The Green Ribbon
of
Corn Street, Bristol, UK

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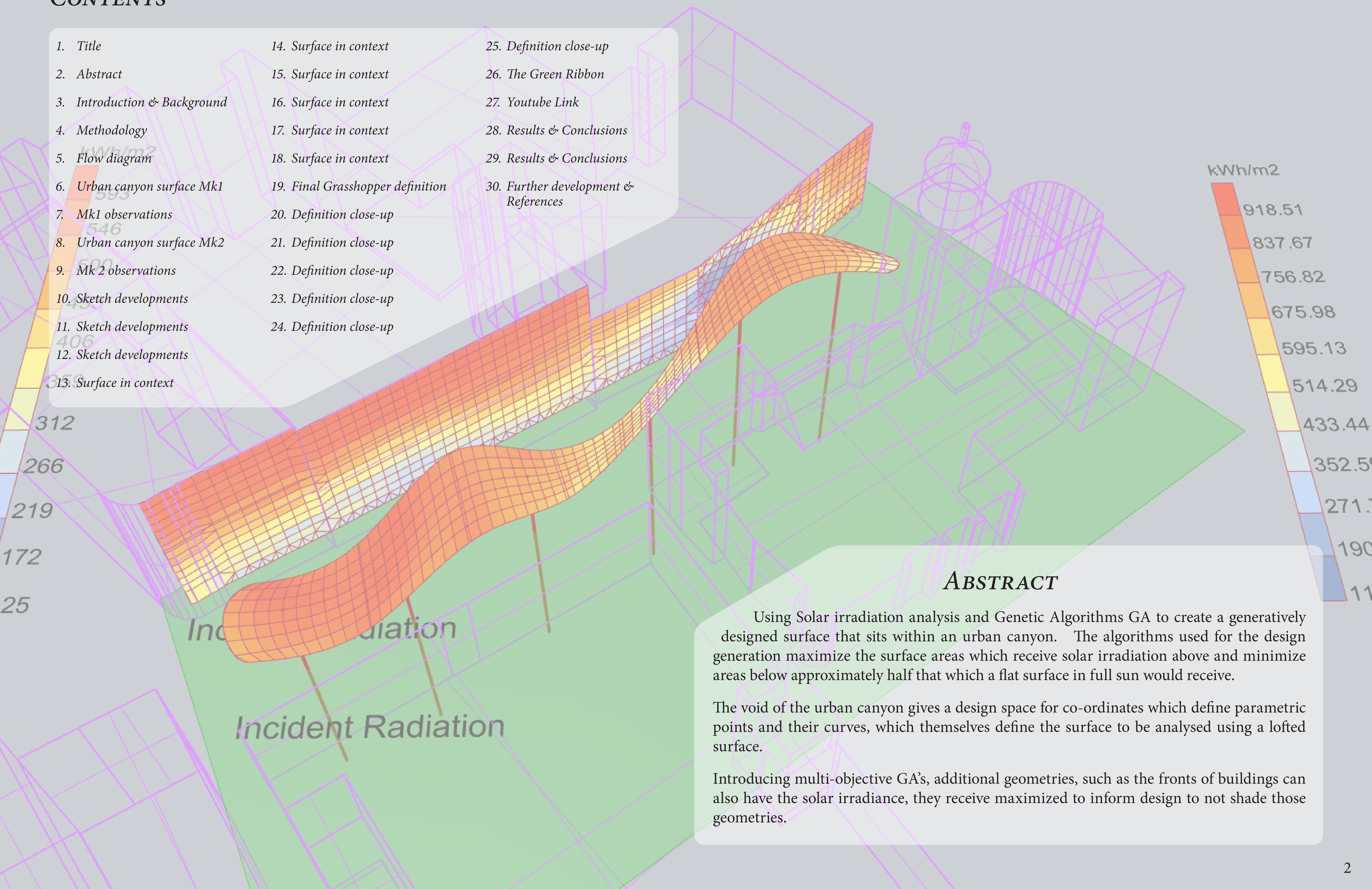
13022456

Contents



Abstract

Using Solar irradiation analysis and Genetic Algorithms GA to create a generatively designed surface that sits within an urban canyon. The algorithms used for the design generation maximize the surface areas which receive solar irradiation above and minimize areas below approximately half that which a flat surface in full sun would receive.

The void of the urban canyon gives a design space for co-ordinates which define parametric points and their curves, which themselves define the surface to be analysed using a lofted surface.

Introducing multi-objective GA's, additional geometries, such as the fronts of buildings can also have the solar irradiance, they receive maximized to inform design to not shade those geometries.

Introduction

Green infrastructure is nothing new, the presence of plant life in our urban environment is understood to benefit our long-term health and well-being (Mardaljevic, 2021). It can also; reduce the effect of greenhouse gases, provide thermal comfort and reduce energy use (Fu et al., 2022).

However, the amount of green infrastructure there is in our urban environment is limited by restrictions of the urban landscape. Regarding the effect of global warming and increasing extreme heat events, optimising urban green infrastructure is increasingly important. (Fu et al., 2022).

Background

Existing urban green infrastructure such as Trees can take many years to mature and require relatively substantial earth works. Green walls often require retrofitting to existing buildings. Both have their complexities and constraints which we could optimize within.

Plants can be trained to grow into architectural forms. Trees can be pleached to form screens and climbing plants grow on structure to envelop its form.

Understanding this a computationally designed structure or pergola could be optimised for highly productive plant growth, maximizing the urban green infrastructure of a space and minimizing physical disturbance to the existing urban fabric.

(Burohappold)

(Remodelista, LLC)

(Crown Topiary)

(Architectural Digest.)

(Angi)

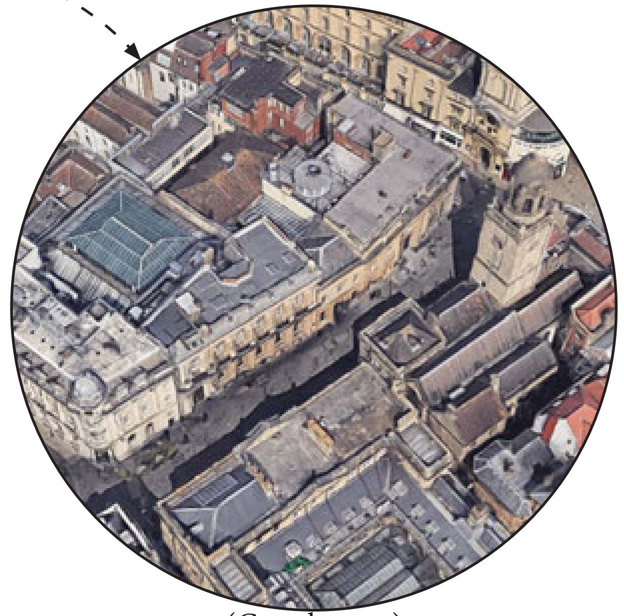
Methodology

Aims

- Develop a computational model that grows a surface which maximizes solar exposure above a threshold within an urban canyon.
- This model could be applied to any site, for this case study it will use Corn Street, Bristol, UK. A pedestrianised street within the old city boundary which runs approximately SW to NE.

To grow a surface within an urban canyon, a lofted surface can be deployed using a series of control curves.

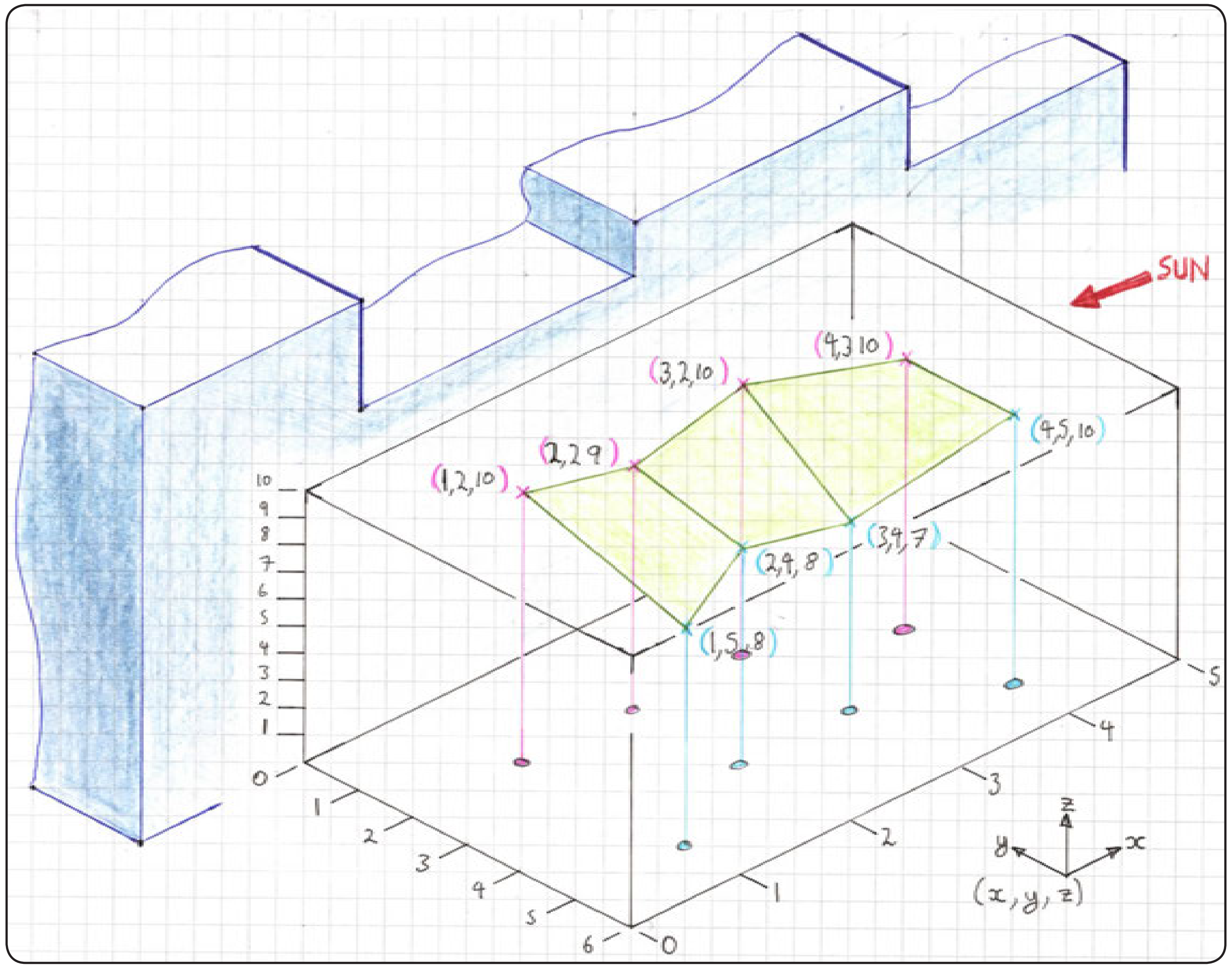

(OpenStreetMap)


(Google.com)

Straight line curves can be defined by a start and end point with their co-ordinates (x,y,z). If the urban canyon is a defined volume, the start and end points can be anywhere within this domain. Creating a surface from these curves, we can run analysis using LadyBug for solar irradiance received by the surface during the growing season (April – October). From Lady Bug analysis, full sun for a flat surface on Corn Street for the year is 1009 kWh/m2 and for the period observed is 838 kWh/m2. Roofs on Corn Street have an Insolation value of around kWh 950 (Open Data Bristol) which validates the LadyBug analysis.

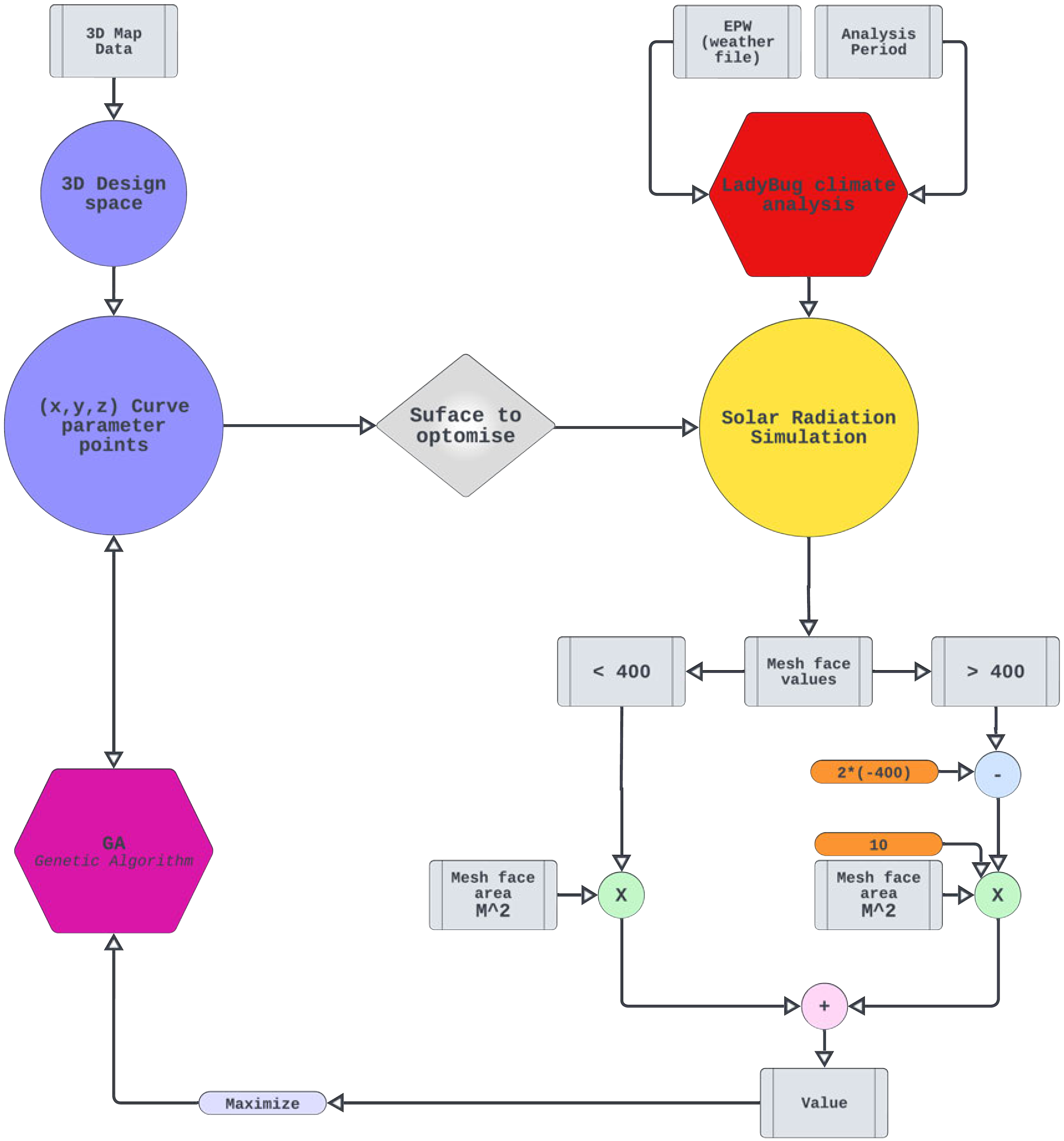
Understanding these values, we can target a value of 400 kWh/m2 which the generated surface should ideally receive as a minimum to allow for full sun to part shade plants to thrive.

A Genetic Algorithm can test and evolve surfaces based on the point co-ordinates in order to reach a maximum total value of solar irradiance across its area.

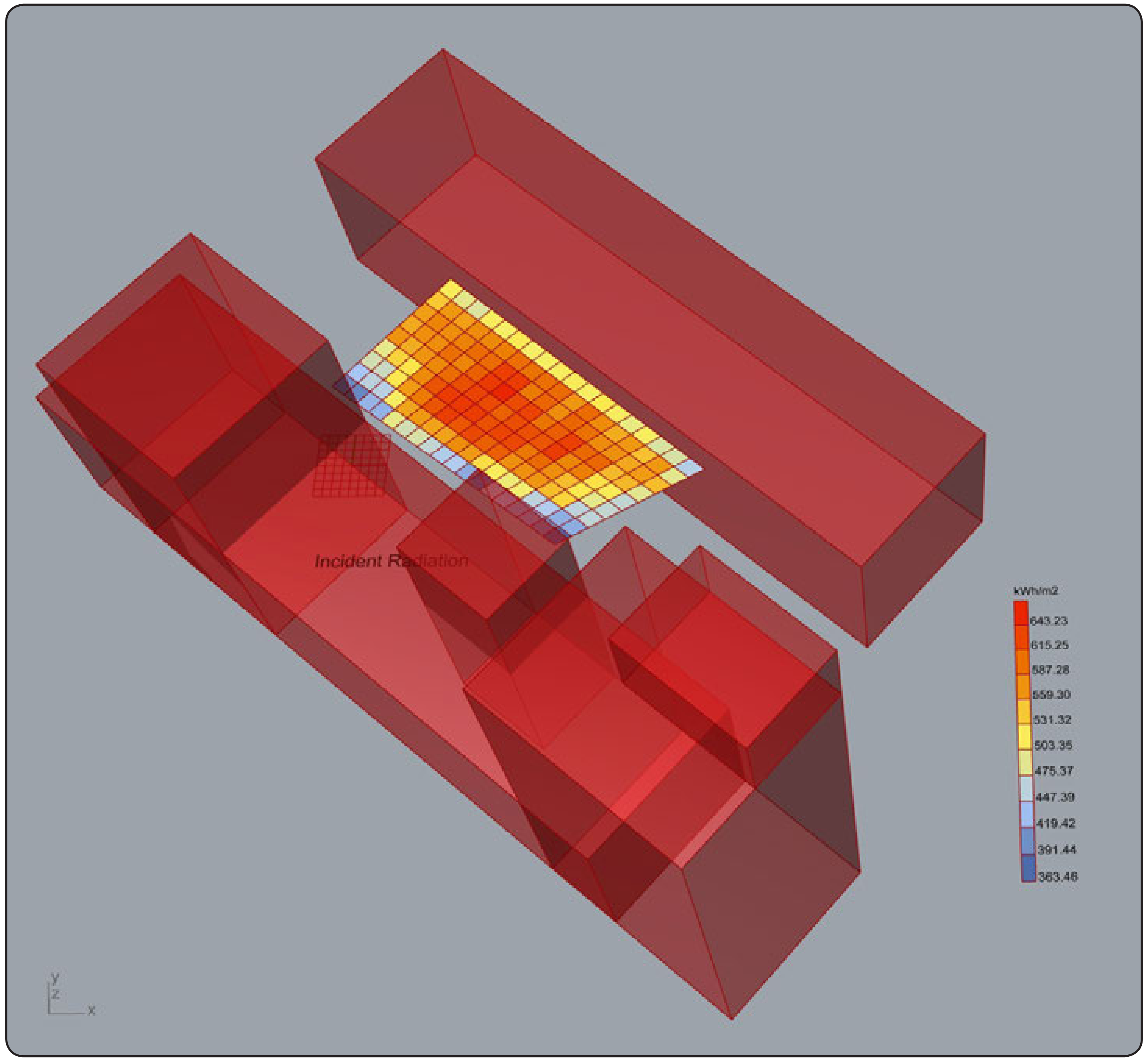


(Open Data Bristol)

Flow diagram



URBAN CANYON SURFACE MK.1

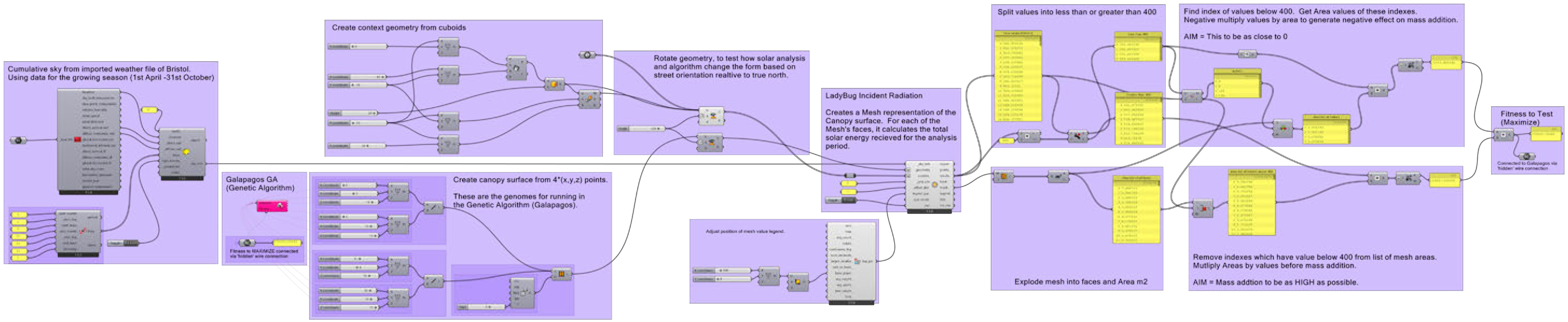


To begin, a simple 4-point surface to test which can be rotated about north to observe the effect of different angled urban canyons.

Weather data is imported into LadyBug and the surface analysed with the context geometry around (shading).

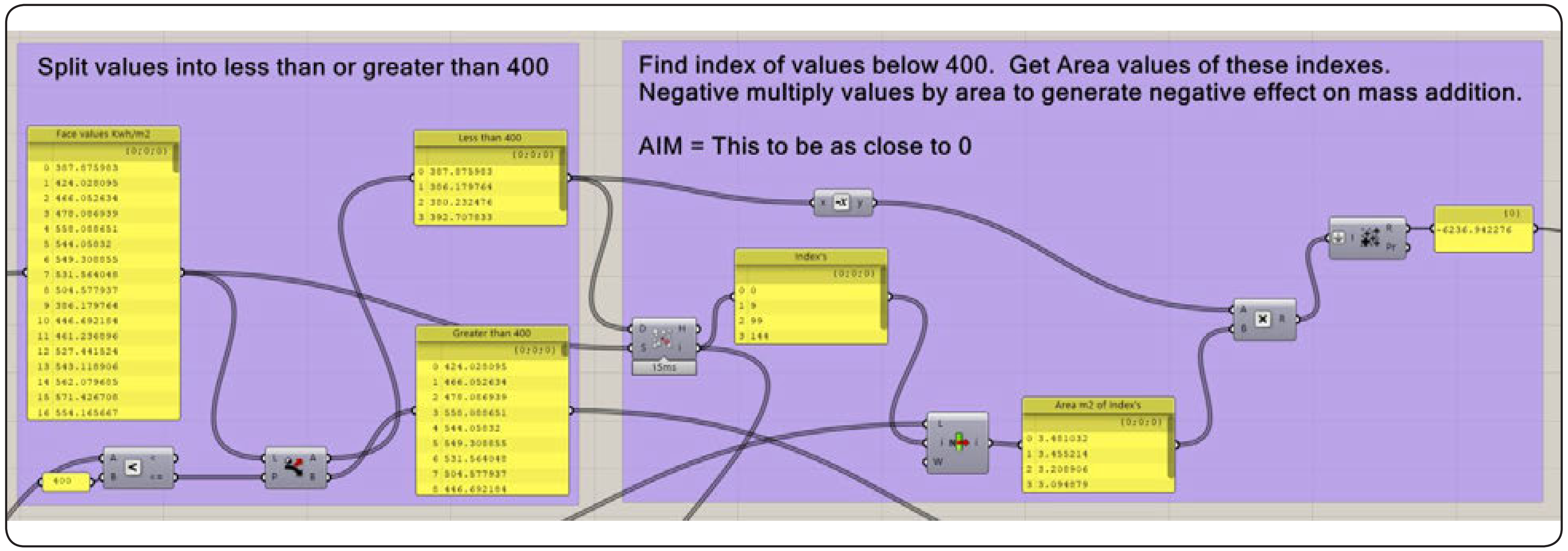
Galapagos searches for the best combination of the 4 points to maximise the total adapted mesh face values based on the algorithm.

Faces with values below 400 are subtracted from the total that is being maximized, so faces with lesser values are unpreferred.



Mk.1 observations

Values of mesh faces just below 400 don't drastically penalise the overall value of the entire mesh which is trying to be maximised.

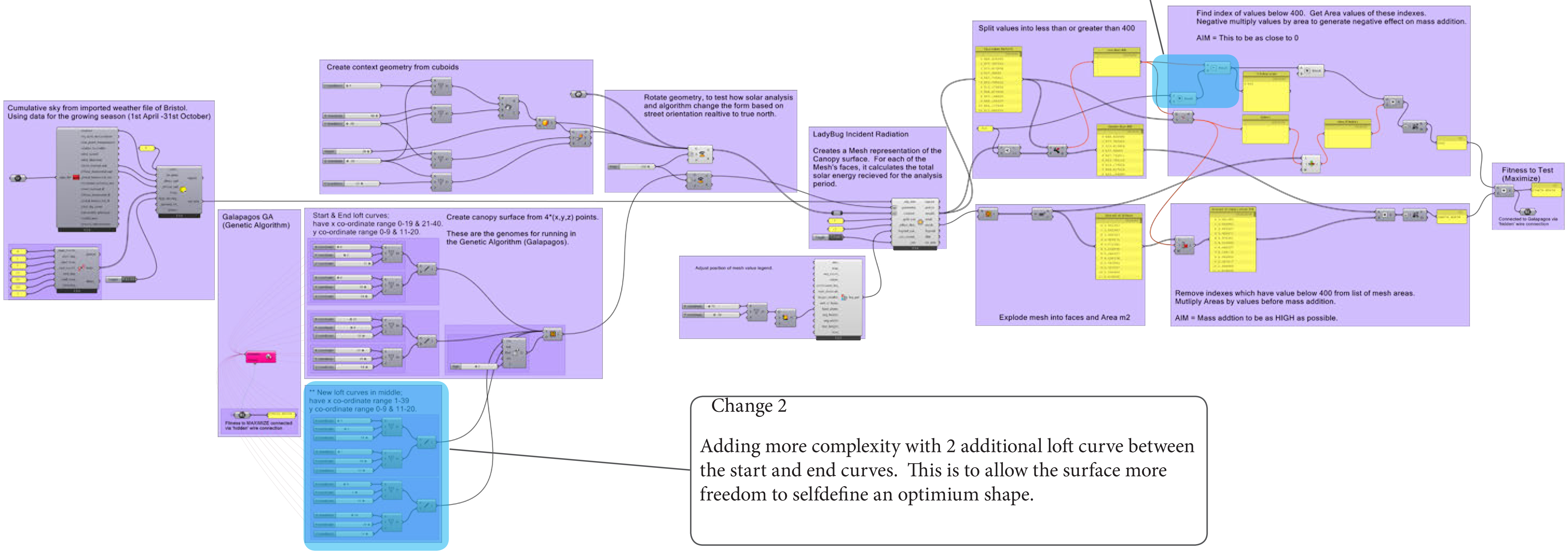


Urban canyon surface Mk.2

Change 1

By adding the splitting value (b) to all face values (a) below 'b', all values below the splitting value (b) have a magnified value (c). The negative of this new value (-c), when multiplied by a factor of 10 has a negative influence on the total which the GA is trying to solve.

This encourages the GA to better seek solutions that have face values (a) above the splitting value(b).

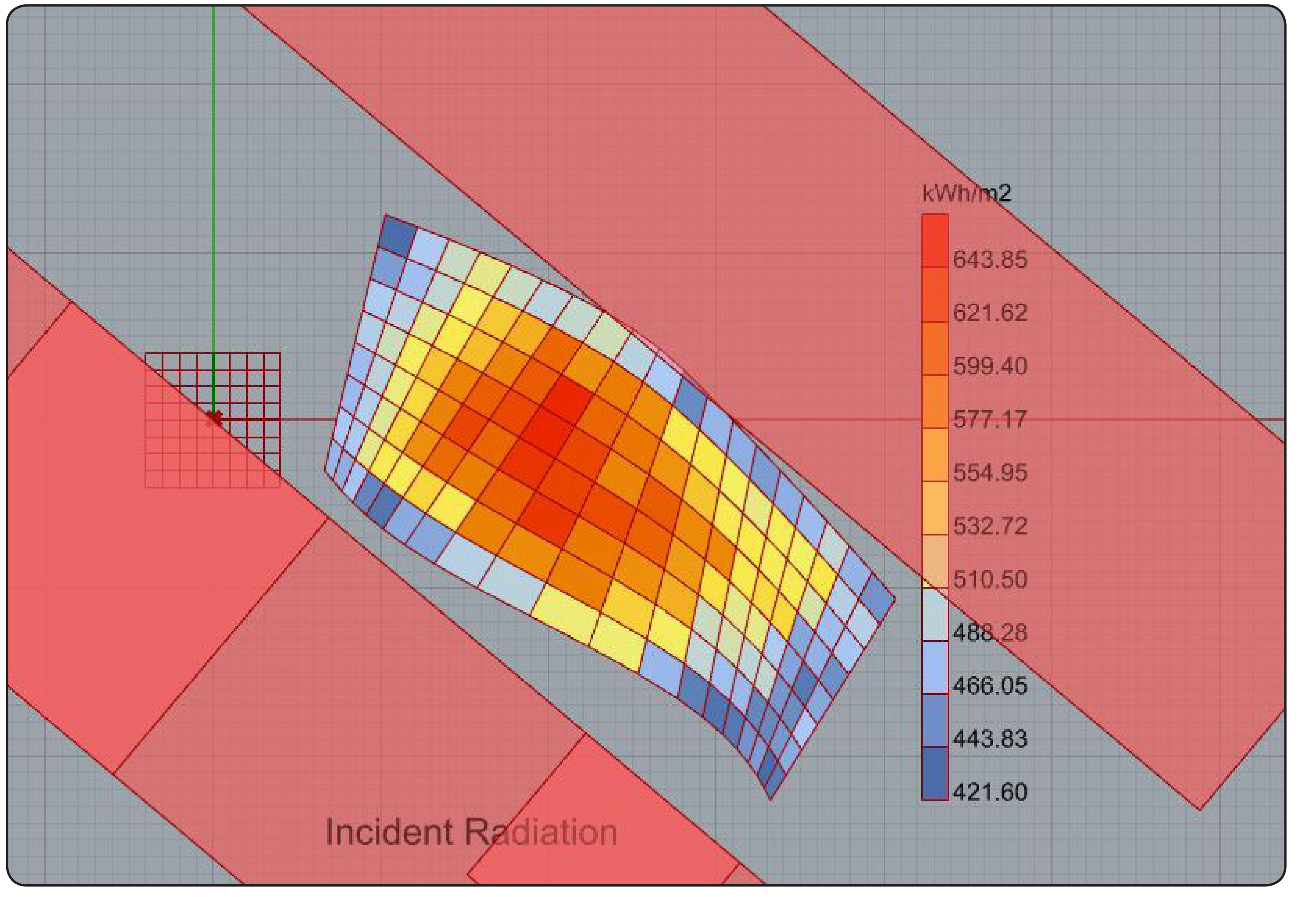


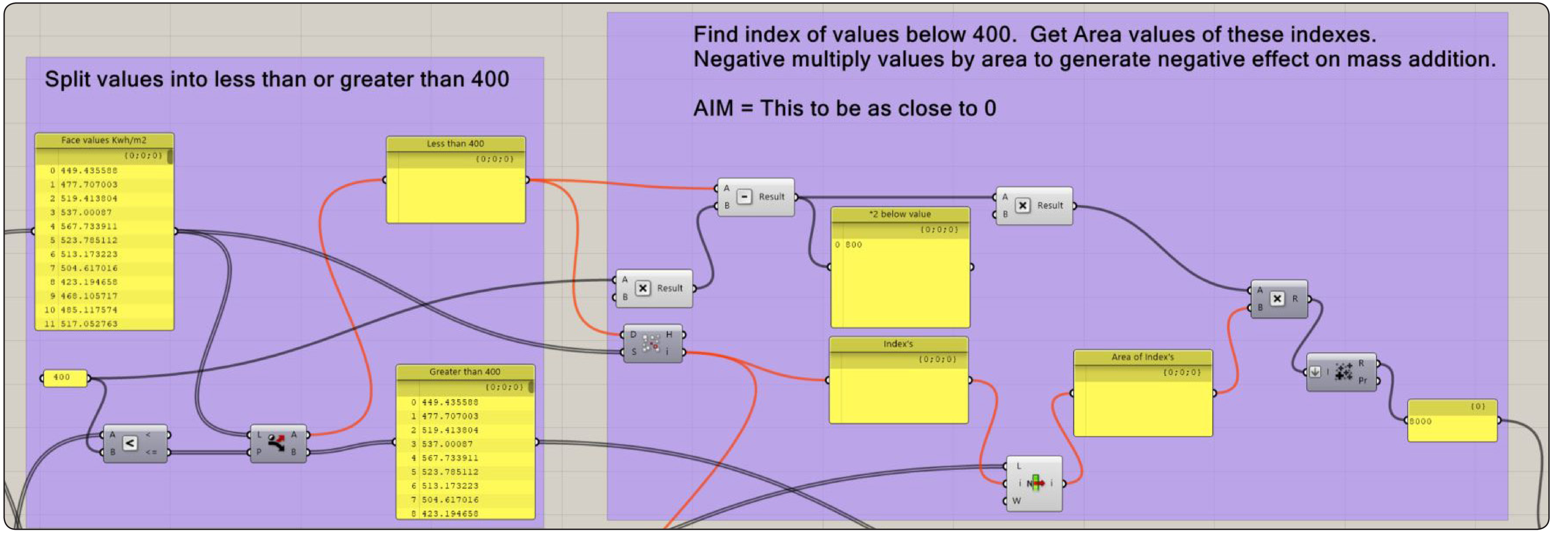
Change 2

Adding more complexity with 2 additional loft curve between the start and end curves. This is to allow the surface more freedom to selfdefine an optimium shape.

Mk.2 observations

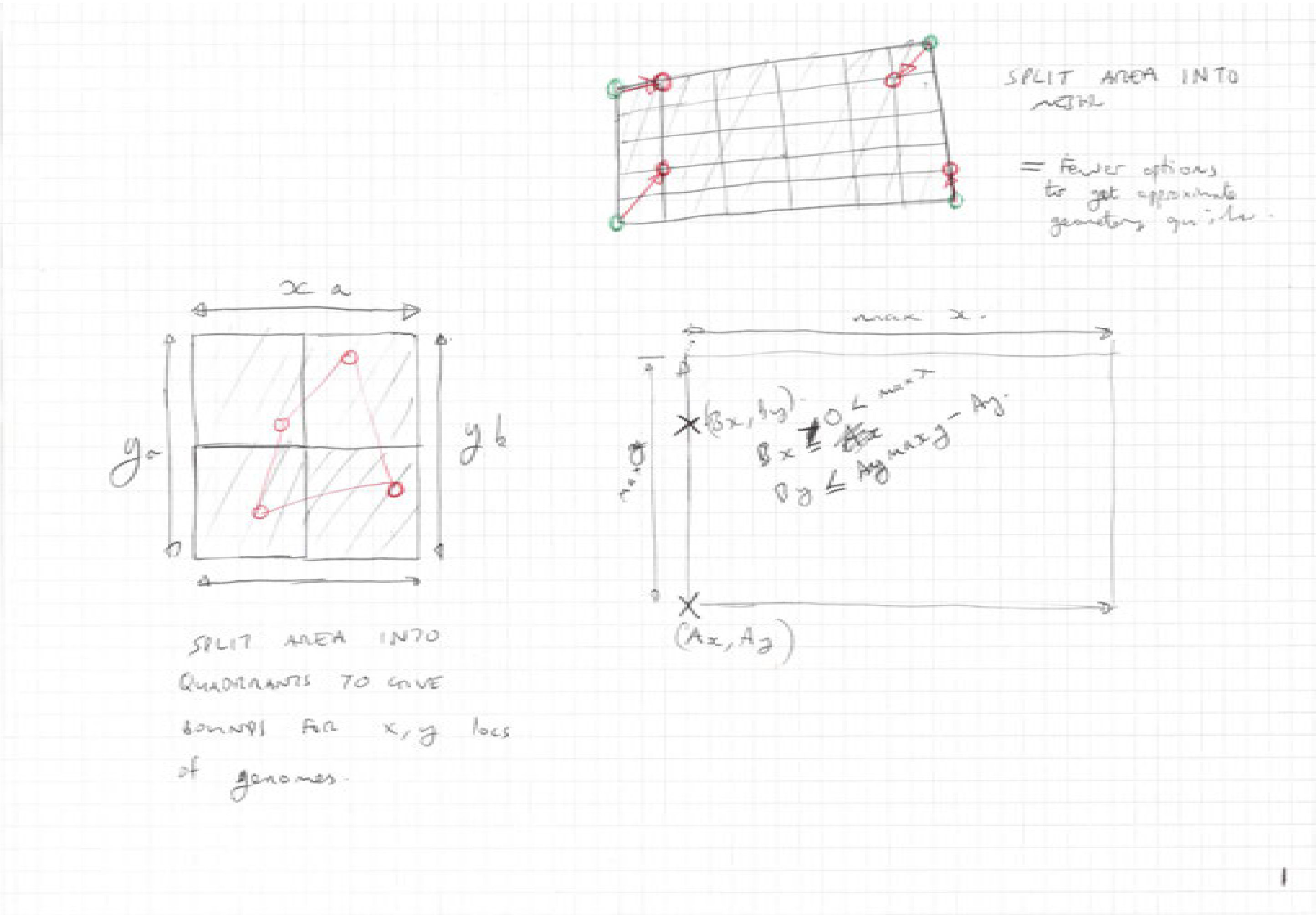
With the additional curves and parameters, the algorithm requires a lot more time to process an increase in possible variations but does allow more freedom for the surface to generate a more optimum form.

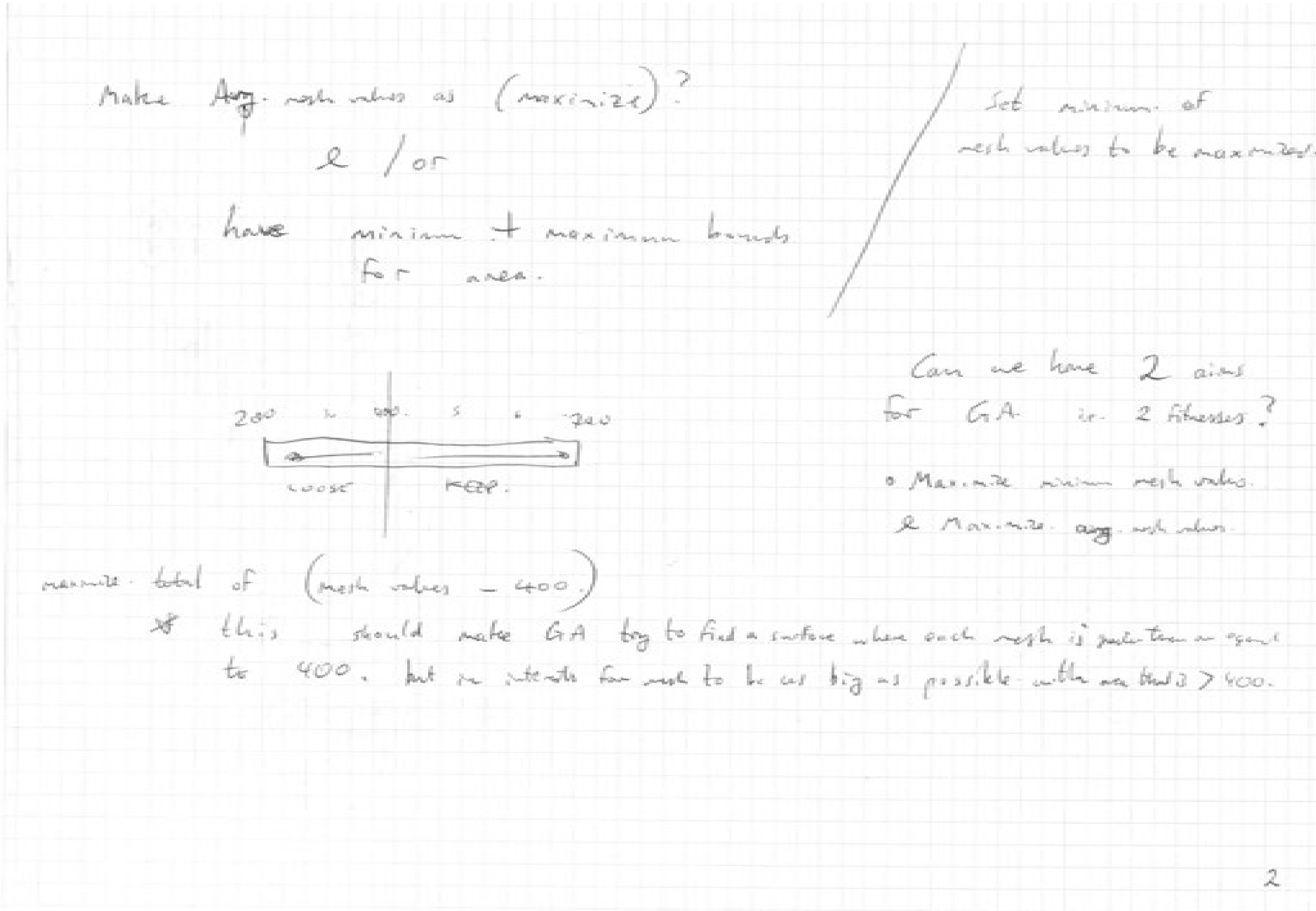




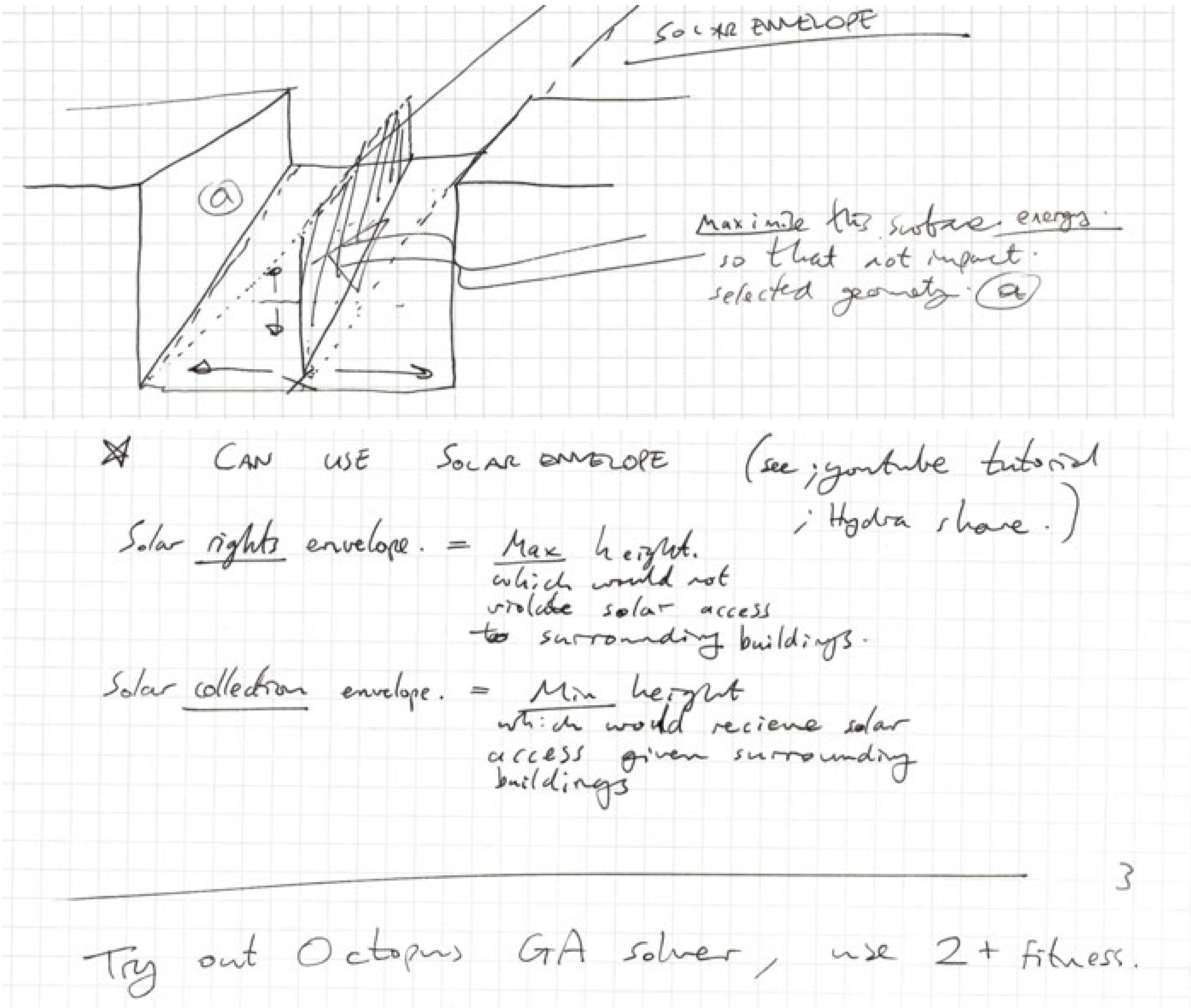
Sketch deveopments

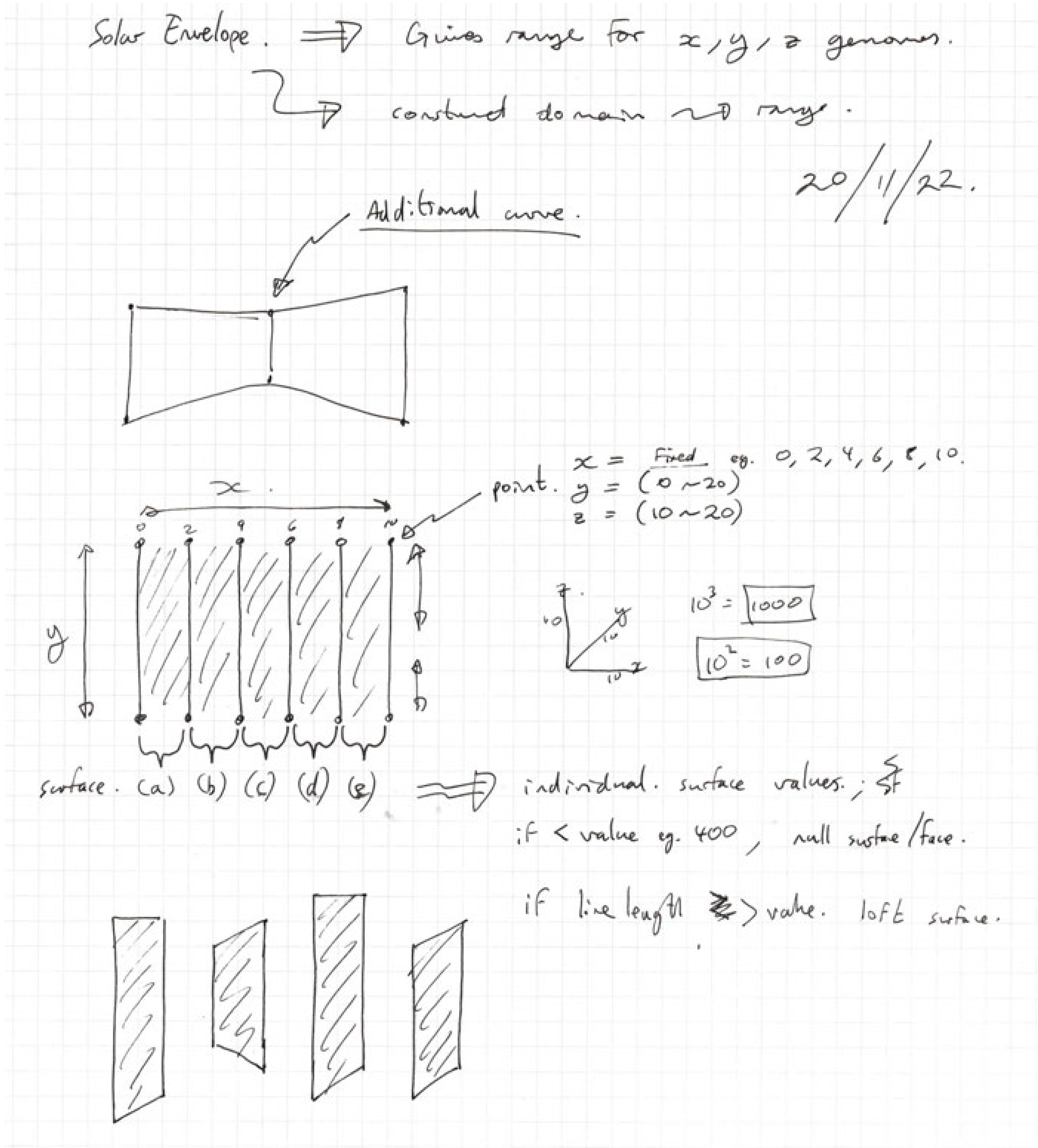
Reducing the complexity of the computing by dividing the design space into domains assigned to each point.

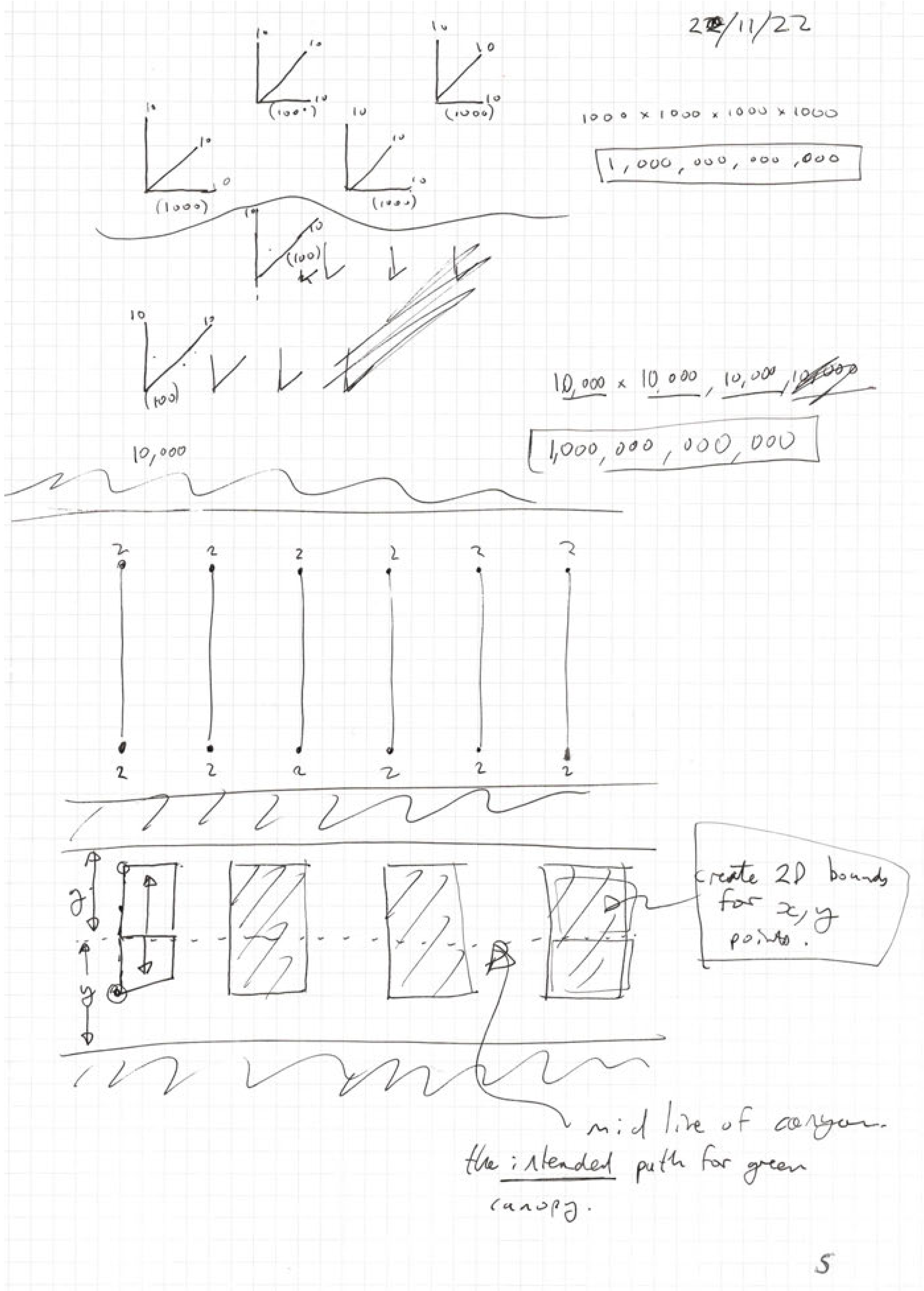




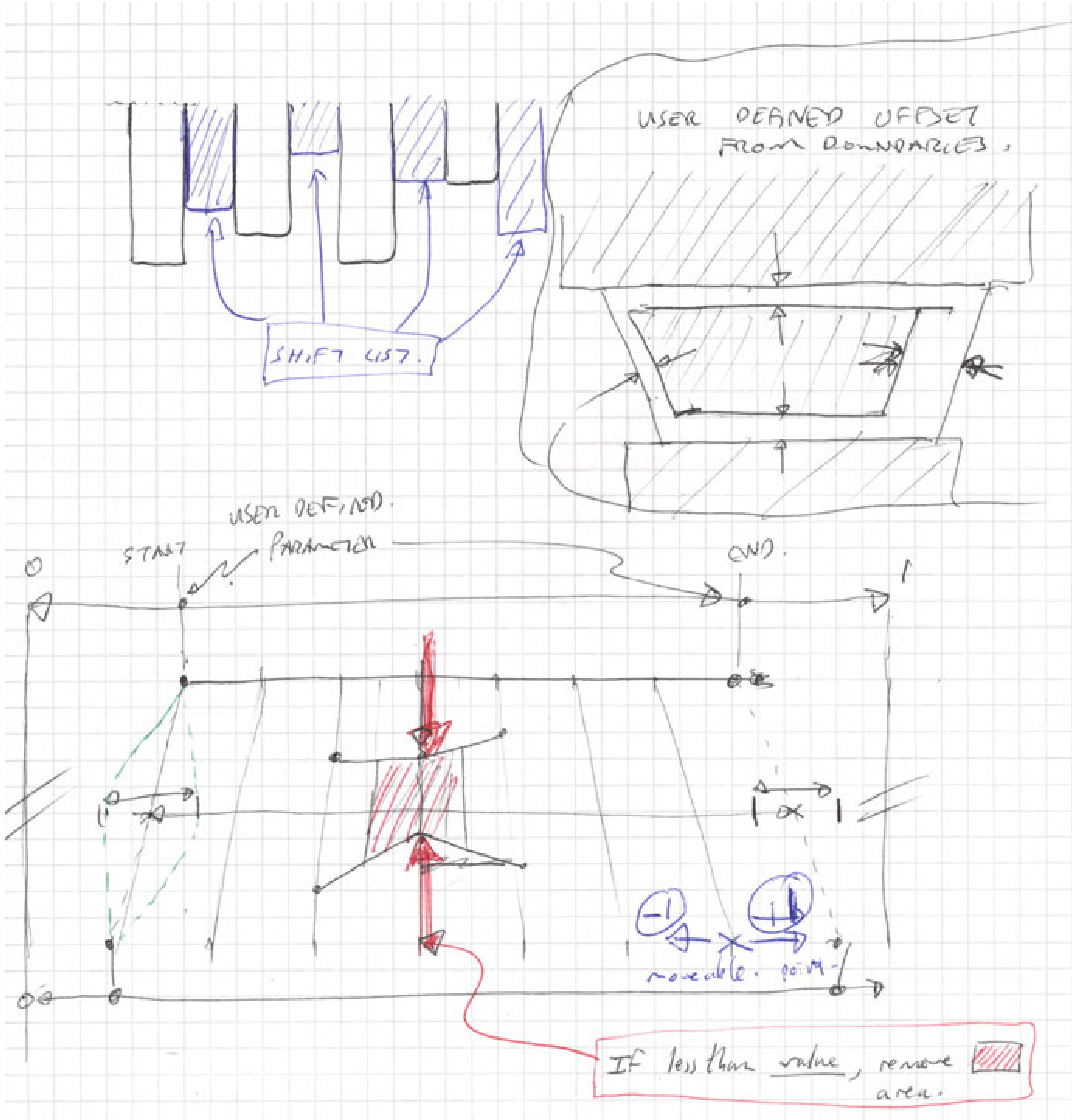
Fixing the x direction of the points could allow for more curves with potentially less computing.







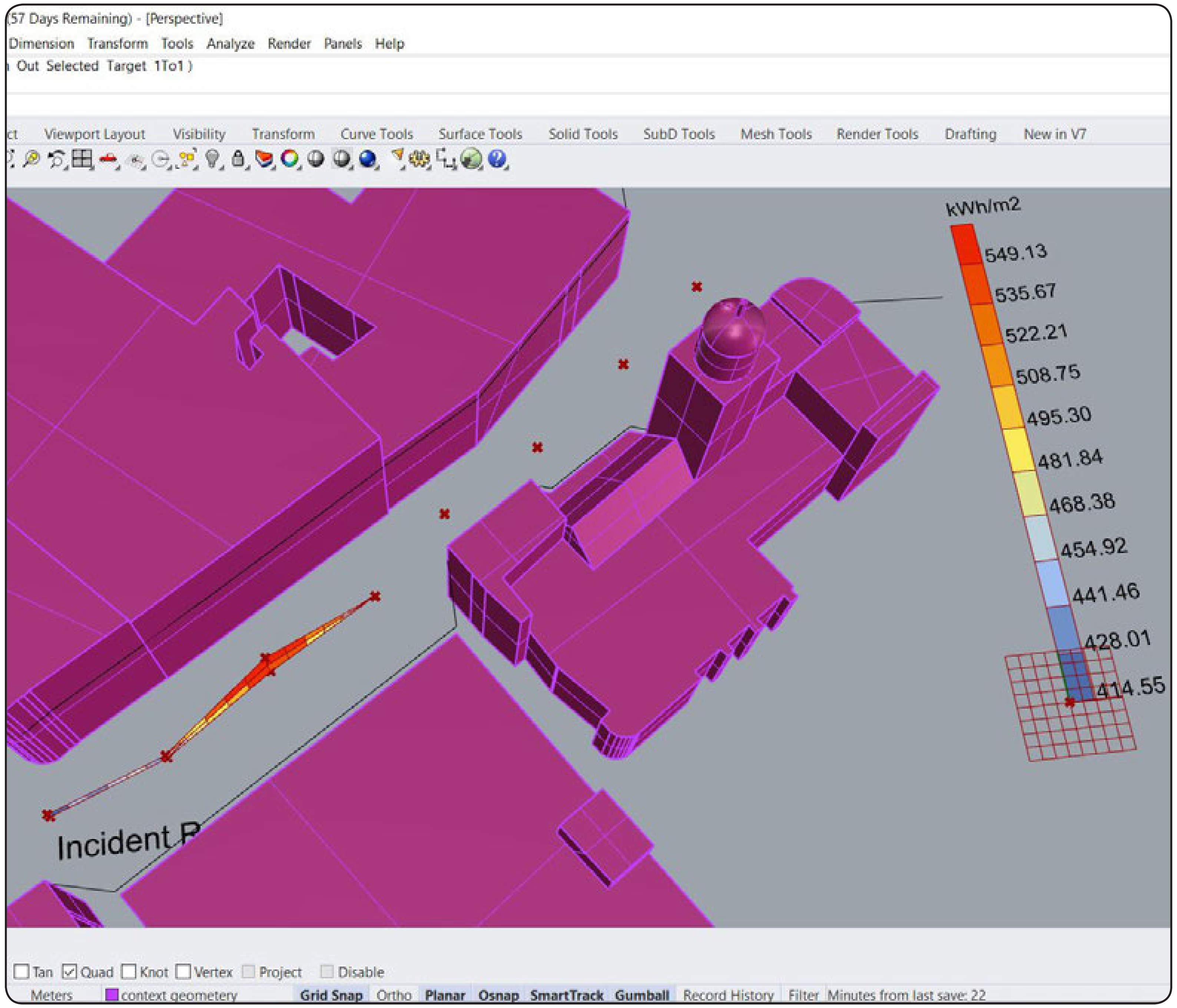
Creating shifted surfaces between curves that only combine if the surface between can grow i.e. if face value is greater than minimum value.

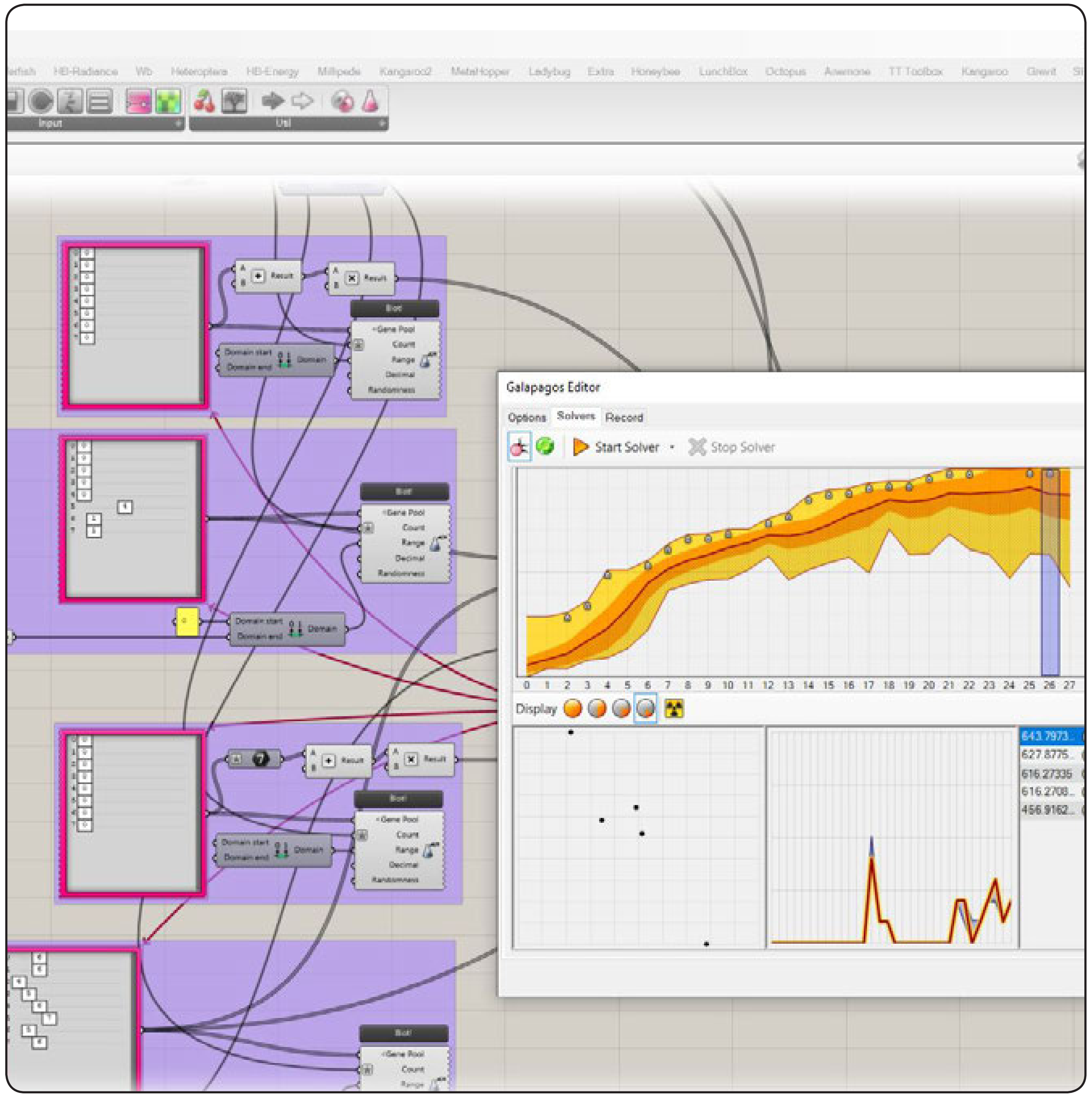


Surface in Context

The loft curve start(a) and end(b) points have a floating range of ***(0≤ a ≤5)*** and ***(5≤ b ≤10).***

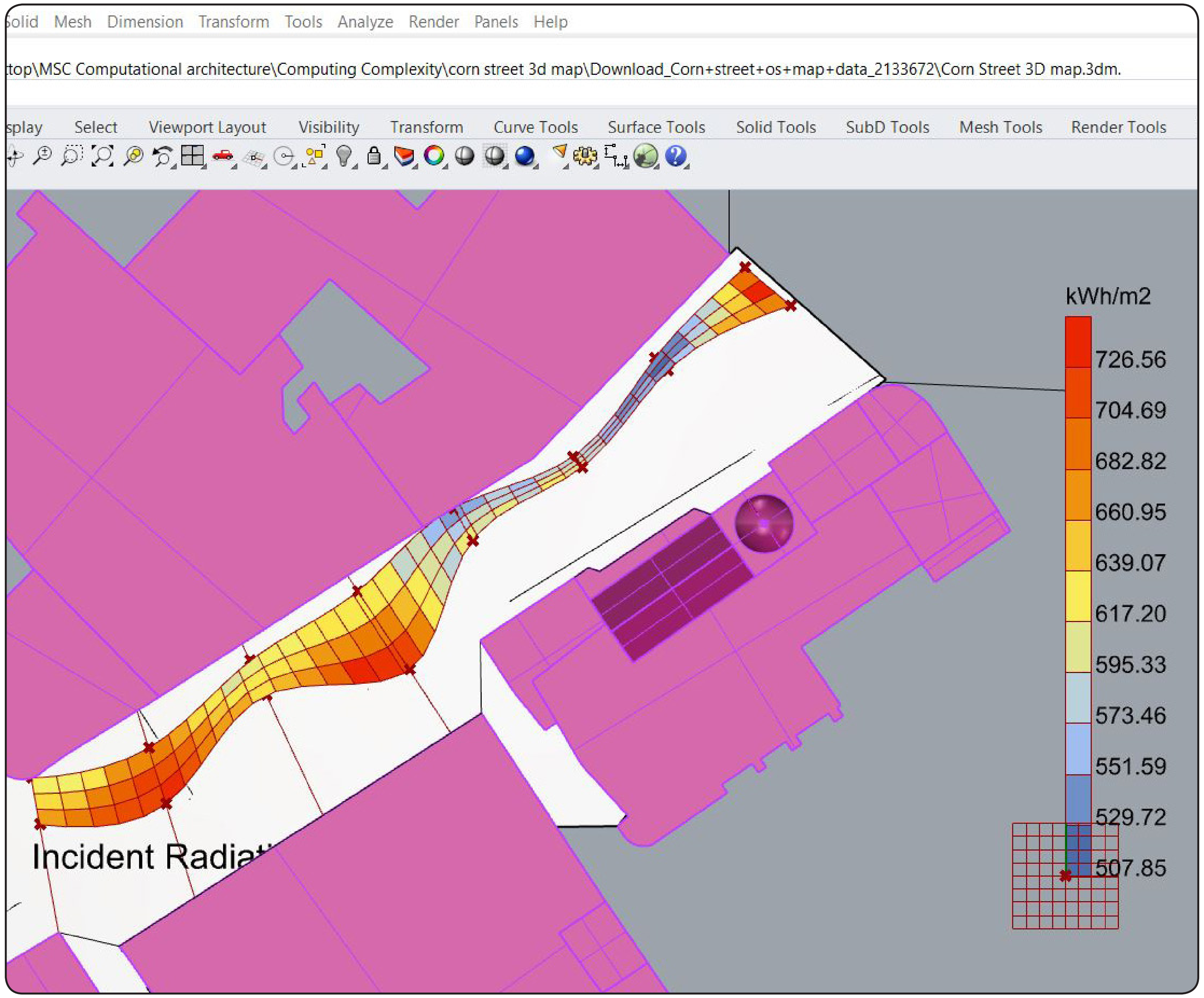
This alongside trying to find the highest average face value has over-constrained the growth development of the surface, growing in only 1 area of the street.

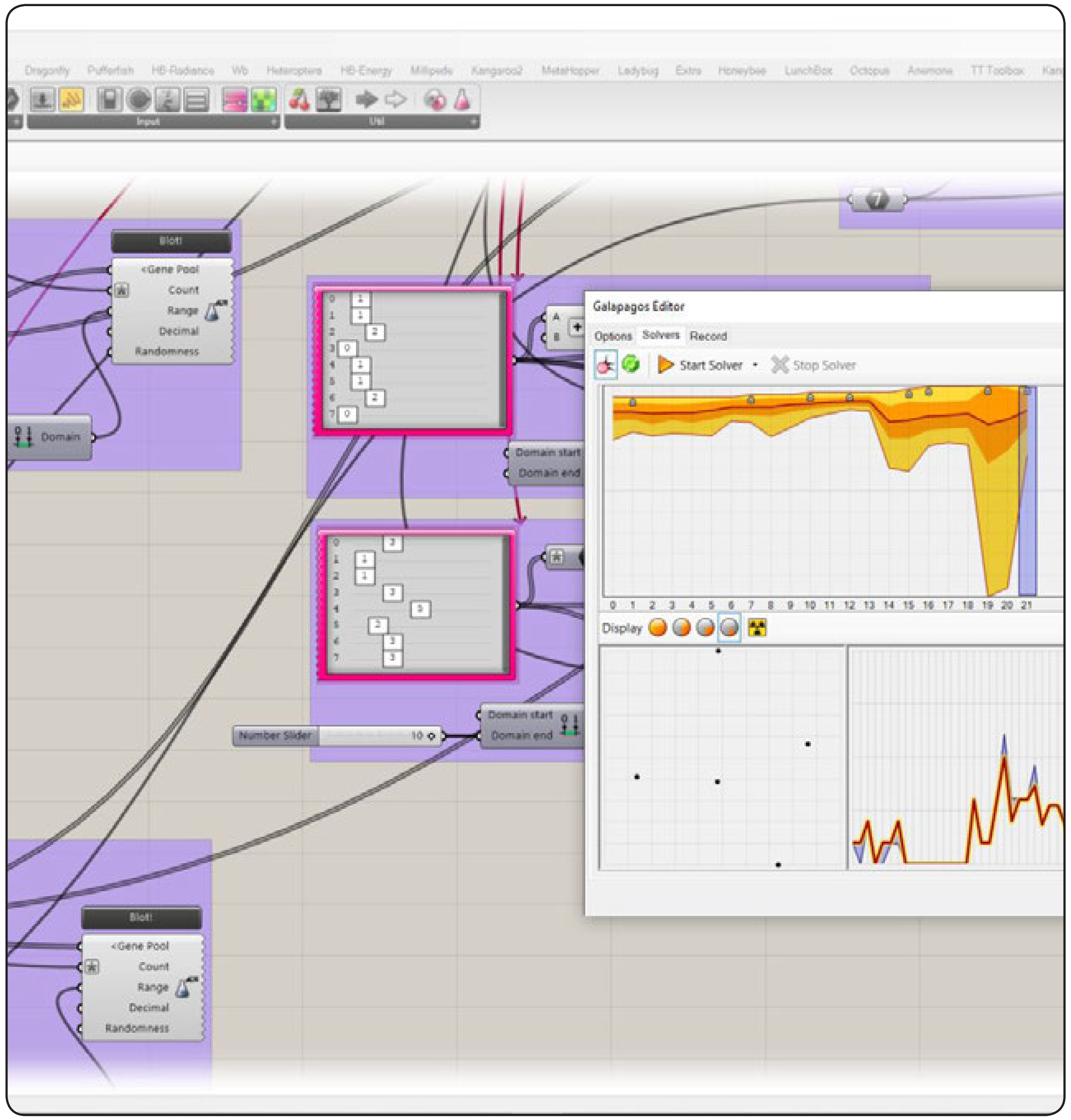




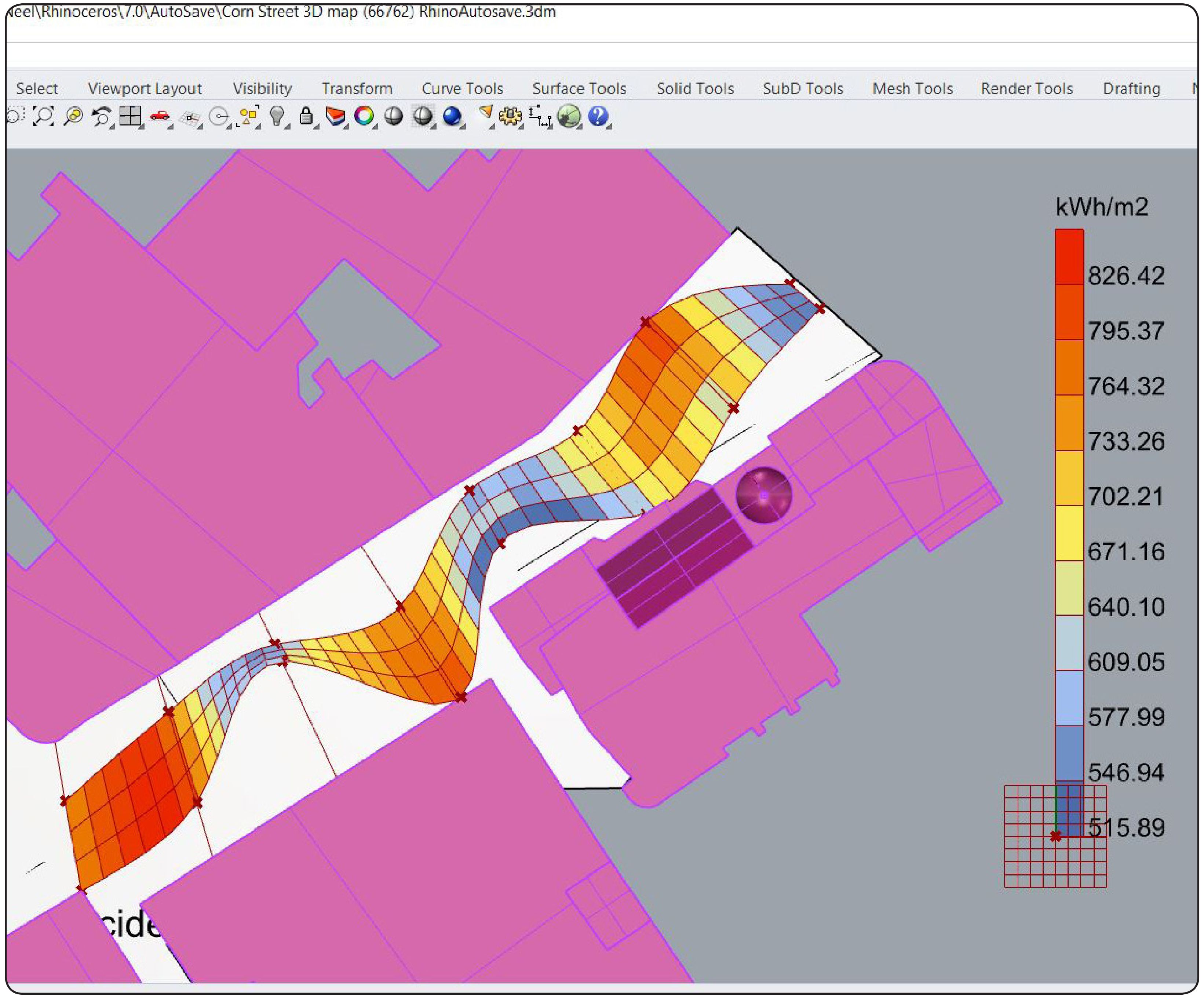
Adjusting the domains of the loft curve start(a) and end(b) points, so that they have freedom to move from points 0 - 10 along the curve, where ***(0 ≤ a ≤ 9)*** and ***(a+1 ≤ b ≤ 10)***.

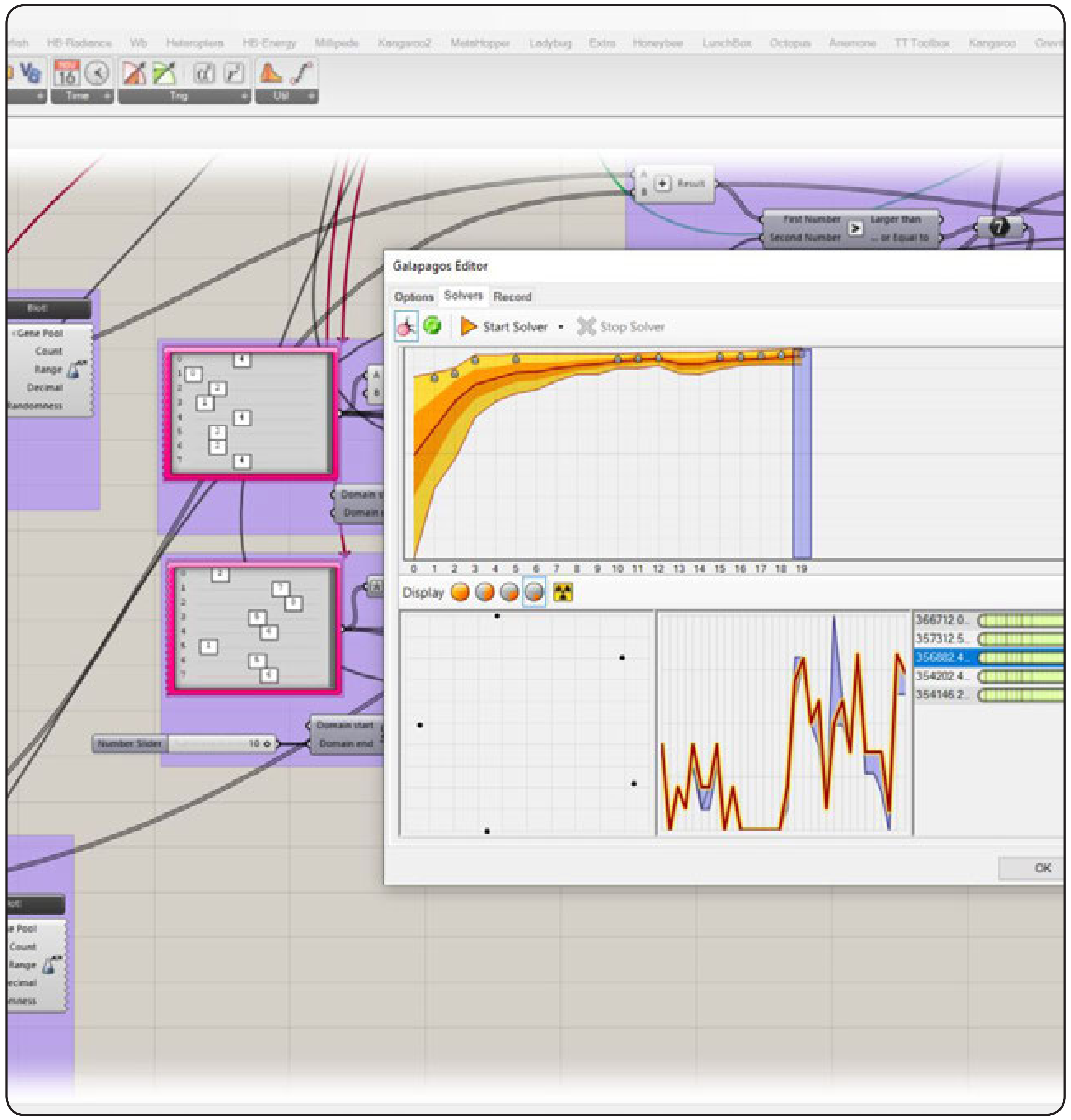
This has forced the surface to grow across all loft curves whilst retaining high surface values as the fitness goal is to still find the highest average face value.





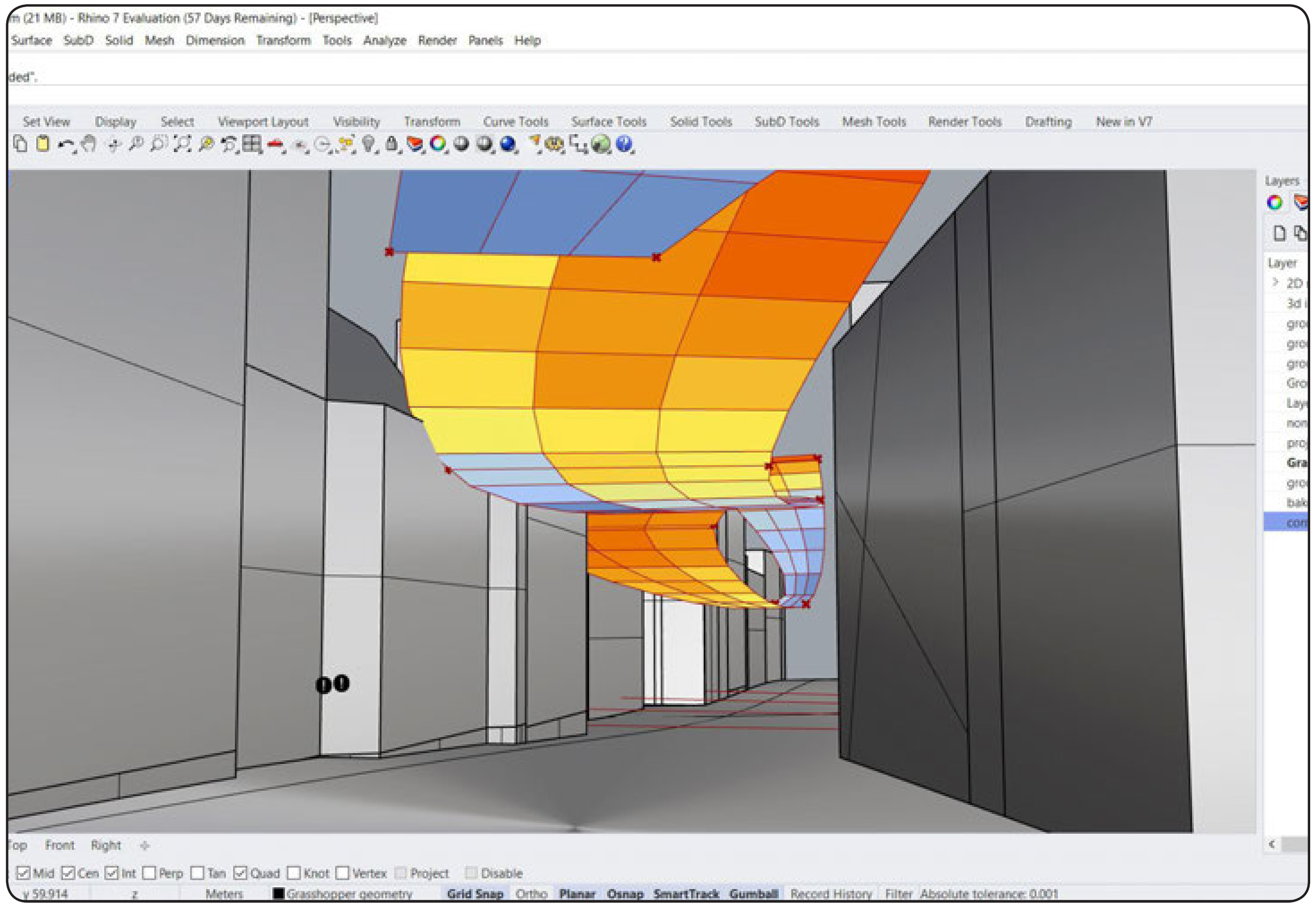
Changing the fitness goal from the average face value to the maximum total value of solar radiation increases the size of the surface and subtly changes its path from the top view.



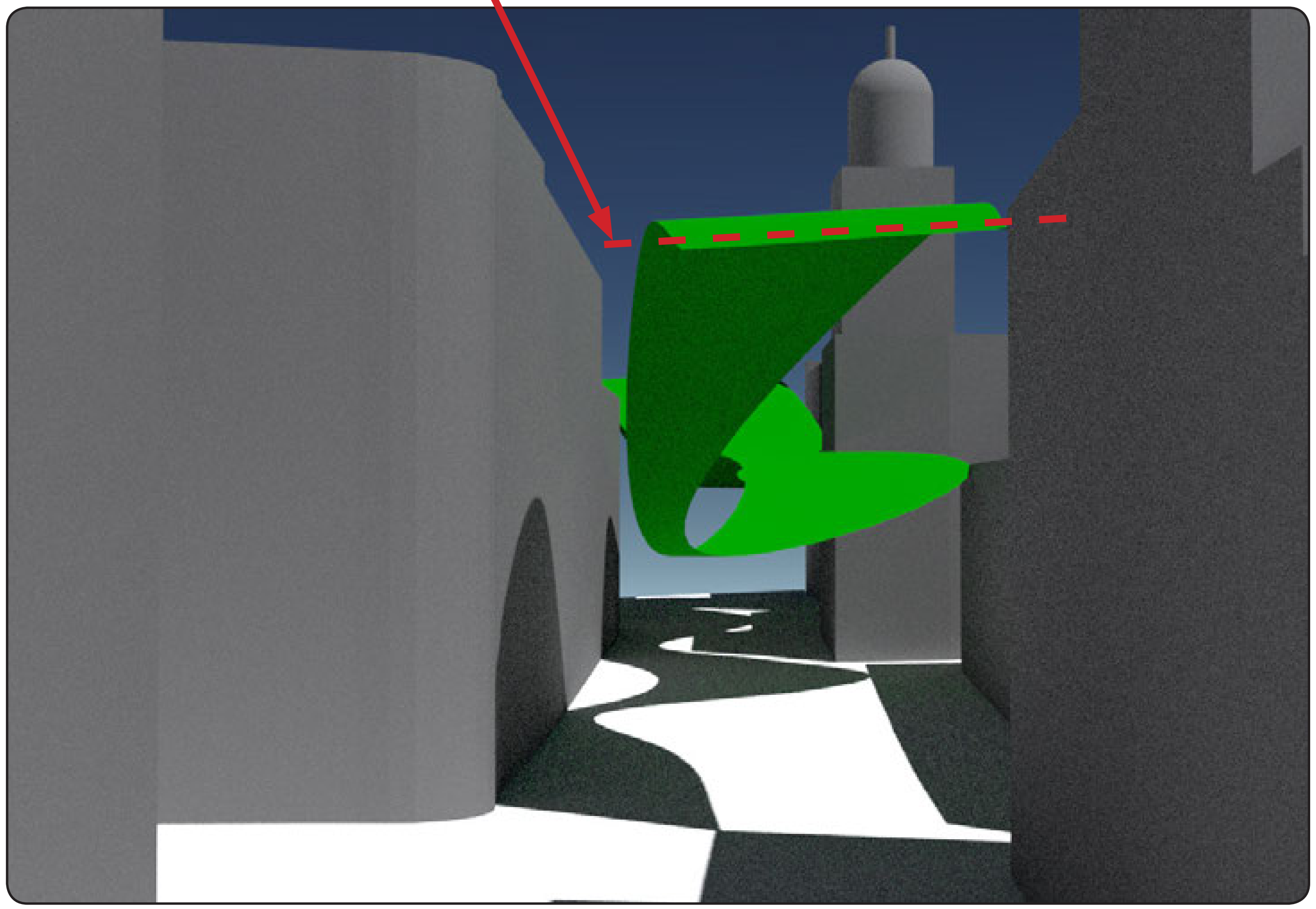


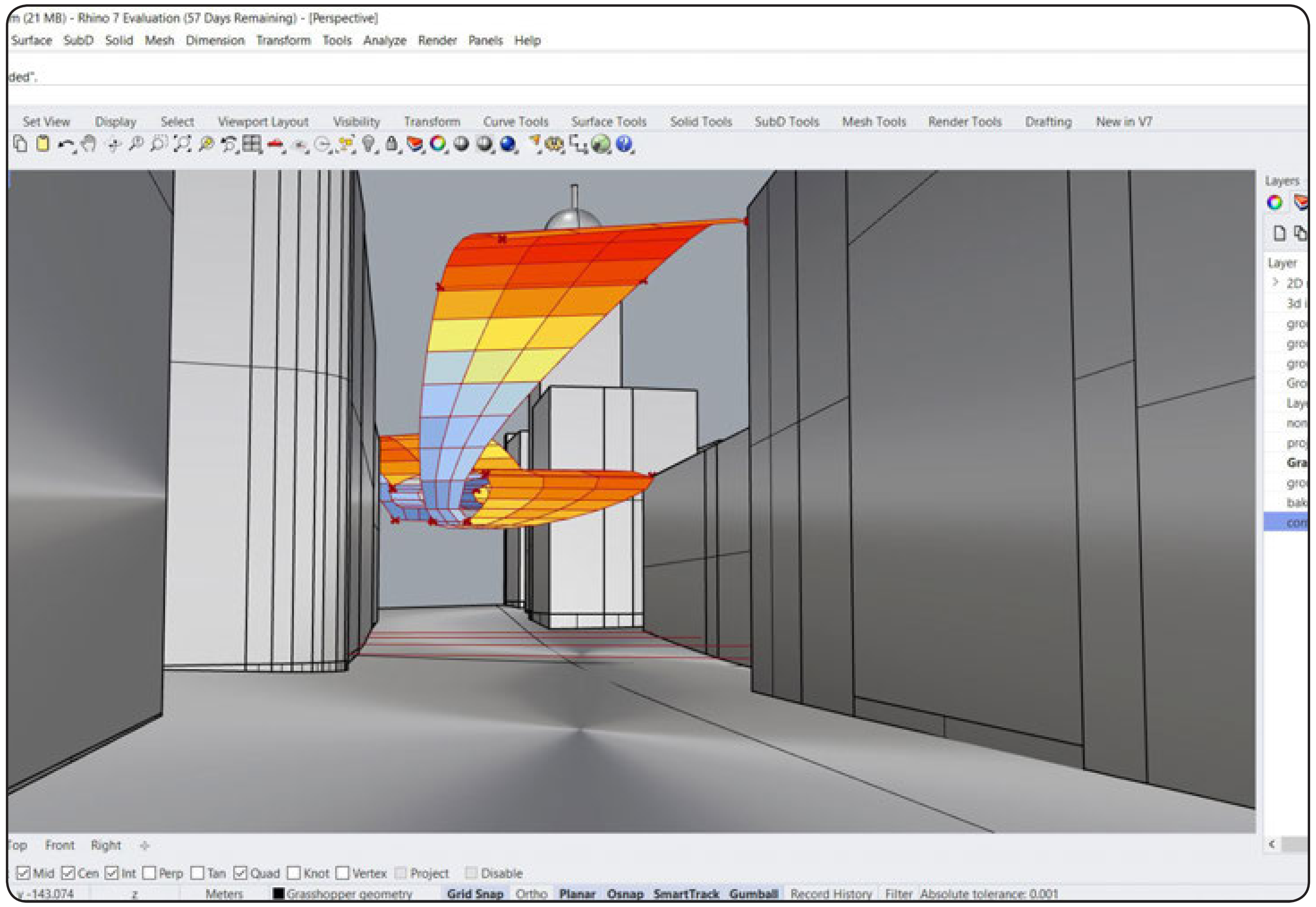
When observing the surface, it is noticeable that the loft curves remain very level.

On closer inspection of the parameters for their start and end points. The parameter which is supposed to allow the height of the northerly most point on each loft curve to be greater than the southerly most one (so that the surface can tilt south - towards the sun) was attributed to the southerly most points.



Angled away from sun?

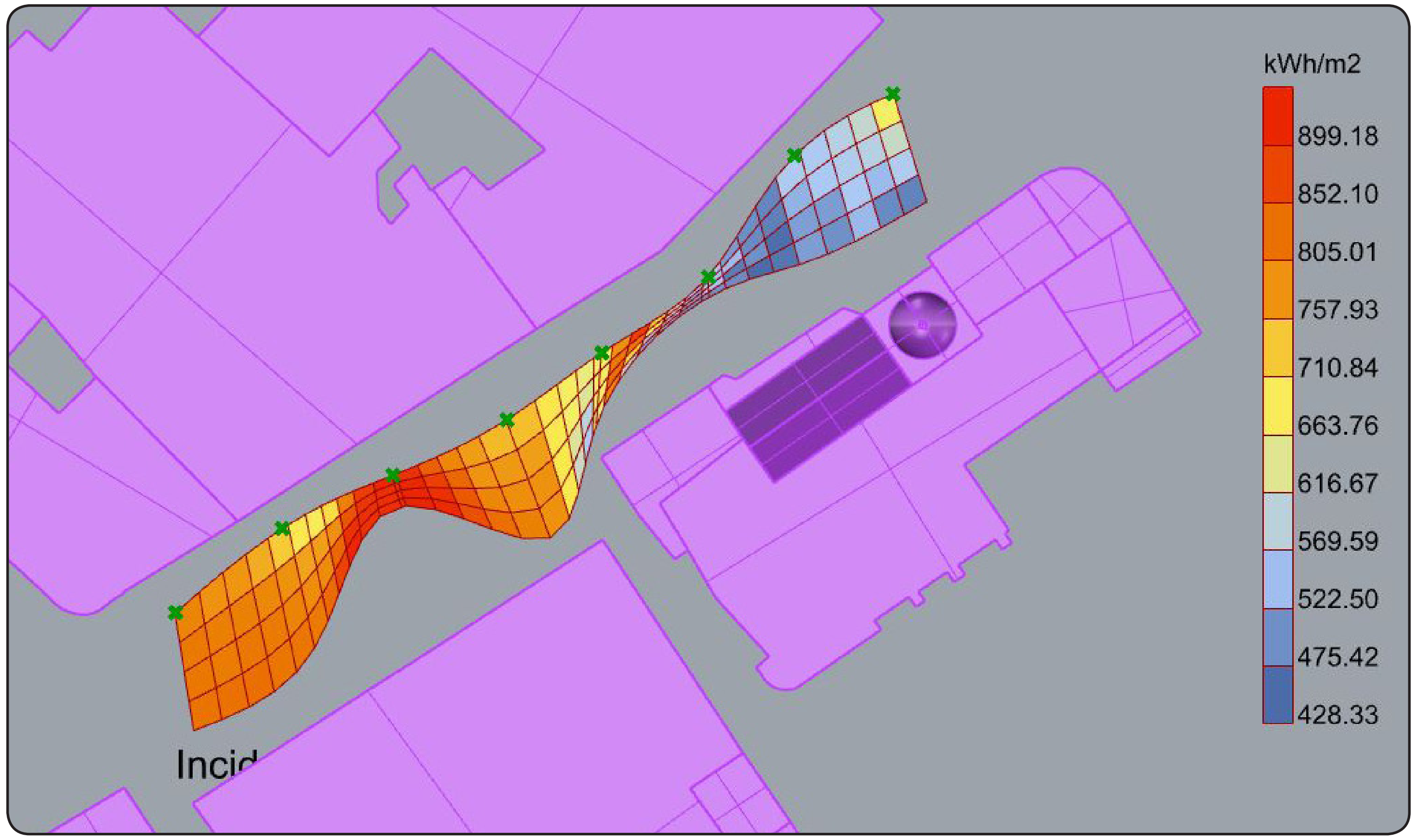


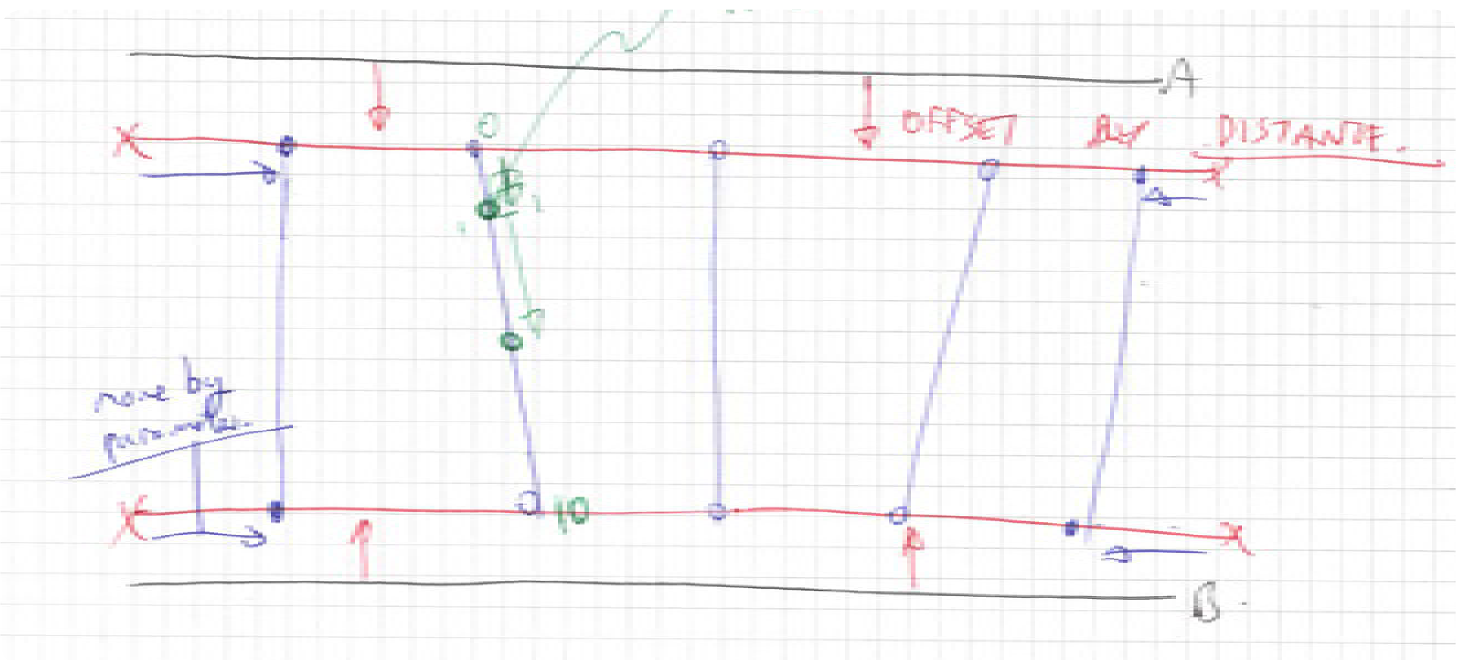


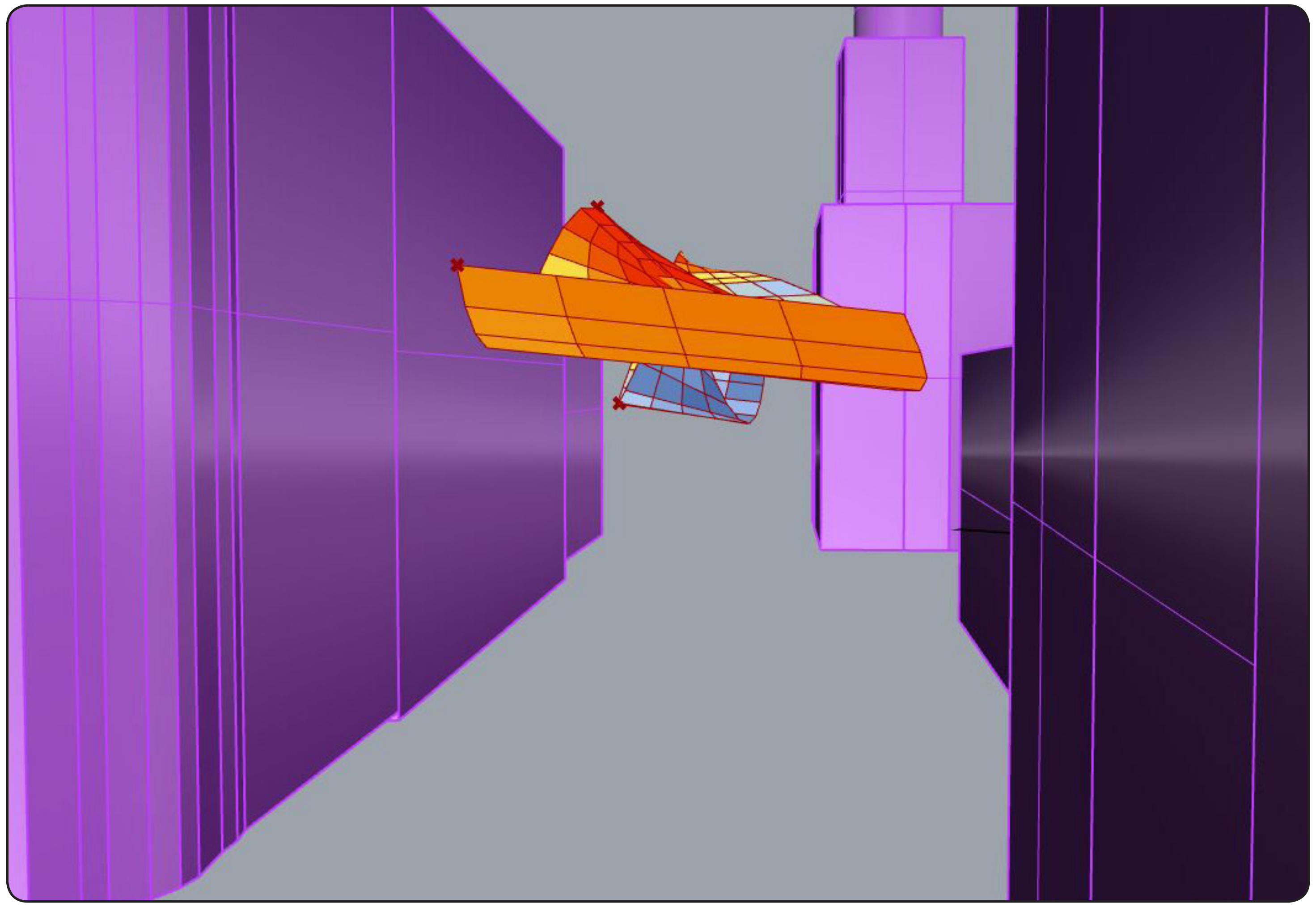
Allowing the loft curves to angle into the sun now allow the surface to twist from horizontal to near vertical.

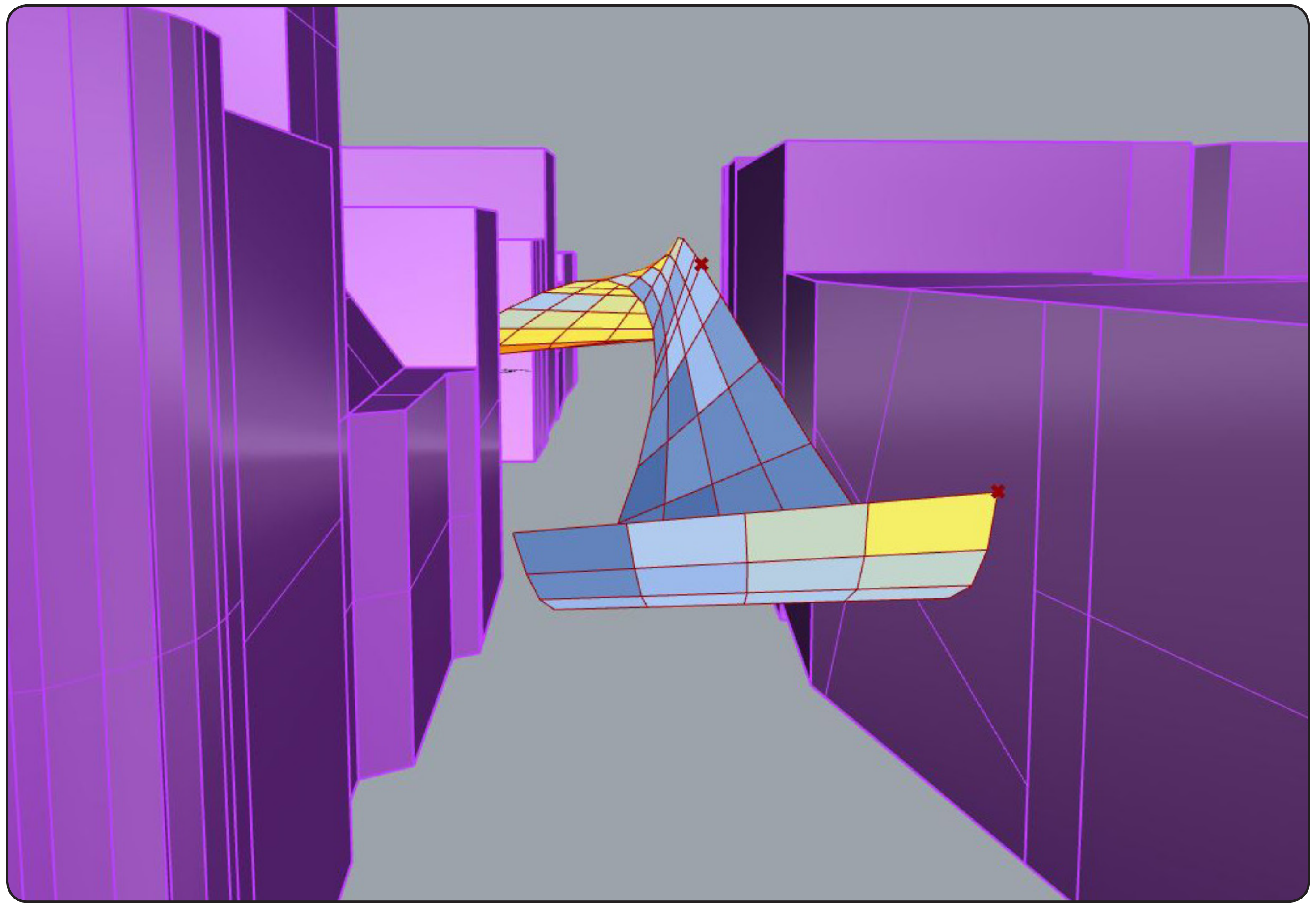
Introducing an offset from the boundary curves allows the surface to work within a safe distance from the buildings.

An extra parameter and genomes for the GA are the locations on the offset boundary curves of the first and last loft curves. This allows the surface some freedom to define its length.

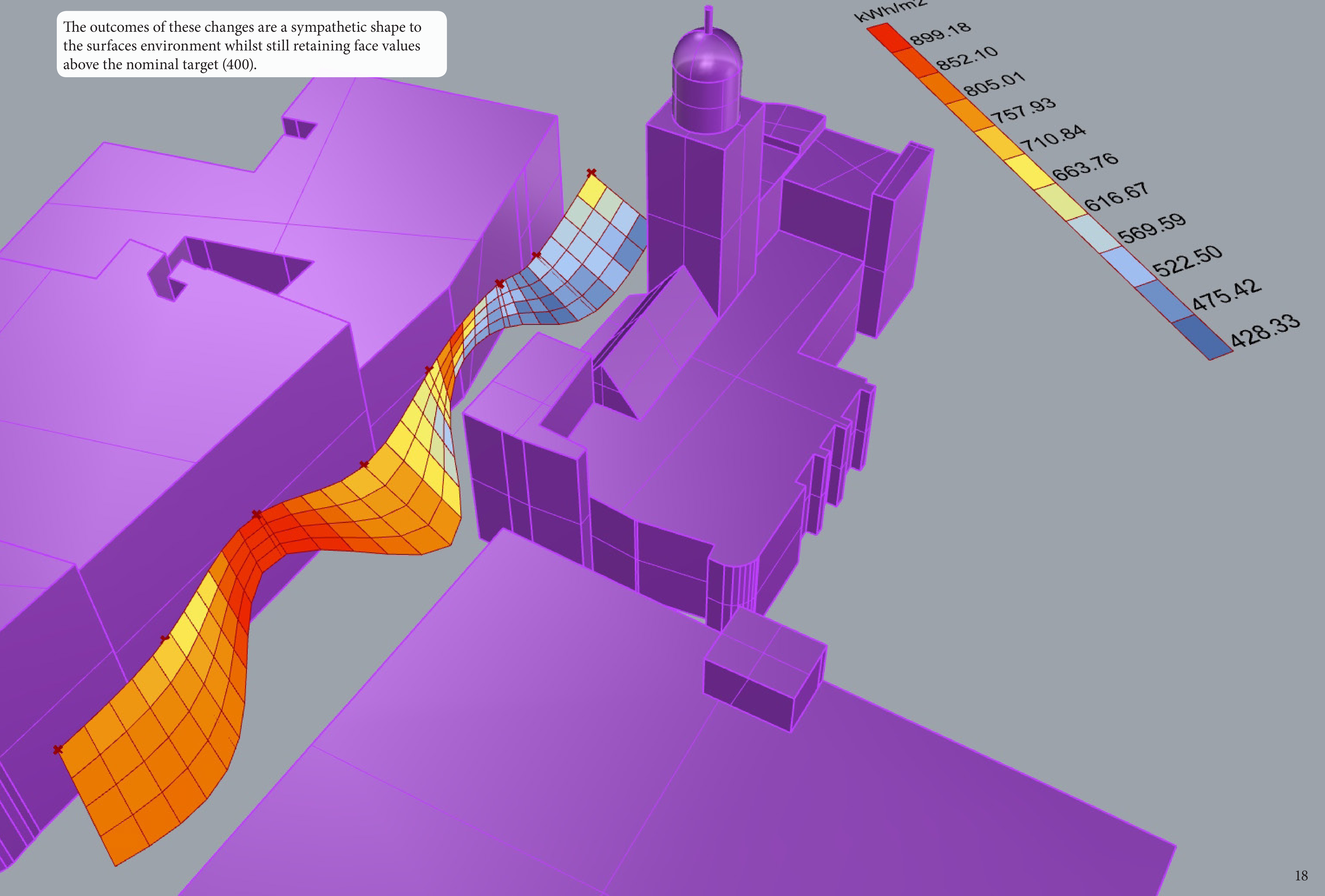






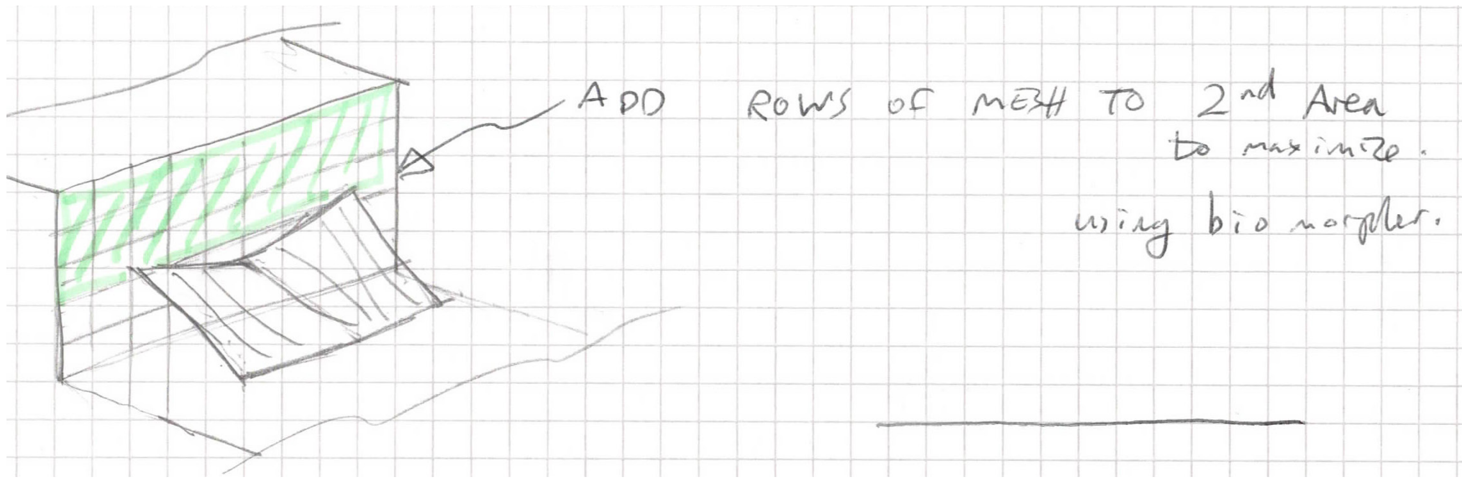


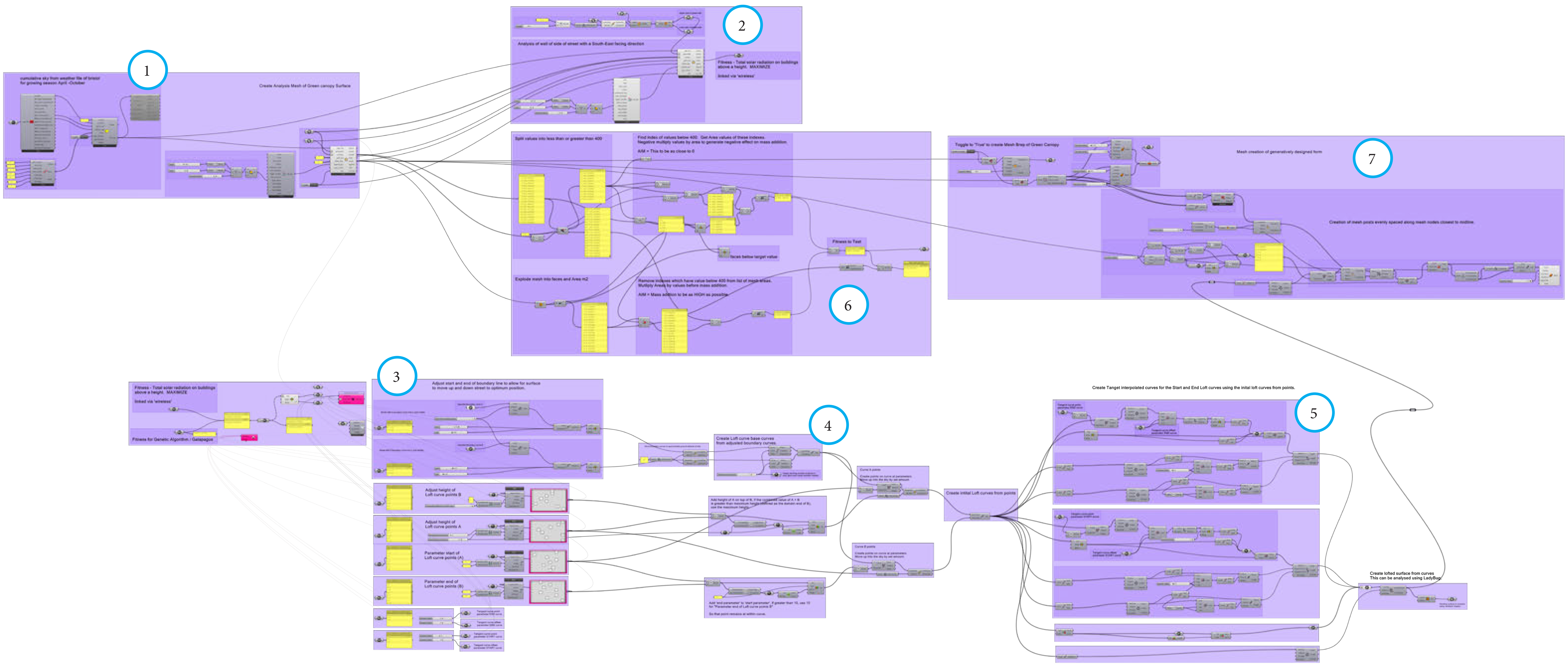
The outcomes of these changes are a sympathetic shape to the surfaces environment whilst still retaining face values above the nominal target (400).



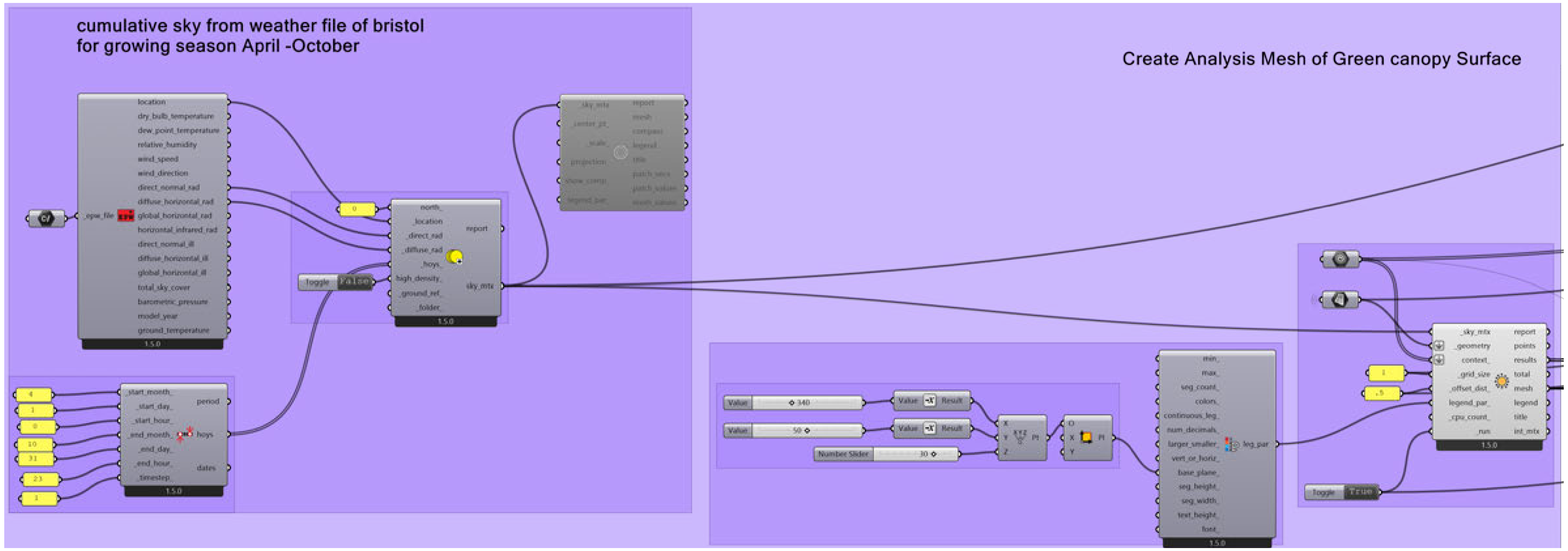
Final Grasshopper Definition

The final definition uses a multi-objective Generative Algorithm ‘Bio-Morpher’ to analyse an additional surface, the south facing side of the street.

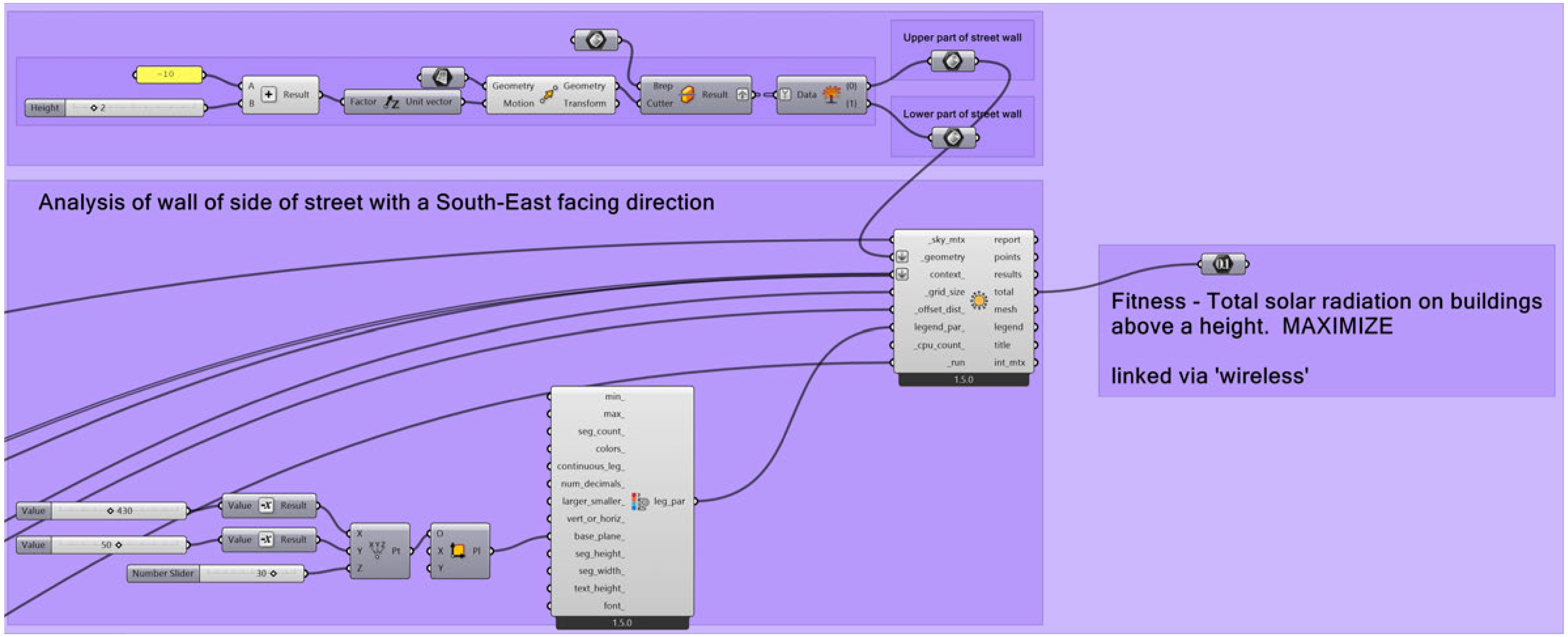




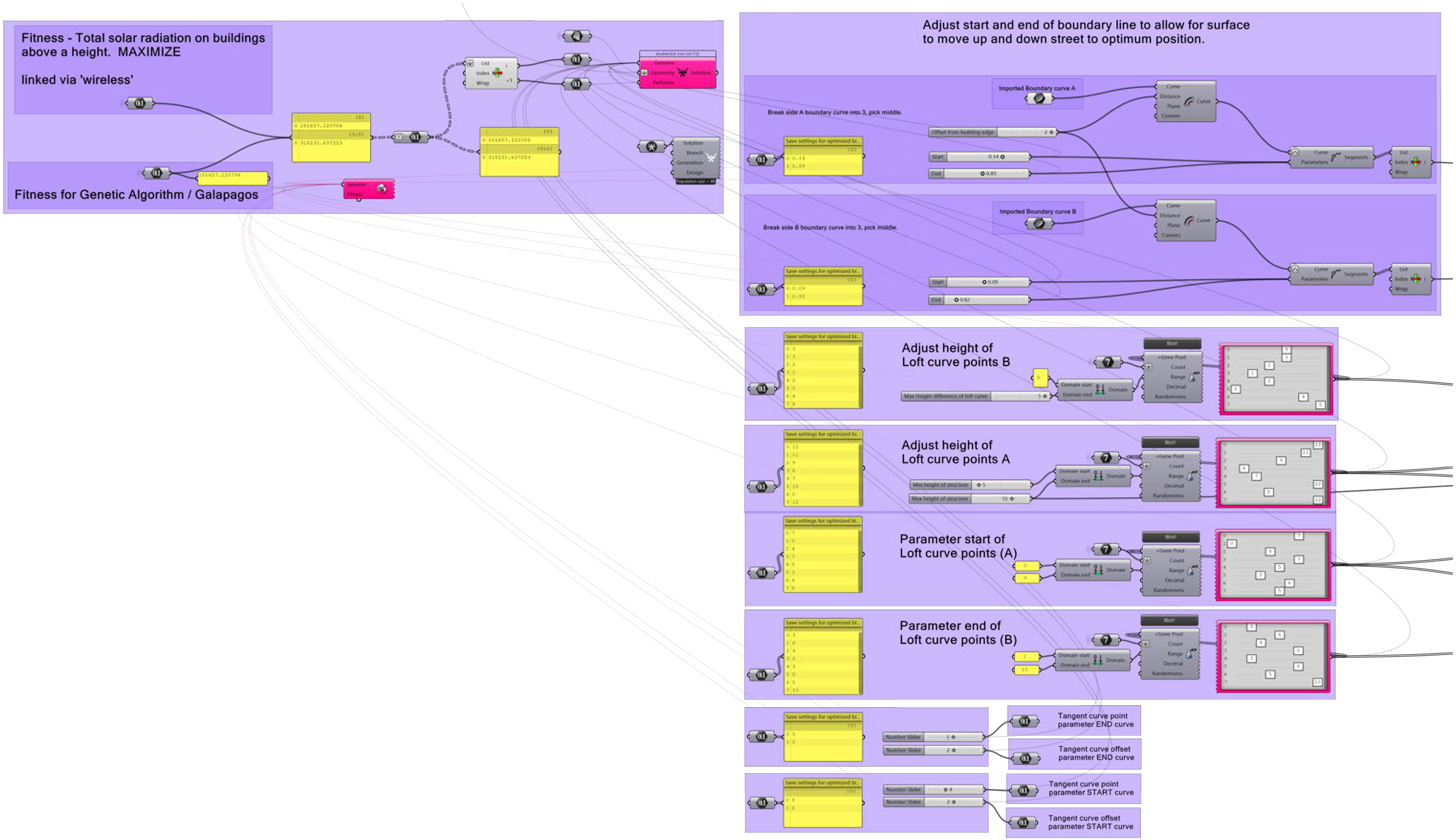
1


cumulative sky from weather file of bristol
for growing season April -October
Create Analysis Mesh of Green canopy Surface

2

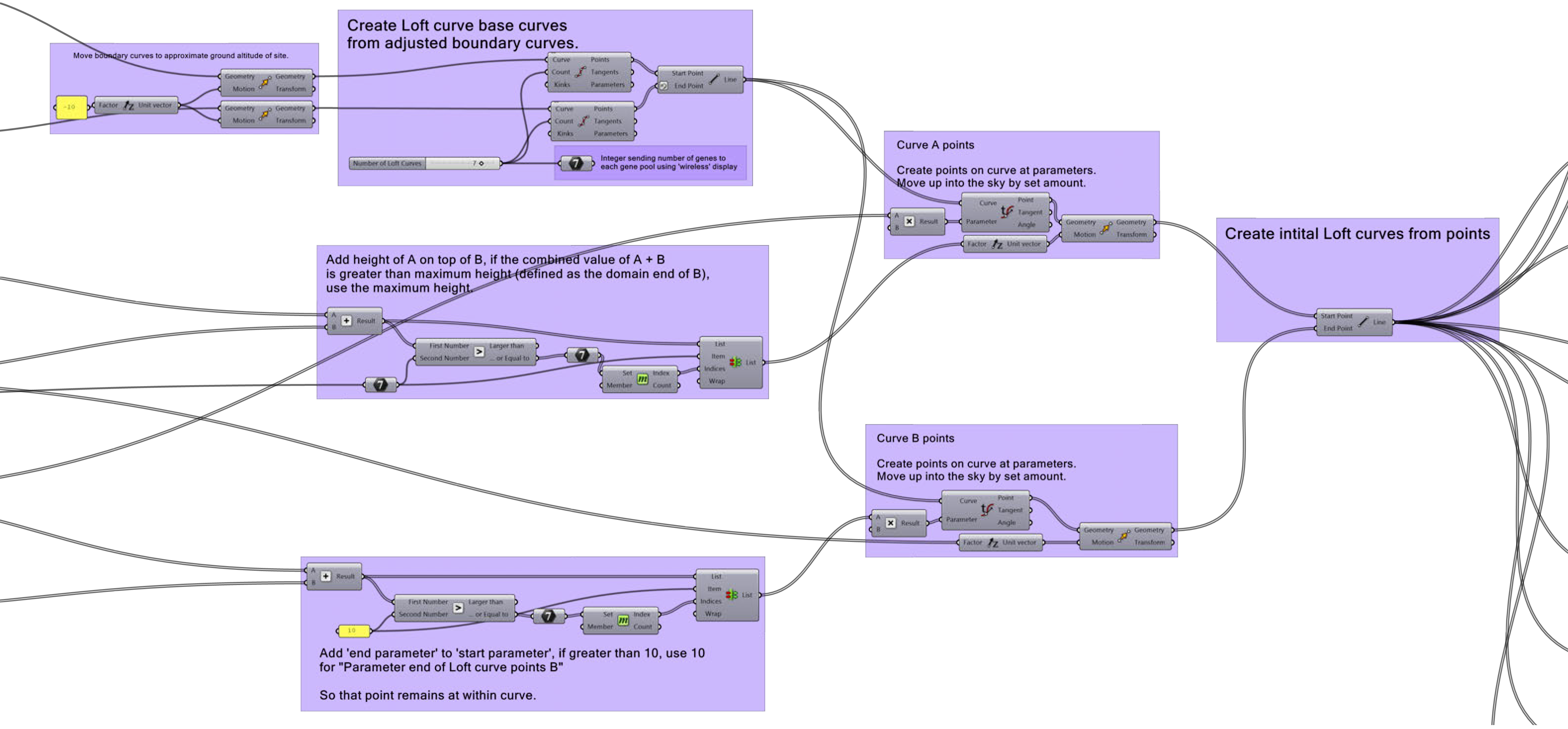

Upper part of street wall
Lower part of street wall
Analysis of wall of side of street with a South-East facing direction
Fitness - Total solar radiation on buildings above a height. MAXIMIZE
linked via 'wireless'

3



Fitness - Total solar radiation on buildings above a height. MAXIMIZE
linked via 'wireless'
Fitness for Genetic Algorithm / Galapagos
Adjust start and end of boundary line to allow for surface to move up and down street to optimum position.
Imported Boundary curve A
Break side A boundary curve into 3, pick middle.
Imported Boundary curve B
Break side B boundary curve into 3, pick middle.
Adjust height of Loft curve points B
Adjust height of Loft curve points A
Parameter start of Loft curve points (A)
Parameter end of Loft curve points (B)
Tangent curve point parameter END curve
Tangent curve offset parameter END curve
Tangent curve point parameter START curve
Tangent curve offset parameter START curve

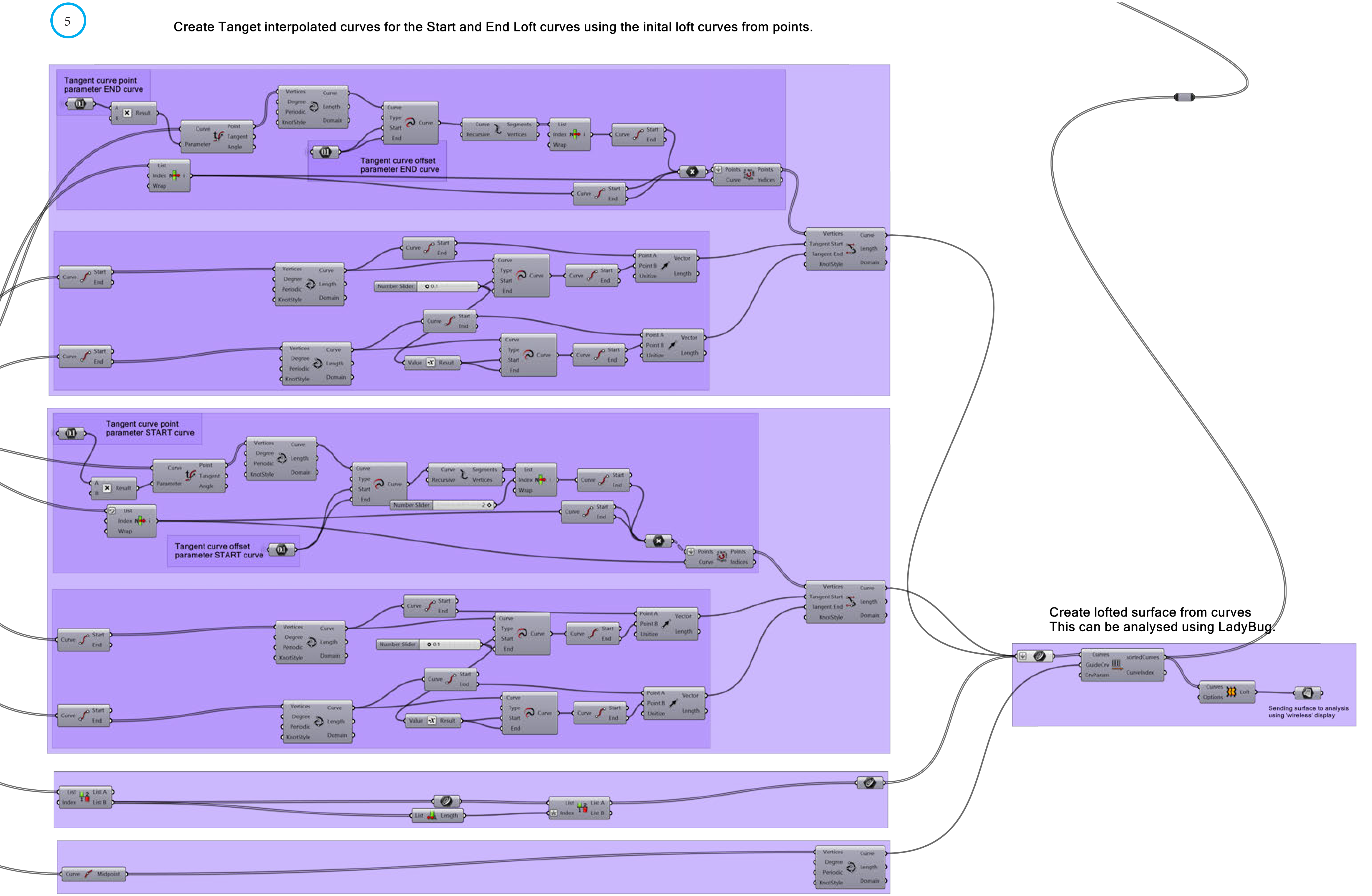
4



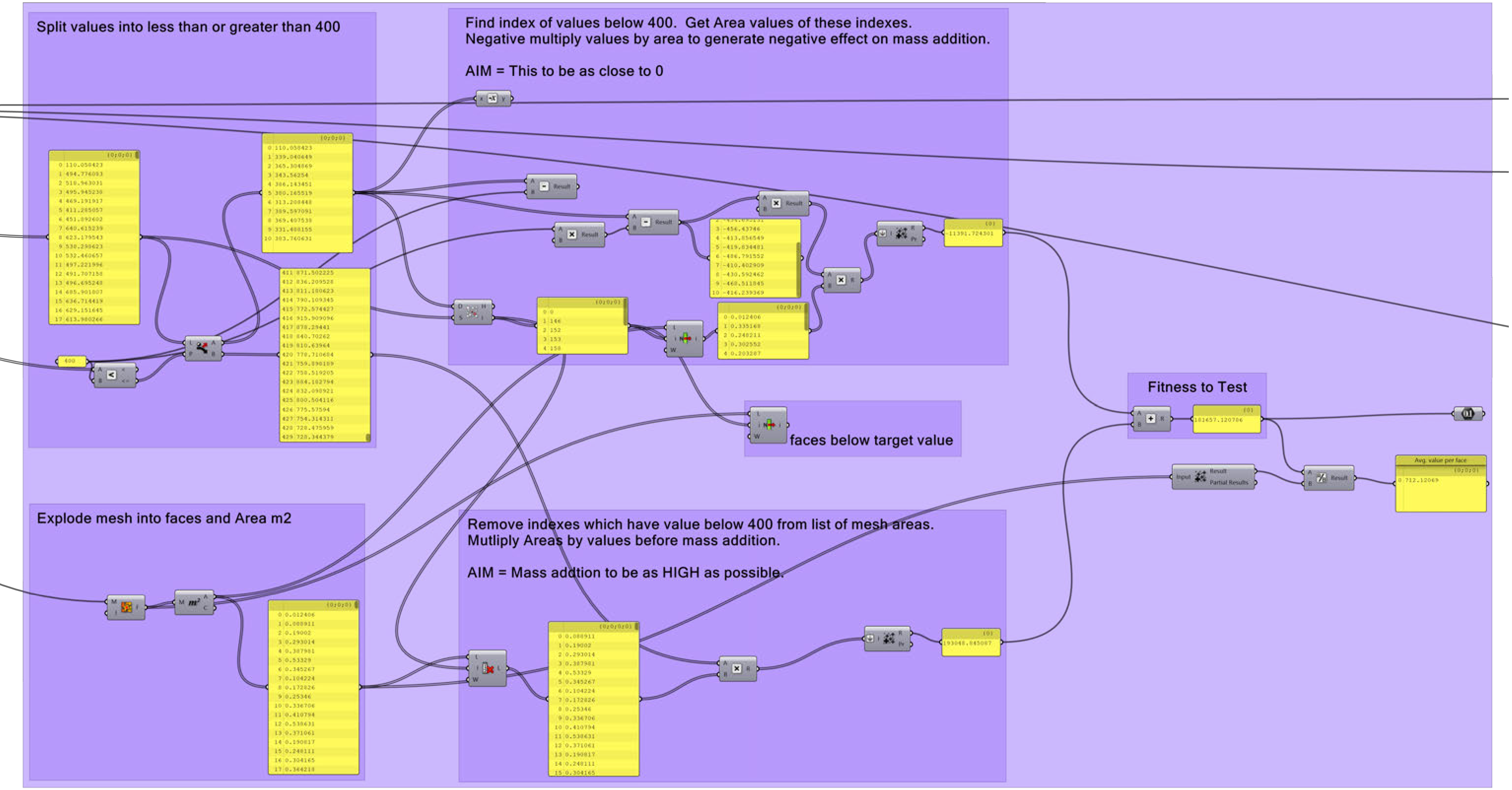
Move boundary curves to approximate ground altitude of site.
Create Loft curve base curves
from adjusted boundary curves.
Number of Loft Curves
Integer sending number of genes to
each gene pool using 'wireless' display
Curve A points
Create points on curve at parameters.
Move up into the sky by set amount.
Create intital Loft curves from points
Add height of A on top of B, if the combined value of A + B
is greater than maximum height (defined as the domain end of B),
use the maximum height.
Curve B points
Create points on curve at parameters.
Move up into the sky by set amount.
Add 'end parameter' to 'start parameter', if greater than 10, use 10
for "Parameter end of Loft curve points B"
So that point remains at within curve.

5

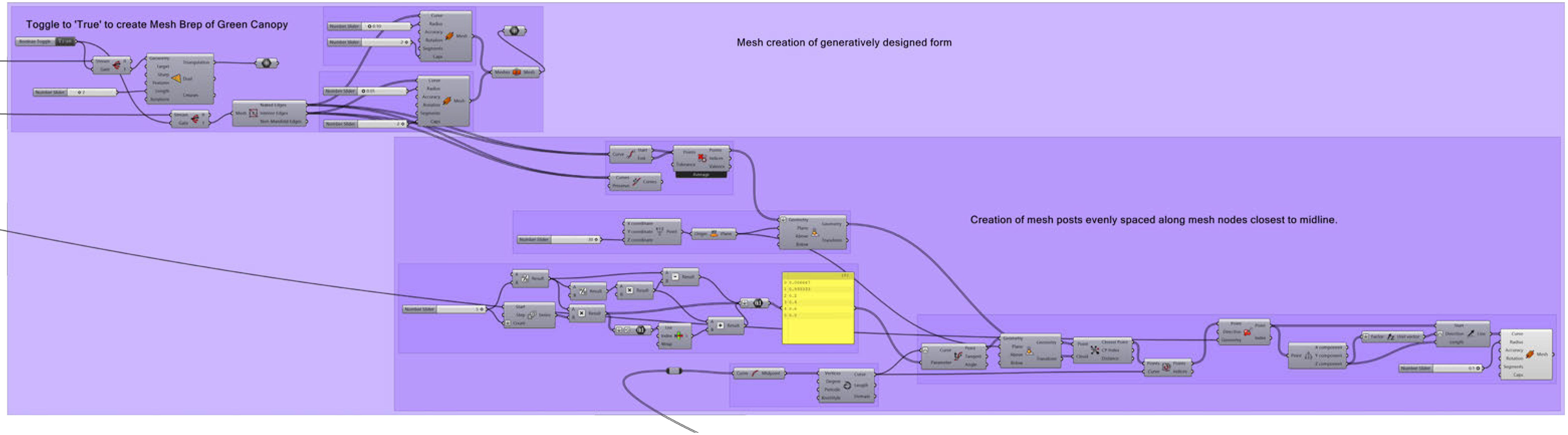
Create Tanget interpolated curves for the Start and End Loft curves using the inital loft curves from points.



6

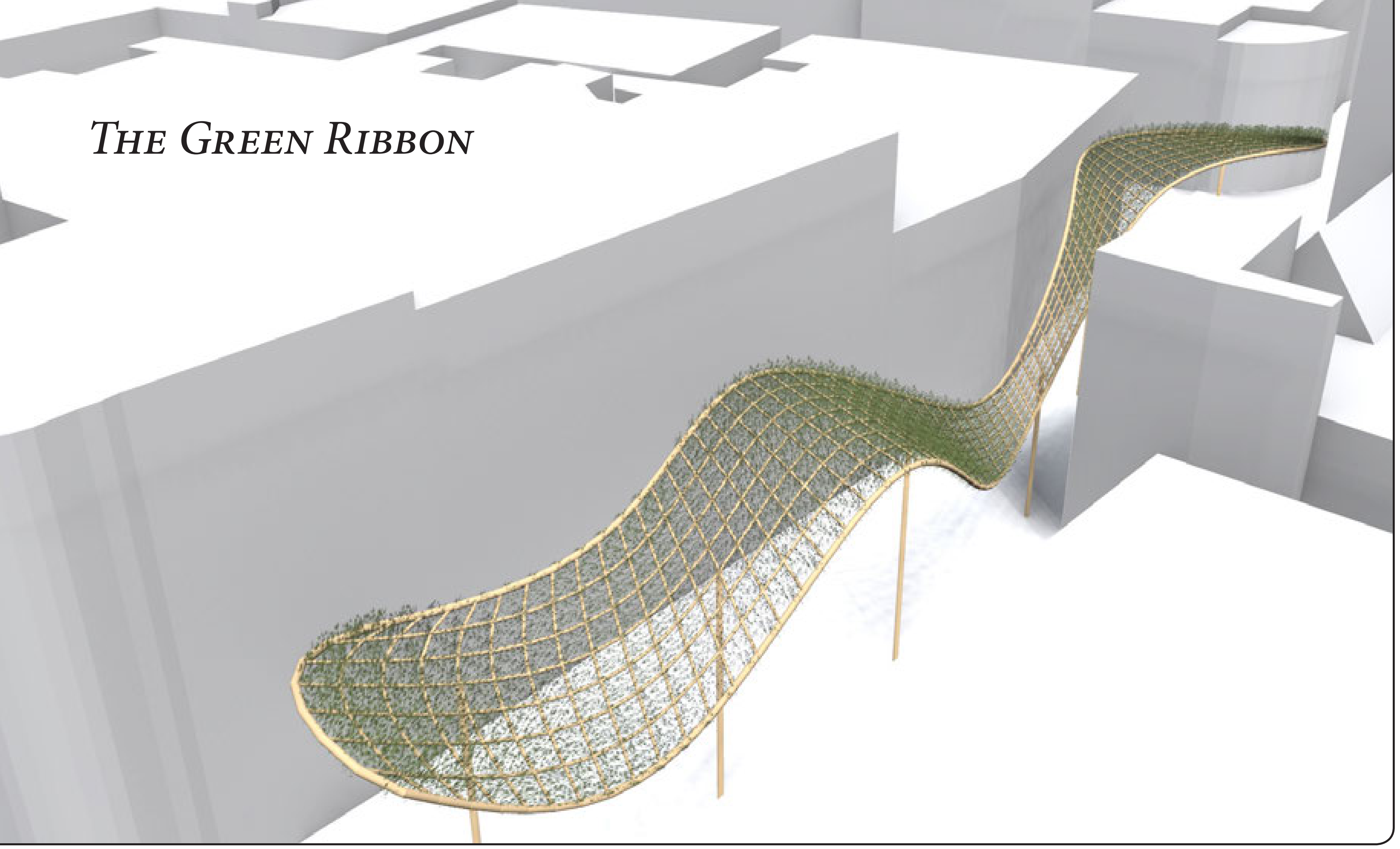

Split values into less than or greater than 400
Find index of values below 400. Get Area values of these indexes.
Negative multiply values by area to generate negative effect on mass addition.
AIM = This to be as close to 0
faces below target value
Fitness to Test
Explode mesh into faces and Area m2
Remove indexes which have value below 400 from list of mesh areas.
Mutliply Areas by values before mass addition.
AIM = Mass addtion to be as HIGH as possible.
Avg. value per face

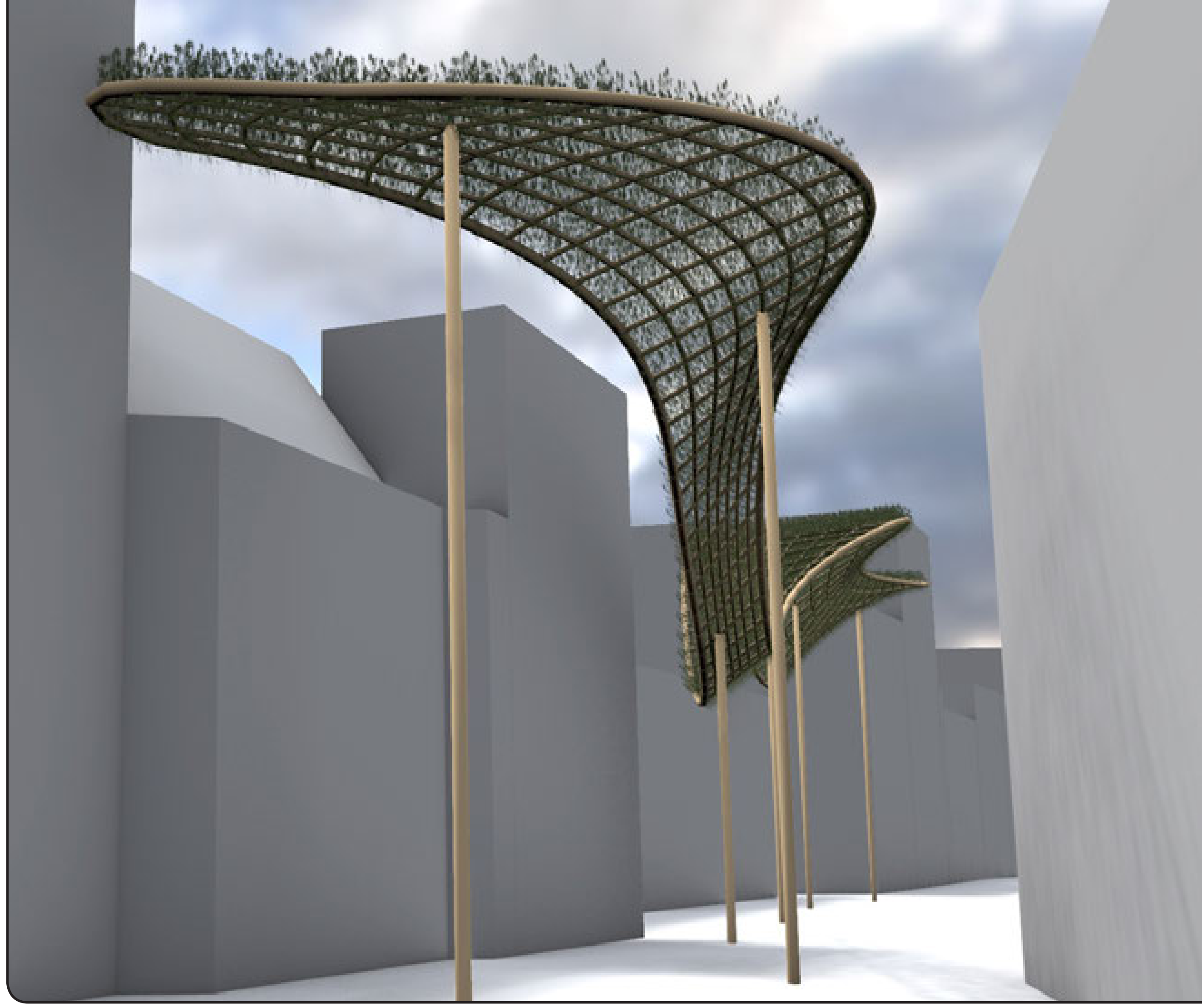
7

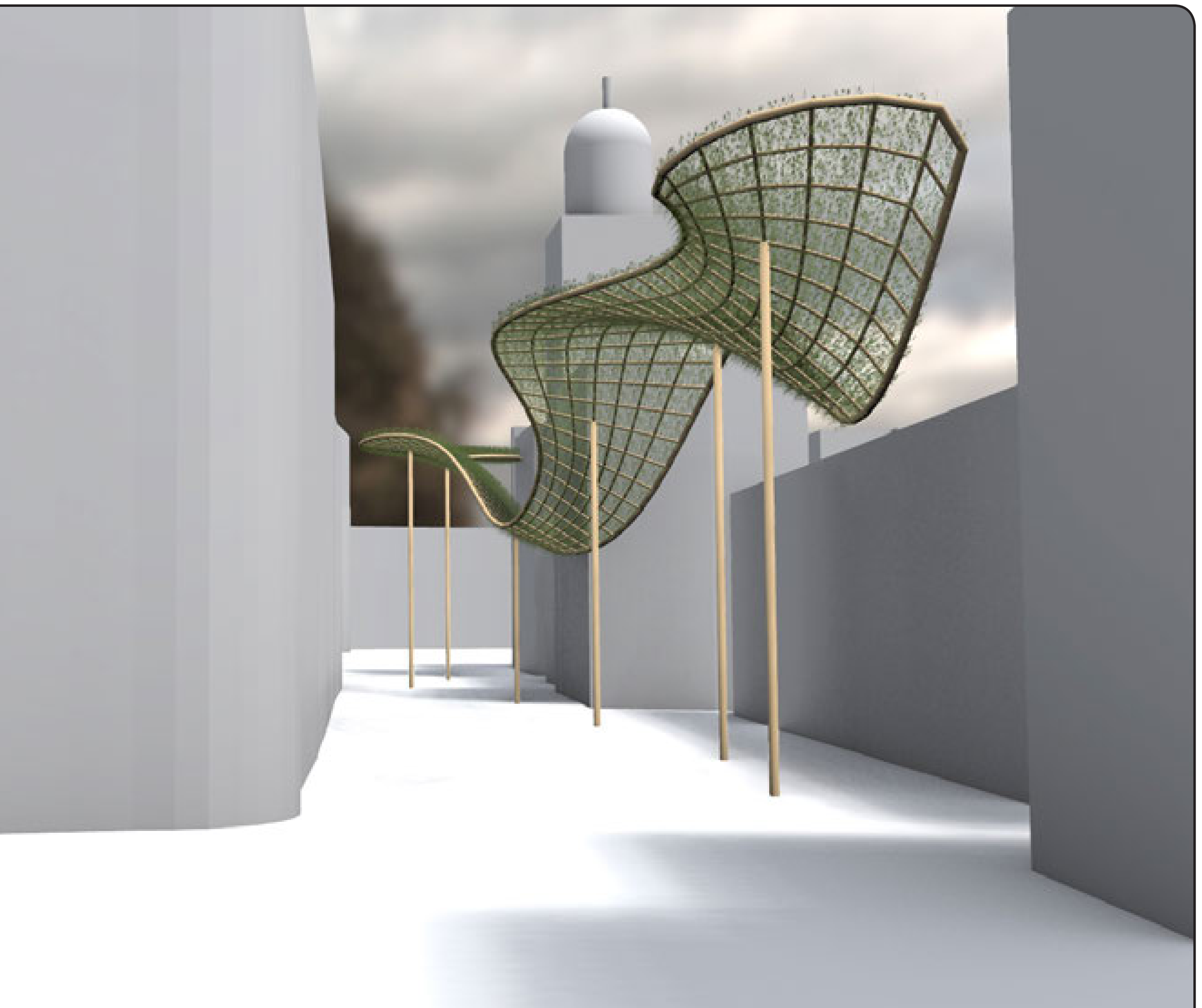


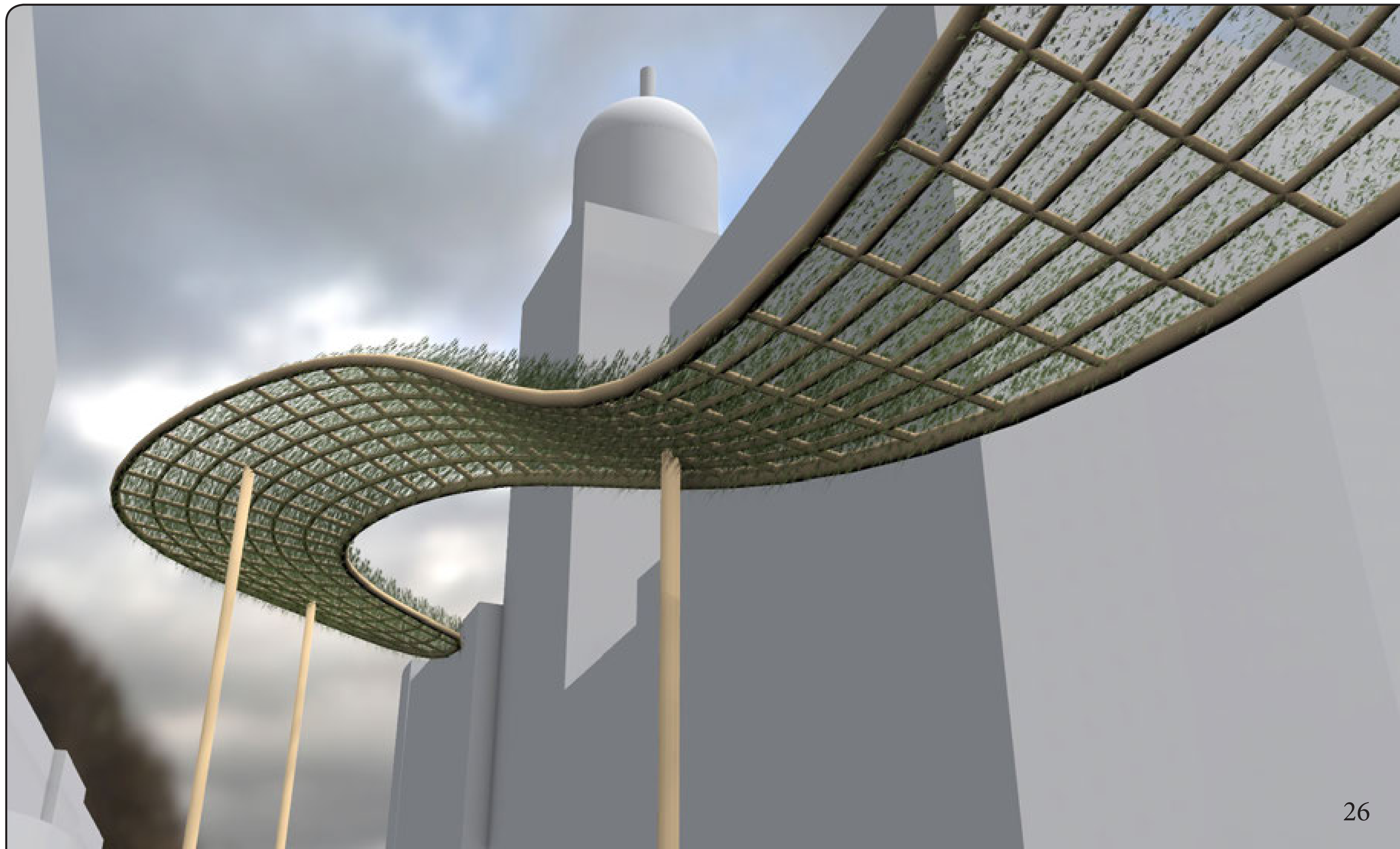
Toggle to 'True' to create Mesh Brep of Green Canopy
Mesh creation of generatively designed form
Creation of mesh posts evenly spaced along mesh nodes closest to midline.

The Green Ribbon

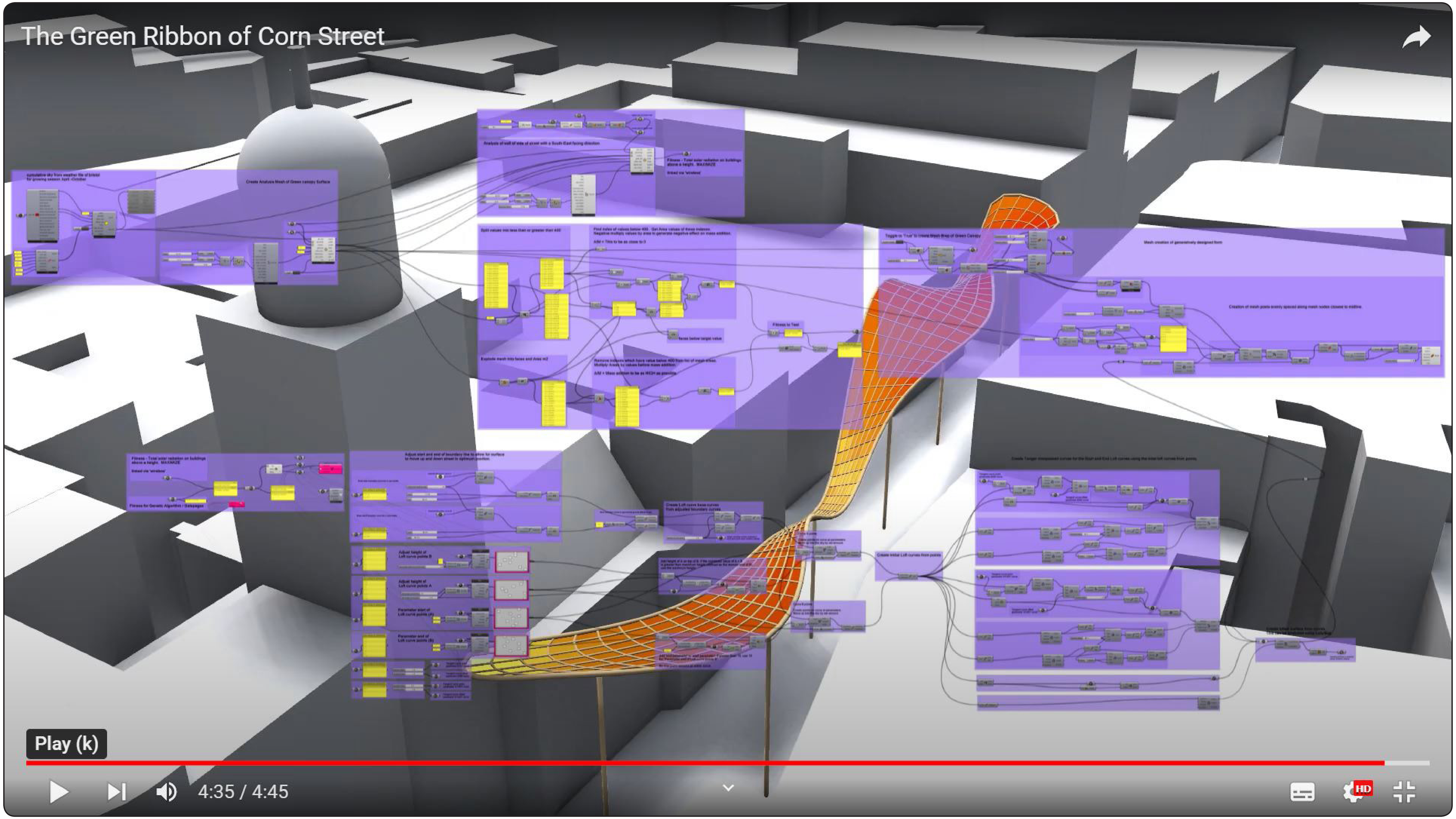








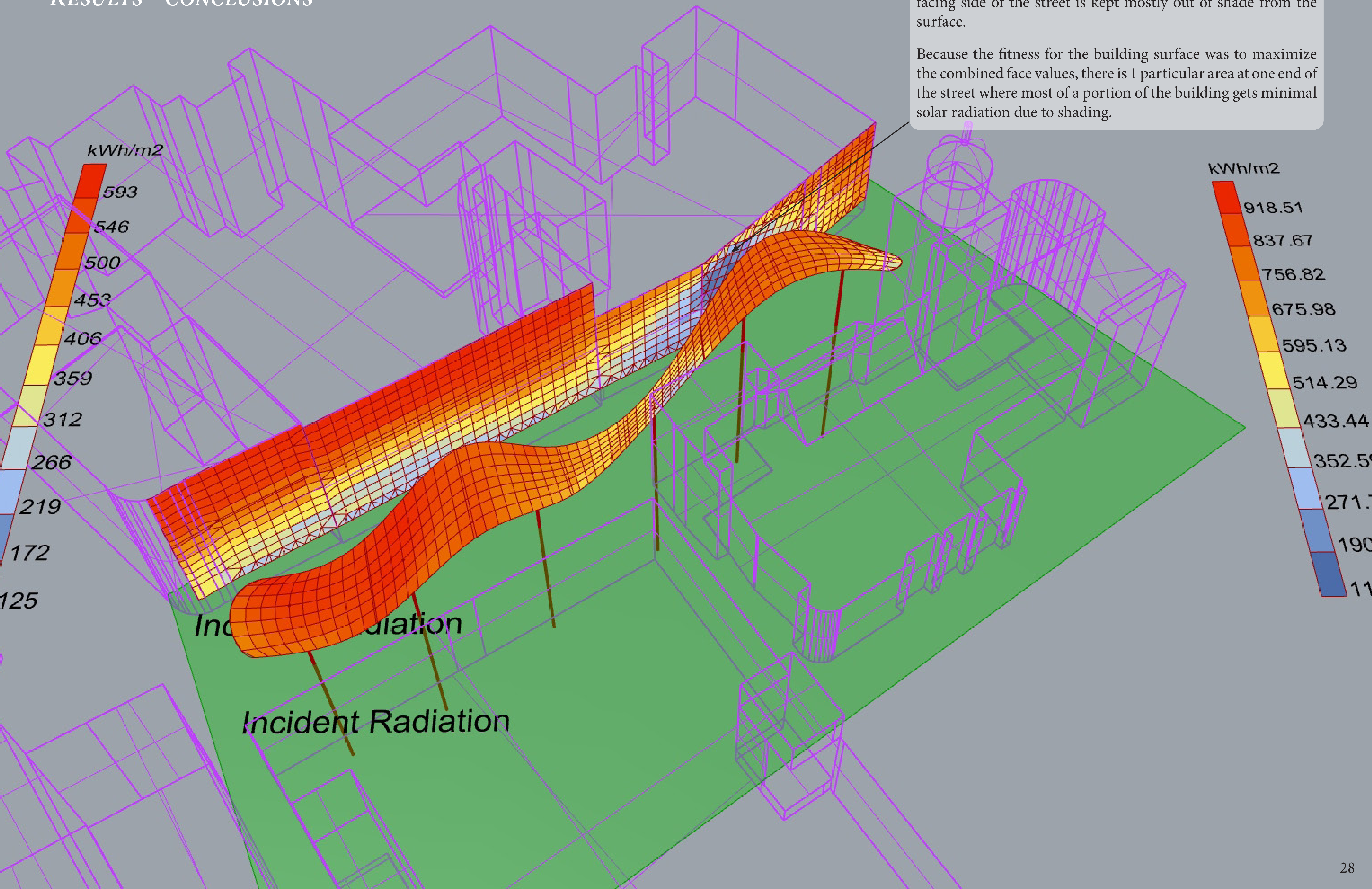
Click on image to open YouTube link



Results - conclusions

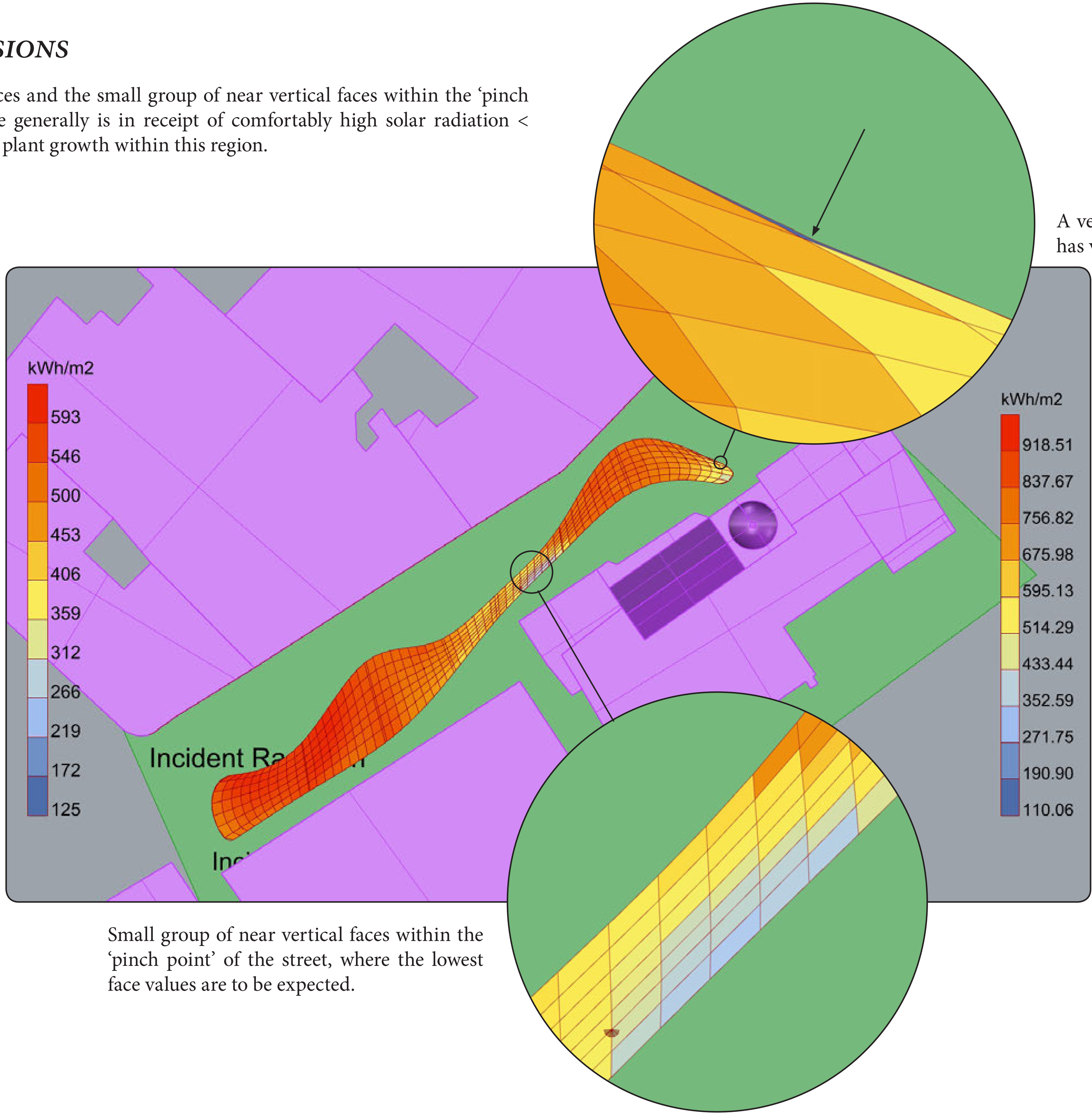
Above the green surface (2m above ground level). The south facing side of the street is kept mostly out of shade from the surface.

Because the fitness for the building surface was to maximize the combined face values, there is 1 particular area at one end of the street where most of a portion of the building gets minimal solar radiation due to shading.



Results - conclusions

Other than a few anomalies faces and the small group of near vertical faces within the 'pinch point' of the street, the surface generally is in receipt of comfortably high solar radiation < 400kWh/m2, ideal for vigorous plant growth within this region.



A very small selection of faces has very low anomaly values.

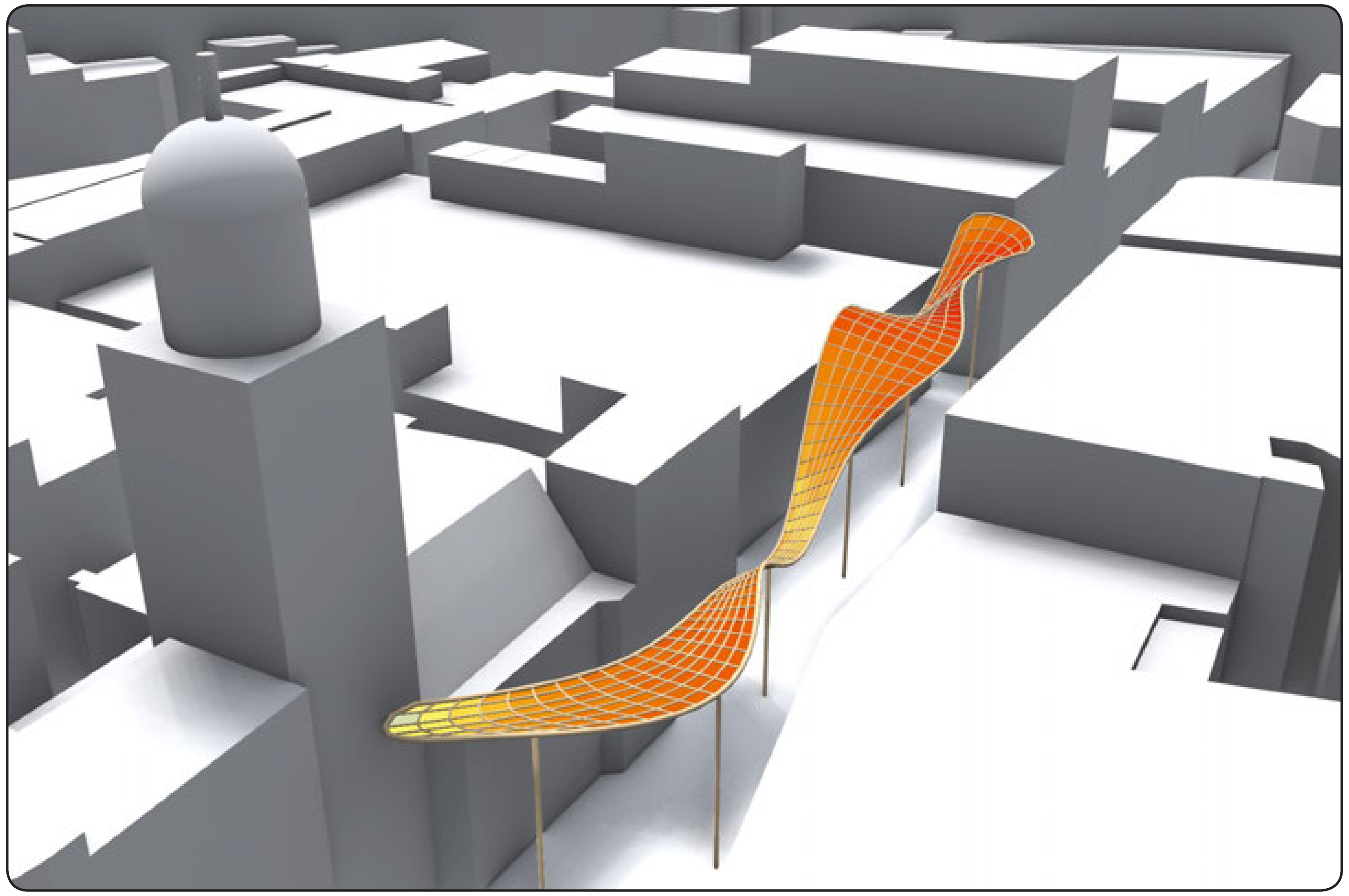
Small group of near vertical faces within the 'pinch point' of the street, where the lowest face values are to be expected.

Discussions / Further Development

Using multiple objective Genetic Algorithms such as 'Bio-Morpher' allows for street context to be considered.

It could seek to maximize the surface area above and minimize the surface area below a certain value.

In theory this should negate having to artificially negatively weight the areas below a value, which itself could cause inaccuracies finding an optimum growing surface. It would be beneficial to compare these 2 methods.



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