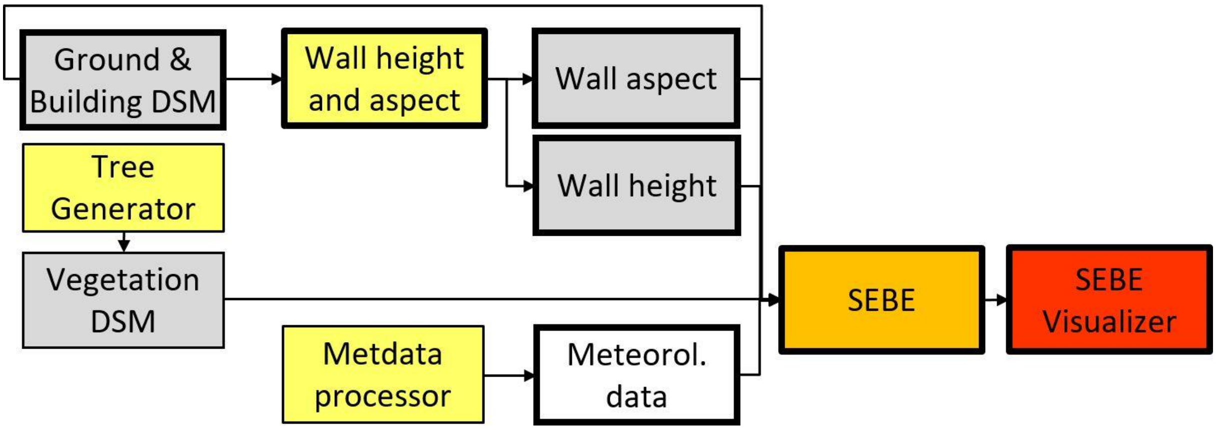
Solar Energy - Introduction to SEBE

Introduction

Lindberg et al.'s (2015) solar radiation model SEBE (Solar Energy on Building Envelopes) allows estimates of solar irradiance on ground surfaces, building roofs and walls. It uses a shadow casting algorithm with a digital surface model (**DSM**) and the solar position to generate pixel-level information of shadow or sunlit areas. The shadow casting algorithm (Ratti and Richens 1999) has been developed to incorporate walls (Lindberg et al. 2015). This is of interest for a broad range of applications, for example solar energy potential and thermal comfort.

SEBE is incorporated in [UMEP (Urban Multi-scale Environmental Predictor)](), a plugin for [QGIS](). As SEBE was initially developed to estimate solar energy potential on building roofs, the Digital Surface Models (DSMs) used need to include roof structures, such as tilted roofs, chimneys etc. Methods to produce accurate ground and building DSMs for SEBE include the use of LiDAR technology and 3D roof structure objects in vector format.



Workflow for potential solar energy modelling in UMEP

In this exercise you will apply the model in Norrköping, Sweden to investigate solar energy potential on building's roof and walls.

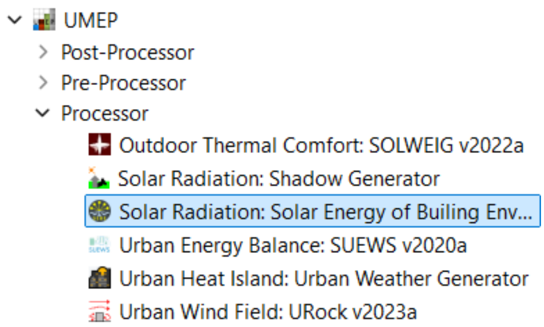
Based on your QGIS and Python skills, there are three options available:

1. **BASIC**: Follow WS-leader and instructions found below
2. **INTERMEDIATE**: Set up the Model Builder in the Processing Toolbox for solar energy modelling with SEBE over part of Norrköping. There is a tutorial here that you can look at for tips. Follow the beginning of the instructions (**initial practical steps**) below to prepare data.
3. **ADVANCED**: Write a script that is doing the same thing. Follow the beginning of the instructions (**initial practical steps**) below to prepare data.

Initial practical steps

- If **QGIS** and **UMEP** is not on your computer you will need to install it. You should have gotten some info before but if you missed it follow the link.

When you open it on the top toolbar you will see **UMEP**. There are two versions of UMEP, one menu based, and one in the Processing toolbox (**UMEP for Processing,** shown below). You will need both for this exercise.



Location of SEBE in the Processing Toolbox (UMEP for Processing)

Data for Tutorial

As we are in Norrköping, we will make use of data within the city centre.

Information about the geodata and meteorological data for **Norrköping, Sweden:**

- Data is projected in SWEREF99 1630 (EPSG:3010).
- Meteorological data come from the ERA5 reanalysis dataset that provides hourly estimates of a large number of climate variables. The data is downloaded from https://shinyweatherdata.com/ where ERA5 data is stored in a format for optimized fast time series access. The grids are lat/lon of 0.25/0.25 degrees, between -56 and 71 latitude degrees and only for non-ocean grids.

Steps

1. Download the **surfacemodels_EPSG3010.zip** from https://nextcloud.liu.se/s/x8cRT3RC5QFZXzp. The data is zipped - unzip the data before starting.
2. Open an empty QGIS-project and add the **dsm_EPSG3010.tif** and **cdsm_EPSG3010.tif** raster files through *Layer > Add Layer > Add Raster Layer or* simply drag the files into the map canvas. Examine the layers.
3. Also download the main datasets using the link above (**visual_city_participant_exhibition_dataset.zip**). We will be using the building footprint vector layer later.
4. The meteorological data can be downloaded from here. This data is already prepared into the correct UMEP-format. It was pre-processed using the **MetdataProcessor** found in the menu-based plugin (*UMEP > PreProcessor > Meteorological Data > Prepare Existing Data*). Open the meteorological file (**ERA5_Norrköping_2023.txt**) in a text editor, or in a spreadsheet such as MS excel or LibreOffice (Open office).
    - Data file is formatted for the UMEP plugin (in general) and the SEBE plugin (in particular).
    - First four columns are *time related*.
    - Columns of interest are **kdn** (global irradiance on the horizontal plane), **kdiff** (diffuse irradiance on the horizontal plane) and **kdir** (beam/direct irradiance on a plane always normal to sun rays).

- All columns must be present but can be filled with numbers to indicate they are not in use (e.g. -999).
- The meteorological file should preferably be at least a year long, but multi-year data improves the solar energy estimation.
- One option is to use a typical meteorological year

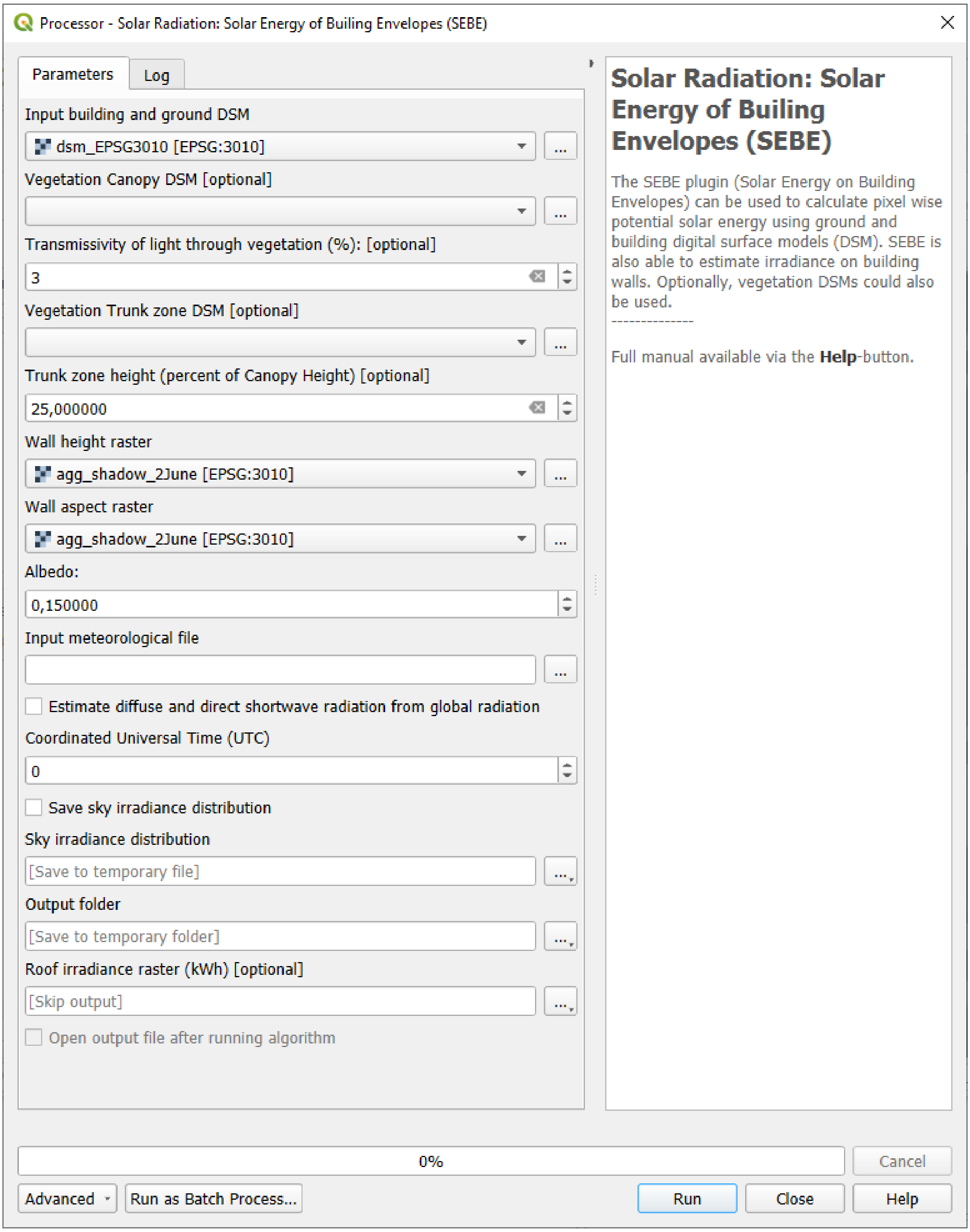
For more details on the meteorological file structure in UMEP, see the meteorological data preprocessor.

For those of you who would like to do **INTERMEDIATE** or **ADVANCED** can stop here.

Preparing data for SEBE

Required inputs

Let's have a look at the SEBE plugin: located in the **Processing Toolbox** at *UMEP > Processor > Solar Radiation: Solar Energy on Building Envelopes (SEBE)*.



The interface for SEBE in UMEP for Processing

Building and ground DSM:

- Critical for the calculations in SEBE is the **building and ground** DSM.
- Optionally **vegetation** (trees and bushes) can be included as they can shadow ground, walls, and roofs, reducing the potential solar energy production.
- You can include two vegetation DSMs if you want to add vegetation to your calculations:
    - One to describe the top of the vegetation: **Vegetation Canopy DSM**. You can also set the transmissivity of light through the vegetation to adjust for seasonal changes.
    - One to describe the bottom, underneath the canopies: **Vegetation Trunk zone DSM**.

Since Trunk Zone DSMs are rare, there is an option to generate one from the canopy DSM. You can define the trunk zone as a percentage of the canopy height—this percentage will apply uniformly to all vegetation in the canopy DSM. Adjust this setting under **"Trunk zone height (percent of Canopy Height)"**. The default value is **25%**.

Wall height and wall aspect:

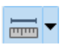
- Two raster datasets, height and wall aspect, are needed to calculate irradiance on building walls.
- You will create these at a later stage using another UMEP tool.

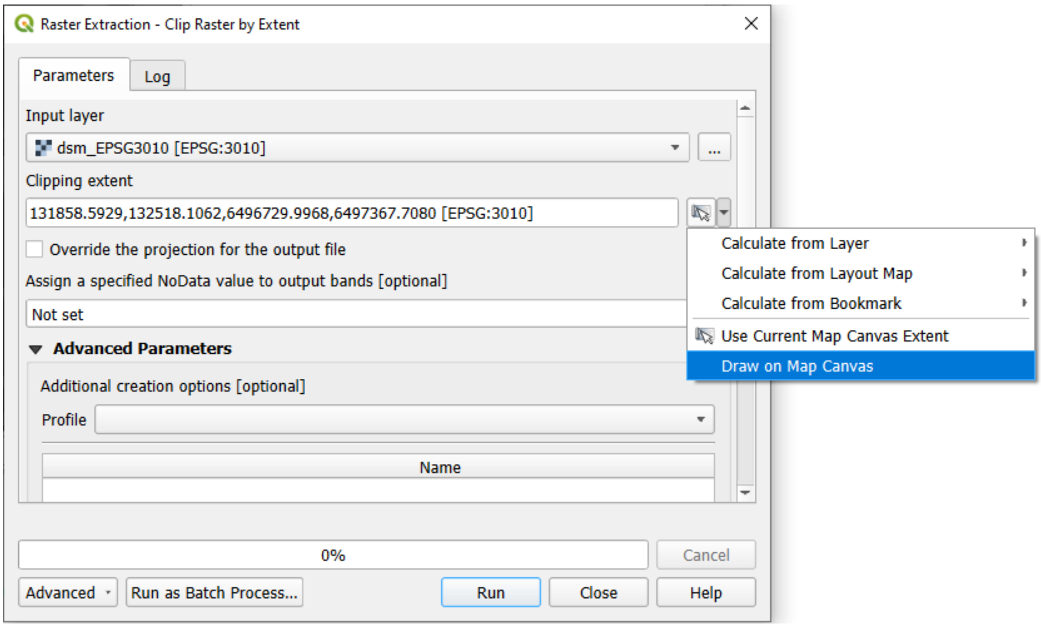
Albedo, time adjustment and meteorological file:

- The average albedo (one value is used for all surfaces) can be changed. The default is set to 0.15.
- The UTC offset is needed to accurately estimate the sun position; positive numbers for easterly positions, relative to the prime meridian, and negative for westerly. For example, Norrköping is located in CET time zone which is UTC +1. **The UTC is related to the meteorological forcing data, and our data is in UTC +1**.
- The path to the meteorological file needs to be specified under **Input meteorological file**. The file should be in .txt format.

Clipping the data

To save some time, we will clip the surface models to approximately 800 times 800 meters (400x400 pixels). You can choose anywhere within the raster layers. We start with the DSM:

1. First, use the *Clip Raster by Extent* from *Raster > Extraction > Clip Raster by Extent...* Select dsm_EPSG3010 as your I**nput layer**.
2. Select an area though either a zoomed in area in your map canvas (**Use Current Map Canvas Extent**), or by **Draw on Map Canvas**, approximately 800 by 800 meters. **TIPS**! You can use the **Measure Line**  to get a sense of how far 800 meter is in this raster.



Clip Raster by Extent in QGIS

3. Save the file as **dsm_clipped.tif** under Clipped (extent).
4. Now clip **cdsm_EPSG3010.tif** to the same extent as **dsm_clipped.tif** using the same tool but calculate extent from layer (dsm_clipped). Save it as **cdsm_clipped.tif**.

Pre-processing: wall height and aspect

Wall data is created with the [UMEP plugin - Wall Height and Aspect](#).

The wall height algorithm uses a 3 x 3 pixels kernel minimum filter where the four cardinal points (N, W, S, E) are investigated. The pixels just 'inside' the buildings are identified and give values to indicate they are a building edge. The aspect algorithm originates from a linear filtering technique (Goodwin et al. 2009). It identifies the linear features, plus the aspect of the identified line (a new addition). Other more accurate techniques include using a vector building layer and spatially relating this to the wall pixels.

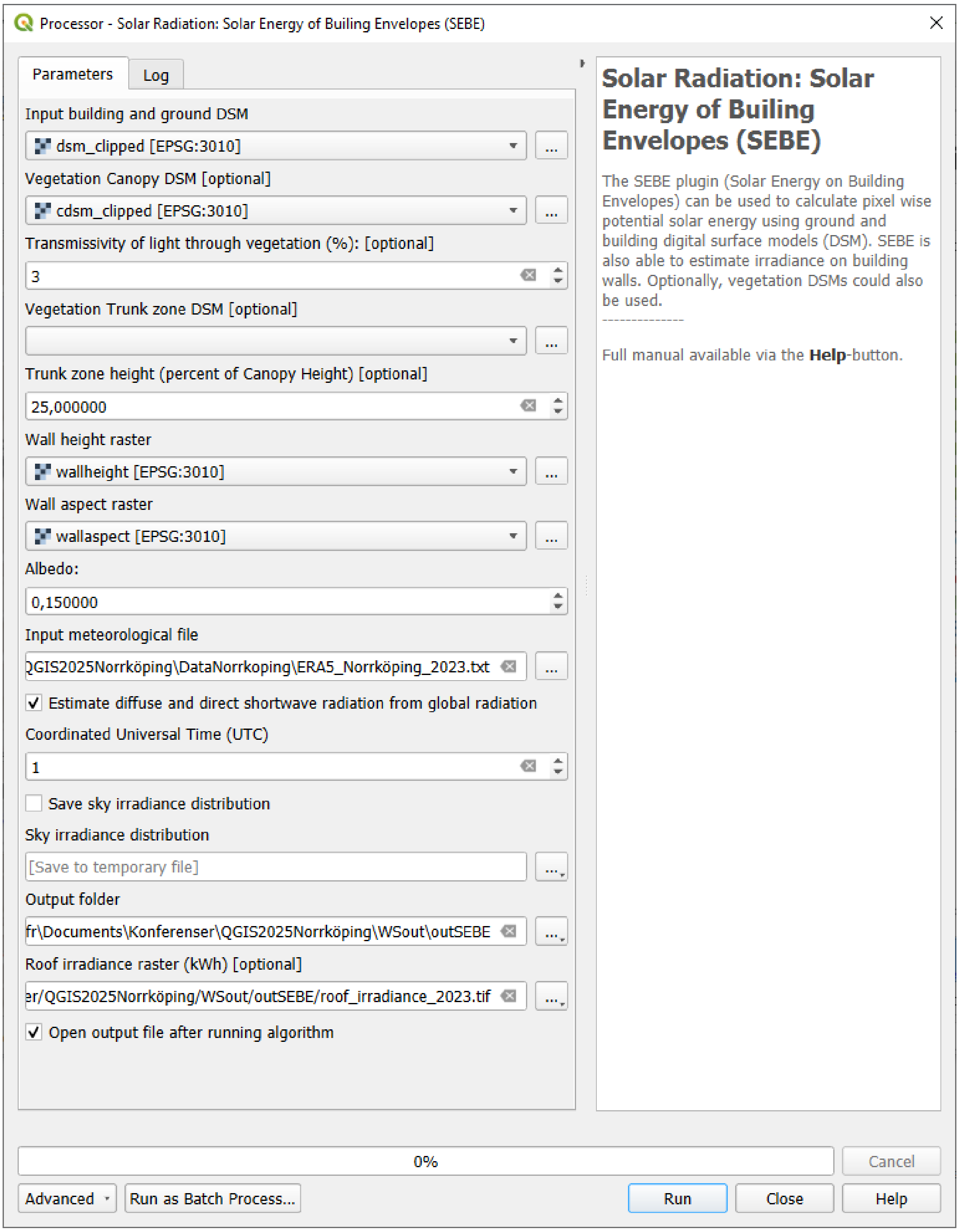
1. Go to the Wall and Height and Aspect plugin: *Processing Toolbox > UMEP > Pre-Processor > Urban Geometry: Wall Height and Aspect*.
2. Use your ground and building DSM (in this case *dsm_clipped*) as input.
3. You can leave Lower limit for wall height as it is.
4. Name your new raster datasets **wallheight.tif** and **wallaspect.tif**, respectively, and save them somewhere on your computer folder.
5. Tick *Open output file after running algorithm for both new layers*
6. Click *Run* to create the rasters.
7. Once the window stating that it has run successfully appears, you can close the tool.

Running the model

Now you have all data ready to run the model. Open SEBE and use the settings below:

NOTE! The model takes some time to calculate irradiance on all the surfaces.

The result added to your map canvas is the horizontal radiation, i.e. irradiance on the ground and roofs.



Example of settings for running SEBE

Irradiance on building envelopes

NOTE: Currently, this section works only on a windows computer. **3D Visualisation for Mac and Linux currently not working properly**

To analyse the irradiance on building walls:

1. Open the **SunAnalyser** located at the **menu based UMEP**: *UMEP > Post-Processor > Solar Radiation > SEBE (Visualisation) in the menu-based part of the plugin*.
    - This tool can be used to visualize the irradiance on both roofs and walls.
2. Choose the output folder where you saved your result and use it as input folder in SEBE Visualizer
3. Click *Area of Visualisation*
4. Click once on the canvas to initiate the visualisation area and then drag to produce an area
5. Click again to finish
6. Click Visualise. Now you should be able to see the results in 3D

Now use the **Profile tool**, which is a plugin for QGIS, to see the range of values along a transect.

If it's not installed, you will need to install it from the official QGIS-plugin repository. Go to *Plugins > Manage and Install Plugins,* find, and install it. Once installed it should be located under *Plugins > Profile tool*

1. Open **Terrain Profile** in the *Profile tool*
2. Choose your roof_irridiance layer and **Add layer** to the tool
3. Draw a line across the screen on the area of interest. Double click and you will see the profile drawn. Make certain you use the correct layer.

Solar Energy Potential

To obtain the solar energy potential for a specific building:

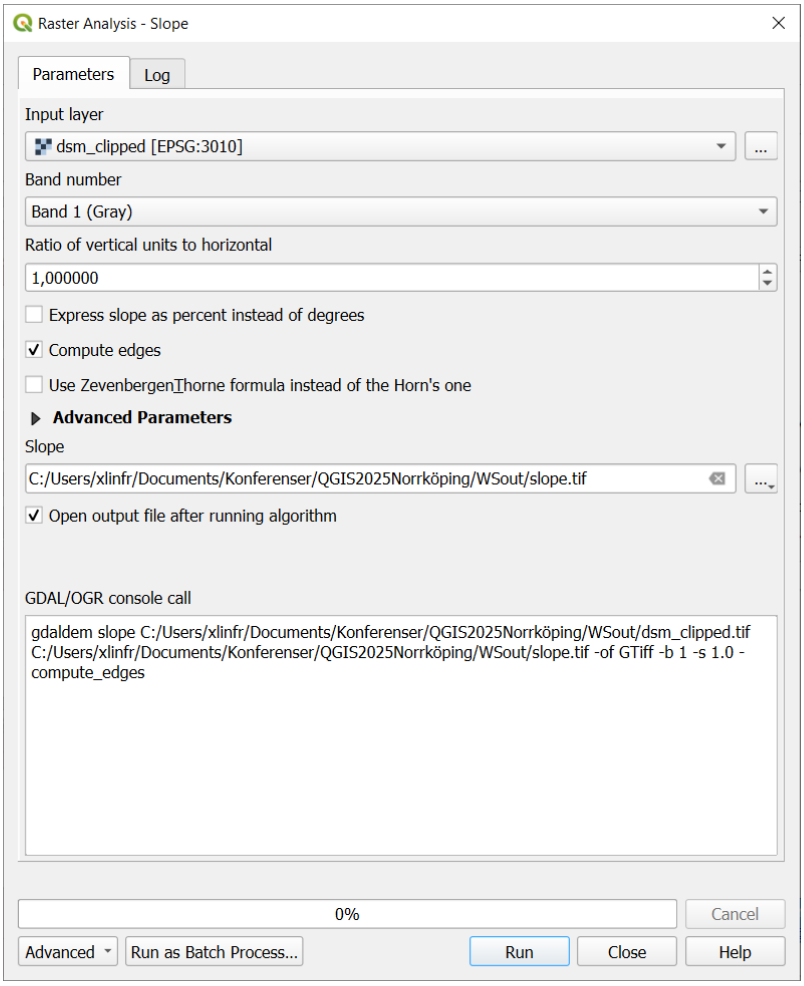
- The actual area of the roof needs to be considered
- Determine the area of each pixel (A_P): e.g. 1 m^2
- As some roofs are tilting the area may be larger for some pixels. The actual area (A_A) can be computed from:

$A_A = A_P / cos(S_i)$

where the slope (S_i) of the raster pixel should be in radians (1 deg = pi/180 rad).

Create a slope raster (S_i)

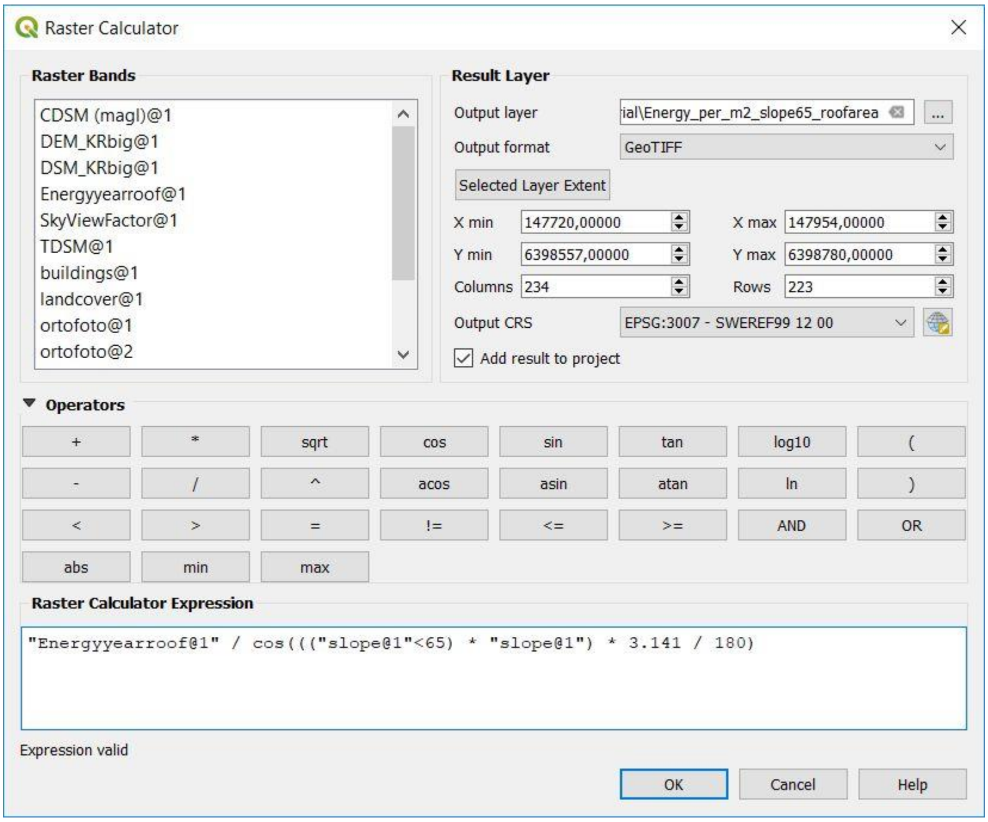
1. Go to *Raster > Analysis > Slope*
2. Use the clipped DSM as the Input layer (elevation)
3. Check *Compute edges*
4. Save your slope layer somewhere on your computer and Run



The Slope tool in QGIS

Now determine the area after you have removed the wall area (assumed to have slope greater than 65 degrees) from the buildings. This will be done in the Raster calculator below.

1. Open the raster calculator: *Raster > Raster Calculator*
2. Enter the equation indicated in the figure below but use the name of your output from before instead of Energyyearroof and save it as a GeoTIFF namned **energy_per_m2_slope65_roofarea**



The Raster Calculator in QGIS

Now it's time to see where the best potential for placing solar panels is!

Visualizing solar panel potential

As a first step we can visualize where to potentially place solar panels, the amount of energy received needs to be cost effective. As irradiance below 900 kWh is considered to be too low for solar energy production, pixels lower than 900 can be filtered out. Changing transparency allows you to make only points above a threshold of interest visible.

- Right-click on the **roof_irradiance** layer and go to *Properties* and then *Transparency*.
- Add a custom transparency (green cross) where values between 0 and 900 are set to 100% transparency.

Irradiance map with values less than 900 kWh filtered out

To estimate solar potential on building roofs we can use the Zonal statistics tool:

First, we need to find the building footprint data from the data provided in the beginning. The easiest way is to unzip **visual_city_participant_exhibition_dataset.zip**, start a new QGIS session and open the **visual_city_exibition** project-file included. Then locate the buildings in the **bgmap_light** layer group and export it as **buildings.shp** and add is to your other QGIS session where you have done the solar energy modelling. After that, follow the instructions below:

1. Go to the **Processing Toolbox** then search for *Zonal statistics*. Be sure to avoid *Raster layer zonal statistics*.
2. Use the roof area raster layer (**energy_per_m2_slope65_roofarea**) created before and use the **building.shp** as the polygon layer to calculate your zone layer.
3. On your building layer – Right click *Open Attribute Table*
4. Or use *identify features* to click a building (polygon) of interest to see the statistics you have just calculated

Note that we will not consider the performance of the solar panels.

End of BASIC tutorial!

References

- Goodwin NR, Coops NC, Tooke TR, Christen A, Voogt JA 2009: Characterizing urban surface cover and structure with airborne lidar technology. Can J Remote Sens 35:297–309
- Lindberg F, Jonsson P, Honjo T, Wästberg D 2015: Solar energy on building envelopes - 3D modelling in a 2D environment. Solar Energy. 115, 369–378
- Ratti CF, Richens P 1999: Urban texture analysis with image processing techniques Proc CAADFutures99, Atlanta, GA