ENERGY AND GREENHOUSE GAS REDUCTION ASSESSMENT IN MANUFACTURING ENVIRONMENT

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Abstract*: This paper aims to identify, analyze, and conclude on solutions to improve the energy performance of an economic agent, by carrying out an energy audit to satisfy part of the energy needs of the organization. The respective economic agent operates in the field of the production of devices for the control and distribution of electricity. The objectives of the paper refer to the identification of the way of using electricity, to the identification and analysis of alternative solutions, such as photovoltaic panels, which could substantially reduce energy costs, to the performance of an economic analysis regarding these alternative solutions to determine which are economically efficient for the economic agent in question. The site energy audit was carried out during the week commencing 10th February 2023 and consisted of a health and safety site induction, followed by a kick-off meeting with key site personnel, followed by data gathering and surveys of the factory operation and processes. The objective of the energy survey is to provide a compliant audit for the ESOS submission for the organisation. The energy audit covers all energy consumption applicable to the site in order to establish an energy use map for the major consumers and identify potential energy saving opportunities.The energy savings identified in this study are based on the findings of the site visits and are considered viable opportunities that will require further work to develop them into investment grade business cases.*

1. INTRODUCTION

There has been a growing realization that earth and its climate are being pressured by human activities. Based on a better understanding of climate change and other scientific and societal factors, expectations have changed to require that more be done – and quickly. If we are to address the threats of a changing climate, all of us need to be actively involved in optimizing energy consumption.

Active stewardship starts in our own backyard, making sure operations are clean and safe, and reducing environmental footprint. Managing our use of energy will help lower the amount of fuel used in manufacturing, heating and cooling, resulting in fewer greenhouse gas emissions, while lowering operating costs.

With growing work demands, a need for accelerated energy reductions, and fewer resources to get work done, this study can assist with existing energy management plans or administer entire energy management programs for an organization from start to finish.

Effective energy management plans and strategies will reduce operating costs, include processes that sustain the improvements, and protect the environment. Most importantly, a well-developed Energy Management Plan will support the energy vision and translate it into actionable, sustainable processes and initiatives. It will include a continual improvement process that examines real-time energy consumption and measures, analyzes, and implements programs to reduce usage.

The value realized from energy audits and the Energy Conservation Opportunities are optimized when linked back to business, or organizational energy objectives.

This study can assist with the development of an energy policy or an energy management strategy and to prepare a roadmap that will guide your sustainable "Energy Culture" into the future.

An energy management roadmap can ensure sustained energy management success.

These can include regulatory requirements, business objectives, facility certifications, specific energy reduction targets, renewable energy integration, and more.

An energy audit is then performed to identify all the possible energy improvement opportunities.

Once these improvement recommendations are implemented, it will be establishe how to verify and measure the effects. The right metering and monitoring equipment will assist in the implementation of an energy management program and help ensure that these improvements are realized and sustained.

The typical energy management plan systematically addresses behavioral, operational, and technological aspects of an operation.

Organization-wide energy management training is conducted, and Key Performance Indicators (KPI) are established. These KPIs are visible at all levels of the organization with the expressed support of senior management.

These energy goals and performance would be systematically reviewed and the energy plan updated as part of a refinement/improvement strategy for long-term sustainability.

A well-defined and deployed energy management plan can be expected to result in:

- An organization that is empowered at all levels to pursue and act on energy-related initiatives.
- Optimized energy and cost reductions.
- Optimized utilization of resources applied to energy initiatives.
- Sustainability: continued success of initiatives and a thriving energy culture within the organization.

2. METHOD USED

It was conducted an energy/greenhouse gas (GHG) reduction assessment for the organisation in February 2023. The assessment was conducted using QUEST methodology (Quick Environmental Savings Technique).

This methodology relies on three pillars, People – Data – Equipment, to identify no- and low-cost improvements for energy (and thus GHG emissions). These opportunities can be implemented quickly for immediate cost savings.

The QUEST approach is different than “traditional” resource efficiency services, which typically focus on capital improvements (i.e., equipment, building technologies). No-cost / low-cost operational improvements are often missed by these approach.

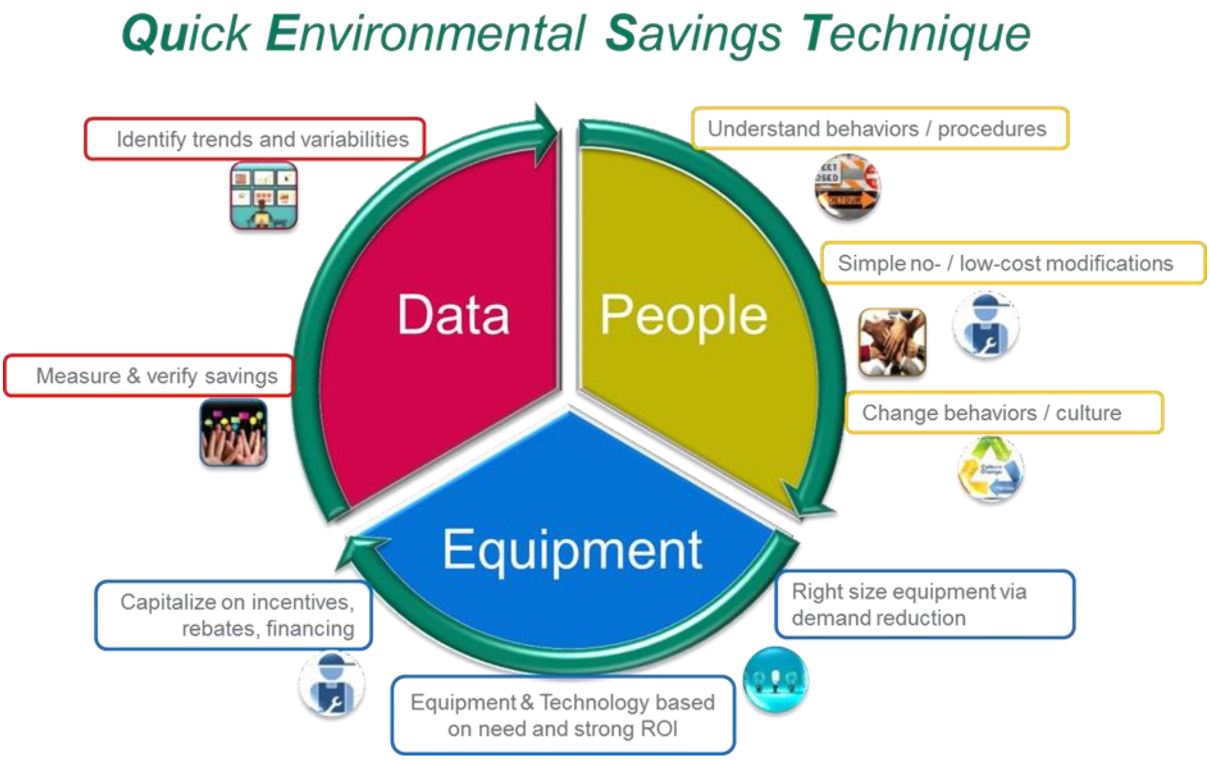

Fig. 1. QUEST methodology (Quick Environmental Savings Technique)

Using QUEST methodology, it was undertook the following:

- Reviewed and analyzed provided energy/emissions data in order to:
    - (1) understand current state, including performance variabilities
    - (2) identify focus areas for the on-site assessment
- Conducted a two-day on-site assessment to identify energy/emissions reduction opportunities, with a focus on no- and low-cost opportunities
- Developed and, where possible, quantified reduction opportunities, leveraging the provided data and the information/observations from the on-site assessment
- Prepared this report to communicate identified opportunities. The full QUEST report includes:

– This summary report, providing an overview of the facility performance and the identified opportunities

– The QUEST workbook, providing the underpinning data for the summary report

The energy audit consists of three main stages:

- Measurement of energy use across the organisation, and identification of areas of significant energy consumption.
- Identification of energy saving opportunities associated with improvement to energy efficiency or operational and behavioural change.
- Evaluation and reporting on the cost-effectiveness of opportunities identified, including setting out the costs and benefits of each energy efficiency opportunity.

Energy use comprises of a period of 12 consecutive months, using data from invoices and meter readings for the calendar year 2022.

Energy consumption units (kWh) will be used to determine the total energy consumption for the site and also identify areas of significant energy use within the facility. The ranking of the energy saving measures are based on a simple payback period (SPP) that is calculated from the capital cost estimate and the savings that will result from the implementation of the measure. Measures that will incur additional on-going costs for operation and maintenance will include those costs as part of the evaluation.

3. FACILITY ENERGY DATA AND ANALYSIS

The following data has been used to collate the energy information for the calendar year 2022:

Electricity Invoices

The site has a single point of supply for all electricity used on site which is measured by a fiscal billing meter for the MPAN 190014428734.

Copies of invoices for each month during 2022 have been obtained for the site.

Gas Invoices

The site has a single point of supply for all gas used on site which is measured and recorded by a fiscal billing meter for the MPRN 835602.

Copies of invoices for each month during 2022 have been obtained for the site.

Energy Metering on Site

In addition to the main billing meters there are a small number of sub-meters installed on the site to measure downstream energy use mostly concerned with electricity consumption.

Not all the meters are recorded by the site but there is a weekly meter reading taken for the main electricity meter, the main gas meter and for a few of the sub-meters.

The manual readings are checked and entered onto a spreadsheet that is used for monitoring the energy use metrics and is useful for checking the invoices if required to challenge any dispute.

The Building Energy Management System (BEMS) records some of the energy information but the system is old and almost obsolete, it is not used at the maximum energy monitoring potential.

Total site energy consumption has been obtained from the energy invoices for the fiscal meters for the calendar year 2022. This data was used to set the general site wide energy consumption figures and benchmark unit costs.

Sub metering data was then used to break down the overall energy consumption into different energy users to start the energy mapping of the site.

The following table provides the overall site level energy consumption data used for this audit.

Table 1. Facility Consumption Data

Resource	Unit	Latest 12 Months	Latest 12 Months Cost (EUR)	Unit Costs (EUR/Unit)
Electricity	kWh	3,279,562	€ 514,891	€ 0.16
Natural Gas	kWh	1,214,759	€ 75,315	€ 0.06

The following tables provide a breakdown of the electricity consumed on the site.

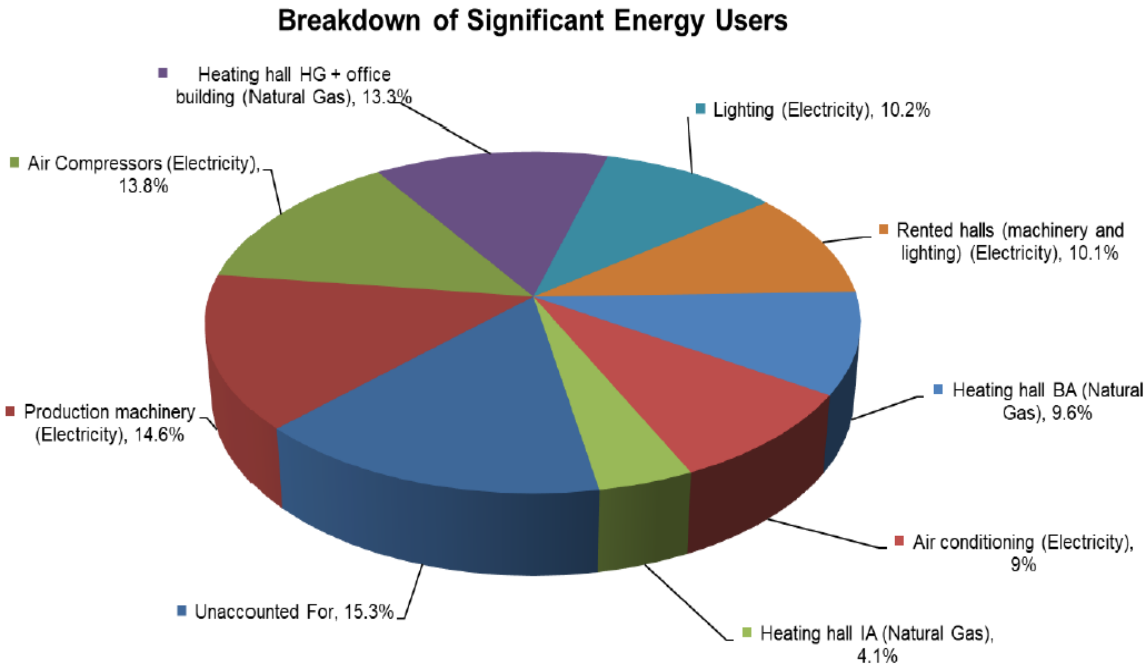

Fig. 2. Facility energy consumption

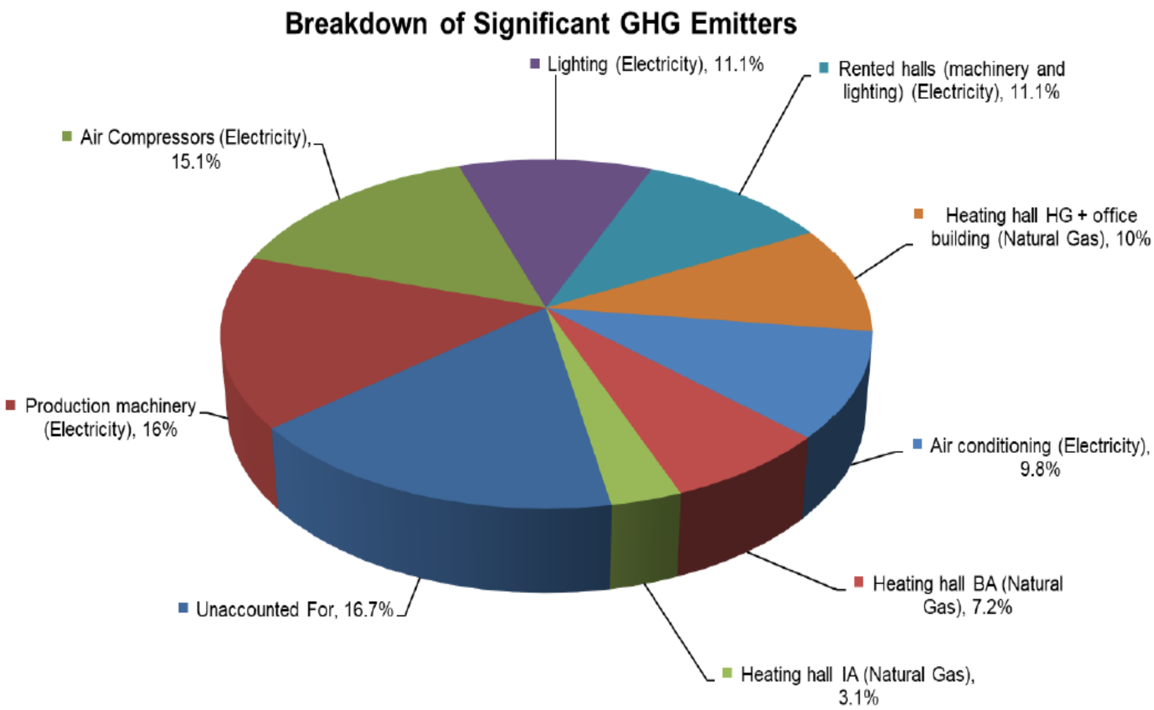

Fig. 3. Facility GHG emissions

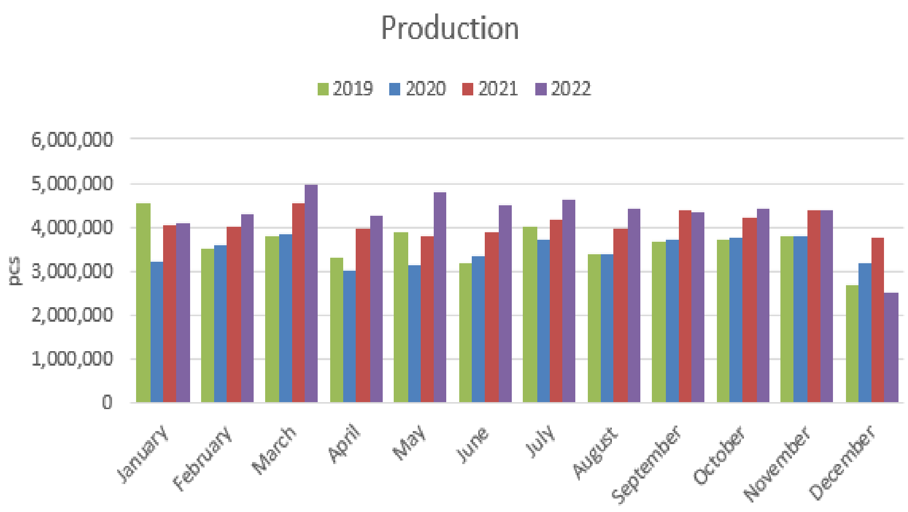

Fig. 4. Production Trend Data

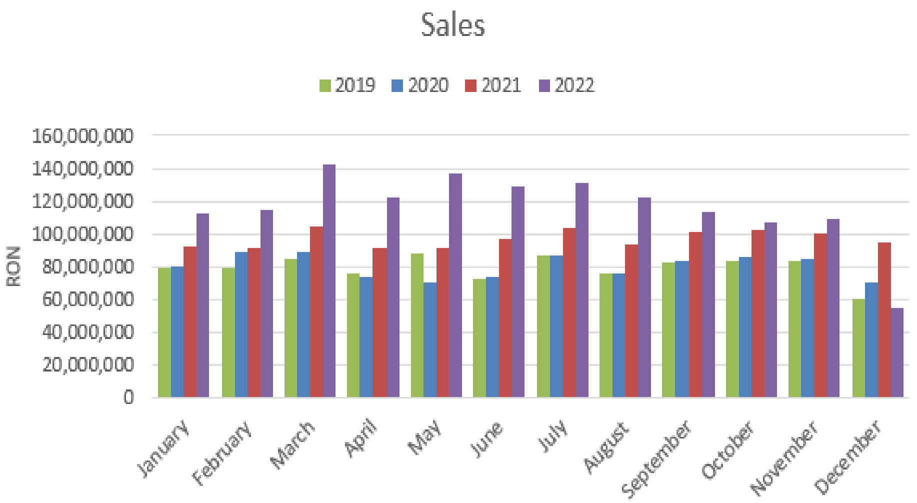

Fig. 5. Sales trend data

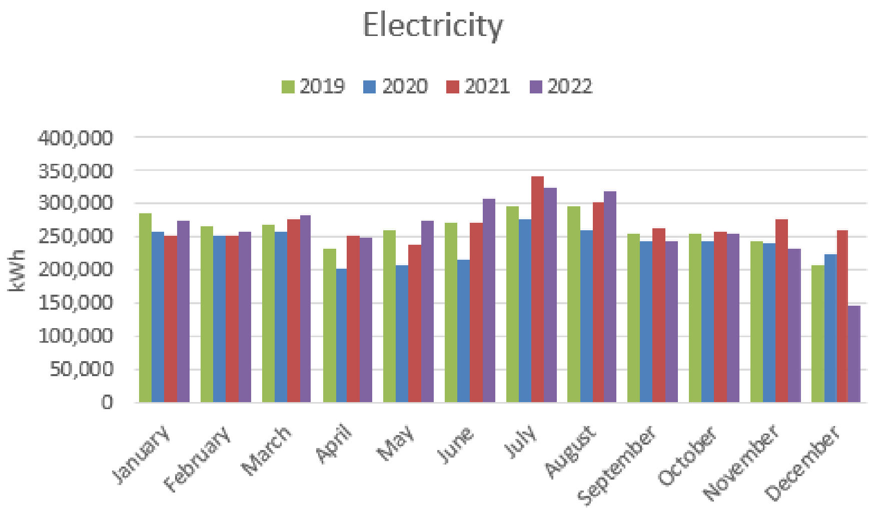

Fig. 6. Electricity trend data

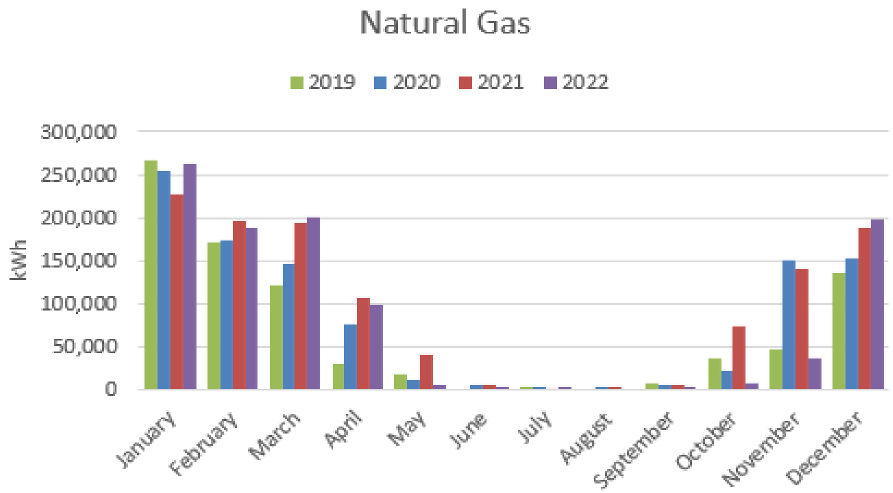

Fig. 7. Natural gas trend data

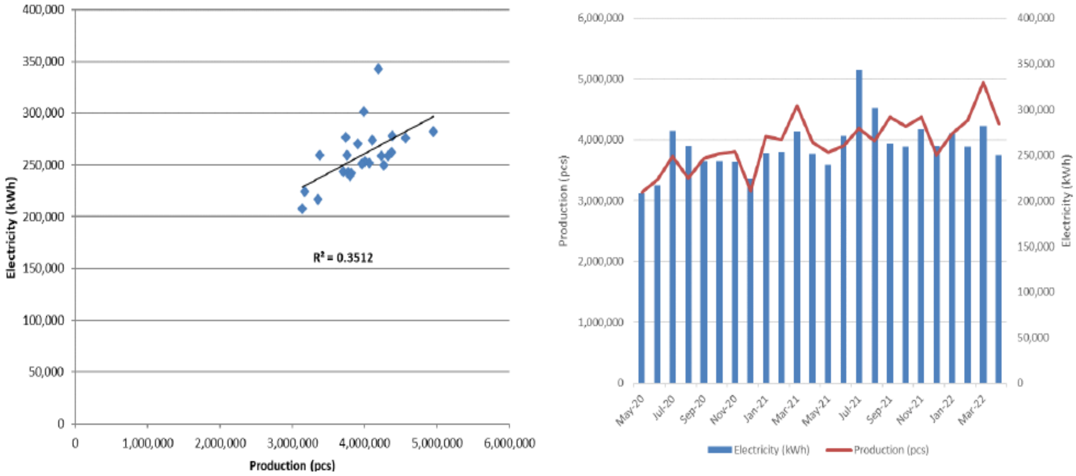

Fig. 8. Regression Observations: Electricity vs. Production

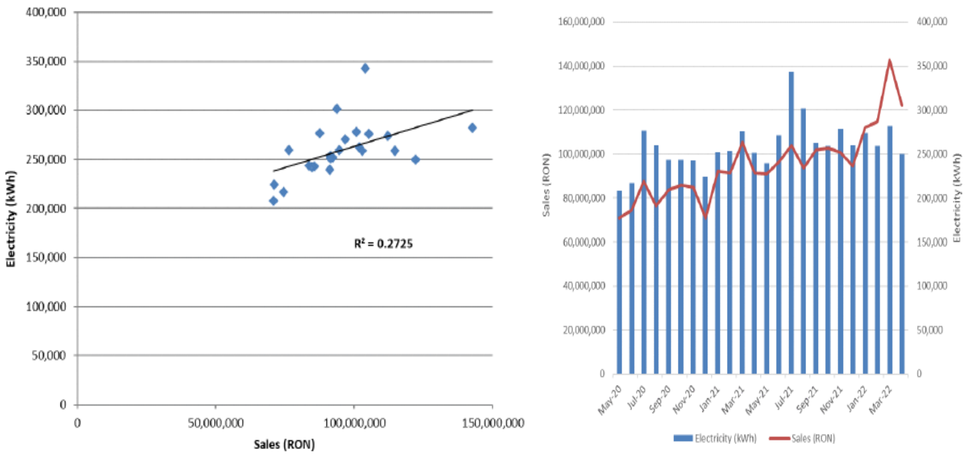

Fig. 9. Regression Observations: Electricity vs. Sales

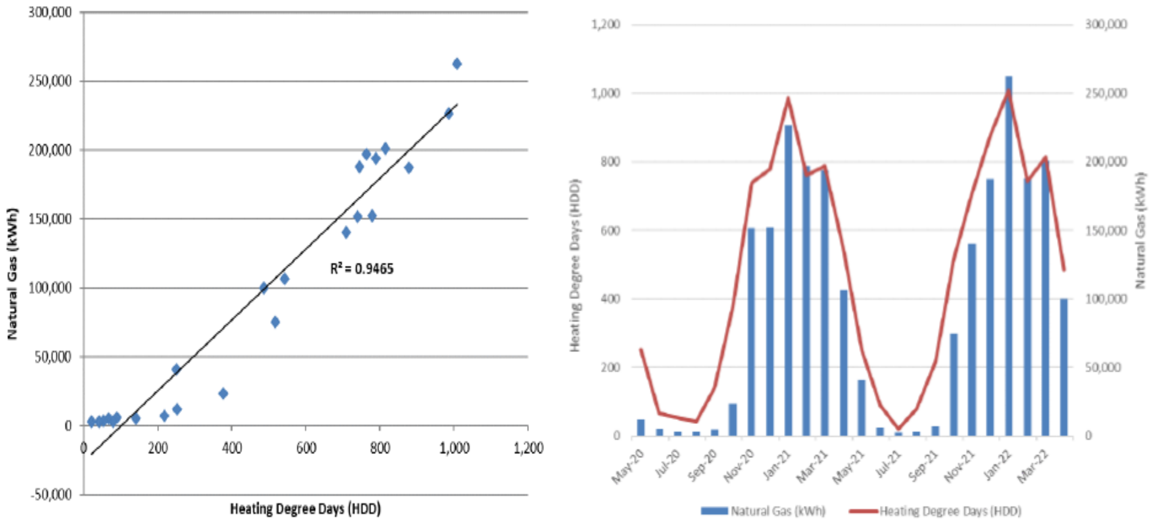

Fig. 10. Regression Observations: Natural Gas vs. Heating Degree Days

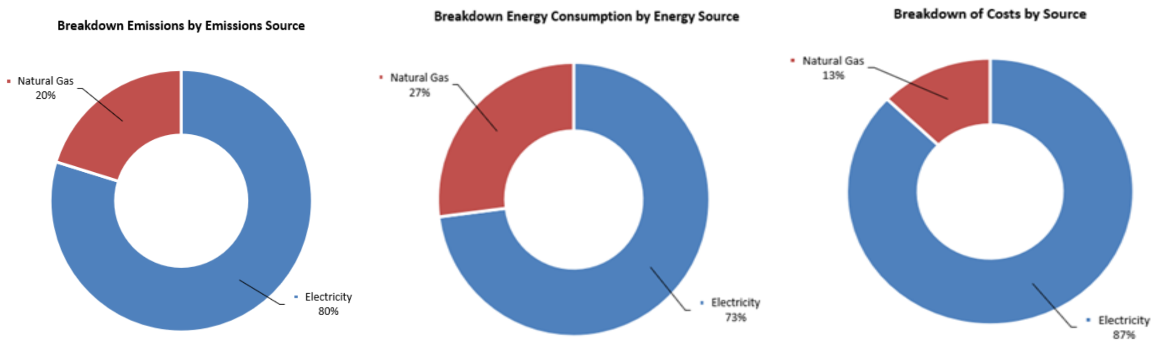

Fig. 11. Baseline emissions, energy and cost by souce

4. RESULTS. ENERGY REDUCTION OPPORTUNITIES

The energy saving opportunities identified at the organisation have been summarised in the table below.

The site survey identified energy saving opportunities relating to the consumption and cost of electricity and gas used on the site. Each of the opportunities will be described in this section of the paper with budget estimates for the cost of implementation of the measure and the time it will take to recover the cost based on the energy savings and the simple payback period. The energy savings will result in a reduction in carbon dioxide emissions that will also be included in the benefits.

The identified reduction opportunities have been sorted into 3 separate “buckets”, as follows:

Table 2. Bucket: < 2 years

Opportunity Title	**Capital Cost (EUR)**	**Financial Savings (EUR/year)**	**Payback (years)**	**Energy Reduction (kWh/year)**	**Carbon Emissions Reduction (MT CO2e/year)**
Close Gates and Windows in Air Conditioned Areas	€ 0	€ 19,023	0.0	121,166	32
Compressed Air Leak Survey and Repair	€ 10,000	€ 14,576	0.7	92,844	25
Lighting-Level Optimization	€ 7,000	€ 14,224	0.5	90,600	24
Process Water Heat Recovery	€ 2,000	€ 4,553	0.4	73,440	13
Replace Natural Gas Water Heaters with Electric Heaters	€ 840	€ 602	1.4	12,860	2

Table 3. Bucket: > 2 years

Opportunity Title	**Capital Cost (EUR)**	**Financial Savings (EUR/year)**	**Payback (years)**	**Energy Reduction (kWh/year)**	**Carbon Emissions Reduction (MT CO2e/year)**
Upgrade HVAC Systems in Production Halls	€ 603,000	€ 62,786	9.6	1,134,957	199
Building Management System	€ 710,417	€ 59,021	12.0	449,432	109
Upgrade Compressors to VSD Compressors	€ 200,000	€ 38,496	5.2	245,200	65
Air Compressor Heat Recovery	€ 80,000	€ 19,188	4.2	309,478	56
Monitoring and Targeting - Utilities	€ 95,000	€ 11,804	8.0	89,886	22
Sahara Units Water Flow Control	€ 18,000	€ 6,026	3.0	97,200	18
Install Additional Pipe Insulation	€ 10,000	€ 3,766	2.7	60,738	11
Utilize Outdoor Air for Air Compressors	€ 12,000	€ 3,297	3.6	21,000	6

Table 4. Bucket: Futher study needed

Opportunity Title	**Capital Cost (EUR)**	**Financial Savings (EUR/year)**	**Payback (years)**	**Energy Reduction (kWh/year)**	**Carbon Emissions Reduction (MT CO2e/year)**
Solar PV	€ 1,250,000	€ 272,333	4.6	0	460

Reduction Opportunities Detail

Close Gates and Windows in Air Conditioned Areas

Gates and windows in air conditioned areas are being left open, closing them will reduce energy consumption for cooling. Note that although automated doors and windows may be a pathway toward achieving this goal, a more cost effective option which is proposed is to encourage behavioural change from workers.

Compressed Air Leak Survey and Repair

Implement a regular leak survey program and repair leaks as soon as practical. Savings are based on estimated compressor system leakage of 15% of total load. Capital costs are mainly maintenance costs and possibly some engineering costs to reduce "air bleeding."

Lighting-Level Optimization

The site has done good progress in LED replacement and will continue to do so until all fluorescent lighting is replaced. However, there is further potential as lighting is generally lit on all floors during production times. It could be switched off in lines close to the windows as well as based on actual lighting need. Lighting can be reduced to safe levels (~500 lux) in production areas, especially during day/afternoon shifts, and lighting can be increased locally (~1000 lux) by means of task lighting, which is not consistently available in all areas.

Process Water Heat Recovery

Recover waste heat from process cooling water unit that is closest to the production hall to provide heat during winter months.

Replace Natural Gas Water Heaters with Electric Heaters

Replace natural gas water heaters with electric instaflow tankless water heaters at each sink in the office building.

Upgrade HVAC Systems in Production Halls

Equip each production hall with sensor-controlled cooling / heating variable refrigerant flow (VRF) systems and air handling units with heat recovery, this solution will eliminate natural gas consumption for heating and cooling and eliminate air handler rental fees.

Building Management System

A building management system, otherwise known as a building automation system, is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. Automated building systems can be programmed to operate and adapt to changing conditions in a manner which can significantly reduce building energy consumption.

Upgrade Compressors to VSD Compressors

Replacement of fixed speed compressors with variable speed drive (VSD) compressors.

During DRAFT review, the site expressed that SIGMA Air Manager (by Kaeser) is currently installed, however the paper maintains that compressors equipped with variable speed drive will offer savings over the current system arrangement.

Air Compressor Heat Recovery

Installing oil/water heat exchangers and a hot water accumulation tank will allow the recovery waste heat from 8 air compressors on-site, thereby reducing boiler natural gas consumption.

Monitoring and Targeting – Utilities

Relate energy consumption data to the weather and/or production figures or other measures in such a way to obtain a better understanding of how energy is being used. In particular, make the energy consumption visible to enable operations personnel to compare consumption in real time with a target to prompt looking for signs of avoidable waste or other opportunities to reduce consumption.

Sahara Units Water Flow Control

Install temperature sensors in every heater zone and equip Sahara water air heaters with 3 way mixing valves and programmable setback controllers.

Install Additional Pipe Insulation

Install additional pipe insulation where it is not present on heated pipes, especially in the boiler rooms and other supporting facilities.

Utilize Outdoor Air for Air Compressors

Utilize outdoor air for air compressor input to reduce air compressor energy consumption.

Solar PV

Use available roof area (and other areas if able) to add solar photovoltaic (PV) panels for on-site renewable electricity production.

5. CONCLUSION

From the analyzes carried out, it emerges that the organisation has an efficient energy management system, which is also validated by the ISO 50001 certification (standard for the energy management system).

I will further present the conclusions and energy efficiency improvements obtained for the respective economic agent.

Regarding the consumption of electricity, it can be seen that it is used at appropriate yields, the quality parameters are in accordance with the regulations in force and also there is a degree of ensuring the continuity of supply of almost 100%, considering the existence of the electric generator , AAR automation and the existence of UPS uninterruptible power supplies.

The energy saving opportunity is equivalent to 529,696 euro per annum, which is 48% of expenditure on electricity and gas in 2022. The investment required to realise these savings is estimated at approximately 2,998,257 euro. However, it is to be noted that there is a wide spread of payback periods, with a number of opportunities paying back within a few months, and a number of opportunities having paybacks significantly longer than currently acceptable thresholds. Should the site wish to proceed with any of the projects identified, then those opportunities would require further development to provide a full engineering solution and verifiable savings.

By implementing these energy optimization solutions, the following results were obtained:

Table 5. Opportunities summary table

Bucket	Capital Cost (EUR)	Financial Savings (EUR/year)	Payback (years)	Energy Reduction (kWh/year)	Percent Site Energy Reduction	Carbon Emissions Reduction (MT CO2e/year)	Percent Site Carbon Emissions Reduction
≤ 2 years	€ 19,840	€ 52,979	0.4	390,909	9%	96	9%
> 2 years	€ 1,728,417	€ 204,384	8.5	2,407,892	54%	485	45%
Further Study Needed	€ 1,250,000	€ 272,333	4.6	0	0%	460	42%
Grand Total	€ 2,998,257	€ 529,696	5.7	2,798,801	62%	1,041	96%

REFERENCES

[1] Allouhi, A.; El Fouih, Y.; Kousksou, T.; Jamil, A.; Zeraouli, Y.; Mourad, Y. *Energy consumption and efficiency in buildings: Current status and future trends*. J. Clean. Prod, 109, pp. 118–130, 2015.

[2] Pérez-Lombard, L.; Ortiz, J.; Pout, C. *A review on buildings energy consumption information.* Energy Build., 40, pp. 394–398, 2008.

[3] Poel, B.; van Cruchten, G.; Balaras, C. *Energy performance assessment of existing buildings*. Energy Build., 39, pp. 393–403, 2007.

[4] Batey, M.; Mourik, R. *From calculated to real energy savings performance evaluation: An ICT-based methodology to enable meaningful do-it-yourself data collection*. Energy Effic., 9, pp. 939–950, 2016.

[5] Bonan J., Cattaneo C., d'Adda G., Tavoni M. *Combining information on others' energy usage and their approval of energy conservation promotes energy saving behaviour*, Nature Energy, 5(11), pp. 832-833, 2020.

[6] Cagno E., Worrell E., Trianni A., Pugliese G. *A novel approach for barriers to industrial energy efficiency*, Renewable and Sustainable Energy Reviews, 19, pp. 290-308, 2013.

[7] Fawzy, S.; Osman, A.I., Doran, J.; Rooney, D.W. *Strategies for mitigation of climate change: a review*, Environmental Chemistry Letters, 18: pp. 2069–2094, 2020.

[8] Moriarty, P.; Honnery, D. *Energy Efficiency or Conservation for Mitigating Climate Change?*, Energies, 12(18):3543, 2019.

[9] Gary P. Moynihan and Frank L. Barringer *Energy Efficiency in Manufacturing Facilities: Assessment, Analysis and Implementation*. Published: January 18th 2017.

[10] Jensen R. John, Prentice –Hall, Inc,: Upper Saddle River, N.J, 2007 xvl, and 592, pp. *Remote Sensing of the Environment : An earth Resource*, 2007.