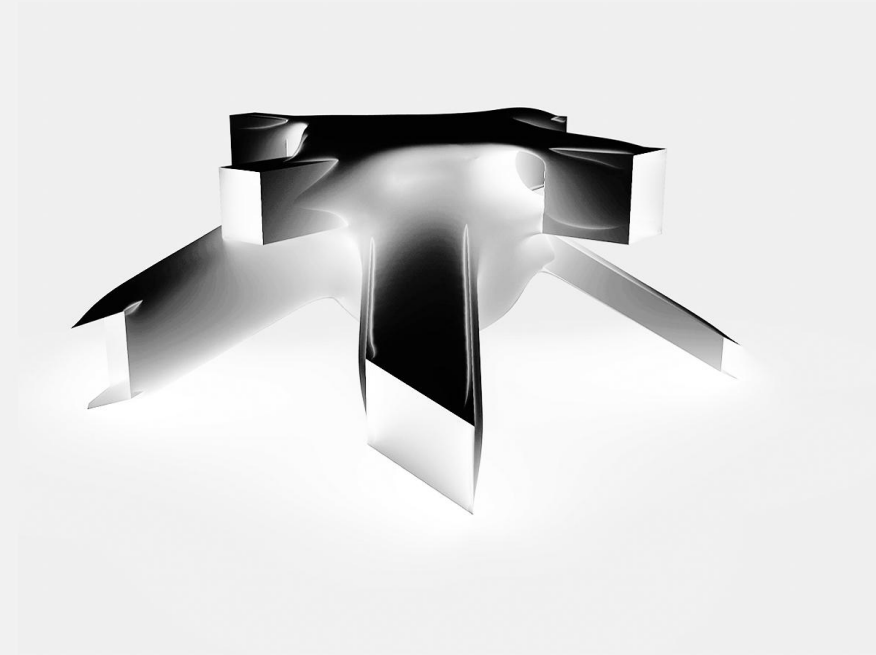
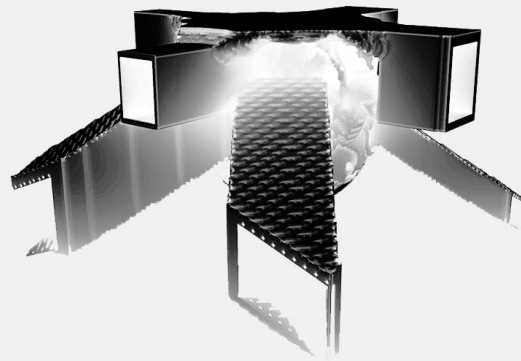
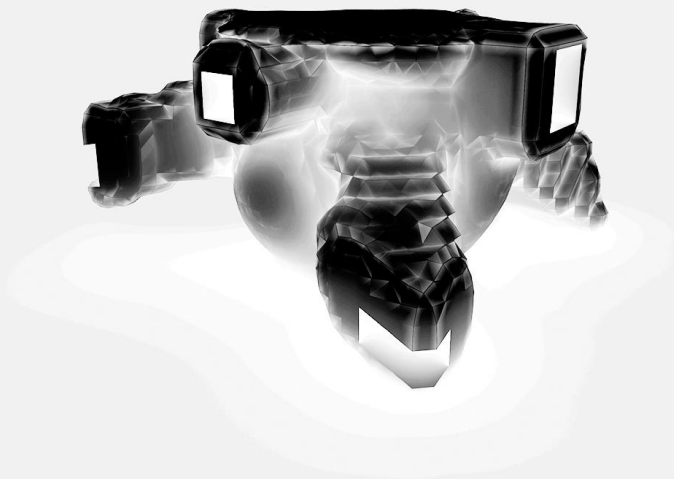


TOWARDS ZERO-WASTE STRUCTURES THROUGH INTEGRATION OF RECLAIMED WOOD AND 3D PRINTING

P5 Presentation

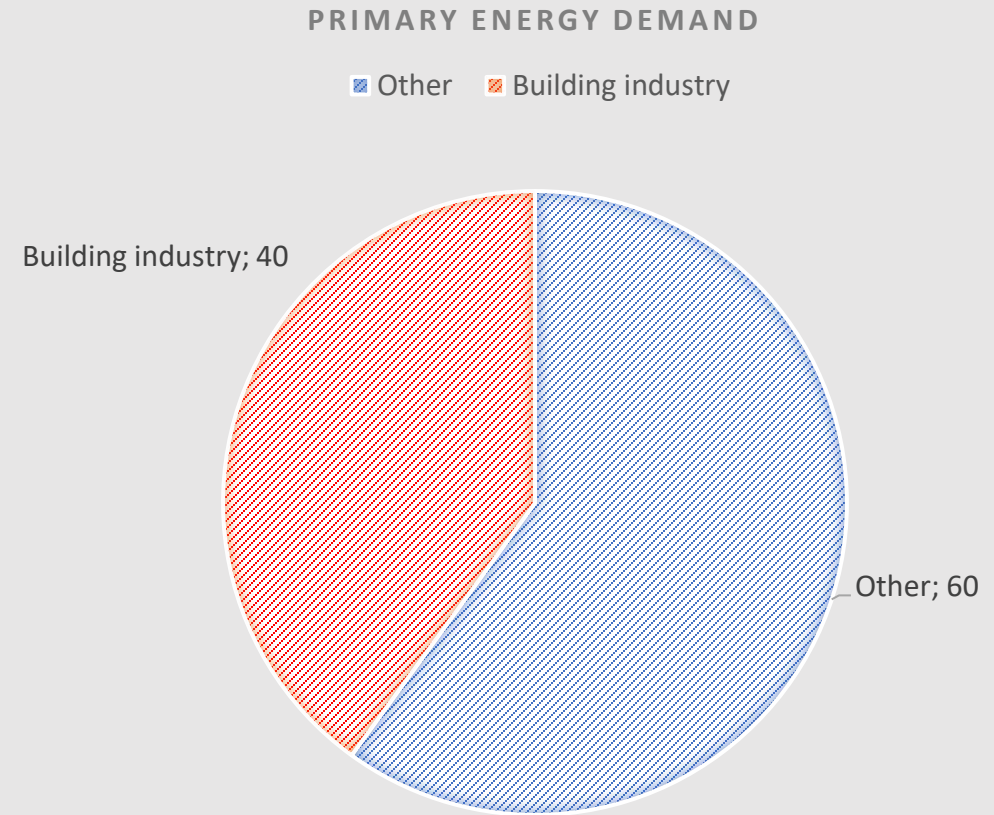
Aron Arend Bakker

5658004



Context

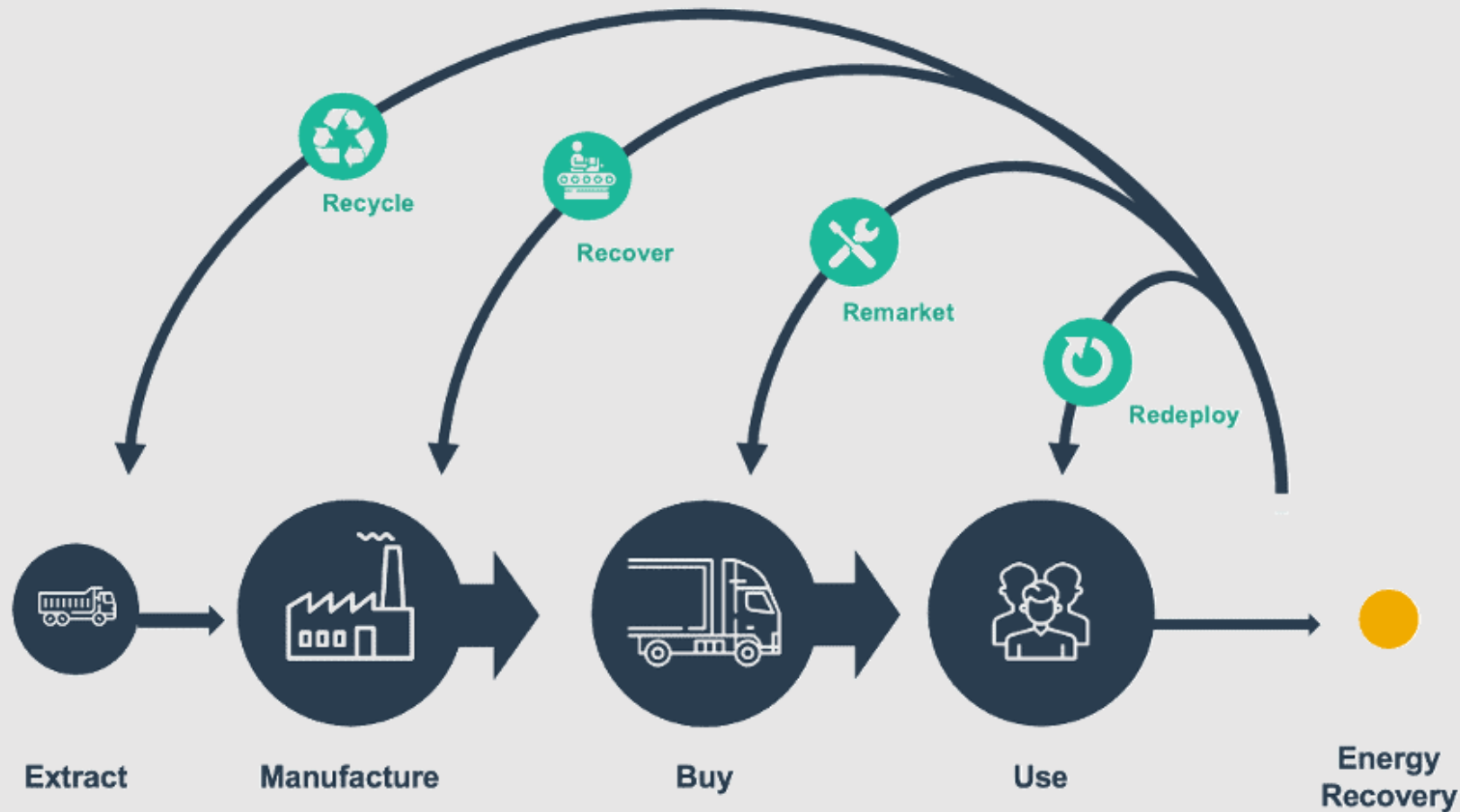
- 40% of primary energy goes to the building industry (*European Commission, 2017*)
- The EU pushes for greater reuse of building components (*Didier, 2018*)



Circularity

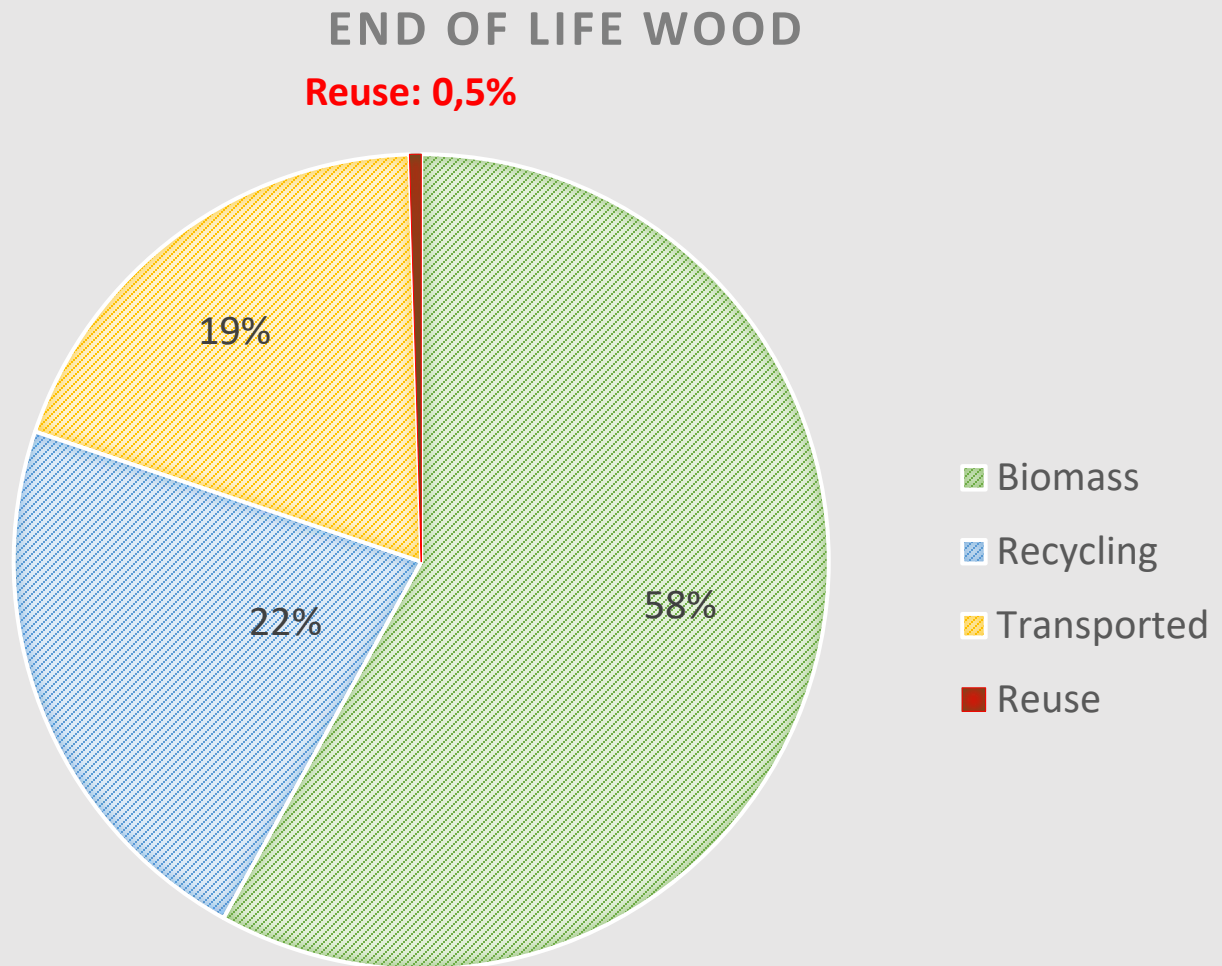


What is the circular economy?



The Circular Economy

Current standing....



So, what seems to be the problem?

Design with a constrained stock increases the complexity of a design project

- Circular material hubs provide storage
- A dynamic stock of elements increases complexity
- Stock constrained design tools give complex connections
- Connections damage the reused elements.
- Remanufacturing is required, creating saw-off losses.



For example:



<https://www.shutterstock.com/nl/image-photo/worried-woman-moving-into-new-apartment-663880423>

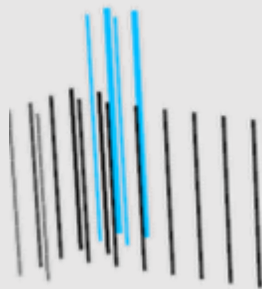
- Like IKEA without instructions
- None of the right elements
- Nothing matches



<https://vimeo.com/654116098>

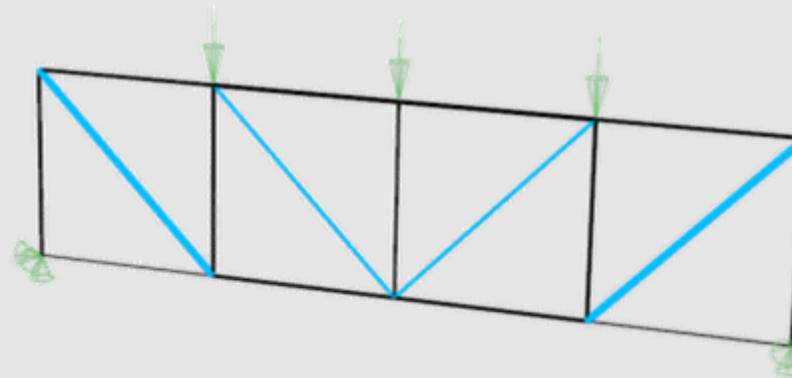
How can we solve this problem?

- Stock-constrained design



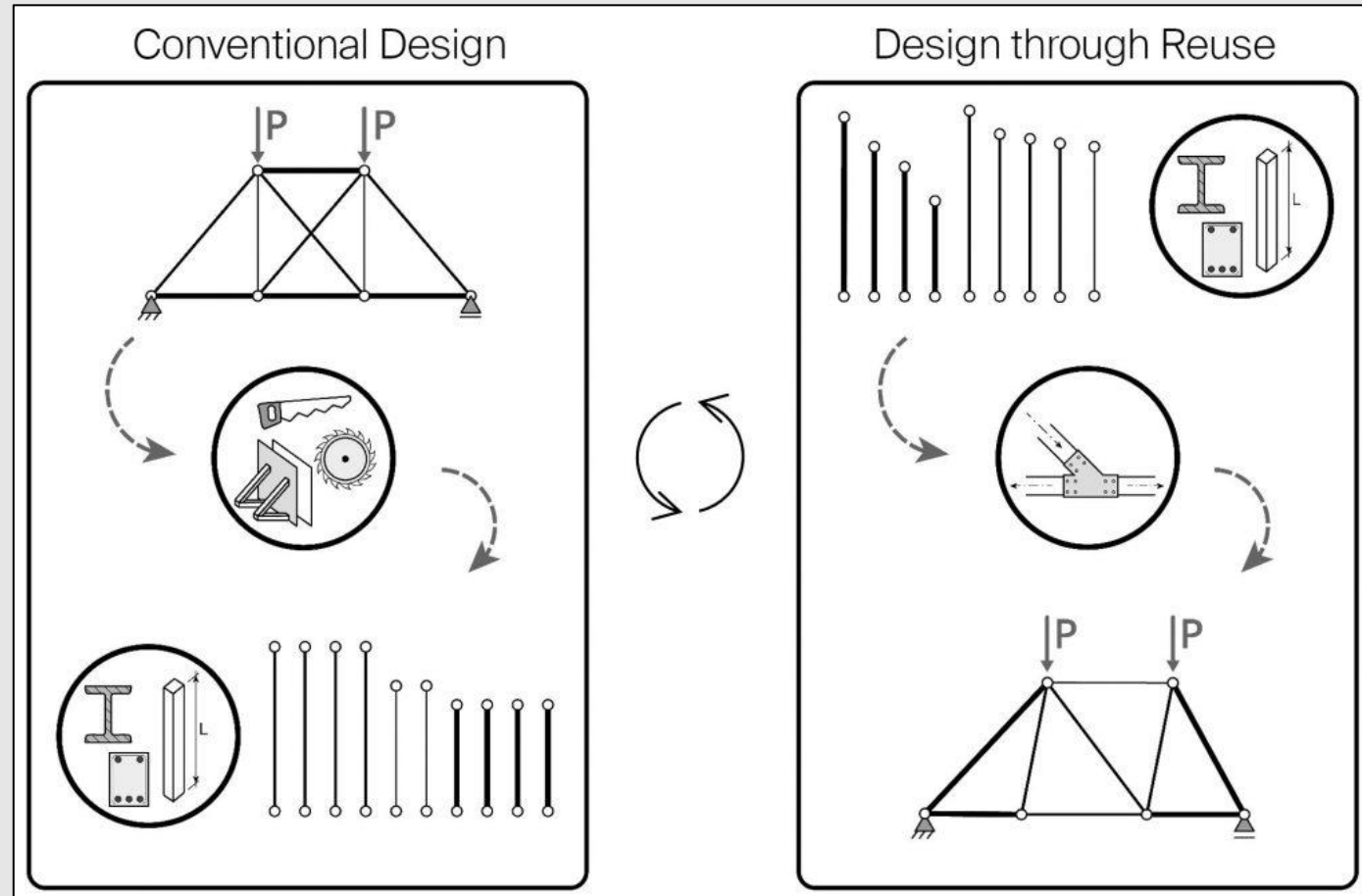
Example:
Reused/**New**
elements

<https://www.epfl.ch/labs/sxl/tools/phoenix3d/>



Example of stock-constrained
designed structure

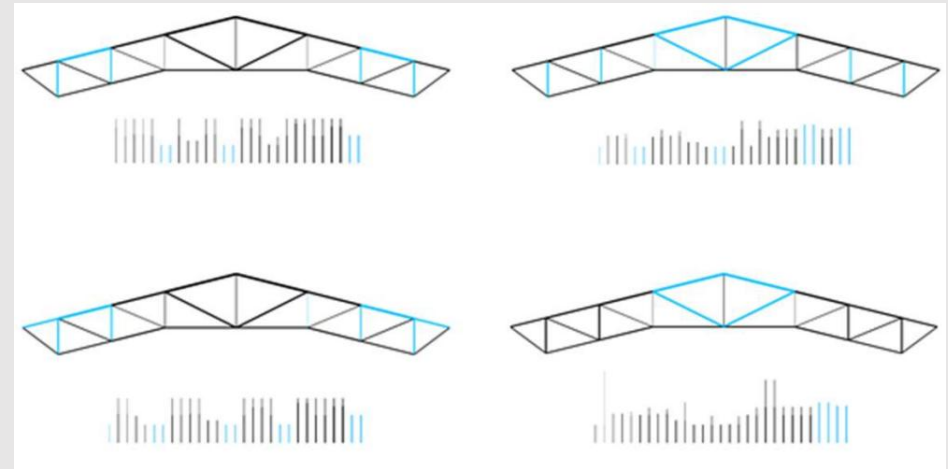
What is stock constrained design?



<https://www.epfl.ch/labs/sxl/tools/phoenix3d/>

Disadvantages stock-constrained design

- Creates complex and unique joints
- Will use larger elements than necessary, creating saw-off loss
- Fills gaps with new elements



https://www.researchgate.net/figure/a-shows-the-optimal-structure-designs-and-element-usage-for-stocks-A-B-and-C-when_fig3_354270307

The proposed solution!

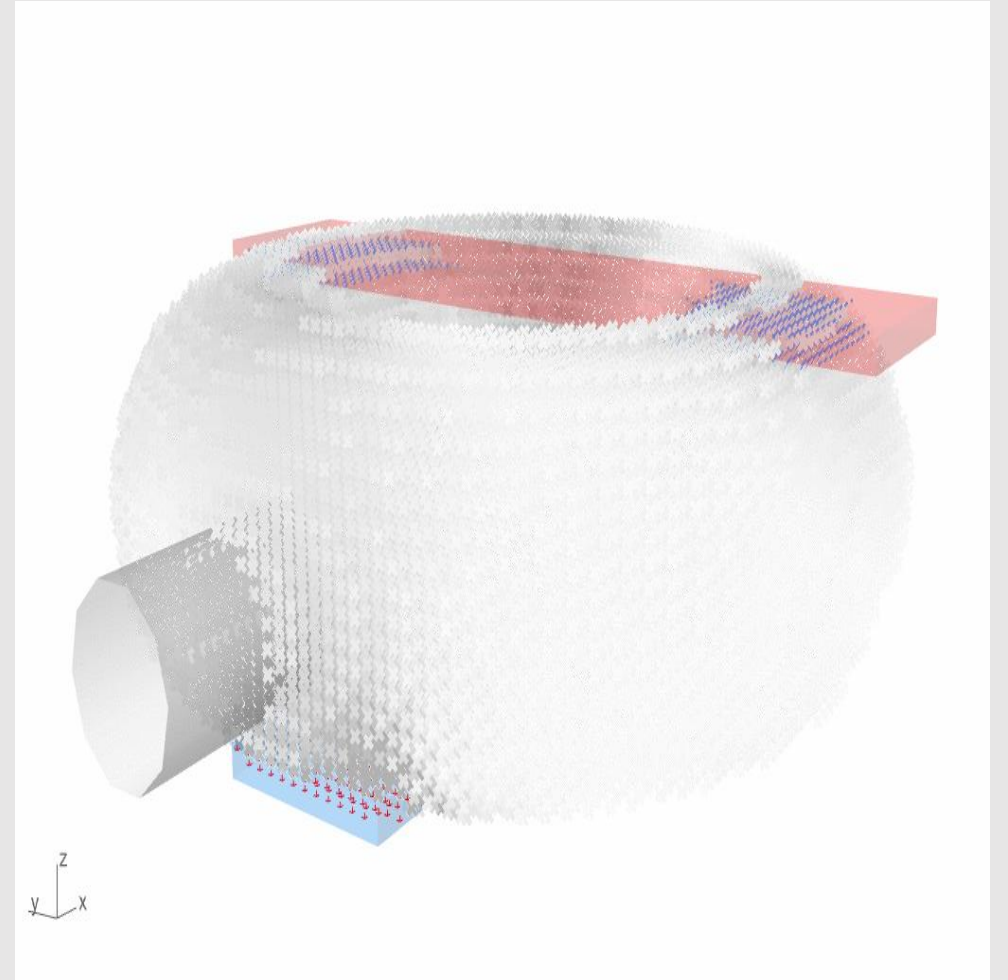
- Make connections grow towards elements
- Element \geq element required
- No saw-off!

<https://external-content.duckduckgo.com/iu/?u=https%3A%2F%2Ffi.redd.it%2Fnssgg09wcxe31.jpg&f=1&nofb=1&ipt=14d75fdbc56d6c583a62013f21d4a5b4d418125f0cd4cbf65037c5e64c2f6f06&ipo=images>

How? Topology optimization + 3D printing

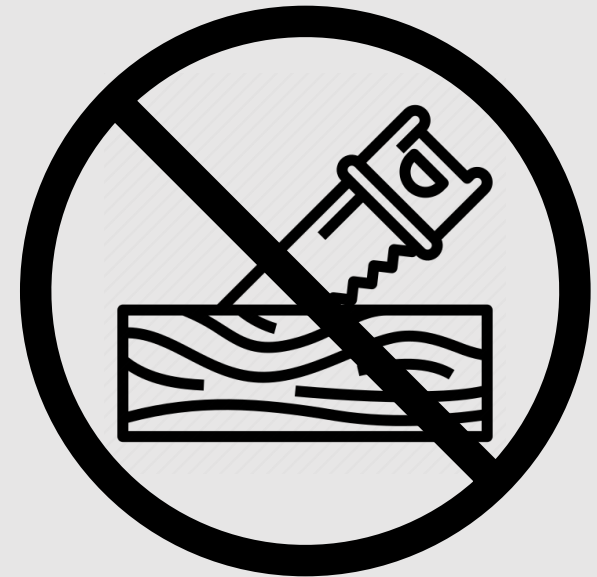
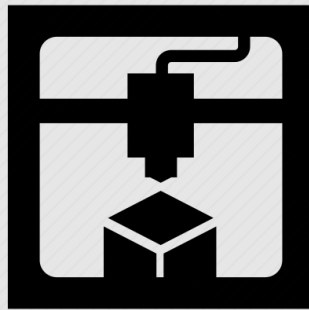
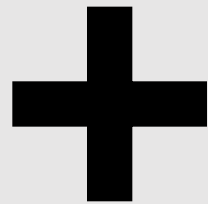


https://www.researchgate.net/figure/3D-printed-wooden-furniture-connectors-2_fig1_375886252



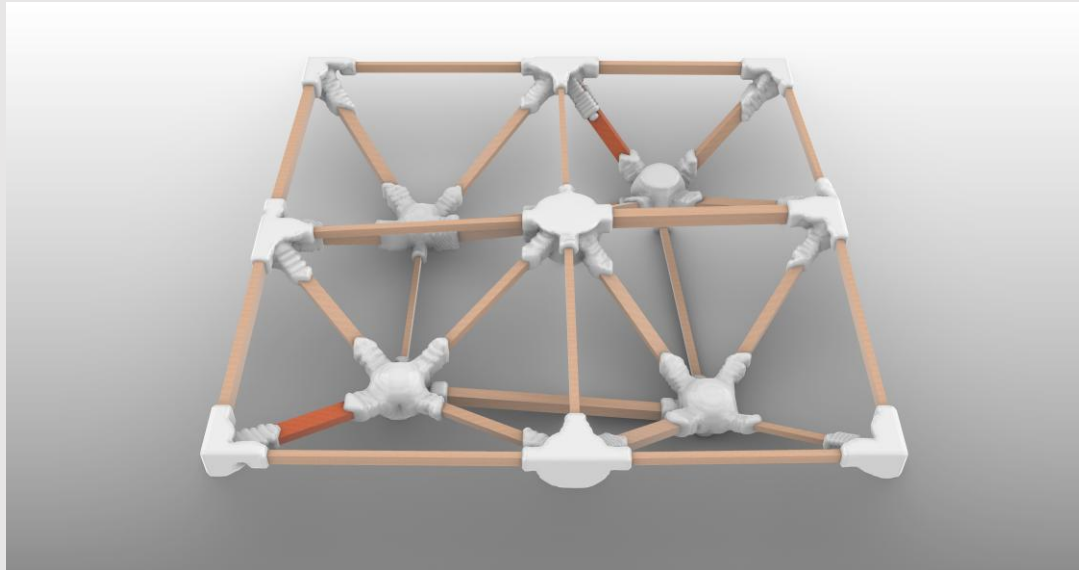
The research question

“Can stock-constrained digital design combined with 3D printing support the reuse of wooden structural elements without saw-off losses in a sustainable way?”

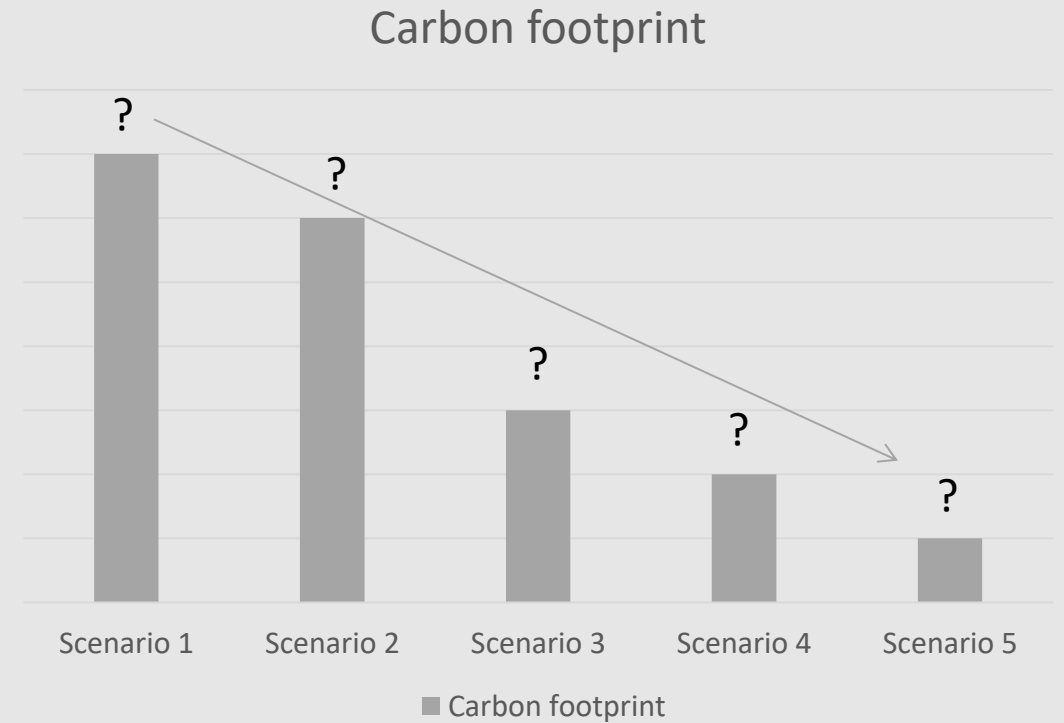


The desired end results

A design tool



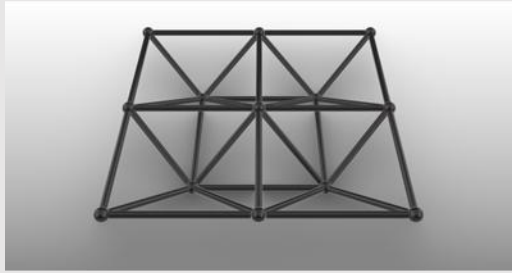
LCA results



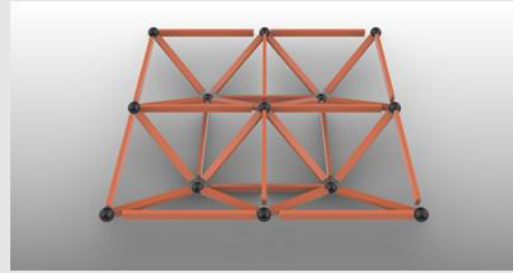
The case study



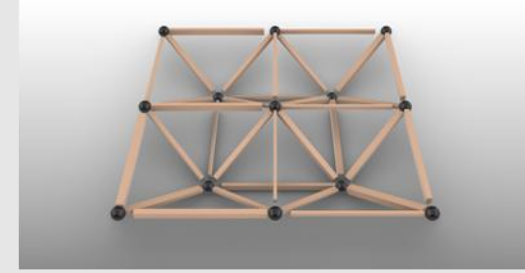
The scenario's



Original



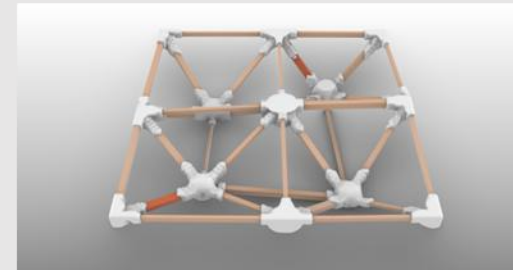
New wood



Reused wood

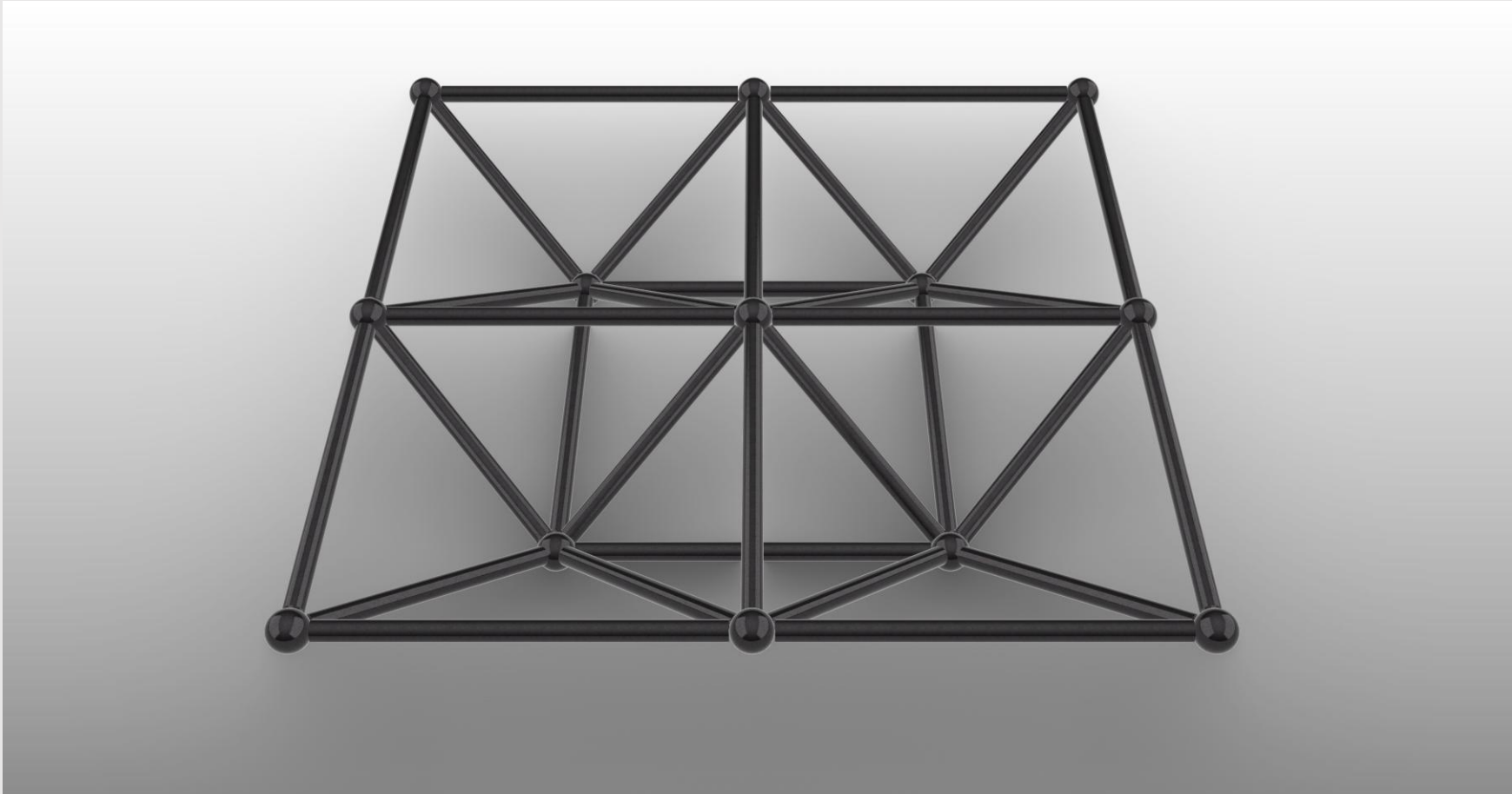


Optimized design

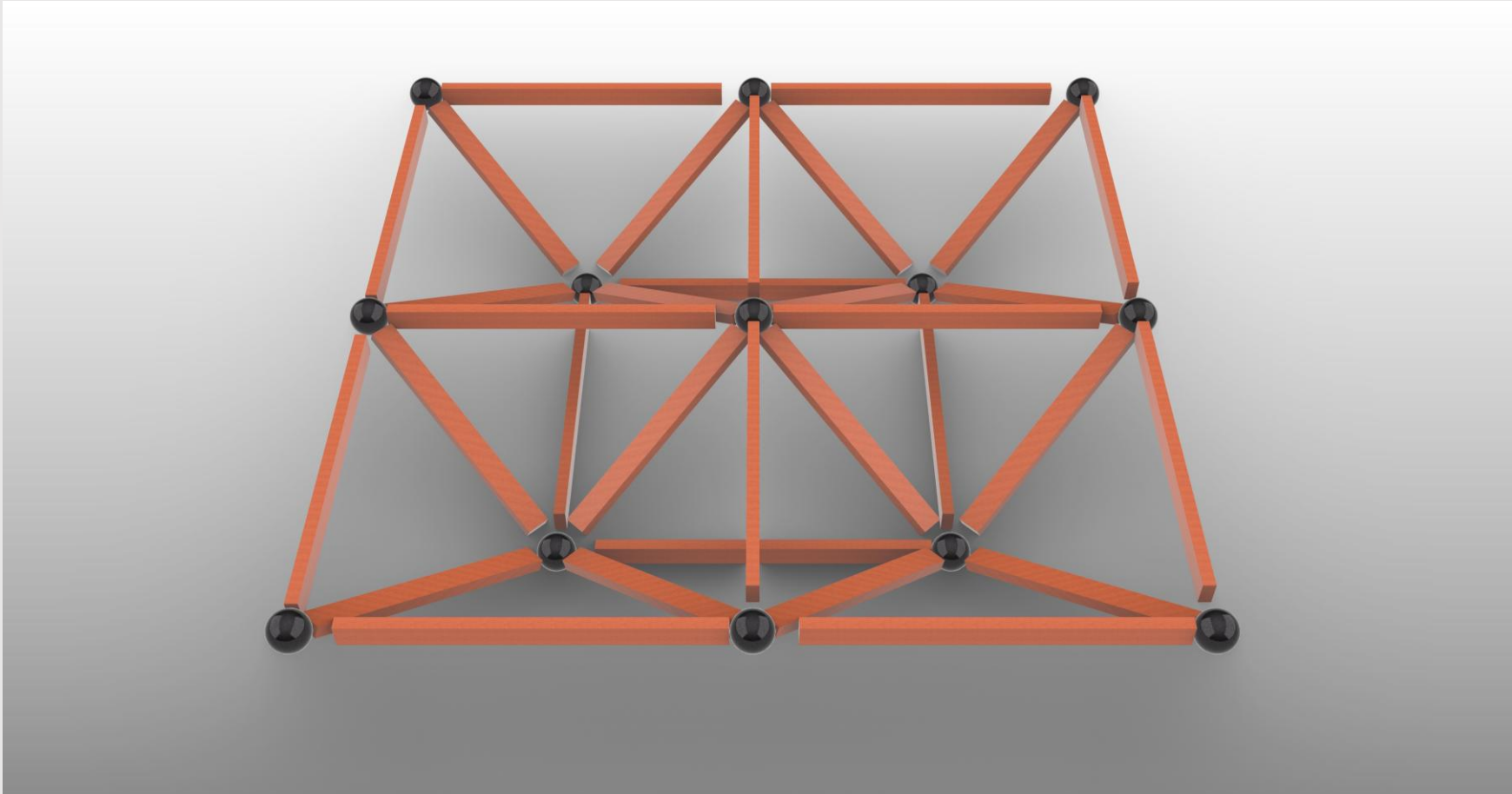


Optimized connections

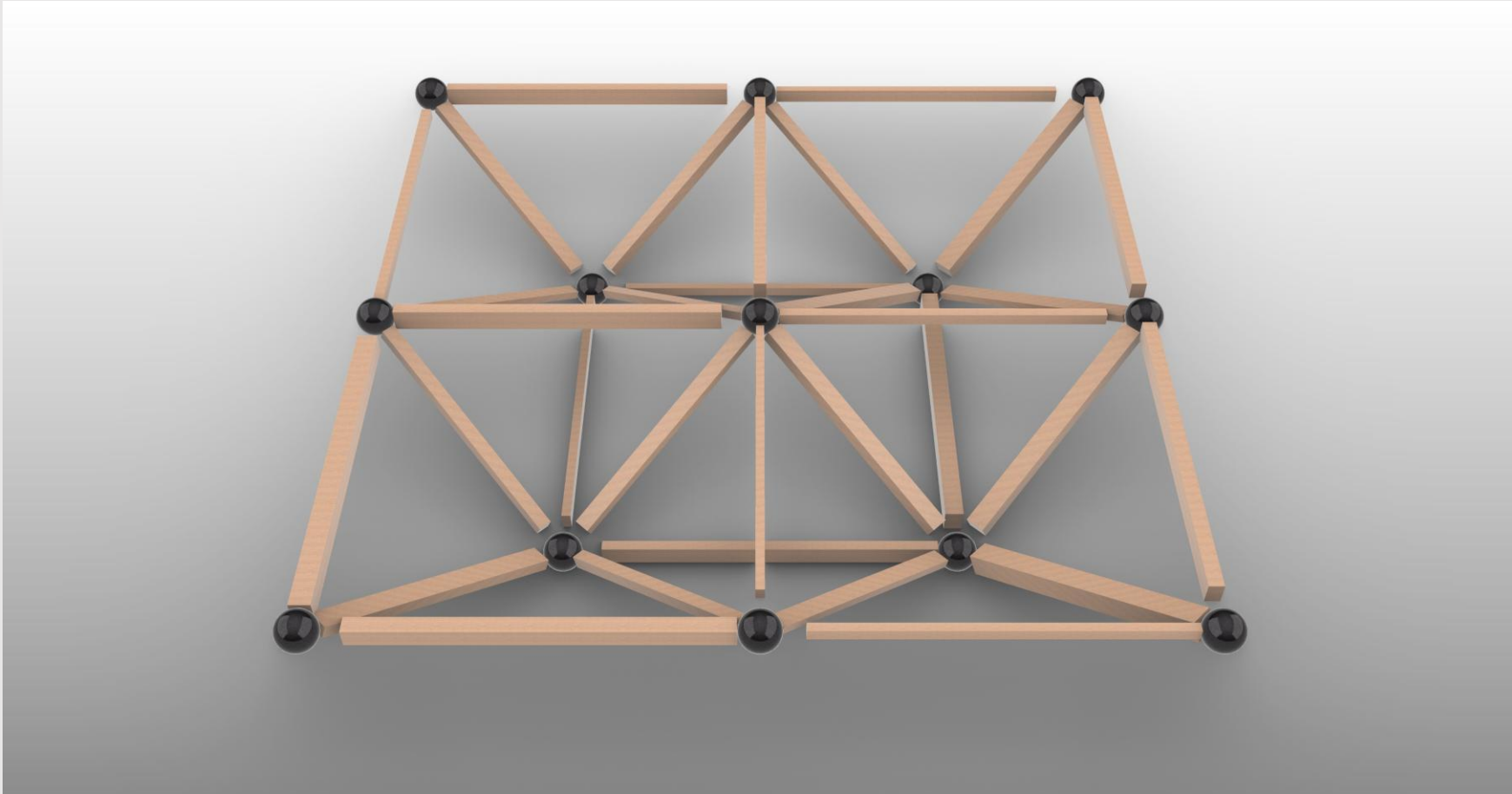
Scenario 1



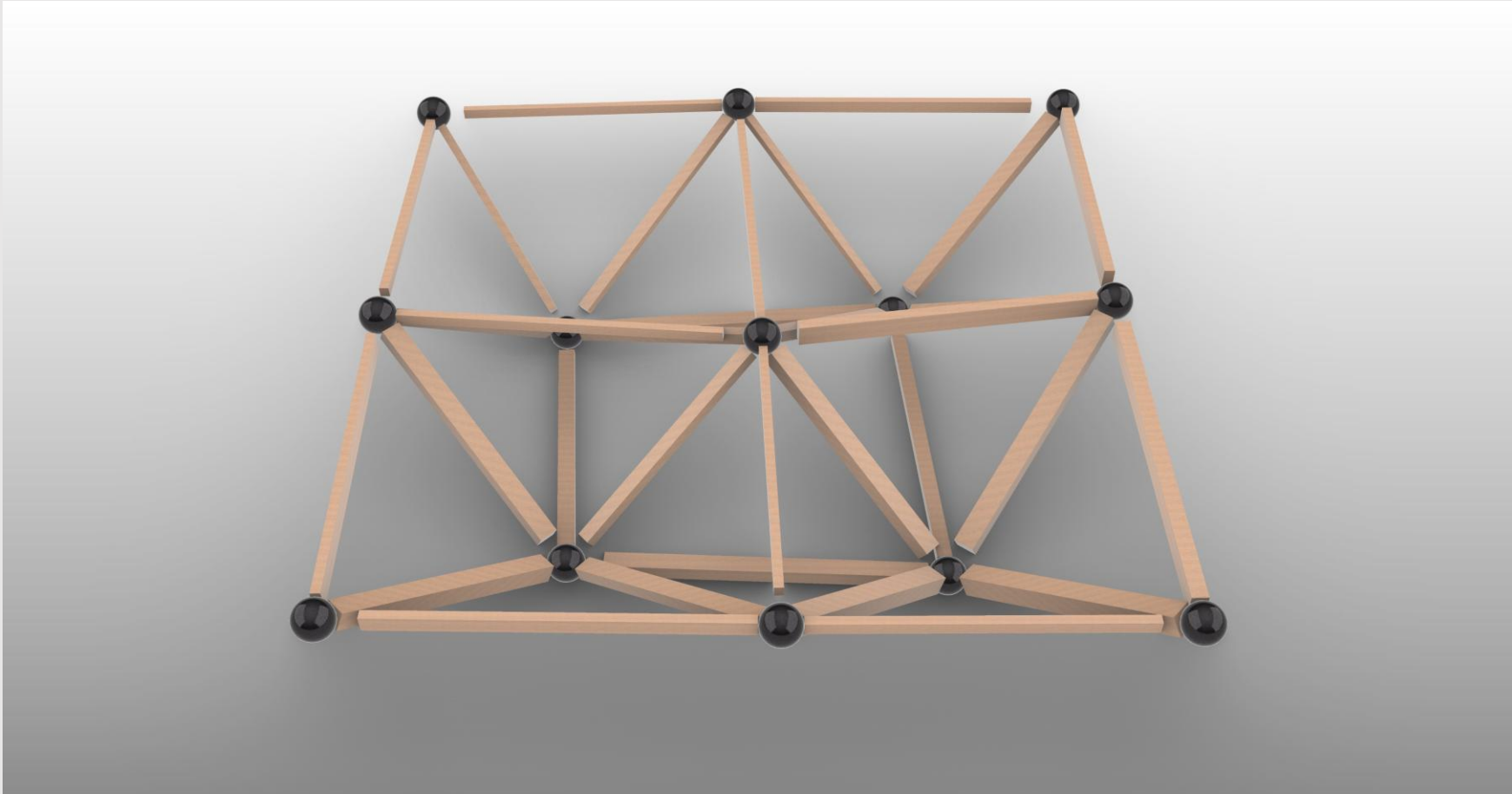
Scenario 2



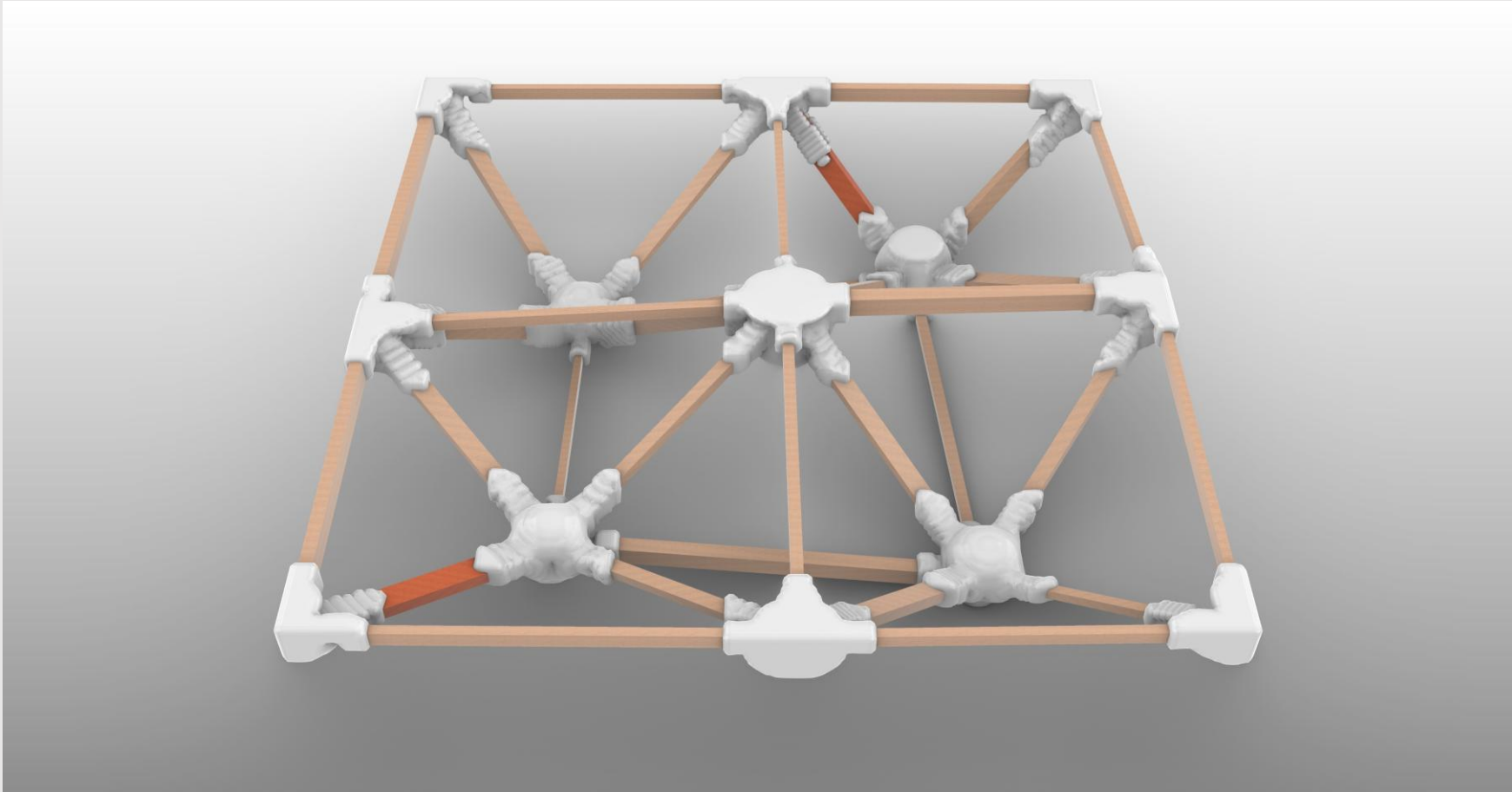
Scenario 3



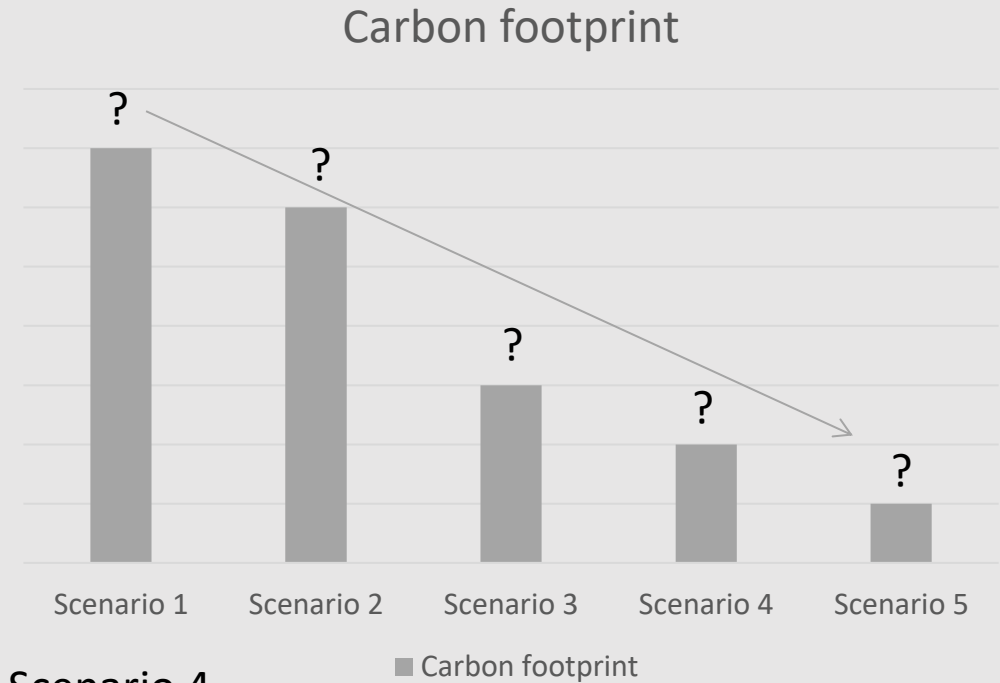
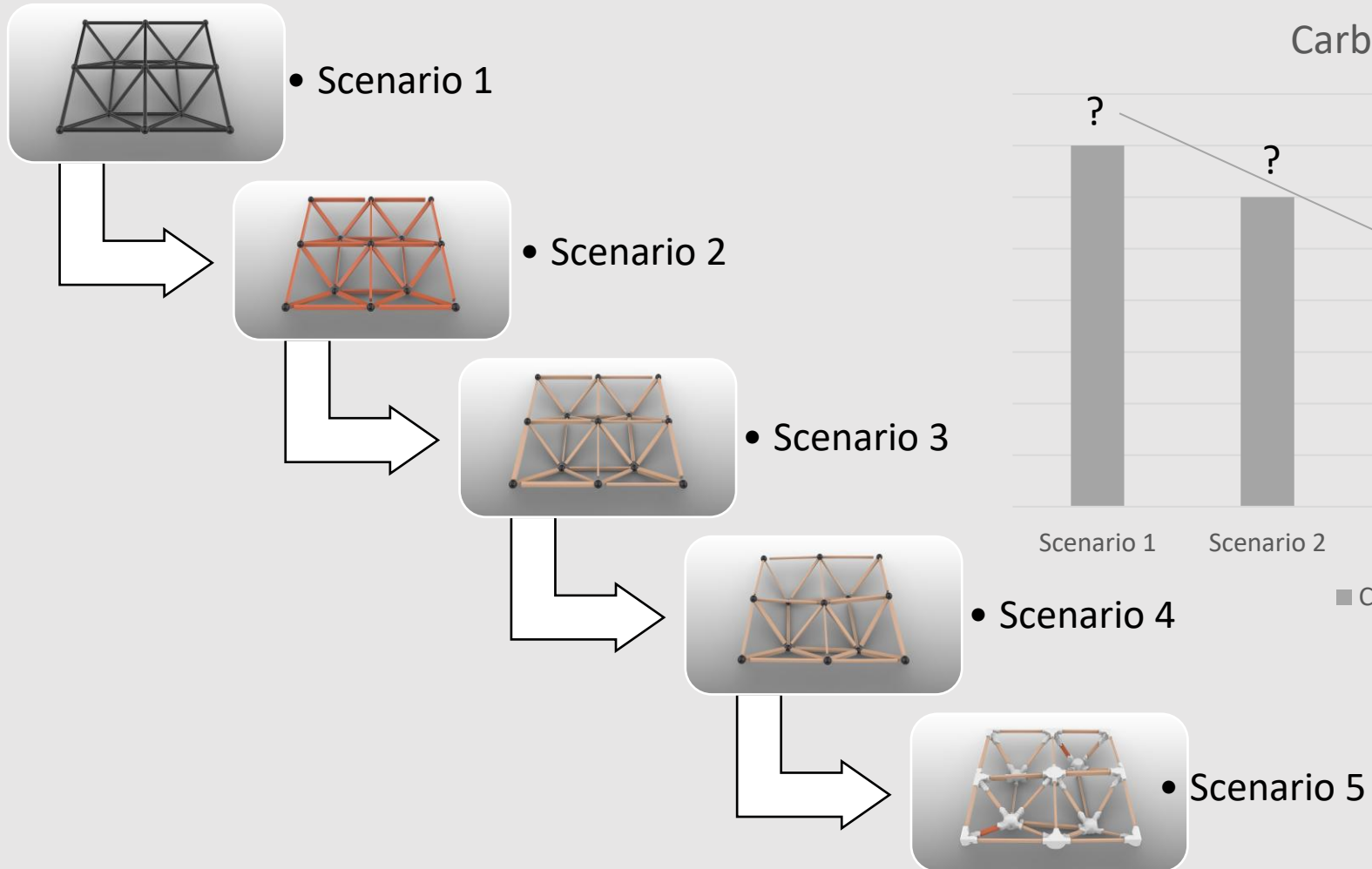
Scenario 4



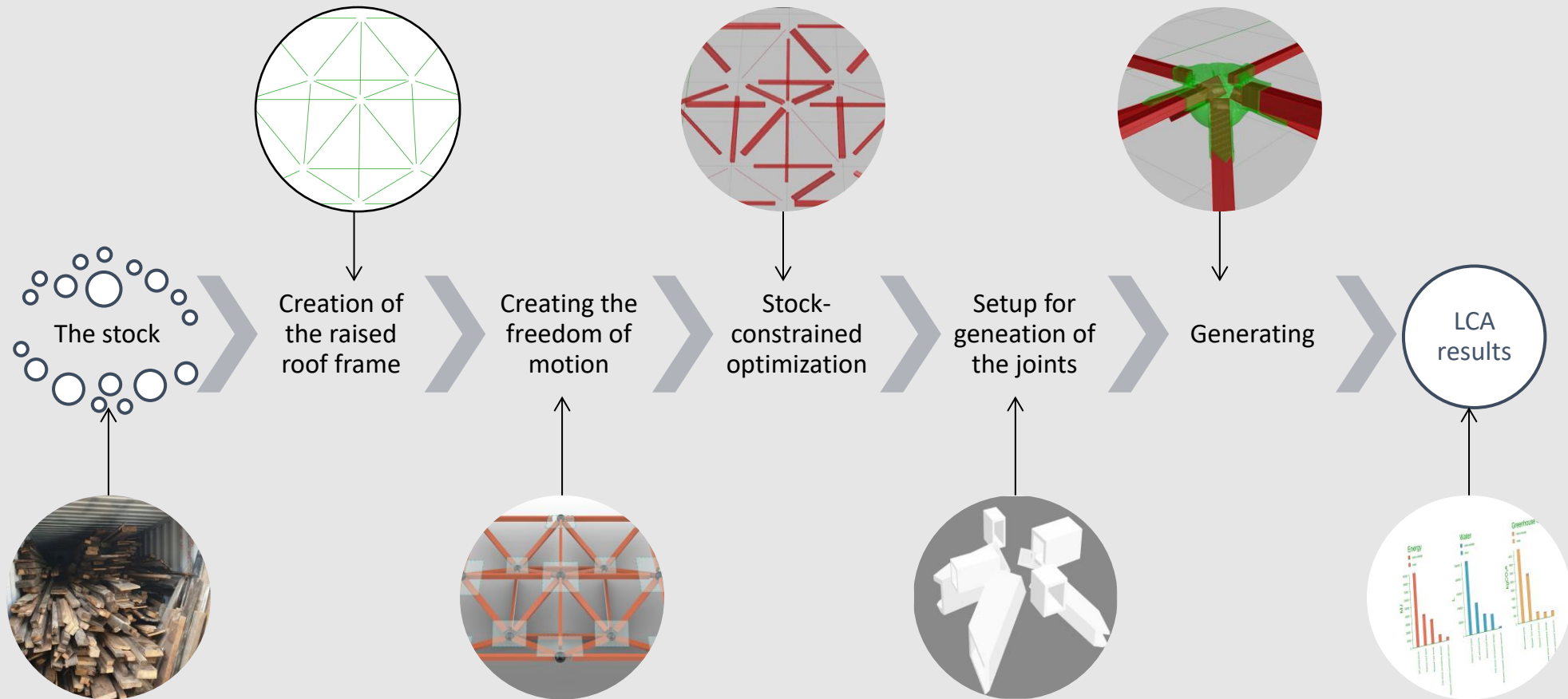
Scenario 5



The scenario's



The workflow

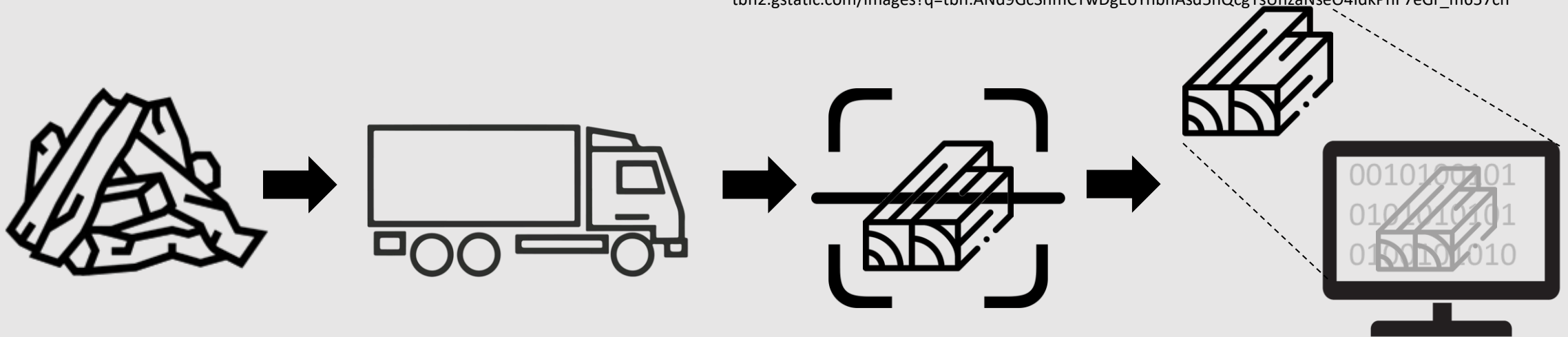


The stock

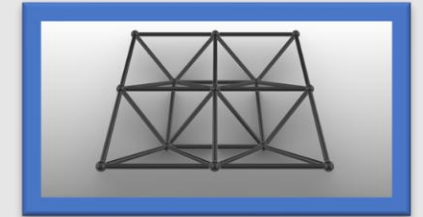
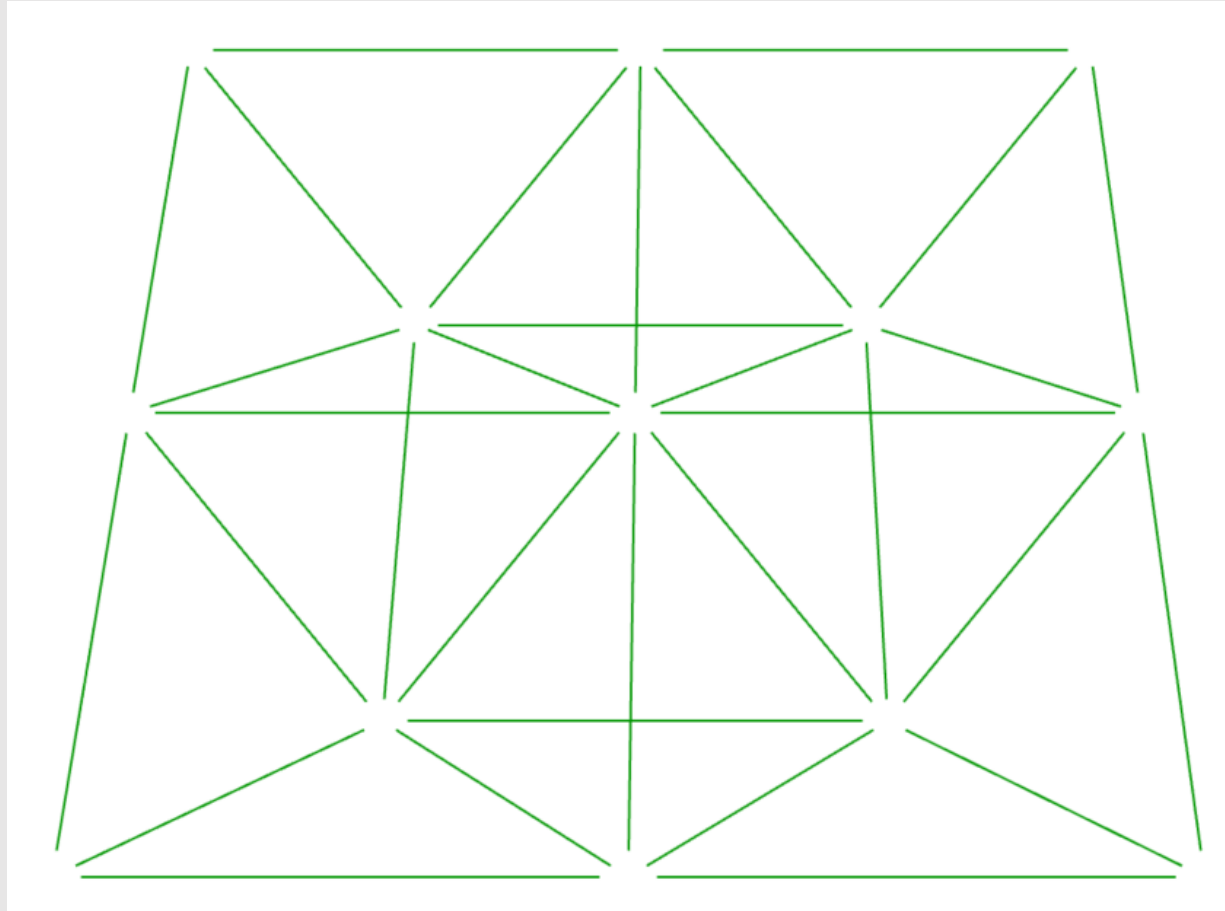
- Reclaimed timber
- Circulair hub
- 3D-digital copies for library



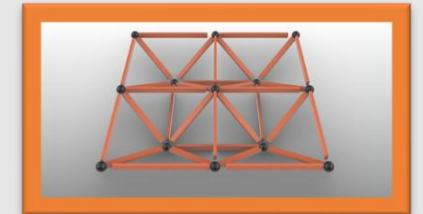
https://encrypted-tbn2.gstatic.com/images?q=tbn:AND9GcSnmCTwDgEoYhbhAsd5nQcgTsUhzaNseO4IdkPnF7eGr_m657ch



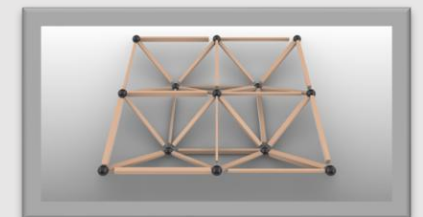
Recreating the original structure



Original

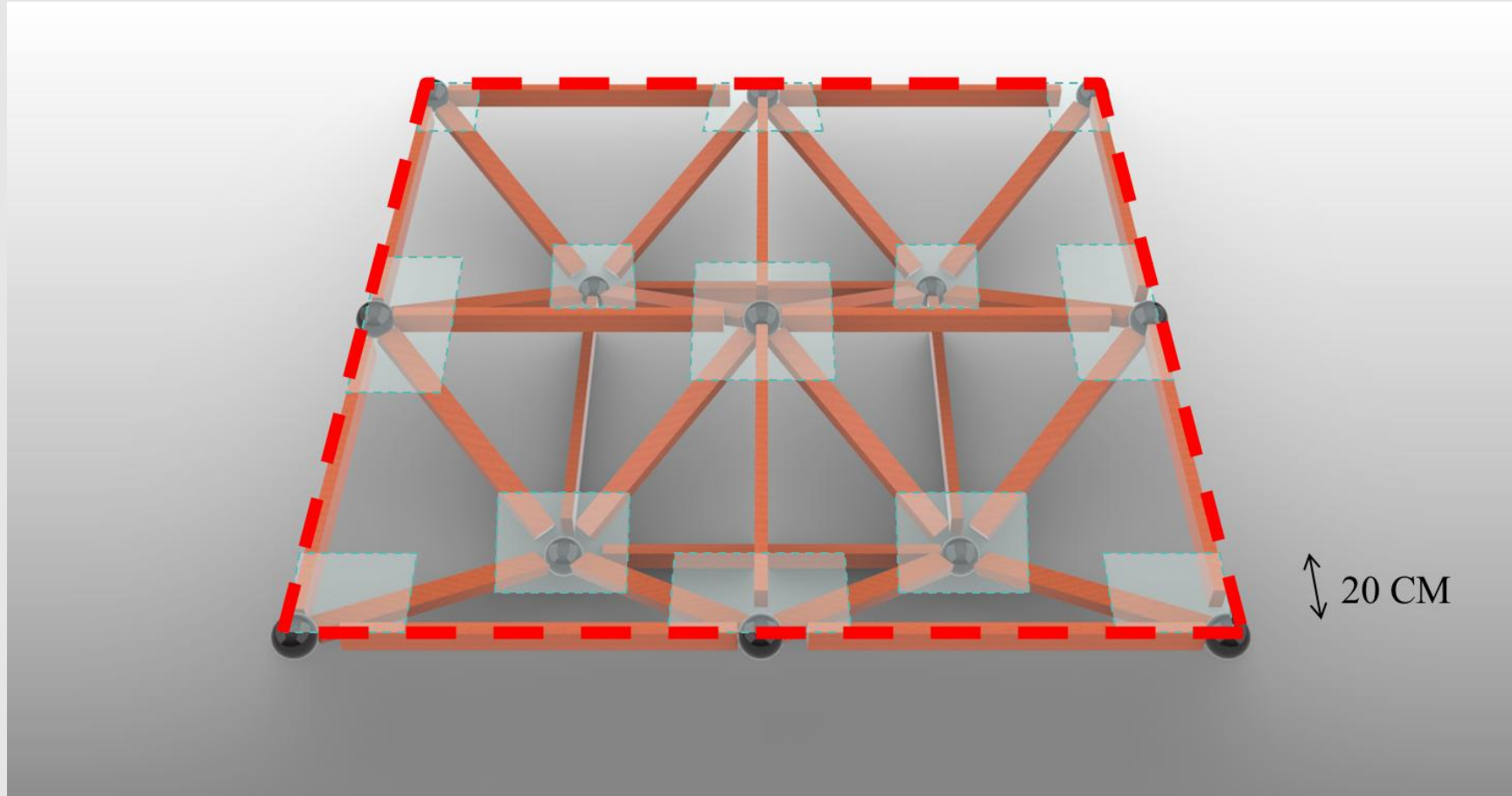


New wood

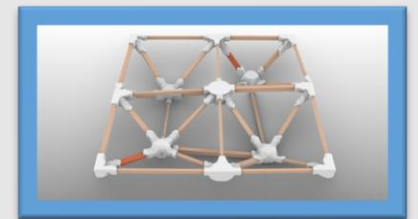


Reused wood

Creating freedom of motion



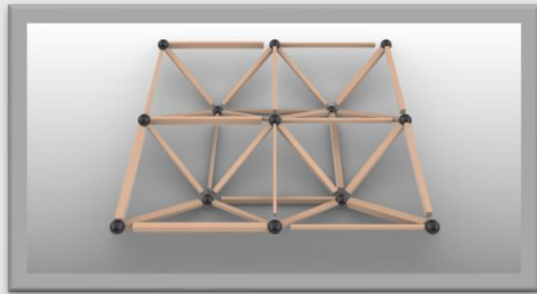
Optimized design



Optimized connections

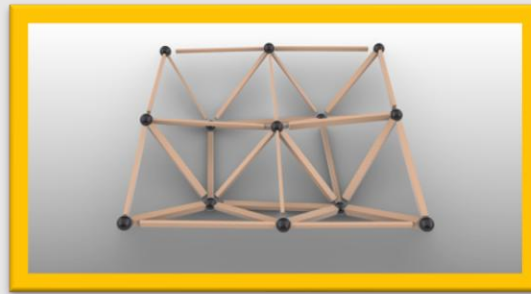
Reuse optimizations

- Element \geq element required
- No stock-constrained optimization
- With saw-off losses



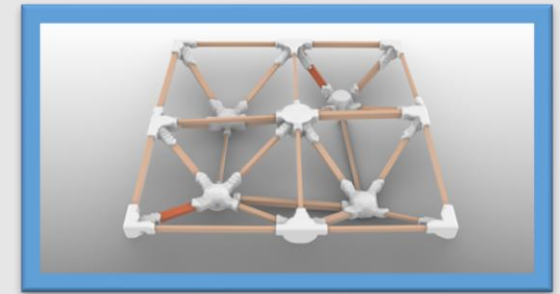
Reused wood

- Element \geq element required
- With stock-constrained optimization
- With saw-off losses



Optimized design

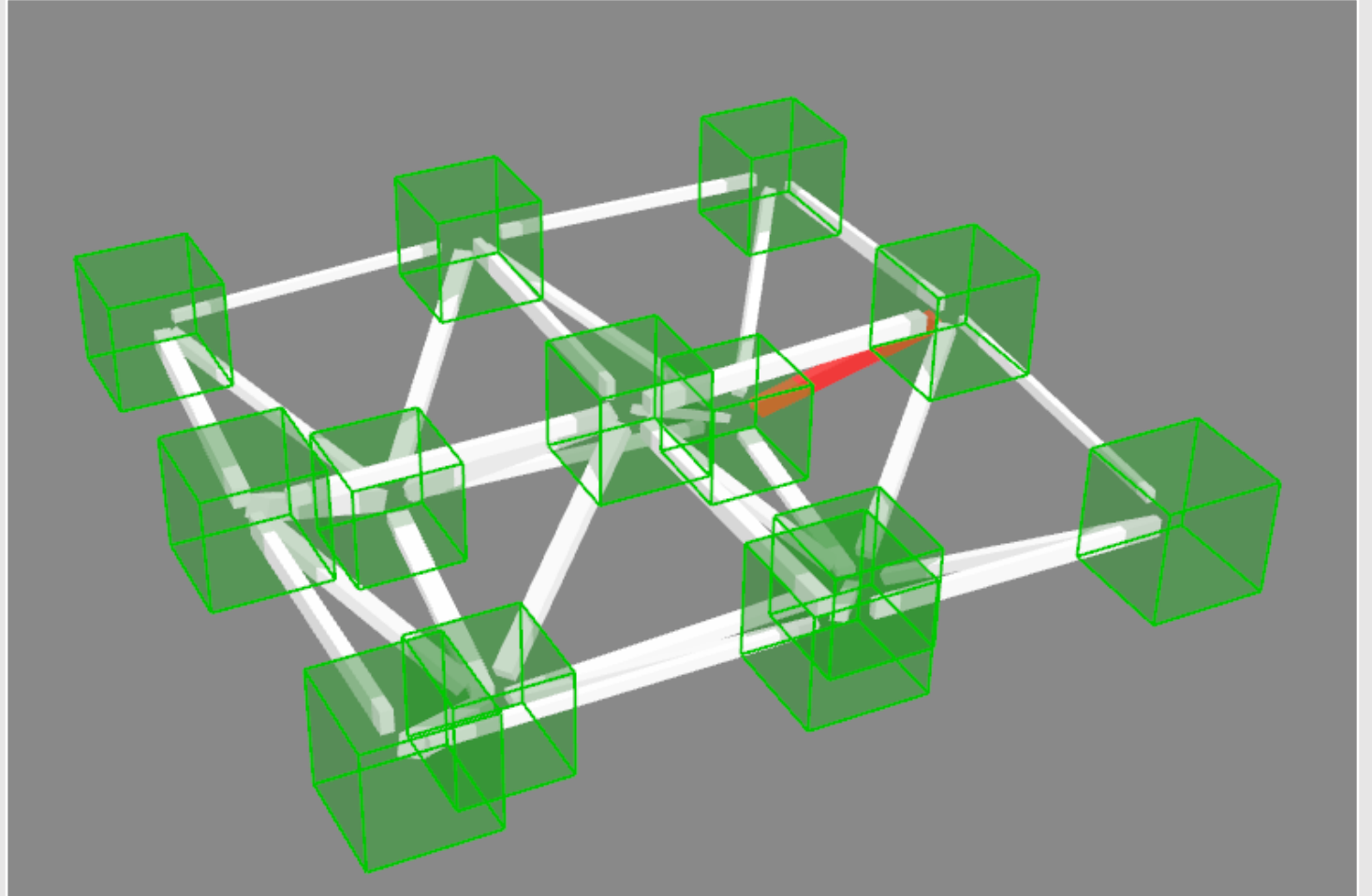
- Element \leq element required
- with stock-constrained optimization
- Without saw-off losses



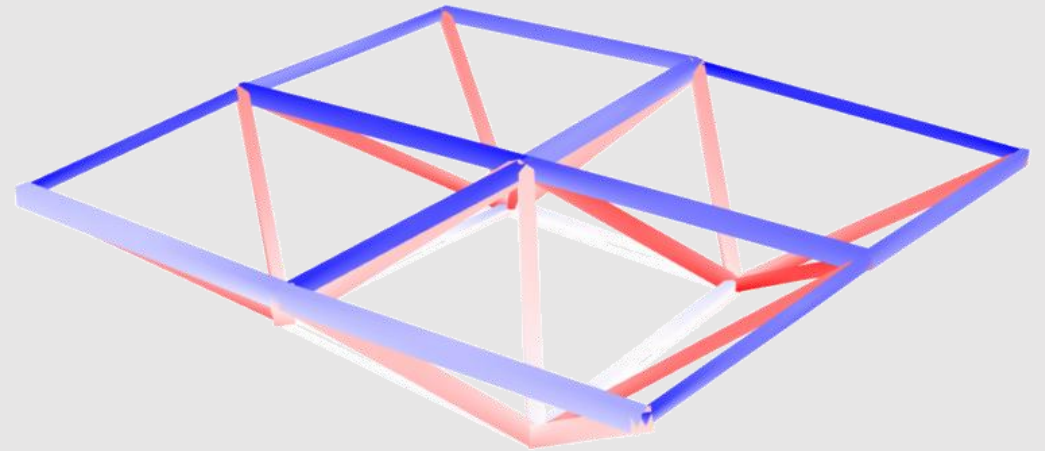
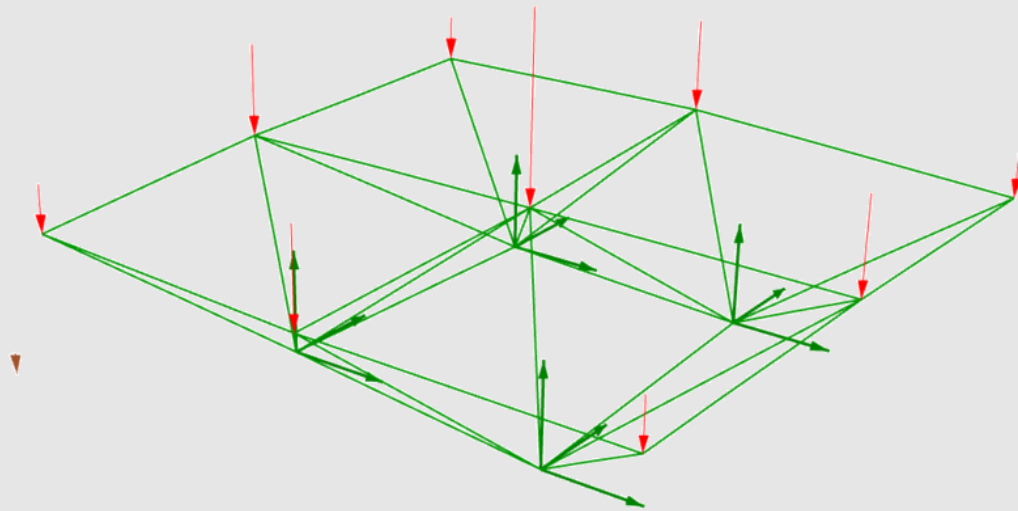
Optimized connections

Creating the printable box

- What goes into the connection?
- Angles, profiles, position etc.



Loads and materials



Loads and materials

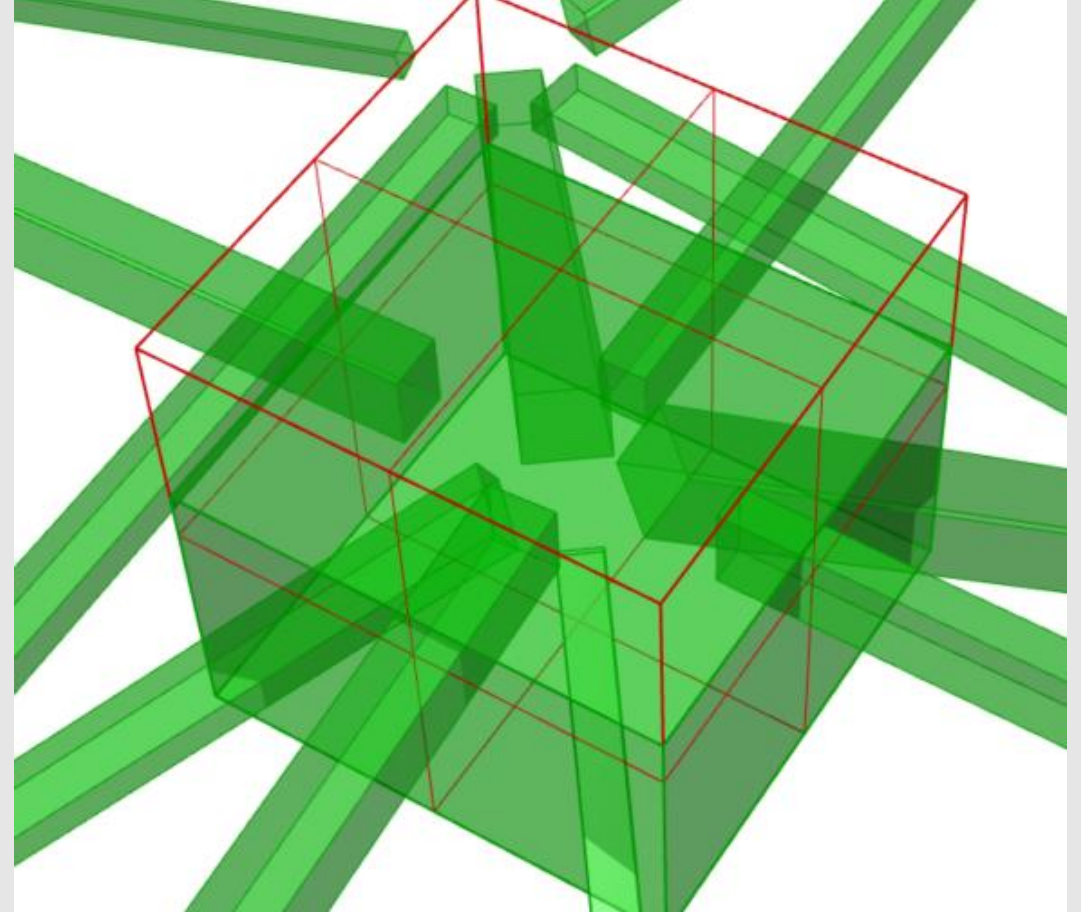
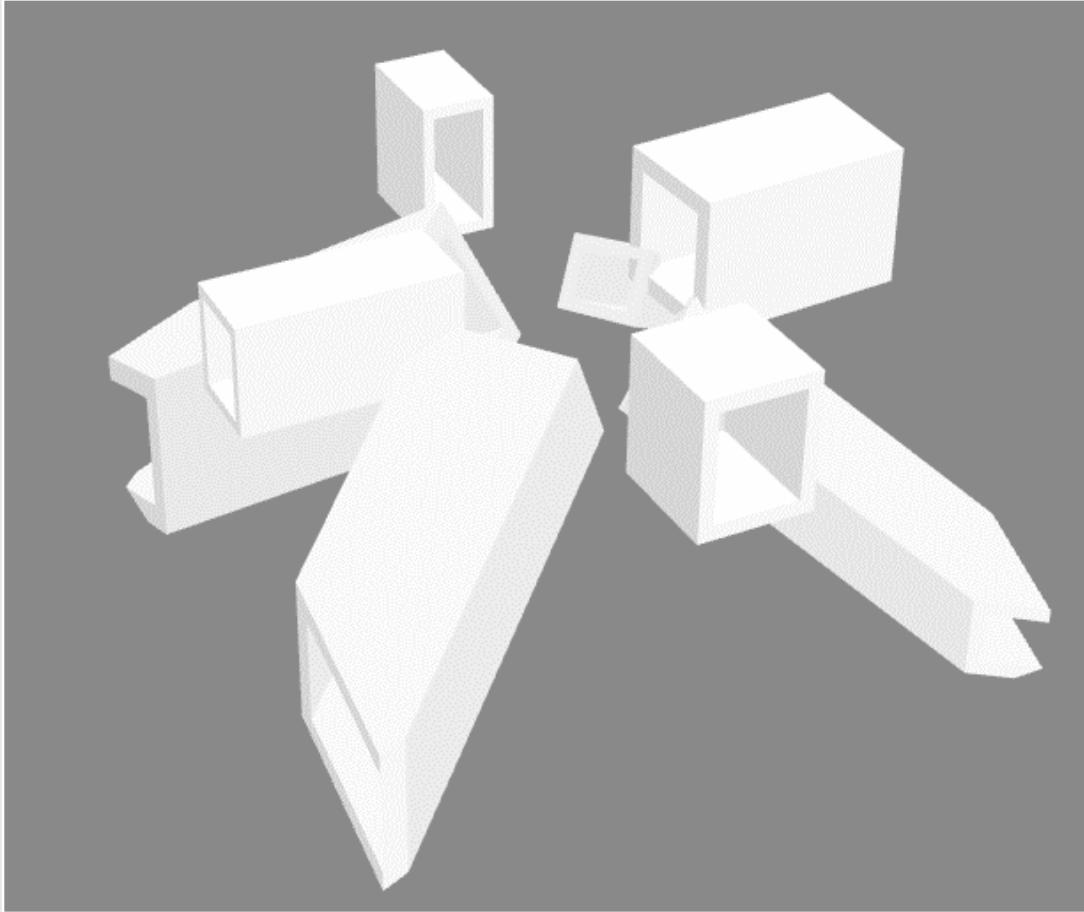
Material properties:

- Density
- Youngs modulus
- Poisson ratio

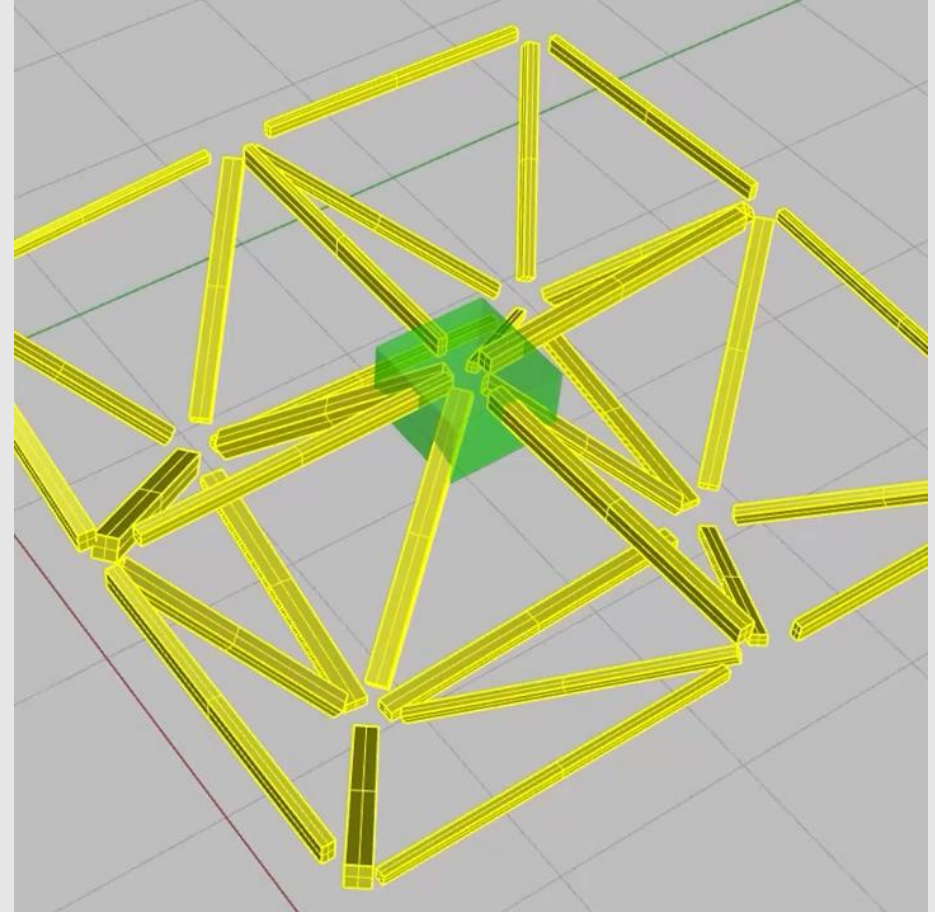
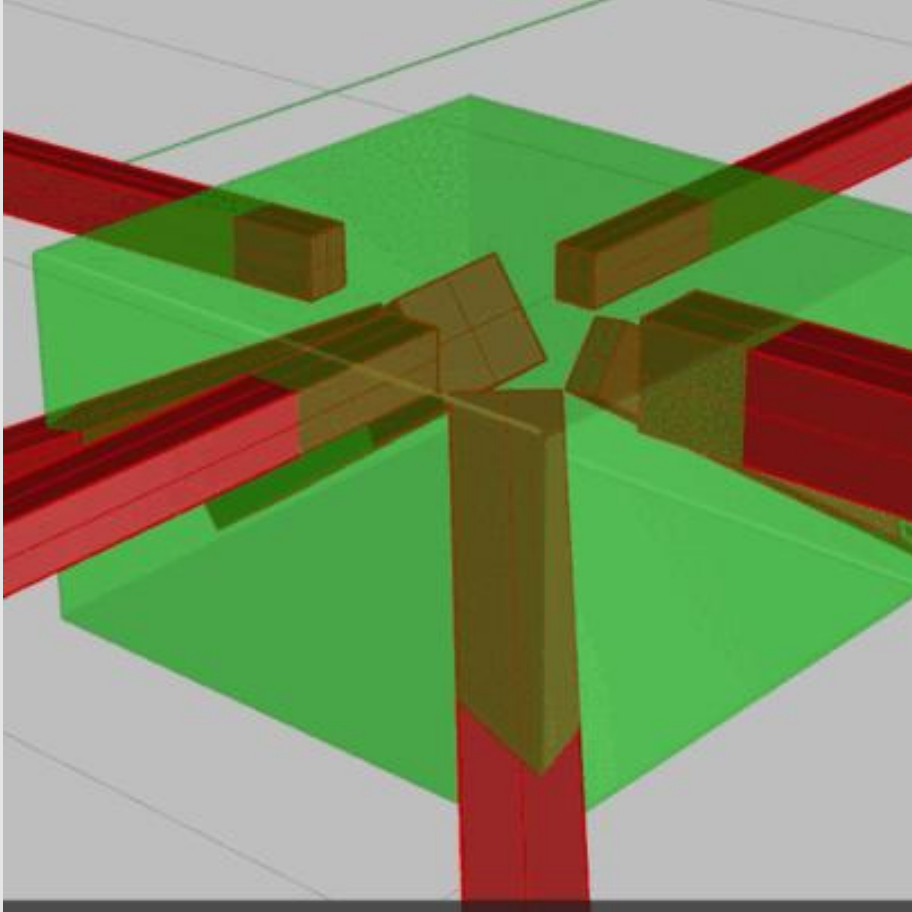


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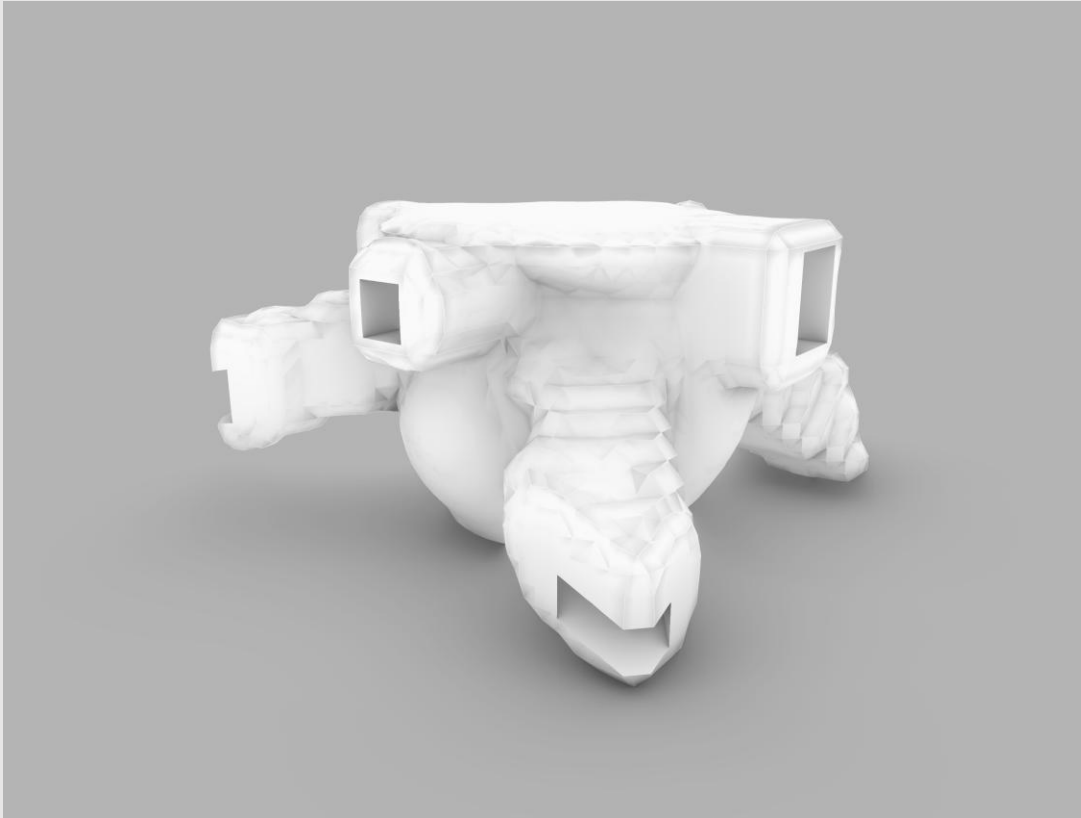
Predefined settings



Generating the connections

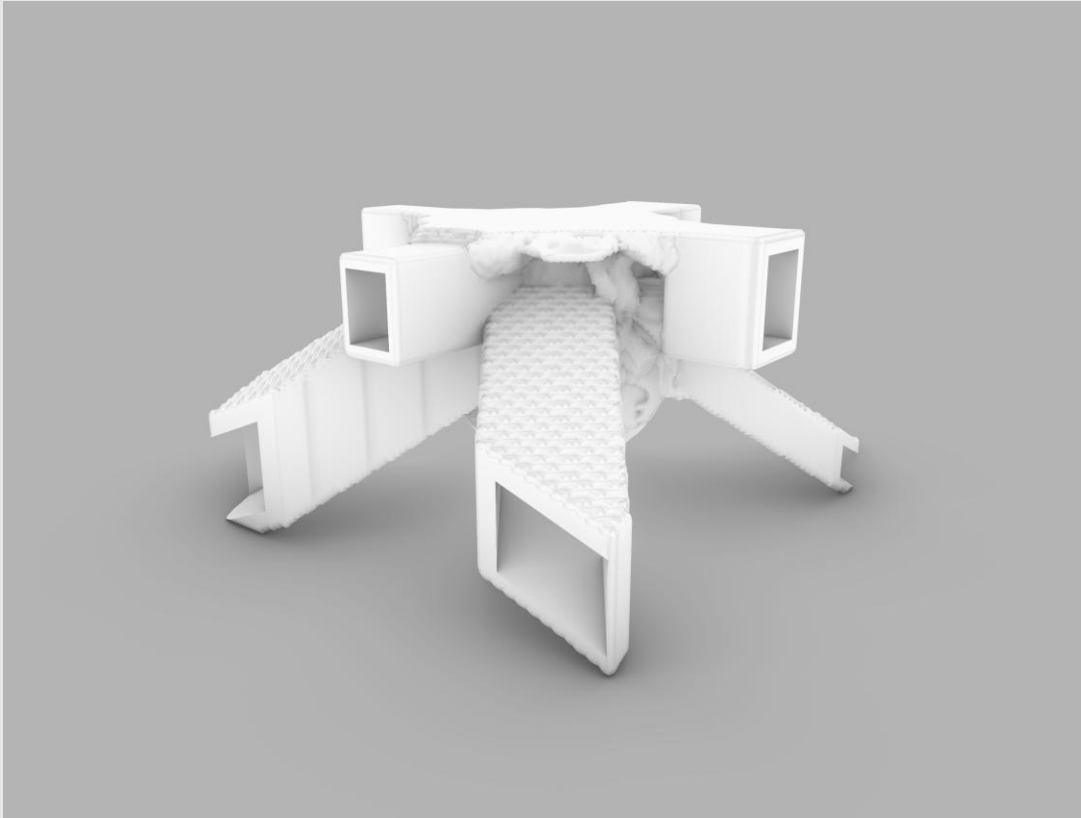


The first result



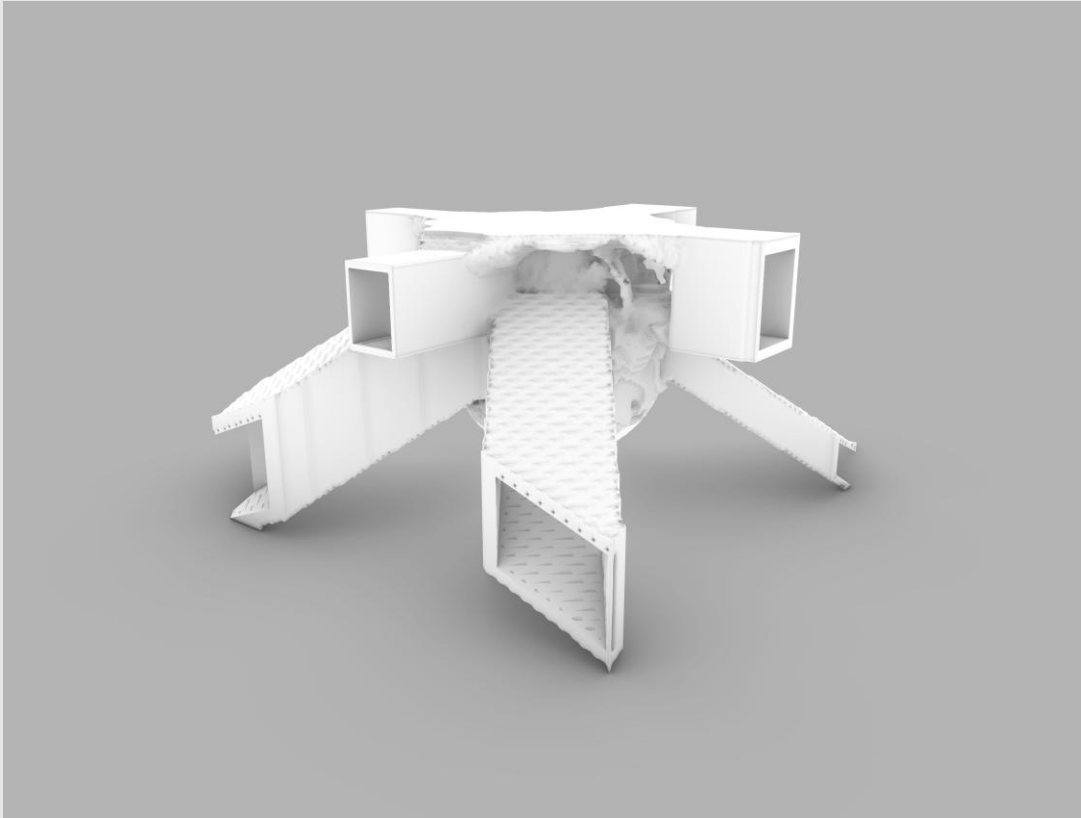
- Fast calculation time
- Low resolution
- 65.176 cm³

Higher resolution



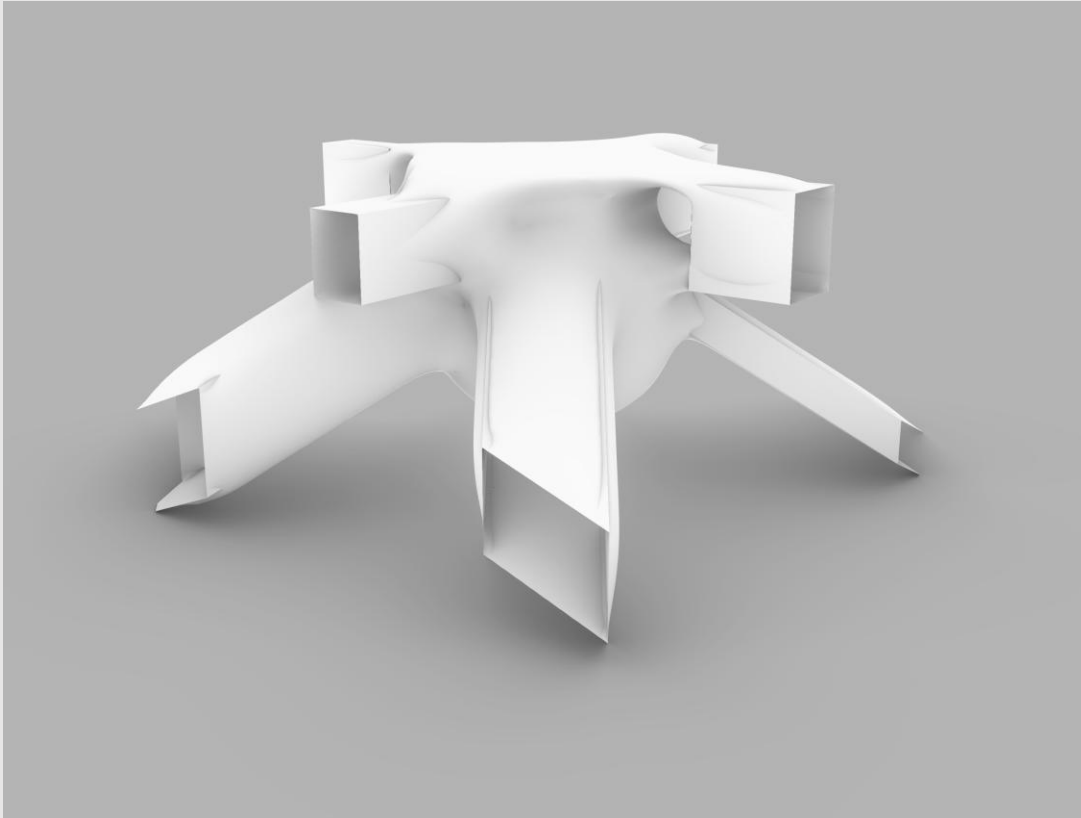
- Slow calculation time
- High resolution
- -54% volume
- 29.781 cm³

Higher iso-value

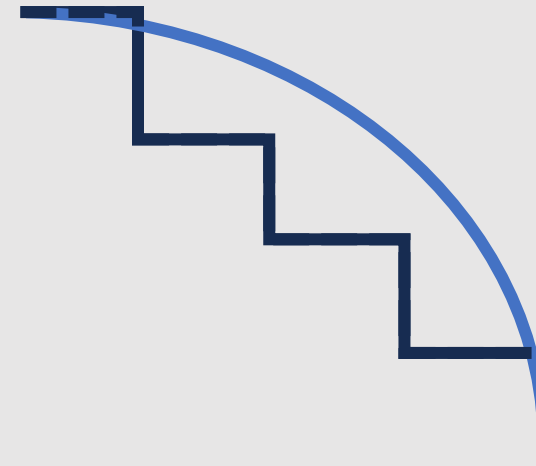


- Takes away “underutilized material”
- -67% volume
- 21.438 cm³

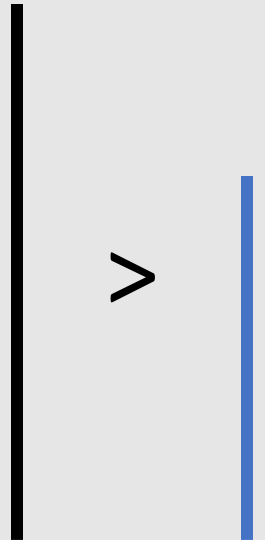
Smoothing surface



- Turning pixels into an surface
- -74% volume
- 16.673 cm³



New surface

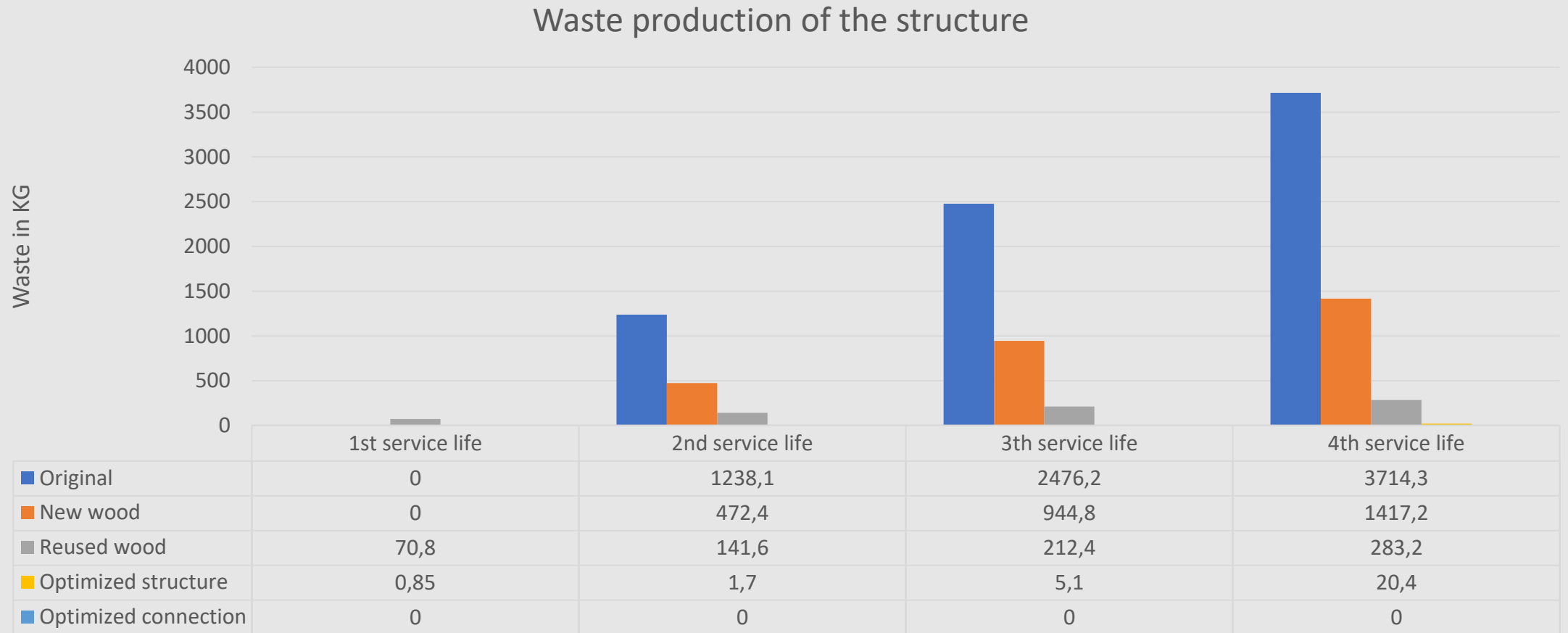


The waste and LCA results



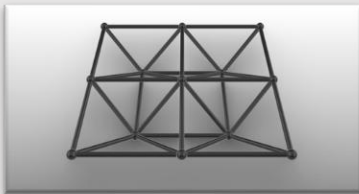
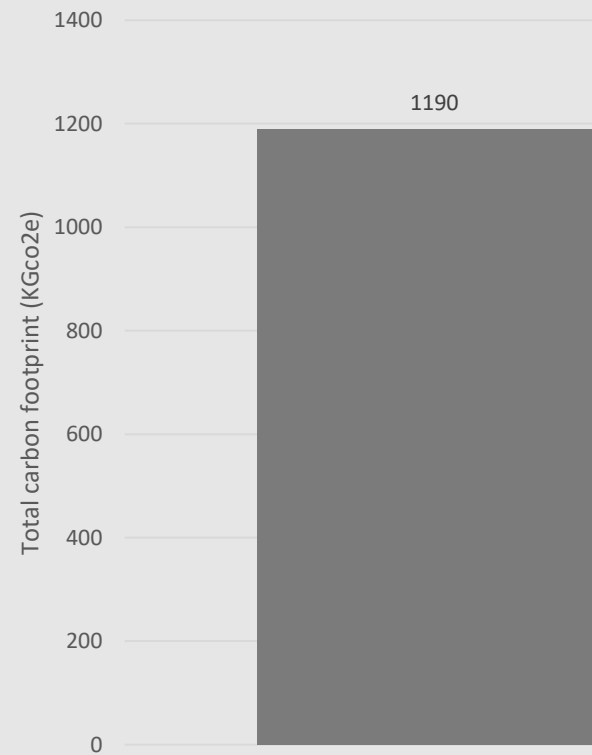
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Waste production results

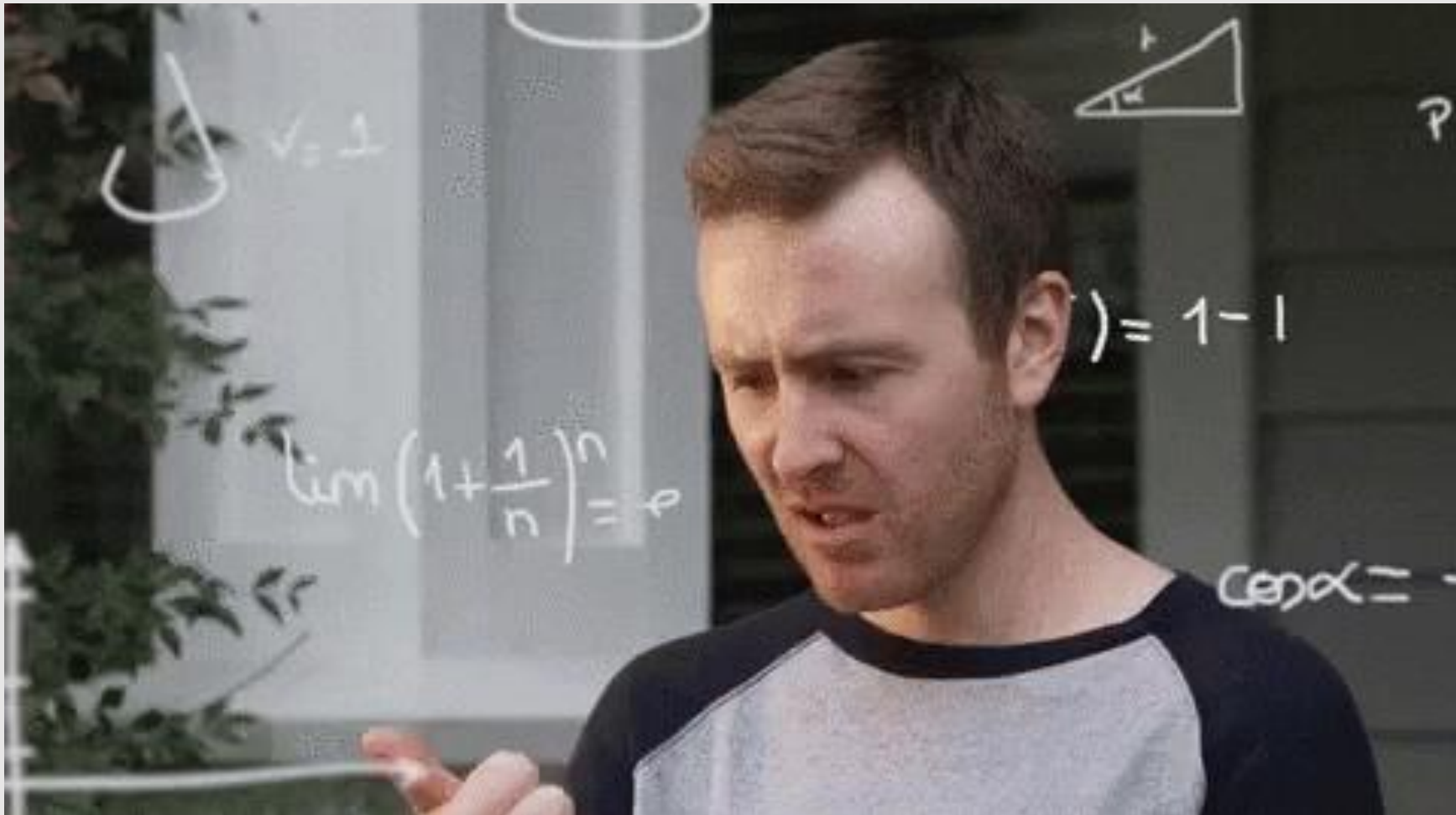


The LCA results

Carbon footprint comparison 1, 5 and 10 years

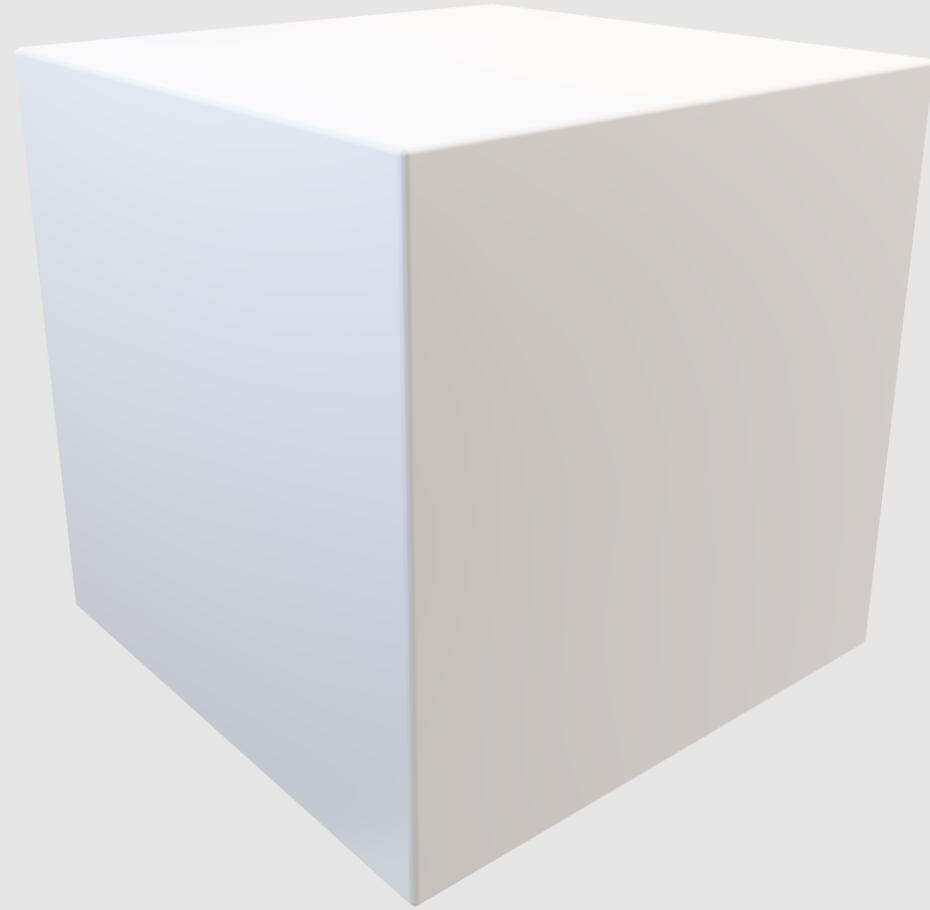


What happend?

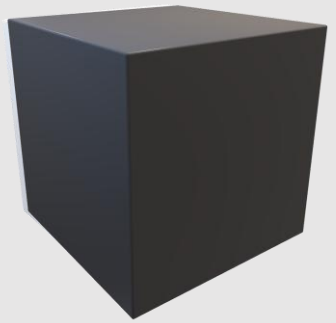


How is this possible?

- 177 kg plastic
- 49 kg steel connections
- Volume increase 25x



PETG



Steel

Conclusion

The question

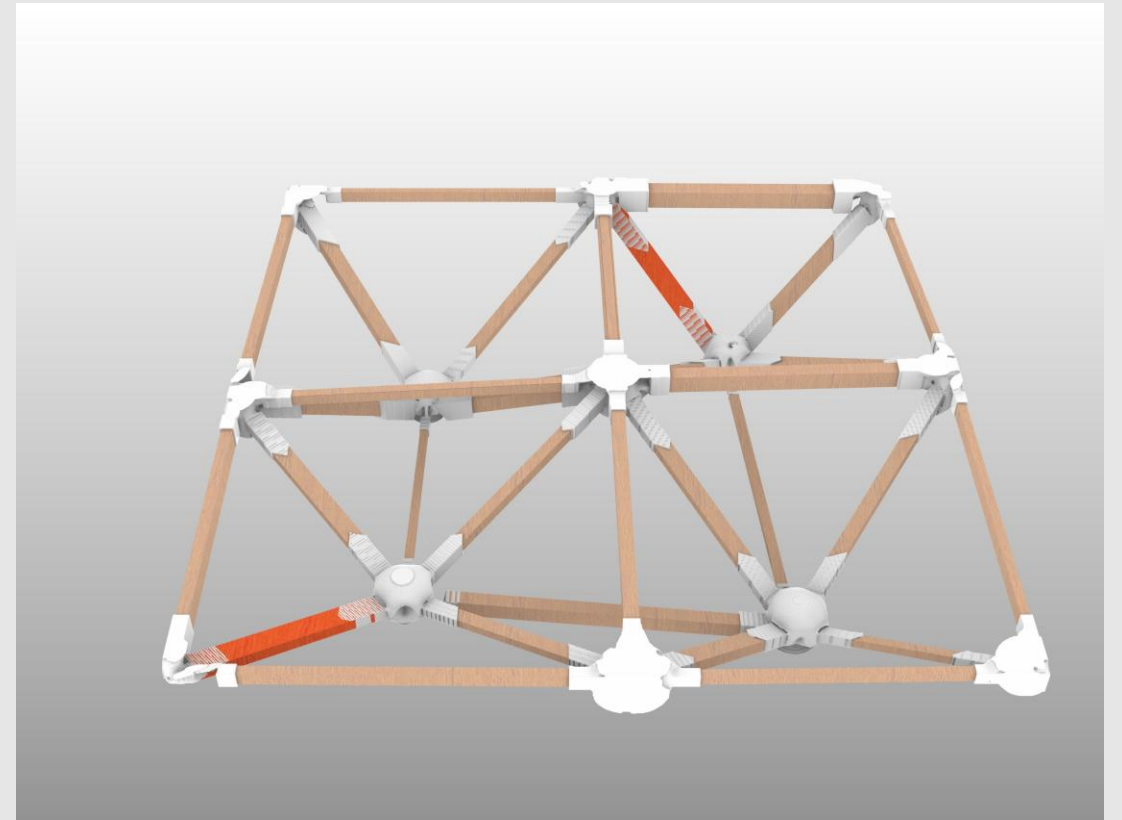
- *“Can stock-constrained digital design combined with 3D printing support the reuse of wooden structural elements without saw-off losses in a sustainable way?”*

My answer

- Yes, it is possible to use this method and design with zero waste
- However, it might not always be the most sustainable option when compared to the alternatives

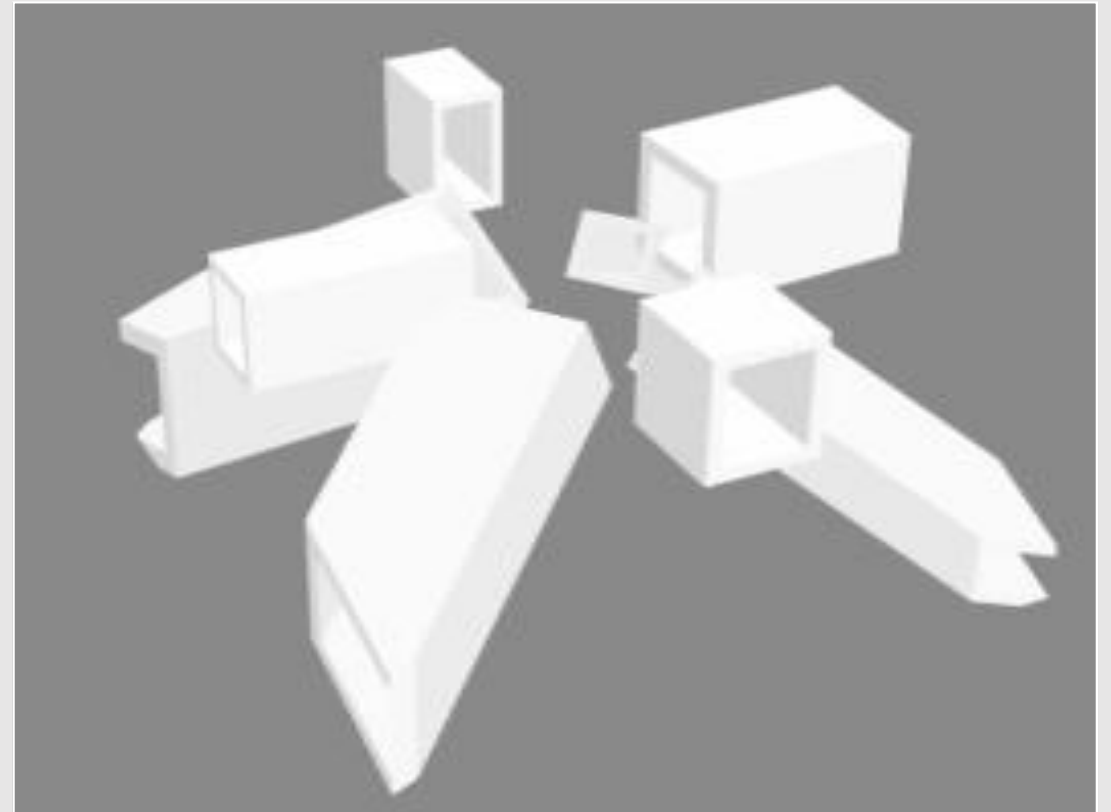
Discussion

- Structural validation of the connections
- Topos is limited for detailed work



Discussion

- A working attachment that survives the simulation
- Attachment could be optimized to save material



Discussion

- Scale was limited during the research



Discussion

- Fire safety
- Unthreaded wood + plastic connections



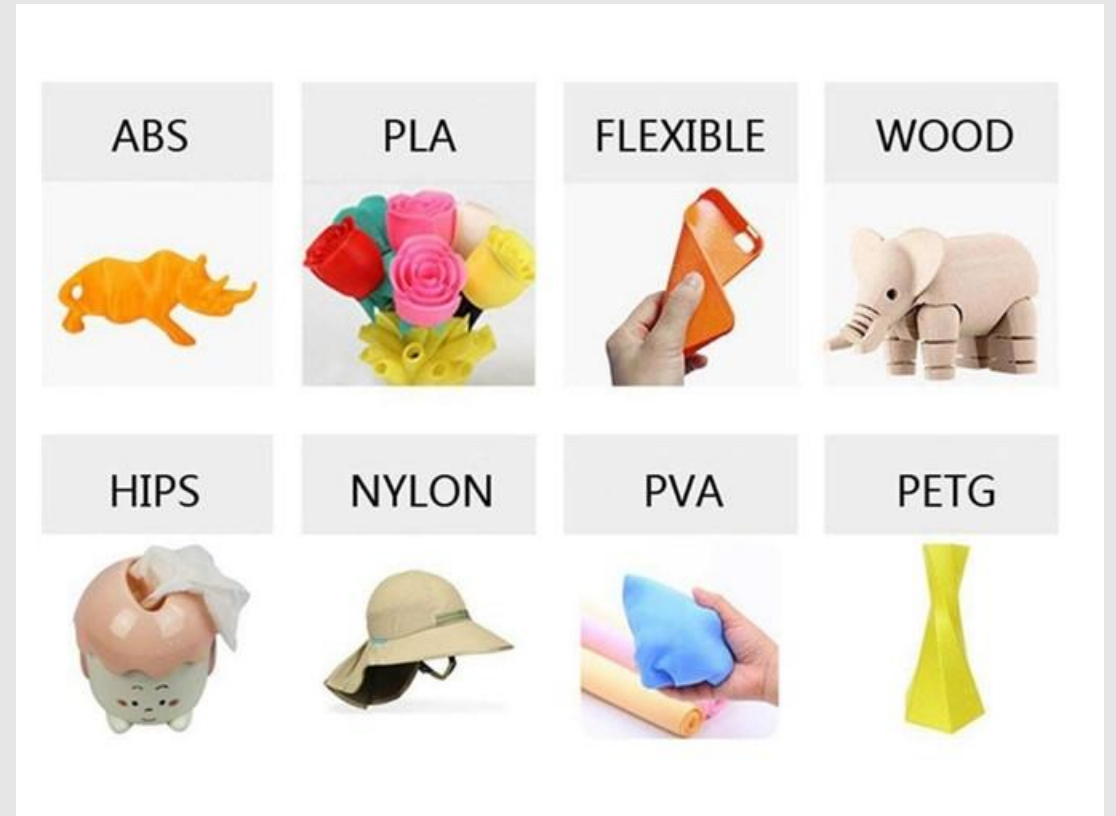
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<https://vimeo.com/654116098>

Opportunities

- Different materials could lead to a more sustainable product



https://encrypted-tbn1.gstatic.com/images?q=tbn:ANd9GcSzZsLJse_5FgLFHTOW3mvdIX8zKNwt1QMERN81_ArgzWGVJR25

Opportunities

- More materials become available to designers with the help of the developed tool
- The supplies can come from more local places



<https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcTZwYWrrfb0sGKMYt0QLlg65a1mBSvS33t8uacb3xyIMek6b4Sy>

Opportunities

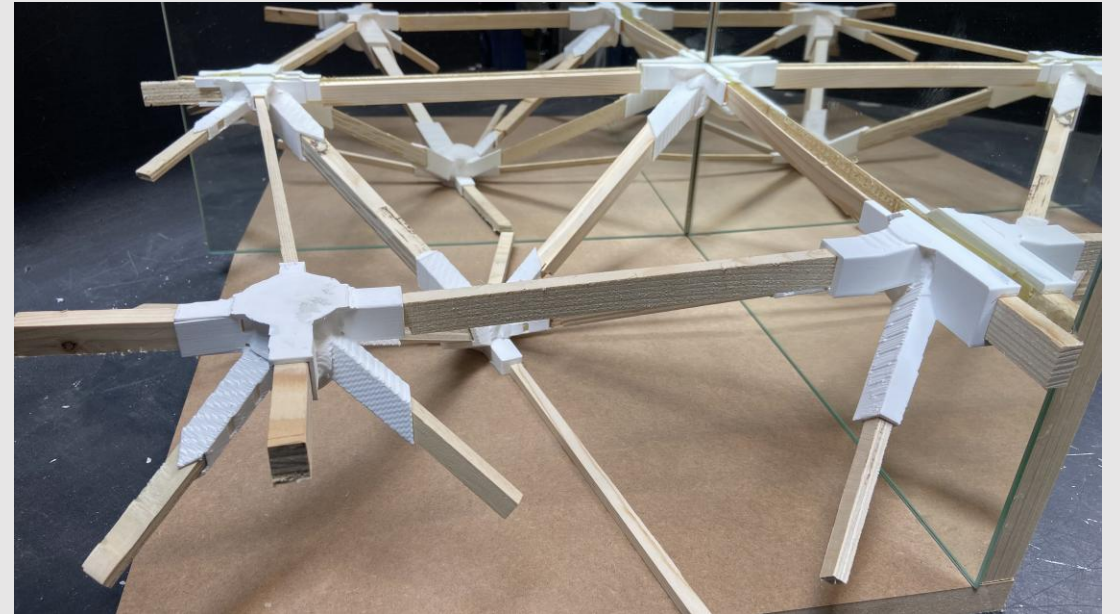
- Only energy goes into the created stream
- If the energy is CO2 neutral, so is the product



<https://encrypted-tbn3.gstatic.com/images?q=tbn:AND9GcQt2tP1CjfXCJEtVc9YcuILBk0FTOljrHCGuvfJaijU0Fzj5wXi>

Reflection

- Easy to compare strategies in a early design stage
- Results might change in the future with new materials and different energy sources



Thank you

