

The modular post-earthquake shell

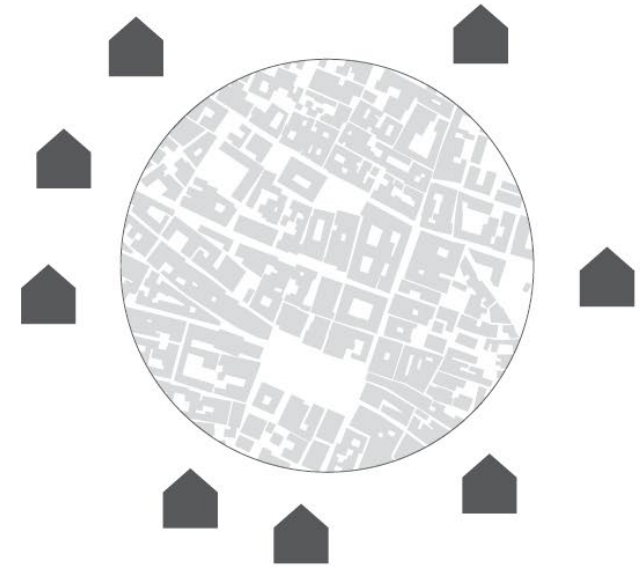
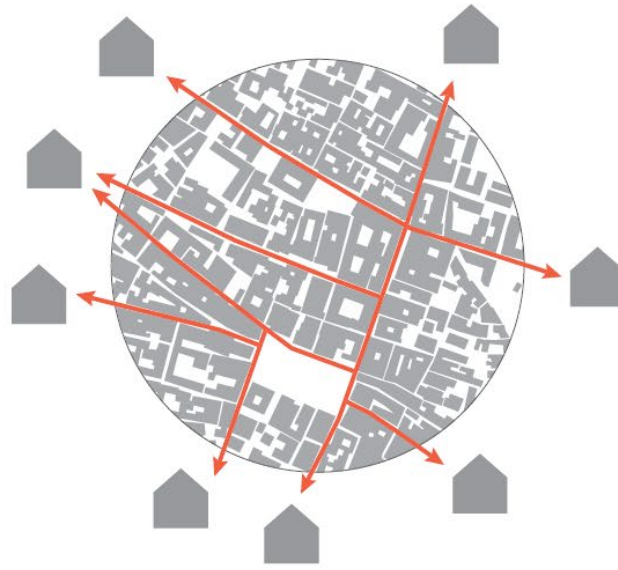
A multi-objective parametric structural design approach

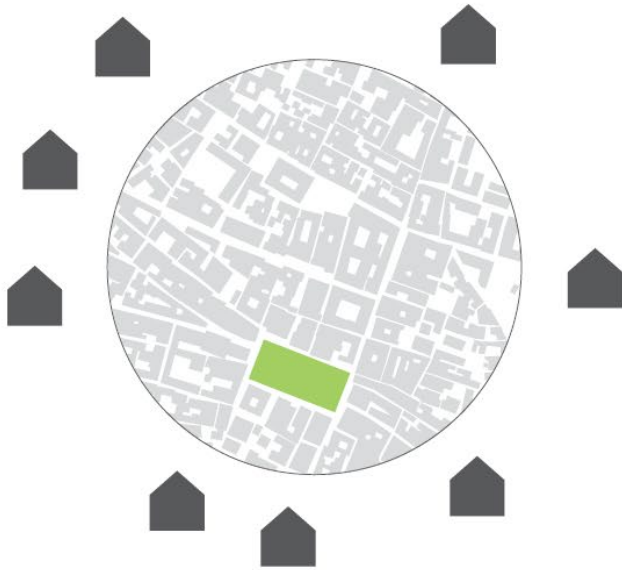
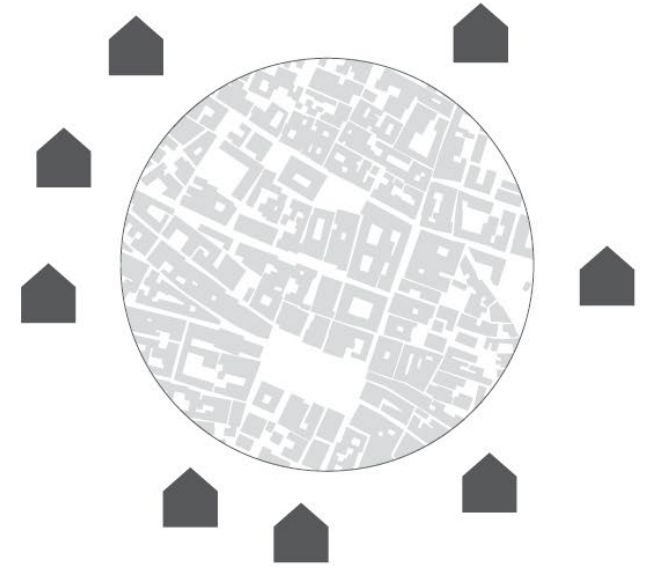
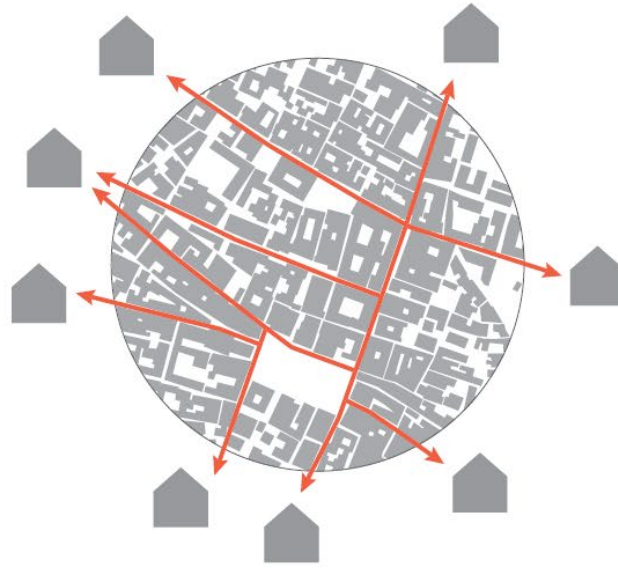
Joanne Jimmink

INTRODUCTION

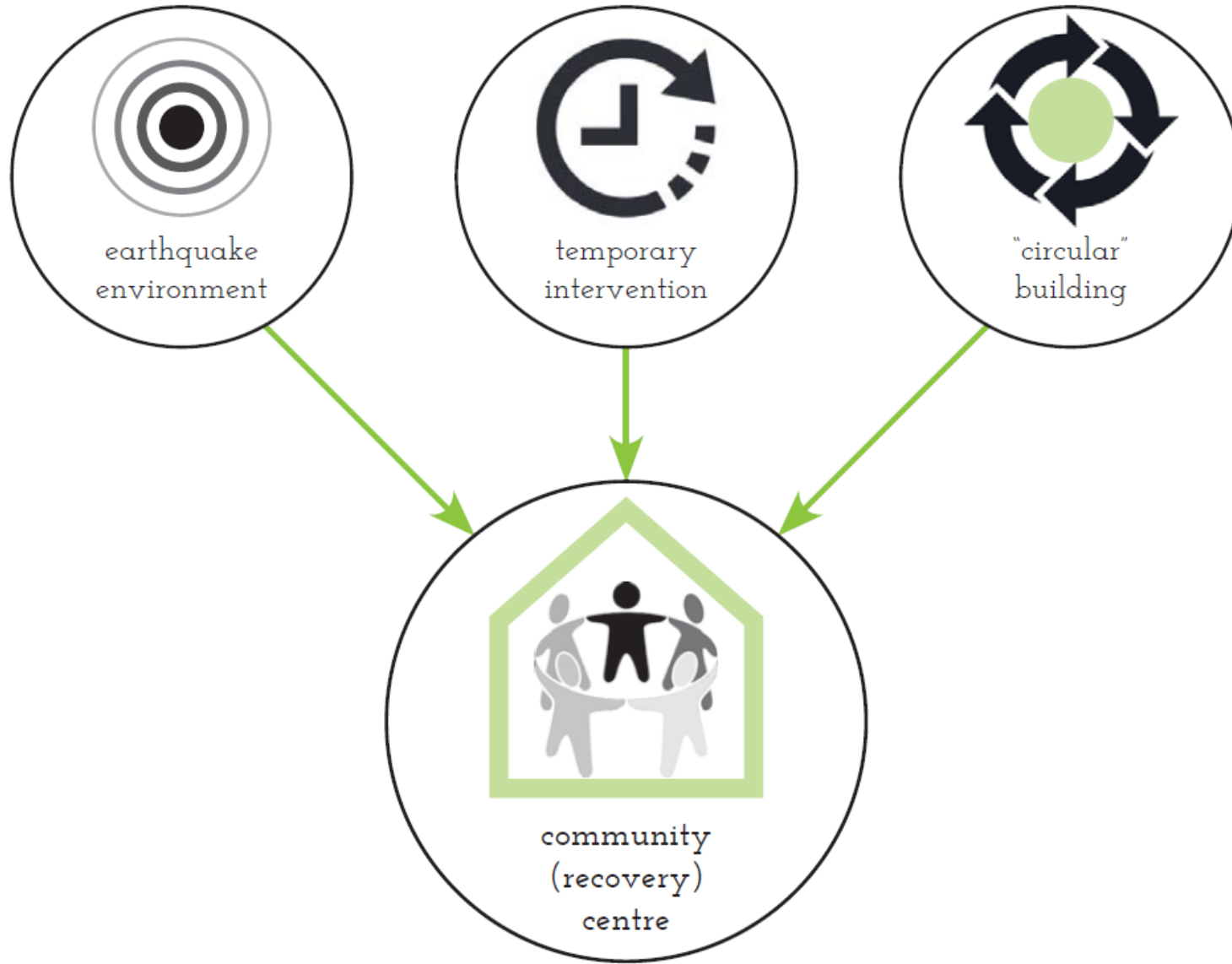




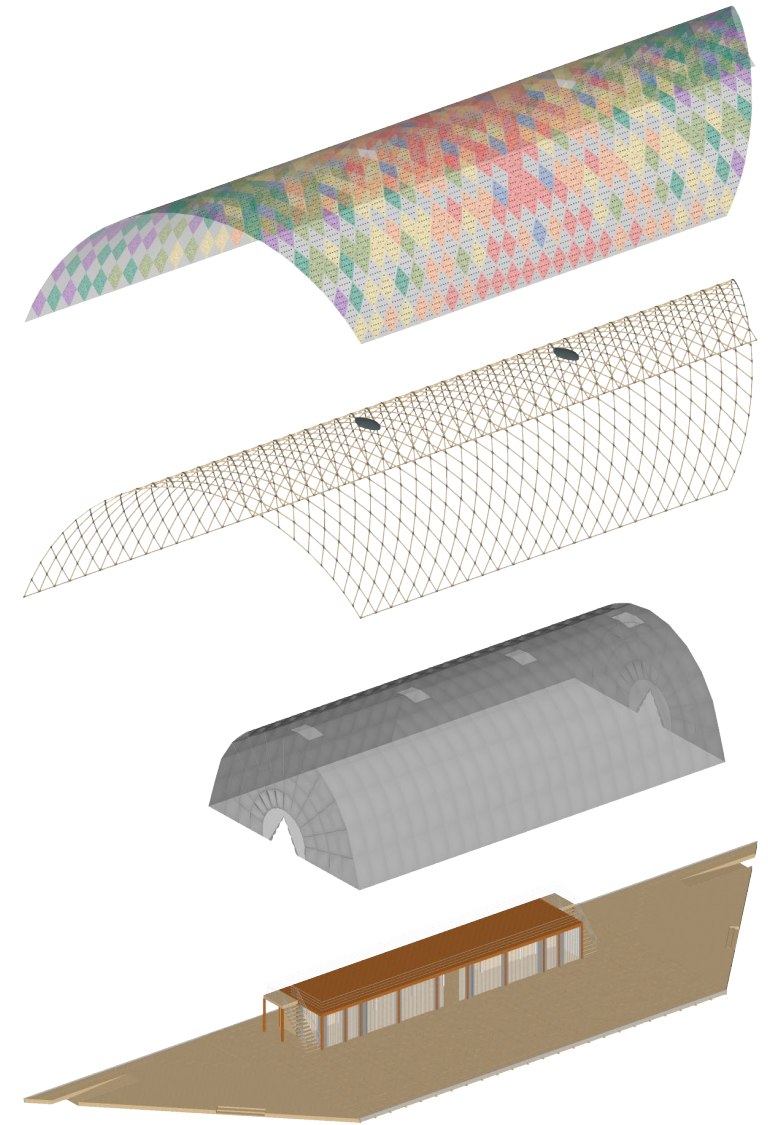
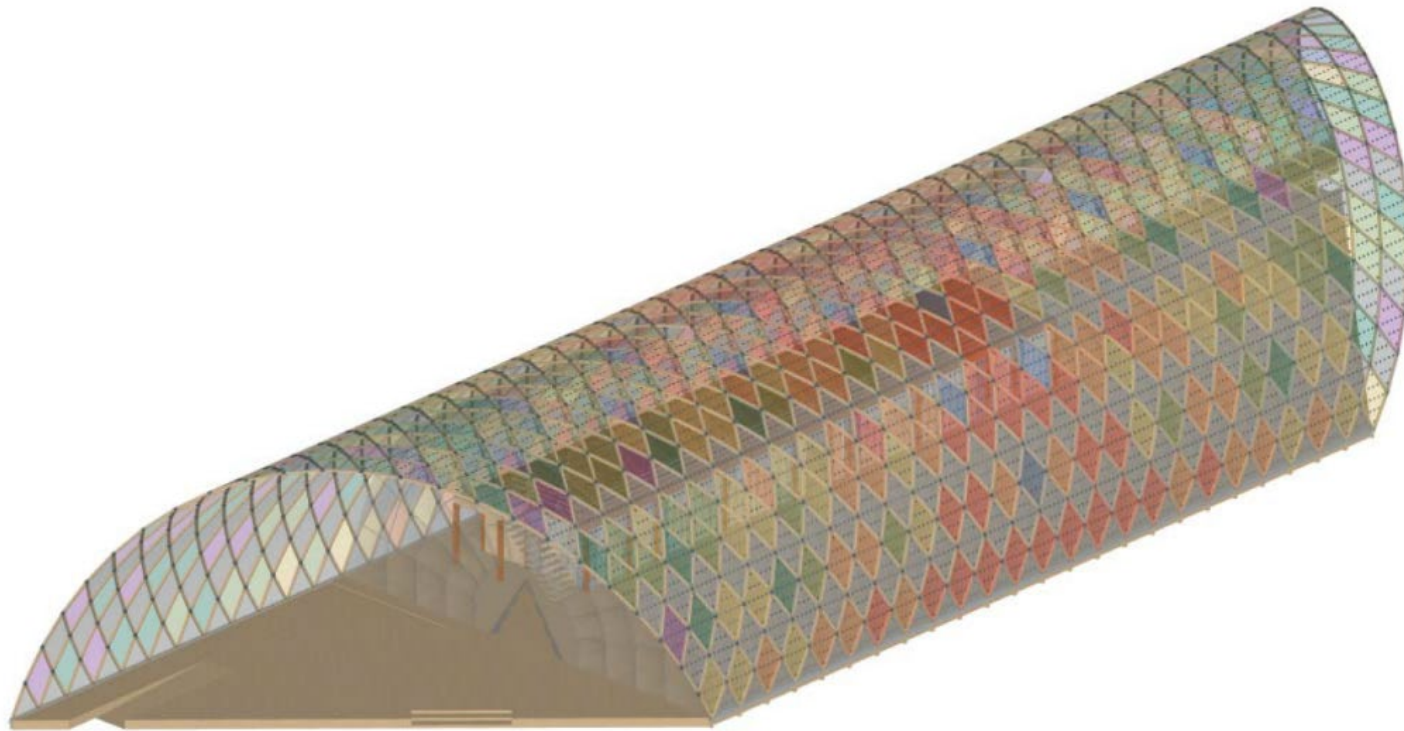


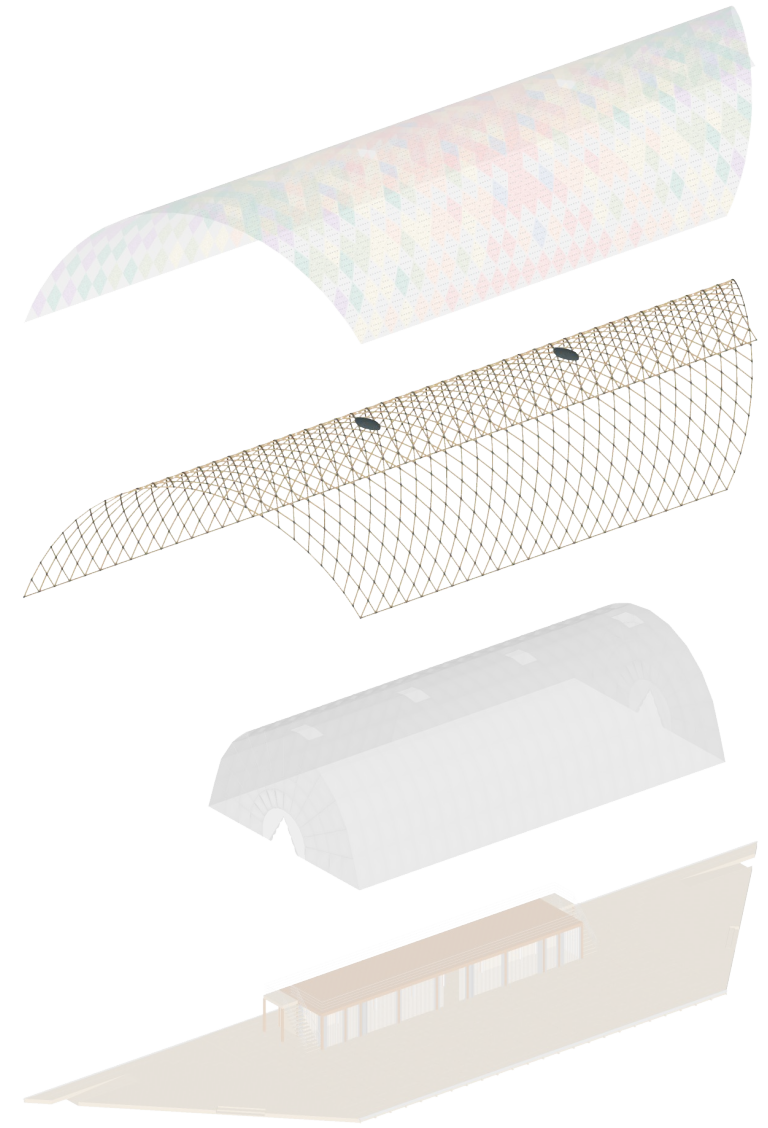
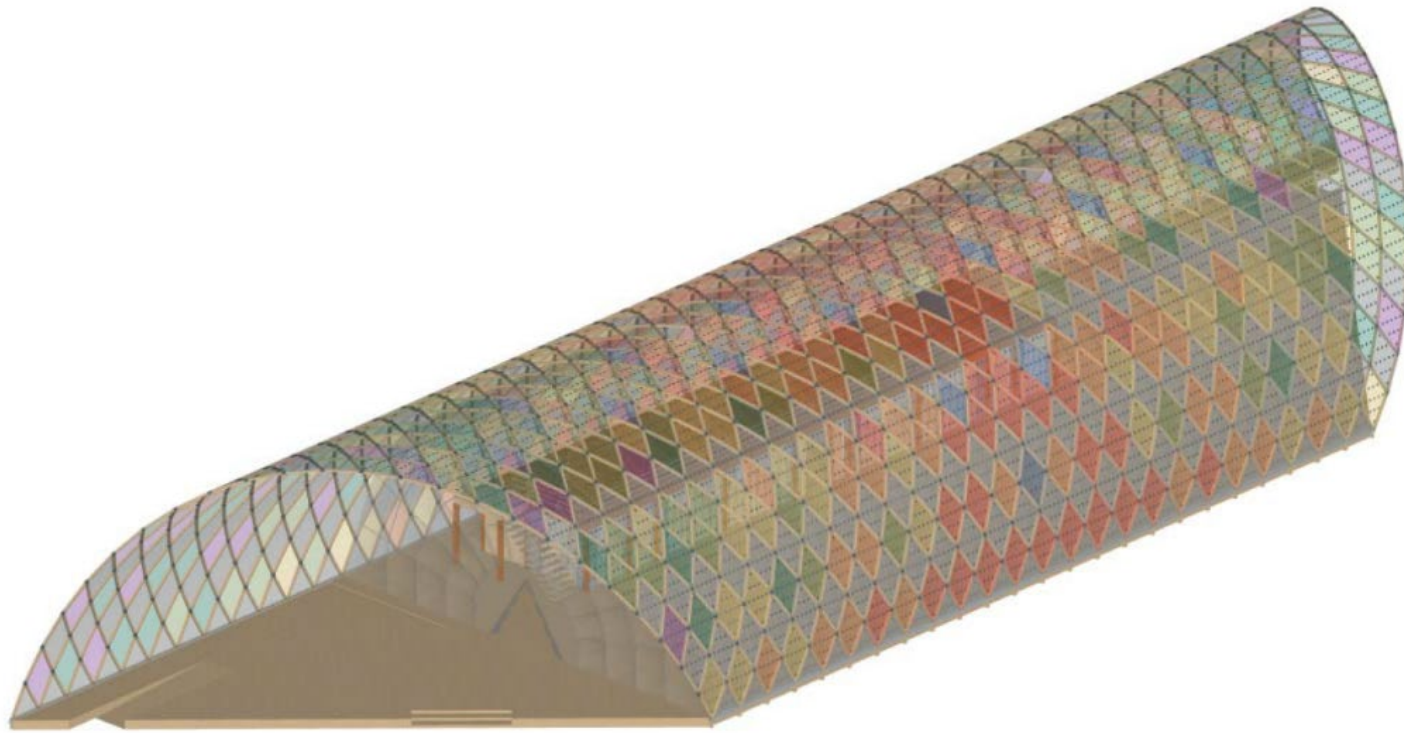


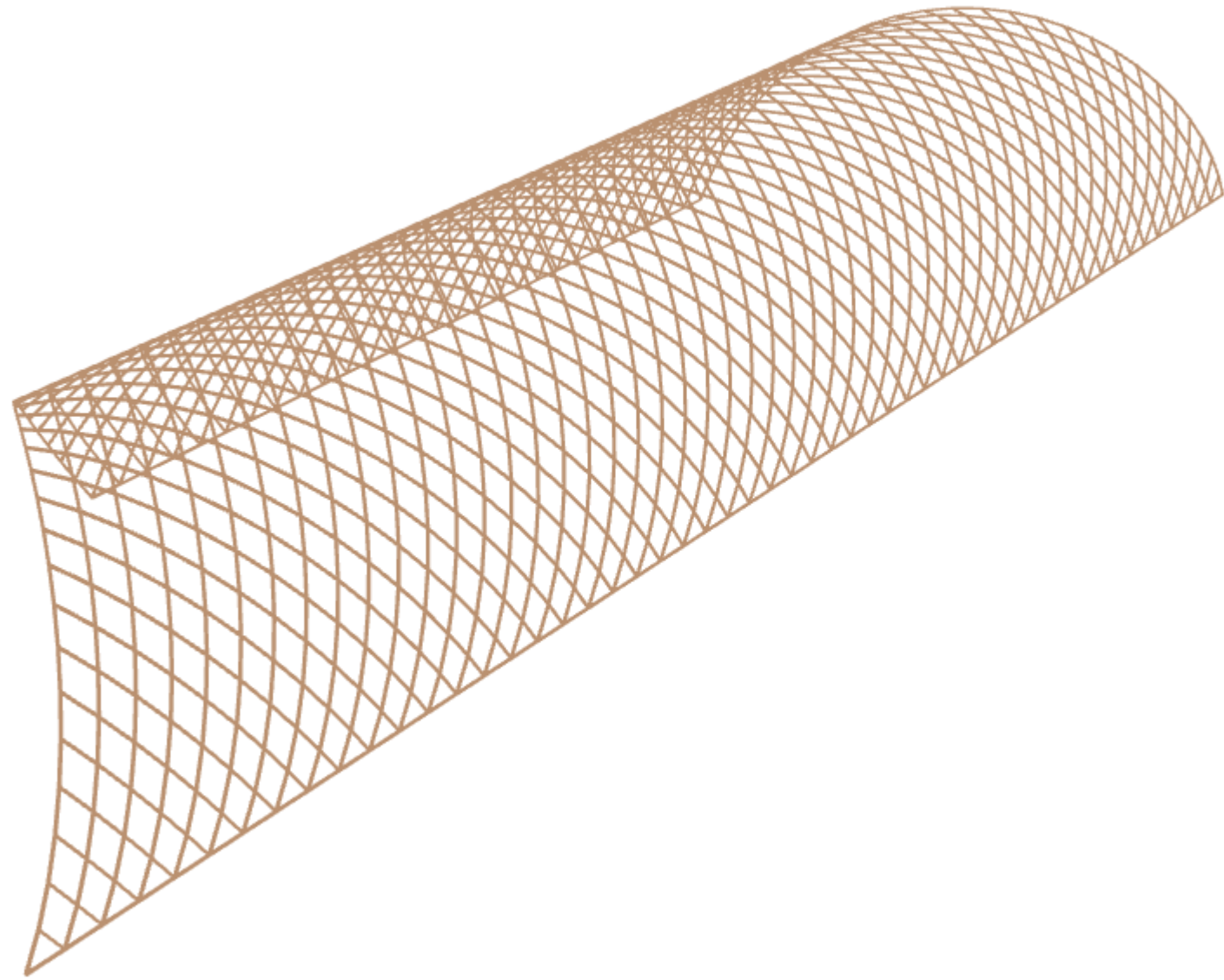


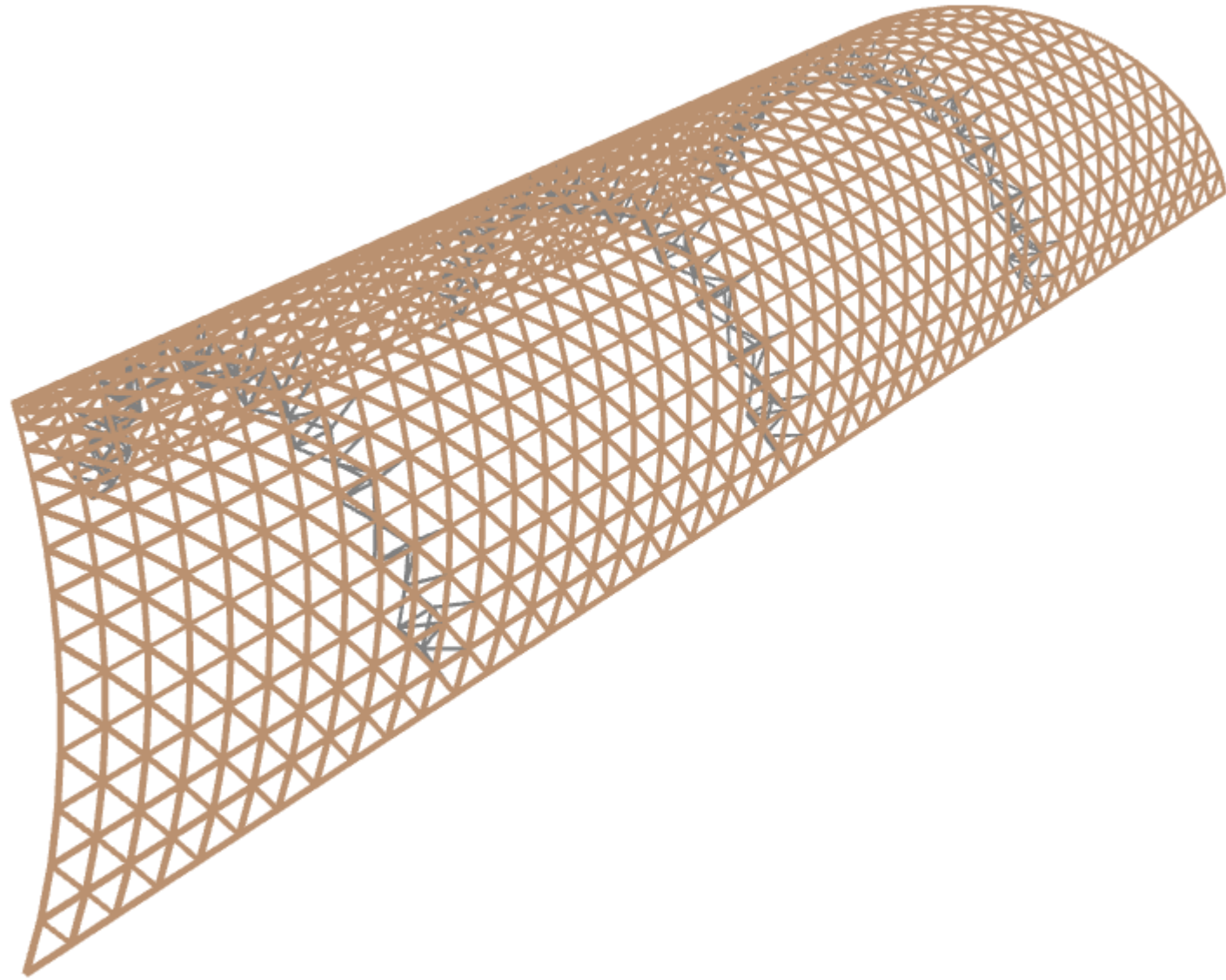












PROJECT



structural
validity



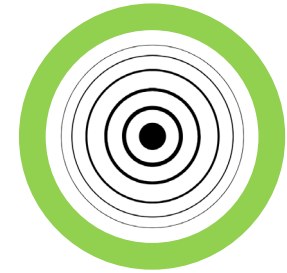
sustainability



aesthetics

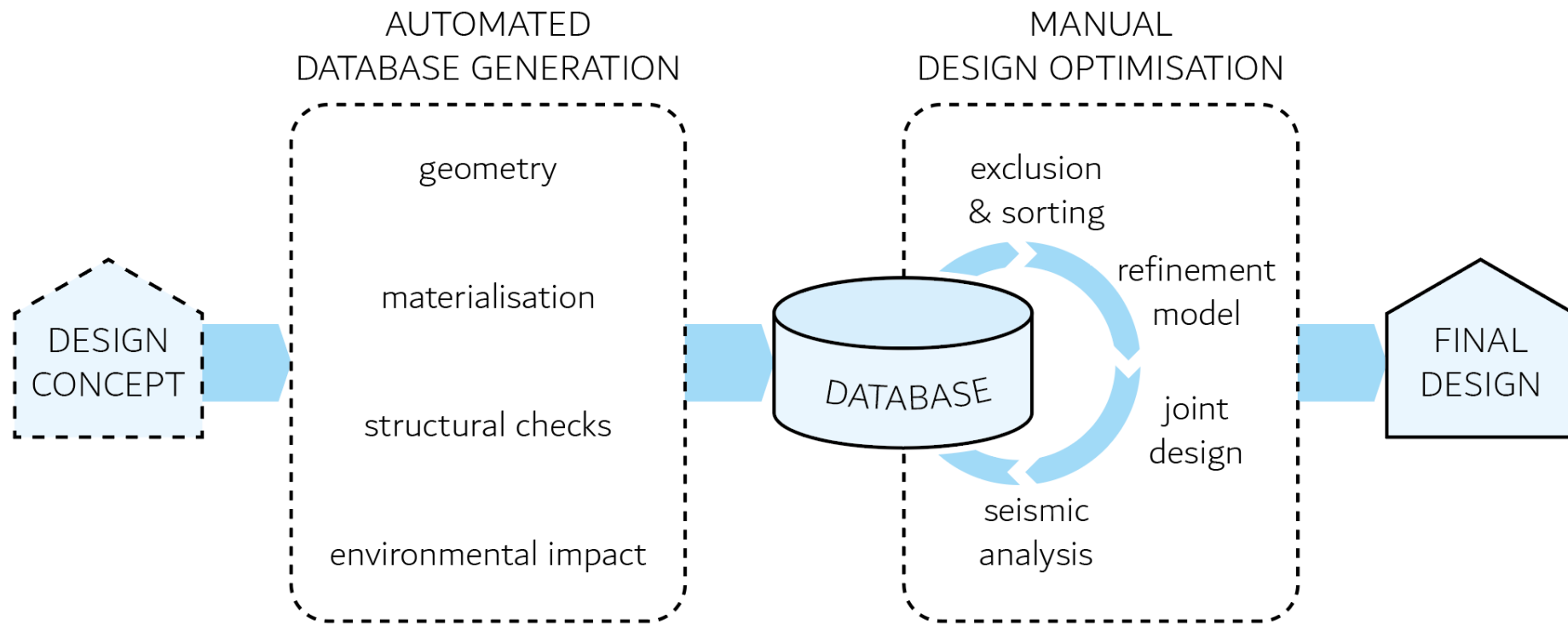


constructability



seismic
resistance







AUTOMATED DATABASE GENERATION

DESIGN CONCEPT

- geometry
- materialisation
- structural checks
- environmental impact

MANUAL DESIGN OPTIMISATION

DATABASE

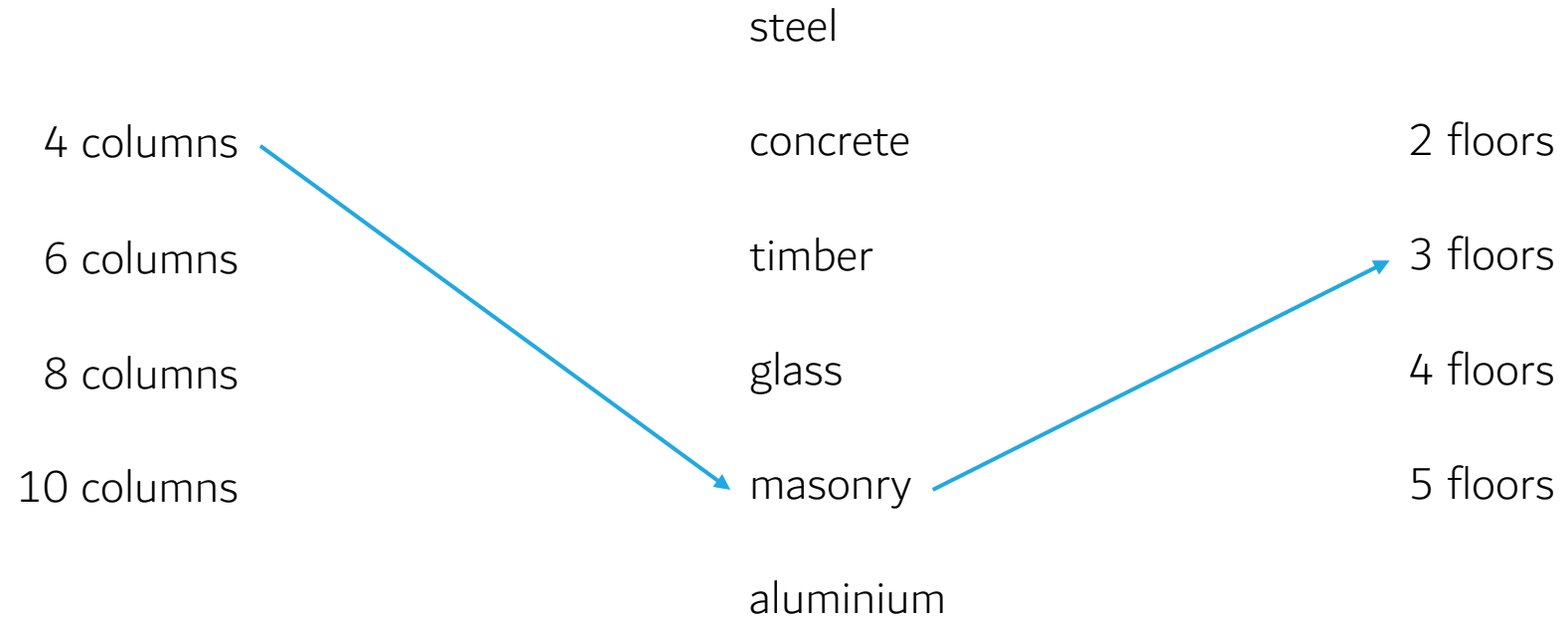
- exclusion & sorting
- refinement model
- joint design
- seismic analysis

FINAL DESIGN

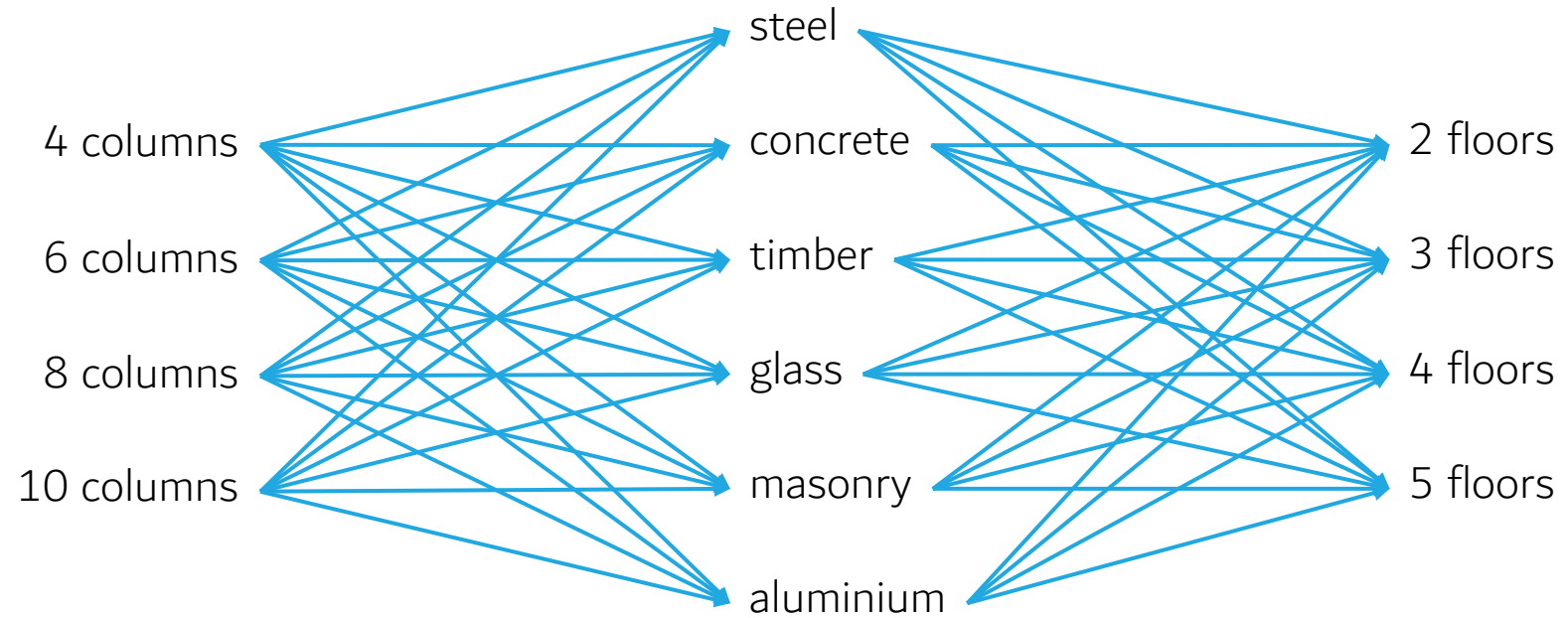
EXAMPLE

| | | |
|------------|-----------|----------|
| | steel | |
| 4 columns | concrete | 2 floors |
| 6 columns | timber | 3 floors |
| 8 columns | glass | 4 floors |
| 10 columns | masonry | 5 floors |
| | aluminium | |

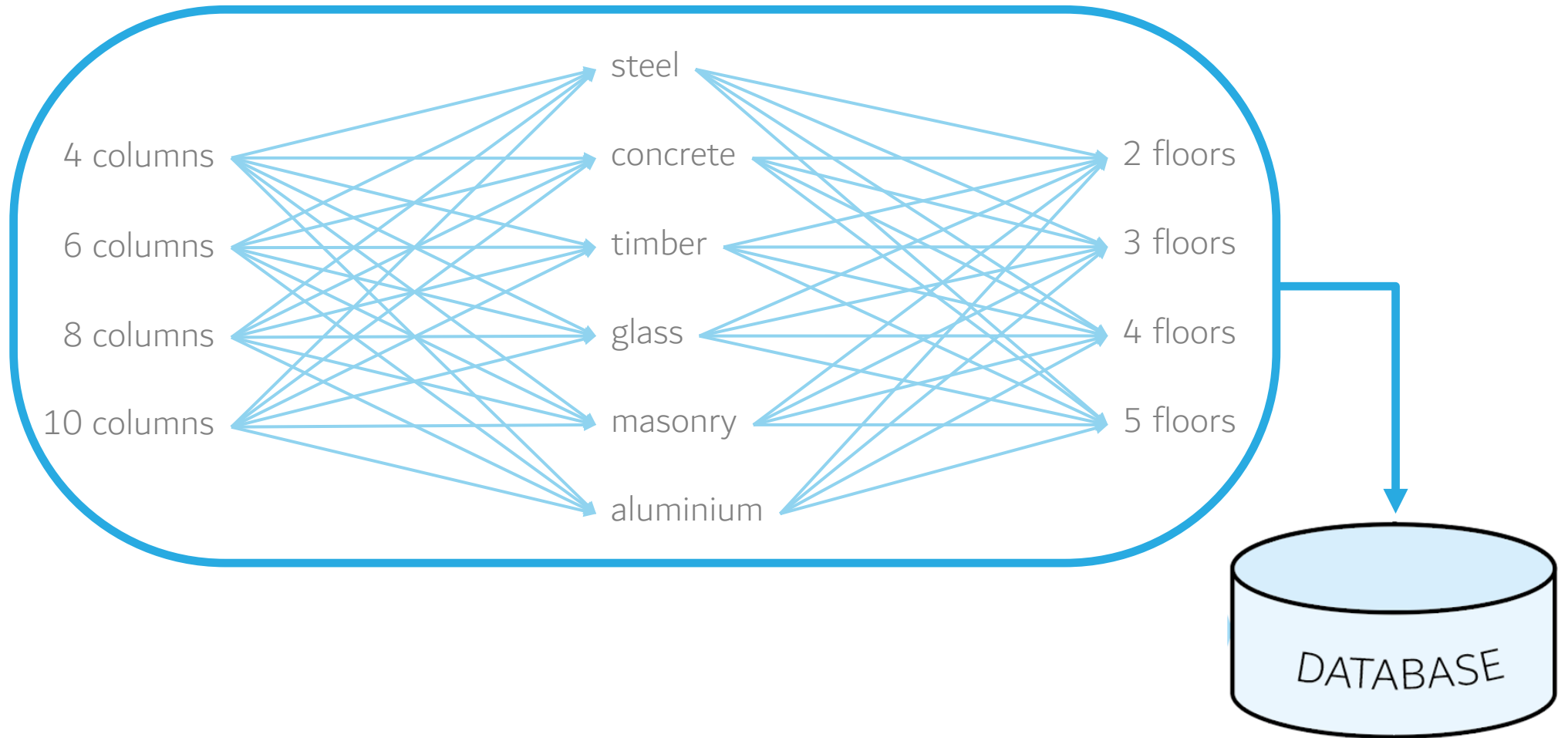
MANUAL MODELLING

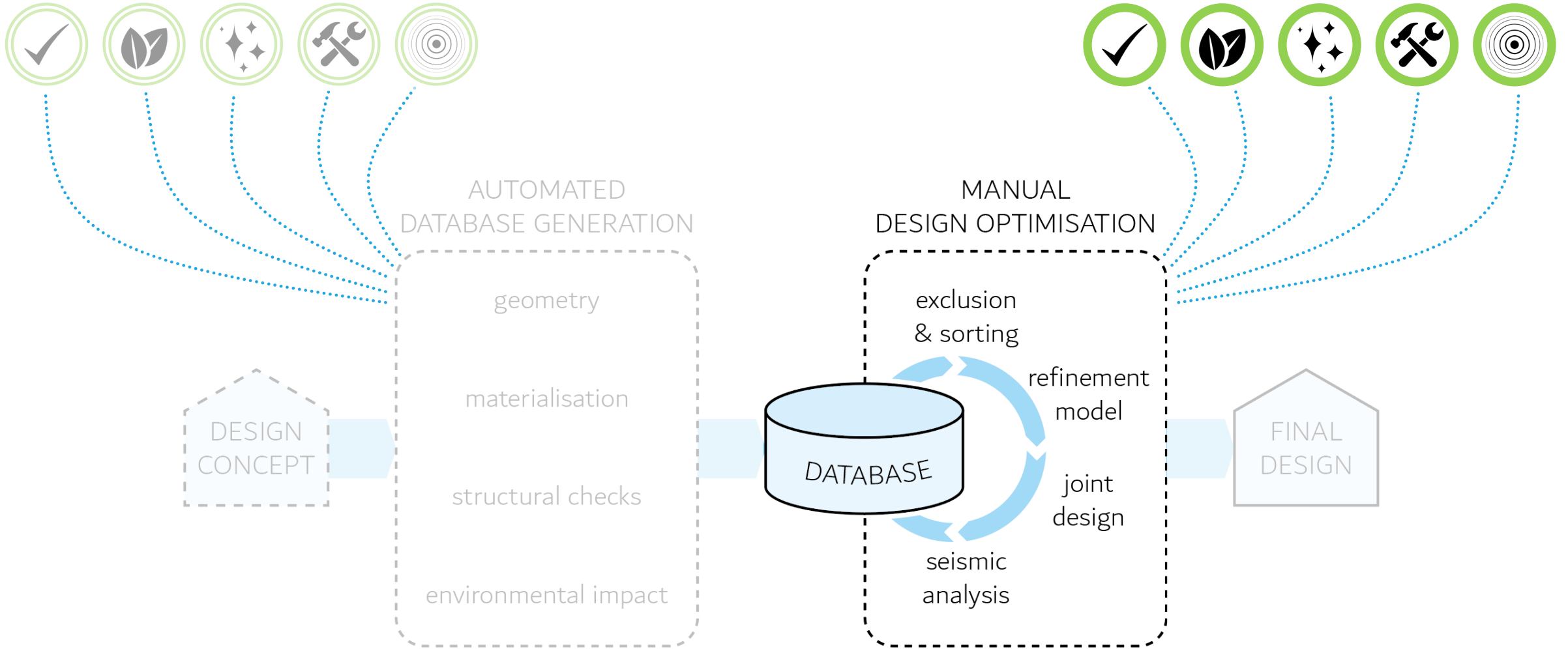


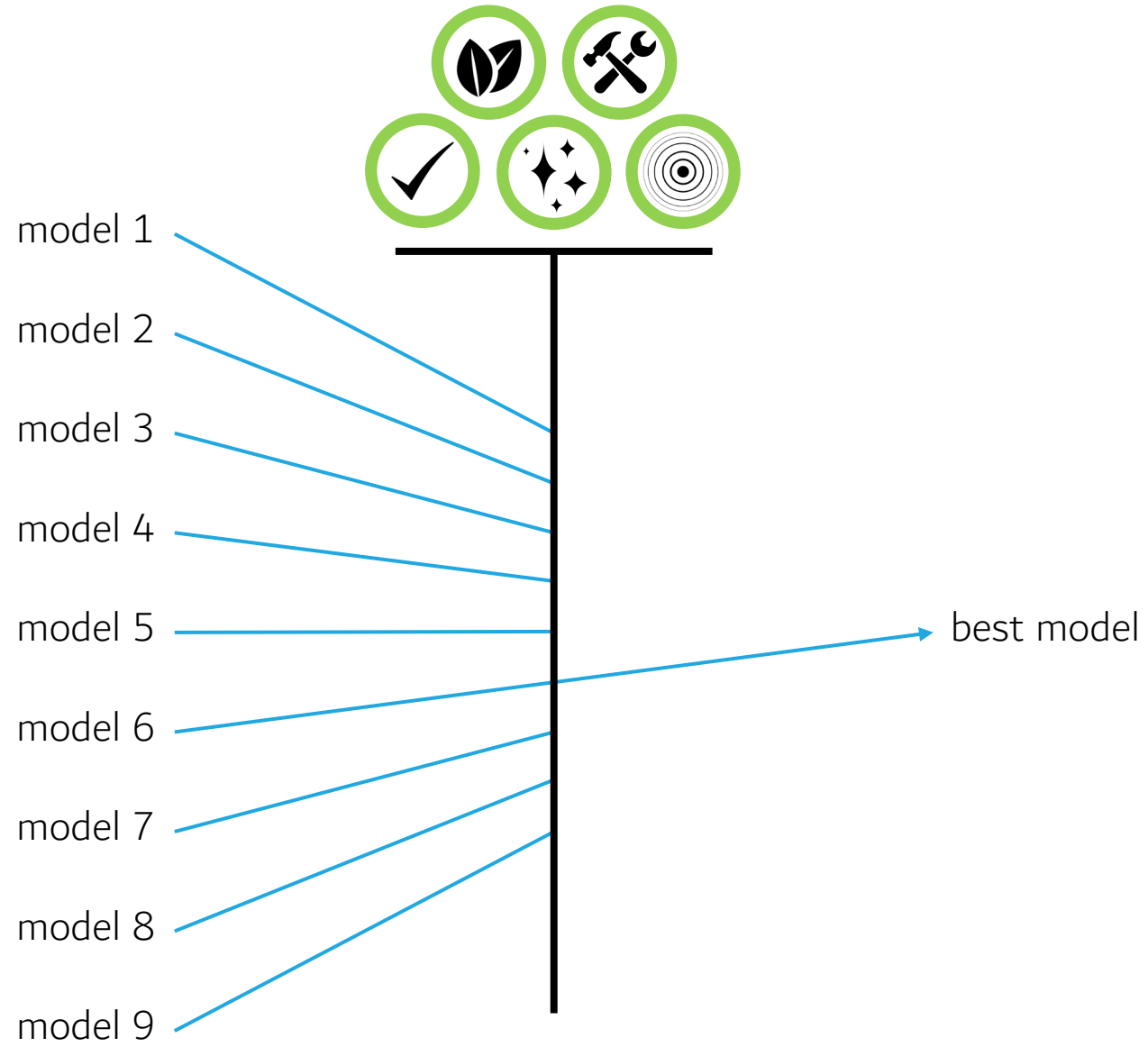
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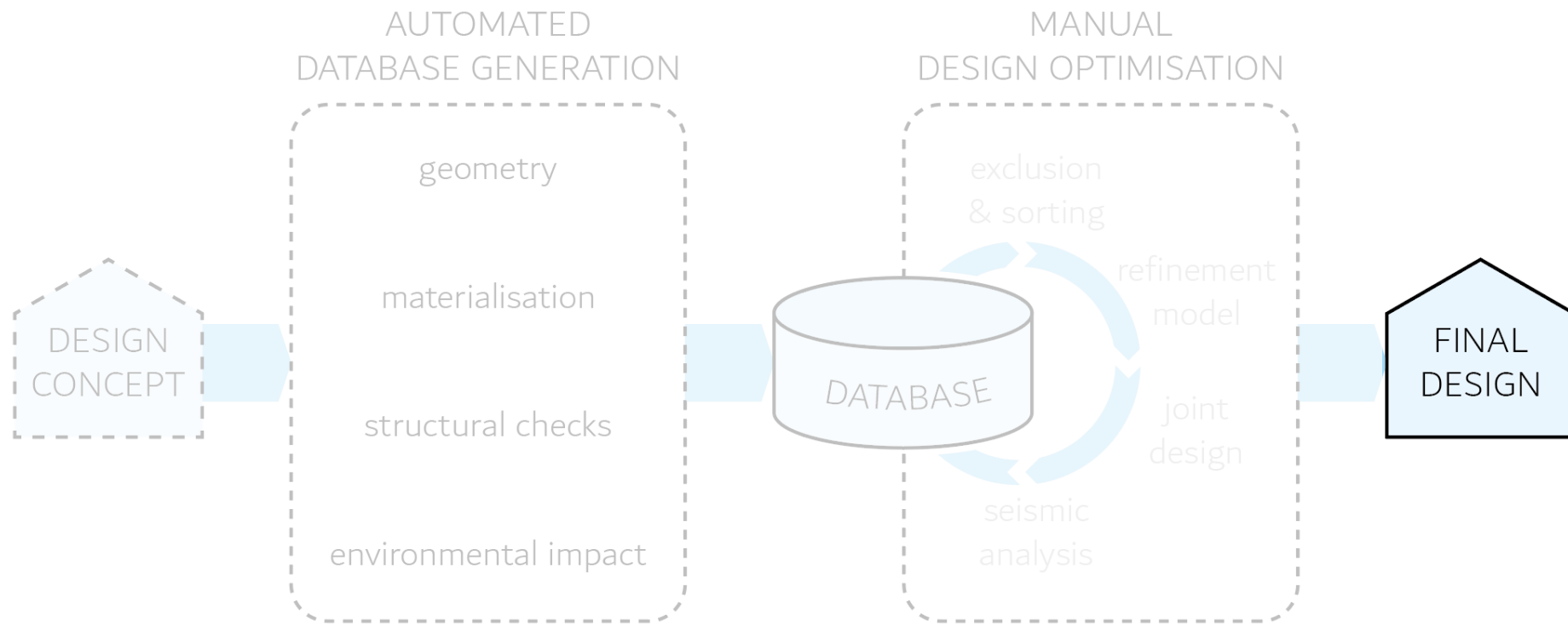


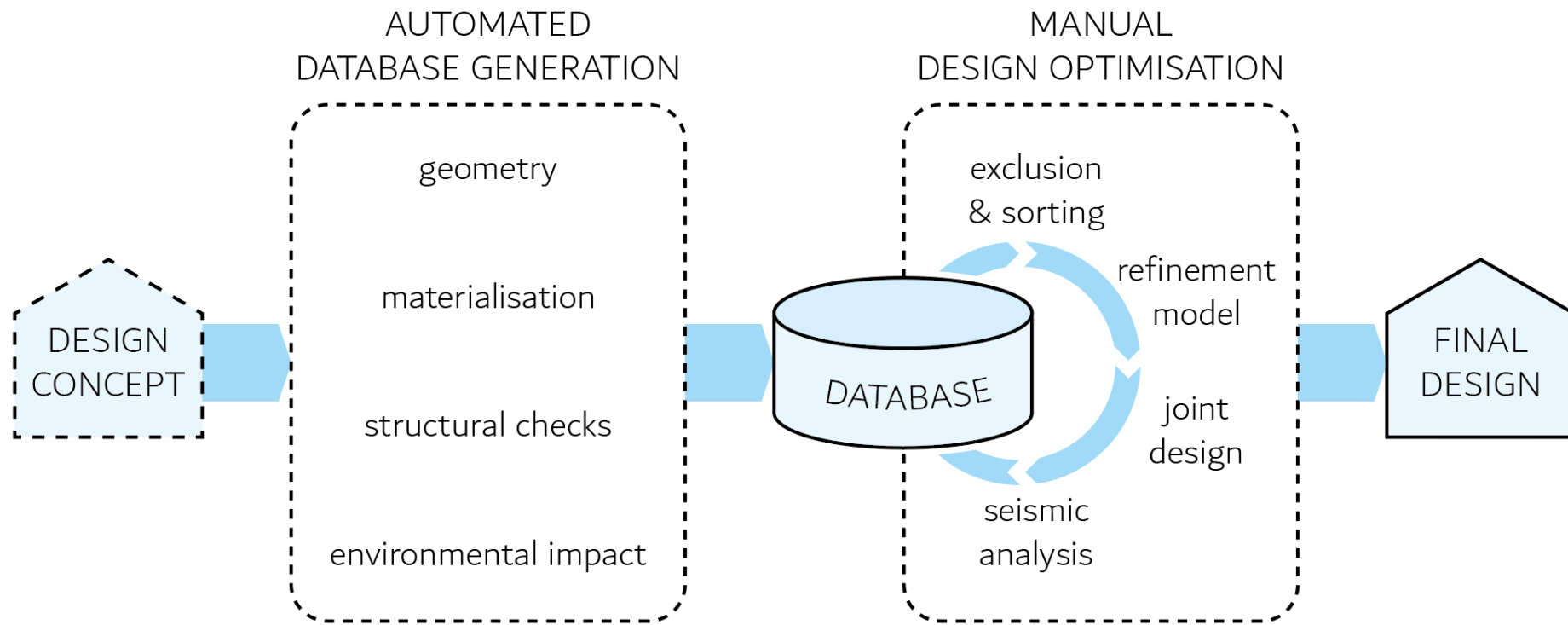
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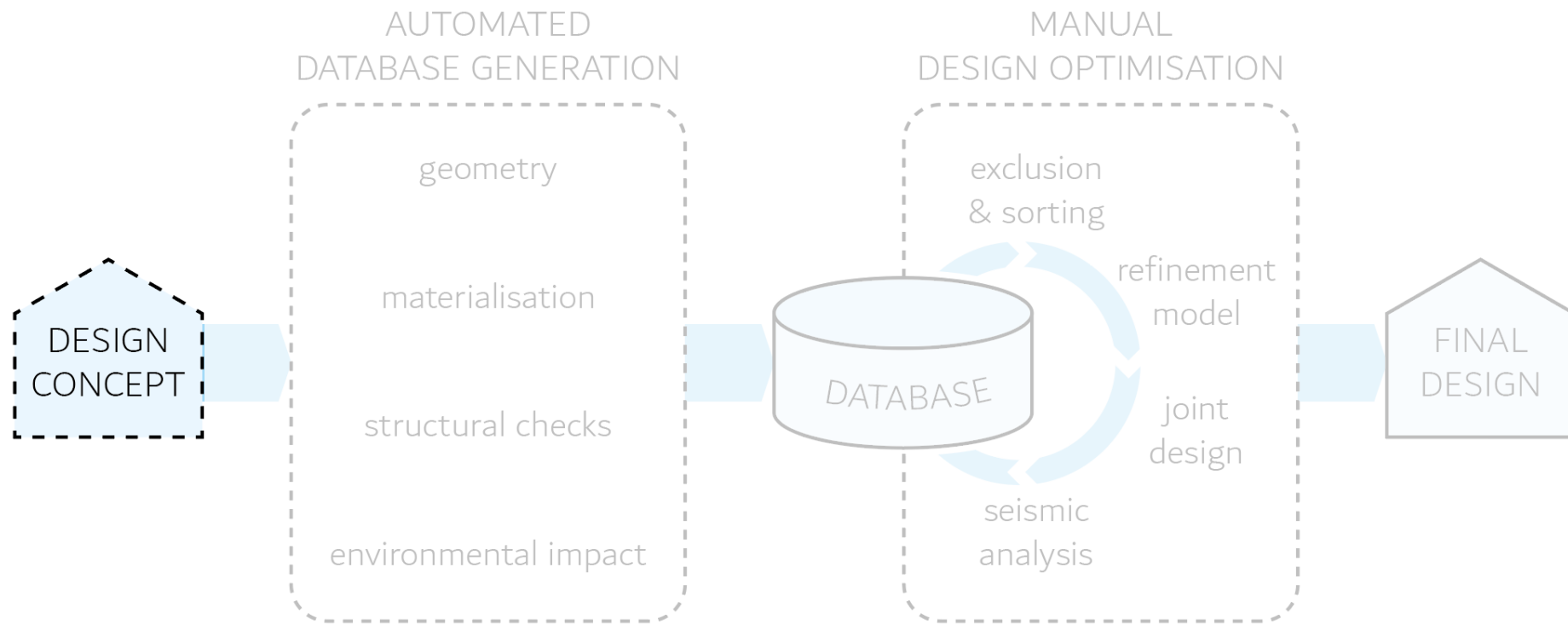


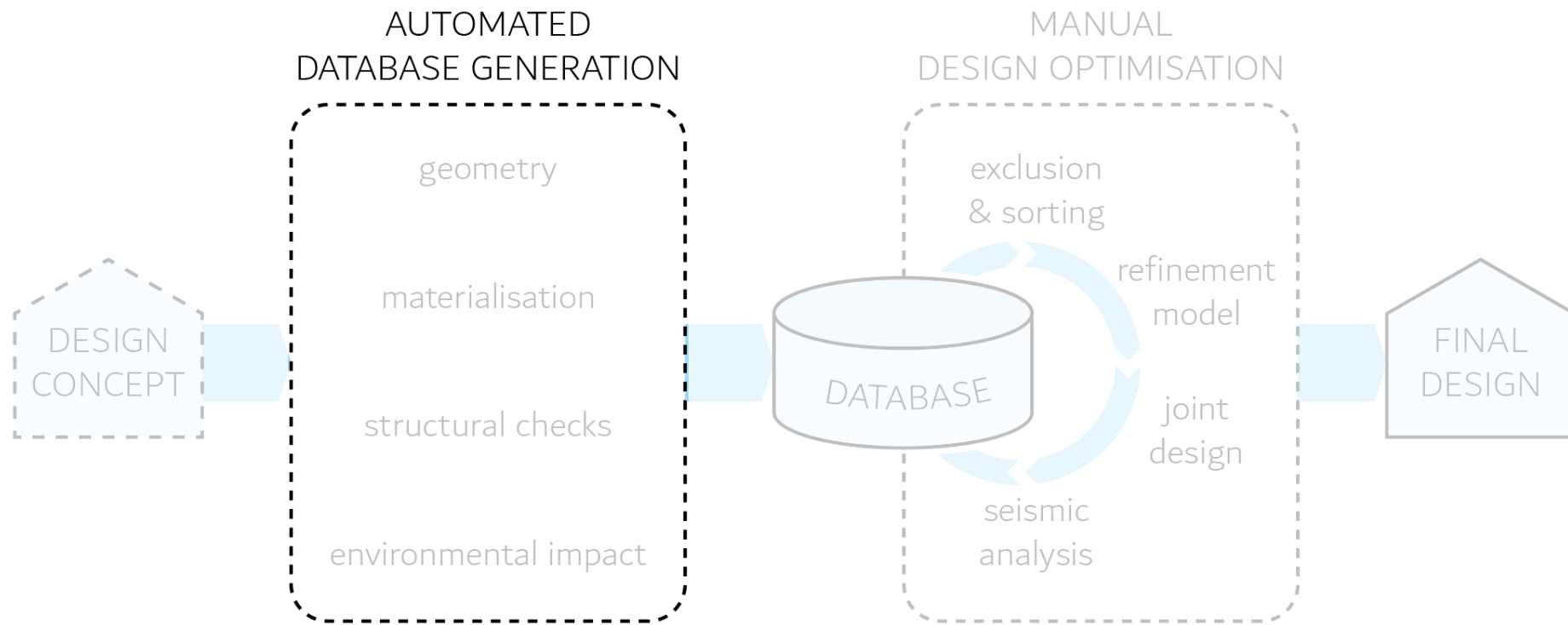


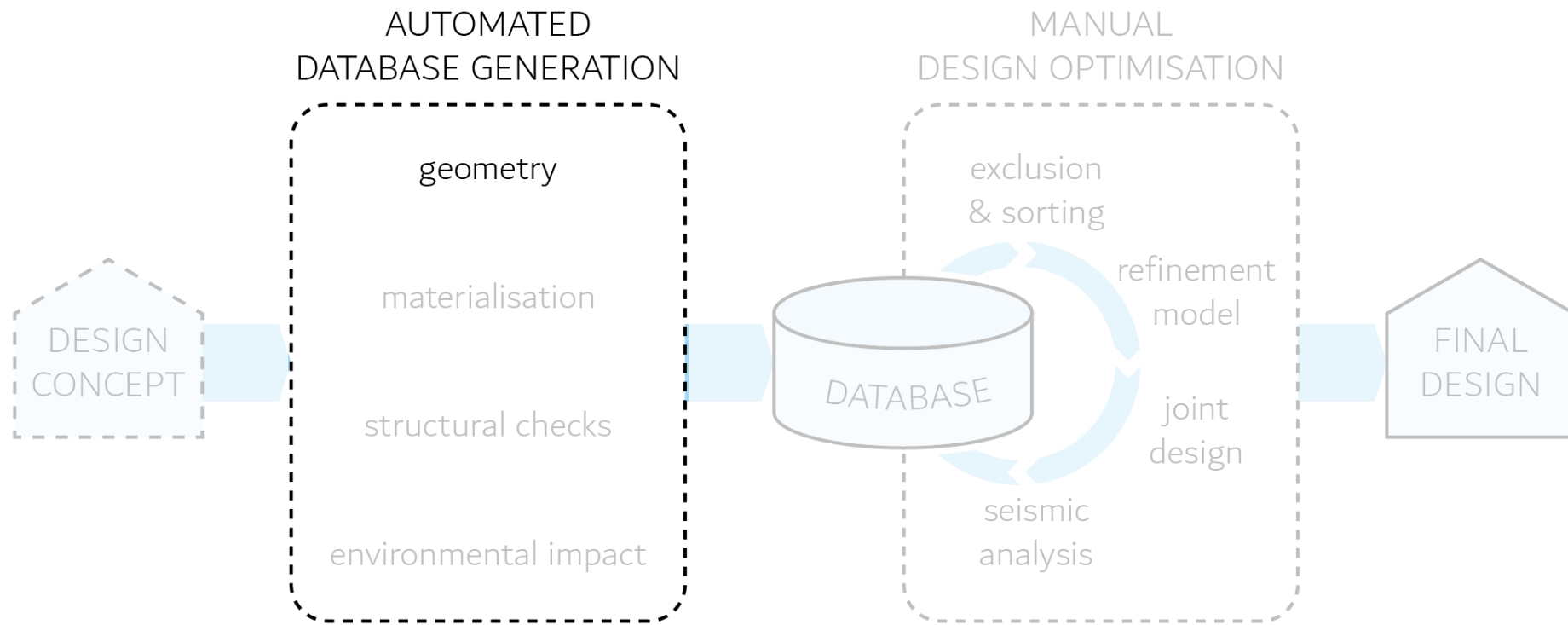






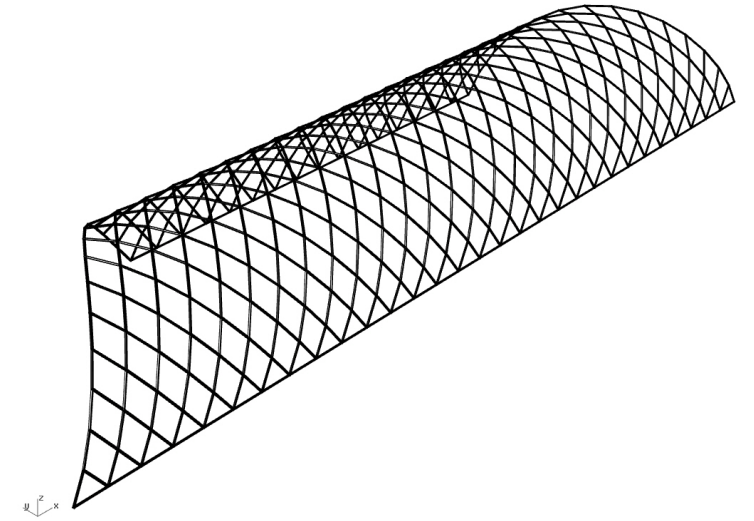
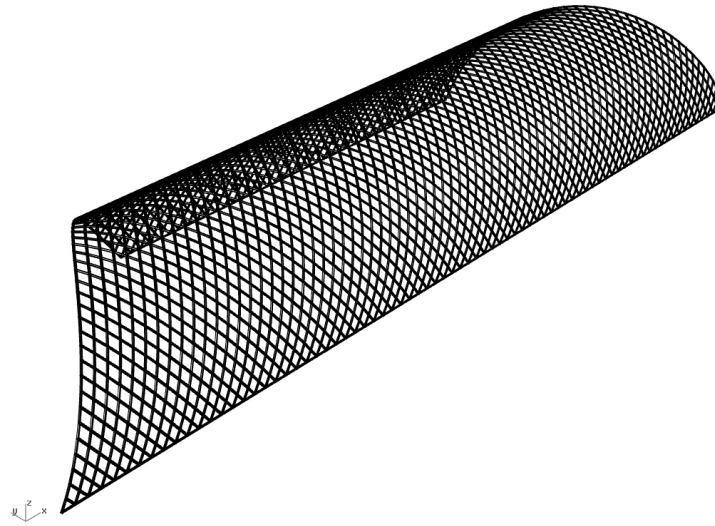






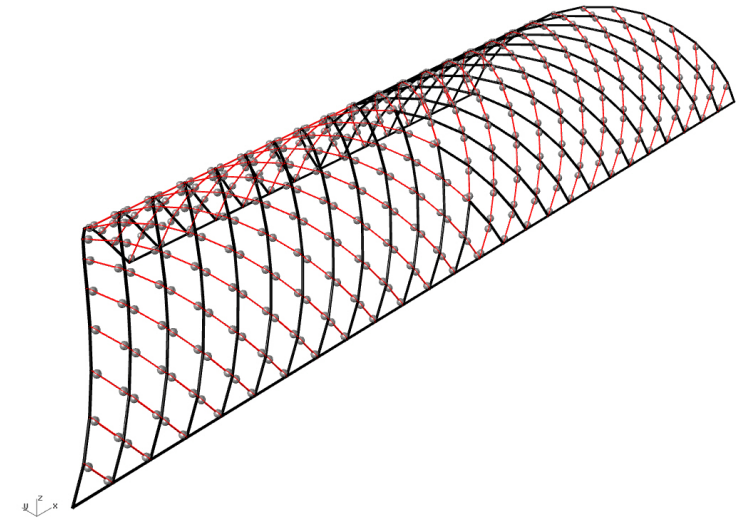
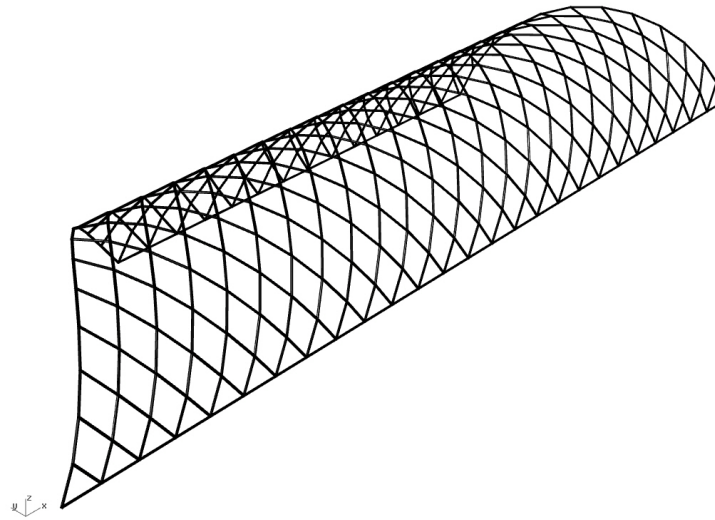
GRID SIZE

7x



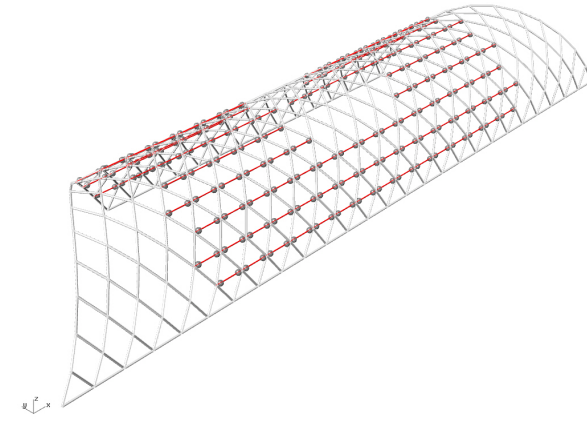
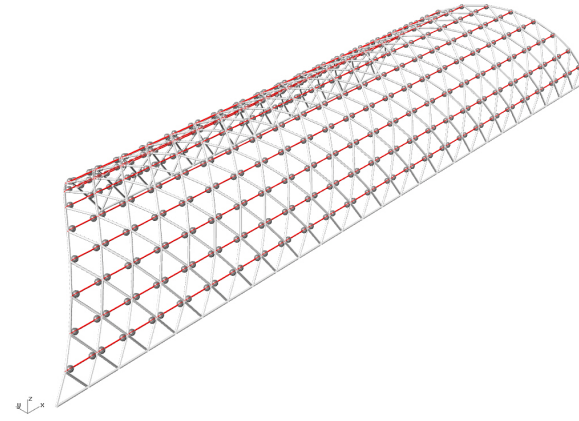
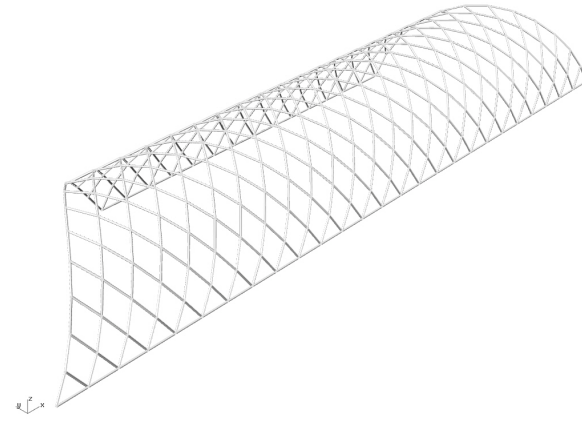
CONNECTIONS

2x



IN-PLANE

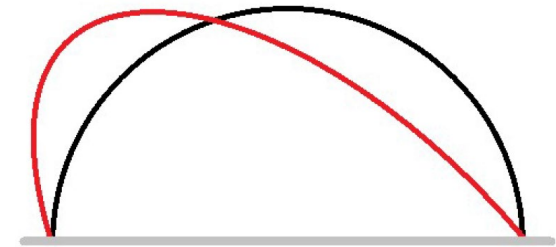
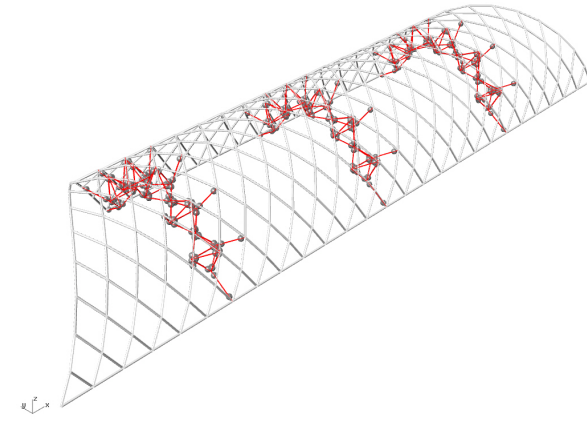
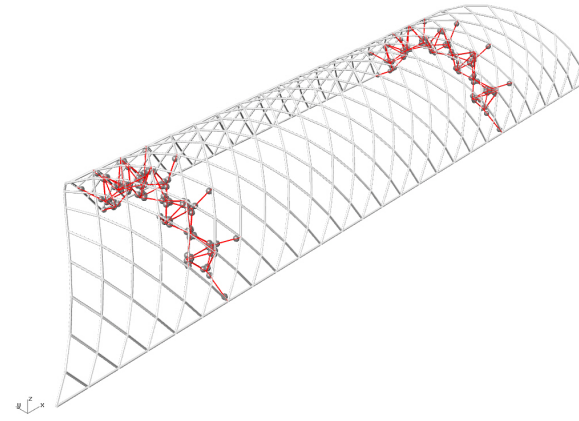
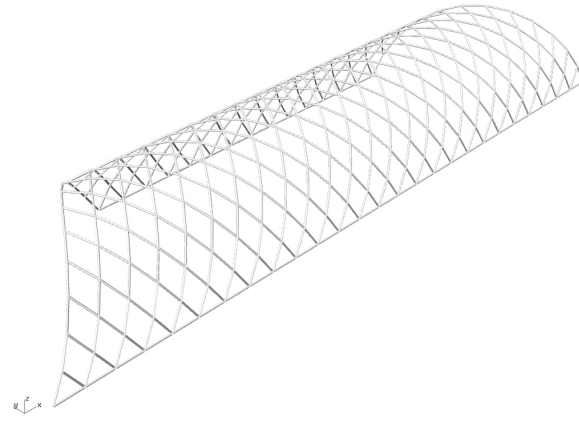
3x



GEOMETRY

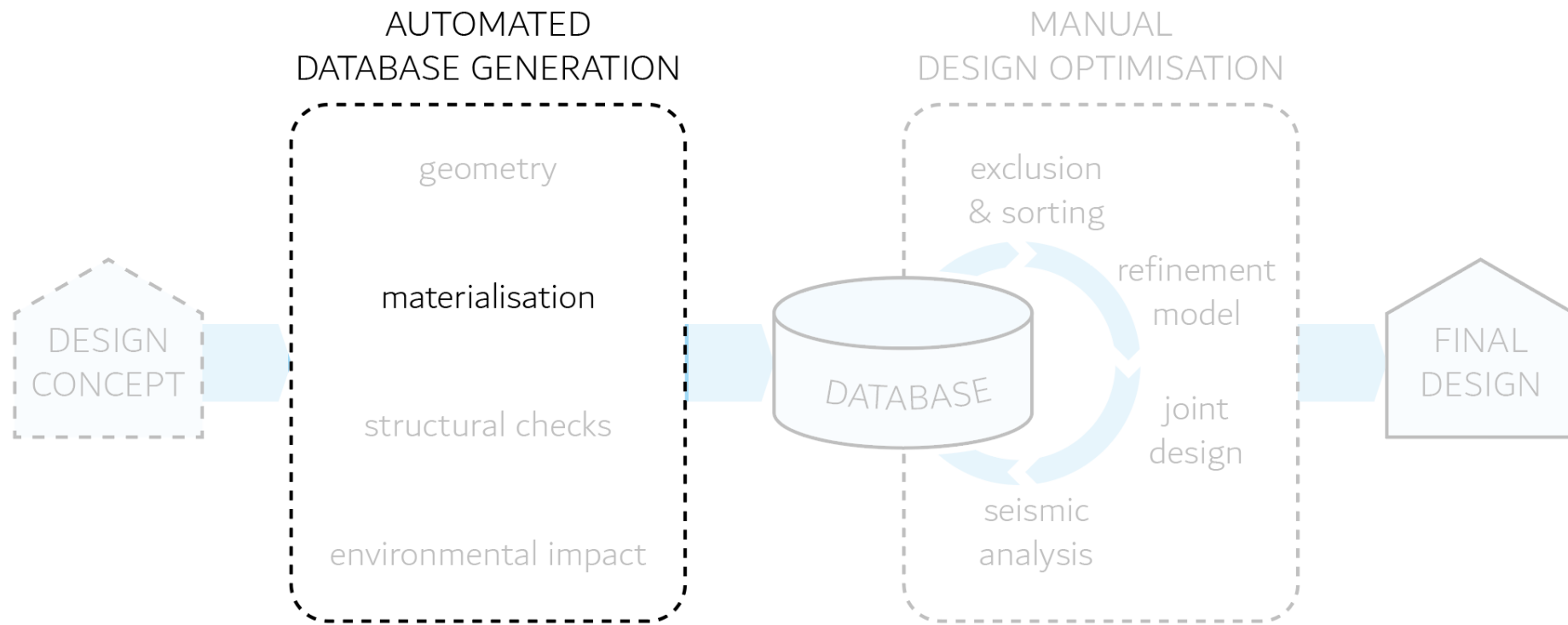
OUT-OF-PLANE

3x



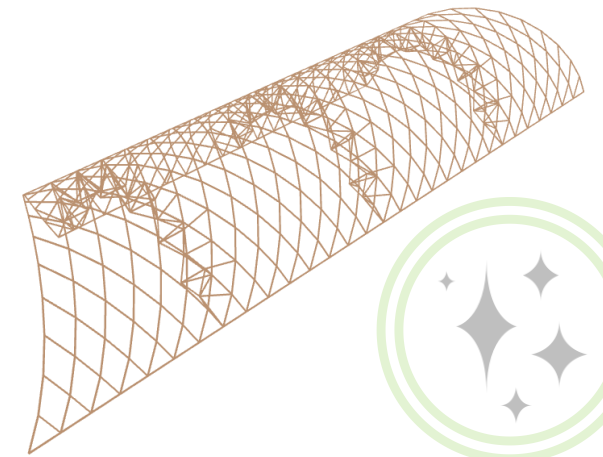
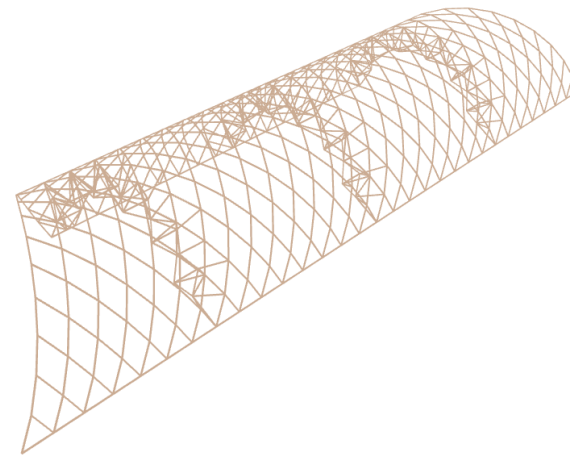
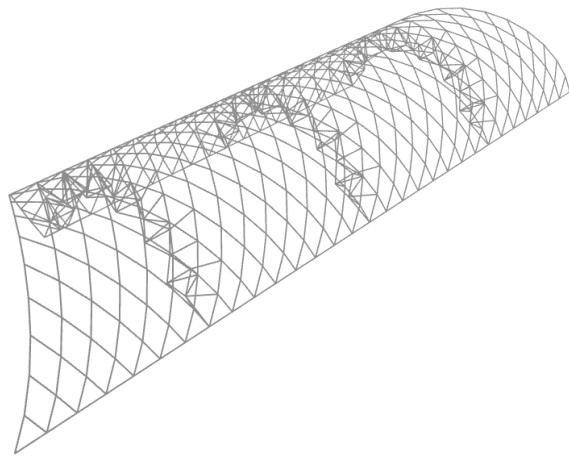
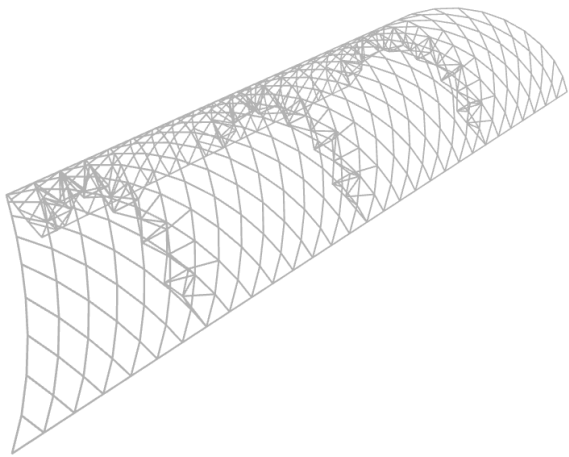
126 variations





ELEMENTS

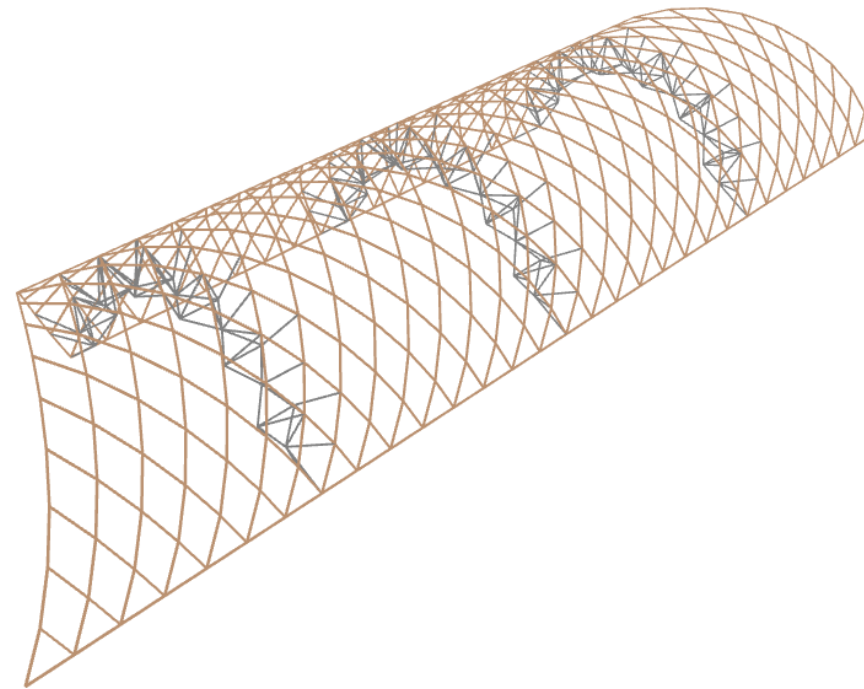
| | | |
|--------|----------------------------|-------------|
| STEEL | Lower strength | $I7 \times$ |
| | Higher strength | $2I \times$ |
| TIMBER | Lower strength (local) | $I6 \times$ |
| | Higher strength (imported) | $I6 \times$ |



STEEL TRUSS

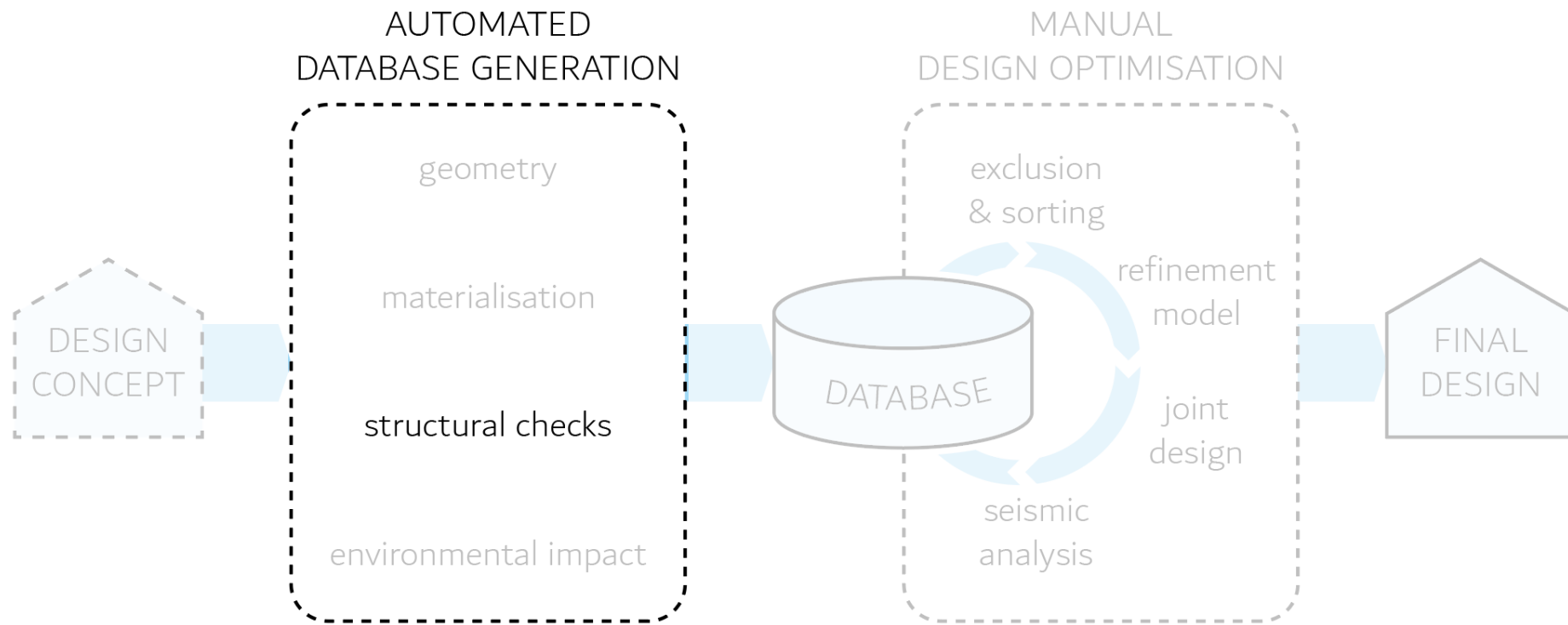
in timber structure

3 ×

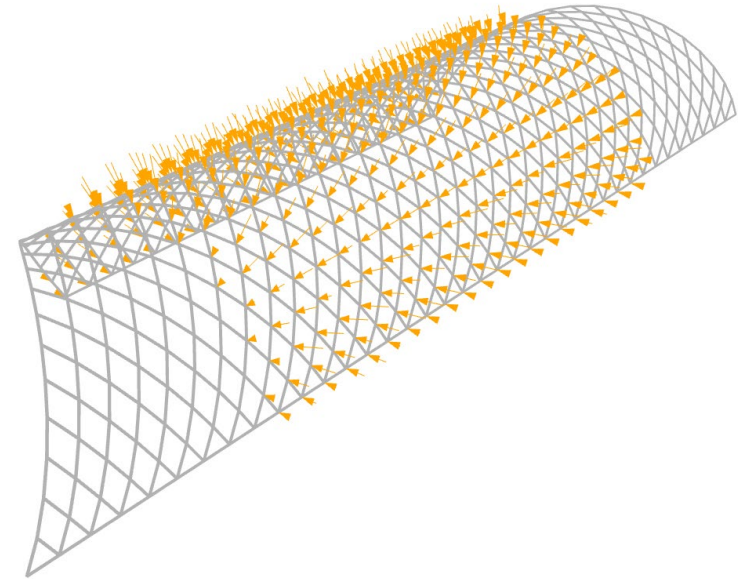
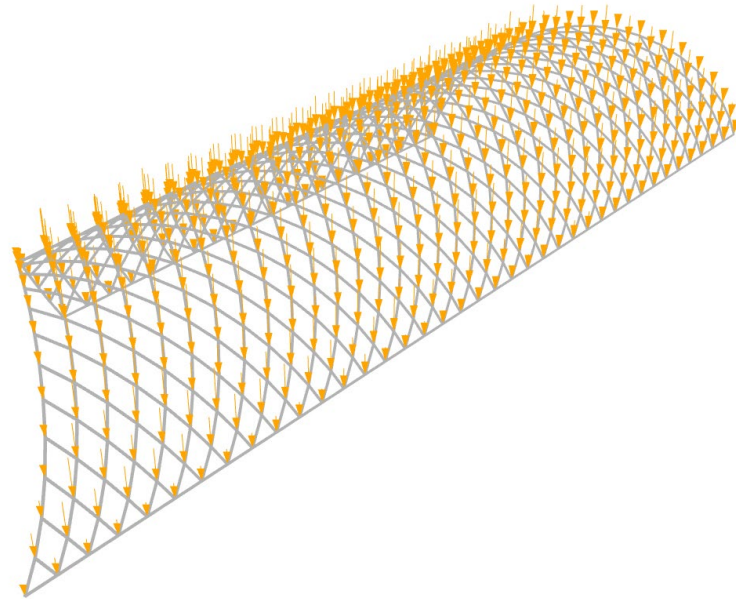


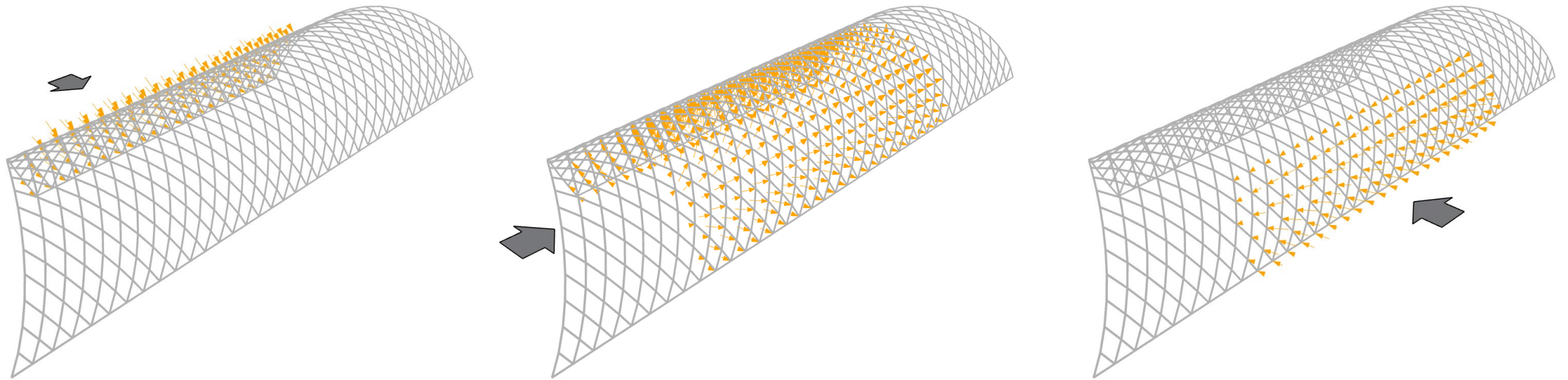
16 884
variations

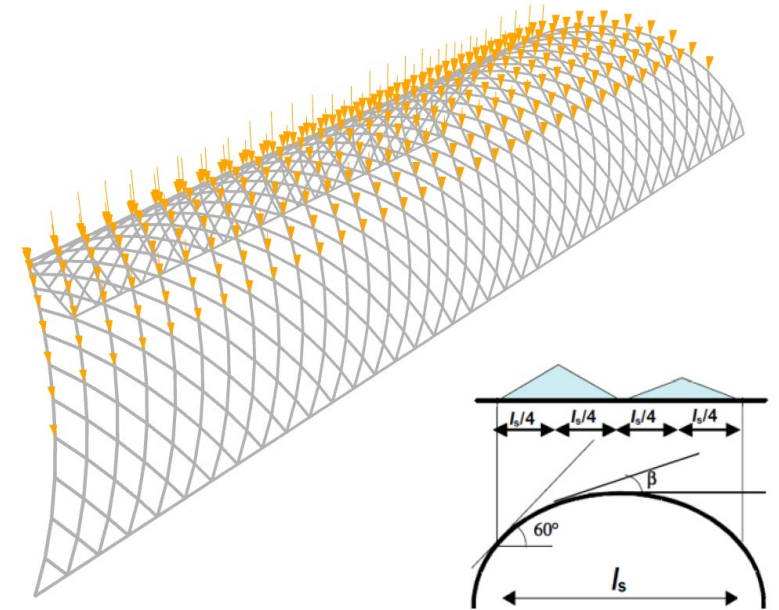
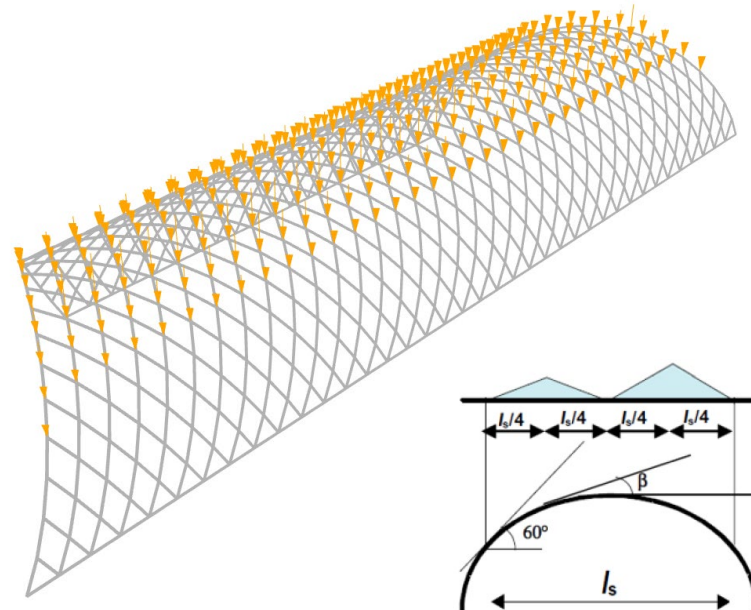
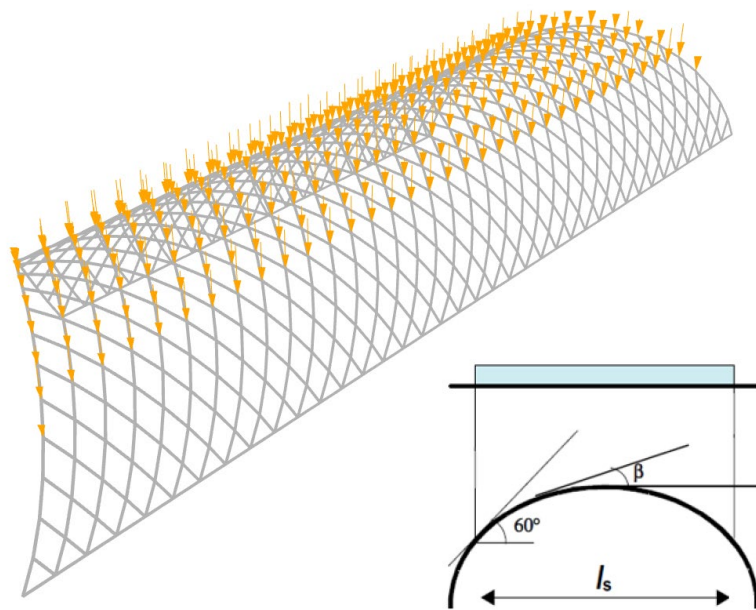


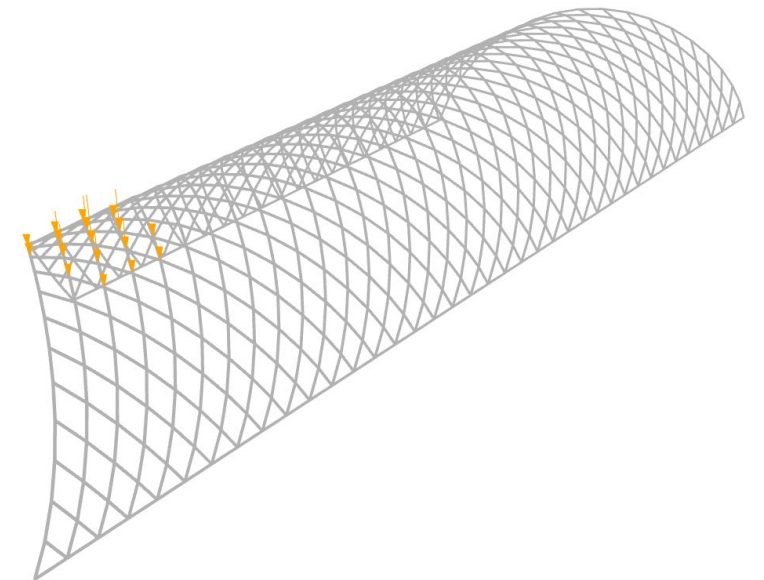
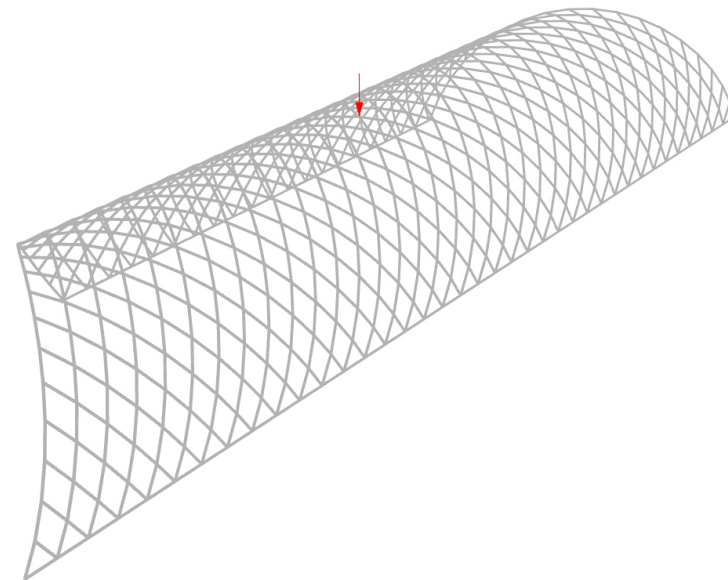


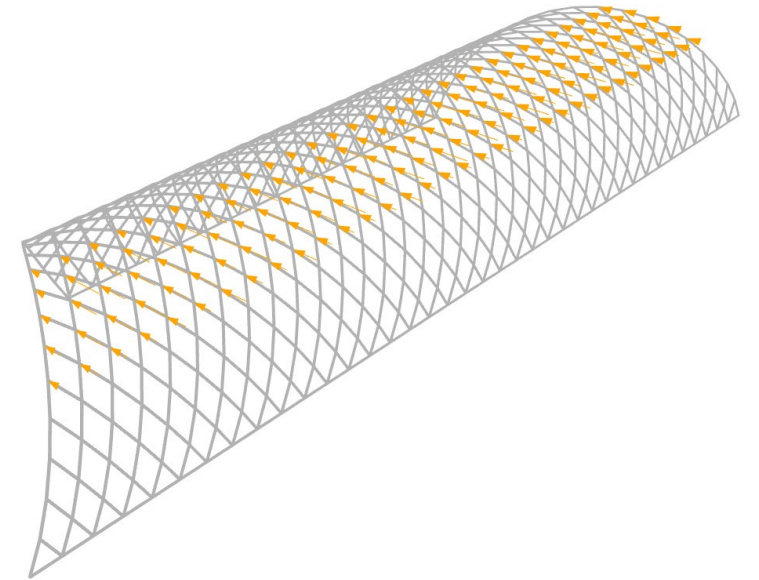
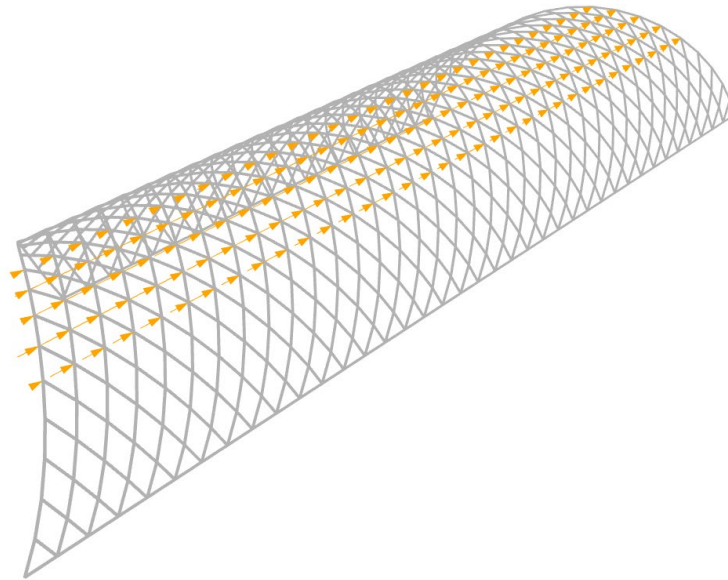
PERMANENT













STRENGTH vs. LOADS

Is the design strong enough?

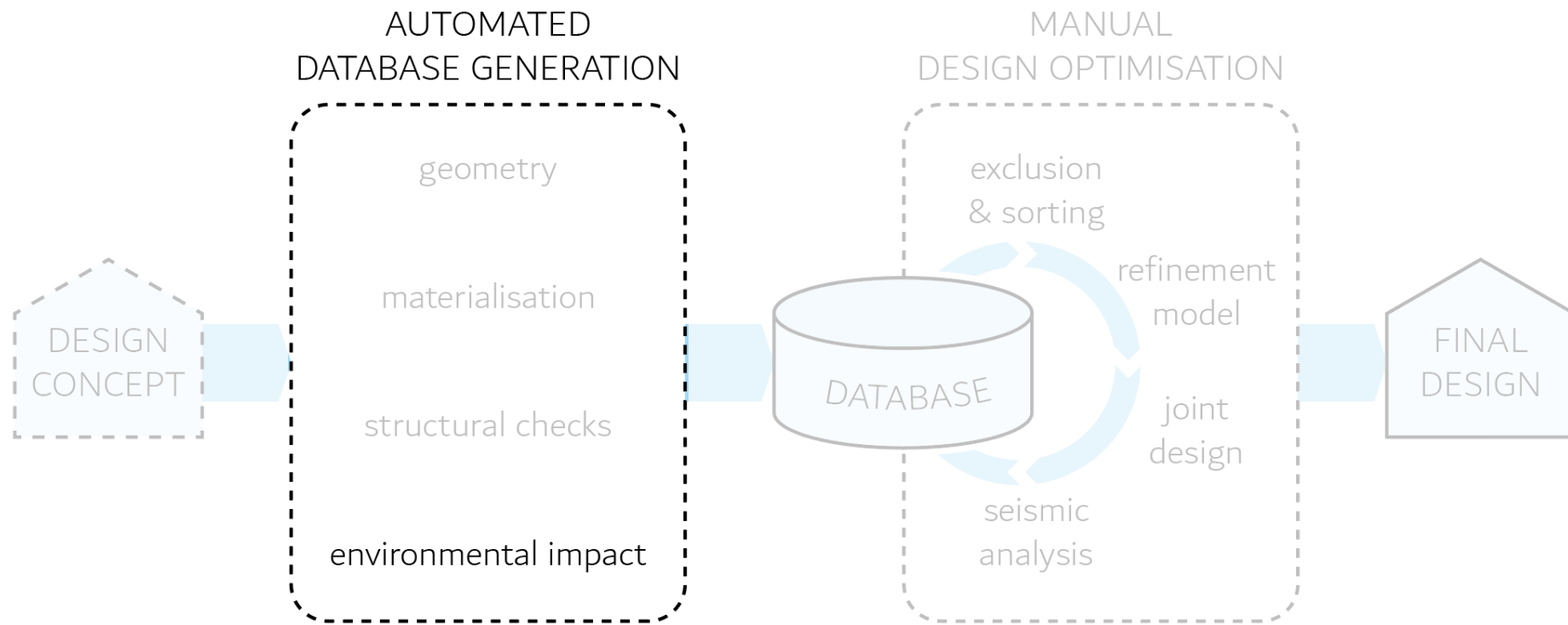
$$\frac{\tau_d}{f_{v,d}} \leq 1$$

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

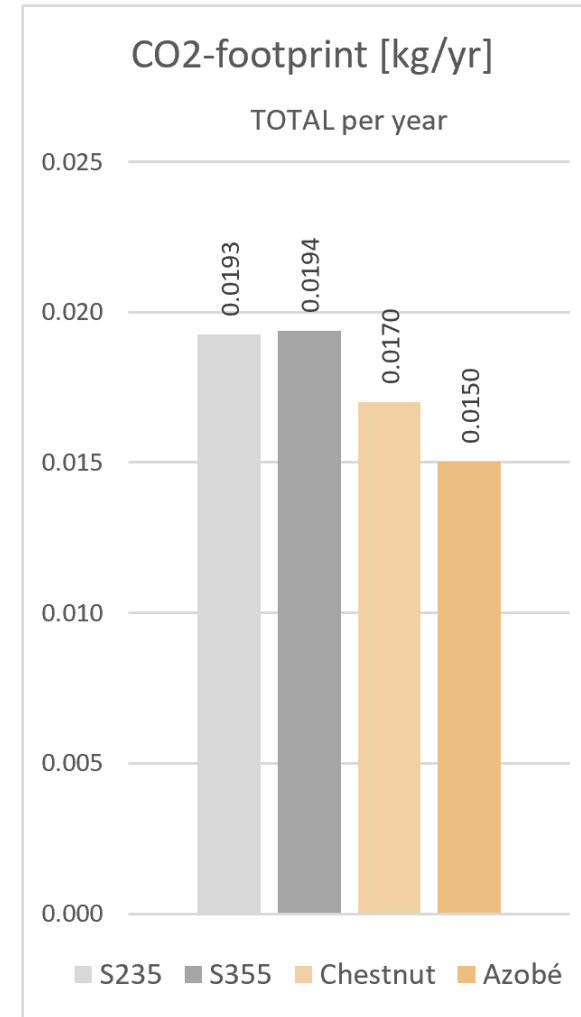
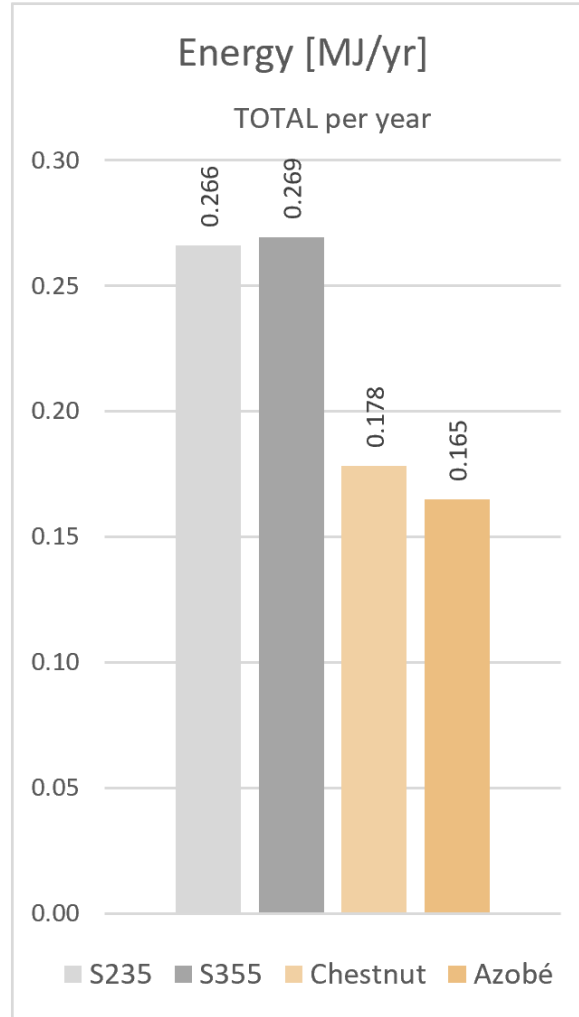
$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + \frac{\sigma_{m,y,d}}{f_{m,y,d}} + k_m \cdot \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$

$$\left(\frac{\sigma_{c,0,d}}{f_{c,0,d}}\right)^2 + k_m \cdot \frac{\sigma_{m,y,d}}{f_{m,y,d}} + \frac{\sigma_{m,z,d}}{f_{m,z,d}} \leq 1$$



ENVIRONMENTAL IMPACT

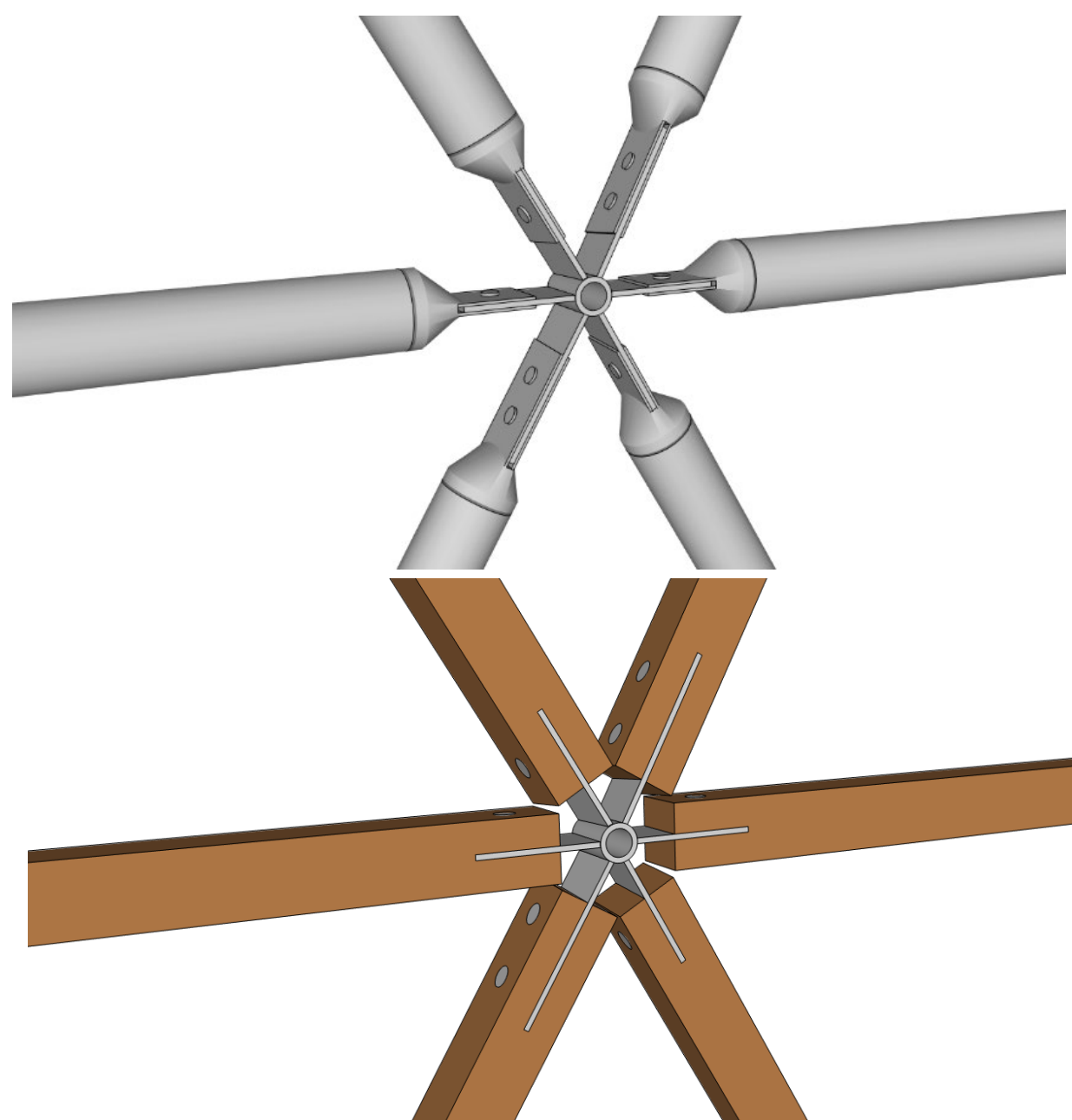
Environmental impact per kg structure



Exclusion:
Chestnut

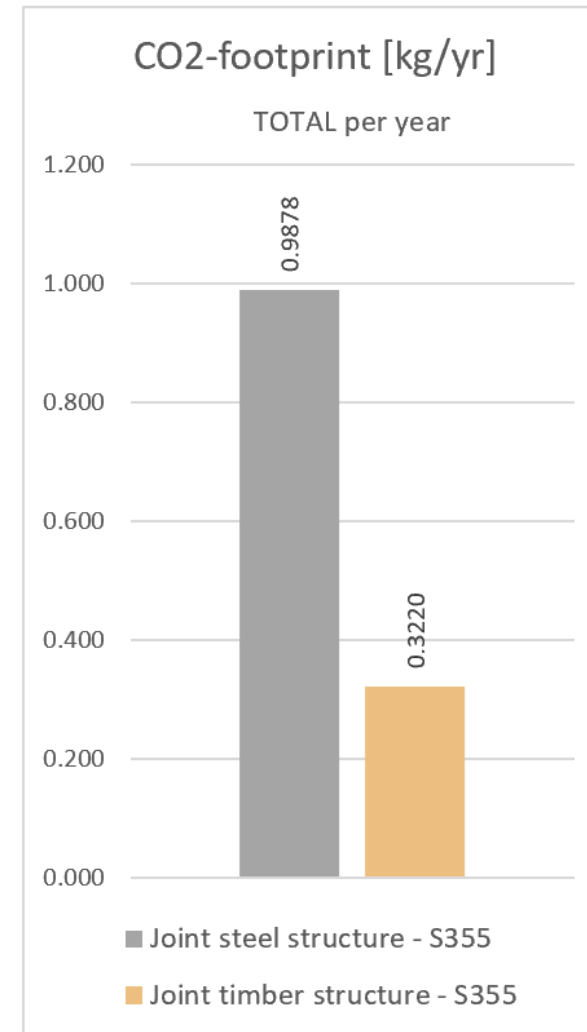
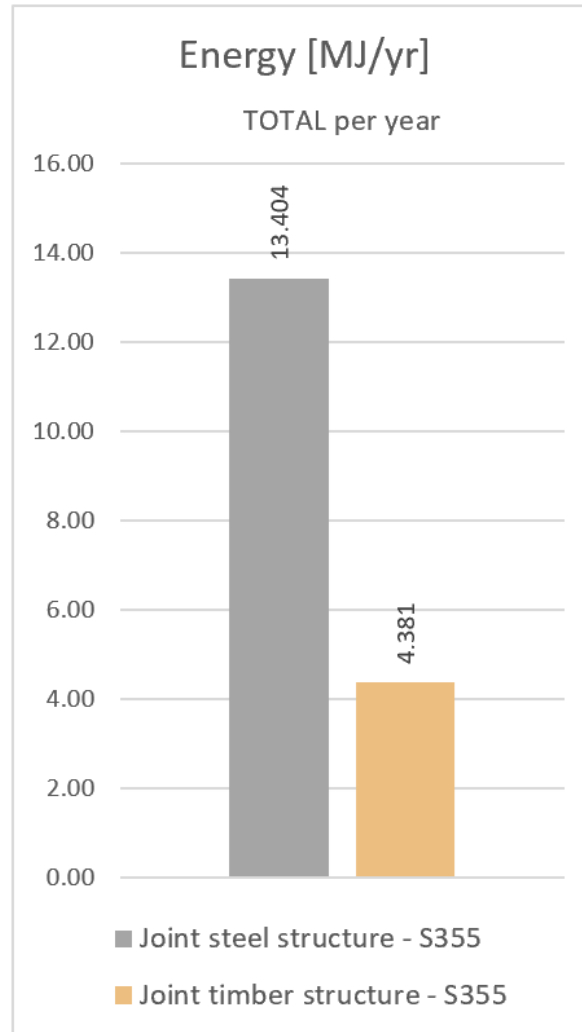
10 836
variations

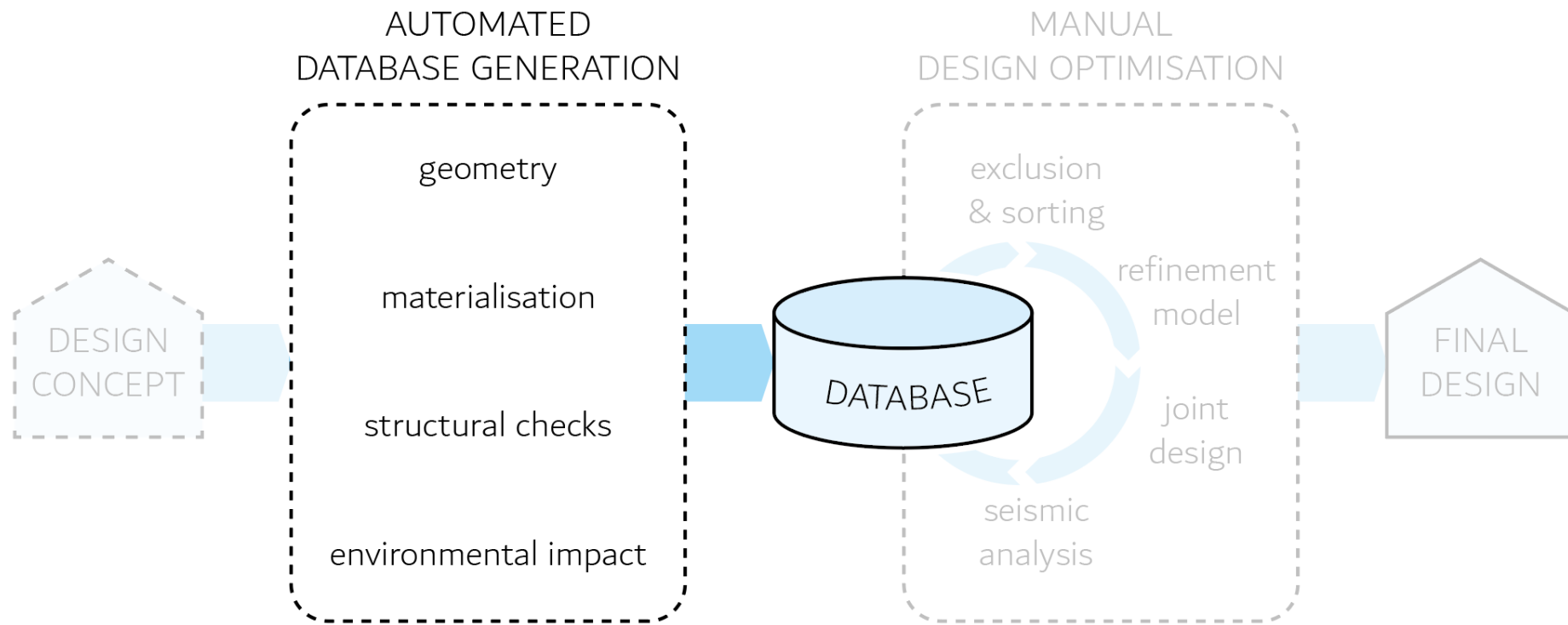
JOINT

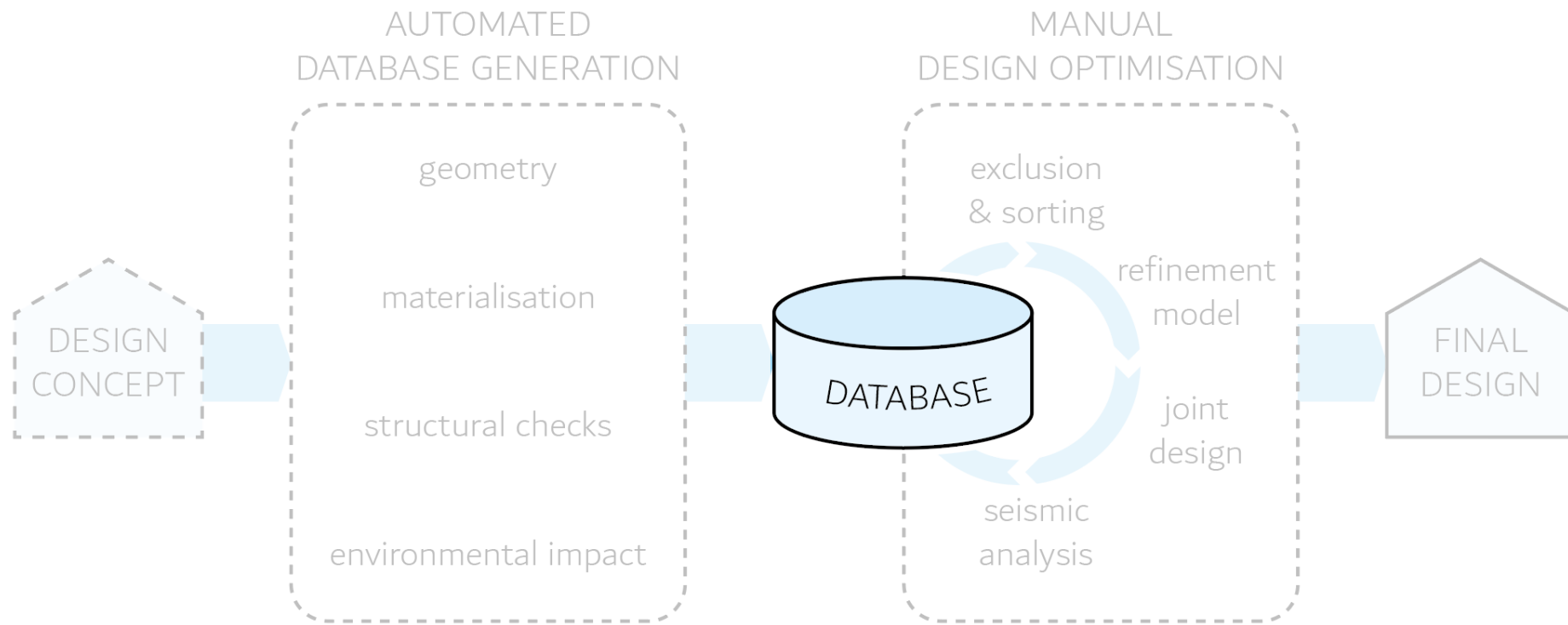


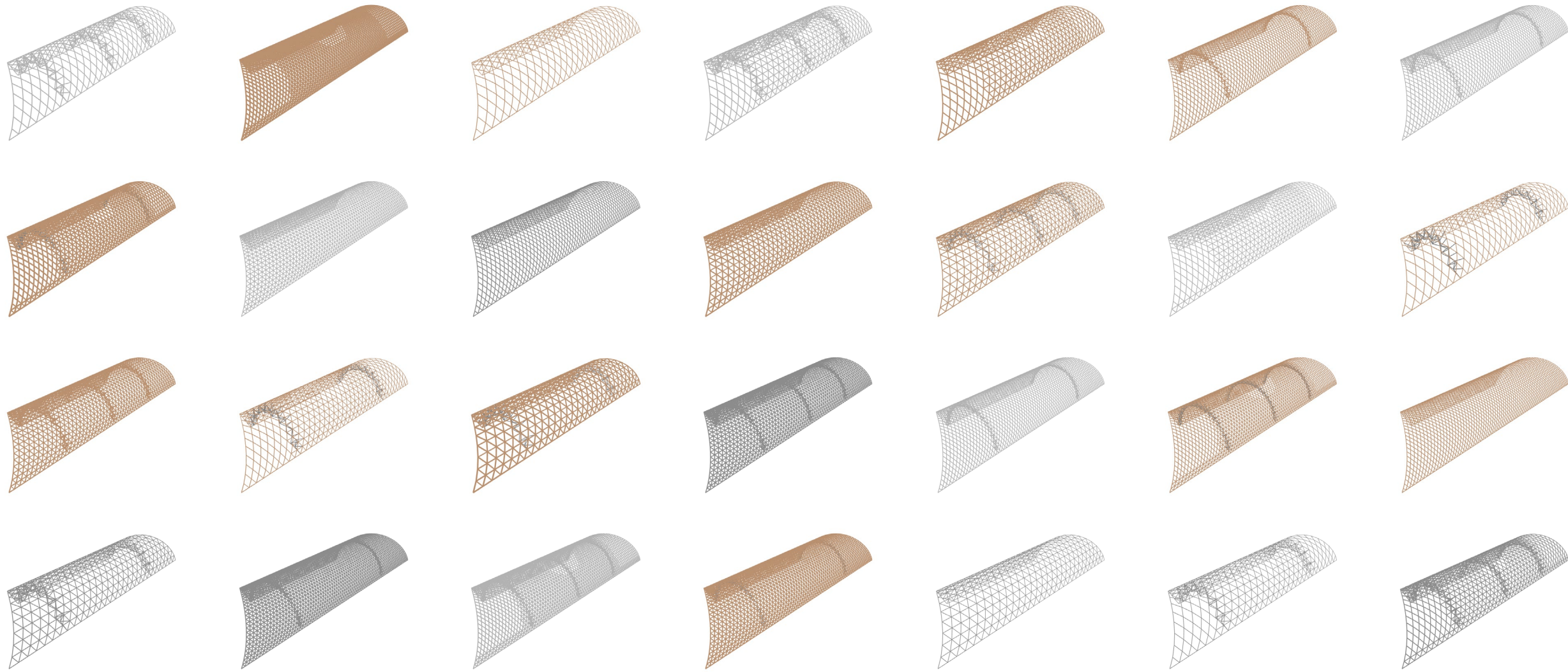
ENVIRONMENTAL IMPACT

Environmental impact per joint



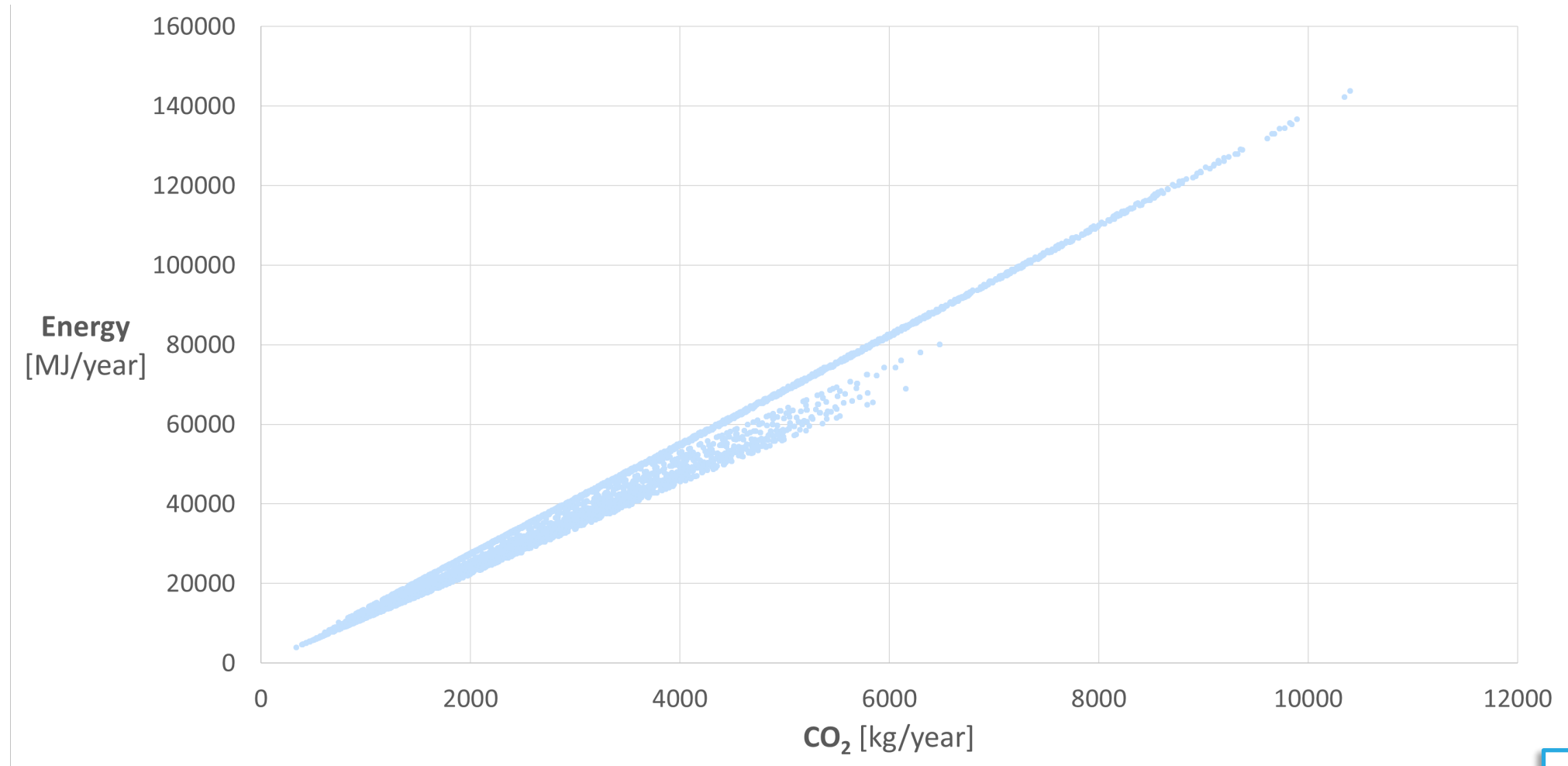






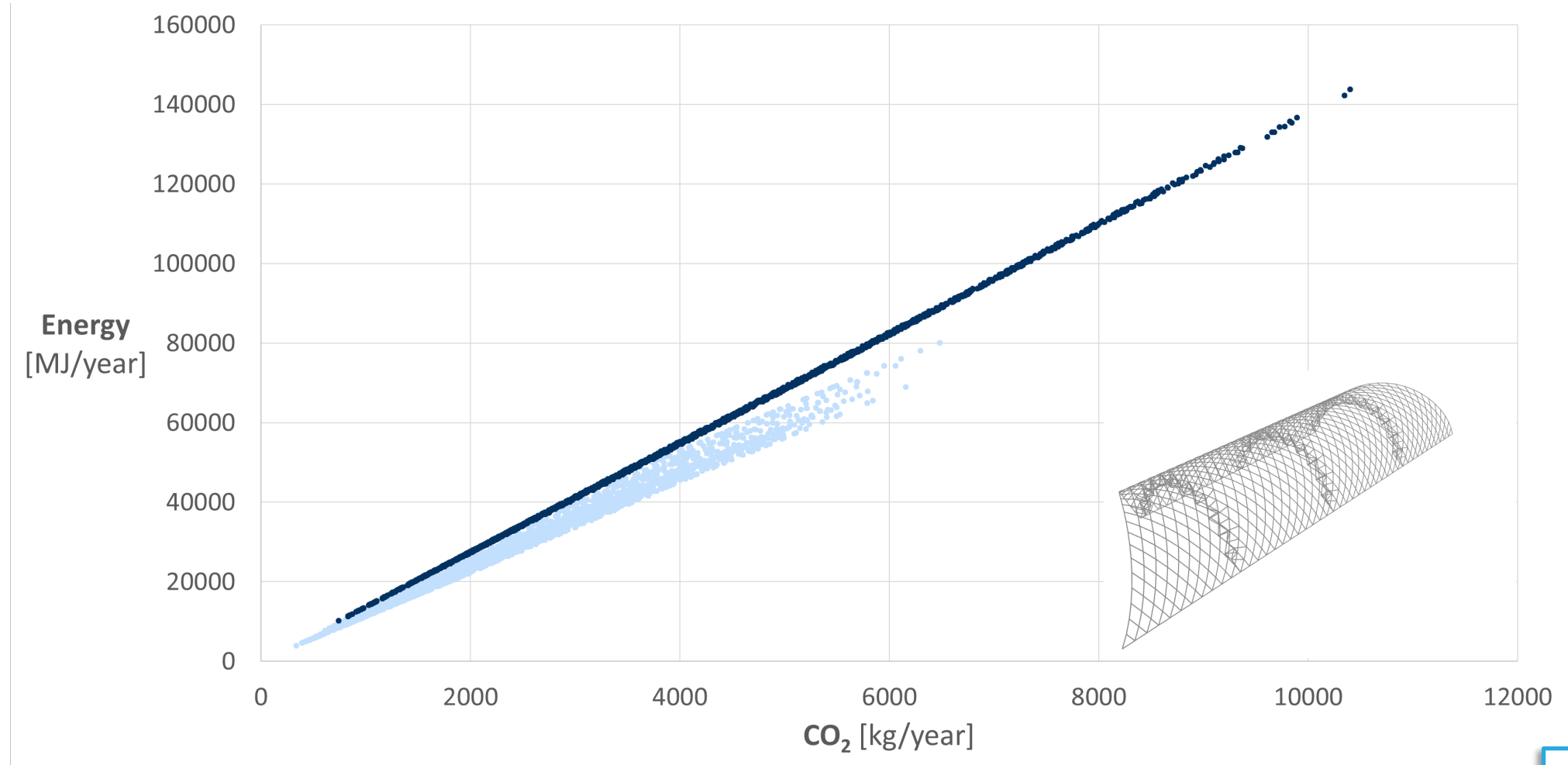
10 836
variations

ALL MODELS



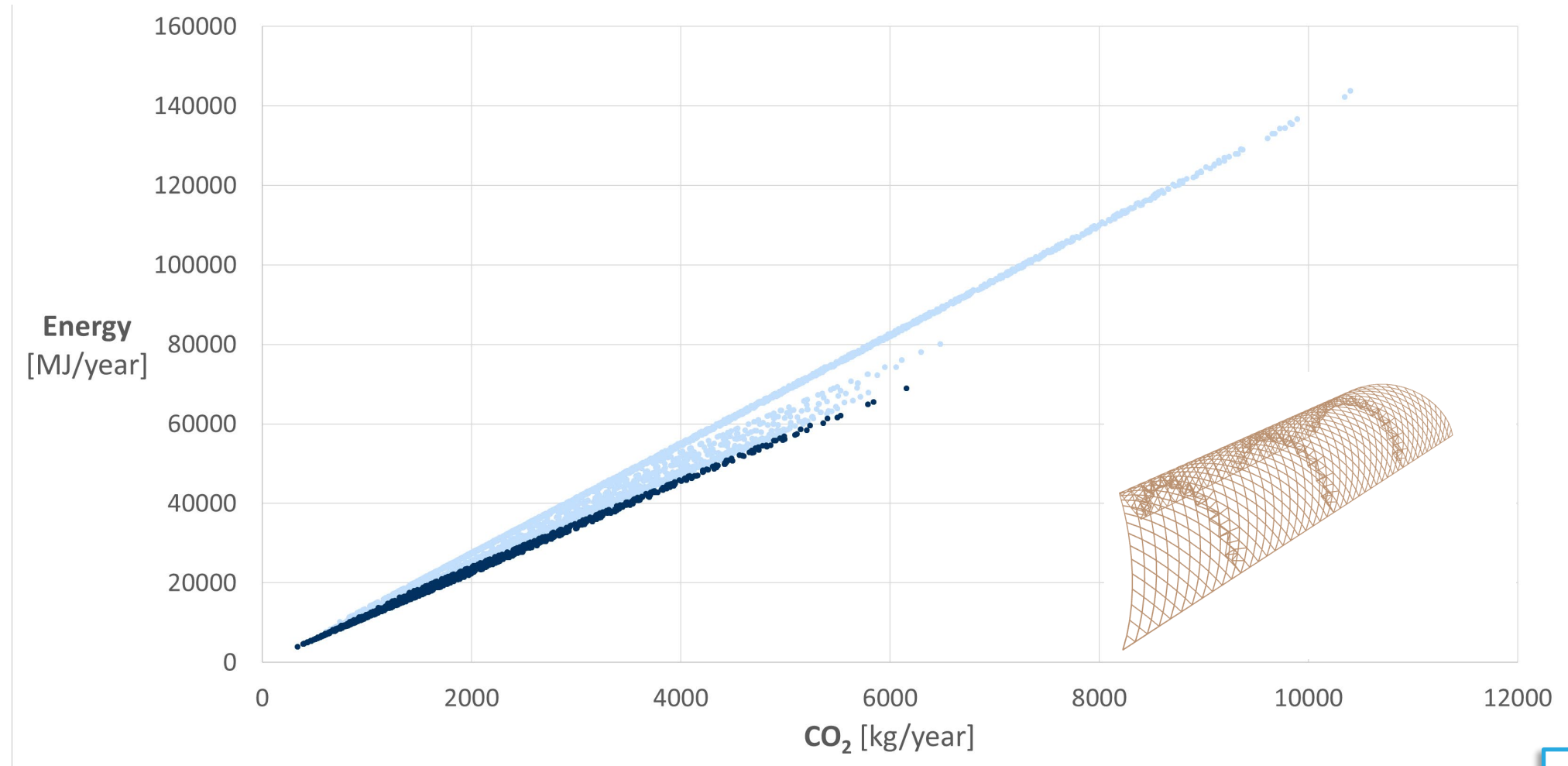
10 836
variations

STEEL



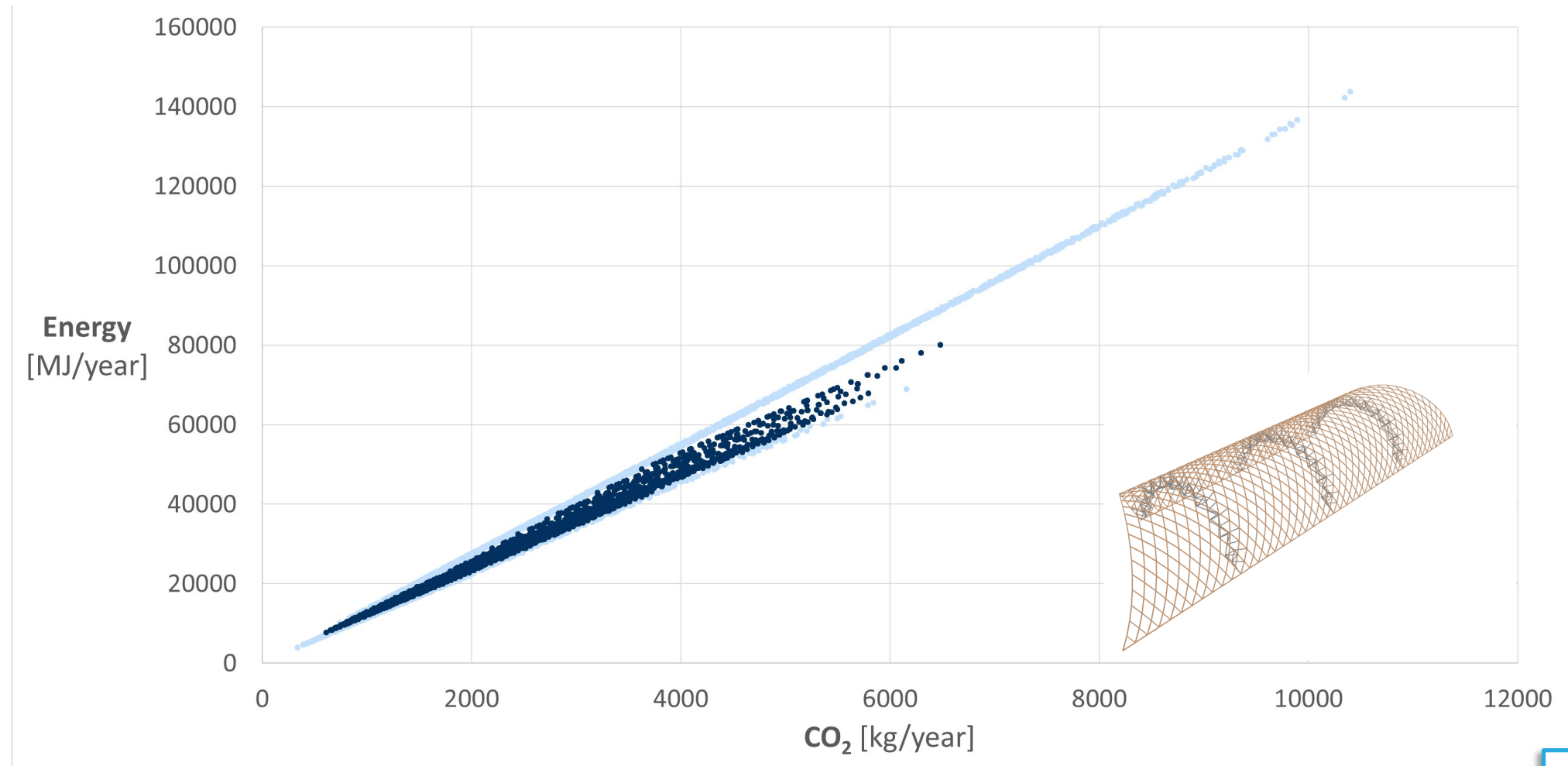
4 788
variations

TIMBER

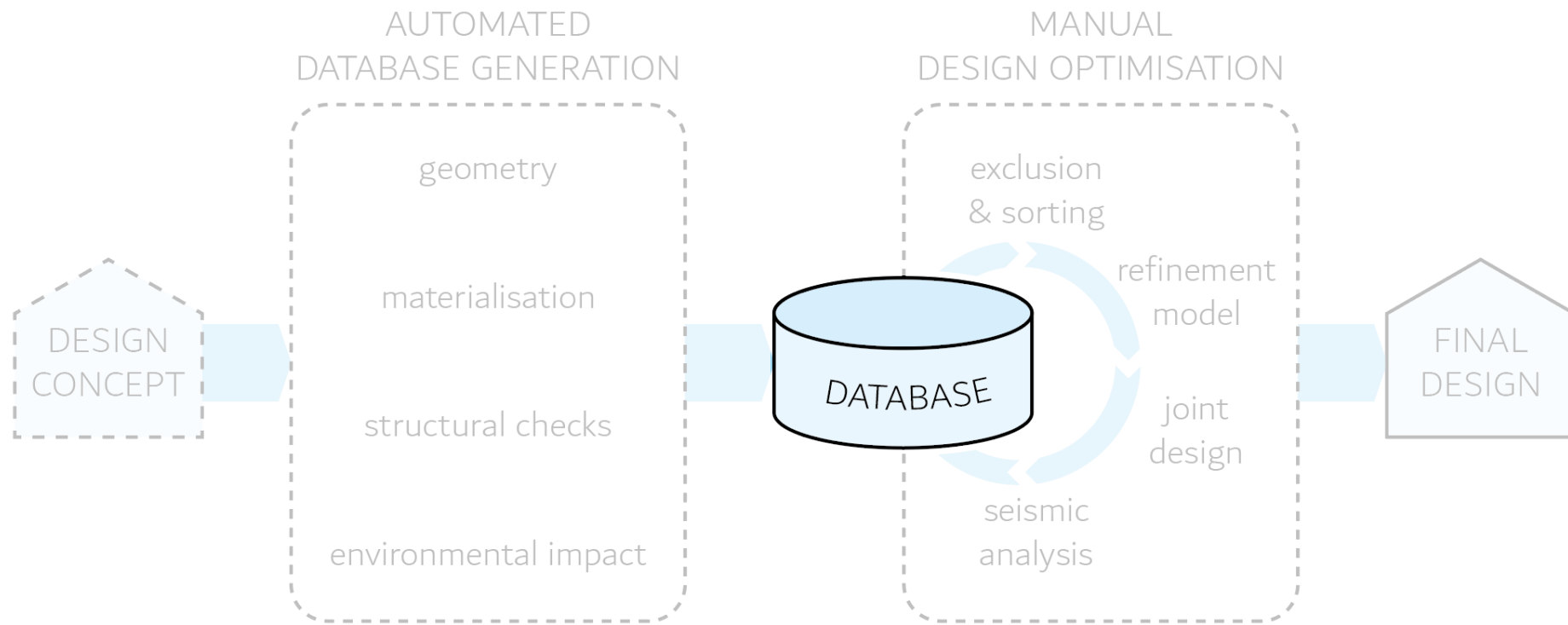


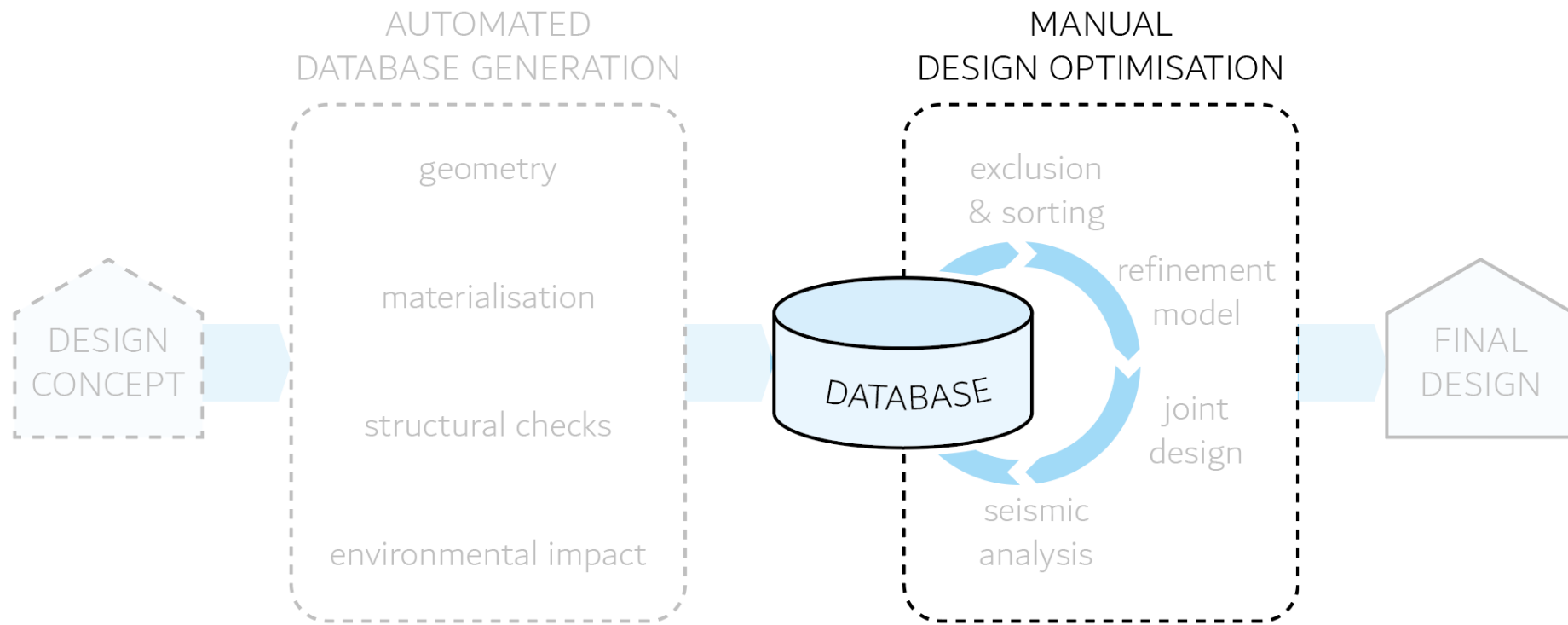
2 016
variations

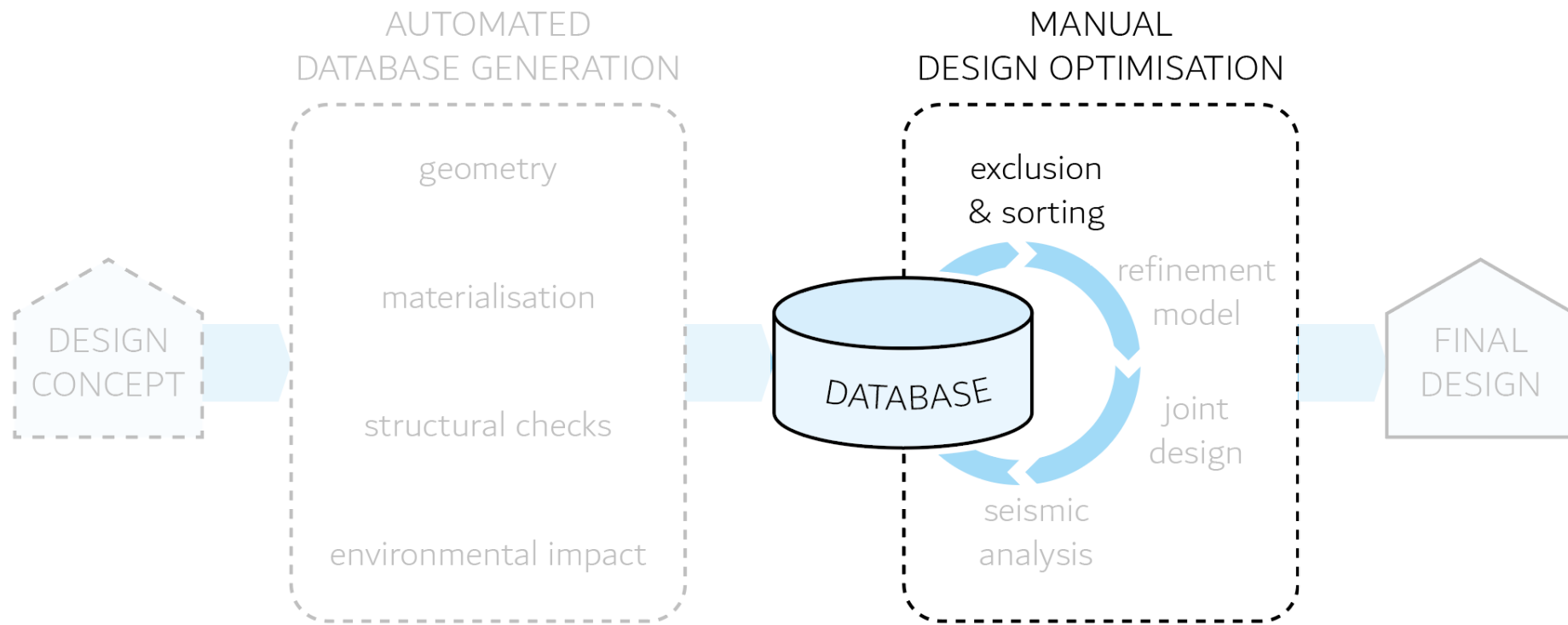
TIMBER & STEEL



4 032
variations



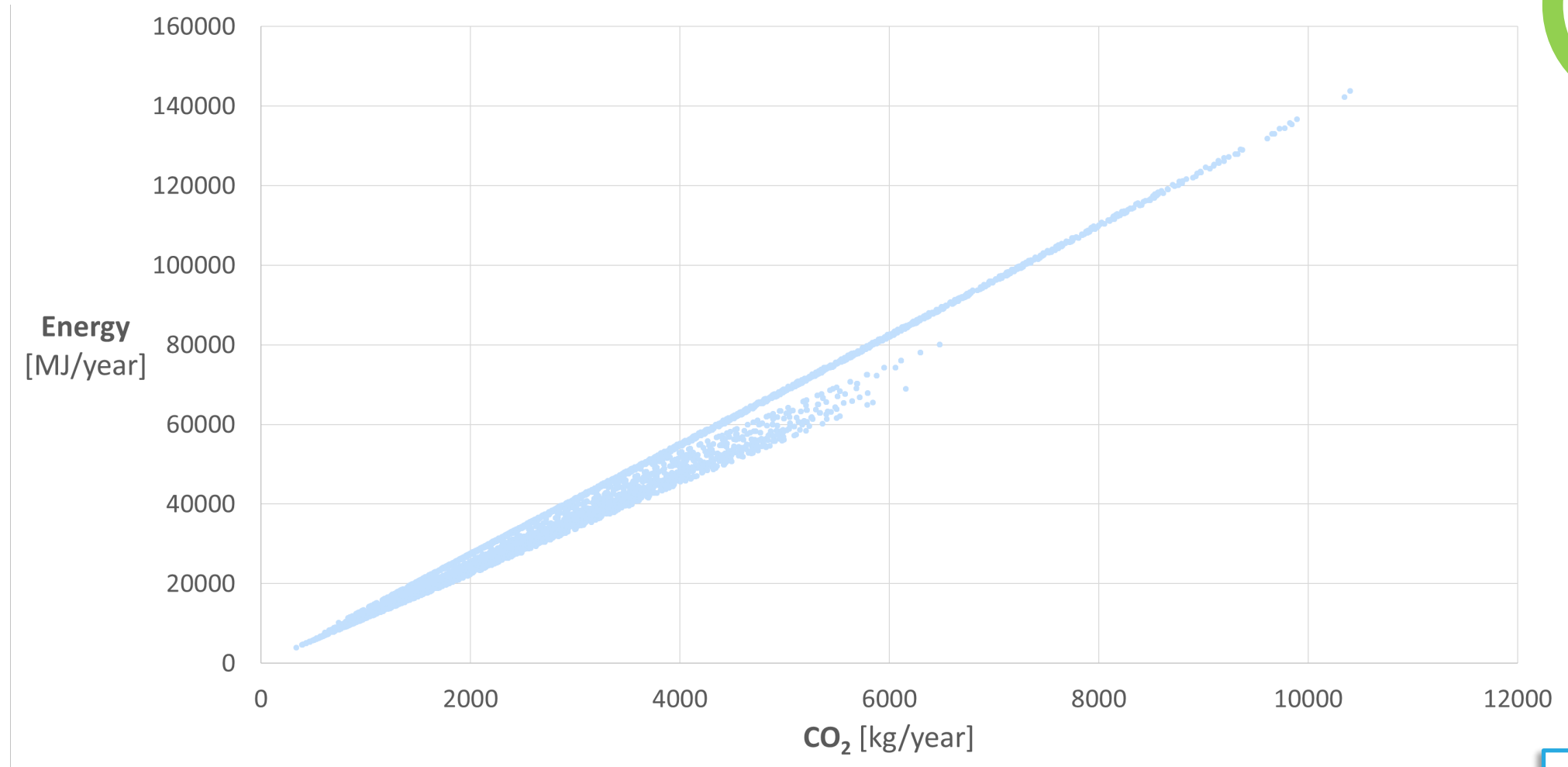




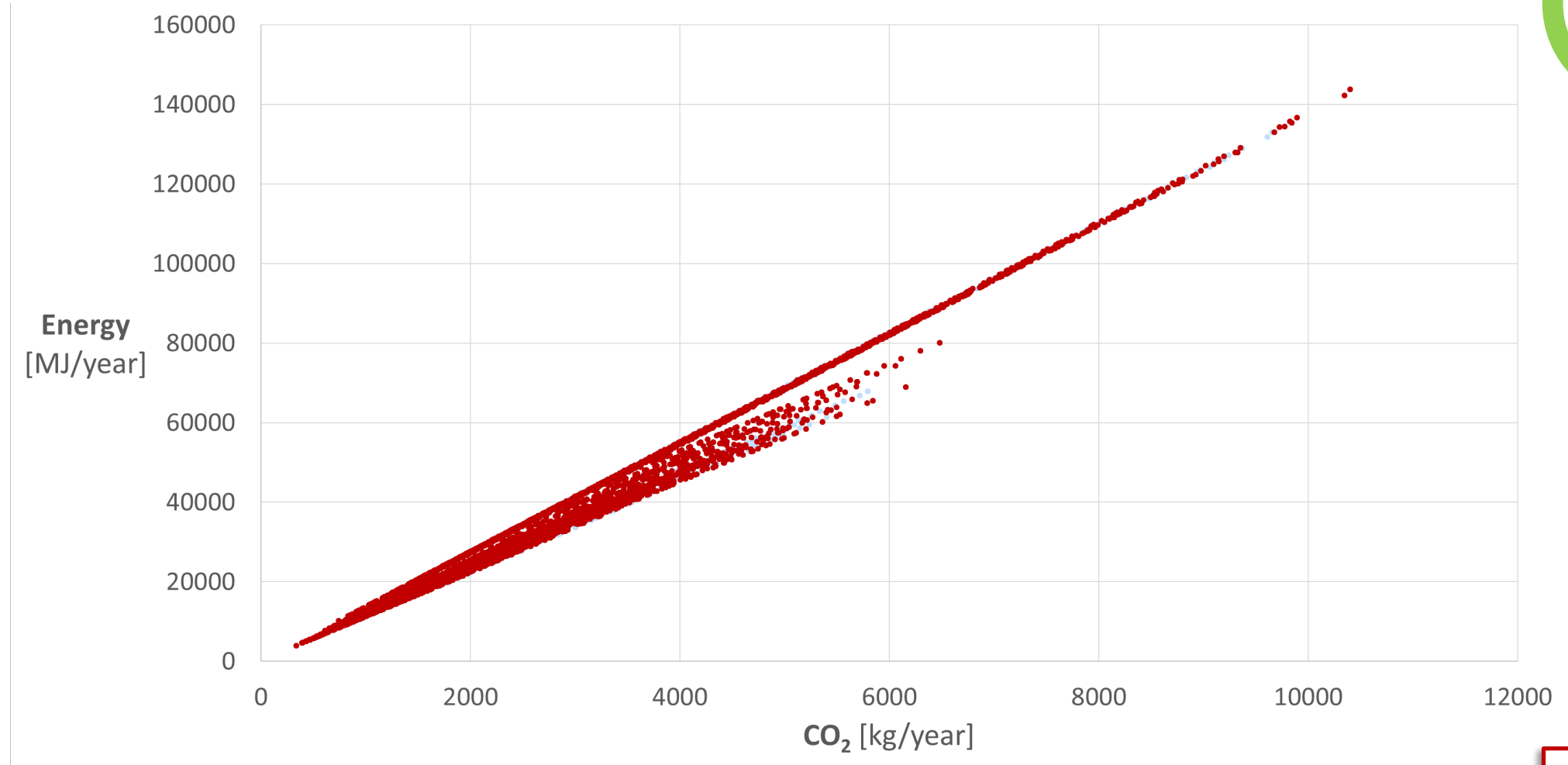
structural checks
O.K.



ALL MODELS



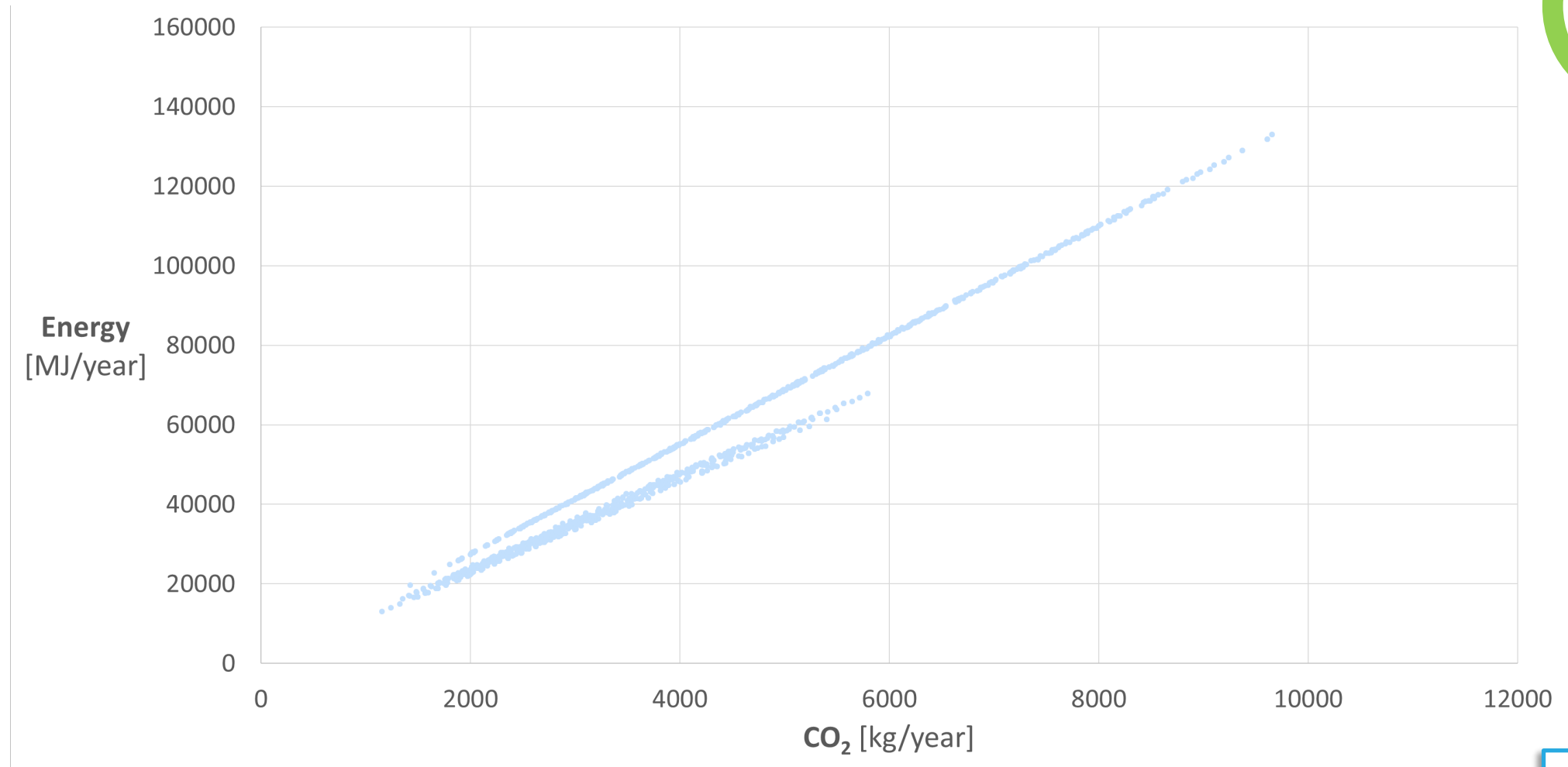
10 836
variations



9 335 variations

STRUCTURAL CHECKS

O.K.

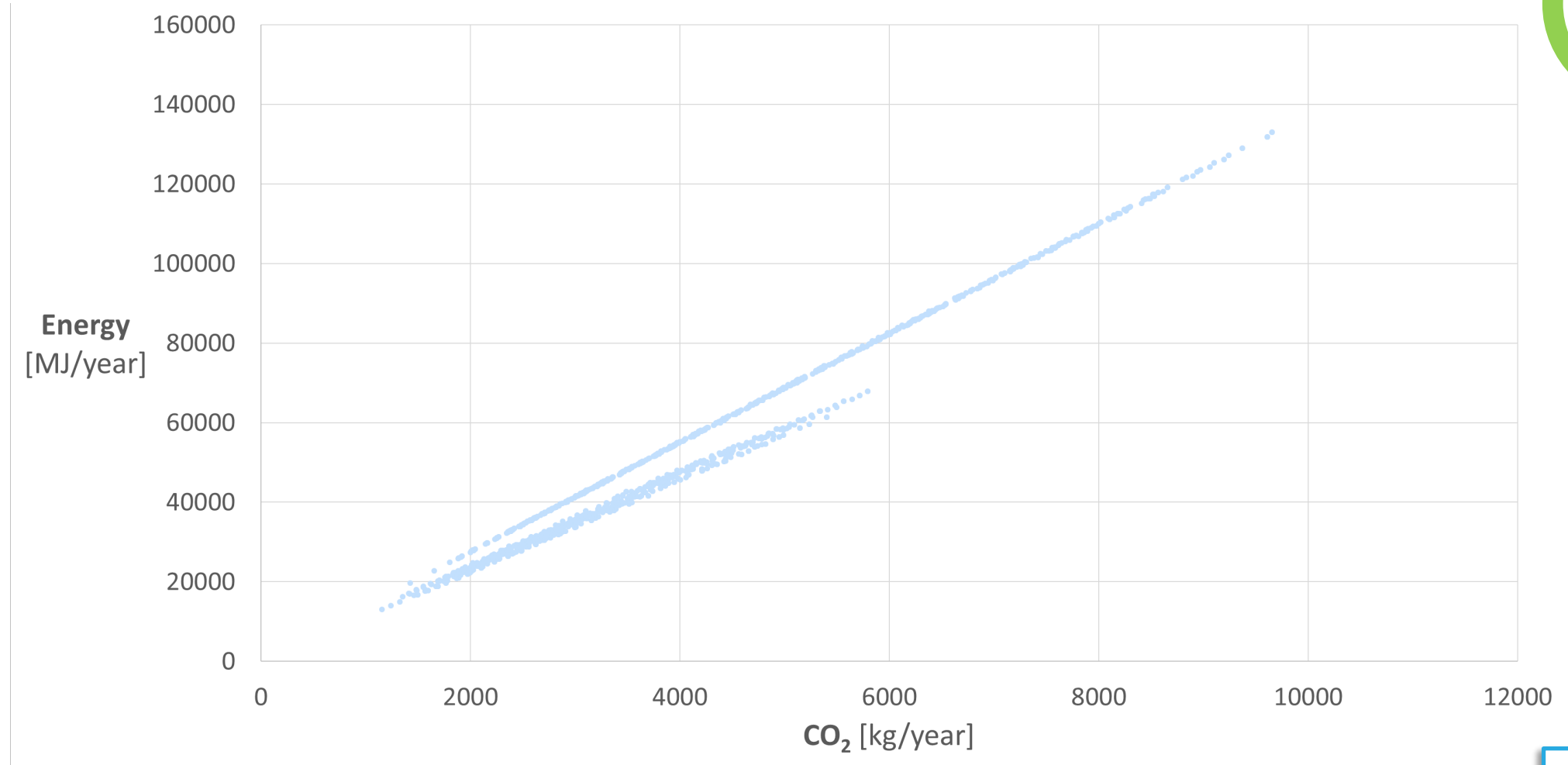


1 501 variations

element weight
< 40 kg



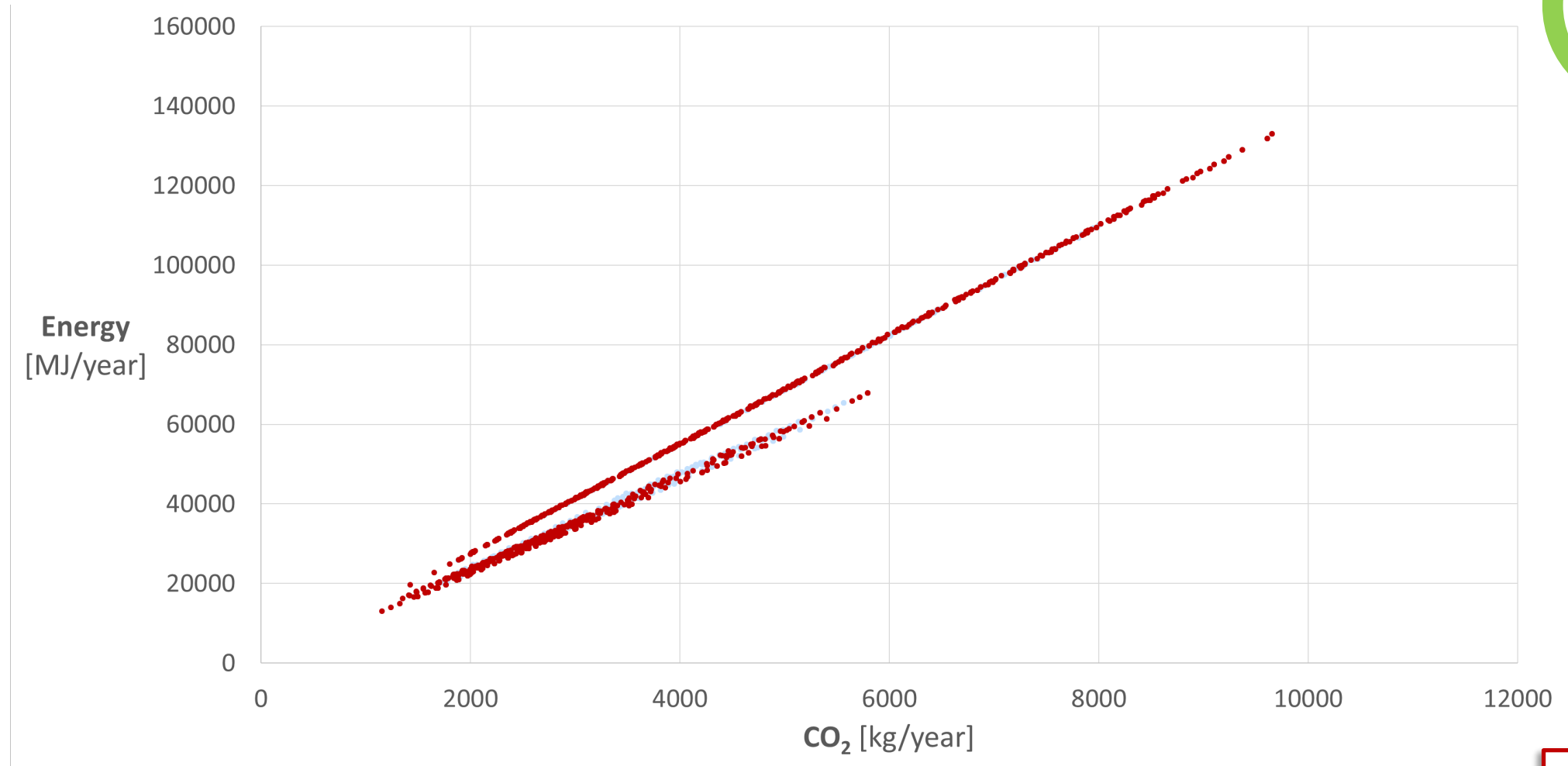
REMAINING MODELS



1 501
variations

ELEMENT WEIGHT

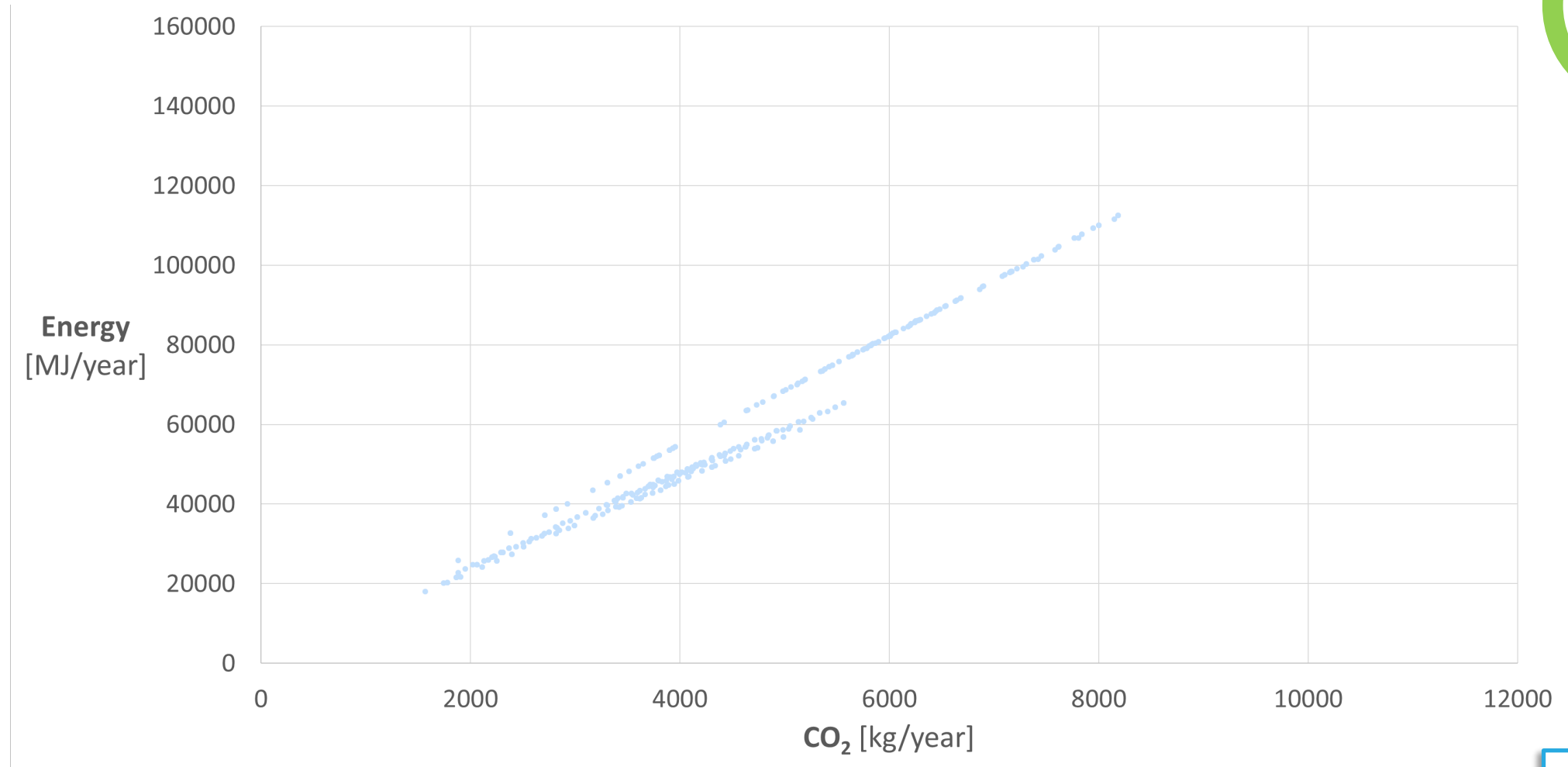
>40 kg



1 124 variations

ELEMENT WEIGHT

<40 kg

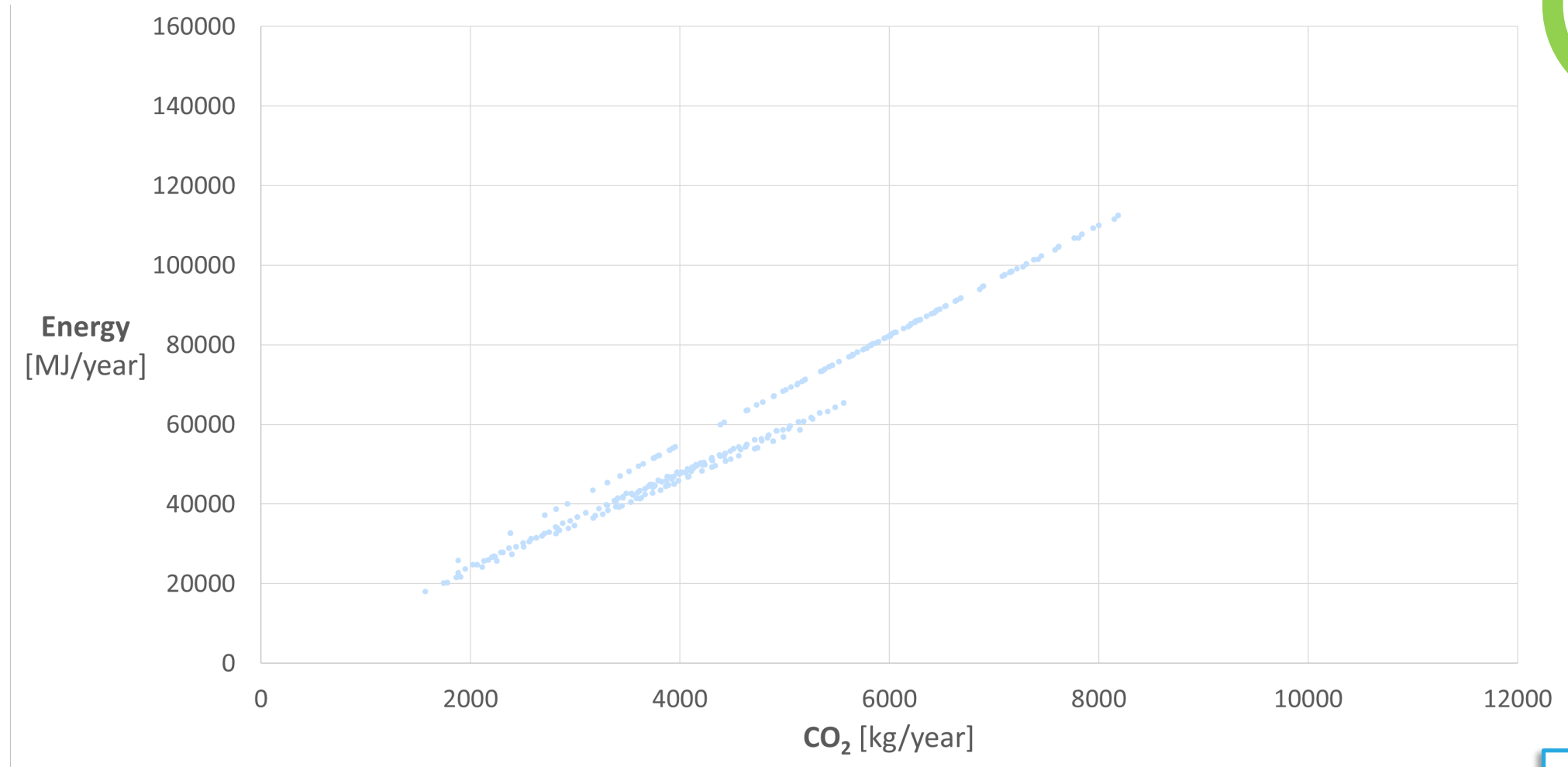


377 variations

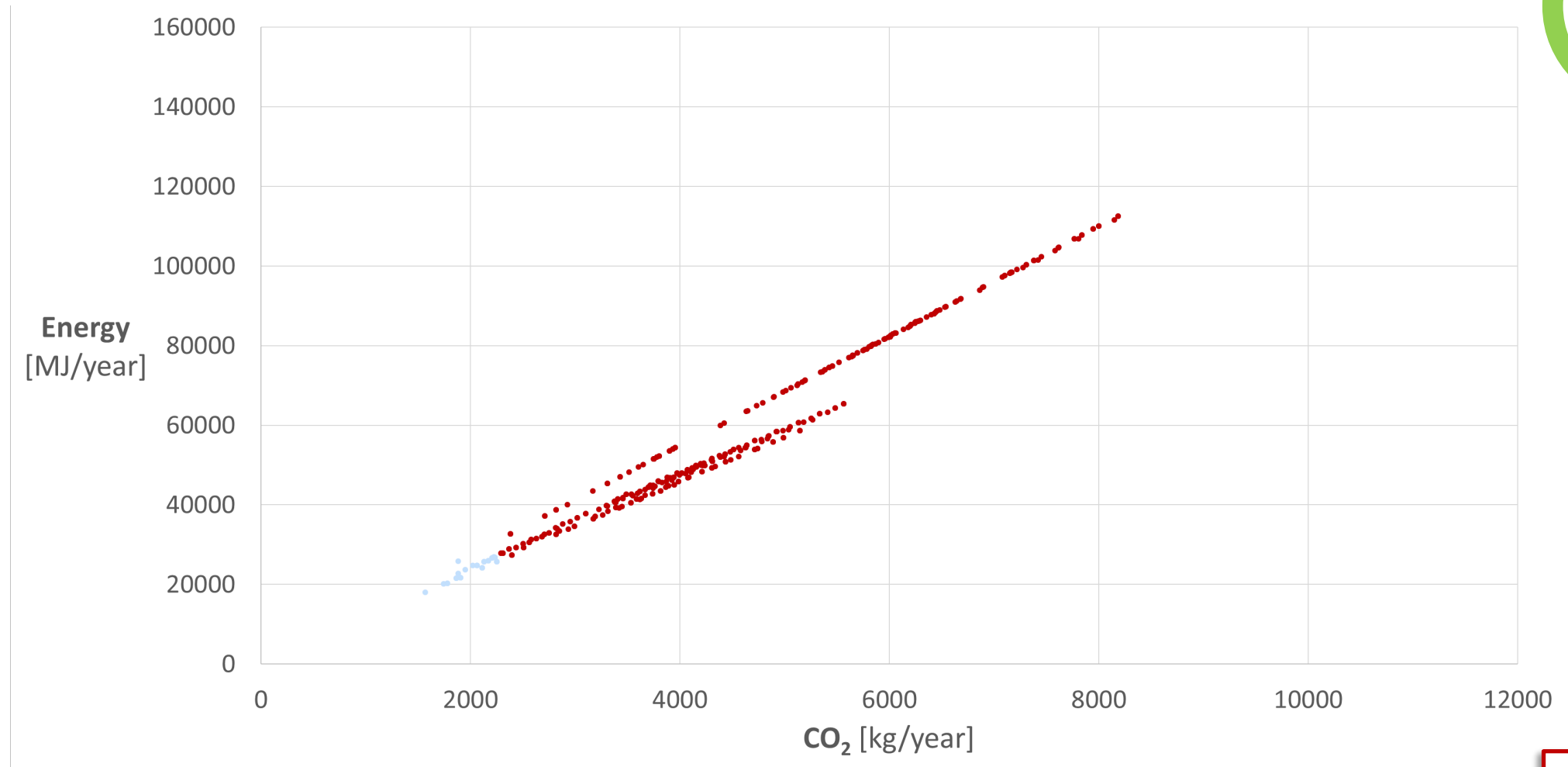
environmentally friendly
top 5%



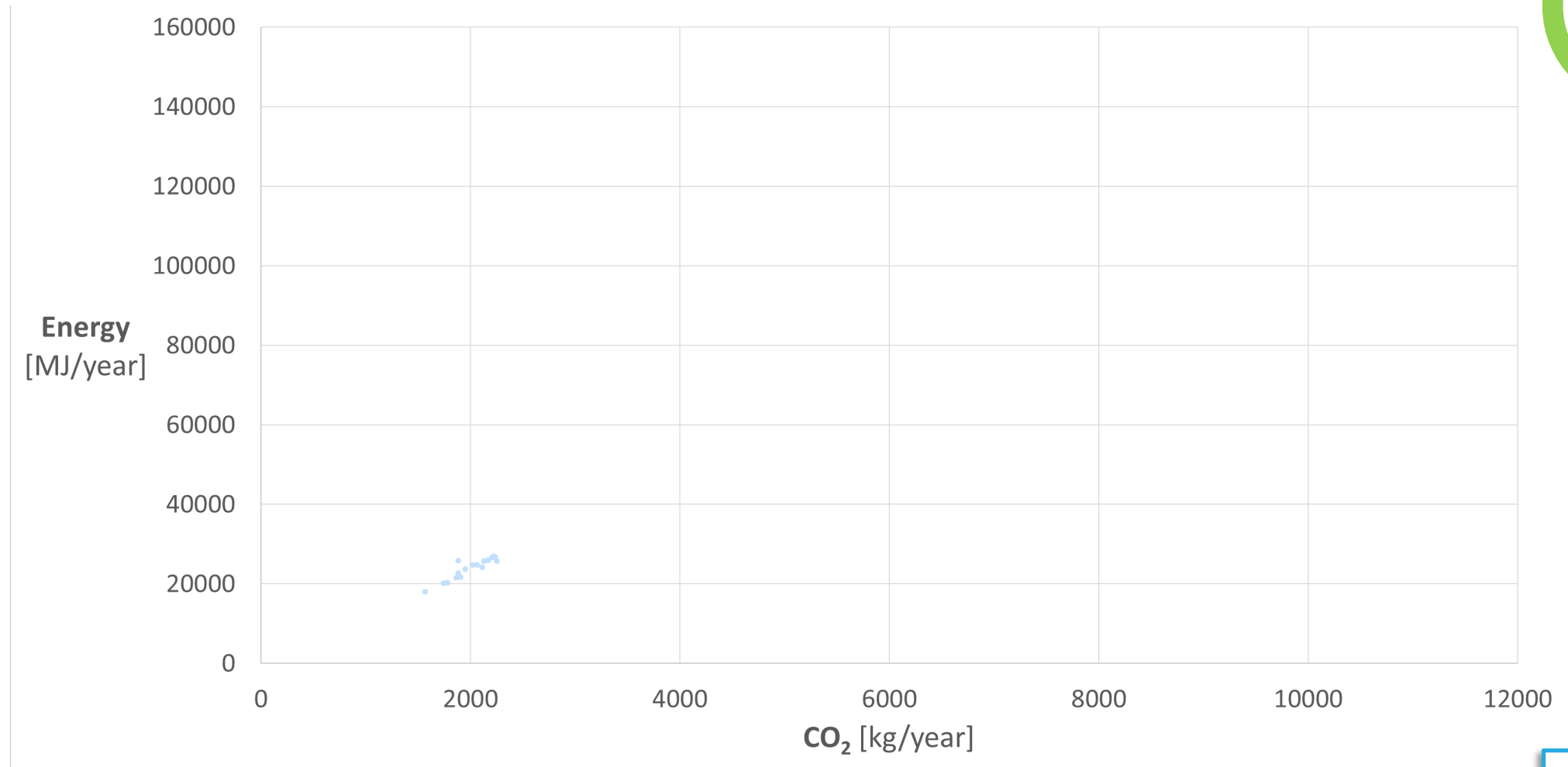
REMAINING MODELS



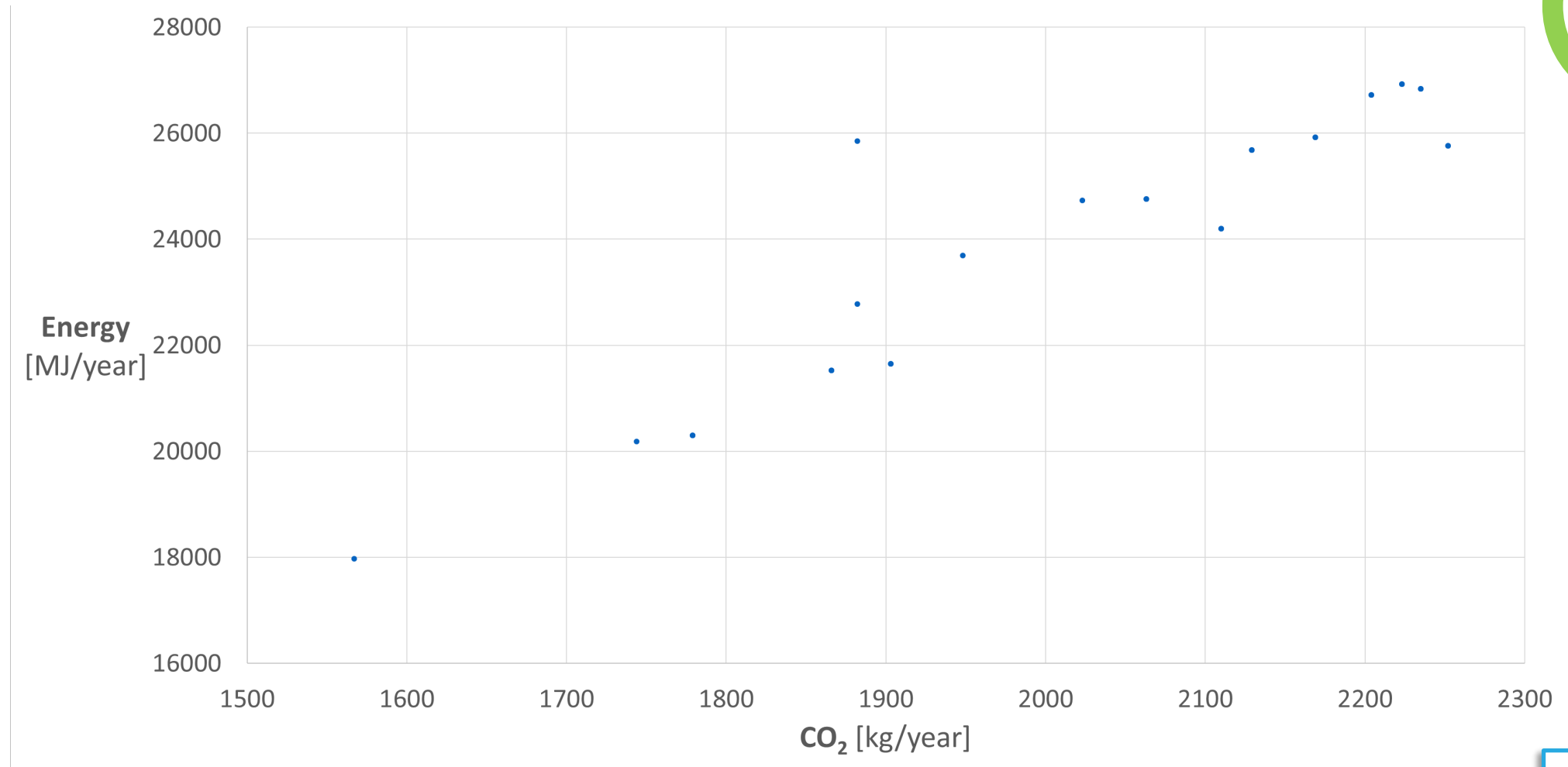
377
variations



349 variations



28 variations

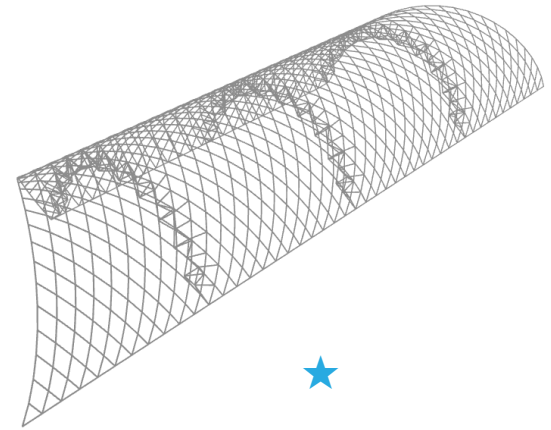
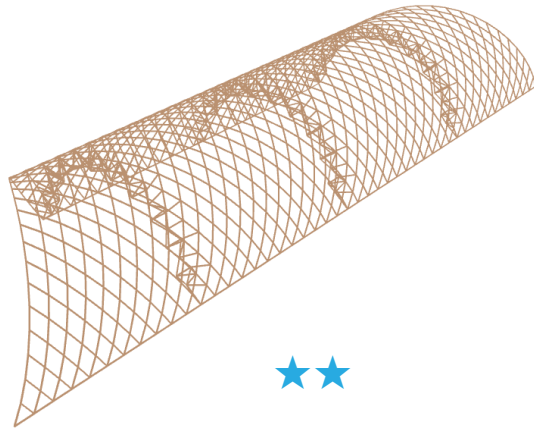
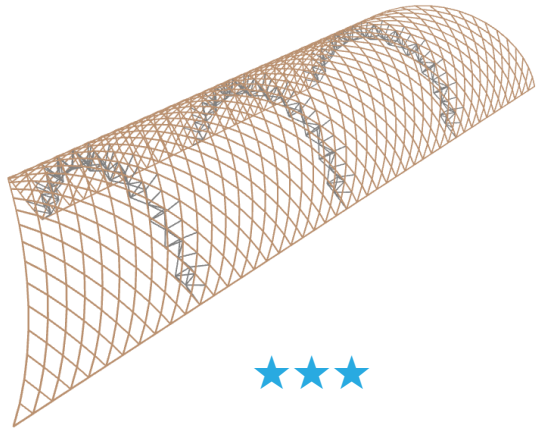
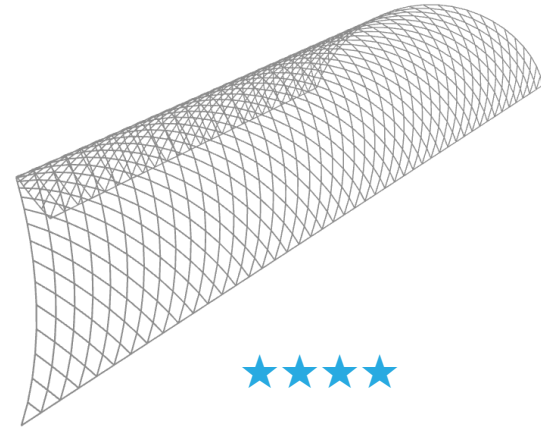
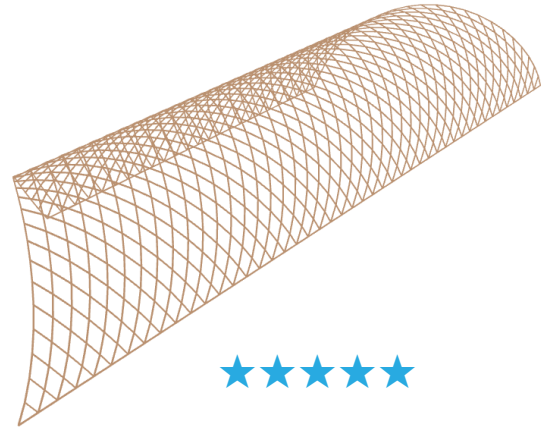


28 variations

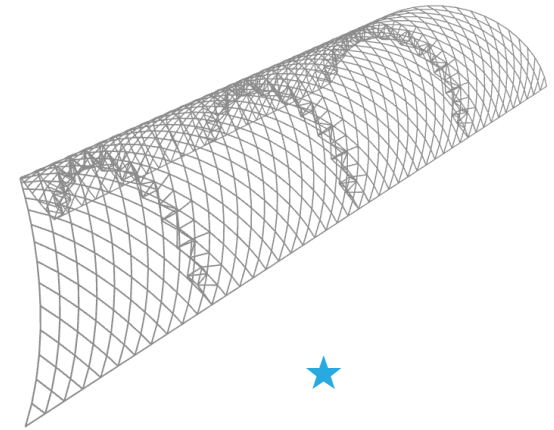
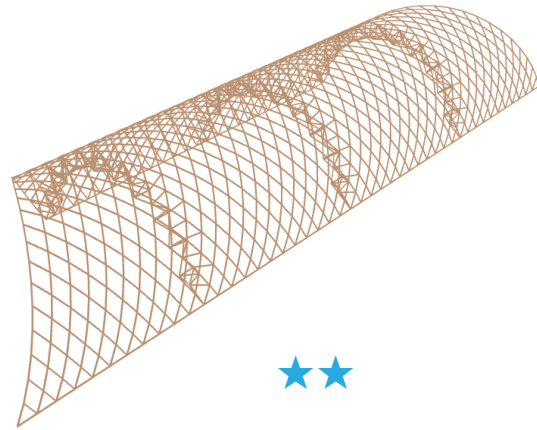
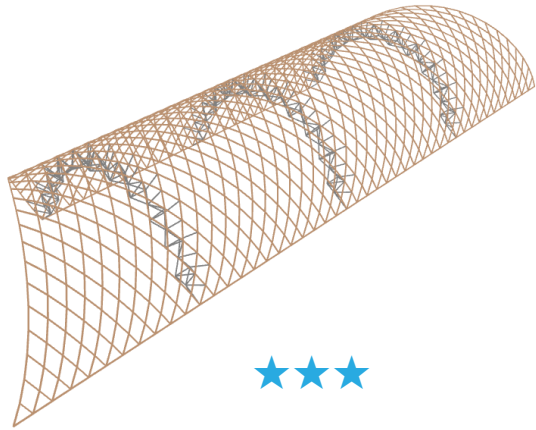
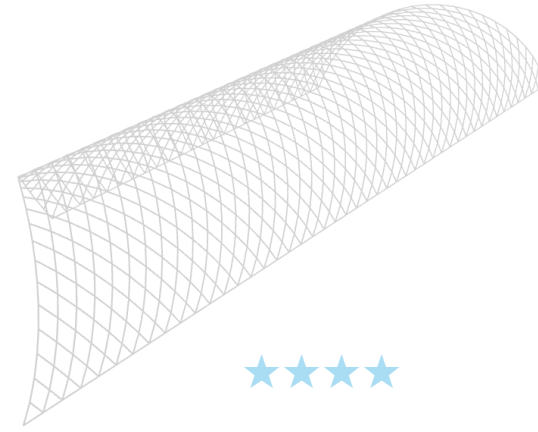
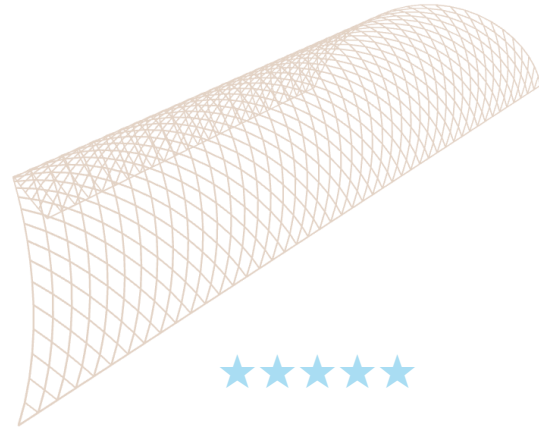
aesthetical value
ranking



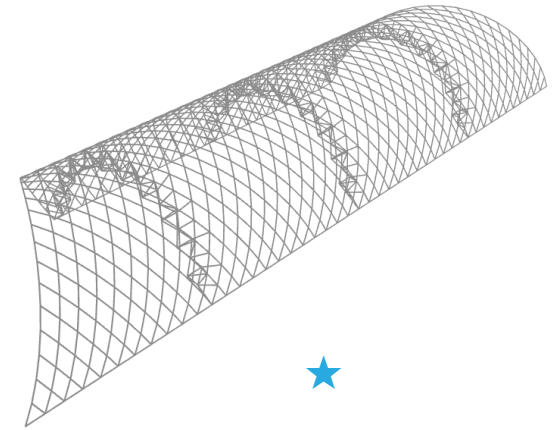
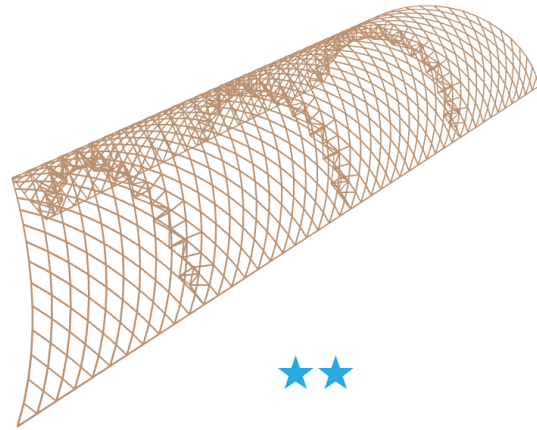
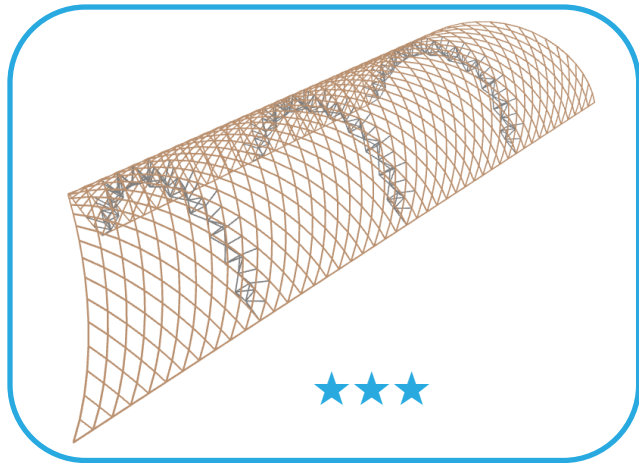
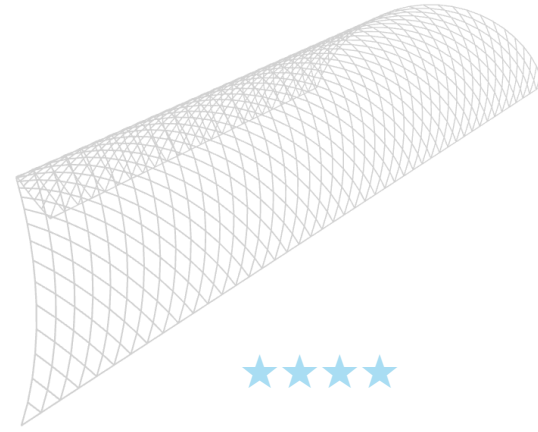
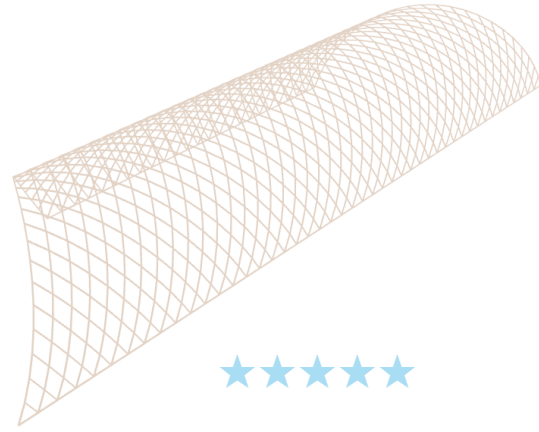
RANKING



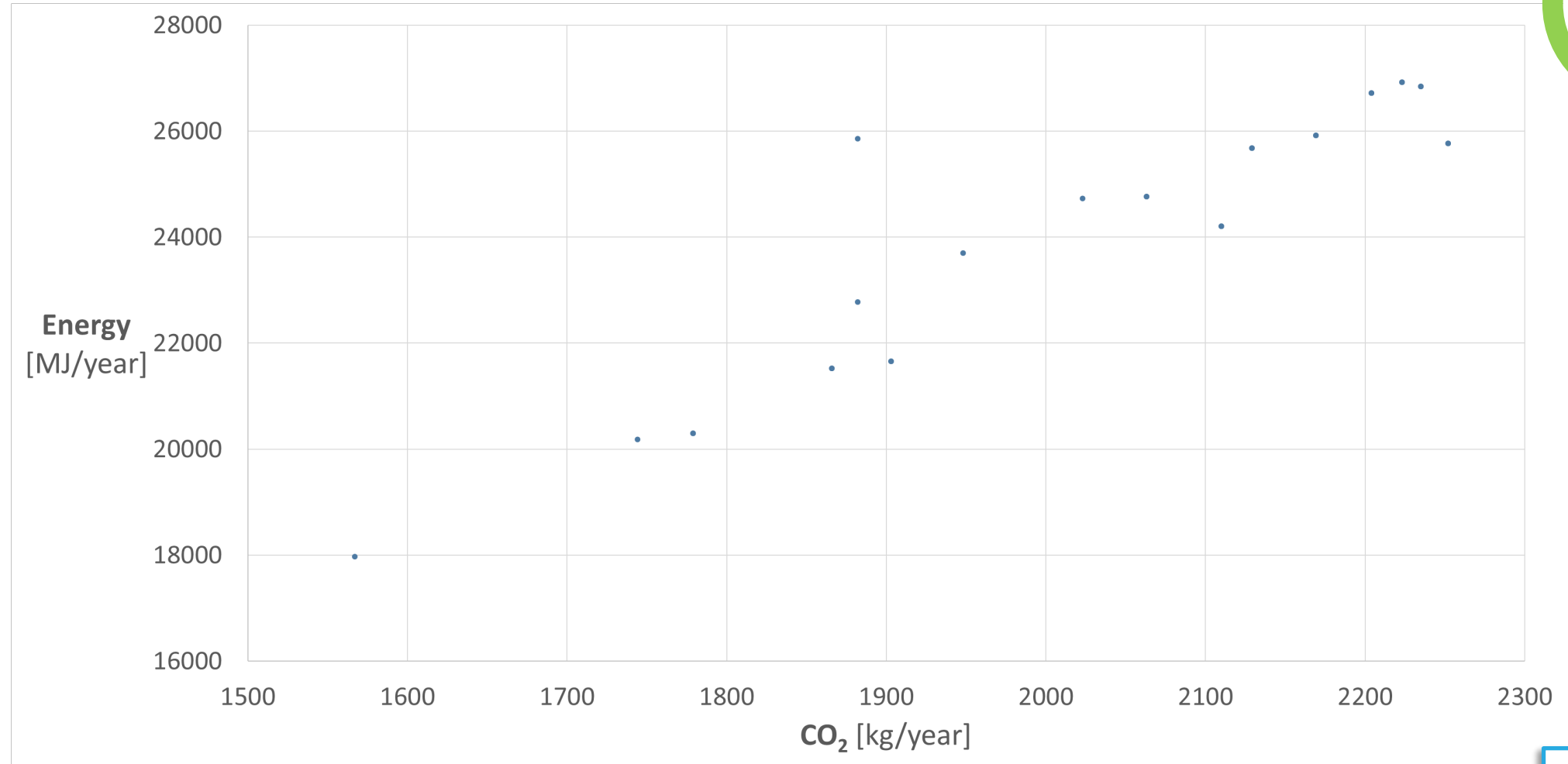
RANKING



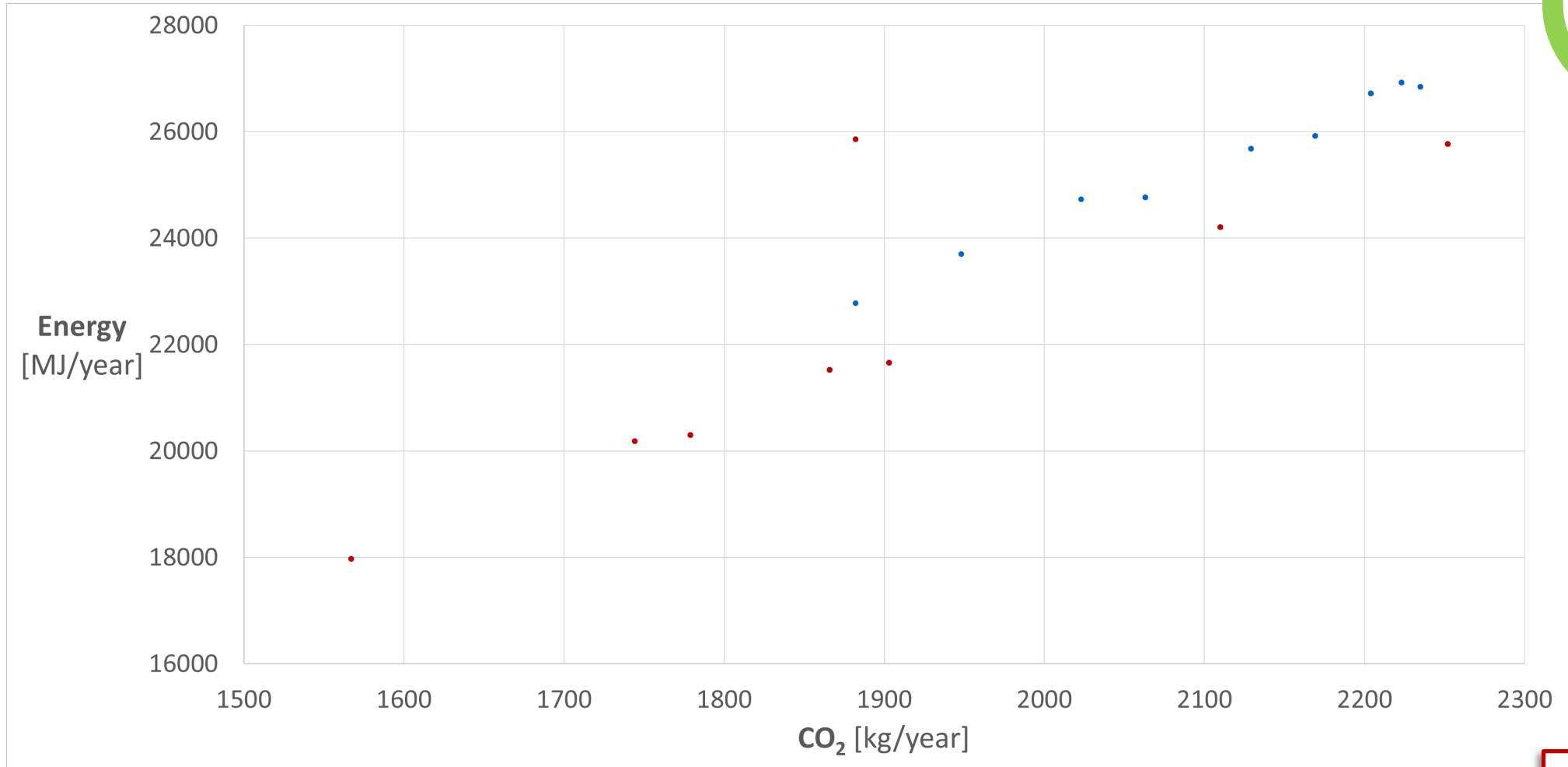
RANKING



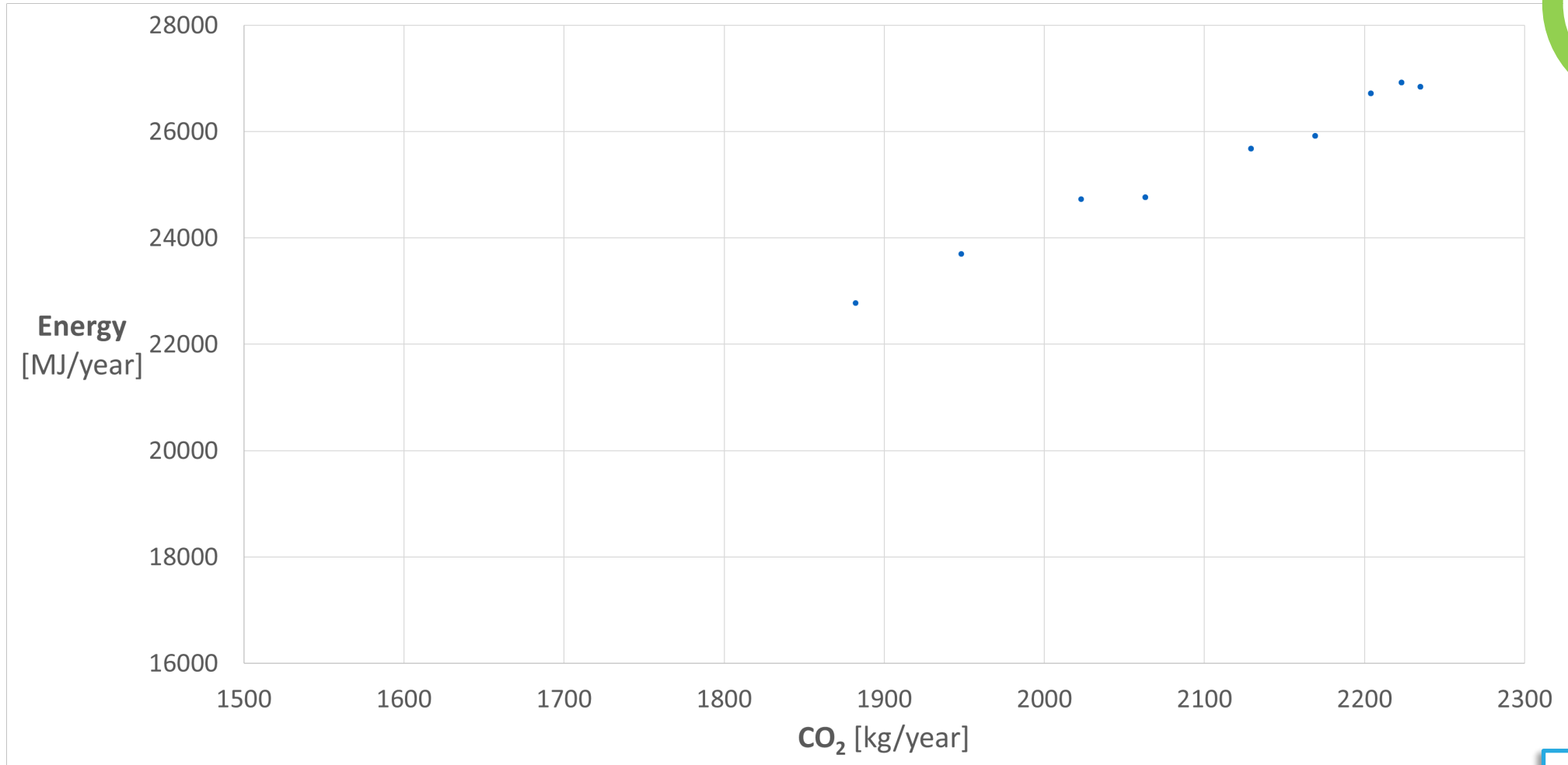
REMAINING MODELS



28 variations

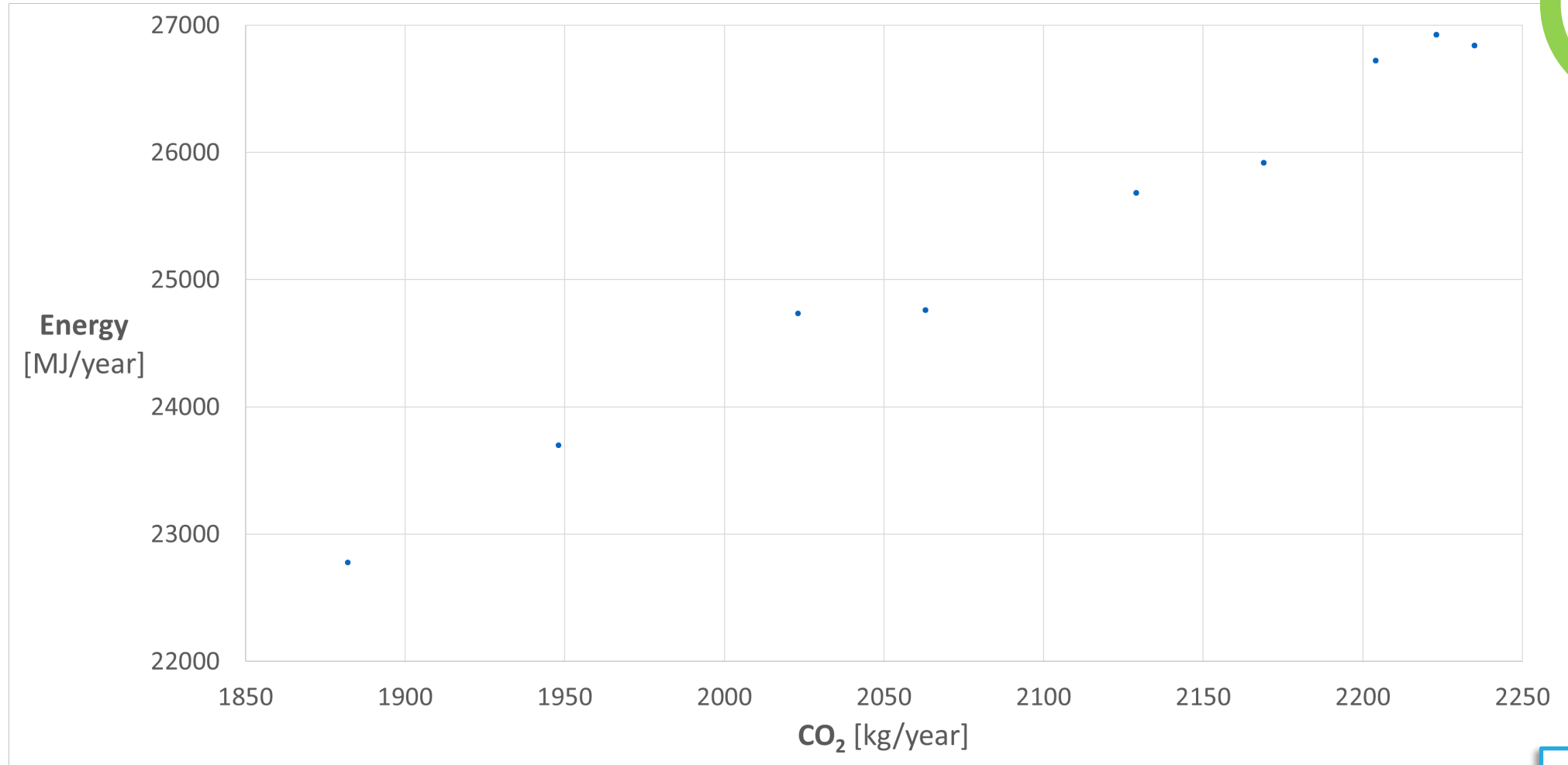


13 variations

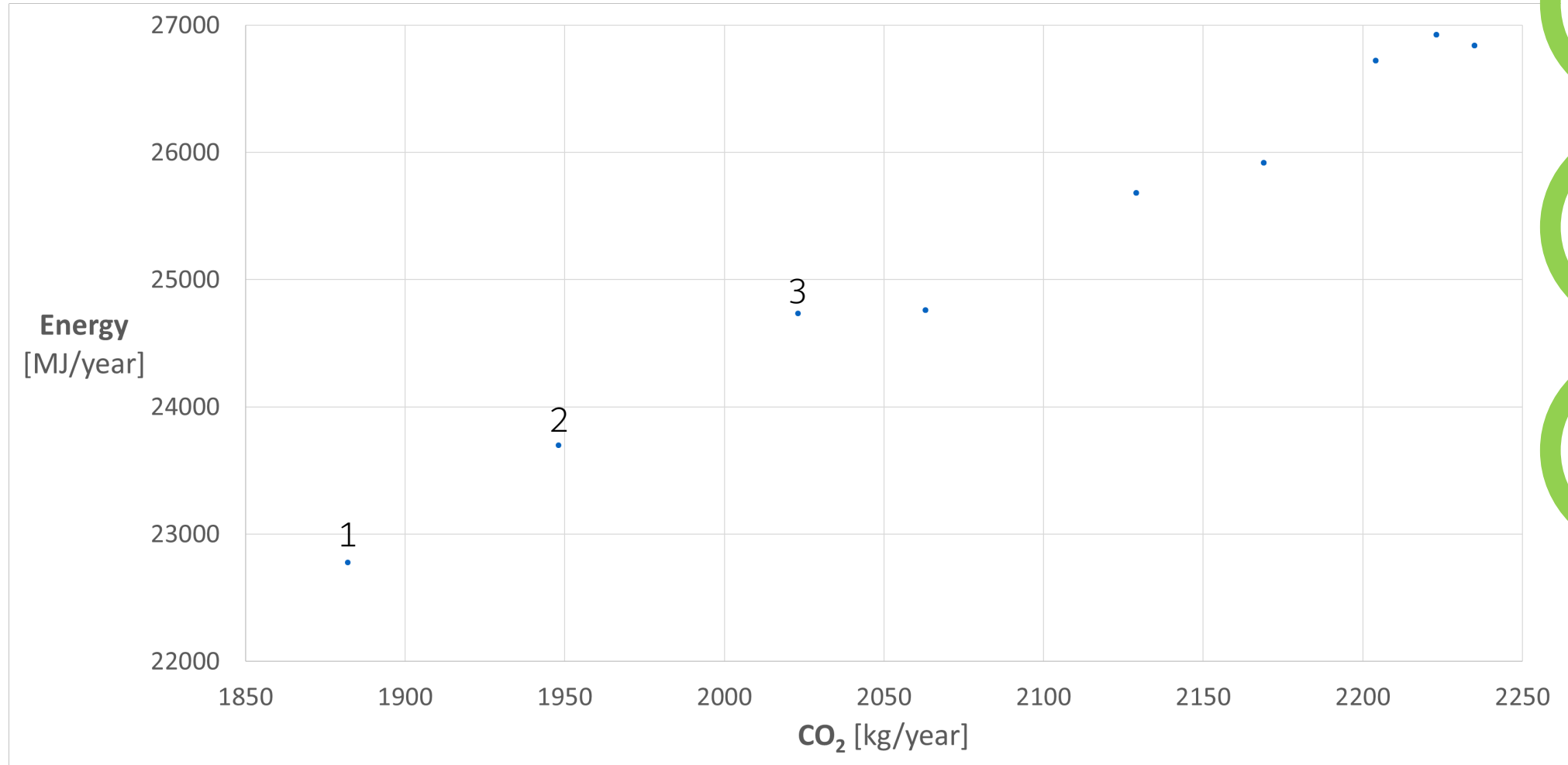


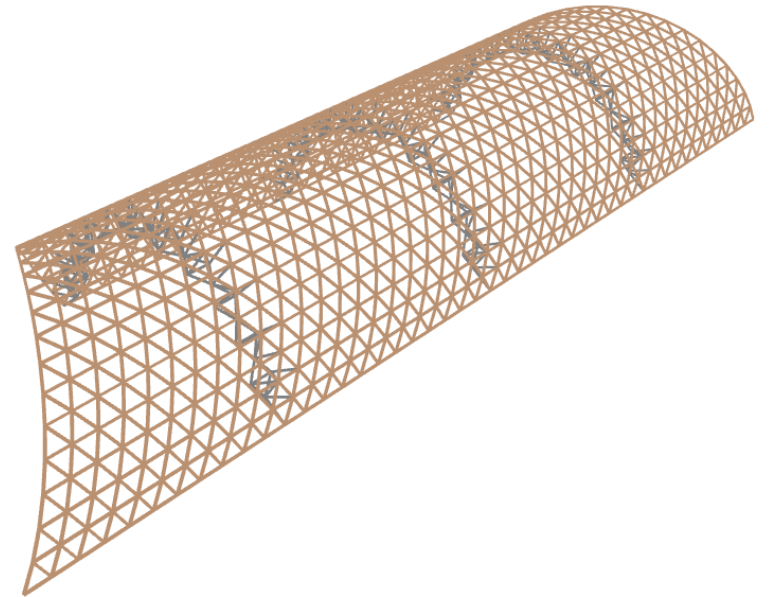
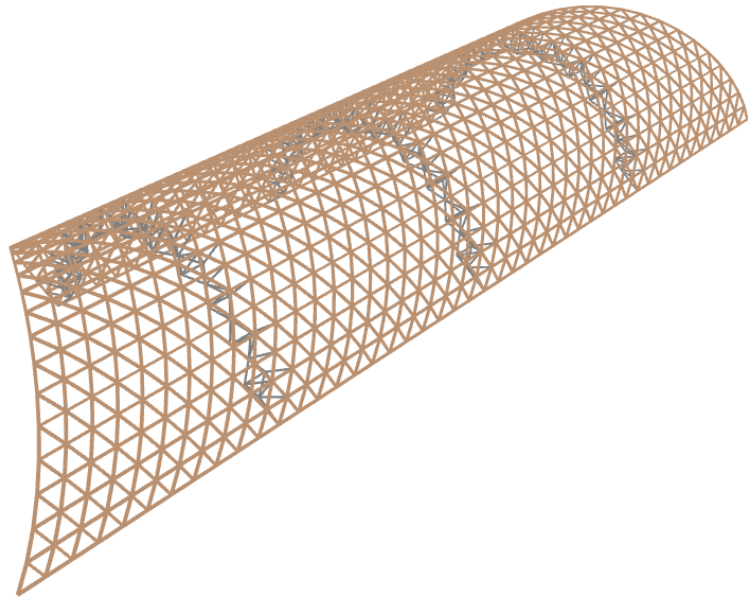
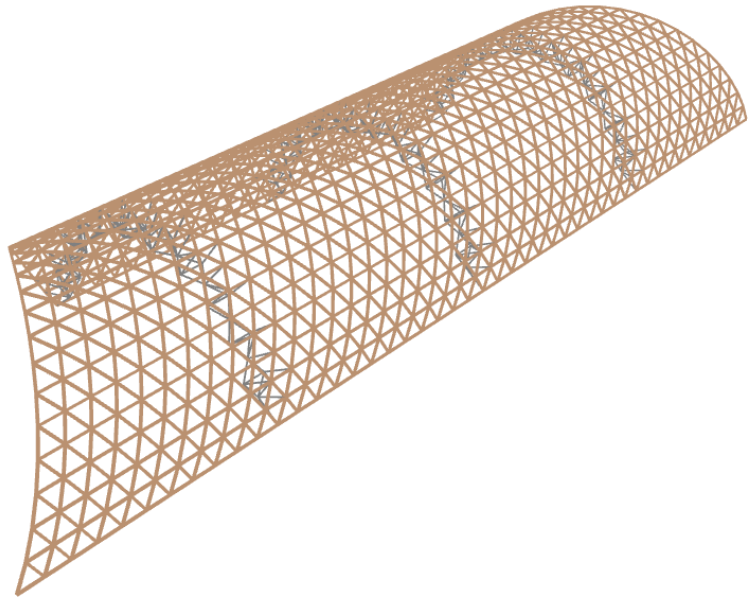
15 variations

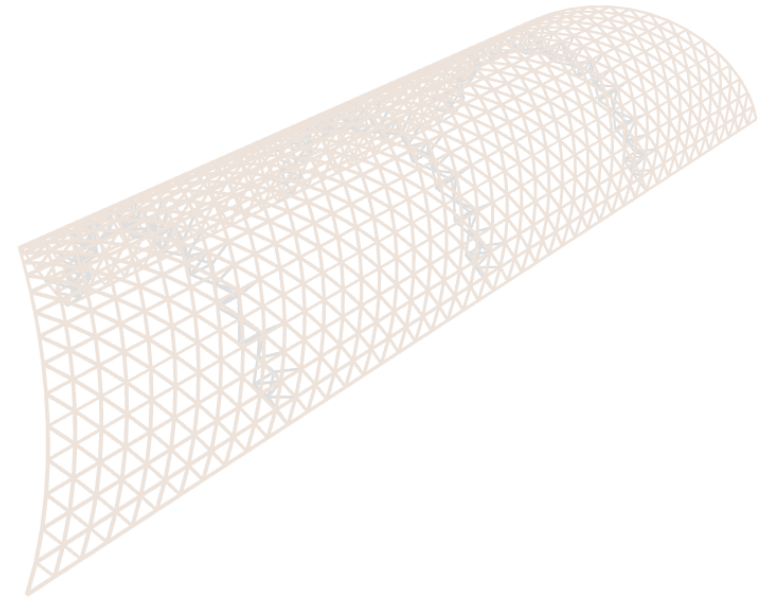
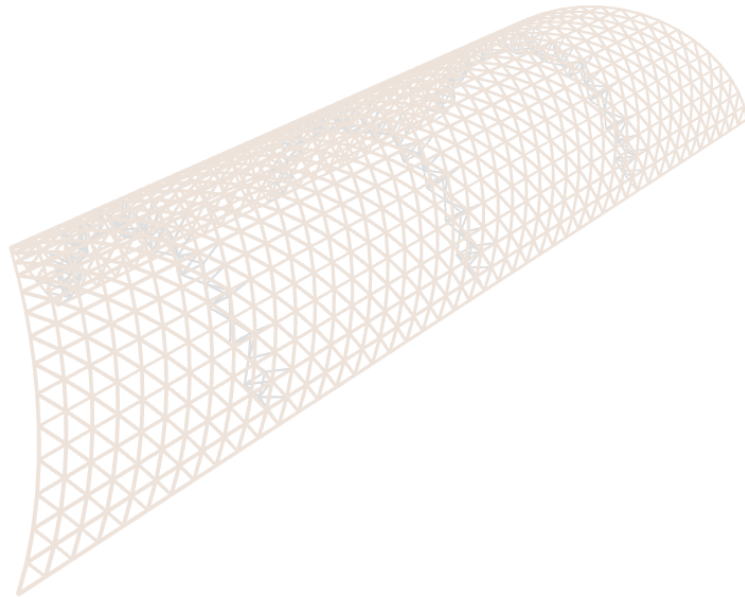
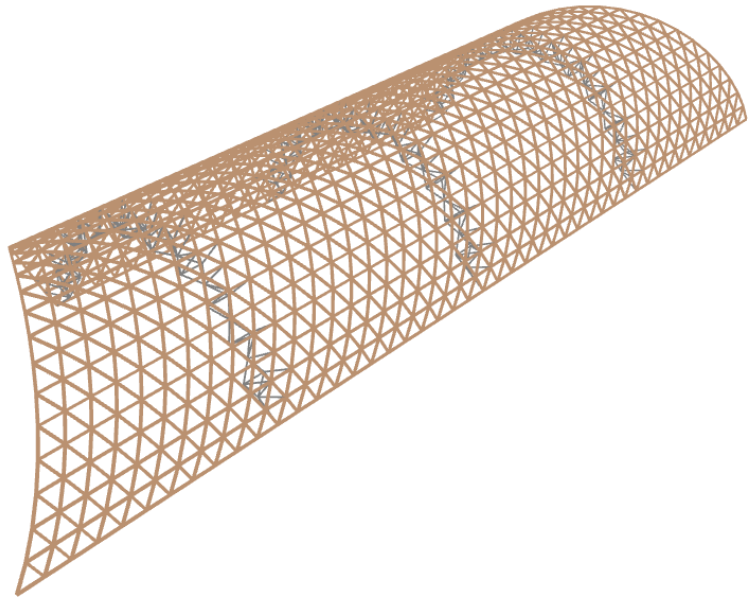
REMAINING MODELS

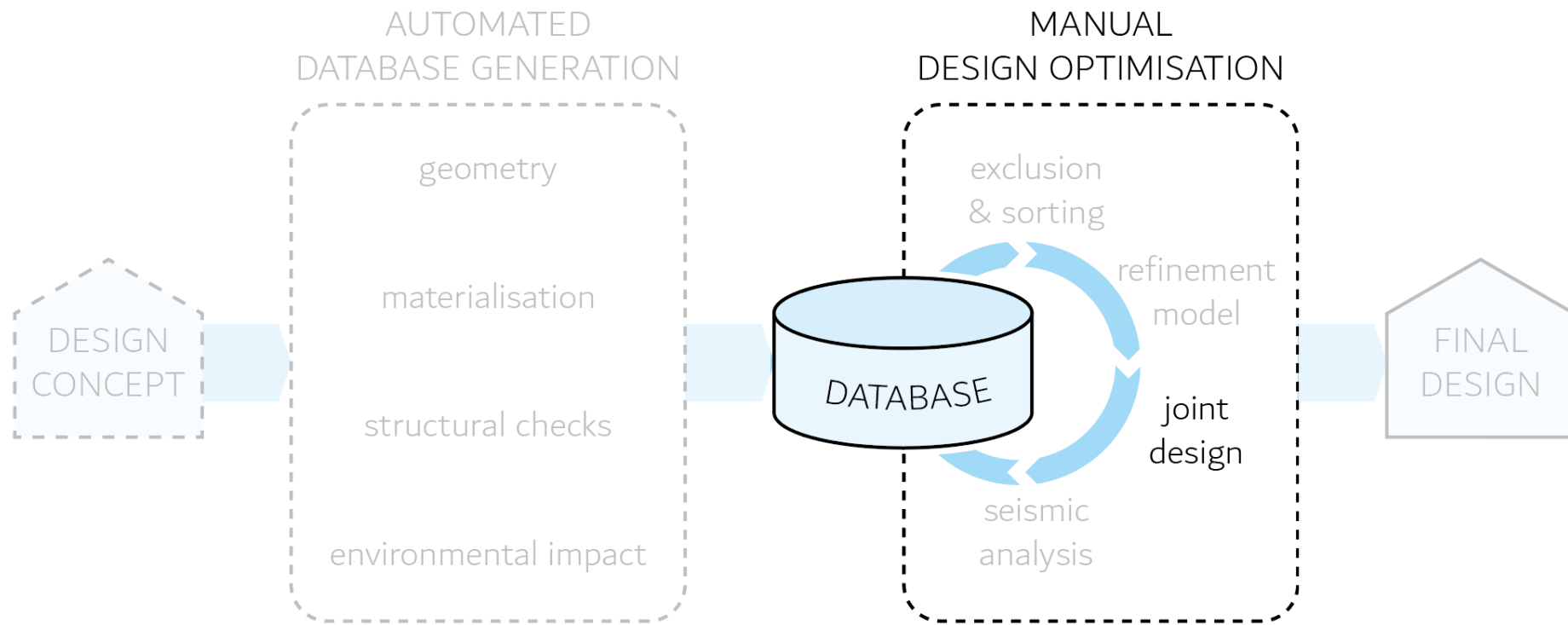


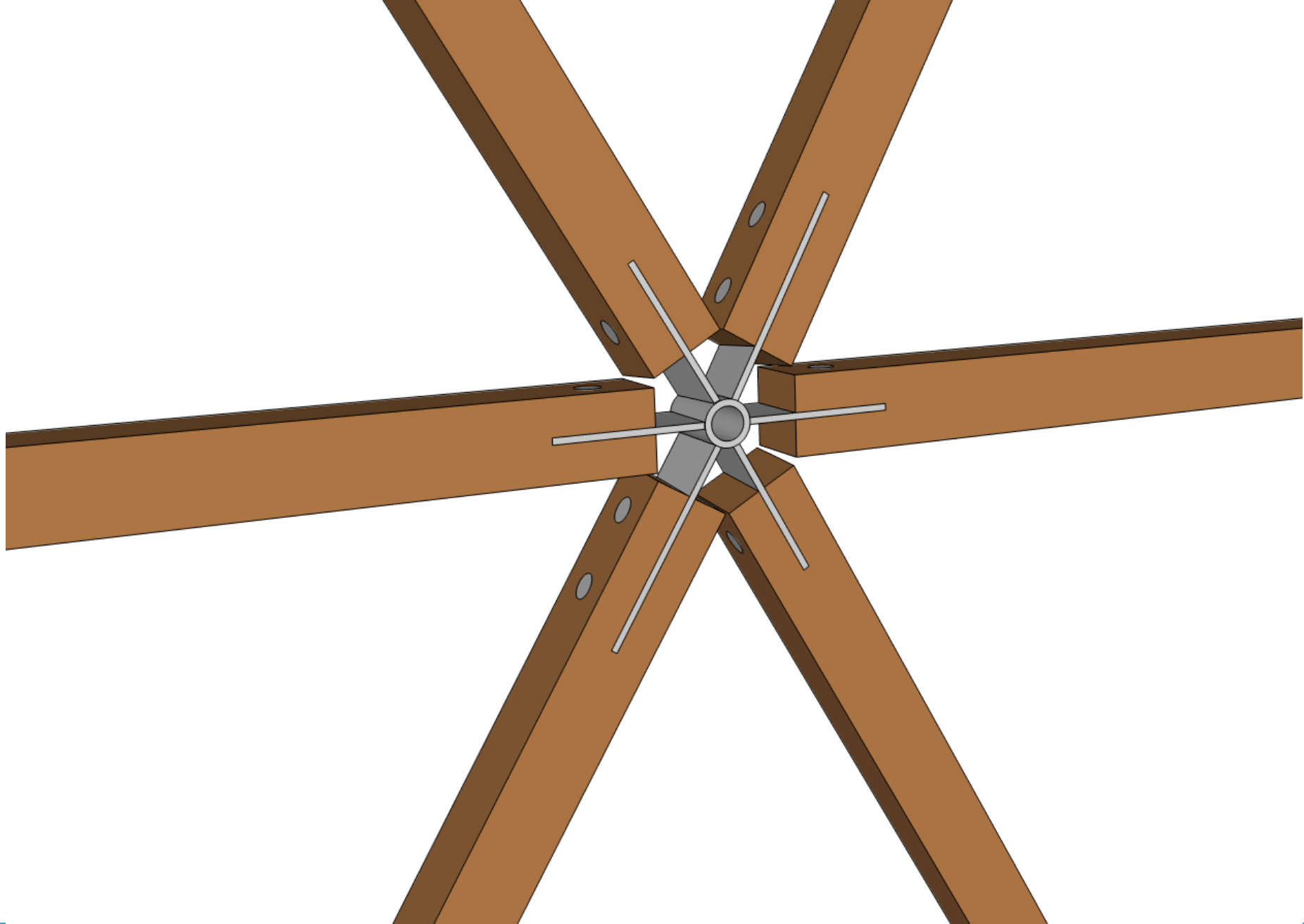
15 variations

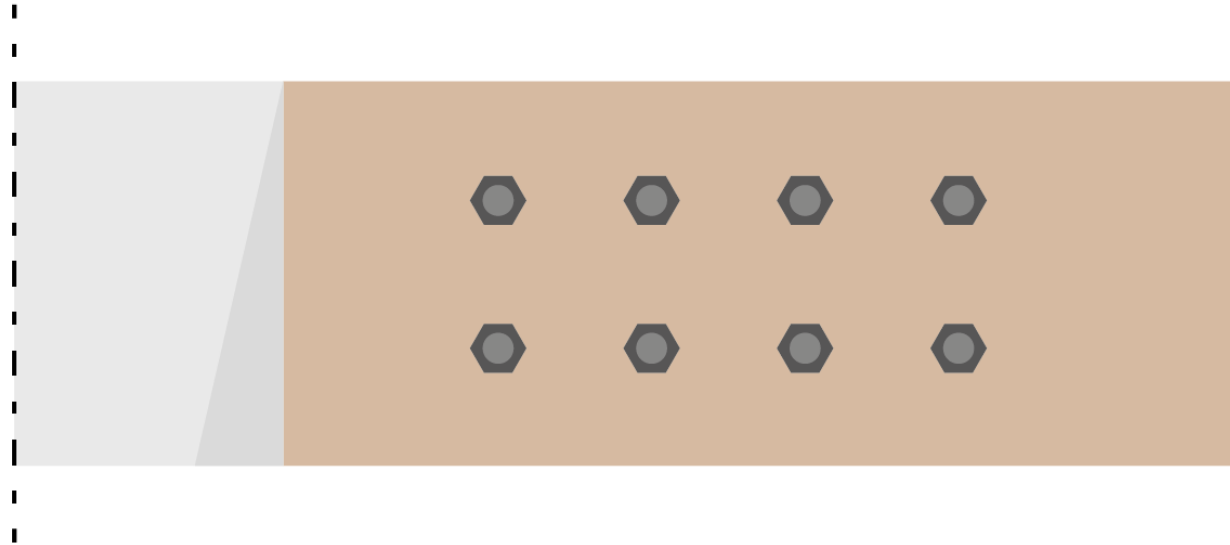




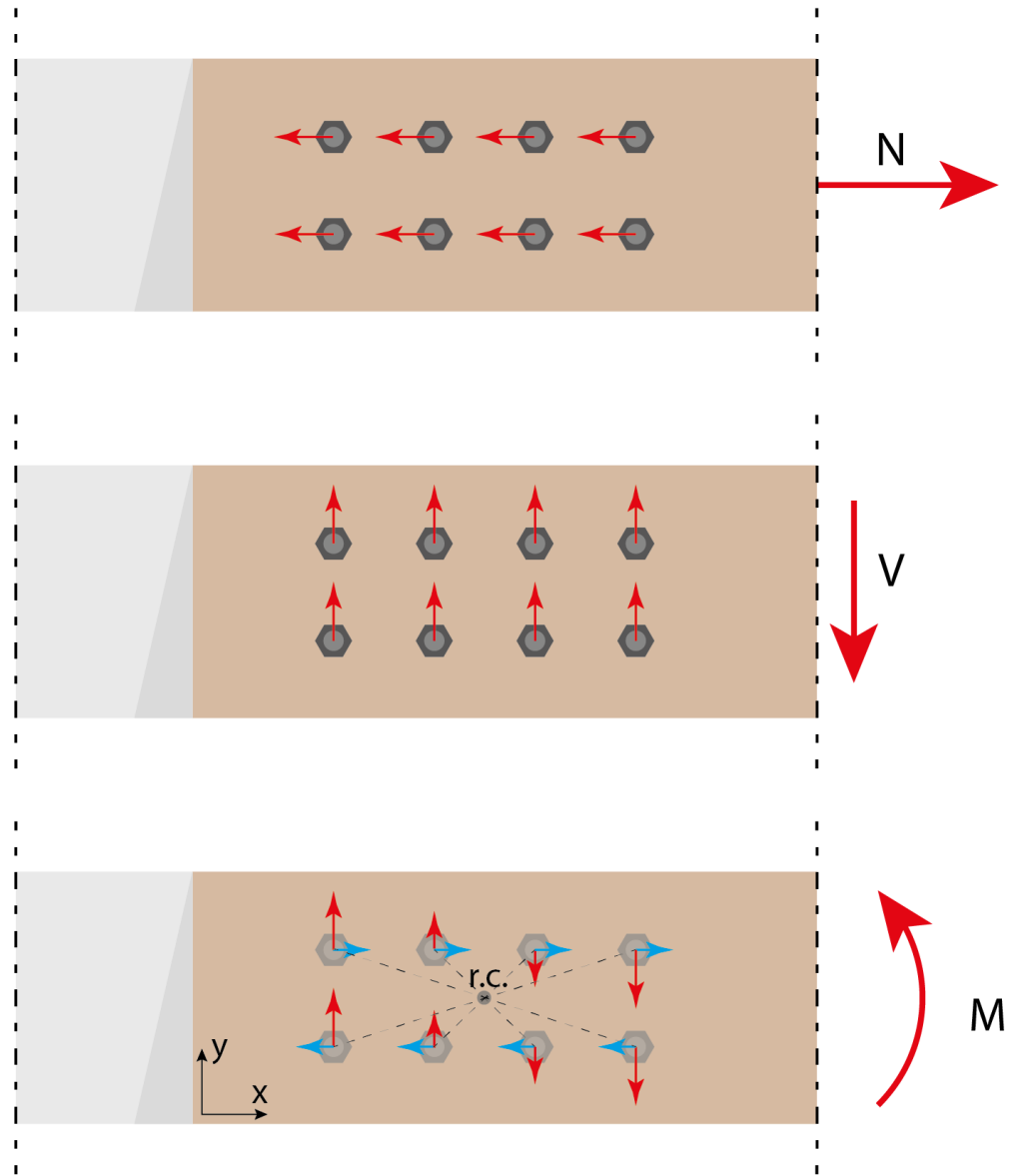






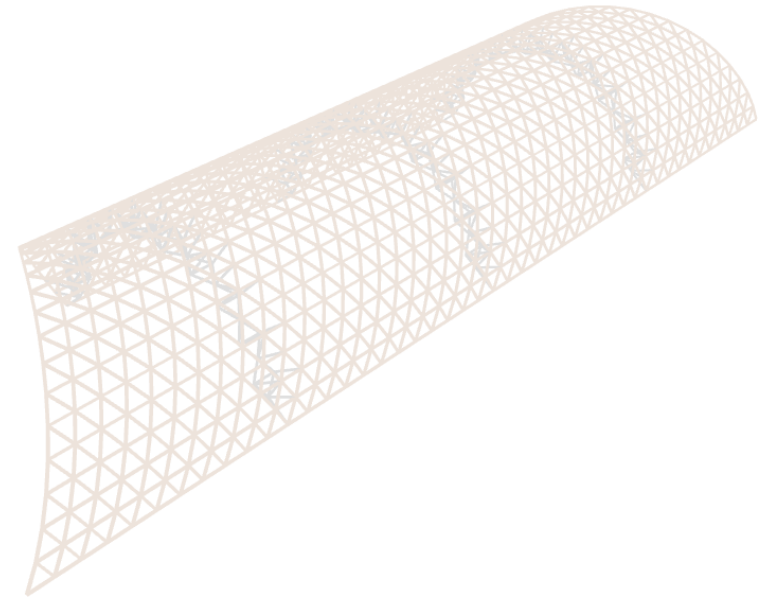
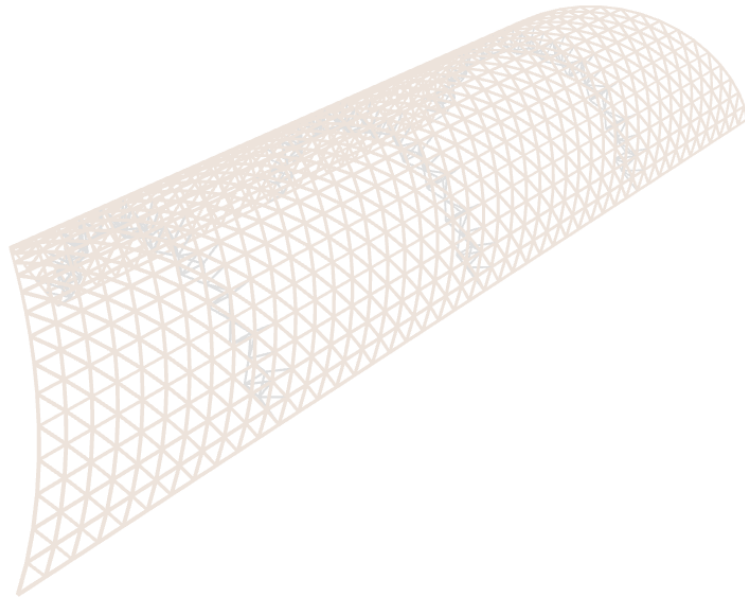
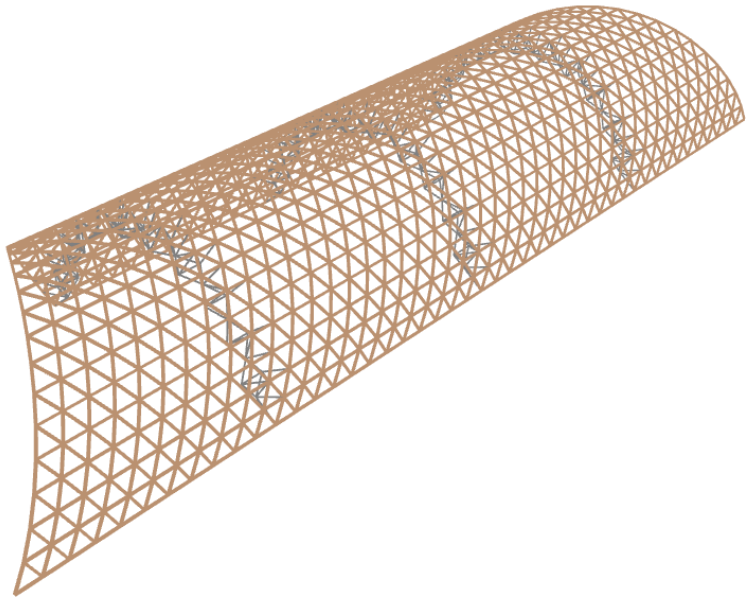


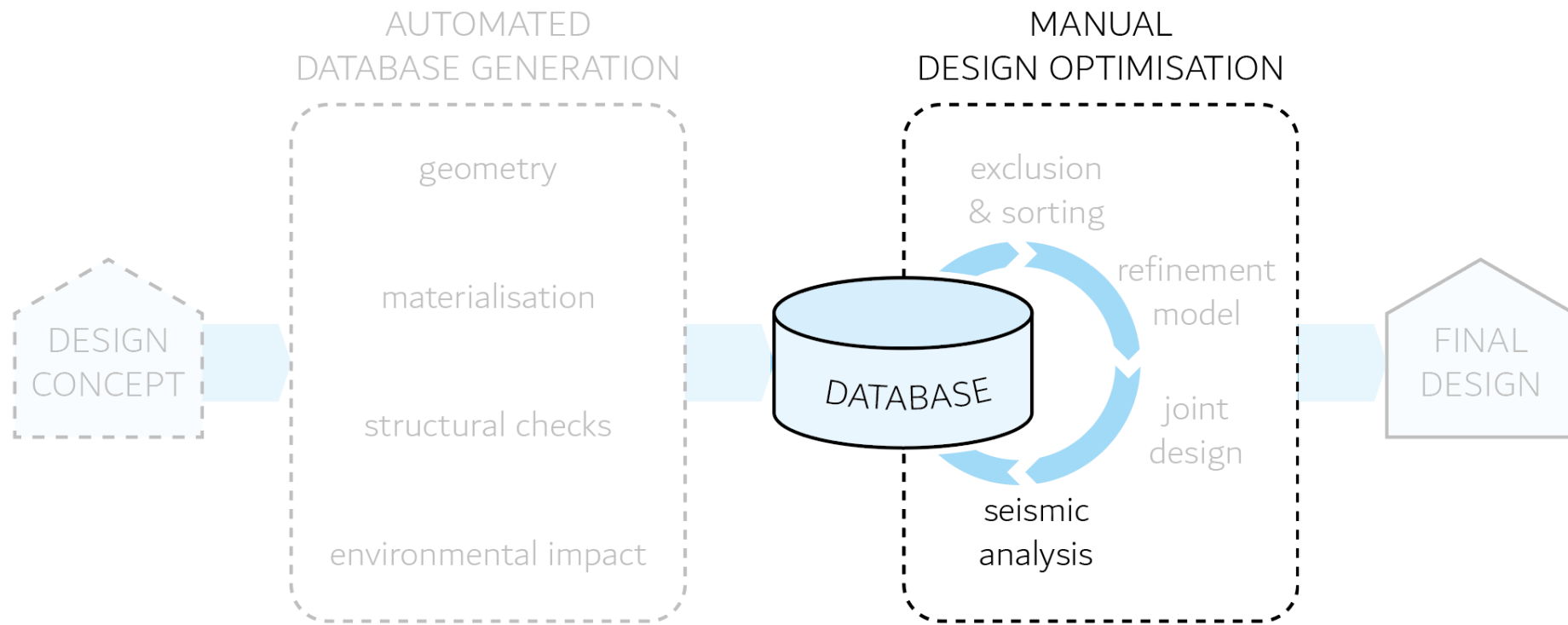
JOINT CHECKS



TOP 1

O.K.

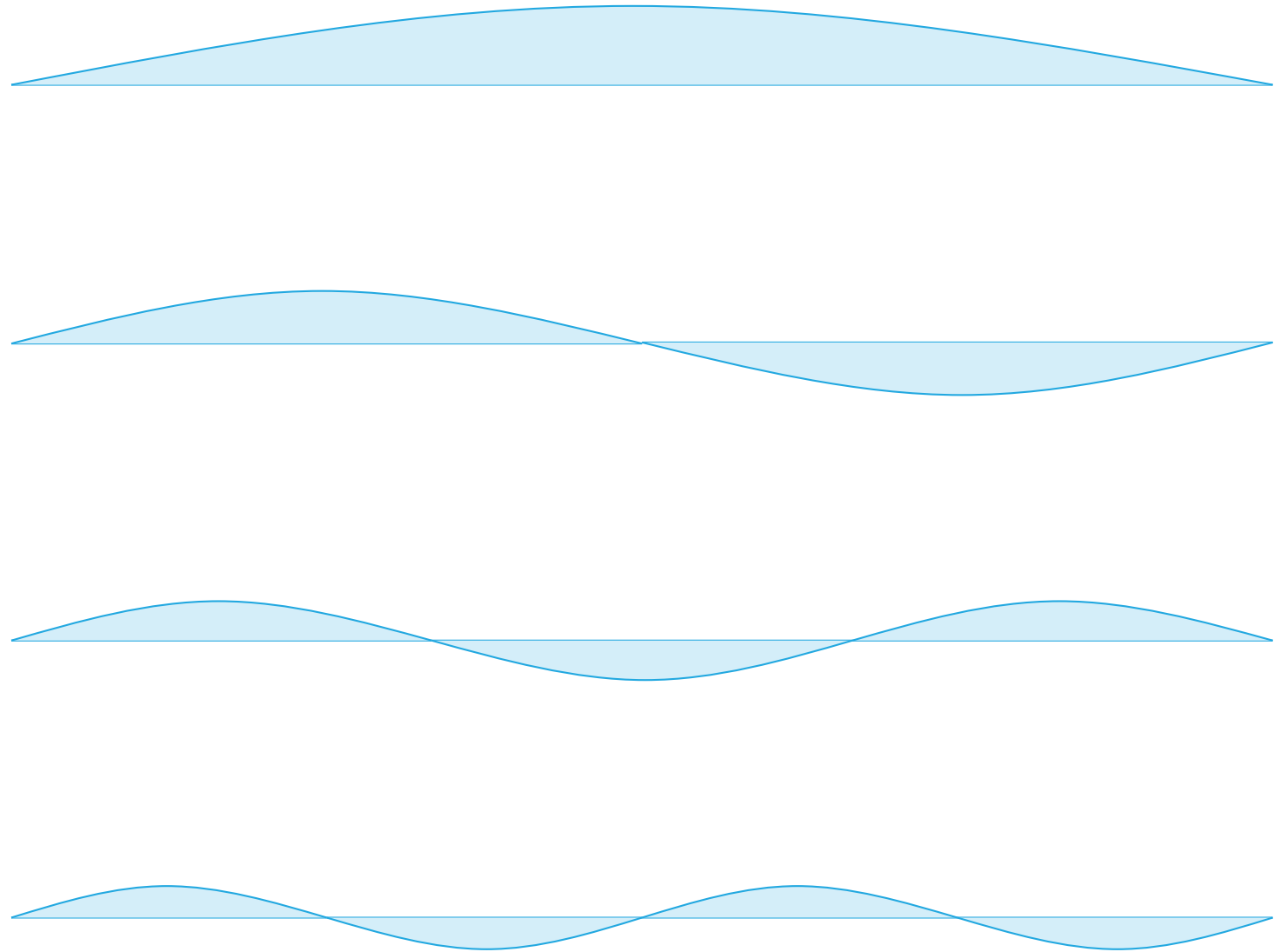


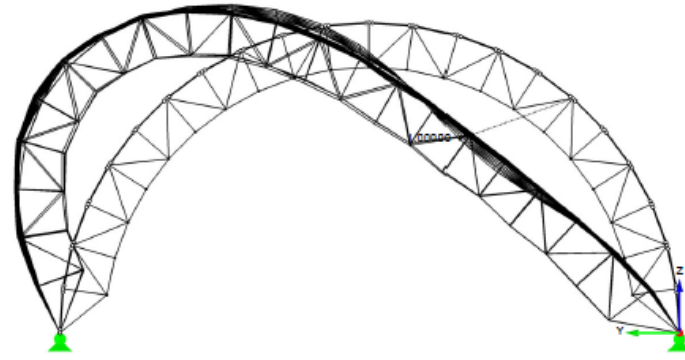


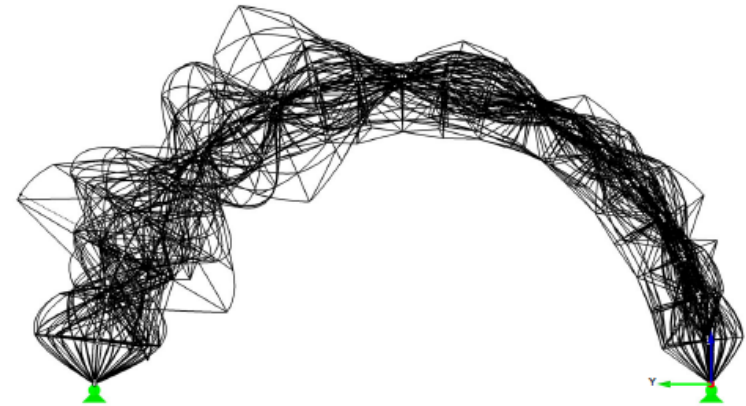
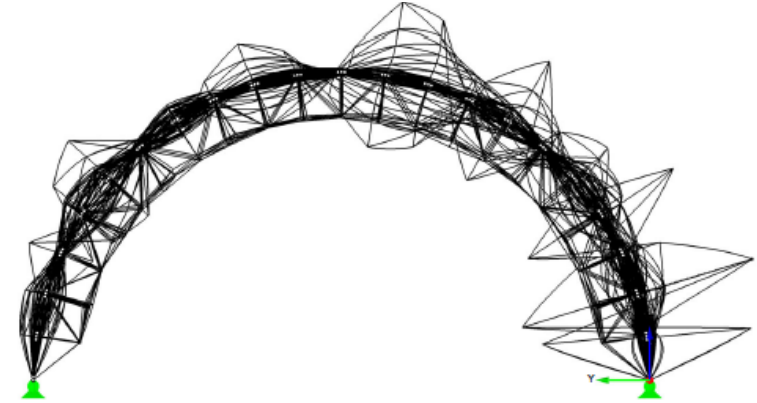
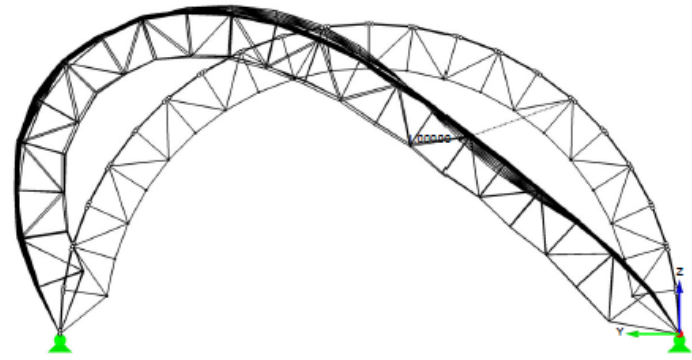


$$F = m \cdot a$$

force = mass · acceleration



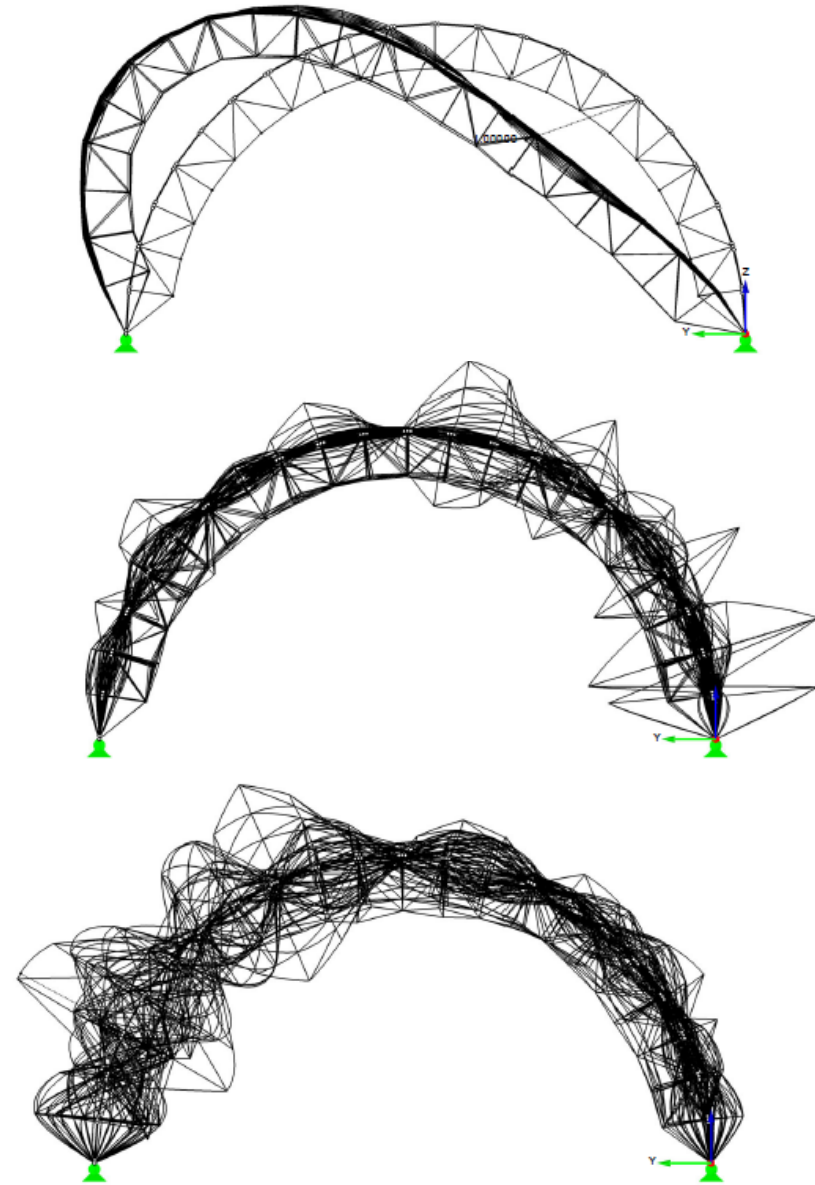
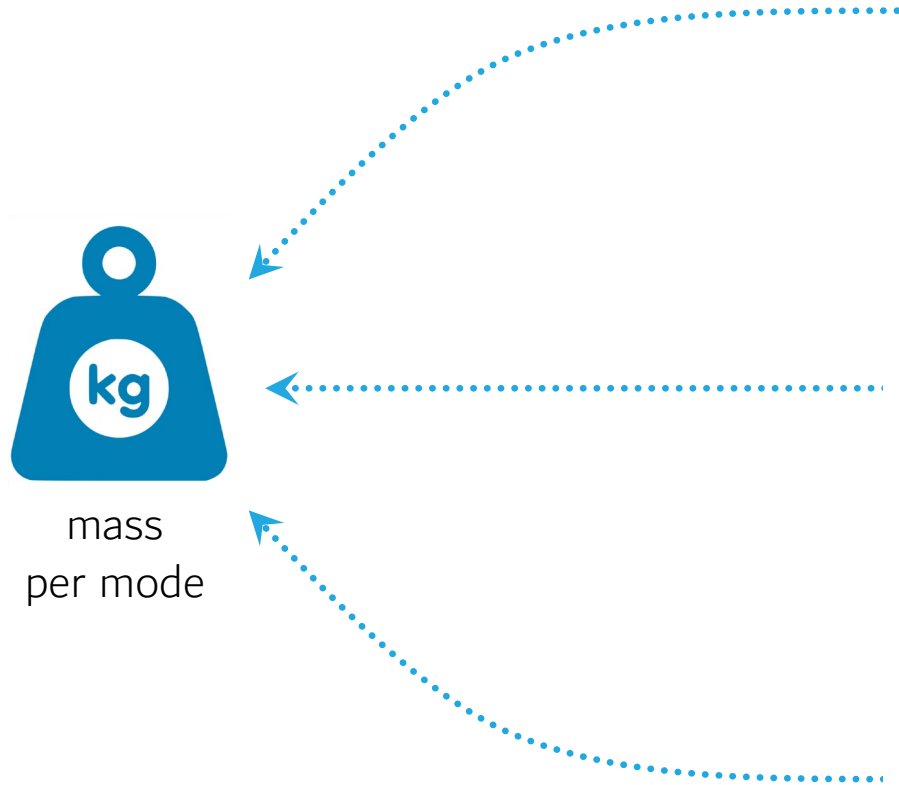






$$F = m \cdot a$$

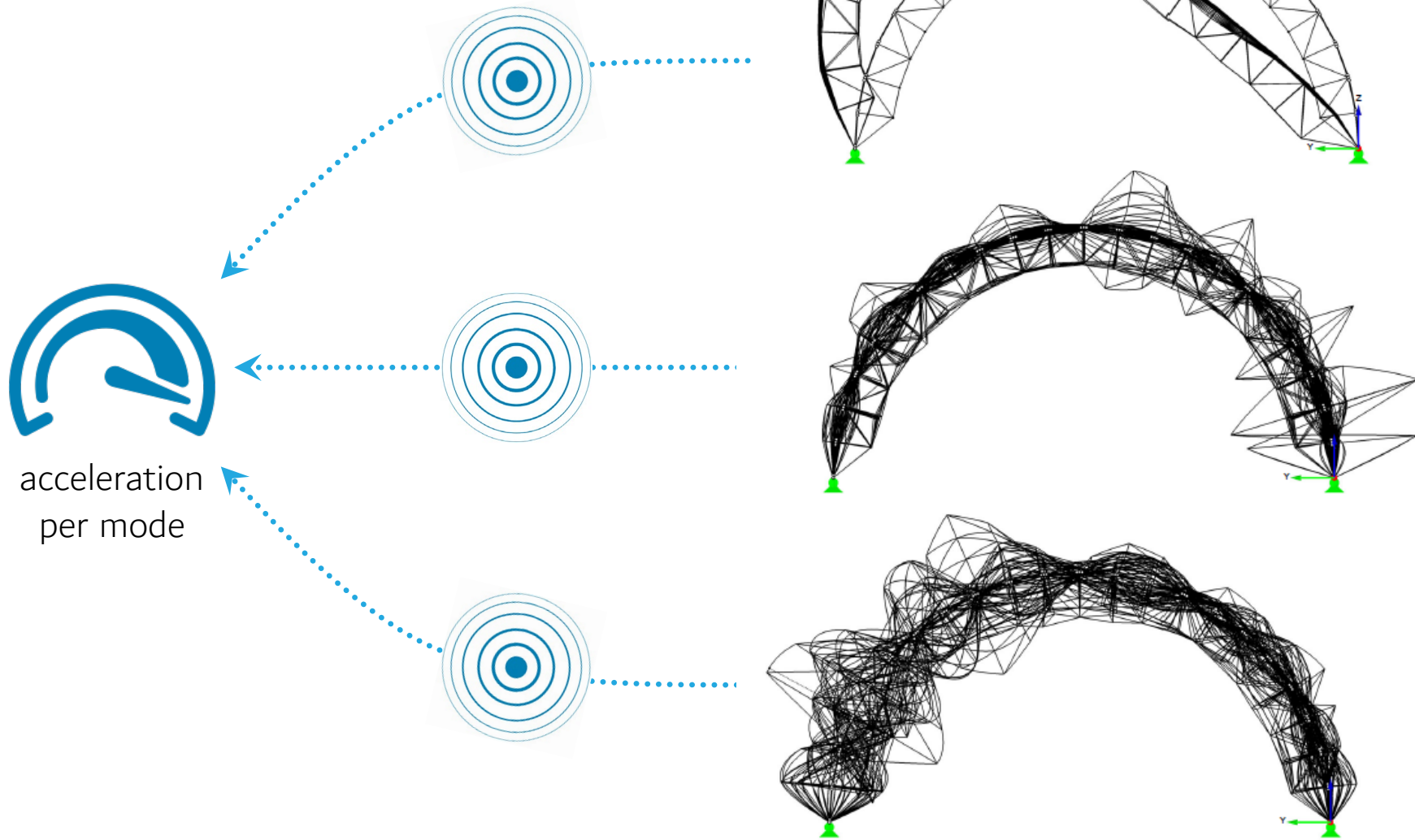
force = mass · acceleration





$$F = m \cdot a$$

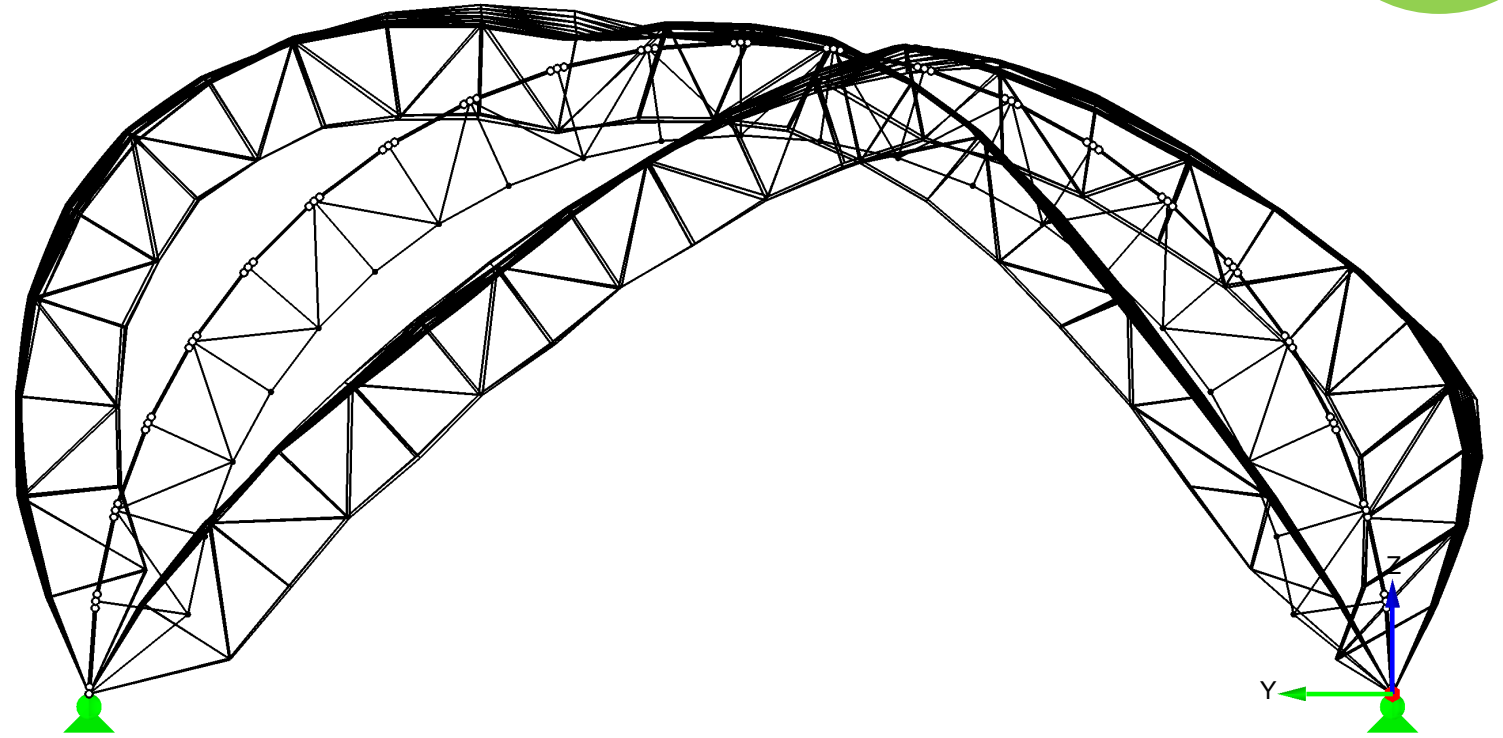
force = mass · acceleration





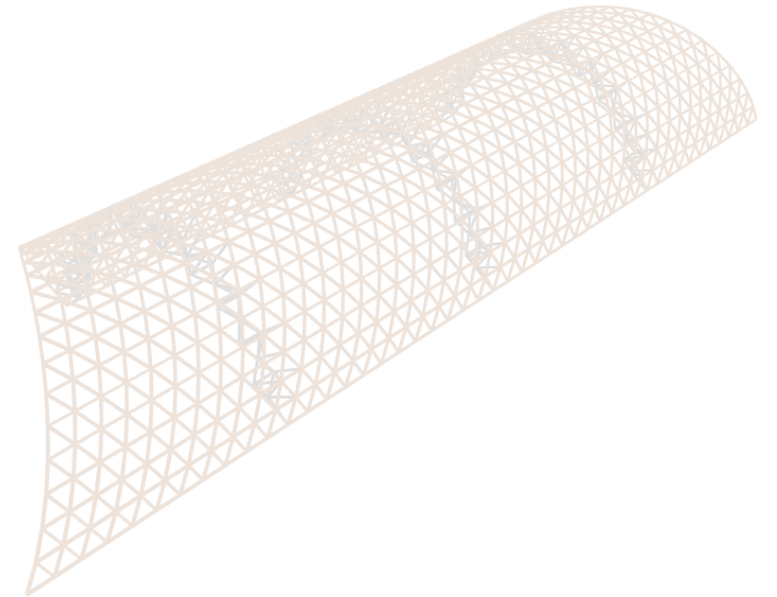
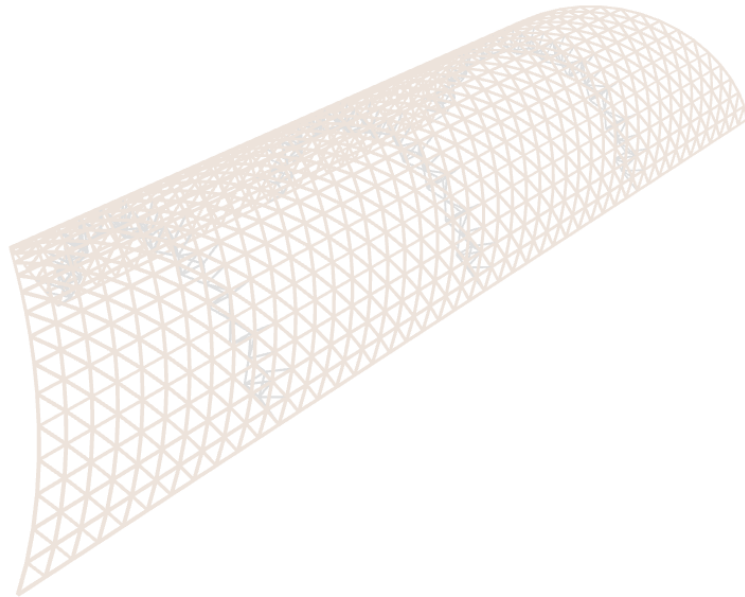
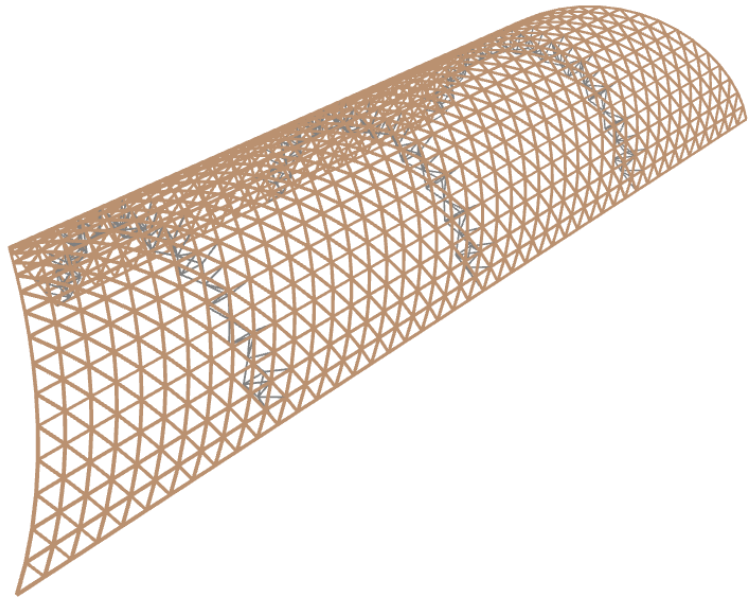
$$F = m \cdot a$$

force = mass · acceleration

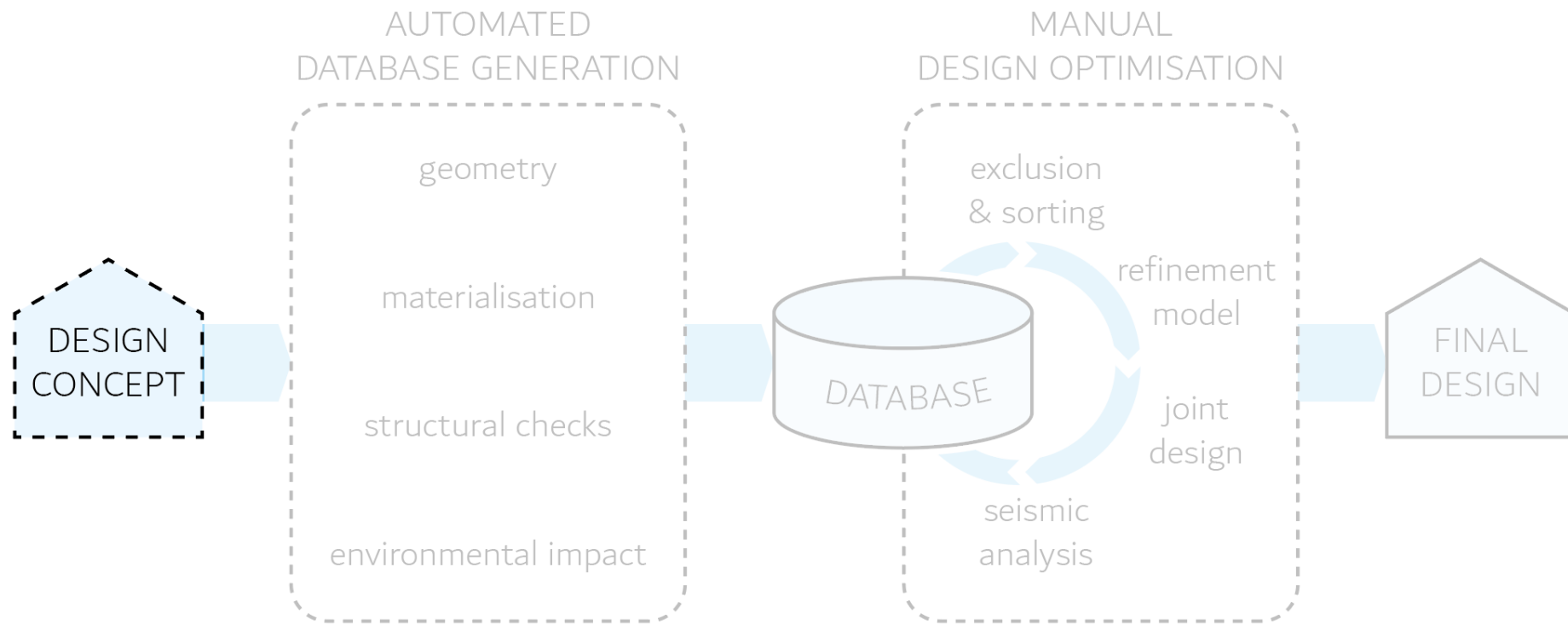


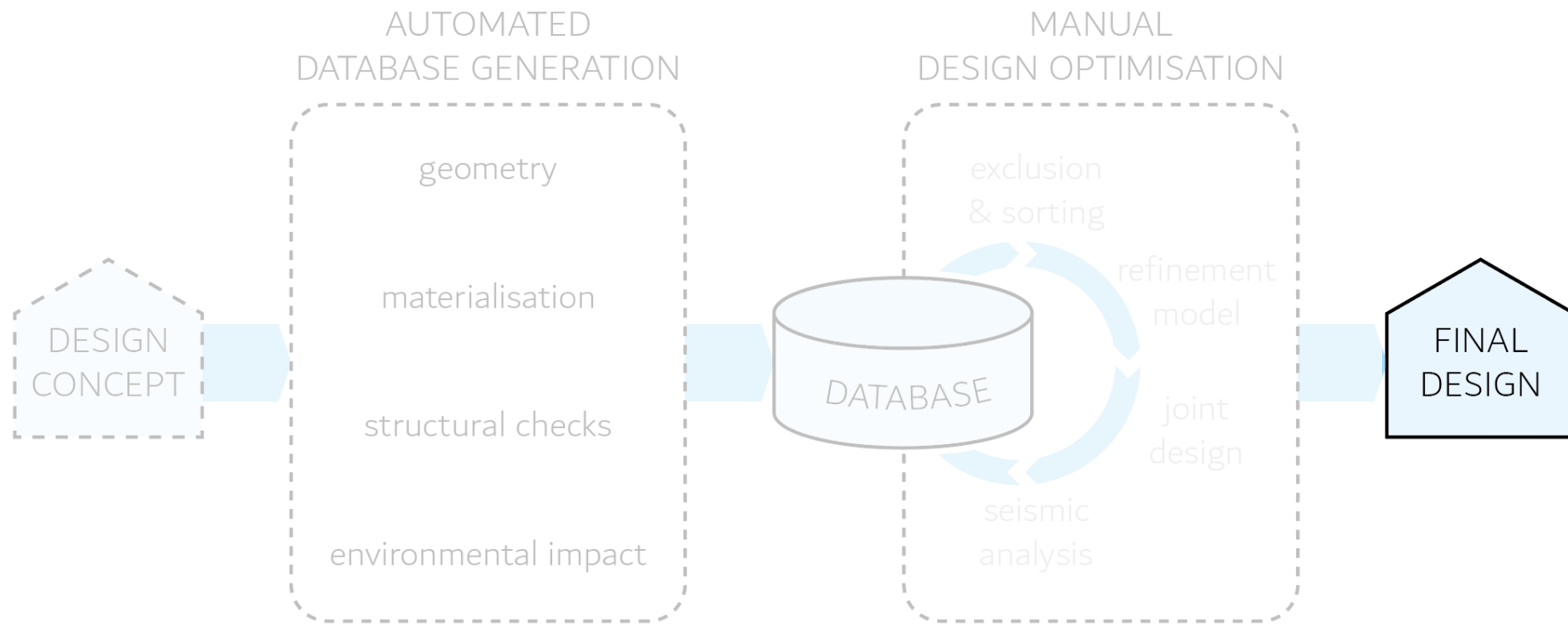
TOP 1

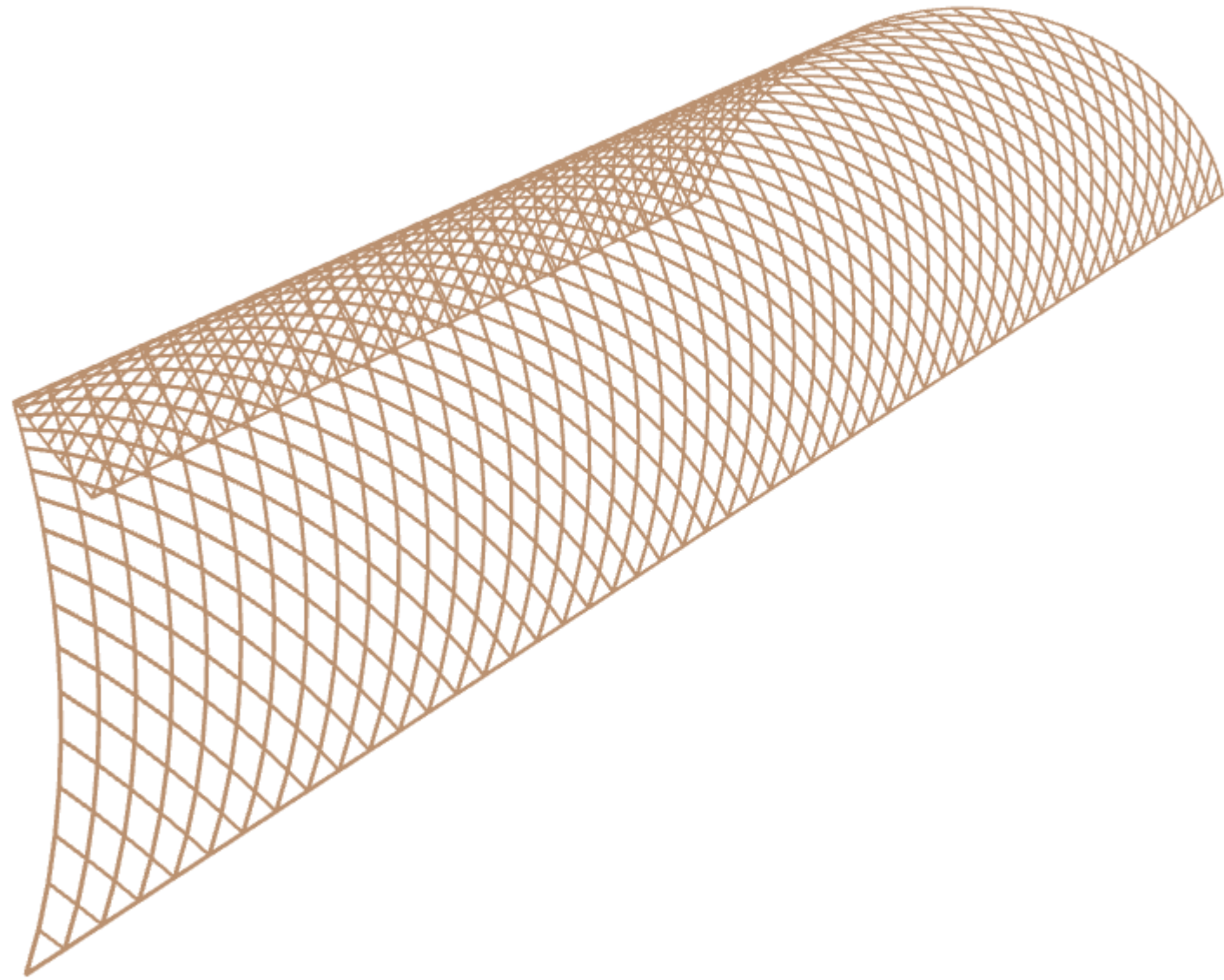
O.K.

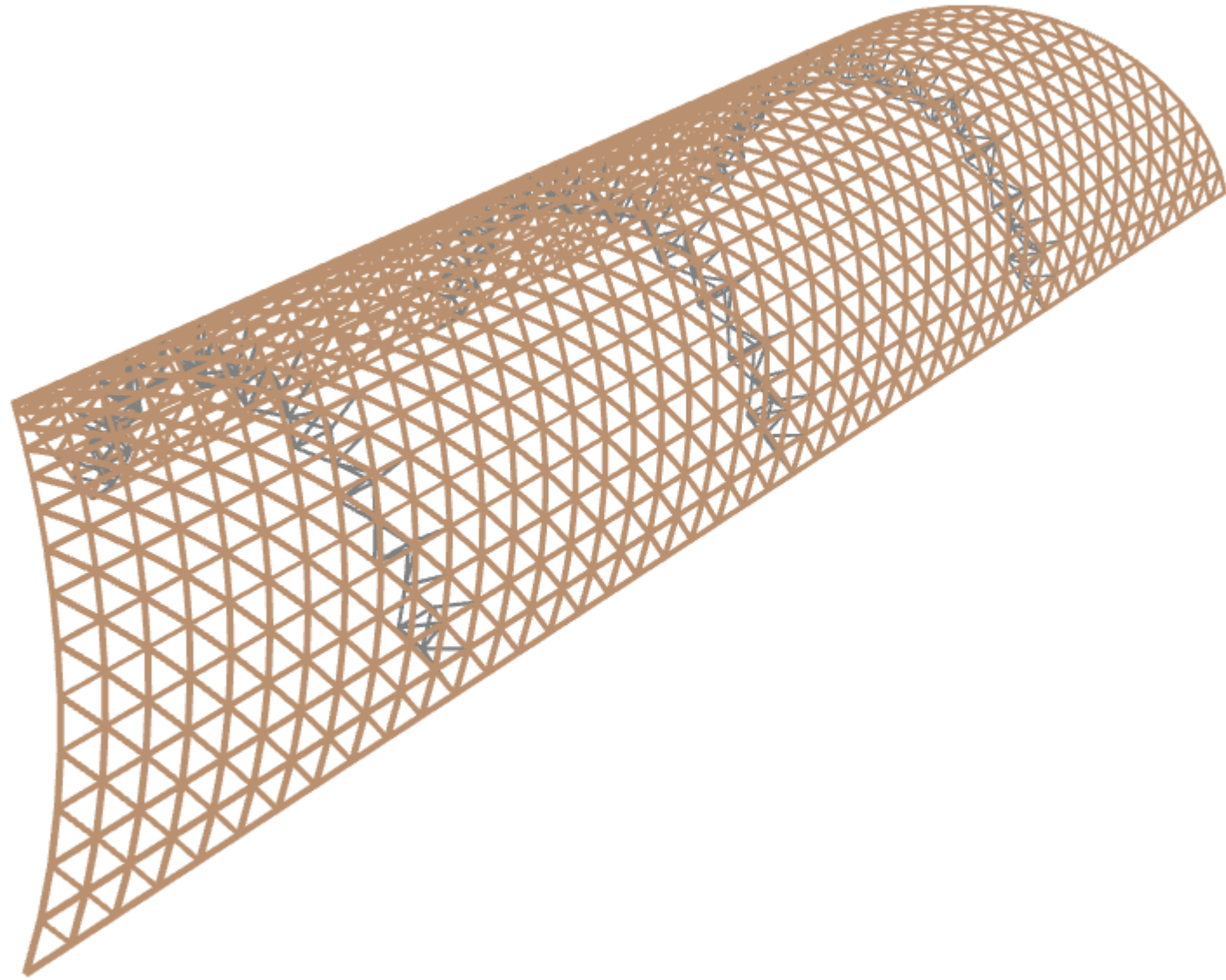


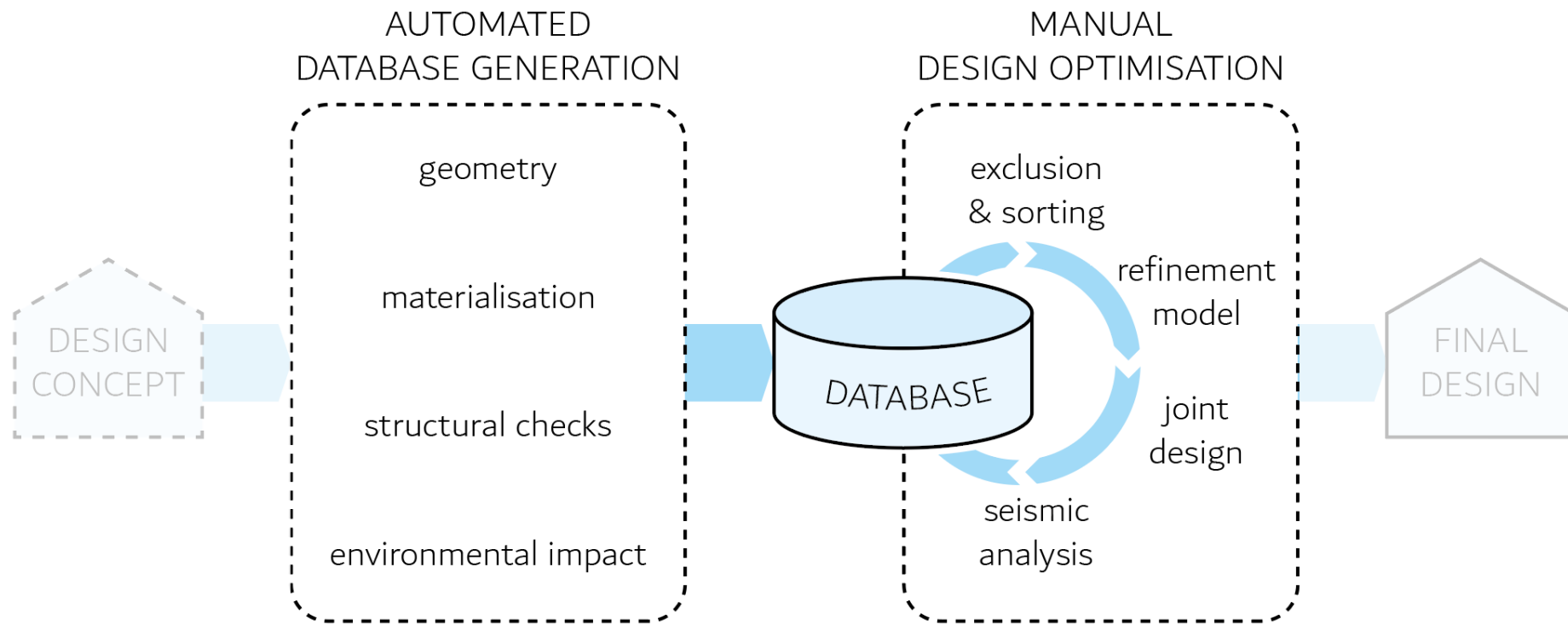
CONCLUSION











structural
validity



sustainability



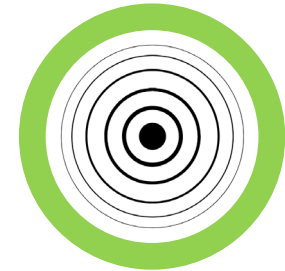
aesthetics

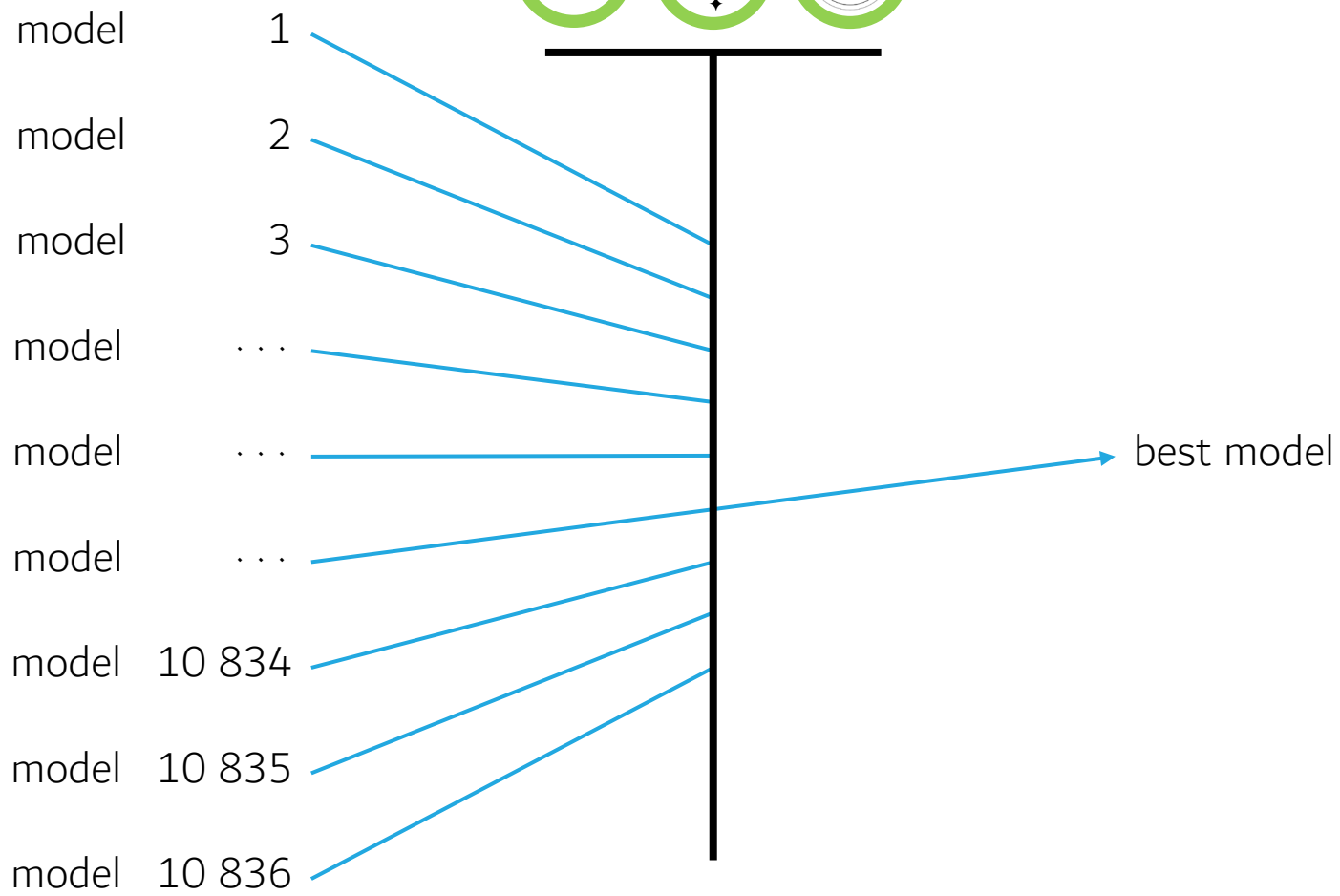


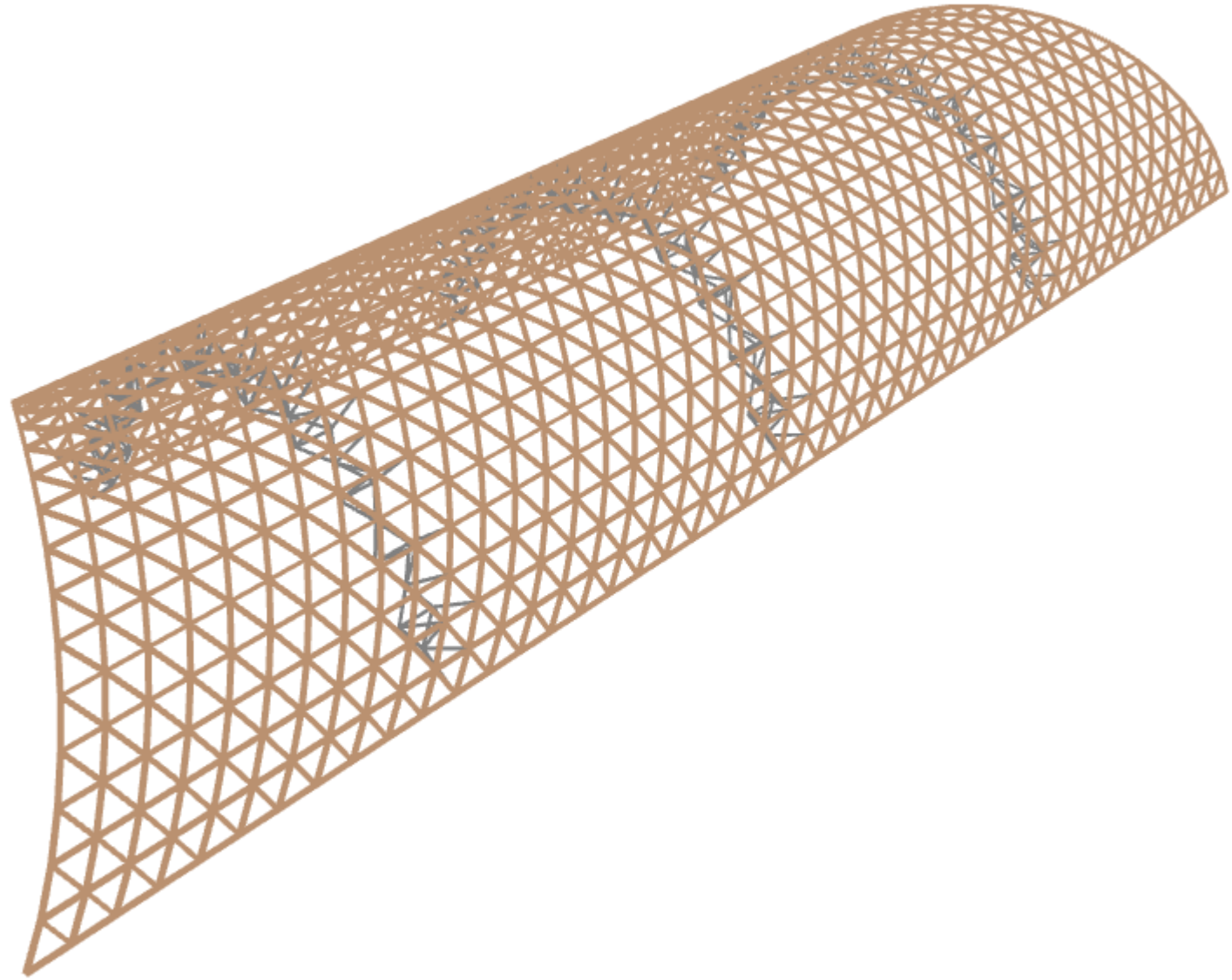
constructability



seismic
resistance







THE END