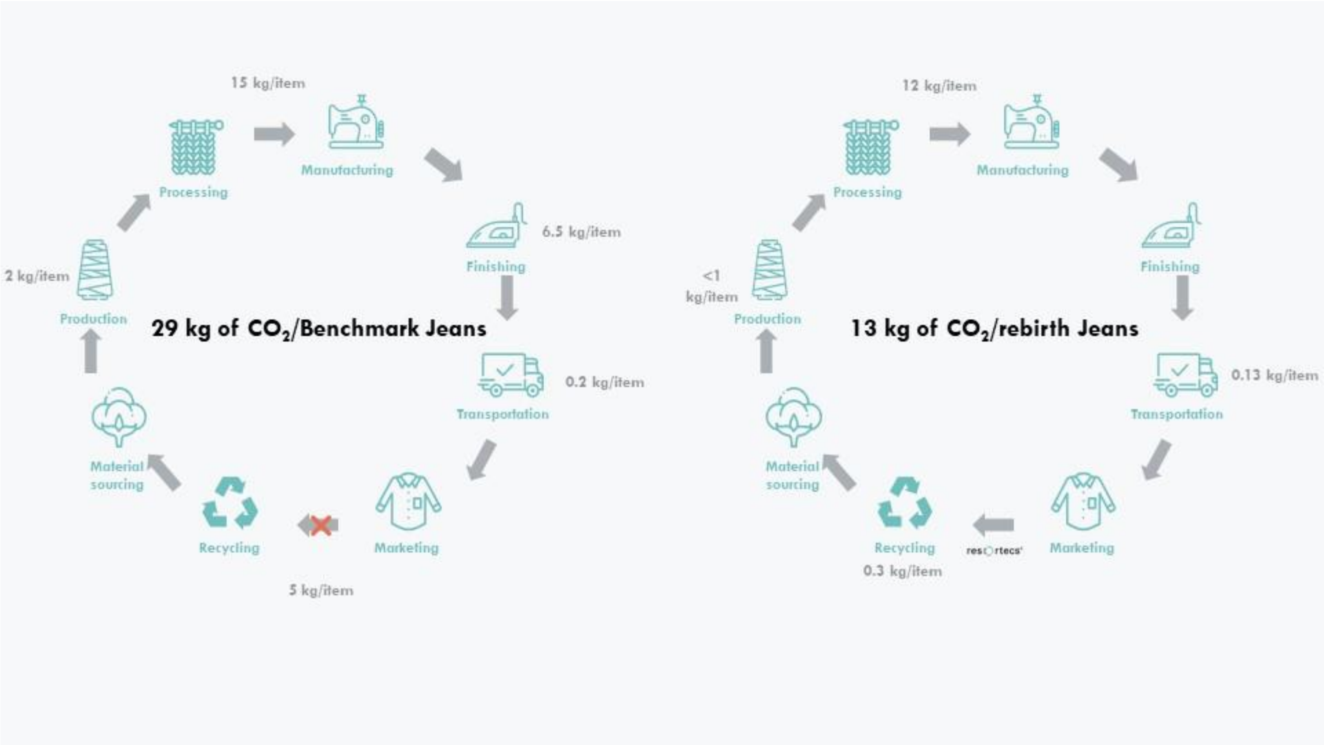
LCA speaks louder than the Ecolableing

Graphical abstract:



Textile industry is growing in a linear economy system by which 98 tonnes of non-renewable resources are consumed each year. Global fibre production was estimated around 106 million tonnes in 2018[1]. Only 1% of the used material in textile production is recycled that is translated to a loss of 100 billion USD worth of material annually. Textile industry is as a major source of greenhouse gas emissions with a CO_2 footprint of 1.2 billion tonnes of CO_2 equivalent per-year[2]. Further it is identified as an important source of plastic microfibers entering to the oceans. Textile overproduction, unsold inventories and difficulties of disassembly render sorting and recycling complicated, imposing polluting disposable options such as landfill and incineration. Producing Eco-sensible garments demands innovative technologies to tackle the issues that are facing textile industry at each step of the manufacturing process.

[1] https://www.weforum.org/agenda/2019/09/ending-the-era-of-dirty-textiles/

[2] Ellen MacArthur Foundation, *A new textiles economy: Redesigning fashion's future,* (2017, http://www.ellenmacarthurfoundation.org/publications).

Unspun® produces custom garments on demand utilizing a 3D weaving technology in an attempt to avoid generation of cut-offs and unsold inventory. To ensure sustainability, the product must be recyclable. *Rebirth*® is an *unspun*® digital fit jeans produced with *Resortecs*® soluble sewing thread that melts at 200 °C allowing sorting and recycling of the different materials without impacting their integrity, ultimately aiming at closing the sustainability loop of circular fashion.

The objective of this white paper is to conduct a comparative Life Cycle Assessment (LCA) between a *Rebirth*® pair of jeans and a benchmark jeans. The LCA will quantify the magnitude of the environmental impact (as kg equivalence of CO_2 emission per item) of producing one pair of jeans under both *Rebirth*® and classical textile production approaches.

What is LCA?

The Life Cycle Assessment (LCA) studies the environmental aspects and potential impacts throughout a product's life cycle, i.e cradle-to-grave (Figure 1), from raw material acquisition throughout production, use, an finally disposal. LCA stems from the increasing need to protect the environment and evaluate the impact of a product on the ecosystem and human health. LCA concept dated back to 1970s studies that were limited to analysing energy associated with packaging alternatives using different methods that generated variant results regardless the use of same objects and inputs[3]. The lack of a common norm and standard framework lead the involvement of International Standard Organization (ISO) in 1994. Consequently, ISO 14040[4] describes the principle and the framework to conduct LCA.

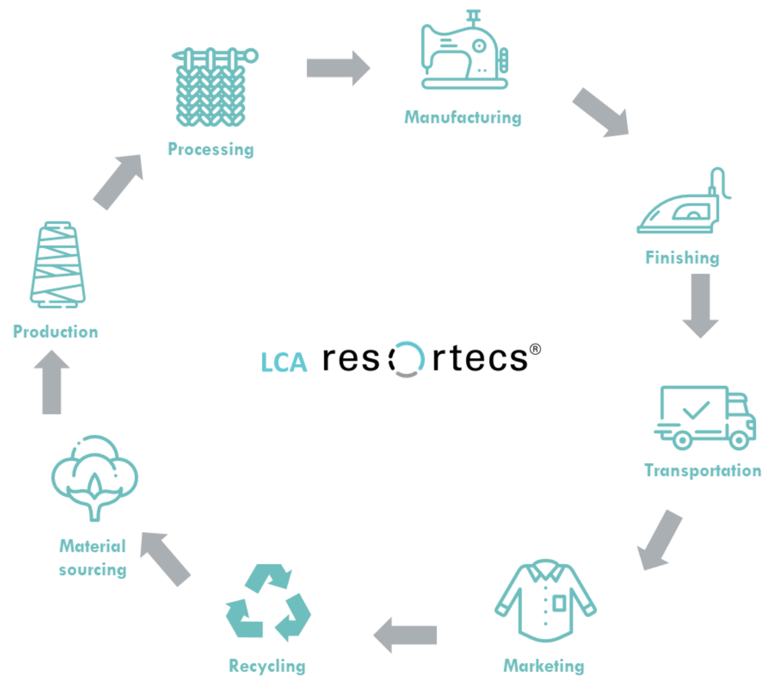


Figure 1: Garment life cycle stages that are covered by the LCA.

[3] International Symposium on Life Cycle Assessment and Construction July 10-12, Nantes, France

[4] International Standard Organization (2006) Environmental Management -LCA- Principles and Framework. ISO 144040 Geneva.

Why we need LCA?

As an environmental management tool, LCA provides a better understanding of the product's environmental impact at each stage of its life cycle. The increasing consumer awareness and the right to take informed purchasing decision necessitates knowing what is behind the product they buy, the traceability of the supply chain, and what is the product's fate after usage.

The LCA reveals the (un)anticipated consequences of the approaches green industry is claiming of having, by testing the actual environmental impact via overarching evaluation of product's life phases including transportation. Emissions equivalence at each stage of product's life will be calculated as part of the total LC assessment. Deep diving into the manufacturing processes in a factual manner based on scientific methodology will verify the ecological credentials of the product by allowing numbers to speak for themselves. Consequently, the LCA outcome provides the required knowledge to have well informed decisions for consumers, input for waste management policies, production strategies and further highlights opportunities to improve process and implement potential CO_2 tradeoffs[5].

Jeans Life Cycle Assessment

The ISO 14040 framework is followed to conduct this LCA. Direct applications of LCA rely on several parameters that should be identified and well characterized to allow appropriate data collection, inventory analysis and interpretation.

"LCA verifies the ecological credentials of the product by allowing numbers to speak for themselves"

LCA goal: the objective of this LCA is to provide a comparative analysis of the environmental impact of jeans produced using two different manufacturing approaches (benchmark jeans vs. *Rebirth*® jeans).

Functional unit: Since the goal of the LCA is for comparative purposes, the products should use the same definition of the functional unit[6]. The functional unit of this LCA is the mass of one pair of men's jeans = 500 g.

LCA scope: The LCA covers the CO_2 emission (equivalence of kg of CO_2 /item) during raw material acquisition (cotton, nylon, polyester, and brass), raw material processing (cotton spinning, weaving, yarn dying, zipper/button moulding), garment manufacturing (sewing, washing, drying and finishing), marketing the finished product, disposal (either incineration, landfill or recycling) along with all the stages of transportation routes between the different points of the life cycle. This LCA excludes the product use, as the environmental impact of the usage is considered equivalent for both products.

5 United Nations Environment Programme (2004), Why Take a Life Cycle Approach? New York: UNEP (ISBN 92-807-24500-9).
6 European Environment Agency, Environmental Issue Series no.6. Life Cycle Assessment (LCA). A guide to approaches, experiences and information sources 2016.

Data collection: The life cycle inventory is crucial for the accuracy of the LCA. Data availability, updated inventory, detailed and comprehensive processes will provide better resolution of the outcome. Conducting LCA is limited by data availability and complexity of the environmental system; therefore all the assumptions and choices taken throughout the project should be reported to ensure that the final result of the LCA remains within the appropriate context[7]. Ecoinvent database (2012) was used as life cycle inventory to calculate the CO_2 emissions from the different stages of jeans life cycle for both products.

Modelling: After data collection for each step of the jeans life cycle for both *Rebirth®* jeans and benchmark jeans, Excel software was used to calculate the environmental flows of the input and output of the jeans life cycle model. The data input for this LCA was based on the required raw material to produce 500 g of pair of jeans and the required energy associated for each processes. While the data output of the activities is translated by quantitative amount of equivalent kg of CO_2 emissions per jeans as depicted in Figure 2. *Unspun®* disclosed their production/manufacturing processes to *Resortecs®*, while available assumptions were used for the benchmark pair of jeans[8].

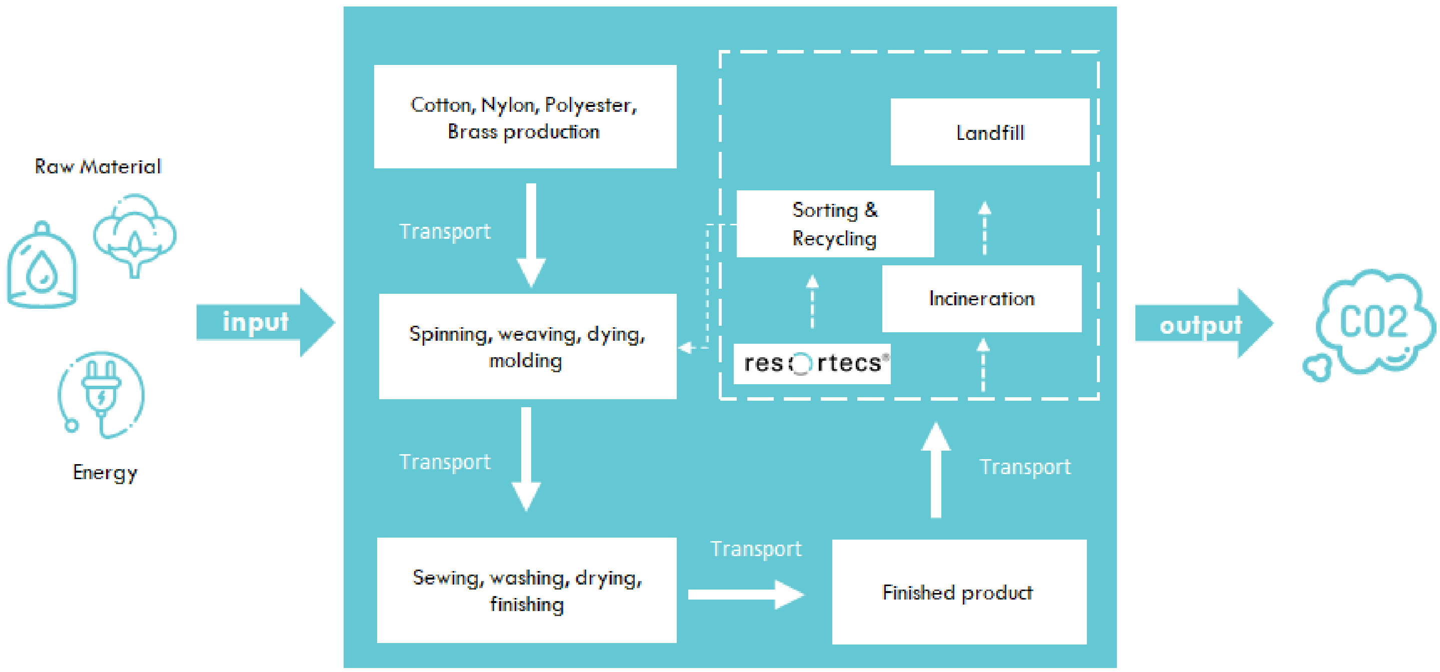


Figure 2: Flow chart of Jeans life cycle used for data collection and modeling.

[7] M. A. Curran Life-Cycle Assessment. Human Ecology, pages: 2168-2174, 2008
[8] Brut Nature France (https://www.youtube.com/watch?v=U9xoi7RSOwo)

Inventory analysis

Raw Material acquisitions of both products are represented in Figure 3. *Rebirth®* Jeans utilize BCI cotton (Better Cotton Initiative[9]), by which recent assessment showed that BCI cotton's primary energy demand is 2510 MJ compared to conventional cotton system of 5375 MJ[10]. Additionally, *Rebirth®* uses recycled polyester for the zipper. Sourcing the raw material to manufacture a product requires transportation of the material from the different countries as shown in Figure 3.

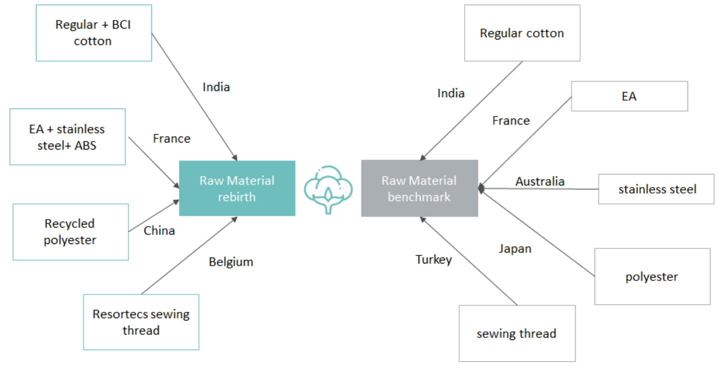


Figure 3: Raw Material types and acquisition routes

Once the raw material is obtained, further processing is required, and based on the particularities of the processes; the various steps take place in different countries (Figure 4). Raw material processing and production is different for *Rebirth®* in comparison to the classical processes that are considered to be utilized by the benchmark jeans. Namely, *Rebirth®* relies on 3D method were cut-offs are reduced, and adopt an eco plating technology for the buttons manufacturing that requires less energy[11].

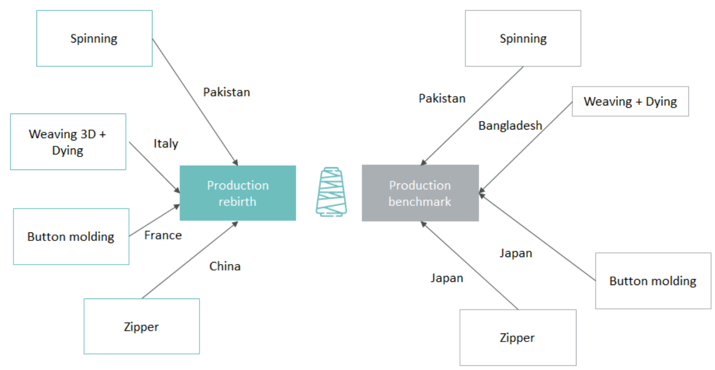


Figure 4: Material processing and their routes

"15% of the material is wasted as cut-offs during manufacturing"

Garment sewing, washing, drying and finishing is taking place in Dongguan China for *Rebirth®* jeans while for the benchmark jeans it is assumed to be in Tunisia (footnote 8).

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[9] https://bettercotton.org
[10] P. Shah, A. Bansal, R. K. Singh, Life Cycle Assessment of organic, BCI, and conventional cotton: A comparative study of cotton cultivation practices in India. Designing Sustainable Technologies, Products and Policies, pages: 67-77 2018.
[11] http://www.dorlet.fr/en/index.html

It was assumed that there is 15% of every jean's total mass is wasted as cut-off during the classical benchmark production methods by which the fate of the cut-offs is incineration[12]. *Unspun®* is targeting zero cut-offs thanks to its on-demand 3D weaving process – currently in development. Hong Kong was considered as the final market for both the rebirth and benchmark jeans after the finishing stage of each manufactured product.

For disposal, different scenarios were applied to have comparative analyses for this particular step of the product's life cycle. The fate of the benchmark jeans can be either incineration or landfill (Figure 1), which is considered to take place in mainland China. While for *Rebirth®* jeans, since disassembly of the jeans is feasible due to *Resortecs®* sewing thread, the jeans will be shipped to Belgium to be disassembled using *Resortecs®* heat disassembly methodology. This heat disassembly approach preserves the integrity of the different textiles and conserves their qualities. This will allow further recycling or even upcycling. The dissassembled textiles will be then shipped to the Netherlands for material sorting[13].

There are two scenarios of recycling after material sorting: either mechanical recycling (Netherlands) or chemical recycling (Sweden)[14]. The recycling process will allow the recovery of the raw material (mainly cotton) which in turn will be utilized for 60% as an input for *Rebirth®* jeans LCA. Regardless the disposal fate of the benchmark jeans (i.e. landfill or incineration), or the recycling method of the *Rebirth®* jeans (mechanical or chemical), emissions of CO_2 of one benchmark jeans is 2 folds higher compared to one *Rebirth®* jeans.

"20% of unsold inventory is estimated for fast fashion market"

Data interpretation: Each pair of jeans manufactured using classical processes releases more than 28 kg of CO_2 into the atmosphere. Both Table 1 and 2 show that the manufacturing of the material, in both cases, is the most polluting step of a jeans lifecycle accounting for almost 50% of the total CO_2 emission. Furthermore, the disposal of the unsold inventory (estimated to be 20% of the benchmark jeans inventory) represents ~16% of the total emission/item (Table 1). *Rebirth* ® will not have unsold inventory as the jeans will be manufactured upon demand. On the other hand, CO_2 emissions from landfill disposal of one benchmark jeans is slightly higher (28.61 kg/jeans) than incineration of the same jeans (28.35 kg/jeans) see Table 1.

12 *The Undiscovered Business Potential of Production Leftovers within Global Fashion Supply Chains:Creating a Digitally Enhanced Circular Economy, Reverse Resources, UK. Avaiable from: https://reverseresources.net/about/white-paper*

13 https://smartfibersorting.com/

14 https://renewcell.com/

Producing one pair of jeans following *Rebirth®* manufacturing releases ~13 kg of CO_2 to the atmosphere compared to 28 kg of CO_2 emitted during classical benchmark jeans production.

The CO_2 emissions from mechanical recycling of *Rebirth®* (13.09 kg CO_2/jeans) is comparable to the chemical recycling (13.37 kg CO_2/jeans) Table 2.

Regardless, the disposal fate of the benchmark jeans (i.e. incineration or landfill), or the recycling method of the rebirth jeans (i.e. mechanical or chemical), the emissions of CO_2 of one-benchmark jeans is 2 folds higher compared to rebirth jeans.

"Producing 1 pair of jeans releases > 28 Kg of CO_2"

Table 1: LCA comparing the incineration to landfill disposal of benchmark jeans.

	Process type	Countries	Benchmark jeans - Incineration	Benchmark jeans - Landfill
Benchmark jeans	Material sourcing (virgin)	India	2.047	2.047
	Material component manufacturing	Bangladesh	14.783	14.783
	Garment manufacturing	Tunisia	6.535	6.535
	Transportation (boat and road)	Hongkong	0.174	0.174
	Cut-off waste disposal (15%)	China	0.011	0.011
	Unsold (20%)	China	4.7252	4.7682
	Disposal Incineration-landfill	Hongkong	0.076	0.291
	Total kg CO2/item		**28.3512**	**28.6092**

Table 2: LCA comparing the mechanical to chemical recycling of Rebirth®

	Process type	countries	rebirth Jeans- Mechanical recycling	rebirth Jeans- Chemical recycling
Rebirth®	material sourcing (60% recycled)	India	0.864	0.864
	material component manufacturing	Italy	11.717	11.717
	garment manufacturing	China	0.346	0.346
	Transportation (boat and road)	HongKong	0.13126	0.13126
	cutoff waste disposal (0%)	China	0	0
	Resortecs processes	HongKong	0	0.038
	Sorting	HongKong	0.00002	0.00002
	Recycling	HongKong	0.0001	0.282
	Total kg CO2/item		**13.09638**	**13.37828**

Unspun® current manufacturing processes reduces 24% of CO_2 compared to the benchmark pair of jeans production. Stitching the jeans with *Resortecs*® sewing thread will achieve further 3% reduction of CO_2 (Figure 5). The objective of *Rebirth*® in the near future is to have zero cut-offs as considered in the assumptions of this LCA, and utilize recycled materials thanks to *Resortecs*® technology. Rebirth® ideal future will reduce CO_2 footprint by 53% compared to a benchmark production for each pair of jeans.

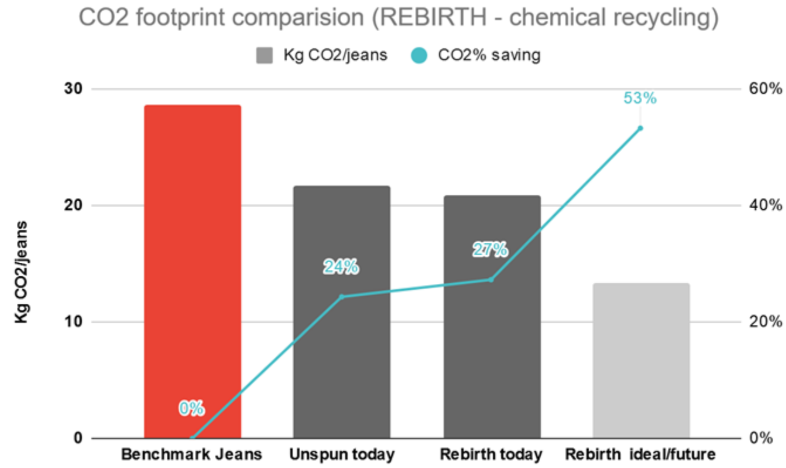
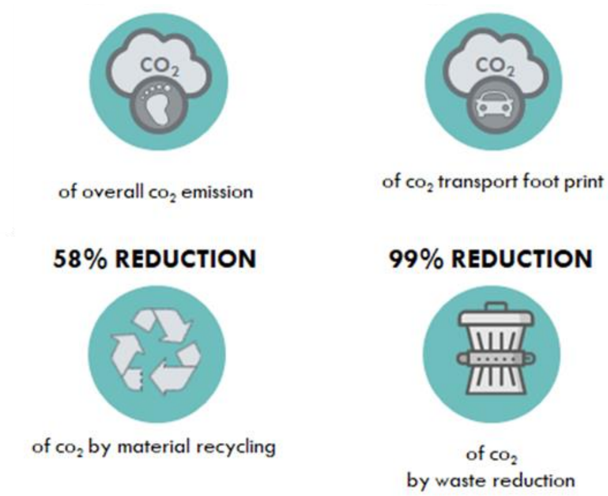


Figure 5: Roadmap of CO_2 footprint of Rebirth

Conclusion

The LCA from production to end-of-life of *Rebirth*® custom-fit dissolvable thread jeans in comparison to benchmark jeans showed reduction of CO_2 emissions at the different life cycle stages of the product. The LCA highlighted the parts of the production cycle that require optimization to further reduce the production environmental impact. Overall CO_2 reduction is estimated to be reduced by 53%, including 25% reduction in transportation, 58% reduction of raw material and 99% reduction of waste generation.



About the author

Rawaa Ammar joined Resortecs® on March 2019 as the sustainability manager. Rawaa holds a Ph.D in Earth and Environmental Sciences from University of Brussels (ULB, Belgium). She has more than 9 years of experience in scientific research, fieldwork and environmental risk assessment. Her research was focused on anthropogenic pollution, remediation, heavy metals impurities, Fe biogeochemistry in ocean and the link to atmospheric CO_2 emissions. Rawaa is a visiting professor at the Lebanese University (Beirut).

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