

Energy efficiency in industry: The impact of the energy performance of equipment on the profitability of an energy-intensive company

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Received: 26/10/ 2024

Accepted: 02/10/2024

Published: 01/12/2024

Abstract: The industrial sector, a strong link in the Algerian economy, is subject to audit and control measures for energy-intensive industrial equipment. Measuring the energy performance of equipment is therefore essential to be able to identify sources of inefficiency. Through our study, we attempted to evaluate the impact of technology on energy consumption, through an econometric and financial study. A descriptive approach of the conceptual framework of the research components such as (Energy efficiency, energy savings, and technology) will be applied. In addition, a deductive and quantitative approach will be adopted allowing for an in-depth content analysis of the key concepts by making a simulation with the EVIEWS 10 software. The results of our study highlighted a significant impact of technological progress in equipment on the reduction of consumption and the increase in production. This ensures long-term profitability for industries.

Keywords: Energy efficiency, Energy performance, Industry, Technology, Profitability.

JEL codes: C1; Q4

Citation: ZOUAI, C.; BOUDAUD, A., (2024), Energy efficiency in industry: The impact of the energy performance of equipment on the profitability of an energy-intensive company, *Journal of economics studies and researches in renewable energies*, 11(2). 156-173

I-Introduction:

The increasing energy demand due to population growth and economic development has intensified the challenges of energy resources: challenges in terms of security of supply, price, and the environment. It is essential for any company to understand its energy consumption and efficiency in order to achieve better performance (ADEME, 2014). Today, Algeria's energy needs are mainly met by hydrocarbons, particularly natural gas. It is therefore essential to use renewable energies, which are an integral part of the long-term energy supply strategy, while placing a particular focus on energy savings and energy efficiency in order to move towards energy transition. The need for energy is accelerating the depletion of fossil fuel resources, particularly in the industrial sector, which is a major consumer of energy and a major source of greenhouse gas (GHG) emissions, the main causes of environmental problems. Indeed, industry poses a challenge for energy management because its energy

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consumption is likely to increase. Rising energy costs and international competition require an improvement in energy performance within industrial companies to gain competitiveness.

Aware of these risks, large industrialists continue to invest in initiatives to improve energy efficiency. This efficiency can be achieved through improved energy management and the introduction of new high-energy-performance uses using low-carbon energy sources. Therefore, when making an investment, the selection of a technology will be influenced by various technical and economic factors, such as energy efficiency, quality, productivity, and flexibility. Often, the use of high-performance techniques involves a higher investment cost, but it also contributes to an improvement in energy efficiency.

These reflections lead us to formulate our research question: What is the impact of the energy performance of industrial equipment on the profitability of an energy-intensive company? The objective of the study is to analyze the energy performance of equipment (technological change) and its impact on ammonia production and natural gas consumption. The objective of this research is to present an analysis of the conditions for the introduction of energy performance in Algeria, and more particularly in the industrial sector because of its consideration as the cornerstone of the energy transition.

II- Background of the study:

1- Energy Performance in Industry:

This section deals with the topic of energy performance in the industrial sector. It is therefore essential to present the definitions of the various concepts related to the energy performance policy in the industrial sector, namely development, technological performance, and energy efficiency policy. Subsequently, we will present the various tools currently used to promote energy efficiency in the industrial sector in order to highlight the strong link between the energy performance of equipment in industries and the long-term profitability of the company.

1-1 Energy Savings:

The topic of energy savings affects our daily lives as well as our future prospects, given that energy is a rare and precious commodity. Energy is essential for carrying out materialized work, we can find it in different forms: (in the form of heat, electricity, chemical energy, etc.). Currently, we use different energy sources such as fossil fuels (coal, oil, gas), nuclear energy (uranium), as well as renewable energies (wind, solar, biomass, hydraulic, etc.). Therefore, energy savings include energy sobriety and energy efficiency behaviors, which aim to reduce energy consumption or prevent losses on the energy produced. Energy savings can be achieved in industry by improving processes (GUELLIL, 2016).

The different methods for achieving energy savings include:

- The elimination or limitation of a consuming activity, in particular through behavioral changes (this is energy sobriety);
- Reducing the consumption of a given activity for an equivalent service, thanks in particular to technical advances (we aim for energy efficiency);

- Improving industrial production processes.

1-2 Sustainable Development:

We cannot carry out an energy savings study without talking about the concept of sustainable development. Sustainable development according to the 1987 Brundtland Report (Brundtland, 1987) is development that meets the needs of the present generations without compromising those of future generations. Sustainable development has therefore emerged in response to a worrying global situation: fragility of ecosystems and natural resources, imbalance between extreme poverty and wealth, climate change. Due to its speed and complexity, climate change is a major political, strategic and security challenge (DJE, 2013). As early as 1974, the concept of energy performance was found with the notion of energy saving, which refers to the reduction of energy waste, that is to say the ability to reduce the use of energy by reducing greenhouse gas emissions, which, of course, contributes to slowing down or eliminating the problem of climate change (Bourque, 2000).

1-3 the relationship between Energy Efficiency and Energy Performance:

a. Energy Efficiency:

Energy efficiency can be defined as the rational use of energy resources to reduce consumption while increasing benefits. This implies reducing heating costs while preserving thermal comfort, and reducing electricity consumption by choosing less energy-consuming but more efficient appliances and installations (LISOLATION.FR, 2019). According to Afnor, energy efficiency refers to the relationship between the results, service, goods or energy obtained and the energy used to achieve (Afnor, 2013). There are different definitions of energy efficiency, which generally refers to a more efficient use of available energy. There is an increase in energy efficiency while using fewer resources to obtain the same service. This contributes to reducing the impact on the environment, which is particularly manifested by a reduction in greenhouse gas emissions.

b. Energy Performance Definition:

These are measured results of energy consumption for a company, building, facility, or product. In energy management systems, it's possible to measure these results based on the company's energy policy, energy objectives, and energy targets (Issor, 2017).

- So the goal of energy performance is to improve thermal comfort by optimizing the annual use of consumed energy. The performance of a boiler, heat pump or technical equipment is evaluated based on energy efficiency. Energy performance is related to annual consumption, primary energy, final energy and energy bills (XPAIR, 2019). In the concept of energy performance, it is noted that there is a complementary link between energy performance and energy efficiency, which has been discussed extensively to achieve energy savings.

The word "efficiency" takes on its full meaning in various practices that focus on:

- **Technological aspects:** The use of high-performance equipment and processes can optimize energy consumption and improve services and living conditions. In addition, the use of appropriate and adapted materials and methods improves energy performance and avoids energy losses.

In Algeria, the Ministry of Energy has launched a program to finance energy management projects in industries to encourage them to invest in energy efficiency and the acquisition of new energy-efficient equipment.

In general, the relationship between the service offered as a whole (performance, product, energy, comfort, service) and the energy used can be defined as energy efficiency. Ultimately, energy efficiency includes both optimizing the energy efficiency of installations and equipment and energy sobriety (EuroGROUP-consulting, 2010). Energy efficiency solutions aim to:

- Improve the performance delivered with lower energy consumption;
- Reduce or slow down the depletion of natural resources;
- Minimize the ecological footprint of energy use, particularly concerning greenhouse gas emissions (DJE, 2013).

1-4 Technological Performance: The term technology revolves around the knowledge and practices concerning an industrial technique (linternaute, 2019). Technological performance can be defined by the definitions of these two terms: technological innovation and technical progress.

- **What is Technological Innovation?** Innovation consists of a set of processes that create or improve products, techniques, or services for an organization or company (Thompson, 1965).
- **What is Technical Progress?** Technical progress can be defined as all the elements that favour the improvement of production methods and productivity, or as all kinds of innovations that have a beneficial effect on production (Debitoor, 2012). It is also part of various forms of innovation, such as creating an innovative product, adopting a new method of production organization, or opening new markets. Technical progress is directly linked to innovations.
- **The Energy Performance of Industrial Equipment:** For several decades, the industrial sector has already made significant progress in reducing its energy consumption, particularly thanks to technical progress and technological innovations.

1-5 Energy Use in the Industrial Sector:

When we talk about industry, we talk about the production of steam, cold, and compressed gas to supply processes, consequently consuming gas or electricity. A large part of the internal energy management program should involve motivating and training personnel, and an effective energy management approach includes both the management techniques described above and appropriate technical measures on site. Regarding energy-intensive equipment in an industry, they can be classified into two main categories: support processes

and production processes. Three uses are particularly energy-intensive among the most significant energy consumptions in the industry: heating installations (furnaces, dryers...), industrial motors, and industry-specific processes (robots...) (Mallier, 2021).

The types of energy efficiency measures differ among industrial companies based on the function, size, and type of production, which in turn affects the relationship between the degree of support and production processes. In addition to consumption audits, it is possible to understand the uses of energy in the industry, as well as the processes and devices directly linked to energy in a factory. The way energy is used in factories is a key parameter for defining the energy efficiency potential of the industry.

a-The Impact of Rising Energy Prices on the Industry: In the industrial sector, the increase in natural gas prices leads to difficulties for companies that use this fuel to produce chemicals or fertilizers (Pescatori, Stuermer, & Valckx, 2021). Above all, it is essential to credibly communicate the rise in energy prices so that industries can incorporate it into their calculations and reorient their consumption and production decisions. As in the case of a price increase, companies have the option to react by raising the price of their products (Bureau, Fontagné, & Martin, 2013). Industrialists are affected by these energy price increases because their consumption is strongly linked to their productivity. Industrialists need to consume to produce.

b- Acquiring Less Energy-Intensive Technological Equipment is Costly: Technology can be relatively affordable or extremely expensive. Therefore, financing technology can play an essential role in its implementation. Ultimately, the use of technology could reduce expenses and increase efficiency and productivity. However, in the short term, acquiring and implementing technology can lead to significant increases in expenditures. The first step of a project generally involves defining the need for new technology. Once a company has decided to acquire new technology, the next step is to select the most cost-effective available technical solutions. Before making a decision, it is crucial to consider all potential expenses and savings to determine if the new technology is feasible. Sustainability is also of paramount importance. Unless there are exceptional circumstances, it is expected that a technology used for an upcoming election will also be beneficial for future elections (project, 2024).

c- Ensuring Company Profitability: With increased energy management, projects and action plans become profitable, which reduces expenses and improves operating accounts. The profitability of the company is positively influenced by these direct benefits. To control energy costs, it is necessary to improve the analysis and control of processes. It is possible to optimize the entire value chain of the company, resulting in an overall improvement in the company's productivity. To ensure its long-term competitiveness, it is essential to reduce emissions by lowering energy consumption. This guarantees long-term competitiveness (ATEE, 2012). The reduction in the energy bill will be used to repay the project. After a period of 2 to 5 years, the energy savings will be entirely returned to the industry (Ademe, 2012).

- Ensuring Return on Investment through Energy Savings: The industry represents a significant challenge in terms of energy efficiency potential. The industry is more responsive to price signals, and cost-effective solutions with a payback period of less than three years will be quickly implemented. Unit energy-saving measures can be significant and lead to savings of several GWh of energy each year.

d- The National Program for Energy Management in the Industrial Sector: The Algerian national energy management program and public energy transition policies aim to encourage industrialists to adopt a more ecological approach to their energy consumption. According to (APRUE, L'efficacité énergétique dans l'industrie, 2019), there will be savings of more than 34 million TOE in this sector by 2030. The program aims to reduce the overconsumption of industrial processes and covers between 100 and 300 projects per year. The state contributes between 10 and 30% depending on the project, adding up to a cumulative state contribution until 2030 of 26 billion DA, or 291 million USD (APRUE, L'efficacité énergétique dans l'industrie, 2019). To improve energy efficiency, the state has emphasized the generalization of internal and external energy audits, as well as the control of industrial processes, to identify significant energy-saving sources and recommend corrective measures.

- **Energy Audit:** The energy audit is an integral part of a program aimed at improving energy efficiency. It involves a thorough analysis of a company's energy consumption to promote the rational use of energy. The primary objective of such an audit is to thoroughly examine the operating expenses of the facility. In most cases, energy data is evaluated over several years to determine energy consumption profiles, particularly power peaks (Krarti & Marchio, 2016).

- **An Energy Management System:** In the current economic, energy, and environmental context, energy performance is an essential and strategic objective for companies. It helps reduce expenses related to energy and other associated environmental consequences. The NF EN ISO 50001 standard aims to help all organizations implement a systematic energy management approach to improve their energy performance and achieve gains (IEA, 2012).

- In conclusion, we can say that all these policies, along with measurement techniques and the replacement of industrial equipment with more energy-efficient ones, can achieve significant profitability for energy-intensive companies.

2- Analysis of the Impact of Technology on Natural Gas Consumption at the Industrial Company Ferial of Oran:

FERTIAL is an Algerian-Spanish company that produces and markets ammonia and nitrogen fertilizers, located in Oran. Aware of the challenges and importance of managing and controlling energy risks, it is committed to continuous improvement by implementing energy efficiency programs in its ammonia production units. We have noticed that gas is the most consumed energy in the "Ammonia 1" unit and throughout the plant, which led us to conduct a simulation with the EVIEWS 10 software. The objective of our study is to analyze the energy performance of the equipment (technological change) and its impact on ammonia production as well as natural gas consumption. The second stage of our study involves forecasting ammonia production in the coming years relative to gas consumption and its cost.

One component of ammonia is gas, and the installations also operate with gas, so its consumption will be homogeneous with ammonia production if there are no disruptions regarding energy losses and gas price increases. After obtaining the results, we will determine whether the change to more efficient equipment will actually increase production in the long term, which would be a significant result for FERTIAL or not.

2-1 The Technical Approach:

Percebois and Hansen mentioned in their book (Jean Pierre Hansen, 2015), that the production process always involves energy consumption by user equipment, which is why it is essential to examine the complementarity and substitutability relationships that link the capital factor, the labor factor, and the energy factor.

This is the purpose of the manufacturing function. Understanding these relationships implies predicting how energy demand will evolve based on economic growth prospects.

2-2 The Share of Energy in the Production Function:

The main production factors (capital: K, labour: L, energy: E, non-energy raw materials: M) can be combined in varying proportions over time and space, under the influence of technical progress and according to the relative price levels of each. Some production functions assume strict complementarity between K, L, E, and M, while others allow for strong substitutability between these factors. It all depends on the time horizon considered: if some substitution is conceivable in the medium and long term, the room for manoeuvre seems much smaller in the short term, and complementarity relationships then seem to prevail (the choice of equipment implies the choice of energy). There are practically three main types of production functions:

"**Putty-putty**" functions allow for ex-ante and ex-post substitutability between the various factors. Factor substitutions are assumed to be able to occur before and after investments have been made. The prototype is the Cobb-Douglas function of the type (Jean Pierre Hansen, 2015):

$$Y = A K^{\alpha} L^{\beta} E^{\gamma}$$

We took an example from Régis Bourbonnais in his econometrics book (Bourbonnais, 2015), on an estimate of a Cobb-Douglas production function in another way:

Let a Cobb-Douglas production function:

The model in its initial form is written as:

$$Q = a_0 K^{\alpha_1} L^{\alpha_2} e_{\varepsilon}$$

Q is the production; K is capital factor; L is labor factor; ε_t is error term meeting classical assumptions.

The coefficient is interpreted as elasticity:

α_1 is elasticity of production to the capital factor; α_2 is elasticity of production to the labor factor.

This is a linear model on its coefficients, that is to say, nonlinear in its initial form but linearizable by a simple logarithmic transformation, the model is log-linear:

$$\text{Log } Q_t = \text{Log } a_0 + a_1 \text{Log } K_t + a_2 \text{Log } L_t + \varepsilon_t$$

We have an ammonia production that depends on an energy source, which is gas, taking into account the cost of gas as well, for the period from 2012 to 2019, after which we will make a forecast up to 2025. According to our formula:

$$\text{Log } Q_t = \text{Log } a_0 + a_1 \text{Log } K_t + a_2 \text{Log } L_t + \varepsilon_t$$

Q_t : represents the production of Ammonia in Tons (T)

K_t : represents the value of gas in Algerian Dinar (DA) (the value represents the cost of gas consumed, and we can consider it as the price of gas because an increase in the gas price will affect the cost of gas consumed)

L_t : represents the amount of gas consumption in cubic meters (Cm^3).

ε_t : error term meeting classical assumptions.

a_1 = elasticity of production with respect to factor K

a_2 = elasticity of production with respect to factor L

Constraint: $a_1 + a_2 = 1$; significance level $\alpha = 0.05$

- **Note:** We chose the Cobb-Douglas function because there is substitutability or complementarity between energy and production in the medium and long term. Over the long term, energy becomes a factor that enters into the labor factor 'L' because the two substitute in complementarity." In our case, we will propose a dummy variable "DUM" that simulates the state of technological contribution to production, in relation to the change in technological equipment from the investment between 2015 and 2016.

{DUM=0, signifies absence of technology (before investment).

{DUM=1, signifies presence of technology (after investment).

2-3 The estimation results are:

Table 1: Extract of FERTIAL data

Years	Quantities of Gas Consumption (Cm^3)	Values of Gas (DA)	Ammoniac Production (T)
2012	328 270,097	757 716 193,430	245 666
2013	248 287,319	615 781 355,690	184 300
2014	224 736,597	693 042 718,300	158 947
2015	189 481,633	584 636 406,220	146 678
2016	201 207,095	792 396 850,600	135 302
2017	311 838,481	1 331 586 002,710	269 494
2018	322 298,083	1 501 100 142,580	265 353
2019	372 491,392	1 877 419 939,400	331 312

Source: prepared by the authors

We add to our equation: the equation $\text{Log } Q_t = \text{Log } a_0 + a_1 \text{Log } K_t + a_2 \text{Log } L_t + \varepsilon_t$

The following variables: DUM, Log (L)*DUM et log(K)* DUM

The production function becomes:

$$\text{Log } Q_t = \text{Log } a_0 + a_1 \text{Log } K_t + a_2 \text{Log } L_t + a_3 \text{DUM} + a_4 \text{Log (L)*DUM} + a_5 \text{log(K)* DUM} + \varepsilon_t$$

• Interpretation of Results:

Table 2: Extract of production data, labor factor, capital factor, and dummy variable

Years	Log (L)	Log (K)	Log (Q)	DUM	DUM*Log (L)	DUM*Log (K)
2012	5,51623132	8,87950657	5,39034506	0	0	0
2013	5,39495454	8,6993465	5,26552534	0	0	0
2014	5,3516738	8,80201344	5,20125234	0	0	0
2015	5,27756712	8,65426514	5,16636498	0	0	0
2016	5,30364329	8,91837891	5,13130422	0	0	0
2017	5,49392971	9,36923187	5,4305491	1	5,493929706	9,369231874
2018	5,50825772	9,47331276	5,423824	1	5,508257722	9,473312764
2019	5,57111624	9,06555629	5,52023717	1	5,571116241	9,065556292

Source: prepared by the authors

Firstly, we estimate: $\text{Log (Q)} = \text{Log } a_0 + a_1 \text{Log (K)} + a_2 \text{Log (L)} + \varepsilon$

Table 3: regression equation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_L	1.225234	0.146530	8.361646	0.0004
LOG_K	0.033105	0.053416	0.619746	0.5626
C	-1.630746	0.610246	-2.672278	0.0442
R-squared	0.963258	Mean dependent var		5.316175
Adjusted R-squared	0.948561	S.D. dependent var		0.143530
S.E. of regression	0.032553	Akaike info criterion		-3.731922
Sum squared resid	0.005298	Schwarz criterion		-3.702131
Log likelihood	17.92769	Hannan-Quinn criter.		-3.932847
F-statistic	65.54232	Durbin-Watson stat		2.831776
Prob(F-statistic)	0.000259			

Source: Eviews output

According to the model, we have:

Included observations = 8

The variable LOG(L) is statistically significant but Log (K) is not.

(Critical probabilities > 0.05).

There is complementarily between:

- Gas consumption and ammonia production.
- Gas cost and ammonia production.

We will estimate our formula :

$$\text{Log (Q)} = \text{Log } a_0 + a_1 \text{Log (K)} + a_2 \text{Log (L)} + b_0 \text{DUM} + b_1 \text{DUM} \times \text{Log (K)} + b_2 \text{DUM} \times \text{Log(L)} + \varepsilon$$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_L	1.137197	0.087173	13.04533	0.0058
LOG_K	-0.193004	0.072310	-2.669110	0.1164
DUM_LOG_K	0.047329	0.144273	0.328053	0.7740
DUM_LOG_L	-0.548361	0.650086	-0.843520	0.4877
DUM	2.738185	4.687136	0.584191	0.6182
C	0.822200	0.646822	1.271138	0.3315
R-squared	0.996722	Mean dependent var	5.316175	
Adjusted R-squared	0.988527	S.D. dependent var	0.143530	
S.E. of regression	0.015374	Akaike info criterion	-5.398582	
Sum squared resid	0.000473	Schwarz criterion	-5.339001	
Log likelihood	27.59433	Hannan-Quinn criter.	-5.800433	
F-statistic	121.6228	Durbin-Watson stat	2.364356	
Prob(F-statistic)	0.008175			

After estimating the theoretical Cobb-Douglas model, using gas consumption in cm³ as the labor variable 'L' and labor-related cost as the capital 'K', we noticed that the model is not significant.

The variables LOG(K), DUMLOG(L), and DUMLOG(K) are not significant (Critical probabilities > 0.05), prompting us to re-estimate the model without the least significant variable. We begin by removing the least significant variable from the model. The new estimation is as follows:

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_K	-0.101779	0.045399	-2.241866	0.0884
LOG_L	1.072832	0.086724	12.37063	0.0002
DUM	0.112401	0.029797	3.772288	0.0196
C	0.365836	0.618281	0.591698	0.5859
R-squared	0.991938	Mean dependent var	5.316175	
Adjusted R-squared	0.985892	S.D. dependent var	0.143530	
S.E. of regression	0.017048	Akaike info criterion	-4.998705	
Sum squared resid	0.001163	Schwarz criterion	-4.958984	
Log likelihood	23.99482	Hannan-Quinn criter.	-5.266605	
F-statistic	164.0563	Durbin-Watson stat	3.022036	
Prob(F-statistic)	0.000122			

The variables are now almost significant. The constant 'a₀', although statistically insignificant ($P = 0.58 > \alpha = 0.05$), is accepted because theoretically, according to the Cobb-Douglas function, it should exist.

The factor 'Log K', although statistically insignificant ($P = 0.0884 > \alpha = 0.05$), is included in the estimation because it is close to $\alpha = 0.05$. Generally, we consider it significant because prices have been disrupted over the years, with prices increasing in 2019 three times more than in 2012. We observe that consumption contributes more to production.

Log (L) is significant ($P = 0.0002 < \alpha = 0.05$).

We note that the dummy variable DUM is significant and explanatory: therefore, there is a significant difference between the period before investment and after investment. For the period before investments, the production function is written as: **(DUM = 0)**

Log (Q) = 0.36 + 1.07 Log (L) - 0.1 Log (K) + e

For the period after investments, the production function is written as: **(DUM = 1):**

Log (Q) = 0.36 + 1.07 Log (L) + 0.1 Log (K) + 0.11 DUM + e

The model is globally significant with an $\bar{R}^2 = 0.98$, and all OLS assumptions are satisfied. The residuals exhibit stable behavior around a zero mean, without outliers, indicating that the data are well-behaved (see following graph):

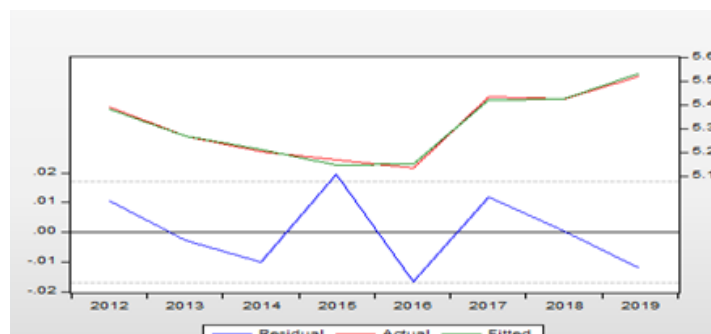


Figure 1: Model residuals

Source: prepared by the authors

- Autocorrelation of errors can be observed for several reasons:

- The absence of an important explanatory variable whose residual explanation would 'whiten' the errors.
- Incorrect model specification, where relationships between the dependent variable and explanatory variables are non-linear and expressed differently than in the estimated model.

- Correlogram :

Autocorrelation	Partial Correlation	AC	PAC	Q-Stat	Prob
1	0.281	0.281	0.9028	0.342	
2	-0.492	-0.619	4.1240	0.127	
3	-0.527	-0.228	8.5754	0.036	
4	0.019	-0.010	8.5823	0.072	
5	0.174	-0.398	9.3897	0.094	
6	0.046	-0.123	9.4760	0.149	
7	-0.001	-0.050	9.4761	0.220	

The peaks are within the confidence interval, there is no autocorrelation. Heteroscedasticity: Breusch-Pagan-Godfrey test for heteroscedasticity: Shows a probability ($P = 0.4385 > \alpha = 0.05$), hence we cannot reject H_0 . We conclude that there is no heteroscedasticity. The heteroscedasticity test (White) confirms the previous result, with: $P = 0.4404 > \alpha = 0.05$, hence we cannot reject H_0 . Normality: The Jarque-Bera normality test shows: $P = 0.62 > \alpha = 0.05$ (therefore, we cannot reject the normality of the Residual distribution).

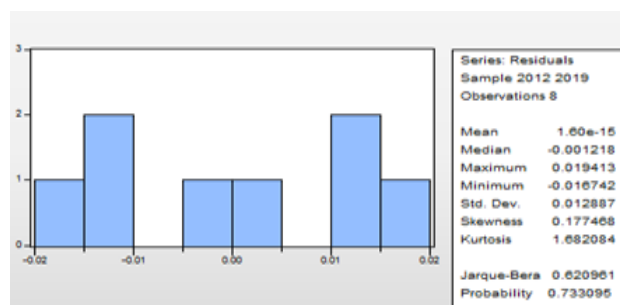


Figure 2: Normality

Source: prepared by the authors

We conclude that the residual process is Gaussian white noise:

$$e_i \xrightarrow{i.i.d} N(0, \sigma_e^2)$$

Based on the achieved results, we observed that the model is significant. Therefore, we notice that there is a difference between the years before investment and after investment. Thus, the model is valid and of good predictive quality, prompting us to calculate forecasts.

Forecasts: According to the validated model, we will make forecasts for the next 10 years, estimating the volume of production based on consumption and gas prices up to 2025. We will make a forecast using exponential smoothing.

Table 3: Production forecasts

	LOG_PROD...	LOG_PROD...
2012	5.390345	5.380074
2013	5.265525	5.322067
2014	5.201252	5.191465
2015	5.166365	5.134043
2016	5.131304	5.076891
2017	5.430549	5.104711
2018	5.423824	5.495293
2019	5.520237	5.518887
2020	NA	5.622509
2021	NA	5.714493
2022	NA	5.806476
2023	NA	5.898460
2024	NA	5.990443
2025	NA	6.082426

Source: prepared by the authors

This table presents forecasts for ammonia production by 2025.

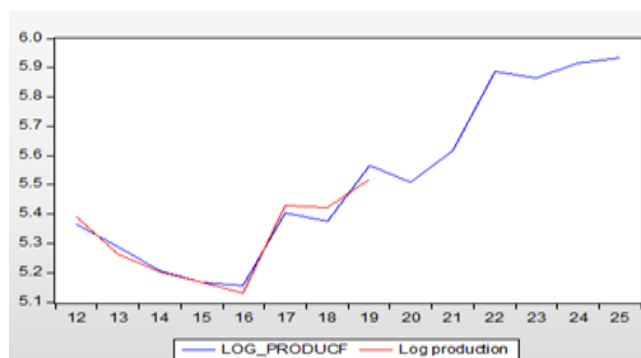


Figure 3: Forecast of production between log (production) and log (production_a)

Source: prepared by the authors

According to the forecast graph, production will increase gradually, with a slight decline in 2020, but it quickly recovers afterward. This justifies that upgrading to more energy-efficient equipment (technological equipment) promotes production growth and generates long-term gains.

Table 4: Model forecasts

	LOG_PROD...	LOG_L_2	LOG_K_2
2012	5.380074	5.516231	8.758783
2013	5.322067	5.394955	8.879386
2014	5.191465	5.351674	8.699527
2015	5.134043	5.277567	8.801911
2016	5.076891	5.303643	8.654413
2017	5.104711	5.516231	8.918115
2018	5.495293	5.358157	9.368781
2019	5.518887	5.548045	9.473208
2020	5.622509	5.595073	9.065964
2021	5.714493	5.719214	9.065964
2022	5.806476	6.029866	9.065964
2023	5.898460	6.006653	9.065964
2024	5.990443	6.061436	9.065964
2025	6.082426	6.085393	9.065964

Source: prepared by the authors

So in 2025:

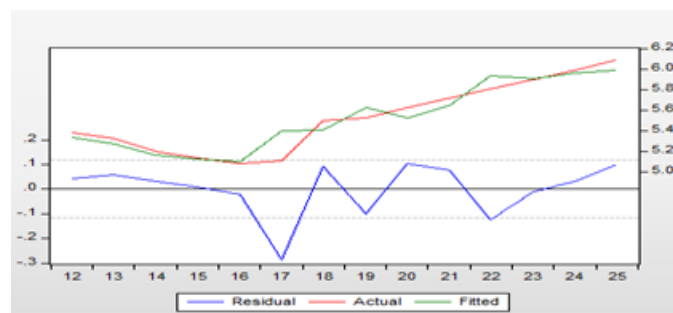
- The cost of gas becomes: 1 164 029 535 (DA)
- The quantity of gas consumed is: 1 217 287 (m³)
- Production: 1 208 999 (tons)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG_L_2	0.945760	0.114783	8.239536	0.0000
LOG_K_2	0.354569	0.147170	2.409250	0.0347
C	-2.986546	1.265191	-2.360550	0.0378
R-squared	0.898910	Mean dependent var	5.524160	
Adjusted R-squared	0.880530	S.D. dependent var	0.339243	
S.E. of regression	0.117257	Akaike info criterion	-1.261480	
Sum squared resid	0.151242	Schwarz criterion	-1.124539	
Log likelihood	11.83036	Hannan-Quinn criter.	-1.274157	
F-statistic	48.90679	Durbin-Watson stat	2.363945	
Prob(F-statistic)	0.000003			

The function is: $\text{Log}(Q) = -2.98 + 0.35 \text{Log}(K) + 0.94 \text{Log}(L) + e$

The model is globally significant with an $\bar{R}^2 = 0.8805$, and all OLS assumptions are satisfied.

The residuals:


Figure 4: Forecast residuals

Source: prepared by the authors

According to the graph, the residuals are acceptable due to disturbances that may occur over time, such as variations in gas consumption, energy losses, or other issues.

- Correlogram:

Autocorrelation		Partial Correlation		AC	PAC	Q-Stat	Prob	
				1	-0.086	-0.086	0.1273	0.721
				2	-0.087	-0.095	0.2680	0.875
				3	-0.078	-0.096	0.3929	0.942
				4	-0.128	-0.157	0.7588	0.944
				5	-0.033	-0.086	0.7866	0.978
				6	-0.121	-0.184	1.1992	0.977
				7	-0.101	-0.201	1.5257	0.981
				8	0.024	-0.113	1.5465	0.992
				9	0.039	-0.090	1.6137	0.996
				10	0.025	-0.107	1.6479	0.998
				11	0.030	-0.091	1.7158	0.999
				12	0.016	-0.089	1.7448	1.000

The peaks are within the confidence interval, there is no autocorrelation.

- Heteroscedasticity: The Breusch-Pagan-Godfrey test for heteroscedasticity shows $P=0.9758 > \alpha = 0.05$. There is no heteroscedasticity, no outliers. White's heteroscedasticity test: Shows $P = 0.8573 > \alpha = 0.05$, hence we cannot reject ($H_0 =$ There is no heteroscedasticity). No outliers. Normality: Jarque-Bera normality test: Shows a $P = 0.62 > \alpha = 0.05$ (therefore, we cannot reject the normality of the Residual distribution).

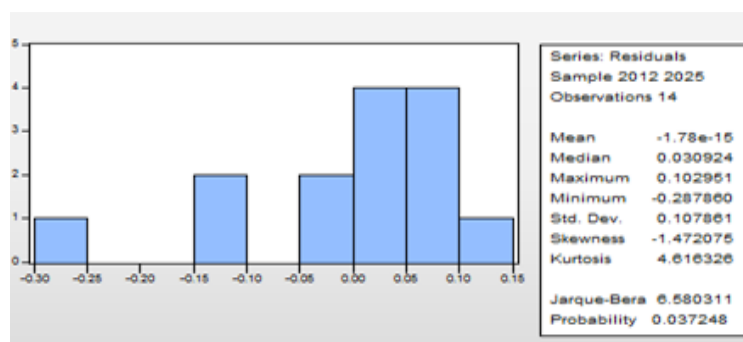


Figure 5: Normality test

Source: prepared by authors

- We created several models with changes in the price of gas or gas consumption using exponential smoothing (single, double, Holt-Winters):

2.4. Scenarios:

a. Scenario 01: Under the assumption that gas prices (costs) « Log (K) » remain moderately stable until 2025, we will simulate this assumption through double exponential smoothing. Regarding the variable gas consumption « Log (L) », we assumed it systematically increases, and we simulated this variable using exponential smoothing (Holt-trend): The model is not significant because the coefficients are greater than $\alpha = 5\%$.

$\alpha_1 = 0.62 > \alpha = 0.05$, $\alpha_2 = 0.46 > \alpha = 0.05$. We do not take into account the value of the constant because we accept it as it is since it is not significant.

The function is: $\text{Log}(Q) = 0.31 + 0.34 \text{Log}(K) + 0.6 \text{Log}(L) + e$.

The graph of this forecast is as follows:

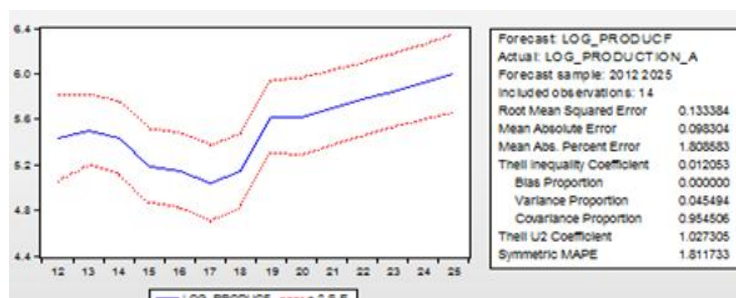


Figure 6: First scenario on the behavior of ammonia production

Source: prepared by the authors

We noticed that production will increase less, but the increased gas consumption causes disruptions, leading to losses that are not reflected in production and also affect the rising gas prices.

b. Scenario 02: Under the assumption that gas prices (costs) 'Log (K)' remain moderately stable in the short and medium term until 2025, we simulated this variable using double exponential smoothing. Regarding the variable gas consumption 'Log (L)', we assumed it remains as in the initial forecasts of the study model: The model is significant because the coefficients are less than $\alpha = 0.05$.

$\alpha_1 = 0.0325 < \alpha = 0.05$, $\alpha_2 = 0.0157 < \alpha = 0.05$. We do not take into account the value of the constant because we accept it as it is since it is not significant.

The function is: $\text{Log (Q)} = -0.11 + 0.41 \text{ Log (K)} + 0.59 \text{ Log (L)} + e$

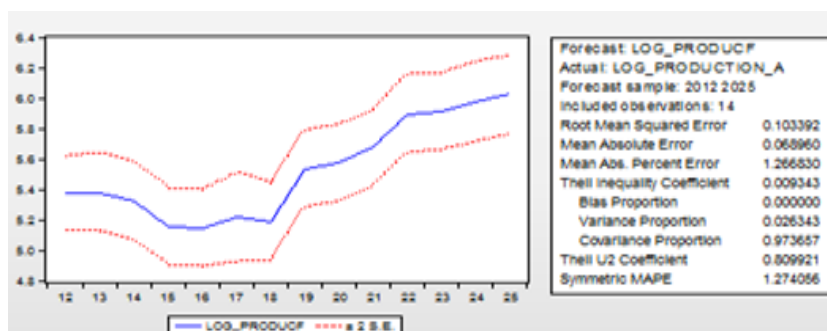


Figure 7: Second scenario on the behavior of ammonia production

Source: prepared by the authors

There is a strong increase in production over time, indicating good performance and control of gas consumption despite a slight subsequent increase in price.

c. Scenario 03: Under the assumption that gas prices (costs) « Log (K) » remain stable in the short and medium term until 2025 as in the initial forecasts of the study model, and regarding the variable gas consumption « Log (L) », we assumed it increases significantly (disrupted), and we simulated this variable using exponential smoothing (Holt-trend): The model is significant because the coefficients are less than $\alpha = 0.05$.

$\alpha_1 = 0.0194 < \alpha = 0.05$, $\alpha_2 = 0.0000 < \alpha = 0.05$, even the constant is significant in this model:
 $\text{Log}(Q) = -3.17 + 0.39 \text{Log}(K) + 0.93 \text{Log}(L) + e$.

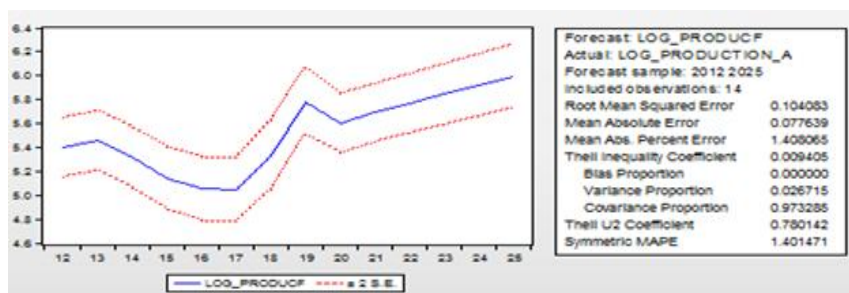


Figure 8: Third scenario on the behavior of ammonia production

Source: prepared by the authors

III. Results:

We noticed that production decreased in 2020 but will increase more in the following years compared to previous years. The increase in the quantity of gas consumed may indicate that FERTIAL wants to increase its production capacity in the long term, which implies that the change to new equipment has a significant long-term impact. This is evidenced by an increase in production and the proper amount of gas consumed within standards. Thus, according to our study of ammonia production at FERTIAL, we observed that production depends on gas consumption, its price, and also on the change of equipment (technology). If gas prices increase in the coming years, FERTIAL may reduce its gas purchases, especially if it cannot save energy or invest in improving the energy performance of its equipment. The increase in gas consumption may mean that FERTIAL has decided to increase its ammonia production, but there must be a homogeneous increase between the two. Another hypothesis is that gas consumption will increase due to losses and wastage, for example, furnace malfunctions. These issues can cause energy losses even if the equipment is good, but the industrial sector is full of surprises. In conclusion, we can confirm our hypothesis that the energy performance of industrial equipment has a significant impact on the company's profitability, both in terms of energy savings and increased production yield.

IV. Conclusion:

FERTIAL has adopted a sustainable development policy to reduce its energy consumption, particularly the energy costs associated with its activities. Our mission is to assess the energy consumption of its ammonia production units, as energy represents a significant portion of these costs. According to the study, the furnace consumes a significant amount of energy. Thanks to the field survey conducted, it was possible to gain insight into the uses concerning energy efficiency, the management of available equipment, and their interest in energy consumption, whether gas, electricity, or steam. The findings indicate that substantial energy savings can be achieved through the measures taken and the replacement of new, less energy-consuming, and technologically advanced equipment. This demonstrates the potential for energy savings in the units, particularly by acting on the energy-saving system at the furnace level, which represents a very significant part of the energy consumption in the ammonia unit.

Forecasts on the state of ammonia production in the long term indicate an increase, but this is dependent on energy and its costs in the coming years. According to the results and calculations, we have successfully measured the energy performance of the equipment and energy consumption at FERTIAL. We have shown that the effect of technical progress plays a crucial role in the energy efficiency of the equipment. Promising technological advances in energy efficiency, including energy integration in each industrial process, such as ultra-fast furnaces, reduce energy consumption, particularly energy costs, and increase production yield. Therefore, technology plays an important role in reducing energy consumption in industries if they invest in energy efficiency.

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