OnSSET/Global Electrification Platform

Hands-on 6: How to run an electrification analysis using GEP Scenario Generator[1]

Installation:

1. First, go here and click **Clone or download** > **Download zip** to download the GEP scenario generator.
2. This exercise has a prerequisite that you have Jupyter Notebook https://jupyter.org/install.html and Python (you can use Anaconda to download all needed Python packages https://docs.anaconda.com/anaconda/install/installed) on your computer.

Learning outcomes

By the end of this exercise, you will be able to:

1) Run a scenario for Benin in the GEP scenario generator

2) Perform different key processes in the GEP scenario generator

3) Create maps in QGIS to visualize the results.

[1] This exercise is an exercise developed by Korkovelos, A., Sahlberg, A., Khavari, B., 2019. Exercise 6: How to run an electrification analysis using GEP scenario generator [WWW Document]. OnSSET Teaching Kit. URL https://onsset.github.io//teaching_kit/courses/module_2/Excercise%206/ (accessed 2.18.21).

GEP Scenario Generator (OnSSET)

The objective of this session is to learn how to use the GEP Scenario Generator (OnSSET) tool to run an electrification scenario. This covers the basic operations of the Jupyter Notebook, how to enter input data, and where to find them.

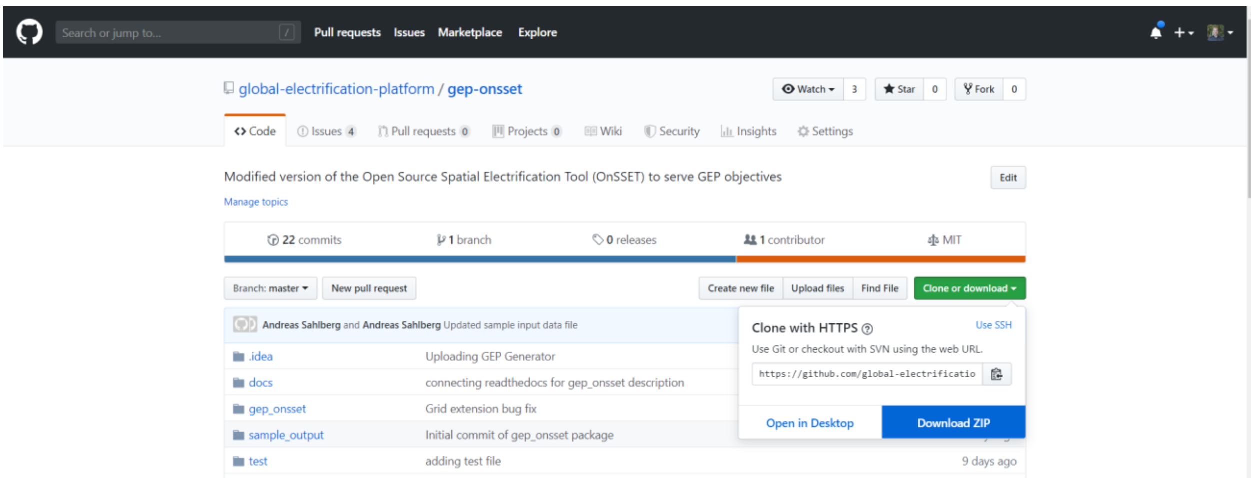

Figure 1

(**Picture source**: gep-onsset GitHub page https://github.com/global-electrification-platform/gep-onsset license under MIT)

Save and un-zip the folder, which will be named **gep-onsset-master**. This contains all of the code required to run the electrification analysis. Also, create a folder named **Results** where you want to save the results of your analysis. Apart from this, you will need the csv-file containing the extracted GIS data from last week's exercise. Go to the **gep-onsset-folder** and open **Jupyter Notebook**.

Exercise 1: Data acquisition and insertion to the electrification model

Click on the GEP_generator.ipynb file, which is the interface for running the electrification tool.

Figure 2

Next, select the first cell with the *Welcome to the GEP Generator* header. When selected, the cell should be surrounded by a border with a blue line to the left.

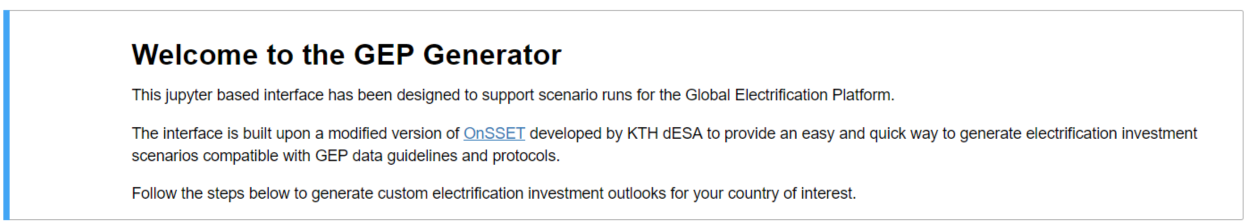

Figure 3

Click the run button to run the cell. While running a code cell, the mode circle in the upper right corner is full while the process is running, and empty again once the process is finished. Note that this may go very quickly for some cells, while others take longer time.

Once a process is finished, the selection automatically moves on to the next cell.

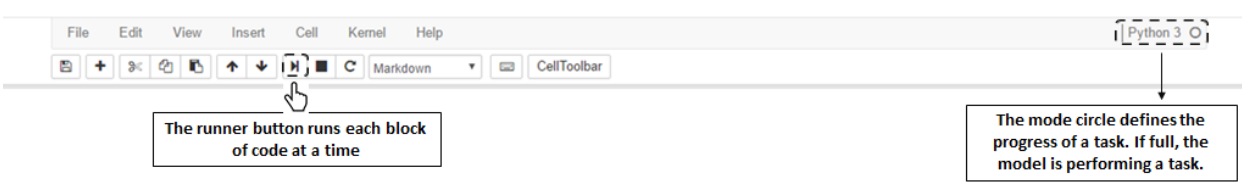

Figure 4

Run the first cell to load the code.

Start by importing the code

```
In [ ]:
from gep_onsset import *
from IPython.display import display, Markdown, HTML
%matplotlib inline
```

Figure 5

Step 1. GIS data selection.

Run the next cell. This opens up the window below, click *OK* to open the browser. Browse to where the input file with all the extracted GIS data is located and select it.

1. GIS data selection

First, run the cell below to browse to the directory your input CSV file is located at and select the input file. Sample file shall be located at .\ gep-onsset\test_data.

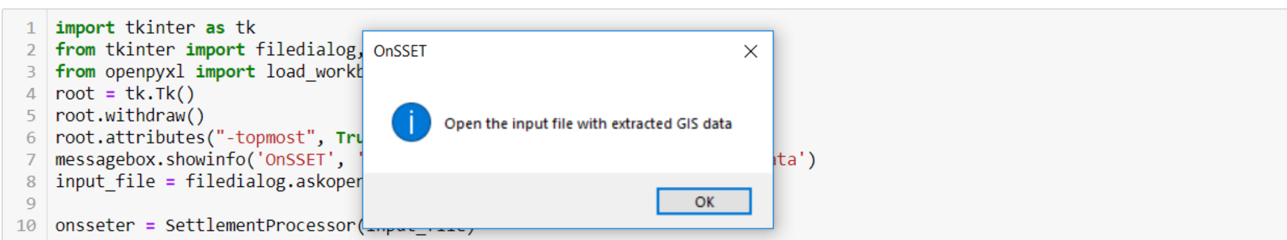

Figure 6

Step 2. Modelling period and target electrification rate.

First, enter the start year and end year as well as the target electrification rate by the end year. Then run the cell. For the intermediate year of 2025 leave the default values as they are.

2. Modelling period and target electrification rate

Next, define the modelling period and the electrification rate to be achieved by the end of the analysis. Further down you will also define an intermediate year and target (in the ***Levers*** section).

```
start_year = 2018
end_year = 2030
electrification_rate_target = 1 # E.g. 1 for 100% electrification rate or 0.80 for 80% electrification rate
```

Figure 7

Step 3. Levers

Move on to the lever section. In each of the cells, follow the description of the lever and enter the value of your choice. Remember to run each cell before moving on to the next one.

For Prioritization choose 5 for Nationwide least-cost approach.

Step 4. Enter country specific data

In addition to the levers above, the user can customize a large number of variables describing the social, economic, and technological environment in the selected country. In total ~100 variables can be adjusted in this section.

For Benin you should collect the data from different sources. These can be, but not limited to, data.worldbank.org, dataportal.opendataforafrica.org, esa.un.org/unpd/wup, UN Household Size and Composition Around the World 2017 etc., and national statistical offices. If you cannot find all of the input data, then keep the default value.

NOTE that you need to at least collect the **population** (start and end year), **urbanization rate** (use the same at end year as 2018 if you do not find any other data), **national electrification rate**, and **household size** for this exercise.

For the social input parameters, under *a. Demographics and Social components* enter:

- the population in 2018 (e.g. **10870000**")
- the projected population by 2030 (e.g., "**15507000**")
- the urban population share in 2018 (e.g., "**0.44**" for 44%)
- the projected urban population share in 2030 (e.g., "**0.51**")

- the number of people per household in urban areas by 2030 (e.g., "**3.1**")
- the number of people per household in rural areas by 2030 (e.g., "**3.6**")
- the national electrification rate in 2018 (e.g., "**0.41**" for 41%)
- the national *urban* electrification rate in 2018 (e.g., "**0.41**" for 41%)
- the national *rural* electrification rate in 2018 (e.g., "**0.41**" for 41%)

In case no other values have been collected then the default values can be used.

Continue with Step 4 and run all the cells there.

Step 5. GIS data import and processing

Run the first cell in Step 5. This calibrates the population and provides some additional basic information based on the GIS data. If successfully run, a preview should appear with a preview of the GIS input data. If this table does not appear, or does not appear correctly, this may be caused either by an error in the csv-file or the code.

The Madagascar.csv file has been imported correctly. Here is a preview:

	Country	X	Y	Pop	GridDistPlan	NightLights	TravelHours	GHI	WindVel	Hydropower	HydropowerDist
2199	Madagascar	5377380.0	-1984130.0	42.48930	134.672	0	5	2049.0	5.0	19.84110	784
2384	Madagascar	5397380.0	-2014130.0	35.86460	102.356	0	2	2049.0	6.0	29.73370	784
2320	Madagascar	5367380.0	-2004130.0	39.46830	116.119	0	2	2041.0	5.0	3.05809	784
2925	Madagascar	4987380.0	-2114130.0	6.67943	304.235	0	9	2268.0	0.0	44.55440	754
1177	Madagascar	5397380.0	-1814130.0	18.99970	301.828	0	11	2225.0	7.0	19.88800	564
2724	Madagascar	5217380.0	-2074130.0	19.64630	93.184	0	2	2347.0	6.0	7.75732	771

Figure 8

Based on the input data in the previous steps, in the next cell the code now creates some additional layers that are useful for the electrification analysis. This can be an iterative process which requires calibration from the user. One of the most important steps in the electrification analysis is the identification of the currently electrified settlements. Based on their location, the model then decides how easy it is to extend the grid to neighbouring cells, or rather choose an off-grid technology.

The model calibrates which settlements are likely to be electrified in the start year, to match the national statistical values defined above. A settlement is considered to be electrified if it meets all of the following conditions:

- Has more night-time lights than the defined threshold (this is set to 0 by default).
- Is closer to the existing grid network than the distance limit.
- Has more population than the threshold.

First, define the threshold limits. Then run the calibration and read the message on the bottom to check if the results seem okay. Else, redefine these thresholds and run again.

```
min_night_lights = 0    ### 0 Indicates no night light, while any number above refers to the night-lights intensity
min_pop = 50      ### Settlement population above which we can assume that it could be electrified

max_service_transformer_distance = 2    ### Distance  in km from the existing grid network below which we can assume a settl
max_mv_line_distance = 2
max_hv_line_distance = 25

Technology.set_default_values(base_year=start_year, start_year=start_year, end_year=end_year, discount_rate=discount_rate)

elec_modelled, urban_internal_elec_ratio, rural_internal_elec_ratio = onsseter.elec_current_and_future(elec_ratio_start_year
                                                                                                        urban_elec_ratio,
                                                                                                        rural_elec_ratio,
                                                                                                        pop_start_year,
                                                                                                        start_year,
                                                                                                        min_night_lights=min_
                                                                                                        min_pop=min_pop,
                                                                                                        max_transformer_dist=
                                                                                                        max_mv_dist=max_mv_li
                                                                                                        max_hv_dist=max_hv_li

onsseter.grid_reach_estimate(start_year, gridspeed=9999)
```

```
2019-06-06 16:51:55,214         Calibrate current electrification
We have identified the existence of transformers or MV lines as input data; therefore we proceed using those for the calibratio
n
The modelled electrification rate achieved is 0.11.Urban elec. rate is 0.51 and Rural elec. rate is 0.03.
If this is not acceptable please revise this part of the algorithm
```

Figure 9

Run the next cell to plot the settlements that are calibrated as electrified (blue) and unelectrified (yellow) in the previous step.

'

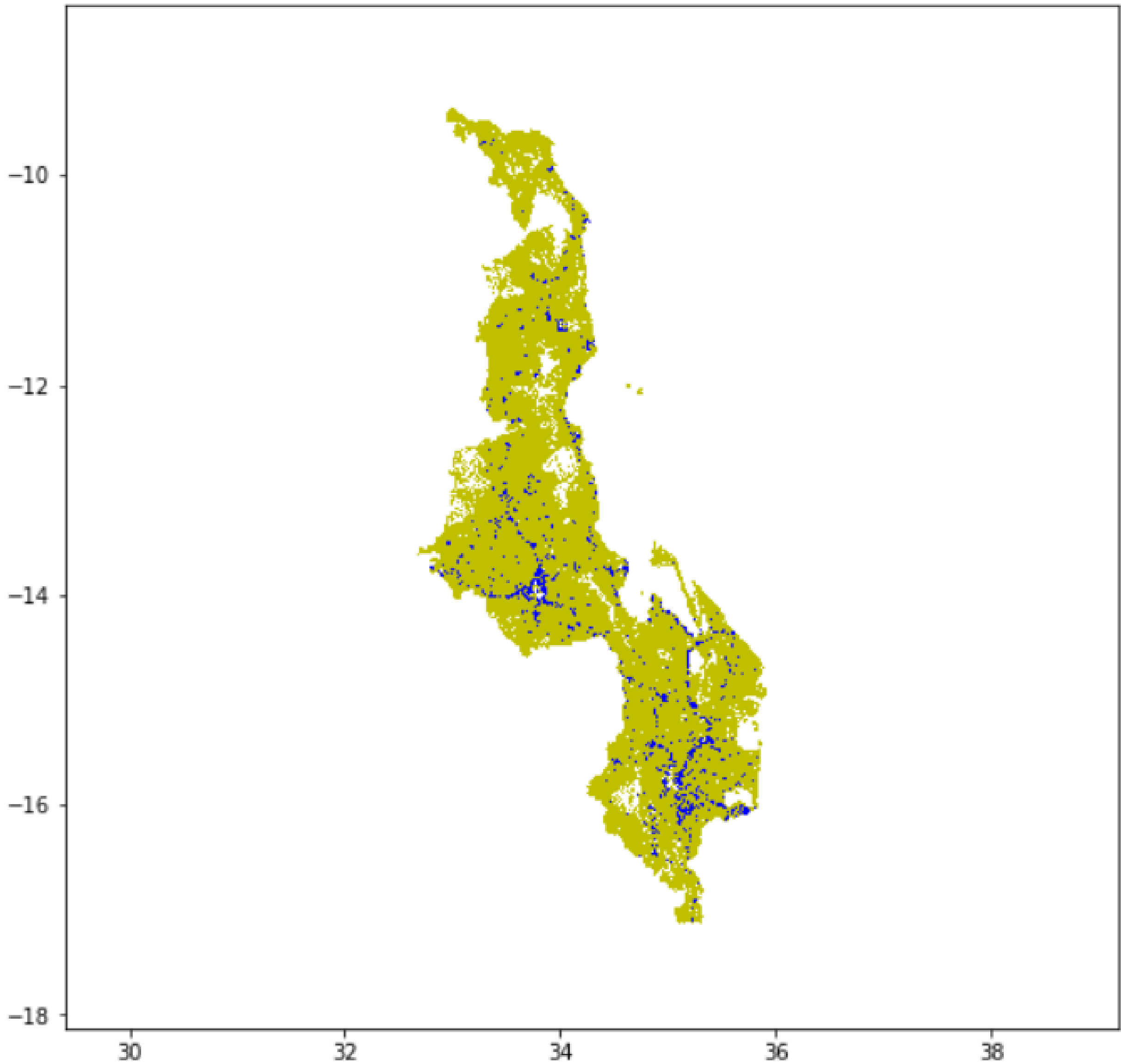

Figure 10

Step 6. Define the demand

Here you can adjust the demand in the scenario further. You may change the number of kWh/household/year a Tier represents or add demand for productive uses of electricity. Note that there is no pre-defined method of estimating the demand for productive uses in the model. Run both cells and move on to the next step.

Step 7. Start a scenario run

This step runs the algorithm to calculate the least-cost electrification technology in every settlement of the country. Note that this will take some time (from minutes to a couple of hours depending on your country).

Step 8. Results, Summaries and Visualization

After completing steps 1–7 the analysis is completed. Run all the cells in Step 7 to retrieve the results. These are presented as summary tables and a simple map.

Based on the optimal split identify per technology:

- New connections by 2030
- Additional capacity needed
- Investments requirements

	Population	Nouvelles connexions	Capacity (MW)	Investissements (millions USD)
Grid	11433608	6972808	632	2349.69
SA_Diesel	0	0	0	0.00
SA_PV	3216738	3216738	86	579.02
MG_Diesel	0	0	0	0.00
MG_PV	780321	780321	128	379.04
MG_Wind	0	0	0	0.00
MG_Hydro	69043	69043	1	13.18
Total	15499713	11038913	849	3320.94

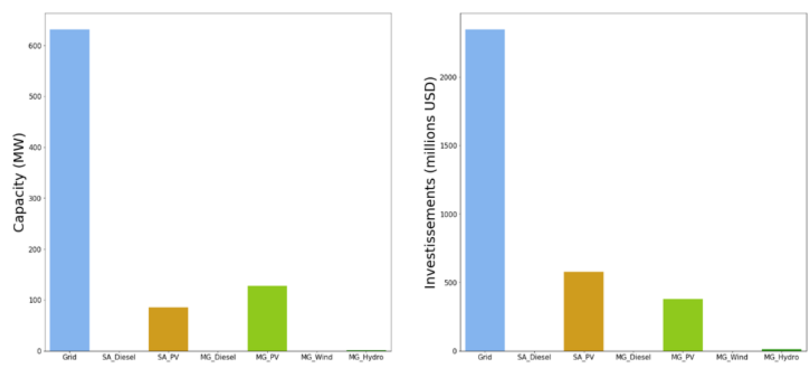

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Figure 11

(Picture source: OnSSET teaching material: https://doi.org/10.5281/zenodo.457403 licensed under [CC-BY 4.0](CC-BY 4.0))

Step 9. Exporting results

In the first cell, name your scenario. In the next cell, run it and click *OK* in the box that appears, and browse to the folder where you want to save your results. Run the final cell to save two csv-files with information for each settlement and summaries for the whole country. The csv-file named "**Results**" can be used to generate maps in QGIS.

Visualization of electrification results in GIS

The following section provides a guide to the basic steps one must take in order to visualize the results of the electrification in a QGIS environment. Please follow the step-by-step process and in case you have further questions you can use the OnSSET forum.

Step 1. Importing the .csv file with the results

After running your OnSSET analysis you will have a csv-file with the results. If you simply import this csv-file into any GIS software you will get a point layer. When visualizing your results, we would, however, like to visualize the clusters that you have used for the population layer. The instructions below will explain how to visualize your csv-file with your population clusters.

1. Start with importing your csv by going to **Layer → Add Layer → Add Delimited Text Layer**.

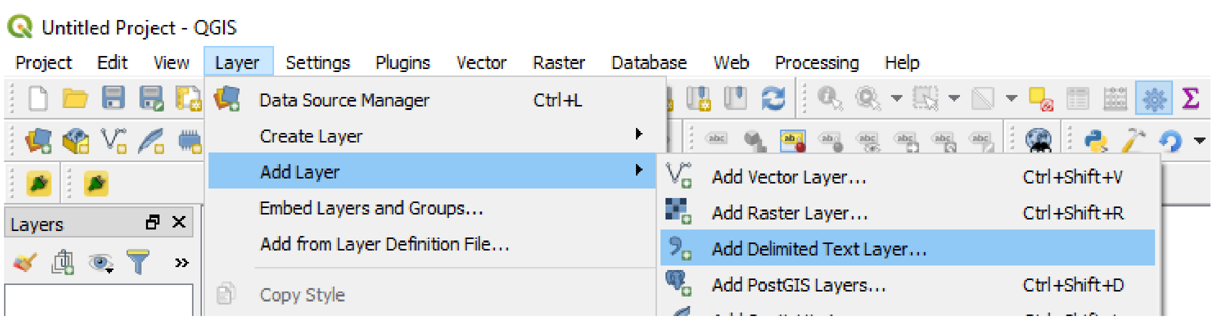

Figure 12

2. The following window will open up:

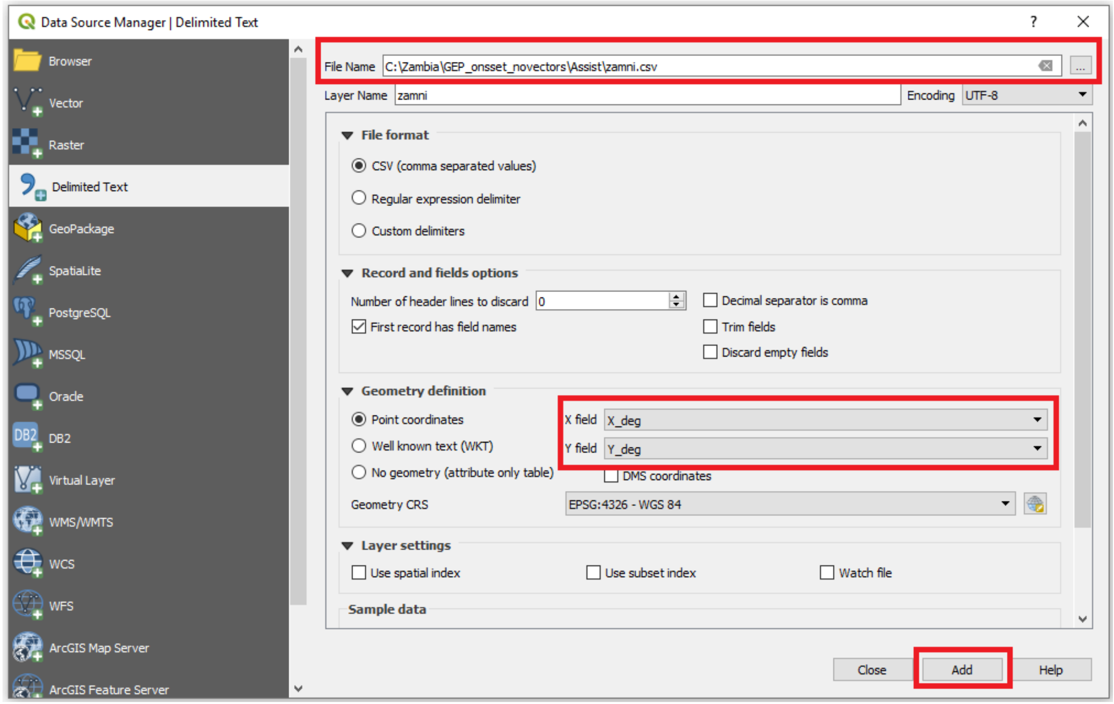

Figure 13

3. Under *File format* make sure that *CSV (Comma separated values)* is checked. A preview of the file is seen in the bottom of the window. Click *Ok*. Next, the coordinate system of the layer must be defined. In the *Geometry CRS* box, select **WGS84**. Also, in the **X field** and **Y field** select **X_Deg** and **Y_Deg**. Finally, click *Add* to load the layer. When the file is loaded (which might take some time) you should be able to see the file in the Layers Panel at the bottom left of your screen.

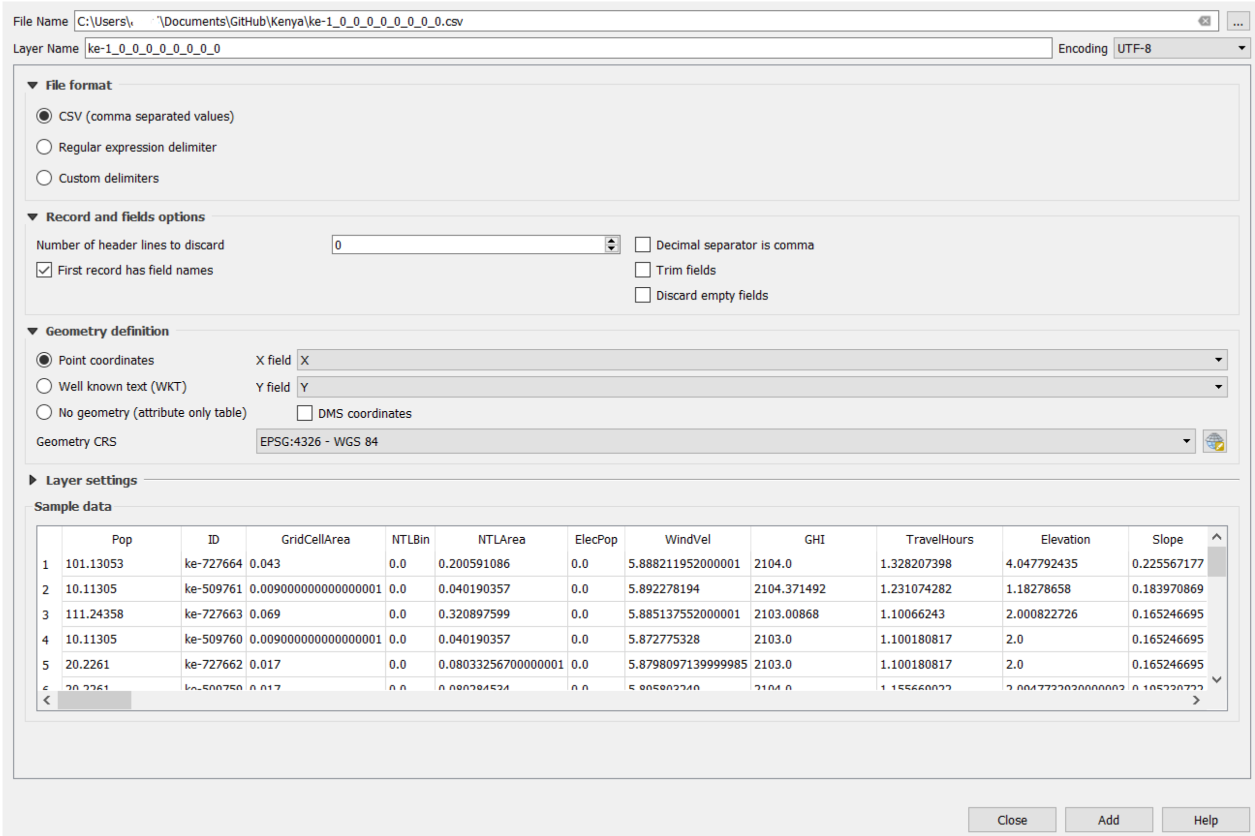

Figure 14

4. After clicking on **Add** you will see that you have added a point layer to your map canvas.

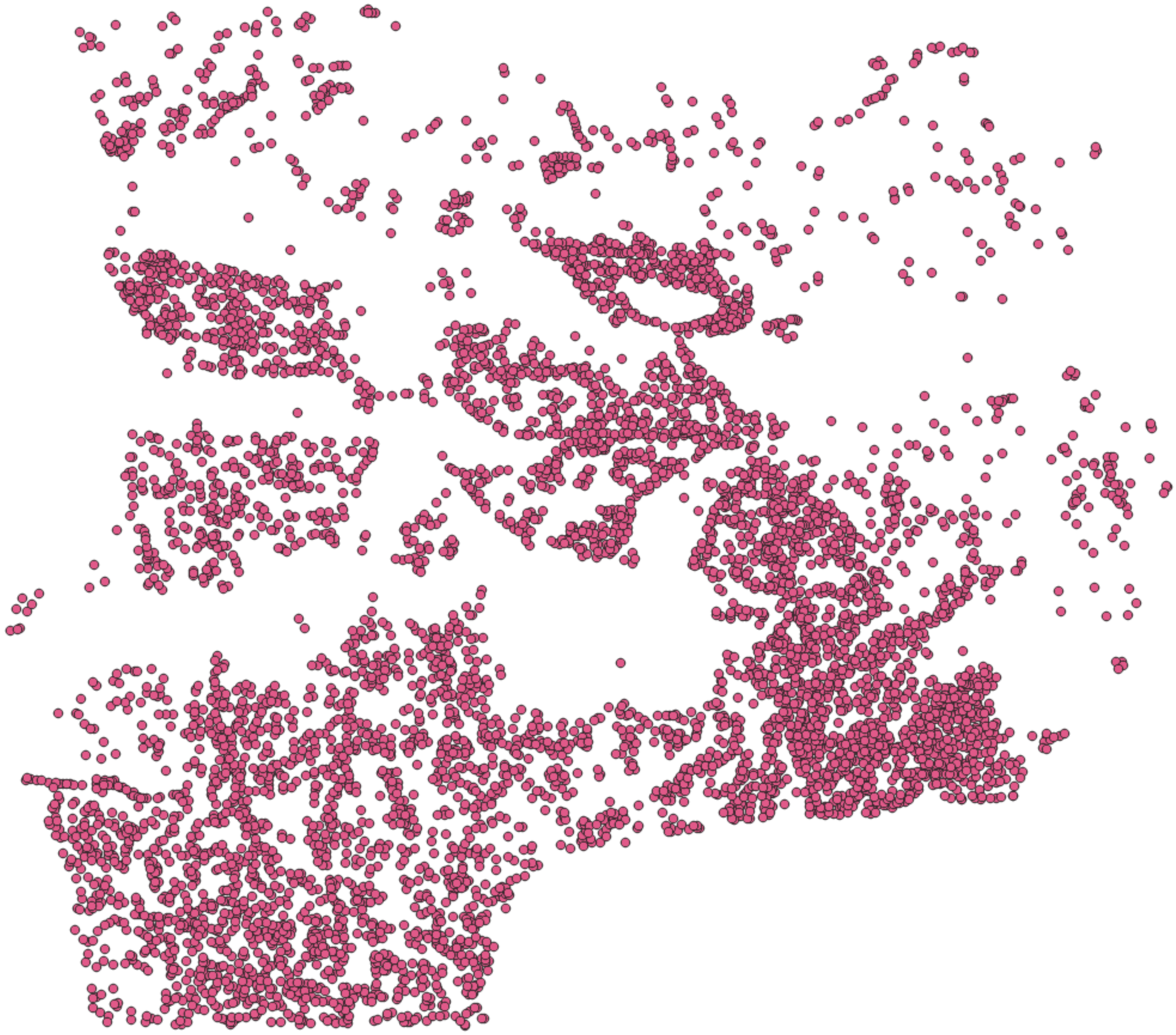

Figure 15

5. Now add the clusters that you used as your population layer during the extraction process by going to **Layer → Add Layer → Add Vector Layer** or simply drag it onto your map canvas.

6. Now we will merge the layers. Open the toolbox and search for "**Join attributes by field value"**.

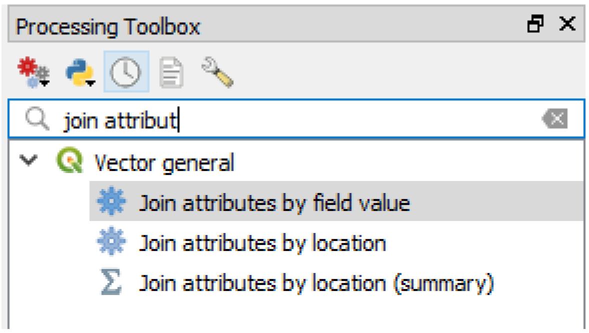

Figure 16

7. The following window opens up:

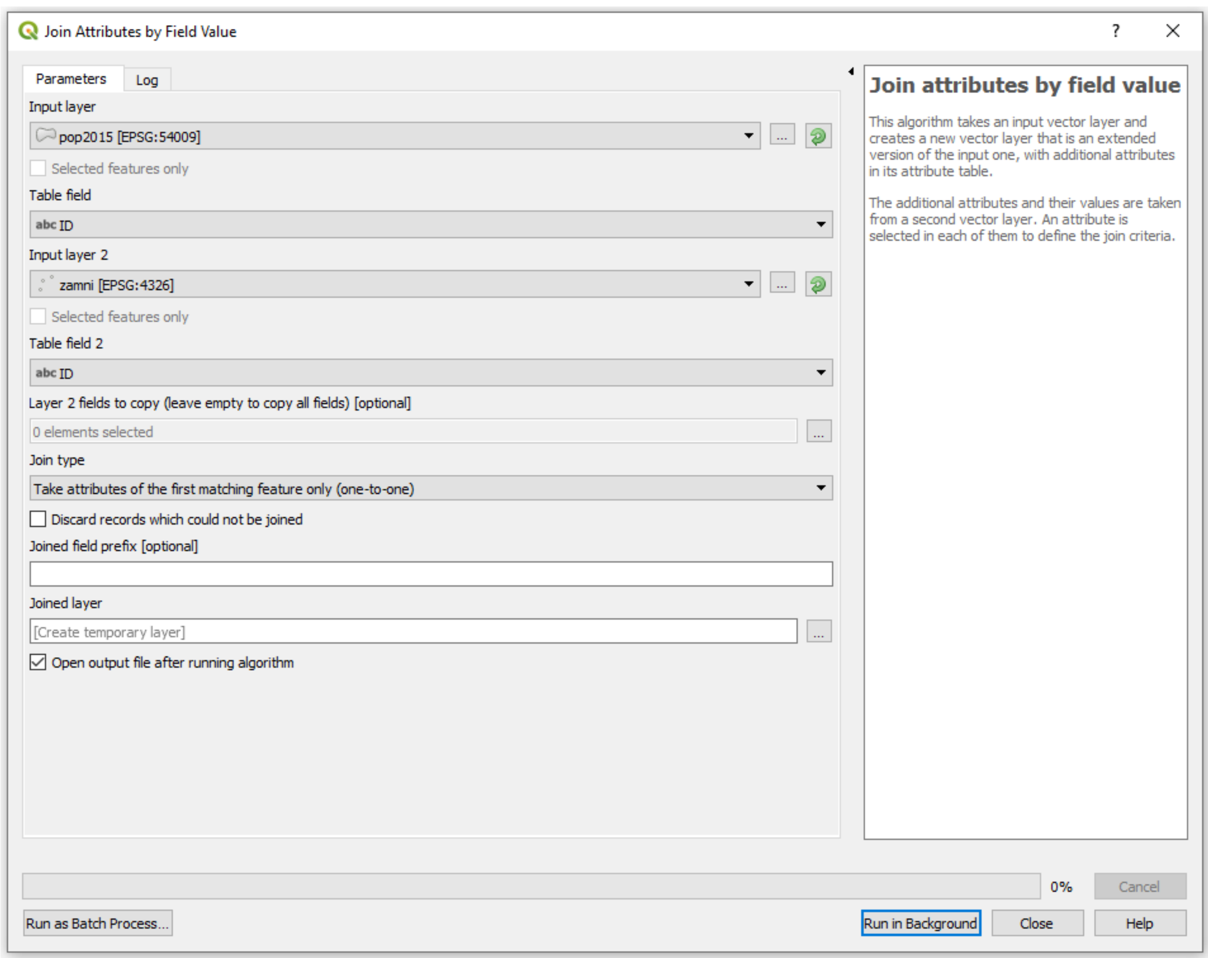

Figure 17

The idea behind this tool is to take the attribute table of one layer and add it to the attribute table of another layer using a field in each layer as identifier.

The field **Input layer** defines the layer that you will see. Since we want to see clusters and not points, we will choose the population clusters in this field.

Table field is the name of the field in the attribute table that will be used as identifier during the merge. Choose the file named ID.

The field **Input layer 2** defines the second layer. Select the point layer defined by your .csv file.

The field named **Table field 2** is the name of the field in the attribute table of the second layer that will be used as the identifier during the merge. Choose the field named ID. This means that all the rows with the same ID in your population clusters and your input file will be matched to one another.

Do not change any of the other options.

When finished click on **Run in Background**.

Step 2. Displaying useful information in QGIS

The map of the imported csv-file does not convey much information at first. Change this by right-clicking on the joined layer in the *Layer Panel* and choose *Properties*. Select the *Style* tab and at the top change from *Single symbol* to *Categorized*.

Next, choose the *Column* option, and from the drop-down list scroll down and choose **MinimumOverall2030** to display the technology option that can provide electricity at the lowest LCOE in each cell in 2030. Next, click on *Classify* to show all technology options that are utilized in the results.

After choosing what to display, one must also make sure that the information can be understood clearly. The first step is to change the appearance of the symbols. Click on *Change…* in the *Symbol* box and then on *Simple marker* (Fig. 10); then on *Outline* select *Transparent boundary* and press *Ok*. You may change the colour of the symbols by double-clicking on them and modifying their appearance. Finally click *Apply* and then *Ok* to display the map. It will take some time for the map to draw in QGIS.

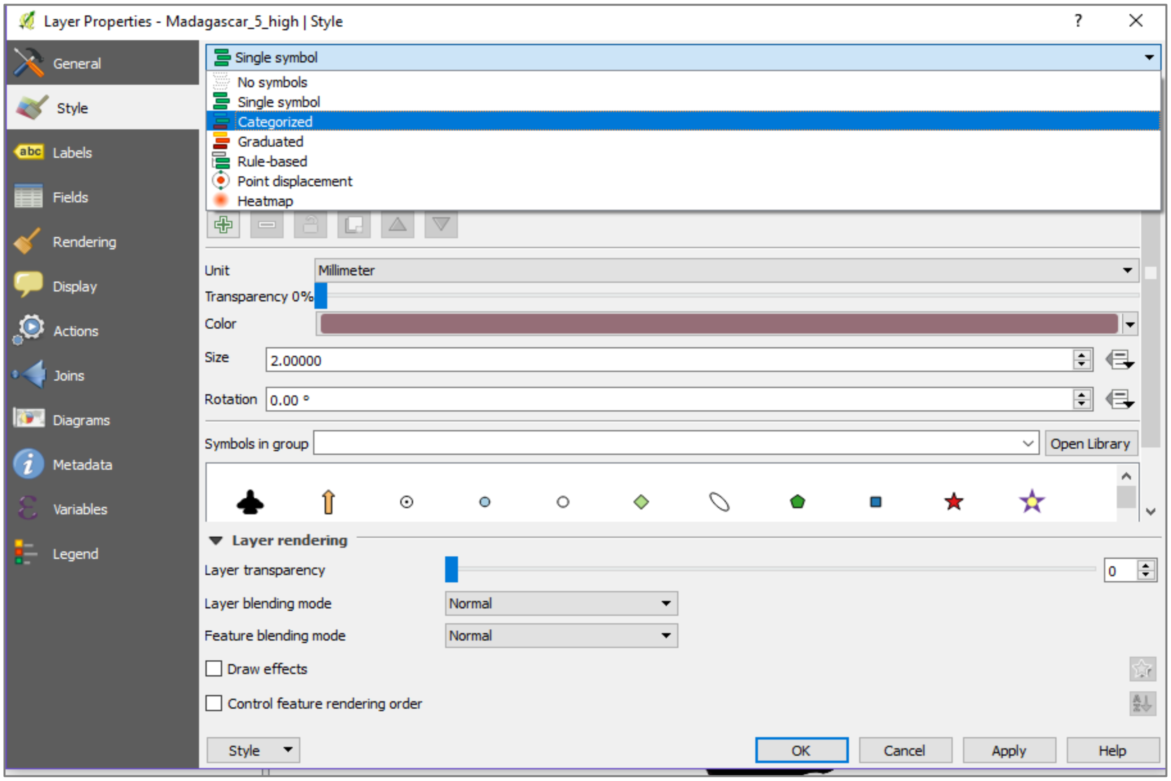

Figure 18

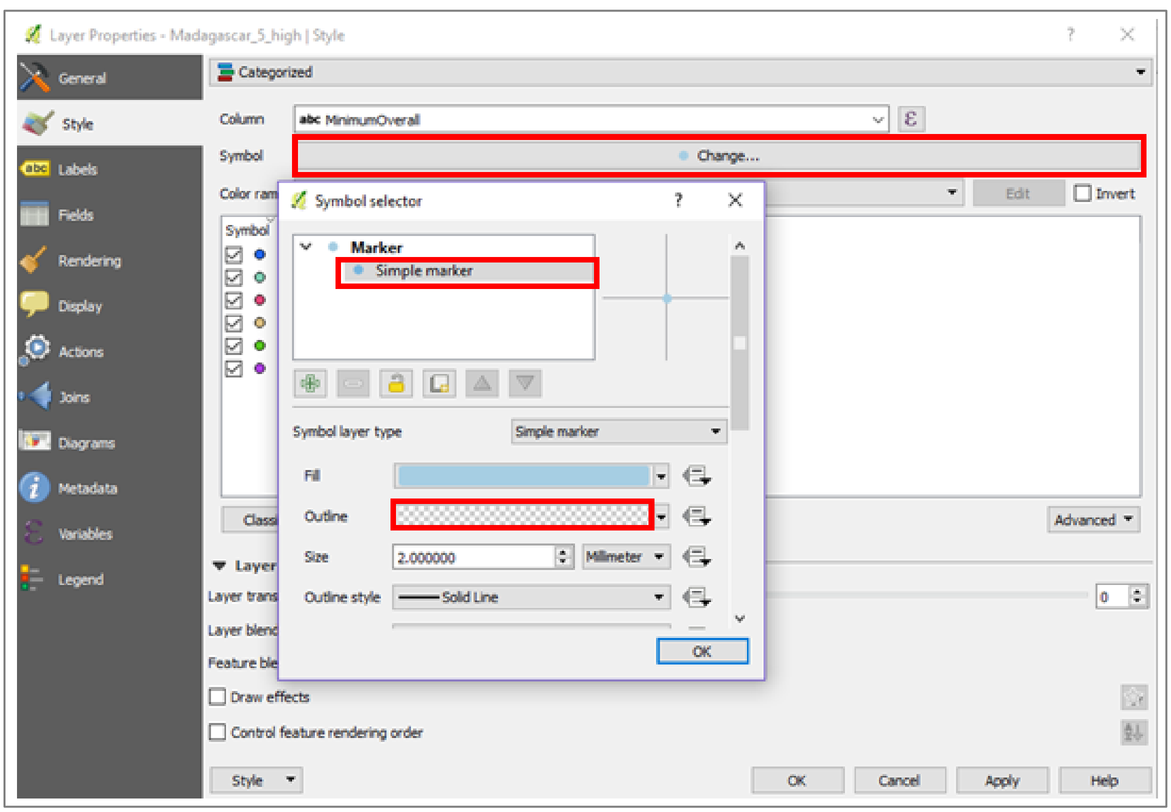

Figure 19

The next step is to add some informative text and figures to the map. In QGIS this can be done in the **Print Composer** view. Open it by selecting *Project > New Print Composer* (Fig. 11).

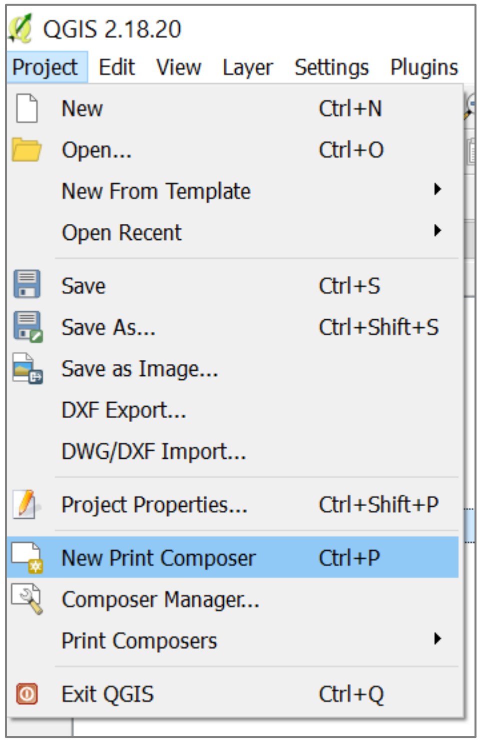

Figure 20

This will prompt you to choose a name for your map. Choose a name and click *OK* or leave it blank to use a random name (Fig 21).

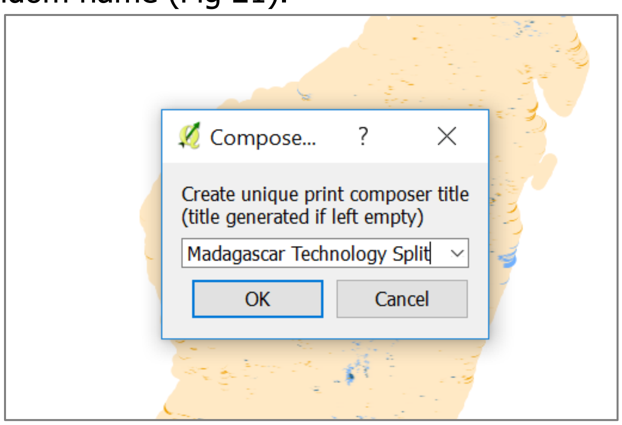

Figure 21

At this stage the map canvas opens (Fig. 22).

1. First set the properties of your map on the right-hand side of the image above in the *Composition* tab. Set *Presets* to **A4** and choose *Orientation* as **Portrait**. Leave the rest as it is.
2. Next, under **Export settings** (still on the right-hand side of the image above) you can set the resolution. For the purpose of these exercises 300 dpi is sufficient. This option is also set in the menu for composition.
3. On your left-hand side you have a number of different tools that you can use for opening maps and preparing your map.

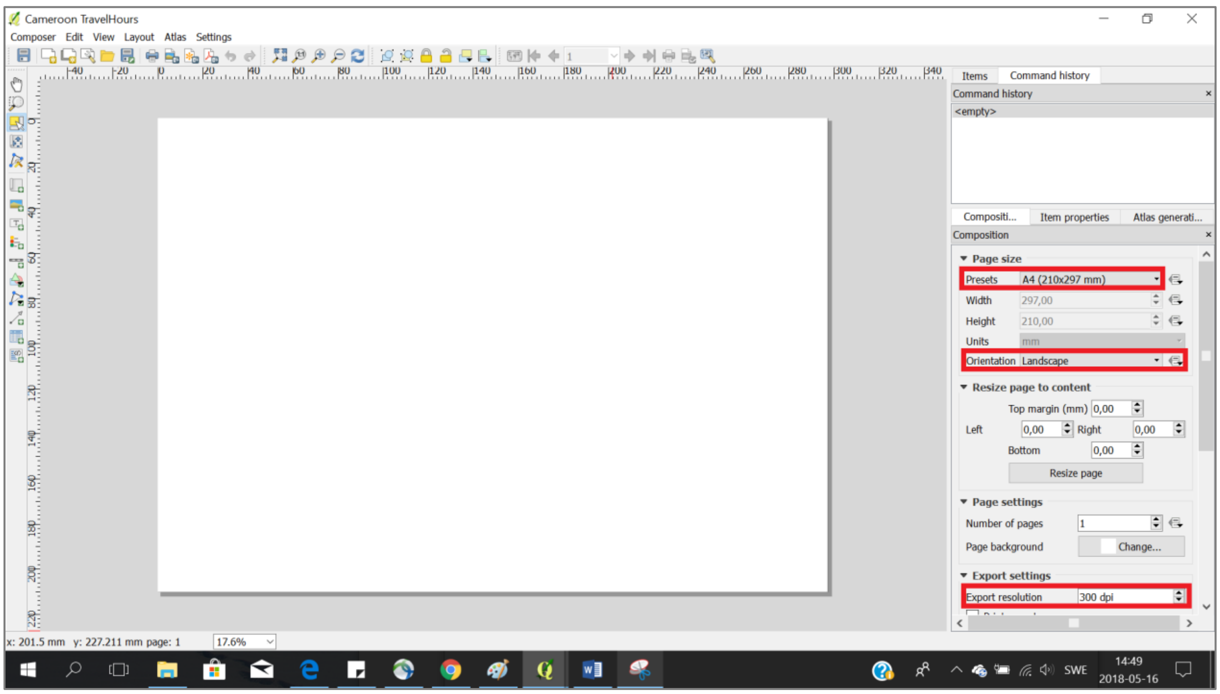

Figure 21

4. Click on **Add new map**  on the left-hand side of the window (Fig. 23) to start creating a map.

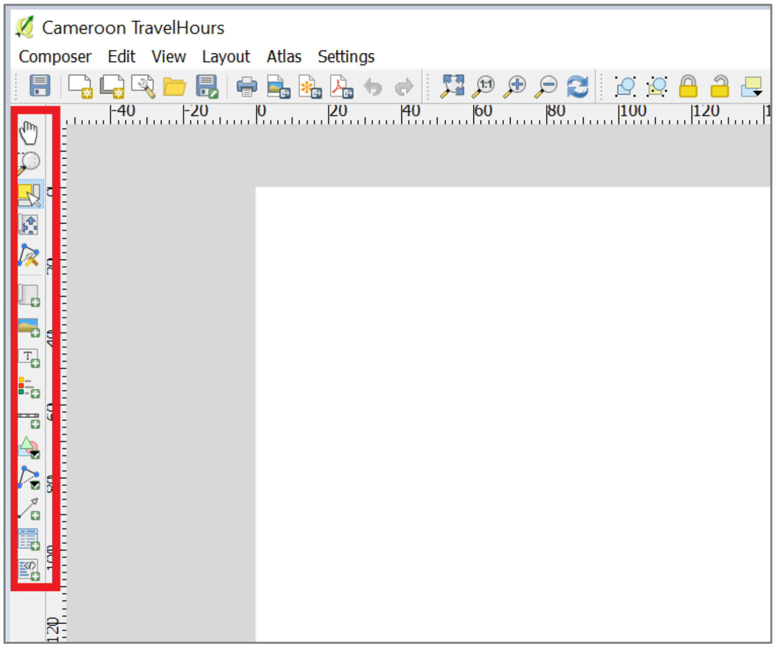

Figure 23

5. Next, put the cursor in one corner of the paper and click and drag to define the area the map should extend to (Fig. 24). The display of the normal QGIS window will appear in this area.

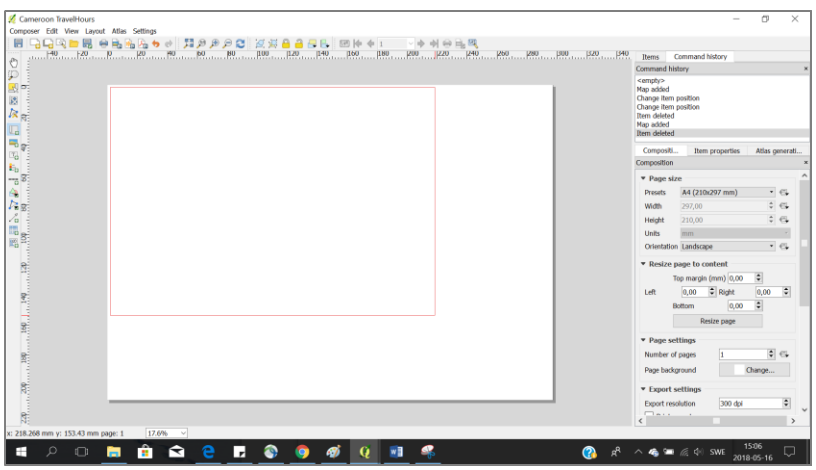

Figure 24

6. In the QGIS map composer every item (e.g., Legend, Title, Scale bar) may be edited by clicking on the item and then choosing the *Item Properties* tab on the right. This includes the size, scale, position, extent, and other attributes.

7. Add Title, Legend, and Scale bar from the menu to the left. Adjust their position and style to create an informative map.
8. After finalizing the content of the map, check the boxes **Lock layers** and **Lock styles for layers** (Fig. 25). This ensures that if you turn off some layers or change their styles in the original window, the view will not change in the composer window.

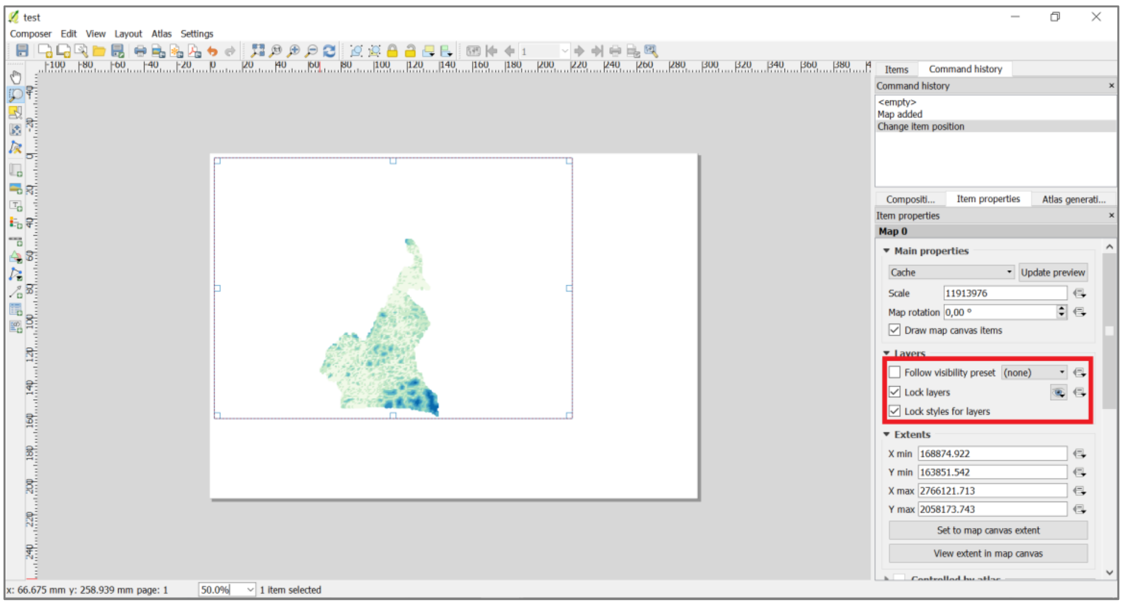

Figure 25

9. Finally, export the map as a picture by clicking the  icon, and save it in the *Results* folder.

Once the map of technology split is satisfactory and saved in the *Results* folder, close the *Composer* window. Open the *Properties* window of the layer and go to the *Style* tab once more. On the top, change from *Categorized* to *Graduated*. Now, choose the MinimumOverallLCOE2030 column on the top to display the LCOE achieved in each cell. Press *Classify, Apply* and *OK* to draw the LCOE map.

Open the *Composer* window and insert a Title, Legend and Scale bar and save the new map once satisfied with the layout.

Congratulations for completing the hands-on exercises! If you have questions or want to contribute to the OnSSET community please go to onsset.org to find out more!