

Case Study

Company name	Belgotex				
Size of company (Based on energy consumption bill)	SMME (R250k –R750k)		Medium (R750k –R24 m)		Large (Above 24m) X
Sector	Clothing and textile				
Location	Pietermaritzburg, KZN				
Company contact	Name: Malcolm Naicker			Position: Engineering Manager	
	Email: malcolm.naicker@belgotex.co.za			Telephone: 033 897 7538	
Year joined project	2016				
Date of implementation	Nov 2017 to Dec 2019	Duration	25 months		
Utility intervention	Compressed air (electricity)				
Case study author	Siraj Williams				
Project manager	Milisha Pillay				

1. BACKGROUND

1.1 Company profile

Since it was established in 1983 as Natal Nylon, Belgotex Floors has grown to become a member of the Belgotex International Group and Africa's leading carpet and artificial grass manufacturer.

With seven companies over four continents, Belgotex Floors offers over 40 different ranges of products that are distributed through a network of agents in more than 40 countries abroad, as well as locally. They offer five types of flooring including carpeting, vinyl, artificial grass, underlays and rubber. Their extensive portfolio of products guarantees high-quality flooring solutions utilising the latest technology.

1.2 Plant profile

The Belgotex manufacturing plant is located under a single roof at their 155 000 m² facility in Pietermaritzburg, KwaZulu-Natal. The plant has embraced sustainability as early as 1995 when they started recycling materials. Other innovations include the upgrading of the effluent plant in 2001 to allow for the recycling of

water, the adoption of a waterless yarn-dying process, and the installation of a 1MW grid tied solar PV system in 2013.

The plant has demonstrated its commitment through various other greening projects, becoming the first company in South Africa to receive a six Green Star rating for an industrial facility that implements sustainability practices, “in all aspects of plant and carpet manufacturing operations”. Their long-term strategic plans include mitigation and management, and the reduction of waste, water and energy.

There are three key processes when manufacturing carpet products, namely: Yarn, Fibre and Finishing. In the yarn process, bulk continuous filament (BCF) is melted and extruded into filaments. After cooling, texturing of the yarn filaments is carried out by the process of twisting and heat setting. Air entangling is also carried out on certain yarns by blowing compressed air into a chamber in order to spread the yarn to form loops. The yarn is then inserted through a backing cloth, this is also known as the tufting process, to create a cut pile of semi-finished carpet.

In the fibre process, fibre is fed into a needle punch machine where barbed needles are used to force the fibre into a webbed fabric at high speed, resulting in a semi-finished carpet. Both the semi-finished carpets from the yarn and fibre processes are then finished in the backing plant, where bitumen is applied to a secondary backing sheet in order to complete the carpet.

1.3 Nature of the challenges

The increasing costs of electricity coupled with the issues around security of supply from the country’s power utility necessitated that Belgotex seek assistance from the National Cleaner Production Centre South Africa (NCPC-SA) to reduce their energy consumption. They implemented an energy management system (EnMS) ~~between from~~ October 2017 ~~to and~~ August 2018, during which they identified compressed air as their largest significant energy user (SEU) of electricity. ~~In line with the company’s sustainability drive, Aa~~ detailed compressed air assessment was consequently undertaken to address the high operating costs of the system.

~~An analysis of the performance of a compressed air system is a technically intensive process. The methodology of regression analysis learnt during the EnMS implementation training provided background for the compressed air assessment, allowing personnel to assist with the analysis.~~

The Belgotex plant has access to fairly accurate energy data for various departments and selected machinery. Sub-metering has been installed at various points in the electrical reticulation network, including a sub-meter in the compressor room that measures total energy consumption of the compressed air system.

1.4 IEE capacity building programme

To date, approximately 70% of the Belgotex workforce, including managers and supervisors have undergone some form of energy awareness training. A two-day in-house EnMS training workshop was attended by top management and other selected members of staff who significantly impact energy consumption. The benefits of attending the training include:

- an understanding of the driving factors that influence energy consumption at the plant

- learning how to establish critical energy performance indicators within each department
- improved operational control and behaviour change amongst those that influence energy consumption
- a greater understanding of “the business case for energy efficiency” especially by the management team.

Key personnel involved in operating and maintaining the compressors also attended a two-day compressed air systems optimisation (CASO) training, from which they derived significant benefit.

2. KEY ACHIEVEMENTS

Key findings table

Implementation period (yyyy-yyyy)	November 2017- December 2019
Total number of projects	7
Monetary savings in ZAR¹	2017: 111 208 2018: 145 510 2019: 2 246 259
Energy savings in GJ (for the compressed air system)	2017: 352.4 GJ (equivalent to 97 895 kWh) 2018: 461.2 GJ (equivalent to 128 090 kWh) 2019: 7118.9 GJ (equivalent to 1 977 341 kWh)
Total investment made ZAR	4 127 500
Overall savings as a % of total site consumption	2017: 0.32% of site annual electricity cons. of 30 150 531 kWh 2018: 0.47% of site annual electricity cons. of 27 191 729 kWh 2019: 7.5% of site annual electricity cons. of 26 502 935 kWh
Total savings from no cost interventions	Not determined
Payback time period in years	1.84 years
GHG emission reduction (tonne CO₂e)²	2017: 102.1 2018: 133.5 2019: 2061.5
Number of females employed prior to implementation	167
Number of females employed after implementation	180 (out of 651 employees)

¹ Based on a blended cost of R 1.136 /kWh

² Based on 1.0425 kg CO₂ per kWh

3. COMPRESSED AIR SYSTEM OPTIMISATION ASSESSMENT BACKGROUND

The facility utilises three energy sources: electricity, coal (for the boiler to generate steam) and LPG (for heating the bitumen in the backing plant). The compressors utilise electricity to produce compressed air.

An initial survey was conducted through a series of questionnaires related to the generation, distribution, and use of compressed air at the plant. It was followed by an initial site survey, or scoping assessment, to gain insight into the operational conditions and system layout. Following the survey, a meeting was held with management to determine the scope, boundaries, objectives and deliverables of the assessment.

System specific data regarding the specific characteristics of the compressors was collated and analysed. A measurement plan was developed in order to collect information on pressure, flow, moisture of the distribution streams and related end-users, and the electrical consumption of the compressors. With the measurements completed, the data was analysed, and potential savings opportunities identified. Analysis included the generation, distribution and usage of compressed air.

A large part of the system relates to determining the actual energy performance of the compressed air system, for which a baseline was developed for comparison against completed improvement projects. A performance model using accepted statistical methods, was developed. The potential value of this model ranges from being able to accurately forecast energy consumption and set data-based targets, to the measurement and verification of savings for performance improvement projects that are implemented.

Savings opportunities were identified based on collated data, measurements and site observations. These were quantified as far as possible and the potential savings opportunities and recommendations for improvement presented to management for evaluation and approval. A final report was written to reflect the assessment and the results thereof.

3.1 Baseline development

3.1.1 Scope and boundary

The scope of the assessment included all generations, distribution and end-use of compressed air within the plant. It also included all electrical energy consumed by the compressors. The main objective was to quantify electrical energy consumption by the compressors, identify opportunities for optimisation from generation to end-user and provide recommendations for implementation.

3.1.2 Modeling the baseline

Belgotex electrical energy consumption data for total site and compressed air system							
Month	BCF (sqm/kg)	Air entangling (sqm/kg)	BCF + Air entangling (sqm/kg)	Comp air elec. consumption (kWh)	Municipal elec. consumption (kWh)	Solar elec. consumption (kWh)	Total plant elec. consumption (Municipal & solar) (kWh)
Nov-16	478 774	62 893	541 667	1 375 974	3 334 583	82 974	3 417 557
Dec-16	216 368	31 837	248 205	586 562	1 616 442	110 255	1 726 697
Jan-17	124 588	25 590	150 177	538 579	1 164 011	122 836	1 286 847
Feb-17	351 254	58 151	409 405	1 225 920	2 814 186	96 466	2 910 652
Mar-17	412 451	58 670	471 121	1 278 717	2 835 060	112 400	2 947 460
Apr-17	448 817	44 770	493 588	1 275 887	2 630 709	112 794	2 743 503
May-17	325 275	75 995	401 269	1 178 626	2 652 697	81 811	2 734 508
Jun-17	298 481	43 816	342 297	993 167	2 502 982	80 350	2 583 332
Jul-17	323 876	41 363	365 239	1 164 392	2 608 066	69 442	2 677 508
Aug-17	379 562	89 566	469 128	1 147 862	2 763 918	78 243	2 842 161
Sep-17	342 978	83 255	426 233	1 037 390	2 200 794	98 707	2 299 501
Oct-17	374 057	64 300	438 357	1 233 924	2 666 965	98 623	2 765 588
Total	4 076 480	680 205	4 756 685	13 037 002	29 790 413	1 144 901	30 935 314

Table 1: Baseline data – Belgotex compressed air

Using the baseline data provided by the company, a simple linear regression model ($y = mX + c$), was developed using BCF + Air Entangling (in sqm/kgs) as the relevant variable, and electrical energy consumption by the compressed air system as the response (dependent) variable such that:

$$\text{Expected electrical energy consumption by the compressed air system [kWh]} \\ = (2.278 \times (\text{BCF} + \text{Air Ent})) + 183\,321 \text{ [kWh]}$$

For the model developed:

- The co-efficient 2.278 represents the marginal electrical energy consumption for every unit volume of yarn (sqm/kgs) required.
- 183 321 represents the baseload electrical energy consumption (in kWh per month) of the compressed air system when there is zero production.

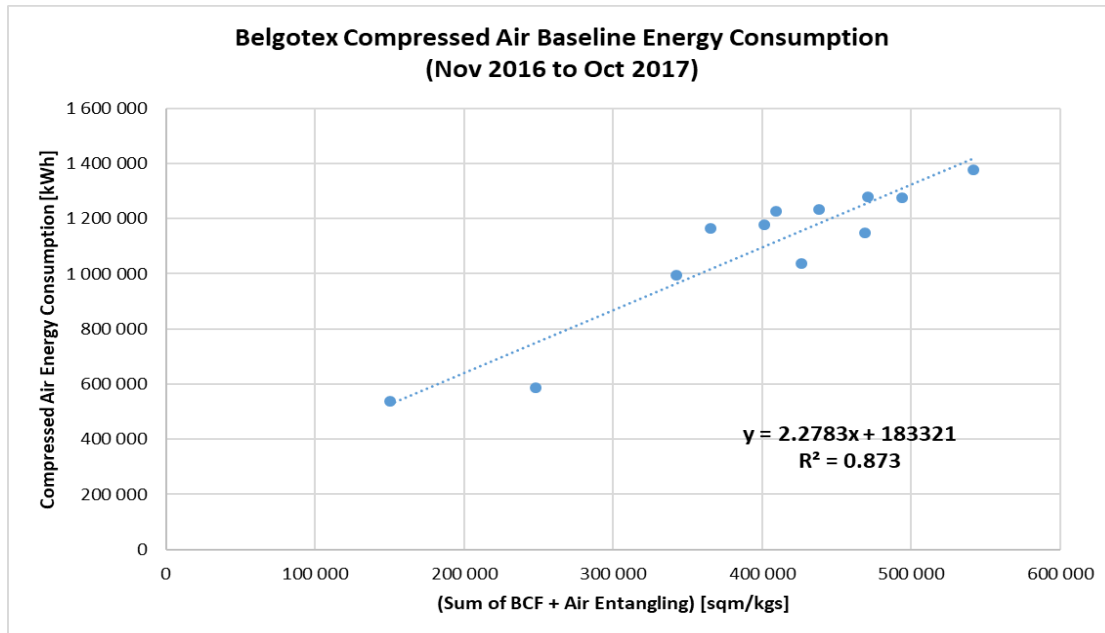


Figure 1: Compressed air baseline energy model

Reviewing the significance (validity for predicting future energy consumption) of the model, the following values have been determined for model significance:

- R^2 (model) = 0.873
- P-value = 0.000000859
- F- Value (model) = 0.000000859

- R^2 is a popular metric illustrating how well the independent variable (in this case sqm/kg product) explains the variation in the dependent variable (kWh consumption). Generally, any value above 0.75 is considered to be good.
- P-value is the probability that the dependent variable (energy consumption) is **not** related to the independent variable (BCF + Air Entangling). A value of $P < 0.1$ is acceptable.
- F -value is the probability that the model does **not** explain the variation in the dependent variable (energy consumption). A value of $F < 0.1$ is acceptable.

It should be noted that the R^2 value of this model (0.873) that was tailored by technical personnel at Belgotex represents an improvement on the R^2 value of 0.821 in the original model that was established during the compressed air assessment. This demonstrates a key success of the programme rolled out by the NCPC-SA. It shows that the transfer of skills has successfully taken place where the technical personnel of a company have continued to improve on the analysis of data to find a better fit that resulted in a more accurate energy performance model.

The predicted (or expected) energy consumption was calculated for each month in the reporting period using the model. This was then compared to the actual energy consumption based on the sub-meter for total compressed air electricity consumption. An actual energy consumption less than the predicted value represents an energy saving for that month, whilst the converse would imply an energy loss.

Figure 2 illustrates the baseline model developed for site total electricity consumption at Belgotex from November 2016 to October 2017. This includes the electricity supplied from the Municipality as well as from the in-house solar PV system. The total electricity consumption for the baseline period was calculated to be 30 935 314 kWh. It is important to show the site electricity baseline so that one may distinguish what the system benefits were in relation to the total site electricity consumption. It is a common occurrence where system related savings are negated by energy losses in other areas characterised by changes in the plant.

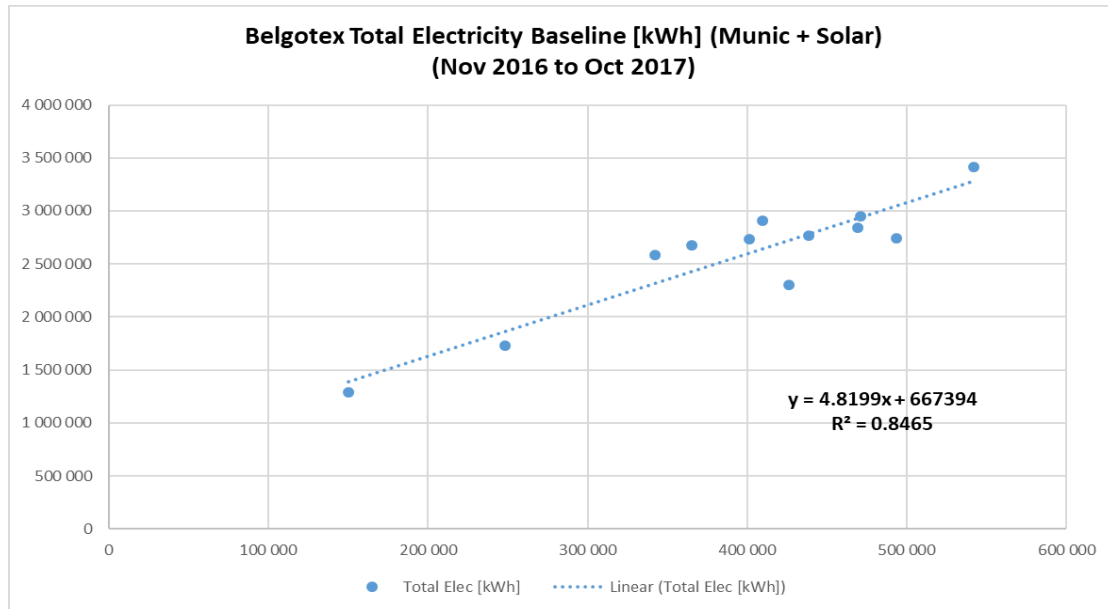


Figure 2: Site total electricity consumption baseline (Municipal & solar)

Figure 3 shows a comparison between the actual and predicted energy consumption for the compressed air system between November 2017 and December 2019. It indicates that in most months the actual energy consumed was less than predicted. The algebraic sum of the monthly differences between actual and predicted energy consumption for the reporting period essentially represents the total savings (or loss) for that period (commonly referred to as the CUSUM of the energy savings).

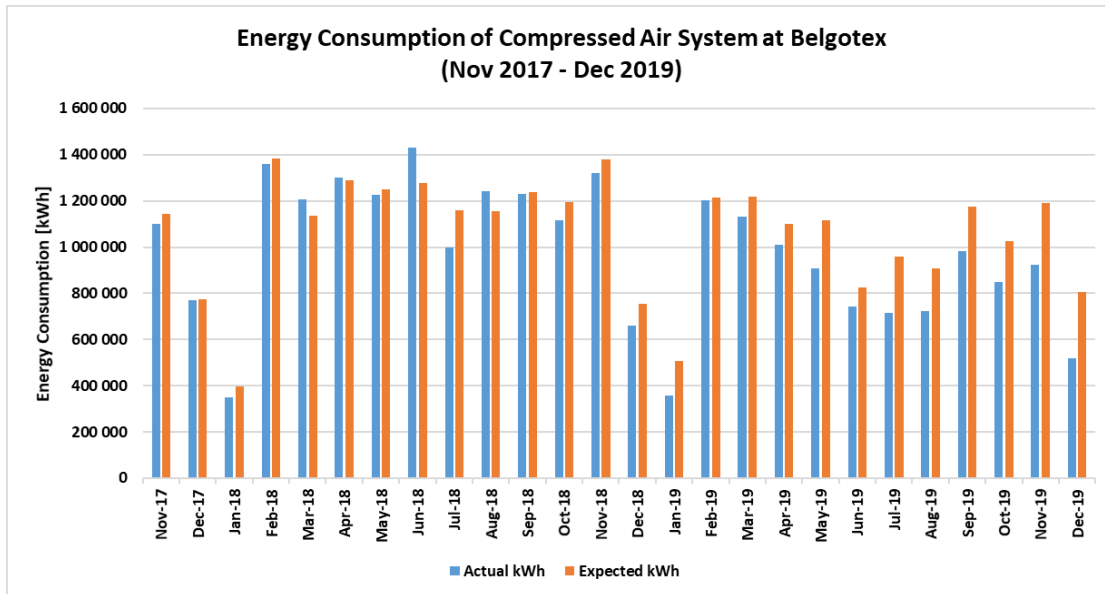


Figure 3: Predicted vs. Actual energy consumption

3.1.3 Assumptions

The baselines and this subsequent case study is based on the following assumptions:

- Baseline total plant electrical energy consumption was 30 935 314 kWh (Nov 2016 to Oct 2017)
- Baseline compressed air energy consumption was 13 037 002 kWh (Nov 2016 to Oct 2017)
- Blended cost of electricity was R 1.136 kWh/month
- The internal energy/sub-meters are correct and accurate.
- The meters are read promptly at the same time each month.
- The production volumes are correct for each month.

3.1.4 Model adjustments

No model adjustments were made. In terms of the system, Belgotex is planning to make significant changes to the piping network to split the compressed air system into two distinct pressure systems. One department (BCF) requires air at 10bar, whilst the rest of the machinery only requires air at 7bar. The operating characteristics of the compressors will be changed, whereby some will operate at 10bar, whilst others will operate at 7bar. Following the savings determination from this change, it is recommended that a new baseline then be established.

4. IMPLEMENTATION CHALLENGES

The compressed air system optimization (CASO) assessment was completed and management was made aware of the potential for improvement. Since compressed air proved to be the largest single user of electricity at the plant, management offered their full support.

However, one of the key challenges was the availability of in-house resources. Belgotex use a very small technical support team that needs to manage a large factory. Allocating time to complete further analyses required for the development of the business case was a challenge.

A second challenge was the time it took to acquire data or information. In some cases, measurement equipment could only be inserted during planned stoppages. Sourcing of suitable monitoring and measurement equipment also provided some challenges, as technical personnel were not familiar with the measurement equipment available. Therefore, further investigations were conducted to ensure that the size and specification of equipment was correct.

A further challenge was to build in the environmental and operating conditions for each business case. The technical team were careful to try and include all the relevant operational and environmental conditions when developing the business case for each project.

5. HIGHLIGHTS OF COMPRESSED AIR SYSTEM OPTIMISATION INTERVENTIONS

5.1 Interventions implemented

5.1.1 Identification and repair of leaks

This is done on an ongoing basis. Leak detection was done using a basic handheld acoustic tool. As the leak sizes were reduced over time, detection of leaks became more challenging. A new state-of-the-art fluke leak detection system was purchased in October 2019 at a cost of R320 000. This tool uses a combination of infrared and acoustic signal technologies to detect leaks.

5.1.2 Improved control of air dryers

Dryers were originally operated via separate control switches and remained in operation even when the associated compressor was switched off. Operating procedures have been changed, whereby dryers are now switched off when the compressors are not operational. This optimisation project was executed at no capital cost.

5.1.3 Improved control on standby compressors

Compressors in general operate most efficiently when fully loaded. An unloaded compressor consumes approximately 35% of its rated power when in unload mode. A standby compressor will consume less than 5% of its rated power when in hot standby. Improvements were made to ensure that compressors only switch on if and when required, and load/unload compressors do not operate unnecessarily. This was achieved through a simple modification of the programmable logic controller (PLC). A human-machine interface (HMI) has also been installed in the compressor house to monitor the pressure and cycling of compressors.

5.1.4 Improved maintenance of inlet air filters

Following the investigation of inlet air conditions during the assessment, it was determined that by improving the inlet pressure, Belgotex could also improve the efficiency of the compressors. This was achieved by changing the maintenance programme for the inlet filters so that they are cleaned daily, resulting in a lower pressure drop across the filter.

5.1.5 Installation of new desiccant dryers

Moisture ingress into the product severely affects quality as well as production volumes. Desiccant dryers that were in place were fairly adequate, but the high moisture content resulted in large volumes of compressed air used in the purge and regeneration cycles of the old dryers. Three new units were installed near the BCF, the largest user of compressed air.

5.1.6 Installation of automatic drain valves on air receivers

The five air receivers in the compressor room had time based valves installed. Smaller receivers inside the plant had either time based valves or manual valves installed. A higher than required frequency to discharge to drain will result in compressed air losses. Automatic drain valves were installed on the five main receivers in the compressor room.

5.1.7 Installation of two new high efficiency oil-free compressors

Two of the existing compressors were out of service and in need of repairs. A business decision was made regarding the repair or replacement of compressors. Using a life cycle costing (LCC) approach, it was determined that the purchase of new compressors would incur a lower life cycle cost than the repair of the older, less energy efficient ones. The two old Atlas Copco 250 kW (load/unload) compressors were replaced with two new Ingersoll Rand 250kW (load/unload) compressors. Oil free compressors are used as air quality is critical for production. Any contamination of oil or water in the production process will result in major production loss. By using oil free compressors, the possibility of contamination of the final product is greatly reduced.

Two of the projects that were identified during the CASO assessment were not implemented by the company. In both cases, technical personnel from Belgotex completed further investigations and concluded that the operating conditions during the site assessment were not representative of normal operating conditions:

- **Control of cooling tower fans by linking them to humidity levels**

It was suggested that the cooling tower fans be interlocked with humidity monitoring. At 95 to 100 % humidity, the fans will automatically stop as they would be performing no work. A pilot phase was implemented to determine the effects on the cooling water system. When the fans were stopped, the water and temperature increased very rapidly resulting in the cooling system becoming stressed for a period whilst bringing the cooling water back to within its operating range. This project was not implemented.

- **Reduction of inlet air temperature**

A reduction of inlet air temperature to a compressor by 4°C would typically lead to a 1% reduction in electrical power consumption. The inlet air is currently taken from inside the compressor room. It was proposed that taking inlet air from the outside via a duct might be more efficient than using the inside air. Belgotex personnel conducted a more detailed test to monitor the air conditions both inside the compressor room, as well as outside. Their analyses showed that the difference in air temperature between inside and outside was not significant enough to have an effect on the compressor efficiency. The project was abandoned.

5.2 Savings determination

~~Figure 4~~ Figure 4 shows the cumulative sum (CUSUM) of the monthly differences between actual energy and predicted energy consumption for the defined reporting period.

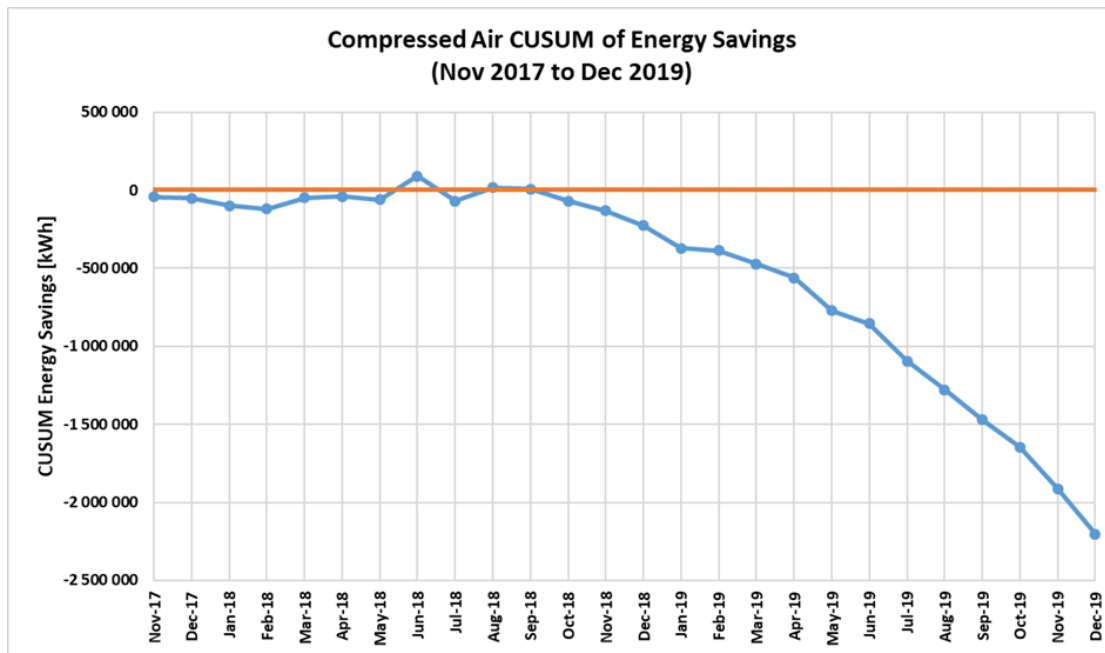


Figure 4: Cumulative energy savings – Belgotex compressed air system

The cumulative energy savings for the compressed air system between November 2017 and December 2019 was 2 203 326 kWh (7 931 GJ) of electricity, with 97 895 kWh (352.4GJ) saved in 2017, 128 090 kWh (461.2 GJ) saved in 2018, and 1 977 341 kWh (7118.9 GJ) saved in 2019.

The majority of savings were reported during the 2019 calendar year. This was due to the fact that most of the improvement opportunities were completed during the 2018 calendar year, and also because the annual consumption had decreased from the previous year. The desiccant dryers were installed in November 2019, and hence energy savings related to this project are only expected to be seen in the 2020 calendar year and beyond.

At an 80% confidence level and a margin of error of 21%, the true savings related to the optimisation of the compressed air system can be reported as 2 203 326 ± 472 255 kWh.

The compressed air savings form a large proportion of the overall savings achieved at the plant. Using the same baseline period between November 2016 and October 2017, the total electrical energy savings for the reporting period (November 2017 to December 2019) was calculated to be 7 544 436 kWh, as shown in [Figure 5](#). The baseline electrical energy consumption was calculated to be 30 935 934 kWh for the period November 2016 to October 2017. A number of other energy savings projects (with some having stemmed from the EnMS implementation project) were undertaken in addition to the compressed air interventions.

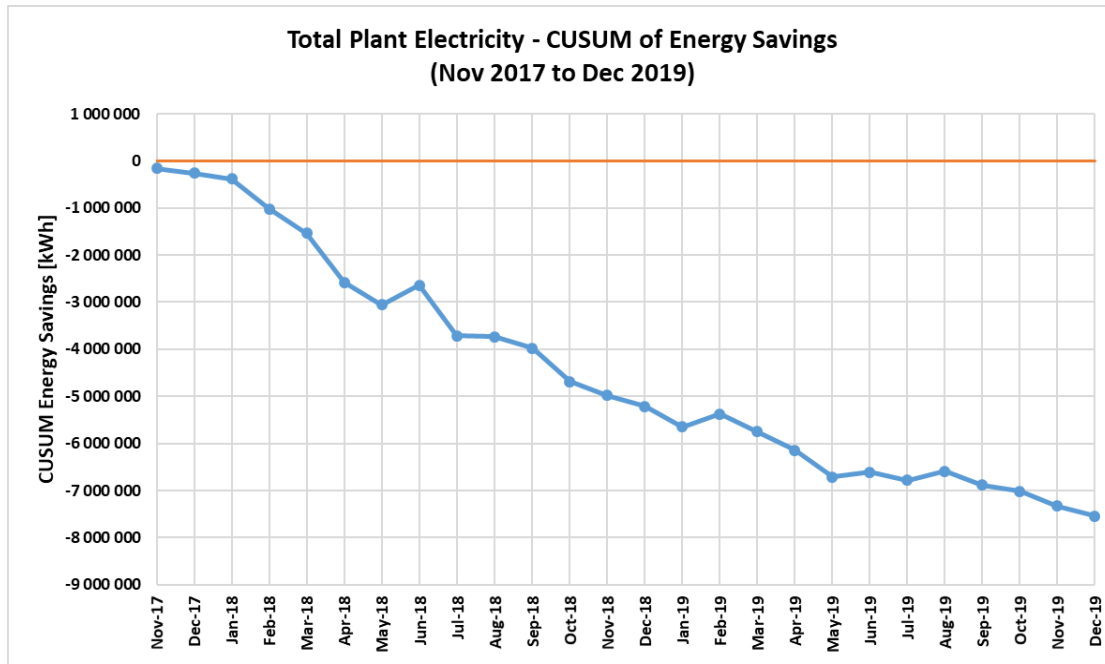


Figure 5: Total plant electricity savings

5.3 Summary of all interventions

CASO	Intervention	Utility saving period	Investment (ZAR)	Savings (ZAR/Year)	Payback (Yrs)	Utility saving (GJ)	GHG emission reduction (tonnes CO ₂ e/year)
1	Repair air leaks	Nov 2017 - Dec 2019	320 000	2 502 978	1.84	7 932	2 297.1
2	Improved control of air dryers	Jun 2018	None				
3	Improved maintenance programme for compressor inlet filters	Sep 2018	None				
4	Improved control on standby compressors	Nov 2017-Apr 2018	None				
5	Installed three new desiccant dryers	Nov 2019	495 000				
6	Automatic drain valves installed on air receivers	Sep 2018	12 500				
7	Purchased two new high efficiency compressors	Nov 2018	3 300 000				
TOTAL			4 127 500	2 502 978	1.84	7 932	2 297.1

Note 1: CO₂ conversion factor is set at 1 GJ = 0.2896 tCO₂.

6. BENEFITS AND LESSONS LEARNED

6.1 Benefits

- Analysis of compressed air systems is a technically intensive process. The implementation of an EnMS at Belgotex facilitated the optimisation of the compressed air system. Awareness training and an understanding of the benefits of energy management made personnel readily respond to the enquiries from the assessment team. This also made the proposals and changes easier to accept.
- Another key benefit was the methodology learnt during the EnMS. The compressed air assessment afforded Belgotex personnel the opportunity to practice their newly acquired skills in developing their energy performance model for the compressed air system. They utilised the methodology in the analysis of the compressed air system proposals presented by the consultant and were able to improve the model, thereby demonstrating that skills transfer had taken place. This supports the objective of sustainability, where local personnel are able to continue with optimisation projects.

6.2 Lessons

By implementing the compressed air projects and other energy related interventions, management and Belgotex staff have learnt and adapted to the changing sustainability landscape. Some important lessons learnt include:

- Change is necessary. Adapting to change and modifying behaviour to sustain the change is a vital skill required to remain competitive in a global market.
- Resources and time are required for successful implementation of any energy saving intervention.
- Identified opportunities should be supported by sound scientific analysis with accurate and timely representative data.
- Understanding the energy performance of each SEU is key to unlocking opportunities and facilitate the development of technically and financially viable business improvement opportunities.

The implementation of many improvement opportunities has had the added benefit of securing plant reliability and ultimate productivity.

Belgotex has also recognised the following success factors that they deem critical to the successful implementation of opportunities:

1. Commitment from top management in ensuring that environmental issues are taken seriously.
2. Understanding by top management of the benefits of assessments by taking a long-term view.
3. Commitment from engineering and production teams in ensuring that tasks are taken seriously and executed properly and timeously.
4. Resources required to execute the work were timeously approved and allocated.
5. Monitoring and critical analysis to ensure that what was planned to be implemented made business sense.

7. FUTURE PLANS

Belgotex understands that in a global context, sustainability is key to profitability. Therefore, they have taken a long-term approach and will continue with the following projects:

1. Air leak management programme to identify and repair leaks
2. Further optimisation of control philosophy for existing compressors.
3. Conversion of pressure for various processes from 10 to 7 bar. This requires piping changes that will be implemented over a period of time. As the new piping network is installed, machinery will be switched to the HP (10bar) or LP (7bar) systems as required. This will be done over a period of time as new piping sections are added. The project is planned to start in August 2020.
4. Improve the management of large intermittent compressed air loads by installing appropriately positioned and sized air receivers.
5. Long-term feasibility study around the BCF for the potential installation of a dedicated compressor.