P5 Presentation

REC-HERO



TU Delft Delft University of Technology

MSc Thesis-Berk Adsan

HERO

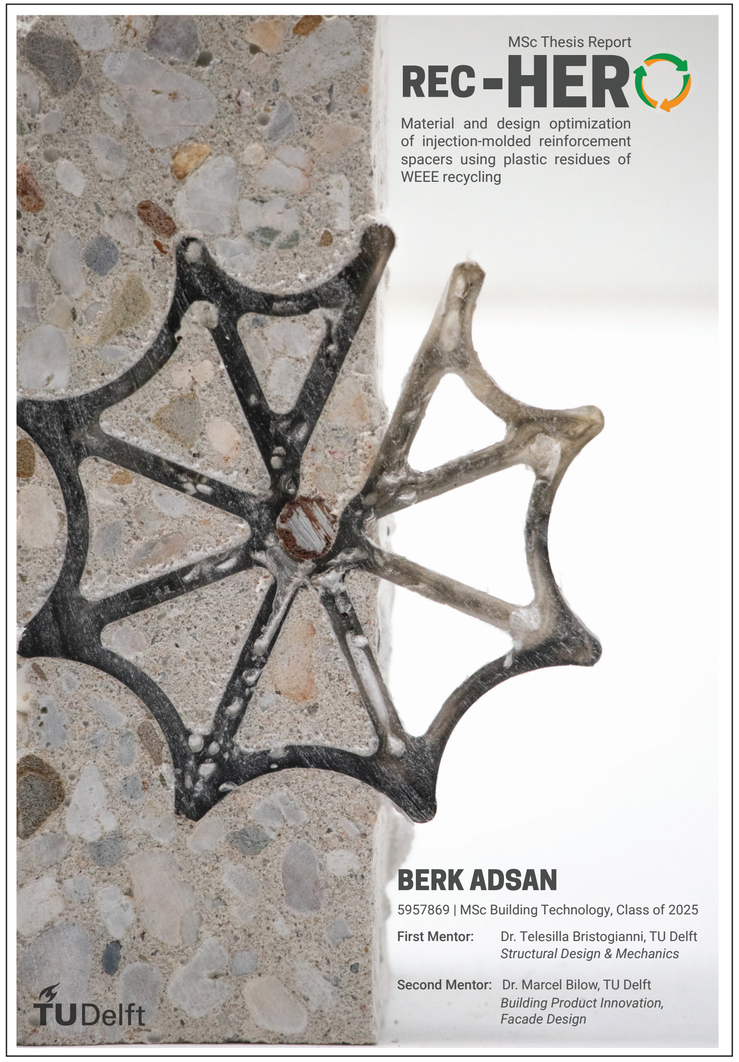
First Mentor: Dr. Telesilla Bristogianni
Structural Design & Mechanics

Second Mentor: Dr. Marcel Bilow
Building Product Innovation, Facade Design

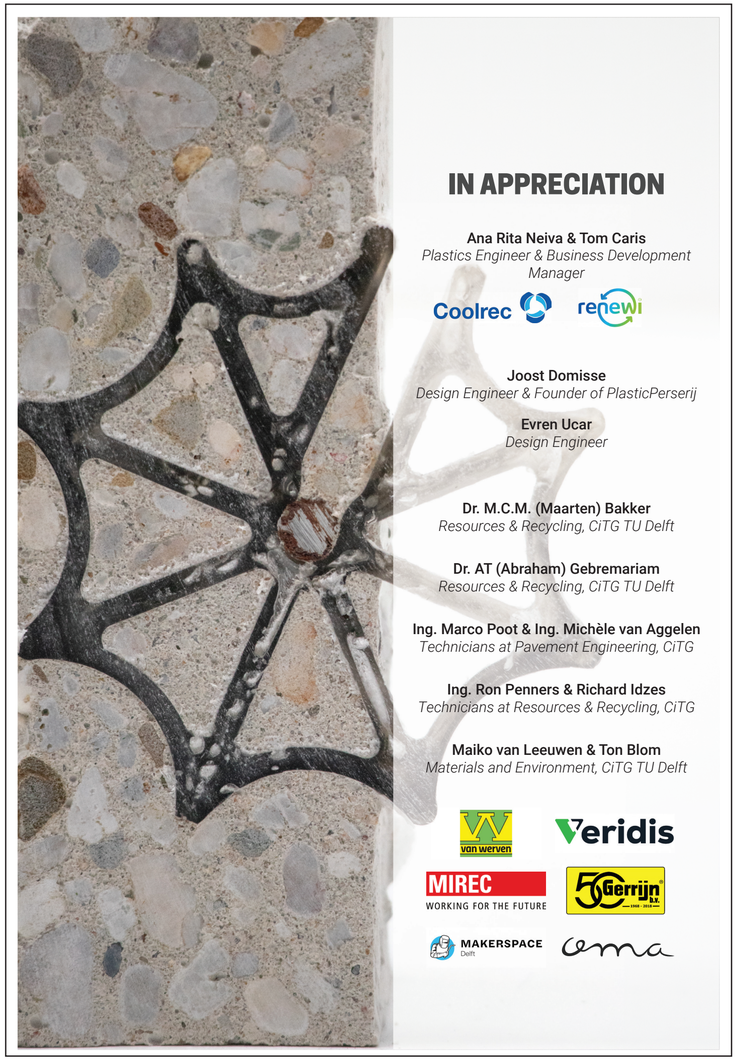
External Examiner: Seyran Khademi



TU Delft Delft University of Technology



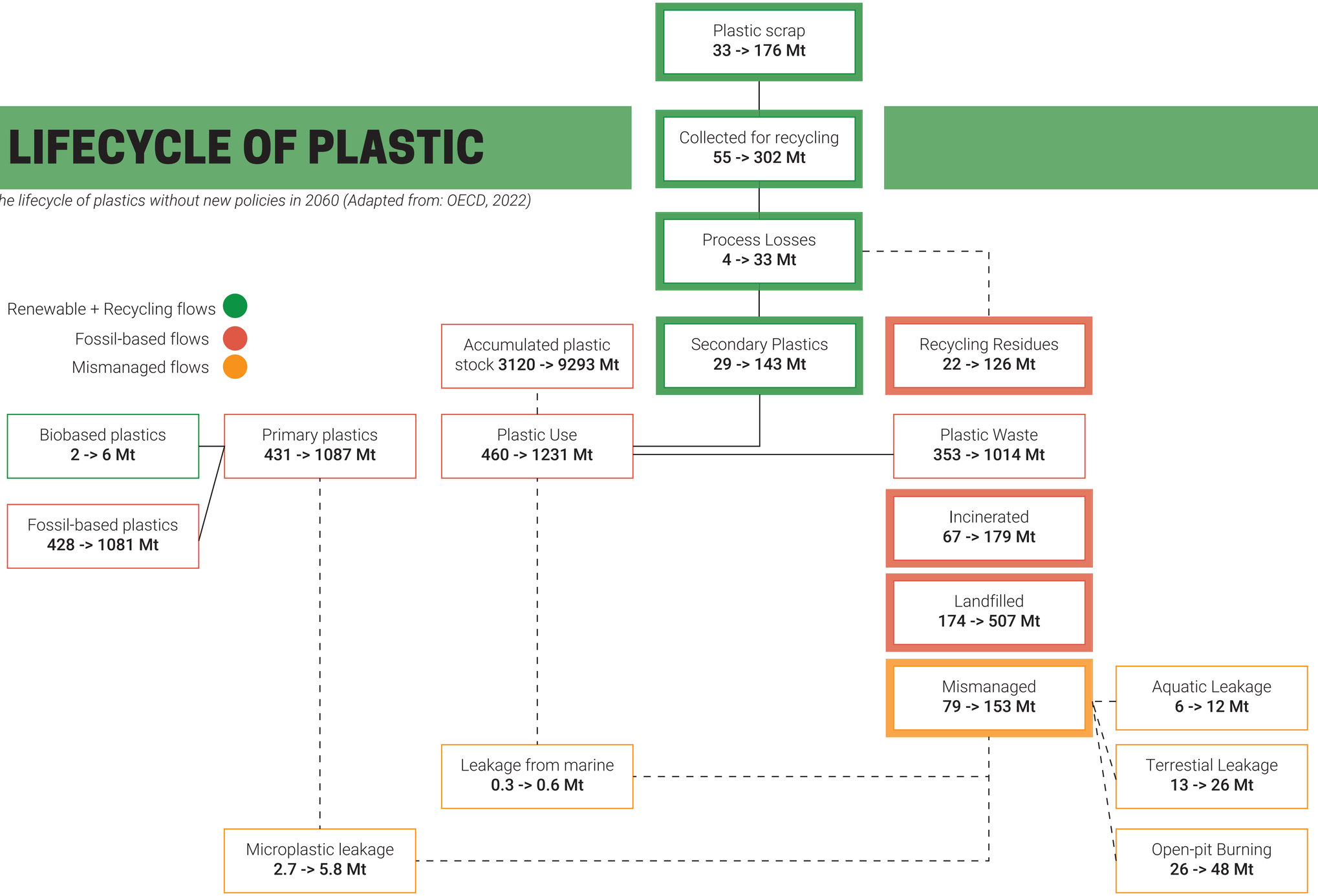
Based on the P5 Thesis Report by Author



Based on the P5 Thesis Report by Author

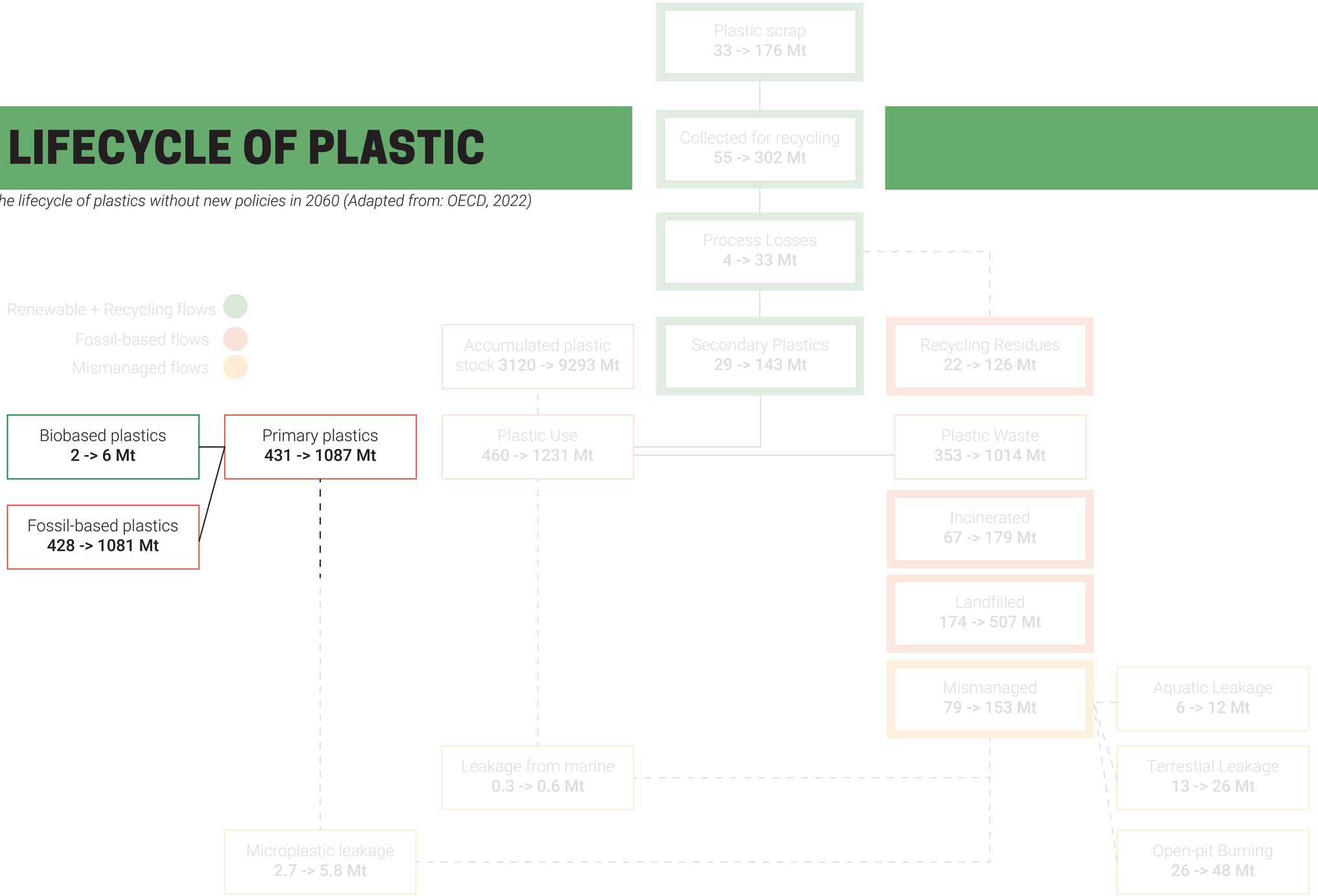
LIFECYCLE OF PLASTIC

The lifecycle of plastics without new policies in 2060 (Adapted from: OECD, 2022)



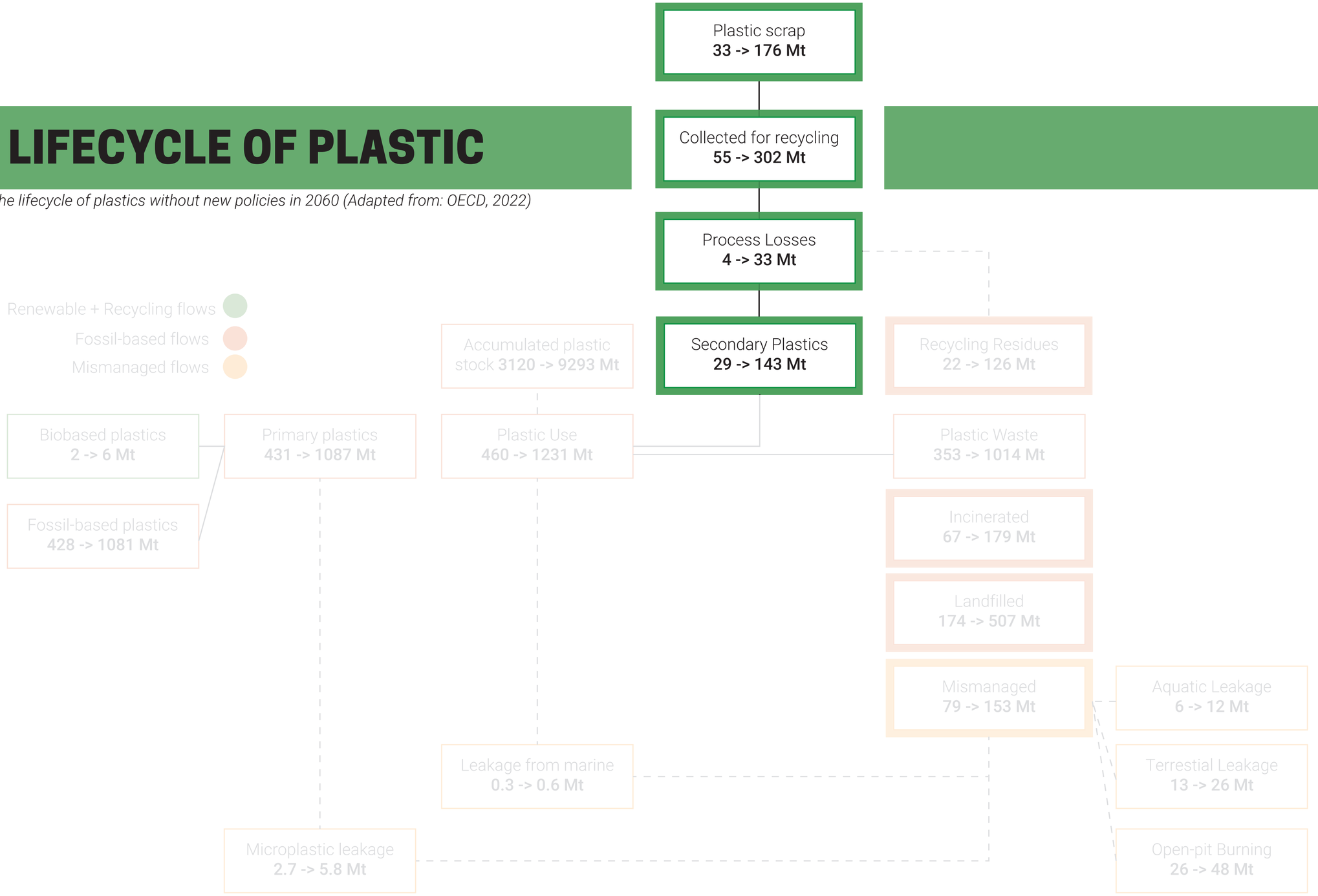
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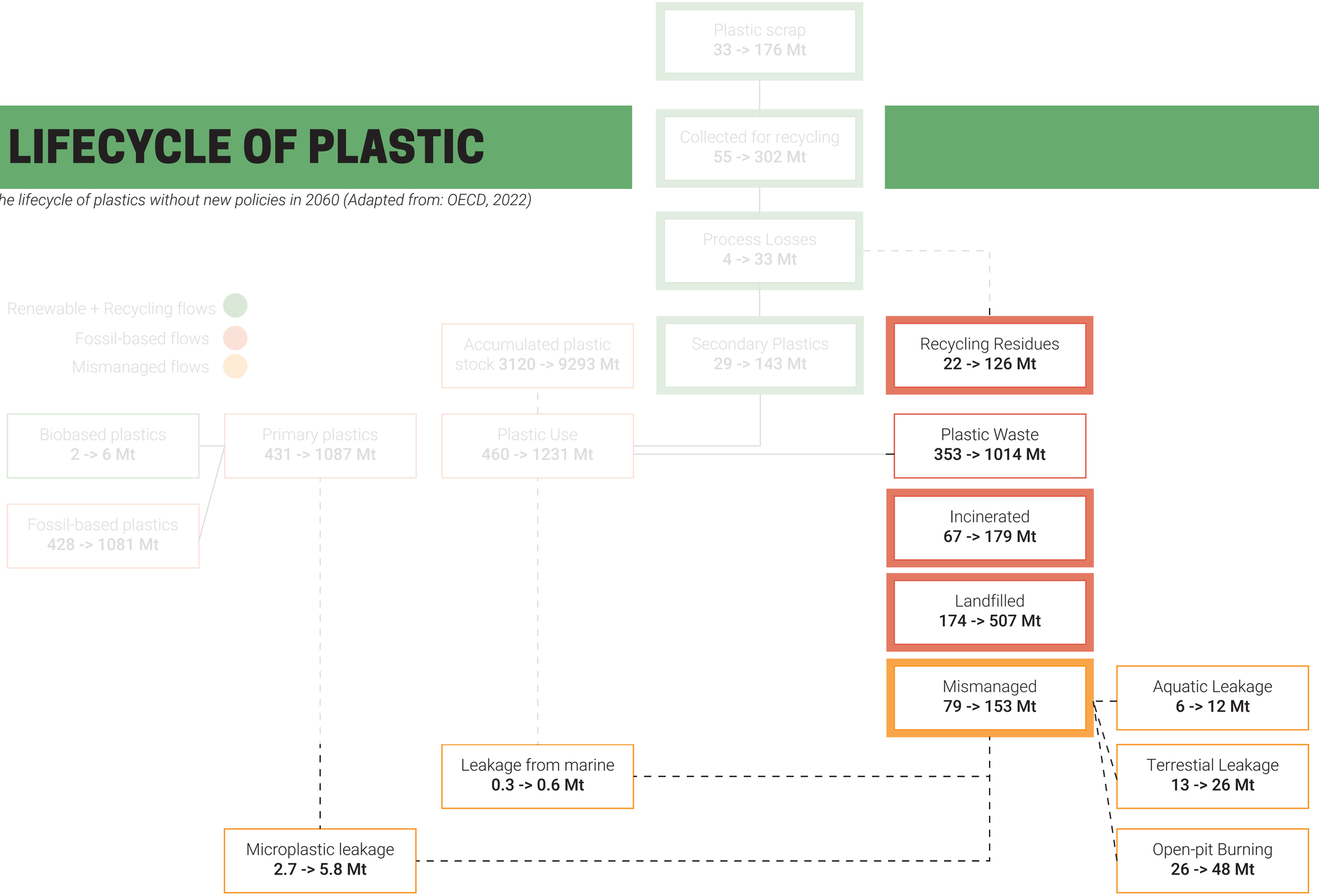
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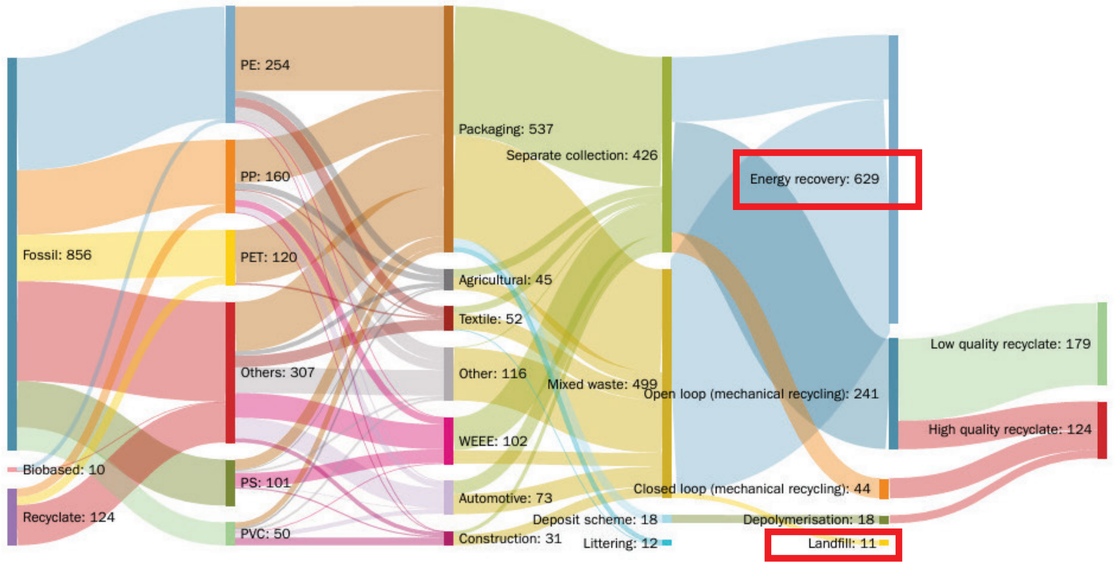
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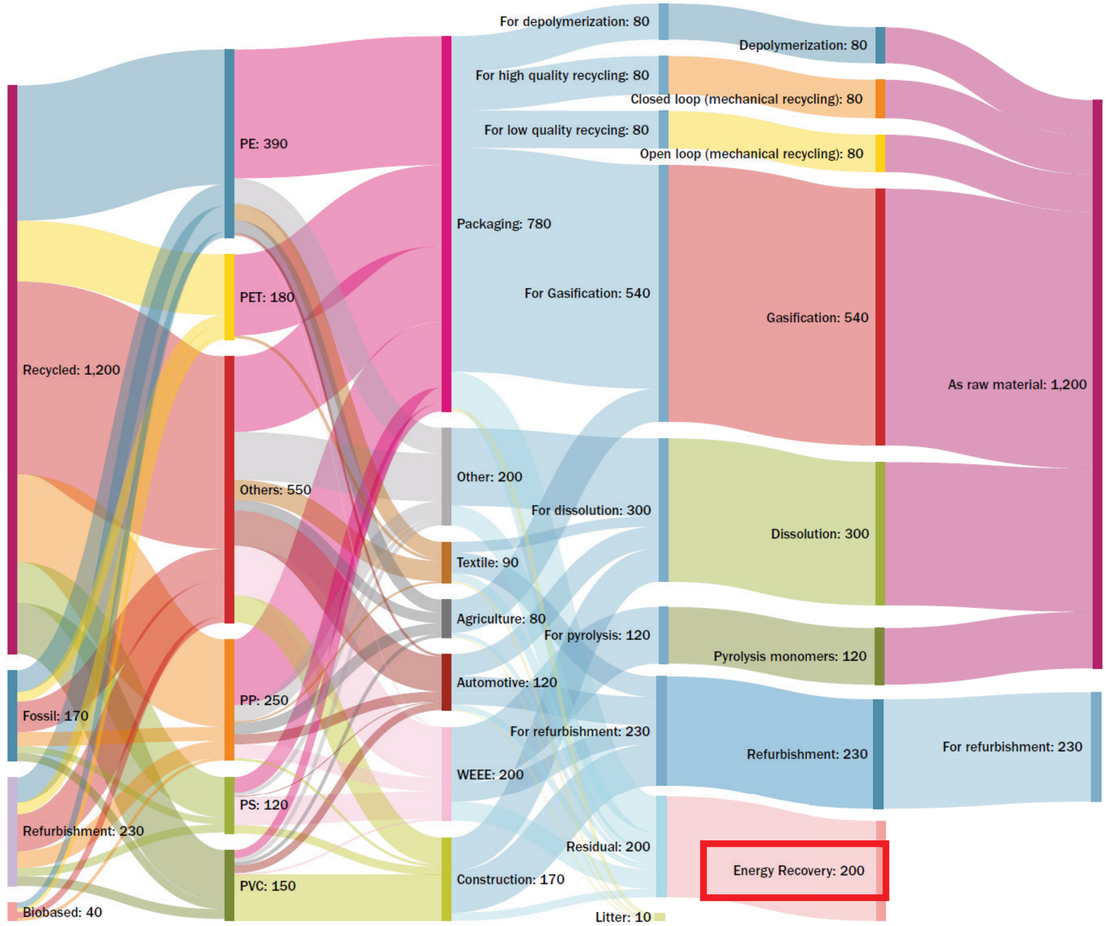


LIFECYCLE OF PLASTIC WASTE IN THE NETHERLANDS

(Source: Wijngaard et al., 2020)



2018 DATA



2050 PREDICTION

PLASTIC WASTE STREAMS

- PACKAGING PLASTICS
- END-OF-LIFE VEHICLES
- CONSTRUCTION AND DEMOLITION WASTE (C&D)
- INDUSTRIAL PLASTICS
- WASTE ELECTRICAL AND ELECTRONIC EQUIPMENTS (WEEE)

PLASTIC WASTE STREAMS

PACKAGING PLASTICS

END-OF-LIFE VEHICLES

CONSTRUCTION AND DEMOLITION WASTE (C&D)

INDUSTRIAL PLASTICS

WASTE ELECTRICAL AND ELECTRONIC EQUIPMENTS (WEEE)

IT & COM. EQUIPMENTS

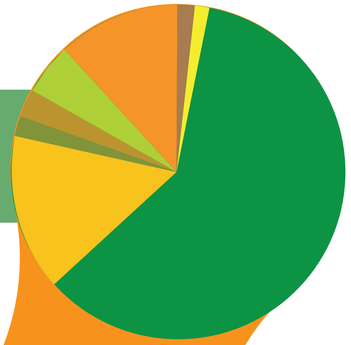
CONSUMER EQUIPMENT

LIGHTING EQUIPMENT

ELECTRIC TOOLS

SMALL DOMESTIC APPLIANCES

LARGE HOUSEHOLD APPLIANCES



WEEE COMPOSITION

(Adapted from: Jadhao et al., 2022)

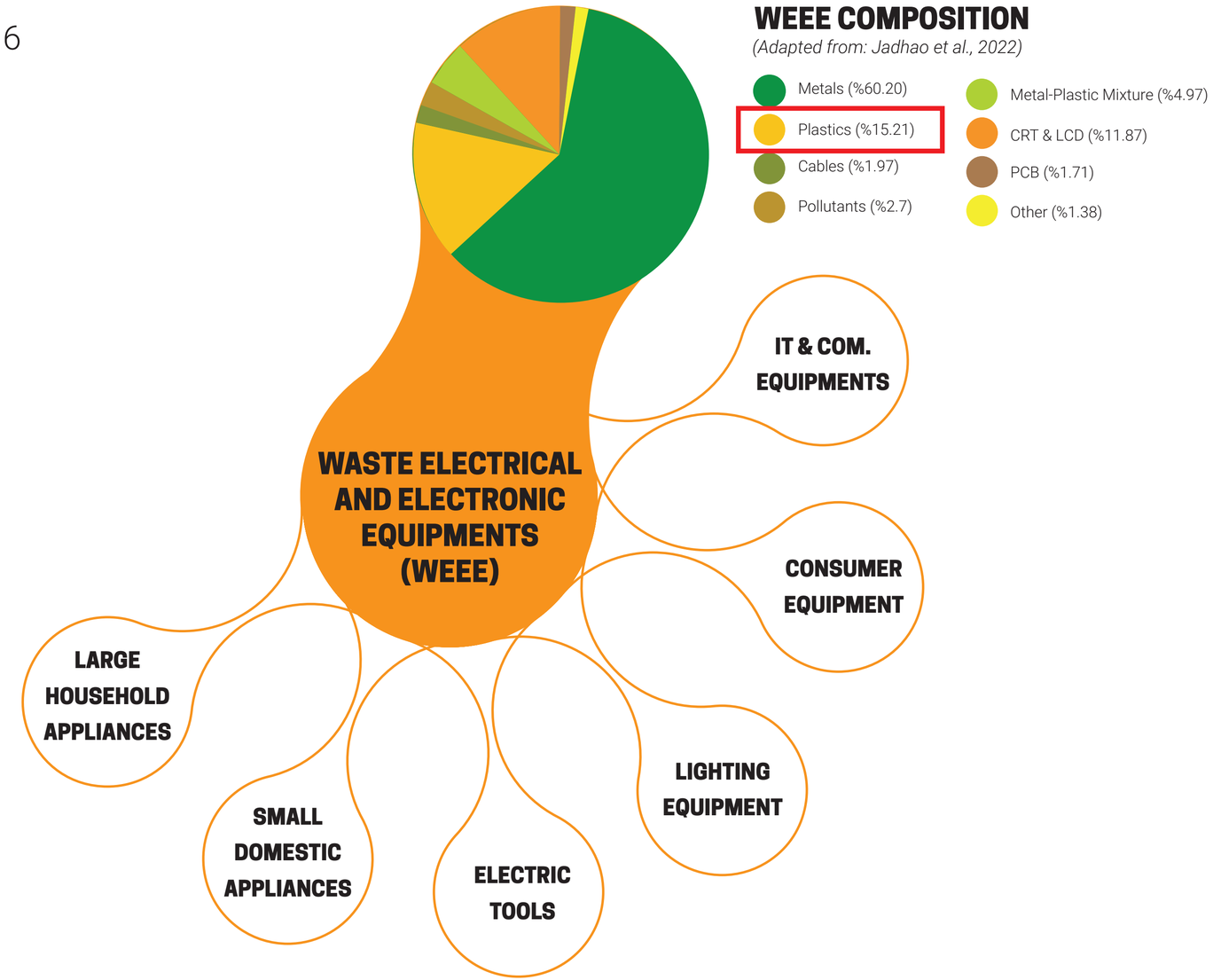
- Metals (%60.20)
- Plastics (%15.21)
- Cables (%1.97)
- Pollutants (%2.7)
- Metal-Plastic Mixture (%4.97)
- CRT & LCD (%11.87)
- PCB (%1.71)
- Other (%1.38)

For the WEEE plastics, available data in 2019 shows that out of 53.6 MMt of generated e-waste, only **%17.4** have been recycled.

(Jadhao et al., 2022)

European Directive reports that an average of %80 of plastic e-waste must be recovered, and **%70** must be recycled based on its respective waste stream.

(Jia et al., 2022)



MIXED PLASTICS
POLYMER BLENDS

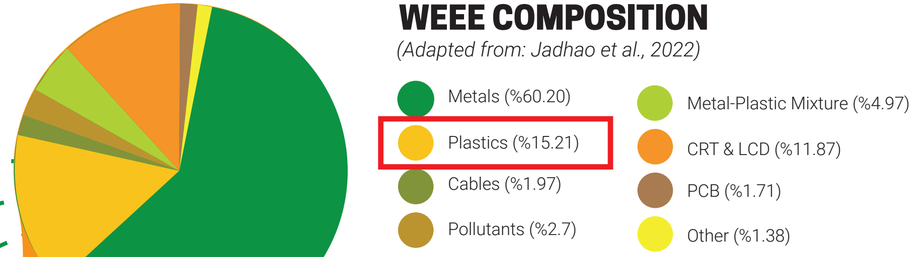
NOT DETECTED DURING RECYCLING

DEGRADATION

CONTAMINATION
ADDITIVES
RETARDANTS
COLOURANTS

WEEE COMPOSITION

(Adapted from: Jadhao et al., 2022)



WASTE ELECTRICAL AND ELECTRONIC EQUIPMENTS (WEEE)

- IT & COM. EQUIPMENTS
- CONSUMER EQUIPMENT
- LIGHTING EQUIPMENT
- ELECTRIC TOOLS
- SMALL DOMESTIC APPLIANCES
- LARGE HOUSEHOLD APPLIANCES

MIXED PLASTICS
POLYMER BLENDS

NOT DETECTED DURING RECYCLING

DEGRADATION

CONTAMINATION
ADDITIVES
RETARDANTS
COLOURANTS

Waste polymers can only have **20%** impurities, while the other 80% needs to be the same already registered polymer before becoming waste.

(De Römph & Van Calster, 2018)

PLASTICS IN ARCHITECTURE

MIXED PLASTICS
POLYMER BLENDS

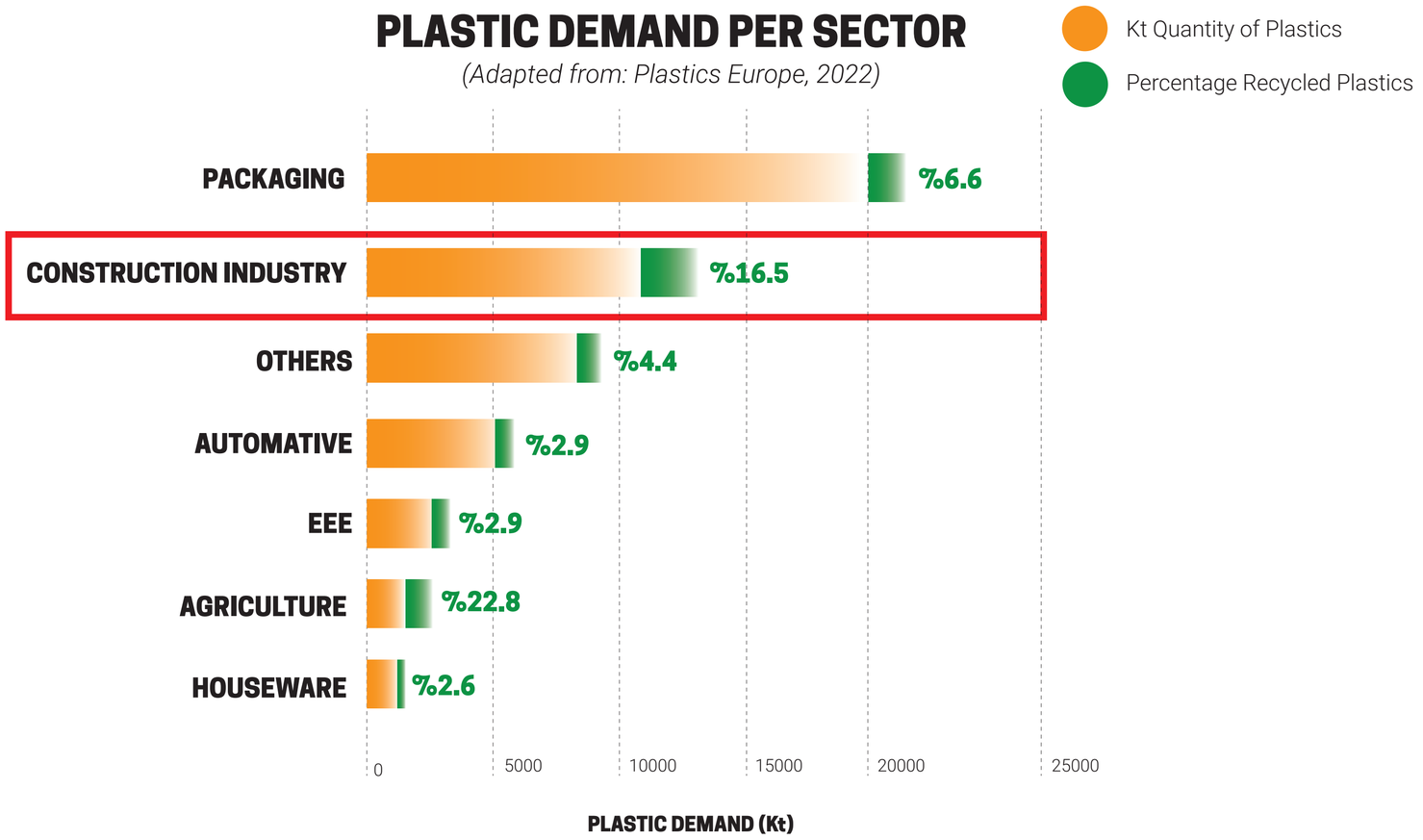
NOT DETECTED DURING RECYCLING

DEGRADATION

CONTAMINATION
ADDITIVES
RETARDANTS
COLOURANTS

PLASTIC DEMAND PER SECTOR

(Adapted from: Plastics Europe, 2022)



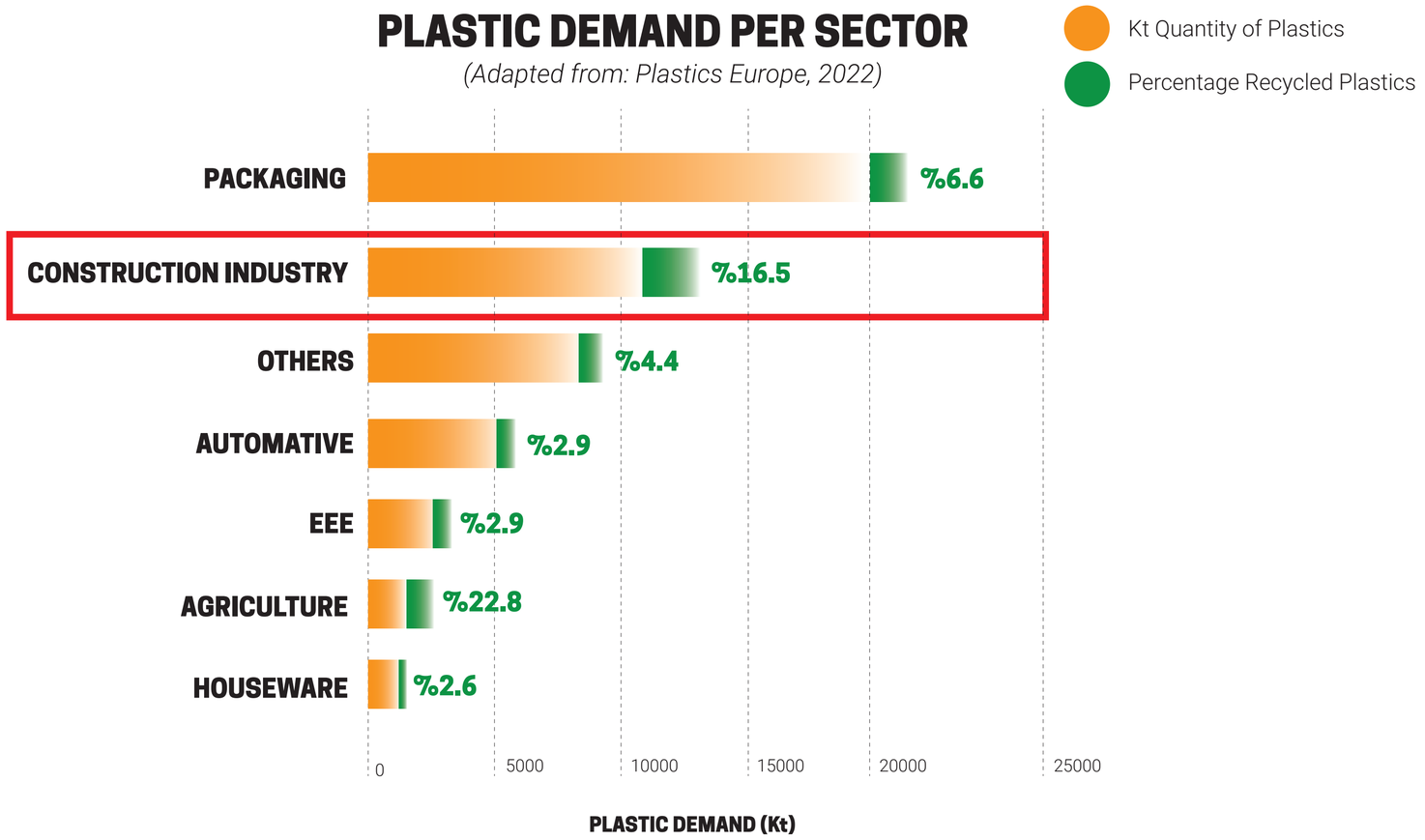
PLASTICS IN ARCHITECTURE

According to projections for 2060, plastic use will triple from 460 Mt to 1231 Mt, with **88%** still being primary plastics and 12% being secondary plastics.

(OECD, 2022)

However, for an optimistic scenario, where %90 efficiency is given to mechanical recycling and %80 efficiency is given to chemical recycling, the overall efficiency for the end product is still at %50. Leaving nearly **%50** of the input material to be lost in the reject fraction.

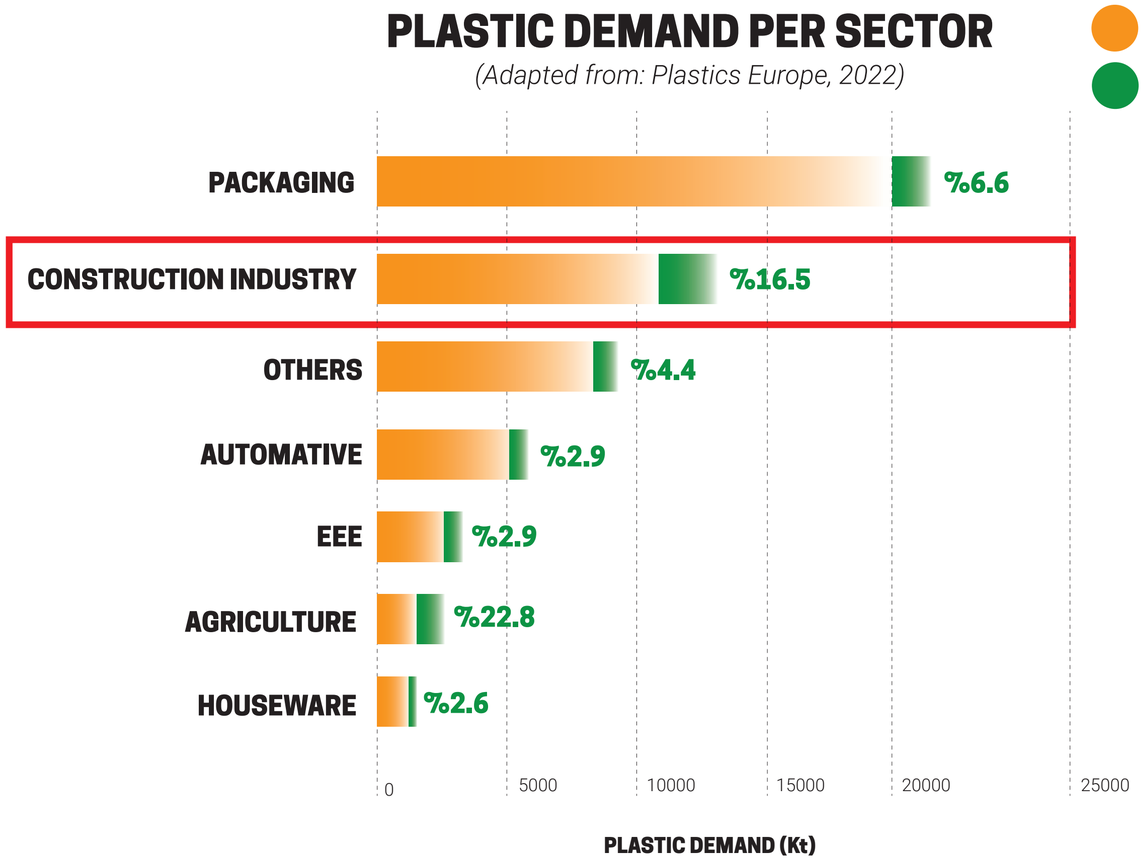
(Lange, 2021)

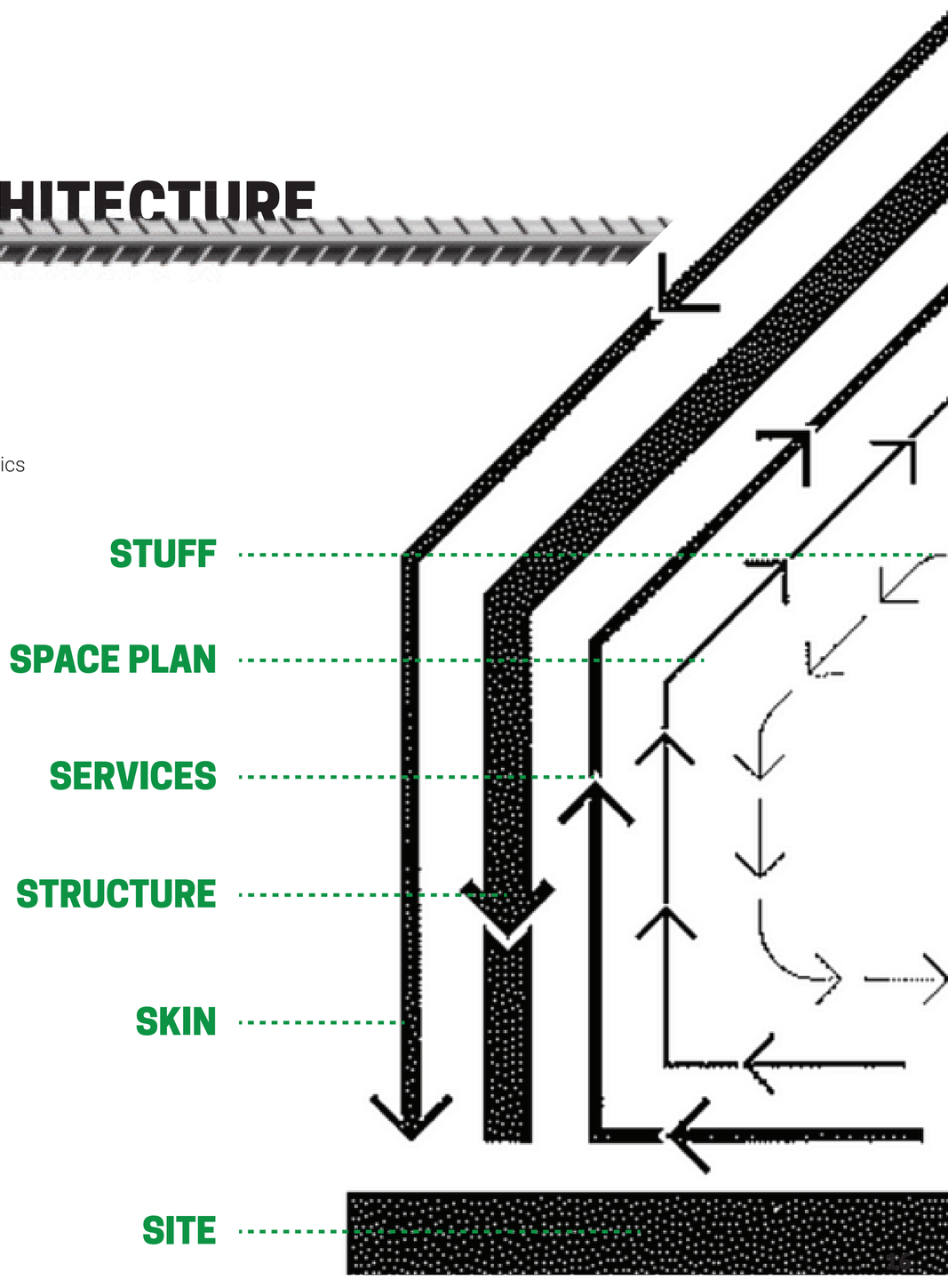


PLASTICS IN ARCHITECTURE

PLASTIC DEMAND PER SECTOR

(Adapted from: Plastics Europe, 2022)





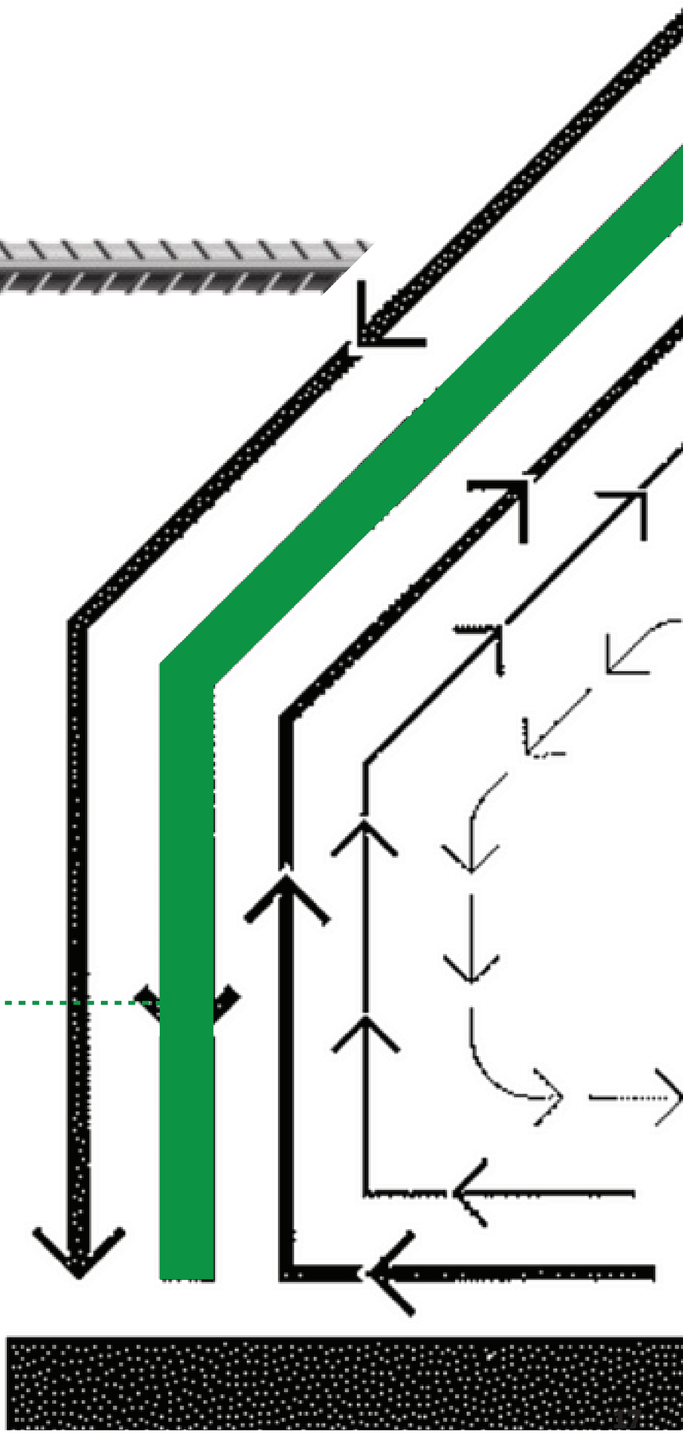
HIDDEN HEROES

MIXED PLASTICS
POLYMER BLENDS

NOT DETECTED DURING RECYCLING

DEGRADATION

CONTAMINATION
ADDITIVES
RETARDANTS
COLOURANTS



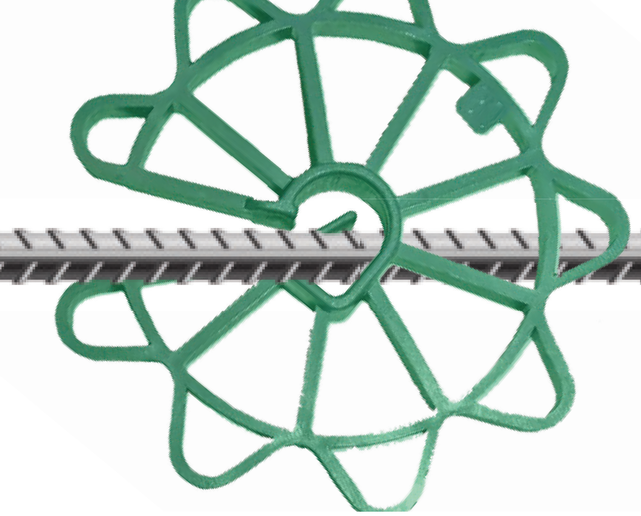
RESEARCH QUESTION

How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?

SUB-QUESTIONS

How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?

What is the state of the art of **plastic manufacturing and plastic recycling**?
What are the primary challenges of **recycling plastics from one waste stream**?
What are the material characteristics of **WEEE plastic waste**?
What are the technical requirements and limitations of **injection molding for plastics**?
How does the **presence of contamination** and unknown polymer composition affect the injection molding behaviour of WEEE plastic waste?
What **architectural applications** are suitable for contaminated and mixed plastic?
What parameters influence the **structural performance, moldability and concrete compatibility** of reinforcement spacers?



HIDDEN HEROES

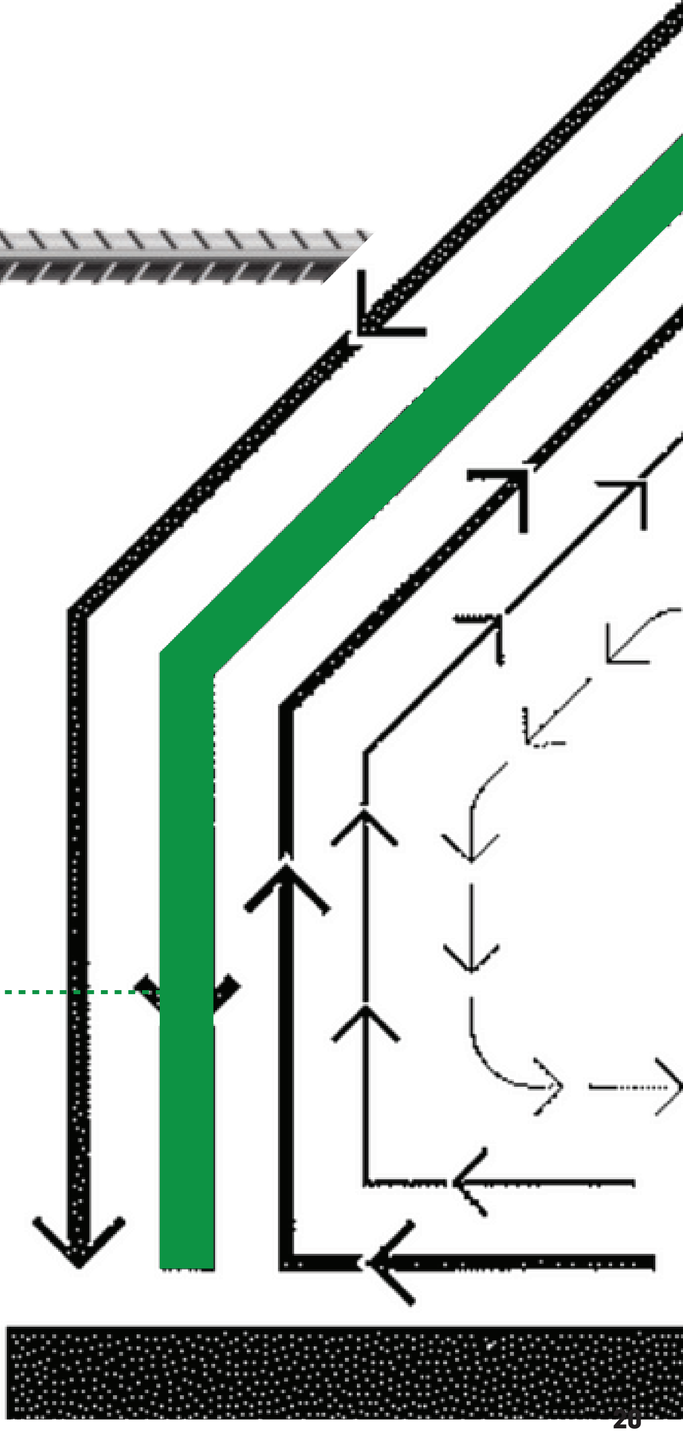
WHEEL SPACERS

GIVE A **DISTANCE** FOR STEEL REINFORCEMENT TO THE OUTER PART OF CONCRETE

MAINTAIN **CORRECT POSITION OF REBAR**

TEMPORARY SUPPORT BEFORE & DURING CONCRETE POURING

STRUCTURE



PLASTIC WASTE STREAMS

PACKAGING PLASTICS

END-OF-LIFE VEHICLES

CONSTRUCTION AND DEMOLITION WASTE (C&D)

INDUSTRIAL PLASTICS

WASTE ELECTRICAL AND ELECTRONIC EQUIPMENTS (WEEE)

LARGE HOUSEHOLD APPLIANCES (FRIDGES etc.)

SMALL DOMESTIC APPLIANCES (SDA)

IT & COM. EQUIPMENTS

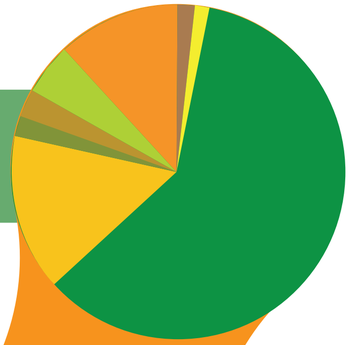
CONSUMER EQUIPMENT

LIGHTING EQUIPMENT

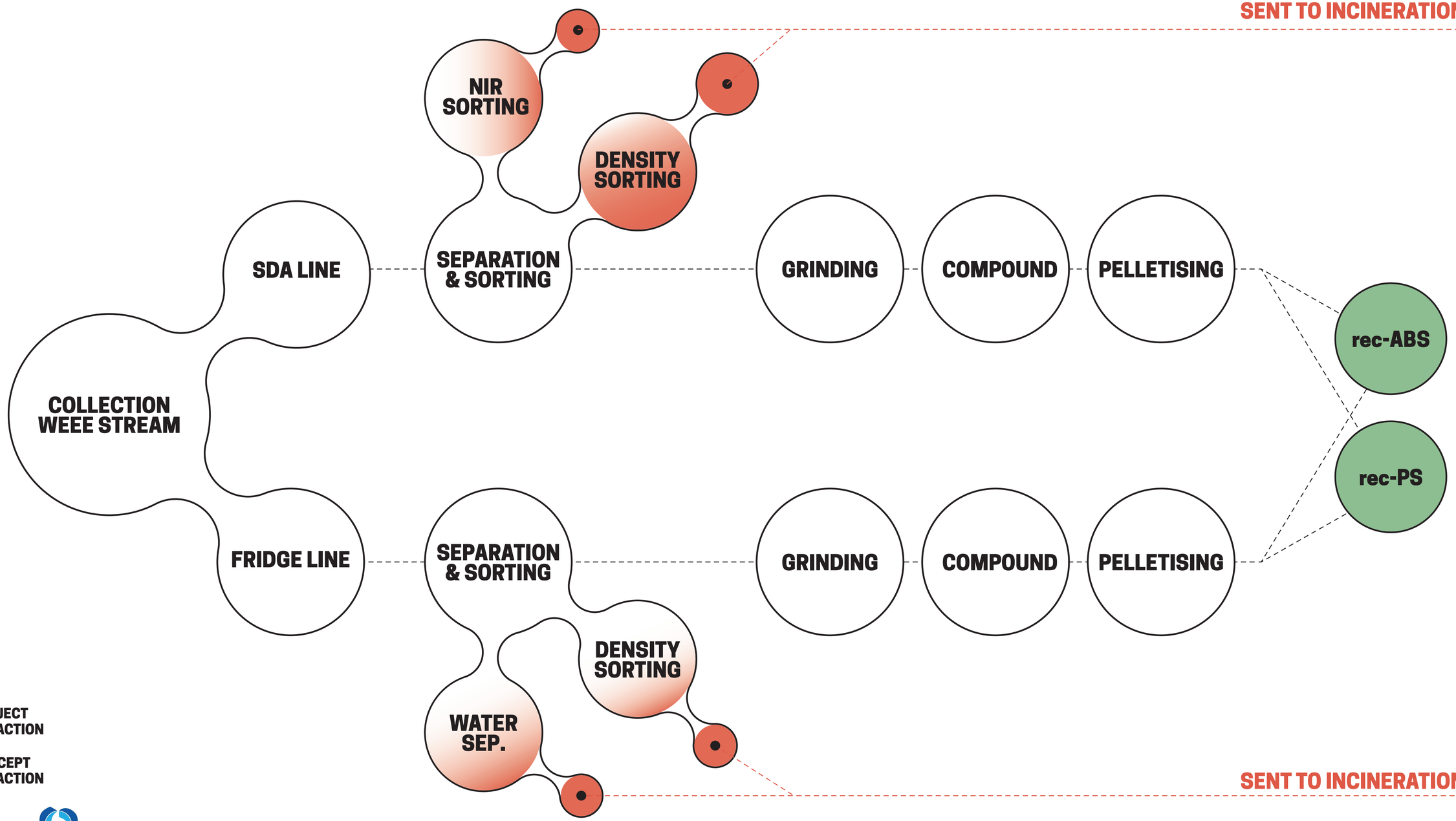
ELECTRIC TOOLS

WEEE COMPOSITION

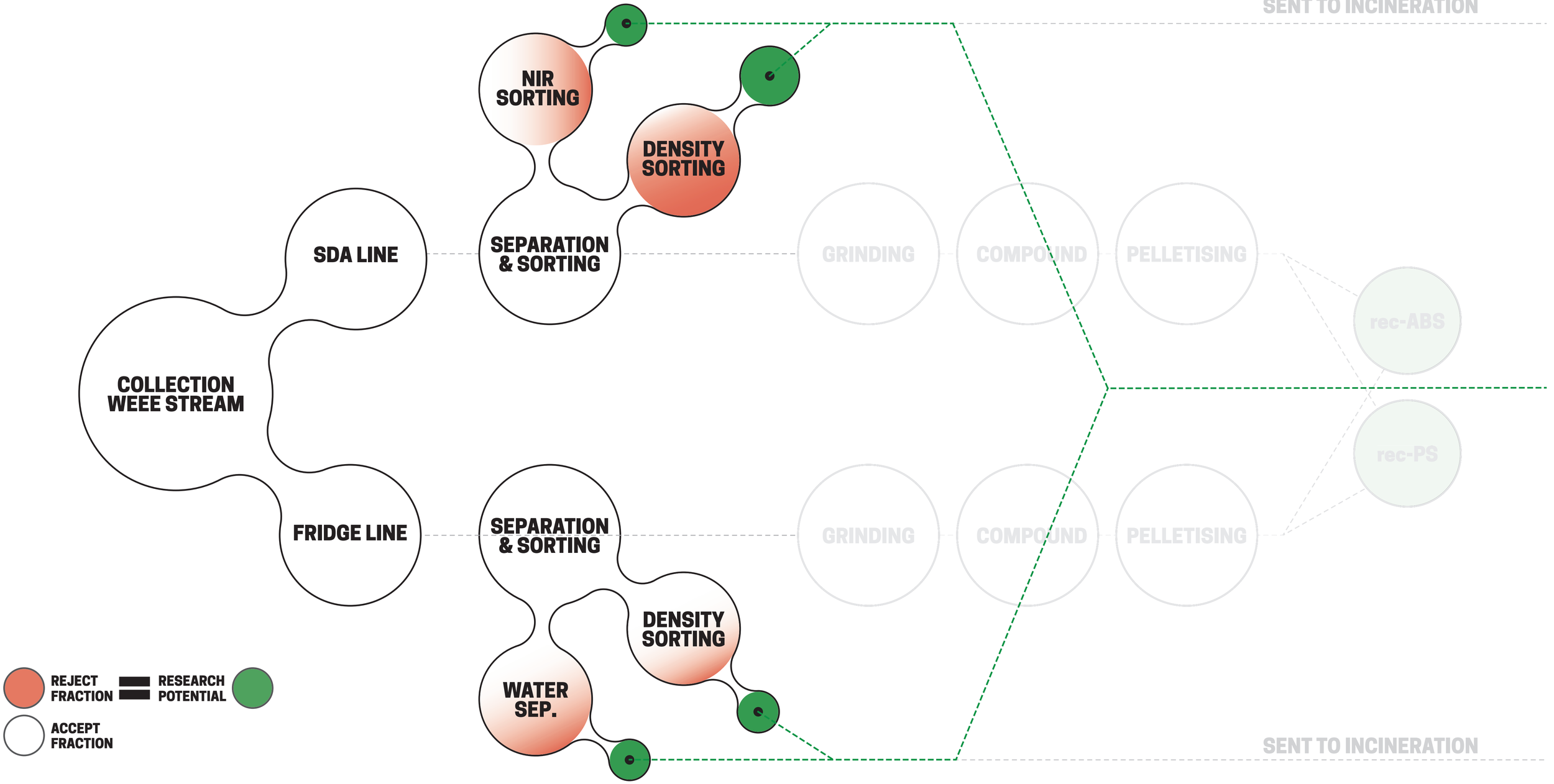
(Adapted from: Jadhao et al., 2022)



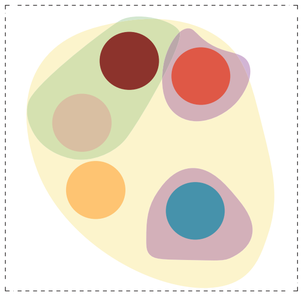
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SENT TO INCINERATION
NIR SORTING
DENSITY SORTING
SDA LINE
SEPARATION & SORTING
GRINDING
COMPOUND
PELLETISING
rec-ABS
COLLECTION WEEE STREAM
rec-PS
FRIDGE LINE
SEPARATION & SORTING
GRINDING
COMPOUND
PELLETISING
DENSITY SORTING
WATER SEP.
SENT TO INCINERATION
REJECT FRACTION
ACCEPT FRACTION

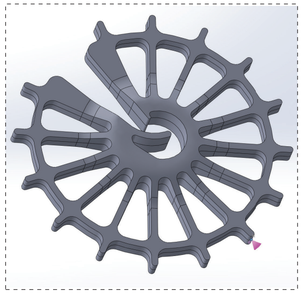
Coolrec


SENT TO INCINERATION
NIR SORTING
DENSITY SORTING
SDA LINE
SEPARATION & SORTING
GRINDING
COMPOUND
PELLETISING
rec-ABS
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DENSITY SORTING
WATER SEP.
SENT TO INCINERATION
REJECT FRACTION
RESEARCH POTENTIAL
ACCEPT FRACTION

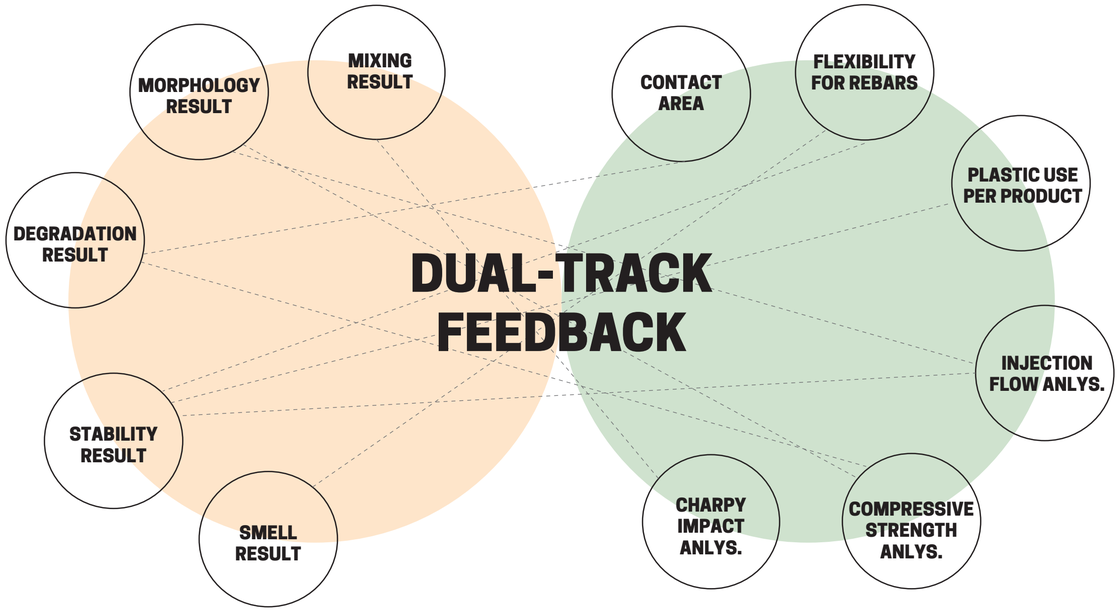
DUAL-TRACK METHODOLOGY



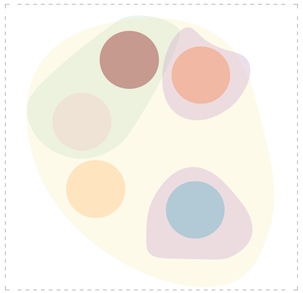
TRACK I.
MATERIAL EXPERIMENTATION



TRACK II.
PRODUCT DEVELOPMENT



BOTTOM-UP APPROACH



TRACK I.
MATERIAL EXPERIMENTATION



TRACK II.
PRODUCT DEVELOPMENT

TOP-DOWN APPROACH

MORPHOLOGY RESULT

MIXING RESULT

DEGRADATION RESULT

STABILITY RESULT

SMELL RESULT

CONTACT AREA

FLEXIBILITY FOR REBARS

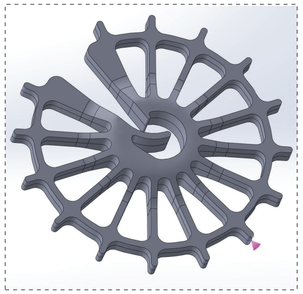
PLASTIC USE PER PRODUCT

INJECTION FLOW ANLYS.

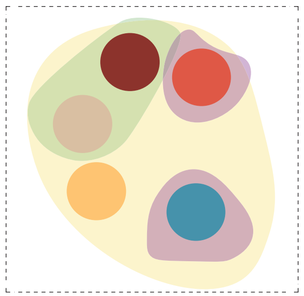
CHARPY IMPACT ANLYS.

COMPRESSIVE STRENGTH ANLYS.

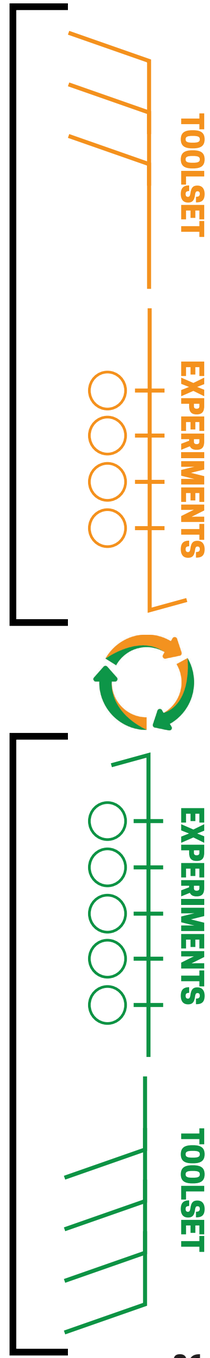
DUAL-TRACK FEEDBACK



TRACK II.
PRODUCT DEVELOPMENT



TRACK I.
MATERIAL EXPERIMENTATION





TRACK I: MATERIAL EXPERIMENTATION

“Bottom-up Approach”

FRIDGE 1

Reject fraction of water seperation tables



FRIDGE 2

Sink fraction of density sorting



SDA 1

Reject fraction of near infra-red sorting after SDA 2



SDA 2

Sink fraction of density sorting



TOOLSET

EXPERIMENTS

28

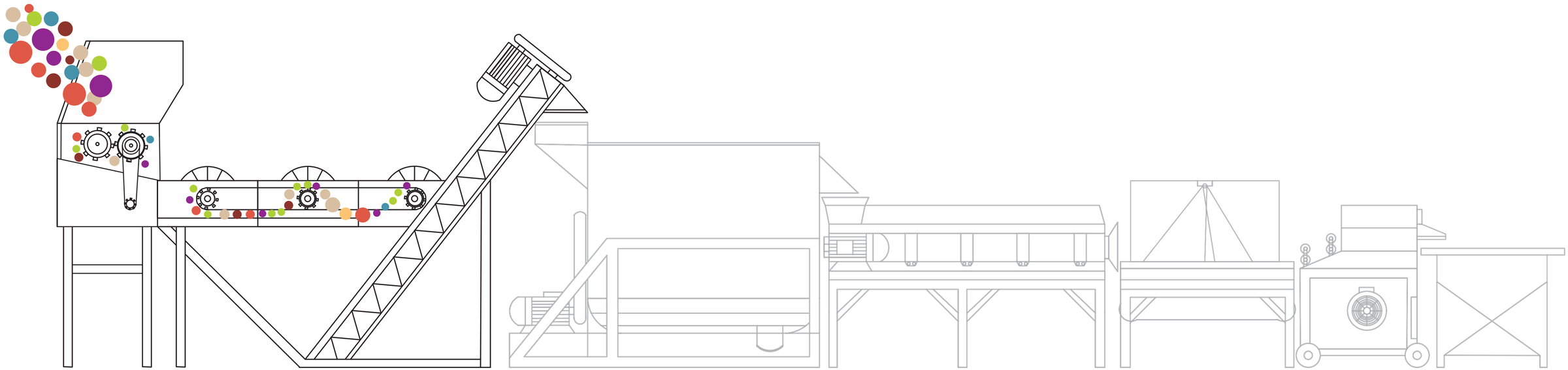
EXPERIMENTS

TOOLSET

WASTE INPUT



INDUSTRY-SCALE



WATER SEPARATION TABLES

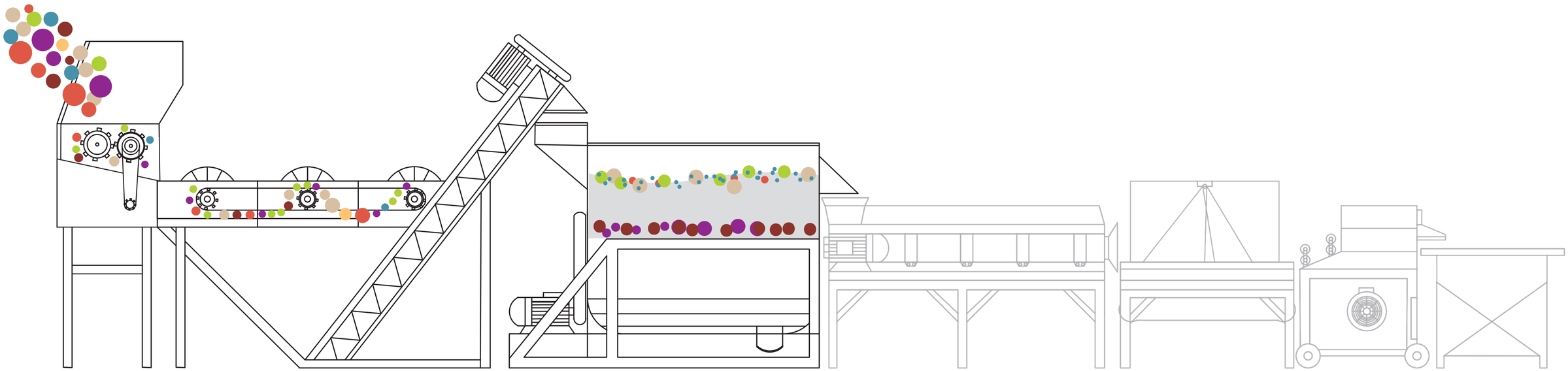
DENSITY SEPARATION

ELECTROSTATIC SEPARATION

NIR SORTING

GRINDING & PELLETISING

INDUSTRY-SCALE



WATER SEPARATION TABLES

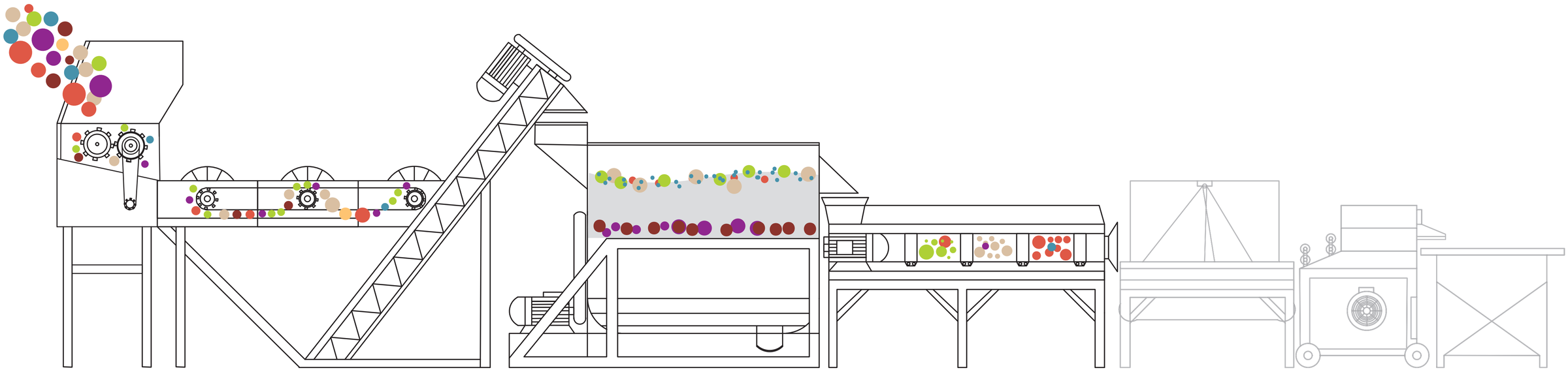
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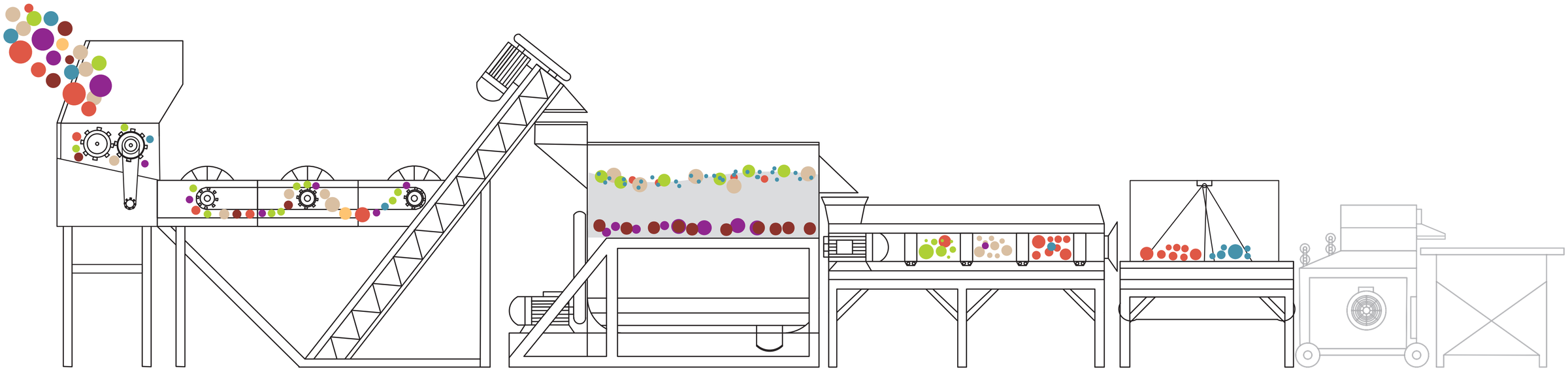
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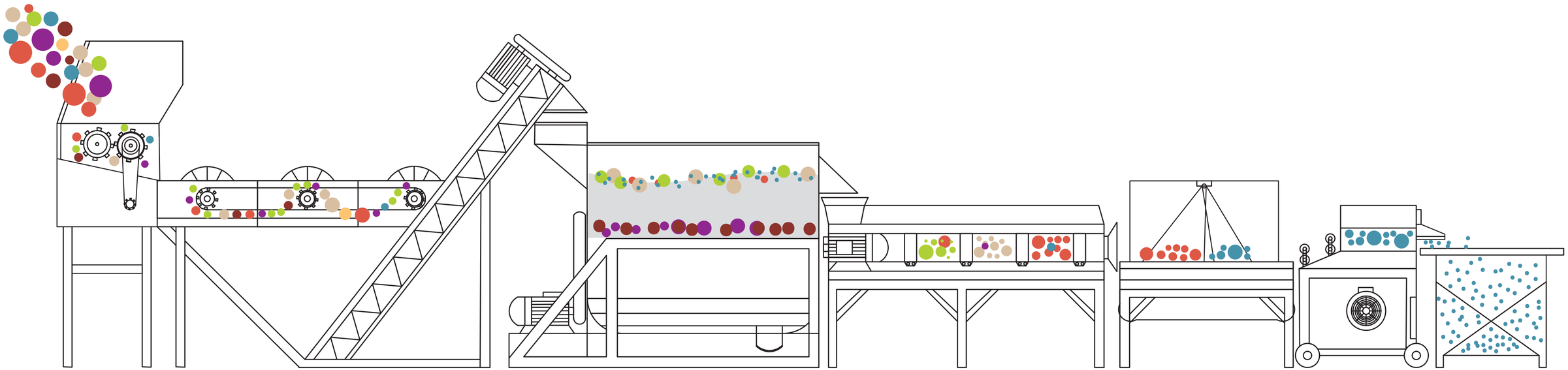
DENSITY SEPARATION

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WATER SEPARATION TABLES

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ELECTROSTATIC SEPARATION

NIR SORTING

GRINDING & PELLETISING



COLLECT



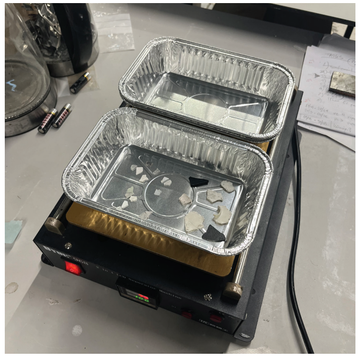
DETERGENT



I. RINSE



II. RINSE



DRYING

1. Washing
2. Density Separation
3. Colour Sorting
4. MIR Sorting
5. Shredding

POLYMER SORTING



SALT / SUGAR



SEPARATOR MEDIUM



MEASURE DENSITY



DENSITY TUBE



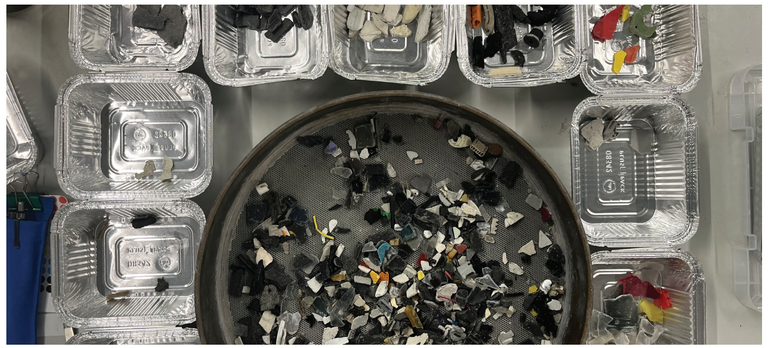
FLOATING FRACTION



DRYING

1. Washing
2. Density Separation
3. Colour Sorting
4. MIR Sorting
5. Shredding

POLYMER SORTING



COLOUR CATEGORIES



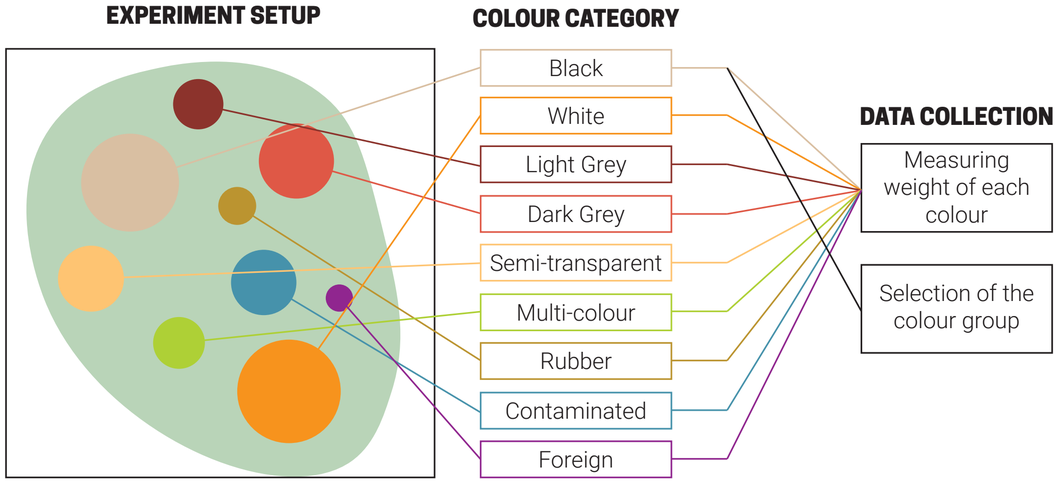
MANUAL SORTING



WEIGH CATEGORY



SELECT COLOUR



1. Washing
2. Density Separation
3. Colour Sorting
4. MIR Sorting
5. Shredding

POLYMER SORTING



COLOUR BATCH



MIR SORTING



POLYMER CATEGORIES



SELECT POLYMER

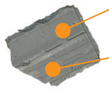
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Min. range: 500

Optical velocity: 0.4747



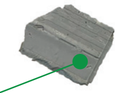
FRONT SIDE

DATA COLLECTION

First scan

Second scan

Third scan



BACK SIDE

LIBRARY SETUP

Hummel Polymer Sample Library

HR Nicolet Sampler Library

HR Aldrich Organometallic, Inorganics Library

Number of Matches: 10

POLYMER MATCH

First scan: %A

Second scan: %B

Third scan: %C

AVG. MATCH

% (A+B+C)/3

POLYMER TYPE

POLYSTYRENE

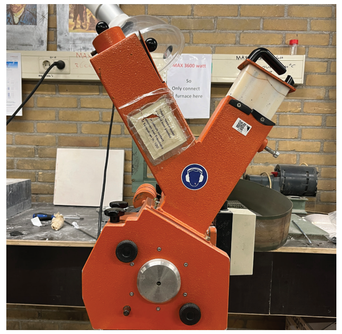
1. Washing
2. Density Separation
3. Colour Sorting
4. MIR Sorting
5. Shredding

POLYMER SORTING

LAB-SCALE



POLYMER BATCH



SHREDDING



COLLECT



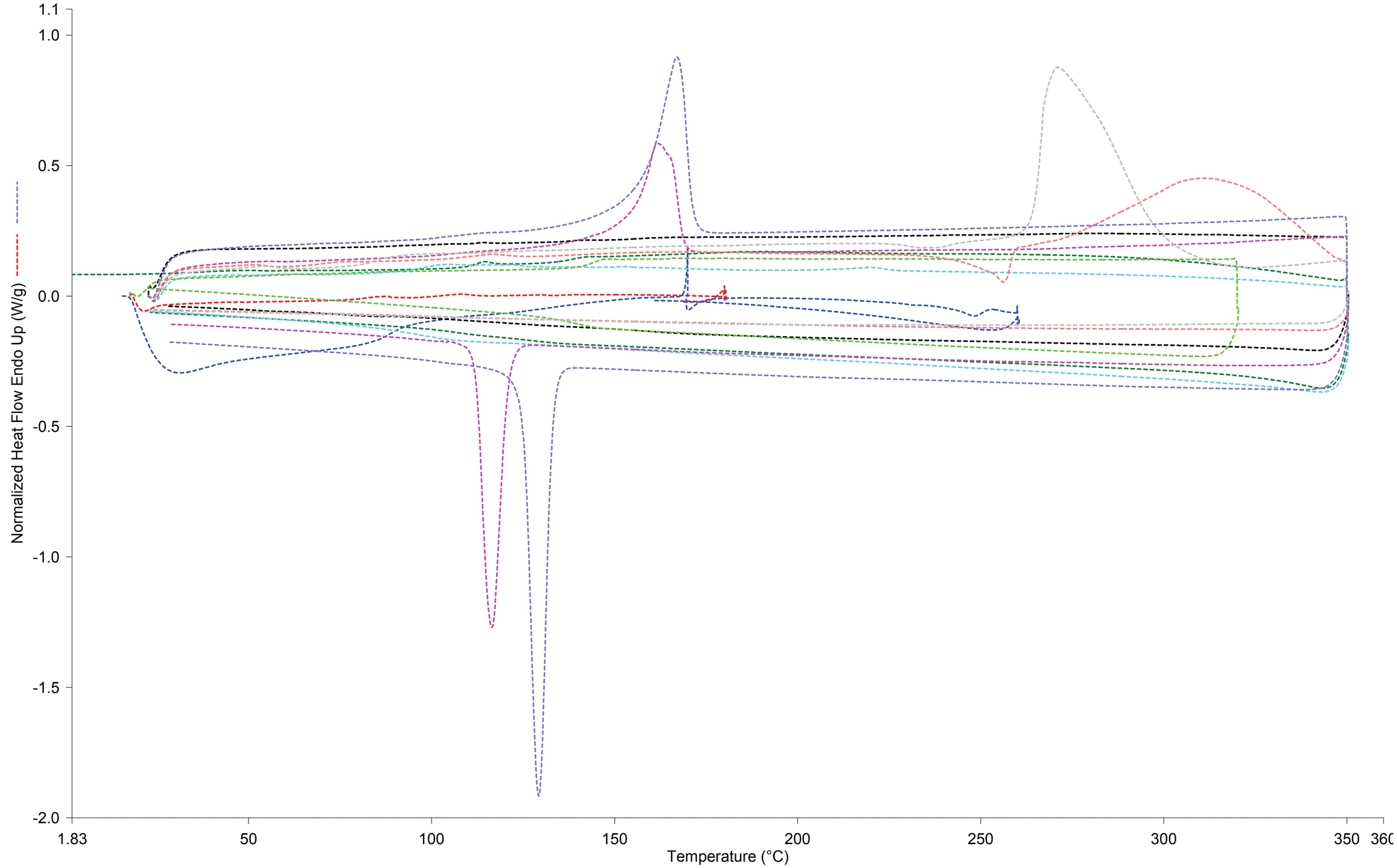
INSPECT



WEIGH SHREDDED BATCHES

1. Washing
2. Density Separation
3. Colour Sorting
4. MIR Sorting
5. Shredding

POLYMER SORTING



TOOLSET

EXPERIMENTS

40

EXPERIMENTS

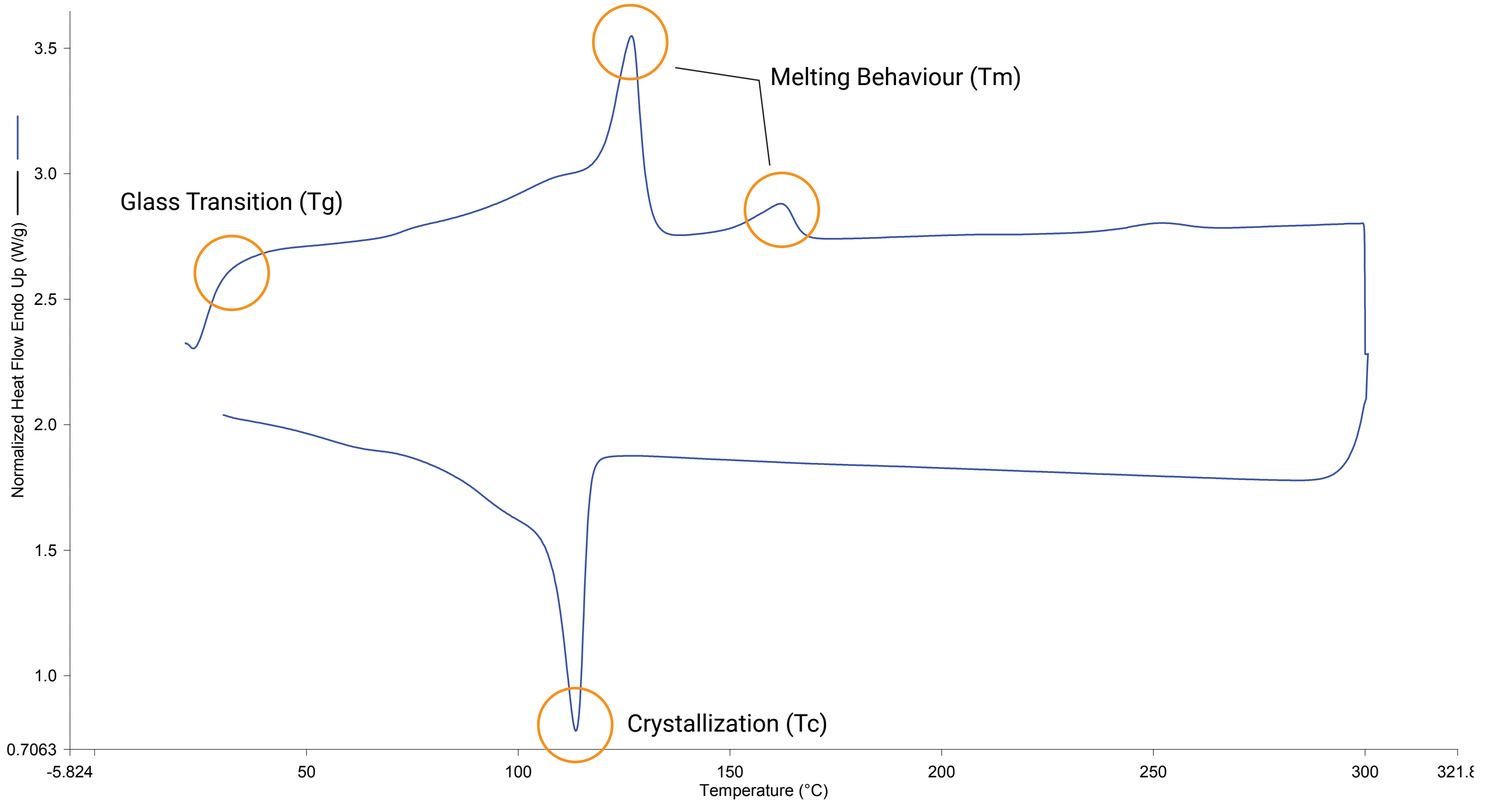
TOOLSET

POLYMER CHARACTERIZATION

THERMAL BEHAVIOUR

TASK LIST:

- ○ IDENTIFY A WORKABLE HEATING/COOLING CYCLE
- ○ AMORPHOUS- CRYSTALLINE-SEMI-CRYSTALLINE
- ○ IDENTIFY IMMISCIBLE POLYMER BLENDS



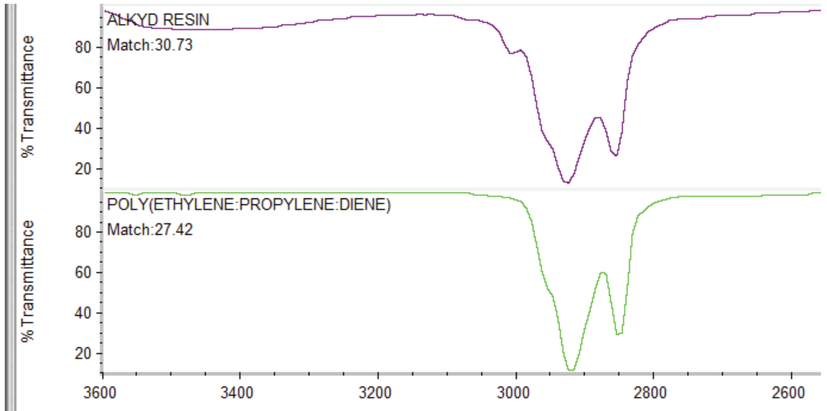
1. DSC Analysis
2. FT-IR Analysis
3. Micrograph
4. XRF Analysis

POLYMER CHARACTERIZATION

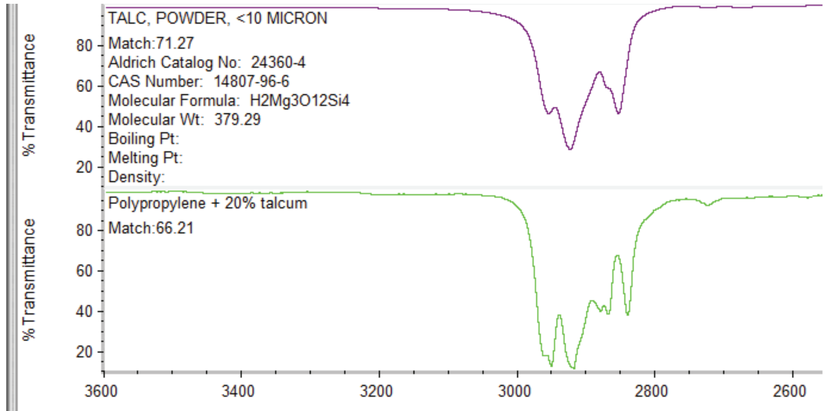
CHEMICAL COMPOSITION

TASK LIST:

- ◯ **IDENTIFY CONTAMINATION**
- ◯ **IDENTIFY POLYMER TYPES / POLYMER BLENDS**
- ◯ **CREATE POLYMER BATCH FOR PROCESSING**



	Index	Match	Compound Name
1	14	30.73	ALKYD RESIN
2	32	27.42	POLY(ETHYLENE:PROPYLENE:DIENE)
3	31	24.12	POLY(VINYL ACETATE:ETHYLENE) 3:1
4	20	23.59	URETHANE ALKYD, LINSEED OIL-RICH
5	7	22.40	POLY(ETHYLENE)
6	39	21.71	POLY(ETHYLENE:PROPYLENE)
7	29	21.69	POLY(VINYL ACETATE:ETHYLENE) 4:1
8	16	20.65	POLY(VINYL PROPIONATE/ACETATE)
9	51	20.13	POLY(ETHYLENE:VINYL CHLORIDE)
10	15	19.23	POLY(VINYL PROPIONATE:ACRYLATE)



	Index	Match	Compound Name
1	1521	71.27	TALC, POWDER, <10 MICRON
2	603	66.21	Polypropylene + 20% talcum
3	580	63.19	Talc
4	624	57.68	Polypropylene+poly(ethylene:propylene)
5	737	57.62	Polypropylene
6	596	52.15	Polypropylene, atactic
7	41	49.99	POLY(PROPYLENE), ATACTIC
8	1410	47.05	SODIUM THIOSULFATE, 99%
9	38	46.93	POLY(PROPYLENE), SYNDIOTACTIC
10	1460	46.80	LITHIUM TETRACHLOROPALLADATE(II) HYDRATE

1. DSC Analysis
2. FT-IR Analysis
3. Micrograph
4. XRF Analysis

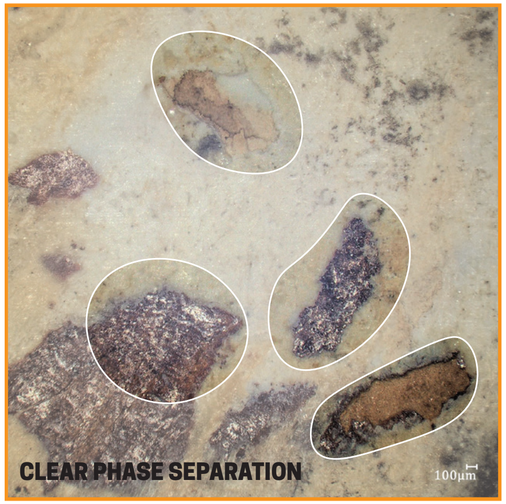
POLYMER CHARACTERIZATION

MICROSCOPIC INSPECTION

TASK LIST:

- ○ IDENTIFY CONTAMINATION
- ○ ASSESING POLYMER BEHAVIOUR
- ○ ASSESING PROCESSED SAMPLE BEHAVIOUR







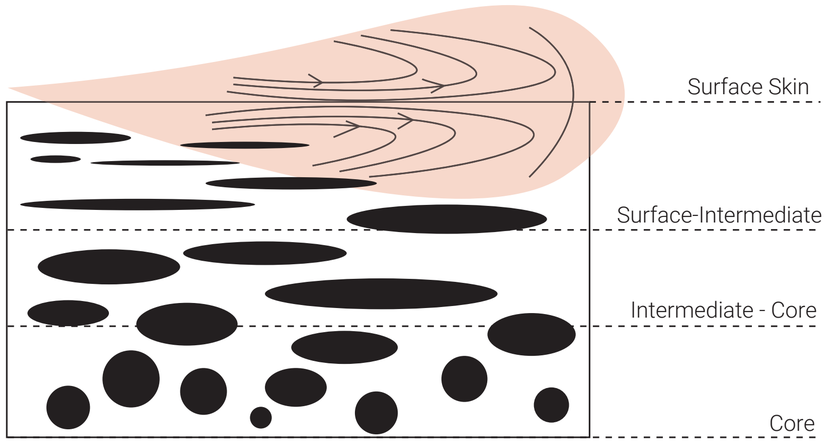
1. DSC Analysis
2. FT-IR Analysis
3. Micrograph
4. XRF Analysis

POLYMER CHARACTERIZATION

MICROSCOPIC INSPECTION

TASK LIST:

- ○ IDENTIFY CONTAMINATION
- ○ ASSESING POLYMER BEHAVIOUR
- ○ ASSESING PROCESSED SAMPLE BEHAVIOUR





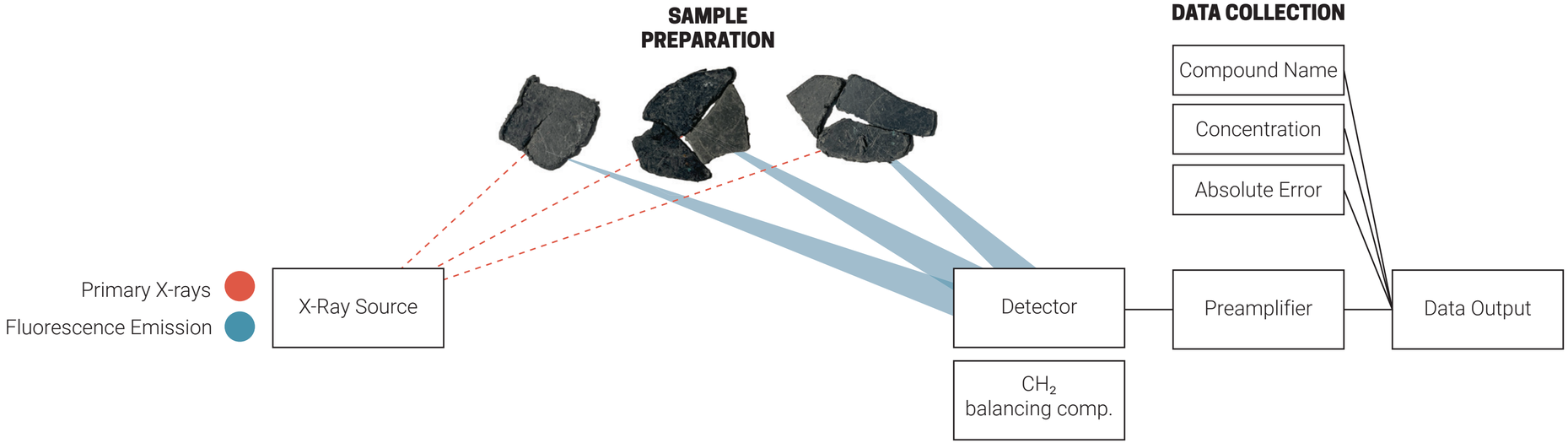
1. DSC Analysis
2. FT-IR Analysis
3. Micrograph
4. XRF Analysis

POLYMER CHARACTERIZATION

INORGANIC ELEMENT DETECTION

TASK LIST:

- ◯ **IDENTIFY WEEE ADDITIVES, RETARDANTS**
- ◯ **IDENTIFY CONTAMINATION**



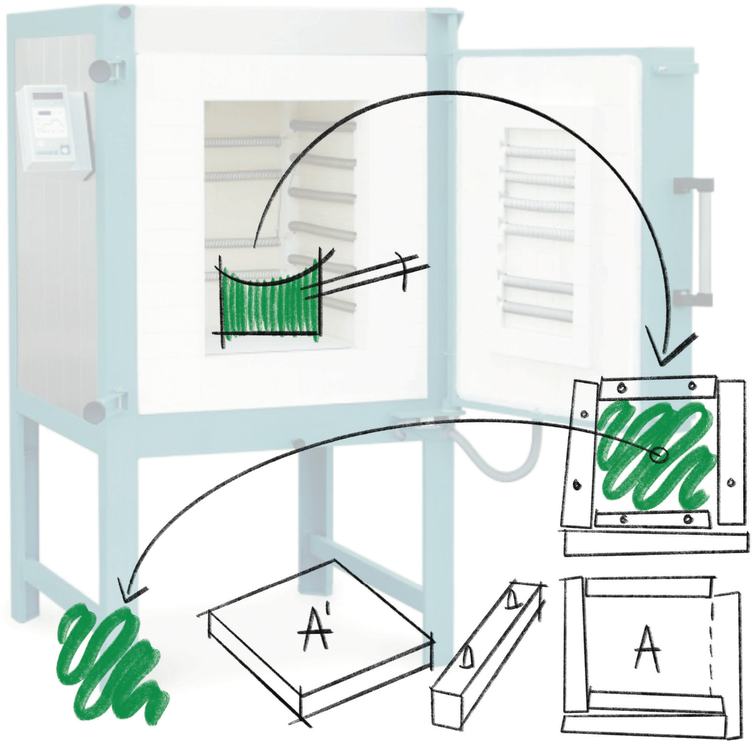
1. DSC Analysis
2. FT-IR Analysis
3. Micrograph
4. **XRF Analysis**

POLYMER CHARACTERIZATION



EXPERIMENT SETUPS

MANUAL PRESS

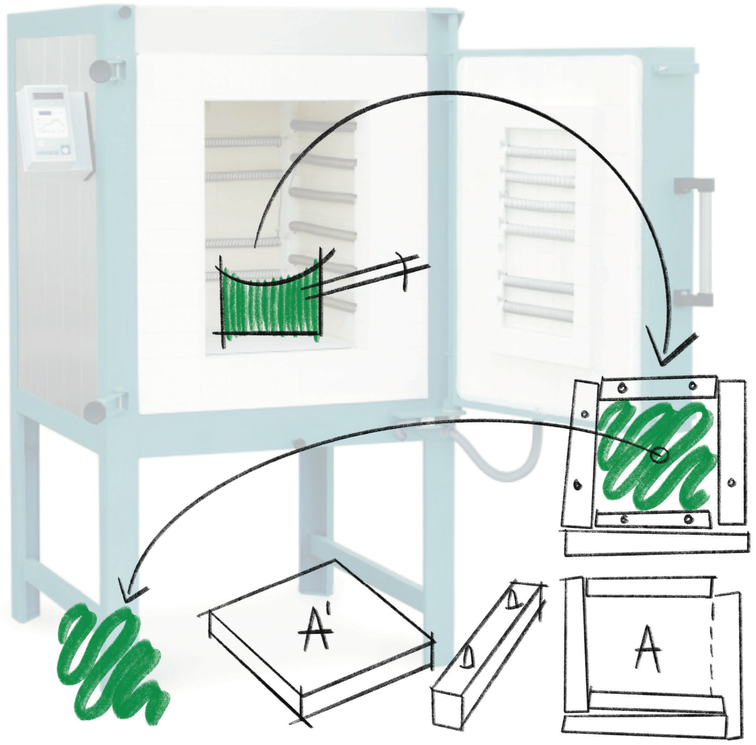


Source: Stevin II Lab, CiTG TU Delft

1. Manual Press
2. Manual Plunger-type
3. Pneumatic Plunger-type

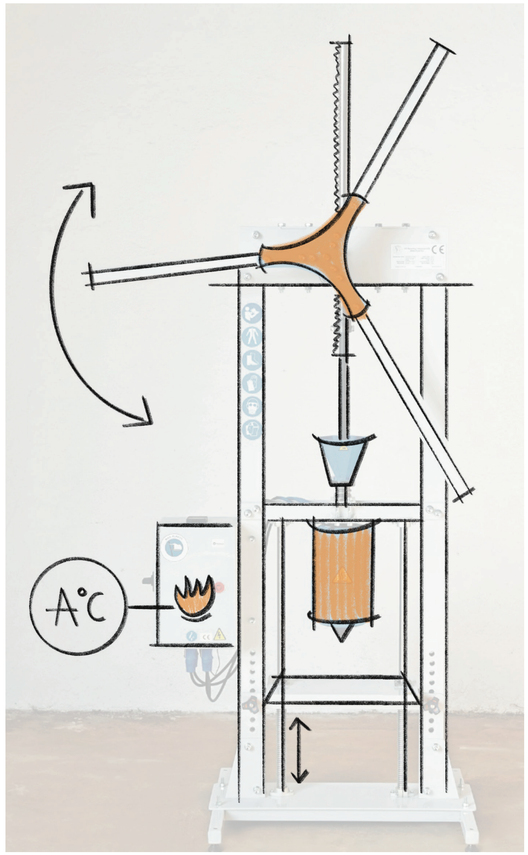
EXPERIMENT SETUPS

MANUAL PRESS



Source: Stevin II Lab, CiTG TU Delft

MANUAL PLUNGER-TYPE



Source: MakerLab, New Science Center TU Delft

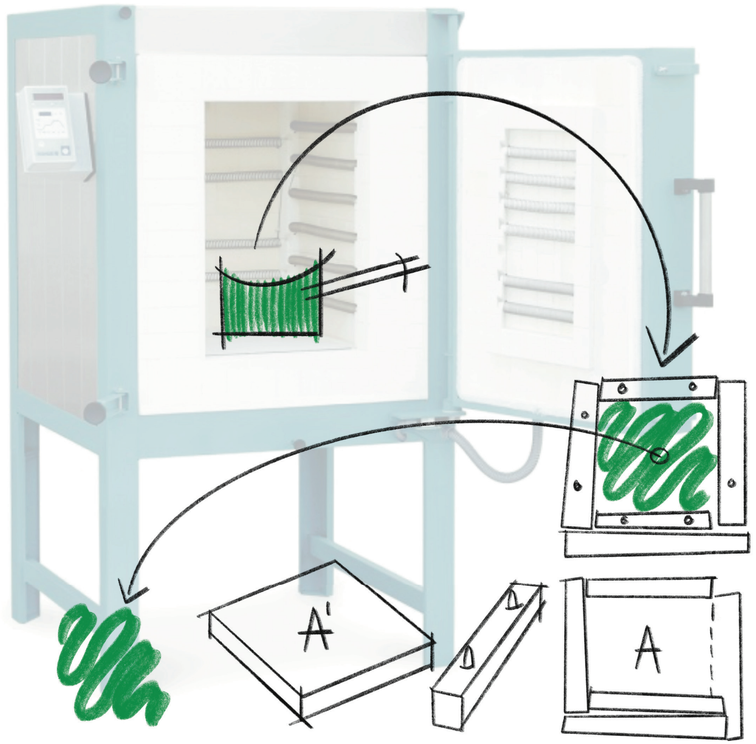
1. Manual Press
2. Manual Plunger-type
3. Pneumatic Plunger-type

EXPERIMENT SETUPS

LESS ADVANCED

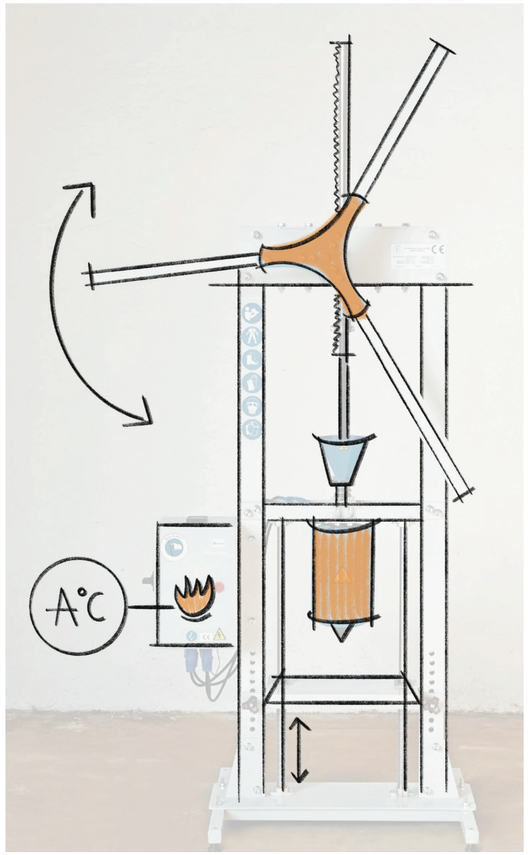
MORE ADVANCED

MANUAL PRESS



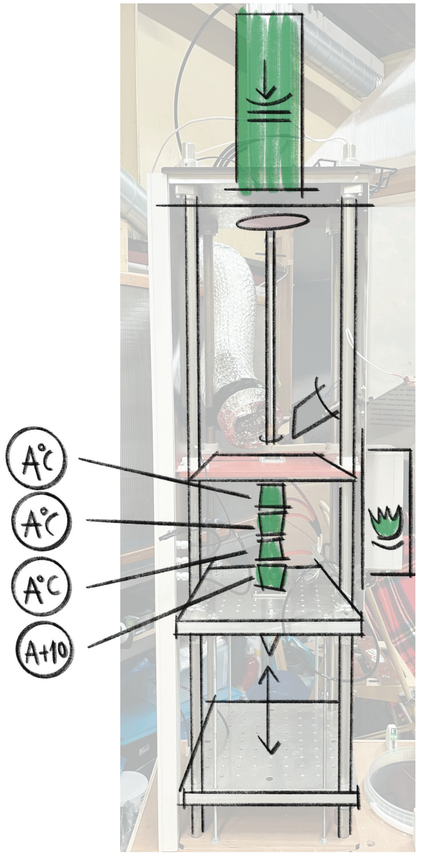
Source: Stevin II Lab, CiTG TU Delft

MANUAL PLUNGER-TYPE



Source: MakerLab, New Science Center TU Delft

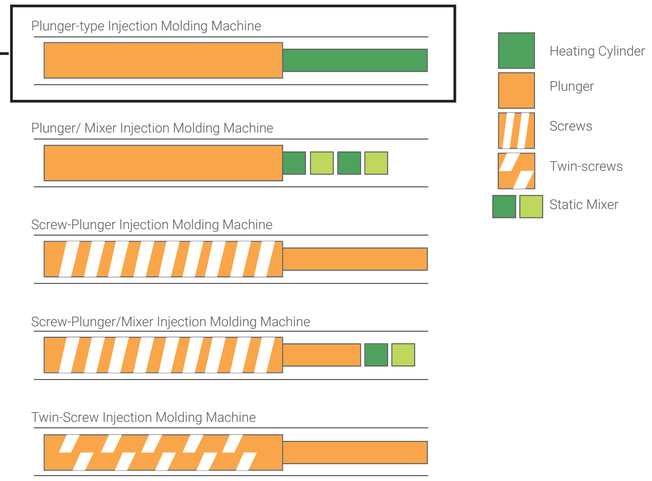
PNEUMATIC PLUNGER-TYPE



Source: Joost Domisse, OMA

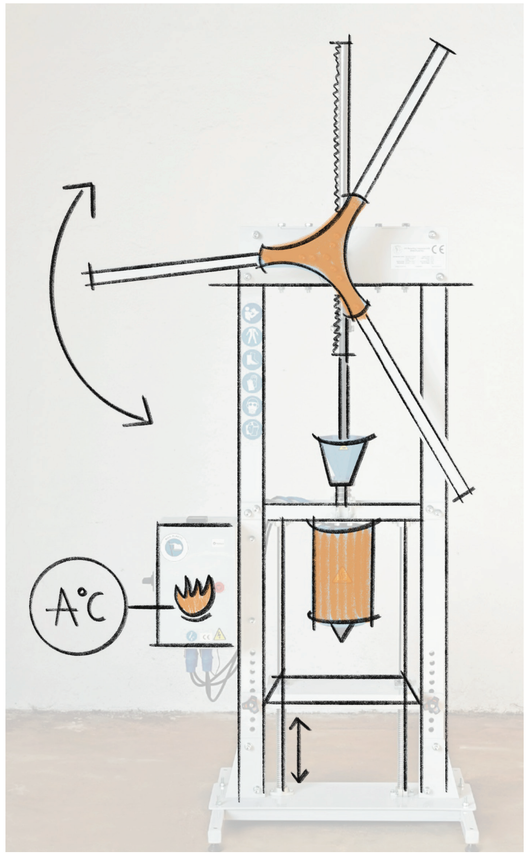
1. Manual Press
2. Manual Plunger-type
3. Pneumatic Plunger-type

EXPERIMENT SETUPS



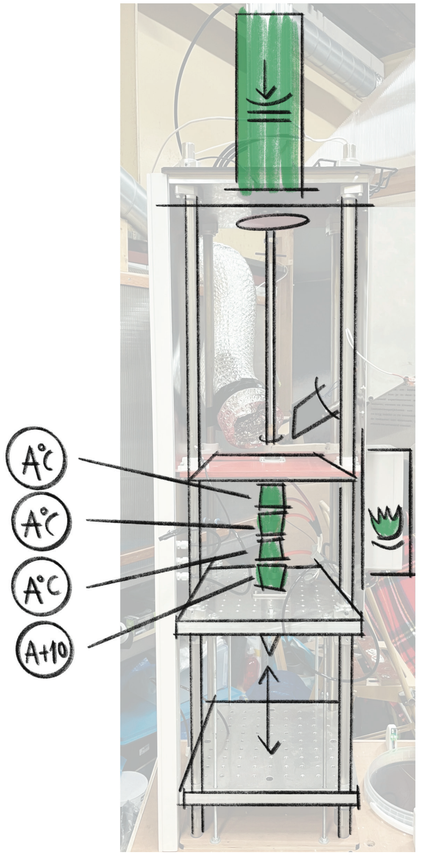
Different types of injection molding machines (Adapted from: Han et al., 1977)

MANUAL PLUNGER-TYPE



Source: MakerLab, New Science Center TU Delft

PNEUMATIC PLUNGER-TYPE



Source: Joost Domisse, OMA

1. Manual Press
2. Manual Plunger-type
3. Pneumatic Plunger-type

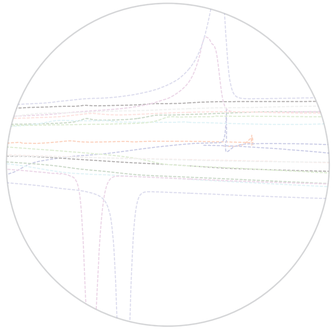
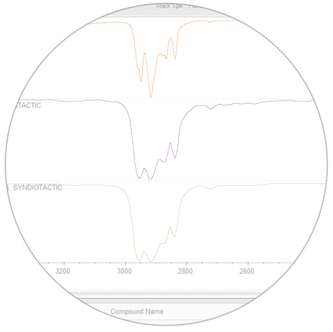
EXPERIMENT SETUPS

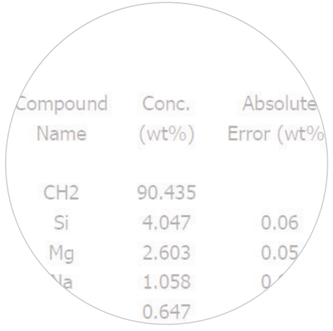


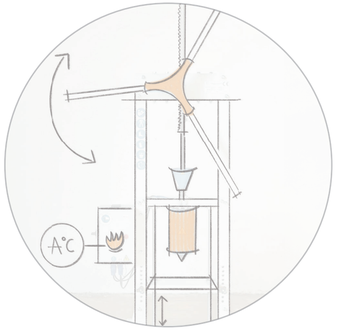
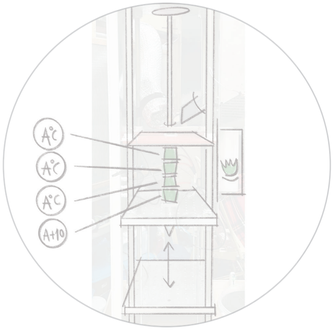









TACTIC
SYNDIOTACTIC
3200
3000
2800
2600
Compound Name


Compound Name
Conc. (wt%)
Absolute Error (wt%
CH2 90.435
Si 4.047 0.06
Mg 2.603 0.05
1.058 0
0.647

A'
A

A°C

A°C
A°C
A°C
A+10







FRIDGE-2



WASHING





COLOUR SORTING







WHITE COLOUR

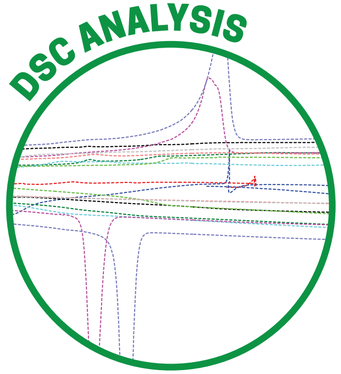


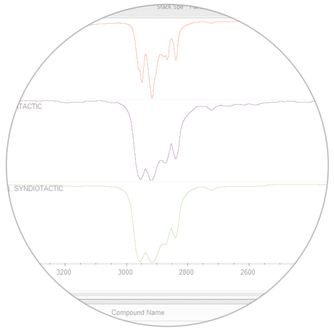
53

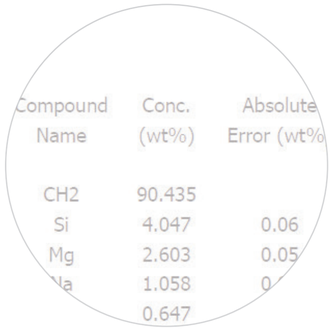
EXPERIMENTS

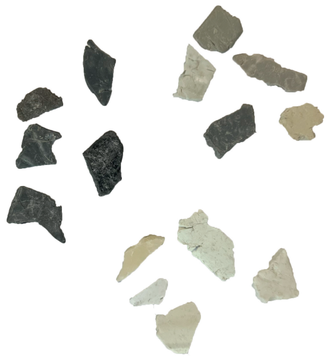
TOOLSET

POLYMER SORTING


DSC ANALYSIS

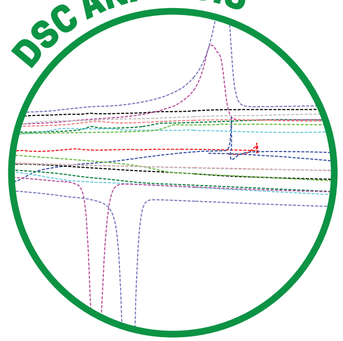

SYNDIOTACTIC
3200
3000
2800
2600
Compound Name

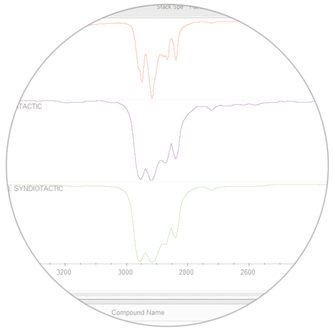

Compound Name
Conc. (wt%)
Absolute Error (wt%
CH2 90.435
Si 4.047 0.06
Mg 2.603 0.05
1.058 0
0.647



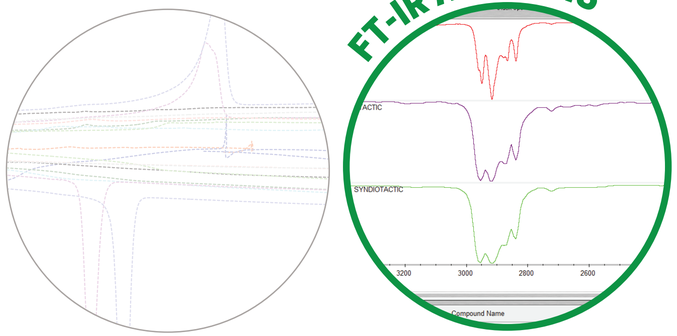
	SAMPLES	SAMPLE WEIGHT (mg)	GLASS TRANSITION TEMP.		MELTING BEHAVIOUR		CRYSTALLIZATION	
FRIDGE 1	A1	9.4	**Observed**	Not Observed	**Observed**	Not Observed	**Observed**	Not Observed
	A2	8.7	**Observed**	Not Observed	Observed	**Not Observed**	Observed	**Not Observed**
	A3	6.9	**Observed**	Not Observed	**Observed**	Not Observed	Observed	**Not Observed**
FRIDGE 2	D1	9.5	**Observed**	Not Observed	**Observed**	Not Observed	Observed	**Not Observed**
	D2	8.7	**Observed**	Not Observed	**Observed**	Not Observed	Observed	**Not Observed**

DSC ANALYSIS

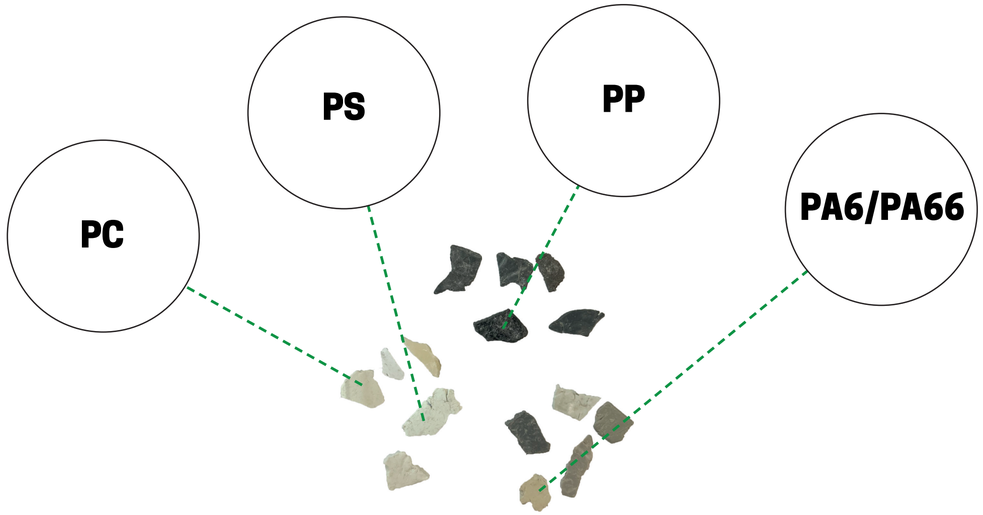


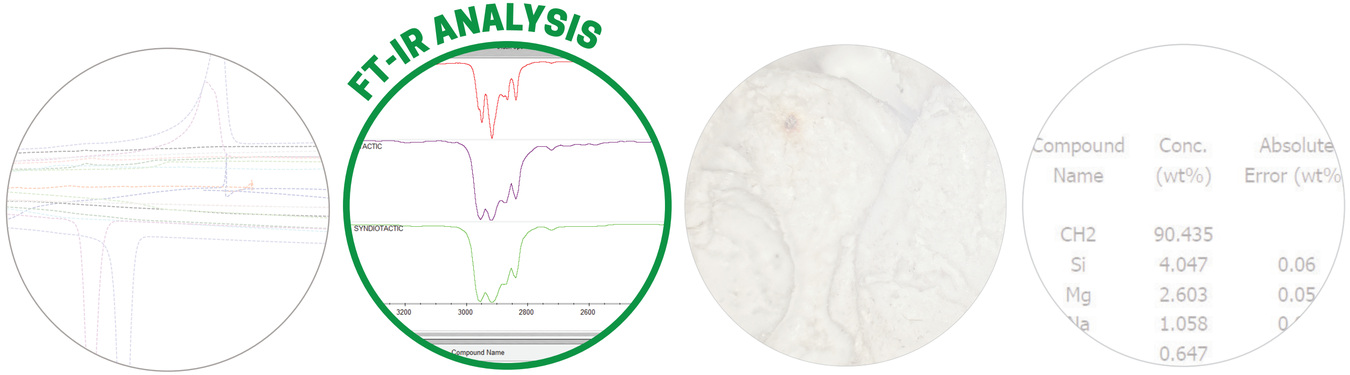


Compound Name	Conc. (wt%)	Absolute Error (wt%
CH2	90.435	
Si	4.047	0.06
Mg	2.603	0.05
Na	1.058	0
	0.647	



Compound Name	Conc. (wt%)	Absolute Error (wt%
CH2	90.435	
Si	4.047	0.06
Mg	2.603	0.05
Na	1.058	0
	0.647	


PS
PP
PC
PA6/PA66


FT-IR ANALYSIS
ATACTIC
SYNDIOTACTIC
3200
3000
2800
2600
Compound Name
Compound Name
Conc. (wt%)
Absolute Error (wt%
CH2 90.435
Si 4.047 0.06
Mg 2.603 0.05
1.058 0
0.647





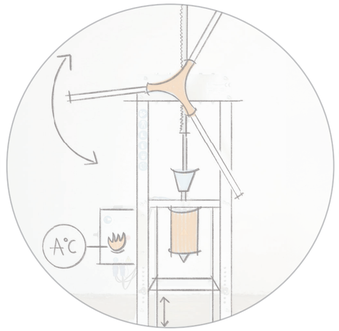
INSIDE HEATING BARREL



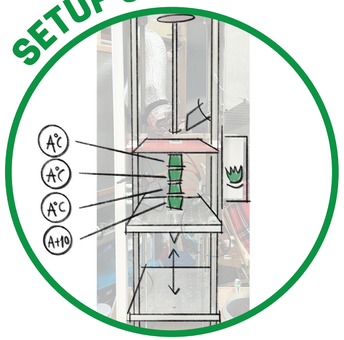
RESULT





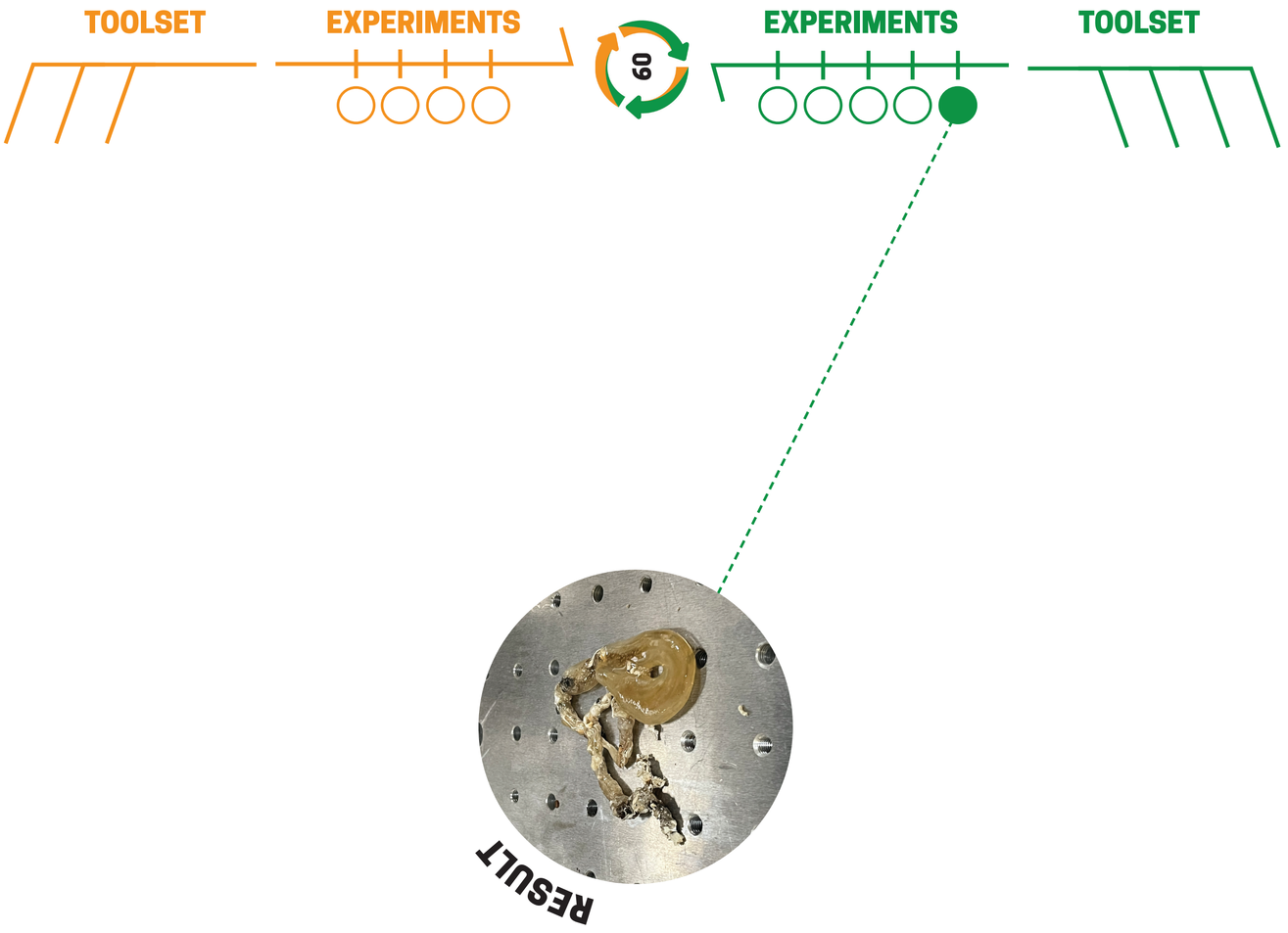


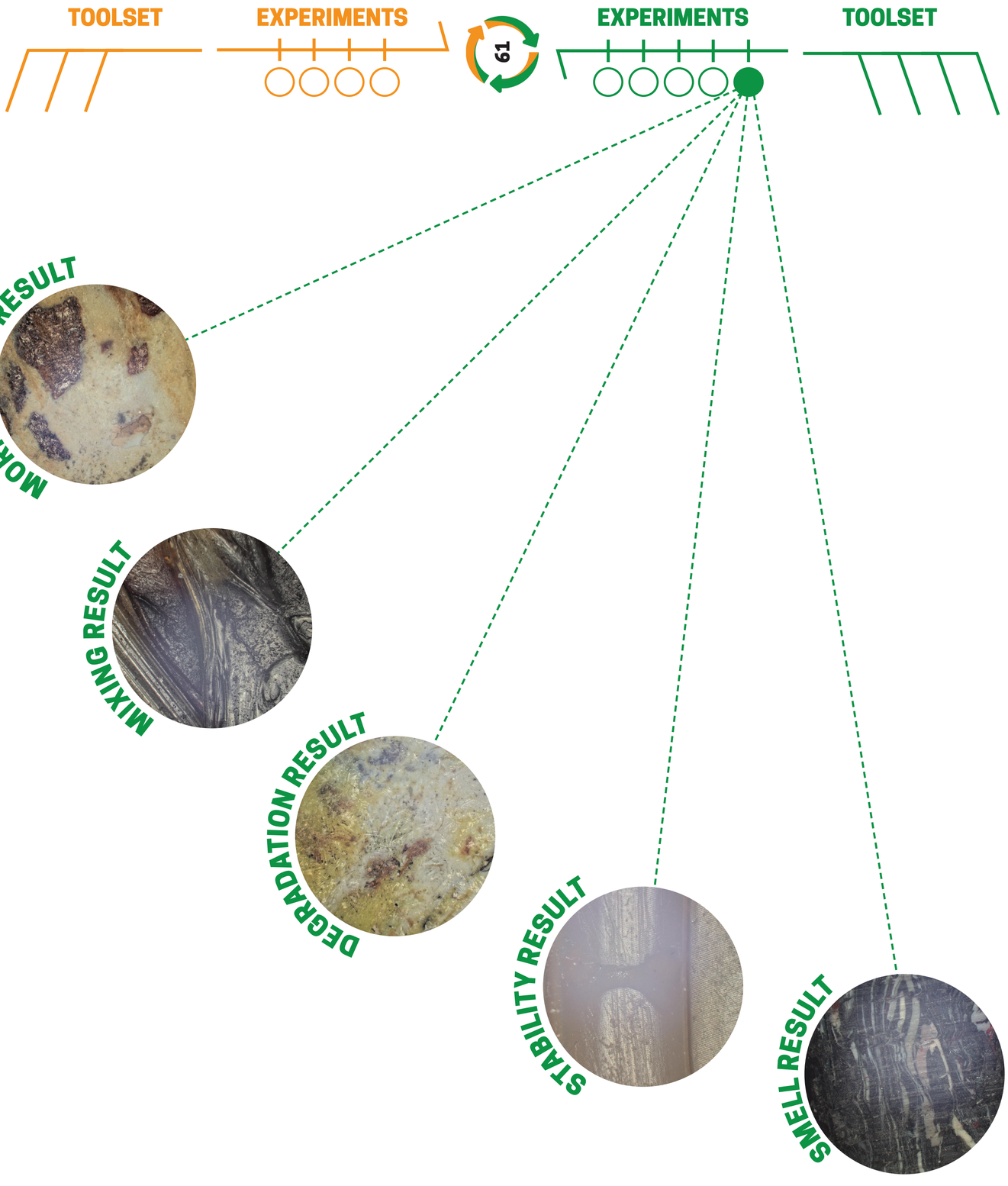
SETUP 3

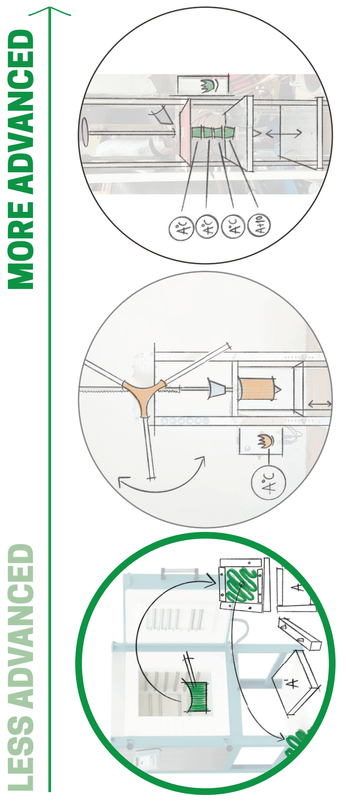


RESULT

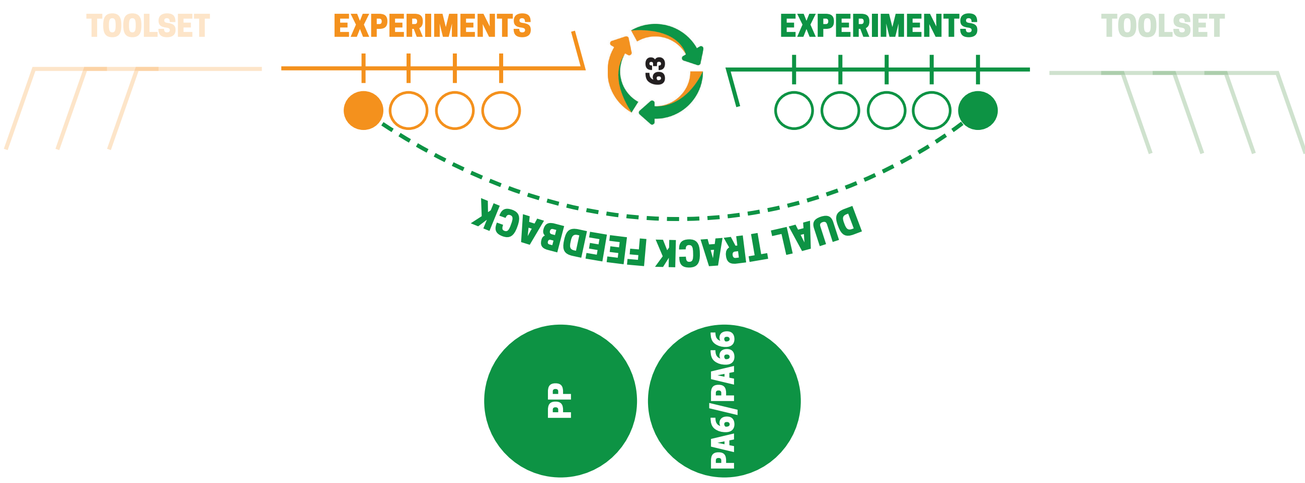



TOOLSET
EXPERIMENTS
60
EXPERIMENTS
TOOLSET
RESULT


TOOLSET
EXPERIMENTS
61
EXPERIMENTS
TOOLSET
MORPHOLOGY RESULT
MIXING RESULT
DEGRADATION RESULT
STABILITY RESULT
SMELL RESULT


MORE ADVANCED
LESS ADVANCED


DENSITY SEPARATION


TOOLSET
EXPERIMENTS
63
EXPERIMENTS
TOOLSET
DUAL TRACK FEEDBACK

PP
PA6/PA66

TRACK II: PRODUCT DEVELOPMENT

“Top-down Approach”



Material

Material: RPI-299X

Melt Temperature (°C): 230

Mold temperature (°C): 80

Fill Properties

Filling Time (sec):

- (•) Automatic
- ( ) User defined

Injection Pressure Limit (MPa): 10

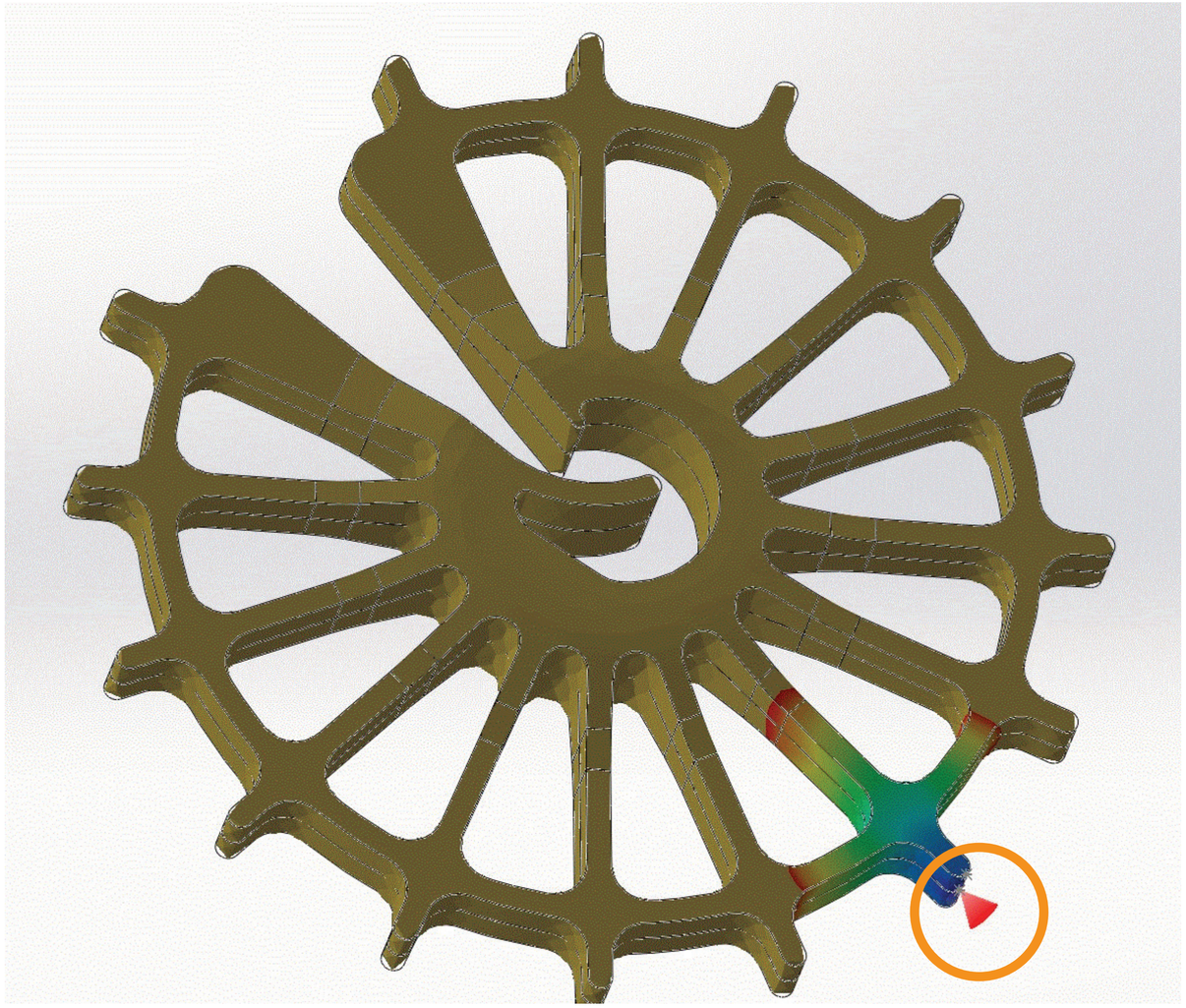
Fill/Pack Switch Point (% Filled Volume): 100

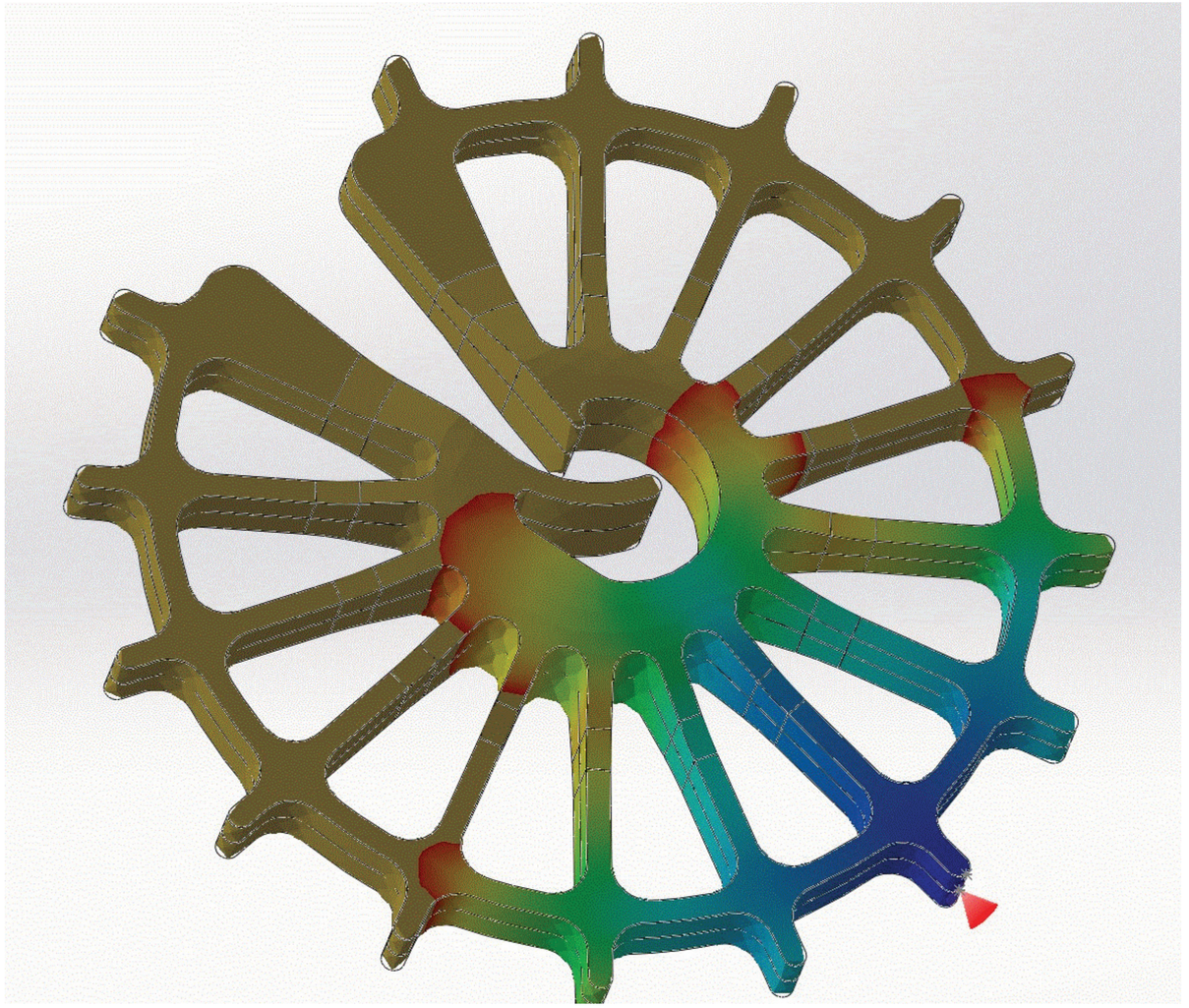
Temperature Criteria for Short Shots (°C): 100

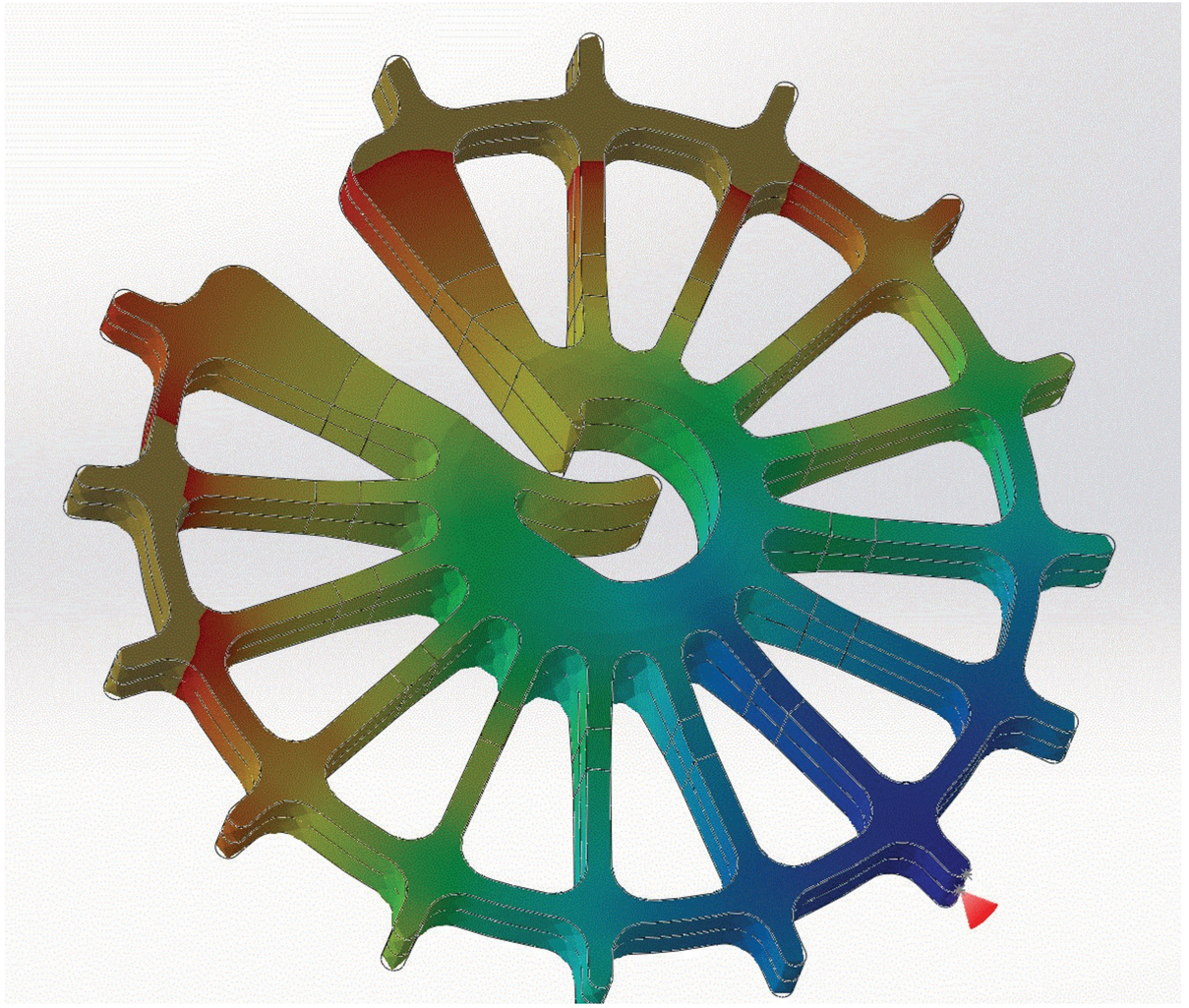
Flow Rate Profile Settings

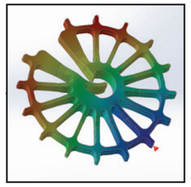
☐ **Mold Temperature Profile**

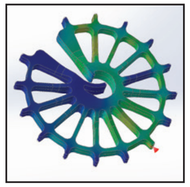
☐ **Mold-Melt Heat Transfer Coefficient**

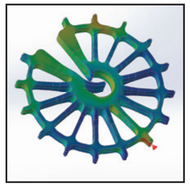


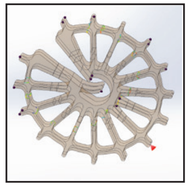


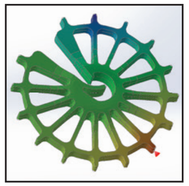


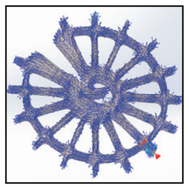

Fill Time


Pressure


Temperature


Weld lines & Air Traps


Shear Stress


Velocity Vector

MIN. VALUE

MAX. VALUE

“3kg concrete falling from 1-meter height”

$$PE=m\times g\times h$$

where:
PE = Potential energy (Joules, J)
m = Mass (kg)
g = Gravitational acceleration (9.81 m/s²)
h = Height (m)

$$v=2gh$$

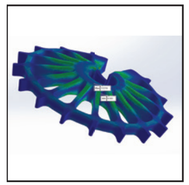
where:
v = Impact velocity (m/s)
g = Gravitational acceleration (9.81 m/s²)
h = Height (m)

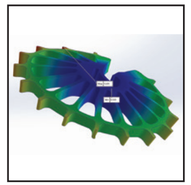
“Hydrostatic pressure from the wet concrete”

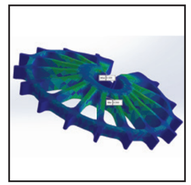
$$p=\rho\times g\times h$$

where:
p = hydrostatic pressure (N/m²)
ρ = density of fresh concrete (~2400 kg/m³)
g = gravitational acceleration (9.81 m/s²)
h = vertical height of the fresh concrete above the point considered (m)

COMPRESSIVE STRENGTH


Stress

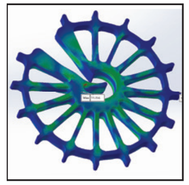

Displacement

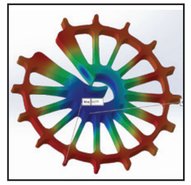

Equilavent Strain

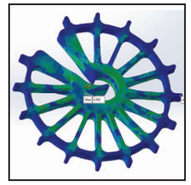
MIN. VALUE

MAX. VALUE

CHARPY IMPACT


Stress


Displacement

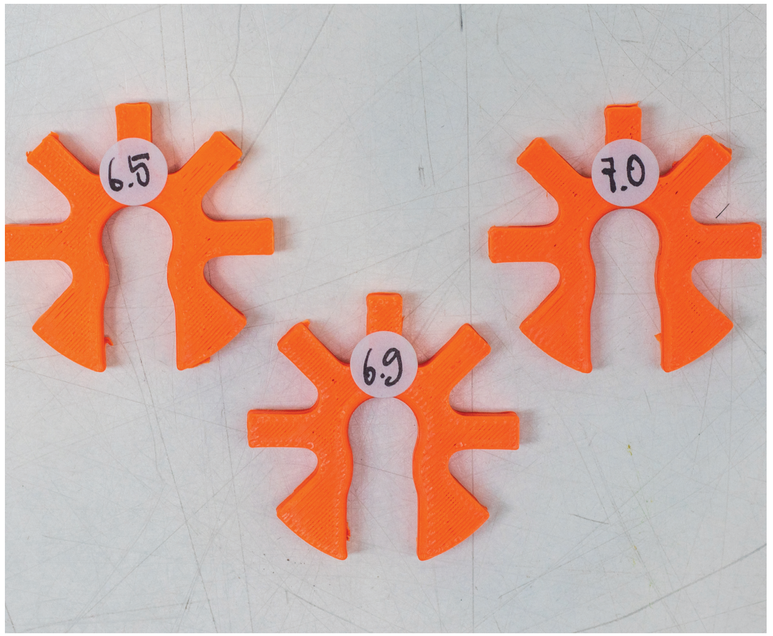

Equilavent Strain

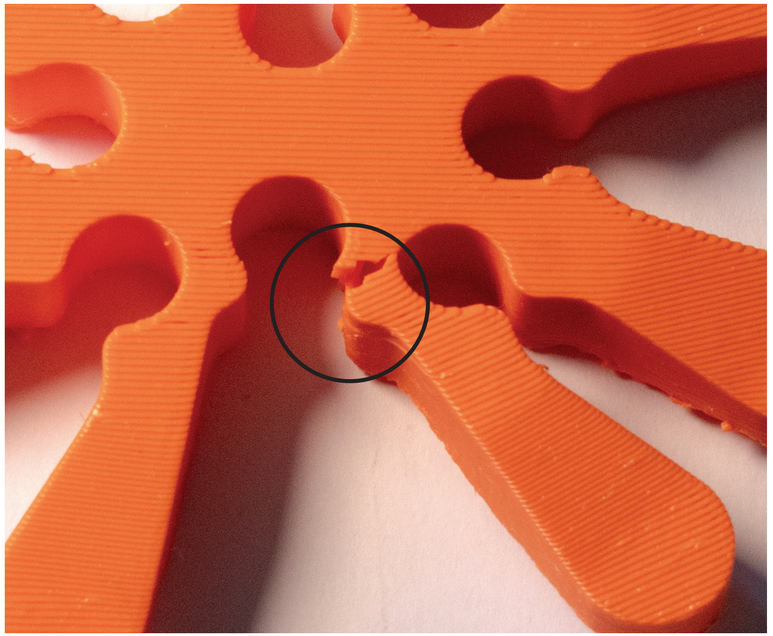
MIN. VALUE

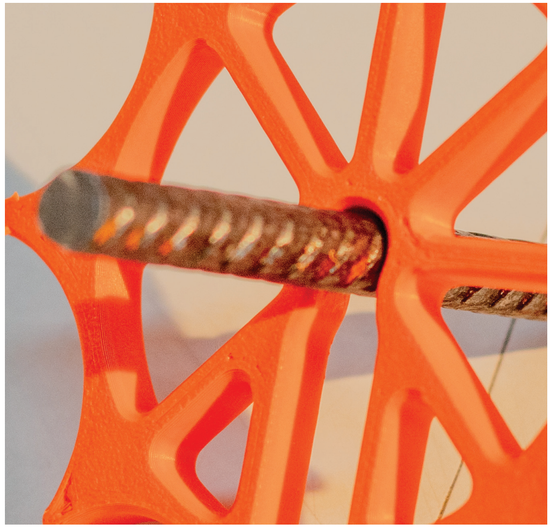
MAX. VALUE

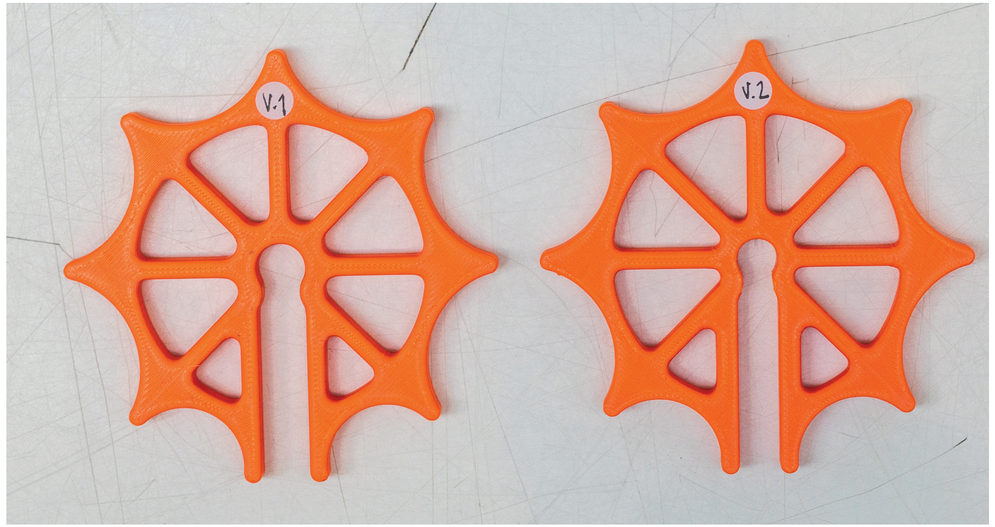
PHYSICAL TEST

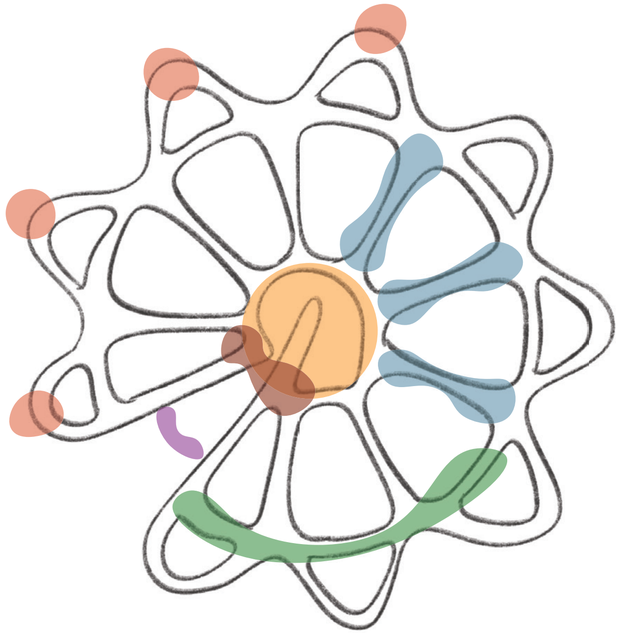
1. Concrete contact points
2. Rebar Snapping



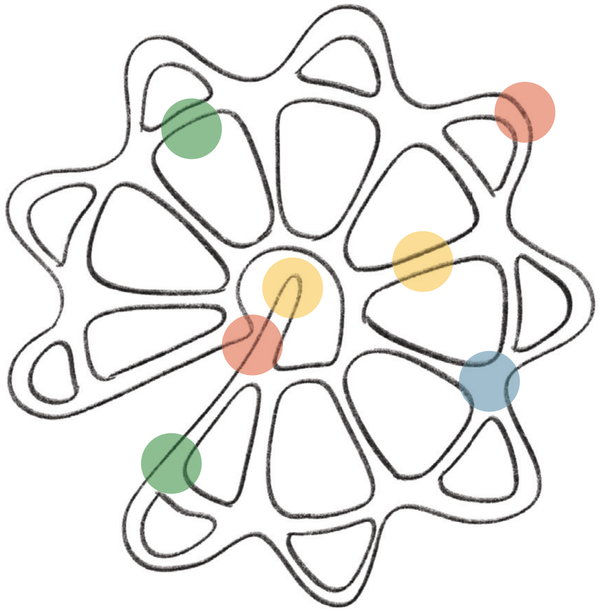




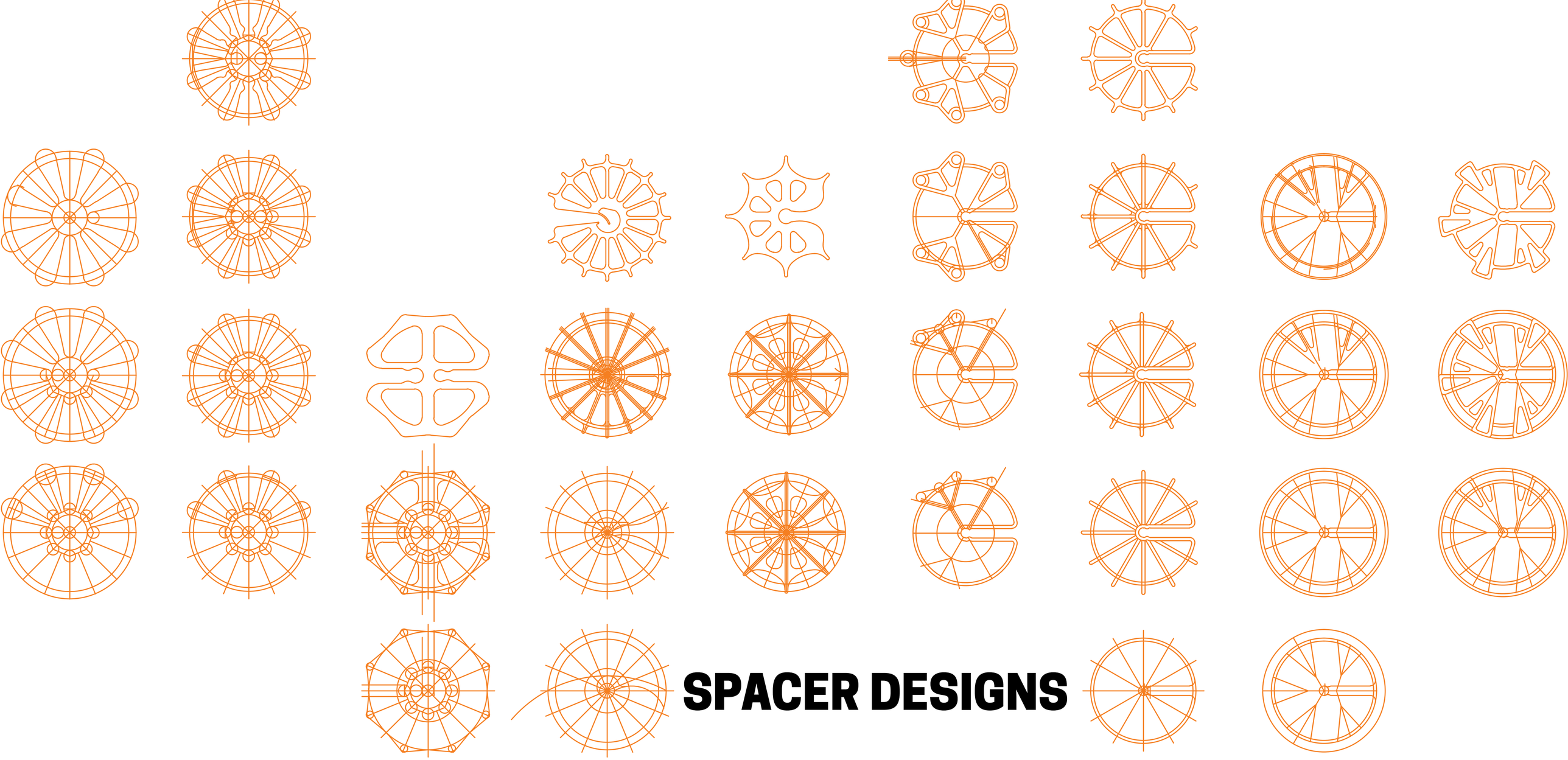




- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE



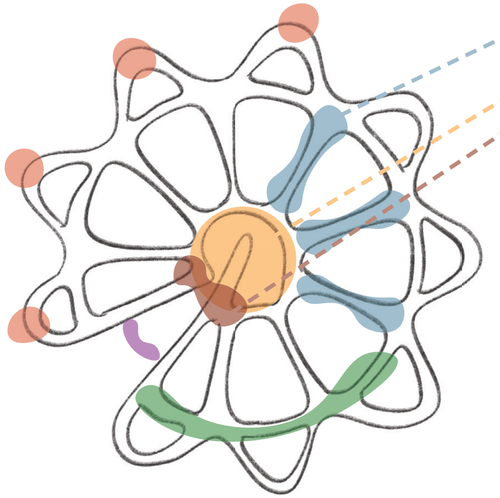
- RANGE 1: IDEAL (10/10)
- RANGE 2: ACCEPTABLE (7/10)
- RANGE 3: RISKY (4/10)
- RANGE 4: FAILURE (0/10)



SPACER DESIGNS



Photo Source: Euro Accessories



- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE

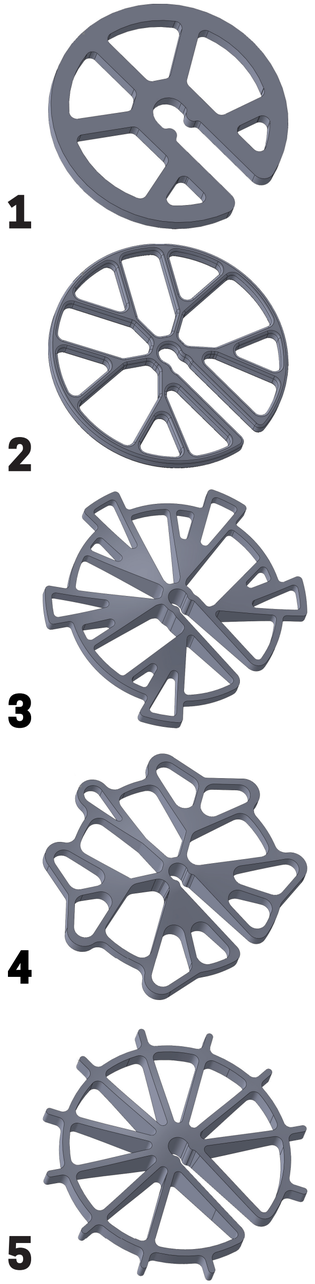
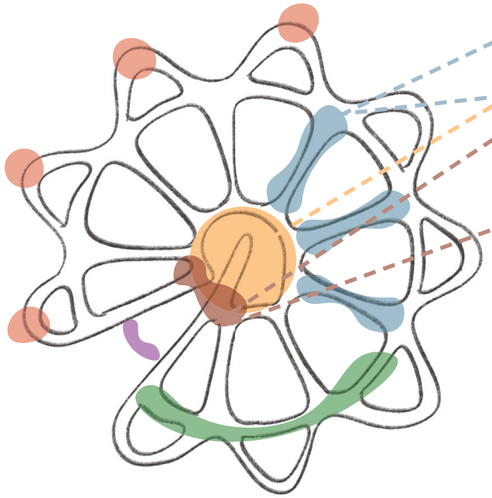




Photo Source: Euro Accessories



- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE

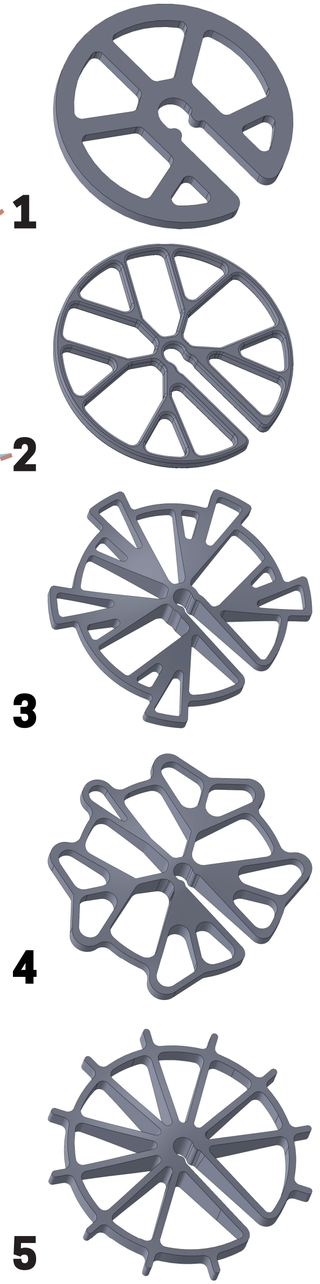
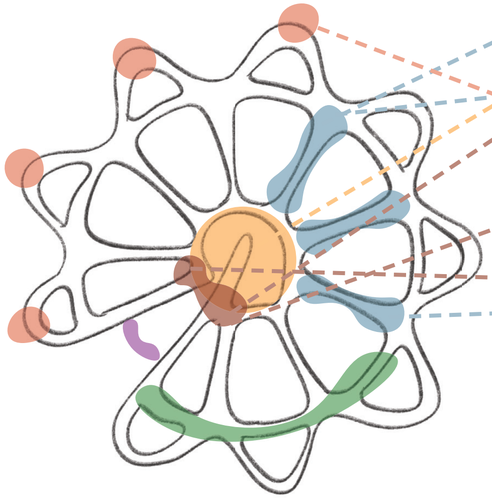




Photo Source: Euro Accessories



- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE

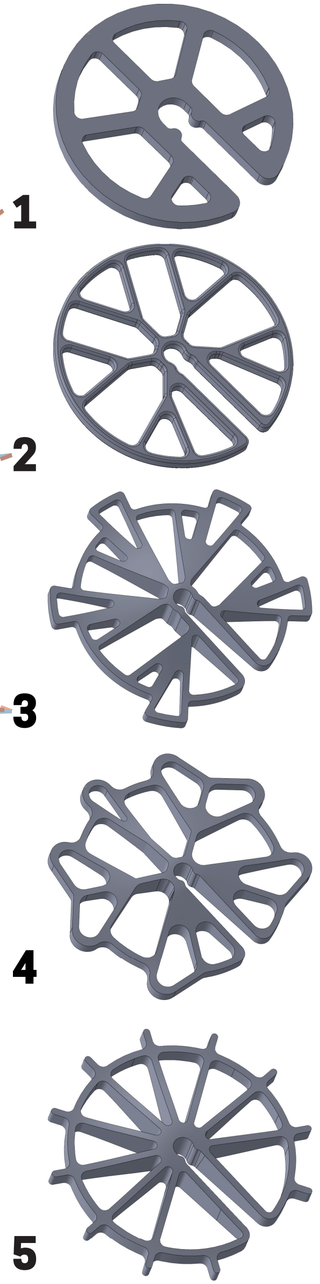
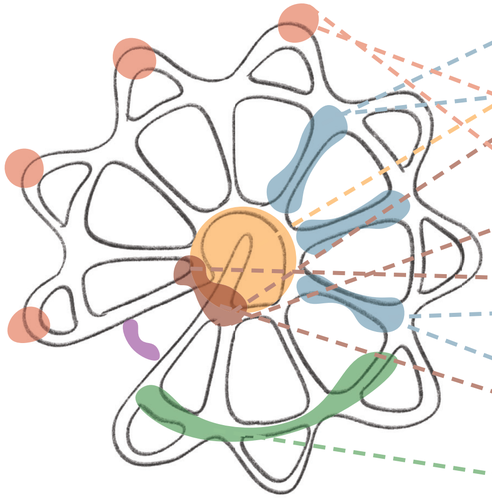




Photo Source: Euro Accessories



- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE

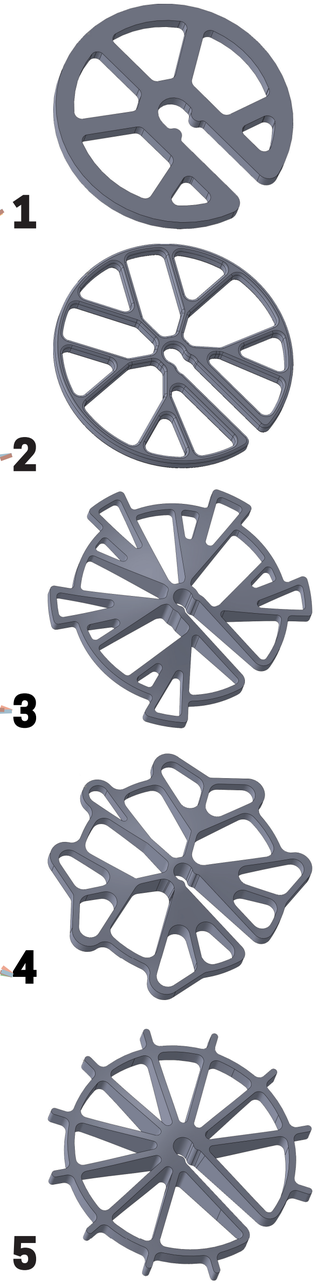
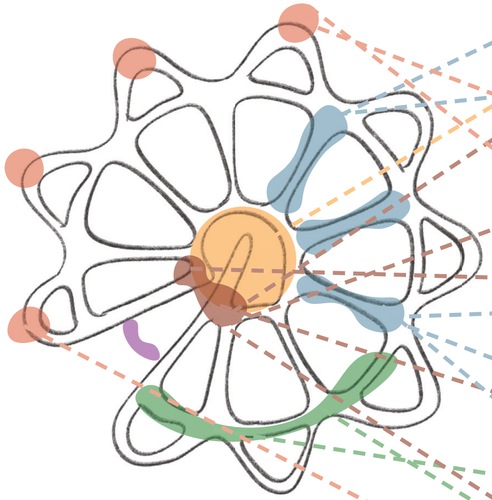
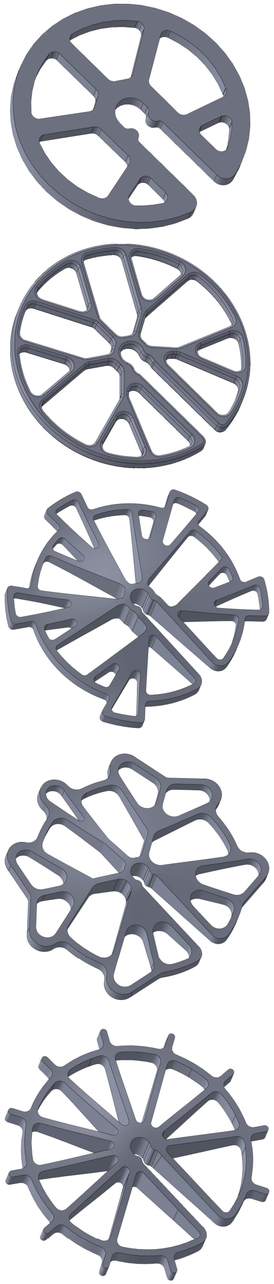




Photo Source: Euro Accessories



- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE

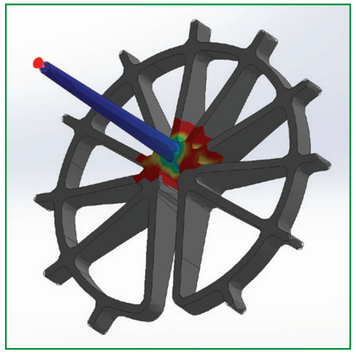
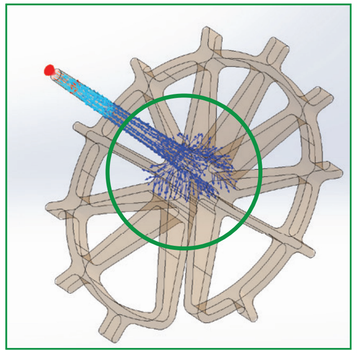


TOOLSET
EXPERIMENTS
77
EXPERIMENTS
TOOLSET
DUAL TRACK FEEDBACK
PP
PA6/PA66

SPACER 5

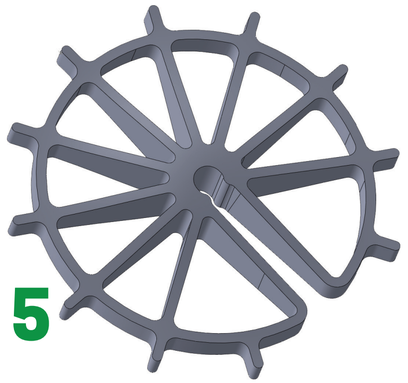
PA6/PA66

INJECTION LOCATION : RUNNER SYSTEM - PA6/PA66

FILL TIME	VELOCITY VECTOR
	

INJECTION LOCATION : RUNNER SYSTEM - PP

FILL TIME	VELOCITY VECTOR
	

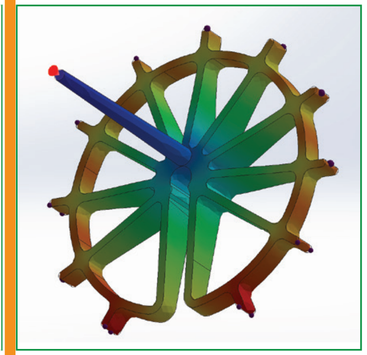
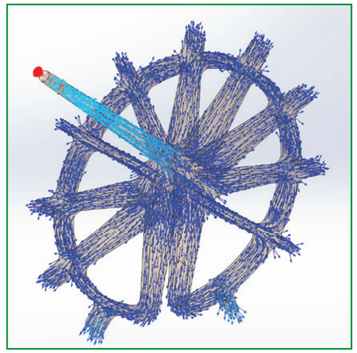


SPACER 5

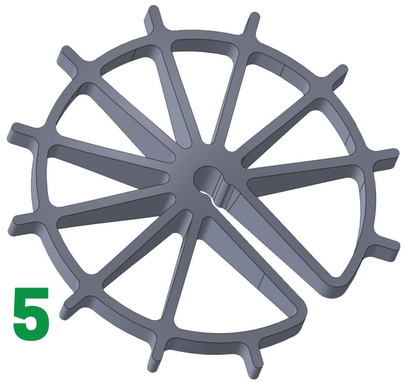
INJECTION LOCATION : RUNNER SYSTEM - PA6/PA66

FILL TIME	VELOCITY VECTOR
	

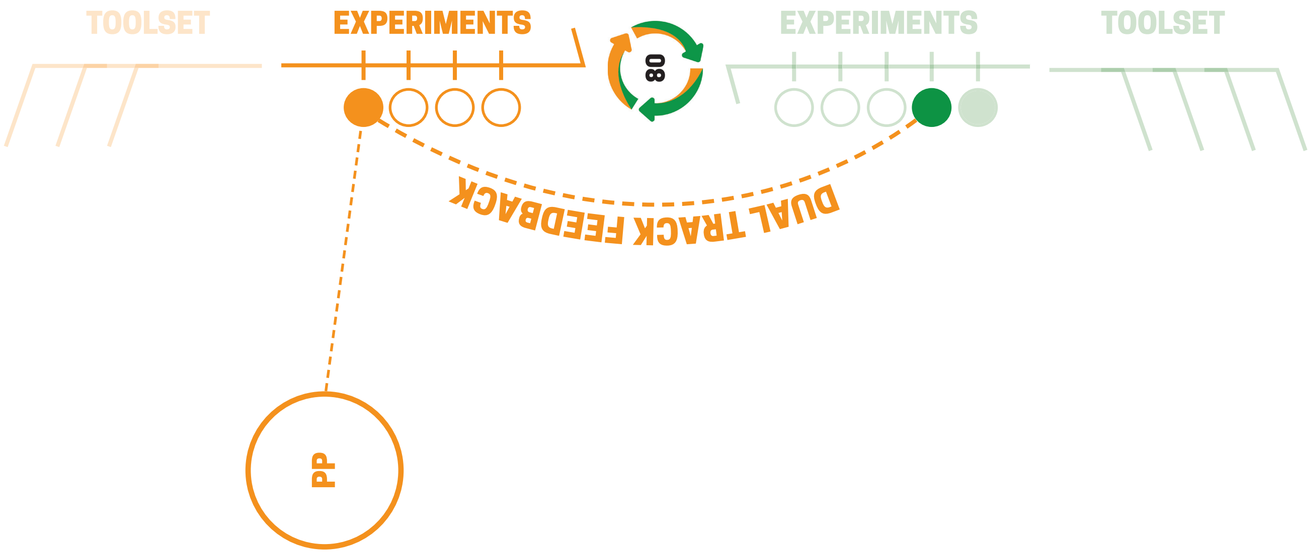
INJECTION LOCATION : RUNNER SYSTEM - PP

FILL TIME	VELOCITY VECTOR
	





SPACER 5


TOOLSET
EXPERIMENTS
80
EXPERIMENTS
TOOLSET
DUAL TRACK FEEDBACK
PP



BACK TO

TRACK I: MATERIAL EXPERIMENTATION

TARGET

PP





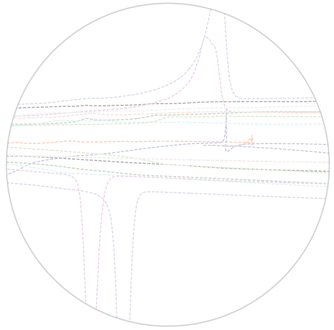
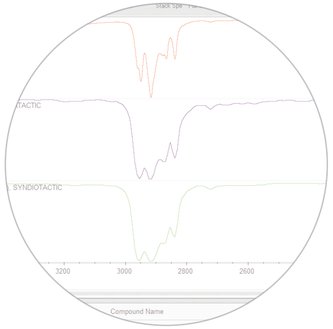


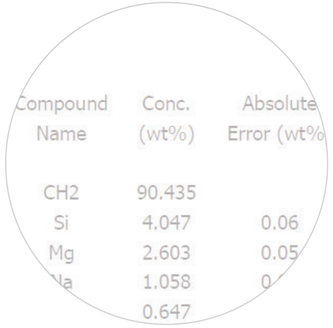


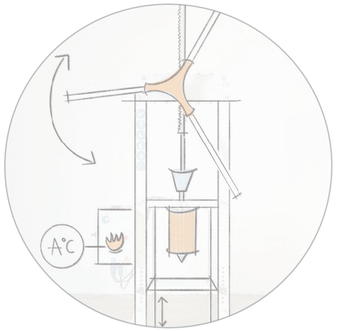
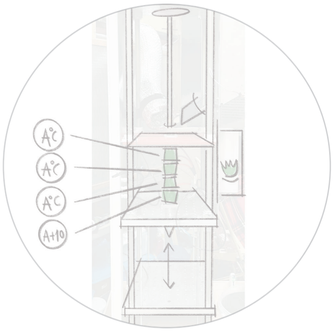









TACTIC
SYNDIOTACTIC
3200
3000
2800
2600
Compound Name

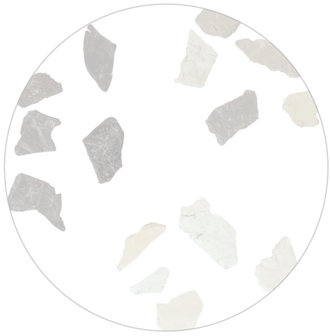

Compound Name
Conc. (wt%)
Absolute Error (wt%
CH2 90.435
Si 4.047 0.06
Mg 2.603 0.05
1.058 0
0.647

A'
A

A°C

A°C
A°C
A°C
A+10



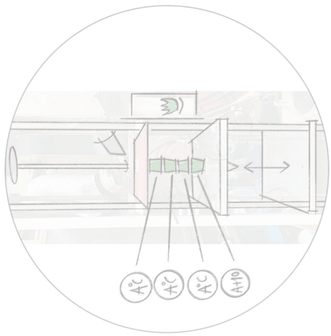






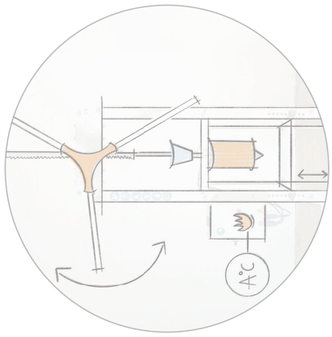




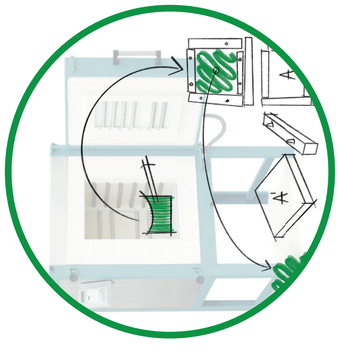





1.13
1.10
1.05







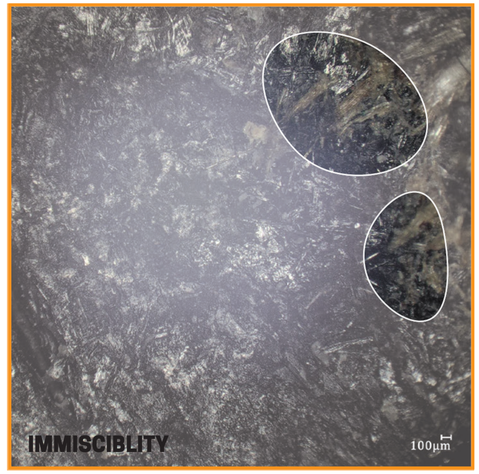
	SETUP 3 - FRIDGE LINE 2 DENSITY SORTED (1.05 + 1.10 g/cm3)		SETUP 4 - FRIDGE LINE 1 DENSITY SORTED (1.05 + 1.10 g/cm3)
	TRIAL 1: ALL POLYMER BLEND	TRIAL 2: ALL POLYMER BLEND	TRIAL 1: ALL POLYMER BLEND
MIXING RESULT	Immiscibility - Heterogeneous blend	Immiscibility - Heterogeneous blend	Immiscibility - Viscous flow
MORPHOLOGY RESULT	Clear phase domains	Agglomeration	Clear phase domains - Fibers
DEGRADATION RESULT	Thermal degradation	Surface carbonization	Little carbonization - Little degradation
STABILITY RESULT	Deformation under light pressure	Deformation under light pressure	Deformation under light pressure
SMELL RESULT	Mild burnt smell	Mild burnt smell	Mild burnt smell









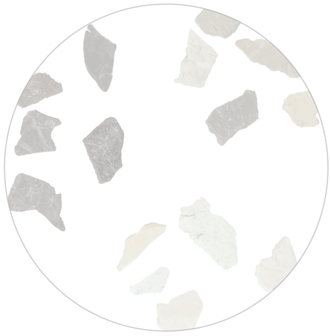






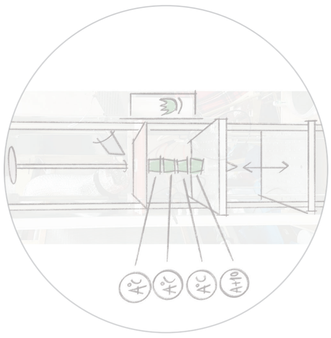






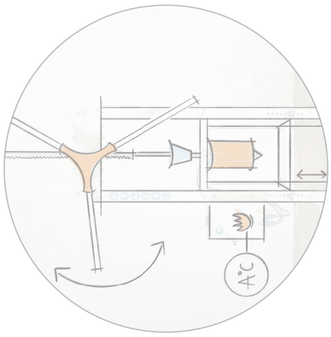




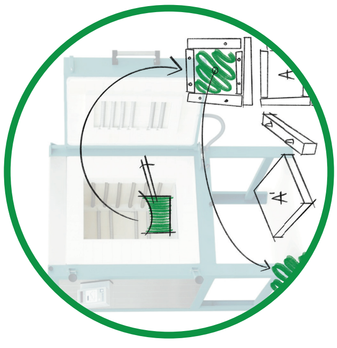





1.13
1.10
1.05









FRIDGE 1-2

x



SDA 1-2

BIGGER SHRED SIZE SDA - LOW RECYCLING EFFICIENCY



FRIDGE 1-2

X



SDA 1-2

EXPERIMENT SETUP

SEPARATING MEDIUM

- NaCL (table salt) + H2O (water)
- C12H22O11 (table sugar) + H2O (water)
- H2O (water)

DENSITY

- 1.05
- 1.10
- 1.00
- 1.13

WEIGHT (g)

WASTE STREAMS	SEPARATOR	WATER	TRIALS	INPUT WASTE	FLOATING	SINK
Fridge Line 1	72.00	1000	2	100.00	**39.35**	160.65
Fridge Line 2	100.00	1000	5	100.00	**68.05**	431.95
Fridge Line 1	165.10	1000	4	100.00	**84.60**	315.40
Fridge Line 2	240.10	1000	3	100.00	**15.00**	285.00
SDA Line 1	-	45000	1	3086.85	**24.50**	2752.20
SDA Line 1	4180.00	24000	1	3213.00	**461.80**	
SDA Line 1.1	6097.00	35000	1	2859.30	**557.30**	2302.00
SDA Line 1.2	6364.75	35000	1	3990.00	**461.90**	3528.10
SDA Line 1.3	6364.75	35000	1	5528.10	**1313.50**	4214.60
SDA Line 2	6637.55	35000	1	6000.00	**8085.00**	6625.00
SDA Line 2.1	6976.50	42000	1	8710.00		

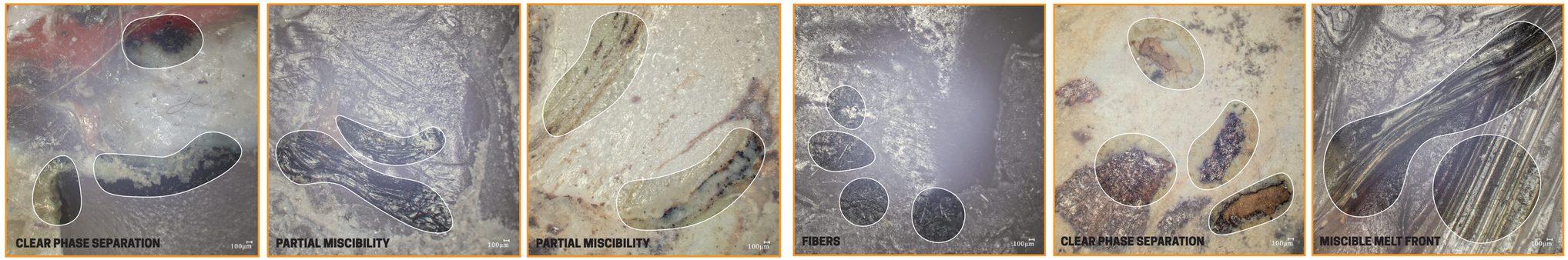
88

24.20% RECOVERING EFFICIENCY

SETUP 5 - SDA LINE 1 DENSITY SORTED (1.13 g/cm3)

TRIALS	TRIAL 1: ALL COLOUR BLEND	TRIAL 2: BLACK COLOUR BLEND	TRIAL 3: WHITE COLOUR BLEND	TRIAL 1: BLACK COLOUR BLEND	TRIAL 2: WHITE COLOUR BLEND	TRIAL 3: SEMI-TRANSPARENT BLEND
MIXING RESULT	Partial compatibility	Partial compatibility	Partial compatibility	Partial compatibility	Partial compatibility	Homogeneous blend
MORPHOLOGY RESULT	Medium indication of phase domains	Matte surface finish	Matte surface finish	Less indication of phase domains	Clear phase domains	Occuring transparency
DEGRADATION RESULT	Little yellowing on some polymers	No visible degradation	Little discolouration on some polymers	Some fume emission	Oxidative breakdown	Discolouration
STABILITY RESULT	Stable geometry	Stable geometry	Stable geometry	Stable geometry	Stable geometry	Stable geometry
SMELL RESULT	Mild burnt smell	Mild burnt smell	Mild burnt smell	Mild burnt smell	Mild burnt smell	Strong burnt smell





IMPROVEMENT





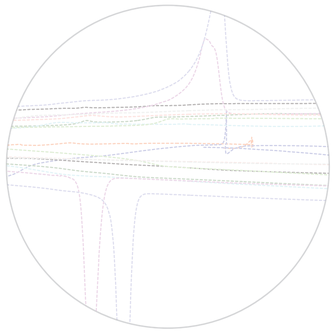
BEFORE DENSITY SEPARATION

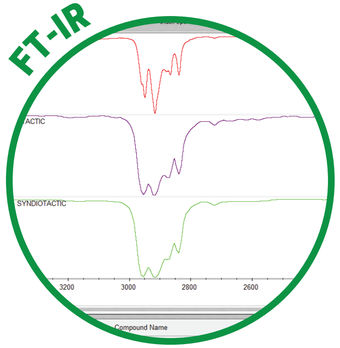


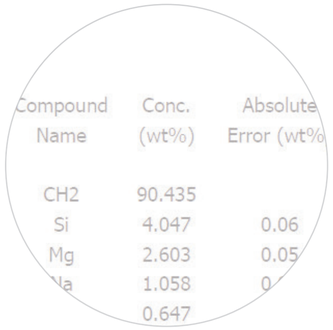
AFTER DENSITY SEPARATION




1.13

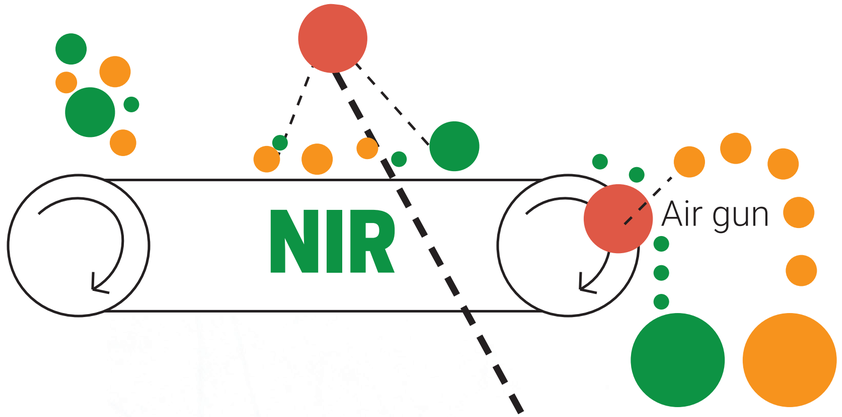



FT-IR
ACTIC
SYNDIOTACTIC
3200
3000
2800
2600
Compound Name


Compound Name
Conc. (wt%)
Absolute Error (wt%
CH2 90.435
Si 4.047 0.06
Mg 2.603 0.05
1.058 0
0.647

COLOUR SORTED POLYMER CATEGORIES	FIRST BATCH	FT-IR IDENTIFIED POLYMER WEIGHTS (g)						
		PP	PE/PP	PS	PA6/PA66	PC	PMMA + PUR	TOTAL WEIGHT (g)
	BLACK	19.52	31.50	15.59	9.53	4.45	9.74	156.31
	WHITE							129.06
	DARK GREY	3.92	18.51	N/A	1.16	N/A	N/A	29.22
	LIGHT GREY	18.98	12.33	8.71	3.44	2.26	0.83	56.18
	SEMI-TRANSPARENT							99.78
	MULTI-COLOUR	17.83	11.69	1.22	2.57	2.62	0.64	42.39
	RUBBER							71.30
	CONTAMINATED							28.11
	FOREIGN							
COLOUR SORTED POLYMER CATEGORIES	SECOND BATCH	PP	PE/PP	PS	PA6/PA66	PC	PMMA + PUR	TOTAL WEIGHT (g)
	BLACK	23.76	45.63	23.74	15.68	5.93	13.28	169.82
	WHITE							136.38
	DARK GREY							N/A
	LIGHT GREY	17.95	22.62	9.86	2.53	1.97	2.60	42.71
	SEMI-TRANSPARENT							80.76
	MULTI-COLOUR	14.43	4.33	2.53	3.06	0.33	2.47	28.29
	RUBBER							72.36
	CONTAMINATED							105.80
		43.71% RECOVERY	**15.96% RECOVERY**	**12.10% RECOVERY**				



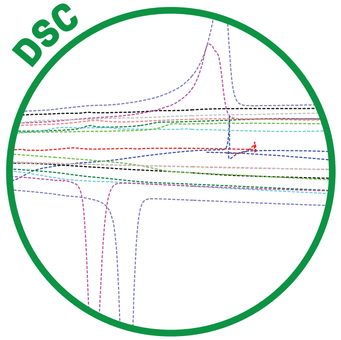


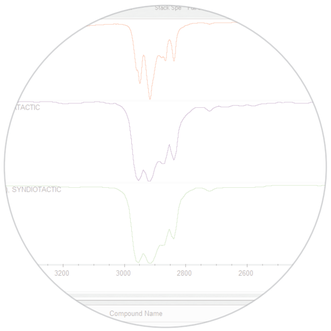


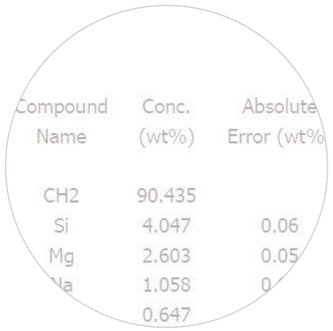
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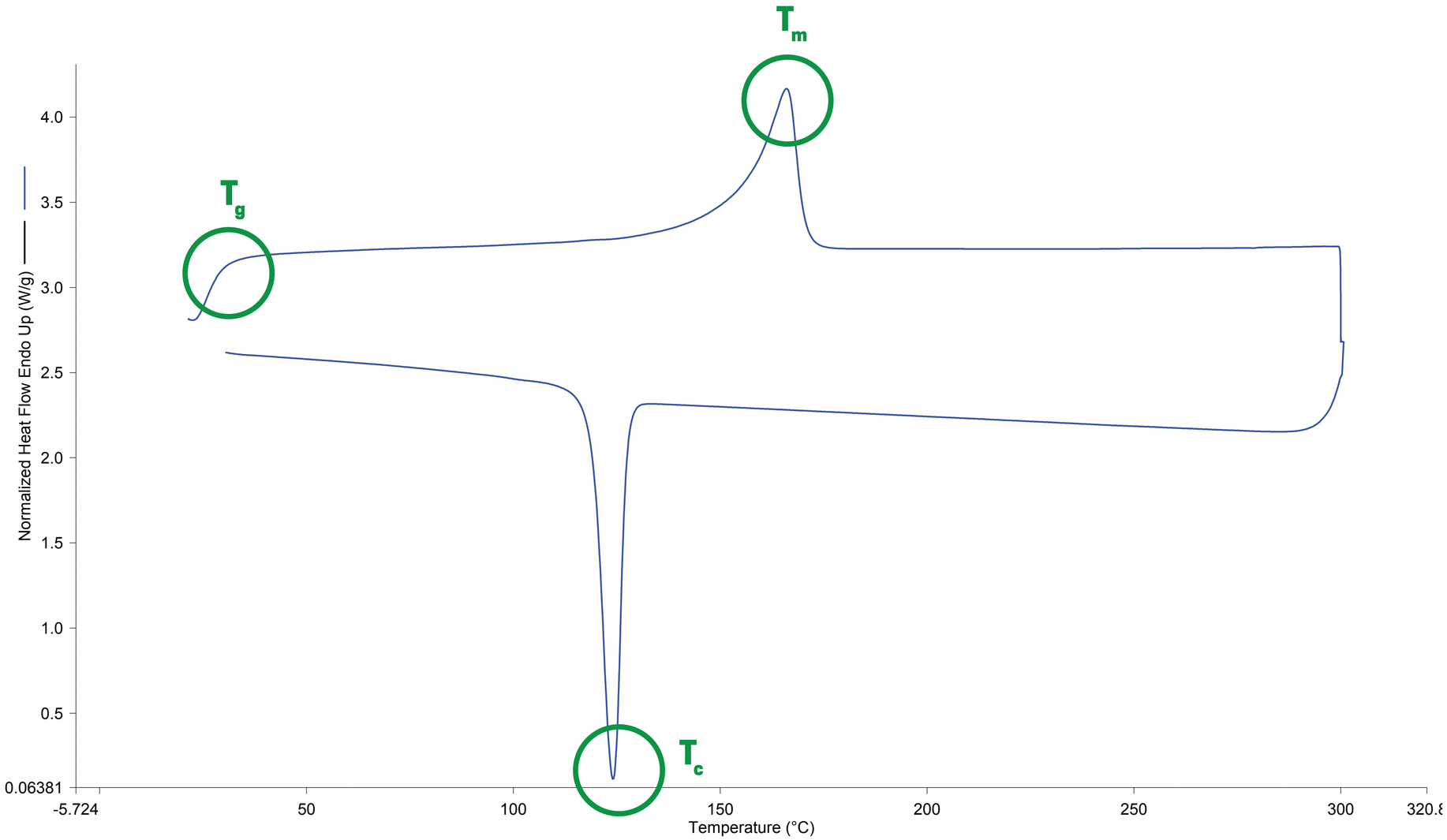

1.13




DSC


ATACTIC
SYNDIOTACTIC
3200
3000
2800
2600
Compound Name


Compound Name
Conc. (wt%)
Absolute Error (wt%
CH2 90.435
Si 4.047 0.06
Mg 2.603 0.05
1.058 0
0.647

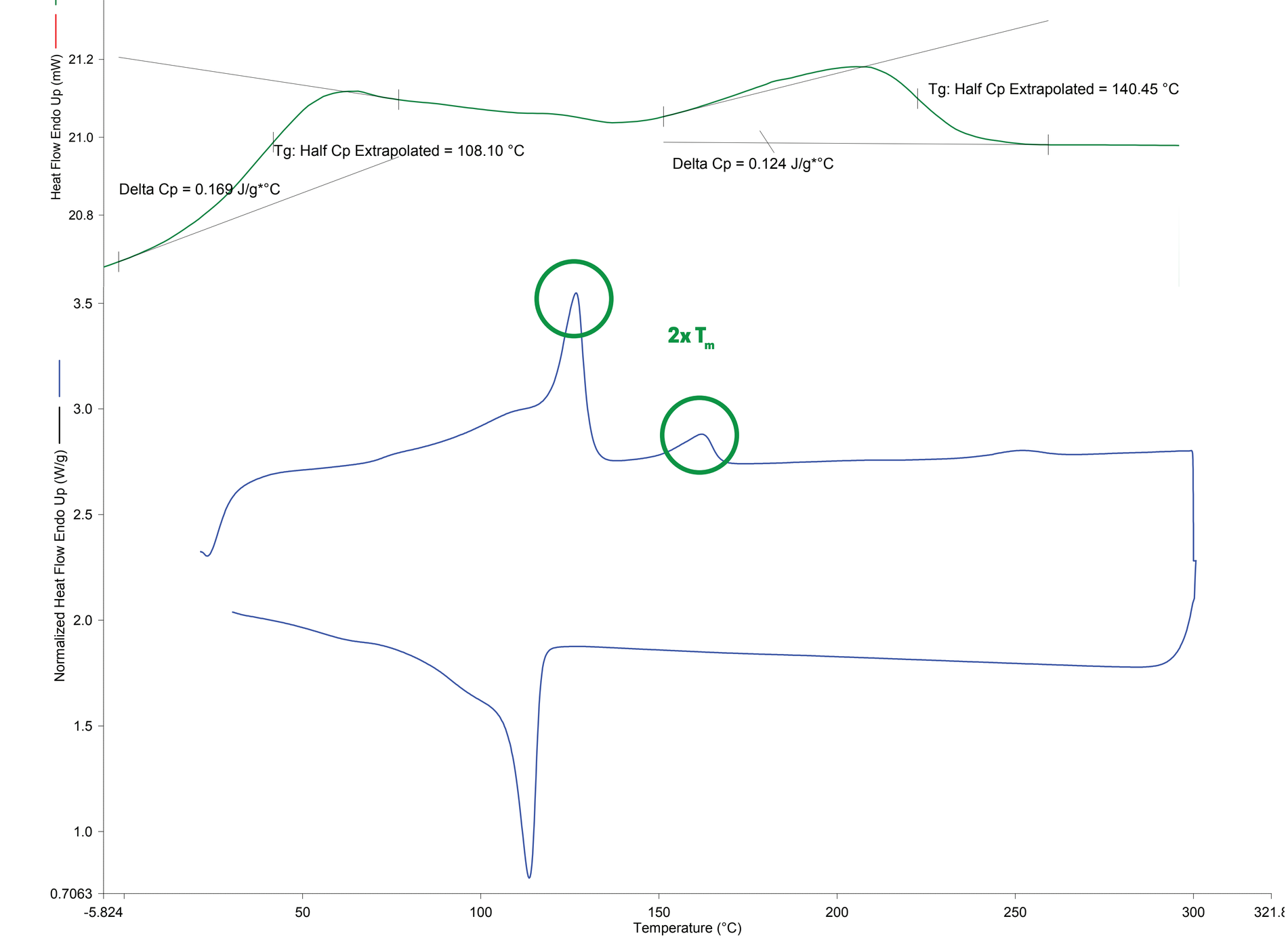




96

EXPERIMENTS

TOOLSET





97

EXPERIMENTS

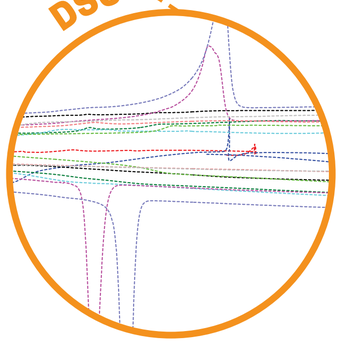
TOOLSET

ADDITIVES
RESIDUAL
SOLVENTS

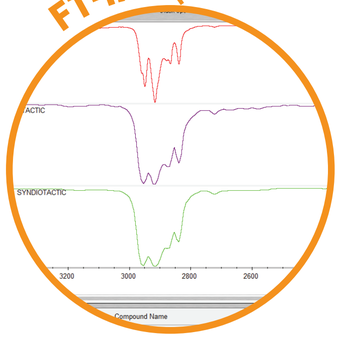
TALCUM POWDER
ALKYD RESIN
CELLOPHANE
AROMATIC
HYDROCARBONS

SILICA-BASED FILLERS
SALT RESIDUES
UV STABILISERS
NON-HALOGENATED
FLAME RETARDANTS

DSC



FT-IR

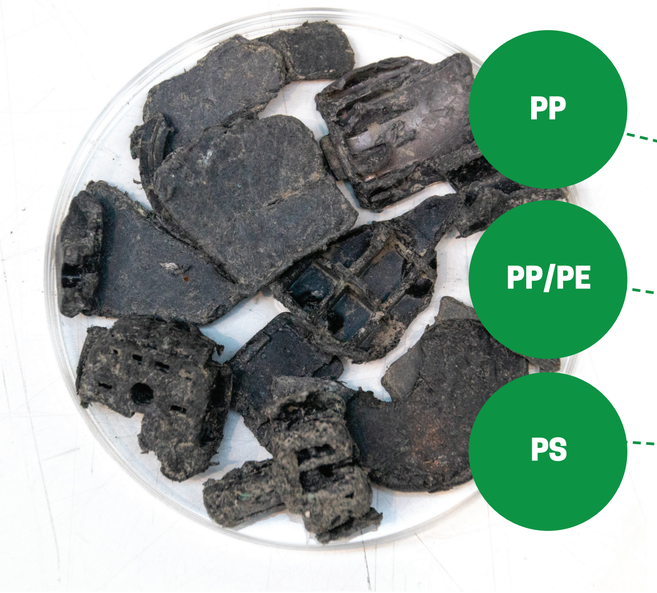


XRF

Compound Name	Conc. (wt%)	Absolute Error (wt%
CH2	90.435	
Si	4.047	0.06
Mg	2.603	0.05
Ia	1.058	0
	0.647	

CONTAMINANTS

Tm (°C)
166.48
126.89 162.28
165.70



PP

PP/PE

PS

TOOLSET

EXPERIMENTS

DUAL TRACK FEEDBACK

99

EXPERIMENTS

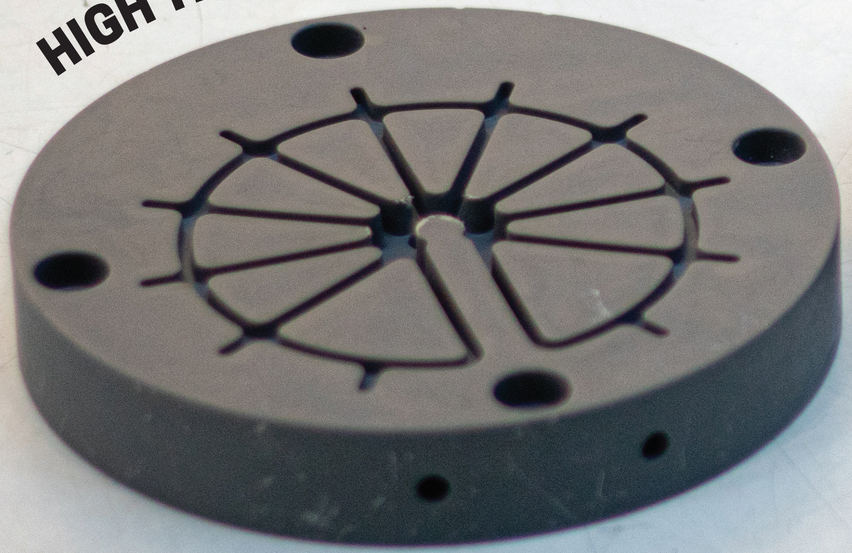
TOOLSET

BACK TO

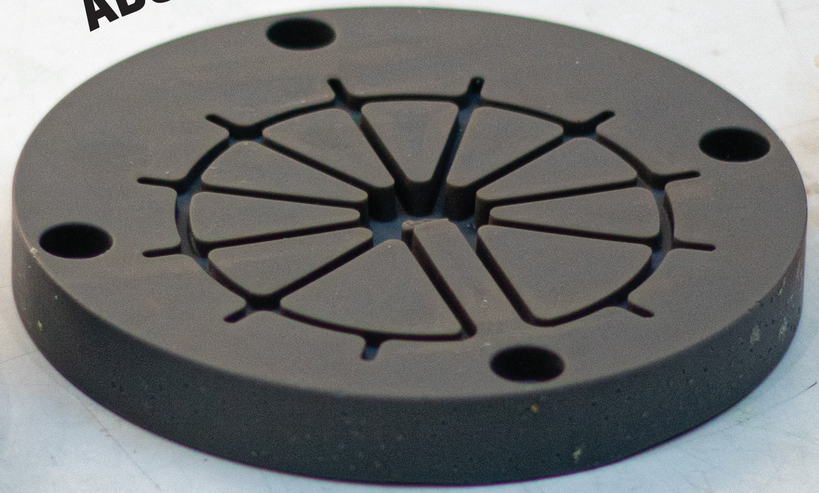
TRACK II: PRODUCT DEVELOPMENT



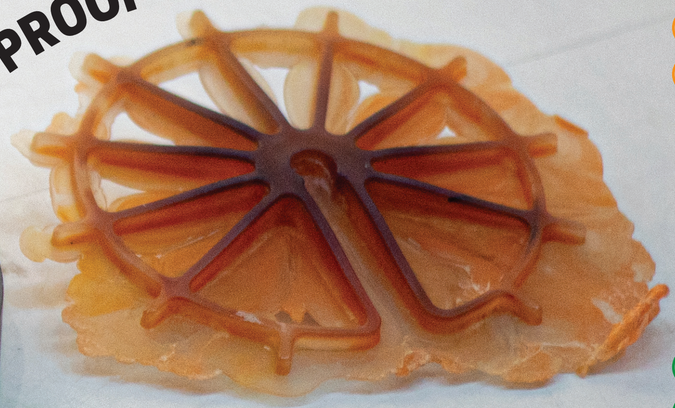
HIGH TEMPERATURE RESIN



ABS-LIKE RESIN



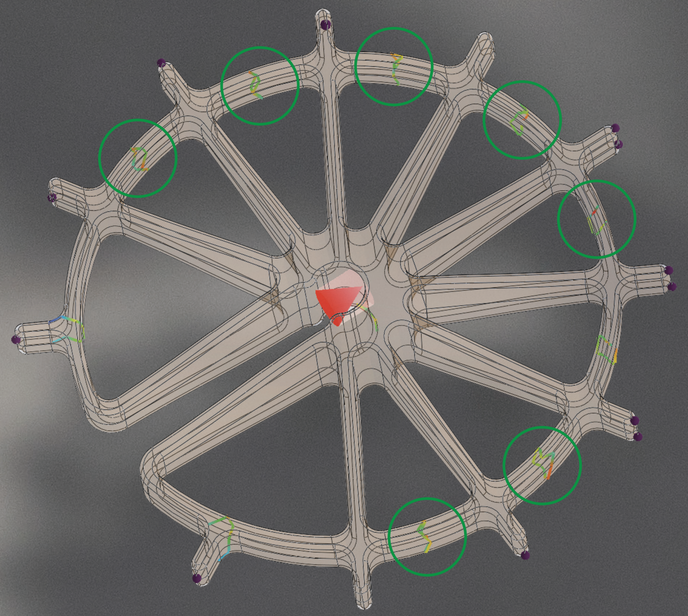
PROOF OF MOULD



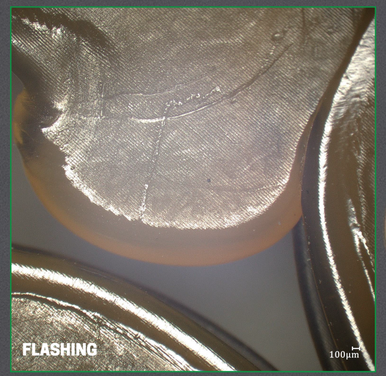


SETUP 8 - RECYCLED PP INPUT

	TRIAL 1	TRIAL 2	TRIAL 3
TRIALS	Anonymous source - recycled PP		
POLYMER IDENTITY	Resin mould	Open-air	Resin mould
MOULD TYPE	0.8	0.8	0.5
APPLIED PRESSURE (MPa)	250	250	240
HEATERS 1-2 (°C)	260	260	250
HEATER 3 (°C)	20 + 0.5	5	20 + 5
HEAT - COOL CYCLE (min)	1	N/A	1
MIXING RESULT	Miscible - Homogeneous blend		
MORPHOLOGY RESULT	Flashing - Visible knit lines - Air traps		
DEGRADATION RESULT	No degradation		
STABILITY RESULT	Stable geometry		
SMELL RESULT	No odor		

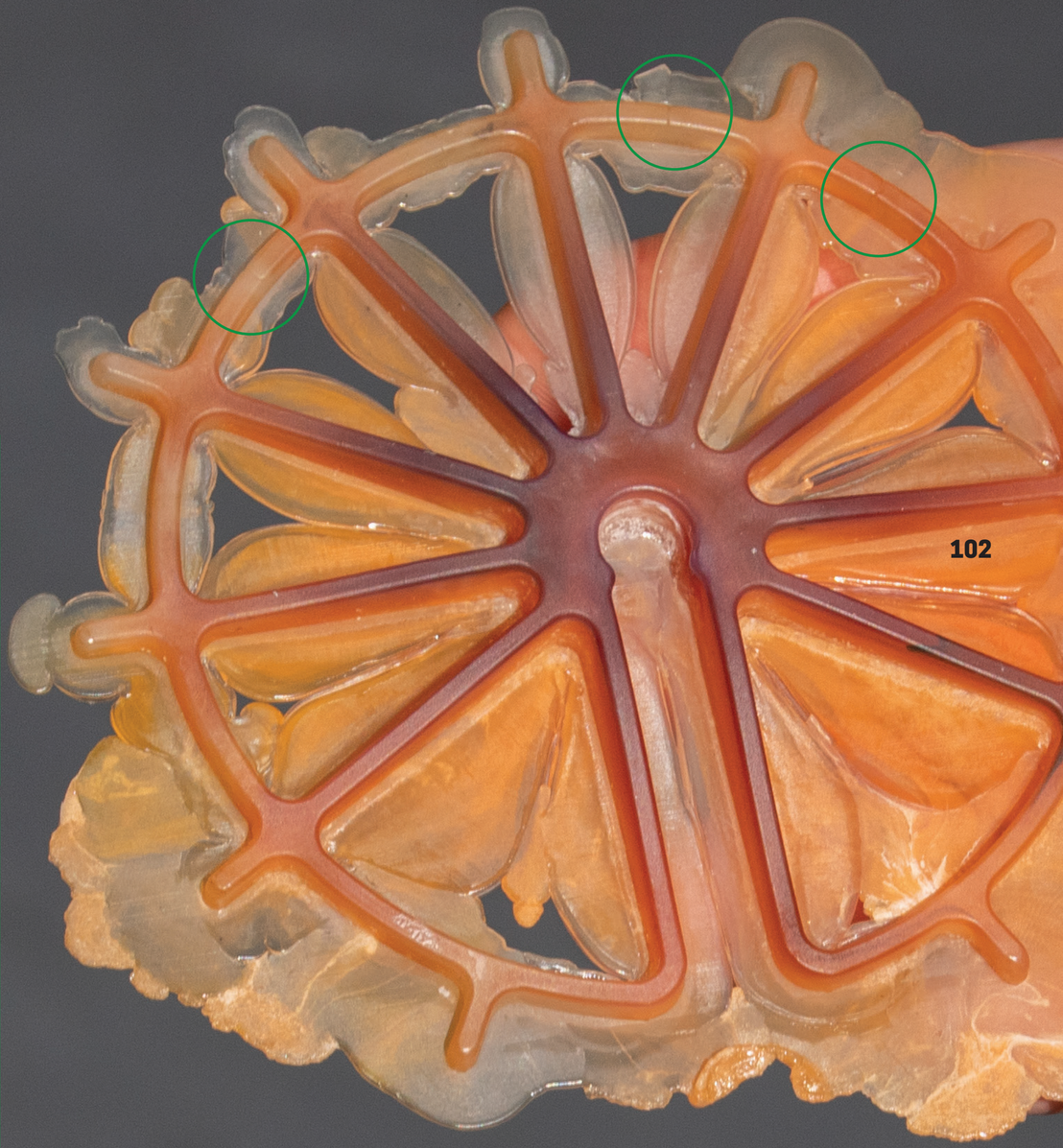




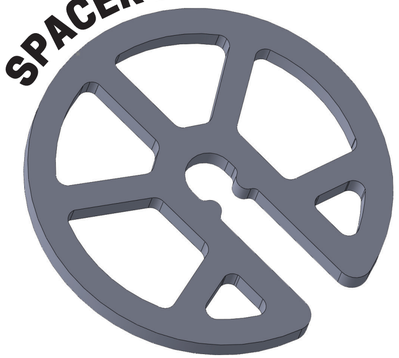








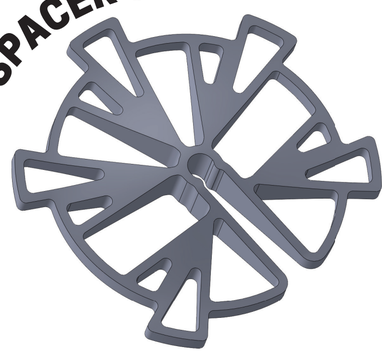
SPACER 1



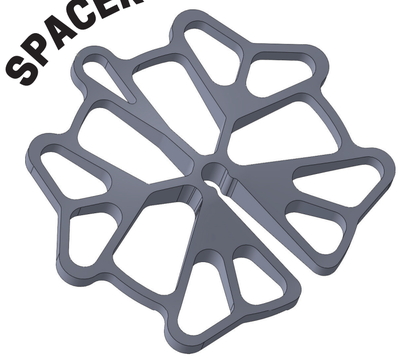
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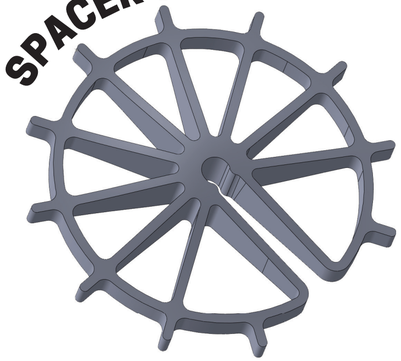
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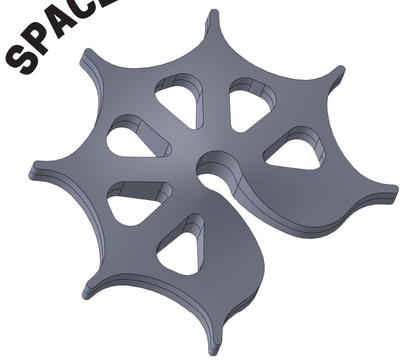
SPACER 4



SPACER 5



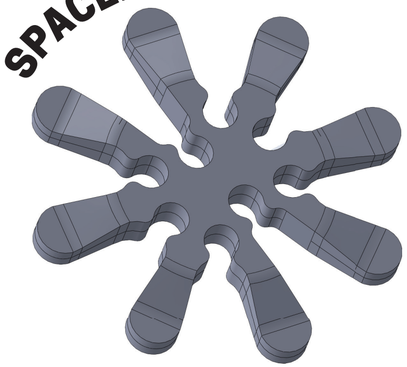
SPACER 6



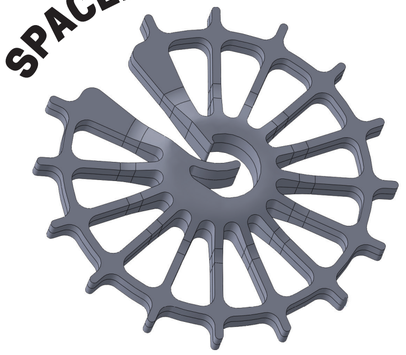
SPACER 7



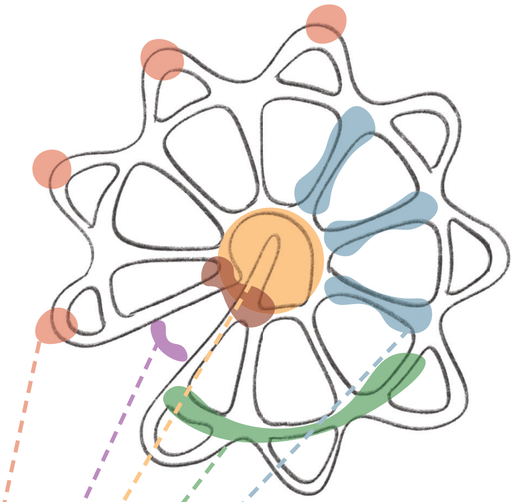
SPACER 8



SPACER 9

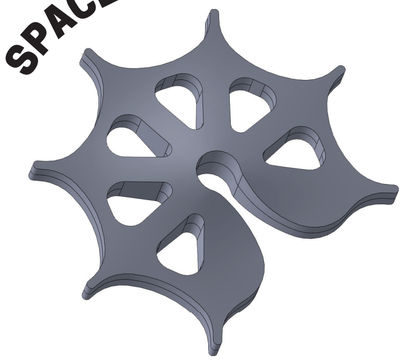


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PCS251220	25	12-20	1000	36000
PCS300812	30	8-12	1500	30000
PCS301220	30	12-20	1000	20000
PCS351220	35	12-20	500	10000
PCS400412	40	4-12	750	13000
PCS400816	40	8-16	750	13500
PCS401220	40	12-20	500	14000
PCS450816	45	8-16	500	10000
PCS500816	50	8-16	250	7500
PCS501220	50	12-20	250	7500



- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE

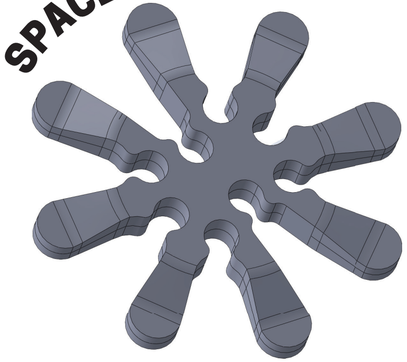
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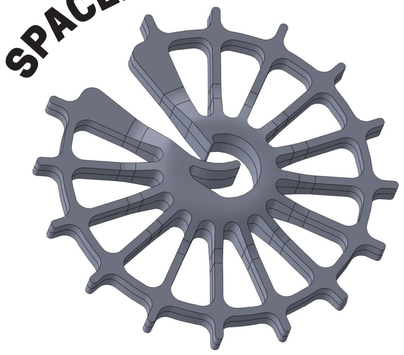
SPACER 7



SPACER 8



SPACER 9

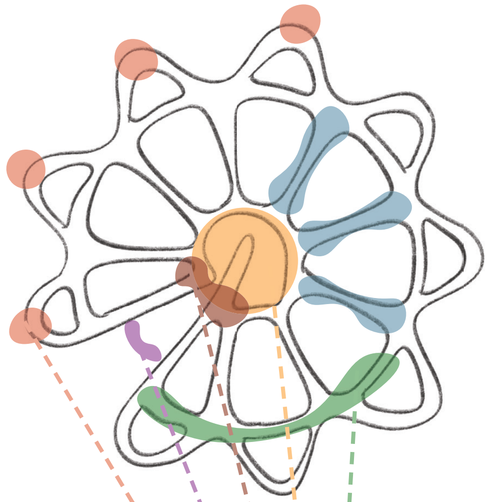


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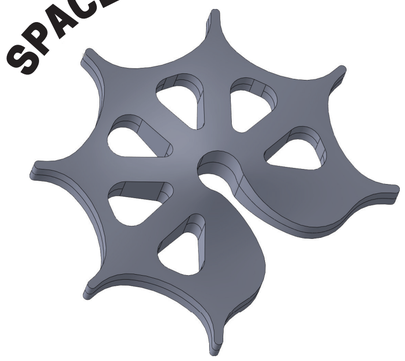
EXPERIMENTS

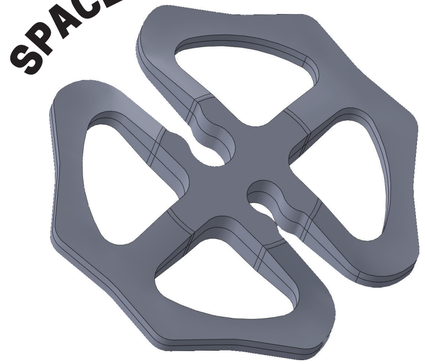
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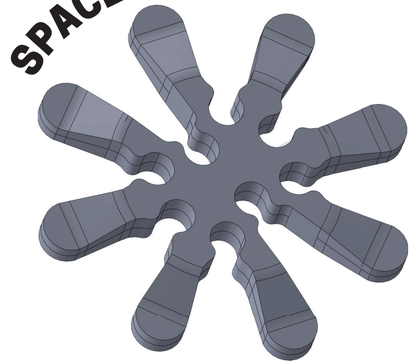
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PCS250812	25	8-12	1000	40000
PCS251220	25	12-20	1000	36000
PCS300812	30	8-12	1500	30000
PCS301220	30	12-20	1000	20000
PCS351220	35	12-20	500	10000
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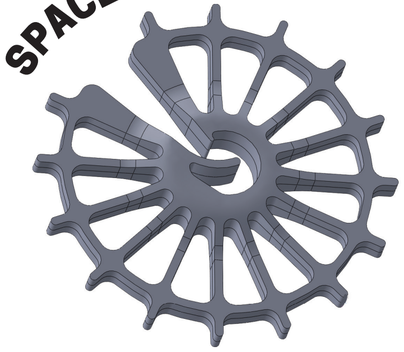


- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE







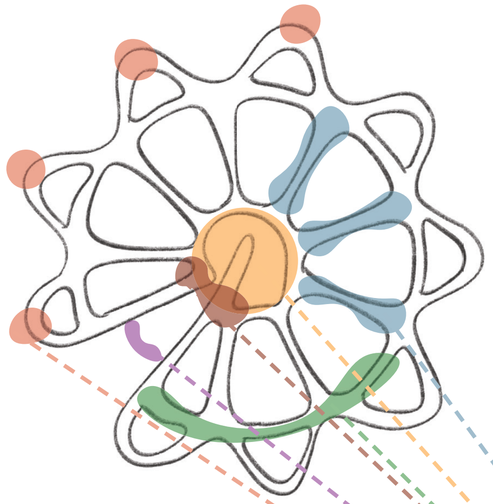


TOOLSET

EXPERIMENTS

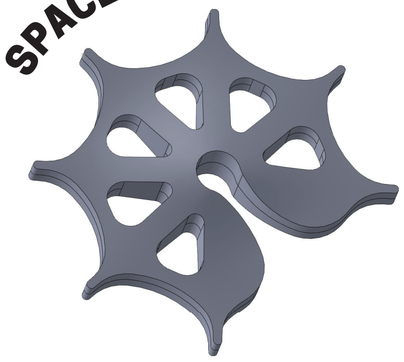
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Product Code	Cover (mm)	Bar Dia. (mm)	Pack Size	Pallet Size
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PCS250812	25	8-12	1000	40000
PCS251220	25	12-20	1000	36000
PCS300812	30	8-12	1500	30000
PCS301220	30	12-20	1000	20000
PCS351220	35	12-20	500	10000
PCS400412	40	4-12	750	13000
PCS400816	40	8-16	750	13500
PCS401220	40	12-20	500	14000
PCS450816	45	8-16	500	10000
PCS500816	50	8-16	250	7500
PCS501220	50	12-20	250	7500



- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE

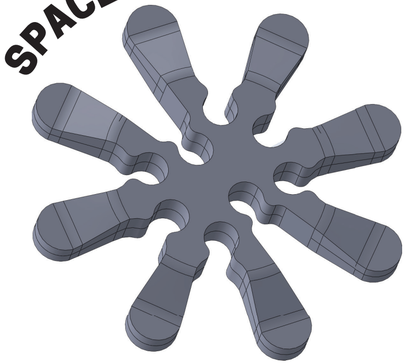
SPACER 6



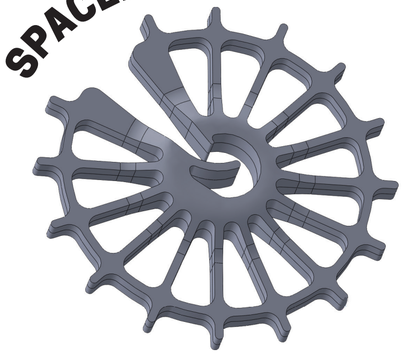
SPACER 7



SPACER 8



SPACER 9

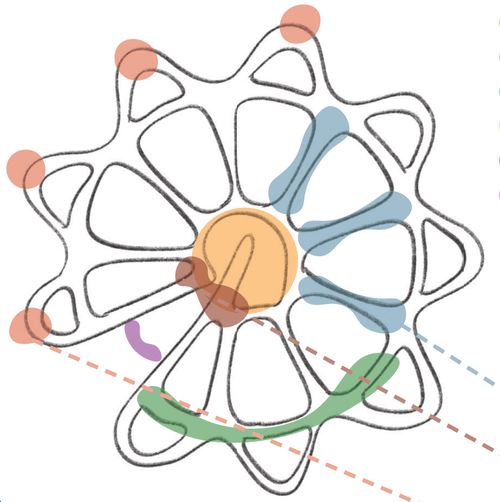


TOOLSET

EXPERIMENTS

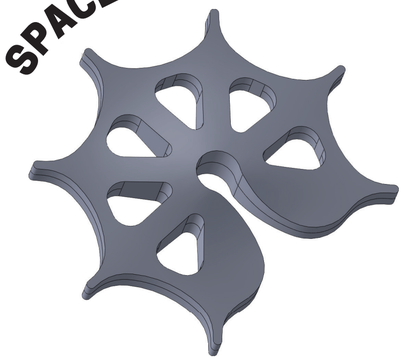
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Product Code	Cover (mm)	Bar Dia. (mm)	Pack Size	Pallet Size
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PCS250812	25	8-12	1000	40000
PCS251220	25	12-20	1000	36000
PCS300812	30	8-12	1500	30000
PCS301220	30	12-20	1000	20000
PCS351220	35	12-20	500	10000
PCS400412	40	4-12	750	13000
PCS400816	40	8-16	750	13500
PCS401220	40	12-20	500	14000
PCS450816	45	8-16	500	10000
PCS500816	50	8-16	250	7500
PCS501220	50	12-20	250	7500



- CONCRETE CONTACT POINTS
- RADIAL RIBS
- COVER RING
- CORE
- CLIP ARMS
- REBAR DIAMETER RANGE

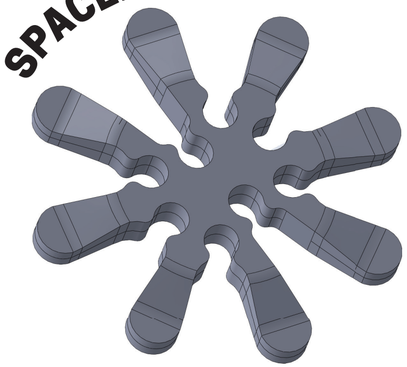
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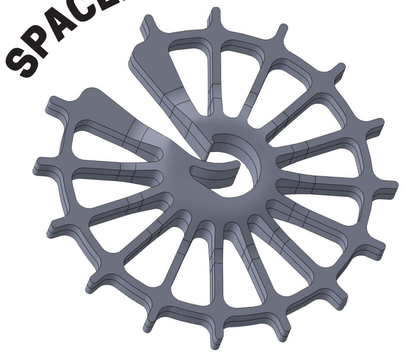
SPACER 7



SPACER 8



SPACER 9

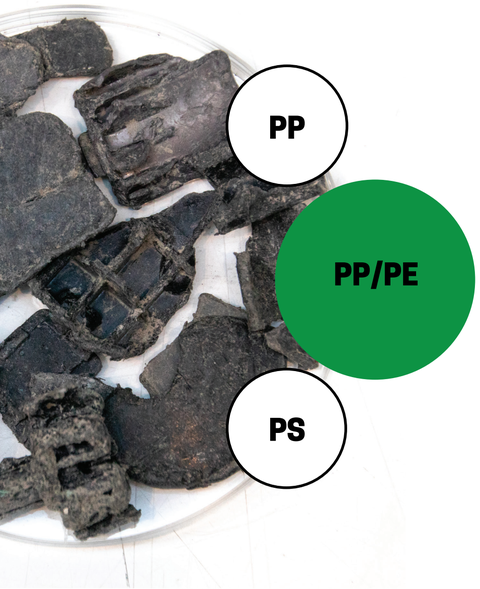


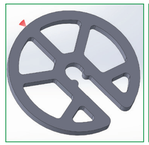
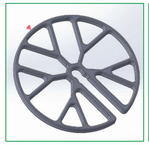
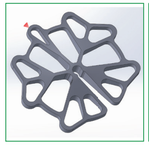
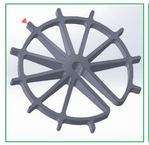
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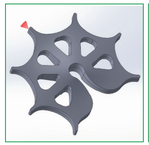
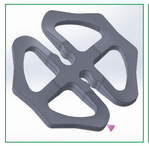
EXPERIMENTS

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FINAL SIMULATIONS
INJECTION FLOW ANALYSIS



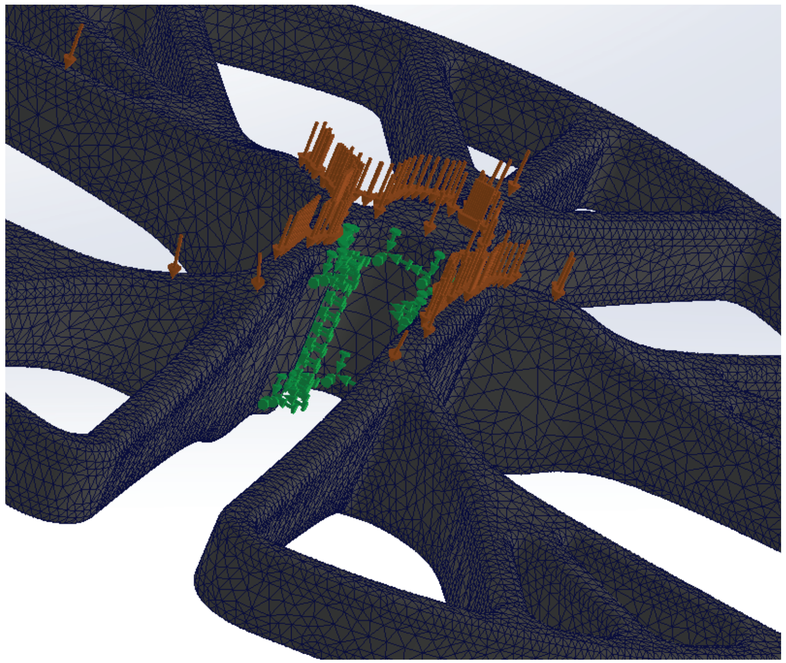
DESIGNS	PROPERTIES	FILL TIME	PRESSURE	TEMPERATURE	SHEAR STRESS	WELD LINES & AIR	VELOCITY VECTOR
	**SPACER 1** Height(mm): 93 Cover(mm): 32 Bar Dia. (mm): 6 Volume(cm3):20.88	**min:** 0.0011 sec **max:** 5.2786 sec	**min:** 0.10 MPa **max:** 2.19 MPa	**min:** 103.07°C **max:** 230.02°C	**min:** 0.00 MPa **max:** 0.04 MPa	**min:** 1.610° **max:** 137.6500°	**min:** 0.0201 m/s **max:** 29.1789 m/s
	**SPACER 2** Height(mm): 100 Cover(mm): 42 Bar Dia. (mm): 8 Volume(cm3): 20.96	**min:** 6.512e-04 sec **max:** 3.4292 sec	**min:** 0.10 MPa **max:** 6.32 MPa	**min:** 90.87°C **max:** 230.08°C	**min:** 0.00 MPa **max:** 0.08 MPa	**min:** 0.7700° **max:** 149.1800°	**min:** 0.0116 m/s **max:** 57.2777 m/s
	**SPACER 3** Height(mm): 120 Cover(mm): 42 Bar Dia. (mm): 8 Volume(cm3): 31.31	**min:** 5.159e-04 sec **max:** 0.7704 sec	**min:** 0.10 MPa **max:** 2.63 MPa	**min:** 80.00°C **max:** 230.14°C	**min:** 0.00 MPa **max:** 0.08 MPa	N/A	**min:** 0.0141 m/s **max:** 60.8905 m/s
	**SPACER 4** Height(mm): 123 Cover(mm): 45 Bar Dia. (mm): 8 Volume(cm3): 27.50	**min:** 6.425e-04 sec **max:** 3.9858 sec	**min:** 0.10 MPa **max:** 7.23 MPa	**min:** 91.55°C **max:** 230.10°C	**min:** 0.00 MPa **max:** 0.08 MPa	**min:** 0.1500° **max:** 149.1700°	**min:** 0.0227 m/s **max:** 51.3741 m/s
	**SPACER 5** Height(mm): 118 Cover(mm): 42 Bar Dia. (mm): 8 Volume(cm3): 28.55	**min:** 3.878e-04 sec **max:** 1.8899 sec	**min:** 0.10 MPa **max:** 4.42 MPa	**min:** 80.00°C **max:** 230.93°C	**min:** 0.00 MPa **max:** 0.10 MPa	N/A	**min:** 0.0034 m/s **max:** 189.2124 m/s

DESIGNS	PROPERTIES	FILL TIME	PRESSURE	TEMPERATURE	SHEAR STRESS	WELD LINES & AIR	VELOCITY VECTOR
	**SPACER 6** Height(mm): 82 Cover(mm): 35 Bar Dia. (mm): 10 Volume(cm3):15.31	**min:** 4.068e-04 sec **max:** 5.9485 sec	**min:** 0.10 MPa **max:** 2.84 MPa	**min:** 83.50°C **max:** 230.01°C	**min:** 3.382e-07 MPa **max:** 0.10 MPa	**min:** 0.9100° **max:** 129.8600°	**min:** 2.871e-04 m/s **max:** 87.6201 m/s
	**SPACER 7** Height(mm): 88 Cover(mm): 35 Bar Dia. (mm): 8-10 Volume(cm3):21.60	**min:** 0.0011 sec **max:** 6.0483 sec	**min:** 0.10 MPa **max:** 2.35 MPa	**min:** 98.68°C **max:** 230.02°C	**min:** 2.499e-04 MPa **max:** 0.06 MPa	**min:** 2.1400° **max:** 144.4800°	**min:** 0.0026 m/s **max:** 26.5677 m/s
	**SPACER 8** Height(mm): 89.5 Cover(mm): 30 Bar Dia. (mm): 8 Volume(cm3):21.22	**min:** 0.0090 sec **max:** 6.6475 sec	**min:** 0.10 MPa **max:** 2.19 MPa	**min:** 91.86°C **max:** 230.00°C	**min:** 4.794e-08 MPa **max:** 0.07 MPa	**min:** 12.2100° **max:** 95.0400°	**min:** 0.00 m/s **max:** 29.56 m/s
	**SPACER 9** Height(mm): 86 Cover(mm): 27 Bar Dia. (mm): 6-8 Volume(cm3):13.41	**min:** 1.272e-04 sec **max:** 2.5370 sec	**min:** 0.10 MPa **max:** 10.04 MPa	**min:** 84.58°C **max:** 230.86°C	**min:** 1.146e-07 MPa **max:** 0.13 MPa	**min:** 0.1000° **max:** 146.9000°	**min:** 0.0016 m/s **max:** 207.7365 m/s

CONDITIONS
“Hydrostatic pressure from the wet concrete”

$$p=\rho \times g \times h$$

where:
p = hydrostatic pressure (N/m^2)
ρ = density of fresh concrete (~2400 kg/m^3)
g = gravitational acceleration (9.81 m/s^2)
h = vertical height of the fresh concrete above the point considered (m)



FINAL SIMULATIONS
COMPRESSIVE STRENGTH

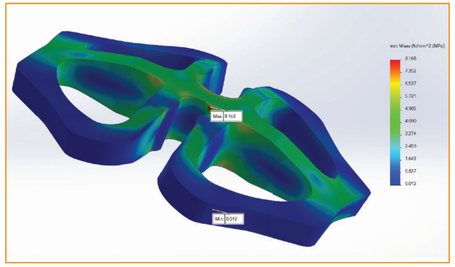
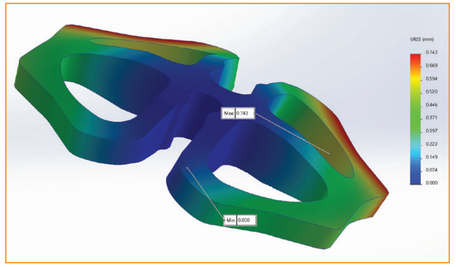
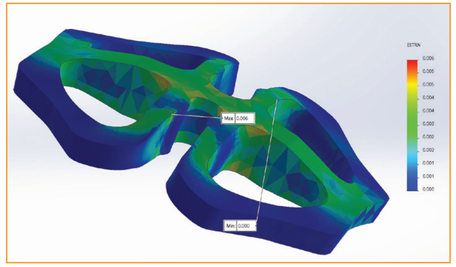
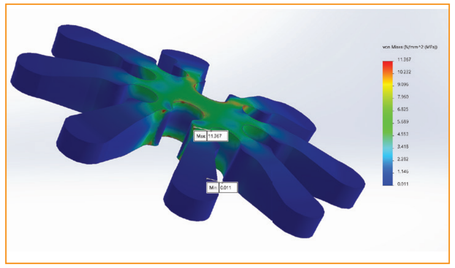
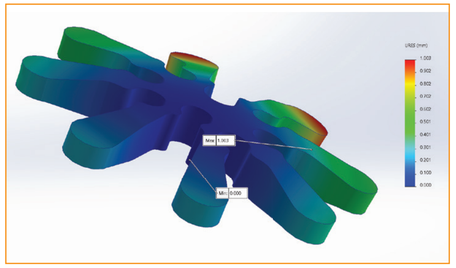
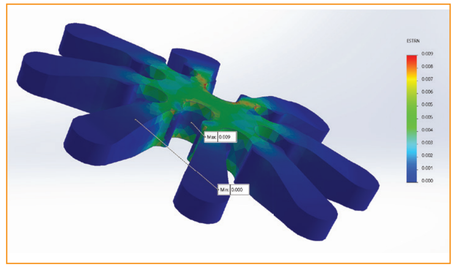
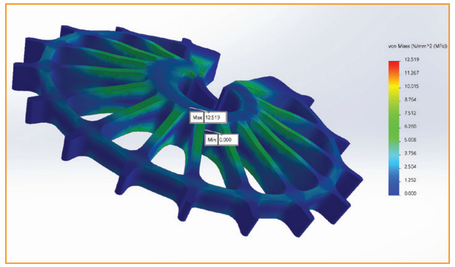
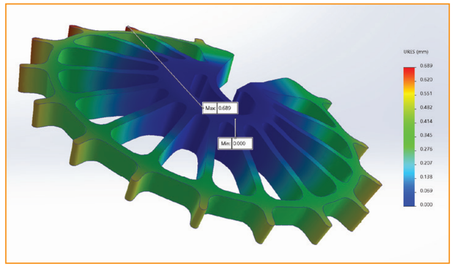
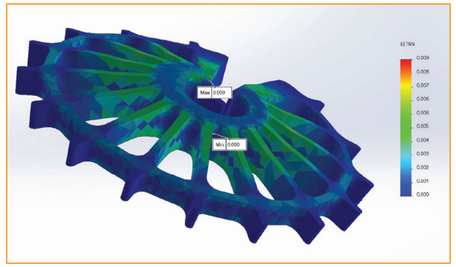
CONDITIONS
“Hydrostatic pressure from the wet concrete”

$$p=\rho \times g \times h$$

where:
p = hydrostatic pressure (N/m^2)
ρ = density of fresh concrete (~2400 kg/m^3)
g = gravitational acceleration (9.81 m/s^2)
h = vertical height of the fresh concrete above the point considered (m)

COMPRESSIVE STRENGTH SIMULATION ANALYSIS RESULTS FOR COLUMN APPLICATION

	STRESS (MPa)	DISPLACEMENT (mm)	EQUIVALENT STRAIN
SPACER 7	**min:** 0.012 **max:** 8.168	**min:** 0.000 **max:** 0.743	**min:** 0.000 **max:** 0.006
SPACER 8	**min:** 0.011 **max:** 11.367	**min:** 0.000 **max:** 1.003	**min:** 0.000 **max:** 0.009
SPACER 9	**min:** 0.000 **max:** 12.519	**min:** 0.000 **max:** 0.689	**min:** 0.000 **max:** 0.009

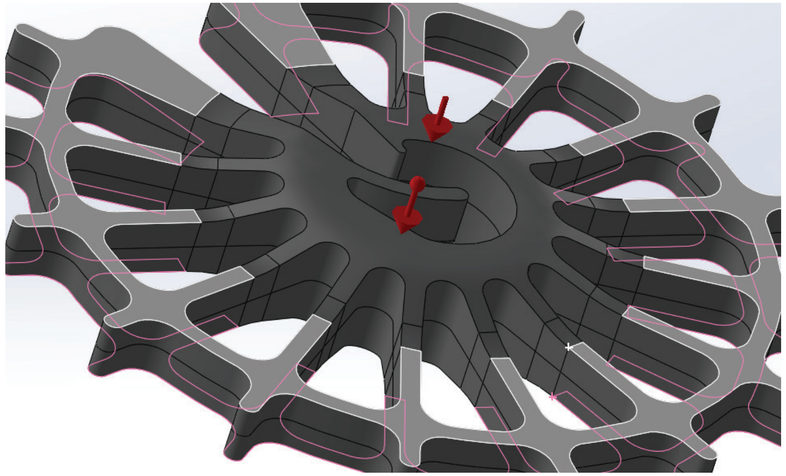
CONDITIONS
“3kg concrete falling from 1-meter height”

$$PE=m\times g\times h$$

where:
PE = Potential energy (Joules, J)
m = Mass (kg)
g = Gravitational acceleration (9.81 m/s²)
h = Height (m)

$$v=2gh$$

where:
v = Impact velocity (m/s)
g = Gravitational acceleration (9.81 m/s²)
h = Height (m)



CONDITIONS

“3kg concrete falling from 1-meter height”

PE=m×g×h

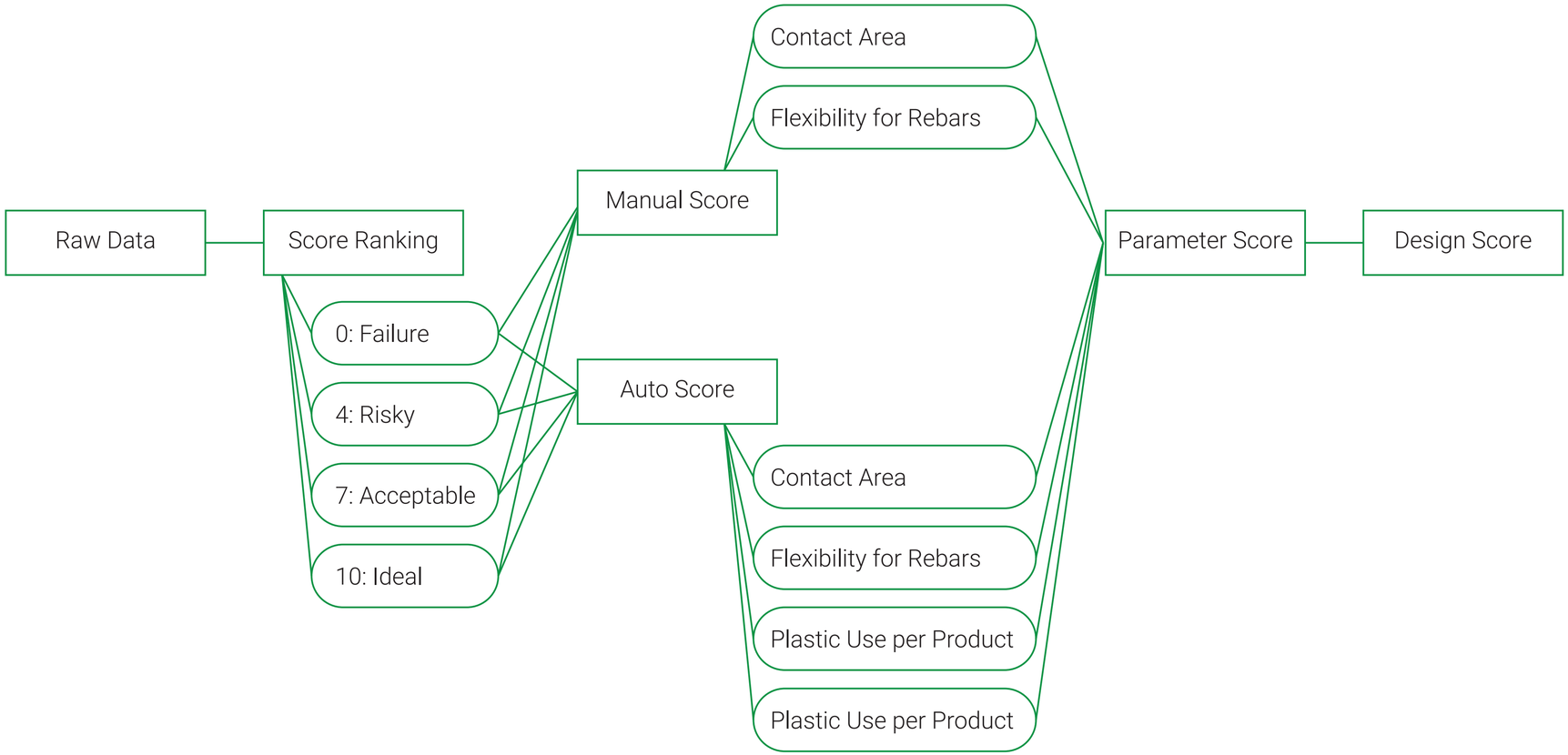
where:
PE = Potential energy (Joules, J)
m = Mass (kg)
g = Gravitational acceleration (9.81 m/s²)
h = Height (m)

v=2gh

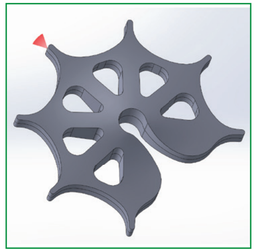
where:
v = Impact velocity (m/s)
g = Gravitational acceleration (9.81 m/s²)
h = Height (m)

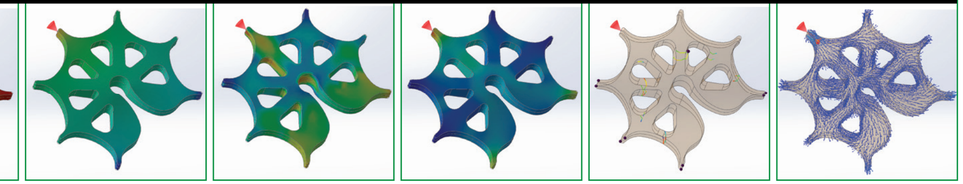
CHARPY IMPACT SIMULATION RESULTS FOR COLUMN APPLICATION

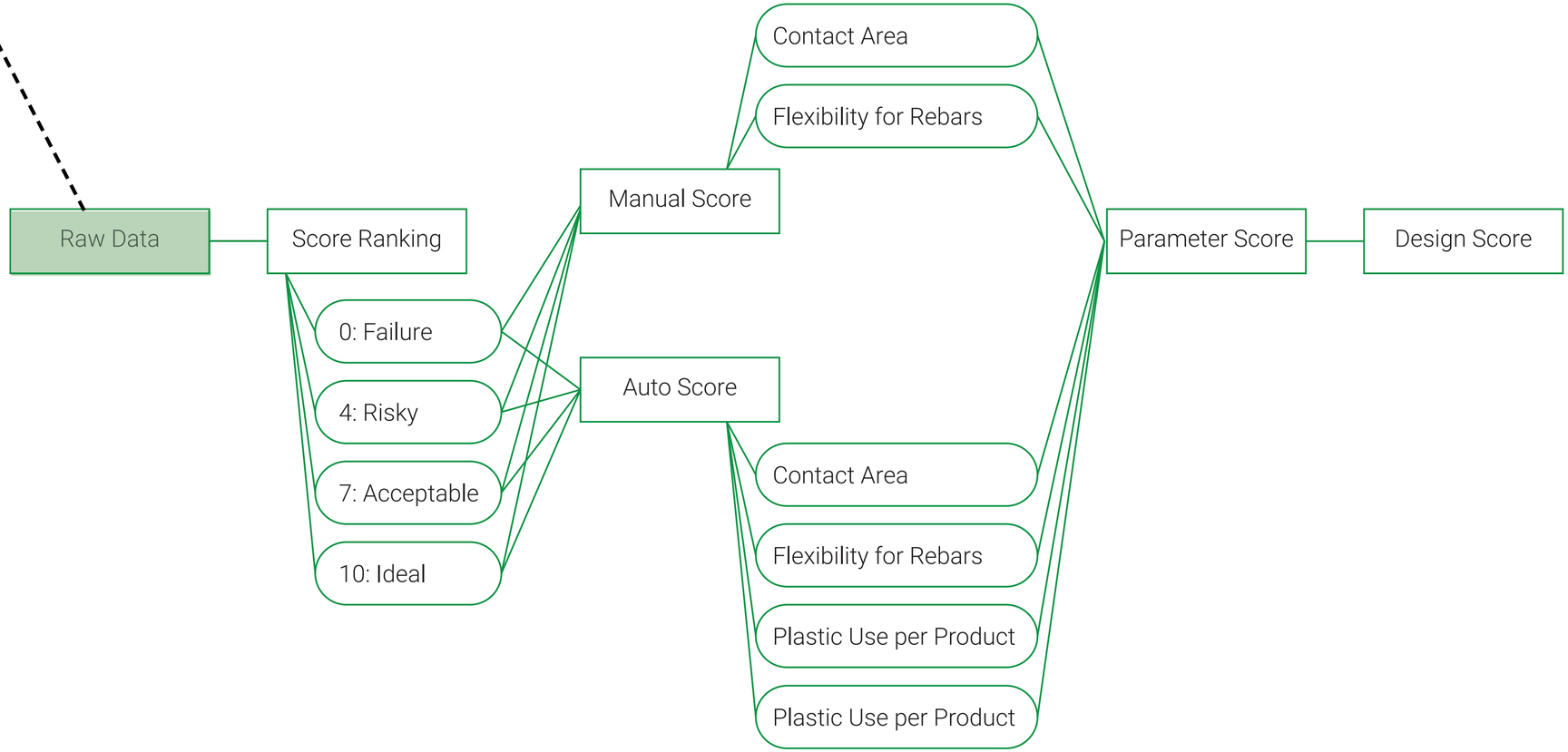
	STRESS (MPa)	DISPLACEMENT (mm)	EQUIVALENT STRAIN
SPACER 7	**min:** 0.038 **max:** 9.400	**min:** 0.002 **max:** 0.343	**min:** 0.000 **max:** 0.007
SPACER 8	**min:** 0.131 **max:** 12.970	**min:** 0.001 **max:** 0.402	**min:** 0.000 **max:** 0.008
SPACER 9	**min:** 0.028 **max:** 11.356	**min:** 0.001 **max:** 0.271	**min:** 0.000 **max:** 0.008


Raw Data
Score Ranking
0: Failure
4: Risky
7: Acceptable
10: Ideal
Manual Score
Auto Score
Contact Area
Flexibility for Rebars
Contact Area
Flexibility for Rebars
Plastic Use per Product
Plastic Use per Product
Parameter Score
Design Score

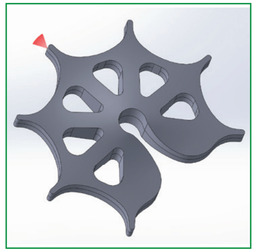
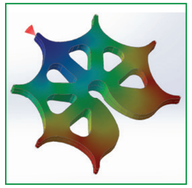
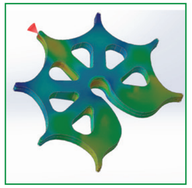
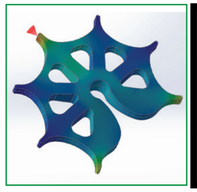
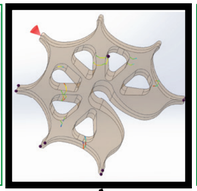
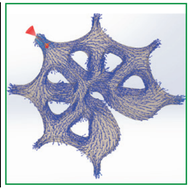
DESIGN OPTIMIZATION

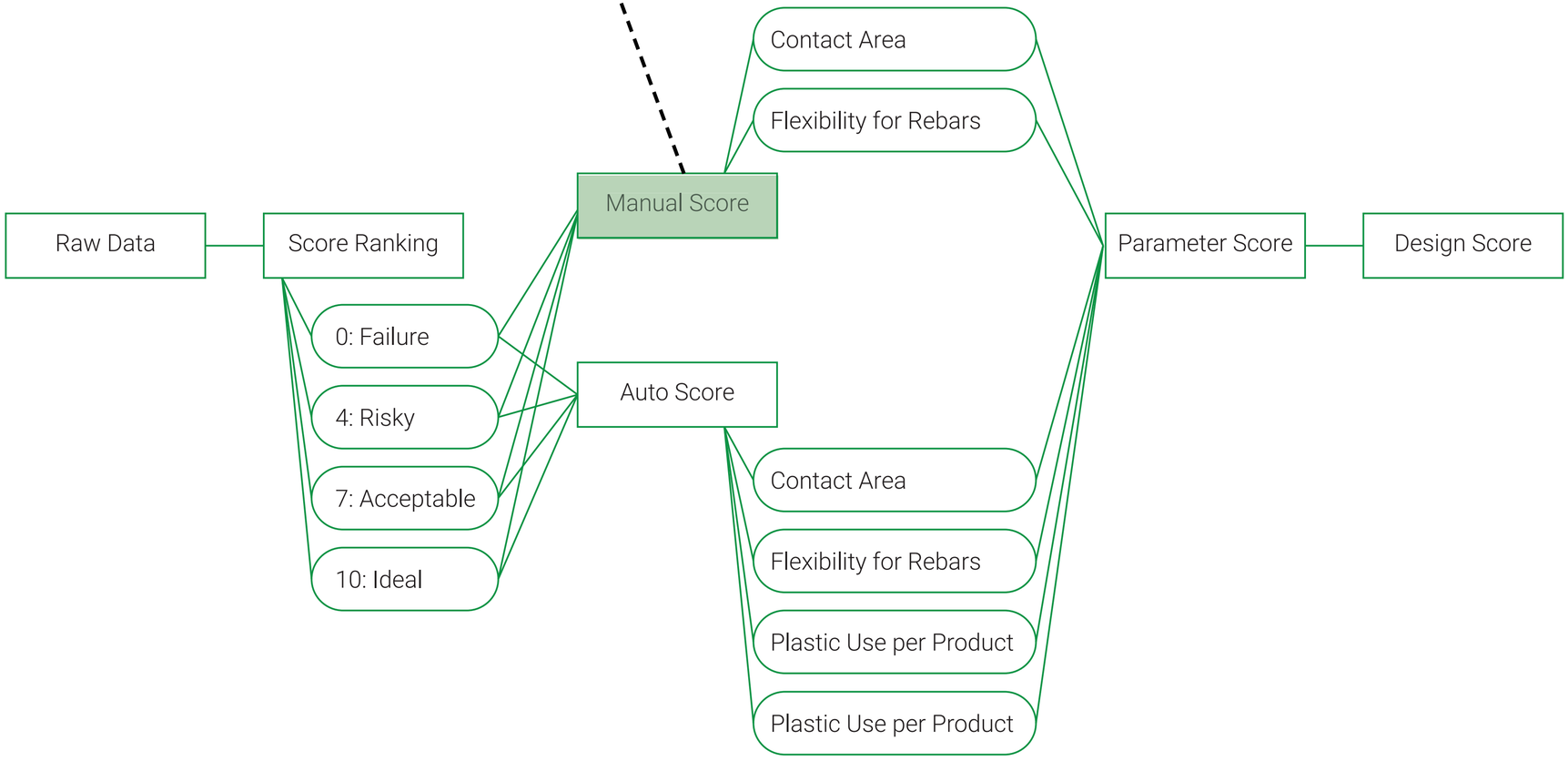
DESIGNS	PROPERTIES	FILL TIME	PRESSURE	TEMPERATURE	SHEAR STRESS	WELD LINES & AIR	VELOCITY VECTOR
	**SPACER 6** Height(mm): 82 Cover(mm): 35 Bar Dia. (mm): 10 Volume(cm3):15.31	**min:** 4.068e-04 sec **max:** 5.9485 sec	**min:** 0.10 MPa **max:** 2.84 MPa	**min:** 83.50°C **max:** 230.01°C	**min:** 3.382e-07 MPa **max:** 0.10 MPa	**min:** 0.9100° **max:** 129.8600°	**min:** 2.871e-04 m/s **max:** 87.6201 m/s



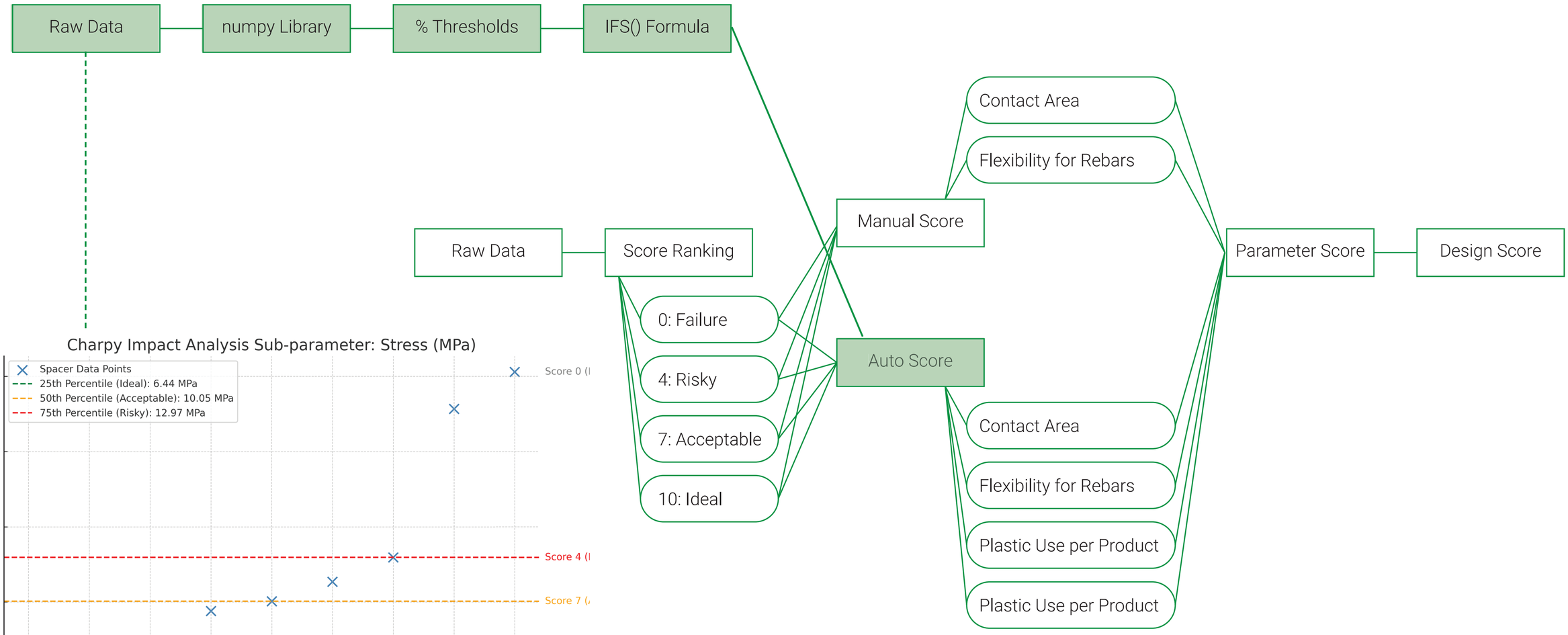


DESIGN OPTIMIZATION

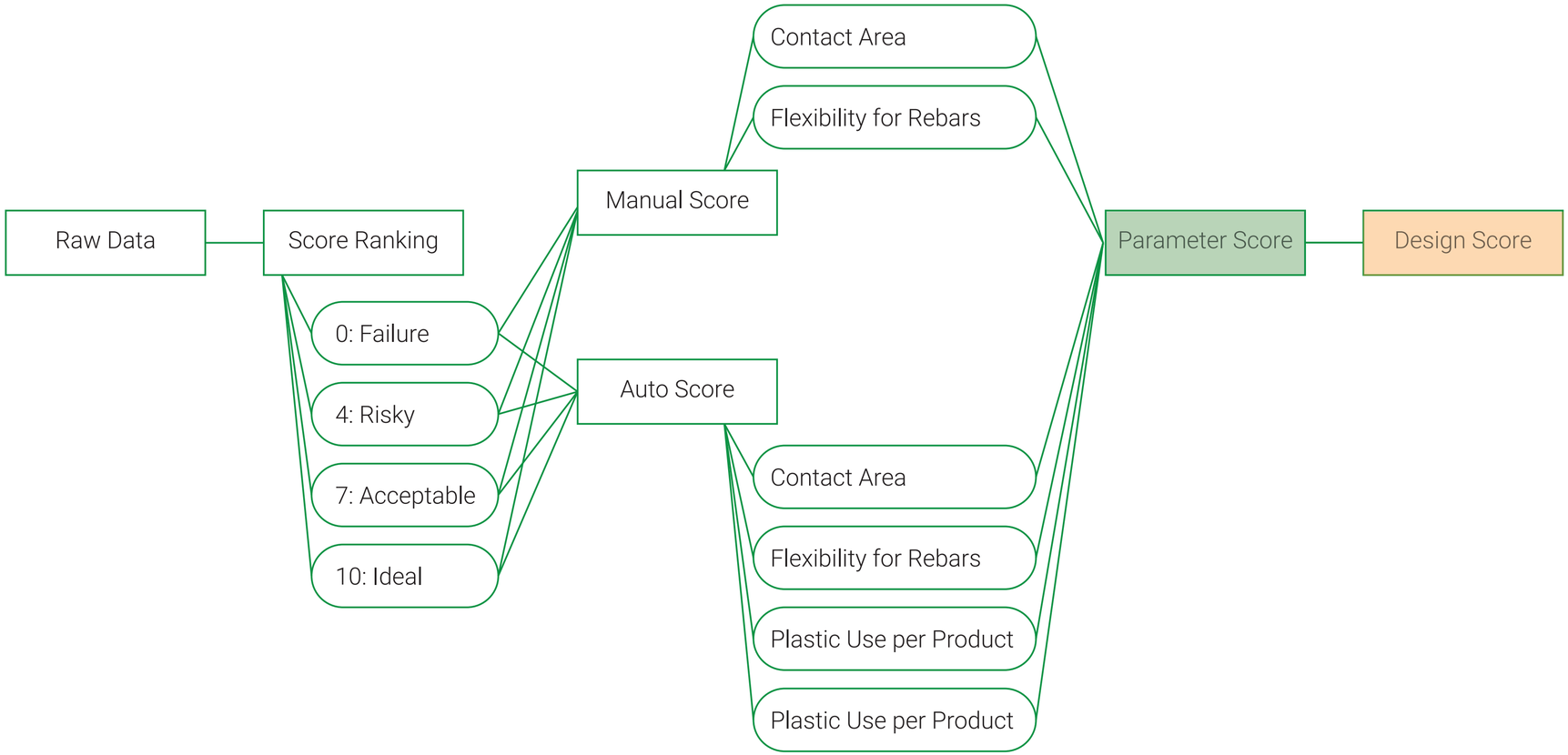
DESIGNS	PROPERTIES	FILL TIME	PRESSURE	TEMPERATURE	SHEAR STRESS	WELD LINES & AIR	VELOCITY VECTOR
	**SPACER 6** Height(mm): 82 Cover(mm): 35 Bar Dia. (mm): 10 Volume(cm3):15.31	**min:** 4.068e-04 sec **max:** 5.9485 sec 	**min:** 0.10 MPa **max:** 2.84 MPa 	**min:** 83.50°C **max:** 230.01°C 	**min:** 3.382e-07 MPa **max:** 0.10 MPa 	**min:** 0.9100° **max:** 129.8600° 	**min:** 2.871e-04 m/s **max:** 87.6201 m/s 



DESIGN OPTIMIZATION



	%25	%10	%10	%25	%15	%15	
Designs	Injection Flow Analysis	Compressive Stregth Analysis	Charpy Impact Analysis	Contact Area	Flexibility for Rebars	Plastic Use per Product	Final Score
Spacer 01	7.33	2.00	9.00	0	0	10	4.43
Spacer 02	5.63	1.92	5.50	0	4	7	3.80
Spacer 03	4.75	3.75	2.67	0	4	0	2.43
Spacer 04	4.75	4.50	1.67	4	4	4	4.00
Spacer 05	2.25	8.25	9.00	10	7	0	5.84
Spacer 06	7.21	8.50	9.00	10	4	10	8.15
Spacer 07	7.38	8.75	6.50	4	7	7	6.47
Spacer 08	7.50	7.00	3.50	7	10	7	7.23
Spacer 09	3.50	8.00	5.75	10	7	10	7.30




PP/PE
MOULD
OUTCOME


PP/PE
MOULD OUTCOME


TOOLSET
EXPERIMENTS
DUAL TRACK FEEDBACK
119
EXPERIMENTS
TOOLSET





BACK TO

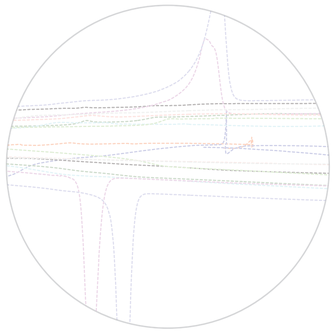
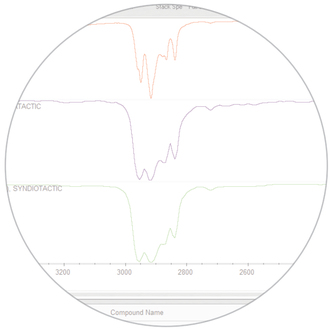
TRACK I: MATERIAL EXPERIMENTATION

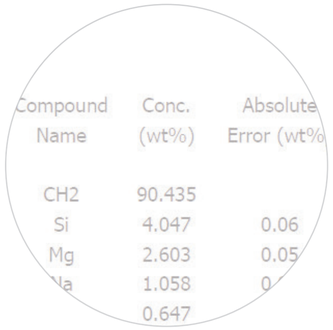


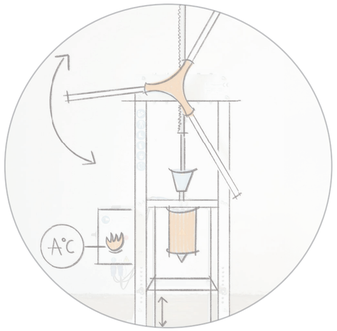
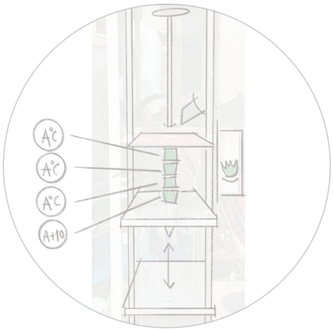









TACTIC
SYNDIOTACTIC
3200
3000
2800
2600
Compound Name


Compound Name
Conc. (wt%)
Absolute Error (wt%
CH2 90.435
Si 4.047 0.06
Mg 2.603 0.05
1.058 0
0.647

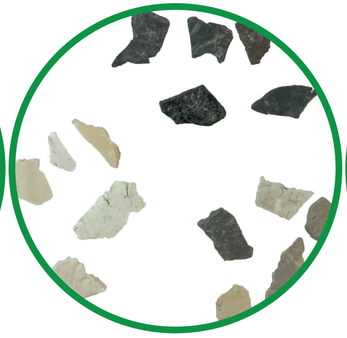
A'
A

A°C

A°C
A°C
A°C
A+10

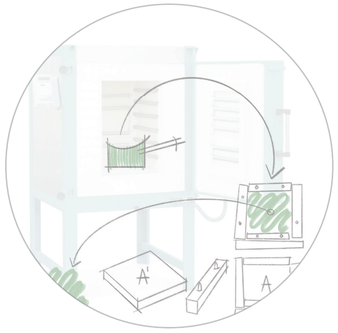
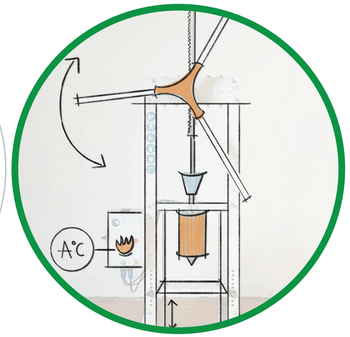
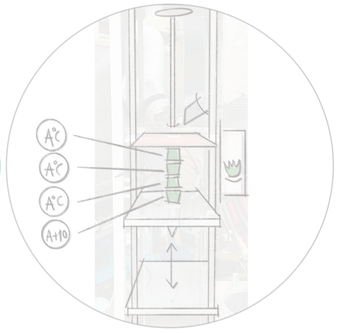

PP
PP/PE
PS









A'
A

A°C

A°C
A°C
A°C
A+10

SETUP 7- FT-IR IDENTIFIED POLYMER INPUT SDA LINE 1

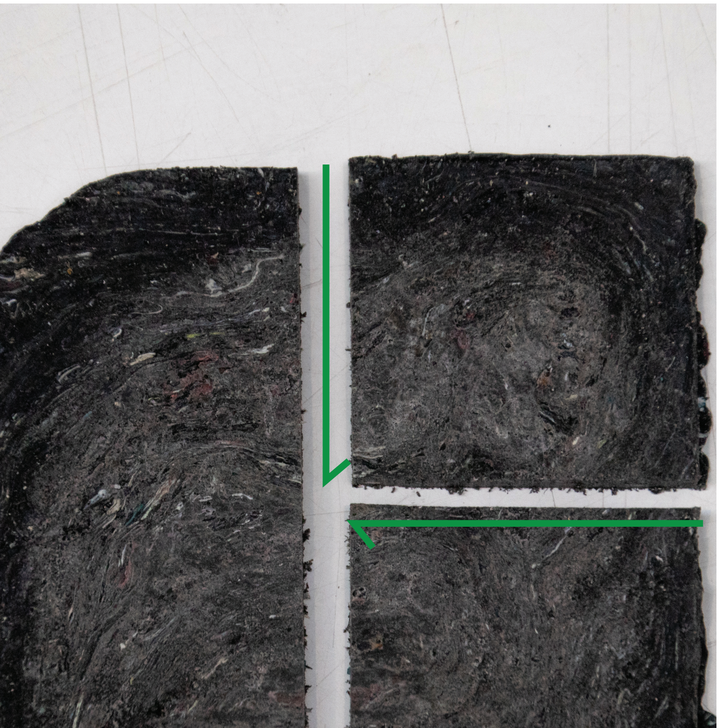
TRIALS	TRIAL 1: PP	TRIAL 2: PS
POLYMER IDENTITY	SDA 1 (1.13 g/cm3) PP 3mm shred	SDA 1 (1.13 g/cm3) PS 3mm shred
WEIGHT (g)	56.60	37.84
MOULD TYPE	100x100x4 mm wood mould	
PRE-HEAT DURATION (min)	25	5
DWELL DURATION (min)	15	15
HEATER (°C)	205-220-225	230
DISTANCE TO MOULD (cm)	10	10
MIXING RESULT		
SECTION 1.	Partially miscible blend	Layered blend
SECTION 2.	Partially miscible blend	Layered blend
MORPHOLOGY RESULT		
SECTION 1.	Uneven melting	Visible melt flow
SECTION 2.	Uneven melting - Some phase domains	Visible melt flow
DEGRADATION RESULT	Odor change during processing	Odor change during processing
STABILITY RESULT	Stable geometry	Stable geometry
SMELL RESULT	Persistent strong chemical smell	Persistent strong chemical smell





SETUP 7- FT-IR IDENTIFIED POLYMER INPUT SDA LINE 1

TRIALS	TRIAL 1: PP	TRIAL 2: PS
POLYMER IDENTITY	SDA 1 (1.13 g/cm3) PP 3mm shred	SDA 1 (1.13 g/cm3) PS 3mm shred
WEIGHT (g)	56.60	37.84
MOULD TYPE	100x100x4 mm wood mould	
PRE-HEAT DURATION (min)	25	5
DWELL DURATION (min)	15	15
HEATER (°C)	205-220-225	230
DISTANCE TO MOULD (cm)	10	10
MIXING RESULT		
SECTION 1.	Partially miscible blend	Layered blend
SECTION 2.	Partially miscible blend	Layered blend
MORPHOLOGY RESULT		
SECTION 1.	Uneven melting	Visible melt flow
SECTION 2.	Uneven melting - Some phase domains	Visible melt flow
DEGRADATION RESULT	Odor change during processing	Odor change during processing
STABILITY RESULT	Stable geometry	Stable geometry
SMELL RESULT	Persistent strong chemical smell	Persistent strong chemical smell









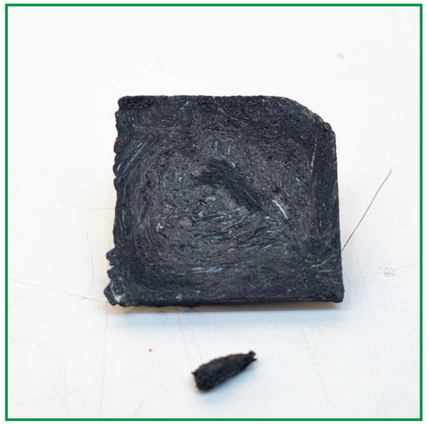






TRIALS	TRIAL 5: PP/PE BLEND
POLYMER IDENTITY	SDA 1 (1.13 g/cm3) PP/PE 3mm shred
WEIGHT (g)	29.79
MOULD TYPE	
PRE-HEAT DURATION (min)	**15 min**
DWELL DURATION (min)	**15 min**
HEATER (°C)	**230°C**
DISTANCE TO MOULD (cm)	10
MIXING RESULT	
SECTION 1.	Homogeneous blend - Partially miscible
SECTION 2.	Layered blend
MORPHOLOGY RESULT	
SECTION 1.	Visible melt flow
SECTION 2.	Visible melt flow
DEGRADATION RESULT	Odor change during processing
STABILITY RESULT	Stable geometry
SMELL RESULT	Persistent strong chemical smell













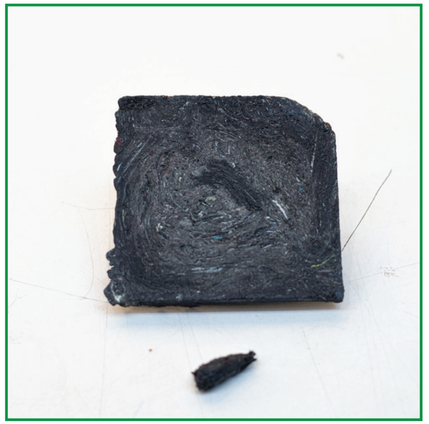






TRIALS	TRIAL 5: PP/PE BLEND
POLYMER IDENTITY	SDA 1 (1.13 g/cm3) PP/PE 3mm shred
WEIGHT (g)	29.79
MOULD TYPE	
PRE-HEAT DURATION (min)	**15 min**
DWELL DURATION (min)	**15 min**
HEATER (°C)	**230°C**
DISTANCE TO MOULD (cm)	10
MIXING RESULT	
SECTION 1.	Homogeneous blend - Partially miscible
SECTION 2.	Layered blend
MORPHOLOGY RESULT	
SECTION 1.	Visible melt flow
SECTION 2.	Visible melt flow
DEGRADATION RESULT	Odor change during processing
STABILITY RESULT	Stable geometry
SMELL RESULT	Persistent strong chemical smell









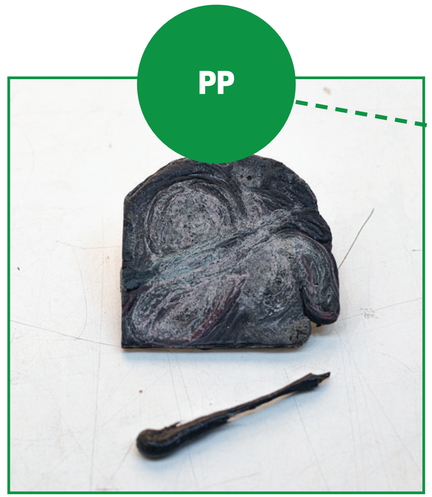


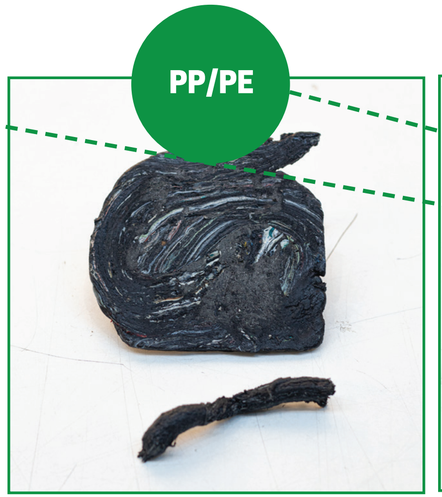


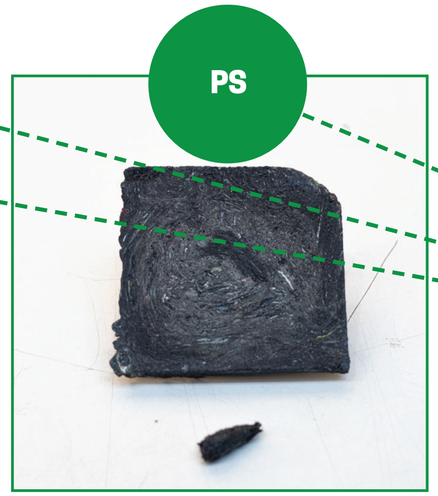












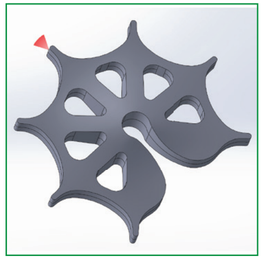
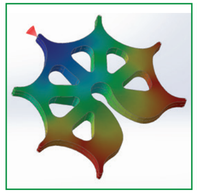
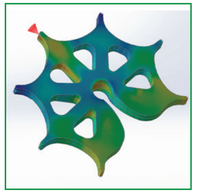
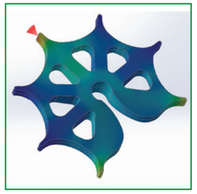
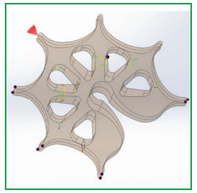
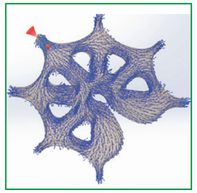
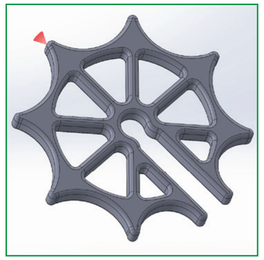
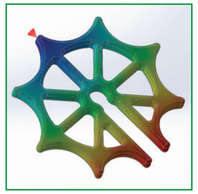
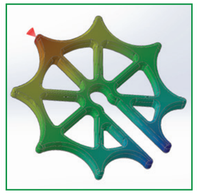
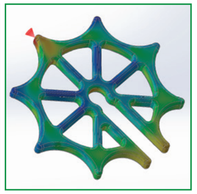
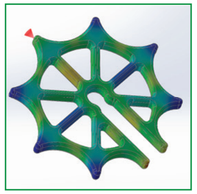
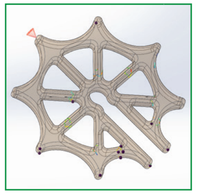
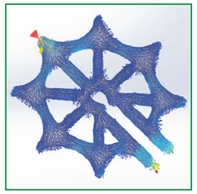
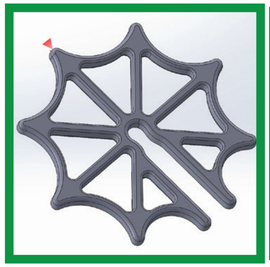
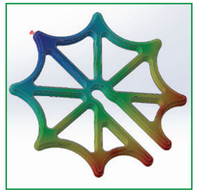
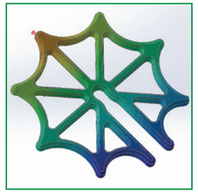
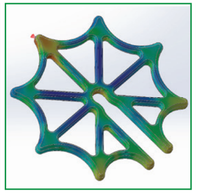
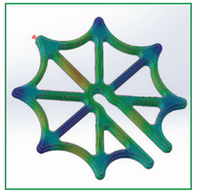
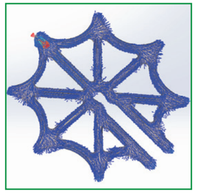
PREHEATING:	**15 min**	**15 min**	**15 min**
DWELL TIME:	**15 min**	**15 min**	**15 min**
HEATING BARREL:	**230°C**	**230°C**	**230°C**

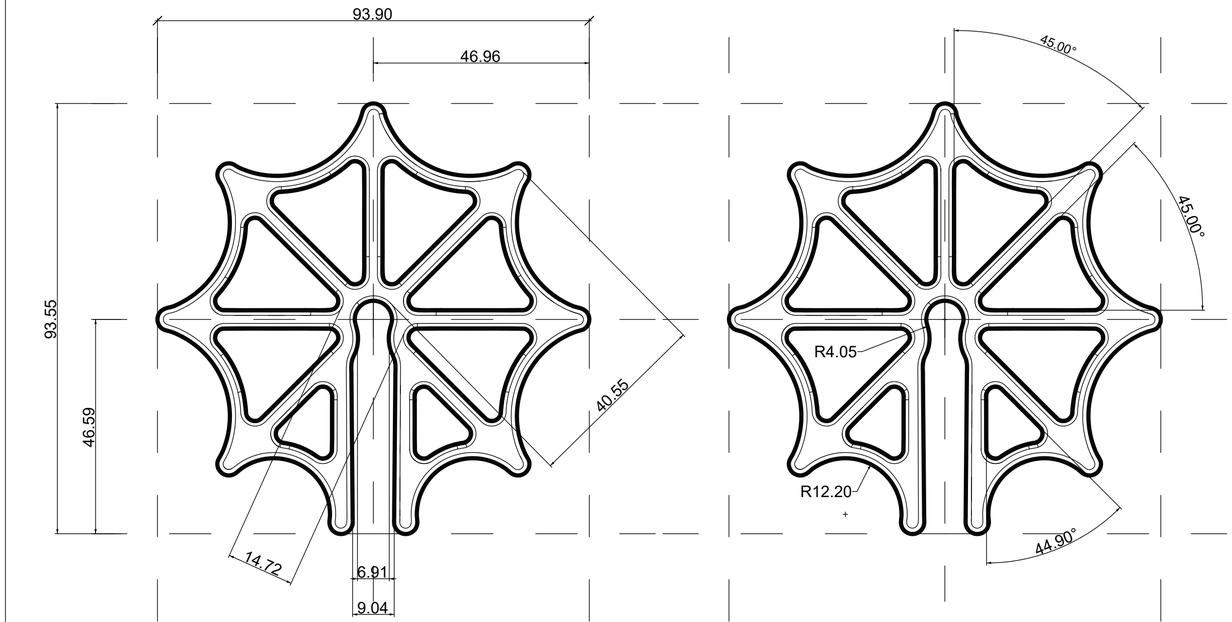
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DUAL TRACK FEEDBACK
128
EXPERIMENTS
TOOLSET

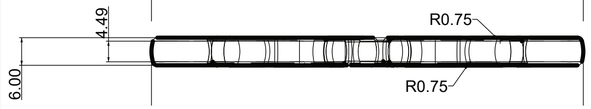
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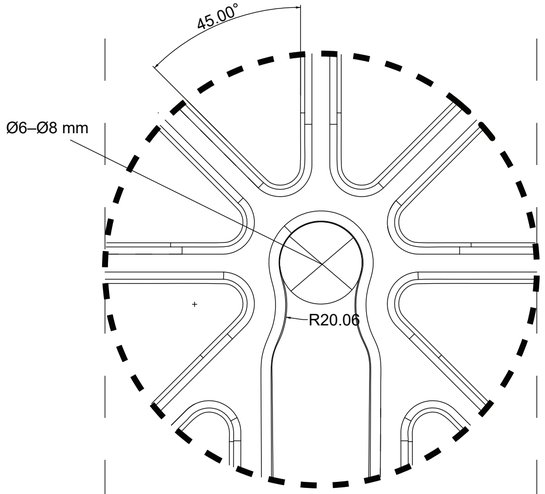
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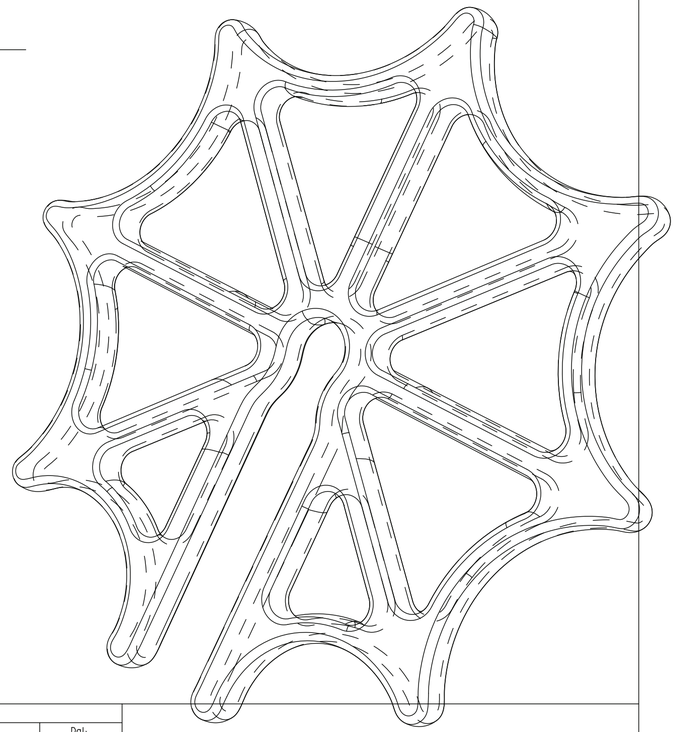


MODIFICATION	PROPERTIES	FILL TIME	PRESSURE	TEMPERATURE	SHEAR STRESS	WELD LINES & AIR	VELOCITY VECTOR
	**SPACER 6** Height(mm): 82 Cover(mm): 35 Bar Dia. (mm): 10 Volume(cm3):15.31	**min:** 4.068e-04 sec **max:** 5.9485 sec 	**min:** 0.10 MPa **max:** 2.84 MPa 	**min:** 83.50°C **max:** 230.01°C 	**min:** 3.382e-07 MPa **max:** 0.10 MPa 	**min:** 0.9100° **max:** 129.8600° 	**min:** 2.871e-04 m/s **max:** 87.6201 m/s 
	**SPACER 6.1** Height(mm): 92 Cover(mm): 40 Bar Dia. (mm): 6-8-10 Volume(cm3):19.89	**min:** 0.0016sec **max:** 5.5859 sec 	**min:** 0.10 MPa **max:** 2.64 MPa 	**min:** 91.92°C **max:** 230.02°C 	**min:** 0.06 MPa **max:** 3.459e-05 MPa 	**min:** 2.1500° **max:** 148.4100° 	**min:** 0.0016 m/s **max:** 5.5859 m/s 
	**SPACER 10** Height(mm): 92 Cover(mm): 40 Bar Dia. (mm): 6-8 Volume(cm3):12.63	**min:** 3.308e-04 sec **max:** 3.8485 sec 	**min:** 0.10 MPa **max:** 4.78 MPa 	**min:** 98.81 °C **max:** 230.14°C 	**min:** 6.986e-05 MPa **max:** 0.09 MPa 	**min:** 5.3800° **max:** 149.9400° 	**min:** 0.0032 m/s **max:** 88.5547 m/s 









Project Title	Note	Remarks	Issues & Revisions			
rec–HERO MSc Thesis Project	REC-HER		No.	Description	Dat.	
			△	Unless otherwise specified dimensions are in milimeters		
			△			
			△			
			△			

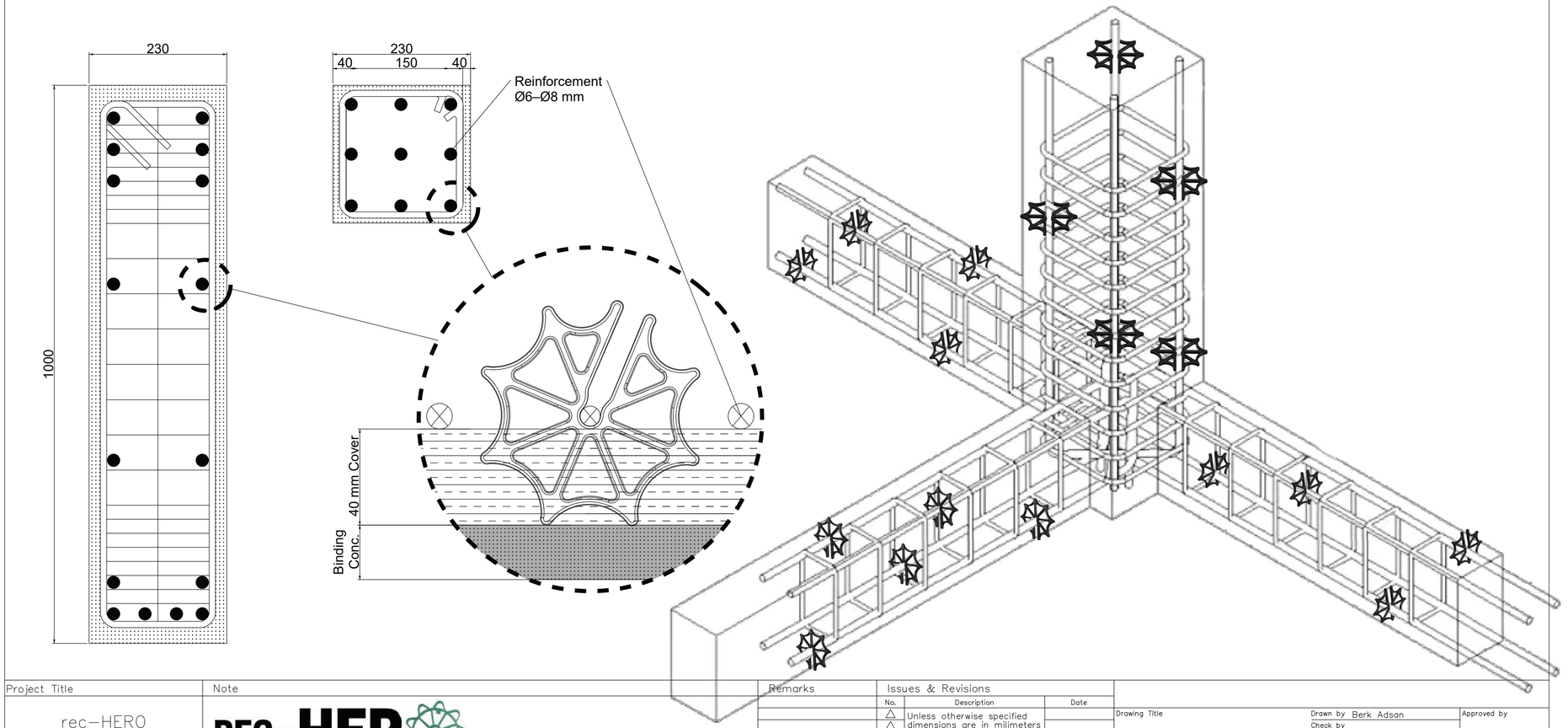
Drawing Title: SPACER 10

Drawn by Berk Adsan | Approved by

Check by

Scale NONE | Date APR. 2025

Sheet No. | Drawing No. A001



Project Title	Note	Remarks	Issues & Revisions			
rec–HERO MSc Thesis Project	REC-HER		No.	Description	Date	
			△	Unless otherwise specified dimensions are in milimeters		
			△			
			△			
			△			

Drawing Title: SPACER 10

Drawn by Berk Adsan | Approved by
Check by
Scale NONE | Date APR. 2025
Sheet No. | Drawing No. A001



APPLICATION

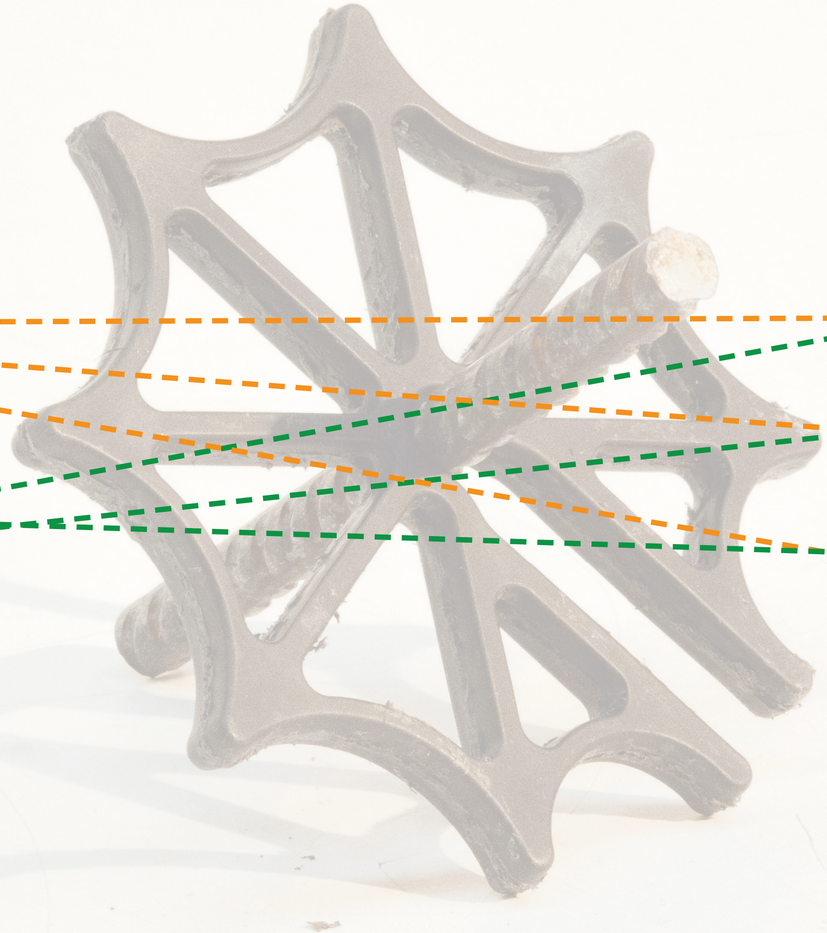


PROOF OF CONCEPT A

PROOF OF APPLICATION B

PROOF OF SUSTAINABILITY C

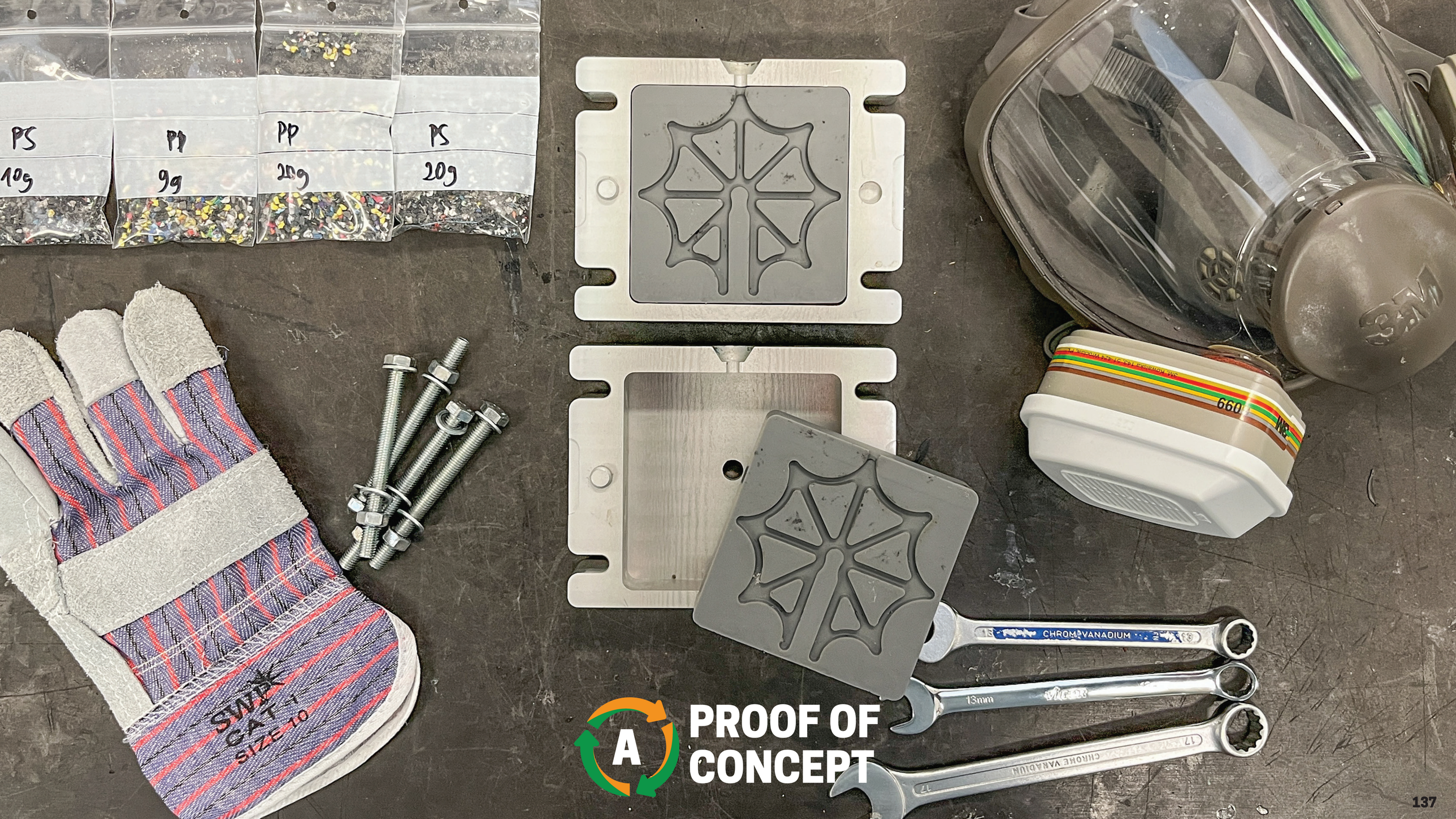
CONCLUSION & REFLECTION



PROOF OF CONCEPT A

PROOF OF APPLICATION B

PROOF OF SUSTAINABILITY C

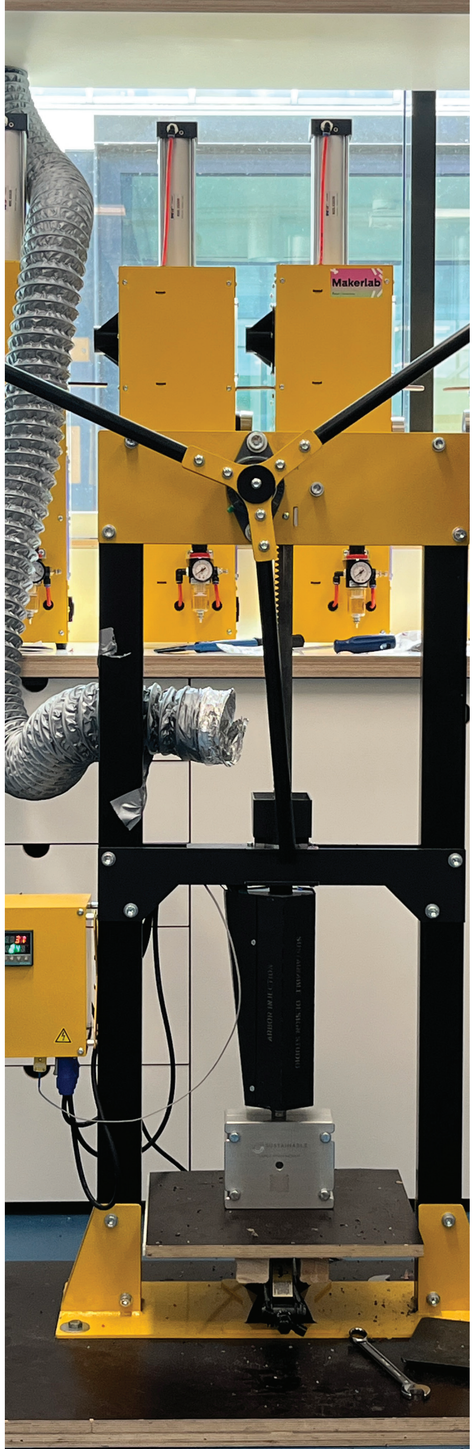

PS
10g
PP
9g
PP
20g
PS
20g
SWP
CAT 1
SIZE 10
CHROM VANADIUM
13mm
CHROME VANADIUM
A
PROOF OF
CONCEPT







+

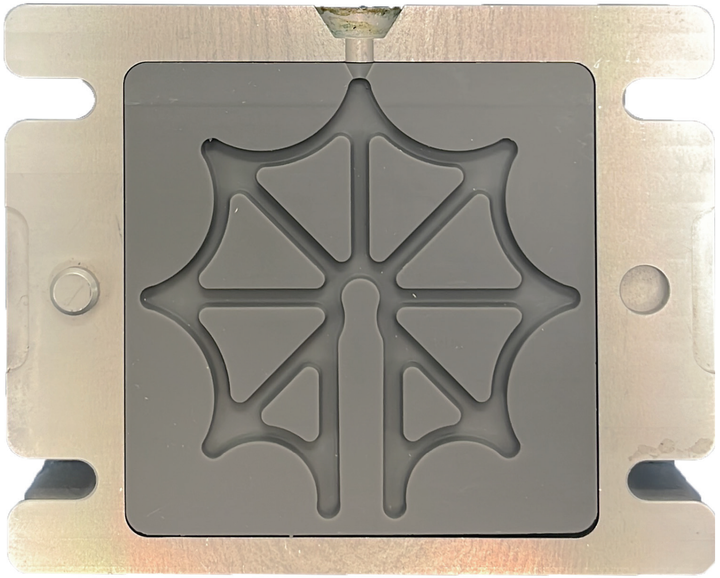


+



ABS-like Resin Mould

+



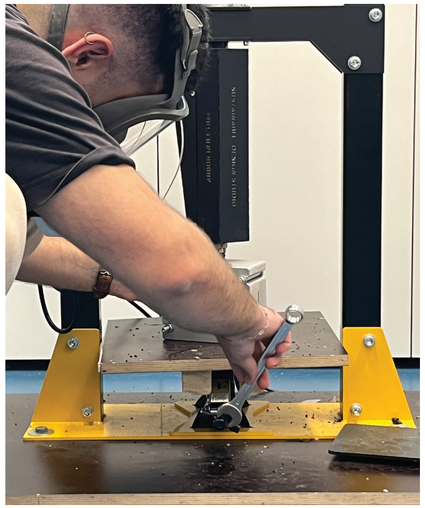
3D-printed Insert Holder Aluminium Mould



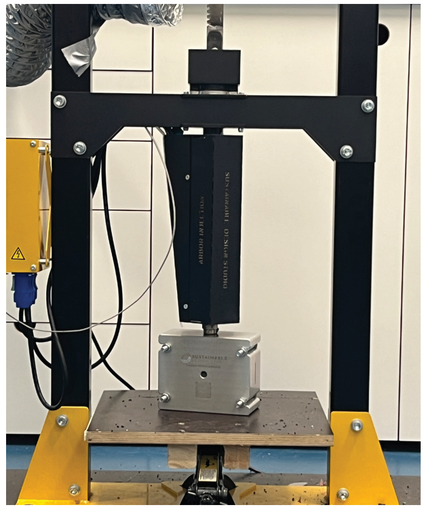
TIGHTEN THE MOULD



PLACE THE MOULD



FIX MOULD TO NOZZLE



INJECTION



UNTIGHTEN THE MOULD



REMOVE SAMPLE

TRIALS 1-11

15 OR 20 gr INPUT

4.78 MPa PRESSURE

15 min 230°C 15 min

15 min 240°C 15 min

100% WEEE RESIDUES

TRIAL 1: rec-PP CARBON BLACK INPUT



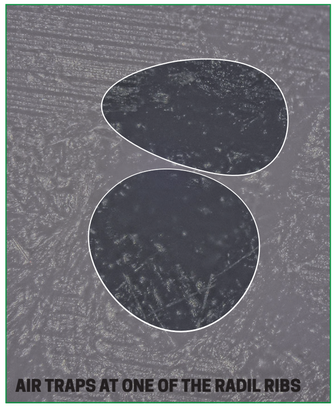


FLASHING IN BETWEEN RADIAL RIBS

WEIGHT (g)	20 + 10
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	30
DWELL DURATION (min)	15
HEATER (°C)	**230°C**
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Rough texture and semi-molten phases
DEGRADATION RESULT	Possible thermal degradationa at flashing
STABILITY RESULT	Stable geometry
SMELL RESULT	Persistent strong chemical smell

TRIAL 2: rec-PP/PE BLEND CARBON BLACK INPUT





AIR TRAPS AT ONE OF THE RADIL RIBS

WEIGHT (g)	20
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYCLE (min)	20
DWELL DURATION (min)	15
HEATER (°C)	**240°C**
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Very rough texture, fibrous surface
DEGRADATION RESULT	Possible thermal deradation bc. of temperature
STABILITY RESULT	Brittle geometry
SMELL RESULT	Persistent strong chemical smell

TRIAL 3: rec-PP/PE BLEND CARBON BLACK INPUT





TORN AREA AT THE CORE

WEIGHT (g)	20
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYCLE (min)	20
DWELL DURATION (min)	15
HEATER (°C)	**240°C**
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Surface irregularities becase of deformed mould
DEGRADATION RESULT	Some warping
STABILITY RESULT	Flashing causing stronger geometry
SMELL RESULT	Persistent strong chemical smell

15 OR 20 gr INPUT

20 gr INPUT

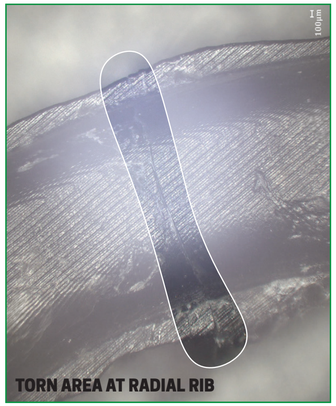
4.78 MPa PRESSURE

15 min 240°C 15 min

100% WEEE RESIDUES

TRIAL 6: rec-PS CARBON BLACK INPUT

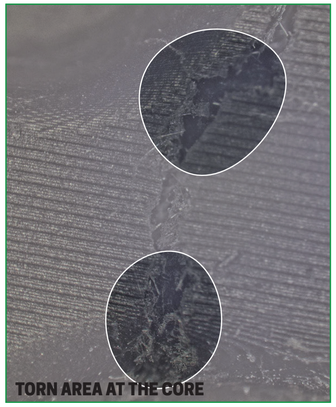




WEIGHT (g)	15
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYCLE (min)	20 g
DWELL DURATION (min)	15
HEATER (°C)	240
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Very rough texture, fibrous surface
DEGRADATION RESULT	Possible thermal deradation bc. of temperature
STABILITY RESULT	Brittle geometry
SMELL RESULT	Persistent strong chemical smell

TRIAL 7: rec-PP/PE BLEND CARBON BLACK INPUT

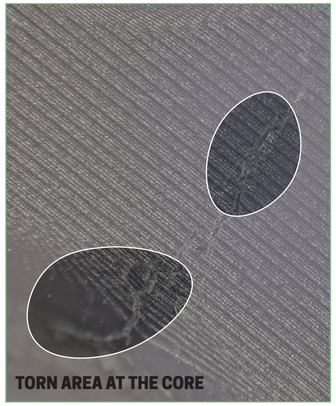




WEIGHT (g)	20 g
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYCLE (min)	20
DWELL DURATION (min)	15
HEATER (°C)	240
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Surface irregularities becase of deformed mould
DEGRADATION RESULT	Flashing at the ribs
STABILITY RESULT	Brittle behaviour after rebar test
SMELL RESULT	Persistent strong chemical smell

TRIAL 8: rec-PP/PE BLEND CARBON BLACK INPUT





WEIGHT (g)	30
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYCLE (min)	20
DWELL DURATION (min)	15
HEATER (°C)	240
MIXING RESULT	Better miscibility
MORPHOLOGY RESULT	Better surface results, Rough texture
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Brittle behaviour after rebar test
SMELL RESULT	Persistent strong chemical smell

20 gr INPUT

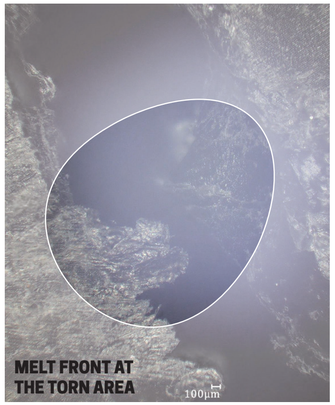
4.78 MPa PRESSURE

15 min 240°C 15 min

100% WEEE RESIDUES

TRIAL 9: rec-PP/PE BLEND CARBON BLACK INPUT

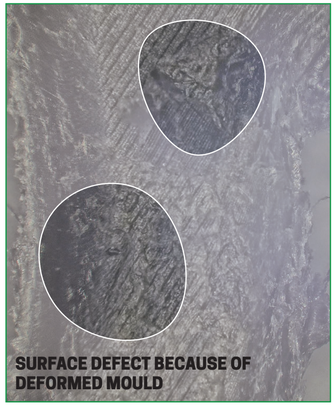




WEIGHT (g)	20
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	20
DWELL DURATION (min)	15
HEATER (°C)	240
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Increased surface irregularities
DEGRADATION RESULT	No thermal degradation at melt front
STABILITY RESULT	Brittle behaviour
SMELL RESULT	Persistent strong chemical smell

TRIAL 10: rec-PP/PE BLEND CARBON BLACK INPUT

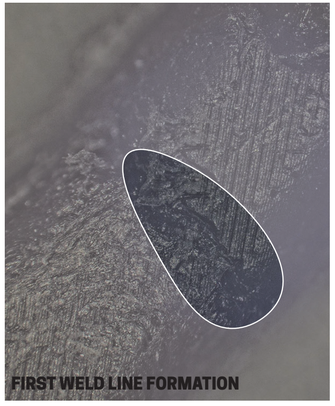




WEIGHT (g)	20
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYCLE (min)	20
DWELL DURATION (min)	15
HEATER (°C)	240
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Increased surface irregularities
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Semi-brittle geometry
SMELL RESULT	Persistent strong chemical smell

TRIAL 11: rec-PP/PE CARBON BLACK INPUT





WEIGHT (g)	20
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYCLE (min)	20
DWELL DURATION (min)	15
HEATER (°C)	240
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Increased surface irregularities
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Semi-brittle geometry
SMELL RESULT	Persistent strong chemical smell

20 gr
INPUT

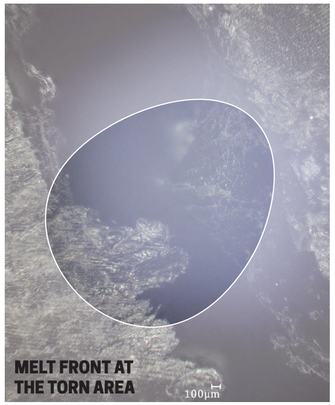
4.78 MPa
PRESSURE

15 min
240°C
15 min

100%
WEEE
RESIDUES

TRIAL 9: rec-PP/PE BLEND CARBON BLACK INPUT





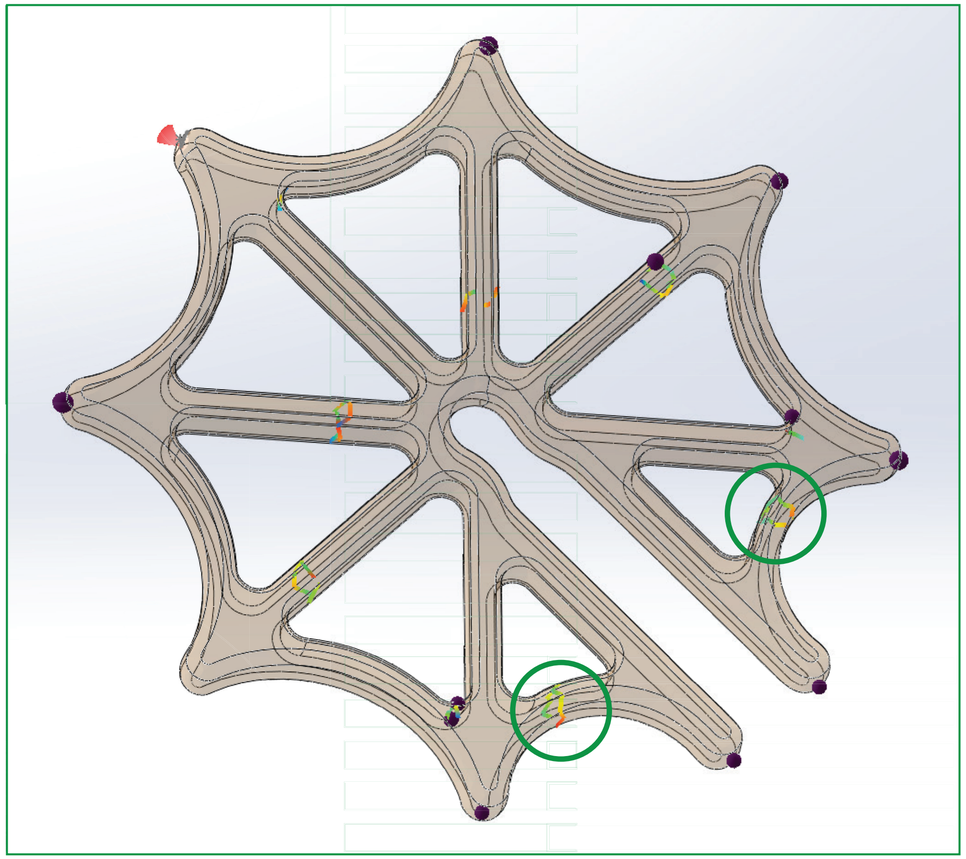
WEIGHT (g)	20
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	20
DWELL DURATION (min)	15
HEATER (°C)	240
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Increased surface irregularities
DEGRADATION RESULT	No thermal degradation at melt front
STABILITY RESULT	Brittle behaviour
SMELL RESULT	Persistent strong chemical smell

TRIAL 10: rec-PP/PE BLEND CARBON BLACK INPUT



TRIAL 11: rec-PP/PE CARBON BLACK INPUT





TRIALS 1-11

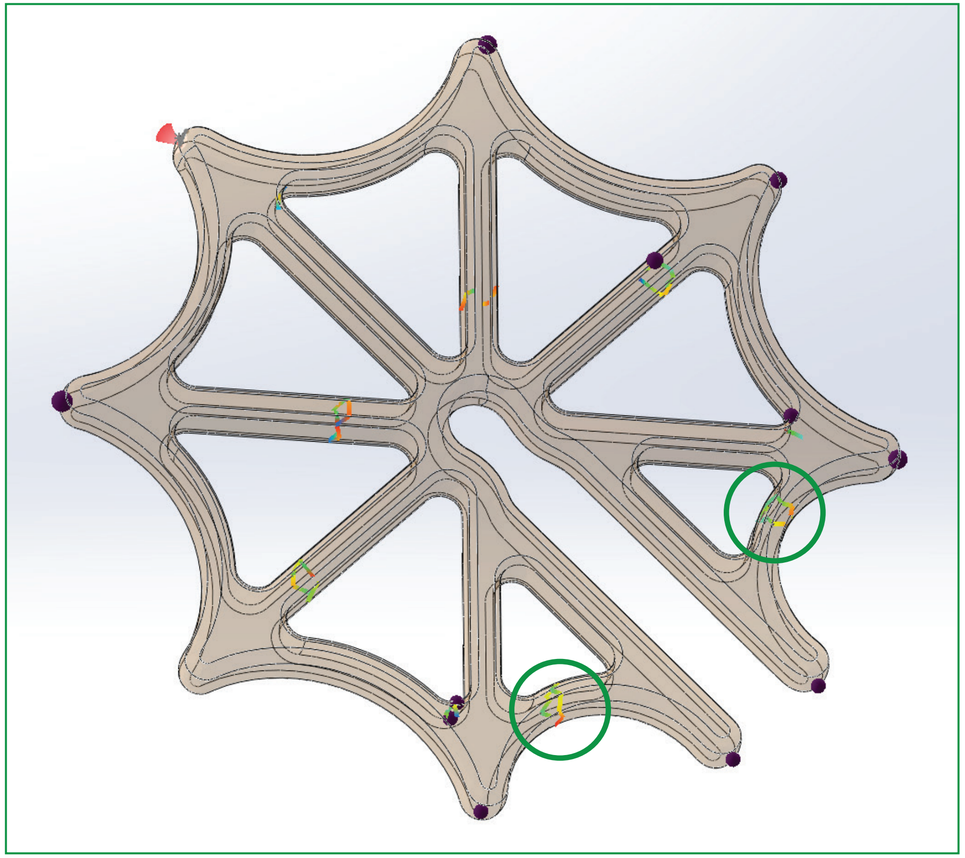
20 gr
INPUT

4.78 MPa
PRESSURE

15 min
240°C
15 min

100%
WEEE
RESIDUES





TRIALS 1-11

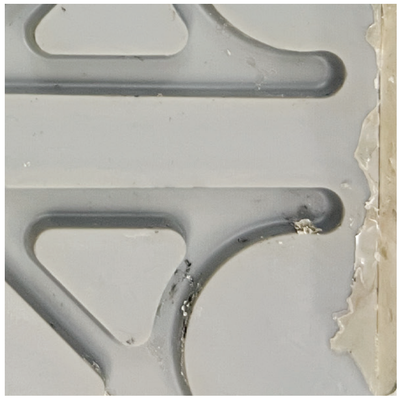
20 gr INPUT

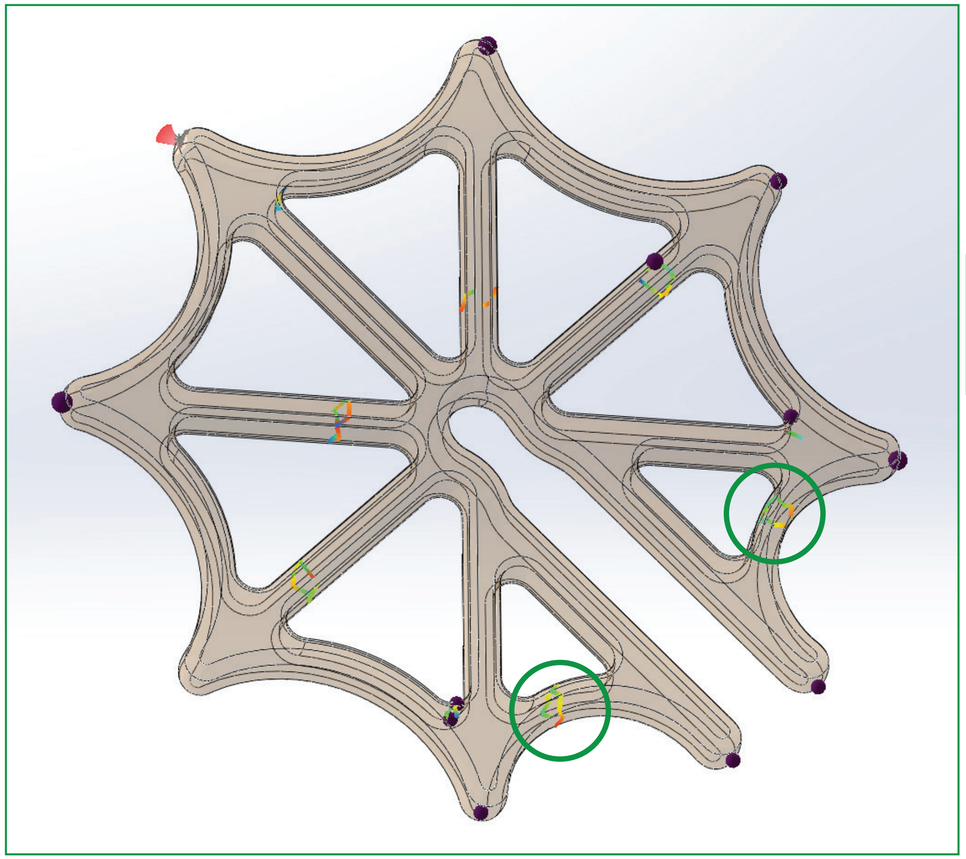
4.78 MPa PRESSURE

15 min 240°C 15 min

100% WEEE RESIDUES





Material

Material: RPI-299X

Melt Temperature (°C):

230

Mold temperature (°C):

80

TRIALS 1-11

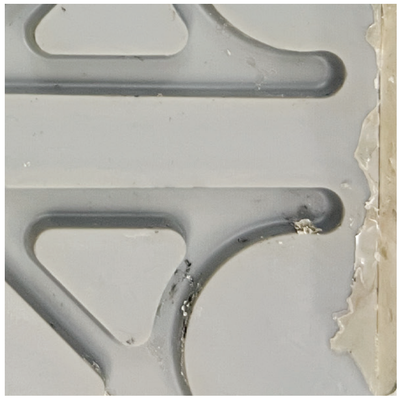
20 gr
INPUT

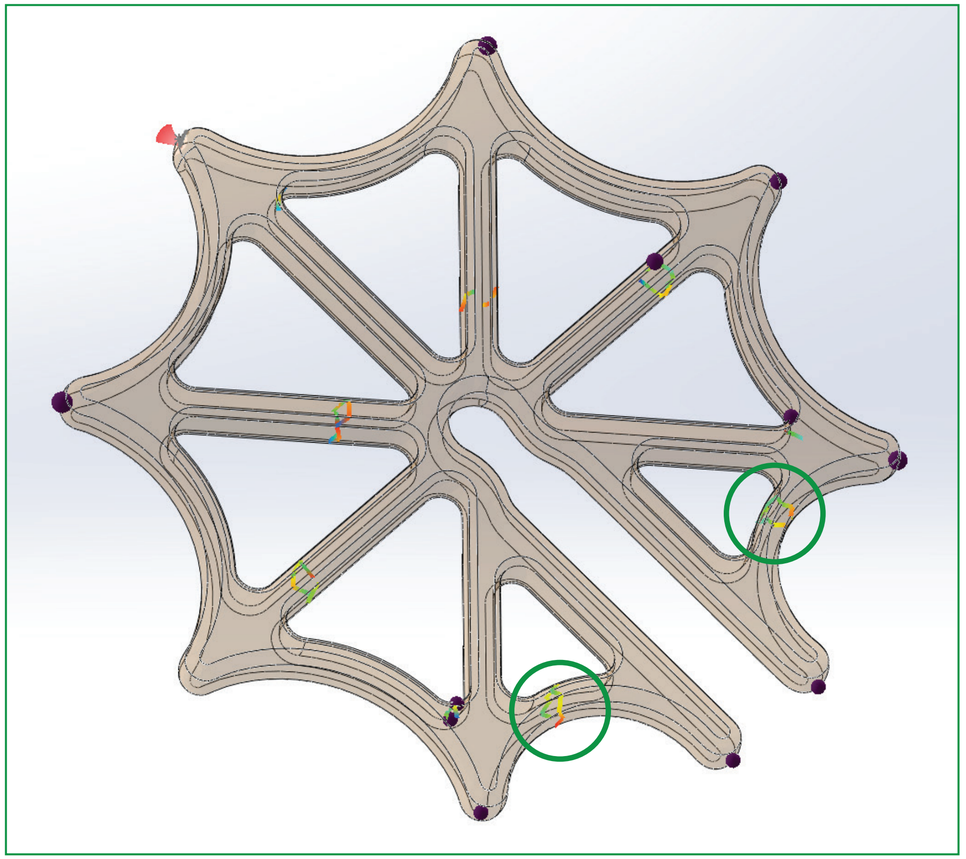
4.78 MPa
PRESSURE

15 min
240°C
15 min

100%
WEEE
RESIDUES





Material

Material: RPI-299X

Melt Temperature (°C):

230

Mold temperature (°C):

80

MIXING RESULT

MORPHOLOGY RESULT

DEGRADATION RESULT

STABILITY RESULT

SMELL RESULT

TRIALS 1-11

100%
WEEE
RESIDUES



70 wt%
30 wt%
POLYMER
BLENDING

MIXING RESULT

MORPHOLOGY RESULT

DEGRADATION RESULT

STABILITY RESULT

SMELL RESULT



TRIALS 1-11

VIRGIN POLYMER

RECYCLED POLYMER

100% WEEE RESIDUES

70 wt% 30 wt% POLYMER BLENDING

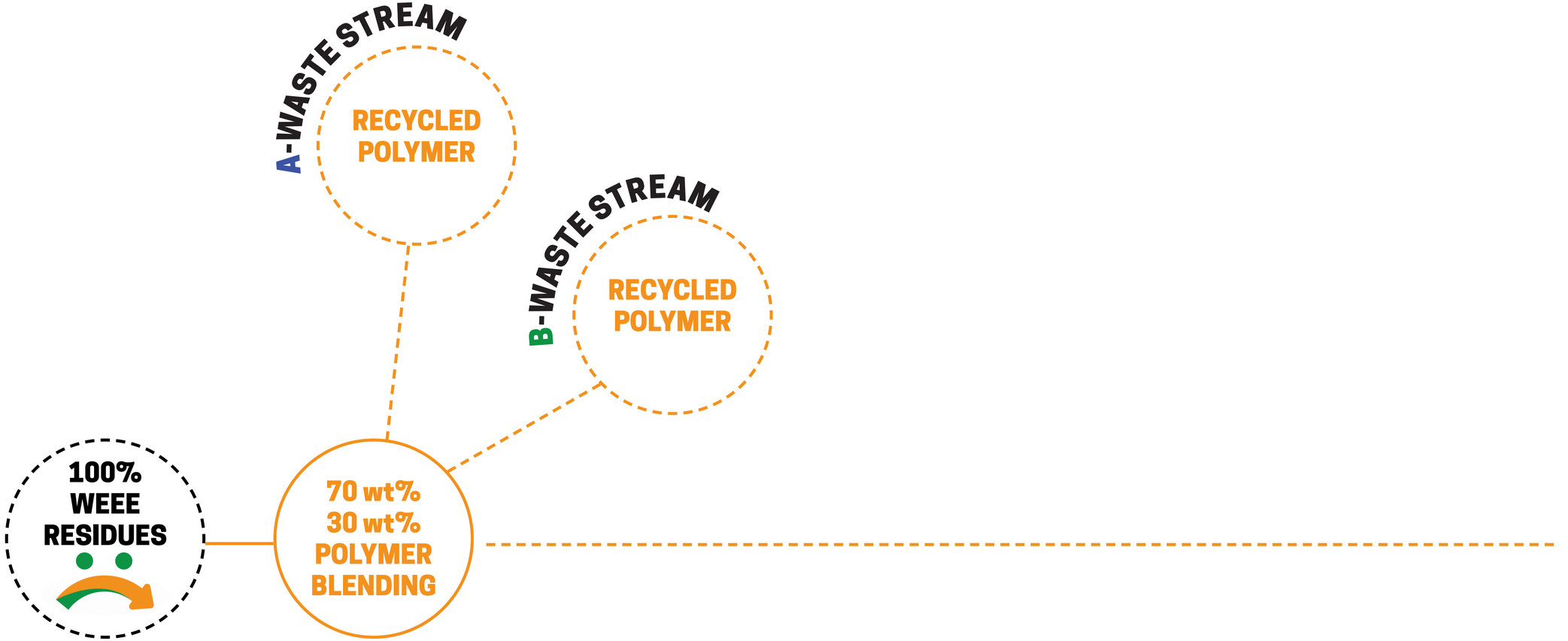
MIXING RESULT

MORPHOLOGY RESULT

DEGRADATION RESULT

STABILITY RESULT

SMELL RESULT



MIXING RESULT

MORPHOLOGY RESULT

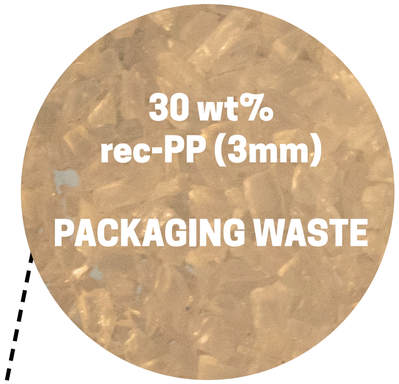
DEGRADATION RESULT

STABILITY RESULT

SMELL RESULT

100% RECYCLED BLEND
PACKAGING + WEEE

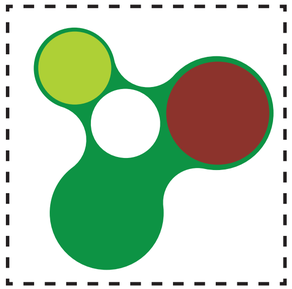
TRIALS 1-11



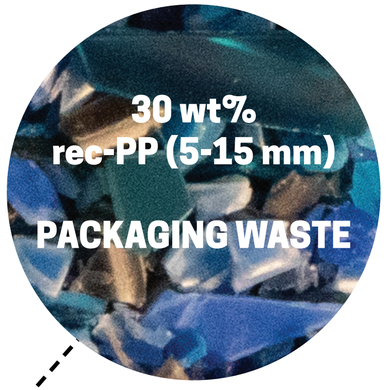
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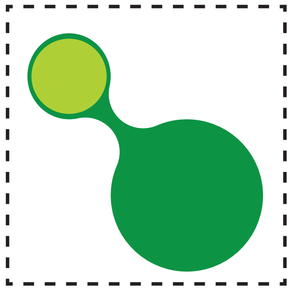
70 wt% PP/PE
blend + 30 wt% PP



+



=



70 wt% PP
+ 30 wt% PP

100%
WEEE
RESIDUES

70 wt%
30 wt%
POLYMER
BLENDING

MIXING RESULT

MORPHOLOGY RESULT

DEGRADATION RESULT

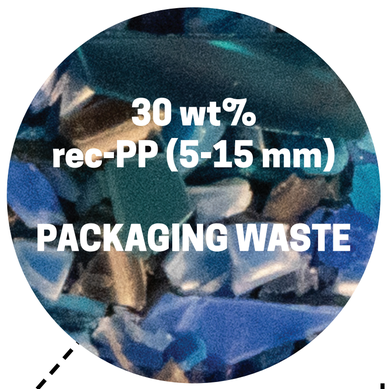
STABILITY RESULT

SMELL RESULT

TRIALS 1-11

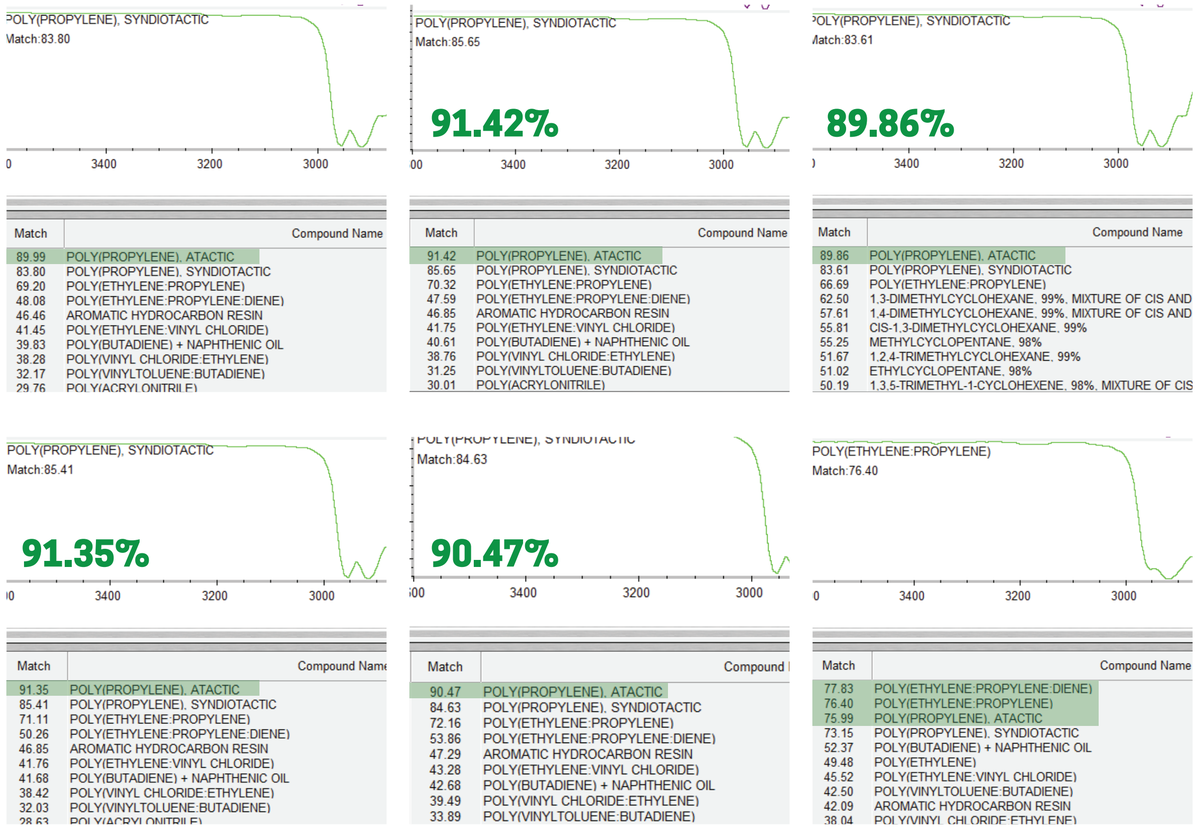
30 wt%
rec-PP (3mm)

PACKAGING WASTE



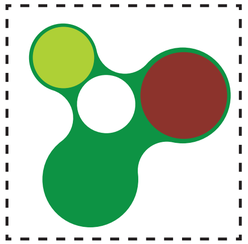
100%
WEEE
RESIDUES

70 wt%
30 wt%
POLYMER
BLENDING



CLEANER & MORE PURE rec-PLASTIC

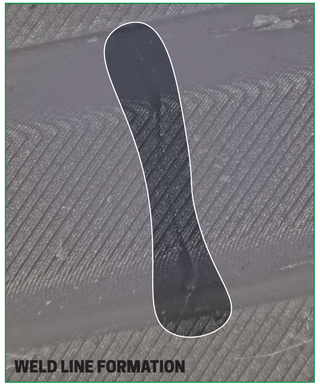
TRIALS 12-16



70 wt% PP/PE blend + 30 wt% PP

TRIAL 13: %70 rec-PP/PE BLEND + %30 rec-PP (PRECIOUS PLASTIC)



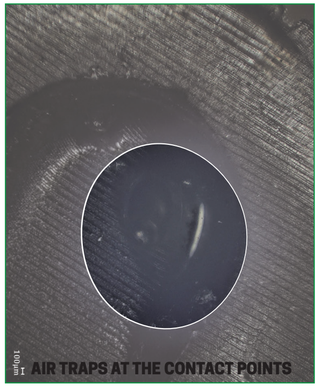


WELD LINE FORMATION

WEIGHT (g)	10.5 + 4.5
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	15
DWELL DURATION (min)	10
HEATER (°C)	220
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Identifiable phase domains - Better surface
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIAL 14: %70 rec-PP/PE BLEND + %30 rec-PP (PRECIOUS PLASTIC)



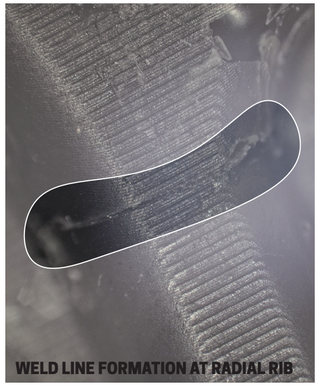


AIR TRAPS AT THE CONTACT POINTS

WEIGHT (g)	17.5 + 7.5
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	15
DWELL DURATION (min)	10
HEATER (°C)	220
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Air traps at the contact points, Flashing
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIAL 15: %70 rec-PP/PE BLEND + %30 rec-PP (PRECIOUS PLASTIC)





WELD LINE FORMATION AT RADIAL RIB

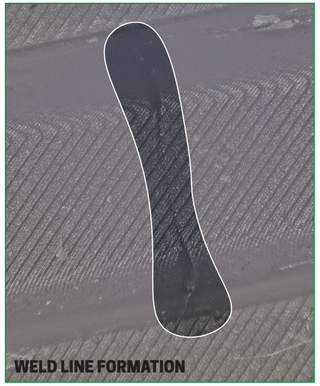
WEIGHT (g)	17.5 + 7.5
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	15
DWELL DURATION (min)	10
HEATER (°C)	220
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Extreme flashing, Resin mould deformation
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIALS 12-16

70 wt% PP/PE blend + 30 wt% PP

TRIAL 13: %70 rec-PP/PE BLEND + %30 rec-PP (PRECIOUS PLASTIC)



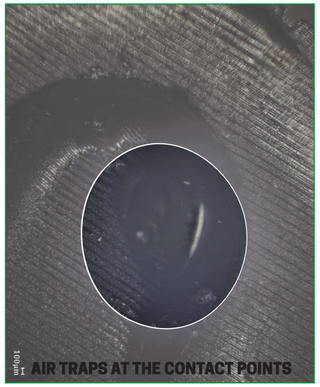


WELD LINE FORMATION

WEIGHT (g)	10.5 + 4.5
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	15
DWELL DURATION (min)	10
HEATER (°C)	220
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Identifiable phase domains - Better surface
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIAL 14: %70 rec-PP/PE BLEND + %30 rec-PP (PRECIOUS PLASTIC)



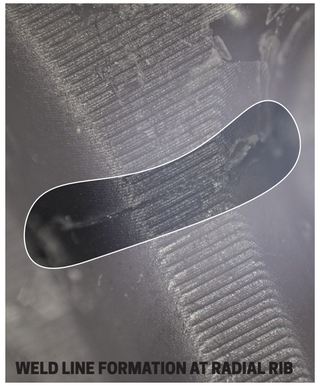


AIR TRAPS AT THE CONTACT POINTS

WEIGHT (g)	17.5 + 7.5
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	15
DWELL DURATION (min)	10
HEATER (°C)	220
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Air traps at the contact points, Flashing
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIAL 15: %70 rec-PP/PE BLEND + %30 rec-PP (PRECIOUS PLASTIC)



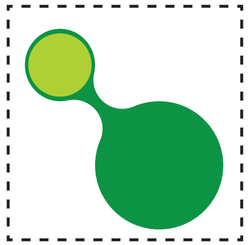


WELD LINE FORMATION AT RADIAL RIB

WEIGHT (g)	17.5 + 7.5
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	15
DWELL DURATION (min)	10
HEATER (°C)	220
MIXING RESULT	Miscible blend
MORPHOLOGY RESULT	Extreme flashing, Resin mould deformation
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIALS 20-23

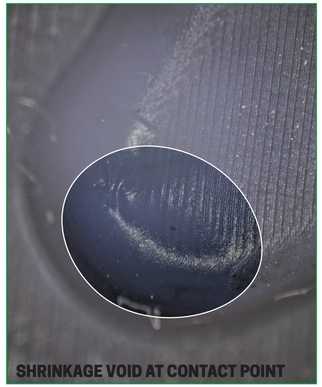
A



70 wt% PP
+ 30 wt% PP

TRIAL 20: %70 rec-PP
+ %30 rec-PP (PRECIOUS PLASTIC)





SHRINKAGE VOID AT CONTACT POINT

WEIGHT (g)	14+6
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	18
DWELL DURATION (min)	15
HEATER (°C)	220
MIXING RESULT	Miscible blend, Better plastic flow
MORPHOLOGY RESULT	Smoother surface
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIAL 21: % 70 rec-PP
+ %30 rec-PP (PRECIOUS PLASTIC)



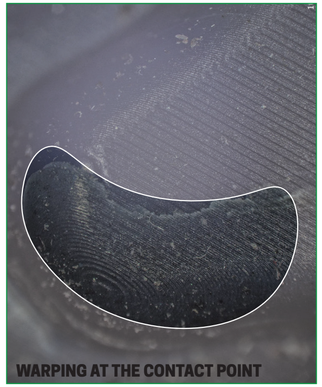


WELD LINE FORMATION AT RADIAL RIB

WEIGHT (g)	14+6
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	18
DWELL DURATION (min)	15
HEATER (°C)	220
MIXING RESULT	Miscible blend, Better plastic flow
MORPHOLOGY RESULT	Smoother surface, Extreme flashing
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIAL 22: %70 rec-PP
+ %30 rec-PP (PRECIOUS PLASTIC)





WARPING AT THE CONTACT POINT

WEIGHT (g)	14+6
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	18
DWELL DURATION (min)	15
HEATER (°C)	220
MIXING RESULT	Miscible blend, Better plastic flow
MORPHOLOGY RESULT	Smoother surface, Extreme flashing
DEGRADATION RESULT	Warping due to mould deformation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIALS 20-23

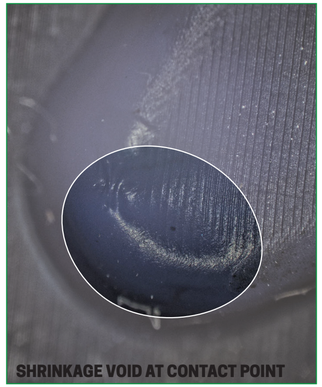
A



70 wt% PP
+ 30 wt% PP

TRIAL 20: %70 rec-PP + %30 rec-PP (PRECIOUS PLASTIC)





WEIGHT (g)	14+6
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	18
DWELL DURATION (min)	15
HEATER (°C)	220
MIXING RESULT	Miscible blend, Better plastic flow
MORPHOLOGY RESULT	Smoother surface
DEGRADATION RESULT	No thermal degradation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

TRIAL 21: % 70 rec-PP + %30 rec-PP (PRECIOUS PLASTIC)

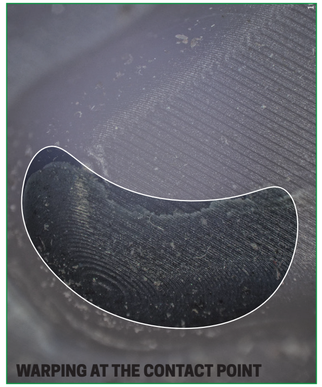




WEIGHT (g)	14+6
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	18
DWELL DURATION (min)	15
HEATER (°C)	220
MIXING RESULT	Miscible blend, Better plastic flow
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STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell

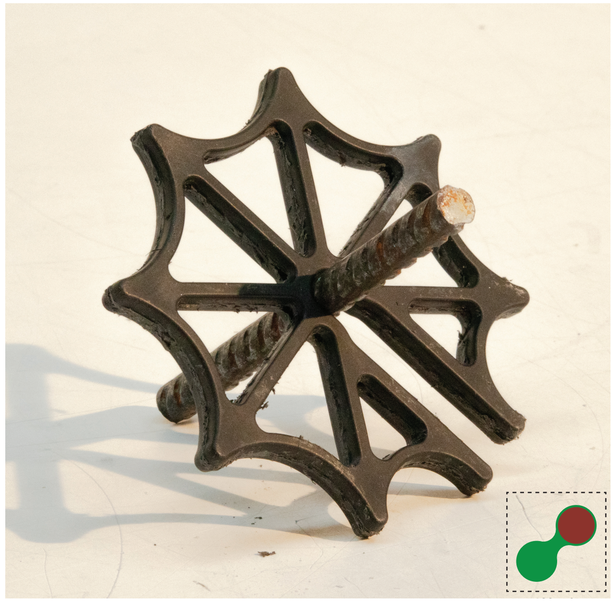
TRIAL 22: %70 rec-PP + %30 rec-PP (PRECIOUS PLASTIC)

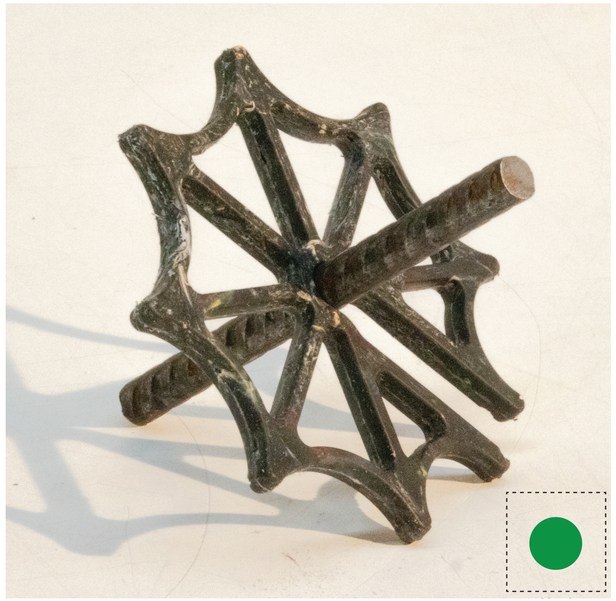




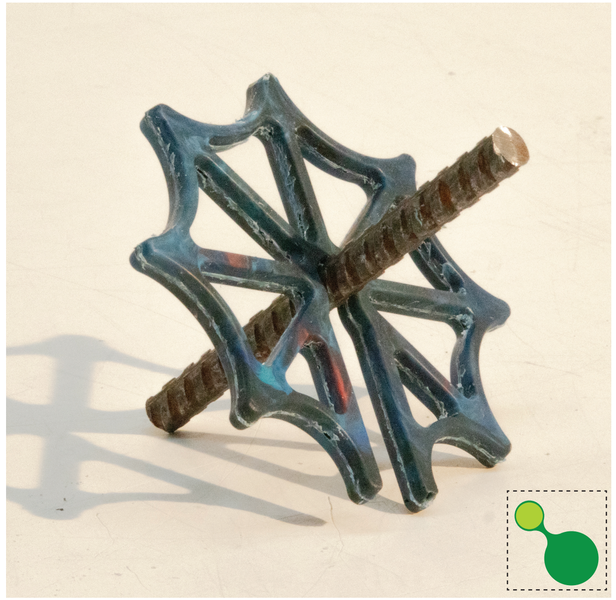
WEIGHT (g)	14+6
MOULD TYPE	Aluminium Cavity + ABS-like Resin Moulds
INJECTION CYLE (min)	18
DWELL DURATION (min)	15
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MIXING RESULT	Miscible blend, Better plastic flow
MORPHOLOGY RESULT	Smoother surface, Extreme flashing
DEGRADATION RESULT	Warping due to mould deformation
STABILITY RESULT	Stable geometry
SMELL RESULT	Less strong chemical smell


FINE-TUNING

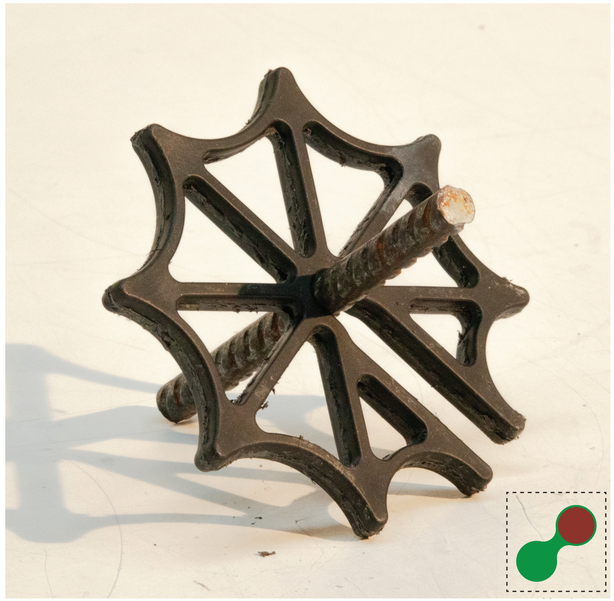


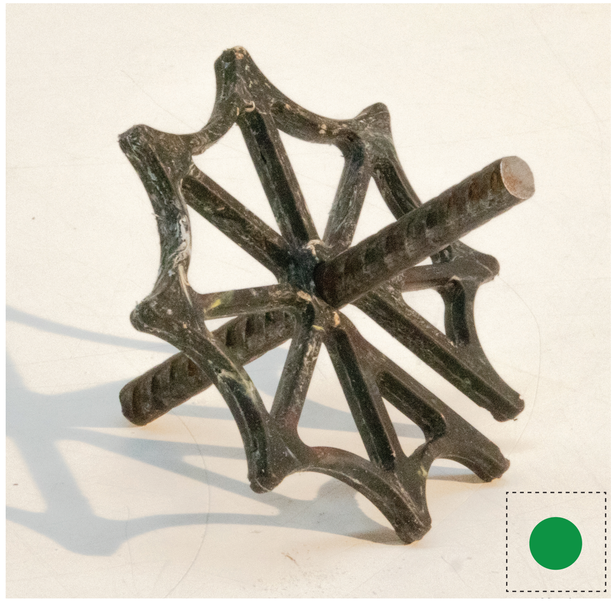










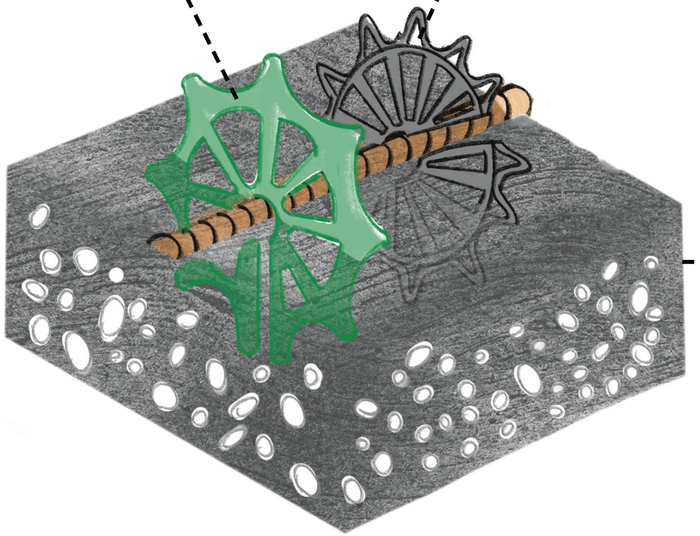


B PROOF OF APPLICATION









PROOF OF APPLICATION

SNAPPING REBAR

SURFACE EXPOSURE

AGGREGATE PENETRATION

RECIPE







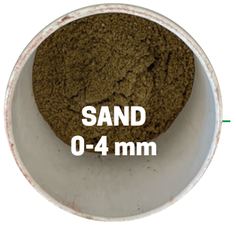
















A + B + C + CEM III + WATER

A + B + C + CEM III + WATER

A + B + C + CEM III + WATER

Prepare Design Mixes I, II, III

Weigh the Dry Mass

Take A+B+C+CEM III

Start Tilting Drum Mixer

Pour Water-400mL into mix

Casting into Mould

15x15x15 mould prep.

Apply mould release agent

Place the moulds in Vibration table

Initial Curing for 48 hours

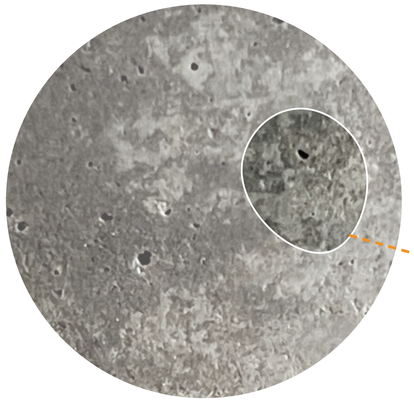
Demoulding with air pressure

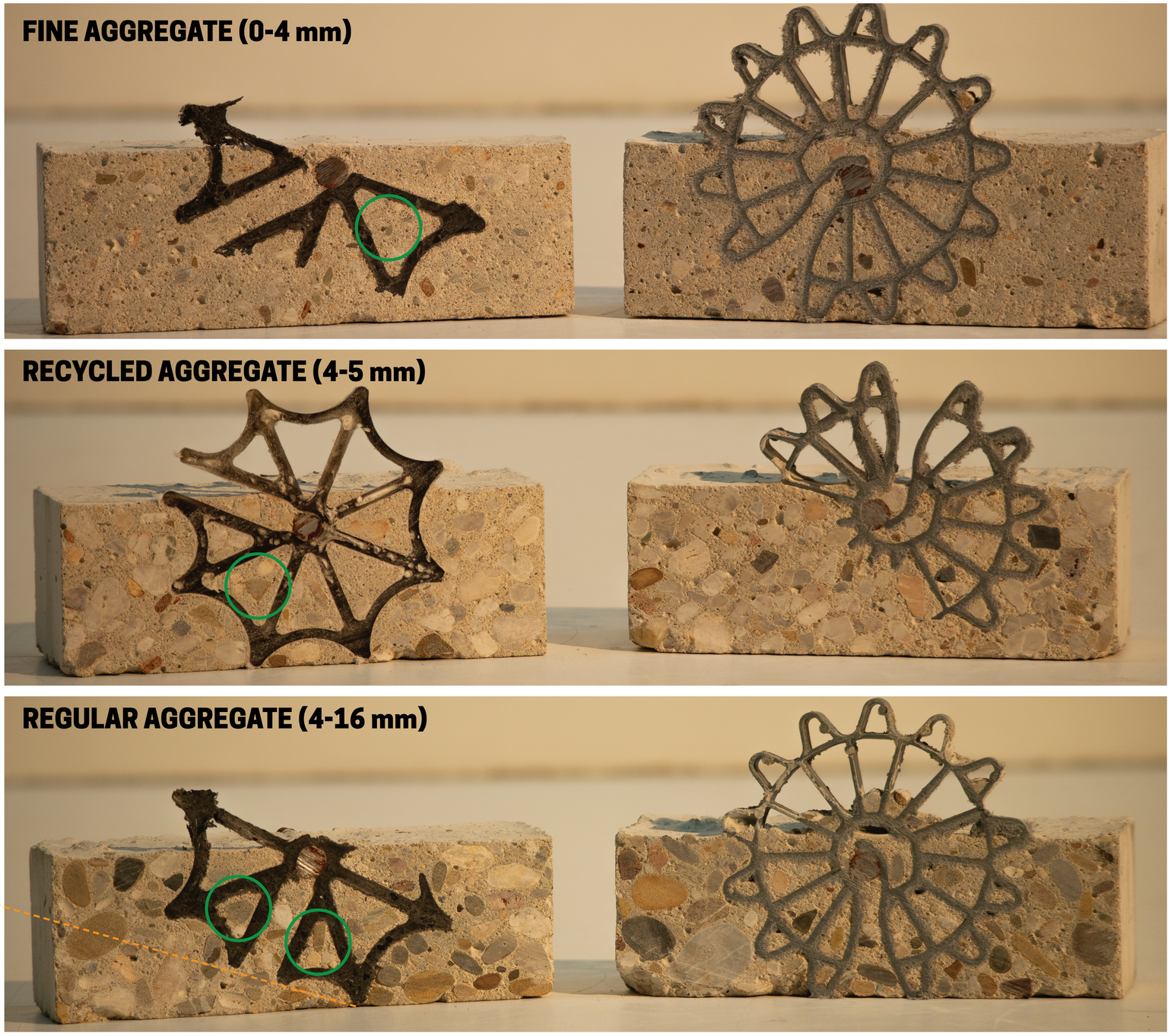
Section cutting after 1-week

SNAPPING REBAR

SURFACE EXPOSURE

AGGREGATE PENETRATION

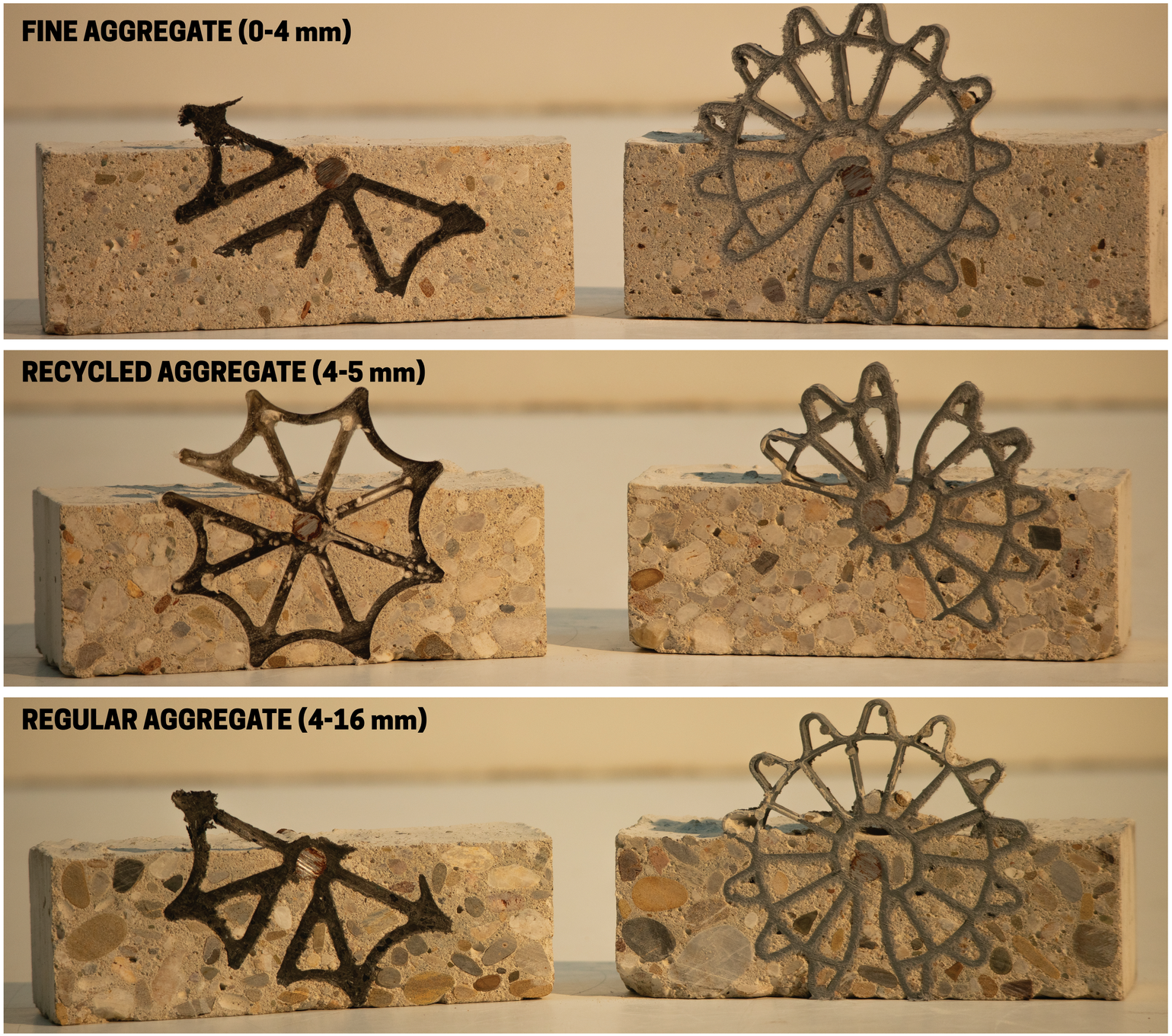




SNAPPING REBAR

SURFACE EXPOSURE

AGGREGATE PENETRATION





PROOF OF SUSTAINABILITY

DATA SOURCE

EPD
INTERNATIONAL EPD SYSTEM

Environmental Product Declaration

EPD®
THE INTERNATIONAL EPD® SYSTEM

In accordance with ISO 14025:2006 and EN 15804:2012+A2:2019/AC:2021 for:

Plastic spacer

(EPD of multiple products, based on the average results of the product group)

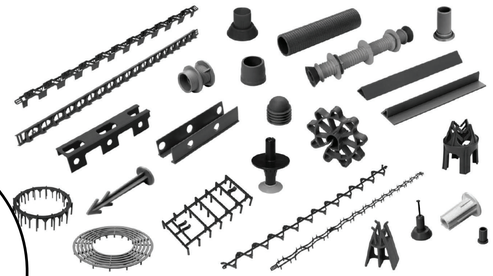
from

Spritz-Plast GmbH

Spritz·Plast KUNSTSTOFFVERARBEITUNG

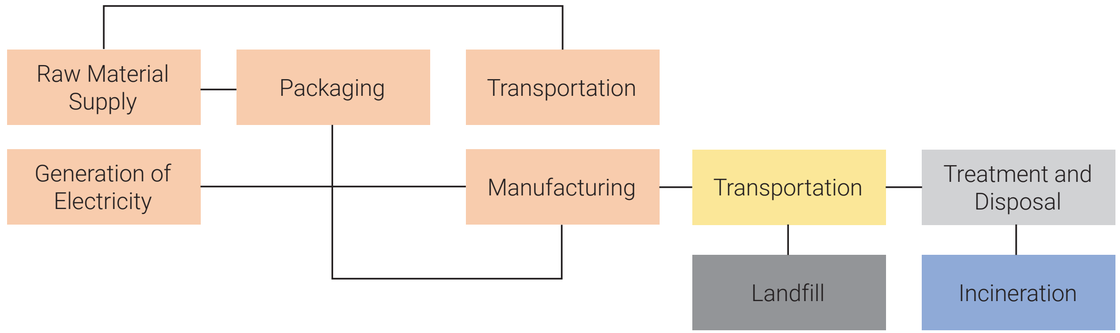
Programme:	The International EPD® System, www.environdec.com
Programme operator:	EPD International AB
EPD registration number:	EPD-IES-0015611
Publication date:	2024-11-29
Valid until:	2029-11-29

An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com



rec-PP/PE PACKAGING WASTE

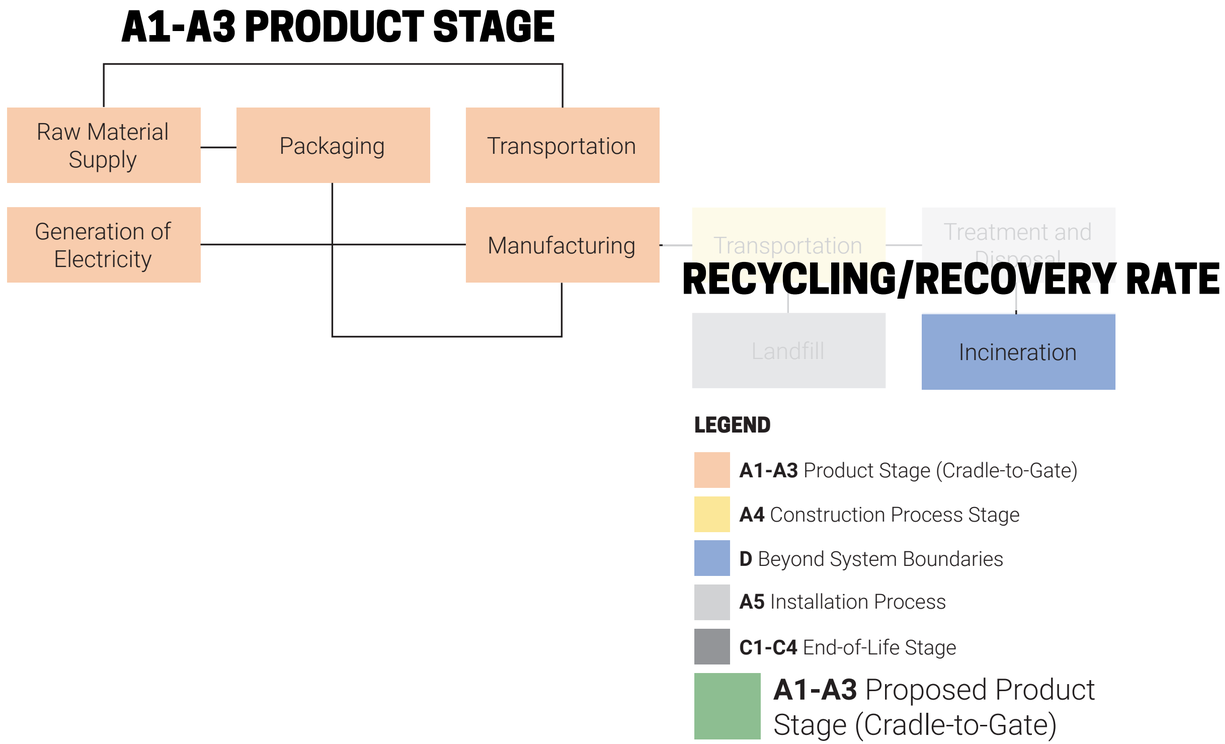
Spritz·Plast KUNSTSTOFFVERARBEITUNG SYSTEM DIAGRAM



LEGEND

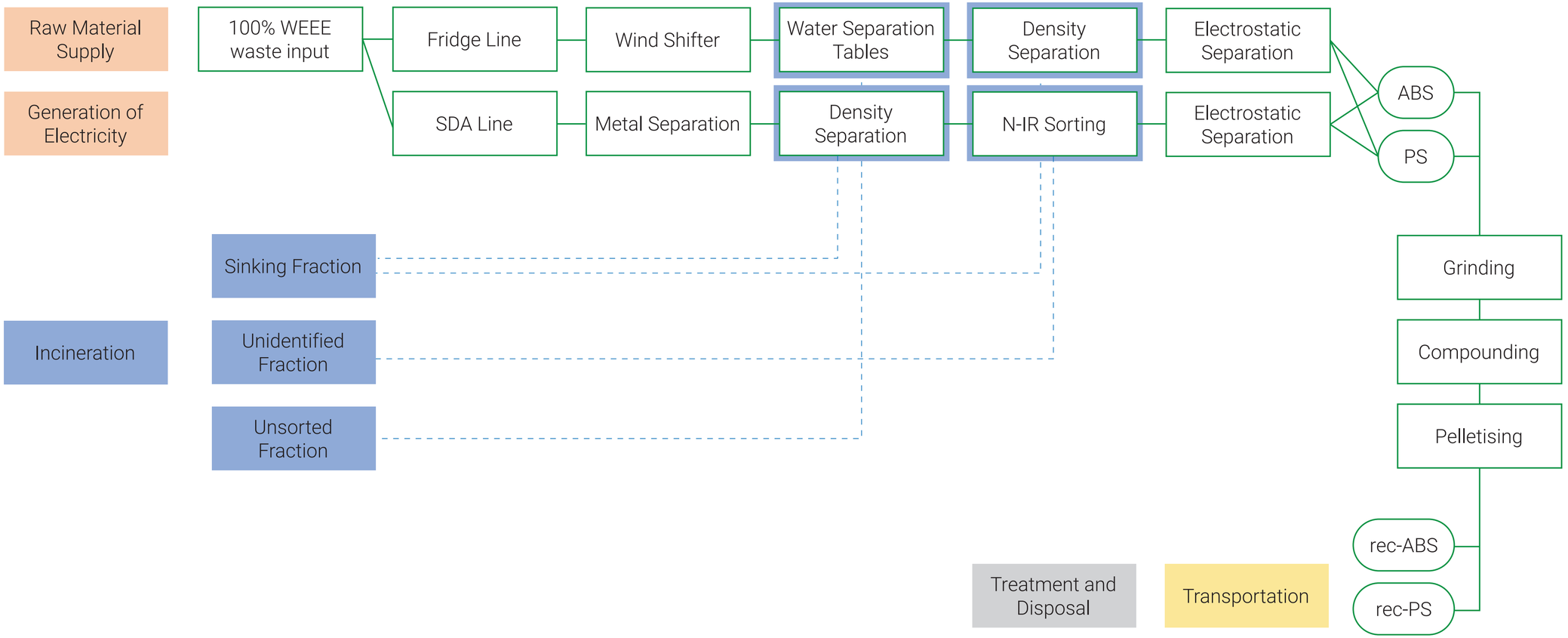
- **A1-A3** Product Stage (Cradle-to-Gate)
- **A4** Construction Process Stage
- **D** Beyond System Boundaries
- **A5** Installation Process
- **C1-C4** End-of-Life Stage
- **A1-A3** Proposed Product Stage (Cradle-to-Gate)

PROOF OF SUSTAINABILITY

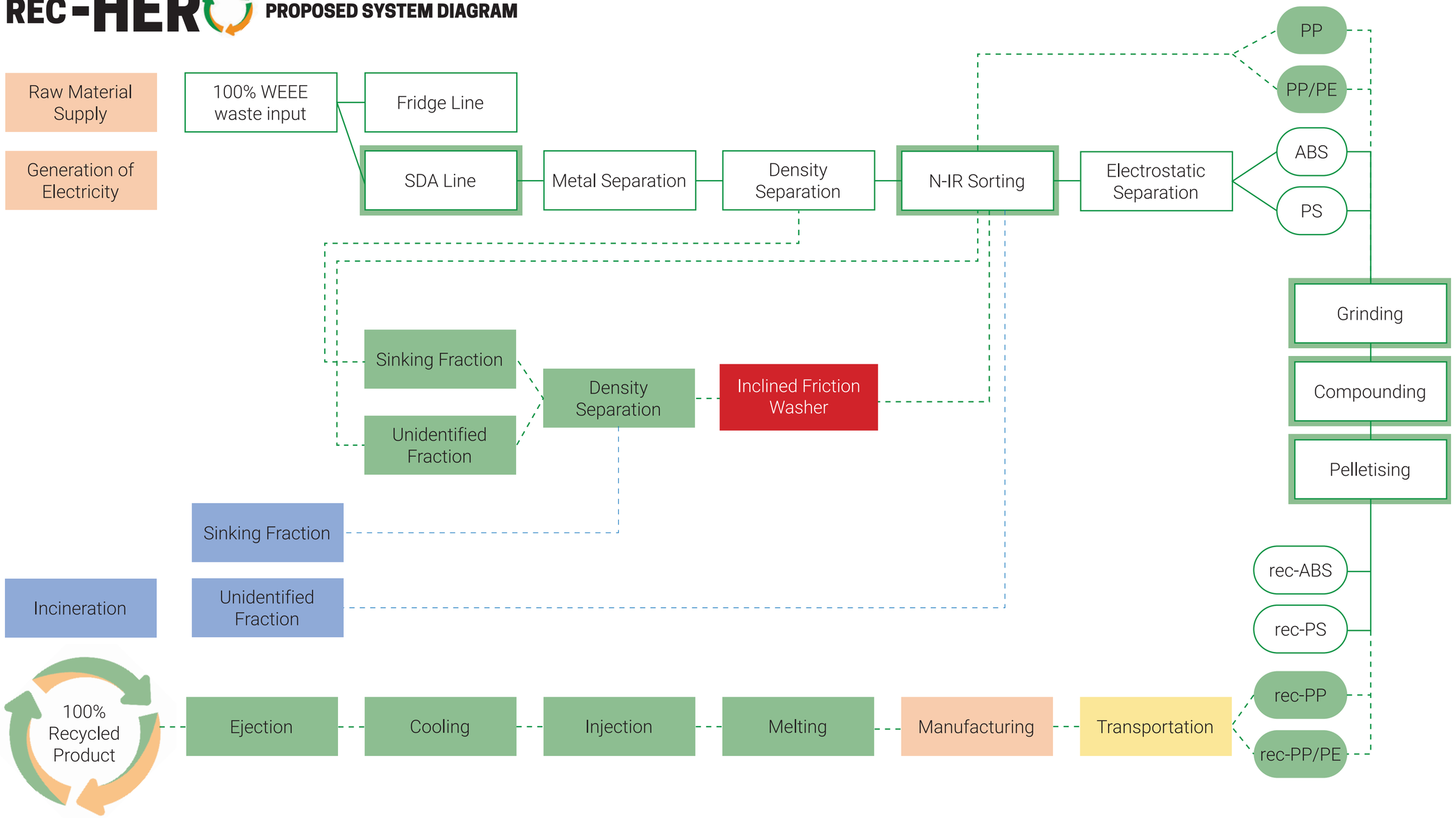


PROOF OF SUSTAINABILITY

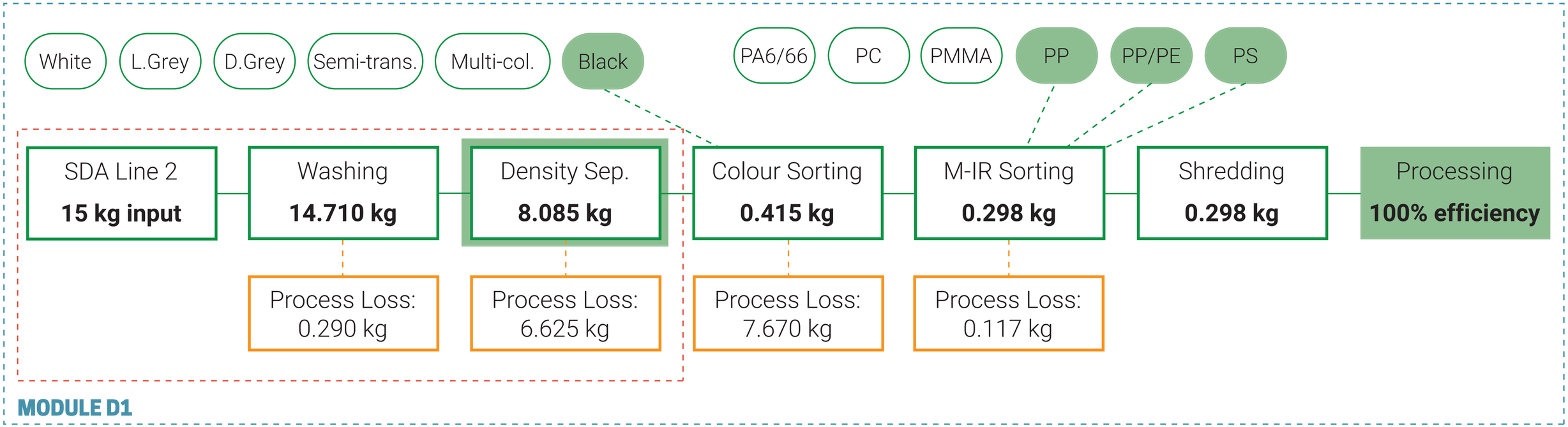
Coolrec SYSTEM DIAGRAM

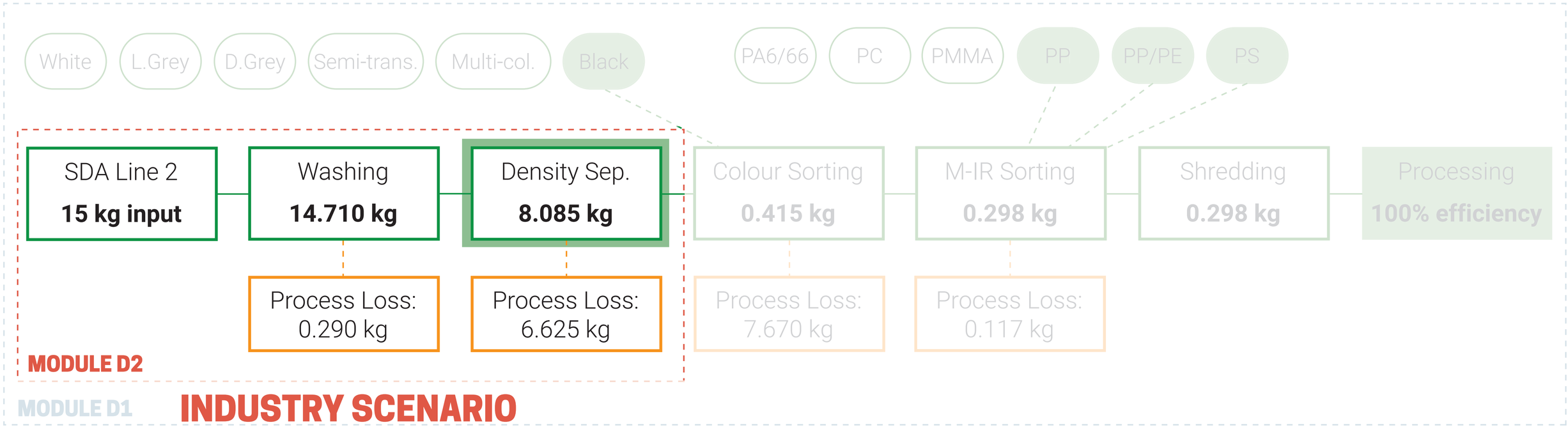


REC-HERO PROPOSED SYSTEM DIAGRAM



THESIS SCENARIO




White
L.Grey
D.Grey
Semi-trans.
Multi-col.
Black
PA6/66
PC
PMMA
PP
PP/PE
PS
SDA Line 2
15 kg input
Washing
14.710 kg
Density Sep.
8.085 kg
Colour Sorting
0.415 kg
M-IR Sorting
0.298 kg
Shredding
0.298 kg
Processing
100% efficiency
Process Loss:
0.290 kg
Process Loss:
6.625 kg
Process Loss:
7.670 kg
Process Loss:
0.117 kg
MODULE D2
MODULE D1
INDUSTRY SCENARIO

PRODUCT TYPE BASED ON POLYMER		WEIGHT (g)	WEEE RECYCLING RESIDUE RATE	BIOGENIC MATERIAL WEIGHT
P.1	Polypropylene	11.37	**100%**	0%
P.2	Polypropylene/Polyethylene	11.49	**100%**	0%
P.3	Polystyrene	13.26	**100%**	0%

Results per 1 kg of plastic spacer made of secondary material *(Adapted from Spritz Plast)*

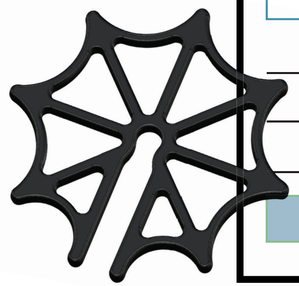
INDICATOR	UNIT	A1-A3	A4	A5	C2	C4	D
GWP-fossil	kg CO2 eq.	**1.47E+00**	8.12E-03	4.42E-03	3.83E-03	2.94E-02	**-2.83E-02**
ADP-fossil	MJ	**1.43E+01**	1.07E-01	2.32E-02	5.05E-02	4.97E-01	**-5.06E-01**
WDP	m3	**8.61E-02**	1.26E-04	1.05E-02	5.93E-05	3.80E-03	**-3.13E-03**

Results for PP/PE (P.2) wheel spacer made of WEEE recycling residues *(Source: Author)*

INDICATOR	UNIT	A1-A3	A4	A5	C2	C4	D1 & D2
GWP-fossil	kg CO2 eq.	**1.689E-02**	9.330E-05	5.079E-05	4.401E-05	3.37Ee-04	**-6.460E-06**
ADP-fossil	MJ	**1.643E-01**	1.229E-03	2.666E-04	5.802E-04	5.711E-03	**-1.155E-04**
WDP	m3	**9.893E-04**	1.448E-06	1.206E-04	6.814E-07	4.366E-05	**-7.145E-07**

LEGEND

- **A1-A3** A1: Raw Material Supply; A2: Transport; A3: Manufacturing
- **A4** Transport
- **A5** Construction Installation
- **C2** EoL Transport
- **C4** EoL Disposal
- **D** Reuse-Recovery Recycling Potential



RECYCLING/RECOVERY RATE

D1 - Thesis Scenario	D2 - Industry Scenario
-6.460E-06	-1.753E-04
-1.155E-04	-3.134E-03
-7.145E-07	-1.938E-05
Low Recovery (1.99%)	**High Recovery (53.9%)**

PRODUCT TYPE BASED ON POLYMER		WEIGHT (g)	WEEE RECYCLING RESIDUE RATE	BIOGENIC MATERIAL WEIGHT
P.1	Polypropylene	11.37	100%	0%
P.2	Polypropylene/Polyethylene	11.49	100%	0%
P.3	Polystyrene	13.26	100%	0%

Results per 1 kg of plastic spacer made of secondary material *(Adapted from Spritz Plast)*

INDICATOR	UNIT	A1-A3	A4	A5	C2	C4	D
GWP-fossil	kg CO2 eq.	1.47E+00	8.12E-03	4.42E-03	3.83E-03	2.94E-02	-2.83E-02
ADP-fossil	MJ	1.43E+01	1.07E-01	2.32E-02	5.05E-02	4.97E-01	-5.06E-01
WDP	m3	8.61E-02	1.26E-04	1.05E-02	5.93E-05	3.80E-03	-3.13E-03

Results for PP/PE (P.2) wheel spacer made of WEEE recycling residues *(Source: Author)*

INDICATOR	UNIT	A1-A3	A4	A5	C2	C4	D1 & D2
GWP-fossil	kg CO2 eq.	1.689E-02	9.330E-05	5.079E-05	4.401E-05	3.37Ee-04	-6.460E-06
ADP-fossil	MJ	1.643E-01	1.229E-03	2.666E-04	5.802E-04	5.711E-03	-1.155E-04
WDP	m3	9.893E-04	1.448E-06	1.206E-04	6.814E-07	4.366E-05	-7.145E-07

LEGEND

- **A1-A3** A1: Raw Material Supply; A2: Transport; A3: Manufacturing
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- **A5** Construction Installation
- **C2** EoL Transport
- **C4** EoL Disposal
- **D** Reuse-Recovery Recycling Potential

RECYCLING/RECOVERY RATE

D1 - Thesis Scenario	D2 - Industry Scenario
-6.460E-06	-1.753E-04
-1.155E-04	-3.134E-03
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Low Recovery (1.99%)	High Recovery (53.9%)

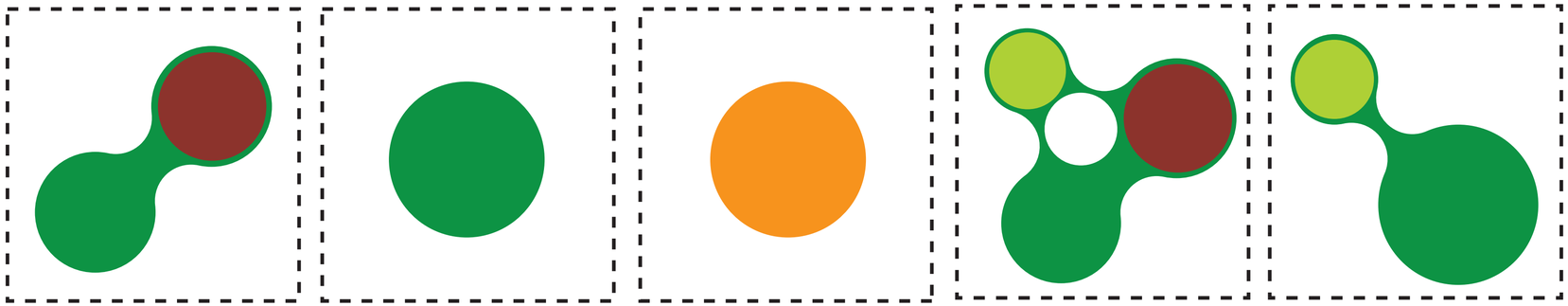


REC-HERO

WAS IT POSSIBLE?

Processing “waste of the waste” plastics for a hidden layer of construction that offers a new circular route for rejected plastics that are destined for incineration

How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?



100 wt% WEEE-sourced PP/PE

100 wt% WEEE-sourced PP

100 wt% WEEE-sourced PS

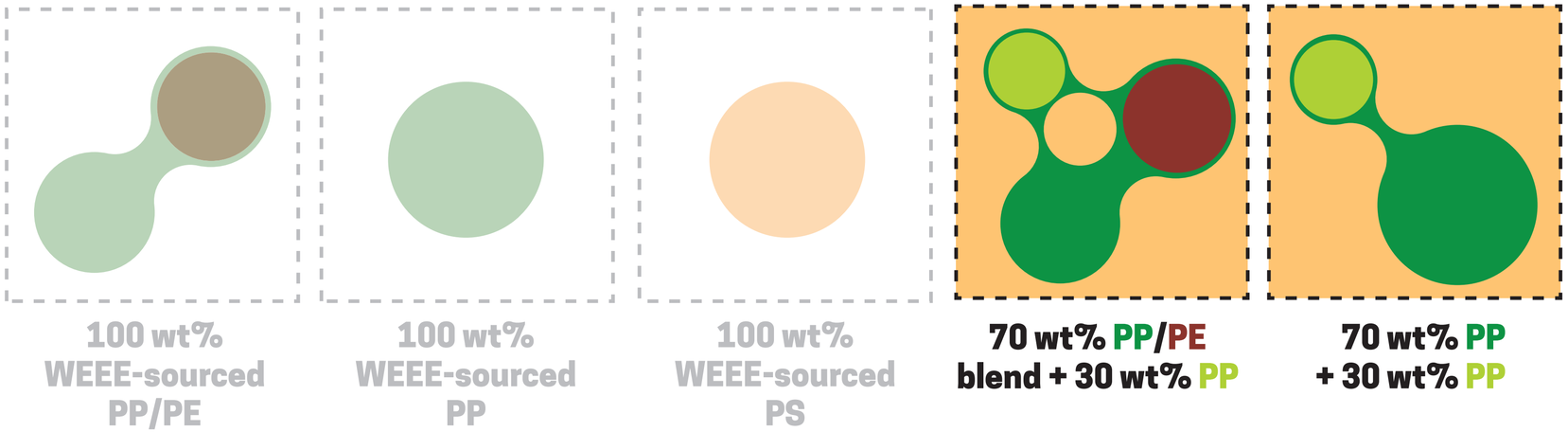
70 wt% PP/PE blend + 30 wt% PP

70 wt% PP + 30 wt% PP

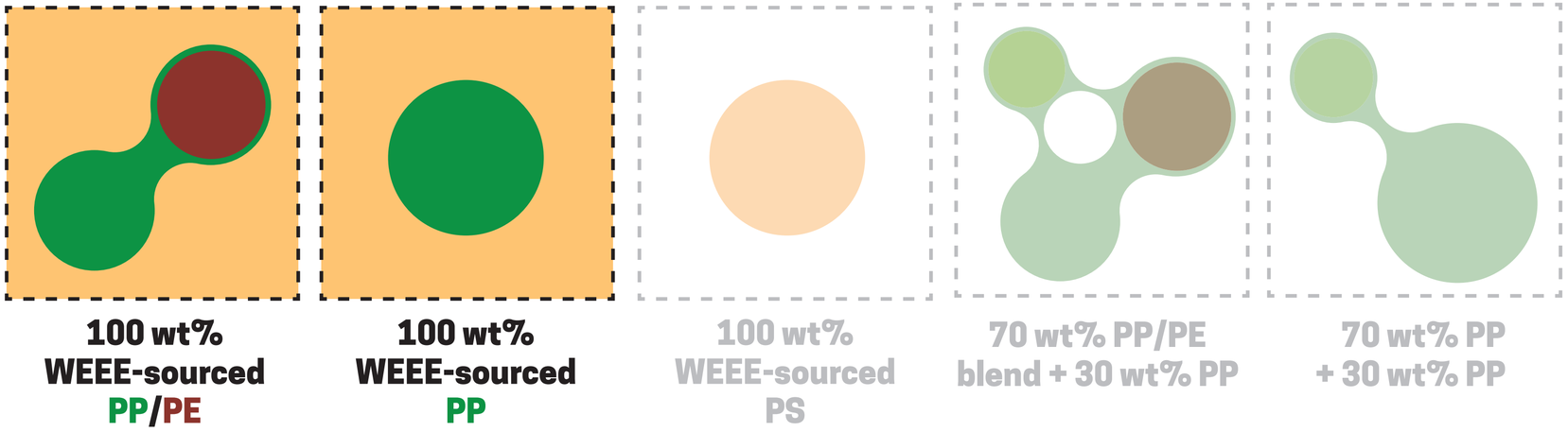
WAS IT POSSIBLE?

Processing "waste of the waste" plastics for a hidden layer of construction that offers a new circular route for rejected plastics that are destined for incineration

How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?



SCIENTIFIC CONCLUSION



HIGH-LEVEL CONCLUSION

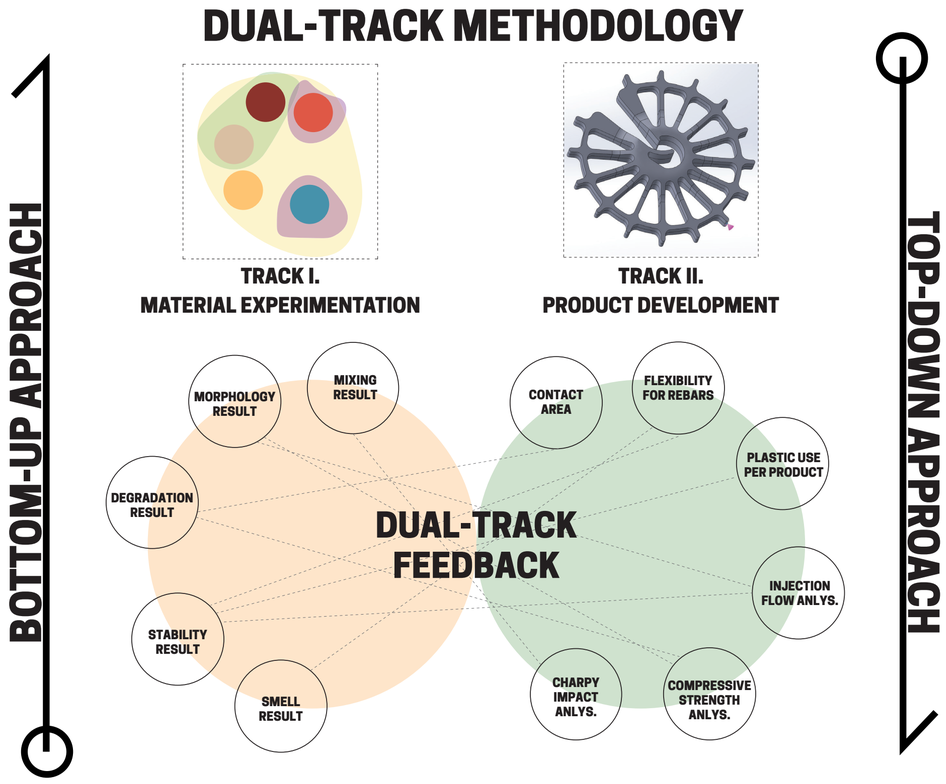
How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?











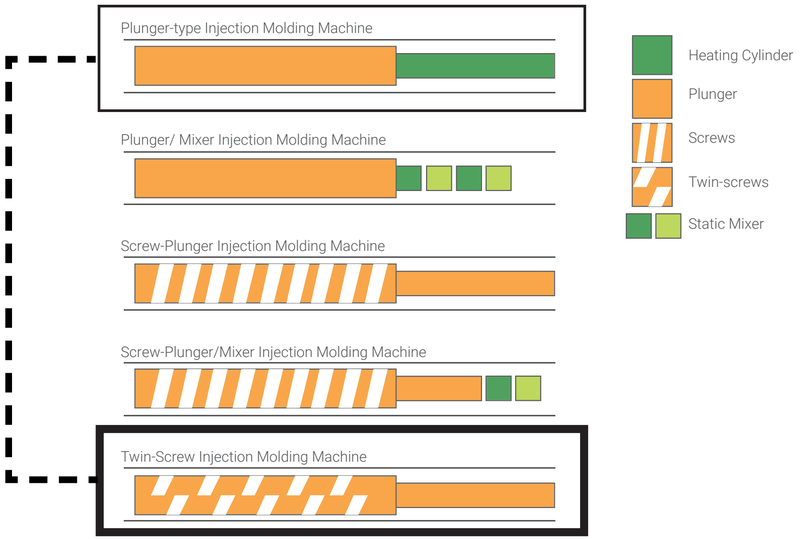
How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?

	POLYMER SELECTION	INJECTION PARAMETERS	DESIGN OPTIMIZATION	APPLICABILITY
SCIENTIFIC CONCLUSION				
HIGH-LEVEL CONCLUSION				

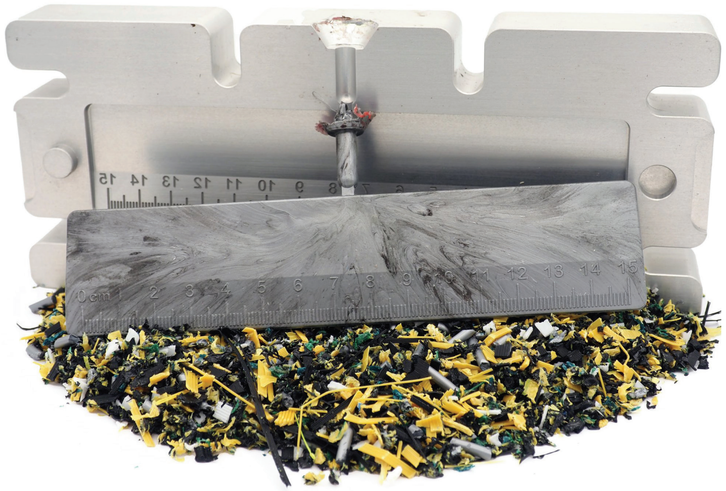
How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?

POLYMER SELECTION

SCIENTIFIC CONCLUSION



Different types of injection molding machines (Adapted from: Han et al., 1977)



Source: Sustainable Design Studio

SUSTAINABLE DESIGN STUDIO

How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?

	POLYMER SELECTION	INJECTION PARAMETERS	DESIGN OPTIMIZATION	APPLICABILITY
SCIENTIFIC CONCLUSION				
HIGH-LEVEL CONCLUSION				

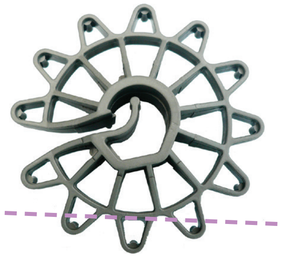
How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?



SPACER WITH CLIP-ON/OFF ACTION



TOWER SPACER



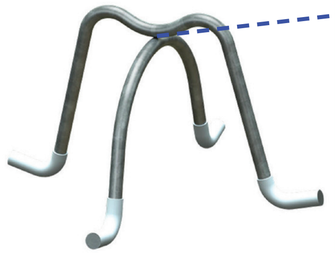
WHEEL SPACER



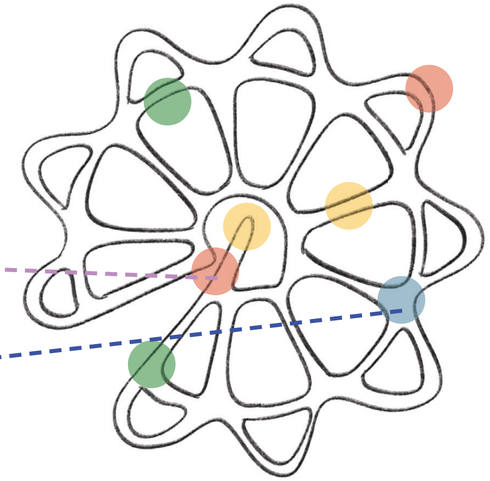
CEMENTITIOUS BLOCK SPACER



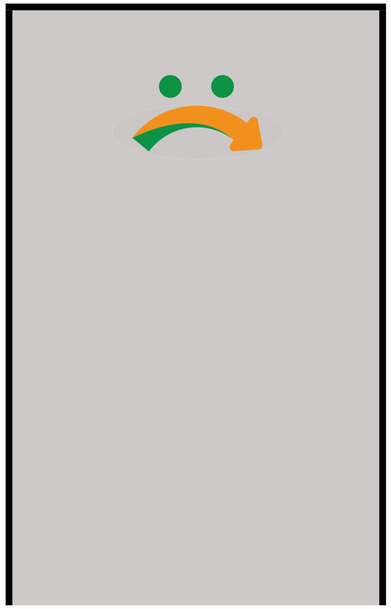
CONTINUOUS LINE SPACER



STEEL WIRE CHAIR



RANGE 1: IDEAL (10/10)
RANGE 2: ACCEPTABLE (7/10)
RANGE 3: RISKY (4/10)
RANGE 4: FAILURE (0/10)



How can plastic residues from WEEE recycling be processed into an optimized injection-moldable building component?

P5 Presentation

REC-HERO



TU Delft Delft University of Technology