



On the possibility of using Modeling and Simulation for environmental footprint in manufacturing. The case of a foundry company involved in the Green Casting Project

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Abstract

This paper presents an interesting industrial case in which a predicted environmental advantage was found to be ineffectual. To investigate how to address these issues, Environmental performance indicators for the company under consideration are assessed. Carbon and Environmental Footprint calculation models are utilized. These indicators do measure relevant performance to monitor, but they do not provide meaningful insights into the issues raised in the case under consideration. Modeling and simulation and/or the digital twin, are thus highlighted as potential support tools for guiding the proper decisions for effective environmental management systems. Modeling and simulation tool can then activate virtuous Green Innovation Practices that can lead businesses towards the right steps to improve their environmental performance.

Keywords: Green Innovation Practices; Green Digital Twin ; Environmental Management Systems

1. Introduction

The assessment of environmental performances is now widespread in the operation management of a company (Garrido et al., 2024; Saetta et al., 2020; Jabbour et al., 2020; Opresnik and Taisch, 2014, 2015; Tripathi et al., 2024; Machado et al., 2017; Magon et al., 2018).

Among these measures, the carbon footprint or, for a broader view, the environmental footprint plays an important role (Chen et al., 2015; Gaussin et al., 2013; Bajan and Mrówczyńska-Kamińska, 2020; Laurent et al., 2010; Hansuebsai et al., 2020; Pihkola et al., 2010).

The improvement of those performances can take place through the introduction of Green Innovation Practices, GIP, that are effective and efficient environmental tool. The evaluation of these GIP is therefore an important issue that can determine the success or failure of a company's

environmental policy, as it guides to proper decisions that allow to maximize outcomes in relation to the resources consumed (Tseng et al., 2013; Fratta et al., 2024; Rahim et al., 2023; Chen and Liang, 2023; Dang et al., 2024). Global green transition goals, on the other hand, are forcing organizations to seek for structural answers to environmental issues. For the next decades, the European Union, for instance, has an ambitious green transition strategy underlined by the Green Deal (European-Union, 2019). It is interesting to note that the worldwide emissions reduction goal of the European Union could not always match the best environmental solution in terms of technical-economic optimization. Below we will show a case whereby the need of an ambitious European emissions reduction plan from a global European point of view does not coincide with the outstanding environmental performance of the individual company. Greater efficacy in



the preventive evaluation of the influence of an innovation, for example of a global type, on the particular company can result from the simulation modeling which has also shown so much success in the green transition, considering also the digital Twin evolution (Van Der Vorst et al., 2009; Moon, 2017; Bottani et al., 2017; Bruzzone et al., 2013; Cimino et al., 2024). The following will show the case encountered; the possibilities for using Modeling and Simulation will be briefly described; the results of the research activity will then be shown.

2. Case Considered

Using innovative materials, inorganic binders, GREEN CASTING LIFE project (LIFE21-ENV-FI-101074439) (2022-2026) is an ongoing research study finalized in lowering VOC emissions at European level. Six European flagship foundries are evaluating the advantages and testing such innovative materials. Then other 15 followers will attempt using such new materials. Globally, this project enables a relevant reduction in emissions by including the more than 600 ferrous foundries in Europe. For further information, see (Fratta et al., 2024). Although emissions reduction is important on a European level, in specific cases it can be negligible. The official project photo is found in Figure 1.

3. The Paradoxal Results of pretest in one case

While in theory there always should be a reduction, in one case of test there was a small increase! This is shown in red part of Figure 4. In reality this result depend on the fact that the only a small part of the total material used can be innovative in this example. This is shown in figure 2, where white parts, a small amount (4 kg), is made with innovative material while the rest (600 kg), in black, is in traditional material. During foundry process the emissions reduction of the innovative material are completely negligible and surely below the accuracy of measurements! Nevertheless for the project the results is good, in the sense that the quality of the product are good and there is a real emission reduction, because the innovative material can not originated emissions. So at global level benefit is relevant but for the specific case not.

4. How to correctly manage company environmental performances

In order to avoid such non effective results an investigation about how environmental performance are evaluated was made. In particular the computation of carbon footprint was made and results are shown in the figure 3 But such kind of measurements are static, they only take in to account year emissions, so they are useful ex-post to check the real benefit, but do not allow preventive evaluations. Then one possibility could be the use of Modeling and Simulation, by which it could be possible to evaluate



Figure 1. The official picture of the Green Casting project



Figure 2. The picture where innovative material in white is much less than traditional material, in black

in advance the real environmental benefit of innovative actions. Basic idea is to develop a digital twin that is able to simulate the studied effect, in our case total emissions and to do evaluation before.

5. Conclusions

The paper aimed to show how, in absolute terms, the improvement of environmental performance might produce contradictory effects in specific industrial reality. Modeling and Simulation tools should be applied to realize a genuine increase in environmental performance and aid to minimize these difficulties. the development of models for specific cases could be a intriguing goal in not too distant future.

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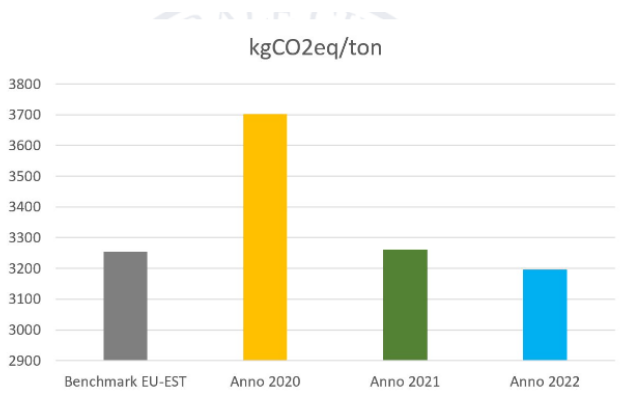


Figure 3. Carbon Footprint emissions of company in the years compared with average european emissions

Casting LIFE Project (LIFE21-ENV-FI-Project101074439). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them. thanks to Solimeno Salvatore for its support.

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N° TEST	LETTER ON THE SAMPLES	BINDER	COAT	N° MOLDS	TEMPERATURE	METALLURGY	TIME	V.O.C. [mg/Nm ³]	Methane [mg/Nm ³]	V.O.C.N.M. [mg/Nm ³]	Benzene [mg/Nm ³]	Phenols [mg/Nm ³]	Formaldehyde [mg/Nm ³]
1	A	FG	AB	10	1380	GrayIron	6:32 AM	45,8	23,5	22,3	0,79	< 0,18	0,89
	B	FG	WB	10	1380	GrayIron	6:54 AM						
2	C	ES	NO	10	1380	GrayIron	7:00 AM	43,2	20,1	23,1	1,08	< 0,19	1,12
	D	ES	NO	10	1380	GrayIron	7:43 AM						
3	E	OB	NO	10	1380	GrayIron	7:43 AM	53,1	32,6	20,5	0,61	< 0,17	0,69
	F	OB	WB	10	1380	GrayIron	7:52 AM						
4	H	FG	NO	10	1410	SIMO	7:53 AM	50,4	22,9	27,5	0,56	<0,17	0,85
	I	OB	AB	10	1410	SIMO							
	Z	ES	NO	10	1410	SIMO							
	S	ES	AB	10	1410	SIMO							
	T	ES	WB	10	1410	SIMO	8:17 AM						

Figure 4. In the table results of emissions are shown. In particular in Red it is underlined an increase in VOC emissions!.

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