

## Adding a roof space over several zones.

Adding a roof space zone connecting to several rooms requires a sequence of actions from the user. There is no wizard for this. And it is possible to do this and similar tasks quickly and with minimal frustration. This section presents a methodology, planning issues and information to be gathered. It then reviews how to use some of the in-built facilities of the *Project Manager* to reuse existing model information.

Let us begin with an existing model of a low energy house with six rooms. The occupied spaces have been defined and the user is at the point of adding a zone to represent a roof space. The procedure should be applicable to a range of models where the number of surfaces and spaces differ between levels of a building. It also provides a general approach for creating a simple roof shape.

Project: Abstract Version LaegehusStenloseSyd

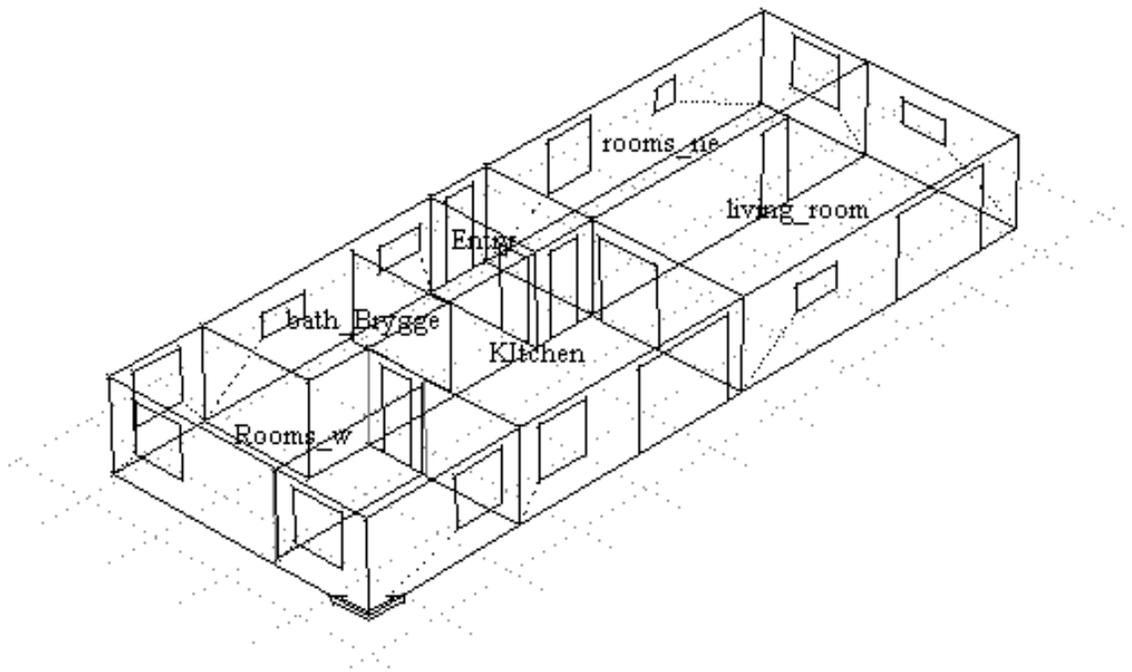


Figure 1: Occupied rooms in house.

The section of the house and roof space is shown in Figure 2. There are several aspects of the section which need to be considered:

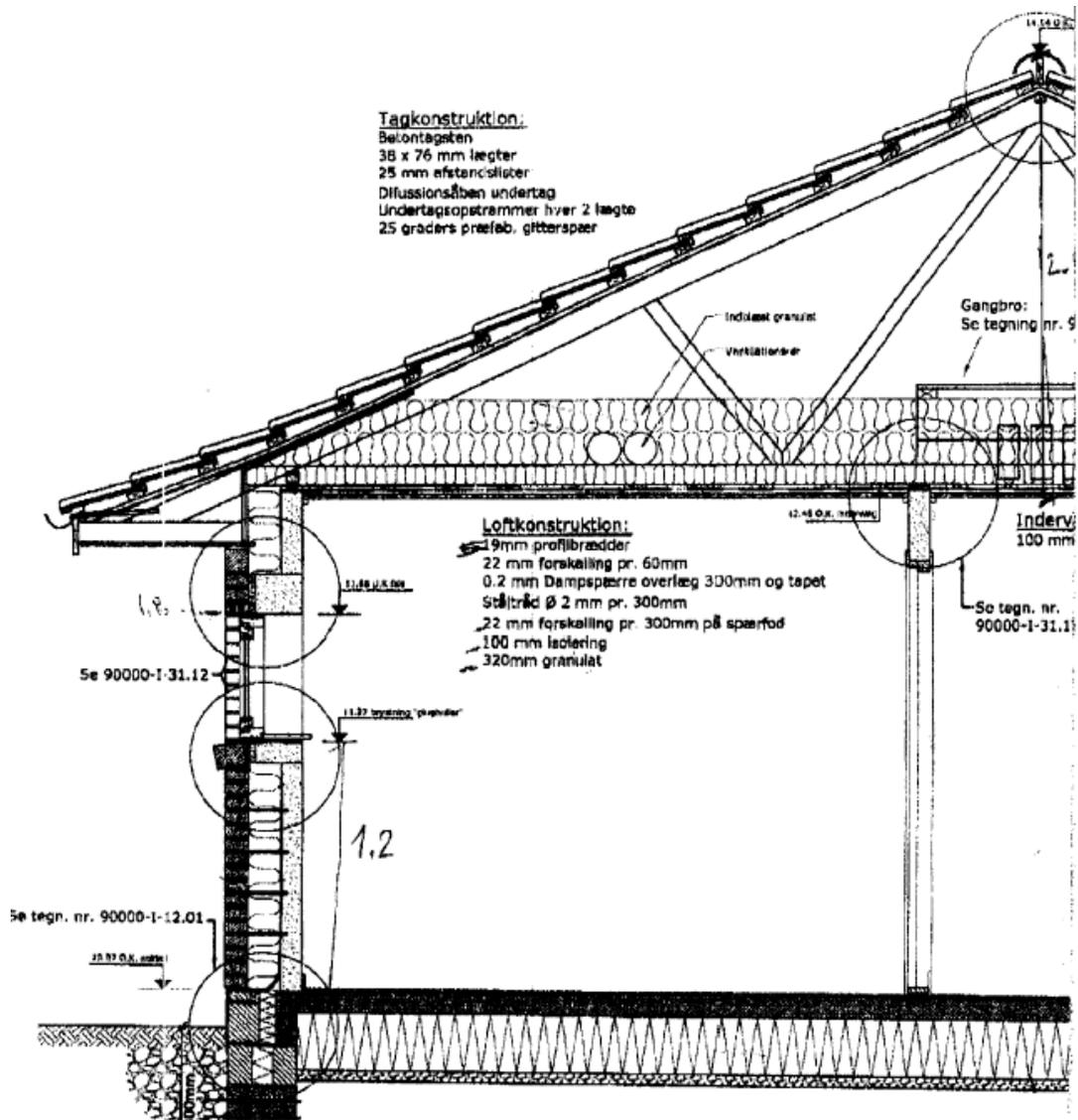


Figure 2: Section of house

- the thickness of insulation is substantial and at the edge is somewhat less thick
- the wall section comprises a number of material types
- there is an overhang which will act to shade the facade of the building
- the overhang is thermally isolated from the air within the roof space
- the overhang forms a boundary for the upper section of the wall.
- there appears to be an air space below the tiles which is separate from the air within the roof space.
- the portion of the roof with the tapering insulation is in direct contact with the layer of wood below the tiles
- it is not clear from the section whether the roof space is well ventilated.
- the area at the top of the insulation layer is somewhat different from the surface area at the ceiling

## Modelling approaches

The geometric and compositional resolution of the simulation model depends on the questions being asked and the resources available. Some thermophysical relationships may require simplification. If at all possible the following aspects of the roof should be preserved in the model:

- the volume of air
- the slope of the roof
- the location of mass within the roof
- the surface area in contact with the air

A *low resolution* model might treat the overhang as a solar obstruction and ignore the different thickness of the insulation. It might assume the air is well mixed within the roof space (i.e. there is no temperature stratification). It would also not explicitly represent the overhang as a boundary condition for the upper portion of the wall.

A *medium resolution* model might subdivide the surfaces to represent full thickness and the partial thickness insulation and extend the roof zone to allow it to form a boundary at the upper wall section.

A *high resolution* model might represent the overhang portion of the roof as a separate zone or zones because there will be times when the air temperature in the overhang is different from that of the main section. A high resolution model would have an upper and lower section so that the temperature near the peak of the roof can be different from the air adjacent to the insulation layer.

By default, ESP-r assumes one-dimensional conduction. The substantial thickness of the insulation seen in Figure 2 poses a challenge compared to a dropped ceiling with a ceiling tile (where it is easy to ignore the tile thickness when defining geometry). For this house some thought is required to make a 1D representation of the heat flow paths within the house section. Use of physical co-ordinates would help to preserve the volume of the roof space and the surface areas but increases the resources required for data input.

Many example models distributed with ESP-r appear to ignore the thickness of partitions while other example models do indicate a separation between rooms. Such differences are typically related to the method of data input. Geometry digitized from CAD drawings will have separated rooms. Zone geometry created from dimensioned data or sketches may tend to have partitions at the centre line of walls and the inner face of a façade.

Such differences typically have little or no impact on the performance predictions. The solver knows from the composition of the partition the full thermophysical properties of the construction and uses them whether or not the two faces are separated in the coordinate system or lie in the same plane. There are exceptions which are covered elsewhere.

If the user is constrained in time, the user could form the base of the roof space by copy and invert the existing ceiling surfaces and then create the sloped roof above that (see Figure 3). This approach results in a model that is crude visually. The surface of the roof is at the correct slope, but the height of the building is not correct.

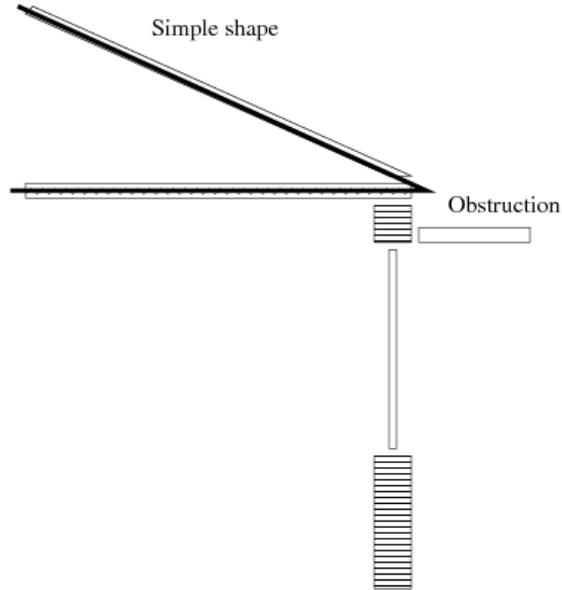


Figure 3: Constrained model

Given a bit more time the user could add a number of perimeter surfaces so as to raise the roof (at the expense of an inaccurate air volume) as in Figure 4. Such trade-offs might not alter the overall performance of the building but may be useful to make the model less crude visually.

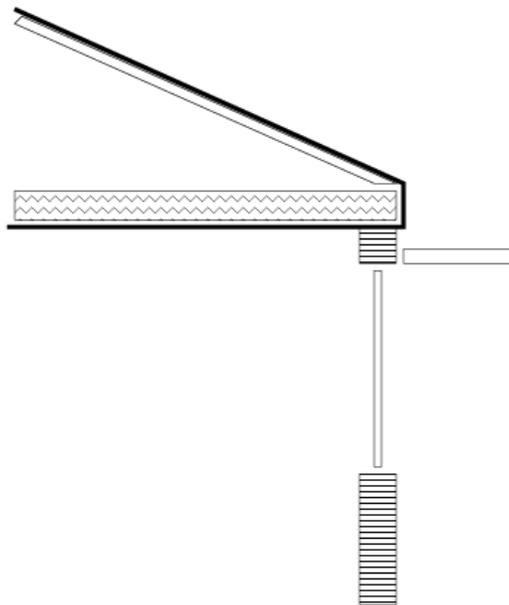


Figure 4: Variant placing roof at correct height

To move from treating the ceiling as a geometrically thin plane towards a model that uses explicit coordinates requires an additional step. The initial copy and invert of surfaces is followed by a surface transforms (along the surface normal). This facility, and several other types of rotation and transform are available in the interface (see Figure 5).

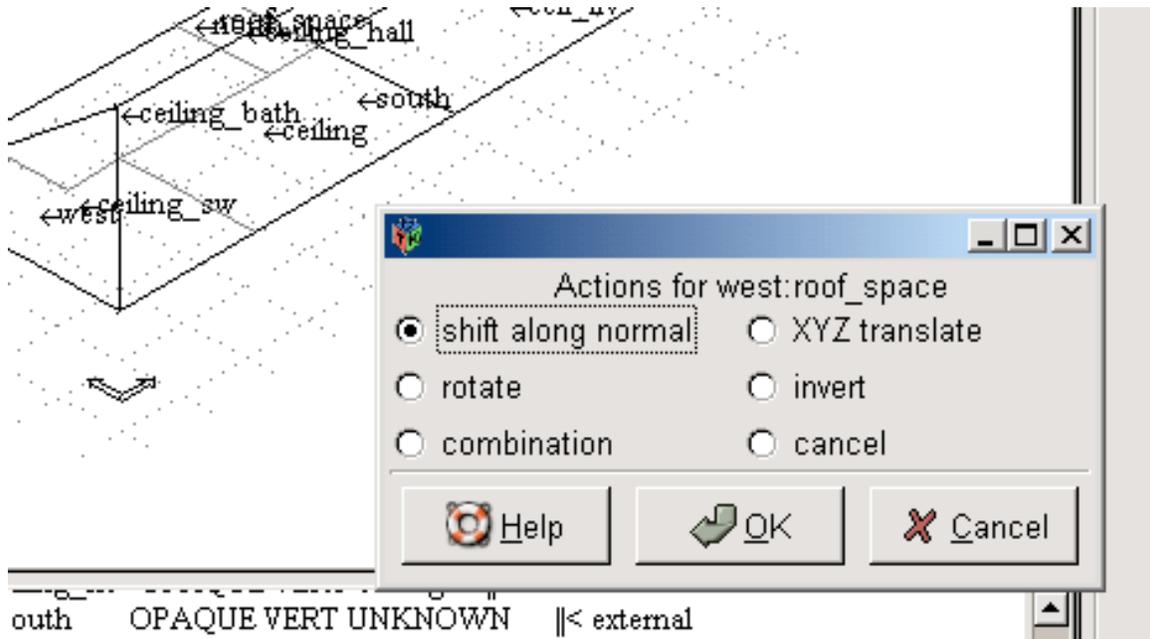


Figure 5: Surface transform options

If there is a gap between the roof zone and the occupied zone (as in Figure 6) this might be visually confusing to some users and their clients (if the ESP-r model was exported to Radiance). This gap could be filled with an appropriately sized solar obstruction block.

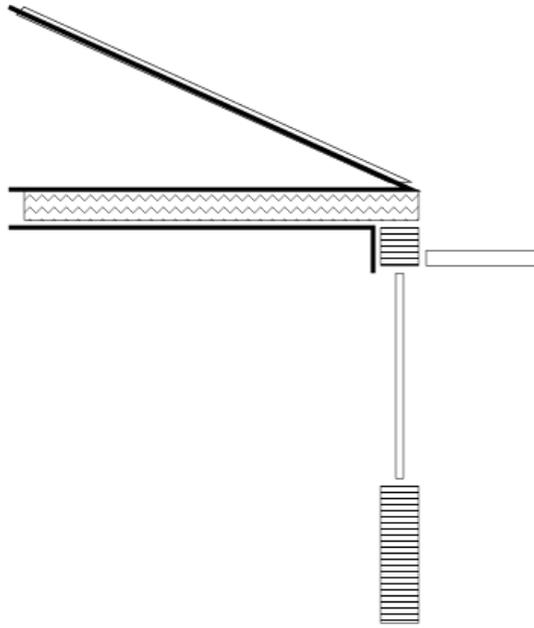


Figure 6: Variant using actual coordinates.

The above approach might be a reasonable thermophysical representation. It is, none-the-less quite abstract for users expecting a CAD representation. To approximate the 3D geometry of an actual roof requires that the initial copy, invert, transform of the ceiling polygons is followed by the addition of surfaces to represent the roof overhang as in Figure 7..

Please note that the surfaces forming the overhang do not (in the current version) shade the wall. Shading requires the use of shading obstruction blocks (as included in the earlier figures).

And this more-explicit approach introduces a problem for the occupied space. The overhang, as drawn in the building section is in contact with the upper portion of the wall. The geometry of the walls should be adapted to sub-divide the wall into surfaces that face the outside and surfaces which connect to the overhang. Clearly this would be tedious to retrofit into the existing zones shown in Figure 1.

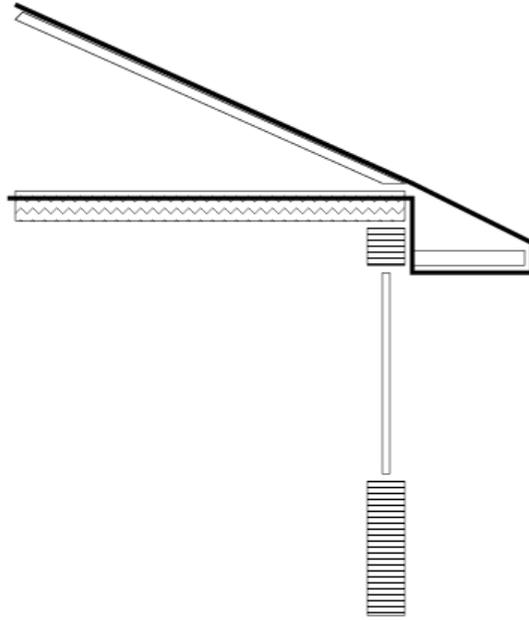


Figure 7: Variant extending roof overhang.

As mentioned in the introduction, the air within the overhang could be at a different temperature than the roof space. If such temperature differences were an issue, the overhang could be represented as a separate zone as in Figure 8. This overhang zone could wrap around the main roof space zone (one overhang zone could represent the overhangs on the North, South, East and West. Again the existing wall will have to be revised to represent the connection to the outside and the connection to the overhang.

One could be pedantic and argue that the temperature of the North overhang might differ from that of the South overhang and require separate zones. Few users would be confronted by projects where such detail is warranted.

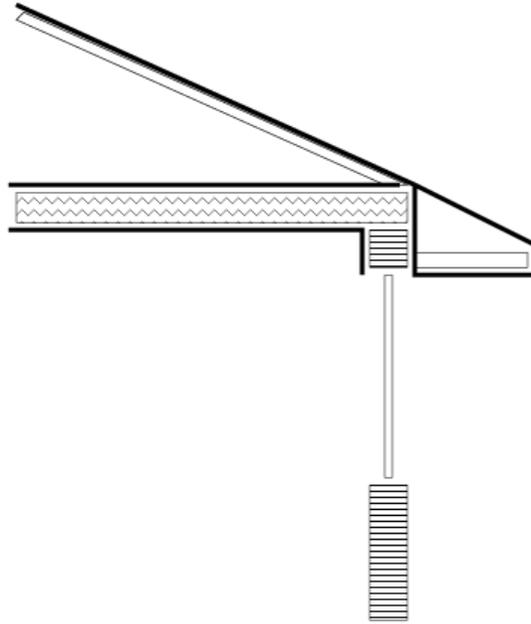


Figure 8: Variant with separate overhang zone.

Investing resources to increase model resolution is a decision that should not be made lightly. Some differences in performance predictions can be subtle rather than dramatic. A user who wishes to explore this could define variant models at different levels of resolution to test the sensitivity of predictions.

### Steps to create a simple roof

A low resolution model, making use of the existing ceiling surfaces, which follows the pattern of Figure 3 has the following critical dimensions:

- the height at the peak of the roof 4.35m
- the lower face of the ceiling 2.35m
- the width of the overhang 0.6m

The following sequence will minimize keystrokes and limit the risk of error. Other sequences are possible - so try variants until you evolve a sequence that works for you.

Enter the 'browse/edit/simulate' -> composition -> 'geometry & attribution' menu and select each of the existing zones and review their contents and ensure that the ceiling surfaces are attributed (to save time in later steps).

Next in the 'geometry & attribution' menu select 'add/delete/copy'. After electing to 'add' a zone, select 'input dimensions' and enter a name such as 'roof\_space' as well as a description to clarify to others the intent of this zone.



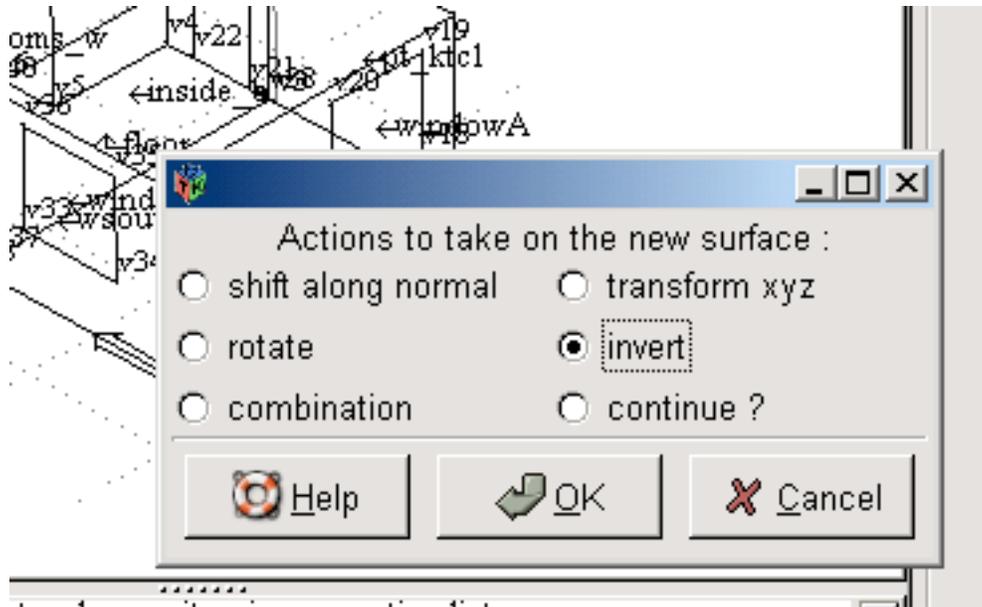


Figure 10 The invert dialogue.

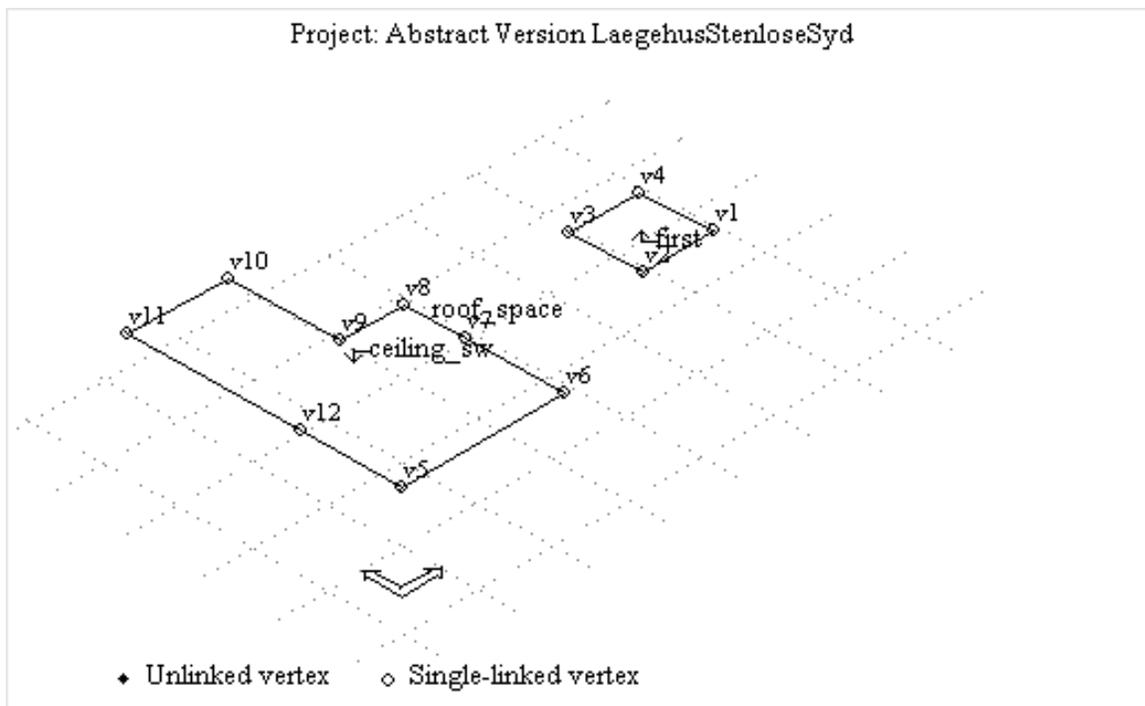


Figure 11 After import and inversion of a surface.

During the import you might find a source surface with a duplicate name. You will be asked to specify a new unique name. Tactical hint: if you follow a clear naming strategy, subsequent tasks will go faster. At some point remember to remove the initial dummy surface. When all of the ceilings have been imported the roof\_space will look like Figure 13. Each surface name provides a clue as to what is on the other side of the ceiling.

Typically, each imported surface will require between 5 and 10 seconds for an experienced user and if there are name clashes it might require 20 seconds per import.

There are a number of steps which you can take at this point which will prevent the propagation of errors. For example, the wire frame image will have open circles drawn at each vertex that is referenced once - so open circles are to be expected at the borders. The wire frame image will have solid circles at vertices not referenced by any surface. You will see four such circles in the wire frame - these are orphan vertices associated with the initial dummy surface. It will save time and limit confusion if you exit from the 'Surface topology' menu and go into the 'vertex coordinates' menu and identify vertex 1, 2, 3 and 4 for removal.

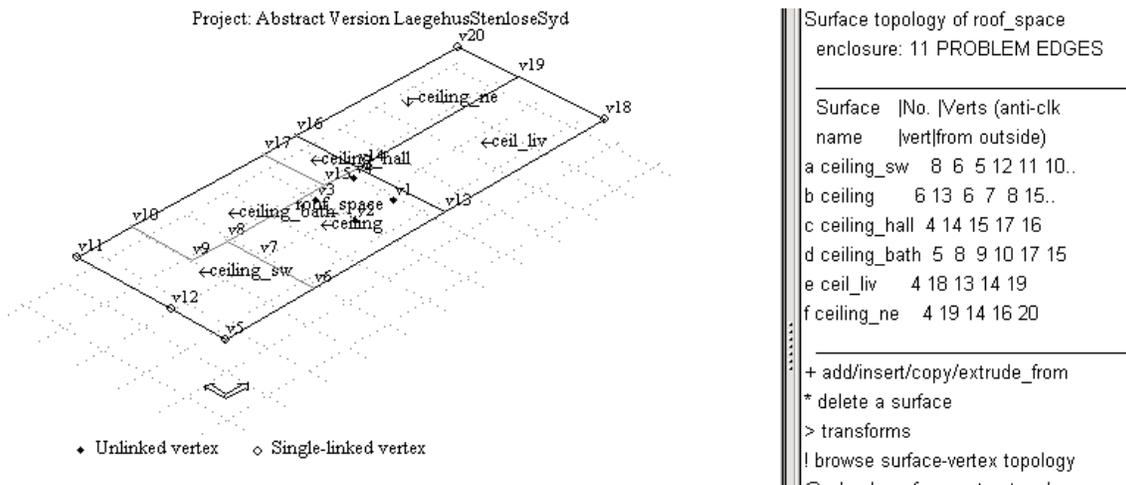


Figure 13: roof\_space with imported ceilings.

While you are in the 'Vertices in' menu take a note of the Z values. The current position of the surfaces is at 2.35m. We want the ridge of the roof to be 2m above this point. The roof is a hip type and the dimension from south to north is 7.2m so the ridge will start 3.6m from the East and West and South edge of the building facade. These two coordinates are then:

- left ridge point X=3.6, Y=3.6, Z=4.35
- right ridge point X=15.77, Y=3.6, Z=4.35

For a gable roof the X coordinate would not be altered to form a pair of triangular walls. The next step is to '+ add' two more vertices to the roof\_space zone. The result should look like Figure 14 (look for v17 and v18).

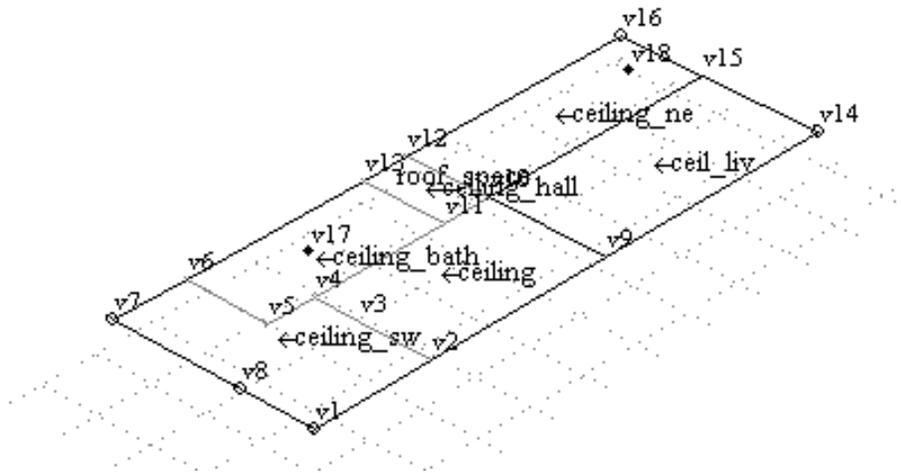


Figure 14: roof\_space with two ridge vertices.

The next step is to compose the South, East, North and West surfaces of the roof by creating new surfaces made up of existing vertices. With reference to Figure 14

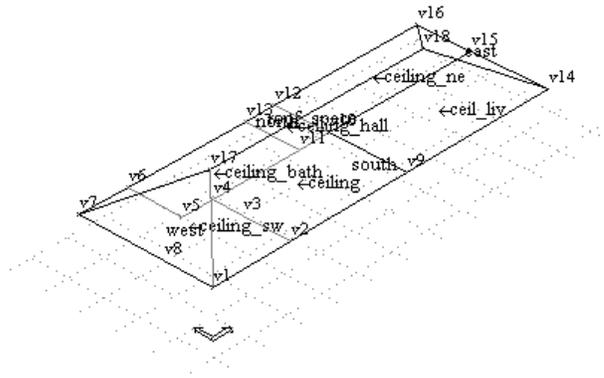
- south surface should include vertices 9 14 18 17 1 and 2.
- east surface should include vertices 15 16 18 and 14.
- north surface should include vertices 6 7 17 18 16 12 and 13.
- west surface should include vertices 8 1 17.

There are patterns in the above definitions. What are they?

- Each surface is defined in an anti-clockwise order (looking from the outside)
- the first edge is horizontal and the second edge is not horizontal
- intermediate vertices (e.g. 2 and 9 and 15 etc.) are included in the list

The first edge horizontal rule is required by the shading and insolation analysis. Look at the surfaces in any of the simple exemplar models and you will see this pattern. With simple shaped surfaces there is usually only one edge along the base of a wall and for such surfaces the normal rule of 'start from the lower left edge going anti-clockwise' applies. In this case because there are several edges in sequence so the rule has to be adapted. If you miss out one of the intermediate vertices (e.g. vertex 15 along the east façade) ESP-r will detect a mismatch and warn you to check the polygon edges.

Project: Abstract Version LaegehusStenloseSyd



Surface topology of roof\_space  
enclosure: properly bounded

Surface name	[No.  verts (anti-clk  vert from outside)
a ceiling_sw	8 2 1 8 7 6..
b ceiling	6 9 2 3 4 11..
c ceiling_hall	4 10 11 13 12
d ceiling_bath	5 4 5 6 13 11
e ceil_liv	4 14 9 10 15
f ceiling_ne	4 15 10 12 16
g south	6 9 14 18 17 1..
h east	4 15 16 18 14
i north	7 6 7 17 18 16..
j west	4 8 1 17 7

Figure 15: Zone with roof surfaces.

If you followed these steps, the interface should look like Figure 15. An experienced user will require about 10 seconds to create a new surface from existing vertices and will also be double checking that data glitches are caught early and corrected before progressing to the next task. Practice until you feel confident with the technique!

Notice the 'enclosure: properly bounded' message at the top of the menu. This signals that all of the edges in the zone are following the rules of syntax and order and that the zone is fully bounded by polygons.

A further check could be done by turning on the surface normal arrows in the wire frame drawing (in the X11 interface this is found in the XX button and in the GTK interface the option is in the 'View' tab wire frame control in the centre of the 'Display information toggles' section (see Figure 16).

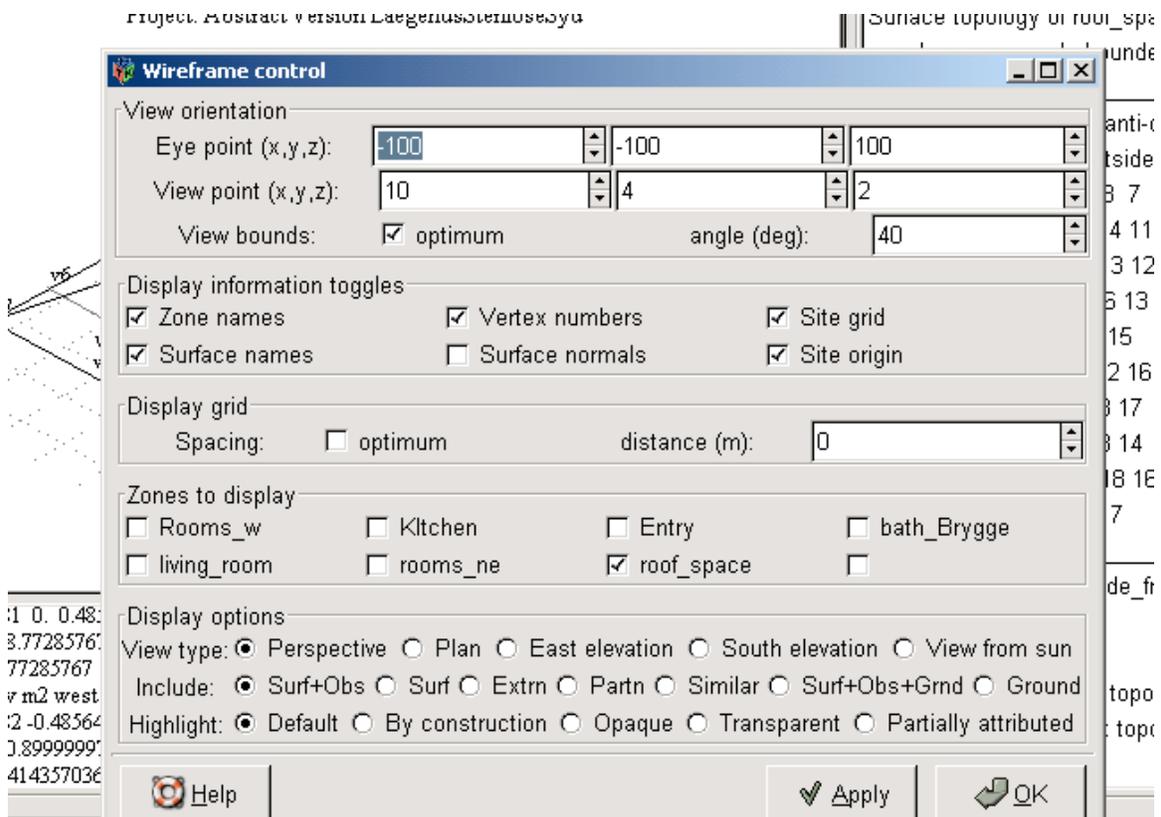


Figure 16: Wire frame control 'surface normal' dialog.

Almost finished. Now is a good time to contrast the visual information in the wire frame with the 'zone & surface details' report as in Figure 17. The few seconds that it takes to generate this report and review it with the wire frame will typically save tens of minutes later.

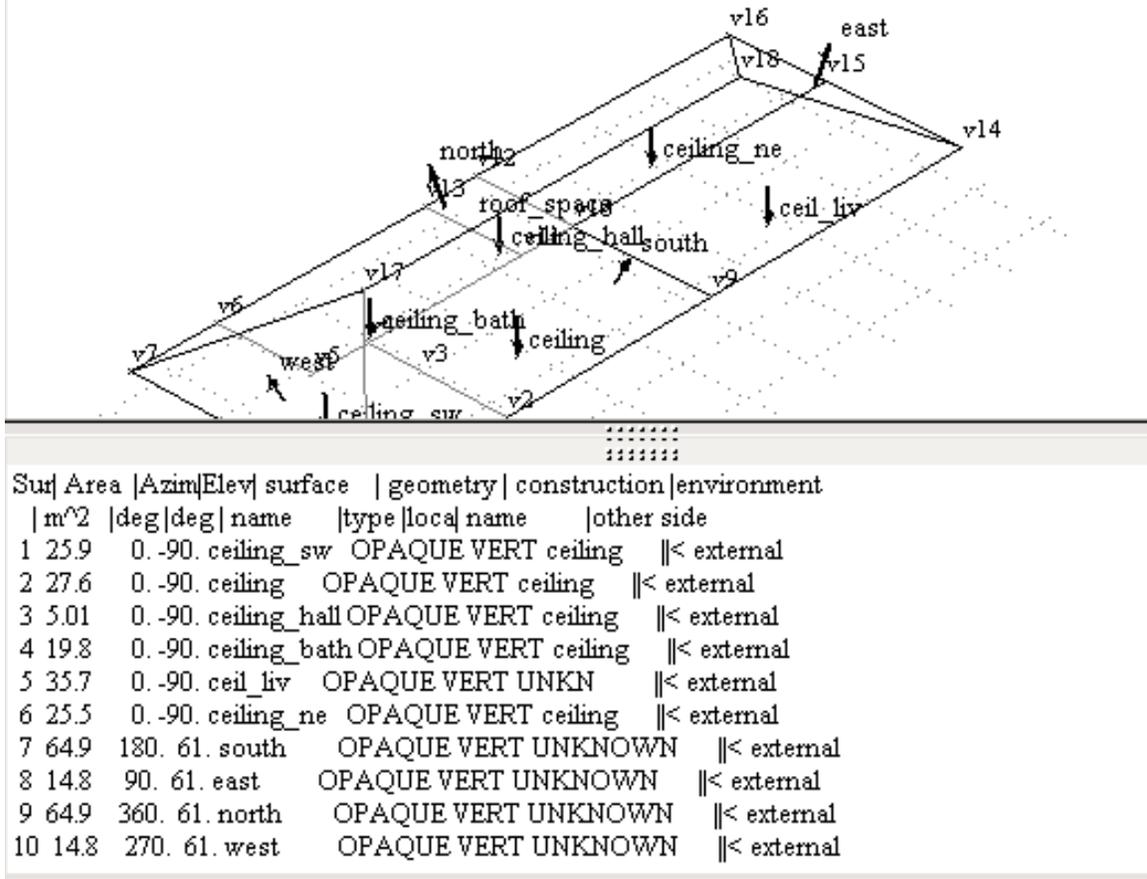


Figure 17: Wireframe and text report for better QA.

Having created the polygons and given them names, the next task is to attribute the surface composition. A copied surface already has inherited attributes. The new surfaces of the roof are partially attributed at this point.

Remember that there is an automated process which looks at the co-ordinates of each surface to find thermophysical adjacency. It may be quicker than attributing each surface in the roof\_space manually.

### Shading obstructions

The roof is formed and attributed but the walls will not be shaded until obstruction blocks are added to the model. << to here >>

Other attribution such as casual gain and air flow schedules are covered elsewhere.

