Validation report

FreyZein NextGen Textiles GmbH

23.09.2024

Validation ID: IG0026

Impact Forecast

Impact Insights & additionality

Contents

Details of the validation process

Timestamps and results:
The validation documented in this report was delivered with the following time stamps and results:

FreyZein GmbH	Validation request	First review	Feedback call	Hand-in revisions	Final review	Wrap-up call
Date	11/09/24 12h21	18/09/24 02h21	18/09/24 11h00	22/09/24 10h00	22/09/24 17h00	23/09/24 13h30
Result	Invalid, Positive and Significant			Valid, Positive and Significant		

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Author	Israel Griol-Barres
Company name	FreyZein GmbH
Project CIF lead	Jan Karlsson, CEO and Founder
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More information	www.impact-forecast.com

Introduction to CIF Validation

To determine the validity of self-assessed climate impact forecasts we provide CIF Validation, which is a third party verification of the calculation of the climate and environmental impact of an innovation, in order to conclude if the Climate Impact Forecast is valid, positive and significant.

Problem solved

There are areas of LCA expertise that cannot be covered in the Climate Impact Forecast workshops or CIF Training, for example where domain knowledge and experience are required. With self-assessments there is also a risk of optimism bias. Validation assures that forecasts do not contain gaps, scoping errors, unsupported assumptions or inappropriate data sources. CIF Validations are made on the request of the project team, and possibly commissioned by an impact organisation. The results are used by teams and organisations to compare and communicate the climate impact of projects.

A validation process performed by an impartial impact expert, who has read about the innovation, seen the forecast and used a checklist to assess its validity. The validator provides detailed written feedback and offers the opportunity for a revision. The goal of this process is twofold: increase the quality of a forecast and to conclude if the forecast is suitable to draw conclusions about the positive climate impact of the innovation. This Validation report documents the results of that process.

Definitions of key terminology

Climate Impact Forecast (CIF)	A Climate Impact Forecast or CIF is an LCA based calculation of the GHG reduction or climate adaptation potential of a project. Using our CIF tool, the project team found the net climate impact of the key differences between business as usual and their innovative solution.
CIF Validation process	A review process delivered by a validator and guided by a structured check of the information entered into a CIF, a sensitivity analysis and the write-up of an Impact story. This process usually takes two weeks and includes a first review, a first feedback call between the team and validator, time for revisions if needed, a final review and a final results call.
Validator	Validations are delivered by Validators; CIF trainers with LCA expertise who are trained to perform this process in a uniform and objective way. Other than providing this service, Validators have no relationship with or obligations to the company or supporting organisation requesting the validation, assuring an impartial third party review.
Validation result	The CIF Validation result consists of three independent outcomes, which in the best case are valid, positive and significant. These qualifications and the alternative outcomes are explained on the next page.

The CIF Validation result consists of three independent outcomes

Validity of the forecast

A CIF is valid if it is representative of the project, using appropriate data and well-justified assumptions. Therefore, the CIF and its results are representative of the potential for the project to mitigate, enable or adapt to climate change.

Detailed requirements for validity are specified on www.impact-forecast.com/ CIF-validations. A CIF can be:

Valid	Plausible	Improbable	Invalid

Reduction potential

A CIF is positive when it shows that the project has a lower climate impact than business as usual, or improved climate resilience in the case of adaptation. A positive mitigation or enabler CIF file shows the avoided GHG emissions in -tCO_2eq.

This outcome depends on a sensitivity assessment. CIF results can be:

Positive	Positive within limits	Unclear	Sensitive	Negative

Impact threshold

A CIF is significant when the project has a climate impact (positive or negative) greater than 5 tonnes of CO_2eq per year. This is roughly the global average annual CO_2 emissions per person and the mass of a male African Elephant.

The threshold for significant impact can be set to a higher amount for a particular organisation or occasion. The result can be:

Significant	Marginal

FreyZein GmbH CIF Validation

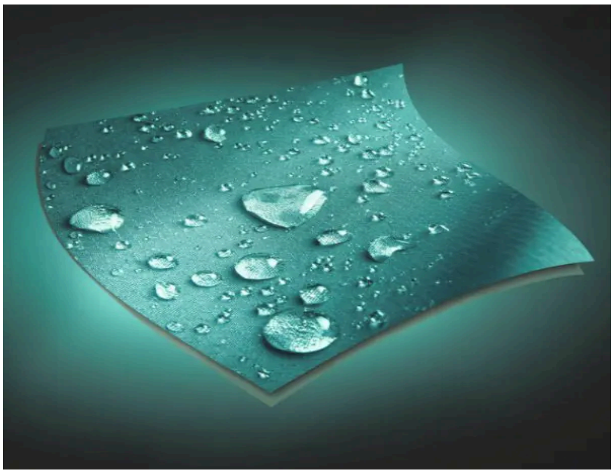
This validation consists of the following sections

Impact story	An impact story is a summary of how a project makes a positive climate impact. It is written by the validating impact expert and contains the key impact data from the Climate Impact Forecast.
Climate Impact Forecast and Validation result	The Climate Impact Forecast shows the scope and parameters of the impact calculation. This includes the resources used and saved by the innovation, their amount and climate impact, the climate impact per unit of user, and the total climate and environmental impact for all units or users in the timeframe. Validator feedback is included on strong and weak points of the forecast as a whole, as well as the conclusion from the sensitivity assessment and the approval status of individual parameters. The conclusion of the validation process is noted in the Validation result.
Sources and assumptions	The differences (resources used and reduced by the innovation, compared to the baseline solution) and quantities (of materials, energy etc.) in the forecast are based on sources and assumptions specified in this section.

Impact story

A new technology to produce fabrics makes textiles more sustainable

FreyZein GmbH provides TerraDown™ performing nano-enhanced cellulose, a thermal insulation solution recyclable, biodegradable, and from renewable and eco-conscious feedstocks. This innovation is a multilayer embedding a non-woven fabric empowered with aerocellulose - a cellulose-based aerogel - a multilayer that can be eventually enriched on the top, with an hydrophobic membrane.



How does this make a positive climate impact? Compared to which baseline?

This innovation is compared in this Climate Impact Forecast to the current baseline behaviour of using PRIMALOFT and ECODOWN mainly, but also THINSULATE, solutions represented by non-woven fabrics made out of PET/r-PET/PLA, or blends of them with wild or natural fibers (e.g., FLWRDWN and BIO PUFF), or recycled feather and down (THINDOWN).

The functional unit used to perform this comparison is 1LM (1 linear metre of fabric - roll width 155cm). The total impact of FreyZein GmbH per year is calculated for 5,000 times this functional unit. The key difference between the innovative and baseline solutions are the extraction, production, recycling and waste stages. Less materials, energy and waste treatment are needed in the innovation.

How much of a climate impact, and what does the impact depend on?

The impact per 1LM (1 linear metre of fabric - roll width 155cm) is the avoidance of 3.239kg of CO_2eq (functional unit).

The impact of 5,000 times this functional unit is the avoidance of 16 tons of CO_2eq.

The positive impact comes mainly from the avoidance of using Dimethyl Terephthalate (liquid DMT). The source for this item in the inventory is custom and comes from Oxxynova GmbH, a company that discontinued the generation of DMT at the end of 2022.

The eco-costs of carbon footprint, the resource depletion, human health and eco-toxicity are not calculated, as custom items are used in this CIF.

Validity

The forecast is valid, positive and significant, and the conclusion that FreyZein GmbH has a positive climate impact is robust when a sensitivity test is performed. The impact per 1LM is -3.239kg of CO_2eq (functional unit). At the scale of 5,000 times the functional unit, the total impact of -16 tons of CO_2eq is similar to the carbon footprint of 2 average humans or 735 trees.

Climate Impact Forecast and Validation result

FreyZein GmbH provides TerraDown™ with performing nano-enhanced cellulose, a thermal insulation solution recyclable, biodegradable, and from renewable and eco-conscious feedstocks. A multilayer embedding a non-woven fabric empowered with Aerocellulose - a cellulose-based aerogel - a multilayer that can be eventually enriched on the top, with an hydrophobic membrane, instead of PRIMALOFT and ECODOWN mainly, but also THINSULATE, solutions represented by non-woven fabrics made out of PET/r-PET/PLA, or blends of them with wild or natural fibers (e.g., FLWRDWN and BIO PUFF), or recycled feather and down (THINDOWN). The difference in impact is calculated per year and the total impact of FreyZein GmbH per year is calculated for 5000 times 1LM (1 linear meter of fabric - roll width 155cm).

Validation	By: Israel Griol-Barres, Started: Mon Sep 23 2024 22:51:07 GMT+0200 (hora de verano de Europa central), Completed: Mon Sep 23 2024 22:58:56 GMT+0200 (hora de verano de Europa central)
Strong points	self explanatory, multiple sources
Sensitivity	robust

Extraction				
–	Average of wind, hydro and PV (renewable)	0.00958 per MJ	3 MJ	-0.02874
–	Ethylene glycol monoethyl ether	1.597 per kg	0.335 kg	-0.5349
+	Sodium Hydroxide, NaOH (European Chlor-Alk	0.65 per kg	0.35 kg	0.2275
–	Dimethyl Terephthalate (liquid DMT)	3 per kg	0.86 kg	-2.58
Production				
–	Average of wind, hydro and PV (renewable)	0.00958 per MJ	6 MJ	-0.05749
–	Waste to recycling prosesses	0 per kg	0.2 kg	0
Recycling				
–	Average of wind, hydro and PV (renewable)	0.00958 per MJ	7 MJ	-0.06707
Waste				
–	Average of wind, hydro and PV (renewable)	0.00958 per MJ	5 MJ	-0.04791
–	Waste to recycling prosesses	0 per kg	0.2 kg	0
–	Methanol	0.9474 per kg	0.235 kg	-0.2226
+	Sodium Hydroxide, NaOH (European Chlor-Alk	0.65 per kg	0.05 kg	0.0325
+	Ethanol (alcohol), synthetic	1.082 per kg	0.005 kg	0.00541
+	PEG	2.00 per kg	0.005 kg	0.01
+	Liquid N2	0.3 per kg	0.08 kg	0.024

FreyZein GmbH's total impact per year

eco-costs of human health euro	unknown
eco-costs of eco-toxicity euro	unknown
eco-costs of resource depletion euro	unknown
eco-costs of carbon footprint euro	unknown

	Carbon footprint CO_2eq.
Impact per 1LM (1 linear meter of fabric - roll width 155cm)	-3.239 kg
Impact of 5000 times 1LM (1 linear meter of fabric - roll width 155cm)	-16t

Validation ID: IG0026
Date: 25-09-2024

FreyZein NextGen Textiles GmbH
Mitigation project

Impact reduction potential	-16 tCO_2eq./year

Validity of the forecast	Valid
Reduction potential	Positive
Impact threshold	Significant

Sources and assumptions

The differences and quantities in the forecast are based on the following sources and assumptions:

Extraction

Baseline process (Polyethylene Terephthalate - PET - fibres and nonwoven fabrics):
PET products represent the baseline for comparison, which are produced through the reaction of the monomers purified terephthalic acid (PTA) or dimethyl terephthalate (DMT) and ethylene glycol (EG) or mono ethylene glycol (MEG), often in the presence of catalysts. Typically, ethylene glycol is derived from natural gas, while terephthalic acid is sourced from p-xylene, which is created from crude oil. The synthesis occurs via an esterification reaction between terephthalic acid and ethylene glycol, producing water as a by-product (also known as a condensation reaction), or through a trans-esterification reaction between ethylene glycol and dimethyl terephthalate (DMT), resulting in methanol as a by-product. This last production route is the baseline process chosen as benchmark for the comparison.
The majority of energy used in PET production (according to baseline process) comes from fossil fuels (natural gas, oil, and coal). These are used in both the raw material extraction (ethylene and terephthalic acid production) and the polymerisation process, which requires heat for transesterification and/or polycondensation.
SOURCE:
- COMET report on plastic emissions:
https://ccsi.columbia.edu/sites/default/files/content/COMET-making-plastics-emissions-transparent.pdf
The baseline process (the transesterification process or dimethyl terephthalate (DMT) process), it requires approximately 2.0 to 2.5 kWh of energy per kg of PET produced - from both virgin or recycled monomers. This includes the energy needed for both the transesterification and/or polycondensation steps, which involves processing dimethyl terephthalate (DMT) and ethylene glycol (EG) at elevated temperatures, as well as heating, stirring, and cooling.
SOURCES: https://pubs.rsc.org/en/content/articlehtml/2022/gc/d2gc02860c &
https://link.springer.com/chapter/10.1007/978-981-19-2572-6_19.
By these same data sources can be also estimated the quantities of dimethyl terephthalate (DMT) and ethylene glycol (EG) needed in the process for 1 kg of final PET, that are reported below, specifically: 0.335 kg (EG) and 0.86 (DMT), per kg of PET fibres - needed for the trans-esterification reaction between ethylene glycol and dimethyl terephthalate (DMT), resulting in methanol as a byproduct (see methanol considerations in the waste streams). The production of 1 kg of dimethyl terephthalate (DMT) is estimated to emit approximately 2.37-3.44 kg of CO2eq, depending on the specifics of the production process and energy sources used.
SOURCE: https://climate.ec.europa.eu/system/files/2020-09/2020_study_main_report_en.pdf &
https://www.nrel.gov/docs/fy21osti/80008.pdf & https://www.methanol.org &
https://www.frontiersin.org/journals/energy-research.
TerraDown™ (FYZ innovative process):
FreyZein TerraDown™ is a 100% cellulose-based, thermo-adaptive multilayer fabric. It features a non-woven layer enhanced with aerocellulose - a colloidal suspensions of nanofibers, processed through freeze-drying to create a porous, lightweight cellulose aerogel. The non-woven fabric is crafted by hydroentangling cellulose fibers, and the aerocellulose is crosslinked within this structure, resulting in a multilayer solution that dynamically adapts to the user's microclimate. Cellulose isolation is performed using sodium hydroxide (NaOH). This method involves treating cellulose-rich biomasses with NaOH to break down lignin and hemicellulose, which are other components of the plant cell wall, leaving behind

pure cellulose. Aerocellulose is synthesized using the sol-gel method, with water and NaOH serving as the solvent and cross-linker, and ethanol and polyethylene glycol (PEG) used in the solvent exchange phase. Liquid nitrogen is employed for freezing the aerogels during the preparation (pre-cooling) and solvent exchange phases. Ethanol and polyethylene glycol (PEG) used in the solvent exchange phase, as well as the liquid nitrogen employed are reported in the phase of waste streams, as by-products [FYZ own data]. Our process is environmentally friendly, as the electricity used is entirely generated from an average of wind, hydro and PV (renewable) energy sources, minimizing environmental impact. Additionally, water is recycled, and no byproducts are produced.
FYZ process requires 0.35 kg of NaOH and save 3 MJ of energy, with respect to the baseline data per kg of material, due to the use of an average of wind, hydro, and PV (renewable) energy sources [FYZ own data].

Production

At this stage, the fibers are consolidated into a multilayer structure through mechanical and thermal processes, resulting in structures entirely made of cellulose.
Baseline process:
The production of 1 kg of nonwoven fabric typically requires an estimated 5-10 kWh of energy, depending on the specific manufacturing process used (e.g., mechanical bonding, thermal bonding, etc.) and the material type. Nonwovens made from synthetic fibers like PET (or other synthetics) may fall on the higher end of this range due to energy-intensive heating and extrusion processes, while natural fiber nonwovens like those from cellulose may require less energy. This estimation reflects the energy demands for powering machinery, heating, and cooling during production, as well as the energy used in fiber bonding processes like needle-punching or hydroentangling.
SOURCES:
- OEcotextiles: https://oecotextiles.blog/2011/01/19/estimating-the-carbon-footprint-of-a-fabric/
- Nonwoven Cost of Production | Q1 2024 | Intratec.us:
https://www.intratec.us/analysis/nonwoven-cost-of-production

The production of 1 kg of nonwoven fabric, particularly from synthetic fibers such as PET (polyethylene terephthalate), typically generates pre-consumer waste at a rate of about 5-15% of the material input. This waste primarily results from cutting, handling, and processing inefficiencies during the fabric manufacturing process. The waste generated can vary depending on the production technique (e.g., meltblown, spunbond), machinery efficiency, and the specific application of the nonwoven fabric.
For nonwoven fabrics made from PET, pre-consumer waste includes fiber residues, scrap material, and by-products from fiber extrusion. Efforts are being made in the industry to recycle this pre-consumer waste back into production, either by reprocessing the fibers or using them in lower-quality applications.
SOURCES:
- Textile World - In their special reports, they discuss how the PET fiber industry is urging the necessity of adopting zero-waste strategies, including reprocessing fiber residues and scrap materials generated during production to minimize waste:
https://www.textileworld.com/textile-world/supplier-notes/2020/08/pet-fiber-production-zero-waste-cycle-thanks-to-retrofitted-components/
- MDPI (Multidisciplinary Digital Publishing Institute) - Research published on nonwoven fabric manufacturing highlights the common levels of waste in fiber extrusion and handling, emphasizing the importance of recycling this pre-consumer waste into lower-quality applications:
https://www.mdpi.com/2504-477X/3/2/21

- INDA (Association of the Nonwoven Fabrics Industry) - Reports by industry bodies like INDA provide further insight into typical waste generation during nonwoven production and efforts to improve recycling and sustainability practices within the sector.
TerraDown™ (FYZ innovative process):
The electricity used in our processes is generated from an average of wind, hydro, and PV (renewable) energy sources, significantly reducing our environmental impact to a calculated value of 6 MJ less, per kg of nonwoven fabric produced [FYZ own data]. The typology of our production and our waste treatment system reduce the quantity of pre-consumer waste of 20% with respect to baseline, facilitating the easy recycling of the industrial scraps generated, mechanically [FYZ own data]. Due to the nature of the materials and the absence of chemicals and bonding adhesives, our multilayer fabric production process is not harmful to workers, simpler, less resource-intensive, and generates less waste, and more easy to up-cycle.

Recycling

Baseline process:
The mechanical recycling of PET fabric typically requires around 5-10 MJ per kg, depending on the specific process and machinery used. This energy consumption comes from simpler reprocessing techniques, like melting and re-extruding the polyester. However, chemical recycling of polyester fabric, such as glycolysis or methanolysis, is more complex and energy-intensive, requiring between 40-70 MJ per kg due to additional chemical reactions, depolymerization, and purification steps. These figures are supported by various studies on polyester recycling technologies, including detailed reviews published by IntechOpen and Royal Society of Chemistry (RSC), which discuss the energy requirements and environmental impacts of both mechanical and chemical recycling processes in the polyester industry.
SOURCES:
- Polyester Recycling - Technologies, Characterisation, and Applications | SpringerLink: https://link.springer.com/chapter/10.1007/978-981-287-643-0_7
- Degradation and Recyclability of Poly(Ethylene Terephthalate) | IntechOpen: https://www.intechopen.com/chapters/39405
- Chemical recycling of polyester textile wastes: shifting towards sustainability - Green Chemistry (RSC Publishing): https://pubs.rsc.org/en/content/articlelanding/2024/gc/d4gc00911h
The energy required to mechanically recycle 1 kg of cellulose fabric is estimated at 2-3 MJ, while chemical recycling, such as the Lyocell process, demands 30-40 MJ per kg due to the additional steps involved in dissolving, chemical processing, and fiber regeneration. The Lyocell process is more energy-efficient than conventional chemical recycling methods, particularly in dealing with post-consumer waste, leading to real upcycling of cellulose fibers.
SOURCES:
- BioResources on the Lyocell process: https://ojs.cnr.ncsu.edu/index.php/BioRes/article/view/BioRes_06_2_1524_Fink_Lyocell_Process
- NREL studies on energy use in textile recycling: https://www.nrel.gov/docs/fy21osti/80008.pdf
These values are estimates and can vary depending on the specific technology, scale, and efficiency of the recycling process used.
TerraDown™ (FYZ innovative process):
As a mono-material product, no separation of different materials or layers is required (on the multilayer solution), allowing for a seamless transition directly to the defibering phase, which feeds into the

mechanical recycling process. This facilitates the recovery of staple fibers to be reused in new textile solutions. In addition to the ease of up-cycling, FYZ's process saves 7 MJ per kg of energy in mechanical recycling, as highlighted in the baseline data above. This reduction is attributed to the material type and the use of renewable energy sources, including wind, hydro, and solar [FYZ own data]. Moreover, due to the absence of harmful chemicals and bonding adhesives, our multilayer fabric is safer for workers, more resource-efficient, and significantly easier to recycle.

Waste

Baseline process:
For the production of 1 kg of PET via the dimethyl terephthalate (DMT) process, approximately 0.2-0.3 kg of methanol is generated as a by-product. This amount of methanol is produced during the transesterification reaction when DMT reacts with ethylene glycol to form PET, releasing methanol as a result of the chemical process.
SOURCES:
- Methanolysis of PET Waste Using Heterogeneous Catalyst of Bio-waste Origin | SpringerLink: https://link.springer.com/article/10.1007/s10924-021-02305-0
- Low-energy Catalytic Methanolysis of Poly(ethylene Terephthalate) | Green Chemistry:https://pubs.rsc.org/en/content/articlelanding/2021/gc/d0gc03536j

TerraDown™ (FreyZein innovative process):
The residues/byproducts of the fiber synthesis processes include methanol and sodium hydroxide, while ethanol, polyethylene glycol, and liquid nitrogen (used as a cooling medium) are utilized in very low quantities in the aerogel synthesis.
To freeze-dry a colloidal suspension of cellulose nanofibers, we need approximately 4.64 kg of liquid nitrogen (LN2), which is equivalent to about 5.74 liters of LN2 - the quantity is the one needed for 1 kg of final aerocellulose. Liquid N2 is used as freezing agent in the process freeze-drying colloidal suspensions of cellulose nanofibers, processed to create a porous, lightweight cellulose aerogels - FYZ's aerocellulose. The aerocellulose is later embedded into a non-woven fabric crafted by hydroentangling other cellulose fibers. We use around 0.0175-0.018 kg of aerocellulose per kg of final product. From here the calculation of 0,08 kg of LN2: 4.64 per 1 kg di aerocellulose, 0.08 per 0.0175-0.018 kg of aerocellulose [FYZ own data].
To estimate the CO2-eq for 1 kg of liquid nitrogen (LN2), we considered the energy needed for its production and transport. The energy required for LN2 production is approximately 0.549 kWh per kg, and based on typical electricity grid emissions, this results in around 0.18-0.20 kg CO2eq per kg of LN2 produced. Additional CO2 emissions arise from transportation, which can add till 0.13 kg CO2eq, depending on the distance.
SOURCE:
- Cytiva Study on Cryopreservation: https://www.cytivalifesciences.com/en/us/support-center/impact-of-cryopreservation-carbon-footprint-10001

Sodium hydroxide (NaOH) is utilized in both the production of nanocellulose fibers and aerocellulose. It plays a crucial role in hydrolyzing the nanofibers and forming colloidal suspensions, which are later freeze-dried to create aerocellulose. The quantity reported - 0.05 kg per kg of product - is calculated according to our actual production processes and considering that NaOH and all the solutions containing it are not recycled for chemicals separation and are treated as side-streams (by-products) [FYZ own data].

Ethanol and PEG are considered in the same way, they are both used in the quantities of 0.005 kg (both same quantity) per kg of product, respectively, in the solvent exchange phase, and treated in the waste management phase, as by-products [FYZ own data].

The CO_2-equivalent (CO_2-eq) emissions for 1 kg of polyethylene glycol (PEG) are estimated to be around 1.77-2.3 kg CO_2-eq, depending on the production process and energy sources used. These figures account for emissions from the raw materials, chemical reactions, and energy consumed during manufacturing. Including PEG in the waste stream further impacts the environmental footprint, especially if it isn't efficiently recycled or managed in waste treatment processes. These values are supported by various assessments and studies related to the environmental impact of polyethylene and its derivatives in waste management and production scenarios. This estimation aligns with data from life cycle assessments (LCAs) and carbon accounting methodologies seen in multiple environmental studies.

SOURCES:

- https://legacy.winnipeg.ca/finance/findata/matmgt/documents/2012/682-2012/682-2012_Appendix_H-WSTP_South_End_Plant_Process_Selection_Report/Appendix%207.pdf
- CO_2 Capture with PEG | SpringerLink: https://link.springer.com/chapter/10.1007/978-3-642-31268-7_4

A significant advantage in the waste management phase is the very limited quantities of by-products from cellulose processing - see data above, self-declared by FYZ. This allows for a reduction of 20% in the waste generated (mainly chemicals in solutions) with respect to the baseline data [FYZ own data]. The electricity used in our processes is entirely generated from renewable sources (including wind, hydro, and solar (PV)) [FYZ own data], significantly reducing our environmental impact and allowing a reduction of 5 MJ per kg of product in the waste management phase, vs. the baseline data. Additionally, our mechanical waste treatments are energy-efficient, further optimizing waste management.

More information

For more information about this validation, and Climate Impact Forecast Validation in general, reach out to Impact Forecast.

Impact Forecast B.V.
The Netherlands
info@impact-forecast.com