Integrated Concentrating Solar Facade
Cast glass component,
embedded photovoltaic solar cells

Studio Building Technology track

Sustainable design graduaion studio

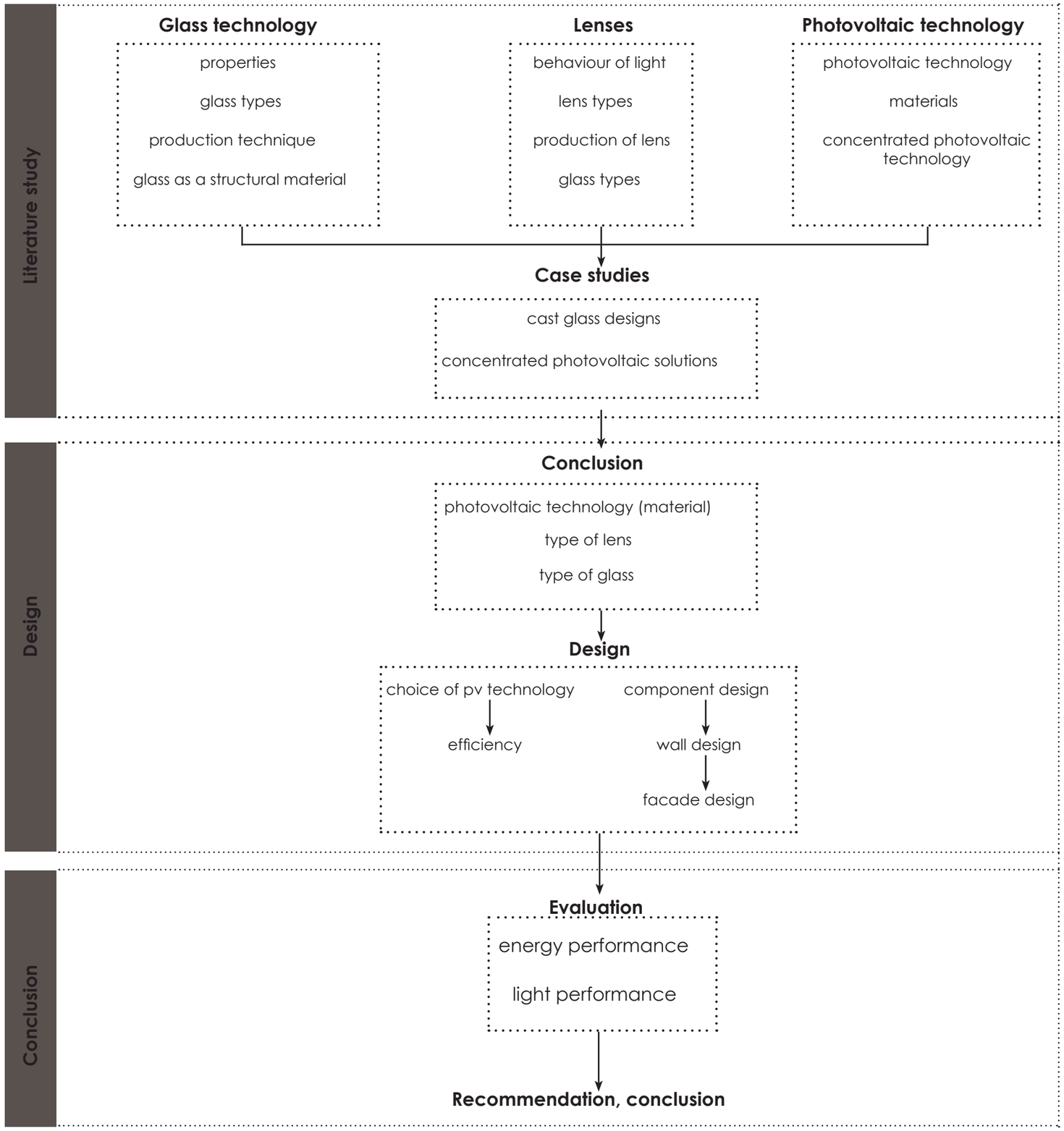
Student Akos Szabo (4630424)

Mentors Faidra Oikonomopoulou

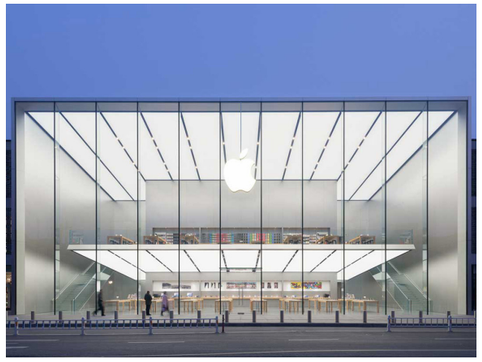
Michela Turrin

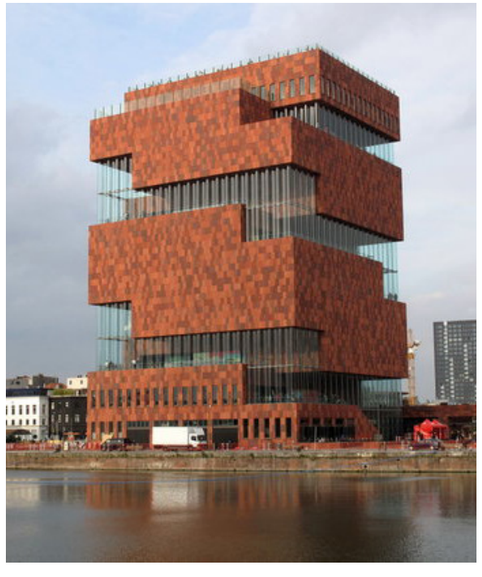
Telesilla Bristogianni

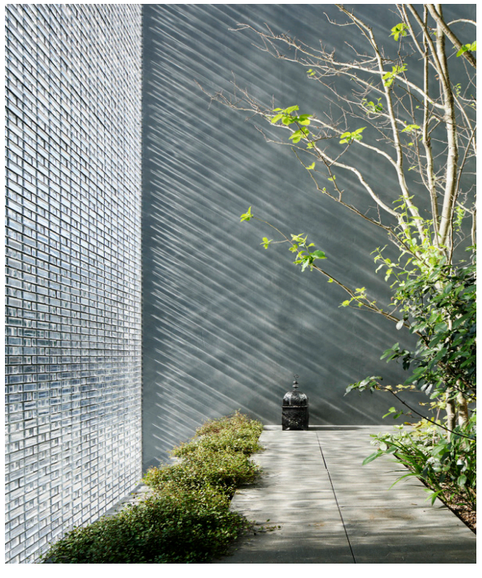
TU Delft Delft University of Technology


Literature study
Glass technology
properties
glass types
production technique
glass as a structural material
Lenses
behaviour of light
lens types
production of lens
glass types
Photovoltaic technology
photovoltaic technology
materials
concentrated photovoltaic technology
Case studies
cast glass designs
concentrated photovoltaic solutions
Conclusion
photovoltaic technology (material)
type of lens
type of glass
Design
Design
choice of pv technology
efficiency
component design
wall design
facade design
Conclusion
Evaluation
energy performance
light performance
Recommendation, conclusion

Cast glass solar concentrator



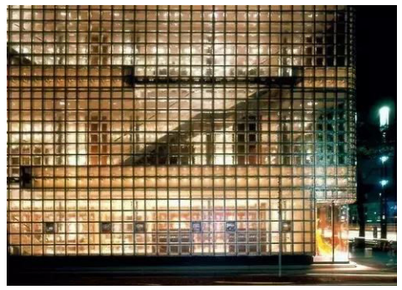


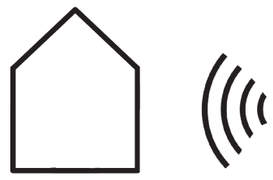


Hollow glass block

Solid cast glass block

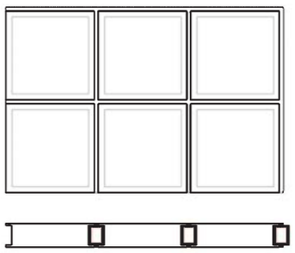
Hollow glass block





Good thermal properties

Good acoustic properties

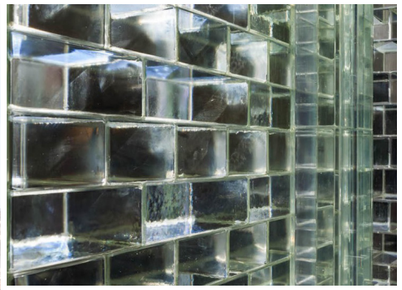


Non-structural system

↓

Need of substructures

Solid cast glass block



Poor thermal properties

↓

Higher energy demand for cooling/ heating

↓

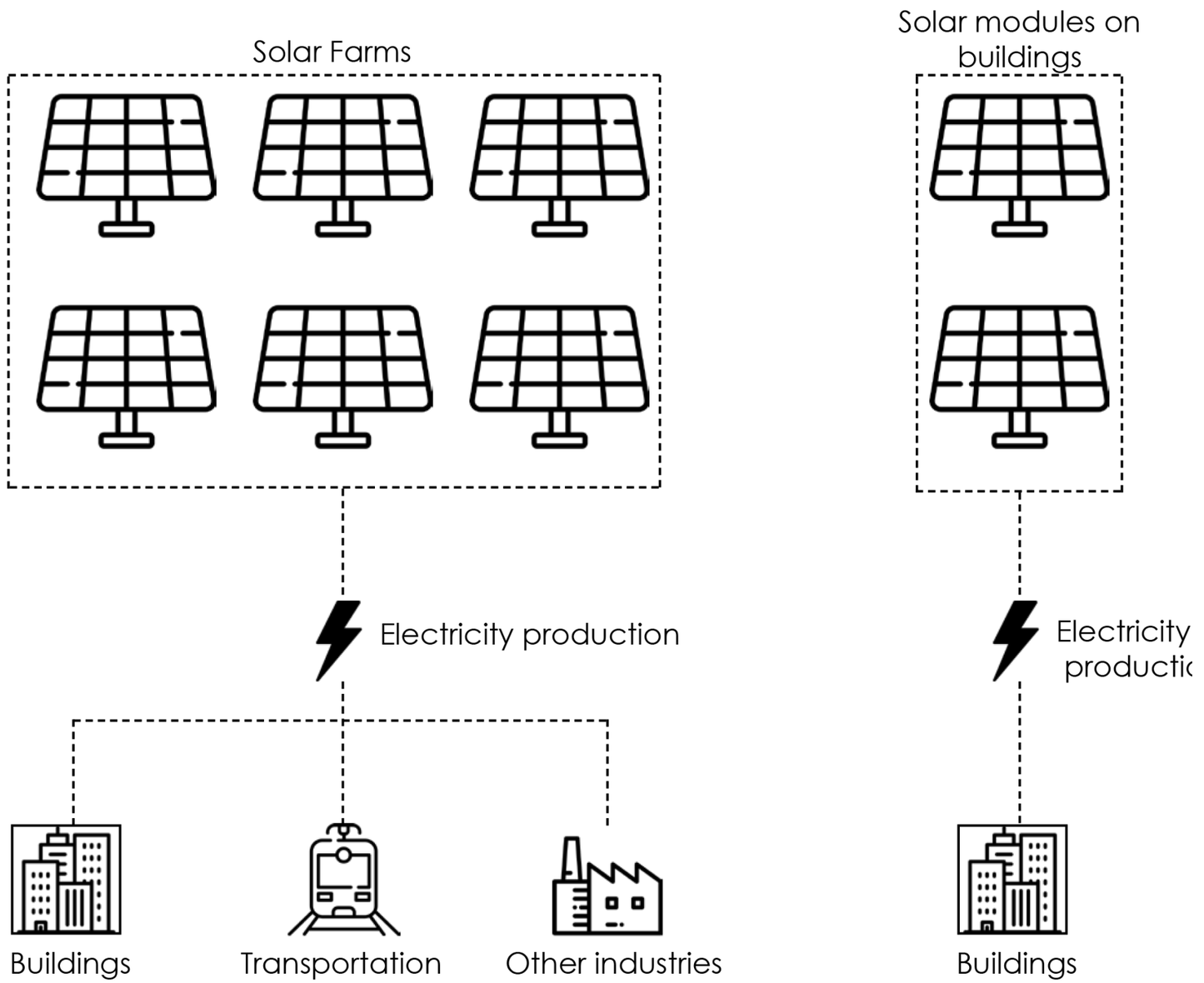
Additional expenses

Self- supporting structure

↓

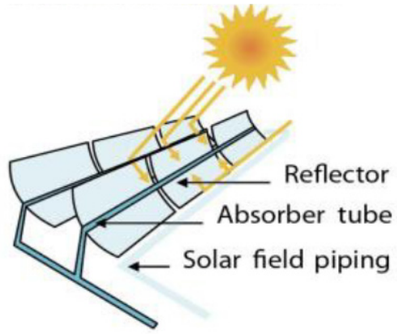
No additional supporting elements

Great freedom in geometry

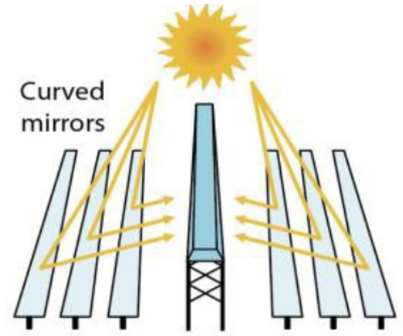

Solar Farms
Electricity production
Buildings
Transportation
Other industries
Solar modules on buildings
Electricity productio
Buildings

Types of concentrator

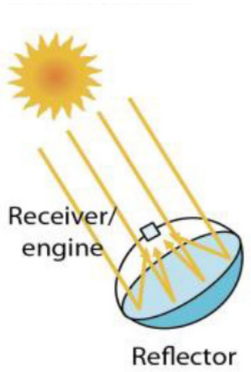
Parabolic Trough Collector



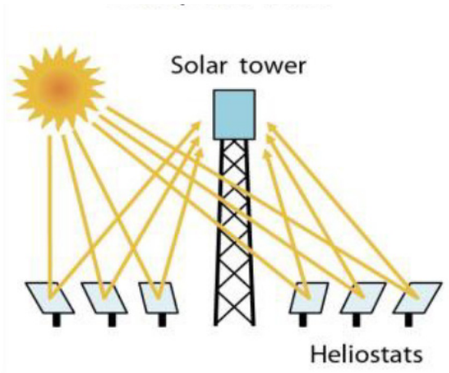
Linear Fresnel Reflector



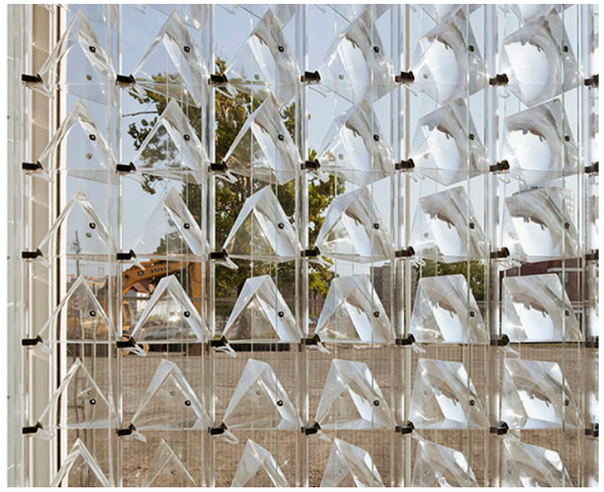
Parabolic dish

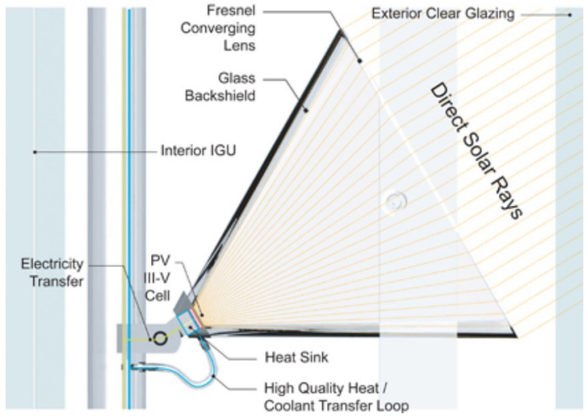


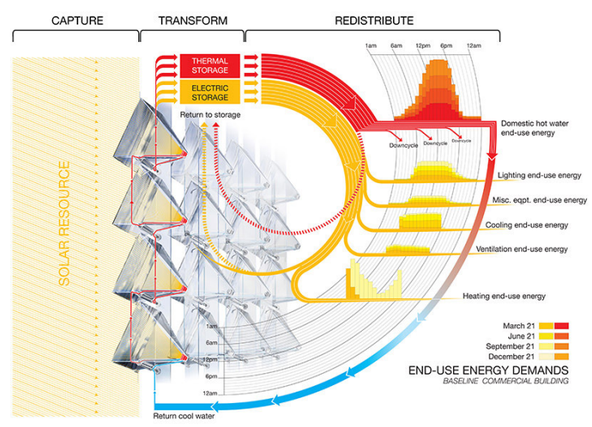
Solar power tower



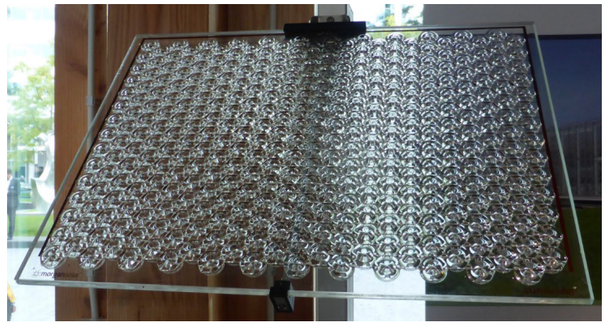
SOM- Solar Facade

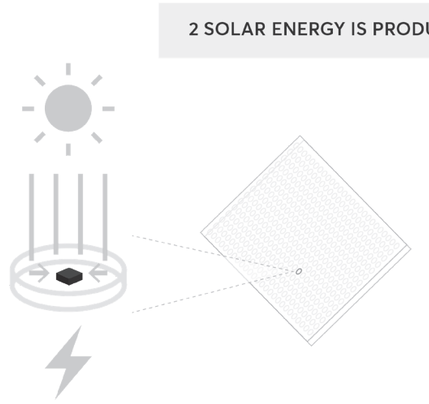






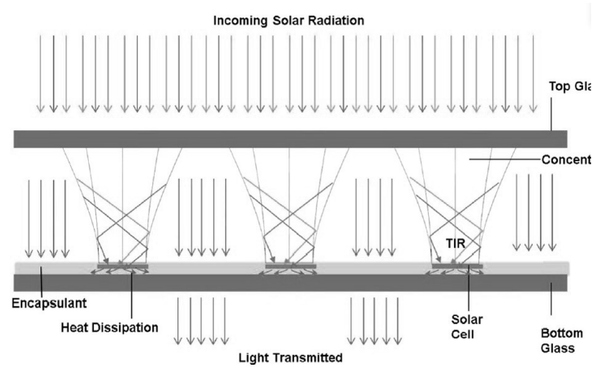
WellSun- Lumidect solar panel

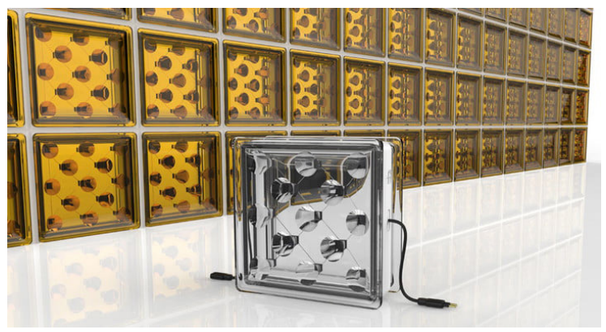




> Panel efficiency is 30%
> Peak power is 300 Wp/m² (under Standard Test Conditions)
> Heat is blocked and can be harvested

Solar Squared





-In what ways can a cast glass component redirect the light in order to maximize the energy production in a facade, and improve its sustainablitity and decrease the need of additional external cooling sources.

Sub-questions:

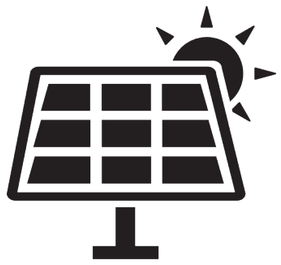
- What manufacturing process should be employed to produce a block of the given complex geometry and high accuracy

- What type of Photovoltaics is more appropriate for such an application?

- In what ways do influence the geometry of the glass brick components the redirection of the light?

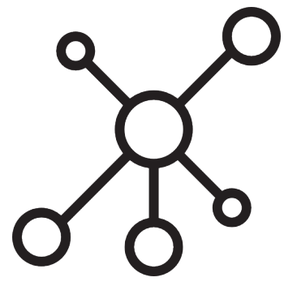
- What are the shapes and forms that are optimum for such a solar energy system that can be achieved in cast glass ?

Type of photovoltaic



Type of lens

Type of glass

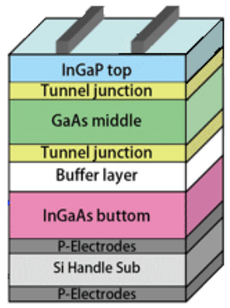


Type of photovoltaic

Type of lens

Type of glass

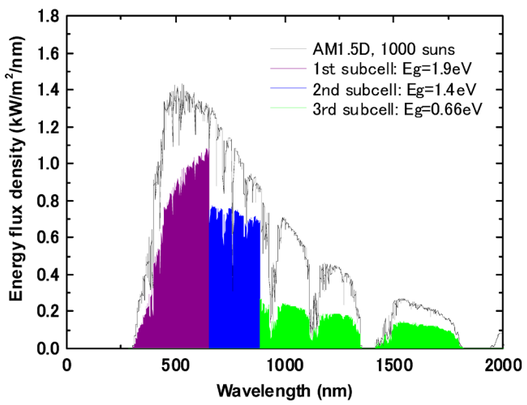
III-V Multijunctional solar cells



Top layer

Middle layer

Bottom layer

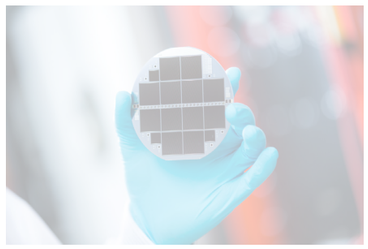


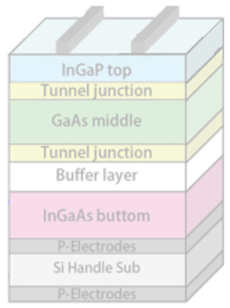
Ultrathin

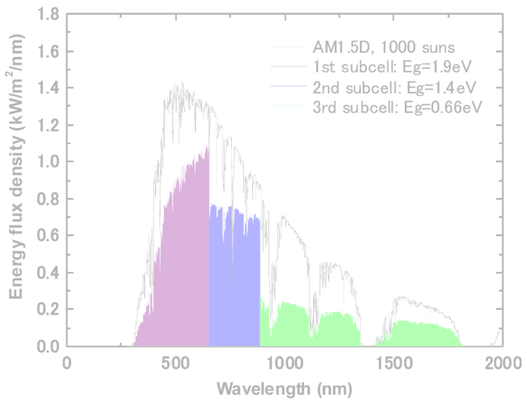
High efficiency rate: 31.3%

Type of photovoltaic

Multijunctional solar cells





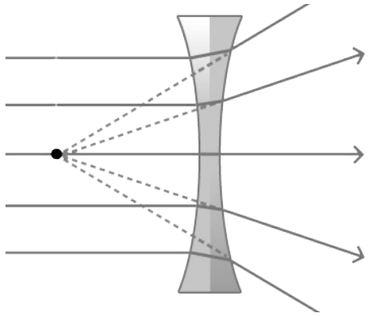


Ultrathin

Efficiency: 31.3%

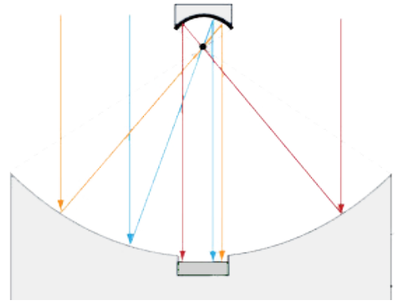
Type of lens

Lens in concentrated system

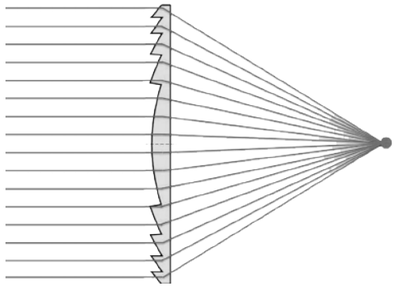


Concave lens

Spreads light

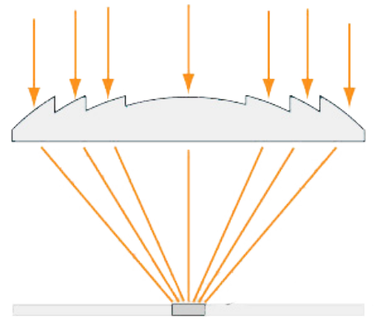


High reflective mirror applications

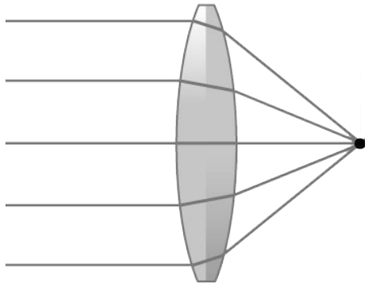


Fresnel lens

Focuses light

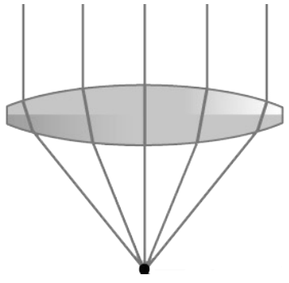


Complex manifacture



Convex lens

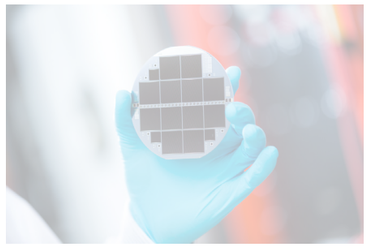
Focuses light

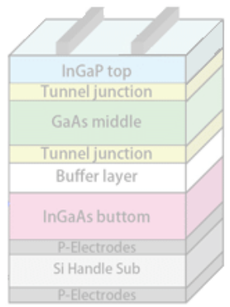


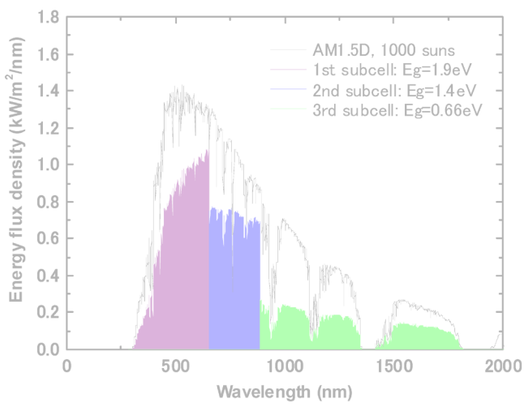
Precision optics application

Type of photovoltaic

Multijunctional solar cells







Ultrathin

Efficiency: 31.3%

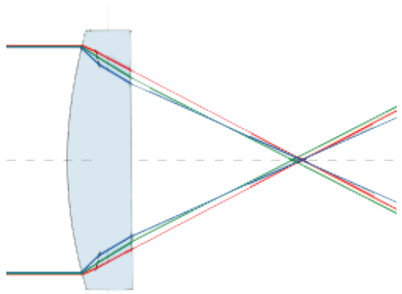
Type of lens

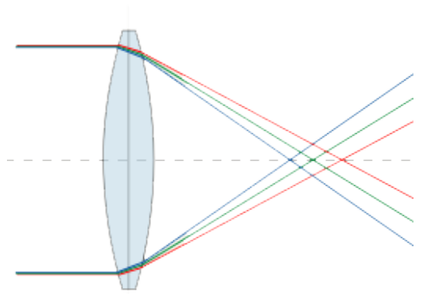
Convex lens

Type of glass

Optical glass

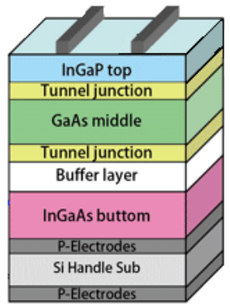
Crown glass	Flint glass
Low refractive index	High refractive index
High abbe number	Low abbe number
↓	↓
Less color abberation	High color abberation

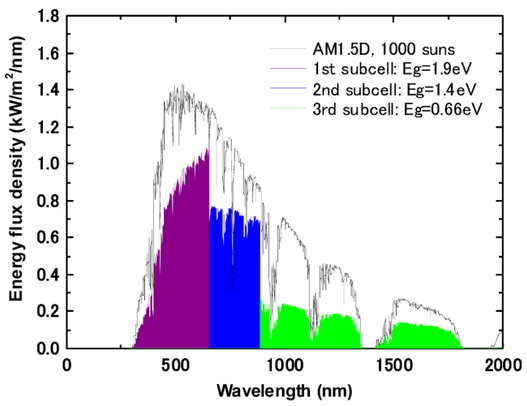




Type of photovoltaic

Multijunctional solar cells



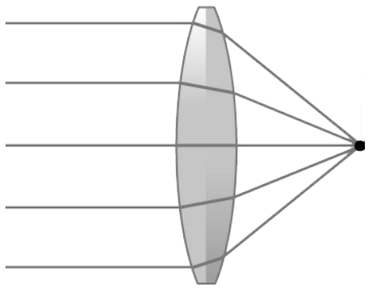


Ultrathin

Efficiency: 31.3%

Type of lens

Convex lens



Type of glass

Borosilicate glass

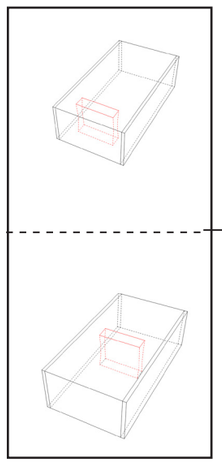
Refractive index: 1.51

Abbe number: 63.96

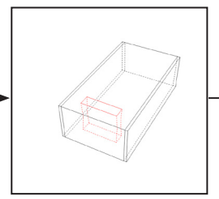
Low thermal expansion coefficient.

Geometry Study

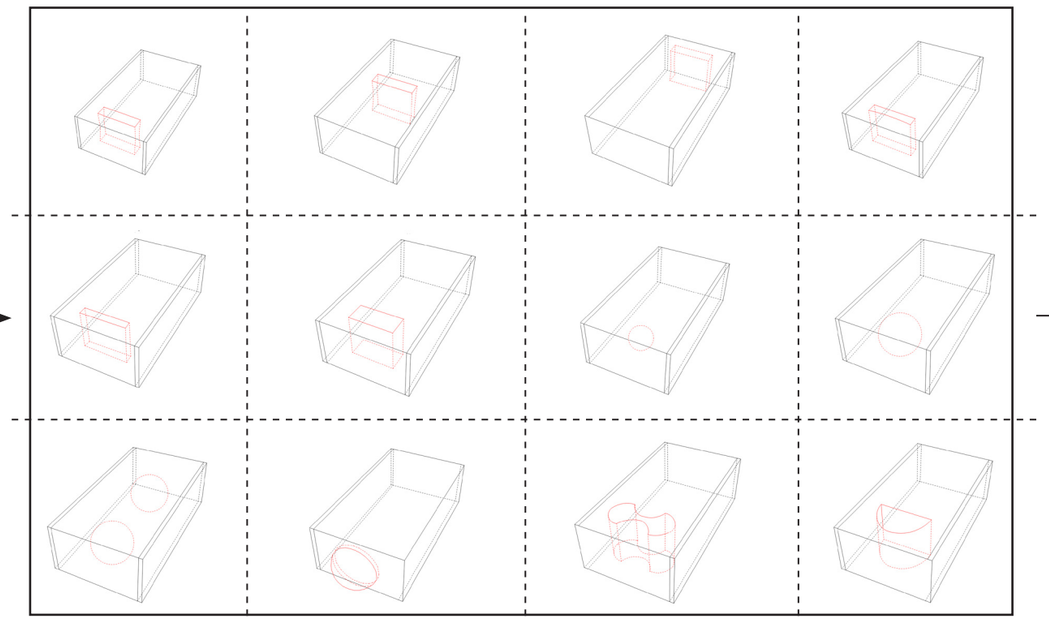
Position of PV



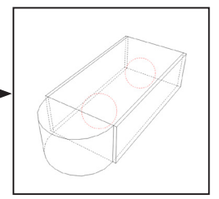
Chosen position



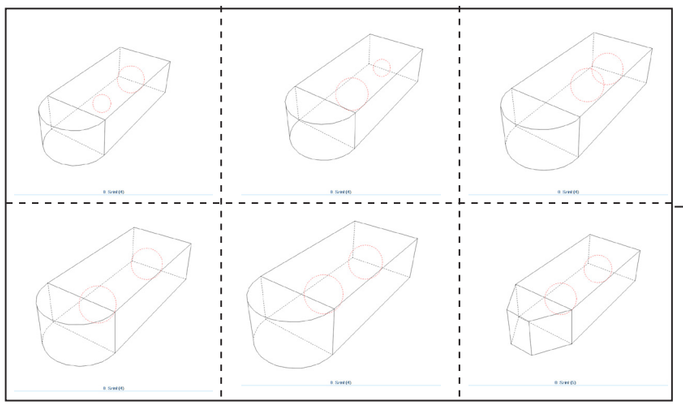
Variety of design experiments by changing the shape of the holes



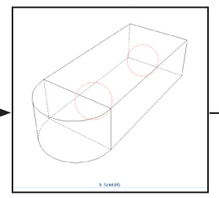
Promisiong solution



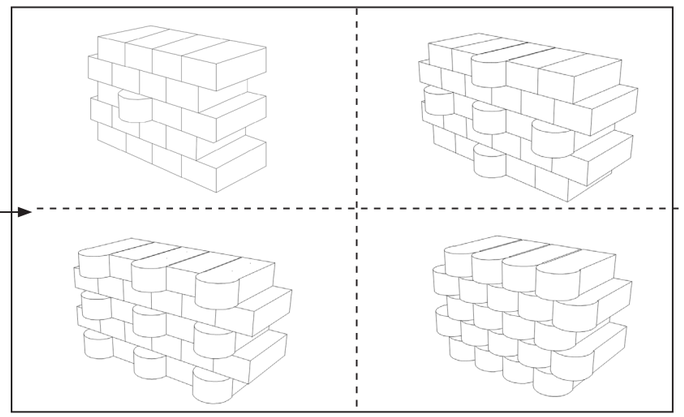
Further elaboration



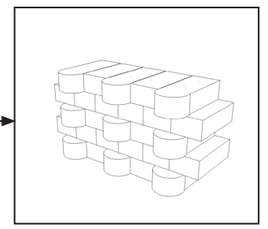
Final component



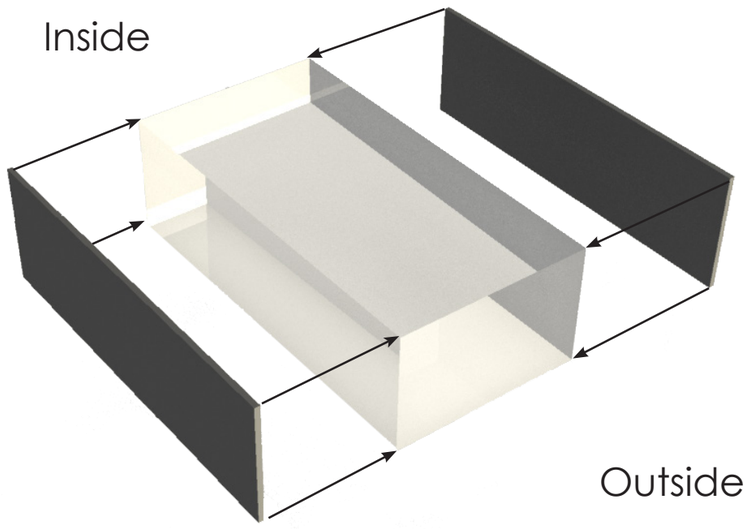
Different wall types



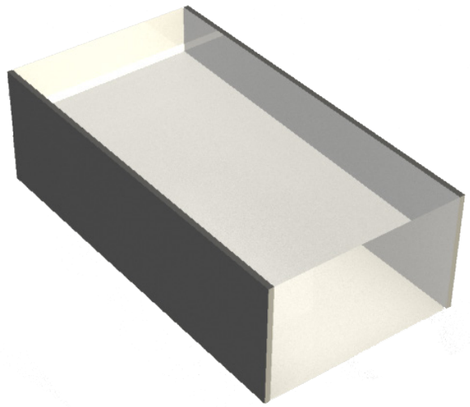
Final wall structure



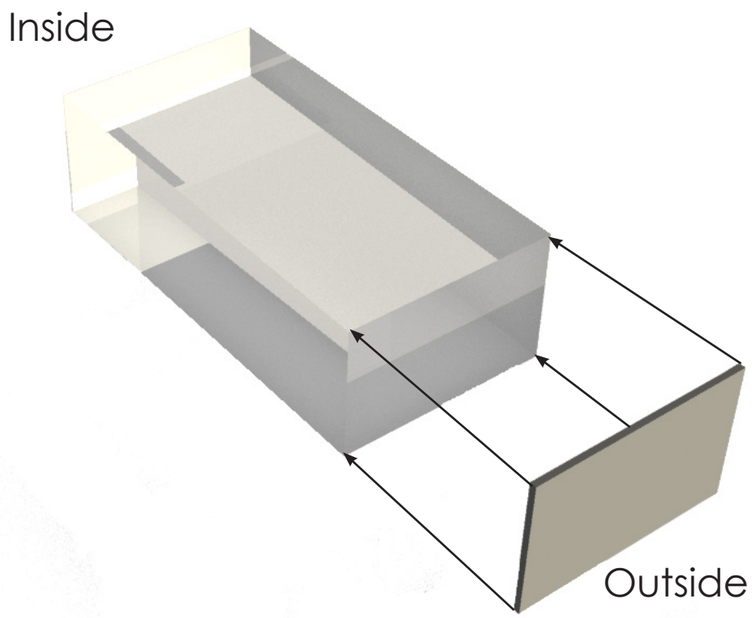
Panels on the side



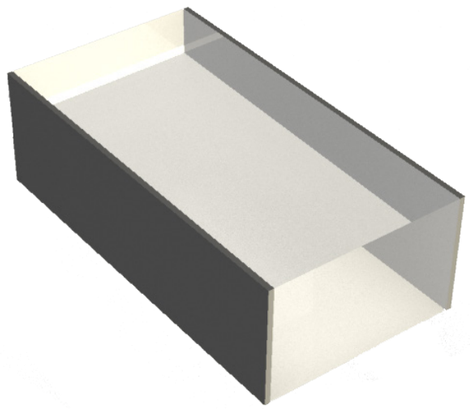
Panels on the side



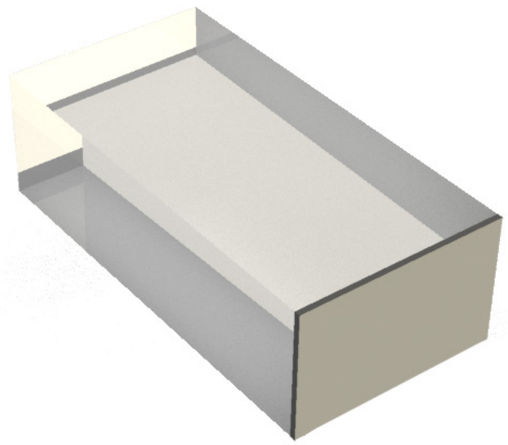
Panels on the front



Panels on the side

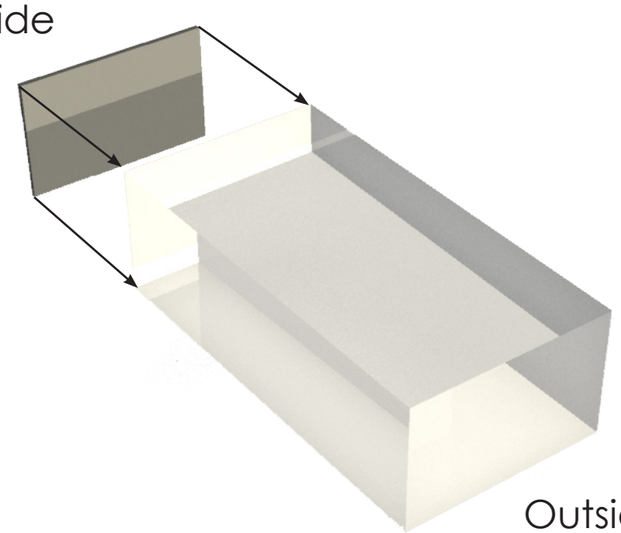


Panels on the front

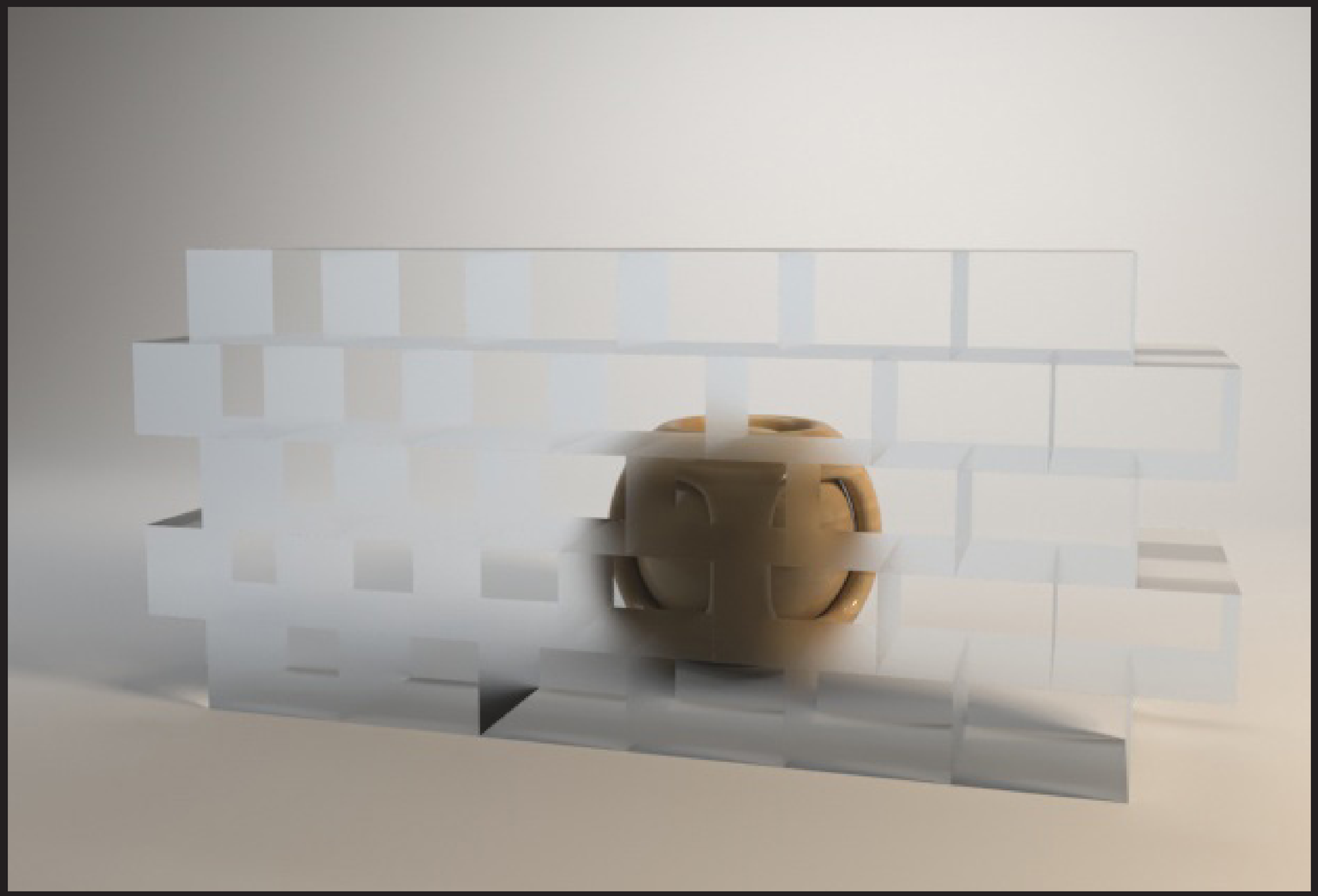


Panels on the back

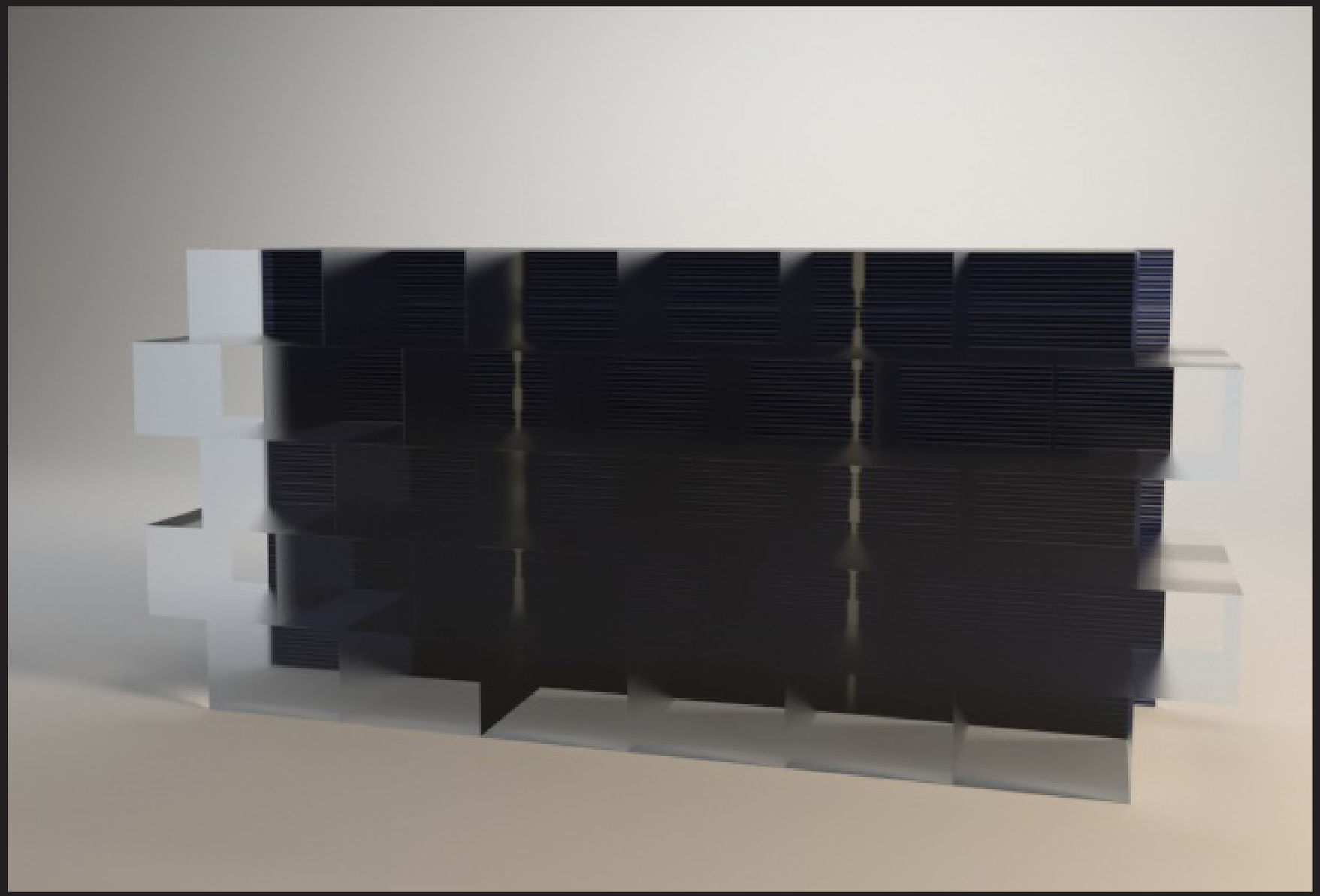
Inside



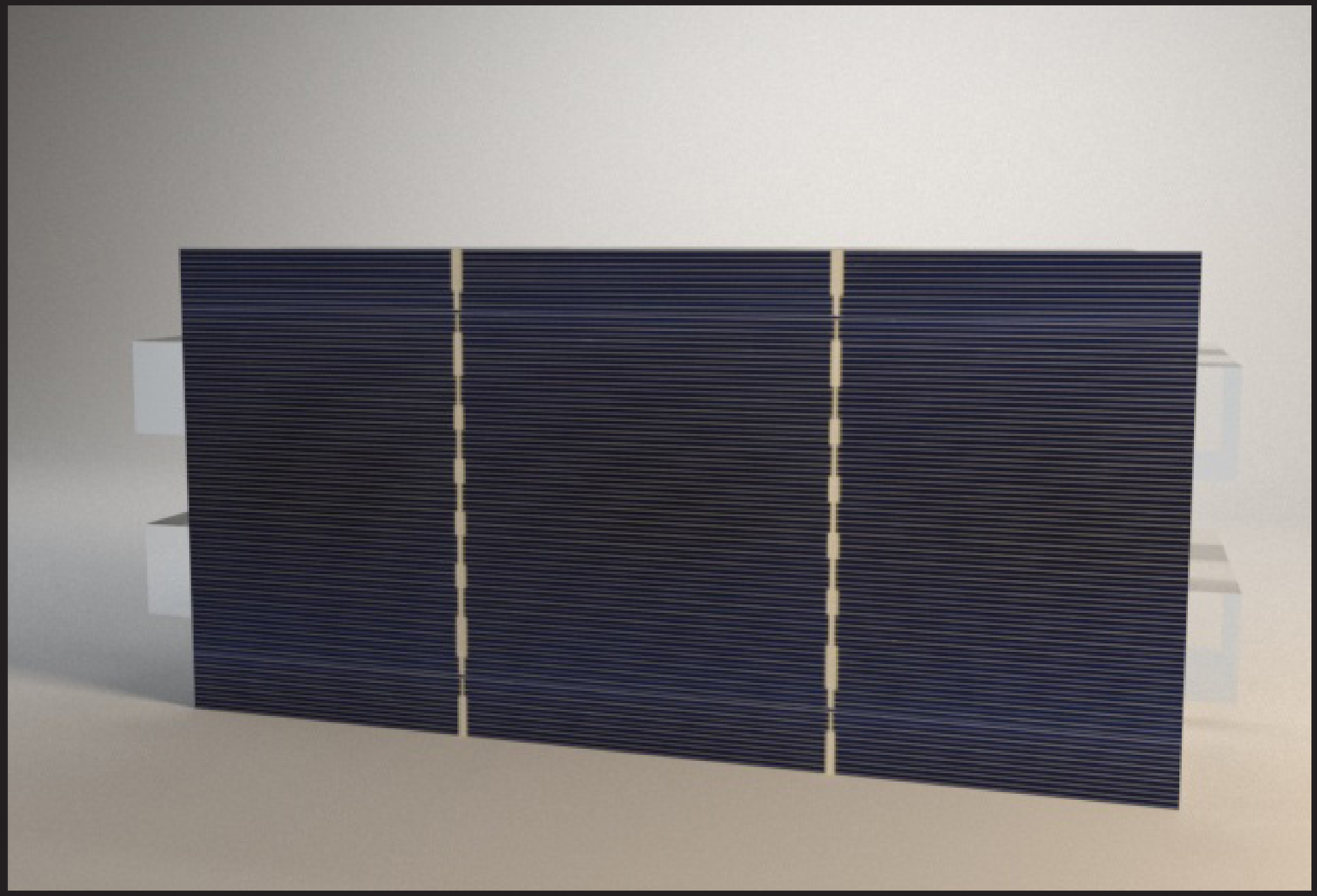
Outside



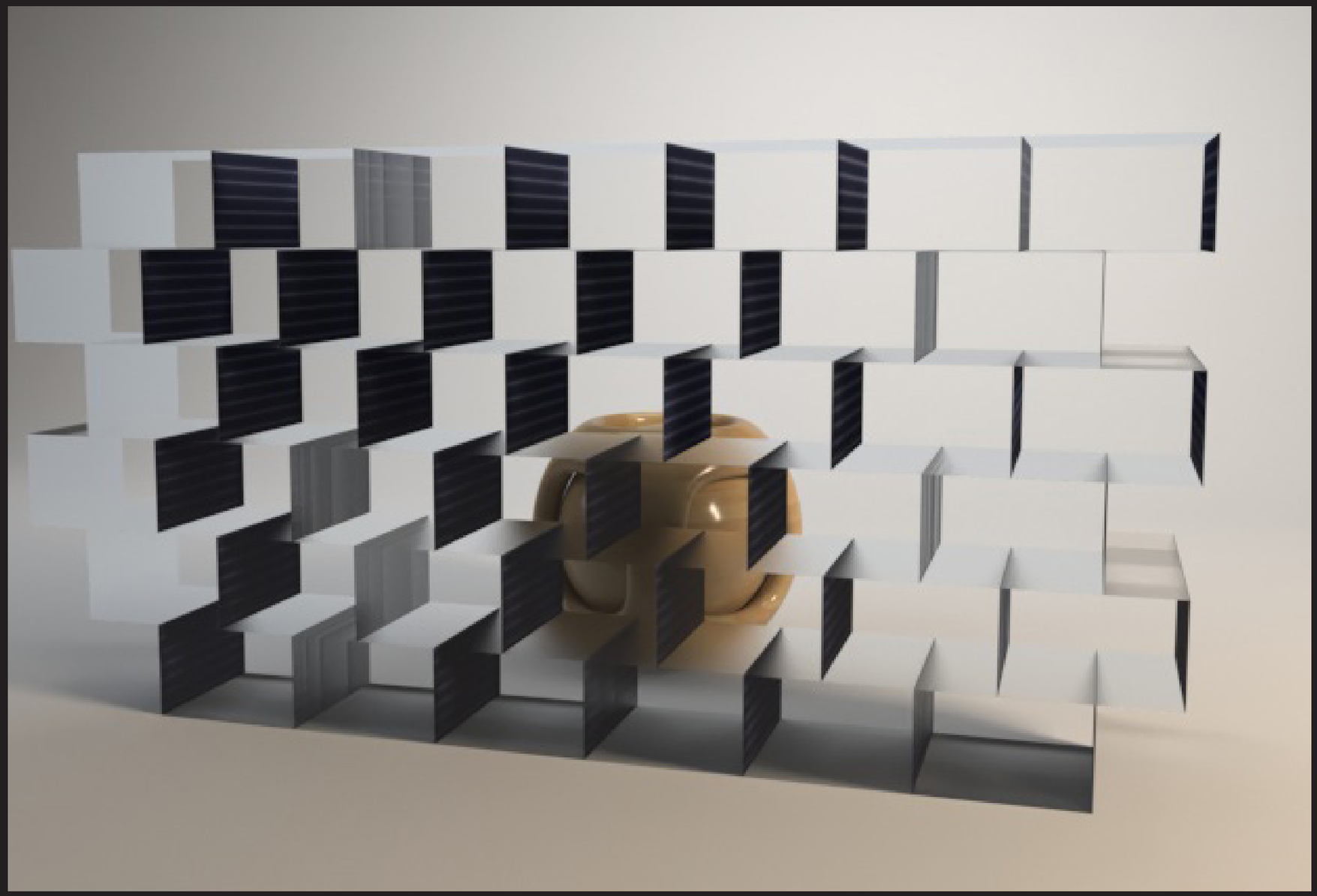
Visualization of the panel position



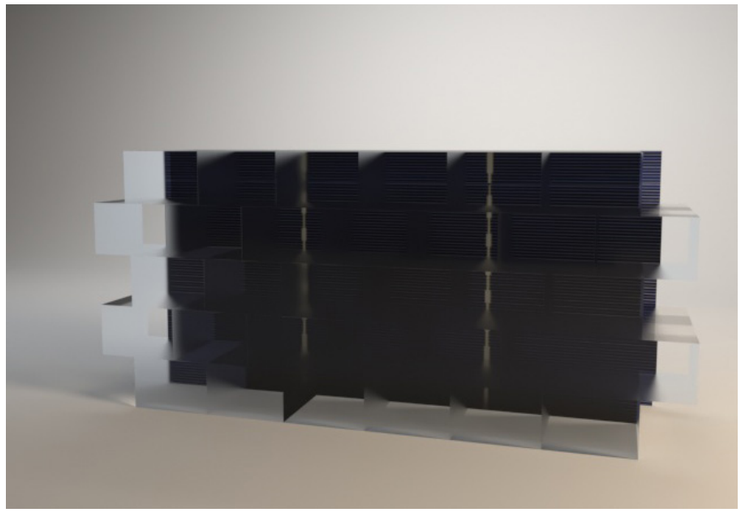
Visualization of the panel position



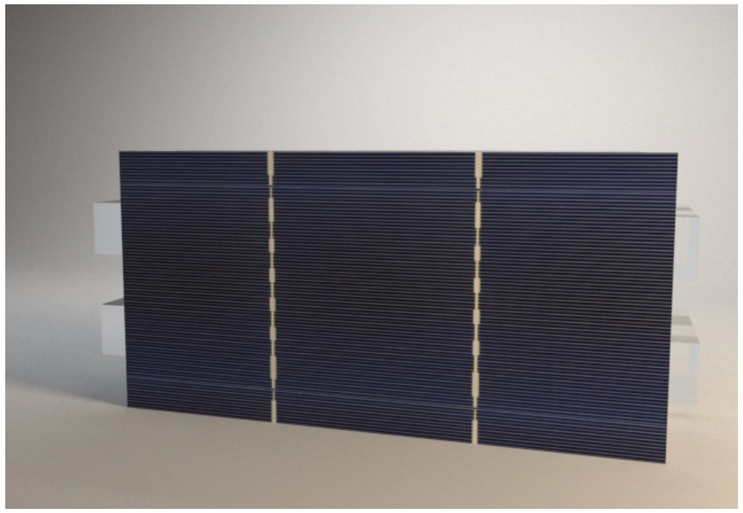
Visualization of the panel position



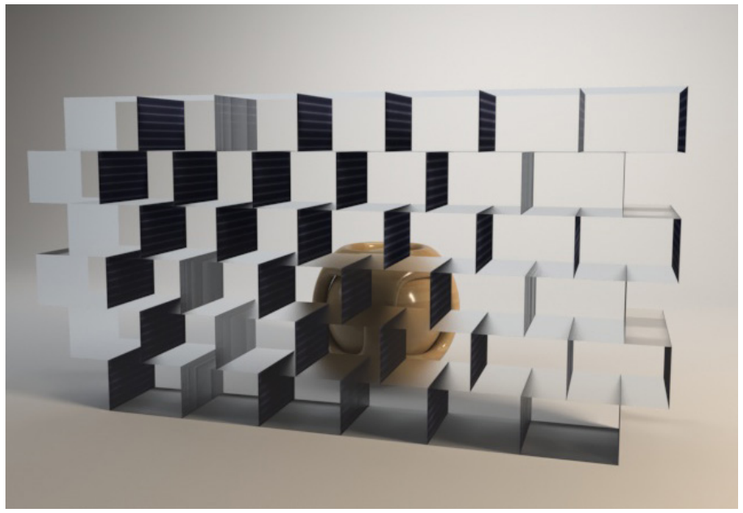
Visualization of the panel position



- Poor visual comfort
- Easy maintenance



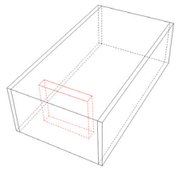
- Best energy production
- Poor visual comfort
- Panels can be ruined due to the outdoor environment



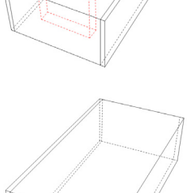
- Good visual comfort
- Panels are protected

Overview of the positions of the panles

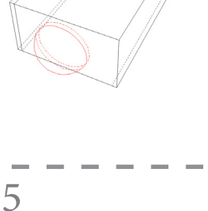
Redirected light/
Radiation



6,0%
3.01*10⁶ W



7.5%
3.06*10⁶ W



8.0%
3.52*10⁶ W

9.0%
4.05*10⁶ W

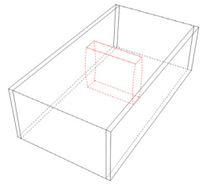
9.4%
4.29*10⁶ W

9.7%
4.35*10⁶ W

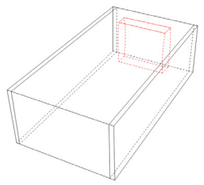
10.0%
4.49*10⁶ W

better performance

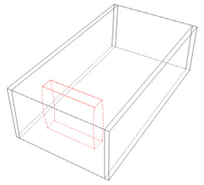
Redirected light/
Radiation



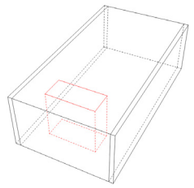
10.7%
4.60*10⁶ W



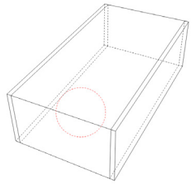
11.7%
4.97*10⁶ W



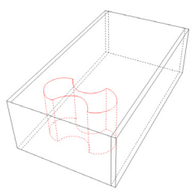
16.6%
5.44*10⁶ W



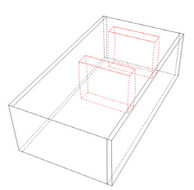
17.0%
7.0*10⁶ W



17.5%
8.10*10⁶ W



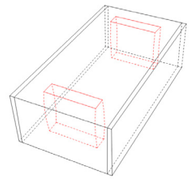
20.0%
9.31*10⁶ W



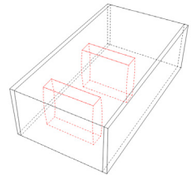
20.7%
9.63*10⁶ W

better performance

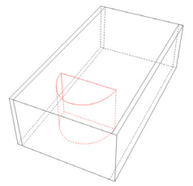
Redirected light/
Radiation



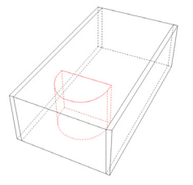
20.9%
9.70*10⁶ W



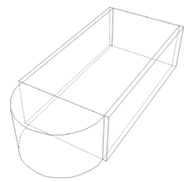
21.0%
9.75*10⁶ W



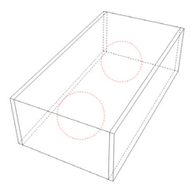
21.6%
10.02*10⁶ W



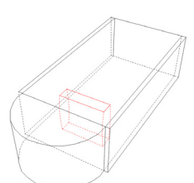
22.4%
10.40*10⁶ W



30.2%
14.0*10⁶ W



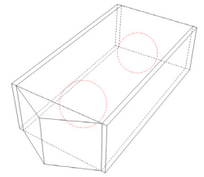
31.7%
14.70*10⁶ W



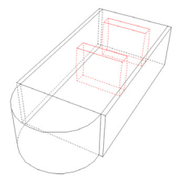
35.1%
16.30*10⁶ W

better performance

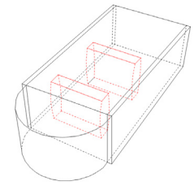
Redirected light/
Radiation



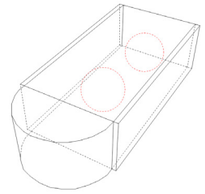
40.9%
19.0*10⁶ W



45.4%
21.07*10⁶ W



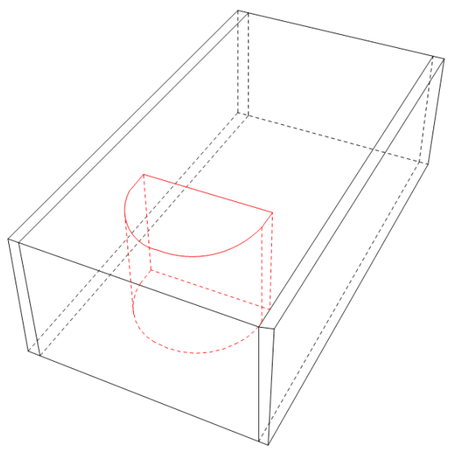
50.5%
23.42*10⁶ W



65.9%
30.58*10⁶ W

better performance

Simple convex lens

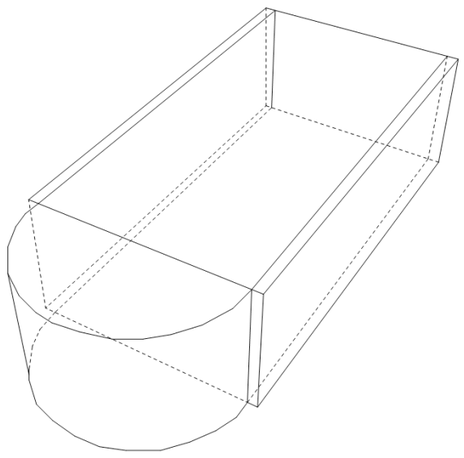


Easy manufacture method

Small visual impact

Good performance
22.4%

Simple curved surface

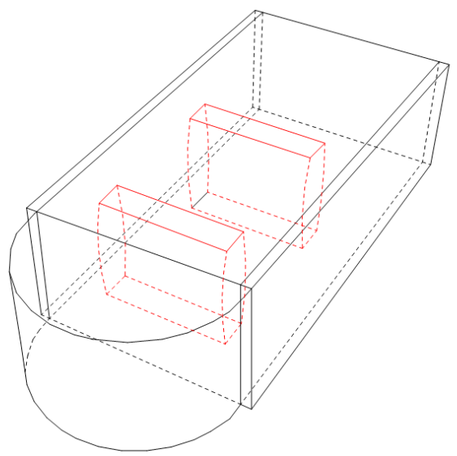


Easy manufacture method

Small visual impact

Good performance
30.2%

Small convex lenses,
curved suface

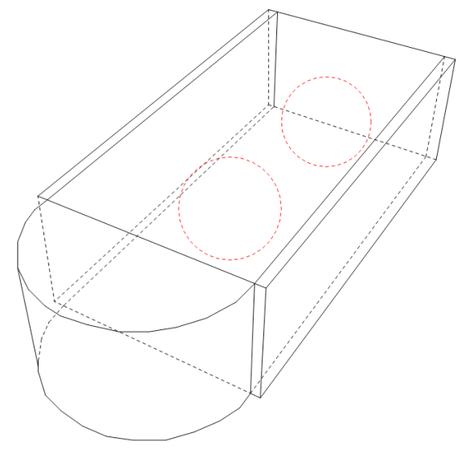


Difficult manufacture method

Big visual impact

Very good performance
50.5%

Hollow spheres,
curved suface



Complex manufacture method

Big visual impact

Best performance
65.9%

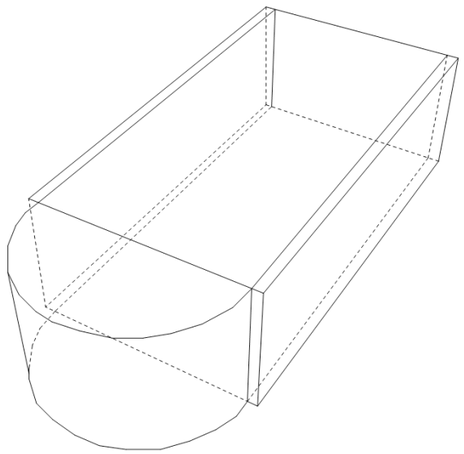
Simple convex lens

easy manufacture method

small visual impact

good performance
22.4%

Simple curved surface



Easy manufacture method

Small visual impact

Good performance
30.2%

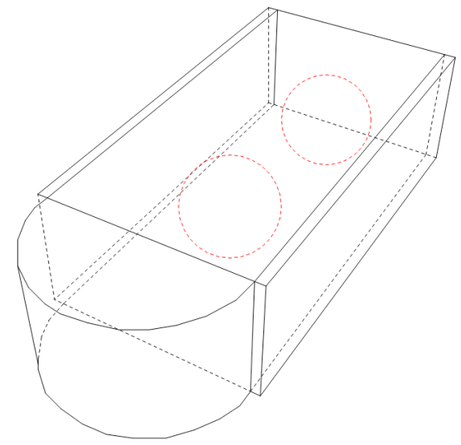
Small convex lenses,
curved suface

difficult manufacture method

Big visual impact

very good performance
50.5%

Hollow spheres,
curved suface



Complex manufacture method

Big visual impact

Best performance
65.9%

Simple convex lens

easy manufacture method

small visual impact

good performance
22.4%

Simple curved surface

easy manufacture method

small visual impact

good performance
30.2%

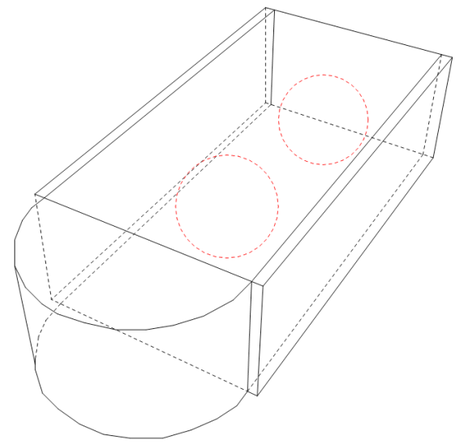
Small convex lenses,
curved suface

difficult manufacture method

small visual impact

very good performance
50.5%

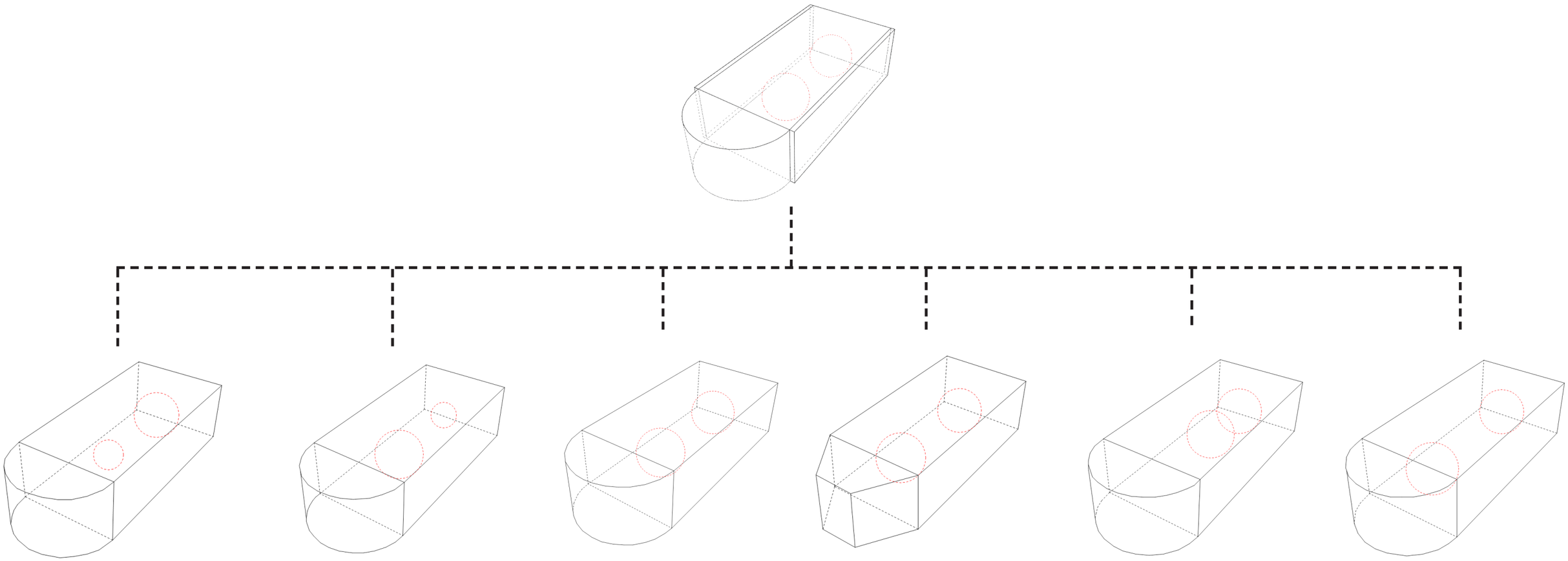
Hollow spheres,
curved suface



Complex manufacture method

Big visual impact

Best performance
65.9%



50%
2.35*10^7 W

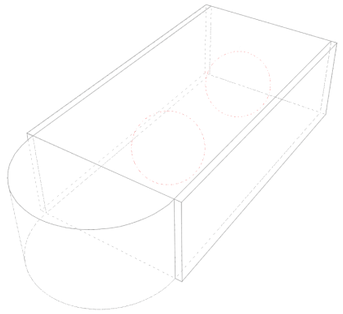
55.5%
2.58*10^7 W

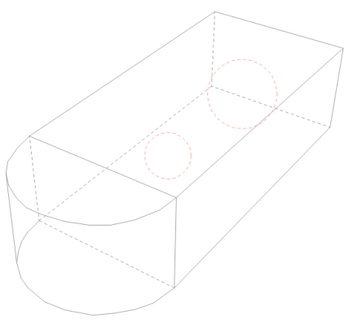
58.7%
2.73*10^7 W

62.4%
2.90*10^7 W

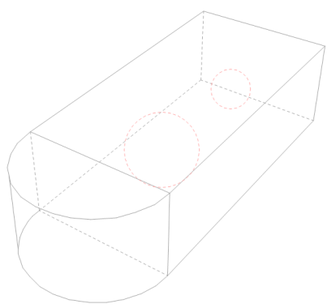
65.6%
3.05*10^7 W

66%
3.06*10^7 W

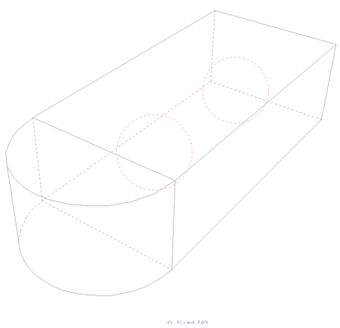




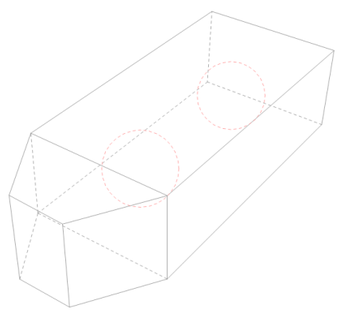
50%
2.35*10^{7} W



55.5%
2.58*10^{7} W



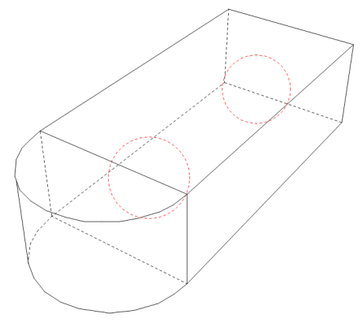
58.7%
2.73*10^{7} W



62.4%
2.90*10^{7} W

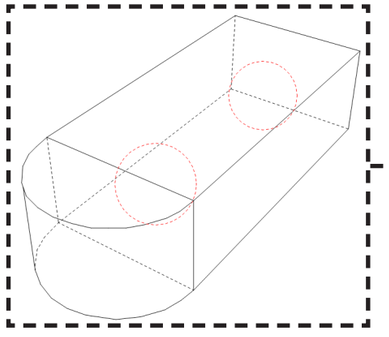
65.6%
3.05*10^{7} W

Two spheres, diamater=4.5 and 4.5cm, new external surface



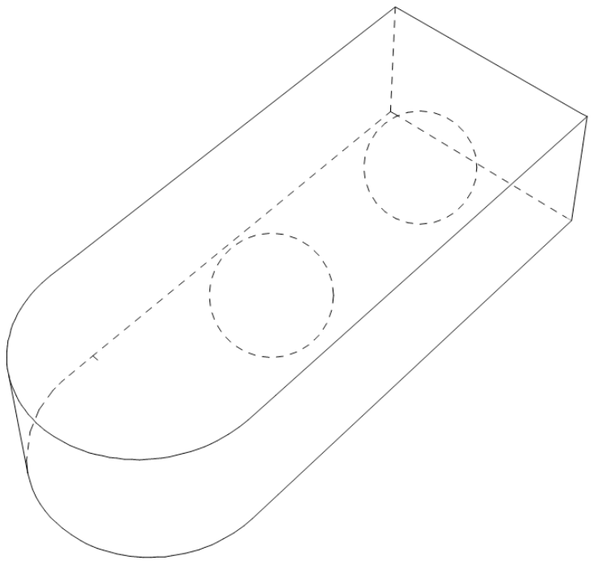
66%
3.06*10^{7} W

Final component

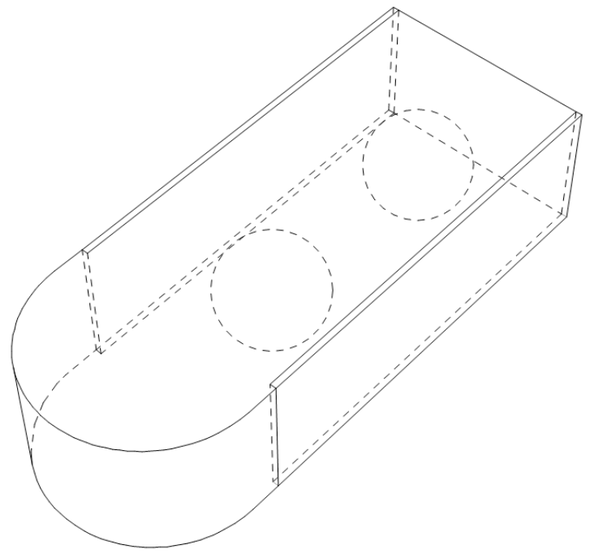


Integration of photovoltaic

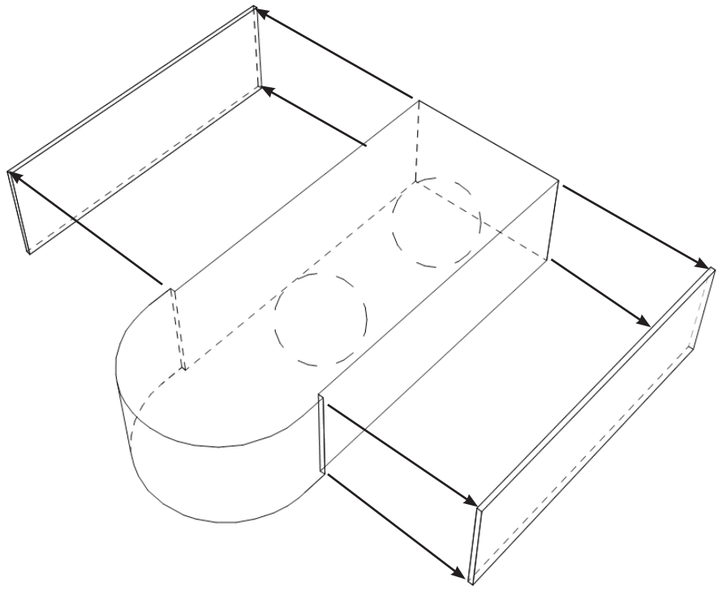
Integration of photovoltaic



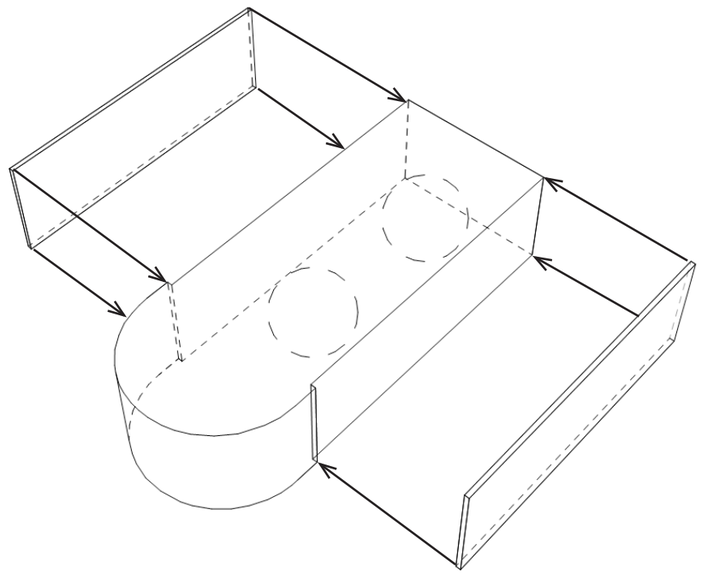
Final component



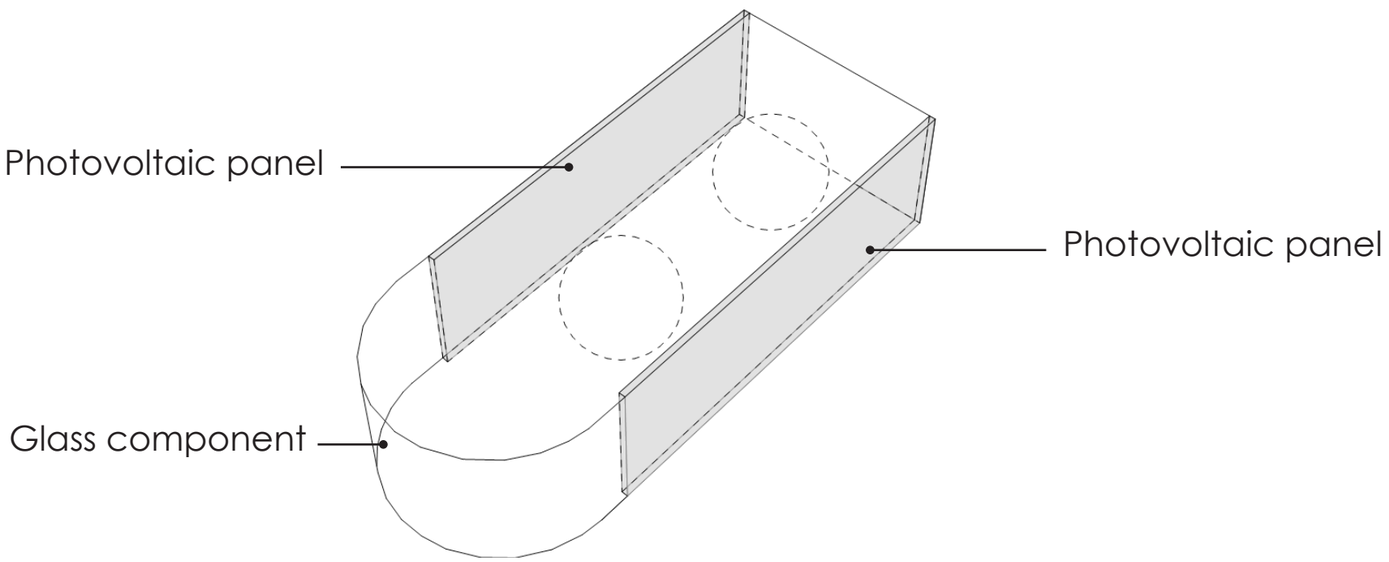
3mm cutting-out from both side of the brick

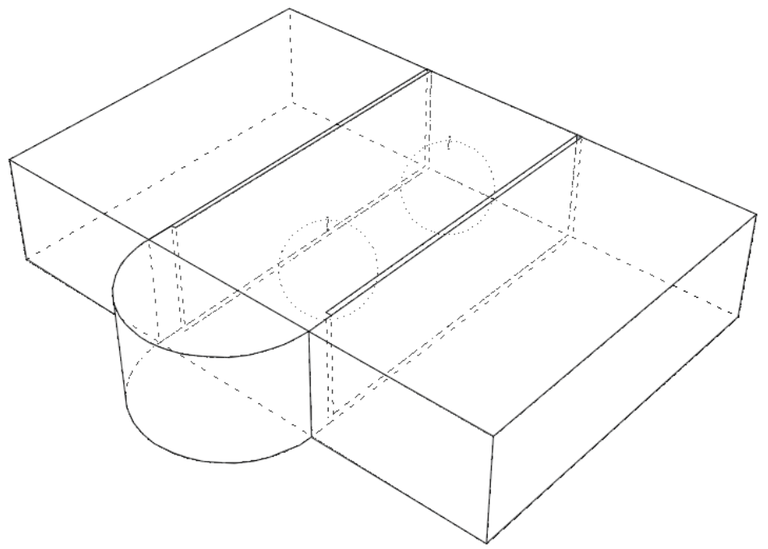


Remove the surplus

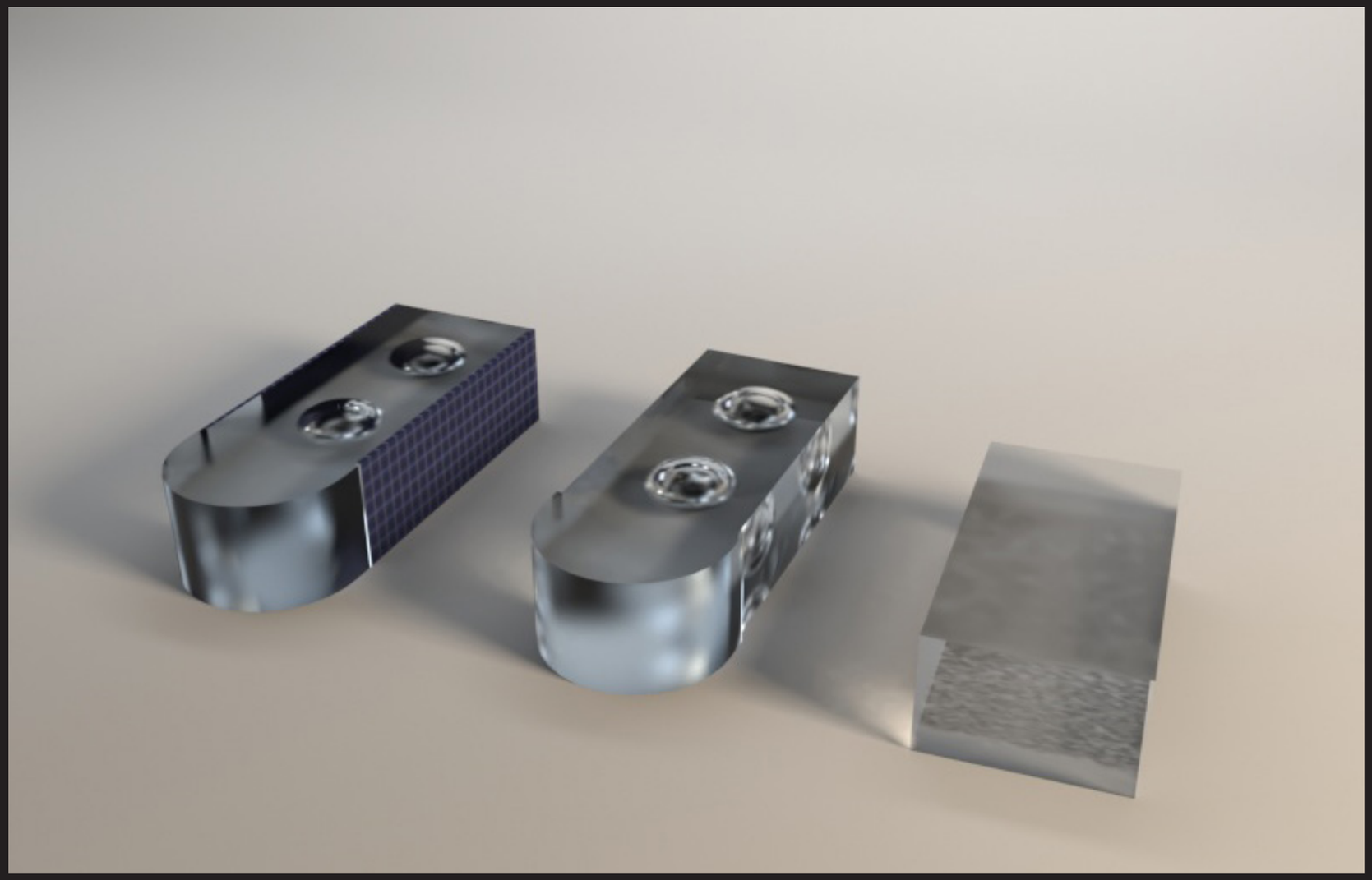


Placing photovoltaics onto the sides



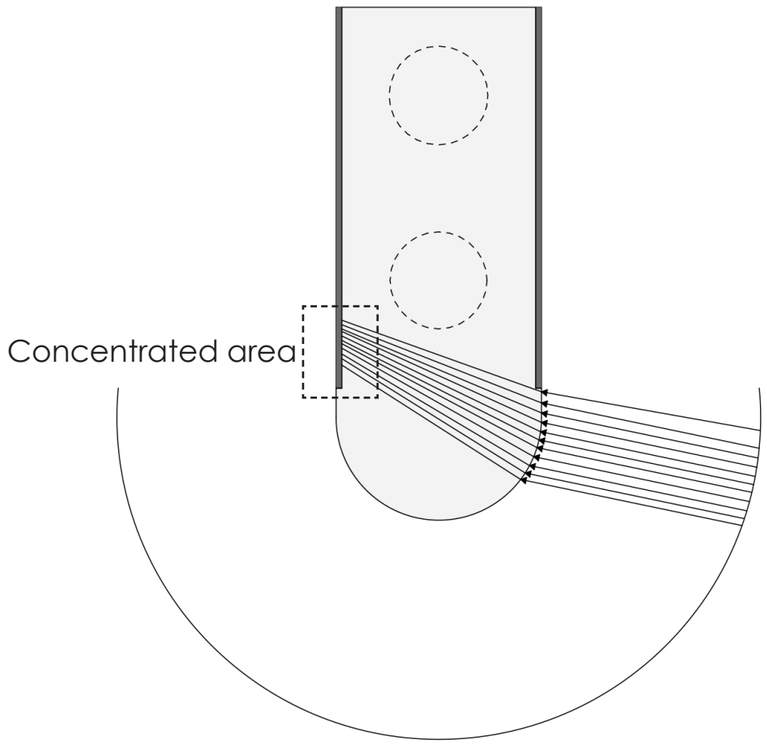


Integration with other glass bricks



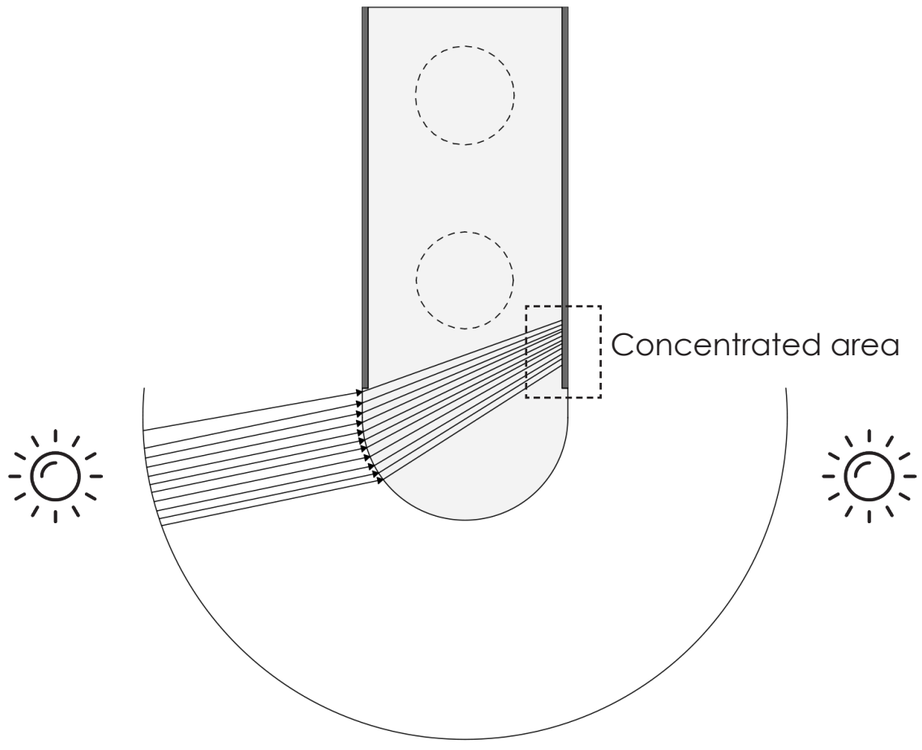
Visualization of the new component

Morning concentration



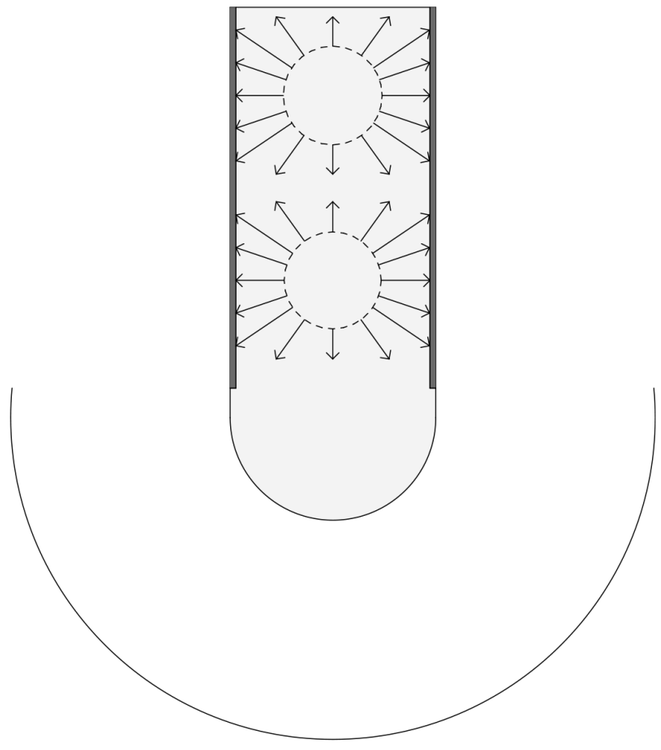
External curved surface

Afternoon concentration



External curved surface

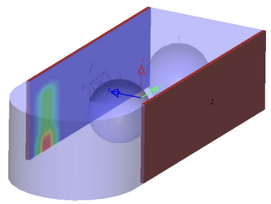
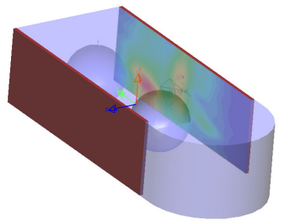
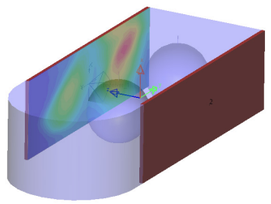
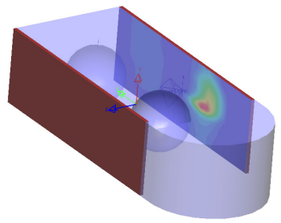
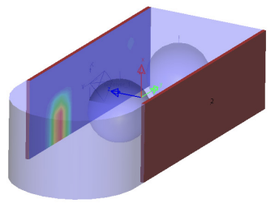
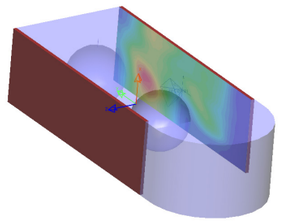
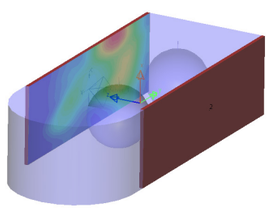
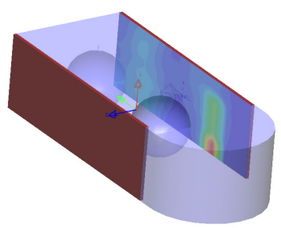
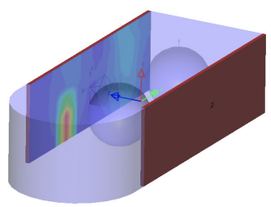
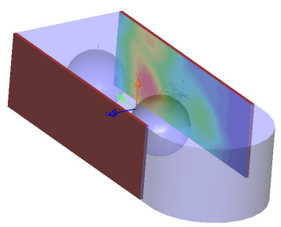
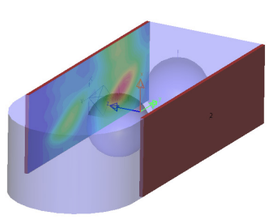
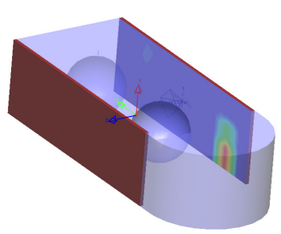
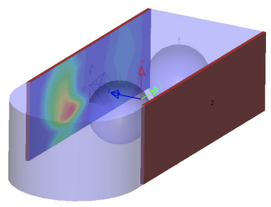
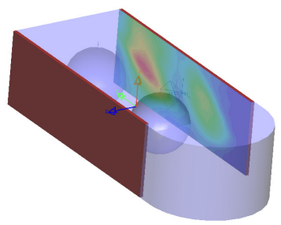
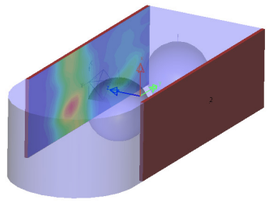
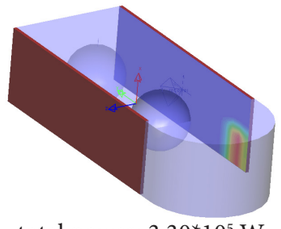
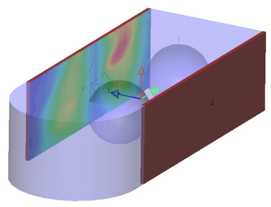
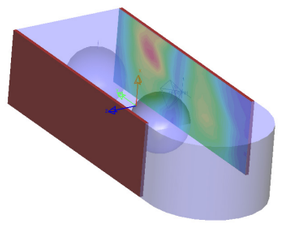
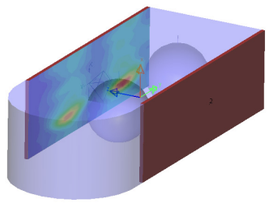
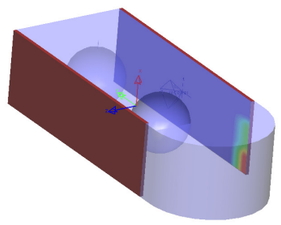
Constant



Hollow spheres

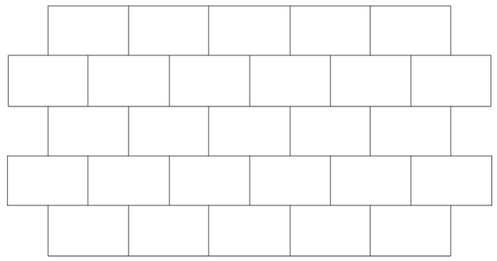
Focuses the light onto a certain area

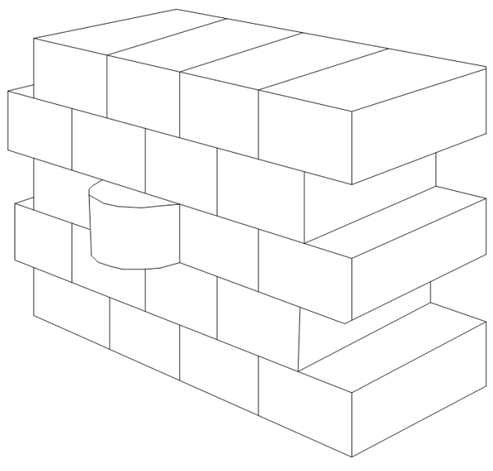
Light is scattered by the sphere

	Left	Right		Left	Right
7:00	 total power: $2.25*10^5$ W	 total power: $3.75*10^6$ W	12:00	 total power: $2.33*10^6$ W	 total power: $6.78*10^5$ W
8:00	 total power: $5.18*10^5$ W	 total power: $2.44*10^6$ W	13:00	 total power: $1.65*10^6$ W	 total power: $8.77*10^5$ W
9:00	 total power: $1.35*10^6$ W	 total power: $8.53*10^5$ W	14:00	 total power: $3.03*10^6$ W	 total power: $4.19*10^5$ W
10:00	 total power: $2.87*10^6$ W	 total power: $5.85*10^5$ W	15:00	 total power: $4.15*10^6$ W	 total power: $3.30*10^5$ W
11:00	 total power: $1.05*10^6$ W	 total power: $1.02*10^6$ W	16:00	 total power: $2.38*10^6$ W	 total power: 75675 W

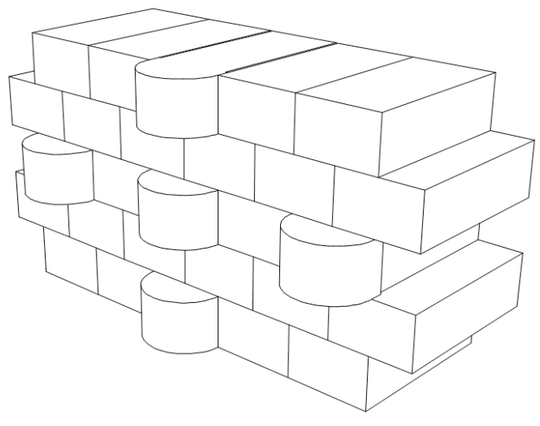
Wall design

5*5 layout





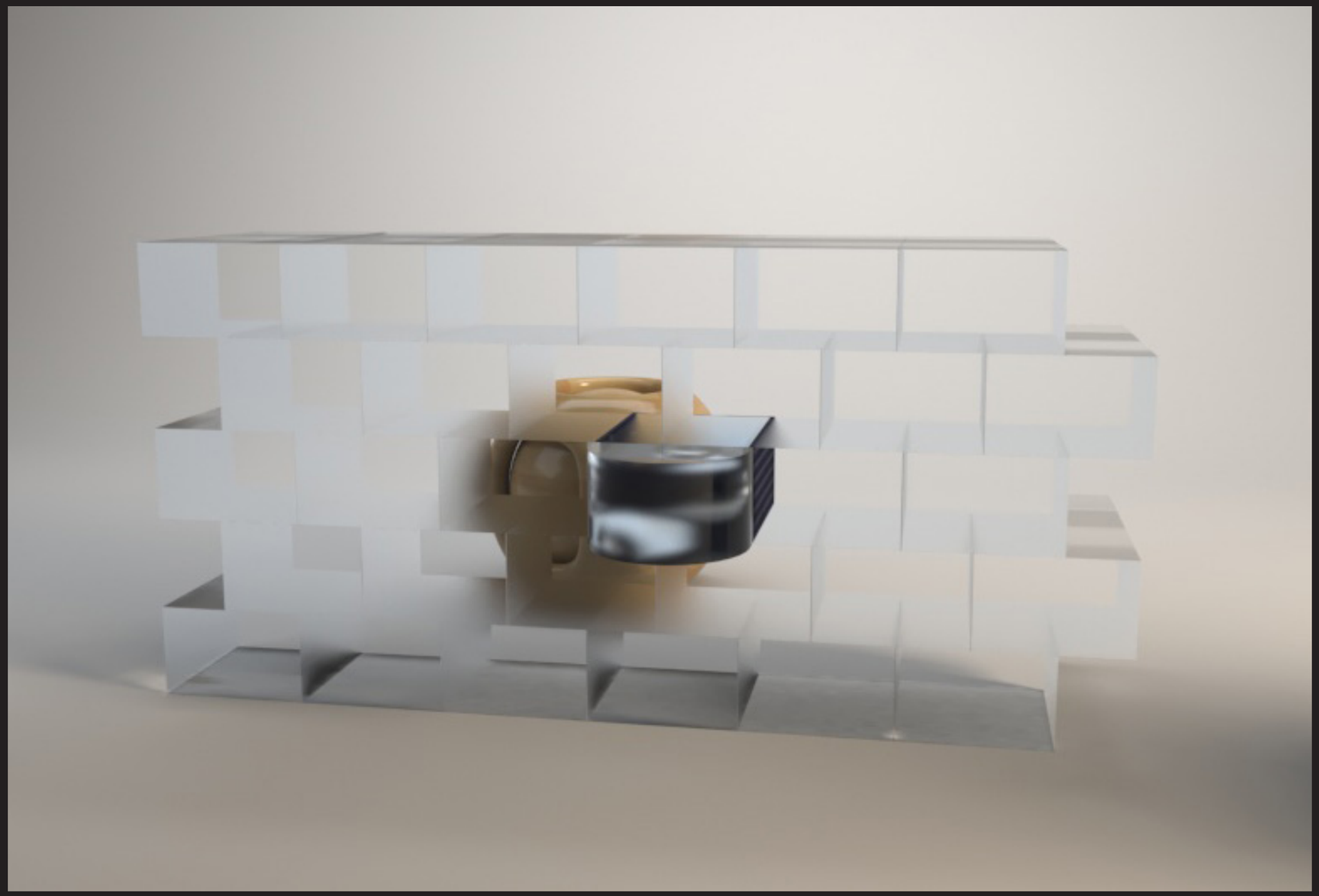
1 brick

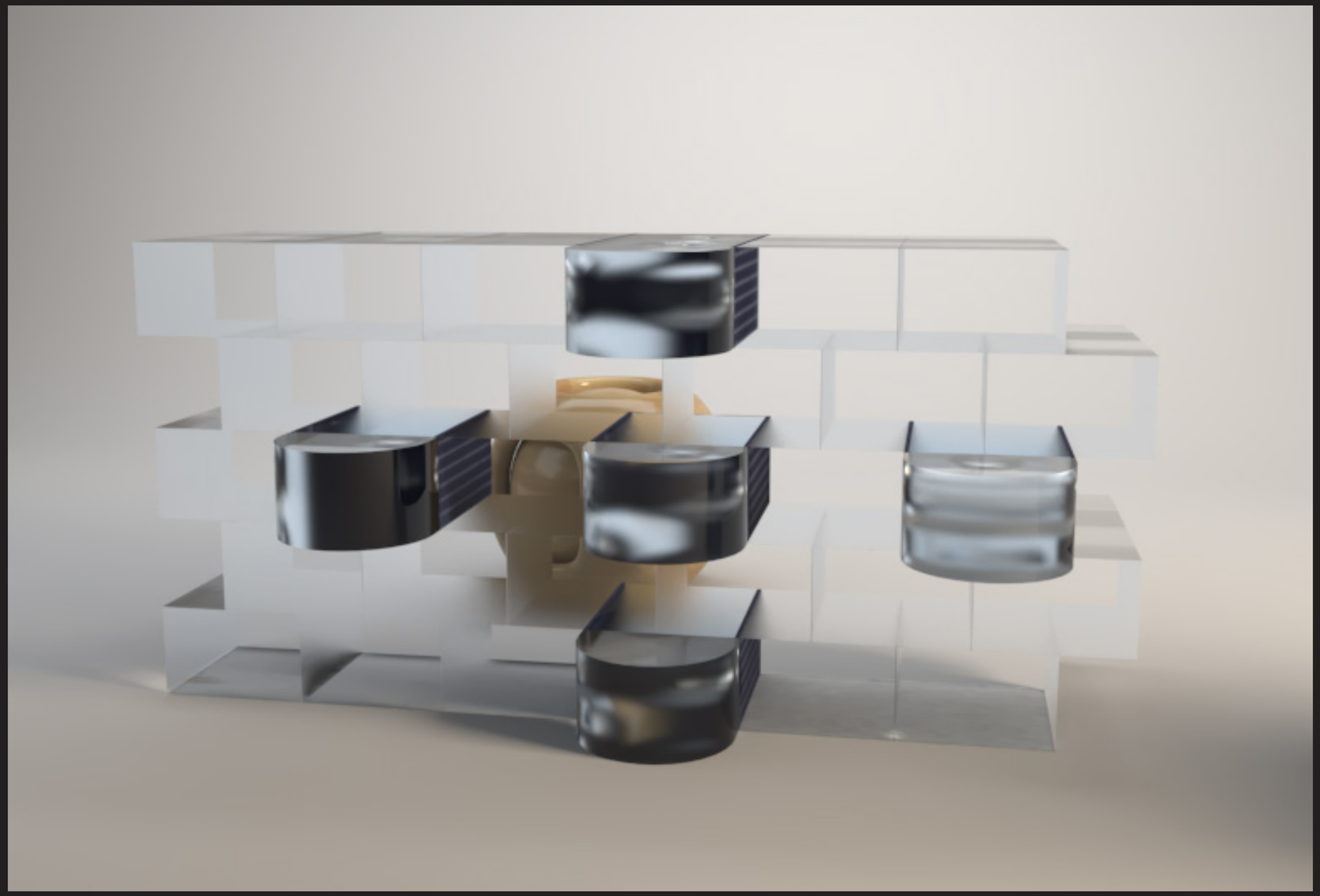


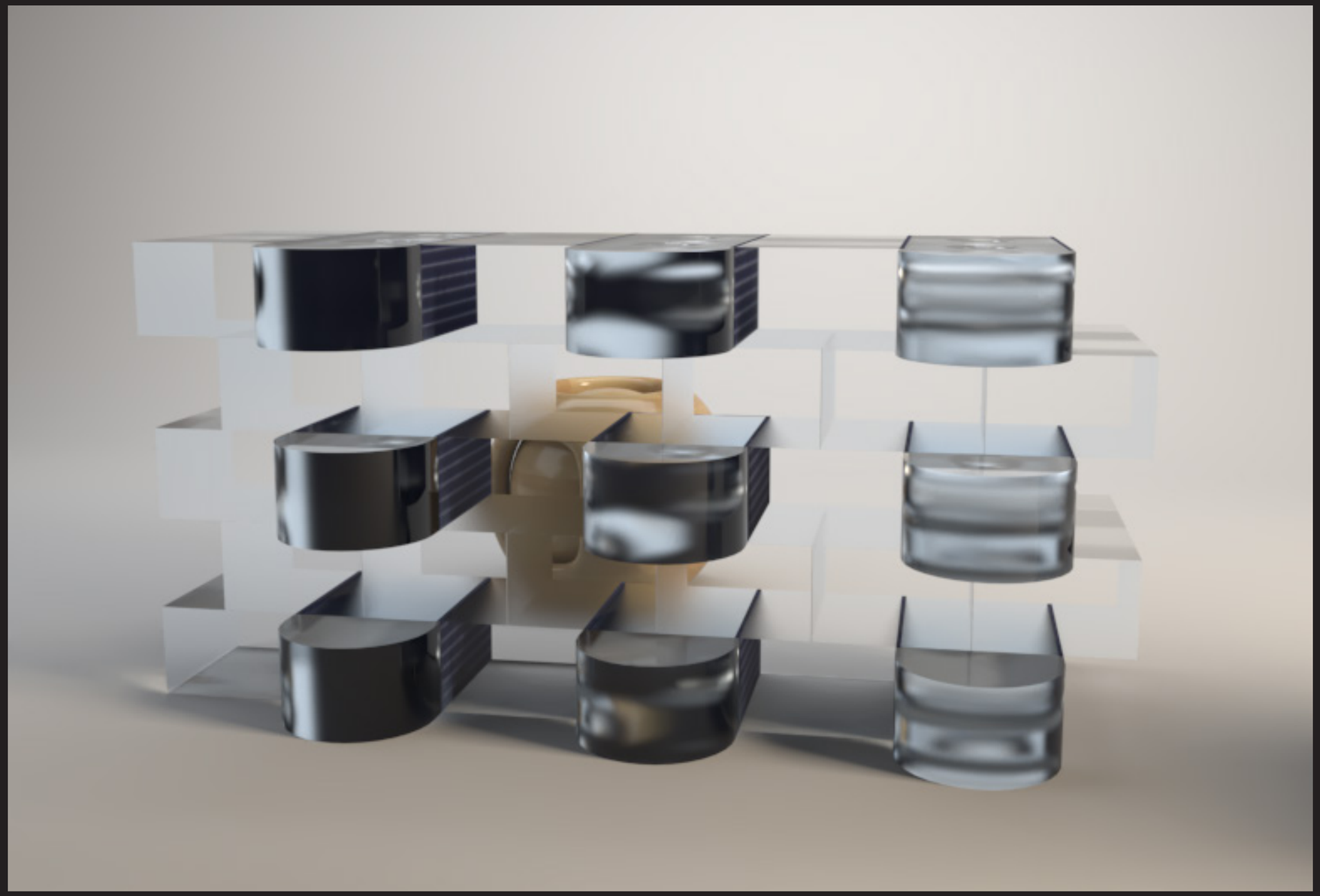
5 brick

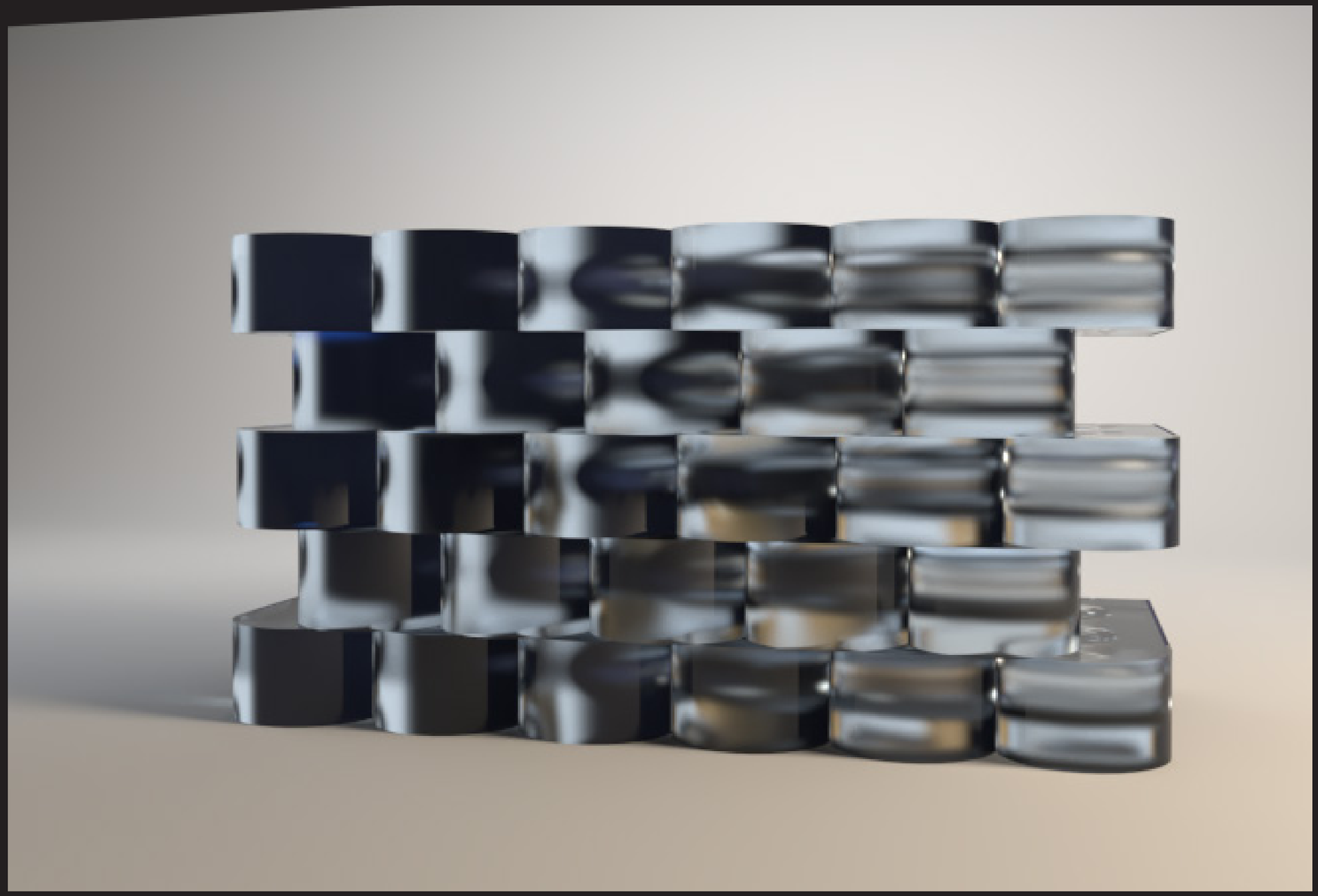
9 brick

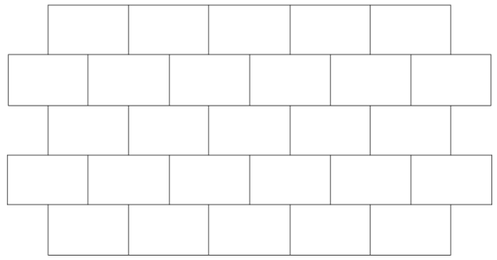
18 brick

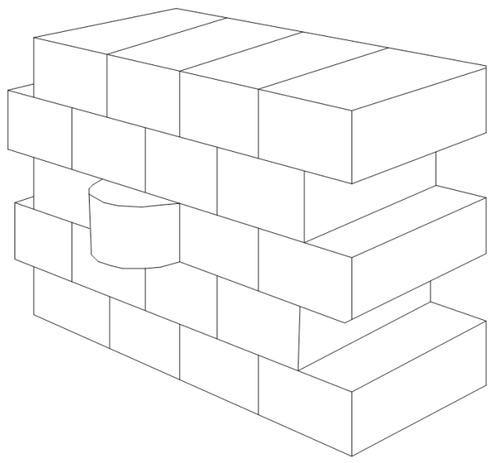




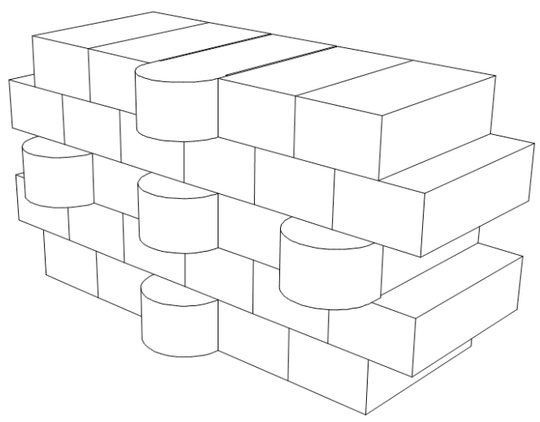








1*2.96*10^7 W= 2.96*10^7



5*2.87*10^7 W= 1.43*10^8

18*1.22*10^7 W=2.20*10^8

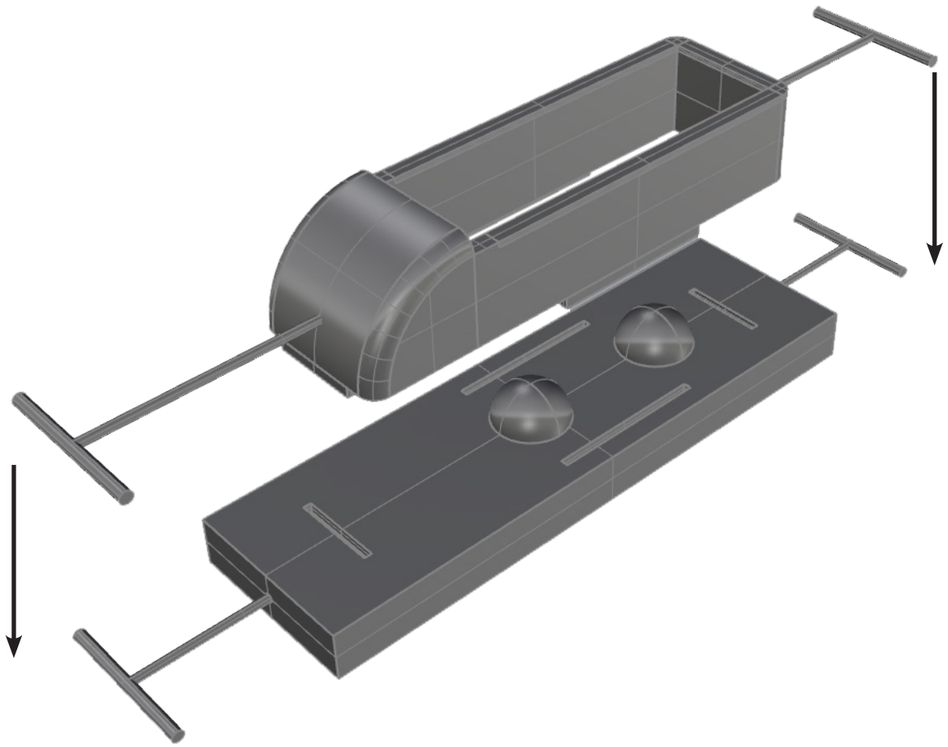
9*1.22*10^7 W=2.55*10^8

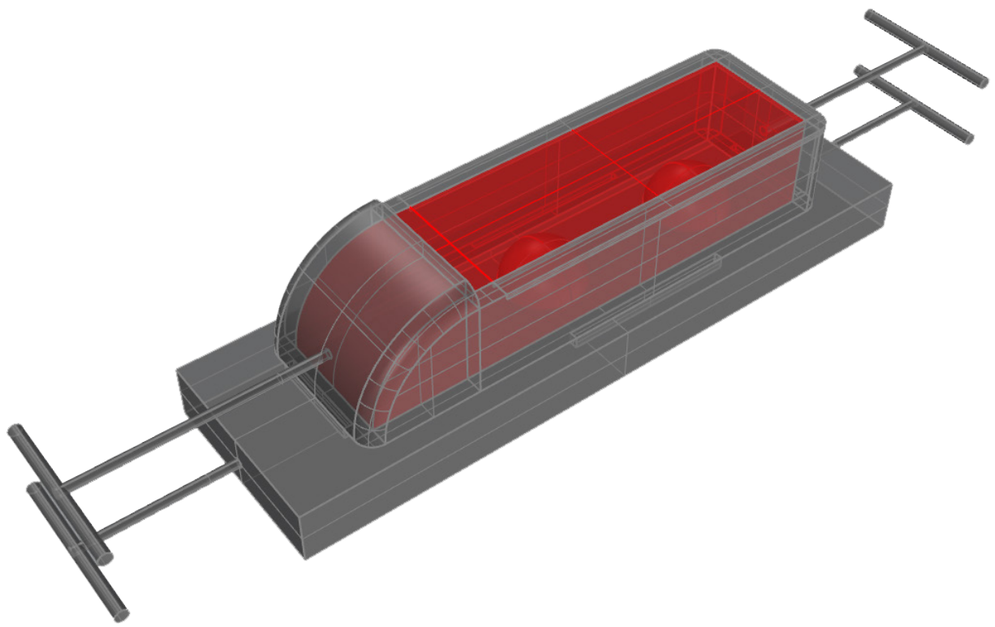
Best performance

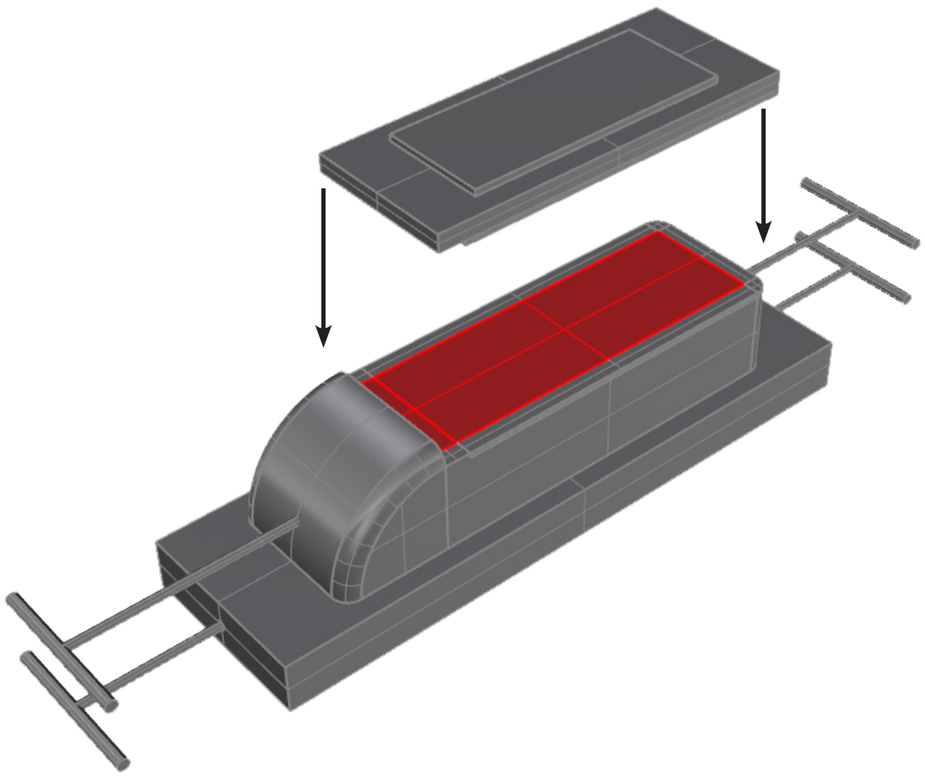
Good visual comfort

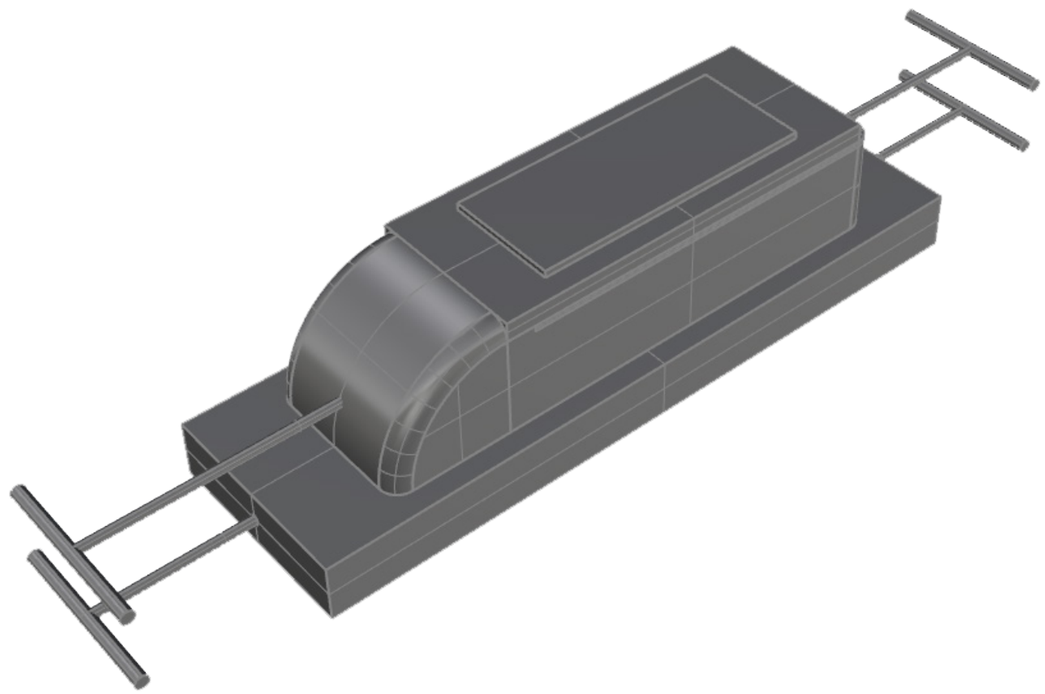
Manifacture

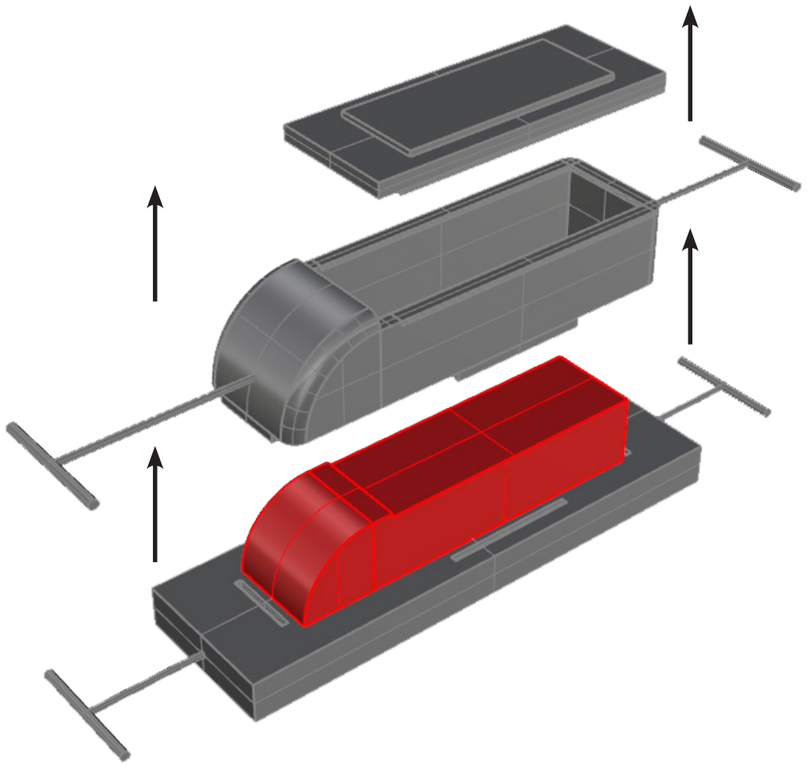
High precision steel mould (under pressure)

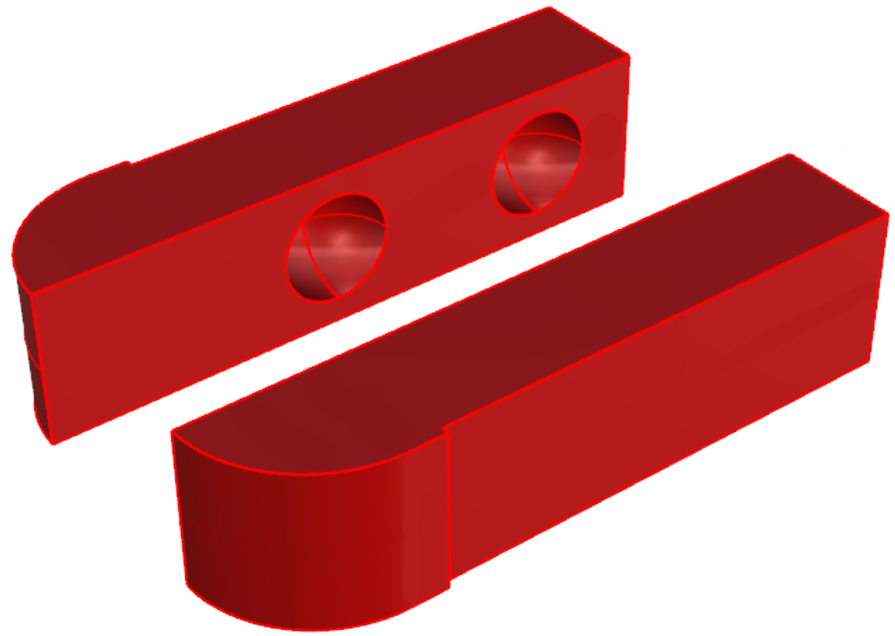


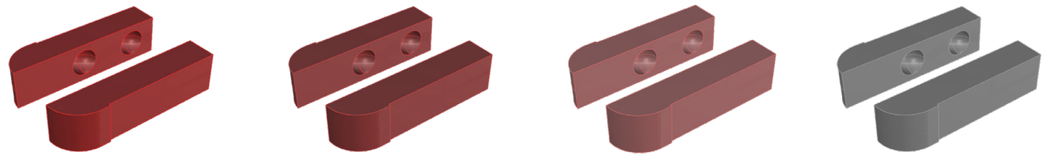


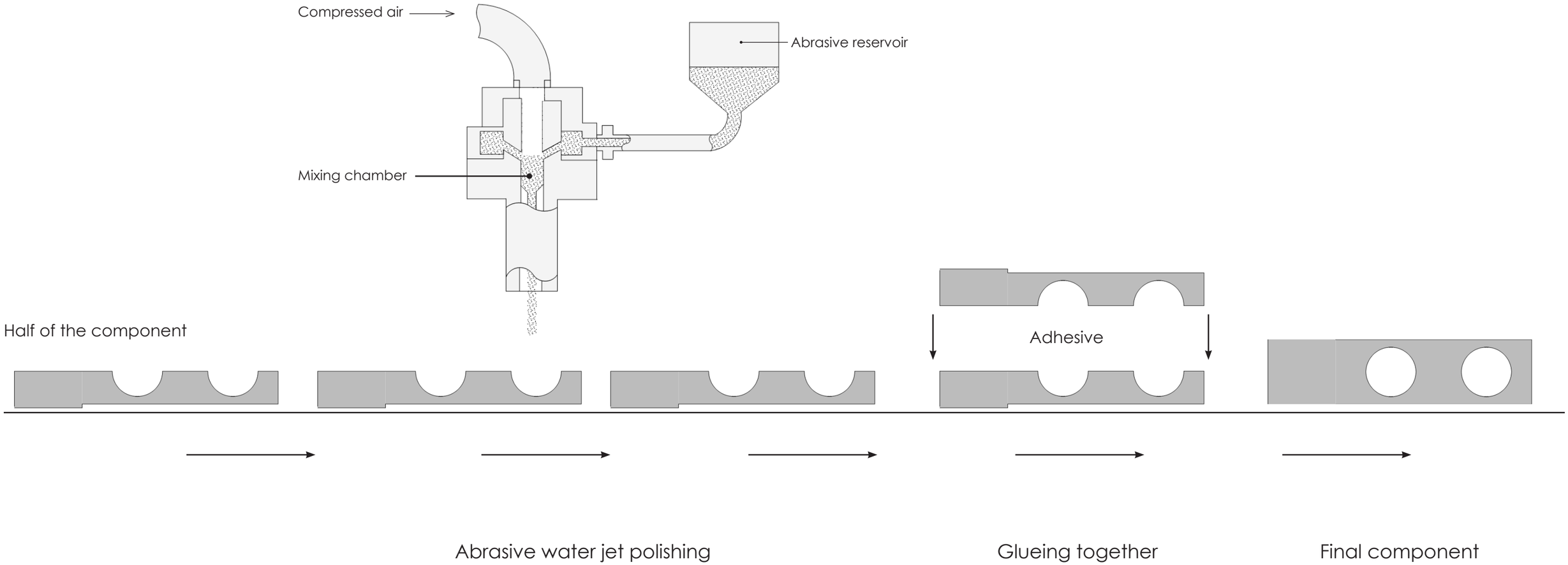








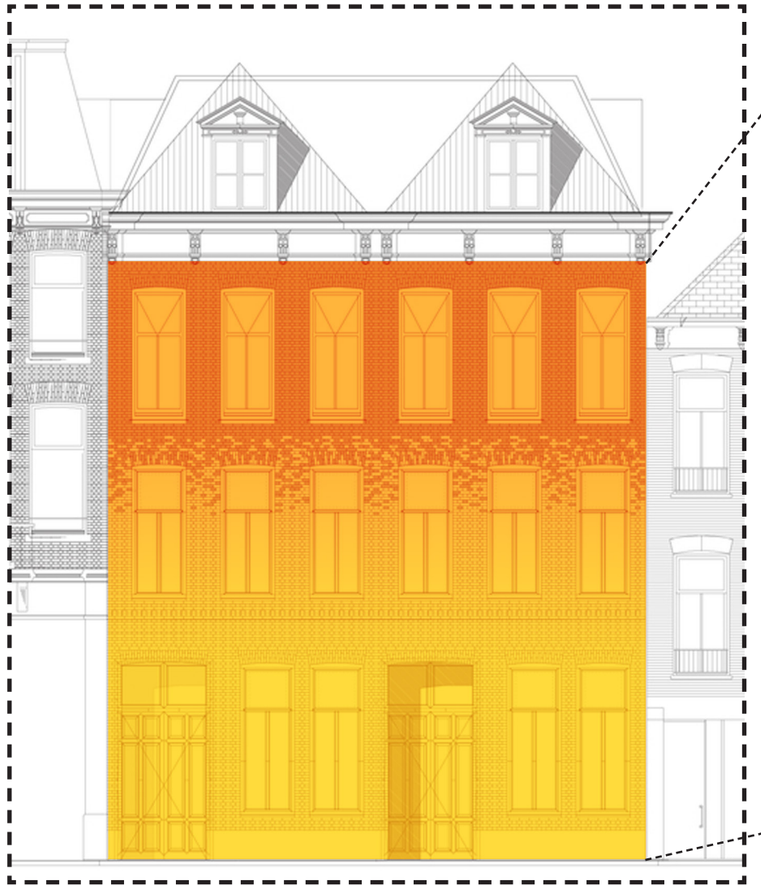


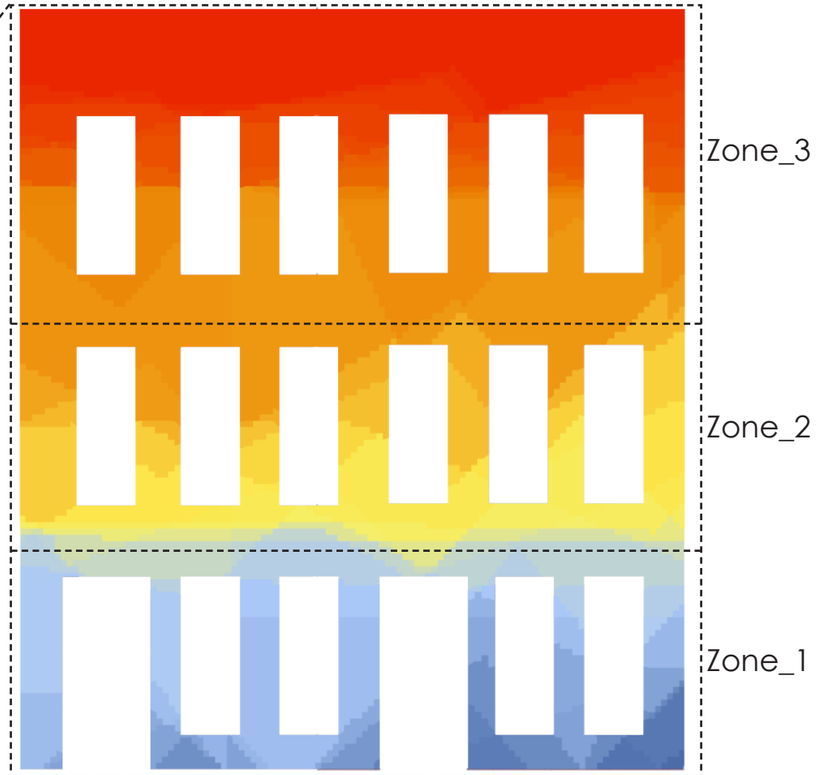

Compressed air
Abrasive reservoir
Mixing chamber
Half of the component
Adhesive
Abrasive water jet polishing
Glueing together
Final component

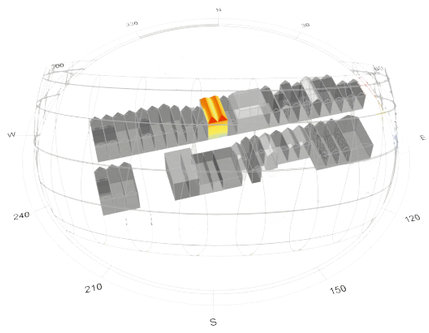

MVRDV
Agent Provocateur
APRIL 01.04.36
CHANEL
ANNE FONTAINE

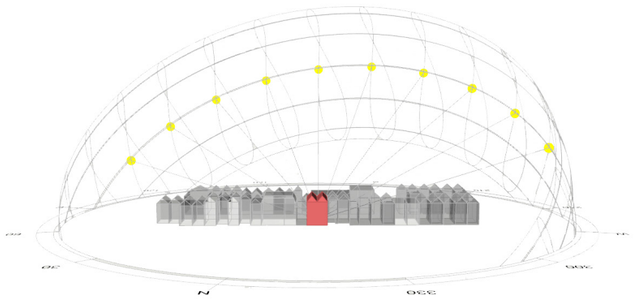
Solar radiation on the facade

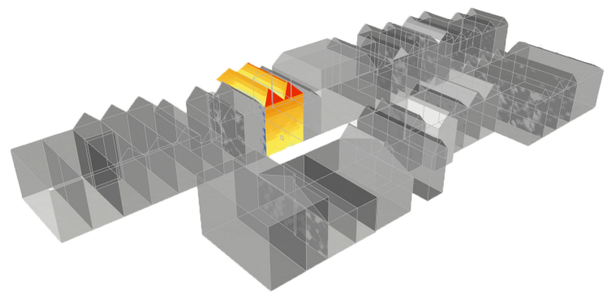
Radiation zones





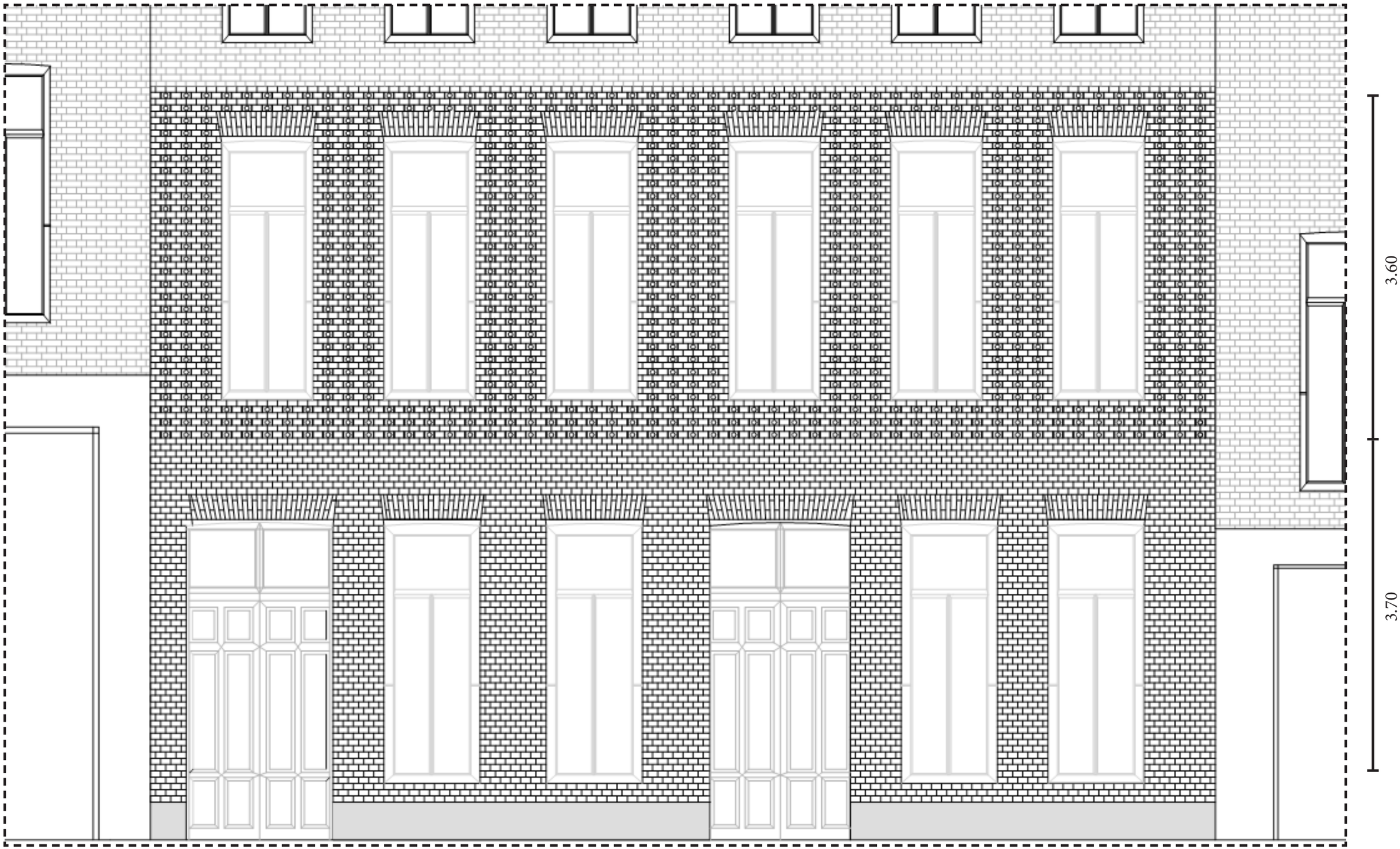


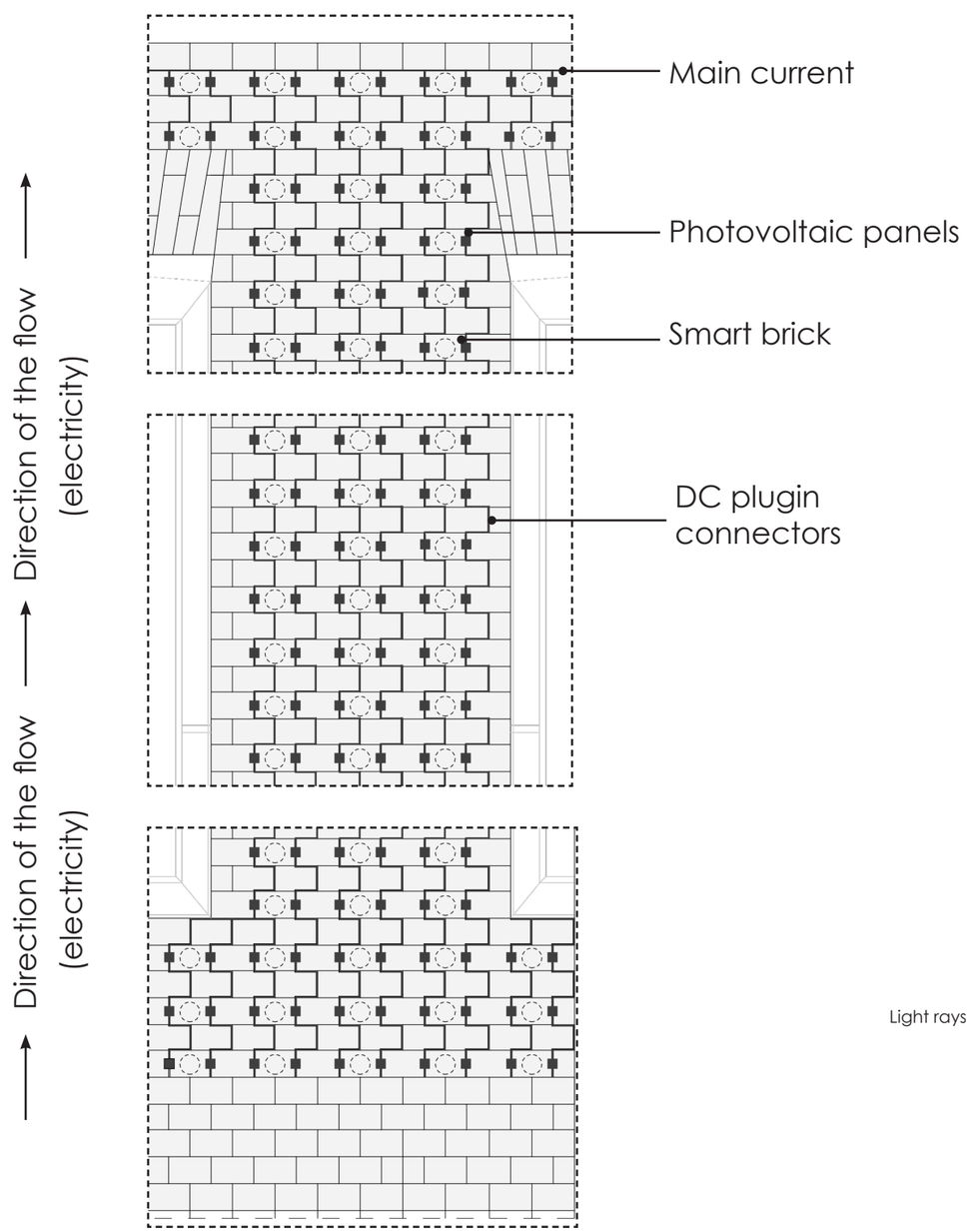


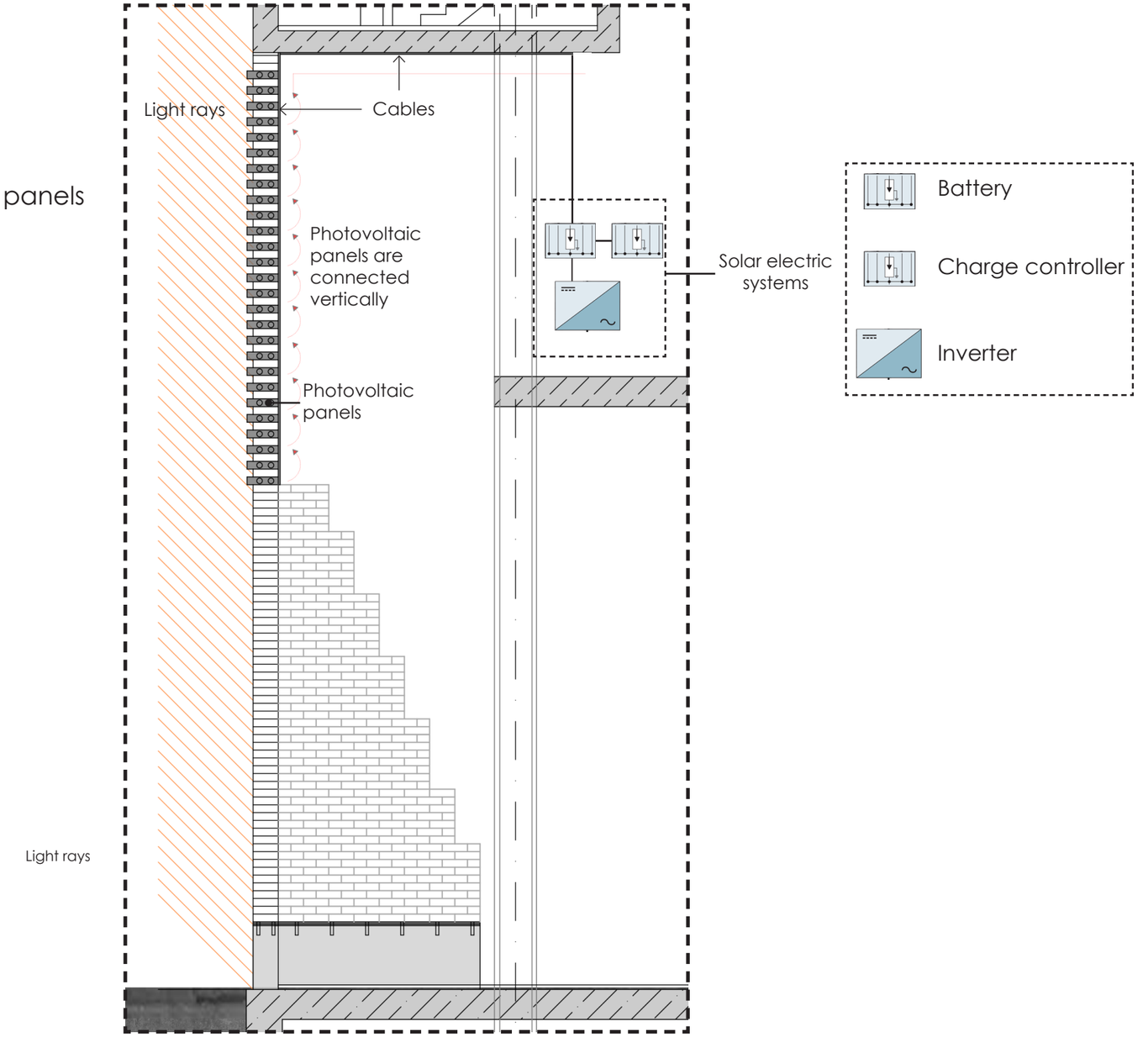


Position of the new bricks

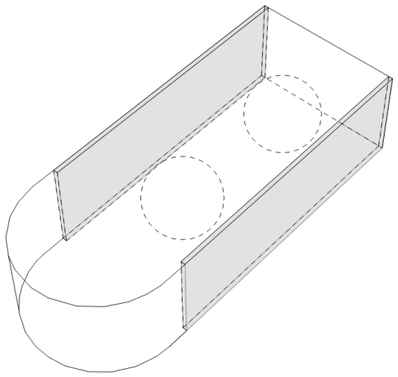

3.60
3.70

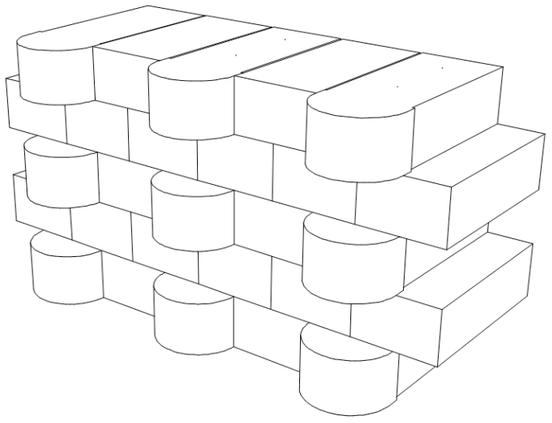

3.60
3.70


Main current
Photovoltaic panels
Smart brick
DC plugin connectors
Direction of the flow (electricity)
Direction of the flow (electricity)


Light rays
Cables
Photovoltaic panels are connected vertically
Photovoltaic panels
Solar electric systems
Battery
Charge controller
Inverter
Light rays

822 bricks



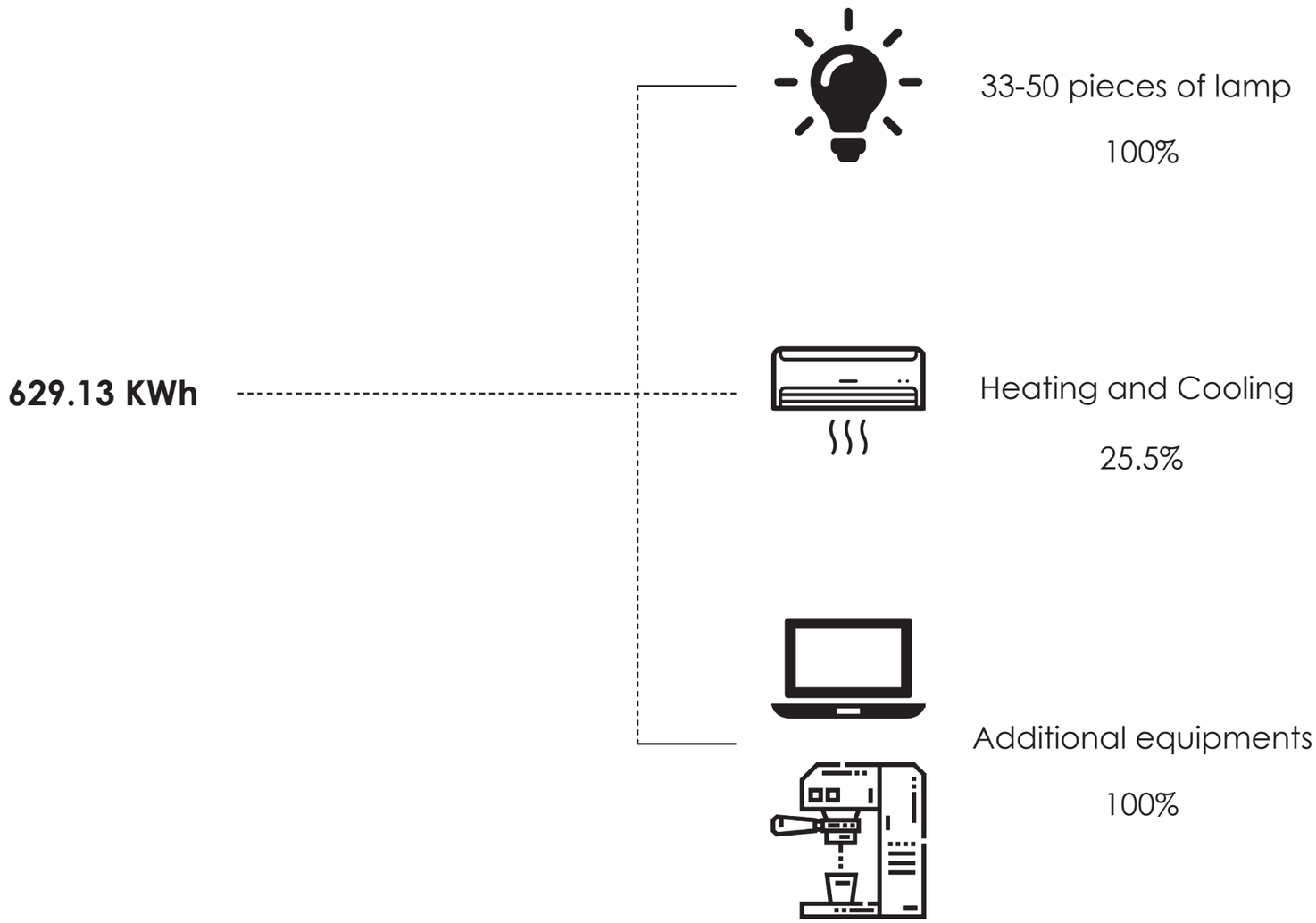


Electricity production

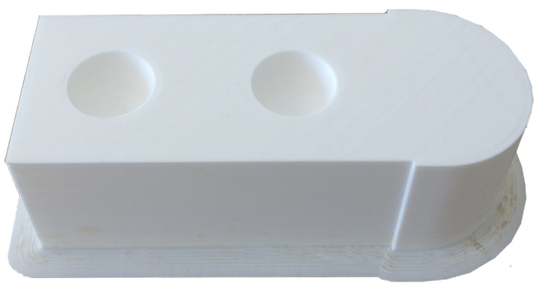
Month	Total radiation KWh	Redirecton %	PV efficiency %	Total Power KWh
January	125.51	42%	31.3%	16.50
February	232.07	59%	31.3%	42.44
March	370.0	68%	31.3%	78.75
April	340.16	72%	31.3%	76.75
May	400.13	76%	31.3%	95.18
June	335.65	75%	31.3%	78.80
July	365.40	69%	31.3%	78.91
August	378.87	62%	31.3%	73.52
September	329.95	46%	31.3%	47.50
October	234.24	30%	31.3%	22.00
November	149.39	26%	31.3%	12.15
December	84.79	25%	31.3%	6.63

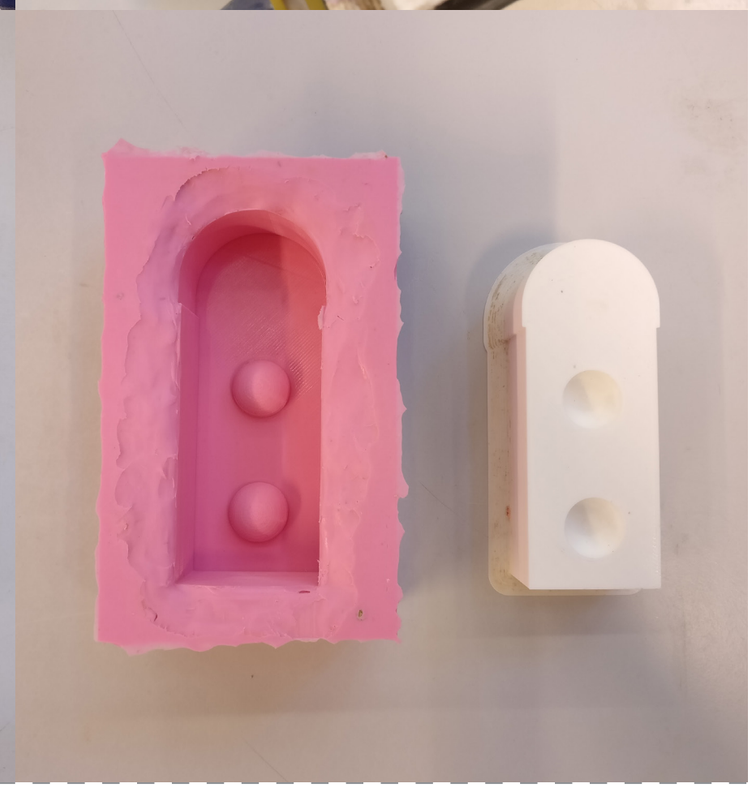
Σ=629.13 KWh

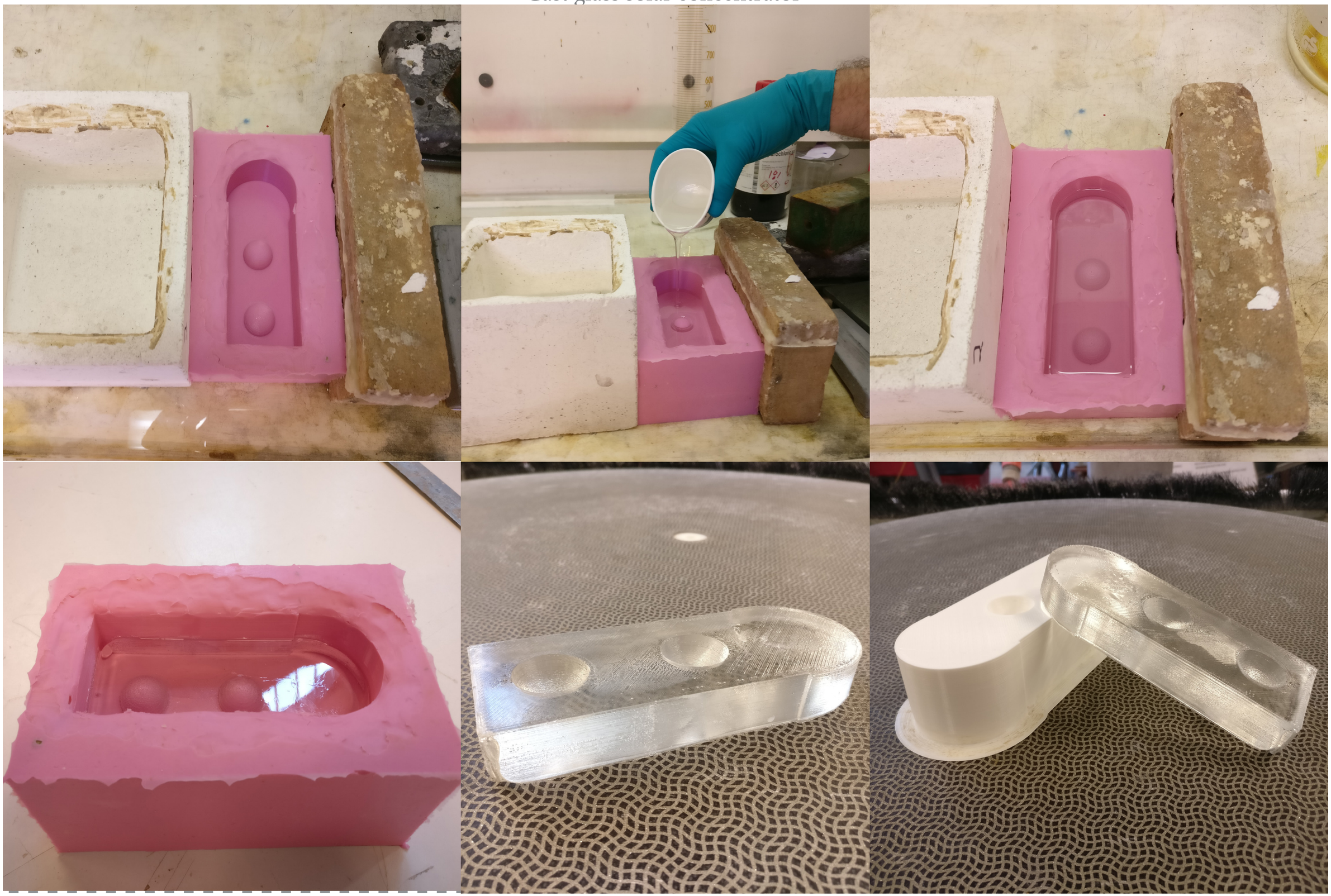
Electricity production in each month


629.13 KWh
33-50 pieces of lamp
100%
Heating and Cooling
25.5%
Additional equipments
100%

Prototype







Conclusion

Strenght

Cast glass as a solar concentrator

Great freedom in geometry

Electricity production

Weakness

Transparency

Many photovoltaic equipments → Cables

Expensive photovoltaic system

Thank you