The evolution of Energy Management Maturity in the Italian Plastics Industry

Santolamazza A.*, Introna V.*, Cesarotti V.* and Martini F.**

** Department of Enterprise Engineering, University of Rome Tor Vergata, Via del Politecnico, 1, 00133, Rome – Italy*

(annalisa.santolamazza@uniroma2.it, vito.introna@uniroma2.it, cesarotti@uniroma2.it)

*** Energy, New Technology and Environment Agency (ENEA), Rome, RM, Italy*

(fabrizio.martini@enea.it)

Abstract: The drastic increase in energy prices is becoming a major concern in the plastics industry. Indeed, rubber and plastic manufacturing companies are recognizing the importance of focusing more on energy management to reduce the energy they use and, consequently, stay competitive in regional and global markets. Moreover, in the European panorama, the promotion of energy efficiency, use of renewable sources, and decarbonization are the key elements of the strategy that guides the common effort. Since the publication of the European Directive 2012/27/EU on Energy Efficiency, which established the obligation for large companies to undergo mandatory energy audits every four years, thousands of companies in Italy have performed an energy audit. Using a maturity model developed in collaboration with the Italian Energy, New Technology and Environment Agency, various Italian companies have been analyzed in reference to their energy management to assess the variation provoked by this obligation. From the results of the analysis conducted on a significant sample of companies from the rubber and plastics manufacturing sector, it emerged that on average the companies that have complied with the obligation of energy audit have increased their maturity in their energy management. The analysis was deepened by assessing the degree of coverage of the five maturity levels identified in the model: "Elementary", "Occasional", "Project-based", "Management" and "Optimized". Moreover, to identify the progress that occurred in the different aspects of Energy Management, the level of development of six different maturity dimensions has been studied: "Strategic approach", "Awareness, knowledge and skills", "Methodological approach", "Organizational structure", "Energy performance management and Information System", and "Best practices". Finally, the observed variations have also been statistically verified through the use of the paired t-test to make statistical inferences about the maturity of the overall population of the plastics industry.

Keywords: energy efficiency, energy management, maturity model, energy audit

I. INTRODUCTION

In the European panorama, the promotion of energy efficiency, the use of renewable sources, and the reduction of polluting emissions are key elements of the strategy that guides the Community effort. In this regard, following the publication of Legislative Decree 102/2014 which, in implementation of the European Directive 2012/27/EU on energy efficiency, established the obligation for large companies and companies with high energy consumption to undergo energy audit every four years, thousands of companies in Italy have performed, sometimes for the first time, an energy audit of their site (or a selection of their sites or "clusters" in the case of multi-site organizations). In December 2015, thousands of companies in Italy carried out, an energy audit of their site, an operation then replicated in December 2019, four years after the first obligation.

This presented the possibility of comparing the two situations analyzed in 2015 and 2019 in order to assess how the mandatory energy audits have influenced the development of energy efficiency in the country.

In the present paper, some relevant results of the research activity aimed to gain greater insight into the current situation and the evolution undergone in these four years by the companies subjected to the legislative obligation, are reported. The activity, conducted as part of a three-year research project in collaboration with the Italian agency ENEA (Energy, New Technology and Environment Agency) focused on the analysis of Energy Management Maturity in Italian companies using a new maturity model developed specifically to study the trend of energy good practices dissemination. In particular, the present paper focuses on the findings achieved concerning the analysis of one of the most energy-intensive manufacturing sectors, the plastics industry.

The structure of the paper is as follows: Section 2 describes the background of the plastics production

sector and describes in more detail the maturity model defined in the previous years; Section 3 describes the data collection activity conducted in collaboration with ENEA and the methodology used for the analysis of the data collected; in Section 4 the results of the maturity model's assessment on a sample of organizations of the plastics sector are presented and discussed; finally, Section 5 concludes the paper, describing the future steps of the research work.

II. Background

A. Characteristics of the sector

The manufacture of rubber and plastic products is identified as a business sector in Europe by NACE code 22 (EUROSTAT, 2008). Plastic production is one of the most energy-intensive manufacturing sectors and causes significant energy costs and greenhouse gas emissions. The main transformation processes identified are (Falconi *et al.*, 2016; Schlüter and Rosano, 2016): film extrusion (cast and blow), injection molding, extrusion-blow molding of hollow bodies, stretch-blow molding of preforms, and thermoforming. Besides the actual material transformation, the production of plastic finished products from raw materials requires various operations, the most common among which are: the transport of raw material (powders or granules), melting, transport of the melted material, raw material drying, and mixing. Electricity is the main energy source in this sector (Canadian Industry Program for Energy Conservation, Canada and Canadian Plastics Industry Association, 2007; Schlüter and Rosano, 2016). The main uses of electricity are hydraulic systems, motors, chilling, heating, compressed air systems, HVAC (Heating, Ventilation & Air Conditioning), and lighting. On the other hand, thermal energy produced through natural gas combustion is used primarily for heating water and facilities.

B. Maturity Model

The concept of maturity model has been conceived in 1979 by Philip Crosby to provide a tool for corporate management to measure and control the quality management in the organization. Today, maturity models have been deployed in various domains (Becker, Knackstedt and Pöppelbuß, 2009; Wendler, 2012).

In energy management, in the last ten years, there have been several attempts to build models to assess the maturity of organizations, with differences in terms of model structure, methodology of analysis, reference to international standards, mode of assessment, results of the assessment, and domain. The model structure most commonly used is the staged one, which fosters an easier understanding by less mature organizations. However, Carbon Trust developed both a staged and a continuous structured model in 2011 (Carbon Trust, 2011). Moreover, the assessment method varies: questionnaires are often deployed to enable a self-assessment by organizations, but also workshops (Ngai *et al.*, 2013) or interviews have been used (Qiang and Jiang, 2009; Curry *et al.*, 2012, 2013). The number of questions in questionnaires ranges from 15-20 (EDF Climate Corps, 2015; Jovanović and Filipović, 2016; Prashar, 2017) to 40-60 (Carbon Trust, 2011; O'Sullivan, 2012; Introna *et al.*, 2014). The scope of the analysis also varies. Most models analyze single sites but Finnerty et al. have focused their attention to evaluate the maturity of multi-site organizations, defining a self-guided assessment comprising sections for both the specific site and the overall organization (Finnerty, Sterling, Coakley and Keane, 2017; Finnerty, Sterling, Coakley, Contreras, *et al.*, 2017). Çoban and Onar had a similar focus but used a fuzzy methodology to implement the assessment (Çoban and Onar, 2020). Moreover, Benedetti et al. have focused on the management of specific energy assets such as compressed air systems (Benedetti *et al.*, 2019).

Whereas different attempts to define models to assess the maturity of organizations regarding energy management can be identified in scientific literature, in this study the maturity model used for the assessment is one specifically defined in collaboration with ENEA in a three-year research project in order to be suitable for the exact purpose of evaluating how the dissemination of best practices in energy management has evolved in companies submitted to mandatory energy audits (Santolamazza *et al.*, 2020).

The maturity model used consists of 5 maturity levels and 6 maturity dimensions in order to analyze all relevant aspects of energy management. For each level, several questions associated with each dimension have been identified, for a total of 48 questions. Level 1 is an elementary stage, not associated with any questions whereas from level 2 to 5, questions are associated with a series of answers to characterize the specific level (4 possible answers for the first three levels, while for the last level there are only two possible answers). To assess how the organizations have evolved in their approach to energy management since the first mandatory energy audit of December 2015, for each question two answers are given:

- The first one is representative of the situation prior to the conduction of the energy audit of 2015;
- The second one is representative of the current situation (after the second mandatory energy audit).

The maturity levels are described in Table I:

TABLE I
DESCRIPTION OF MATURITY LEVELS

Level	Description
Elementary (1)	Energy consumption is not deemed relevant. In the organization, the energy performance of the organization has never been evaluated.
Occasional (2)	There is a tentative interest in the organization towards the issue of energy consumption. Generally, there is a lack of adequate

	commitment and support from above and energy efficiency is pursued in an occasional manner. Preliminary collection of consumption data and energy costs might start.
Project-based (3)	A first strategy is identified and targets set. Typical of this stage is the execution of an energy audit o the identification of specific opportunities for improvement. Energy data collection and evaluation are systematized.
Management (4)	The company is led towards the development of an Energy Management System with an adequate information system and monitoring and the development of a plan of activities to achieve efficiency targets.
Optimized (5)	Inside the organization, an Energy Management System is present and continuously optimized, with the support of top management and the full involvement of the whole organization.

The maturity dimensions of the model are:

- Strategic approach (i.e. energy policy, measurable objectives, responsibilities, and action plan) (SA);
- Awareness, competence, and knowledge (i.e. knowledge of the energy market, self-generation systems, capability to manage relationships with energy suppliers and services, equipment and materials providers, knowledge of the energy consumption structure of the site, analytical and statistical tools and methods of financial analysis) (ACK);
- Methodological approach (i.e. the consistency, continuity, and systematization of planned actions) (MA);
- Organizational structure (i.e. relations within the organization and the approach used to define and coordinate tasks) (OS);
- Energy performance management and Information Systems (i.e. measurement system, data collection, analysis and reporting, energy performance indicator definition) (EPMIS);
- Best practices (i.e. standardization and optimization of activities and processes that have an impact on the energy performance of the organization, such as maintenance and usage of machines and systems, purchase, design and plant modifications, risks and opportunities assessment) (BS).

The achievable score for each question varies linearly from 0 to 100. Three different indicators have been developed to support the maturity assessment, describing the maturity at different levels of detail:

- global maturity index, a number between 1 and 5, which summarizes the overall level of maturity of the organization;
- degree of coverage of the different levels (from 0 to 100%);
- development of maturity in different dimensions (from 0 to 100%).

For details regarding the questionnaire and the specific calculation of the indexes refer to the previous paper (Santolamazza *et al.*, 2020).

III. Methodology of the sector analysis

A. Sample collection

In the first months of 2021 with the collaboration of ENEA, the questionnaire for the maturity model has been published in an online form on a private section of the same portal used by the Italian companies to submit the data from their mandatory energy audit. The delivery and collection of the maturity assessment questionnaires met with success, making it possible to establish relevant results.

B. Methodology Analysis

In order to analyze the results deriving from the delivery of the maturity questionnaire to a sample of Italian companies in the plastics production sector, main descriptive statistics tools were selected to assess the mean, central trend, and variability (Montgomery and Runger, 2018) for the global maturity index.

The analysis was deepened further by assessing the degree of coverage of the five maturity levels identified in the model. Moreover, to identify the progress that occurred in the different aspects of Energy Management, the level of development of six different maturity dimensions has been studied. Finally, the observed variations have also been statistically verified using the paired t-test to make statistical inferences about the maturity of the overall population of the plastics industry.

IV. Results and discussion

A. Sample description and global results

The sample of companies in the plastics production sector (NACE code 22) collected comprises 20 companies, all subject to mandatory energy audits by Italian legislation. Each company has answered the questionnaire online and the collected data has been analyzed to study the performance of the sector.

From the results of the analysis conducted on the sample, it emerged that on average the companies that have complied with the obligation of mandatory energy audit have increased their maturity in energy management. Indeed, Table II presents the mean and standard deviation associated with the sample and Fig. 1 presents the comparison between the global maturity index in 2015 and after the second cycle of energy audits (titled "NOW").

Table II
The mean and standard deviation of the Global maturity Index 2015 and after the second cycle of energy audits

Group	Mean	Standard deviation
2015	2.39	0.783
NOW	3.32	0.992

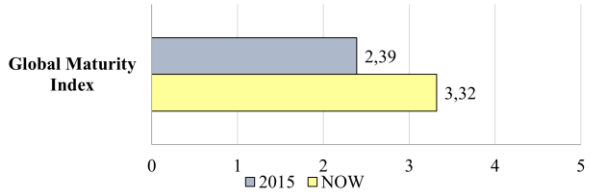

Fig. 1. Comparison between the global maturity index in 2015 and after the second cycle of energy audits (NOW)

The observed variations have also been statistically verified through the use of the paired t-test. The p-value resulting from the analysis is inferior to 0.001, so it is possible to conclude that the maturity index of the sample has increased in these years with a significance level of 0.05 and that the maturity index of the sector is generally improved.

B. Maturity levels' trend

Fig. 2 and Fig. 3 present the comparison between the situation in 2015 and the situation after the second cycle of energy audits (2021) in reference to the coverage of maturity levels (mean values and box-plot).

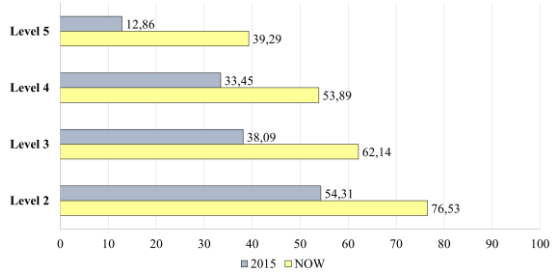

Fig. 2. Comparison between the level of coverage of maturity levels in 2015 and after the second cycle of energy audits (NOW)

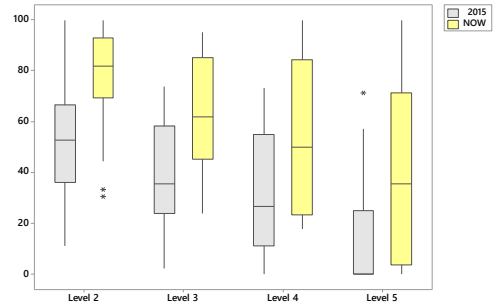

Fig. 3. Box-plots of the level of coverage of maturity levels in 2015 and after the second cycle of energy audits (NOW)

To verify the actual statistical significance of the apparent variation observed, a paired t-test was carried out concerning the variations in the degree of coverage of the levels. The results are reported in Table II.

TABLE II
THE P-VALUE FOR THE T-TEST FOR THE VARIATIONS IN THE DEGREE OF COVERAGE OF MATURITY LEVELS FOR THE SAMPLE

Maturity Level	p-value
Level 2	1.44E-04
Level 3	8.25E-05
Level 4	6.60E-04
Level 5	9.62E-04

All p-values are less than 0.05, so it can be concluded that all changes are significant.

By observing the variations that have occurred and referring to the meaning of the individual levels of maturity, it is possible to conclude that at an average level Italian Plastics companies have shown a consolidation of the "Occasional" and "Project-based" levels, thus showing that in general, the organizations subjected to the Italian obligation have developed a strong sensitivity to the issue of energy consumption, so that an occasional approach to reducing energy consumption has given way to a systemic approach with the definition of a strategy for reducing energy consumption and costs. However, from Level 4, "Management", there is great variability in the degree of coverage presented by companies at the moment. This means that while the percentage of companies oriented, in a more or less conscious way, towards the development of a real Energy Management System in 2015 was lower, the current situation shows that this has been developed to different degrees.

C. Maturity dimensions' trend

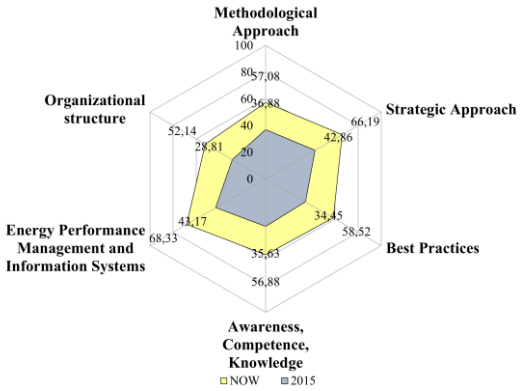

Fig. 4. Comparison between the level of coverage of maturity dimensions in 2015 and after the second cycle of energy audits (NOW)

Fig. 4 and Fig. 5 present the comparison between the situation in 2015 and the situation after the second cycle of energy audits (2021) in reference to the coverage of maturity dimensions (mean values and box-plot).

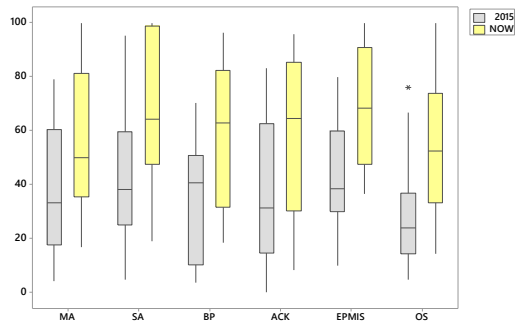

Fig. 5. Box-plots of the level of coverage of maturity dimensions in 2015 and after the second cycle of energy audits (NOW)

To verify the actual statistical significance of the apparent variation observed, a t-test was carried out concerning the variations in the degree of coverage of the dimensions. The results are reported in Table III. All p-values are less than 0.05, so it can be concluded that all changes are significant.

TABLE III
THE P-VALUE FOR THE T-TEST FOR THE VARIATIONS IN THE DEGREE OF COVERAGE OF THE SINGLE DIMENSIONS FOR THE SAMPLE

Maturity Dimension	p-value
Methodological Approach (MA)	5.46E-04
Strategic Approach (SA)	2.77E-04
Best Practices (BP)	1.20E-04
Awareness, Competence, Knowledge (ACK)	4.18E-04
Energy Performance Management and Information Systems (EPMIS)	5.97E-05
Organizational structure (OS)	2.82E-04

Observing the changes that have occurred in relation to the different dimensions, the two most developed dimensions at present are the "Strategic Approach" and "Management of Energy Performance and Information Systems". The improvement of the "Strategic Approach" dimension highlights the growth of the level of support from top management in the development of actions concerning energy efficiency, which could be the result of the fact that the obligation of energy audits has led to the management's attention to the energy issue. The improvement of the "Energy Performance Management and Information System" dimension, on the other hand, highlights the general improvement of the data collection and analysis system.

This result could easily be explained by the need to collect reliable data to make the energy audits, and in particular by the stimulus for the development of the system provided by the guidelines formulated by ENEA in view of the second cycle of energy audits which defined percentage thresholds of coverage for the monitoring system. In general, the other dimensions also showed significant improvements, demonstrating an overall improvement in the practices with which the companies that have complied with the diagnosis obligation manage energy.

D. Analysis of the individual requirements (analysis for each question)

After having found an actual change in the level of coverage of all levels of maturity management and dimensions, we proceeded to further investigate. In order to identify which specific aspects have changed more significantly and which, on the contrary, have remained more stable over the years, we have proceeded to analyze in detail the variation of the individual questions of the questionnaire, observing how the individual requirements of the maturity dimensions so far studied are satisfied by each company.

Fig. 6, 7, 8, 9, 10 and 11 show the box-plots relating to the answers connected to the different dimensions. The x-axis of each graph shows the single questions associated with the dimension studied, while the y-axis shows the answers collected (from 0 to 3 for maturity levels 2, 3 and 4; from 0 to 1 for level 5). The main insights that can be gained are here presented.

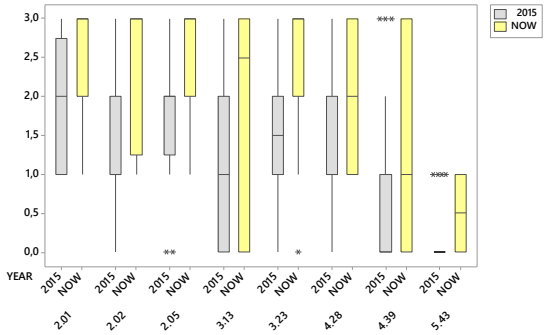

Fig. 6. Box-plot for answers' distribution – Dimension "Strategic Approach"

The result in Fig. 6 testifies to a significant change in the importance attributed to energy management in companies, while at the same time indicating further margins for growth in the systematization of the approach to reducing consumption and costs (2.01).

Previously, the situation was very varied in reference to energy performance indicators. Now, almost all companies use at least energy performance indices at a global level (entire organization) (e.g. absolute consumption of the site) and some companies also use specific performance indices for the main functional areas (3.23). In this case, the improvement can easily be related to the requirement for the evaluation of energy performance indicators envisaged by the mandatory energy audits.

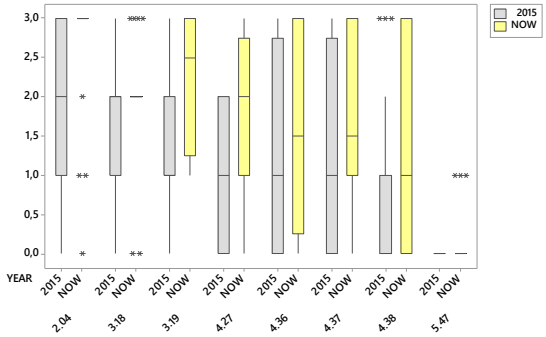

Fig. 7. Box-plot for answers' distribution – Dimension "Methodological Approach"

Regarding the organization's attitude towards energy efficiency opportunities, it is possible to state that currently, energy audits are conducted periodically with a frequency greater than the one required by law (2.18) and that relevant efficiency opportunities are reported in a list that provides a description and gives a summary cost and implementation plans are prepared (2.19) (Fig.

7). It is evident that this new approach is a direct consequence of the practices introduced with energy audits.

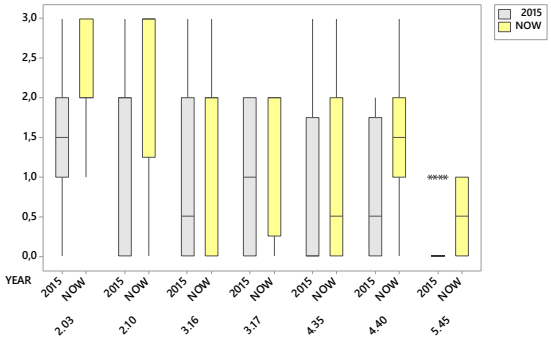

Fig. 8. Box-plot for answers' distribution – Dimension "Awareness, Competence, Knowledge"

Currently, ad hoc initiatives for the development of staff awareness regarding the importance of energy efficiency are being defined or already systematically applied internally and externally to the organization (2.03).

Moreover, the level of technical knowledge relating to energy aspects of personnel responsible for energy management has been improved (2.10). However, training programs are not considerably improved in their design and implementation (3.16 and 3.17) (Fig. 8).

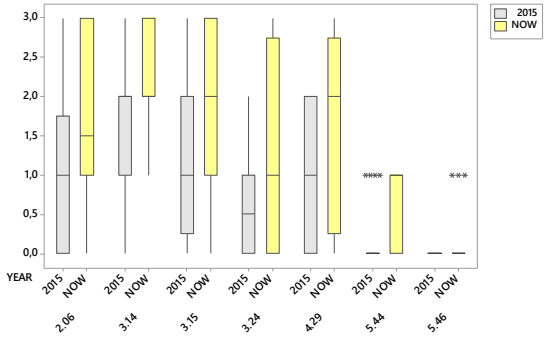

Fig. 9. Box-plot for answers' distribution – Dimension "Organizational structure"

Fig. 9 shows that, currently, the majority of managers are convinced of the importance of energy efficiency and are reactive if involved in specific projects or even encourage the reduction of consumption with a proactive attitude. This is another fundamental improvement given the absolute need for full involvement of the organization to achieve significant and continuous improvements over time (3.14).

Moreover, team meetings are held for which representatives for the various functional areas are identified with a variable degree of systematicity depending on the company observed. The greater involvement of the entire organization passes through greater communication (3.24).

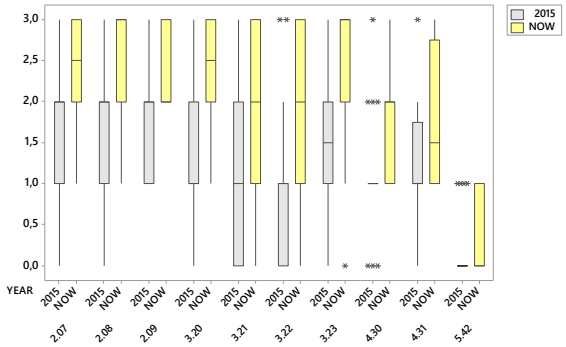

Fig. 10. Box-plot for answers' distribution – Dimension "Energy Performance Management and Information Systems"

Currently, a thorough energy cost analysis is widely applied (2.07). Furthermore, costs and consumption of the various energy sources are collected and analyzed several times during the year, as well as data for main factors of influence (e.g. produced units, hours, temperature, etc.) (2.08 and 3.21) (Fig. 10).

Moreover, the methods for data collection have been defined and a permanent data collection system has been set up for the main functional areas (e.g. main activities, auxiliary services, and general services) (3.20). This is also another fundamental improvement that can be easily correlated to the attention paid by the energy audit to the measurement of consumption data, also following the monitoring guidelines issued by ENEA.

Almost all companies use at least energy performance indicators at a global level (entire organization) (e.g. absolute consumption of the site) which also take into account the energy factors capable of influencing performance (production volumes, working hours, etc.) (3.23).

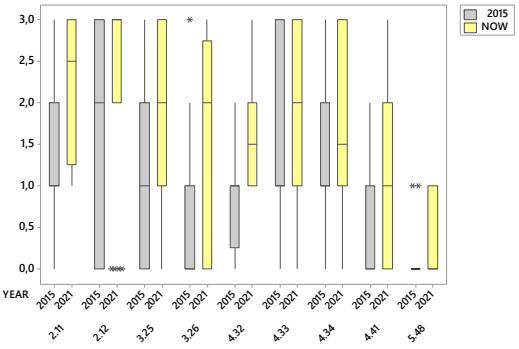

Fig. 11. Box-plot for answers' distribution – Dimension "Best Practices"

Finally, in Fig. 11 are presented the answers associated with the "Best Practices" dimension. The self-production of energy (e.g. Combined Heat and Power, photovoltaics, etc.) is now widely investigated (2.12).

Moreover, the efficiency opportunities in energy usage and maintenance typically identified during energy audits are now generally exploited. The result shows how companies have developed greater confidence in

the diagnostic tool represented by an energy audit (3.25). Finally, risk analyses are now commonly performed and preventive actions and emergency plans are implemented (3.26 and 4.41).

V. CONCLUSIONS

Since the publication of the European Directive 2012/27/EU on Energy Efficiency, which established the obligation for large companies to undergo mandatory energy audits every four years, thousands of companies in Italy have performed an energy audit.

This paper presents the results of the analysis of the Plastics sector carried out using an energy management maturity model developed in collaboration with the Italian Energy, New Technology and Environment Agency during a three-year research project. The objective was to assess the variation in the diffusion of energy management practices inside the specific sector provoked by this legislative obligation.

From the results of the analysis carried out on a significant sample of companies from the rubber and plastics manufacturing sector (NACE code 22), it emerged that on average the companies that have complied with the obligation of mandatory energy audit have increased their maturity in their energy management.

The analysis was deepened by assessing the degree of coverage of the individual levels and individual maturity dimensions and the observed variations were also statistically verified through the use of the paired statistical t-test. One of the main changes that occurred has been in regard to the organization's approach to energy efficiency in terms of energy performance indicators and targets.

Moreover, another relevant change has been identified in reference to the "Energy Performance Management and Information Systems" dimension. Indeed, data collection systems and methodology have greatly improved in the years since the first mandatory energy audit.

Further developments will lead to the replication of the sectorial analysis to other energy-intensive sectors in order to assess their evolution in energy management practices.

VI. REFERENCES

[1] Becker, J., Knackstedt, R. and Pöppelbuß, J. (2009) 'Developing Maturity Models for IT Management', *Business & Information Systems Engineering*, 1(3), pp. 213–222.

[2] Benedetti, M. *et al.* (2019) 'Maturity-based approach for the improvement of energy efficiency in industrial compressed air production and use systems', *Energy*, 186.

[3] Canadian Industry Program for Energy Conservation, Canada and Canadian Plastics Industry Association (eds) (2007) *Guide to energy efficiency opportunities in the Canadian plastics processing industry*. Ottawa, ON: Natural Resources Canada.

[4] Carbon Trust (2011) 'Energy management—a comprehensive guide to controlling energy use', *Energy Management - A Comprehensive Guide to Controlling Energy Use*.

[5] Çoban, V. and Onar, S.Ç. (2020) *Energy management maturity model based on fuzzy logic*.

[6] Curry, E. *et al.* (2012) 'A maturity model for energy efficiency in mature data centres', in *SMARTGREENS 2012 - Proceedings of the 1st International Conference on Smart Grids and Green IT Systems*, pp. 263–267.

[7] Curry, E. *et al.* (2013) 'Measuring energy efficiency practices in mature data center: A maturity model approach', in *Computer and Information Sciences III - 27th International Symposium on Computer and Information Sciences, ISCIS 2012*, pp. 51–61.

[8] EDF Climate Corps (2015) 'EDF Smart Energy Diagnostic Survey'.

[9] EUROSTAT (2008) *NACE rev. 2*. Luxembourg: Office for Official Publications of the European Communities.

[10] Falconi, P. *et al.* (2016) 'Dalla diagnosi alla caratterizzazione energetica di processi industriali: metodi per la valutazione e la promozione degli interventi di riqualificazione energetica'.

[11] Finnerty, N., Sterling, R., Coakley, D. and Keane, M.M. (2017) 'An energy management maturity model for multi-site industrial organisations with a global presence', *Journal of Cleaner Production*, 167, pp. 1232–1250.

[12] Finnerty, N., Sterling, R., Coakley, D., Contreras, S., *et al.* (2017) 'Development of a Global Energy Management System for non-energy intensive multi-site industrial organisations: A methodology', *Energy*, 136, pp. 16–31.

[13] Introna, V. *et al.* (2014) 'Energy Management Maturity Model: an organizational tool to foster the continuous reduction of energy consumption in companies', *Journal of Cleaner Production*, 83, pp. 108–117.

[14] Jovanović, B. and Filipović, J. (2016) 'ISO 50001 standard-based energy management maturity model - Proposal and validation in industry', *Journal of Cleaner Production*, 112, pp. 2744–2755.

[15] Montgomery, D.C. and Runger, G.C. (2018) *Applied Statistics and Probability for Engineers*.

[16] Ngai, E.W.T. *et al.* (2013) 'Energy and utility management maturity model for sustainable manufacturing process', *International Journal of Production Economics*, 146(2), pp. 453–464.

[17] O'Sullivan, J. (2012) 'Energy Management Maturity Model (EM3)—A strategy to maximize the potential for energy savings through EnMS'.

[18] Prashar, A. (2017) 'Energy efficiency maturity (EEM) assessment framework for energy-intensive SMEs: Proposal and evaluation', *Journal of Cleaner Production*, 166, pp. 1187–1201.

[19] Qiang, R. and Jiang, Y. (2009) 'Enterprise Energy Saving and Emission Reduction Level Assessment Research Based on the Capability Maturity Model', in *2009 International Conference on Management and Service Science*. Beijing, China: IEEE, pp. 1–5.

[20] Santolamazza, A. *et al.* (2020) 'Proposal of an energy management maturity model to assess the progress achieved through mandatory energy audit application in the eu energy efficiency directive context', in *Proceedings of the Summer School Francesco Turco*.

[21] Schlüter, B.A. and Rosano, M.B. (2016) 'A holistic approach to energy efficiency assessment in plastic processing', *Journal of Cleaner Production*, 118, pp. 19–28.

[22] Wendler, R. (2012) 'The maturity of maturity model research: A systematic mapping study', *Information and Software Technology*, 54(12), pp. 1317–1339.