Circular Economy in Consumer Goods Packaging

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Abstract

There is an increasing need for efficient monitoring methods that assist the transition for new business models with Circular Economy at its core. The industry of plastics, being one that has a significant impact in several living systems across the earth, requires a new paradigm to mitigate and slowly reverse its negative impact on the past decades.

A new tool was suggested to a company that is involved in the flexible plastic packaging industry and has its own recycling facility, Company A. This organization is pursuing a circular economy mindset for strategic and social responsibility reasons but lacks robust monitoring tools to determine its effectiveness.

The proposed tool is a metric, composed by a set of several indicators that was divided into two different sensus of the Circular Economy, where one is relative to the circularity of materials in a close-loop cycle, applied to the lifecycle of a set of products from Company A and to the inflow material of the recycling facility. The other sensus is relative to broad aspect of sustainability where the three pillars of sustainability and respective trade-offs, were considered. It was applied to two different sectors of Company A.

The results were promising by showing clear improvement points along the process and enhance accountability along the product life cycle between all the entities that are involved. It resulted on a new framework that can be visually and easily understood inside Company A and to its external stakeholders.

The present work is in its early stages of development and is setting the basis where further work can be developed. Recommendations for future work are displayed.

Keywords: Flexible packaging; Circular Economy; Sustainability; Business strategy control; metrics and measuring tool; recycled polymers.

1 Introduction

The most recent steps towards Circular Economy are taking place across the world, with a consistent and motivating momentum. Several cities, regions, countries, or full continents are committing to this new, responsible, and more efficient way of supporting our economic, financial, social, and environmental systems. In fact, Ellen MacArthur Foundation, an organization that pioneered in several matters across the circular economy spectrum, arguments that to reach the 2050 goal of net-zero emissions, set by many geographies in the *Paris Agreement 2015*, Circular Economy, as a systemic approach, is responsible for a staggering 45% of that decrease, with the following 55% related energy source and energy-efficiency measures. (Ellen MacArthur Foundation, 2019)

Up to date, the most consensual definition for Circular Economy was proposed by Ellen MacArthur Foundation. Their definition:

"A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models."

Another relevant definition considers the two different *sensos* that (Moraga *et al.*, 2019) finds to exist in Circular Economy, *sensu stricto* and *sensu latu.* Firstly, *sensu stricto* refers to the technical aspect of the materials, where the most operational measures are implemented, like slowing down and closing the loop of the products life cycle. Secondly, the *sensu latu* considers that the Circular Economy is a tool of a much broader theme, Sustainability, reason why it must have strategical thinking from upper layers inside organizations (public or private) to guarantee that new operational measures referred to *sensu stricto* do not fall into irrational trade-offs where the solution ends up being worse than current practices for the overall system. Due to this reason a relevant definition was proposed by *Van Buren et al* (Van Buren *et al.*, 2016):

"A circular economy aims for the creation of economic value (the economic value of materials or products increases), the creation of social value (minimization of social value destruction throughout the entire system, such as the prevention of unhealthy working conditions in the extraction of raw materials and reuse) as well as value creation in terms of the environment (resilience of natural resources). "

The scope of this work is applied under a business context, with a collaboration of Company A, a company that operates in the flexible plastic packaging industry. Under the adopted Circular Economy definition, (Van Buren *et al.*, 2016), the goal of this work was to develop a metric with several indicators that several layers of the company could follow to promote progress towards more sustainable practices.

Parallel to the manufacture of products, Company A also as a recycling facility that receives flexible plastic waste in bales and turns it into plastic pellets for the beginning of a new life cycle for products. It is vital for the company's business sustainability to measure and track transition to the circularity of their plastic products.

The plastics industry is far from being efficient. According to a 2016 report (Ellen MacArthur Foundation, 2016), around 95% of its value, or approximately 80-120 billion dollars, was wasted annually following a single and brief use, where only 14% of the total weight was sent to recycling. Additionally, of all the plastic packaging sent for recycling, there is the inherent inefficiency of the sorting, washing, and reprocessing processes, which results in a lower-quality plastic (downcycling), resulting in just 5% of the value being effectively recovered. With so many inefficiencies it should be common practice that the producers should pay for the externalities they cause to everyone else. However, reality is different, and it is estimated that the externalities associated with this industry's production are close to 40 billion dollars, or roughly equal to the industry's revenue (Ellen MacArthur Foundation, 2016).

2 Methodology

Among the several indicators existing in the literature for the ***sensu stricto***, the current work proposes a set of seven indicators that are put together under a visual framework, adapted from the one presented by the consulting group BCG (fig. 1). (Holger Rubel, Alexander Meyer zum Felde, Jan Oltmanns and Bayer, 2020)

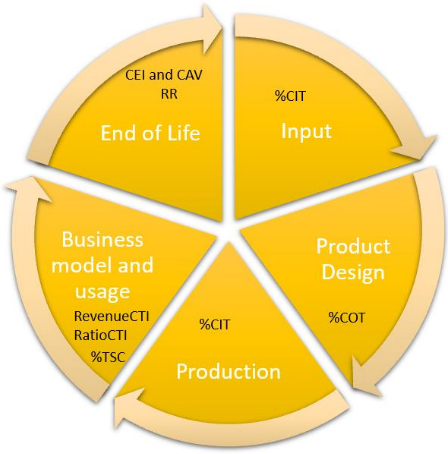

Figure 1 – Seven indicators in BCG framework

- ***Input*** **and *Production***, it is proposed to use the indicator %Circular Inflow Total (%CIT). This indicator represents the ratio of mass of material coming from recycled or renewable sources over the total material input.

- ***Product Design,*** it is proposed to use the indicator %Circular Outflow Total (%COT). This indicator considers both the design of the product for recovering and recycling and its effective collection through the value chain to re-enter the loop, calculated in mass units.

- ***Business model and usage***, it is proposed the indicators Revenue CTI (Circular Transition Indicators) and the %Circular Outflow Total (%COT) already mentioned. Both indicators can give positive inputs into what are the business models that favour better circular practices. The Revenue CTI returns the total revenue, in monetary units, from certain product/sector/company that comes from circular measures. We further developed an additional indicator which gives the values of revenue under a percentage, called Ratio CTI which is the ratio of the Revenue CTI to the total revenue for the object in study (product, sector, or company).

- ***End of Life,*** it is proposed the indicators CEI (Circular Economy Index), CAV (Circular Added Value) and RR (Recycling Rates). The indicator CEI, is defined as the ratio of the recycled polymer value to the expected virgin polymer value from the waste stream that originated the pellets after the recycling process, meaning value as a function of quantity and price. On the other hand, CAV is defined as the ratio of the recycled polymer value to the purchasing value from the waste stream that originated the pellets after the recycling process. This indicator was created to complement the CEI indicator, since it was quickly evident that the latter was not giving complete information. Both indicators are applied to the plastic bales that enter in the recycling facility, coming from partners as a post-consumer resin. This indicator CAV was created to complement the CEI indicator, since it was quickly evident that the latter was not giving complete information. Both indicators are applied to the plastic bales that enter in the recycling facility, coming from partners as a post-consumer resin.

Since Company A buys material to be recycled based on the purity of the bale, it would naturally evident that the purer the bale is, the bigger CEI gets. However, with its purity, the price of the bale naturally changes, meaning that the turnover could end up being lower for higher CEI bales and higher for lower CEI bales, less pure. The CAV comes to play a crucial part on the negotiating of the waste streams, by providing an indication of the turnover for the processed bales, as well as understanding what is the best processing strategy to acquire maximum CEI and CAV at the same time.

Other useful tools for quality control of the bales that arrive to the recycling facility are the Recycling Rates (R1, R2 and R3. There are three different rates and R1 is the ratio of the final material that comes out of the process to the quantity of desired material that arrives to recycling. The R2 is the ratio of the quantity of material after the sorting process to the material that arrives for recycling. Finally, the R3 is the ratio of the material that comes out of the sorting process to the final material that comes out of all process.

The indicators %Circular Inflow Total, %Circular Outflow Total and Revenue CTI are suggested by the Circular Transition Indicators report (WBCSD, 2021) and the indicator CEI was suggested by Francesco Di Maio (Di Maio and Rem, 2015). Finally, the indicators RR, Ratio CTI and CAV were developed in this work as an added valuable information for the company measurement of business sustainability.

The first set of four indicators %Circular Inflow Total, %Circular Outflow Total, Revenue CTI and Ratio CTI were applied to Company A product and its life cycle, and the second set of three indicators CEI, CAV and RR are suitable for the recycling facility.

The **sensu latu** indicators proposed for monitoring the company's three pillars of sustainability were the OEE (Overall Efficiency Equipment) and Waste rate. They are located at the intersection

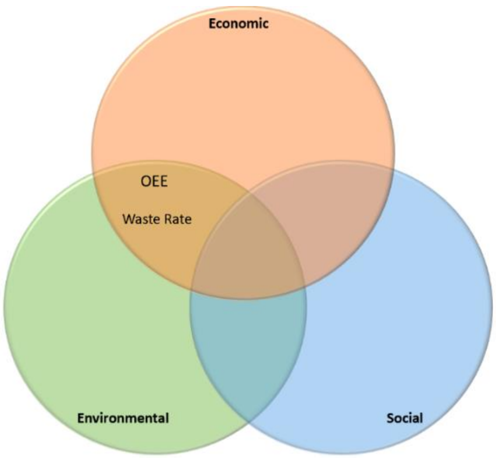

Figure 2- Sensu latu indicators

of the economic and environmental sustainability pillars and are used to track the performance of the company's various production lines and their evolution over time, fig.2.

The OEE establishes a comparison between the actual efficiency of a machine/process and the ideal efficiency, in the context of three fundamental aspects, **Availability, Performance and Quality.**

The formula to achieve an OEE result is the product between three fundamental aspects forementioned.

In a perfect production cycle, the OEE would be hundred percent, indicating hundred percent for Availability (A), Performance (P), and Quality (Q). In practice, it refers to a process that produced items/products intermittently (A) and at a maximum rate (P), exceeding the permissible standard of quality (Q).

Regarding the Waste Rate, it was decided to highlight this indicator because it is a component of the manufacturing process that is of particular interest to the management of Company A, and so ought to be closely monitored, using a clear and easy-to-share format.

This indicator implicitly states the objective of the calculation, which is to determine the amount of waste as a result of Company A's manufacturing activity. It is similar to the OEE's Quality aspect, with the exception of the calculation's focus, which is on material with a quality above the defined standards, while the Waste rate concentrates on material that has been wasted.

3 Results and Discussion

3.1 Product Life Cycle Indicators

Product	%Renewable /Green/BIO	% REC	% CIT	*%Potential Recovery*	*%Efective Recovery*	%Flx / %COT	RevenueCTI	RatioCTI
A	0,0%	90,3%	**90,3%**	0,0%	0,0%	**0,0%**	**28 763,08 €**	**45,2%**
B	0,0%	90,3%	**90,3%**	0,0%	0,0%	**0,0%**	**32 834,06 €**	**45,2%**
C	0,0%	90,3%	**90,3%**	0,0%	0,0%	**0,0%**	**6 813,68 €**	**45,2%**
D	0,0%	90,3%	**90,3%**	0,0%	0,0%	**0,0%**	**26 609,83 €**	**45,2%**
E	0,0%	90,3%	**90,3%**	0,0%	0,0%	**0,0%**	**15 568,73 €**	**45,2%**
F	0,0%	80,0%	**80,0%**	100,0%	33,9%	**33,9%**	**30 409,51 €**	**57,0%**
G	0,0%	80,0%	**80,0%**	100,0%	33,9%	**33,9%**	**13 780,99 €**	**57,0%**
H	0,0%	94,3%	**94,3%**	0,0%	0,0%	**0,0%**	**23 114,64 €**	**47,1%**
I	0,0%	90,0%	**90,0%**	0,0%	0,0%	**0,0%**	**4 618,15 €**	**45,0%**
J	20,0%	80,0%	**100,0%**	100,0%	8,6%	**8,6%**	**23 766,45 €**	**54,3%**
L	10,0%	85,0%	**95,0%**	0,0%	0,0%	**0,0%**	**3 788,03 €**	**47,5%**
M	10,0%	85,0%	**95,0%**	0,0%	0,0%	**0,0%**	**397,78 €**	**47,5%**
N	25,0%	70,0%	**95,0%**	100,0%	88,9%	**88,9%**	**27 249,70 €**	**91,9%**

Figure 3- Results for Product Life Cycle Indicators

To carry out the Life Cycle Indicators, many products from Company A were chosen as models to ensure the results validity, fig.3. The products from A to M were chosen because they belong to a category of High Runner products (products with significant sales for Company A) and so have an impact on the strategic decisions made. The product M was included because it is part of a newly launched line of products that emphasizes a more personal relationship with the customer in relation to a value chain based on the Circular Economy. The data is related to the first quarter of 2021.

Results of %CIT

It displays in a much more visual and simple way, the share of the product that is related with circular materials, either renewable or secondary material. The previous method was more time-consuming, where you had to compare the data sheets of the products, where it was included many information non-crucial for this analysis.

Recycled material represents the majority of the circular material that the product has, leaving a small share to renewable. With this data in hand, it could be later concluded that the reason for such difference is based on market tendency, where more and more companies are engaged with the policy of introducing recycled PCR in their products as well as the fact that recycled material is, at current prices, five times cheaper than renewable polymers (0,8€/Kg to 4€/Kg).

Results of %COT

This indicator shows how inefficient Company A is, in recovering the products they put into the market, where only four out of thirteen products have a value different than zero regarding this indicator.

It is possible to assess that the main concern for the good performance on this indicator is the %Recovery Potential, more precisely, how well designed is the product to take into account the end-of-life stage of the product life cycle. If such critical nuance of the indicator is jeopardized, then the second segment %Effective Recovery is inevitably threatened.

However, the reason for such thin score in %TSC is no less to the weak product design than the lack of systemic options to mitigate the problem that these products solve. For example, the products considered in this analysis with 0% on %TSC are all bin bags. Surely, at current practices, there are no better large scale alternatives to pack waste (organic and unsorted) than plastic bags. For the purpose they serve, there is no possible way for recovery if the proper waste stream they pack are disposed in landfill or incineration. Additionally, if one might comment that one solution would be to eliminate waste plastic bags altogether, than one have to consider how better are the solutions that follows. It does not mean there are no better solution, certainly there is, but these trade-offs must be considered before pointing current practices as the worst possible.

When this study lacked information regarding %Effective Recovery for a specific product, it was necessary to assume some recovery rates, in this case, Portuguese and USA national rates for plastic packaging recycling. The need for assumptions proves the lack of shared information between partners, an essential piece for a good transition for Circular Economy.

Product N was developed under a commitment between partners for Circular Economy. The close feedback kept by both parts and their clear share of information reflects the above the average scores on all the indicators.

Results of RevenueCTI

This indicator is not made to draw any conclusions, but rather, on a more visual way, to know how much revenue of this product, in absolute terms, comes from circularity models.

Results of RatioCTI

The necessity to turn the previous indicator in a relative and comparable structure is accomplished with RatioCTI. It is possible to compare, across an all set of product from a company, to assess which are the ones that offer greater revenue coming from circularity business models. It is then possible to define targets and work towards continuous improvement.

With extra analysis of the inflow of material for the entire Company A, it was possible to calculate the total internal %TEC. Although for the selected products the minimum value for %TEC was 80%, the %TEC for the total company in the first four months of 2021 is 45,3%. Such value lacks comparison examples to assess its good or bad performance. However, current legislations are being considered in Europe to impose a minimum of 30% recycled content in all plastic products by 2030. Although the value of %TEC for Company A is not considered product by product, something that could be done in the future, its average by total material inflow is clearly above that 30% target, revealing promising results.

3.2 End of Life Indicators

These indicators were proposed in order to assess the efficiency of the recycling facility of Company A, regarding quality and performance. The following set is composed by three different indicators, CEI, CAV and RRs.

The Bales Quality refers to their purity, or the amount of desired material (percentage-wise) for each order. During the recycling process, the material is subjected to two distinct stages of sorting, dubbed Pass, which is divided into 1^{st} Pass (1P) and 2^{nd} Pass (2P). Each of these passages corresponds a extrusion process, described in Produced Pellets.

The last element to examine is the Max Theoretical CEI. Ideally, the CEI indicator is valued between 0 and 1, with 0 being the minimum and 1 being the maximum. Recycled plastic is a commodity with high volatility regarding market value. As such, since the value is mutable, the Max Theoretical CEI refers to the maximum amount of CEI that may be obtained at any given time. This value considers the market price of virgin material, as the denominator, and the maximum price at which the recycled material may be sold, as the numerator. In the cases studied, the value may be different since it was obtained at various time intervals.

Different Supplier, Different Quality

Order	Weight (kg)	Bales Quality	Pass	Produced Pellets (kg)	CEI	CAV	Max Theoretical CEI	R1
O1	24020	98/2	***1º***	12527	**0.235**	**1.574**	**0.441**	**83%**
			2º	*7032*	**0.356**	**2.390**		
O2	16440	80/20	***1º***	7343	**0.228**	**0.784**	**0.441**	**80%**
			2ª	*3219*	**0.327**	**1.128**		

Figure 4- Scenario 1: Different Supplier, Different Quality

For this case scenario, fig.4, both orders were mixed after first pass. On a fast-paced industry, such cases might happen, although not desired, and so must be assessed.

The analysis allows to conclude that even mixing orders together, the one with higher quality, O1, is the one with better scores. However, it can be stated that the act of mixing orders has positively influenced the scores for O2 and negatively influenced the scores for O1, reason why the values for CEI and R1 are so similar.

The difference in scores for CAV is explained by two factors. The first, is the fact that the buying price for O2 was higher despite its lower quality. The second, because O2 has lower quality, the final product that results have also lower quality, selling at lower prices. These two factors, combined, accentuate the gap of CAV between O1 and O2.

Same Quality, Different Supplier

Company A does business with many suppliers, the quality of the bales, at least theoretically, have the same quality. In order to check for compliance, this scenario compares two different orders with the same quality but coming from different suppliers.

This time, both orders were processed independently, with no mixing between the two.

Order	Weight (kg)	Bales Quality	Pass	Produced Pellets (kg)	CEI	CAV	Max Theoretical CEI	R1
O3	18680	98/2	***1º***	11231	**0,280**	**1,270**	**0,557**	**91%**
			2º	5369	**0,414**	**1,877**		
O4	20600	98/2	***1º***	13882	**0,314**	**1,998**	**0,557**	**89%**
			2ª	4091	**0,407**	**2,587**		

Figure 5- Scenario 2: Same Quality, Different Supplier

It can be seen, fig.5, that both orders have similar CEI and R1 values. Additionally, Max Theoretical CEI has also increased in its value since the market for secondary polymers have valued up, compared to virgin polymers. Once again CAV is the factor that offers bigger change. This time, the buying price was the main driver for such discrepancy since the final material from both orders were sold at the same price. Moreover, what can be stated is the fact that none of the orders have the 100% on R1, more precisely, it could not be extracted all the desired material that was present on the orders. It could be for two main reasons, or the quality of the bales is lower and therefore R1 is higher, or the quality of the bales is correct, but the process has some degree of inefficiency. The true reason and the weight they have on results must be assessed on future work.

At the current scenario, based on this unique experiment, supplier from O4 is the one that offers the biggest balance between profit and quality. However, it would be needed several analyses more, to have a confident result on which one is the better supplier.

Same Supplier, Same Quality, Different Dates

The following scenario, fig.6, is composed by orders from the same supplier, same quality but different dates. Applied in the long term, Company A can build a historic that helps to predict outcomes on future orders.

With even bigger qualities on the orders, CEI tends to increase accordingly. Both orders with quality 99/1 were the ones with bigger CEI values from all the total six.

In this scenario, there is a slight change. CEI and CAV barely change on values but is the ratio R1 the offers higher gap. The values are different because in each pass, O6 could produce much more final material than O5. In the end, besisdes extracting more material with O6, we had better CEI score with O5. The main conclusion on this scenario is that, even if CEI gets similar in values, we can not assume if that value comes from true quality or mainly by big quantity. Extraction process for O6 was based on extracting more material (as in R1) at medium quantity and O5 extracted less quantity (as in R1) at higher quantity. In the end, based on CEI values, quality tops quantity, and every time there both options are possible is always better to decide for quality, both for CEI or CAV.

The indicators R2 and R3 were not obtained because, at the time of this work, Company A did

Order	Weight (kg)	Bales Quality	Pass	Produced Pellets (kg)	CEI	CAV	Max Theoretical CEI	R1
O5	27825	99/1	*1º*	17673	**0,357**	**1,636**	**0,557**	**82%**
			2º	4922	**0,439**	**2,009**		
O6	15415	99/1	*1º*	10788	**0,323**	**1,478**	**0,557**	**94%**
			2ª	3493	**0,427**	**1,957**		

Figure 6- Scenario 3: Same Supplier, Same Quality, Different Dates

not have the necessary equipment for such measures. It is, however, part of the plan for future work.

Results of *OEE in sector IMP and SeR*

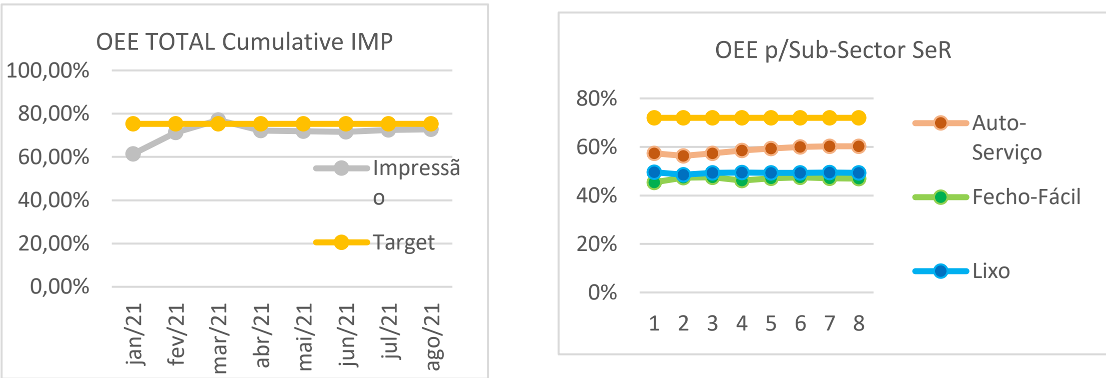

Figure 7- OEE results for IMP and SeR

The values, fig.7, indicate that, first and foremost, all sub-sectors of SeR have the same objective of 72 percent, and as a result, the whole SeR sector has the same target of 72 percent. In comparison to the IMP sector, the objective of 72 percent for the SeR is lower than the previously defined target of 75 percent, indicating that the IMP sector's performance on the OEE indicator is more developed.

Results of Waste Rate in sector IMP and SeR

The graphs, fig.8, says that IMP produces way less waste than SeR, however is still above target by a slim margin and added efforts are necessary. For sector SeR, the analysis of the graphs enables to conclude that the sub-sector Auto-Serviço is the only one that consistently delivers results below the 6.5% goal. On the other hand, the sub-sector Fecho-Fácil has waste rates that are always higher than the company's target. In the case of Lixo-Atilho, the results are very close to the target of 6,36%, oscillating within a range that does not exceed [6,15%; 6,75 %].

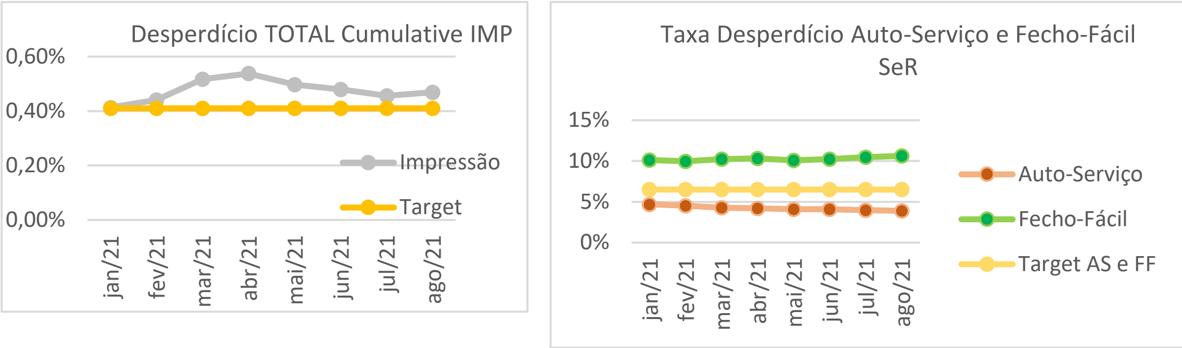

Figure 8- Waste Rate results for IMP and SeR

4 Conclusion

This work allowed the formulation of a new measurement tool or metric, corresponding to two sets of indicators that helps Company A to control and manage the transition to new business models that have Circular Economy at its core. The first set of seven indicators is responsible for assessing the life cycle of products along several stages as well as manage and track the efficiency of the recycling process regarding quality, quantity, and compliance of the suppliers. The second set of two indicators is responsible for monitoring the equipment efficiency from all the sectors of the company, regarding performance, quality and availability. They were both put into practice in real case scenarios. The results were very promising by allowing Company A to assess for the first time several aspects related to Circular Economy that were of great importance to monitor. These indicators give room to new and stronger collaborations between partners, help for a clear share of information and a serious commitment for continuous improvement of the product and the process. It sets the beginning of monitoring process for Circular Economy in Company A and gives momentum for the adoption of such metric in similar companies of the plastics industry.

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