problematic. All were previously defined back in the Define Phase taking in consideration how most of them could be considered as causes of an overproduction of the CO<sub>2</sub> emissions of the brewery.

The following list of items is the result of the study of the Measure Phase.

## **Sound sensor**

Being the possibility of air leaking through several points of the pipeline installation one of the first cases of study in our project, we faced it by measuring the amount of lost air in different points of the brewery facilities.

This was done, first, by actively hearing the buzz produced by compressed air escaping a pipeline through a groove in the buildings that frame the factory (actively walking hearing) and secondly, when the place of the leak was detected, by pointing an ultrasound high tech camera to each of them, which allowed us to actually measure the amount of leaked air at the moment and estimate the cost per year of every leak.

The issues detected with this powerful tool were then sent to the Maintenance Department with a specific code and description of the location of the found leak so they could fix it and prevent it from expanding or keep wasting energy.

This process was done repeatedly several times for every leak detected in pipeline parts and working areas and within the different buildings that shape the factory, especially in the Packaging Department, where the factory employees pointed out the most quantity of air was being lost.

## **Walk hearing**

The first idea we placed over the table about how to detect and count the approximate number of leakages in the installation was simply hearing them: whenever you entered a facility of the brewery you could hear a high pitch buzz that outstanced from the general noise produced by the machinery of a working factory.

That is how we knew there were at least a few leakages in that area that were causing the noise, apart from machinery malfunctioning, production ineffectiveness and stress on the employees located at that same place.

Once the noise was detected we approached the different parts of the pipeline looking for it through our hearing sense, which sometimes could be confusing due to the general noise of the machines at the factory and the fact that some leakages were located really close one to another or in places of difficult reach.

Even though some of them could be fixed at the moment by connecting a loose pipe back to its working placement or making small repairs by sealing gaps in connection points or replacing entire parts of the pipeline, all of the leaks found using this method were notified to the Maintenance Department so that they could design a steady solution for every one of them.

## **Sensor pressure**

Another of the possibilities that was discussed at the starting phase of definition of the problem was the next assumption: if the consumption data provided by the software was so odd it had no logical explanation (because a problem that big would have to be visible somewhere in the brewery) maybe the issue was with the measurement of the compressed air itself.

To do so, we asked ourselves how that data was delivered to the computer: a series of sensors were placed along the pipelines, and they were measuring different thermodynamic variables such as pressure and temperature and by that calculating the amount of air that was circulating on that section.

- The next logical step was to physically check them: maybe they were old, dirty, or not properly connected and this could be preventing the software to have all the necessary information to display the proper measurements of the sensors.
- The other option was an internal problem; the sensors were poorly calibrated or a physical phenomenon (like backflow) was happening at some point inside of the pipes. We also checked this possibility by talking to the Maintenance Department and asking them to show us when the last maintenance stop for checking the sensor system was done and the results they provided about it, which indicated that the whole system was thoroughly studied less than two years ago and showed no apparent problem.

## Interviews

The best way to get to know the different buildings and facilities of the brewery and how the processes that take part in the production are done is by talking to the people that work in them and make them possible every day.

We studied the problem by interviewing the brewery staff on two levels, providing at the same time the technical and practical insight of the problem:

- On the ground level we asked the operators that worked on field with the different machinery, because they knew firsthand when and where the problem usually occurred and how to temporarily fix it to keep the production pace, apart from the typical signals that comes with it like the noise or the delay in some points of the production.
- On the other hand, we arranged interviews with engineers and heads of the different departments involved in the air production, distribution and usage; so that they could tell us how the installation was designed to work, its current problematic stage and the several means they were applying to fix it in the short and long time period.

This information helped us to have a general view of how the problem was seen and faced by the employees and allowed us to make a route to find the most problematic or unknown aspects of the process.

## Responsibility

In order to be able to implement all the changes we suggested; we needed permission from the responsible employee or department so that everything was done under notification and with strict control.

This goes from walking in a specific part of the production line where we think air is being lost or produced (operators), to entering surveilled departments because of the importance of sterilization or the chemical processes that is being done (department managers) and on last instance, when we wanted to go to the brewery in unproductive hours to search for the problem thoroughly or to be able to isolate some sections of the installation (production department).

In this way, we rapidly learned that every step we wanted to take should be notified to the responsible person in advance, so everything must be done with precise planification and enough time to adapt to the employees and brewery schedule; especially if what we wanted to investigate was a new branch of the problem instead of the next step in a previously defined route.

Special mention to our coach company, since he was responsible for us during the whole program and for most of our actions, we needed his presence to get access to buildings, people or information.

The other point of view of the responsibility is that at the time we started to study a problem, it was not really clear who do we had to address since the leakage may be located inside a specific building or department, but depending on the type of issue or the time we found it some other departments were involved, like the Maintenance or Energy Department.

This connection between departments made the resolution of the leak or item to study way harder due to the fact that several and different sections of the brewery were involved and leaving the responsibility of dealing with the problem in the air, since fixing the mentioned issue meant stop working on more demanding areas at the moment.

## **Technical drawings**

At some point in the beginning of our time in the brewery, our coach started to show us the technical drawings that formed the compressed air installation including its production, distribution, storage and usage.

We studied those technical drawings because they had precise information of all the pipeline routes and most important: with them we were able to draw a map of how the air flowed through the whole brewery, allowing us to create a line from the compressor area to the final process that used the air and see every connection or split in between them.

With this information we thought that if there was a leakage, maybe the best way to detect it was by shutting off valves along the pipelines and checking with the software if there was any difference in the consumption.

Now with this idea in mind and the information provided from the technical drawings we were able to create a set of three main diagrams:

- **The Compressor Room:** All the demanded air is produced here while the several compressors are connected to each other so as to provide the necessary amount of air and divert the rest, working as well as a first storage point.
- **The Buffer Room:** Once the air is produced, it is stored in different buffers according to the pressure necessities of the process in the facilities, being all of them connected to make the system as multifunctional as possible.
- **The General Diagram:** Here we could see how the air was distributed to every department, building and main process from the buffer room (located under the Energy Department), showing the possibility of isolating entire areas of production with just one or a few valves.

Some departments or processes were designated a specific compressor or buffer individually which made them system possible to study at separate installations for some of them.

The three of them together showed how the air moved through the pipelines and the valves that allowed or interrupted that flow, along with other important elements such as compressors, buffers and buildings.

### 4.3 Summary of Measure Phase

By studying these items, we have declared what, why and how every one of them influences the main goal to study on the project (abnormal electricity consumption and air distribution) and have several insights of the same problem studied on different steps of the process.

Some of the conclusions we can take out of the study of the Measure Phase are:

- The fluctuations on the amount of compressed air production and usage are a combination of factors that together prevent the proper functioning of the brewery.
- The possible causes of the problem are a combination of organizational inefficiency, a strong segmentation in the internal hierarchy, human mistakes, an old-fashioned installation and the acknowledgment of the productive process.
- Even though the air consumption and CO<sub>2</sub> emissions are a current problem the brewery wants to solve, they are not making the necessary changes due to the

fact that it is not a priority included in the main scope of the company, which is to deliver the demanded amount of quality beer on time besides the extra costs the ineffectiveness of production may cause.

Now, with all the information gathered from these months of research, we need to analyze it in order to take conclusions and discard irrelevant items or change the initial concept of the investigation.

## Chapter 5: ANALYSIS

### 5.1 Objective of the Analyze Phase

The goal of the Analyze phase is to figure out what is causing problems with the compressed air system, at the Heineken facility. The team want to find out why the air pressure is not stable and why much air is being used when nothing is being produced. The Analyze phase uses the information got from the Measure phase to do this. There is the need to know if the problems are because of air leaks or fixed problem or if they are because of how the compressed air system's set up. The solution rely in looking at the compressed air system at the Heineken facility to see what is going on with the air.

This phase is essential because, although Heineken considers replacing the compressor due to limited adaptability to demand changes, the project scope explicitly requires determining whether current inefficiencies originate from waste within the distribution network rather than the compressor itself.

### 5.2 Data Inputs Used for Analysis

As outlined in the previous paragraph, the project team adopted several approaches to identify and understand the root causes of air losses within the air production and distribution system. Based on the data collected during the measurement phase, the next step is to interpret and derive meaningful insights from the information gathered.

We can divide the measurements in:

- Data received from pressure and flow meter sensors; retrieved from the **ERP**.
- Gemba walk within the company and its underground
  - o With the usage of the technical drawing generated both by the project group and the company Heineken itself.
- Data collected with the sound camera
- Information retrieved from all the interviews, see

This project investigated the causes of unnecessary compressed air consumption at the Heineken brewery in 's-Hertogenbosch, with a particular focus on non-production hours. Using the DMAIC methodology, data analysis, site inspections, interviews, and technical drawings were combined to develop a comprehensive understanding of the compressed air system.

The results show that air leakage, while present, is not the main cause of the observed fluctuations in air consumption. Instead, structural and operational factors such as insufficient isolation of air consumers during non-production periods, intermittent air

usage, and the compressor control strategy are the primary drivers of inefficiency. These factors cause pressure and flow variations that lead to increased energy consumption and unnecessary CO<sub>2</sub> emissions.

The study concludes that replacing the compressor alone will not resolve the issue. The greatest improvement potential lies in reducing air demand, improving system isolation, and optimizing pressure levels and control logic. Implementing these measures will enable Heineken to reduce energy costs, lower CO<sub>2</sub> emissions, and improve the reliability and sustainability of its compressed air system, supporting the company's long-term environmental objectives.

- Appendice.

Based on this we can elaborate on different considerations.

## 5.3 Analysis of ERP Pressure and Flow Data

The ERP data shows that there are changes in pressure and flow during non-production hours, like on weekends, this can be seen in the image in the ERP System data paragraph in the

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Appendices. You would think that when Heineken is not producing anything the system would use a low of air and be steady, that is not what happens with the ERP data. The ERP data shows that the system has highs and lows which means it is still using a lot of air even when Heineken is producing nothing.

When comparing production and non-production periods, the packaging area shows the most pronounced variation, supporting employee statements that this department is a major contributor to air losses, as can be read from the interviews in the

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Appendice. These fluctuations suggest that compressed air is being consumed by leaks, uncontrolled consumers, or permanently open branches rather than by production equipment.

## 5.4 Localization of Losses Using Technical Drawings

Technical drawings were examined to map out the compressed air distribution system to identify areas of loss, isolation logic was applied by using conceptualized valves to divide the network into its branches and then monitor how much consumption was affected, using the Enterprise Resource Planning (ERP) system. This methodology allowed the areas that had caused most of the non-production consumption to be identified. Many of the branches had a very small reduction in air demand when production ceased, indicating that they were consuming a continuous baseline amount regardless of their operational requirements.

## 5.5 Physical Verification and Reassessment of Leakage Impact

To determine where the system was losing energy, the team started by looking at the information contained in the compressed-air-network-system-data to find a schematic representation of the system and how it was configured. This was accomplished by conducting on-site inspections in the areas where the team had determined that losses were occurring. Walking through the building, visually inspecting the equipment, listening while the equipment operated for unusual noises, and using acoustic imaging devices to find and measure the size of any potential leaks were the types of inspections completed during the Gemba walk. Doing the Gemba walk provided the team with the opportunity to gain hands-on experience in the areas of concern and confirmed, in that air leakage was a valid explanation for the changes in pressure and flow reported in the system data.

The investigation identified multiple leaks in both the packaging area and the underground piping systems. The leaks were identified as steady state during the periods of investigation when they were not changing in size and confirmed by measurements taken with the acoustic imaging camera. Therefore, the identified leaks could not be the cause of the large spikes and drops recorded in the ERP data for the non-production hours of operation. While the issue of air leakage exists within the compressed air network, the trend of steady-state leakage does not relate to the spikes and drops in ERP data that have been recorded.

Leaking devices will usually generate either a constant or gradually increasing demand for compressed air and will therefore generate less total demand than would interrupting production. The variables of both the flow rates and pressures of air observed during the study appear to be evidence of actions contributing to this variability, the intermittent operability of components requiring compressed air is likely the main contributor to this variability.

The Gemba walk also provided additional support for these conclusions, in that the walk was conducted at times when the electrical demand of many of the air consuming devices was cyclical (the electrical demand to operate these devices cycled on and off). As such, when taken in conjunction with the compressor's control logic, these factors can enhance minor fluctuations in electrical demand created by the actions of other devices causing oscillations in the entire compressed air supply system.

Based upon this re-examination, the original assessment of leaks as a primary contributing risk factor has now been amended to a **secondary contributing risk factor**. Future root cause analyses will be directed at identifying those devices that do not isolate out the compressed air supply and understanding the effects of the compressor's control logic on the operation of the compressed air system.

## 5.6 Interpretation of Findings and Root-Cause Reasoning

In the analysis phase, the complete analysis of what each type of measurement means was achieved through the use of logical reasoning and through triangulating the results of the measurements with one another. The analysis phase of this study did not use any formal root cause analysis method (e.g., Ishikawa diagrams, FMEAs) to evaluate the results however it did use logical reasoning and the method of triangulation. Triangulation was particularly useful because it provided greater confidence in the identification of the most reasonable explanation for the variations in compressed air.

After combining trends from ERP data with visual inspection results and layout drawings, the team was able to determine if there were any singular dominant factors that would give rise to the observed behaviors. Initially, leakage was thought to be an overriding factor, however, as shown in 5.5 Physical Verification and Reassessment of Leakage Impact, the measured leaks could not account for either the size or dynamic behavior of pressure and flow variations.

A further investigation into this field has identified that the variations seen in these datasets are due to the intermittent or uncontrolled demands placed on the Compressed Air System by Air Consumer Hardware products such as those that turn on and off intermittently. The result of the sudden changes in demand placed on the Central Compressed Air Supply System and subsequent Pressure Control Actions from compressors has resulted in the increased amplification of pressure variations across the entire system. Compressed Air Pipeline Systems were constructed so that sections or branches of the air pipeline system would still be connected to the Main Compressed Air Supply System while the Main Supply System is not in operation and its valves are closed, some air pipeline branches remain connected to the Main Compressed Air Supply Network when there are no operating hours of production activity, as can be seen in the schematics in the paragraph . This possibly creates an error in the understanding of total consumption increases during Non-Production.

Although measurement errors and sensor malfunctions were evaluated as possible alternative explanations, they were shown to be improbable, as both visual observations of the compressed air supply system, as well as operator feedback, support the result patterns seen in the enterprise resource planning (ERP) data sets.

## 5.7 Summary of Analyze Phase Outcomes

The results of this analysis indicate that leakage is **NOT** the predominant cause of air compression inefficiencies during non-production periods, rather it is due to system performance and operational conditions. Key conclusions include:

- While leakage results in a steady-state minimum loss of air compressed, there is no indication that it can explain large fluctuations in air use.
- That some uncontrolled and/or intermittent use of compressed air will continue to occur after production hours.
- System isolations and compressor control setups produce significant increases in pressure fluctuation because of minor increases in compressor demand.

It is clear from these findings that structural and operational causes account for a majority of observed lost energy and provide a solid basis for establishing a target for improvement without the need for unsupported assumptions.

## Conclusion

This project investigated the causes of unnecessary compressed air consumption at the Heineken brewery in 's-Hertogenbosch, with a particular focus on non-production hours. Using the DMAIC methodology, data analysis, site inspections, interviews, and technical drawings were combined to develop a comprehensive understanding of the compressed air system.

The results show that air leakage, while present, is not the main cause of the observed fluctuations in air consumption. Instead, structural and operational factors such as insufficient isolation of air consumers during non-production periods, intermittent air usage, and the compressor control strategy are the primary drivers of inefficiency. These factors cause pressure and flow variations that lead to increased energy consumption and unnecessary CO<sub>2</sub> emissions.

The study concludes that replacing the compressor alone will not resolve the issue. The greatest improvement potential lies in reducing air demand, improving system isolation, and optimizing pressure levels and control logic. Implementing these measures will enable Heineken to reduce energy costs, lower CO<sub>2</sub> emissions, and improve the reliability and sustainability of its compressed air system, supporting the company's long-term environmental objectives.

# Appendices

## Notes

**Notes meeting with Martin at Heineken 26/09/2025 13:35 -> 14:55, a transcription of the meeting was done and a summary of it was generated thanks to the use of Chat GPT version 5.2. The Prompt "Summarise this transcription by making bullets points of the topics"**

### Context

- Interview with **Martin van Nuus, 26 Sept 2025, Heineken Den Bosch.**

### Energy cost & share of compressed air

- Annual electricity bill is about **€8.5 million.**
- **~7%** of electricity use/cost is attributed to **compressed air** (around **7.0%**, approx. **7.02%**).

### Business case for a variable frequency compressor

- A **frequency-controlled (VSD) compressor** could reduce energy needed to produce the same amount of compressed air by **~30%**.
- Savings estimate: **30% of the 7%** electricity share  $\approx$  **€185,000 per year** (order of magnitude).

### Drying air is a major topic

- Current drying level is **very dry (around -50°C dew point).**
- Question raised: **Is air really required to be that dry?** Drying costs energy.
- Current system uses **steam** (for drying) and **cooling water** (for cooling), both adding energy/pumping costs.
- Newer compressors can use **compressor heat/energy internally to dry air**, potentially eliminating or reducing external drying utilities.
- If a new compressor is installed, existing drying/cooling-related parts could possibly be **removed**, saving additional energy beyond the €185k estimate (exact value unknown; he planned to calculate later).

### Mismatch between air quality and use

- Noted inefficiency: using **high-quality dry air** to transport **wet materials** (e.g., spent grains).

- Claim/estimate: **~20% of air** is used for “wet” applications where **laboratory-quality dryness is unnecessary**.
- Suggestion: **split air qualities** (dry only what needs to be dry; don’t over-dry the rest).

### Principle / prioritization

- Emphasized sustainability hierarchy (“triangle of the devil”): **consume less first**, then optimize/technology choices.
- Key questions: **Can we use less air? Do we need 10 bar? Do we need -50 dew point?**
- Possible concept: consider **multiple pressure levels** (e.g., smaller 6 bar + separate lower-pressure compressor) instead of one high-pressure system.

### Project direction / what he expects in your report

- Even if the project is not to install a new compressor, he encourages including **all improvement ideas**, including new technology options.
- Given limited time, focus first on **consumption reduction opportunities** and “where the air goes.”

### Cost heuristics / useful figures

- Approximate compressed air cost: **~€0.01 per Nm<sup>3</sup> energy + ~€0.01 per Nm<sup>3</sup> maintenance** □ **~€0.02 per Nm<sup>3</sup> total**.
- He can provide: electricity price and possibly total air volume supplied, but he says the key is identifying **opportunities to use less**.

### How to detect issues (practical measurement mindset)

- Simple leakage check method: put a **bag over a leak** and time how fast it fills (rough estimation).
- Recommends professional leak detection using **sound/ultrasound** companies when needed.
- Strongly recommends doing a **weekend (Sat/Sun) walk-through**: if you hear air noise, it’s enough evidence maintenance closure/leak plan is not effective.
- Message: “I don’t want pictures, I want repairs” — focus on fixing, not only documenting.

### System behavior / pressure

- Large leakage can force **higher system pressure** because the system must supply the leak as well.
- Reducing leaks/consumption can reduce required pressure and save additional energy.

### **Payback / broader energy picture**

- Payback discussions depend on including **steam/natural gas impacts** as well as electricity.
- He suggests that when including non-electric savings (e.g., reduced steam/natural gas), payback assumptions can change (he mentions **3 years electricity-only** vs longer acceptable horizons when broader savings are included).

### **Stakeholders / contacts**

- Main contact in energy department: **Freddy Verhagen**.
- Secondary contact / energy lead: **Robert van der Meulen** (also linked to sustainability responsibilities).
- Advice: use them to navigate departments instead of searching alone.

### **Where the biggest air use is likely**

- Packaging is expected to be the main contributor (he refers to previous indication like "yellow line").
- Other buildings may have valves that vent briefly (normal behavior) and are not major issues.

### **Benchmarking**

- Mentions a **Utility Benchmark (UBM)** with expected air consumption per production output (e.g., **Nm<sup>3</sup> per hectoliter beer**) and kWh per Nm<sup>3</sup> conversion.

## Wider sustainability context

- Company target: **CO<sub>2</sub> neutral by 2027**, important for corporate positioning/advertising.
- Energy focus increased significantly around the **Ukraine war / gas supply concerns**, prompting contingency measures (e.g., temporary backup fuel installation that was never used).

## Notes Aldo's interview:

This section summarizes the information obtained from an interview with a company employee carried out as part of the project.

The interview focused on the maintenance plan and energy efficiency measures, especially in relation to the compressed air system. The maintenance plan is organized by sections to improve efficiency. Inspections are carried out every 26 weeks, and the *Maximo* system is used to manage maintenance data. Preventive maintenance is mainly applied in the packaging area, while other areas such as brewing, filtration, and utilities have been included more recently.

According to the interviewee, energy losses reached about *€195,507 by the end of 2023* and increased to *€218,584 in 2024*. *The Energy Manager estimated savings of €45,883 within three months* by repairing compressed air leaks.

The interview also showed that energy consumption will not change significantly until a variable frequency drive (VFD) compressor is installed. The reported savings are based on the leaks repaired at the time of measurement. Since the maintenance plan started in 2020, savings have mainly come from improvements in the compressed air system.

In addition, a new acoustic camera was introduced in September 2019 to detect air leaks. This investment made it possible to identify yearly losses and achieve estimated savings of *\*around €70,000 per year, with a payback period of about \*six months*. Repairing air leaks was identified as the most effective action, while other measures, such as reducing air pressure, require higher investment and additional maintenance work.

Finally, the interviewee mentioned some challenges, including unclear responsibility for leak repairs, difficult access to some areas, and limited time and financial resources.

## **Iteration 1 - feedback**

### **Questions**

Is there a technology with air that can fix leakage by itself?

If not the leakage, what is the reason for the wasted air?

Could the air be transformed between working stages so it's more efficient to transport?  
(Gas to liquid and vice versa)

### **Feedback**

Automate the valves for the lines, an example can be if they know they're not going to use the production line they just switch up a button so the line won't have air, therefore there will be no leakage.

Go small at first (start by the smallest problem and try to make it as large as possible depending on the time).

Compressor model/prototype to experiment with possible solutions (we can make a small prototype by simulating how a compressor works for detect leakage or improve the design).

Having someone to address if the company tutor is unavailable (we already are working on it and we already have different persons to address to).

## Iteration 2 – feedback

13/11/2025

Verify whether the issue occurs at other Heineken facilities.

Understanding if this is

a local or widespread problem will help determine whether the root cause is systemic, process-related, or installation-specific.

Consider designing a manually adjustable valve to regulate airflow.

A manually operated valve could provide a simple, low-cost method to control excessive air leakage and allow operators to make adjustments as needed.

Investigate the possibility of unlisted air-consuming equipment.

There may be components, tools, or small systems connected to the compressed-air network that are not shown in the existing documentation. A walk-through inspection could help identify these.

Improve the visual quality of the technical drawings.

The drawings should be clearer, more structured, and visually appealing to support decision-making. Use colors or visual cues to highlight leakage severity, risk areas, or priority zones to better convince management.

Add a clear breakdown of leakage impact.

Include estimates of energy loss, cost implications, and potential savings from resolving the leaks. This strengthens the business case.

Provide a short summary of recommended actions.

A concise, actionable list at the end of the report will help management quickly understand next steps.

Ensure consistency in terminology and symbols.

Align drawings, legends, and terminology with Heineken's internal engineering standards to avoid confusion.

### **Feedback Iteration 3 (11/12/2025)**

Questions asked:

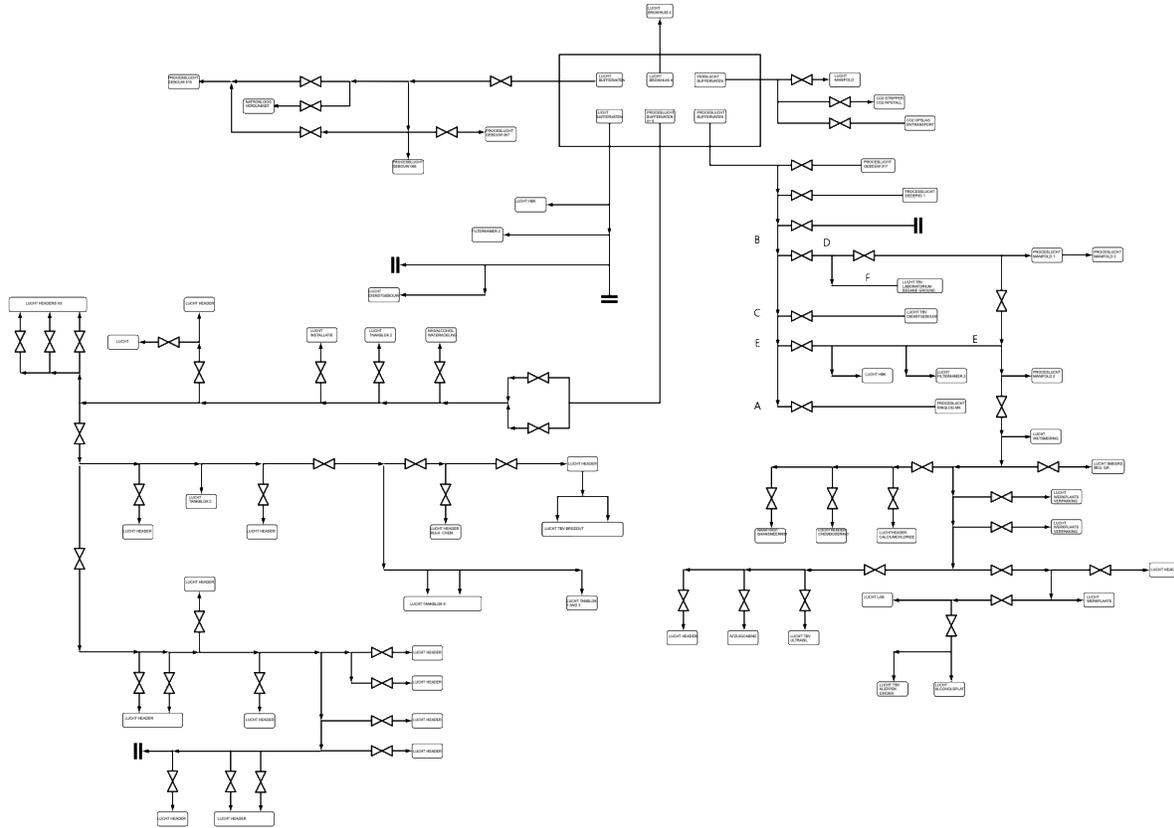
1. Are the diagrams understandable for people outside our field?
2. Do you understand the causes of our problem?
3. Do you understand the way we are studying the issue?
4. Do you think adding more colour to the technical drawings makes them easier to understand?

Main feedback received:

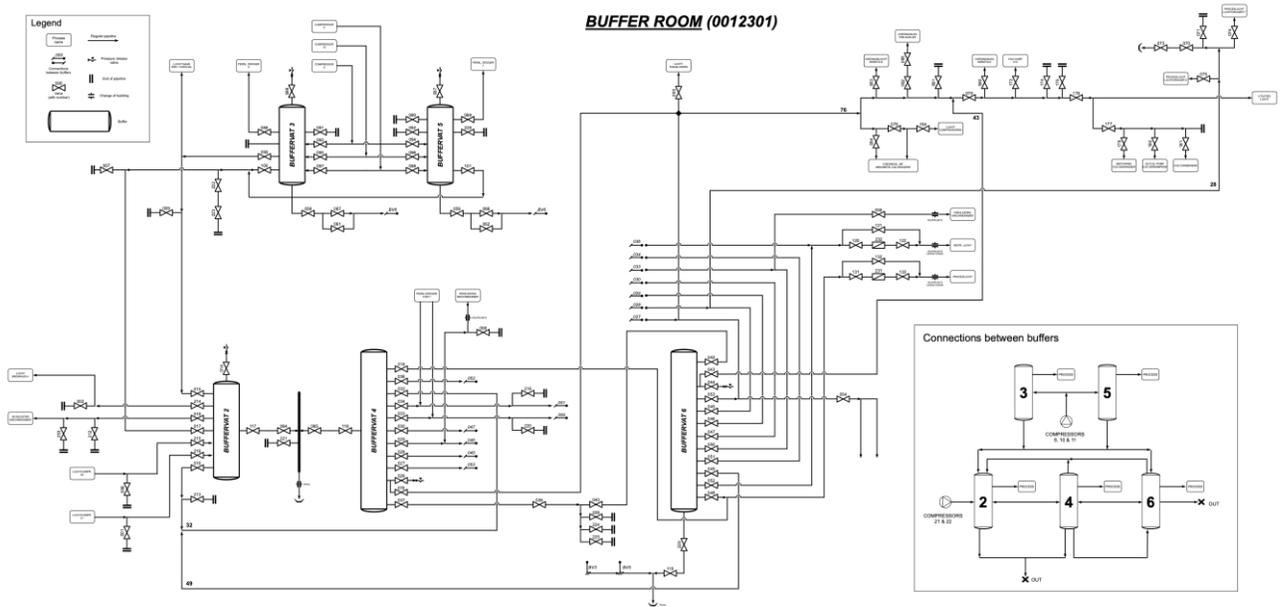
- Colours and symbols would help to make the diagrams more understandable, at the moment they look more similar to an electrical installation.
- Try to figure out the reason for the pressure – air consumption graphs to have simultaneous ups and downs, since it looks like that relation could help your project to discard a lot of possibilities for the malfunctioning of the installation.
- When the sensor measurement data arrives, try to analyse it and take a conclusion about the impact on the installation or the cause of the problem instead of just showing a template with numbers.
- At the time of closing the valves, how are you going to see some difference on the air consumption installation?

# Drawings

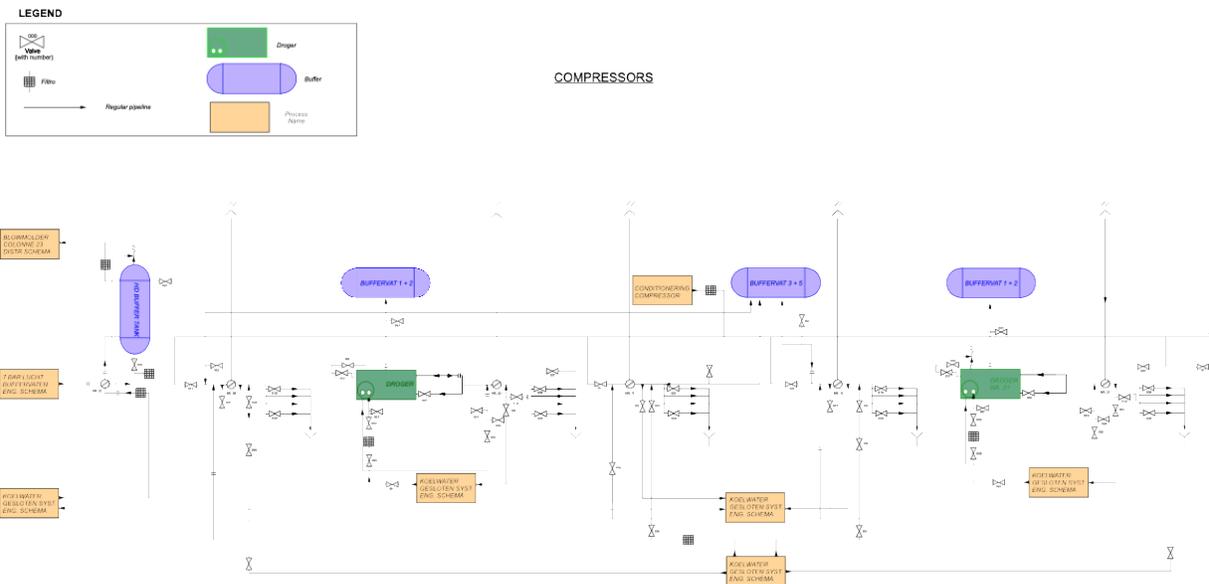
## General drawing



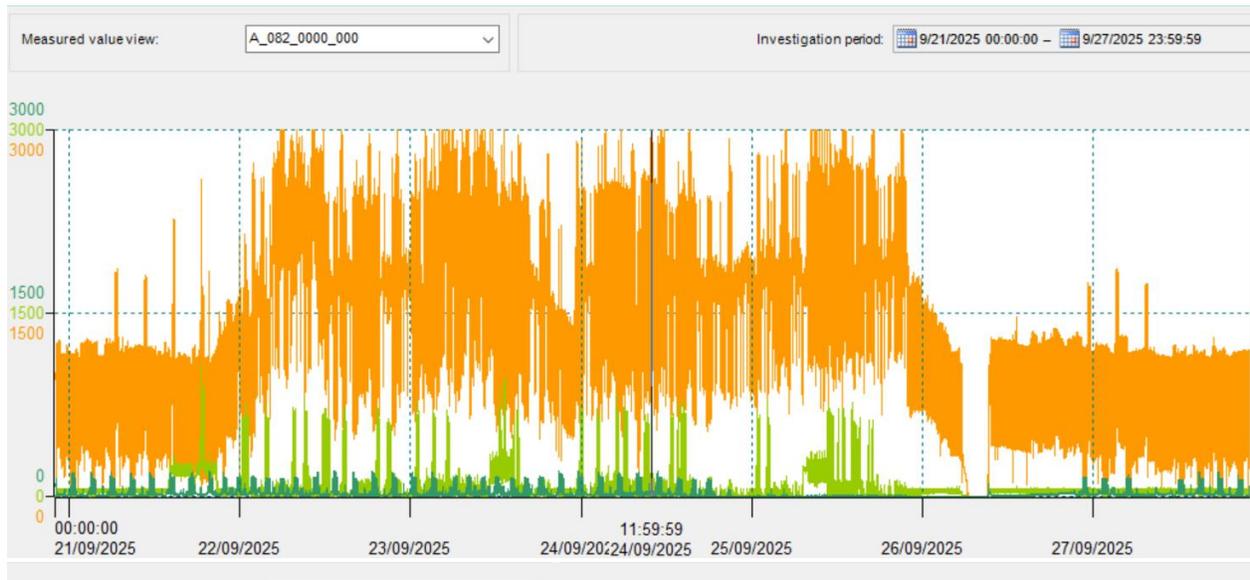
## Buffer room



## Compressor room

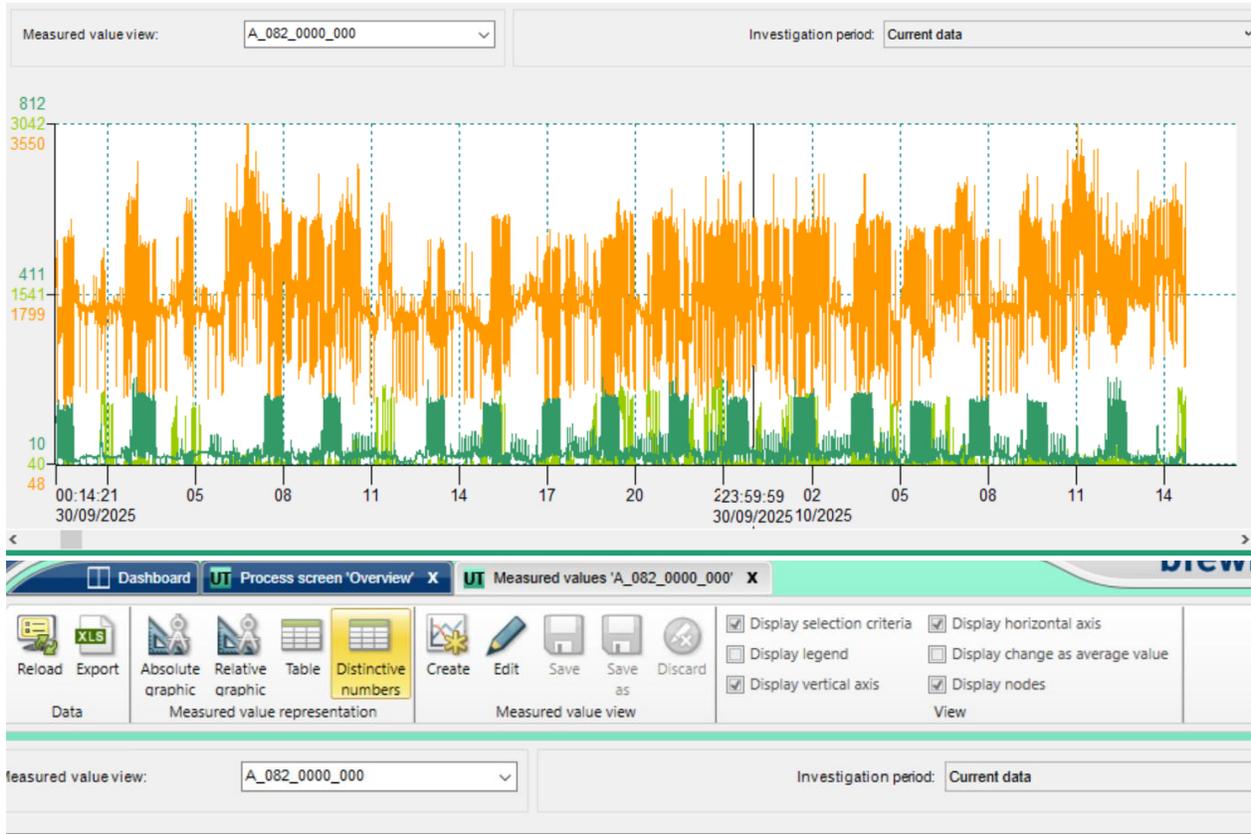


## ERP System data



26/09/2025 10:21:53 - 26/09/2025 16:29:12

Measuring point	Designation	Unit	Decimal places	Minimum	Maximum	Average value	Standard deviation	Integral
MVA_FT_082_0000_006	Proceslucht flow	Nm <sup>3</sup> /h	1	2,8	1.480,4	769,2	470,1	16.953.812,0
MVA_FT_082_0000_008	Instrumenten lucht flow	Nm <sup>3</sup> /h	1	0,9	152,1	42,8	19,3	943.633,5
MVA_FT_082_0000_011	Brouwhuis 4 lucht flow	Nm <sup>3</sup> /h	1	-1,6	117,1	14,0	14,8	309.233,4



30/09/2025 00:14:21 - 01/10/2025 16:27:31

Measuring point	Designation	Unit	Decimal places	Minimum	Maximum	Average value	Standard deviation	Integral
MVA_FT_082_0000_006	Proceslucht flow	Nm <sup>3</sup> /h	1	439,8	3.775,0	1.829,7	486,3	253.556.592,0
MVA_FT_082_0000_008	Instrumenten lucht flow	Nm <sup>3</sup> /h	1	0,9	914,9	73,6	126,2	10.200.838,0
MVA_FT_082_0000_011	Brouwhuis 4 lucht flow	Nm <sup>3</sup> /h	1	-1,6	219,7	52,5	41,8	7.275.001,0

Picture