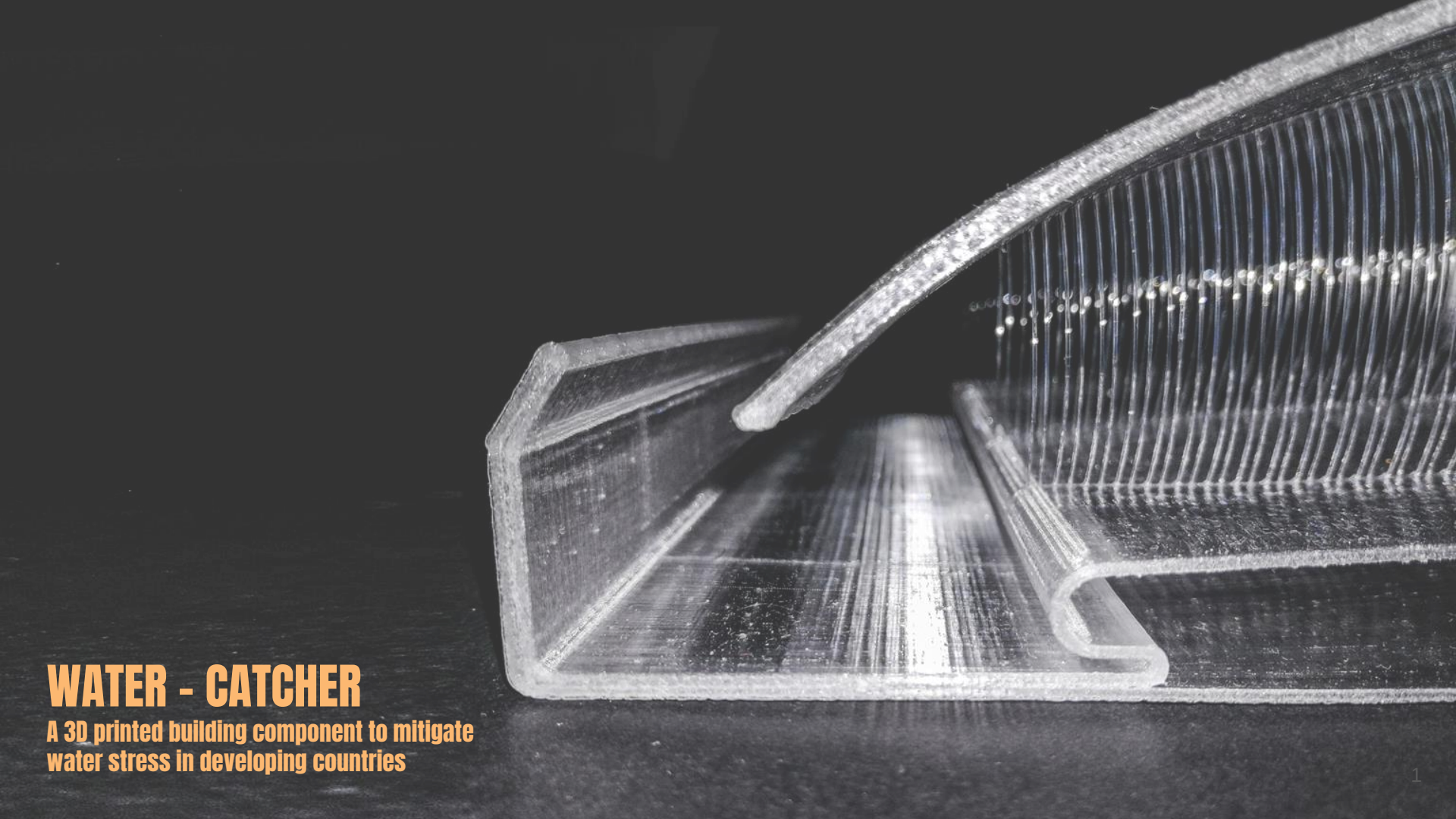
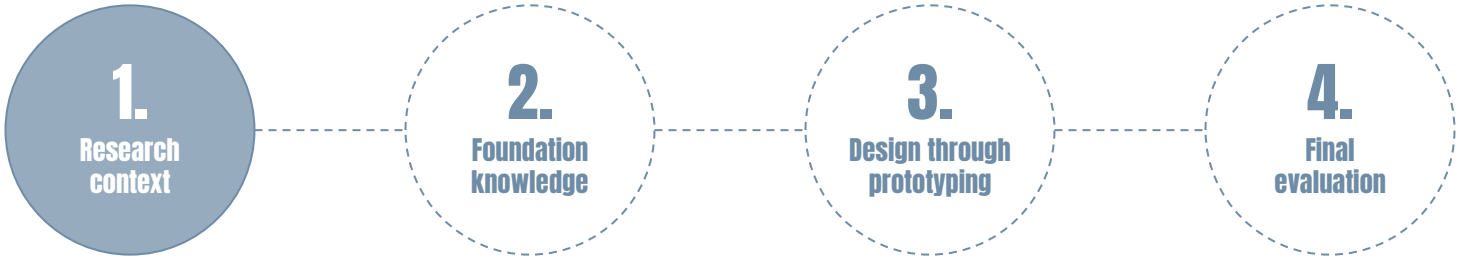


WATER - CATCHER

A 3D printed building component to mitigate water stress in developing countries

Index


1.
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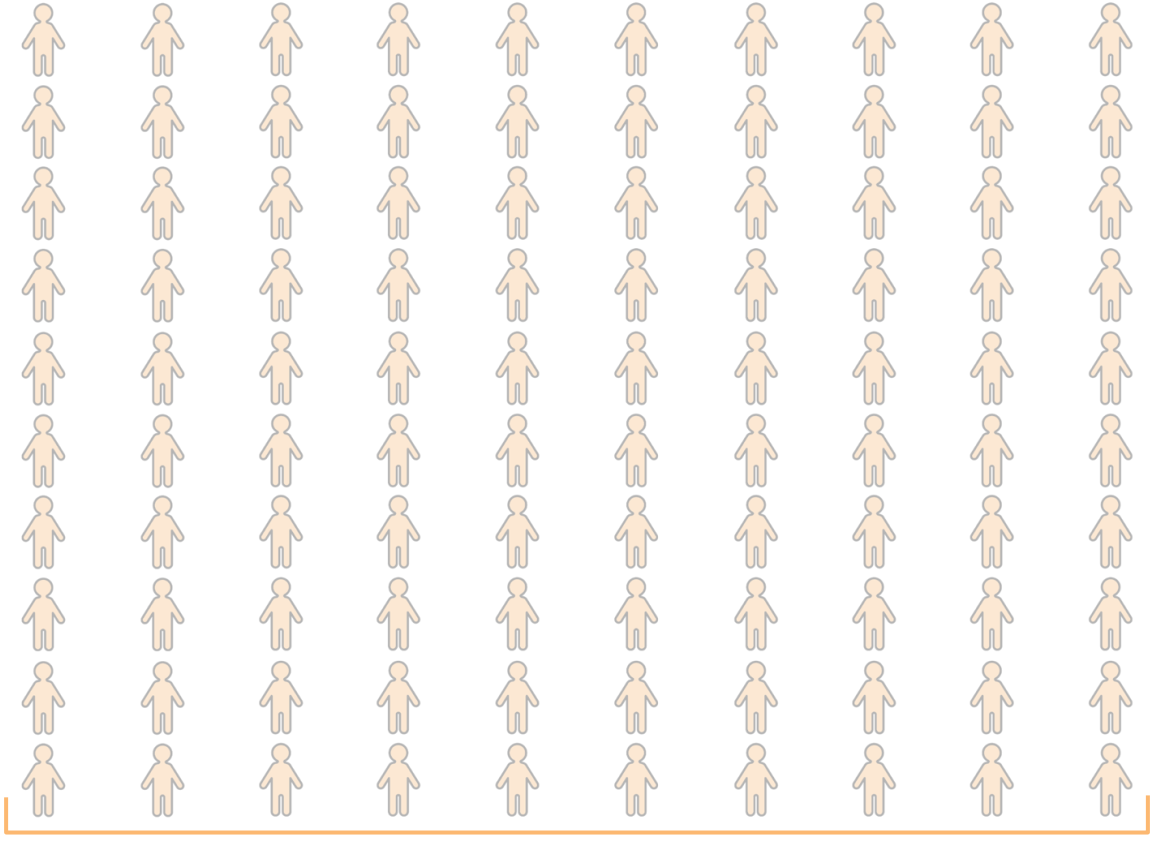
Final evaluation

Research context



WORLD POPULATION BY 2100: 11 BILLIONS

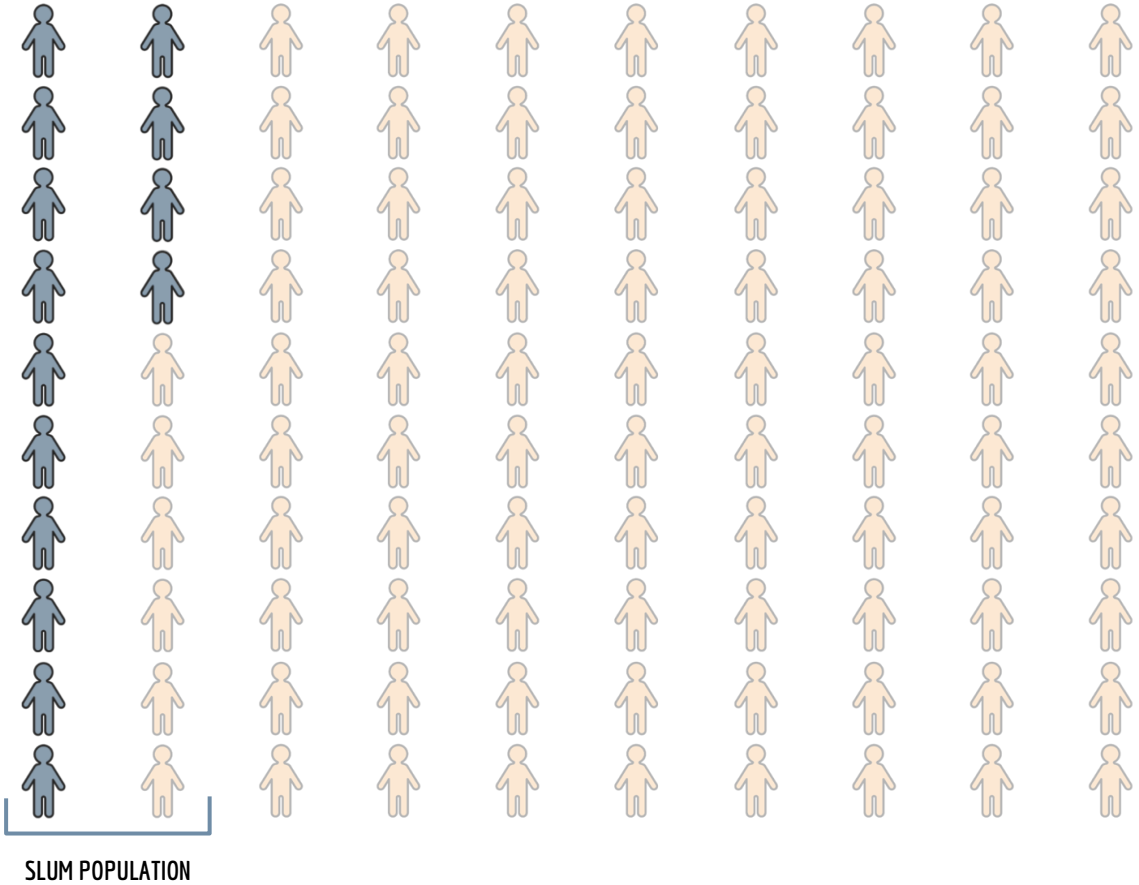
01

Research context

URBAN POPULATION SHARE

01

Research context



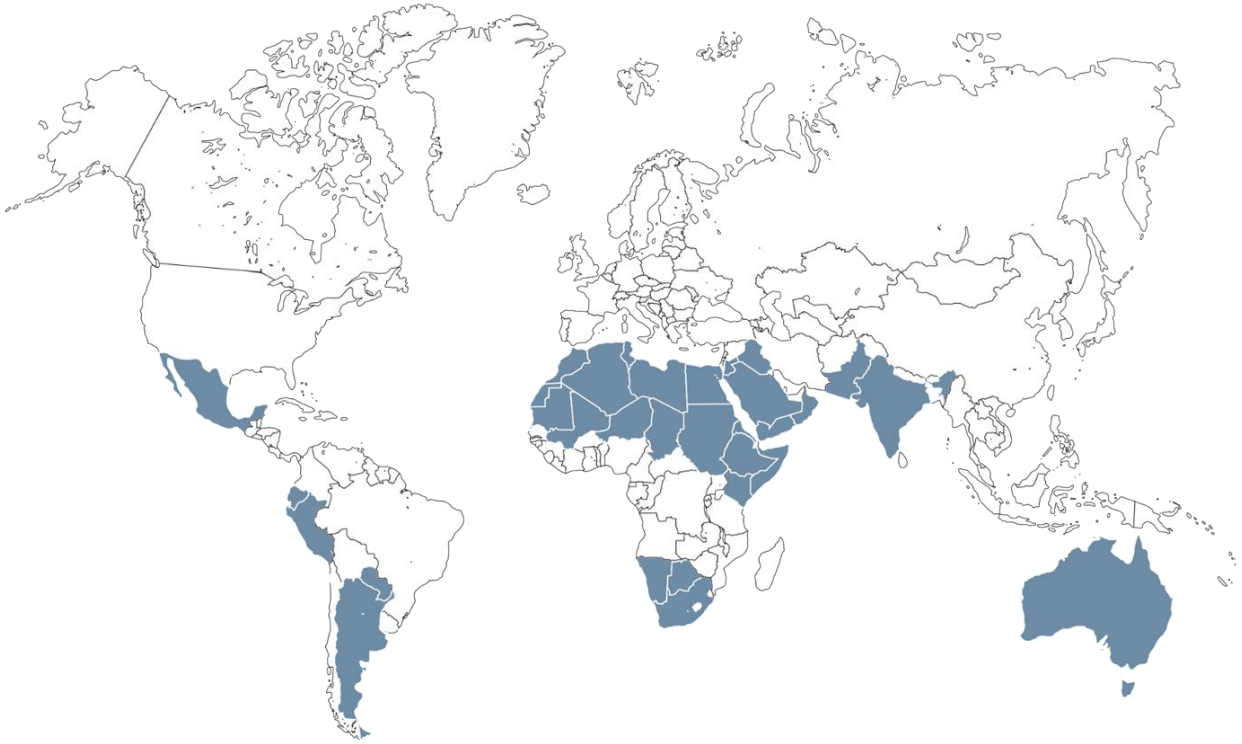
01

Research context

ASIAN AND AFRICAN SHARE OF POPULATION

01

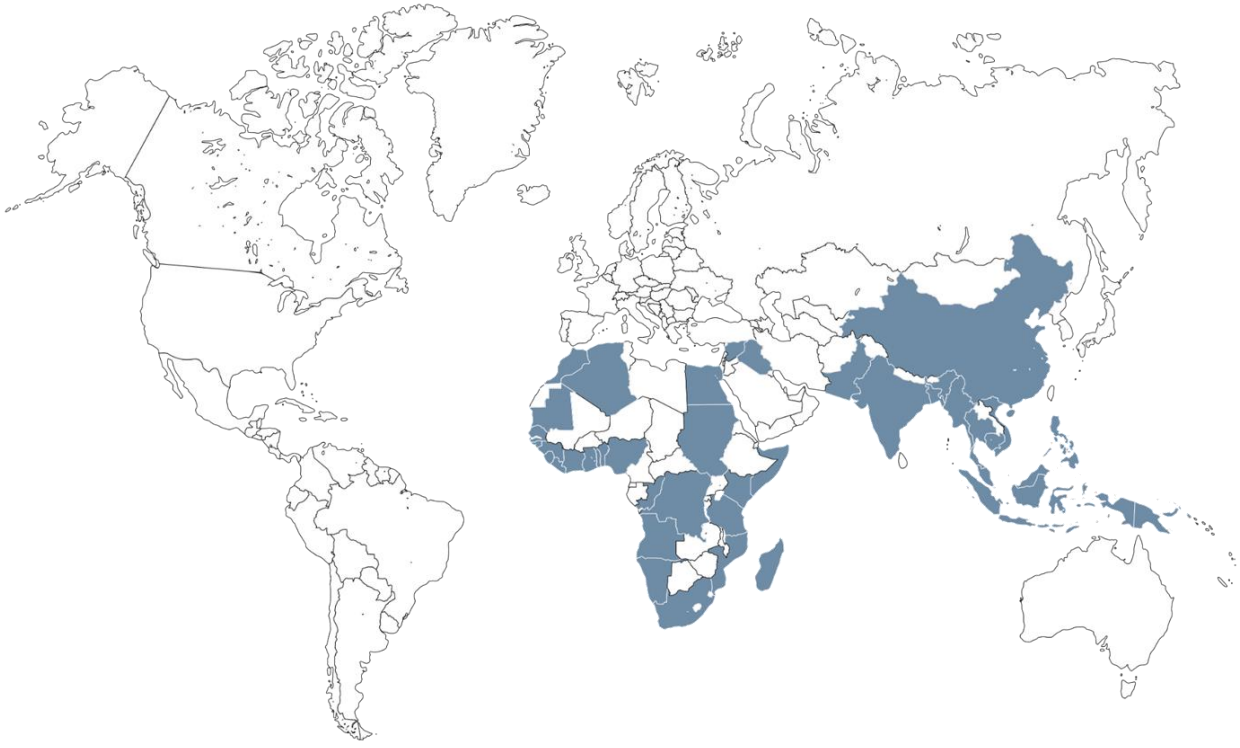
Research context



"In 2018, 844 million people still lacked a basic drinking water service" (UN, 2018)

01

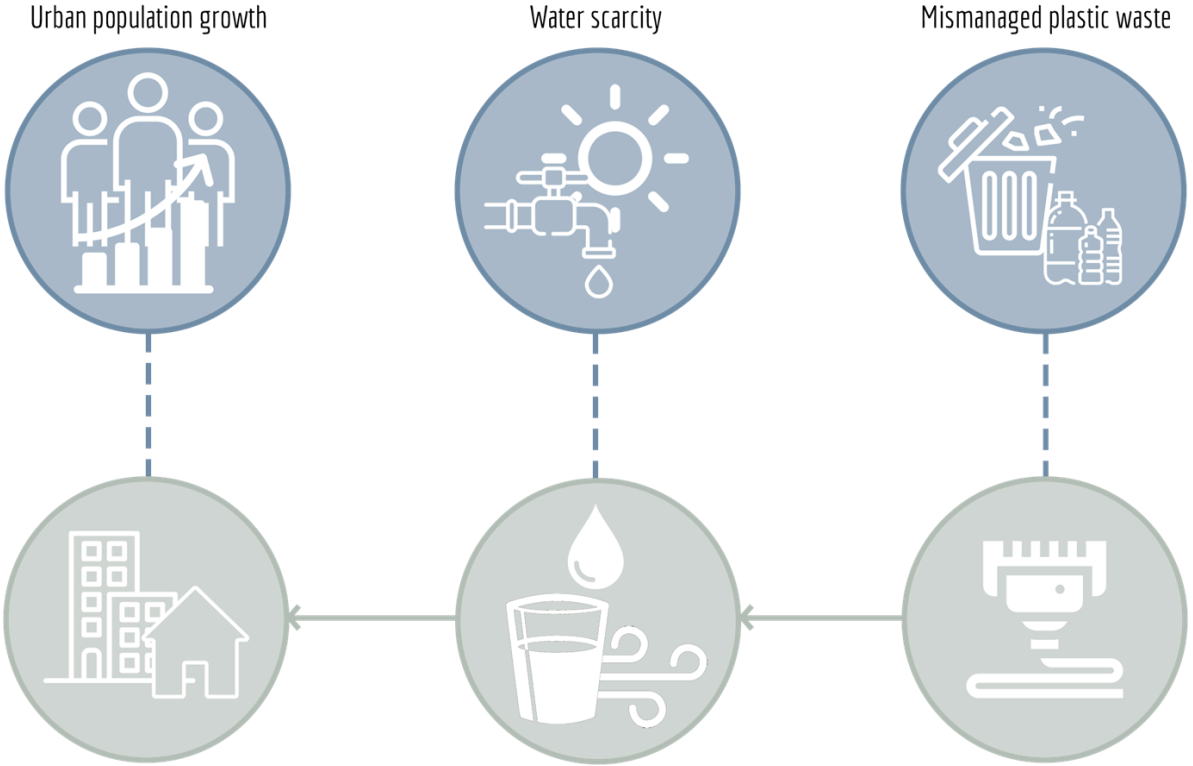
Research context



"40% of produced plastic is estimated to be single-use" (Parker, 2019)

01

Problem statement

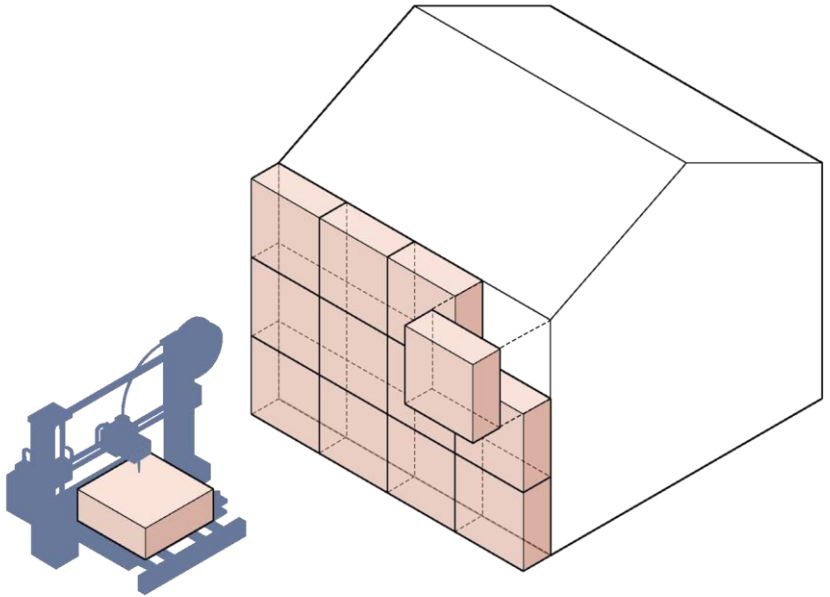


Research question

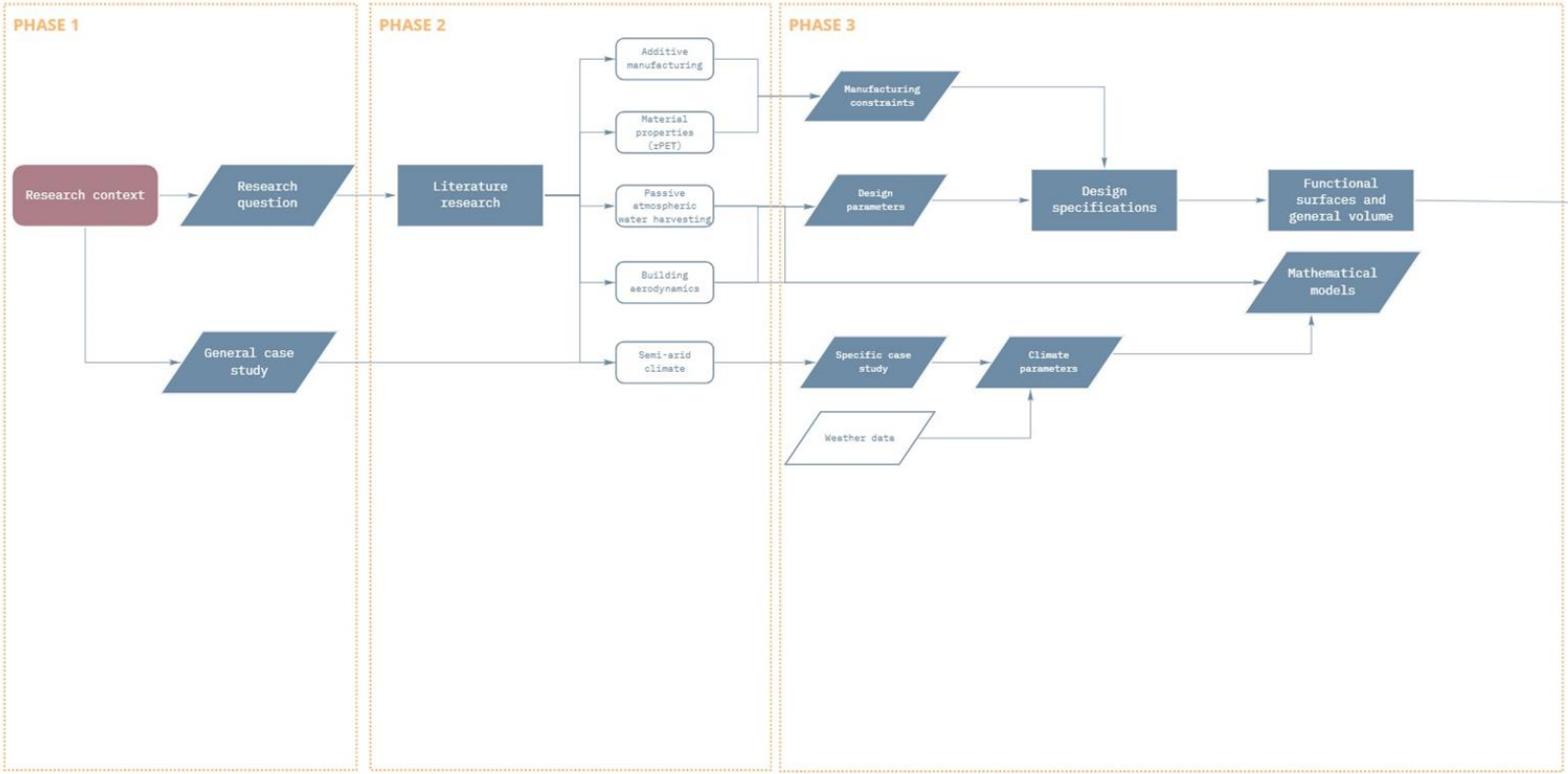
"How can AM (Additive Manufacturing) with rPET be used to design an atmospheric water harvesting system that can be integrated into a building component and therefore mitigate water stress in semi-arid regions?"

Research objective

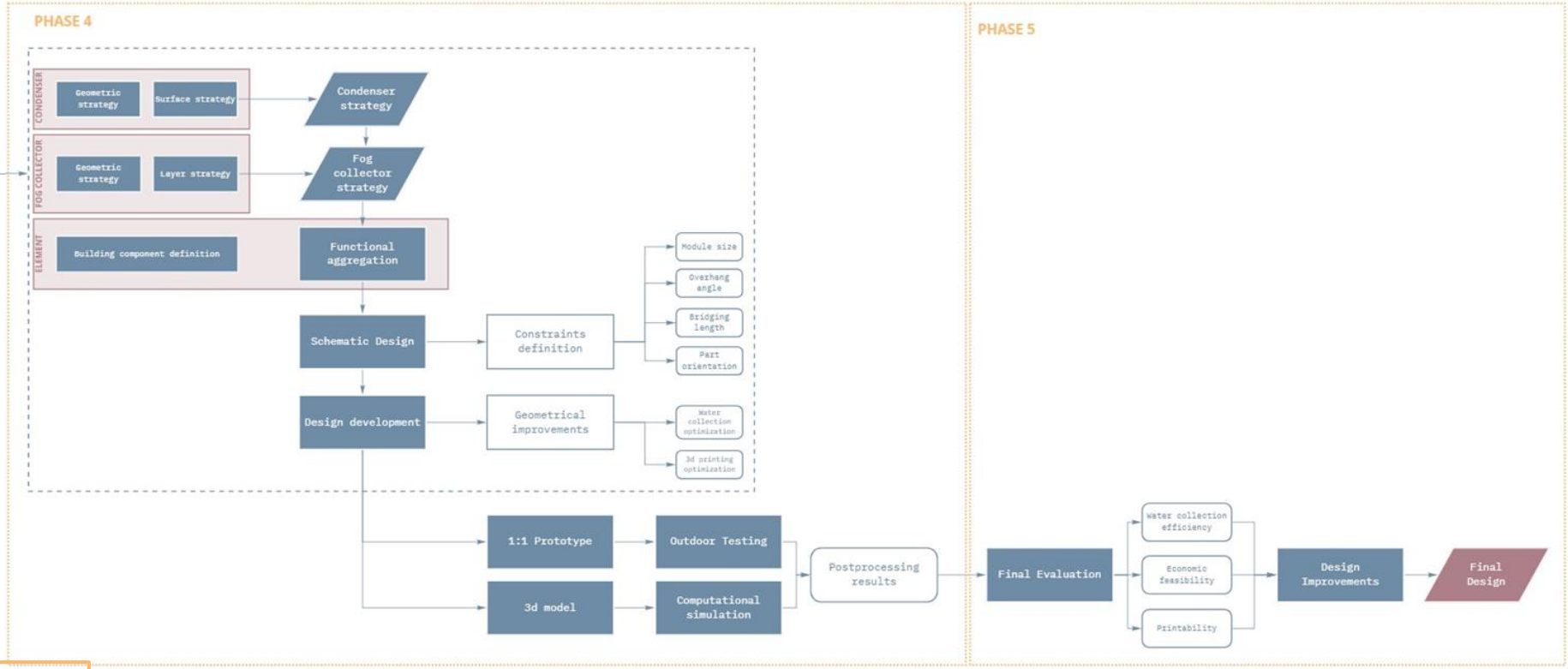
"The design of a mono-material modular building component, optimized for atmospheric water harvesting and for Additive Manufacturing with recycled PET plastic. The design has to be adaptable to different climatic conditions, be easily manufacturable locally and on demand."

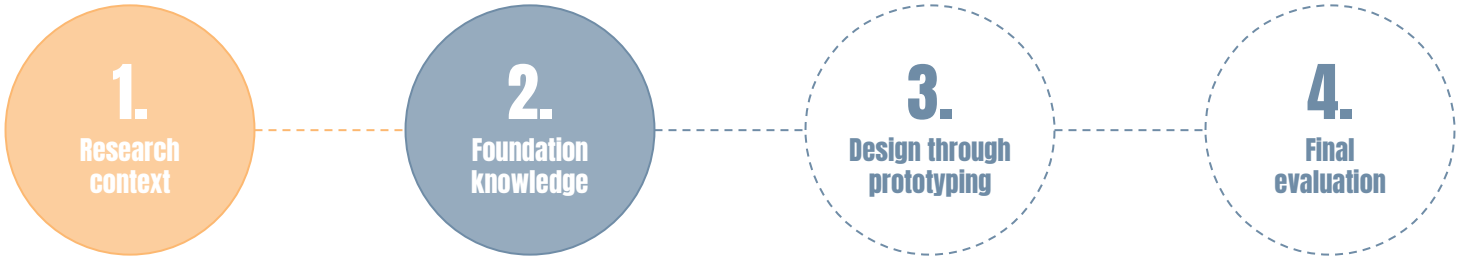


Research methodology



Research methodology




1.
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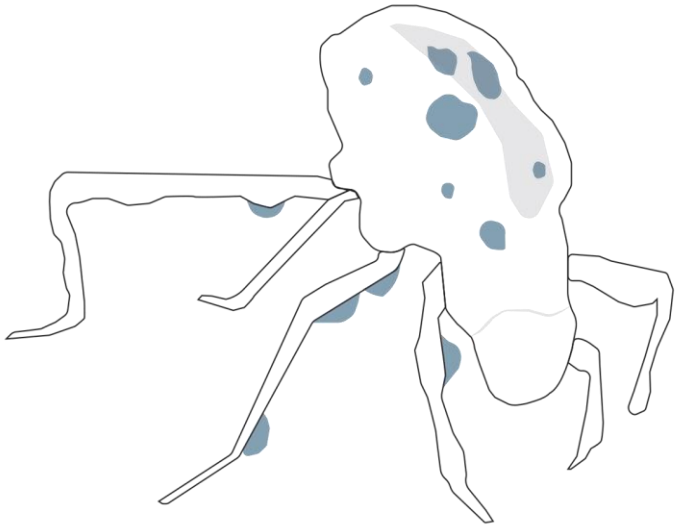
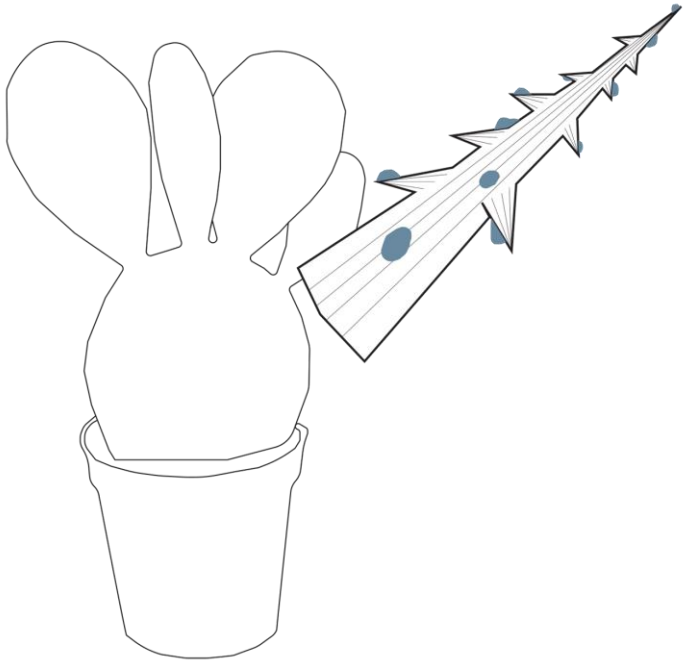
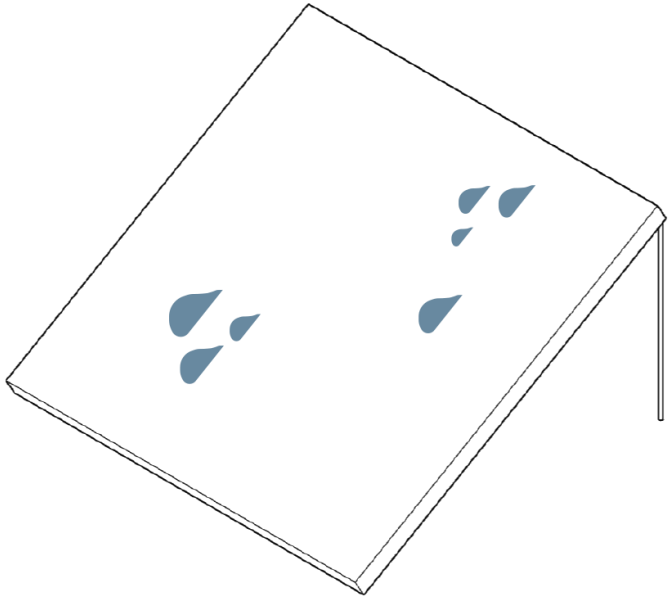
Final evaluation

Biomimetic inspiration





Radiative condensers



Condensation process

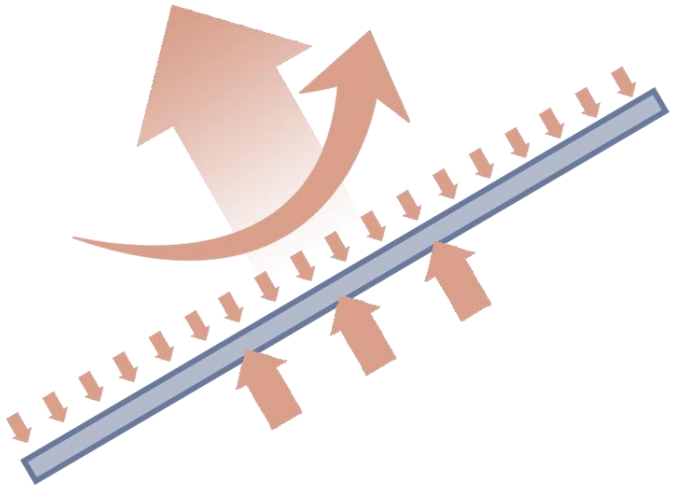
Radiative heat loss

$$P = LE + Q_{cond} + Q_{conv}$$

Latent heat transfer

Conduction heat gain

Convection heat gain



Condensation process

Relative Humidity

Saturated vapor pressure

T_{amb}

Wind speed

Heat transfer coefficient

Saturated vapor pressure close to surface

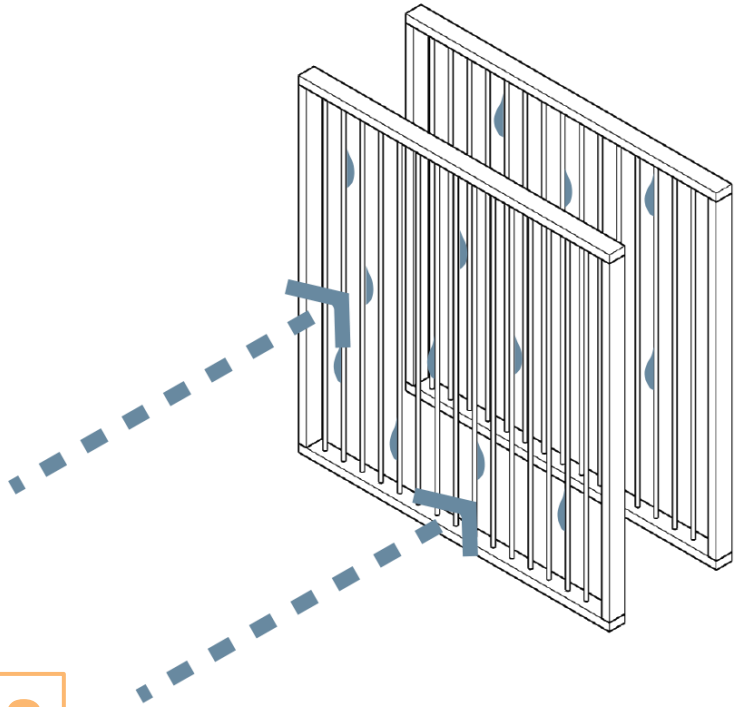
T_{foil}

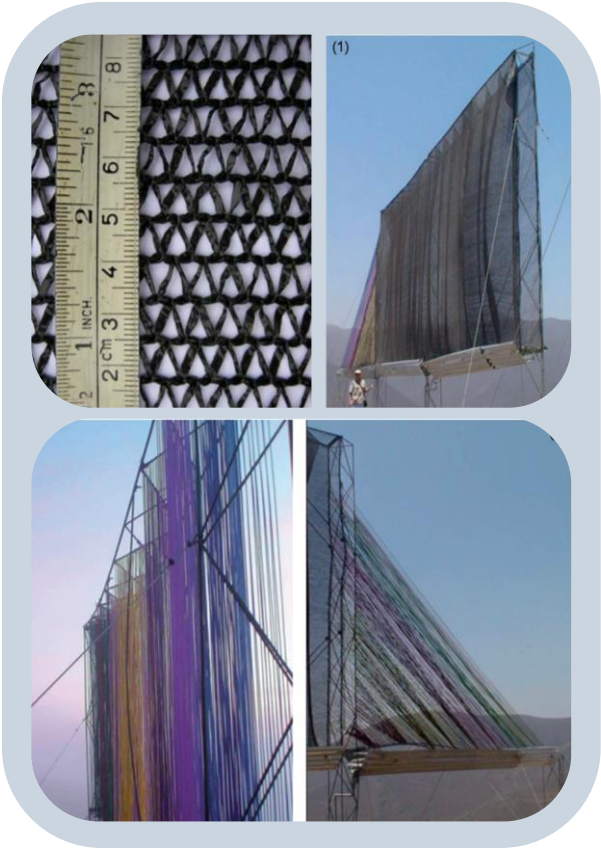
$$E = \frac{h(RHe'_{amb} - e'_f)}{L\xi}$$

$$T_f = \frac{LE + \alpha_{conv}T_e + \frac{k}{x}T_e + SVF\alpha_{rad}T_{sky}}{SVF\alpha_{rad} + \alpha_{conv} + \frac{k}{x}}$$

03

Fog collectors





02

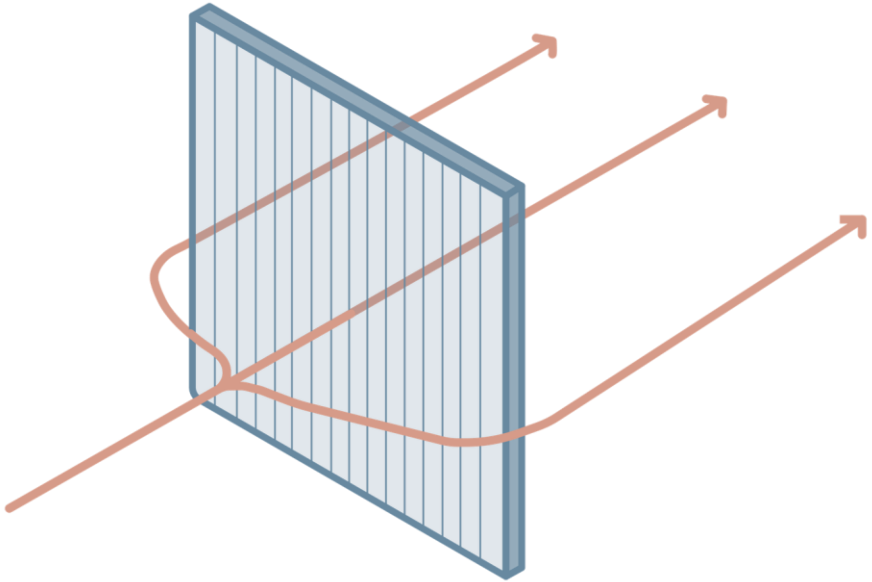
Fog collection process

$$\eta_{tot} = \eta_{ACE}\eta_{capt}\eta_{drain}$$

$$\eta_{ACE} = \varphi\chi$$

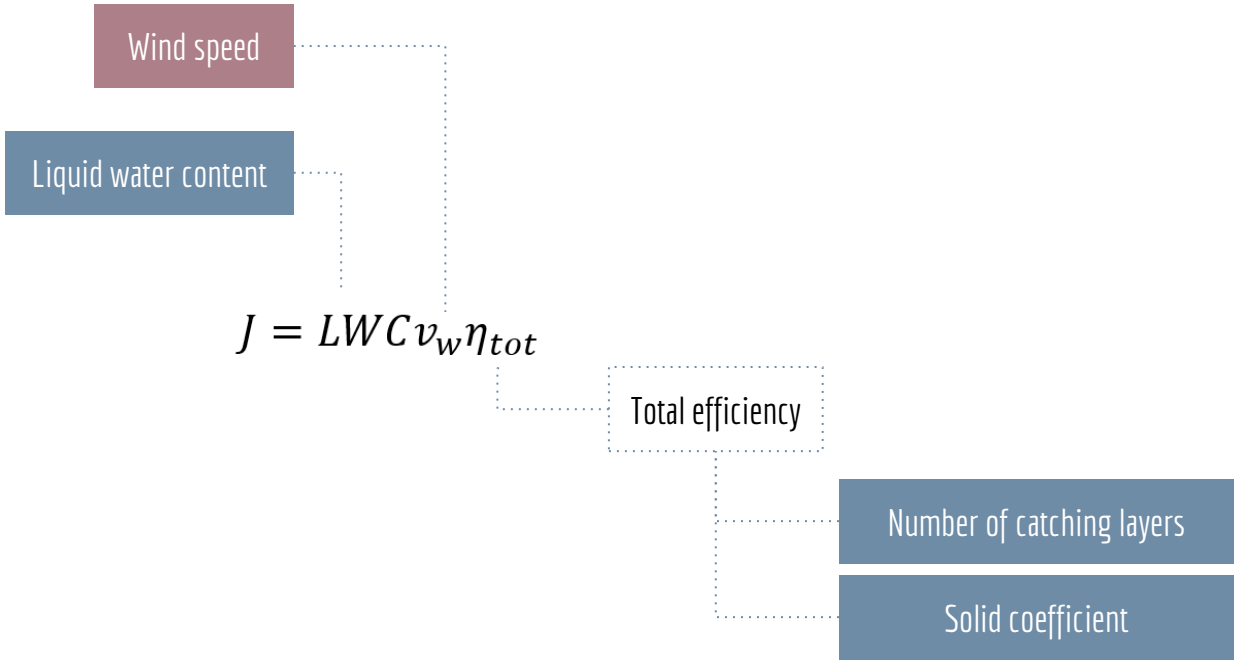
$$\chi = (1 - (1 - s)^N)$$ Incident fog fraction

$$\varphi = \sqrt{\frac{C_D}{k}}$$ Filtered fog fraction



03

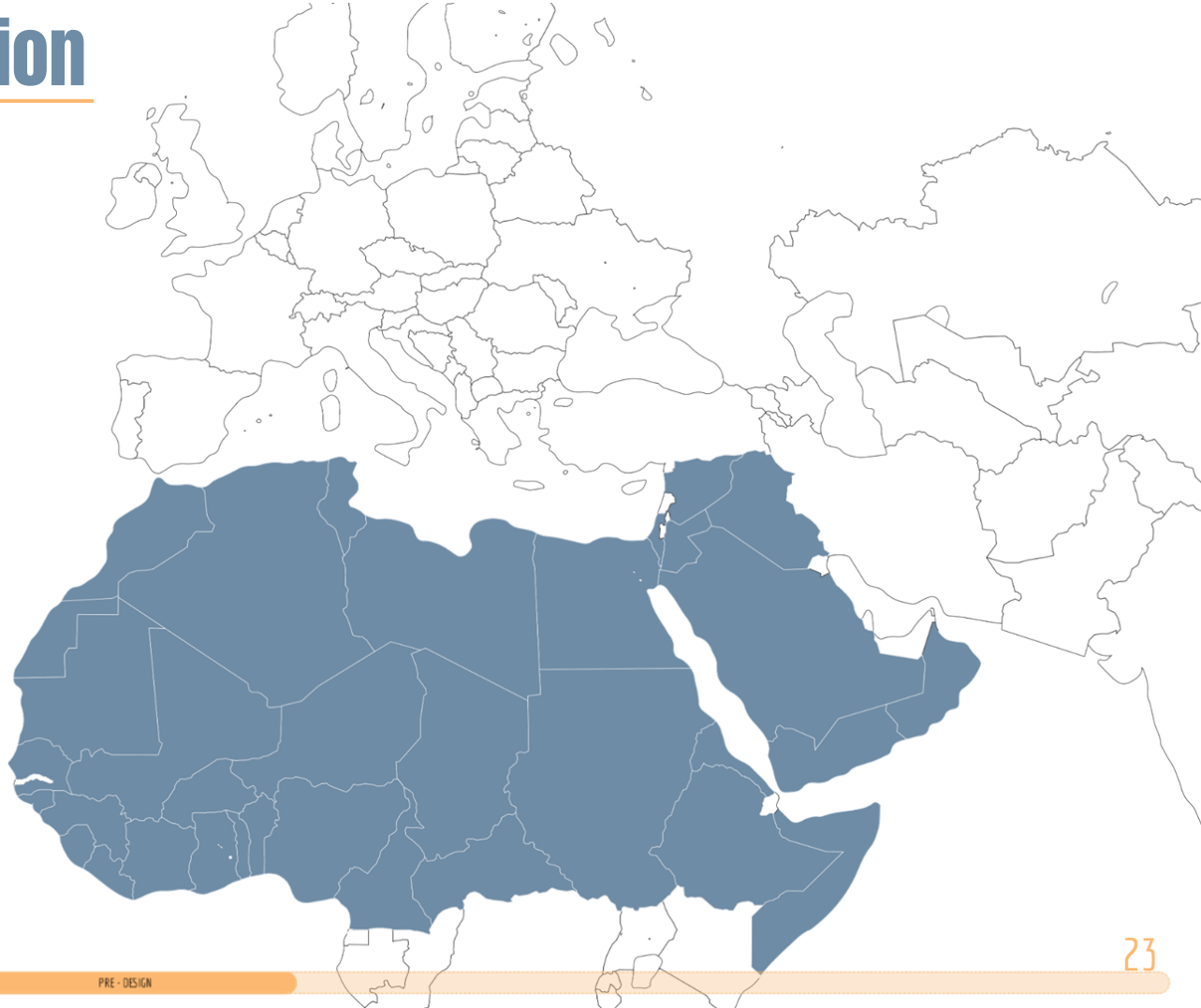
Fog collection process



Case study definition

Choice of a climate area:

- predicted urban growth
- predicted water scarcity
- mismanaged plastic waste

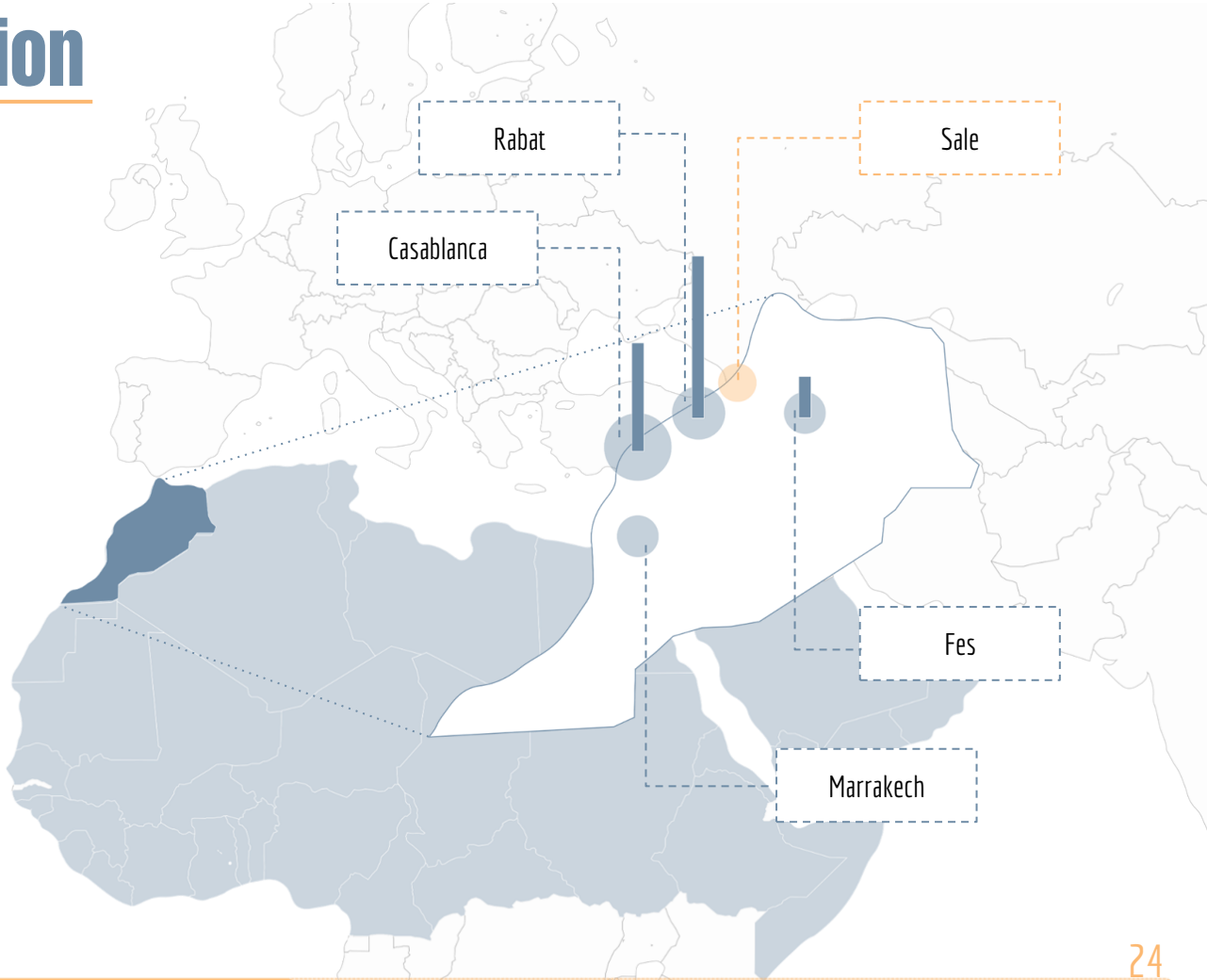


03

Case study definition

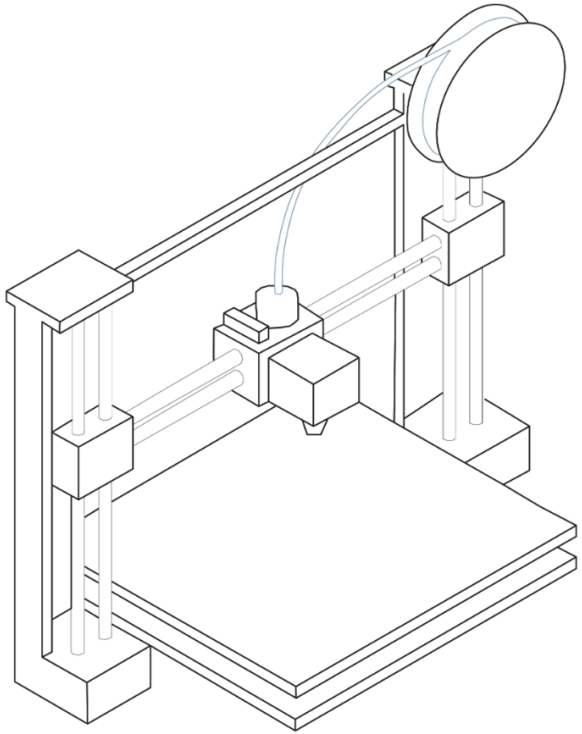
Choice of a country:
- availability of weather data
- similar precedents in literature

Choice of a location:
- population
- favourable weather conditions



03

Additive Manufacturing

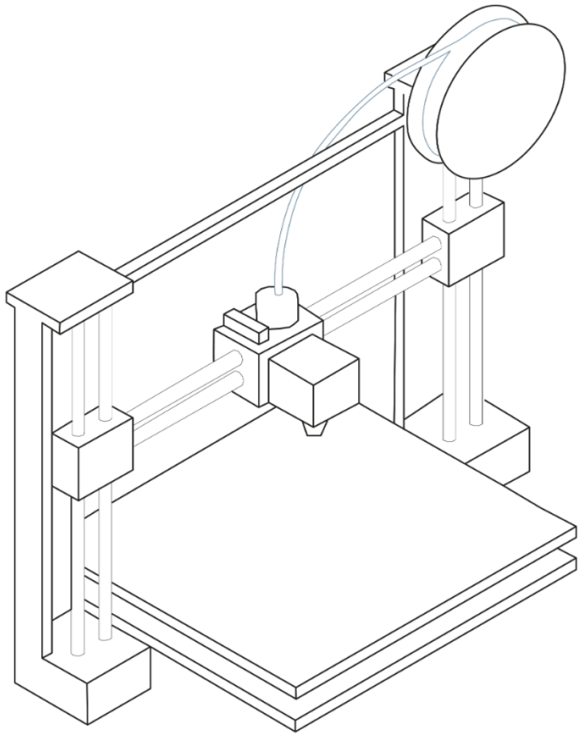


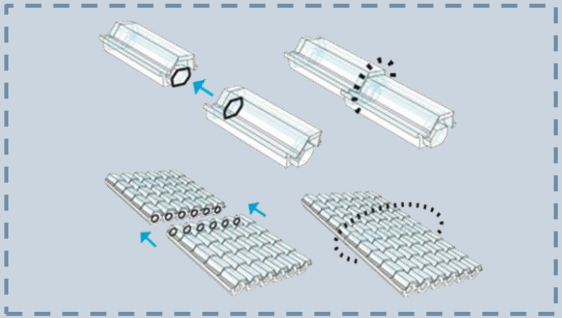
Recycled filaments from fishing nets

Plastic flakes and granulate from waste

02

Additive Manufacturing



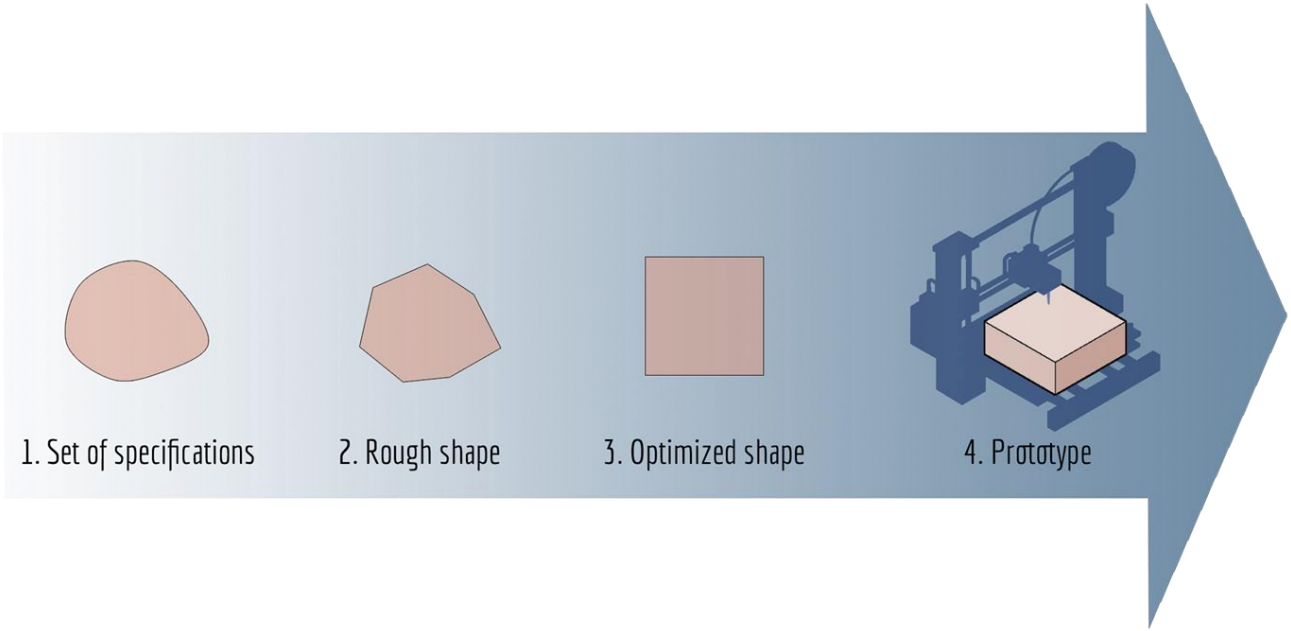


3d printed roof system

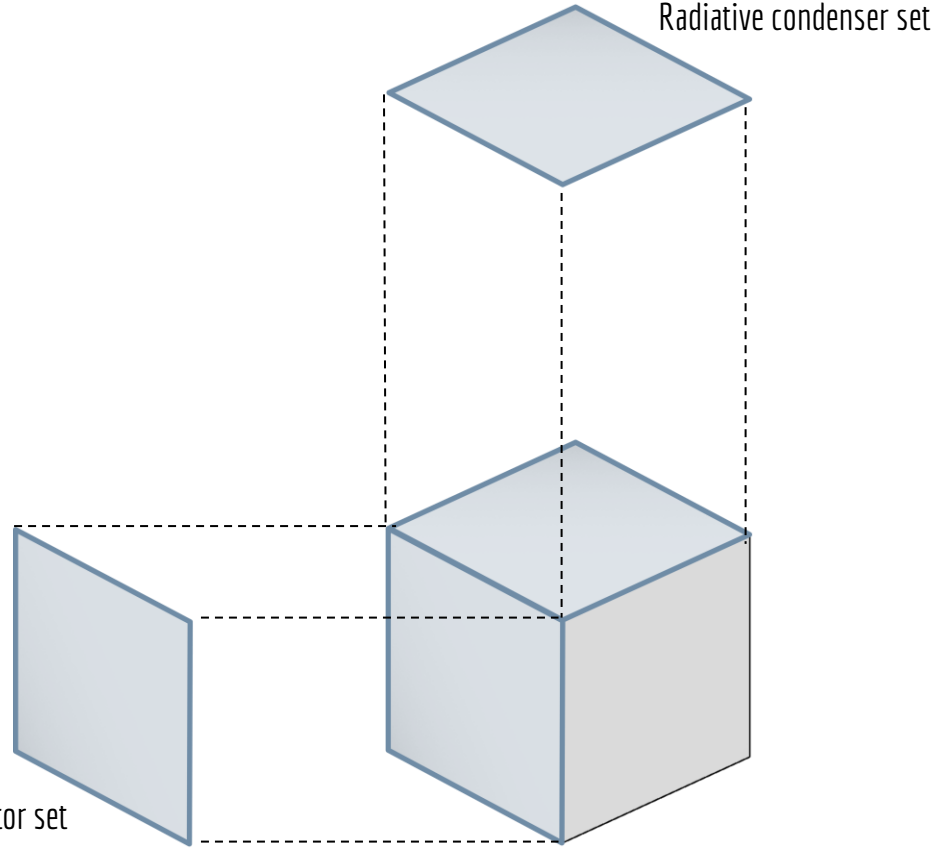
Fluid morphology - 3d printed facades

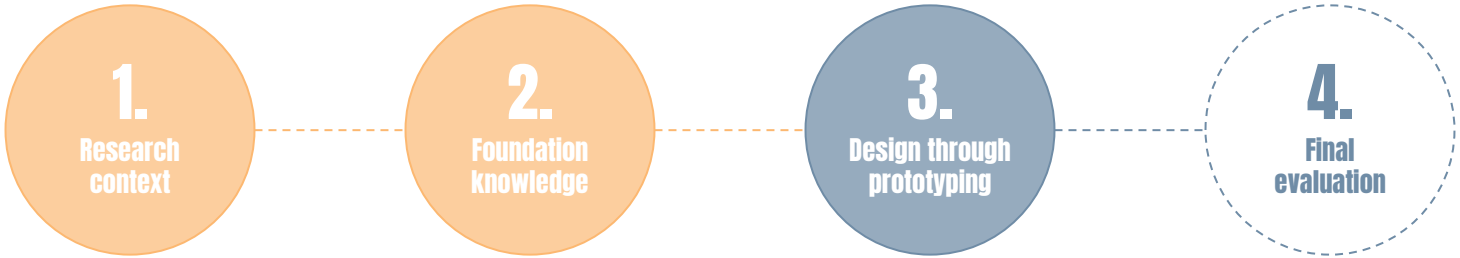
02

Pre-design for AM



Pre-design for AM

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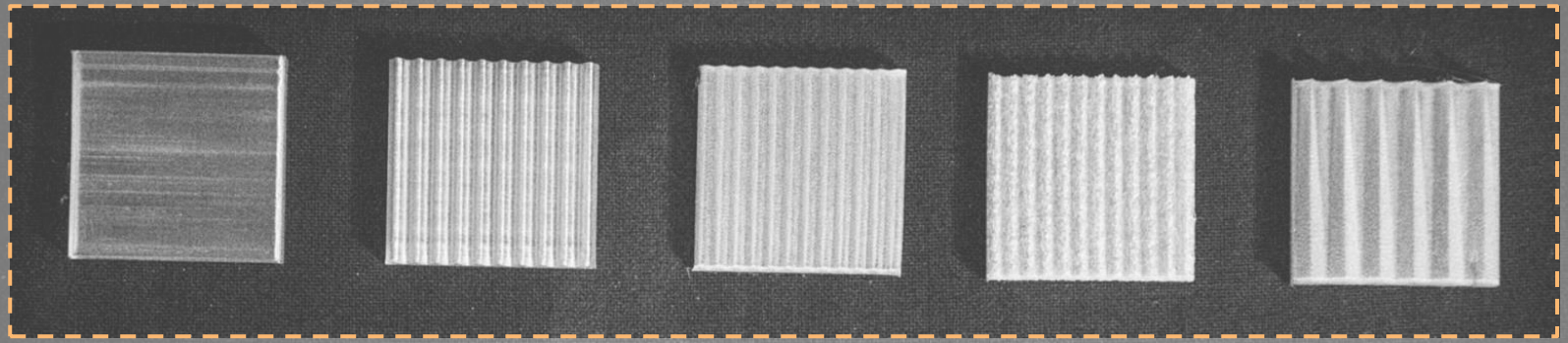
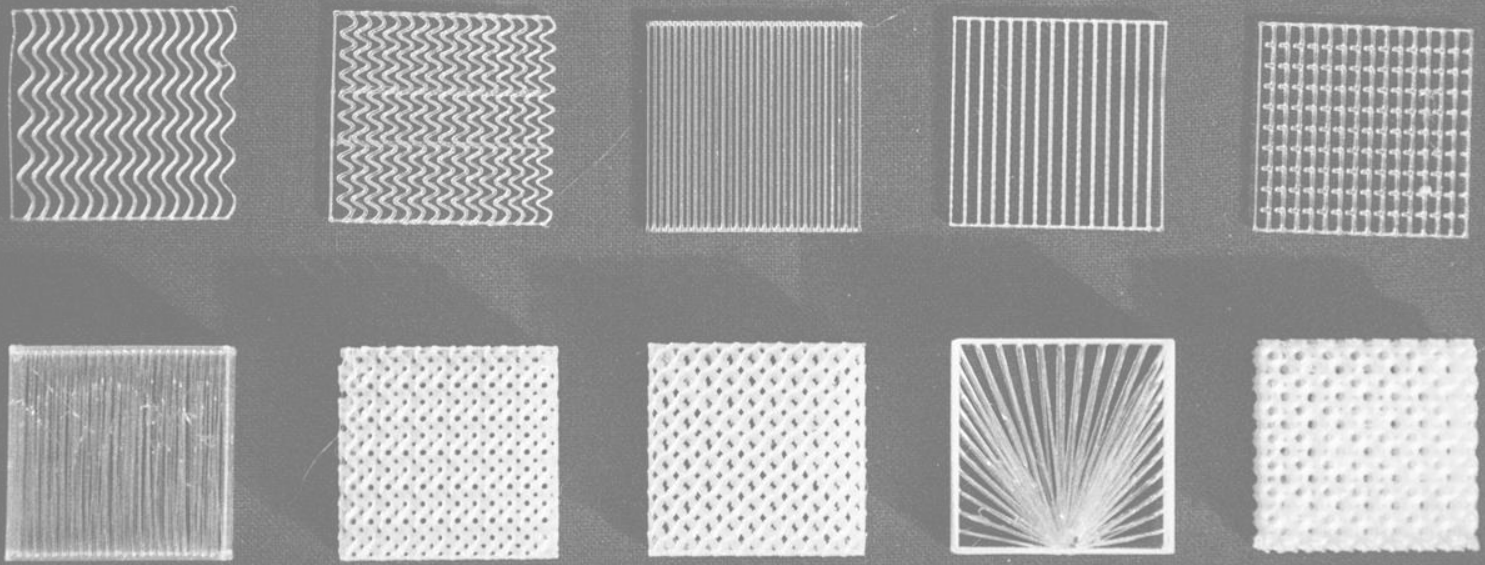
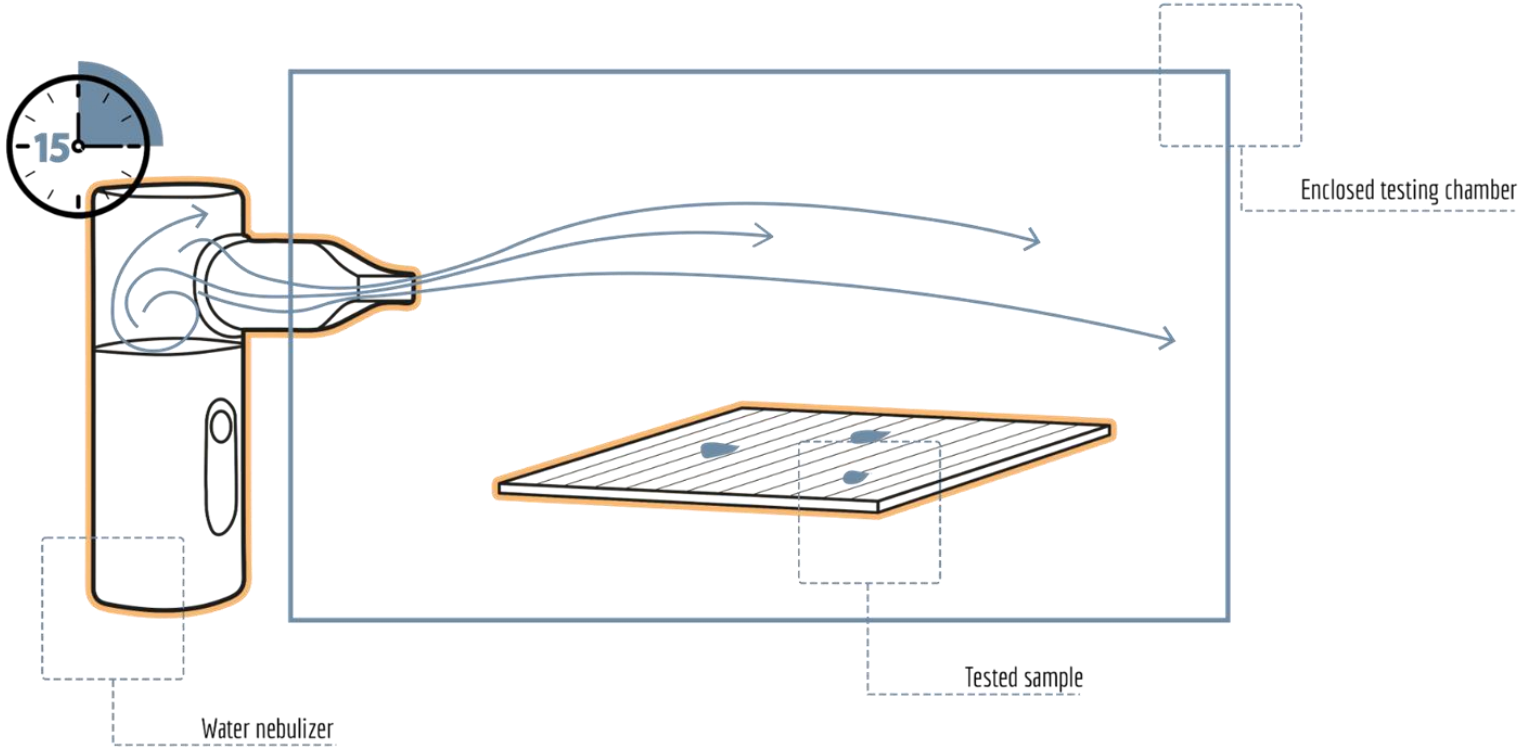




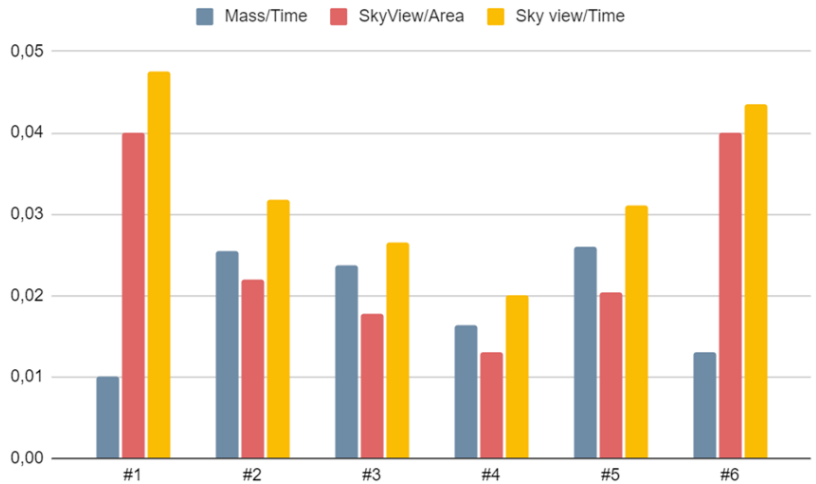
Nucleation rate tests



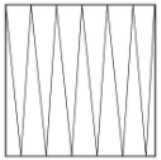
04

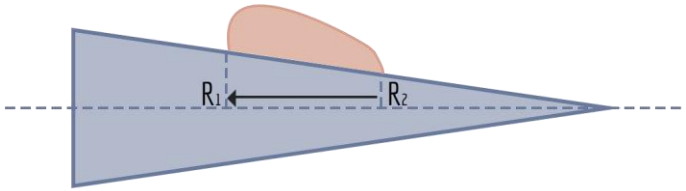
Nucleation rate tests

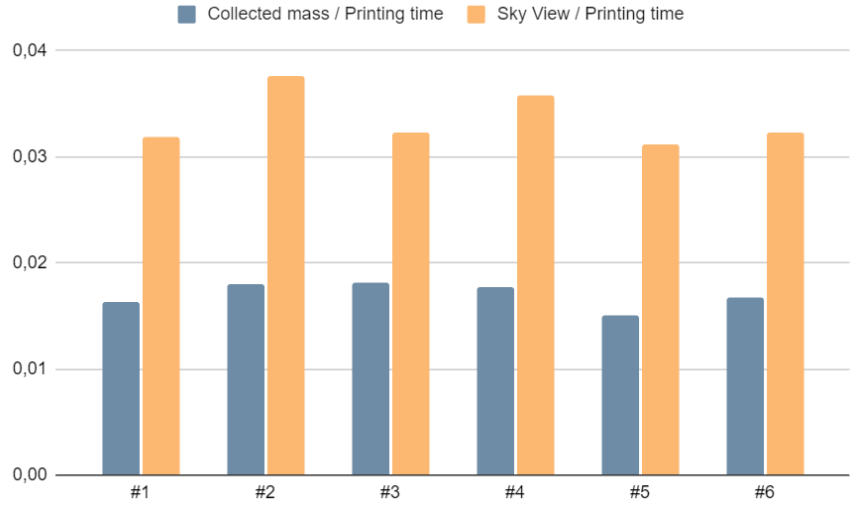
#	Profile	Description	Area [mm2]	Average sky view [%]	Sample weight [g]	Printed length [m]	Printing time [min]	Collected water mass [g]	Collected mass/printing time	Sky view/Area	Sky view/Printing time
#1		Flat sample	2500	100	2,82	0,94	21	0,21	0,010	0,040	4,76
#2		Ondulated (Sharp)	3905,12	86	3,4	1,13	27	**0,69**	**0,026**	**0,022**	**3,19**
#3		Ondulated (Round)	4037,19	71,68	3,5	1,15	27	0,64	0,024	0,018	2,65
#4		Ondulated (Square)	5500	72	4,22	1,39	36	0,59	0,016	0,013	2,00
#5		Ondulated (Concave)	4103	84	3,41	1,14	27	**0,7**	**0,026**	0,020	3,11
#6		Bumpy	2500	100	3,84	1	23	0,30	0,013	0,040	4,35



Nucleation rate tests

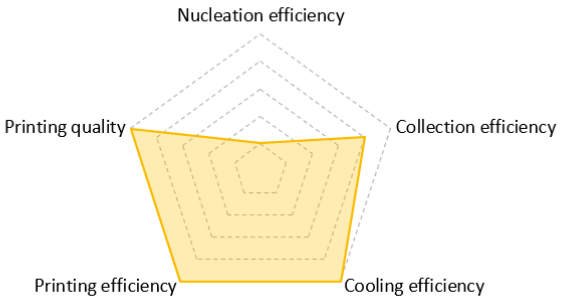
#	Pattern	Laplace Curvature		Number of ridges	Area [mm2]	Average sky view [%]	Sample weight [g]	Printing time [min]	Collected water mass [g]	Collected mass/printing time	Sky view/Printing time
		Δr Ridges [mm]	Δr Grooves								
#1		2	0	12	3305	86	2,72	27	0,44	0,016	3,185
#2		2	0	6	2759	94	2,72	25	0,45	0,018	3,760
#3		2	2	12	3483	84	2,73	26	0,47	0,018	3,231
#4		2	2	6	2809	93	2,72	26	0,46	0,018	3,577
#5		2	4	12	3868	81	2,75	26	0,39	0,015	3,115
#6		2	4	6	3100	87	2,73	27	0,45	0,017	3,222



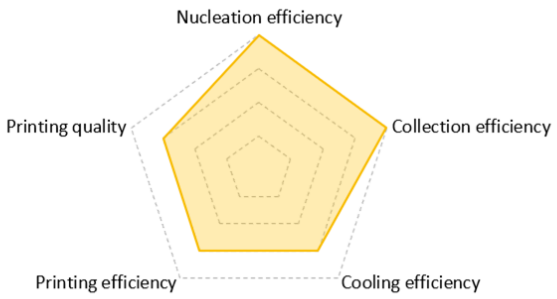


Radar charts

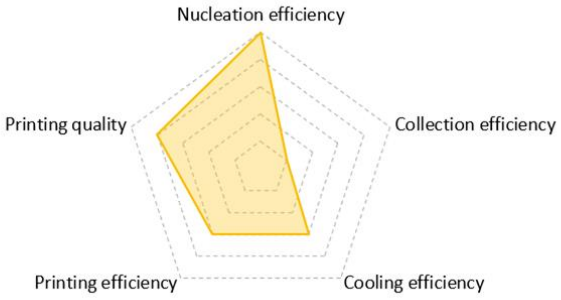
Flat condenser



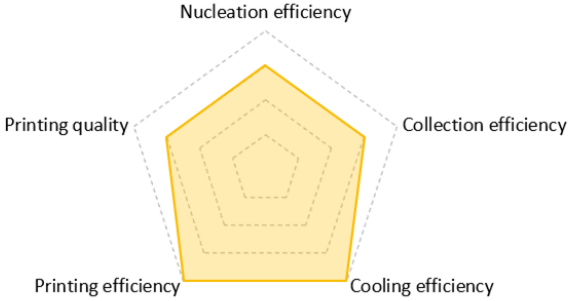
Ondulated condenser - Parallel layers



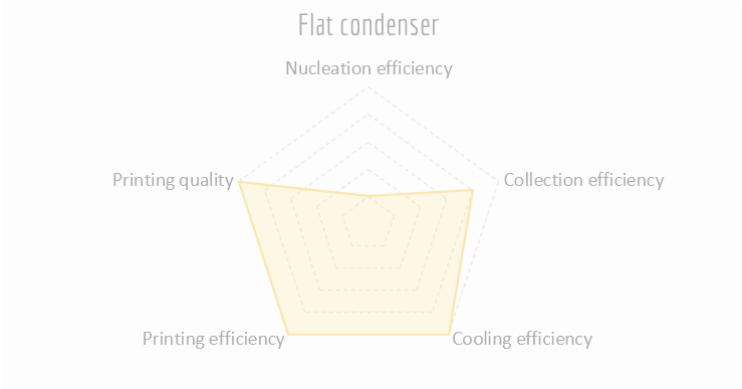
Ondulated condenser - Perpendicular layers

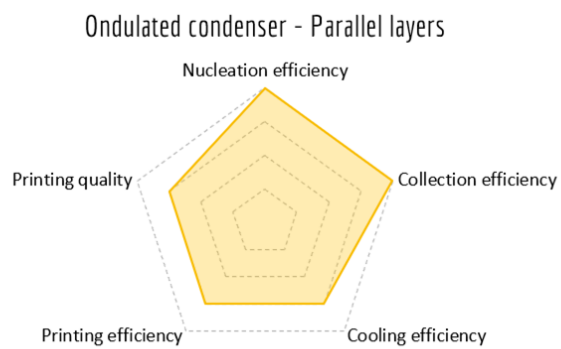


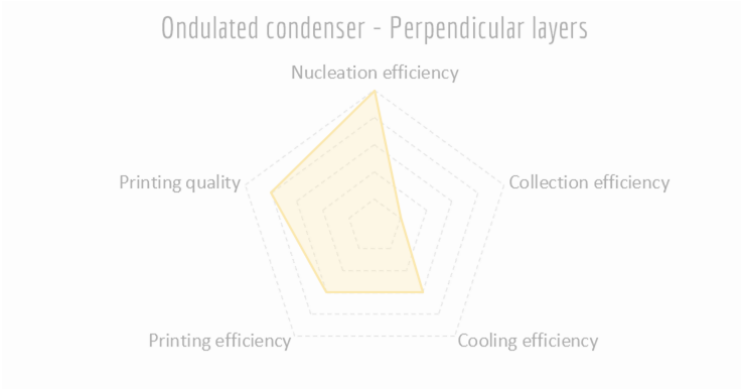
Ondulated condenser with less ridges

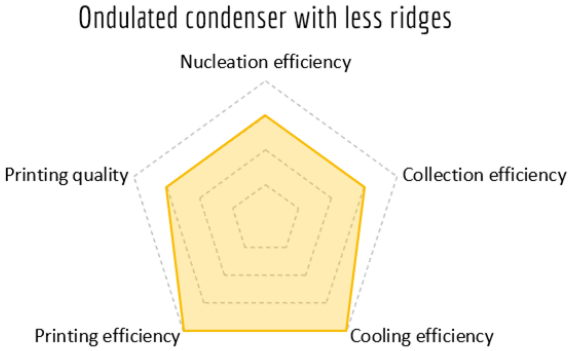


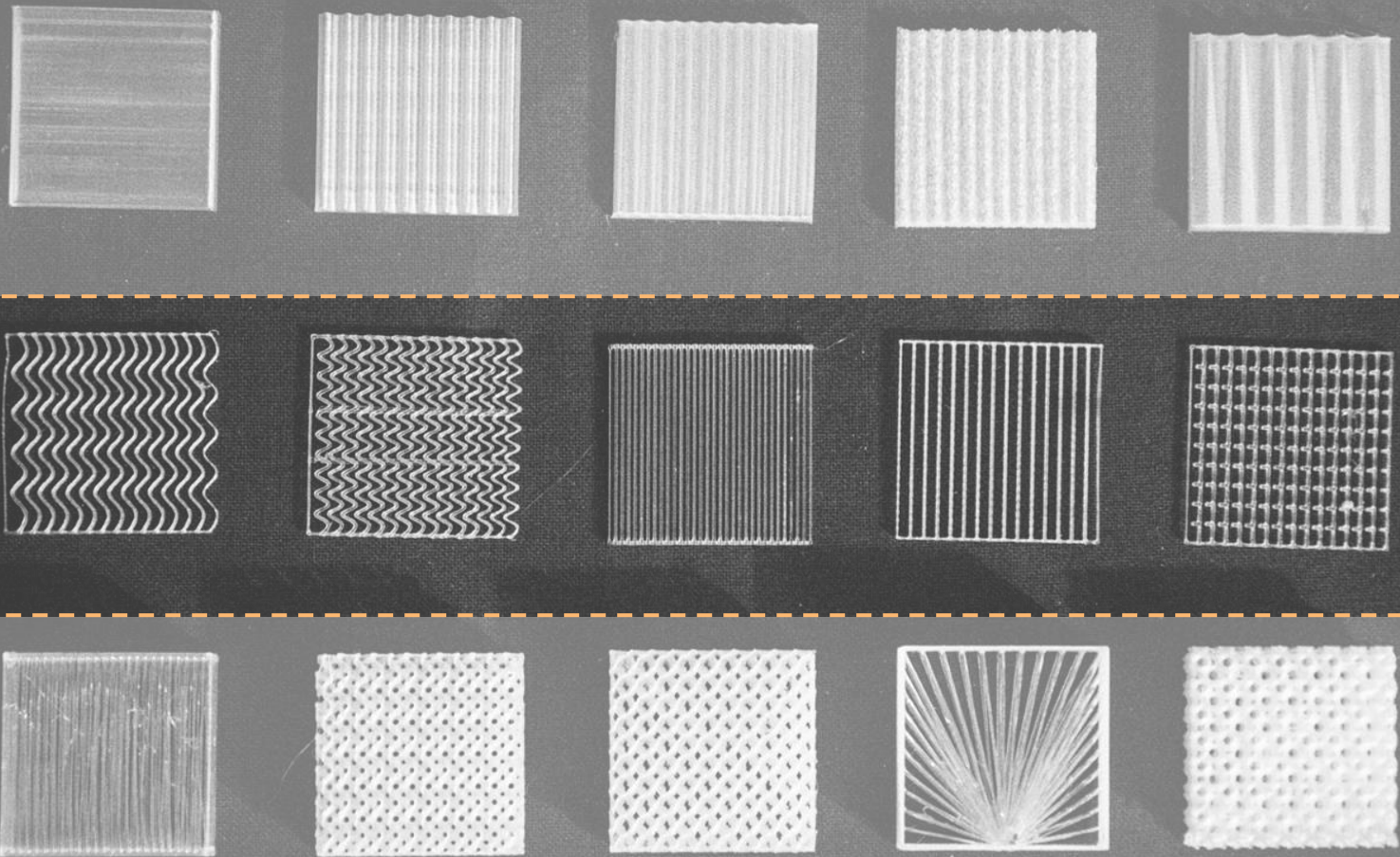
Radar charts



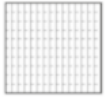




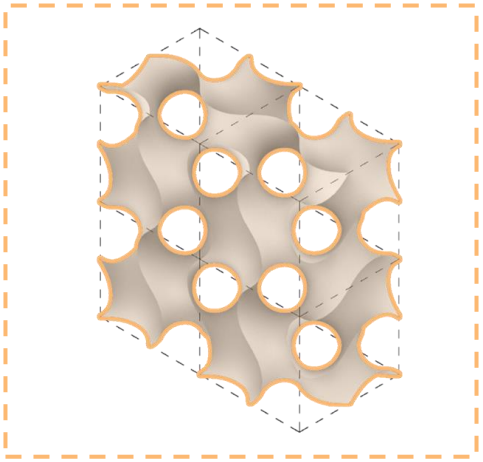


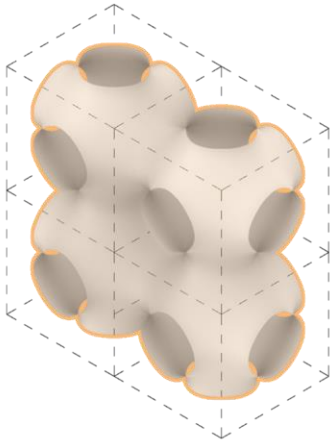


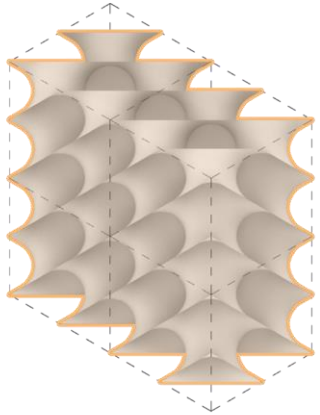
Single-layer collectors

#	Pattern picture	Description	Area [mm2]	Shade coefficient [%]	Sample weight [g]	Printing time [min, sec]	Collected water mass [g]	Collected mass/printing time
1		Straight lines	2500	15	1,13	4,26	0,11	**0,026**
2		Wavy lines, with 6 bumps	2500	15	1,32	5,15	0,11	0,021
3		Straight lines with protrusions on one side	2500	15	1,37	6,47	0,07	0,011
4		Radial pattern	2500	15	1,27	5,56	**0,24**	**0,043**
5		Wavy lines, with 12 bumps	2500	15	1,82	7,08	0,17	0,024
6		Straight lines with facing protrusions	2500	15	1,62	6,22	0,11	0,018

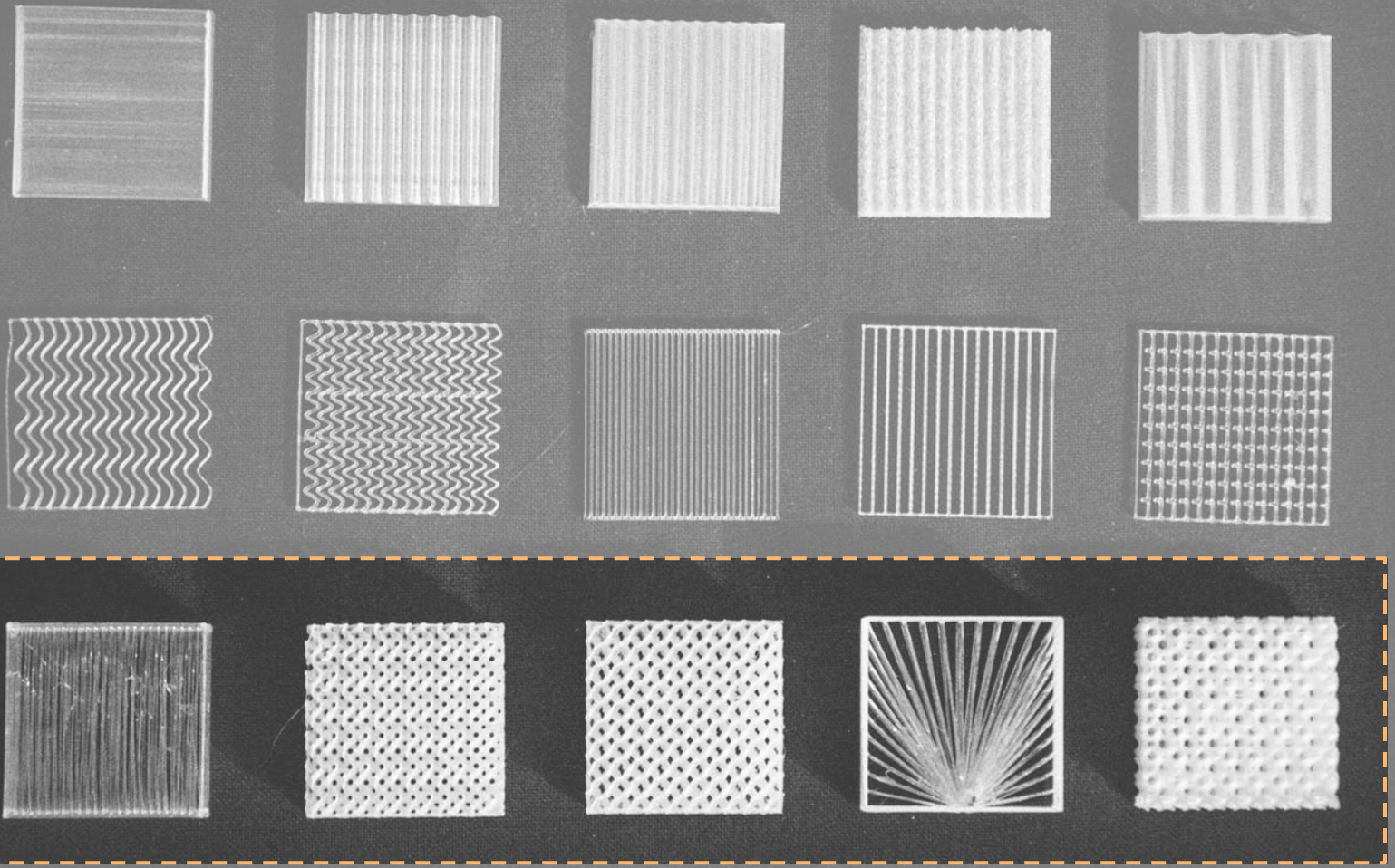
3D-Infill Collectors





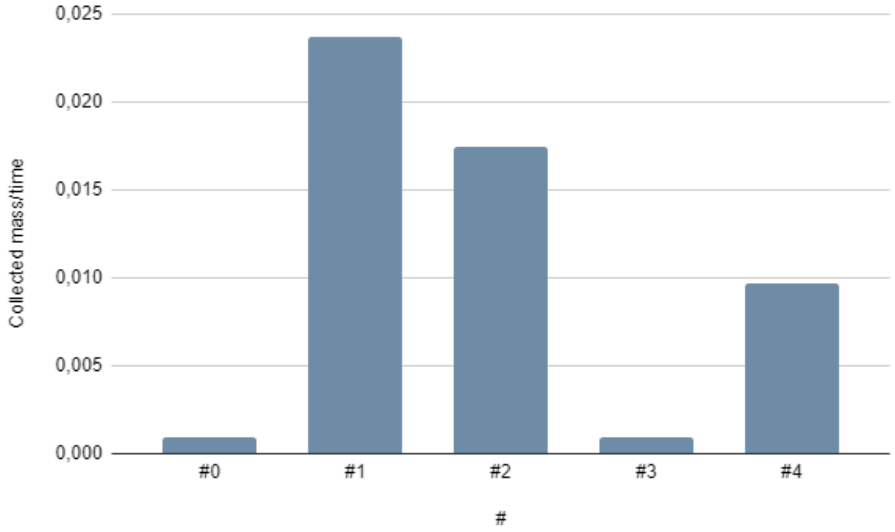


#	Description	Solidity [%]	Print quality	Structural capacity	Shape flexibility	Print time [min]	Print length [m]	Mass [g]	Final mass [g]	Collected mass [g]	Collected mass/time
#1	Infill collector. Gyroid	12	++	++	++	34	2	8,76	9,33	0,57	0,017
#2	Infill collector. Primitive	12	-	++	+	38	1,89	8,67	9,23	0,56	0,015
#3	Infill collector. Diamond	12	+	++	++	35	1,95	8,39	8,91	0,52	0,015



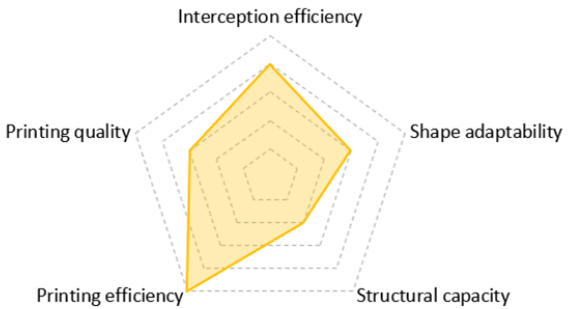
Multi-layer collectors

#	Description	Solidity [%]	Print quality	Structural capacity	Shape flexibility	Print time [min]	Print length [m]	Mass [g]	Final mass [g]	Collected mass [g]	Collected mass/time
#0	Hollow specimen. Tested for reference	0	/	/	/	11	0,56	1,58	1,59	0,01	0,001
#1	Multilayer harp collector. 4 layers	40	+	-	+	16	0,82	2,39	2,77	0,38	0,024
#2	Multilayer radial collector. 4 layers	40	+	-	-	16	0,7	3,72	4	0,28	0,018
#3	Infill collector. Lines.	40	++	+	++	100	6,57	19,91	20	0,09	0,001
#4	Infill collector. Gyroid	40	++	++	++	86	3,23	12,83	13,66	0,83	0,010

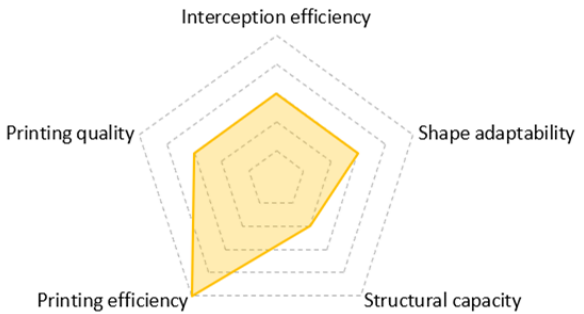


Functional surfaces definition

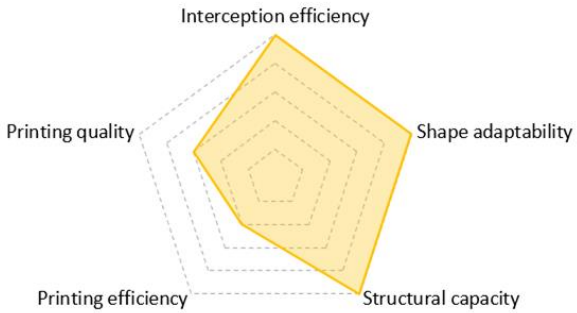
Multilayer Harp Collector



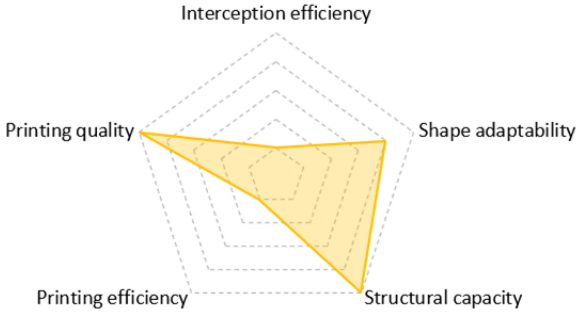
Multilayer Radial Collector



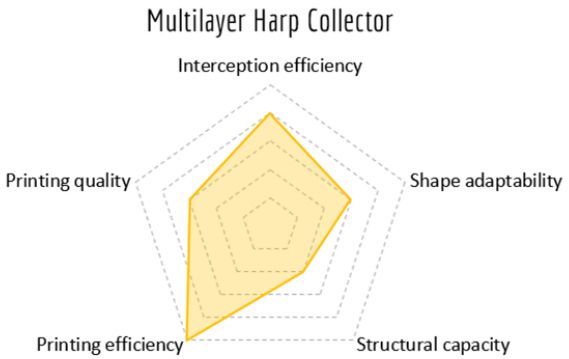
Gyroid Infill Collector

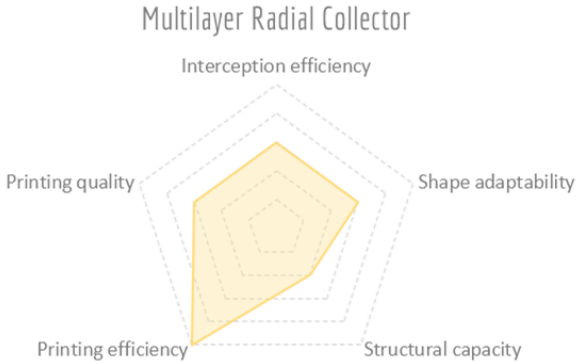


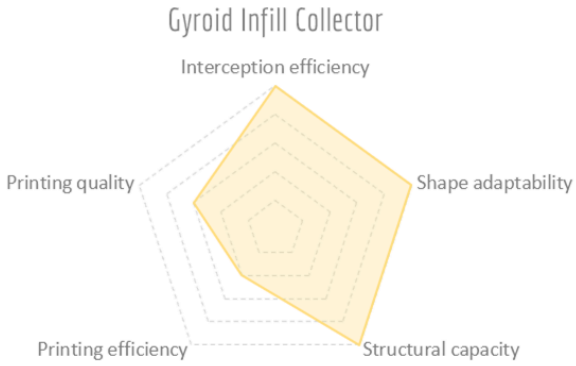
Linear Infill Collector

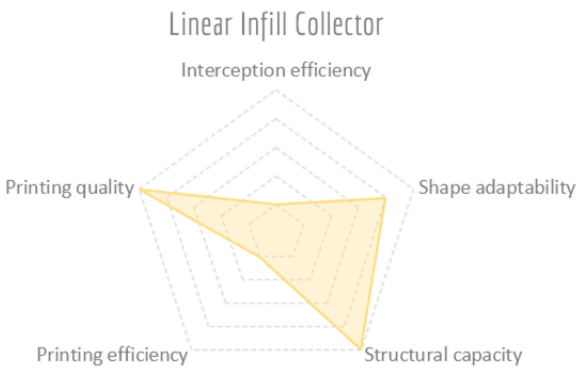


Functional surfaces definition

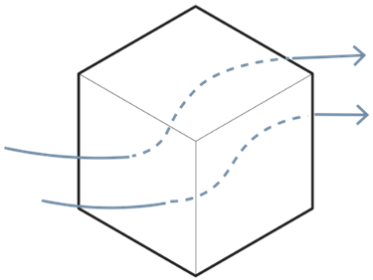




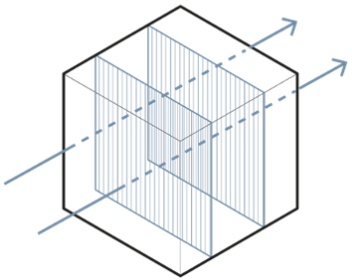




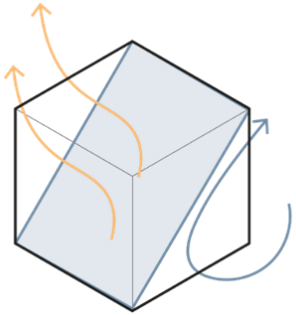
Component Design Workflow



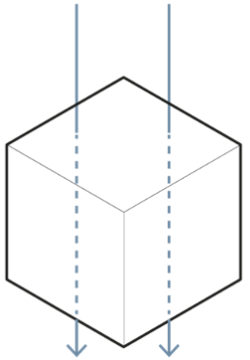
F1. AIRFLOW



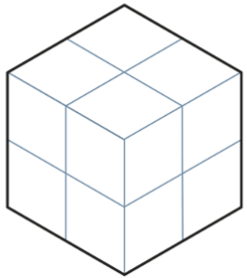
F2. FOG FLOW



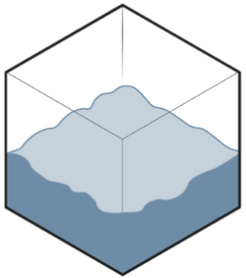
F3. DEW COLLECTION



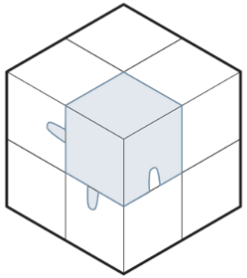
F4. WATER DISTRIBUTION



F5. STRUCTURAL CAPACITY

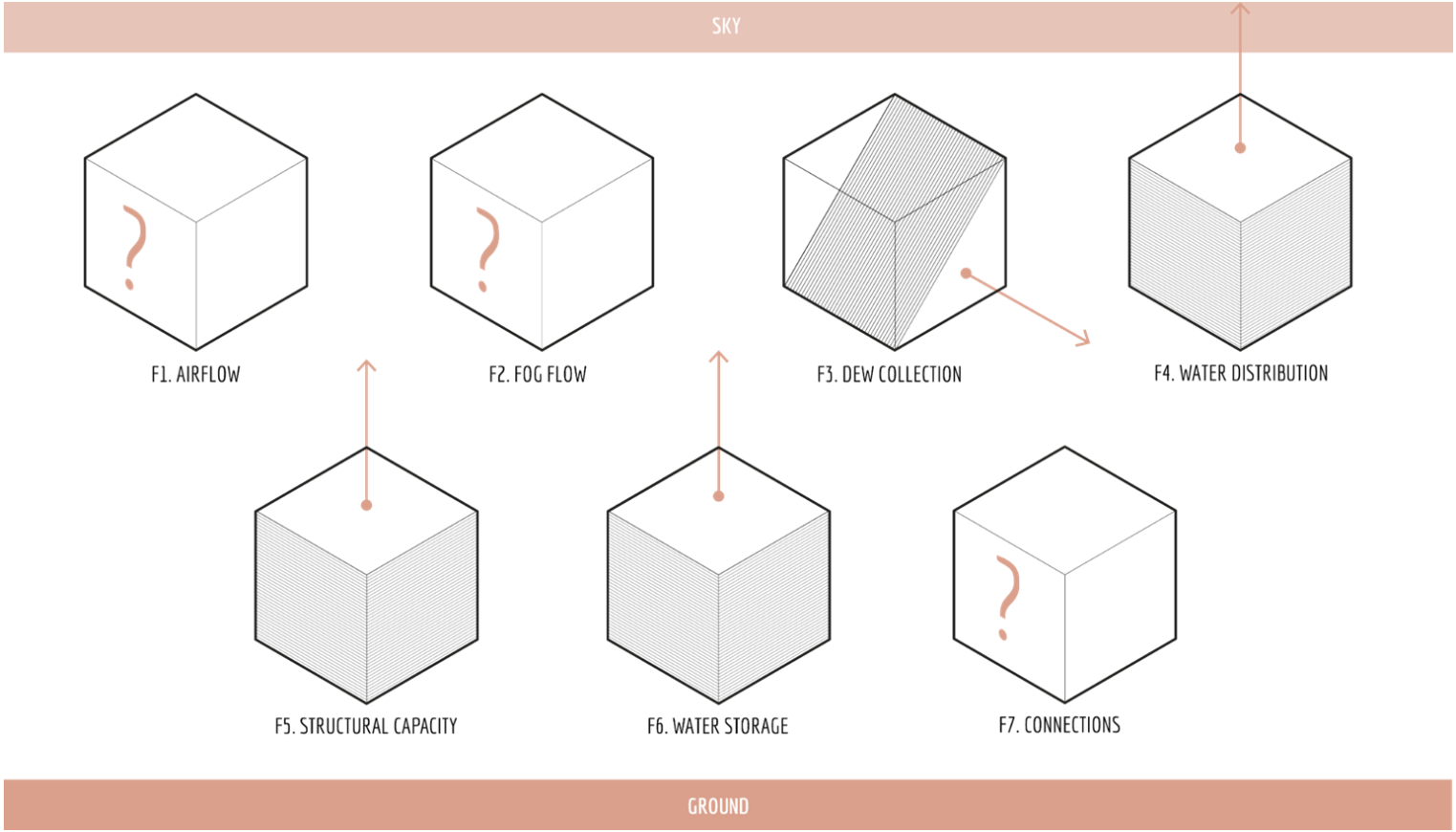


F6. WATER STORAGE

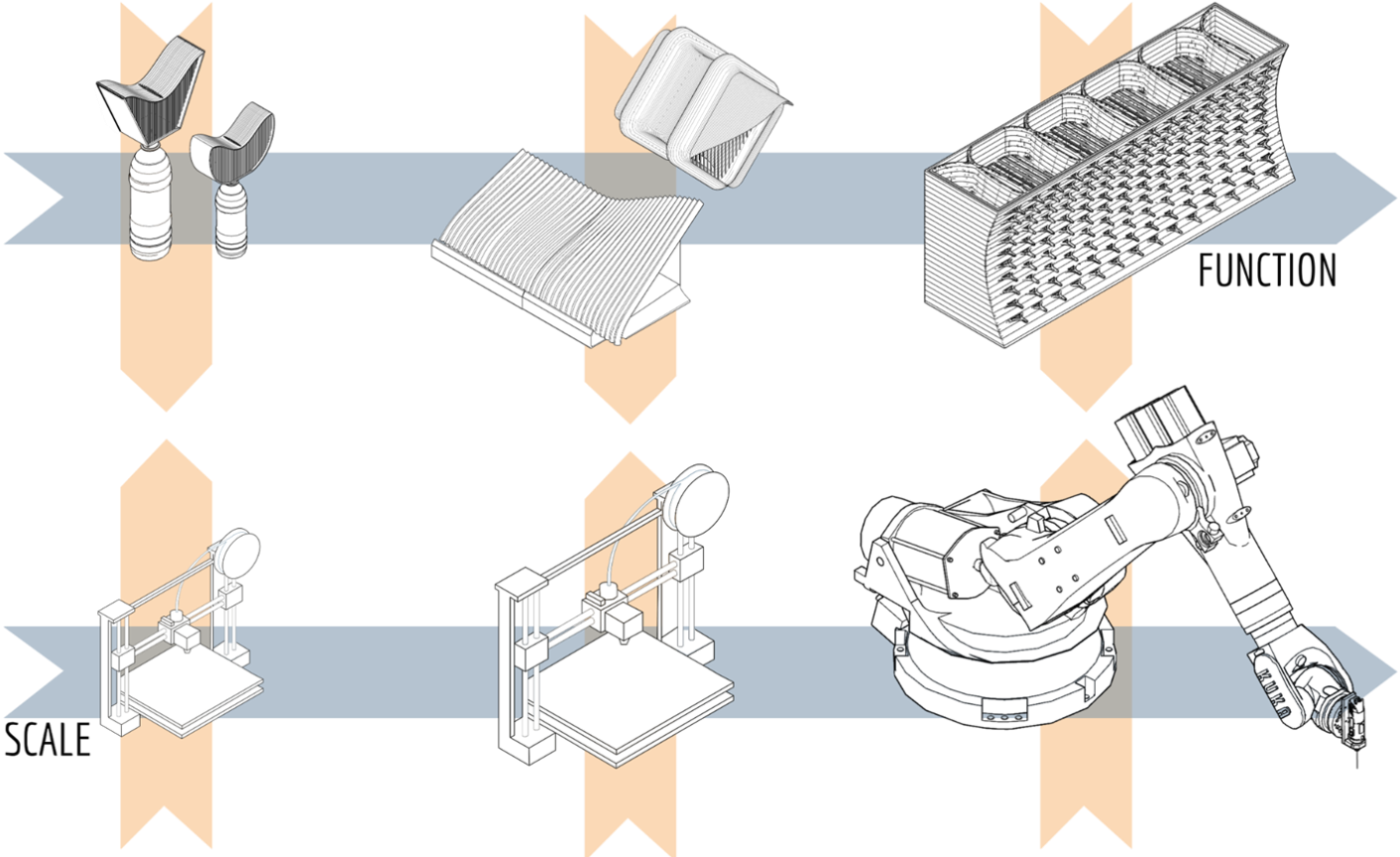


F7. CONNECTIONS

Component Design Workflow

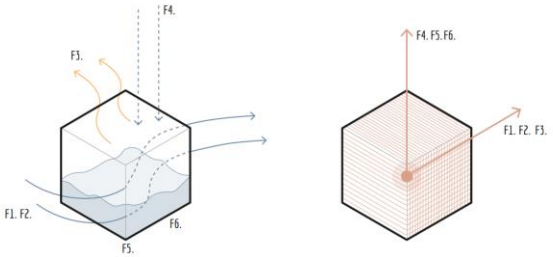


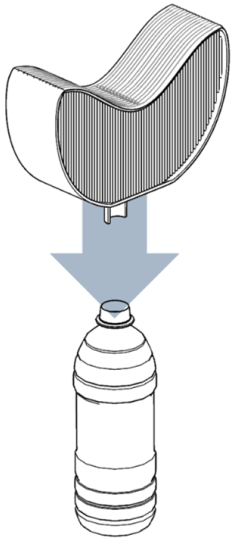
Workflow flexibility

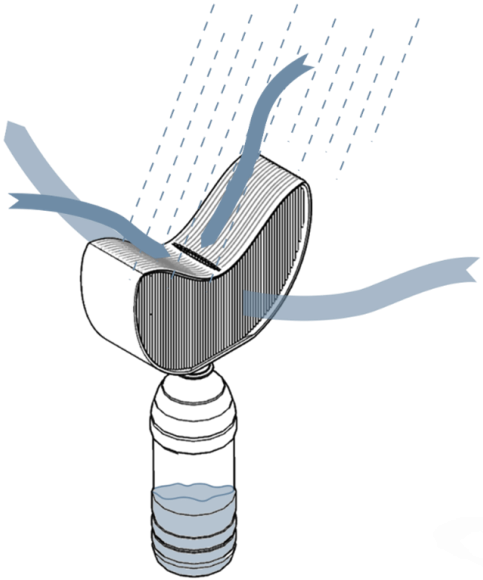


04

Workflow flexibility

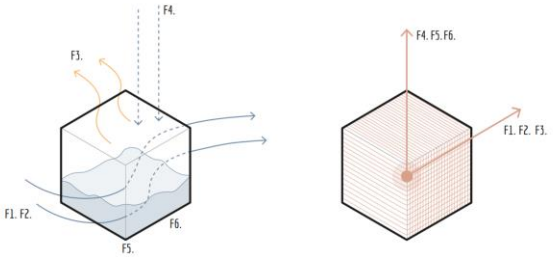


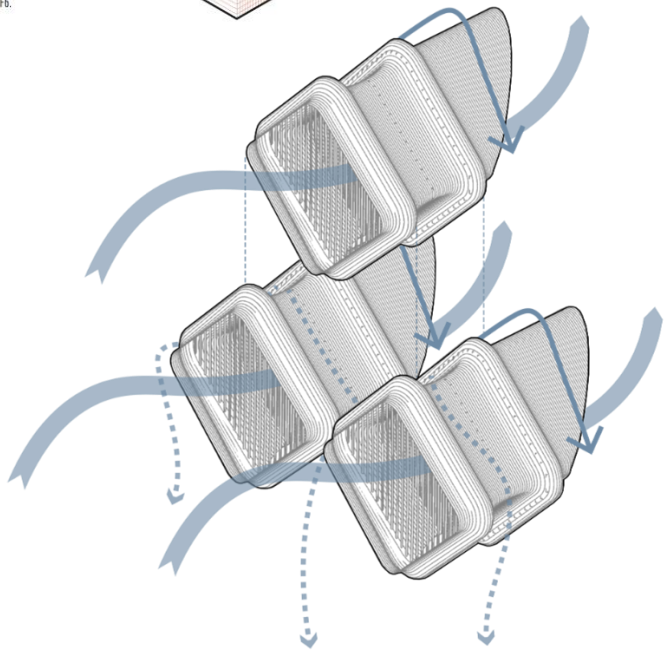




04

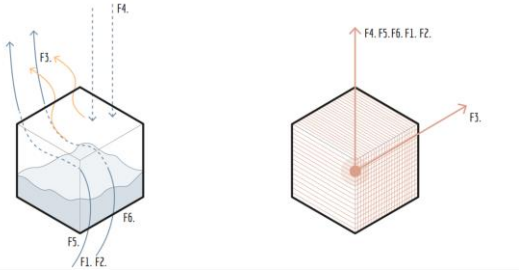
Workflow flexibility

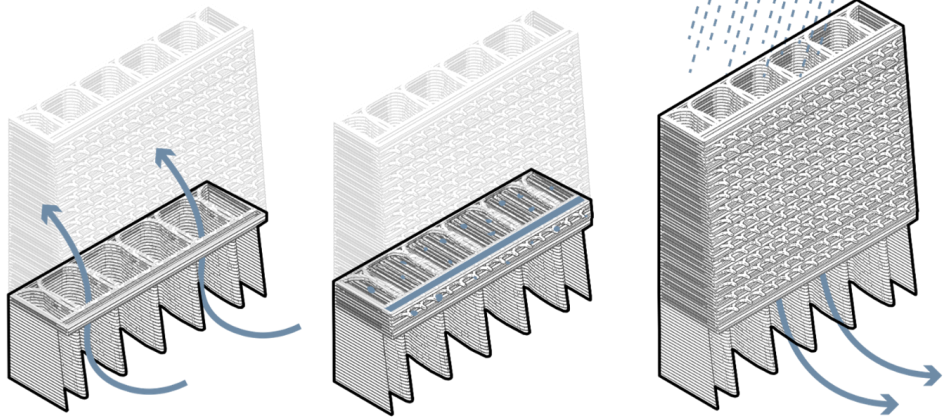


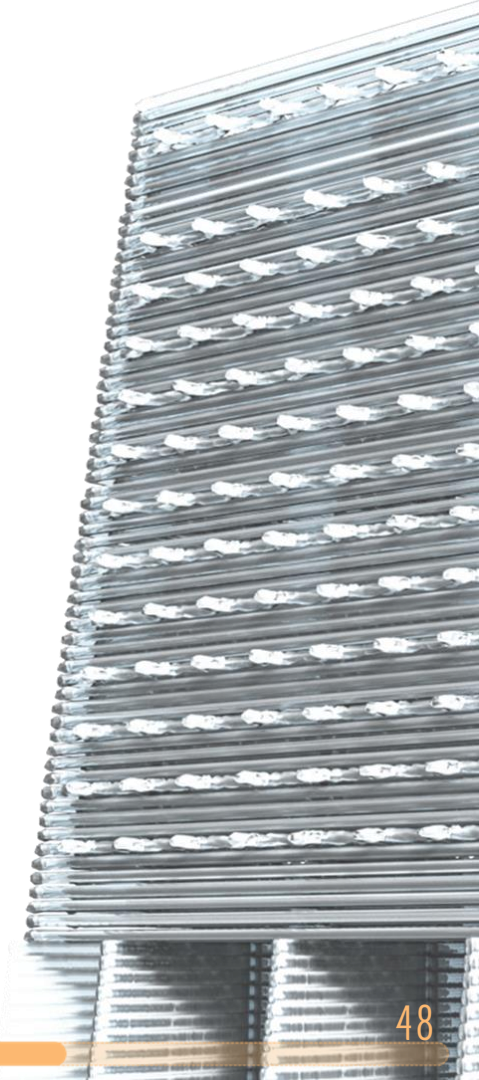


04

Workflow flexibility

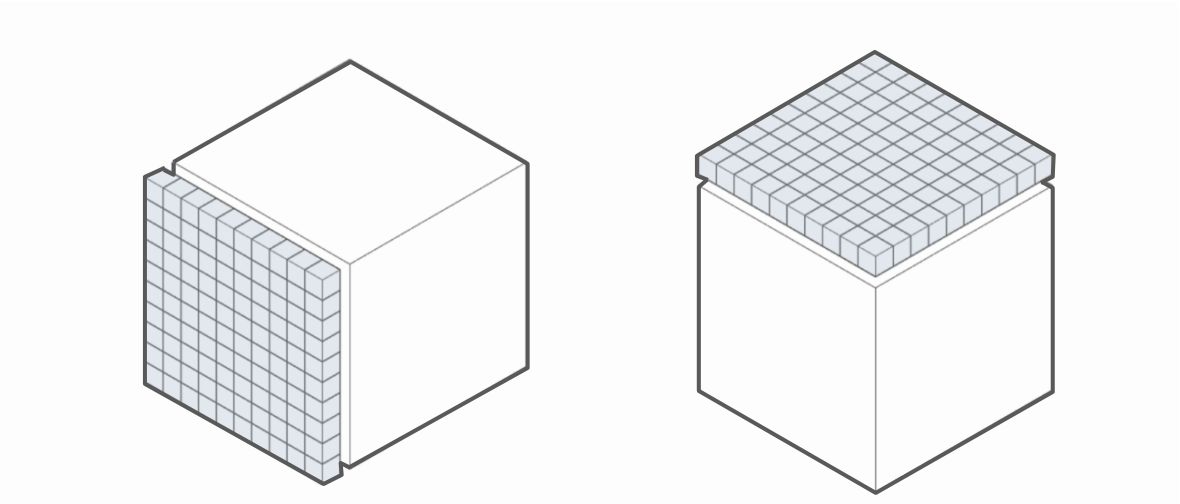






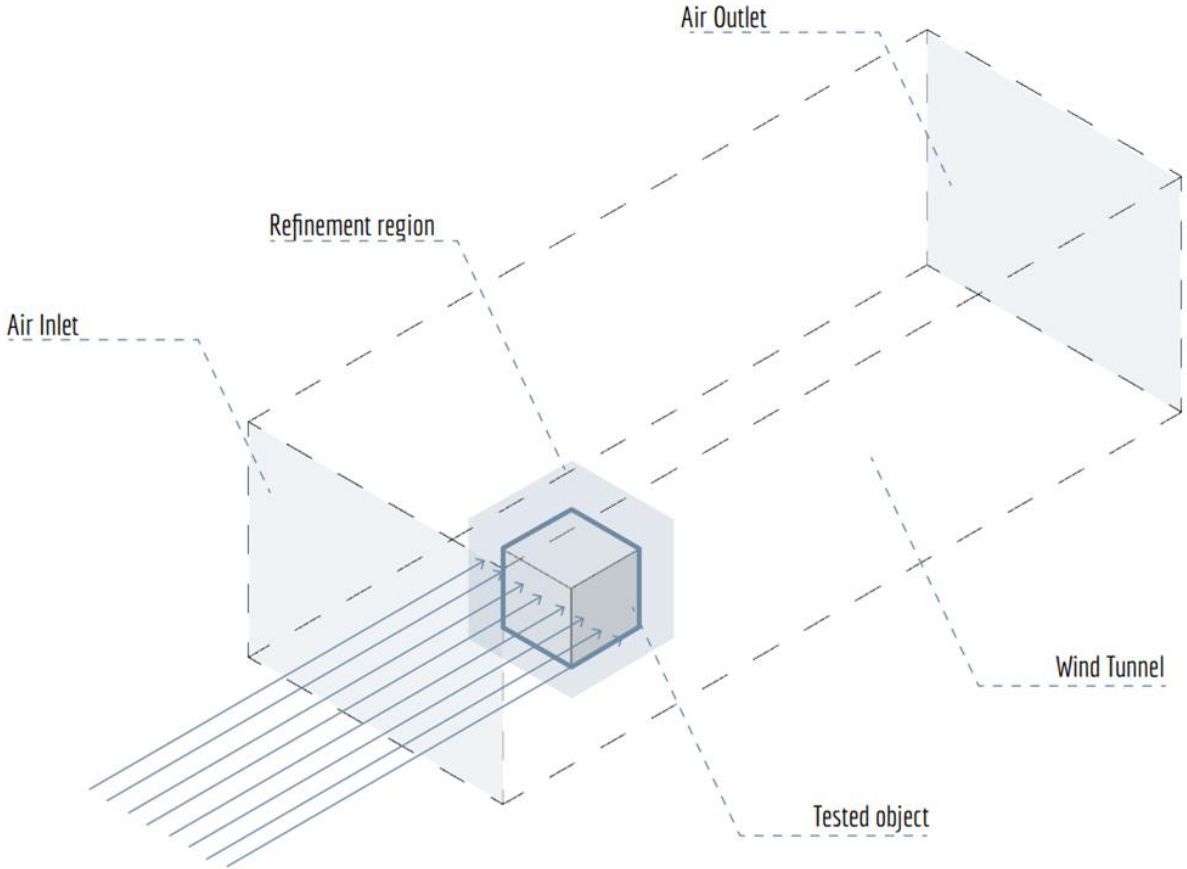
04

Orientation Studies

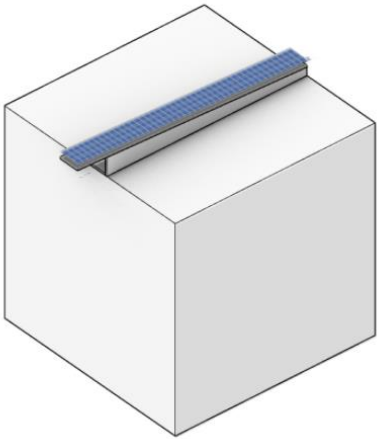


04

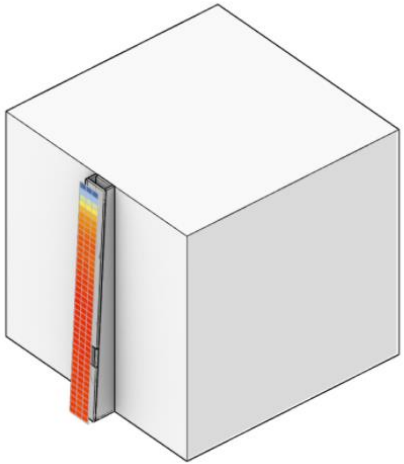
Orientation Studies



Orientation Studies



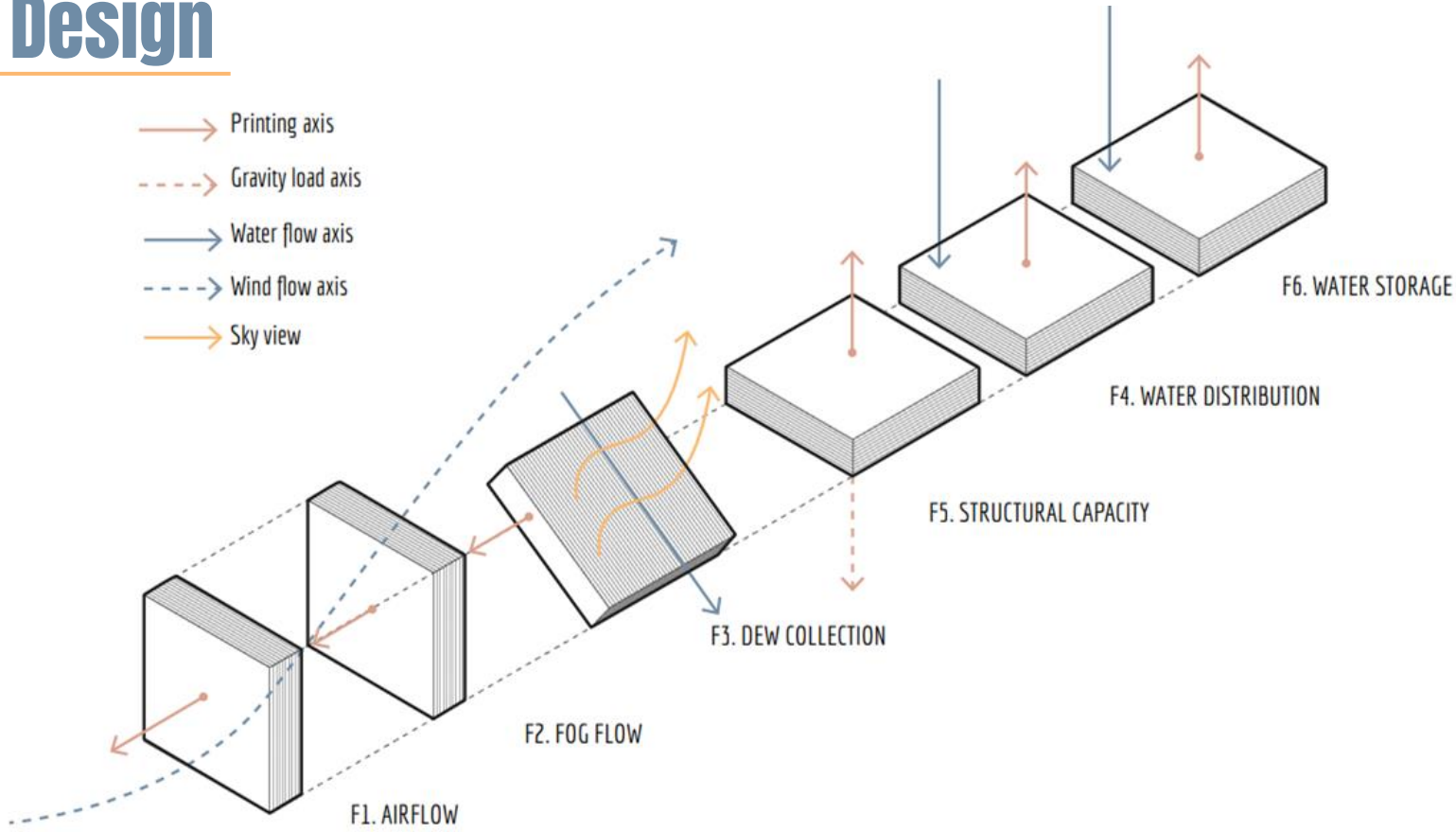
Average SVF: 1,00



Average SVF: 0,61

	Fog [l/hm2]	Dew [l/hm2]	Total [l/hm2]	Weighted total [l/hm2]
Vertical	2,2	1,9E-03	2,2	4,4E-02
Horizontal	1,8	1,5E-02	1,8	4,9E-02

Final Design

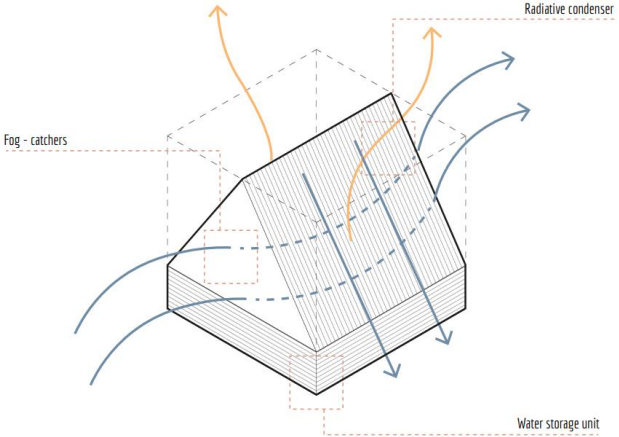


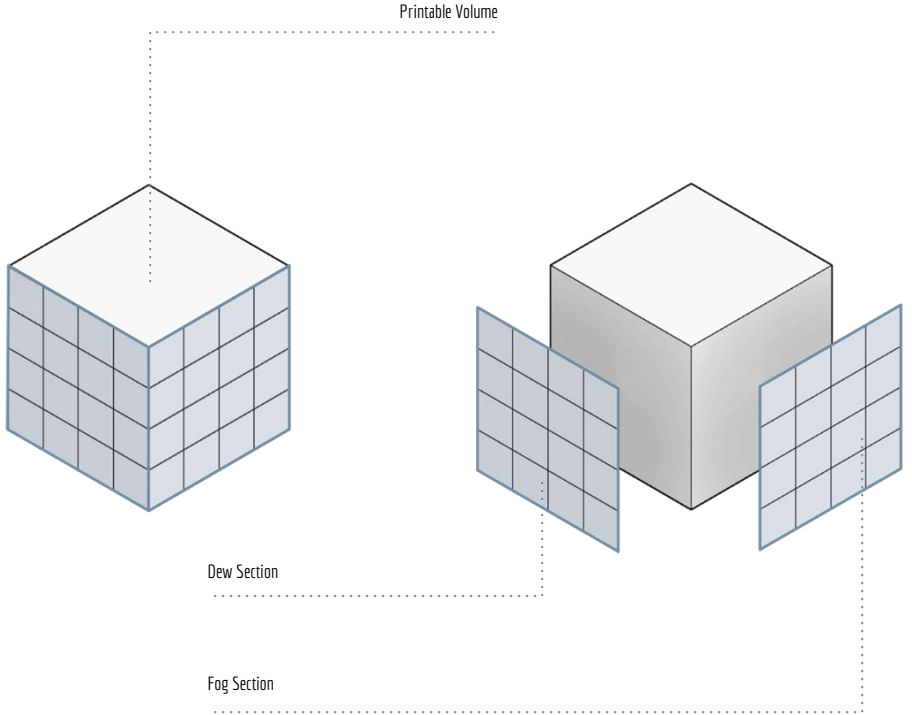
Same optimal part orientation

Minimum amount of functions

04

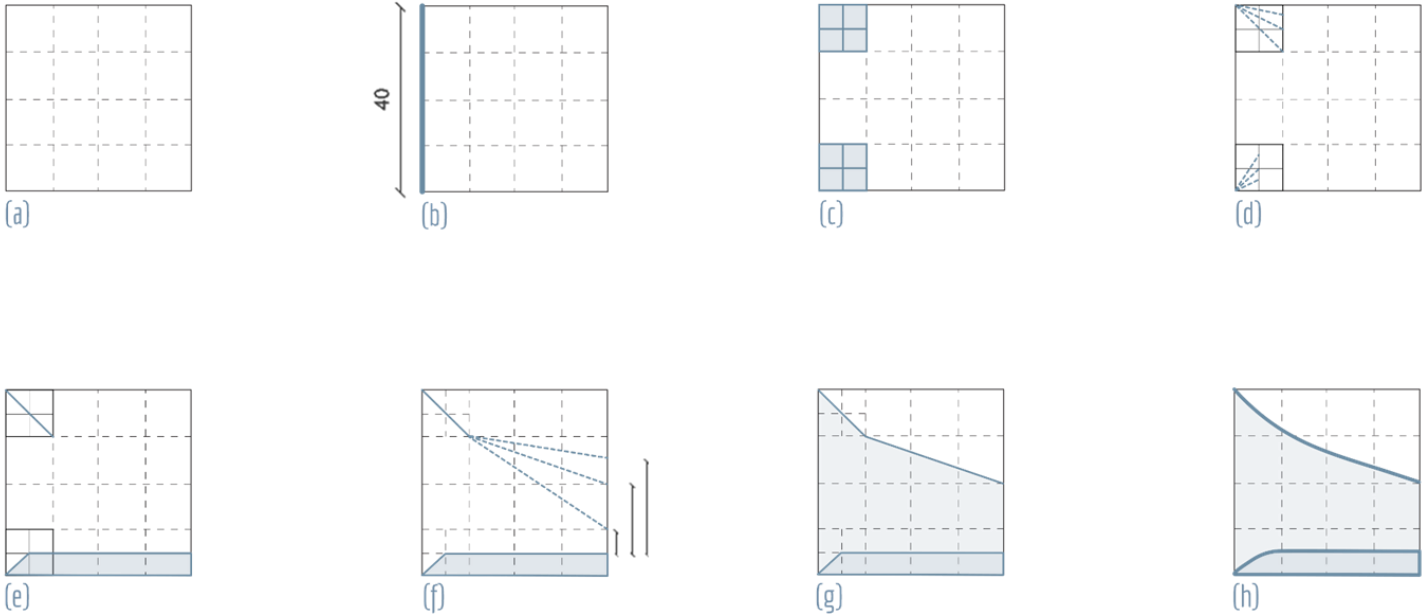
Schematic Design





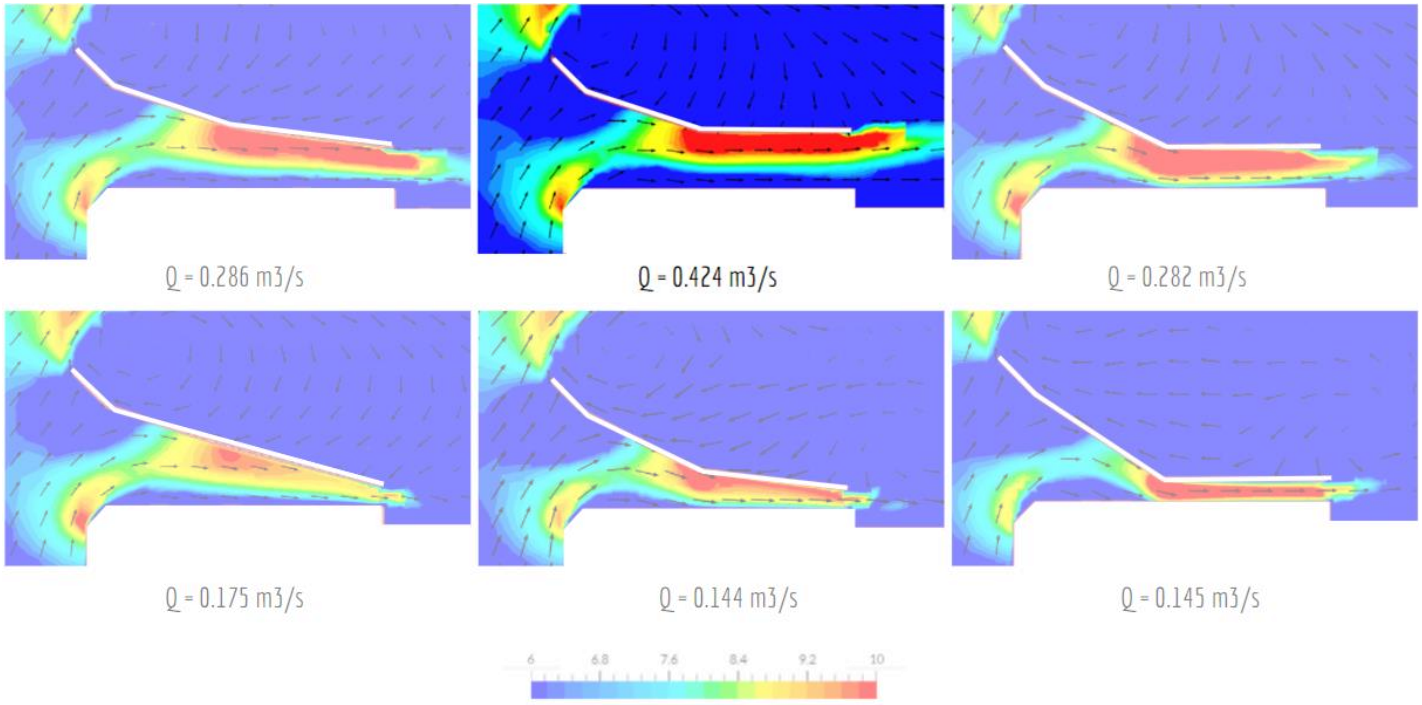
04

Fog Section Design



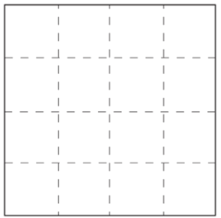
04

Fog Section Design

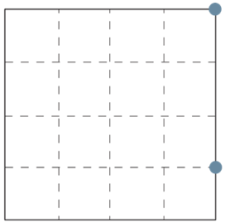


04

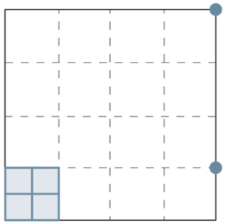
Dew Section Design



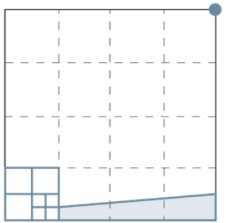
(a)



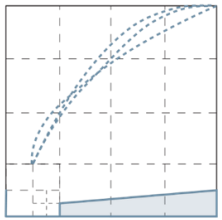
(b)



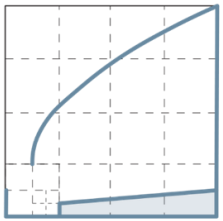
(c)



(d)



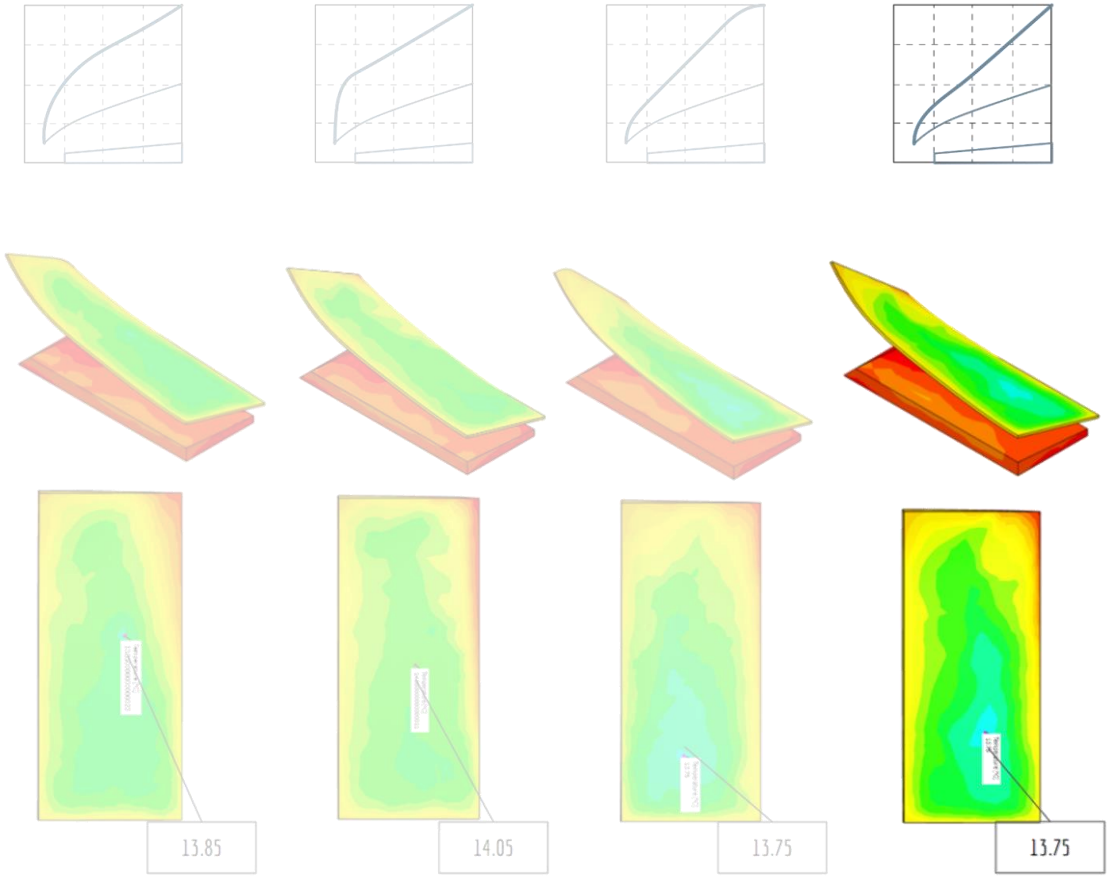
(e)



(f)

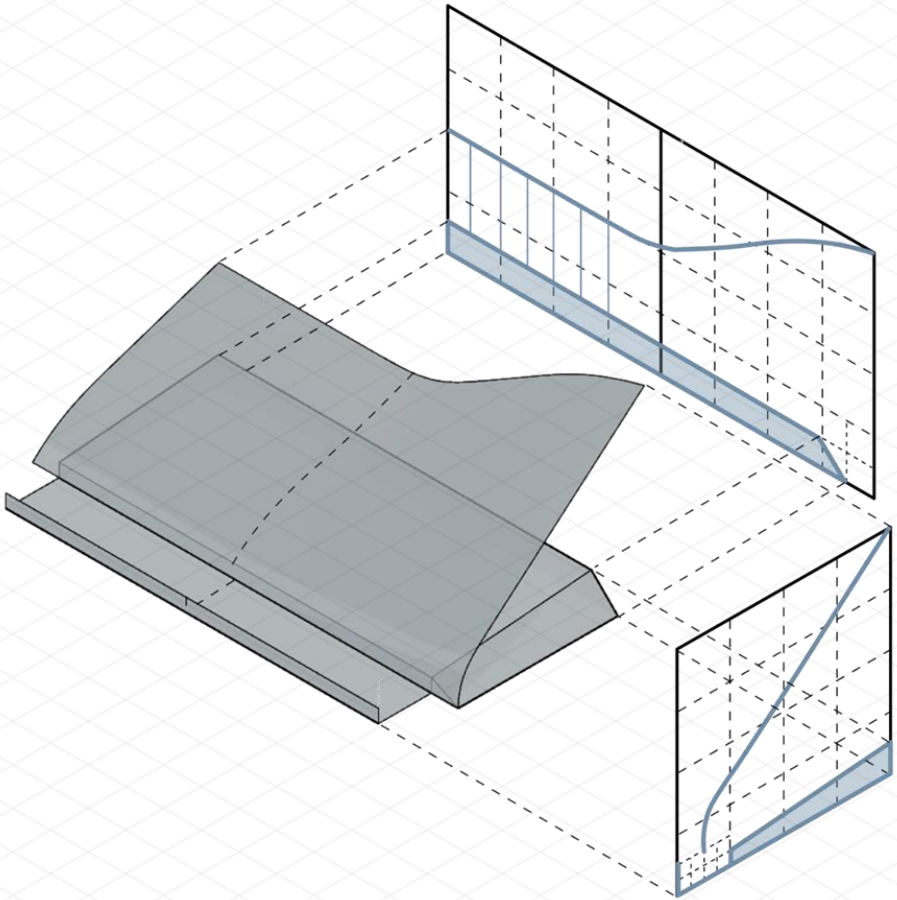
04

Dew Section Design



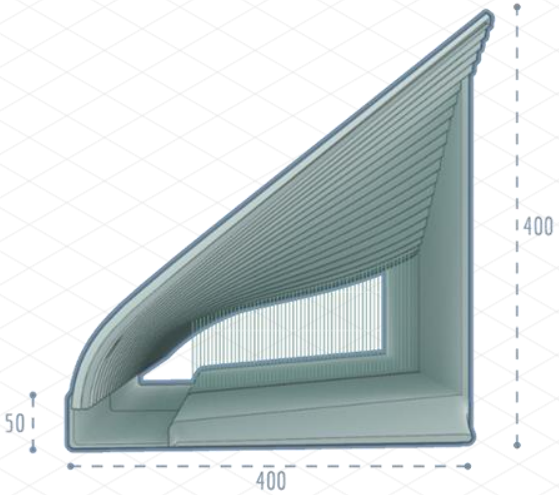
04

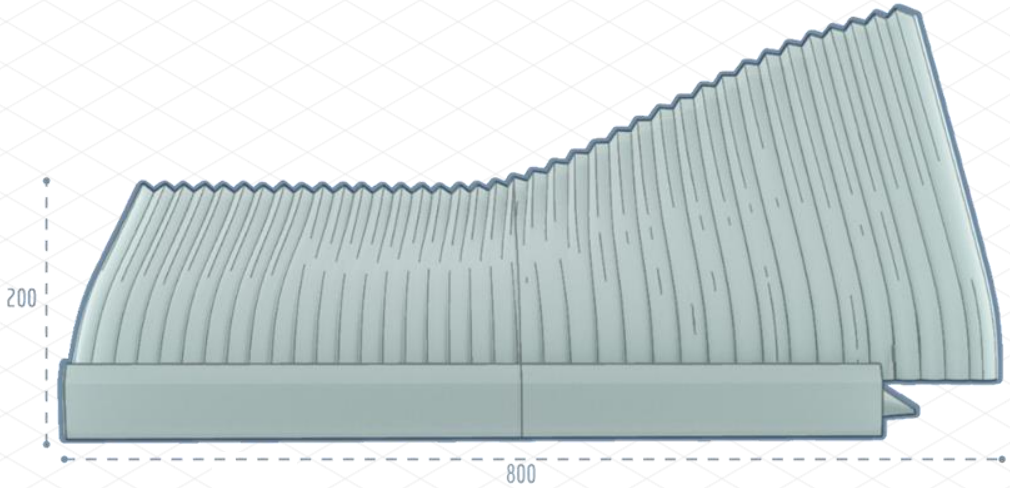
Schematic Design Result



04

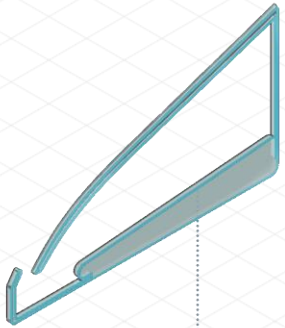
Final Design





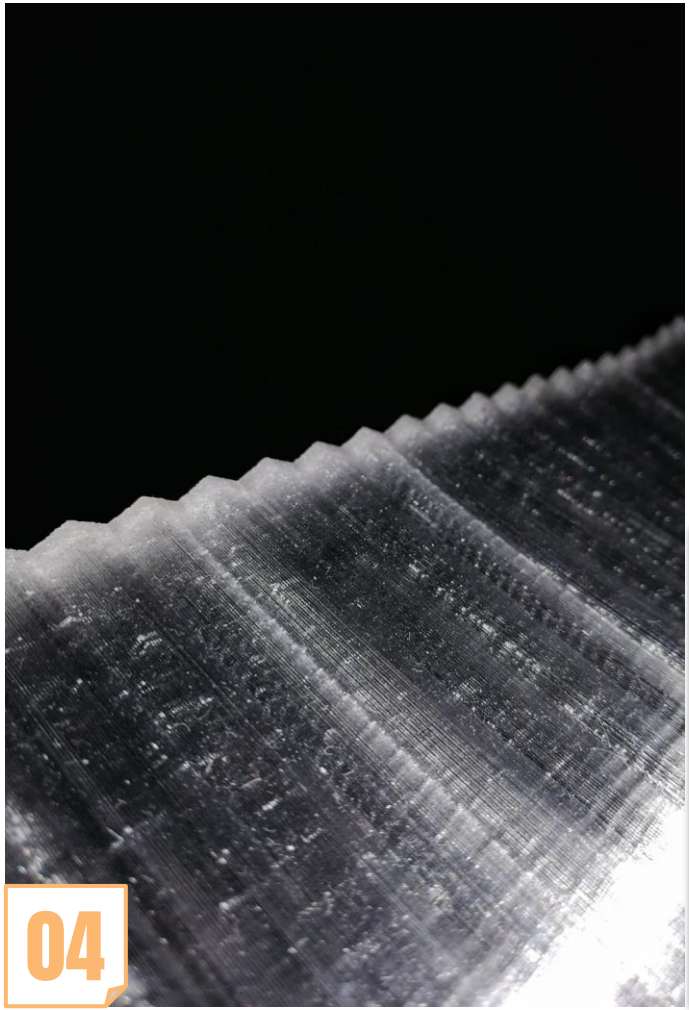
04

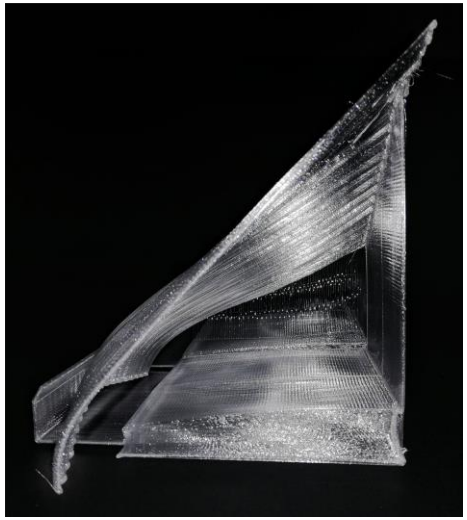
Final Design

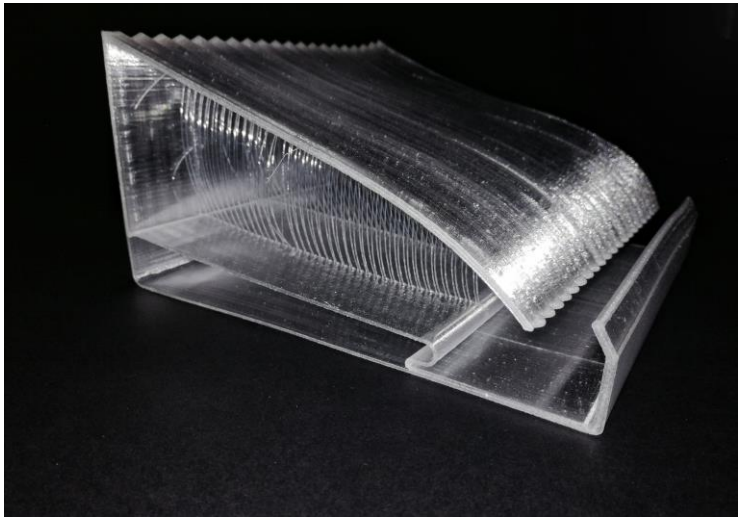


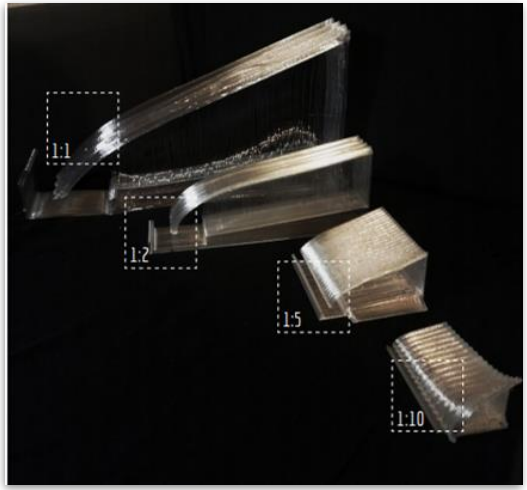
A closed continuous printing path is designed to reduce travelling and therefore improve printing efficiency.

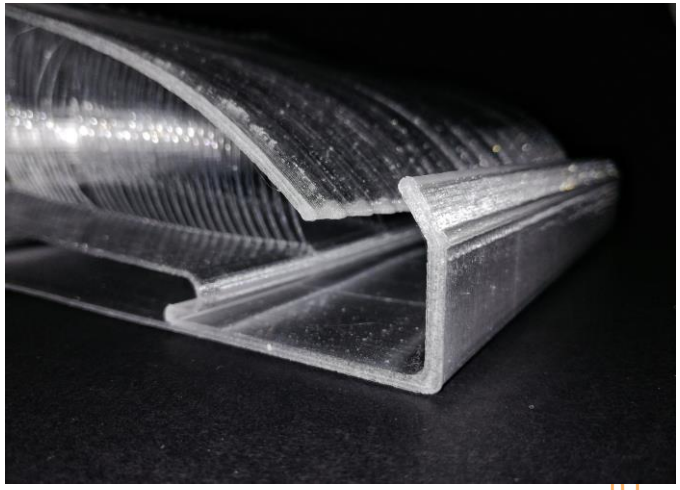
04









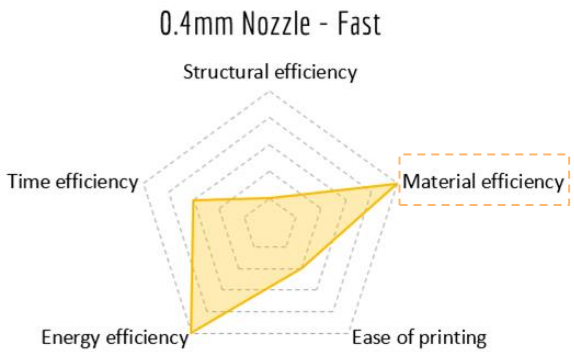


04

Printing Settings Definition

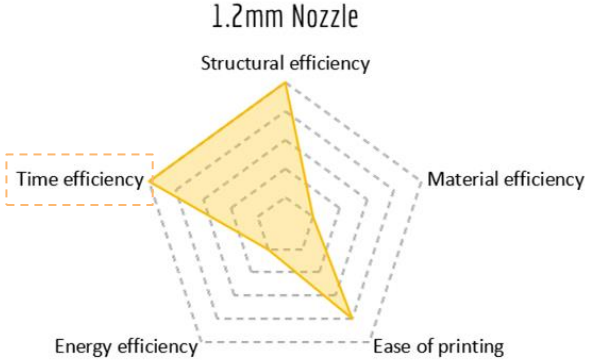
#9
Layer height: 0.3 mm
Wall count: 1
Wall speed: 80
Inf%: 60
Inf speed: 80
Inf flow: 120%

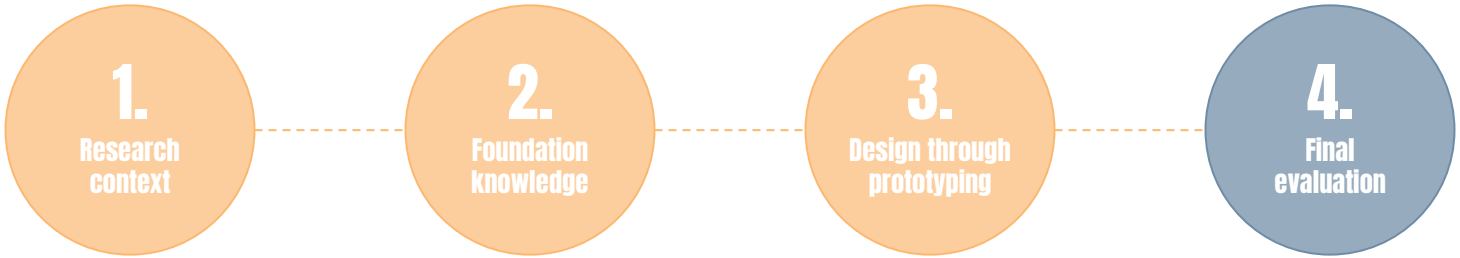
Time: **9h36min**
Mass: 444g
Length: 133.84m



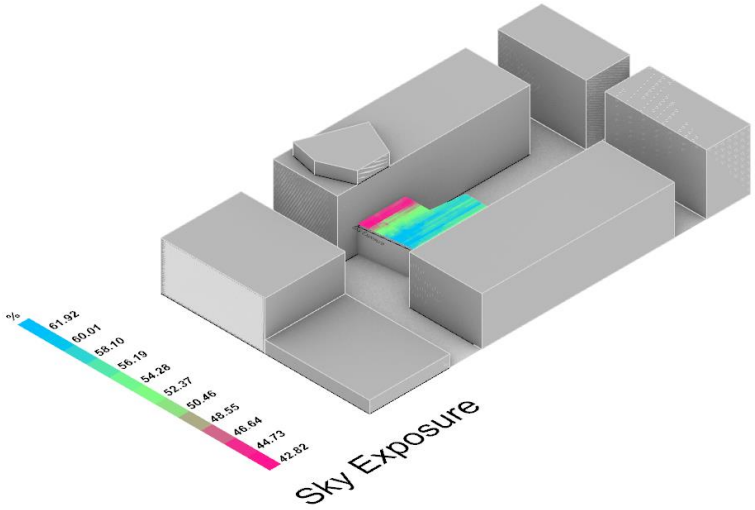
#10
Layer height: 0.9 mm
Wall count: 1
Wall speed: 60
Inf%: 60
Inf speed: 80
Inf flow: 120%

Time: **4h23min**
Mass: 1280g
Length: 385.71m




1.
Research context
2.
Foundation knowledge
3.
Design through prototyping
4.
Final evaluation

Outdoor Testing

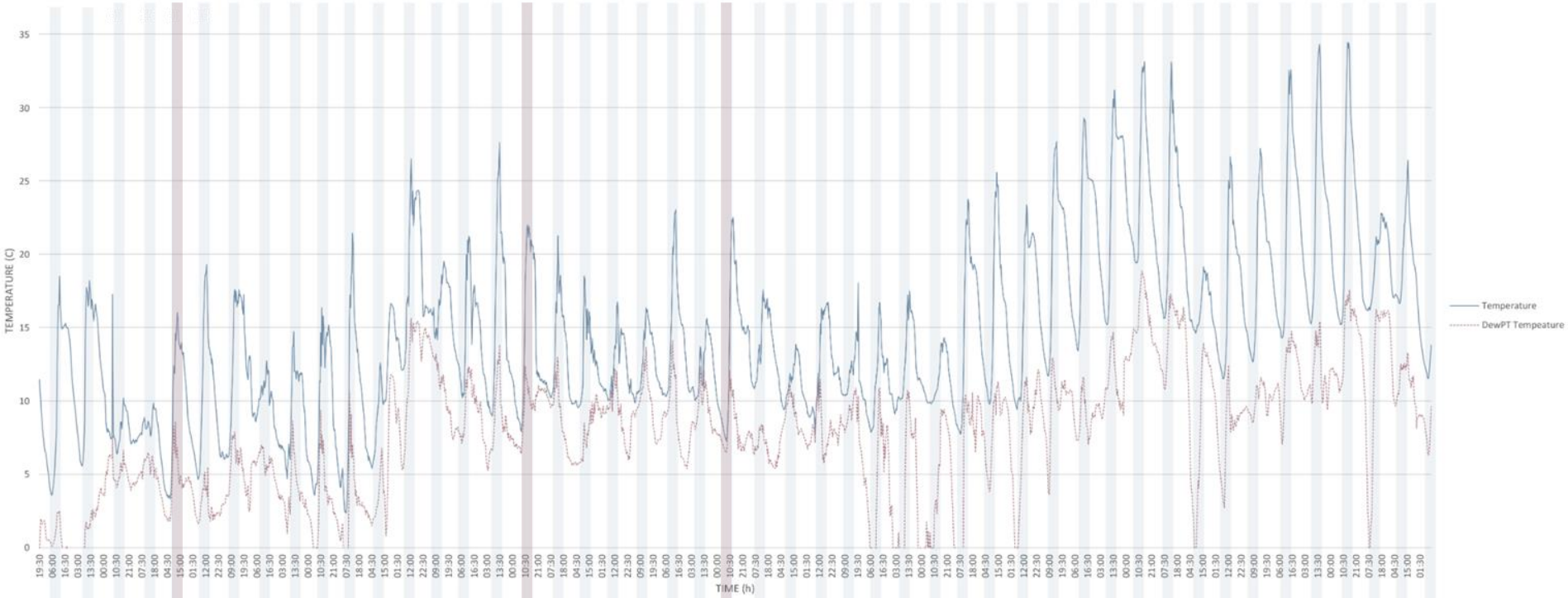


05

Outdoor Testing

05

Outdoor Testing



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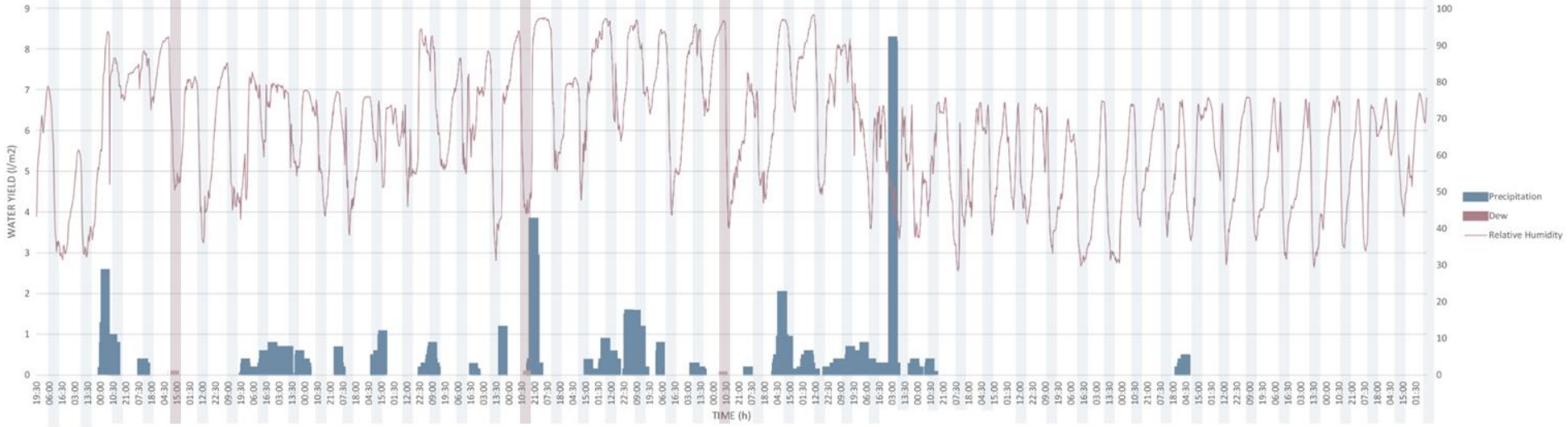
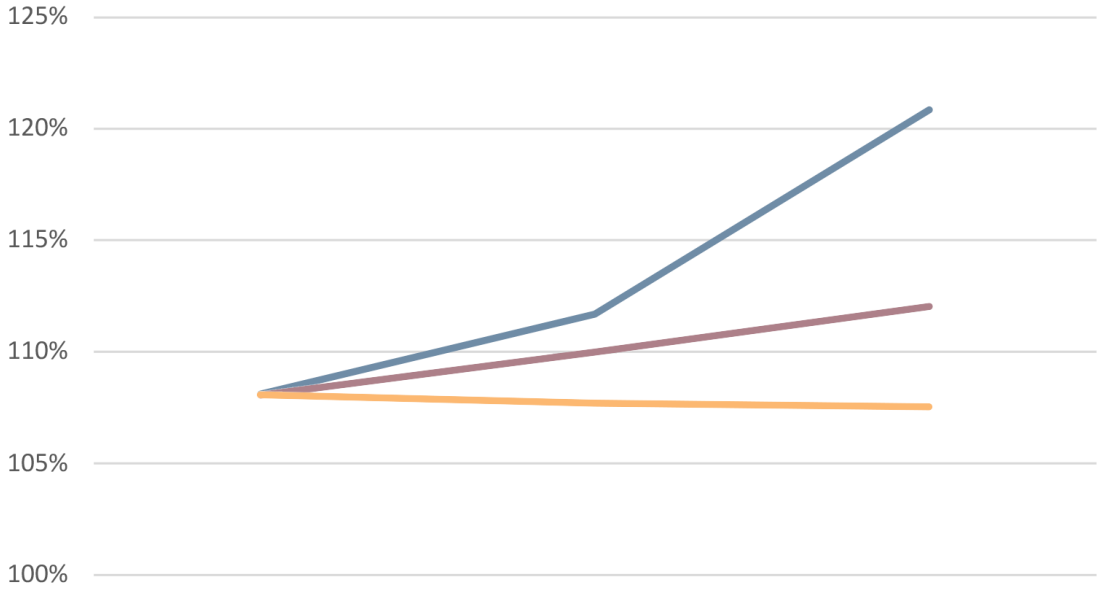
Outdoor Testing



Date	Time	Te [C]	RH [%]	DewPT [C]	vwind [m/s]	Rain [l/m2]	Cloud coverage	Dew [l/m2]	Theoretical value [l/m2]	αrad [W/m2K]	αrad theory [W/m2K]	%
01/05/2021	07:00	3,5	91,8	2,0	1,9	0	0,12	3,4E-02	4,20E-03	4,3	4,0	108%
13/05/2021	07:00	8,4	93,8	7,2	0,0	0	0,25	2,0E-03	4,98E-03	4,5	4,2	107%
20/05/2021	07:00	7,7	96,6	7,0	0,0	0	1	1,0E-02	7,36E-05	4,5	4,2	108%

Outdoor Testing

RH [%]	Etheory [W/m2K]	Ecorrected [W/m2K]	%
90%	2,22E-02	2,40E-02	108%
85%	1,54E-02	1,72E-02	112%
80%	8,44E-03	1,02E-02	121%
Vw [m/s]	Etheory [W/m2K]	Ecorrected [W/m2K]	
1	2,22E-02	2,40E-02	108%
2	2,29E-02	2,52E-02	110%
3	2,15E-02	2,41E-02	112%
Te [C]	Etheory [W/m2K]	Ecorrected [W/m2K]	
15	2,22E-02	2,40E-02	108%
13	2,20E-02	2,37E-02	108%
10	2,11E-02	2,27E-02	108%



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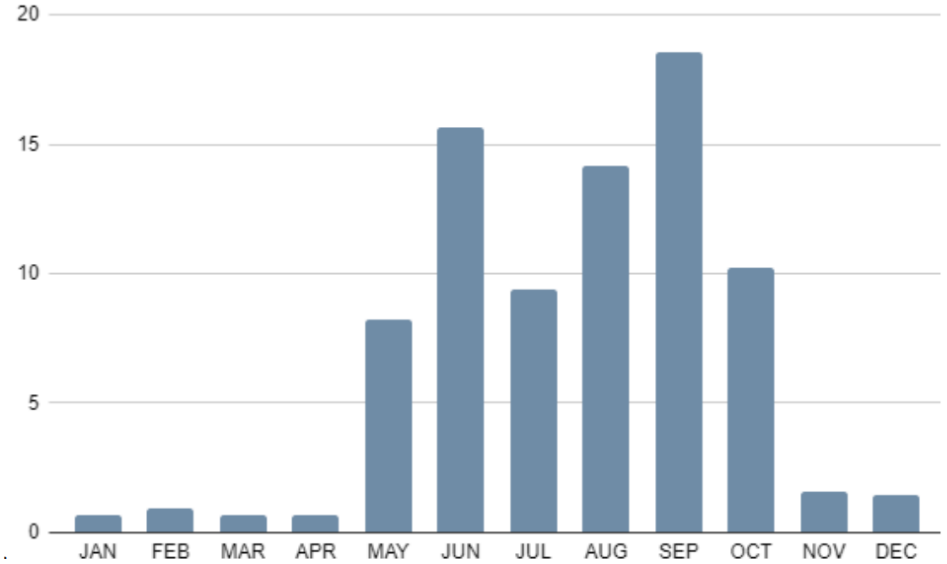
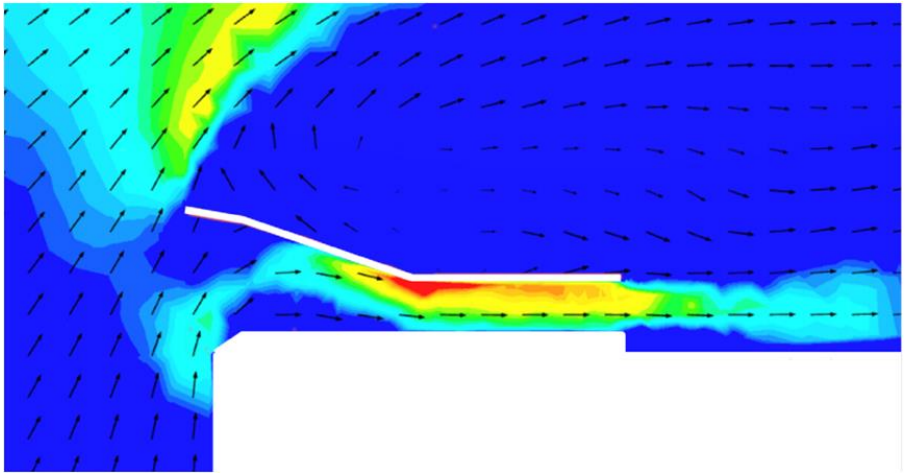
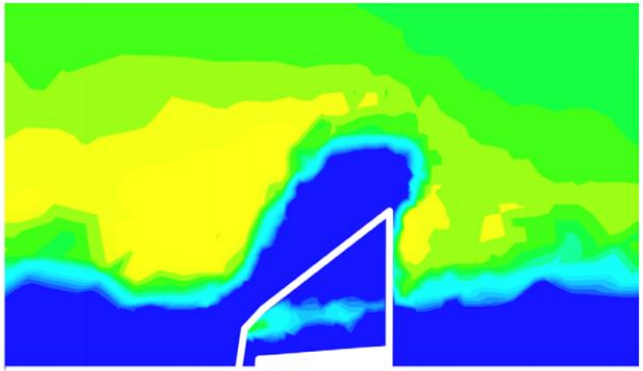
Case Study Performance Simulation

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Dew yield [l/m2]	0,67	0,93	0,70	0,64	8,22	15,67	9,38	14,18	18,54	10,21	1,59	1,46	82,19
Dew yield [l/module]	0,23	0,32	0,24	0,22	2,79	5,33	3,19	4,82	6,30	3,47	0,54	0,50	27,95



Case Study Performance Simulation





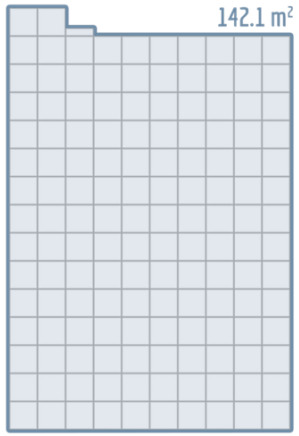
	Num. screens	Shade coefficient	Area [m2]	Flow [m3/s]	v_{ref} [m/s]	Total efficiency	J [l/hm2]	%
Standard collector	4	0,6	0,08	/	3	0,29	1,58	100%
Water-catcher	4	0,6	0,08	0,106	1,325	0,97	2,31	146%

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Fog yield [l/m2]	38,93	12,62	93,94	3,92	11,08	4,77	8,69	6,39	21,23	66,09	38,24	31,93	337,81
Fog yield [l/module]	3,11	1,01	7,51	0,31	0,89	0,38	0,70	0,51	1,70	5,29	3,06	2,55	27,02

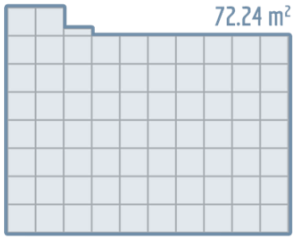
Case Study Performance Simulation

Water yield [l/module]		Water demand = 50 litres		Water demand = 32 litres	
		Required area [m2]	Required modules	Required area [m2]	Required modules
Yearly supply scenario	0,15	113	332	72	212
Summer supply scenario	0,26	66	195	42	**125**

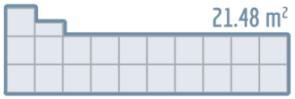
Water yield [l/module]		Water demand = 50 litres		Water demand = 32 litres	
		Required area [m2]	Required modules	Required area [m2]	Required modules
Yearly supply scenario	0,51	34	99	21	63



DEW



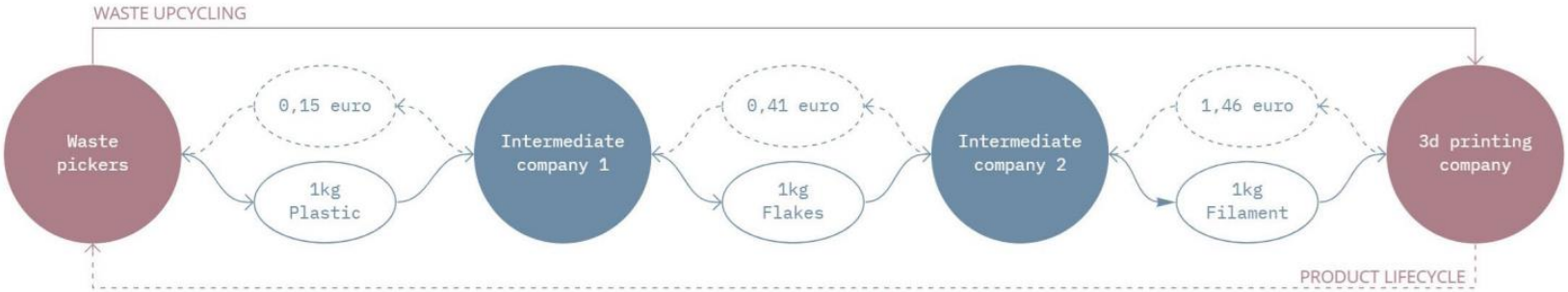
DEW + FOG



DEW + FOG + RAIN

Economic Feasibility Evaluation

Economic Feasibility Evaluation



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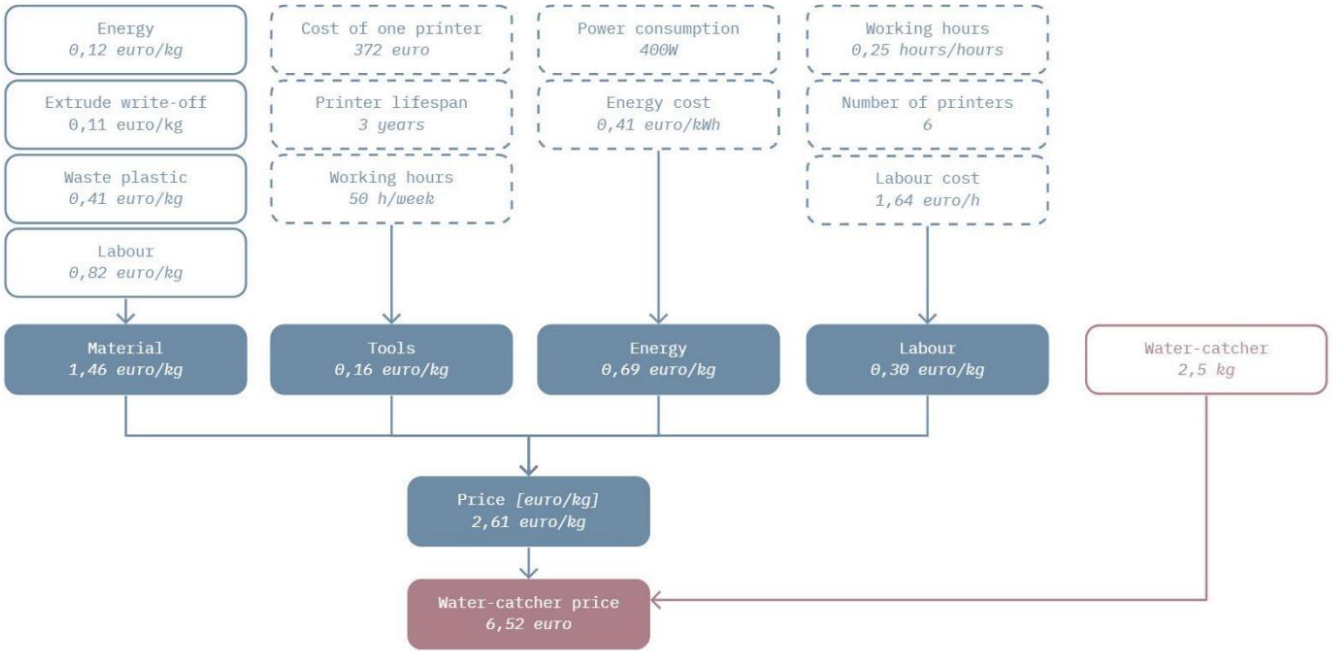
Economic Feasibility Evaluation



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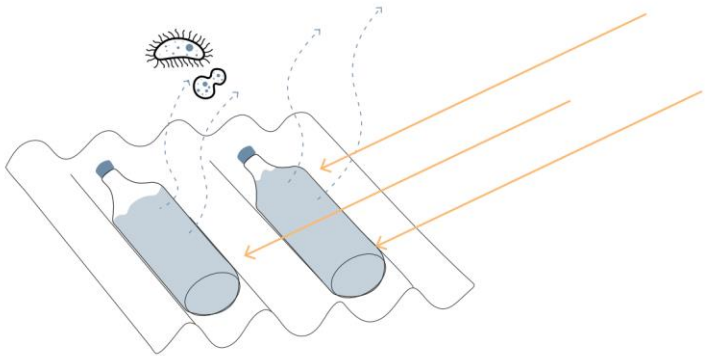
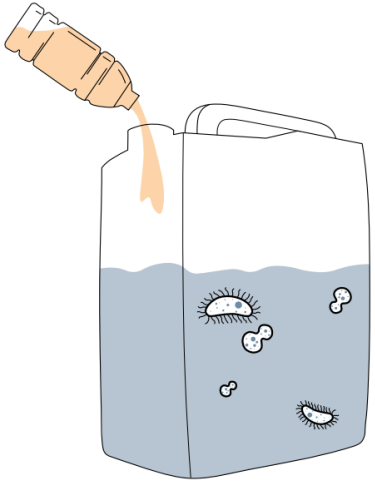
Economic Feasibility Evaluation



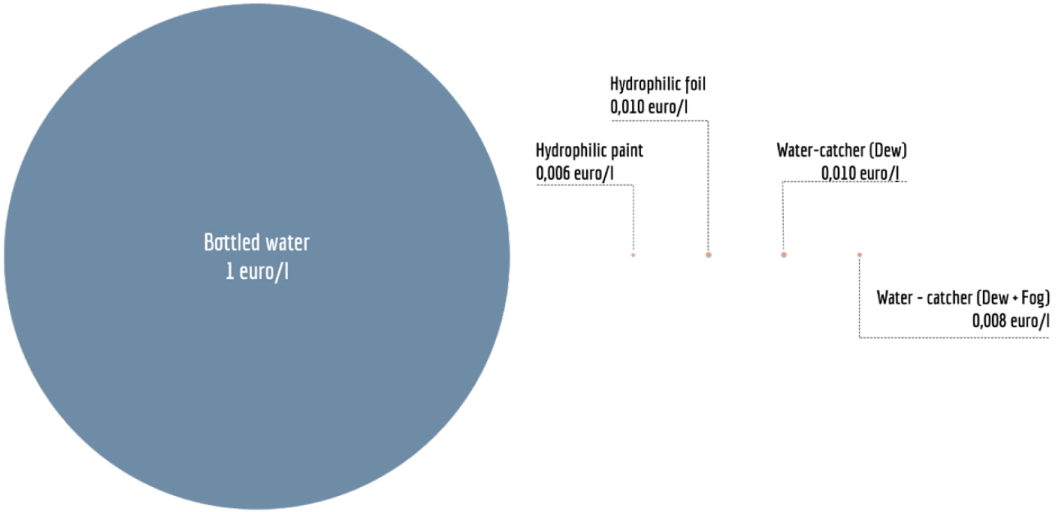
Solar disinfection



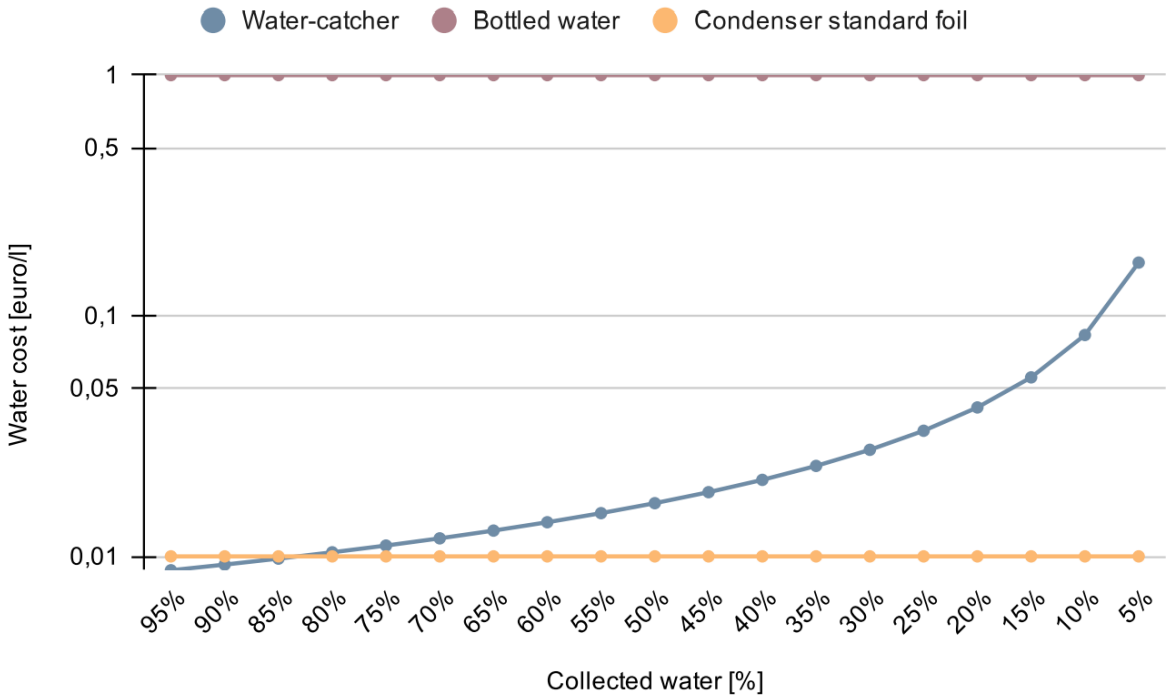
Chlorination

Sanitation method	Equipment		Basic water cost *[euro/l]*	Sanitation additional cost *[euro/l]*	Total cost *[euro/l]*
	Cost	Units			
Solar disinfection	0	*euros*	0,008	0	0,008
Chlorination	0,17	*euros/bottle*	0,008	0,0002	0,0082

Economic Feasibility Evaluation



Economic Feasibility Evaluation



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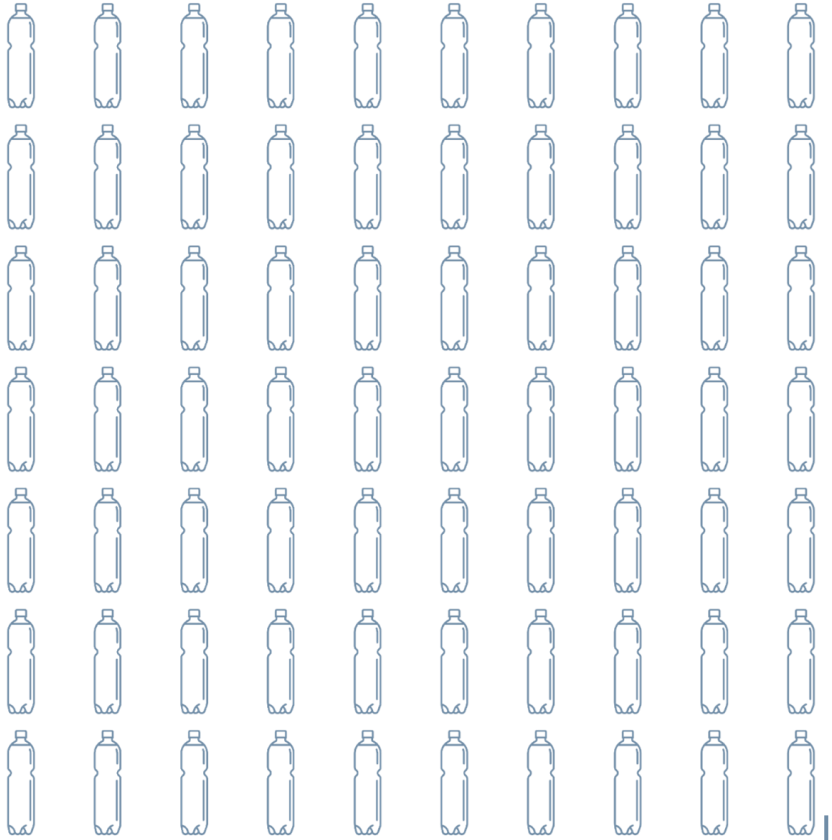
Economic Feasibility Evaluation

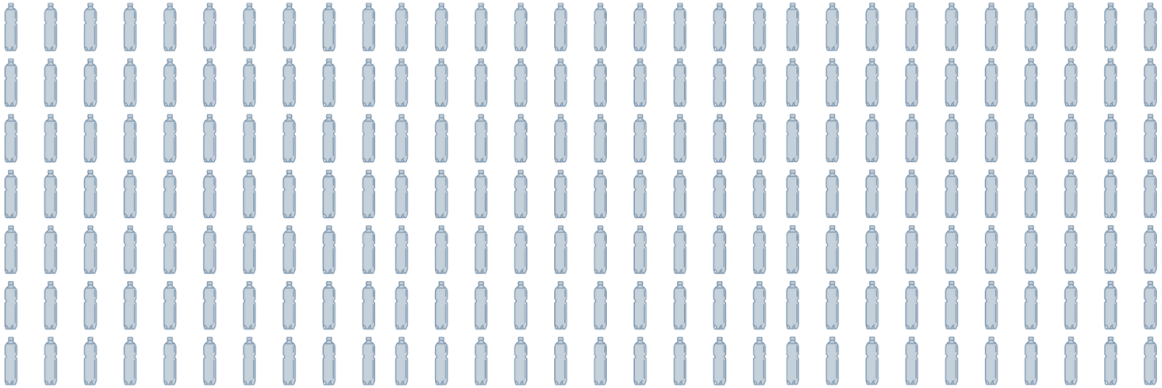


1 BOTTLE = 33g

1 WATER-CATCHER = 77 bottles

Economic Feasibility Evaluation

115,5 L



372 L

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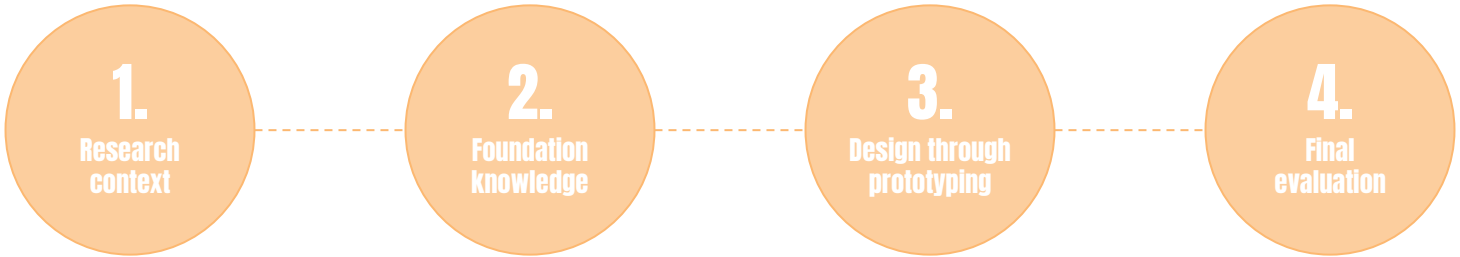
* Durability of 2 years


1.
Research context
2.
Foundation knowledge
3.
Design through prototyping
4.
Final evaluation

Conclusion and next steps

- Flexible workflow for the design and fabrication of a water-catcher
- Design of a solution easy to replicate with a mid-size 3d-printer
- Significant reduction of required surface to provide minimum water supply
- Competitive solution in the field of atmospheric water harvesting

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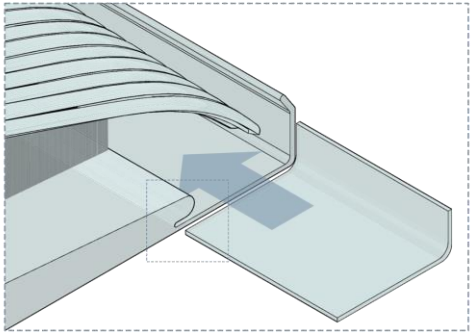
Conclusion and next steps

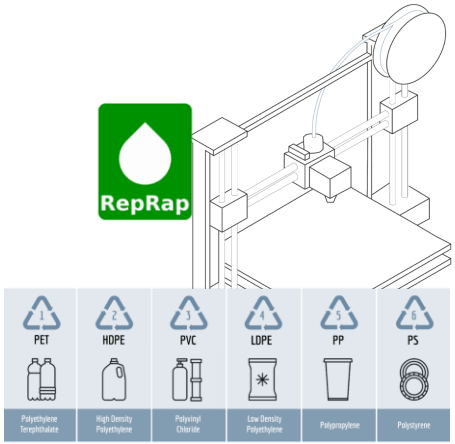
DESIGN

- Water storage
- Modules interlocking
- Condenser back insulation



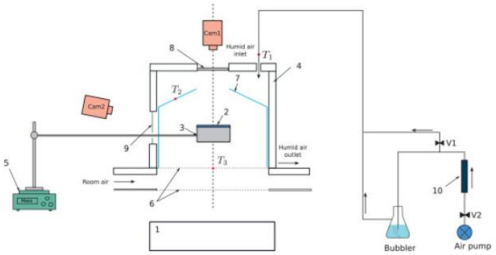
FABRICATION

- Customized printing setup
- Waste polymers testing



EVALUATION

- Computer model refinement
- Local outdoor testing
- Controlled environment testing



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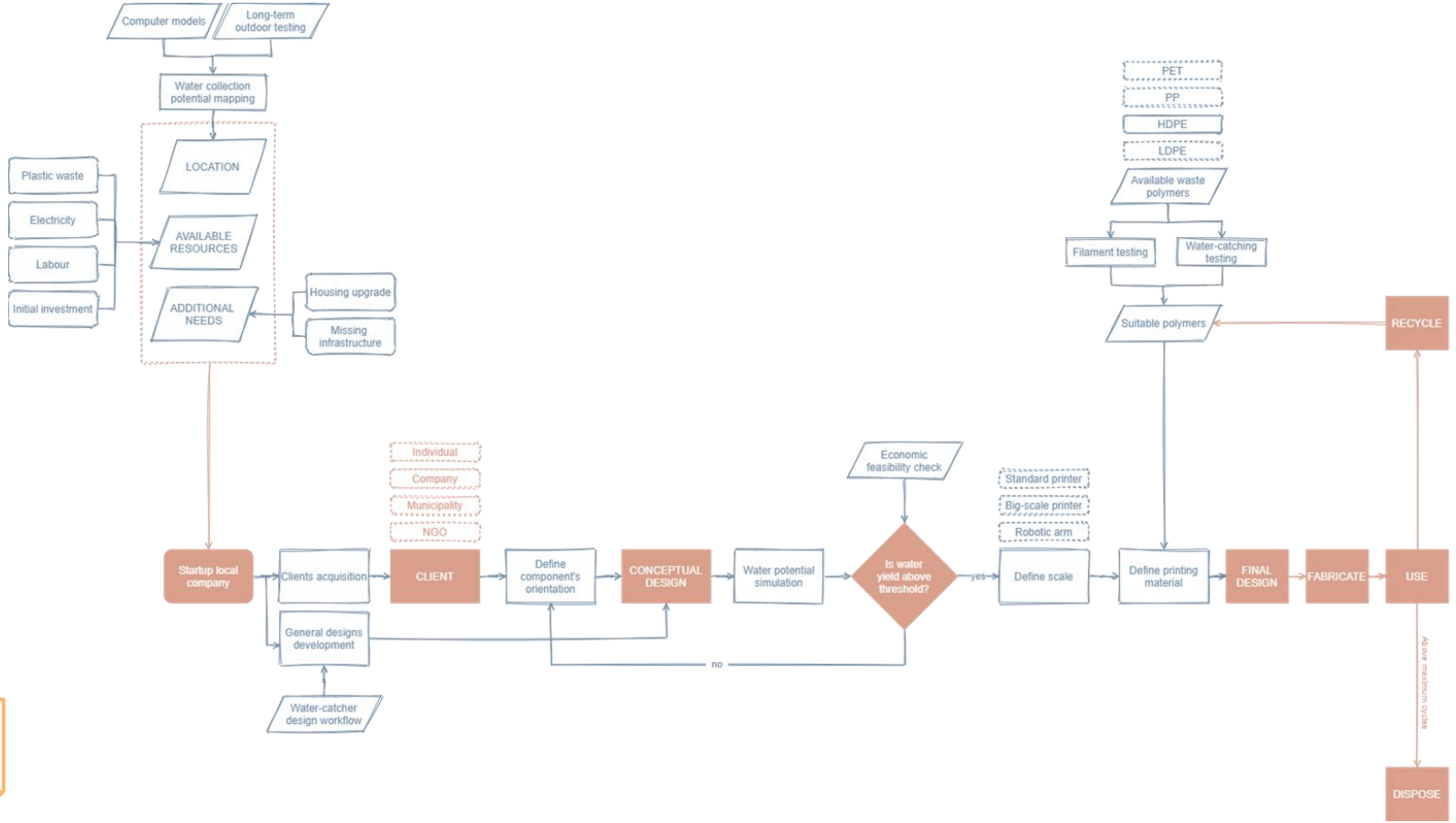
Conclusion and next steps



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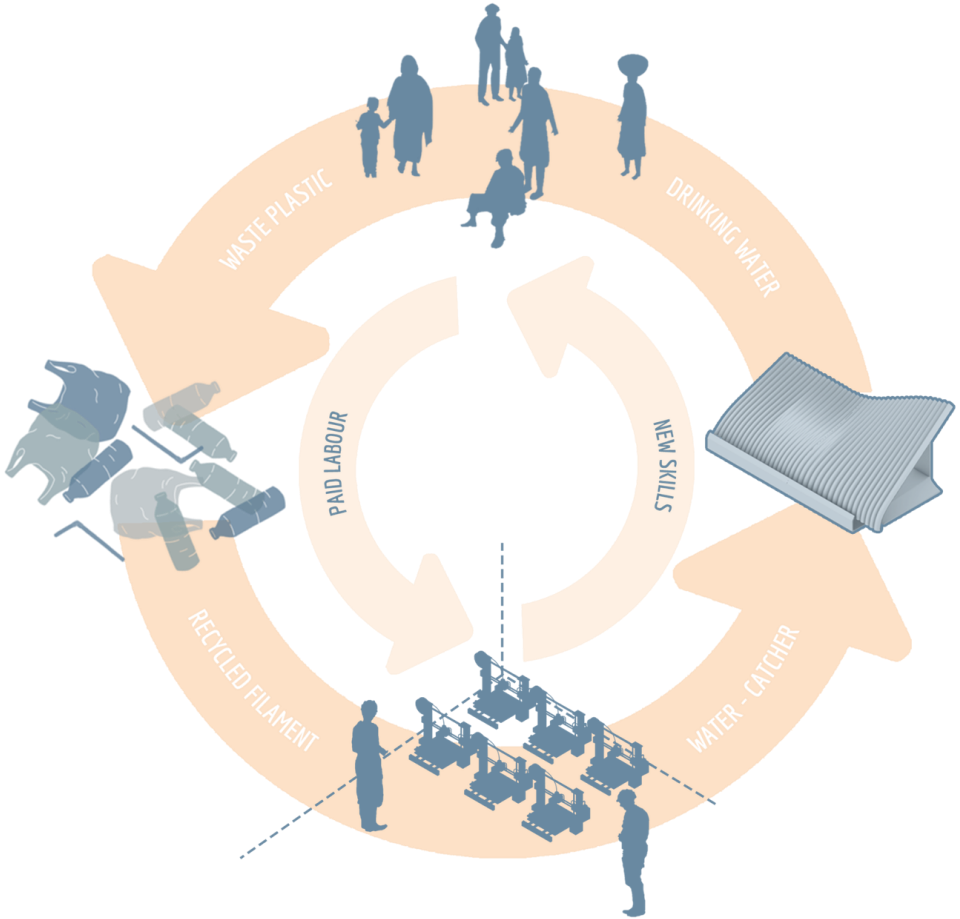
Conclusions



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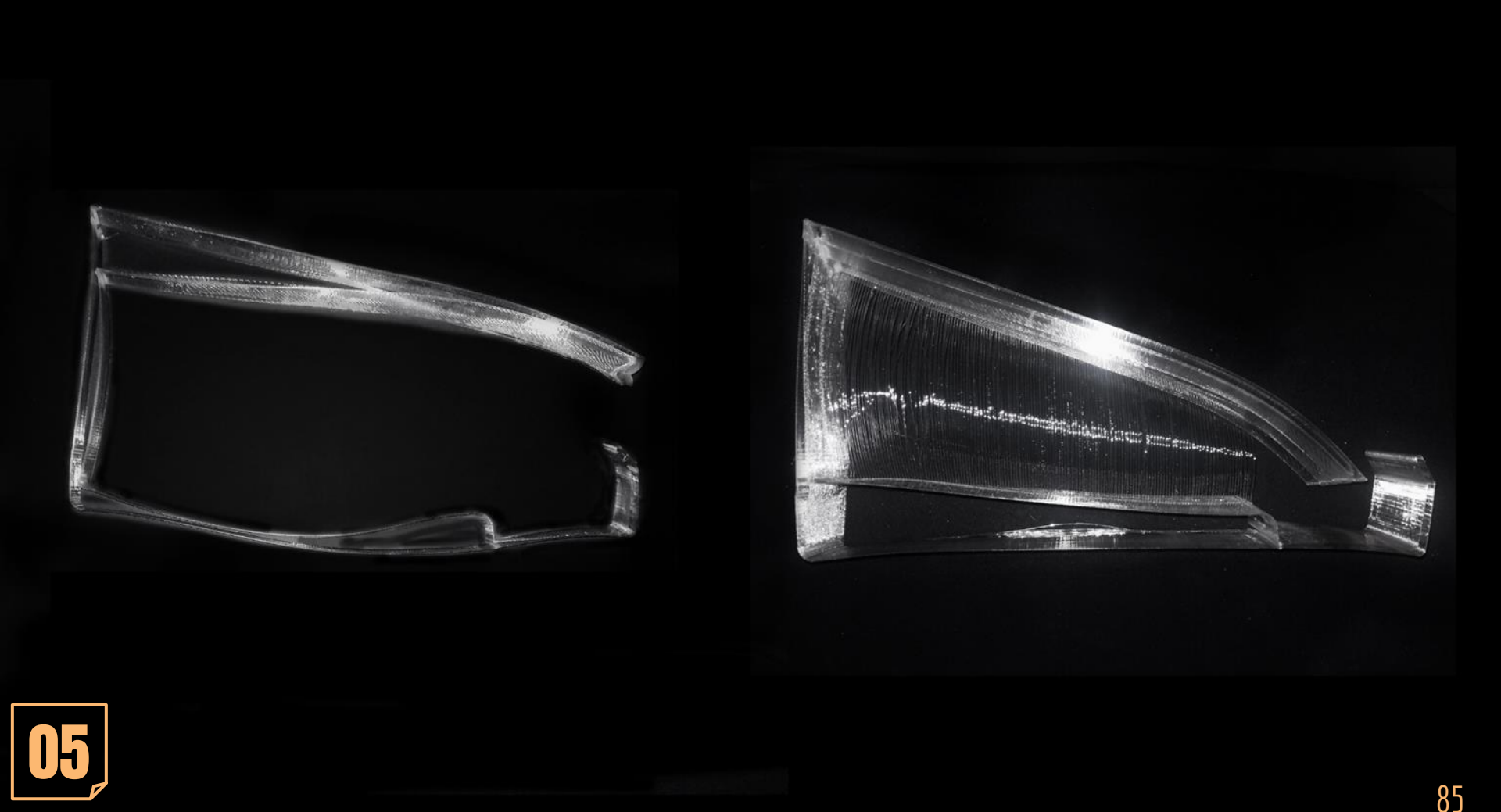
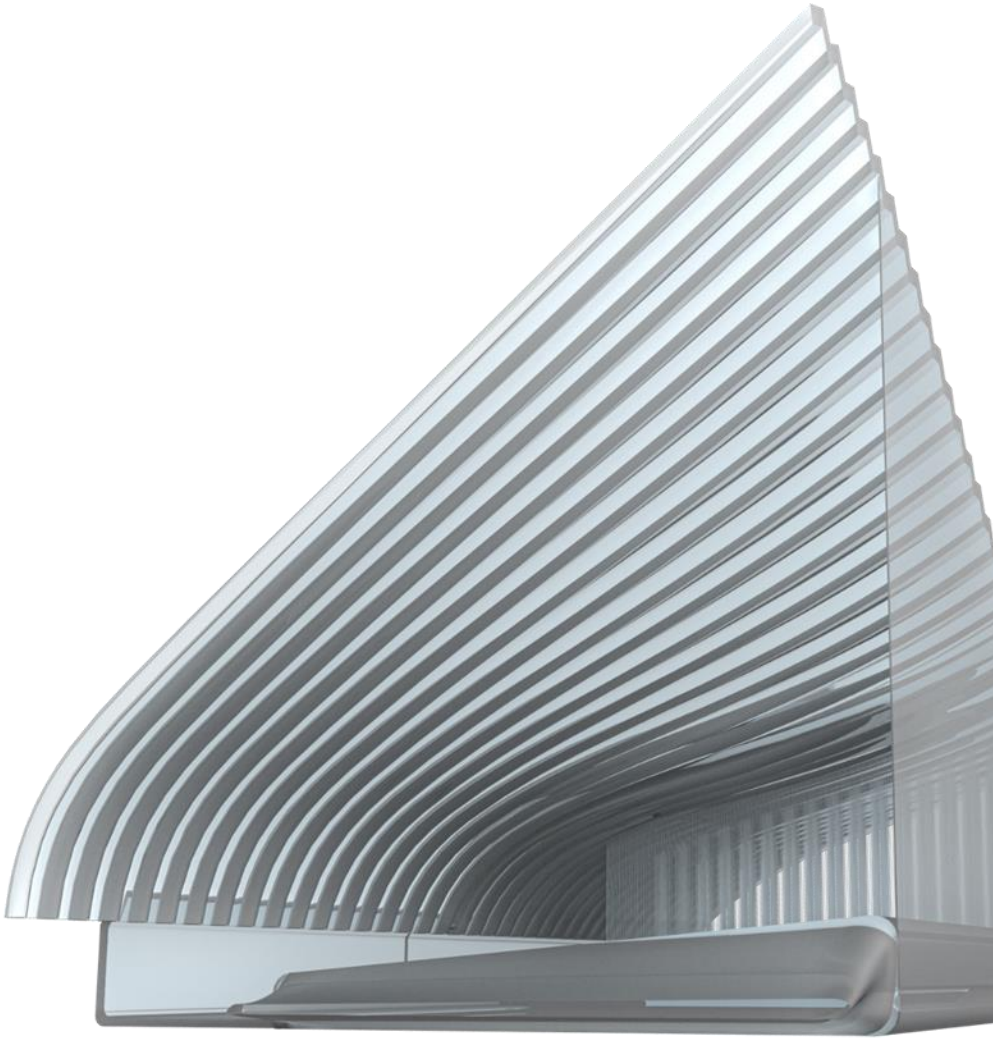
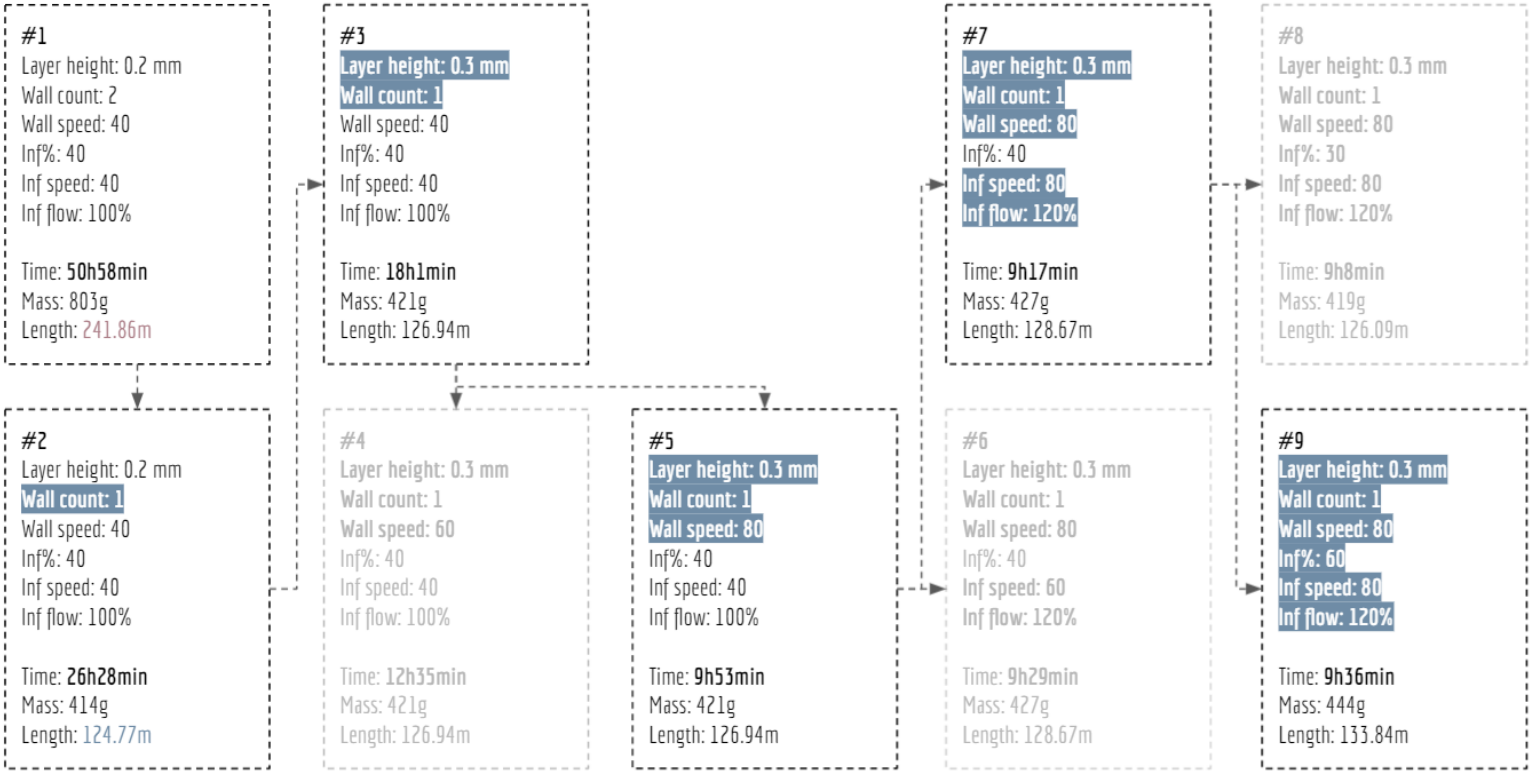


Thank you for the attention

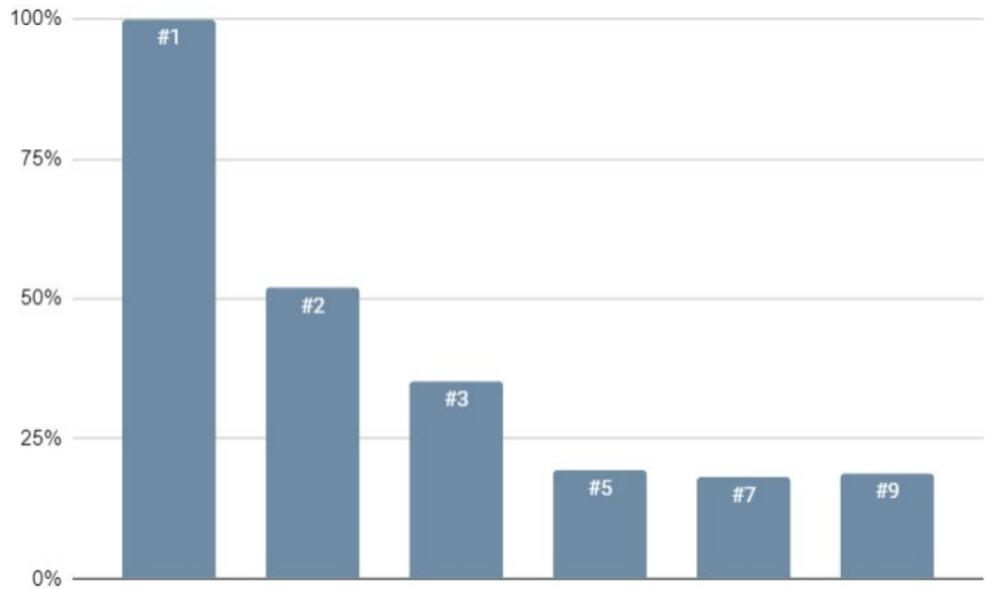
Questions



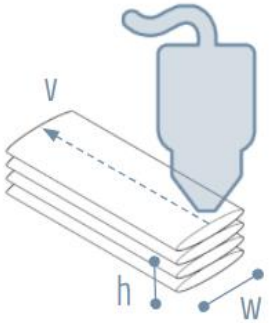
Printing Settings Definition



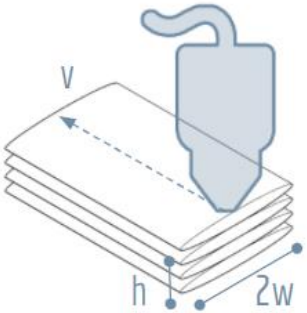
Printing Settings Definition



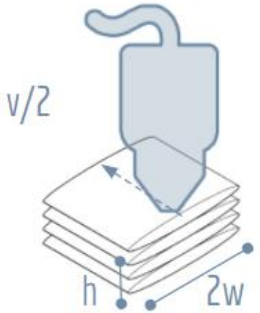
Printing Settings Definition



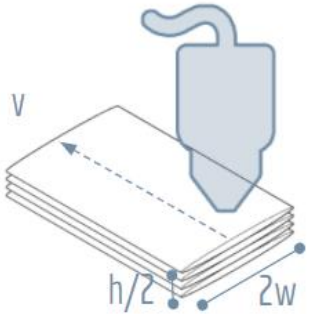
Standard Flow



Double Flow



Standard Flow



Standard Flow