GIS-Exercise
Sustainable Development Goals
Click-by-Click

The 17 goals of the UN

The "Agenda 2030 for Sustainable Development" is a global United Nations action plan for people, the planet and prosperity adopted by the UN General Assembly in September 2015. With Agenda 2030, the member states of the United Nations have developed a roadmap for the "transformation of the world for the better" in the sense of a sustainable transformation of society, economy and environment by the year 2030. Agenda 2030 includes 17 global goals divided into 169 subgoals (cf. indicators of the UN sustainability goals[1]).

The 17 Sustainable Development Goals (SDGs) are political objectives of the United Nations (UN) that are intended to secure sustainable development at the economic, social and ecological levels (see Sustainable Development Goals[2]). The goals were designed in line with the development process of the Millennium Development Goals (MDGs) and entered into force on 1 January 2016 with a duration of 15 years (until 2030). In contrast to the MDGs, which applied in particular to developing countries, the SDGs apply to all states. If you want to get an overview of the sustainability goals, watch the UN-Video[3].

UN goals for a sustainable development

Exercise:

In the exercise, you will deal with one of more than 200 indicators on the 169 subgoals. Please note that not all indicators have comprehensive data (we would like to have data on all countries over longer periods for evaluation purposes). A comprehensive description of all indicators can be found under List of indicators[4]. The path to

[1] https://unstats.un.org/sdgs/indicators/indicators-list/
[2] https://www.un.org/sustainabledevelopment/sustainable-development-goals/
[3] https://www.youtube.com/watch?v=0XTBYMfZyrM&feature=youtu.be
[4] https://unstats.un.org/sdgs/indicators/indicators-list/

download the freely available original data is Database[5]. Before you start editing, please read the meta information for the selected indicator carefully in order to assess whether a meaningful question can be edited and evaluated.

Regardless of the selected processing level (Advanced, Basic or Click-by-Click), the following statements could be worked out in the document, for example:

- In which direction does the selected indicator move worldwide?
- Which country has the greatest progress/regression relative to the indicator to be evaluated in the period under consideration?
- Which region/continent on earth presents itself as problematic/progressive?
- Compare some countries with respect to the indicator to be evaluated in the period under consideration.

Try to establish connections with the global political situation or other knowledge about the topic.

1. Try to understand and penetrate the topic on the basis of the literature. Take a very close look at the metadata description (thematic classification, methodology and validation, data quality ...) of the selected indicator so that you can specify your question precisely and interpret the results obtained correctly.

2. Design a workflow for your data processing (tabular evaluation, GIS evaluation).

3. Create a structure of your document (no process description or work report, style of a scientific paper).

4. Evaluate your data and prepare it, both the table data in the form of measures and diagrams, and the geoinformation in the form of thematic maps. For this purpose you link the attribute data with suitable spatial data of the national borders, for which we need a common key in both data sets (a mostly numerical country code such as ISO 3166-1, compare e.g. https://www.laenderdaten.info/laendercodes.php).

Land	ISO 3166-1 alpha2	ISO 3166-1 alpha3	ISO 3166-1 numerisch	IOC	Fips 10	Kfz Kennzeichen	Domain
Afghanistan	AF	AFG	004	AFG	AF	AFG	.af
Ägypten	EG	EGY	818	EGY	EG	ET	.eg
Ålandinseln	AX	ALA	248			AX	.ax
Albanien	AL	ALB	008	ALB	AL	AL	.al
Algerien	DZ	DZA	012	ALG	AG	DZ	.dz
Amerikanisch Samoa	AS	ASM	016	ASA	AQ	USA	.as
Andorra	AD	AND	020	AND	AN	AND	.ad
Angola	AO	AGO	024	ANG	AO	ANG	.ao
Anguilla	AI	AIA	660		AV	AXA	.ai

Different country codes

5. At the end we create thematic maps with all necessary information in DIN A 4 format.

Document delivery: Prepare a maximum of ten pages (text, diagrams, maps) on the thematic context (topic, UN goal, significance of the indicator, critical examination of the data situation, own calculation and interpretation of the results) in a document with common Office and GIS programs (Word, Excel, OpenOffice, LibreOffice, ArcGIS, QGIS etc.). Your elaboration should contain at least 1 diagram and at least 1 thematic map. Briefly introduce the chosen topic and interpret the result. Please indicate the sources used (including data sources) in a correct and comprehensible manner, as is customary for scientific research.

Note: In this click-by-click instructions we present the processing of attribute data with Excel (commercial software, here Excel 2016) and LibreOfficeCalc (open software) in parallel and geo processing with ArcGIS Desktop (commercial software, here ArcMap 10.5.1) and QGIS (open software). Thus the user has in any case the chance to

[5] https://unstats.un.org/sdgs/indicators/database/

perform the processing with open software, or otherwise, depending on availability, to use common commercial software in his working environment.

Problem statement

Select a meaningful statistical data set on one of the SDG topics (e.g. poverty, hunger, .. peace, partnerships) with temporal statements (time series) related to the national aggregation level. This dataset should be completely downloadable (e.g. as ASCII, csv, xls) and can therefore be evaluated on the desktop with the standard tools known to you. Do not use a completely prepared indicator, but a raw data set.

Topic here: Global trend in renewable energies

For this example, the global trend in renewable energies will be examined. In other words, the exact extent to which the share of renewable energies in total energy consumption changed between 2000 and 2016. Indicator 7.2.1 - Renewable energy share in the total final energy consumption (%)" (indicator EG_FEC_RNEW) is selected for this purpose. This is an estimated percentage, based on national data, of the share of final consumption of energy derived from renewable resources in relation to total consumption.

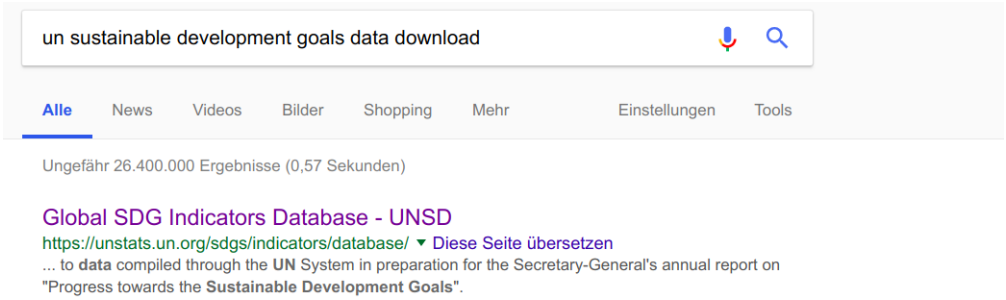
In addition to looking at the situation worldwide (spatially and temporally), we would like to make a comparison of countries. For this purpose, we look at one country on each continent, for which we choose the example:

Europe: Germany	Australia: Australia	North America: Costa Rica
South America: Ecuador	Africa: Algeria	Asia: Vietnam

Data search

UN records

The first step is to locate the relevant records; this can be done by navigating the UN website, or (often faster) by making a search using a search engine. Finally, the records can be found at: https://unstats.un.org/sdgs/indicators/database/

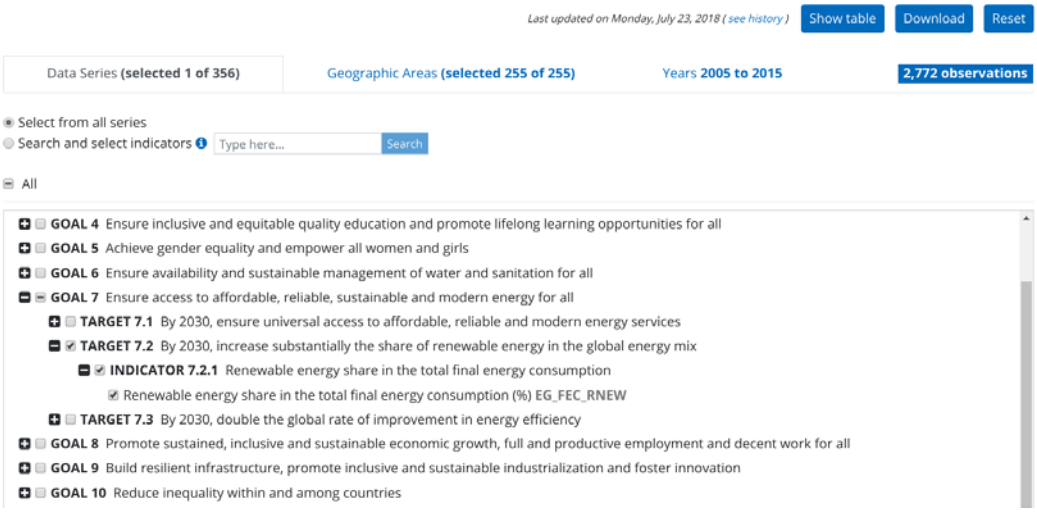


Data search for SDG indicators

At https://unstats.un.org/sdgs/indicators/database/, search for a data set on one of the 17 sustainability goals and consider what you want to (or can) present in the end, do not forget the time series reference. An overview of all UN indicators can be found in the document "Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development". The metadata (i.e. what the indicator says, how it is collected, etc.) can be found in the Metadata repository. You should definitely take a look at this in order to adapt your evaluations accordingly and critically question them.

Topic here: Global trend in renewable energies

Consumption of renewable energy includes consumption of energy from water, solid biofuels, wind, solar, liquid biofuels, biogas, geothermal energy, seawater and waste. Total final energy consumption is calculated from national reports and statistics as total final consumption minus non-energy consumption. This indicator is based on comprehensive, annually updated energy statistics on supply and demand for all energy sources - statistics that should be used to establish a national energy balance and thus have a fairly high reliability. Internationally agreed methods for energy statistics are described in the "International Recommendations on Energy Statistics" (IRES) adopted by the United Nations Statistical Commission and available at the following address: IRES[6]. The IRES time series dates back to 1990.



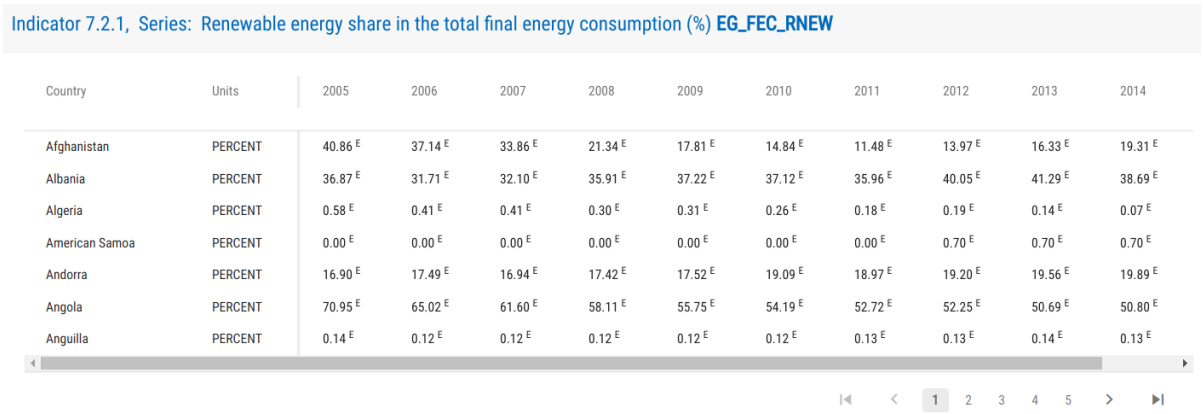
SDG Goal 7

Under *Show table* you can find a preview of the data and under *Years* you can select the period. At the beginning of August 2019, the data for the selected indicator cover a total of 4,624 observations for the period 2000 to 2016. It is important that these factual data can later be linked to the spatial data, i.e. the national borders (the relational operator JOIN), via a unique key. This is, as we will explain later, the column geoAreaCode, namely a numeric country code.

In order to download the correct data set, it is necessary to click on the *Years 2000 to 2016* tab. Then click on *Show table* to download the dataset as an Excel spreadsheet at the end of the page. If the data set meets your requirements, click on Download.

We download the dataset in csv format, even if here some additional steps are necessary, because the data are different in this case (rows and columns transposed, so that a pivotation is necessary). Excel format would also be possible. In both cases, you have to check the cells for usable data types, which we describe for csv.

[6] https://unstats.un.org/unsd/energy/ires/



Indicator 7.2.1, Series: Renewable energy share in the total final energy consumption (%) **EG_FEC_RNEW**

Country	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Afghanistan	PERCENT	40.86 E	37.14 E	33.86 E	21.34 E	17.81 E	14.84 E	11.48 E	13.97 E	16.33 E	19.31 E
Albania	PERCENT	36.87 E	31.71 E	32.10 E	35.91 E	37.22 E	37.12 E	35.96 E	40.05 E	41.29 E	38.69 E
Algeria	PERCENT	0.58 E	0.41 E	0.41 E	0.30 E	0.31 E	0.26 E	0.18 E	0.19 E	0.14 E	0.07 E
American Samoa	PERCENT	0.00 E	0.00 E	0.00 E	0.00 E	0.00 E	0.00 E	0.00 E	0.70 E	0.70 E	0.70 E
Andorra	PERCENT	16.90 E	17.49 E	16.94 E	17.42 E	17.52 E	19.09 E	18.97 E	19.20 E	19.56 E	19.89 E
Angola	PERCENT	70.95 E	65.02 E	61.60 E	58.11 E	55.75 E	54.19 E	52.72 E	52.25 E	50.69 E	50.80 E
Anguilla	PERCENT	0.14 E	0.12 E	0.12 E	0.12 E	0.12 E	0.12 E	0.13 E	0.13 E	0.14 E	0.13 E

1 2 3 4 5

SDG-Indikator 7.2.1 Renewable Energy share in the total finakl energy consumption

Table structure

The structure of the SDG tables is largely homogeneous. The only difference is the technical content of the indicators. In the following the information important for your later elaboration is presented and explained:

- Indicator
- Series Description
- GeoAreaCode
- GeoAreaName
- TimePeriod
- Value
- Units
- Source

Indicator: The SDG data are subject to a strict structure. It is divided into Goal, Target, Indicator, where Goal is the macro level, Target is the meso level and Indicator is the micro level. The indicator thus names the exact designation of the affiliation of the data to the UN targets. This information is very valuable because not all the data in the table comes from the indicator you have selected. It is advisable to process the metadata of each listed indicator, as they have been selected to match your indicator. This may offer new interfaces.

Series Description gives a short description or the name of the previously specified indicator.

GeoAreaCode is a country ID selected by the UN. However, these do not correspond to the standardized country IDs. Nevertheless, this ID should be used for possible links later.

GeoAreaName contains the country names. This column could also be used for the join of the table with the country shape file in GIS editing, but different spelling of the names is a hindrance here.

TimePeriod indicates the year the data is viewed. In the metadata, the entire observation period can also be read.

Value lists the values that you analyze and with which you will calculate. Pay particular attention to decimal numbers or possible 1000 digits for larger numbers. It should also be mentioned that the values are often subdivided again. This subdivision is indicated in one or more further columns. For example, the indicator 3.c.1 "Health worker density, by type of occupation" divides into the medical specialties in the column "Type of occupation".

Units indicate the unit of the numerical values (value) and are therefore an important component of their later analysis.

Source indicates the primary source of the indicators. You should pay special attention to these during your research. Using this information, try to relate the results of your analysis to the political or economic situation in the areas you select.

The metadata (what the indicator says, how it is collected, etc.) can be found in the Metadata repository[7]. You should definitely take a look at this in order to adapt your evaluations accordingly and to critically question them.

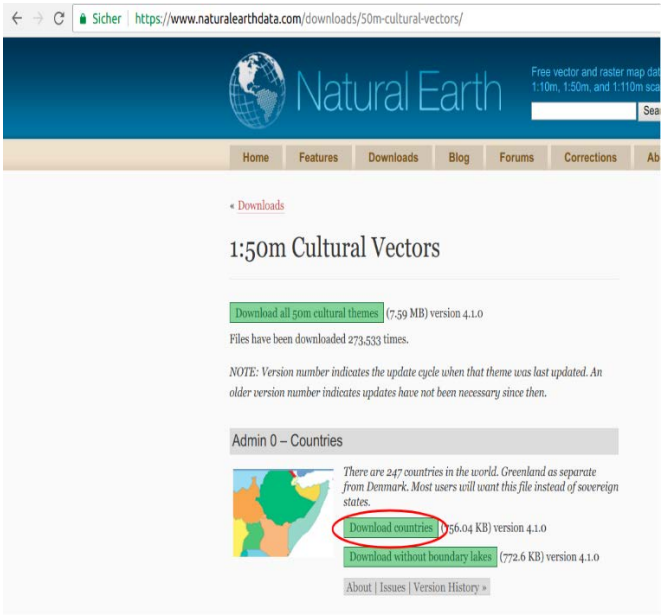
[7] https://unstats.un.org/sdgs/metadata/

The metadata provides information on how your data was structured and collected. Only with this information you will be able to interpret your data correctly. In addition, information on the period under review and the sources of the studies is also provided here. These will be particularly important in your later report.

Each UN data set can have a slightly different structure, which is why the next step shows only one example of an indicator. Here it is important for you to get an overview of the data yourself and to define a question. Write it down in a structured way and search for statistical evaluation methods. Think about what you want (or are able) to display at the end, do not forget the time reference in addition to the spatial reference.

Country borders

Next, a data set with the country borders is required. On the Open Data Website Natural Earth[8] you can find some matching vector data sets. Natural Earth is a publicly accessible map dataset that is available at scales of 1:10,000,000, 1:50,000,000, and 1:110,000,000 and does not require permission for use. However, you are welcome to quote the data source, e.g. in the form "Made with Natural Earth. Free vector and raster map data @ naturalearthdata.com."



Natural Earth Entry

Under the Downloads tab, select vector data on the subject of cultural vectors on a scale of 1:50 000 000 and download the Shapefile Admin 0 - Countries.

Data preparation

Data organization

In order to work efficiently on a project, it is very important to organize it properly. This starts with the folder structure on your computer. Create a folder (right click on the location => *New* => *Folder*). In this case it could be named "SDG". Make sure that you do not use any umlauts, special characters or spaces in the name. In some cases these can cause problems for the individual software types. Especially when processing with ArcGIS, error messages may occur. The length of the file path should also be kept as short as possible. Therefore in this example "Sustainable Development Goals" was abbreviated as "SDG".

In the next step some subfolders can be created. For this example you could create the following structure:

[8] http://www.naturalearthdata.com/

- 01_Basic data: In the folder "01_Basic data" only the basic data of the project are saved. These will not be changed later.
- 02_Analysis: The partial steps as well as the results of the analysis are stored in the corresponding folder "02_Analysis". When saving the substeps, make sure that they are properly named. Depending on the length of the project, you can select the current date as the name supplement here (for example SDG_10122018.xls).
- 03_Sources: The folder "03_Sources" contains, as the name already says, the sources of your project. Always save them directly in this folder, which can save you a lot of work when writing the document.
- 04_Dispense: You can save the final files in the folder "04_Dispense". This way you have an overview of all important documents for the later upload and do not forget to upload any.

Excursus csv files: csv files are text files that can be read in software such as the Editor or Notepad++. In a table-like structure, the columns are separated by a comma, space or semicolon. The format is supported by many software products and is therefore often used as an exchange format. You can learn more about this in the Data Formats tutorial[9].

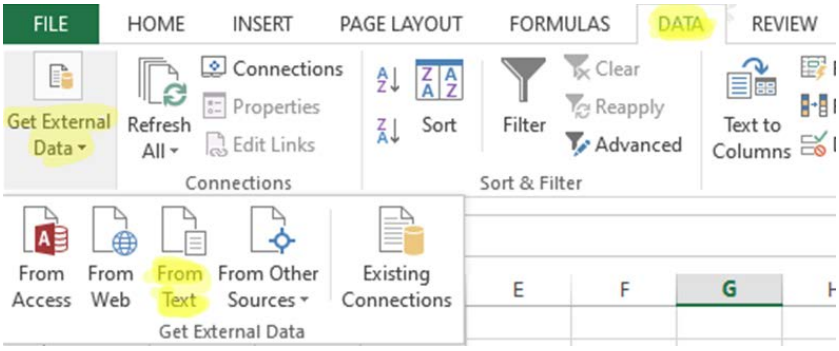
UN data with Excel 2016

This section uses the commercial program Excel 2016. If this program is not available to you, or you prefer to work with Free/Open Software for other reasons, you can switch to the section Data Preparation with LibreOffice Calc.

Import data into Excel

Before the UN dataset can be processed with a GIS, it must first be converted into an appropriate form. Open Excel and import the CSV file with the sustainability goals. Importing CSV files in Excel 2016 works as follows:

Open Excel. *Click Data => Retrieve External Data => From Text* and select the CSV file containing the UN data.



Input of CSV data

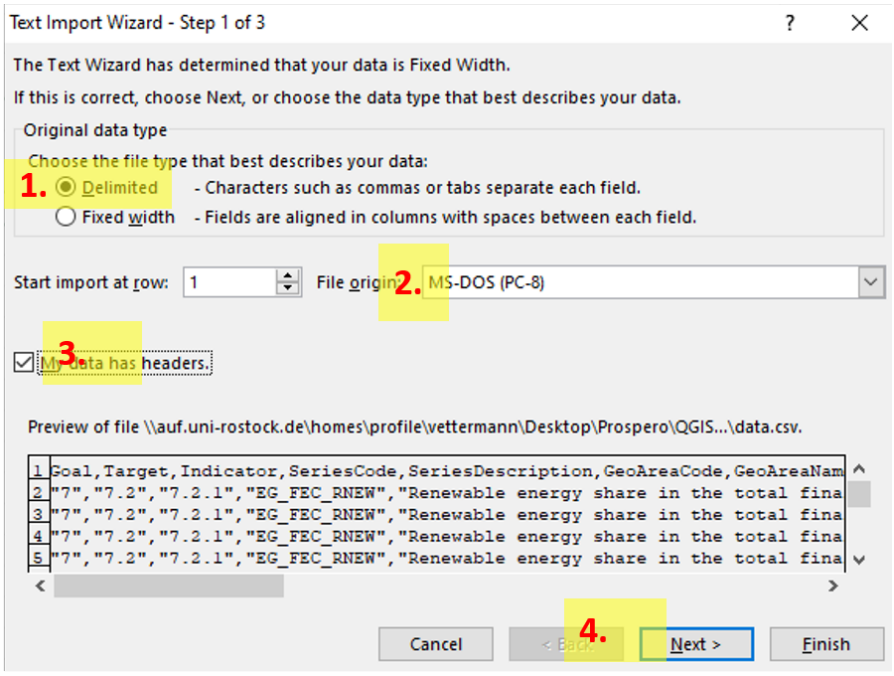
Next, you need to specify the conditions under which the CSV file should be imported. At steps 1 and 2, select the settings as shown in the images. In step 3 you can change the data format of the columns and exclude individual columns from the import. Both can be changed afterwards. The important thing with step 3 is that you import the column with the numerical values first as text, since Excel has the habit of interpreting numbers with periods as decimal separators as dates.

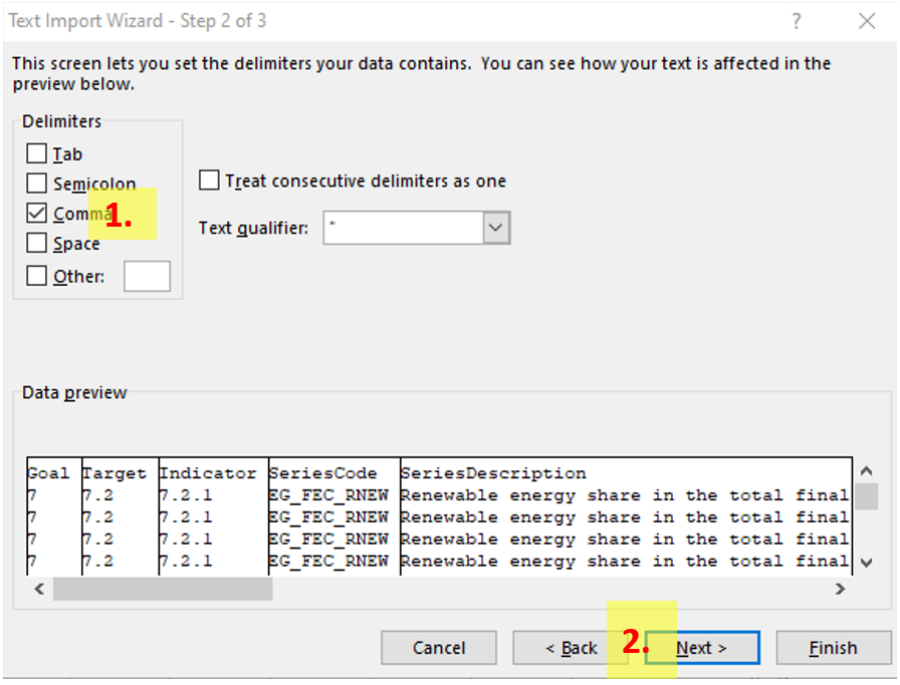
The indicator or goal designations can be imported as text, since they are not values with which to calculate. In case of a declaration as a number, Excel would also often output it as a date, so that the indicators would no longer be readable.

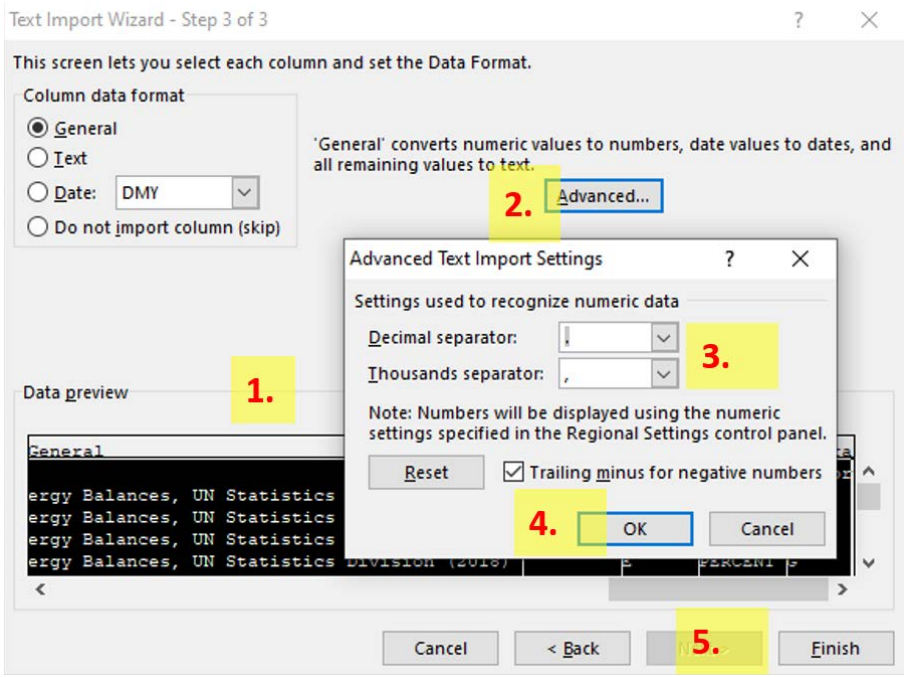
- Goal (Text)
- Target (Text)
- Indicator (Text)
- GeoAreaNames (Text)
- geoAreaCode (Standard)
- Value_xxxx (Standard)

[9] https://learn.opengeoedu.de/tutorials#tutorial-datenformate

The *value column*(s), i.e. the column in which our energy values are located, must be declared as standard (i.e. as a number). However, since a decimal value is often present, a character must also be selected for this. This can be set under the button "*More*". For the settings a new window opens, where on the one hand the "*1000 digits*" and on the other hand the decimal digits are listed. Since the SDG data are international, the decimal places are marked with a dot. The 1000 digits, on the other hand, are marked with a comma. You can now use these settings, if available, for the remaining value columns.







3 steps to convert csv to Excel

After pressing the *Finish* button, the table will look something like this:

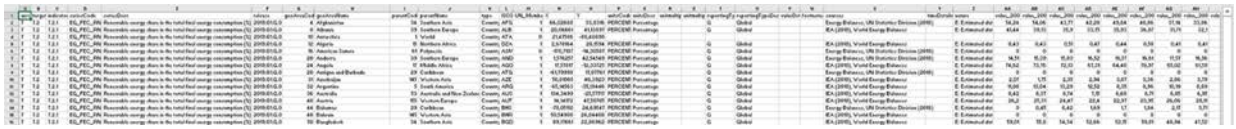


Table view in Excel

Tip: For further processing, it is advisable to create copies of the data for each important step, give them meaningful names and organize them sensibly on the computer.

So at this point we create a copy of the previously created Excel dataset, once as csv- and once as xls-file, and name it UNSDG721Original.

Data viewing and revision

Now we look at the table in more detail and prepare it further. The columns have headings whose meaning and formatting are described in the metadata. A total of 249 lines are occupied (including one heading line). Many of the attributes (columns) listed in the table are not relevant for the actual calculation and can therefore be deleted.

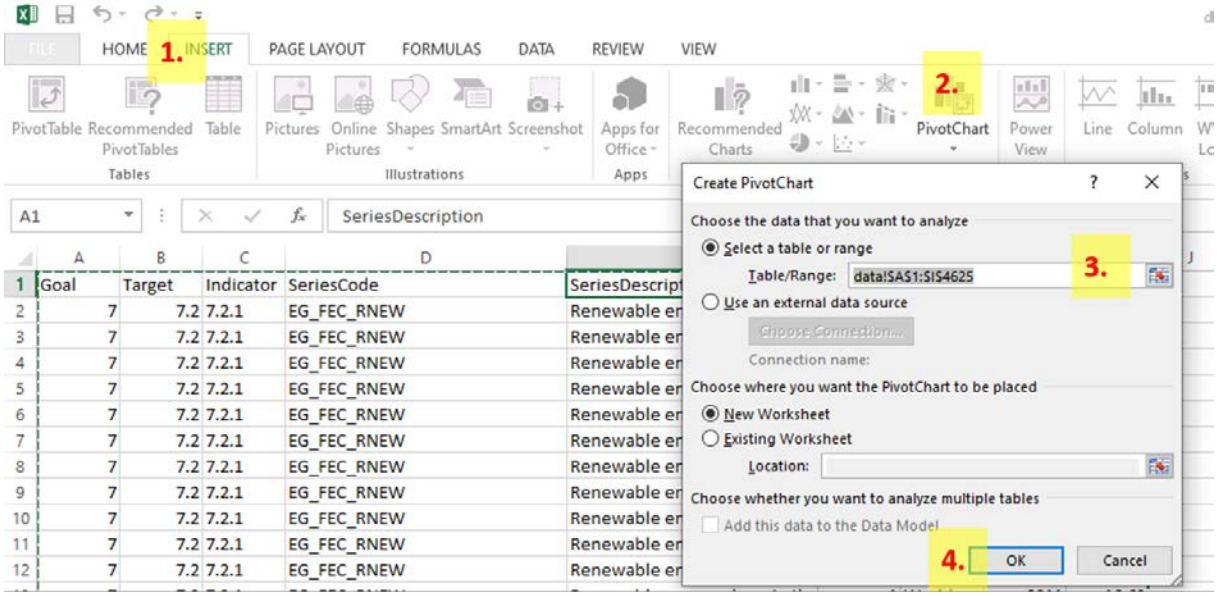
So we first reduce the table to the necessary columns (goal, target, indicator, geoArea-Code, geoAreaName, value_2000 .. value_2016) and have a much better overview. After deleting superfluous columns, the revised CSV file should now look like this:

	A	B	C	D	E	F	G	H	I
1	Goal	Target	Indicator	SeriesCode	SeriesDescription	GeoAreaC	GeoAreaN	TimePeric	Value
2	7	7.2	7.2.1	EG_FEC_RNEW	Renewable energy share in the	4	Afghanist	2000	54.24
3	7	7.2	7.2.1	EG_FEC_RNEW	Renewable energy share in the	4	Afghanist	2001	54.06
4	7	7.2	7.2.1	EG_FEC_RNEW	Renewable energy share in the	4	Afghanist	2002	43.77
5	7	7.2	7.2.1	EG_FEC_RNEW	Renewable energy share in the	4	Afghanist	2003	42.28
6	7	7.2	7.2.1	EG_FEC_RNEW	Renewable energy share in the	4	Afghanist	2004	49.84
7	7	7.2	7.2.1	EG_FEC_RNEW	Renewable energy share in the	4	Afghanist	2005	40.86
8	7	7.2	7.2.1	EG_FEC_RNEW	Renewable energy share in the	4	Afghanist	2006	37.14

Desired appearance of the Excel table

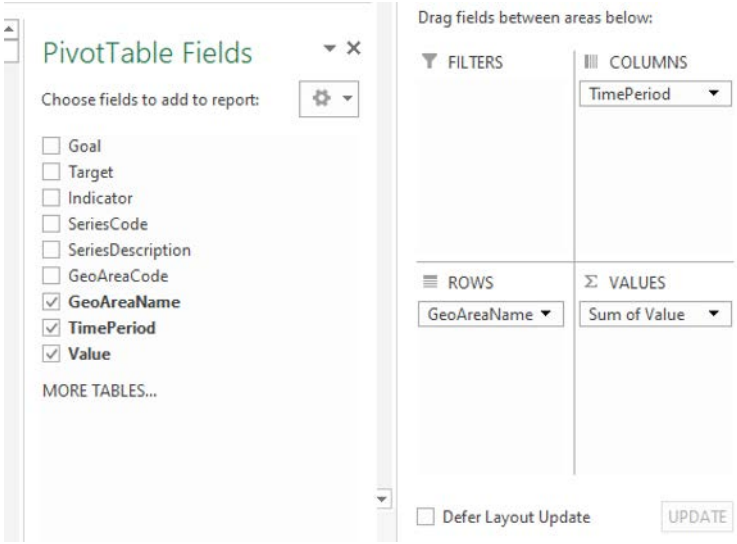
If the column values in your table are below each other (as it is shown here), it is now necessary to transpose the values per year so that one column is assigned to each value from 2000 - 2016. However, this is only necessary with the data as CSV, the Excel data are already correctly formatted. A pivot table is used for this purpose. Via

Insert (1.) => Pivot table (2) a new window opens in which the data area (all data cells) is selected (3). With the click on 4. a new table sheet with the pivot table is created.



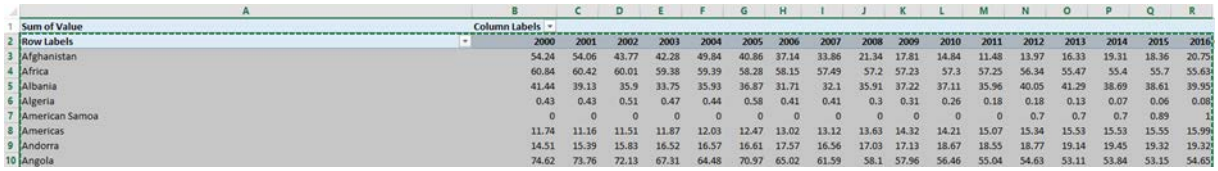
Insert the Pivot table

To convert the individual years into columns for each country, it is necessary to select the GeoAreaName, TimePeriod and Value fields in the pivot table settings. These are then assigned to the column (TimePeriod), the rows (GeoAreaName) and the values.



Formatting the Pivot table

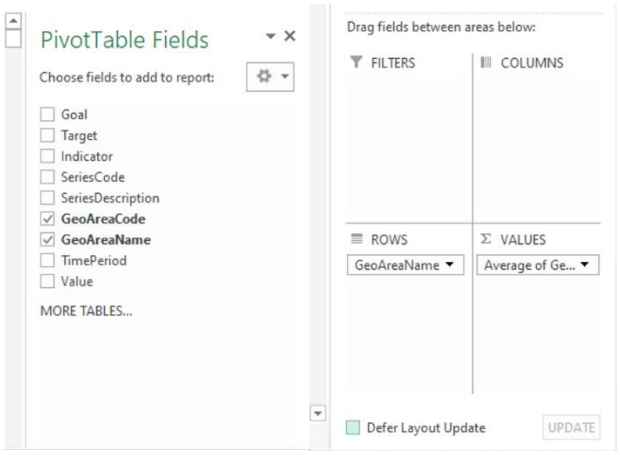
The table should now be displayed as shown here.



Sum of Value	Column Labels																	
Row Labels	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Afghanistan	54.24	54.06	43.77	42.28	49.84	40.86	37.14	33.86	21.34	17.81	14.84	11.48	13.97	16.33	19.31	18.36	20.75
Africa	60.84	60.42	60.01	59.38	59.39	58.28	58.15	57.49	57.2	57.23	57.3	57.25	56.34	55.47	55.4	55.7	55.63
Albania	41.44	39.13	35.9	33.75	35.93	36.87	31.71	32.1	35.91	37.22	37.11	35.96	40.05	41.29	38.69	38.61	39.95
Algeria	0.43	0.43	0.51	0.47	0.44	0.58	0.41	0.41	0.3	0.31	0.26	0.18	0.18	0.13	0.07	0.06	0.08
American Samoa	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0.7	0.89	1
Americas	11.74	11.16	11.51	11.87	12.03	12.47	13.02	13.12	13.63	14.32	14.21	15.07	15.34	15.53	15.53	15.55	15.99
Andorra	14.51	15.39	15.83	16.52	16.57	16.61	17.57	16.56	17.03	17.13	18.67	18.55	18.77	19.14	19.45	19.32	19.32
Angola	74.62	73.76	72.13	67.31	64.48	70.97	65.02	61.59	58.1	57.96	56.46	55.04	54.63	53.11	53.84	53.15	54.65

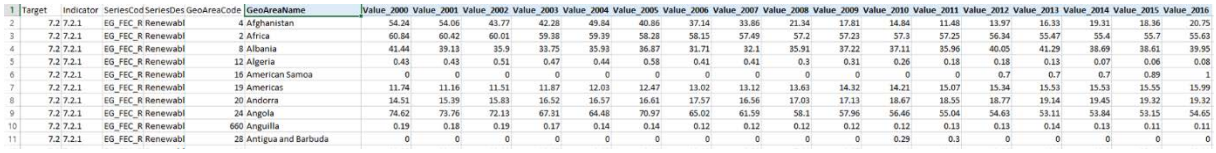
Ready to use pivot table

Now, each column of the pivot chart can be copied to a new worksheet. To make the country codes also available, the pivot table has to be edited. Therefore, only the fields GeoAreaCode (as average value) and GeoAreaName (as row) should be selected.



Adding the area codes

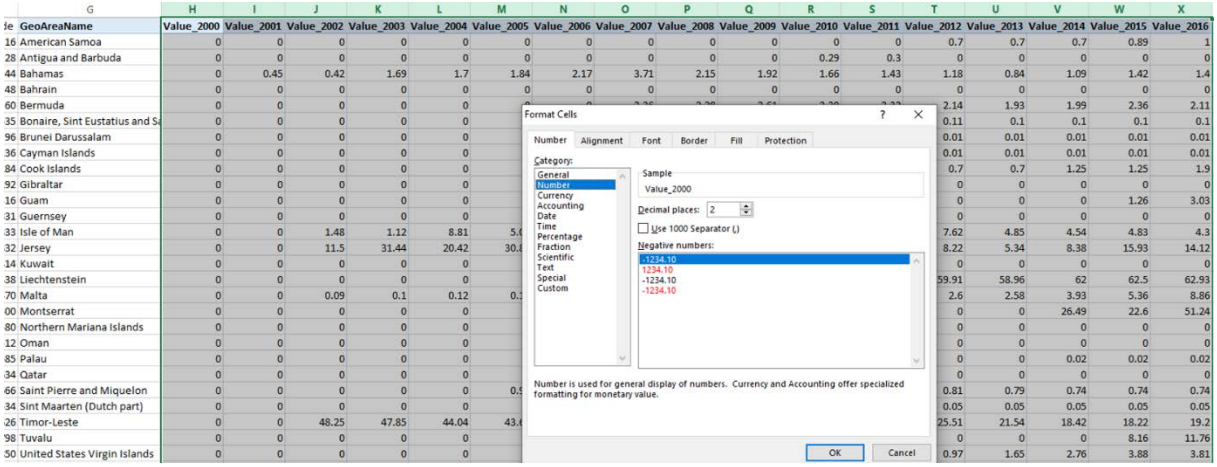
The GeoAreaCode column can then also be copied to the new spreadsheet. Now only the columns Goal, Target, Indicator, SeriesCode and SeriesDescription have to be added. Since these are identical for each row, you can simply copy them for all rows and paste them into the new worksheet. The finished data table is shown below.



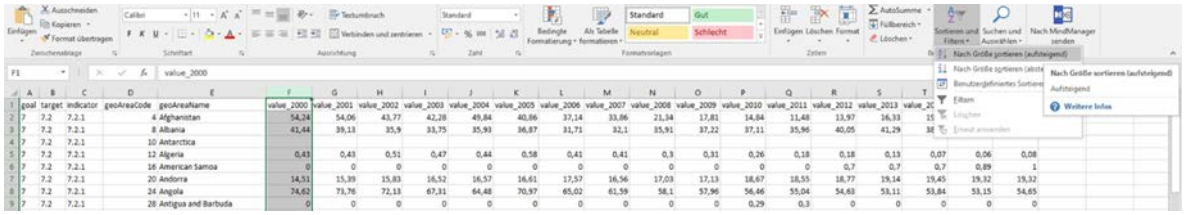
Target	Indicator	SeriesCod	SeriesDes	GeoAreaCode	GeoAreaName	Value_2000	Value_2001	Value_2002	Value_2003	Value_2004	Value_2005	Value_2006	Value_2007	Value_2008	Value_2009	Value_2010	Value_2011	Value_2012	Value_2013	Value_2014	Value_2015	Value_2016
7.2	7.2.1	EG_FEC_R	Renewabl	4	Afghanistan	54.24	54.06	43.77	42.28	49.84	40.86	37.14	33.86	21.34	17.81	14.84	11.48	13.97	16.33	19.31	18.36	20.75
7.2	7.2.1	EG_FEC_R	Renewabl	2	Africa	60.84	60.42	60.01	59.38	59.39	58.28	58.15	57.49	57.2	57.23	57.3	57.25	56.34	55.47	55.4	55.7	55.63
7.2	7.2.1	EG_FEC_R	Renewabl	8	Albania	41.44	39.13	35.9	33.75	35.93	36.87	31.71	32.1	35.91	37.22	37.11	35.96	40.05	41.29	38.69	38.61	39.95
7.2	7.2.1	EG_FEC_R	Renewabl	12	Algeria	0.43	0.43	0.51	0.47	0.44	0.58	0.41	0.41	0.3	0.31	0.26	0.18	0.18	0.13	0.07	0.06	0.08
7.2	7.2.1	EG_FEC_R	Renewabl	16	American Samoa	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0.7	0.89	1
7.2	7.2.1	EG_FEC_R	Renewabl	19	Americas	11.74	11.16	11.51	11.87	12.03	12.47	13.02	13.12	13.63	14.32	14.21	15.07	15.34	15.53	15.53	15.55	15.99
7.2	7.2.1	EG_FEC_R	Renewabl	20	Andorra	14.51	15.39	15.83	16.52	16.57	16.61	17.57	16.56	17.03	17.13	18.67	18.55	18.77	19.14	19.45	19.32	19.32
7.2	7.2.1	EG_FEC_R	Renewabl	24	Angola	74.62	73.76	72.13	67.31	64.48	70.97	65.02	61.59	58.1	57.96	56.46	55.04	54.63	53.11	53.84	53.15	54.65
7.2	7.2.1	EG_FEC_R	Renewabl	660	Anguilla	0.19	0.18	0.19	0.17	0.14	0.14	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.13	0.11	0.11
7.2	7.2.1	EG_FEC_R	Renewabl	28	Antigua and Barbuda	0	0	0	0	0	0	0	0	0	0	0.29	0.3	0	0	0	0	0

Finished data table

If your selected UN table makes it necessary, assign meaningful names for the headers (it is best not to use only numbers, otherwise ArcMap will not recognize them as headers). Finally, the data formats of the columns should be checked or set (*select cells => right click => format cells*; headers and text as text, numerical values as number). For several columns (e.g. all values from 2000 to 2016) hold down the Shift key when selecting headings.



Formatting of all value columns as numbers



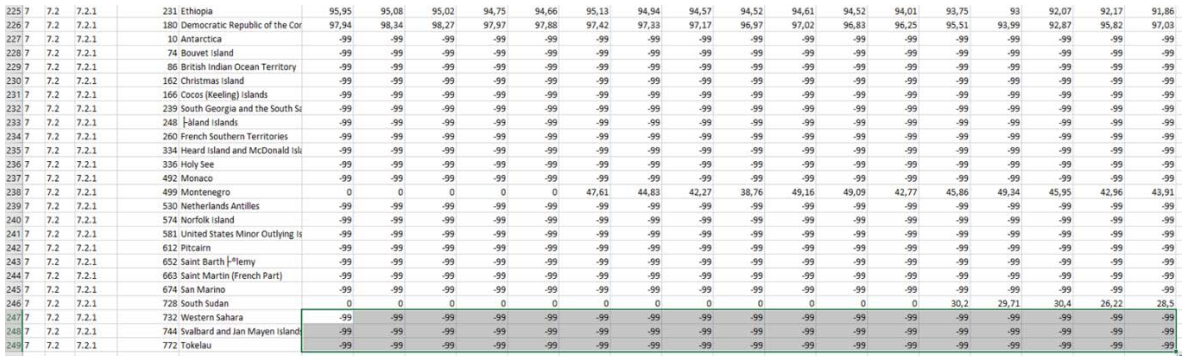
Sort by size in ascending order

	A	B	C	D
1	GeoAreaCode	GeoAreaName	Value_2005	Value_2015
2	1	World	16.50	17.46
3	4	Afghanistan	40.86	18.42
4	8	Albania	36.87	38.62
5	9	Oceania	11.78	13.51
6	12	Algeria	0.58	0.06
7	15	Northern Africa	13.78	9.71
8	16	American Samoa	0.00	0.89
9	20	Andorra	16.90	19.75
10	21	Northern America	7.64	10.18
11	24	Angola	70.95	49.57
12	28	Antigua and Barbuda	0.00	0.00
13	30	Eastern Asia	14.05	11.13
14	31	Azerbaijan	3.37	2.31
15	32	Argentina	8.96	10.04
16	34	Southern Asia	39.29	31.09
17	35	South-Eastern Asia	33.62	30.26
18	36	Australia	6.71	9.18
19	40	Austria	24.17	34.39
20	44	Bahamas	1.84	1.21

Formatted temporal table

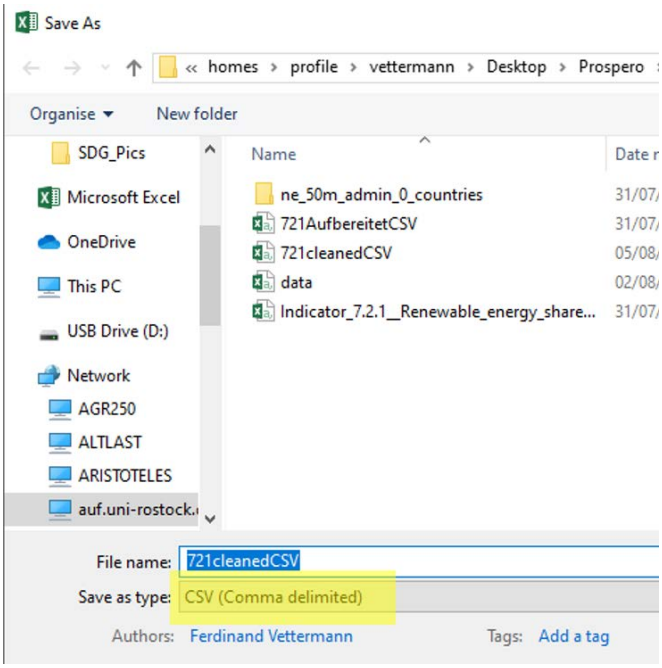
If you look at the data, you can see that some rows (Antarctica) has no values. For the visualization later on it is necessary to insert therefor no data value. In our case we insert -99. Therefore, the column Value_2000 should be sorted ascending and the empty fields should be filled with our no data value.

Furthermore, there are some young countries like Montenegro or South Sudan, so there are no values before their founding year. In this case, we fill the empty fields with the value 0,0. The final table should look like this:



Final data table

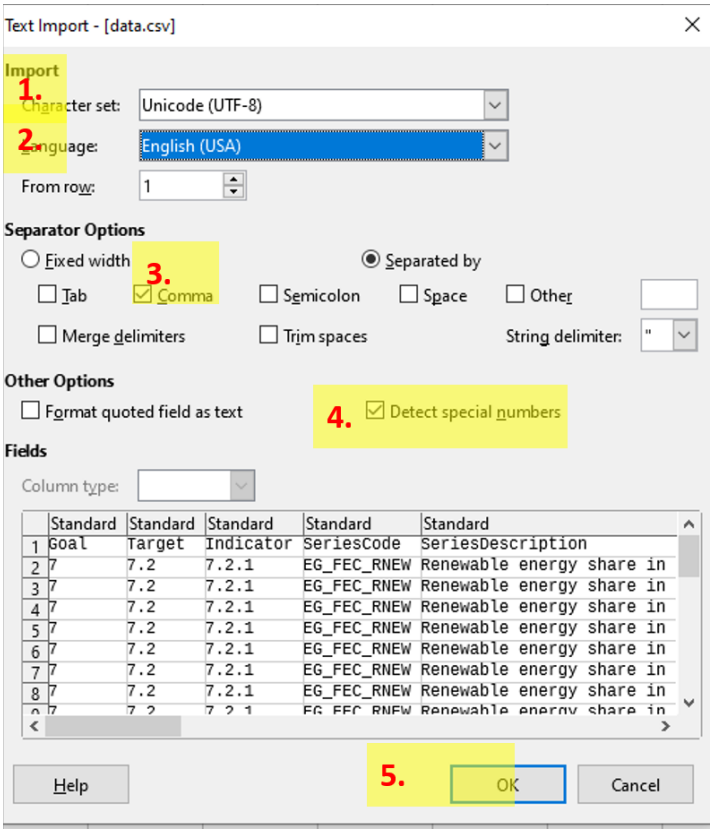
The data preparation is now complete, save the table as CSV.



Store as csv

UN Data with LibreOffice Calc

In this section the data are prepared with LibreOffice Calc, this is intended as an alternative to the section Data preparation with Excel. Before the UN dataset can be evaluated with a GIS, it must be converted into a form that can be read and processed by a GIS. Open the CSV file of the UN dataset with LibreOffice Calc (Start LibreOffice => *Open button* => *Select file*) and make the following settings for the import:



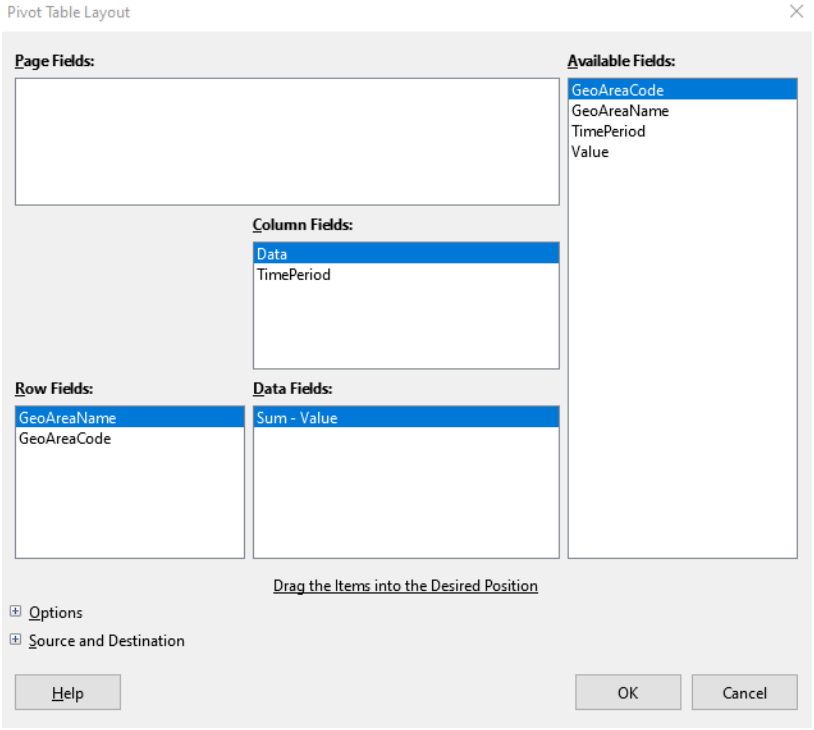
Import in LibreCalc

After importing, all superfluous columns can be deleted. Every column except goal, target, indicator, geoAreaCode, geoAreaName, TimePeriod, Value can be deleted.

	A	B	C	D	E
1	GeoAreaCode	GeoAreaName	TimePeriod	Value	
2	1	World	2005	16,5	
3	1	World	2006	16,54	
4	1	World	2007	16,35	
5	1	World	2008	16,46	
6	1	World	2009	16,94	
7	1	World	2010	16,67	
8	1	World	2011	16,62	
9	1	World	2012	16,94	
10	1	World	2013	17,15	
11	1	World	2014	17,3	
12	1	World	2015	17,46	
13	4	Afghanistan	2005	40,86	
14	4	Afghanistan	2006	37,14	
15	4	Afghanistan	2007	33,86	
16	4	Afghanistan	2008	21,34	
17	4	Afghanistan	2009	17,81	
18	4	Afghanistan	2010	14,84	

Desired appearance of the table

In addition to the countries, the UN table also contains aggregated regions. Although these are not relevant for this evaluation, they do not interfere any further, since they disappear automatically during the later join. One problem, however, is that the values for the respective years are given in a single column and therefore the country names occur several times. For this reason, the year numbers (*TimePeriod*) and their values (*Value*) must be broken down into separate columns. This can be done with a pivot chart. Create a new pivot chart and set the time periods as columns, GeoAreaName and GeoAreaCode as row and values as the column value.



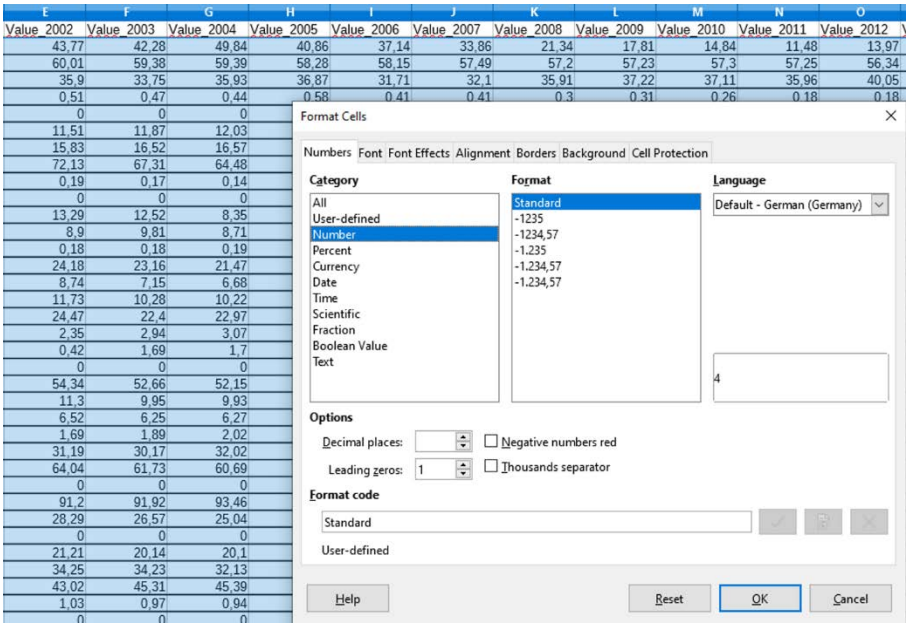
Create a pivot chart

The resulting pivot chart is shown below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Sum - Value		Data																
2	GeoAreaN	GeoAreaC	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
3	Afghanistan	4	54,24	54,06	43,77	42,28	40,84	40,86	37,14	33,86	21,34	17,81	14,84	11,48	13,97	16,33	19,31	18,36	20,75
4	Africa	2	60,84	60,42	60,01	59,38	59,39	58,28	58,15	57,49	57,2	57,23	57,3	57,25	56,34	55,47	55,4	55,7	55,63
5	Albania	8	41,44	39,13	35,9	33,75	35,93	36,87	31,71	32,1	35,91	37,22	37,11	35,96	40,05	41,29	38,69	38,61	39,95
6	Algeria	12	0,43	0,43	0,51	0,47	0,44	0,58	0,41	0,41	0,3	0,31	0,26	0,18	0,18	0,13	0,07	0,06	0,08
7	American Sa	16	0	0	0	0	0	0	0	0	0	0	0	0	0,7	0,7	0,7	0,89	1
8	Americas	19	11,74	11,16	11,51	11,87	12,03	12,47	13,02	13,12	13,63	14,32	14,21	15,07	15,34	15,53	15,53	15,55	15,99

Final pivot chart

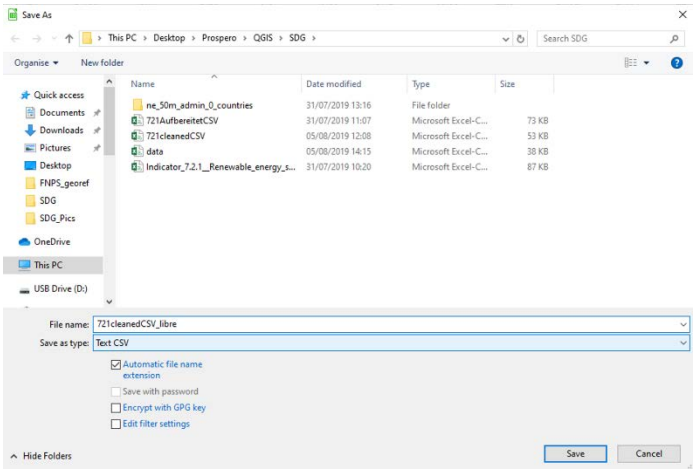
Don't forget to delete unnecessary rows and columns. Assign meaningful names to the headers. Finally, the data formats of the columns should be checked or set (*select cells* => *right click* => *format cells*; headers and text as text, numerical values as number).



Formattings

Finally, missing values have to be filled. This is important for Montenegro and South Sudan. The empty fields are filled with 0,0.

The data preparation is now complete, save the table as CSV.

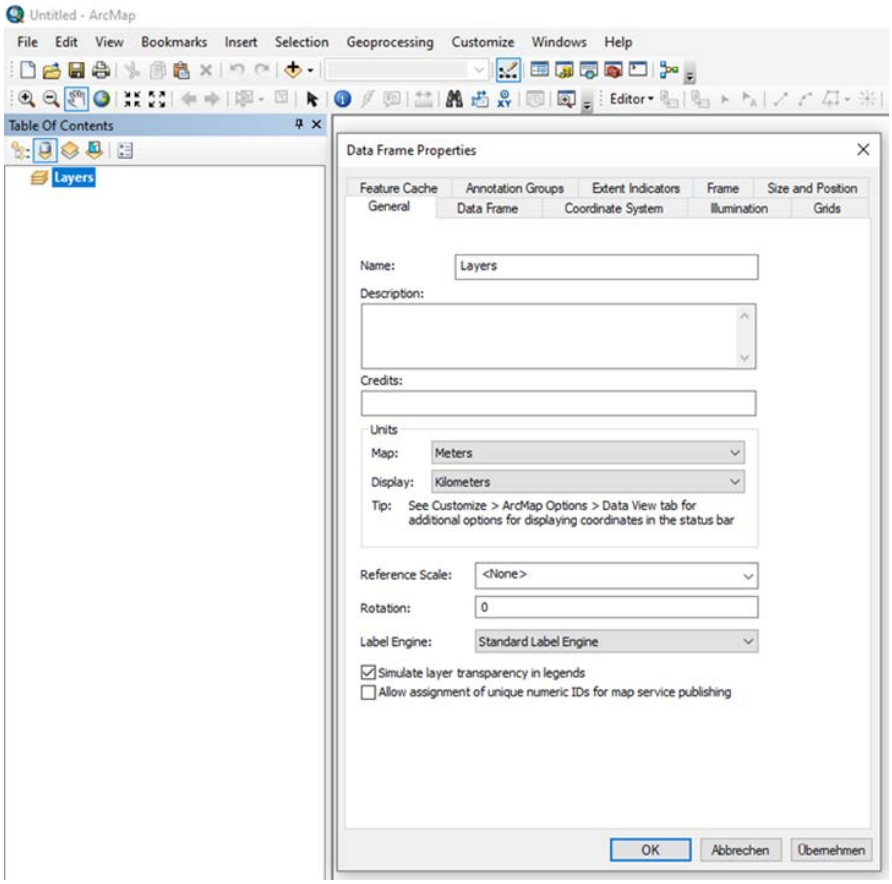


Store

Country data with ArcMap

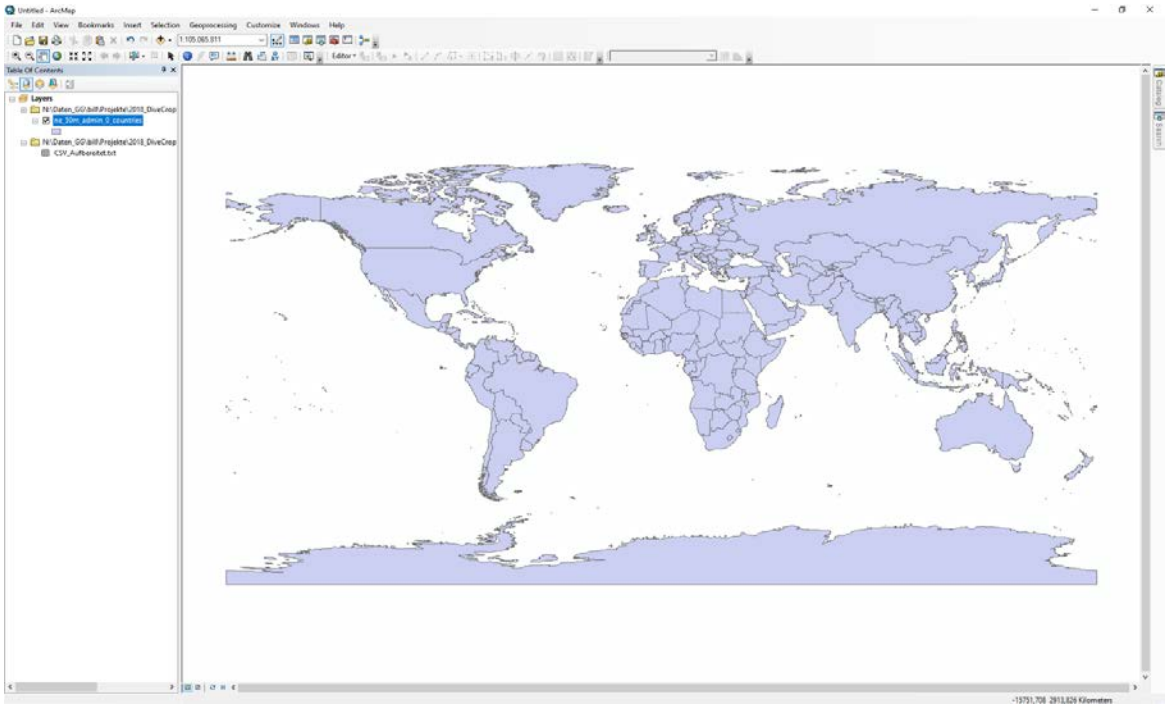
General Settings

We also take a look at the data of the country borders and prepare them for a later evaluation and visualization. To do this, open ArcMap and first set two general properties of the layer: map units in meters, display units in kilometers.



General settings for layers

Now add the shapefile with the country boundaries World_Countries_Generalized.shp via *Add Data*.



Shape file of country borders

A look into the table of country borders (right click on the layer in the layer window => open attribute table) shows that there are 239 entries. Some countries (TYPE) are also assigned to another country (Sovereign country or

Dependency), for example in the case of the British (e.g. the Cayman Islands namely United Kingdom) and French Overseas Territories (e.g. French Guiana). Since these territories are also listed separately in the SDG table, this is not an obstacle.

Tip: Many columns can be hidden, because they are not needed for further processing, e.g. the names in different languages. You can do this by right-clicking on column header => *Turn Field Off*. Or - better for many changes - right-click on the layer => *Properties* => *Fields*. The following columns should be retained (FID, shape, featurecla, name, POP_EST ...) INCOME_GRP and ISO_N3.

The clearly arranged table will look like this:

FID	Shape *	featurecla	NAME	POP_EST	POP_RANK	GDP_MD_EST	POP_YEAR	LASTCENSUS	GDP_YEAR	ECONOMY	INCOME_GRP	ISO_N3
0	Polygon	Admin-0 country	Zimbabwe	13805084	14	28330	2017	2002	2016	5. Emerging region: G20	5. Low income	716
1	Polygon	Admin-0 country	Zambia	15972000	14	65170	2017	2010	2016	7. Least developed region	4. Lower middle income	894
2	Polygon	Admin-0 country	Yemen	28036829	15	73450	2017	2004	2016	7. Least developed region	4. Lower middle income	887
3	Polygon	Admin-0 country	Vietnam	96160163	16	594900	2017	2009	2016	5. Emerging region: G20	4. Lower middle income	704
4	Polygon	Admin-0 country	Venezuela	31304016	15	468600	2017	2001	2016	5. Emerging region: G20	3. Upper middle income	862
5	Polygon	Admin-0 country	Vatican	1000	3	0	2015	-99	0	2. Developed region: nonG7	2. High income: nonOECD	336
6	Polygon	Admin-0 country	Vanuatu	282814	10	723	2017	2009	2016	7. Least developed region	4. Lower middle income	548
7	Polygon	Admin-0 country	Uzbekistan	29748859	15	202300	2017	1989	2016	6. Developing region	4. Lower middle income	860
8	Polygon	Admin-0 country	Uruguay	3360148	12	73250	2017	2004	2016	5. Emerging region: G20	3. Upper middle income	858
9	Polygon	Admin-0 country	Micronesia	104196	9	314	2017	2000	2016	6. Developing region	4. Lower middle income	583
10	Polygon	Admin-0 country	Marshall Is.	74539	8	180	2017	2011	2016	6. Developing region	4. Lower middle income	584
11	Polygon	Admin-0 country	N. Mariana Is.	52263	8	682	2017	2010	2013	6. Developing region	2. High income: nonOECD	580
12	Polygon	Admin-0 country	U.S. Virgin Is.	107268	9	3792	2017	2010	2013	6. Developing region	2. High income: nonOECD	850
13	Polygon	Admin-0 country	Guam	167358	9	4882	2017	2010	2013	6. Developing region	2. High income: nonOECD	316
14	Polygon	Admin-0 country	American Samoa	51504	8	711	2017	2010	2013	6. Developing region	3. Upper middle income	16
15	Polygon	Admin-0 country	Puerto Rico	3351827	12	131000	2017	2010	2016	6. Developing region	2. High income: nonOECD	630
16	Polygon	Admin-0 country	United States of America	326625791	17	18560000	2017	2010	2016	1. Developed region: G7	1. High income: OECD	840
17	Polygon	Admin-0 country	S. Geo. and the Is.	30	1	0,3	2017	-99	2016	7. Least developed region	5. Low income	239
18	Polygon	Admin-0 country	Br. Indian Ocean Ter.	4000	4	160	2013	-99	2013	2. Developed region: nonG7	2. High income: nonOECD	86
19	Polygon	Admin-0 country	Saint Helena	7828	5	31,1	2017	-99	2010	6. Developing region	4. Lower middle income	654
20	Polygon	Admin-0 country	Pitcairn Is.	54	1	0	2016	-99	2016	7. Least developed region	5. Low income	612
21	Polygon	Admin-0 country	Anguilla	17087	6	175,4	2017	-99	2009	6. Developing region	3. Upper middle income	660
22	Polygon	Admin-0 country	Falkland Is.	2931	4	281,8	2014	-99	2012	2. Developed region: nonG7	1. High income: OECD	238
23	Polygon	Admin-0 country	Cayman Is.	58441	8	2507	2017	2010	2014	5. Emerging region: G20	2. High income: nonOECD	136
24	Polygon	Admin-0 country	Bermuda	70864	8	5198	2017	2010	2013	2. Developed region: nonG7	2. High income: nonOECD	60
25	Polygon	Admin-0 country	British Virgin Is.	35015	7	500	2017	-99	2010	2. Developed region: nonG7	1. High income: OECD	92
26	Polygon	Admin-0 country	Turks and Caicos Is.	52570	8	632	2017	2001	2007	6. Developing region	2. High income: nonOECD	796
27	Polygon	Admin-0 country	Montserrat	5292	5	43,8	2017	-99	2006	6. Developing region	4. Lower middle income	500
28	Polygon	Admin-0 country	Jersey	98840	8	5080	2017	2001	2015	2. Developed region: nonG7	2. High income: nonOECD	832
29	Polygon	Admin-0 country	Guernsey	66502	8	3465	2017	2001	2015	2. Developed region: nonG7	2. High income: nonOECD	831
30	Polygon	Admin-0 country	Isle of Man	88815	8	7428	2017	2006	2014	2. Developed region: nonG7	2. High income: nonOECD	833
31	Polygon	Admin-0 country	United Kingdom	64769452	16	2788000	2017	2011	2016	1. Developed region: G7	1. High income: OECD	826
32	Polygon	Admin-0 country	United Arab Emirates	6072475	13	667200	2017	2010	2016	6. Developing region	2. High income: nonOECD	784
33	Polygon	Admin-0 country	Ukraine	44033874	15	352600	2017	2001	2016	6. Developing region	4. Lower middle income	804
34	Polygon	Admin-0 country	Uganda	39570125	15	84930	2017	2002	2016	7. Least developed region	5. Low income	800
35	Polygon	Admin-0 country	Turkmenistan	5351277	13	94720	2017	1995	2016	6. Developing region	3. Upper middle income	795
36	Polygon	Admin-0 country	Turkey	80845215	16	1670000	2017	2000	2016	4. Emerging region: MIKT	3. Upper middle income	792
37	Polygon	Admin-0 country	Tunisia	11403800	14	130800	2017	2004	2016	6. Developing region	3. Upper middle income	788
38	Polygon	Admin-0 country	Trinidad and Tobago	1218208	12	43570	2017	2011	2016	6. Developing region	2. High income: nonOECD	780
39	Polygon	Admin-0 country	Tonga	106479	9	557	2017	2006	2016	6. Developing region	4. Lower middle income	776
40	Polygon	Admin-0 country	Togo	7965055	13	11610	2017	2010	2016	7. Least developed region	5. Low income	768
41	Polygon	Admin-0 country	Timor-Leste	1291358	12	4975	2017	2010	2016	7. Least developed region	4. Lower middle income	626
42	Polygon	Admin-0 country	Thailand	68414135	16	1161000	2017	2010	2016	5. Emerging region: G20	3. Upper middle income	764
43	Polygon	Admin-0 country	Tanzania	53950935	16	150600	2017	2002	2016	7. Least developed region	5. Low income	834
44	Polygon	Admin-0 country	Tajikistan	8468555	13	25810	2017	2010	2016	6. Developing region	5. Low income	762
45	Polygon	Admin-0 country	Taiwan	23508428	15	1127000	2017	-99	2016	2. Developed region: nonG7	2. High income: nonOECD	158
46	Polygon	Admin-0 country	Syria	18028549	14	50280	2017	2004	2015	6. Developing region	4. Lower middle income	760
47	Polygon	Admin-0 country	Switzerland	8236303	13	496300	2017	2010	2016	2. Developed region: nonG7	1. High income: OECD	756
48	Polygon	Admin-0 country	Sweden	9960487	13	498100	2017	-99	2016	2. Developed region: nonG7	1. High income: OECD	752
49	Polygon	Admin-0 country	eSwatini	1467152	12	11060	2017	2007	2016	6. Developing region	4. Lower middle income	748
50	Polygon	Admin-0 country	Suriname	591919	11	8547	2017	2004	2016	6. Developing region	3. Upper middle income	740
51	Polygon	Admin-0 country	S. Sudan	13026129	14	20880	2017	2008	2016	7. Least developed region	5. Low income	728
52	Polygon	Admin-0 country	Sudan	37345935	15	176300	2017	2008	2016	6. Developing region	4. Lower middle income	729

1 (0 out of 239 Selected)

ne_50m_admin_0_countries

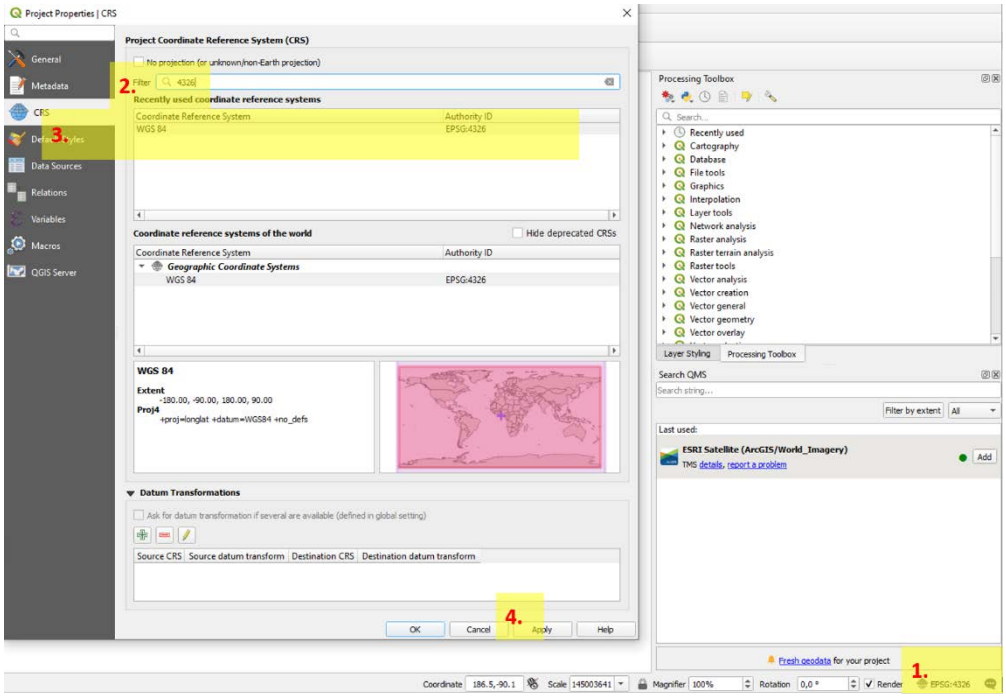
Attribute data of the countries

Save the status achieved with ArcMap as Map document with *File* => *Save as* with the name Country dataPrepared.

Country data with QGIS

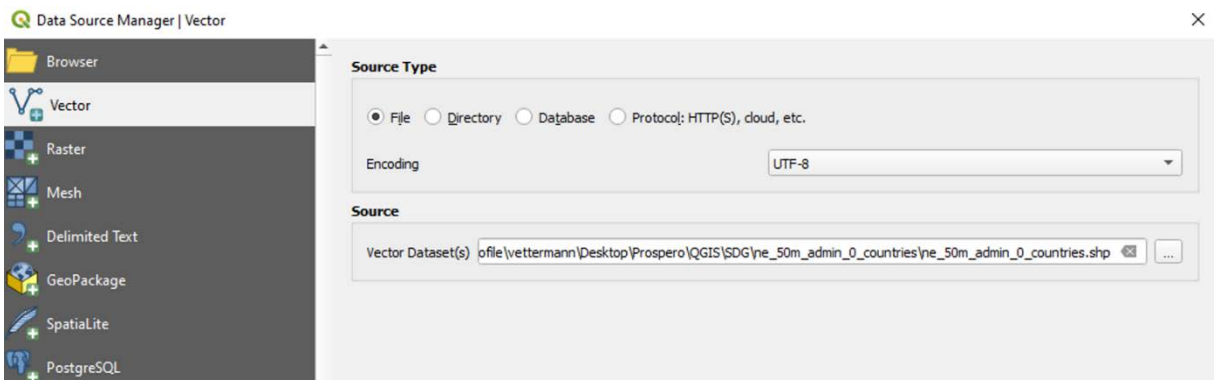
General settings

We also take a look at the data of the country borders and prepare them for a later evaluation and visualization. Open QGIS and adjust the projection of the map window first. Search for the EPSG code 4326, which allows a global representation.



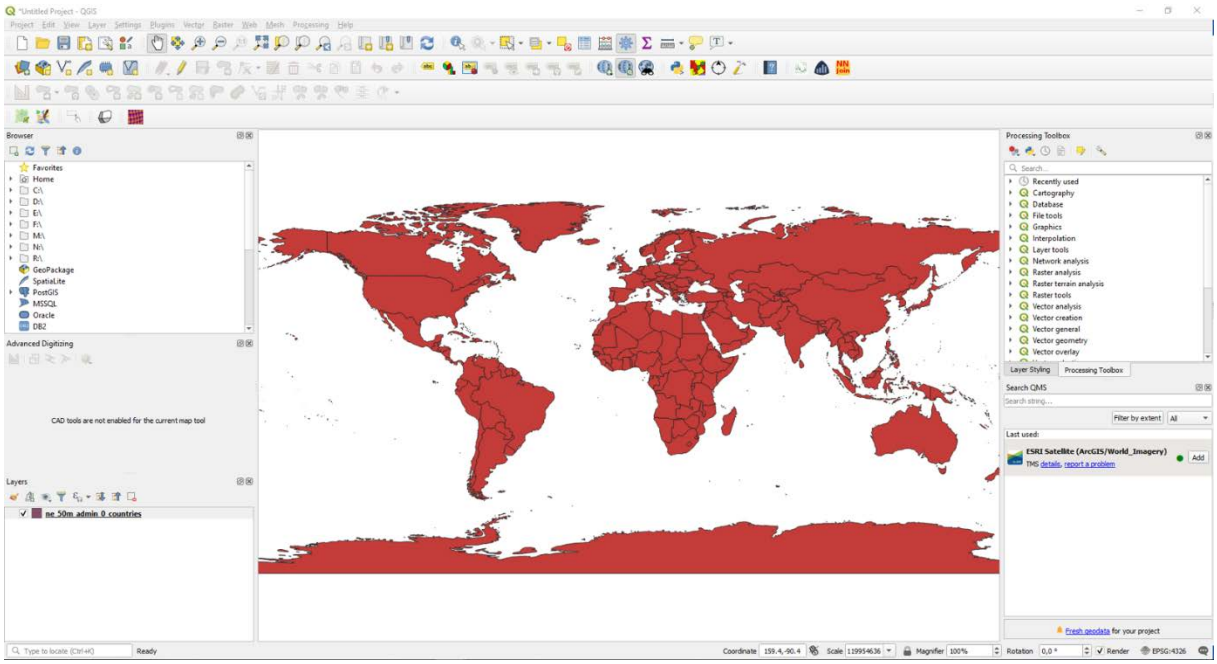
Set projection in QGIS

Then add the countries as a new vector layer to visualize them in QGIS. This can be done via *Layer => Add Layer => Add Vector Layer.*



Add a vector layer

The result should look like the following figure:



Shape file with the boundaries

A look into the table of country boundaries (right click on the layer in the layer window => *open attribute table*) shows that here some countries (ADMIN) are assigned to another country (SOVEREIGNT), for example in the case of the British (e.g. the Cayman Islands namely United Kingdom) and French overseas territories (e.g. French Guiana). Since these territories are also listed separately in the SDG table, this is not an obstacle.

> **Tip**: Columns can be hidden by right-clicking on *Column header* => *Hide Column*. Another way is to hide multiple columns with a click on *organize columns*. The following columns should be still visible: featurecla, Name, POP_EST .. INCOME_GRP und ISO_N3.

The table should look like the following:

ne_50m_admin_0_countries :: Features Total: 241, Filtered: 241, Selected: 0

	featurecla	NAME	POP_EST	POP_RANK	GDP_MD_EST	POP_YEAR	INCOME_GRP	ISO_N3
1	Admin-0 country	S. Sudan	13026129	14	20880,00	2017	5. Low income	728
2	Admin-0 country	Somaliland	3500000	12	12250,00	2013	4. Lower middl...	706
3	Admin-0 country	Serbia	7111024	13	101800,00	2017	3. Upper middl...	688
4	Admin-0 country	Sudan	37345935	15	176300,00	2017	4. Lower middl...	729

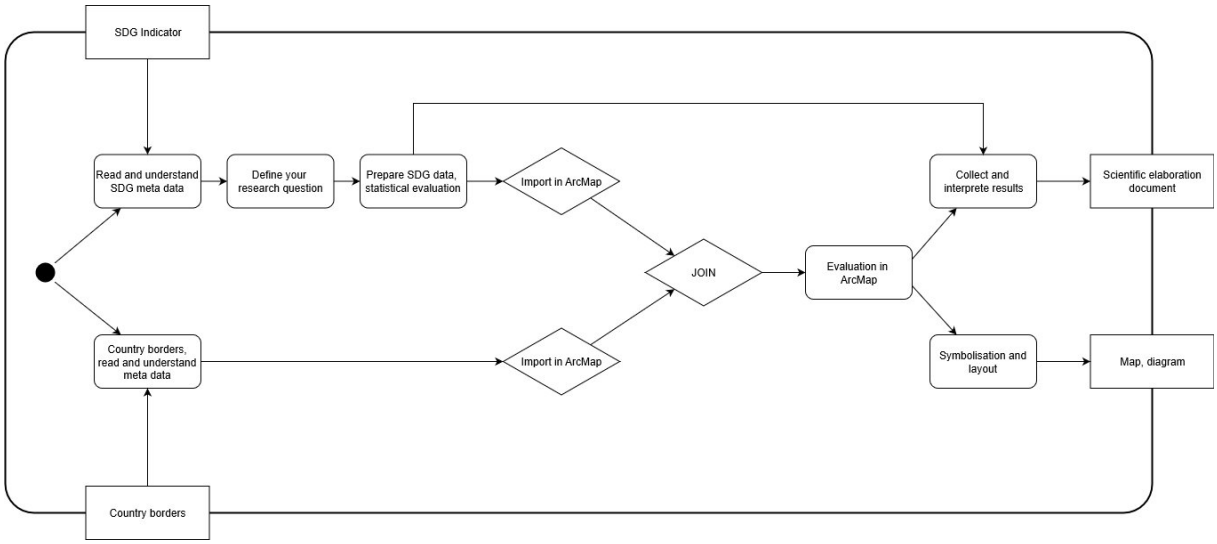
Attribute table of the countries

Modeling

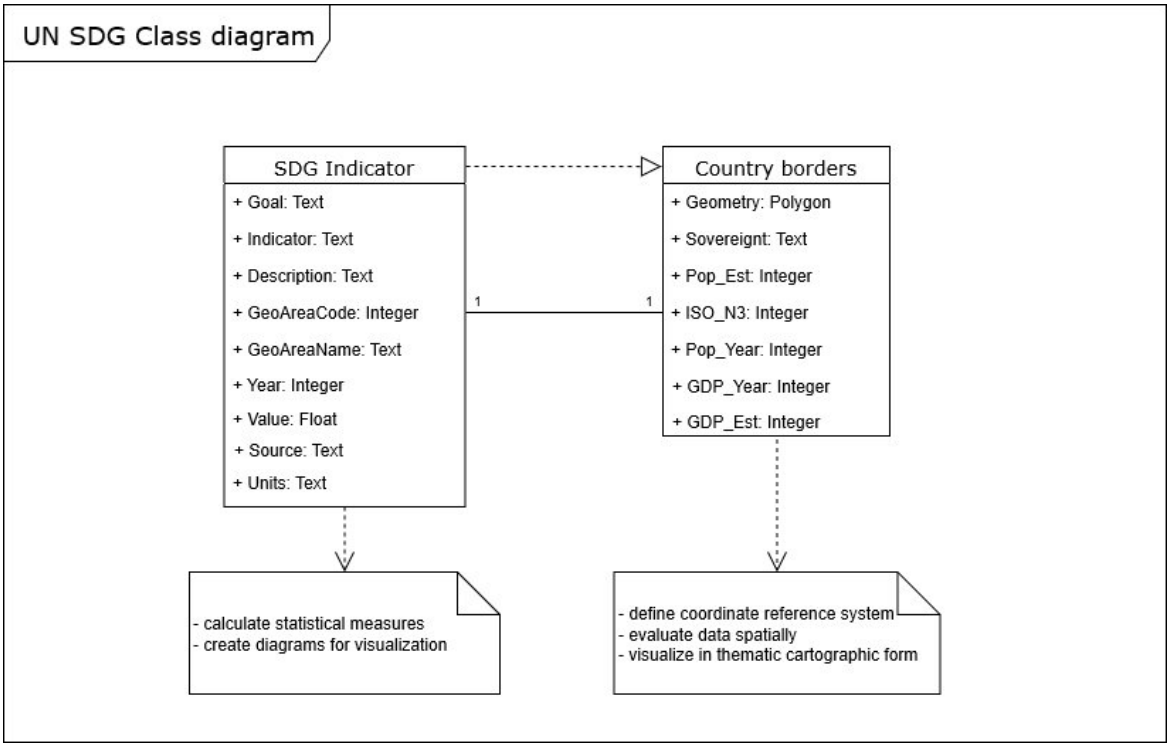
In the next step, the data is modeled using a flowchart to indicate which data is linked and how. Detailed instructions can be found in the tutorial Modeling in UML and ER[10] as well as in the tutorial UML Class and Activity Diagram[11].

[10] https://learn.opengeoedu.de/tutorials/OGE-Tutorial_UML_Vorlesung-en.pdf
[11] https://learn.opengeoedu.de/tutorials/OGE-Tutorial_UML_uebung-en.pdf

The activity diagram models the intended sequence, the class diagram models the data and its link. Open draw.io[12], a program to produce various chart types, and use the blocks on the left side to draw a corresponding diagram. You can export the diagram as PNG under *File => Export as*.



UML activity diagram



UML class diagram

Evaluation

The evaluation can be done with the commercial desktop GIS ArcMap from ESRI, the open source desktop GIS QGIS or any other familiar GIS environment. Selected steps are shown here first in ArcGIS, then in QGIS. The

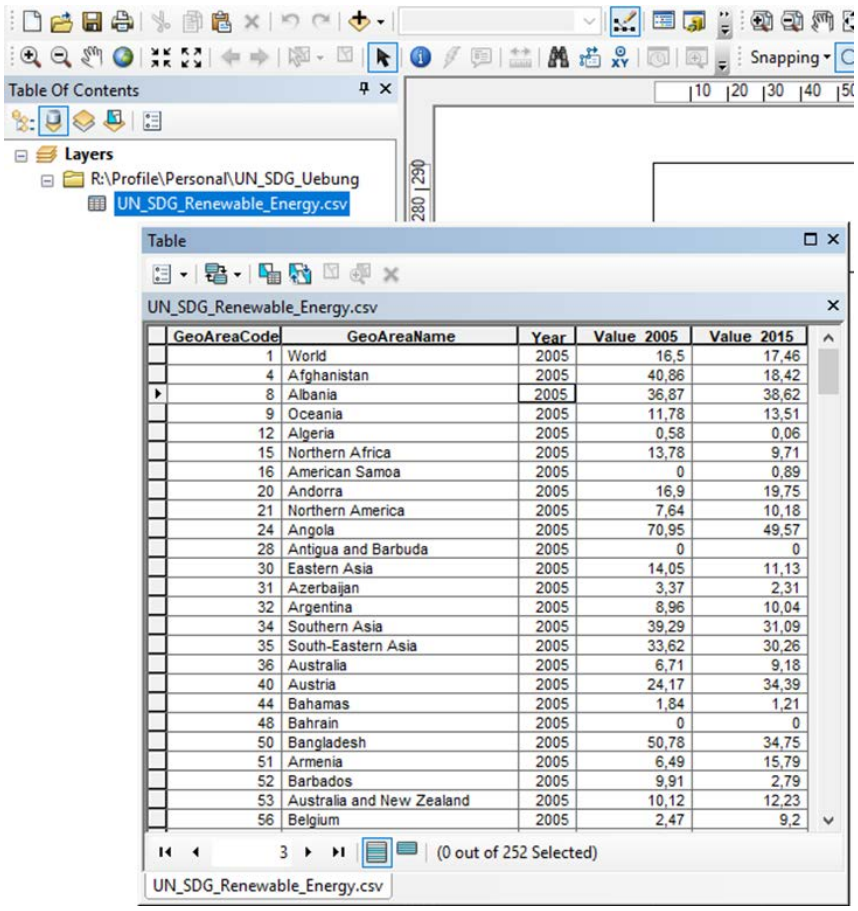
[12] https://www.draw.io/

temporal development is again considered from the point of view of the factual data, for which an evaluation using spreadsheet software, i.e. Excel or Libre Calc, is recommended. A spatial reference is established by comparing selected countries with the worldwide development.

with ArcMap

Import data

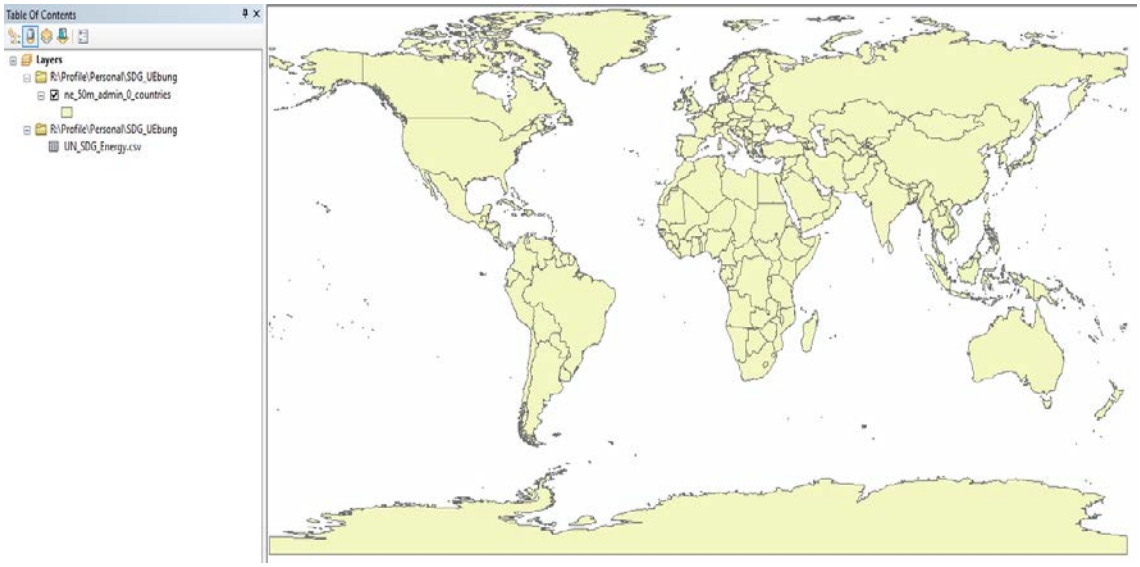
Use *Add Data* to add the formatted UN data record to your open ArcMap. The table appears in the *Table of Contents* of ArcMap. Right-click on the table and choose *Open* from the context menu. If the table has a similar shape to the one in the picture below, the previous work in Excel or LibreCalc was successful.



GeoAreaCode	GeoAreaName	Year	Value_2005	Value_2015
1	World	2005	16,5	17,46
4	Afghanistan	2005	40,86	18,42
8	Albania	2005	36,87	38,62
9	Oceania	2005	11,78	13,51
12	Algeria	2005	0,58	0,06
15	Northern Africa	2005	13,78	9,71
16	American Samoa	2005	0	0,89
20	Andorra	2005	16,9	19,75
21	Northern America	2005	7,64	10,18
24	Angola	2005	70,95	49,57
28	Antigua and Barbuda	2005	0	0
30	Eastern Asia	2005	14,05	11,13
31	Azerbaijan	2005	3,37	2,31
32	Argentina	2005	8,96	10,04
34	Southern Asia	2005	39,29	31,09
35	South-Eastern Asia	2005	33,62	30,26
36	Australia	2005	6,71	9,18
40	Austria	2005	24,17	34,39
44	Bahamas	2005	1,84	1,21
48	Bahrain	2005	0	0
50	Bangladesh	2005	50,78	34,75
51	Armenia	2005	6,49	15,79
52	Barbados	2005	9,91	2,79
53	Australia and New Zealand	2005	10,12	12,23
56	Belgium	2005	2,47	9,2

UN-SDG-Tabelle

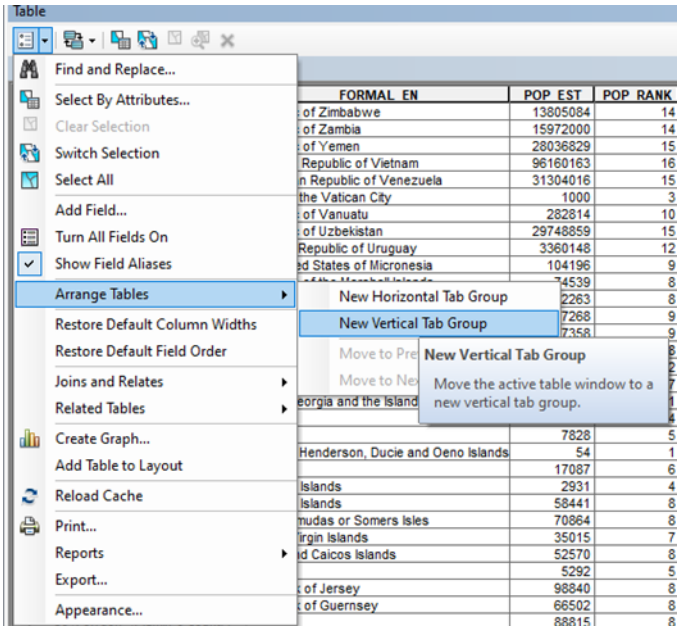
If you have not already done so in the formatting step, now also open the attribute table for the country data World_Countries_Generalized.shp via *Add Data*.



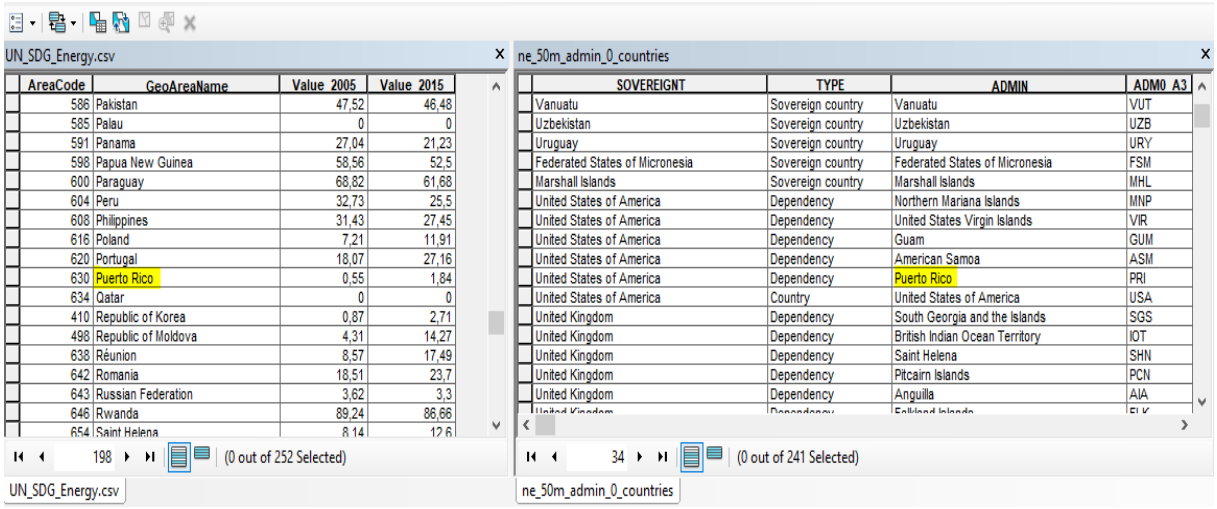
Shape files of country borders

Data preparation

The two opened tables can be arranged side by side: with *Arrange Table* e.g. vertically side by side.



Arrange tables



UN_SDG_Energy.csv

AreaCode	GeoAreaName	Value_2005	Value_2015
586	Pakistan	47,52	46,48
585	Palau	0	0
591	Panama	27,04	21,23
598	Papua New Guinea	58,56	52,5
600	Paraguay	68,82	61,68
604	Peru	32,73	25,5
608	Philippines	31,43	27,45
616	Poland	7,21	11,91
620	Portugal	18,07	27,16
630	Puerto Rico	0,55	1,84
634	Qatar	0	0
410	Republic of Korea	0,87	2,71
498	Republic of Moldova	4,31	14,27
638	Réunion	8,57	17,49
642	Romania	18,51	23,7
643	Russian Federation	3,62	3,3
646	Rwanda	89,24	86,66
654	Saint Helena	8,14	12,6

198 (0 out of 252 Selected)

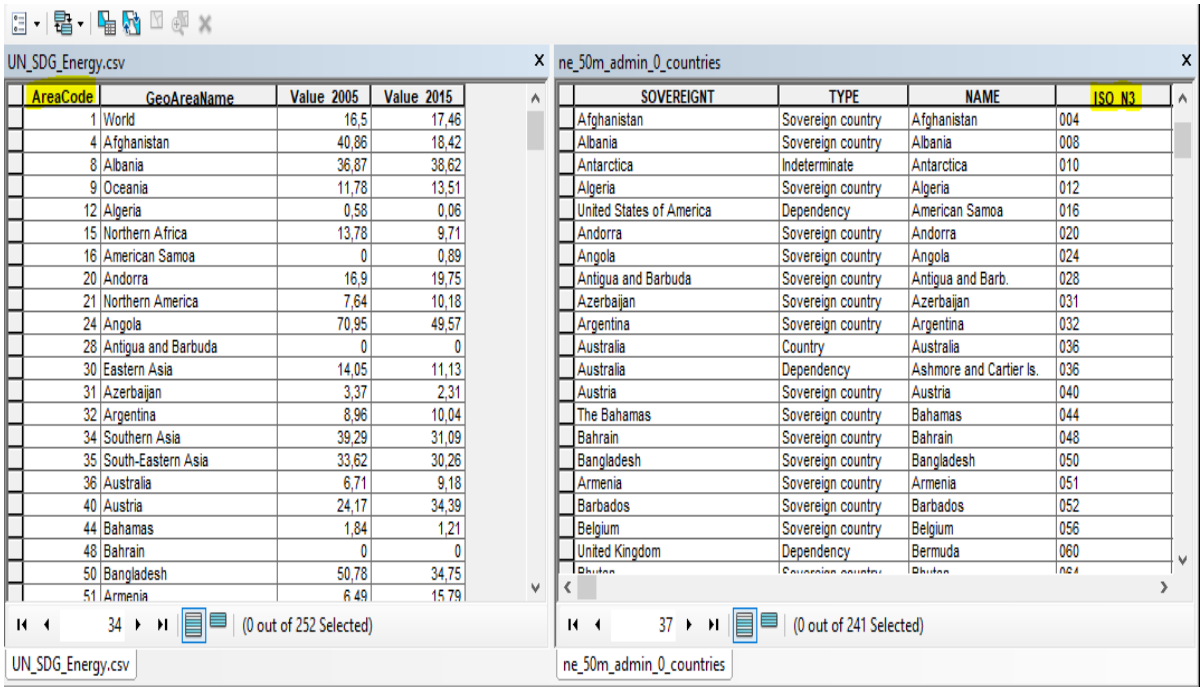
ne_50m_admin_0_countries

SOVEREIGNT	TYPE	ADMIN	ADM0_A3
Vanuatu	Sovereign country	Vanuatu	VUT
Uzbekistan	Sovereign country	Uzbekistan	UZB
Uruguay	Sovereign country	Uruguay	URY
Federated States of Micronesia	Sovereign country	Federated States of Micronesia	FSM
Marshall Islands	Sovereign country	Marshall Islands	MHL
United States of America	Dependency	Northern Mariana Islands	MNP
United States of America	Dependency	United States Virgin Islands	VIR
United States of America	Dependency	Guam	GUM
United States of America	Dependency	American Samoa	ASM
United States of America	Dependency	Puerto Rico	PRI
United States of America	Country	United States of America	USA
United Kingdom	Dependency	South Georgia and the Islands	SGS
United Kingdom	Dependency	British Indian Ocean Territory	IOT
United Kingdom	Dependency	Saint Helena	SHN
United Kingdom	Dependency	Pitcairn Islands	PCN
United Kingdom	Dependency	Anguilla	AIA

34 (0 out of 241 Selected)

Left: UN data, Right: Country borders

In the next step, the join of the two tables is prepared. To do this, a column must be found that is identical in both tables for each country and uniquely assigns a value to each country. The country name is only suitable to a limited extent, since the spelling for the countries in the data records is not uniform. For example: Viet Nam and Vietnam, Republic of Korea and South Korea etc. More suitable is the country code according to ISO 3166-1 given in both data sets. The matching column is called geoAreaCode in the UN data set and ISO_N3 in the data set of the country boundaries.



UN_SDG_Energy.csv

AreaCode	GeoAreaName	Value_2005	Value_2015
1	World	16,5	17,46
4	Afghanistan	40,86	18,42
8	Albania	36,87	38,62
9	Oceania	11,78	13,51
12	Algeria	0,58	0,06
15	Northern Africa	13,78	9,71
16	American Samoa	0	0,89
20	Andorra	16,9	19,75
21	Northern America	7,64	10,18
24	Angola	70,95	49,57
28	Antigua and Barbuda	0	0
30	Eastern Asia	14,05	11,13
31	Azerbaijan	3,37	2,31
32	Argentina	8,96	10,04
34	Southern Asia	39,29	31,09
35	South-Eastern Asia	33,62	30,26
36	Australia	6,71	9,18
40	Austria	24,17	34,39
44	Bahamas	1,84	1,21
48	Bahrain	0	0
50	Bangladesh	50,78	34,75
51	Armenia	6,49	15,79

34 (0 out of 252 Selected)

ne_50m_admin_0_countries

SOVEREIGNT	TYPE	NAME	ISO_N3
Afghanistan	Sovereign country	Afghanistan	004
Albania	Sovereign country	Albania	008
Antarctica	Indeterminate	Antarctica	010
Algeria	Sovereign country	Algeria	012
United States of America	Dependency	American Samoa	016
Andorra	Sovereign country	Andorra	020
Angola	Sovereign country	Angola	024
Antigua and Barbuda	Sovereign country	Antigua and Barb.	028
Azerbaijan	Sovereign country	Azerbaijan	031
Argentina	Sovereign country	Argentina	032
Australia	Country	Australia	036
Australia	Dependency	Ashmore and Cartier Is.	036
Austria	Sovereign country	Austria	040
The Bahamas	Sovereign country	Bahamas	044
Bahrain	Sovereign country	Bahrain	048
Bangladesh	Sovereign country	Bangladesh	050
Armenia	Sovereign country	Armenia	051
Barbados	Sovereign country	Barbados	052
Belgium	Sovereign country	Belgium	056
United Kingdom	Dependency	Bermuda	060

37 (0 out of 241 Selected)

Common key: right geoAreaCode, left ISO_N3

But even here there are still small discrepancies, so the codes were entered in the UN data set without and at the country borders with leading zeros (4 vs. 004). At this point, the two tables still have to be harmonized. The fastest way to do this is probably to delete the leading zero of the data set of the country borders (ne_50m_admin_0_countries) (to do this, open the table and click on the *Edit Mode button*). On this occasion you can also add the missing ISO codes for some countries (Norway: 578, Kosovo: 412).

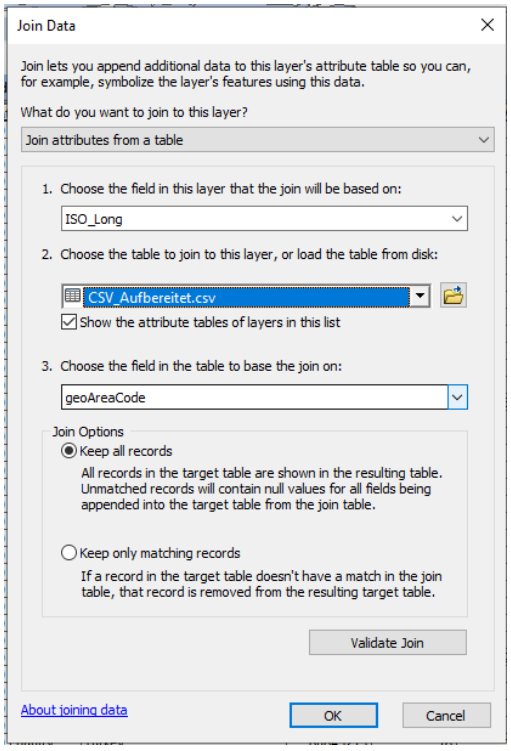
The next problem is that the country code column is created as a string for the country borders and as a long for the UN data, so the join does not yet work. To solve this problem, open the table of country borders and add a

column with data type *Long*. Right click on the new column => *Field Calculator* and enter *"New field" = [ISO_N3]*. The join can now be performed via this newly created field.

Joining two tables

The join is finally performed via Right click on Layer of country borders => *Joins and Relates* => *Join* with the following settings:

1. Select column with the country name of the country boundary data set.
2. Select the dataset which should be connected to the country boundary dataset.
3. Select column with country name of the UN dataset.
4. Keep all records to keep rows to which no values have been assigned.



Join process

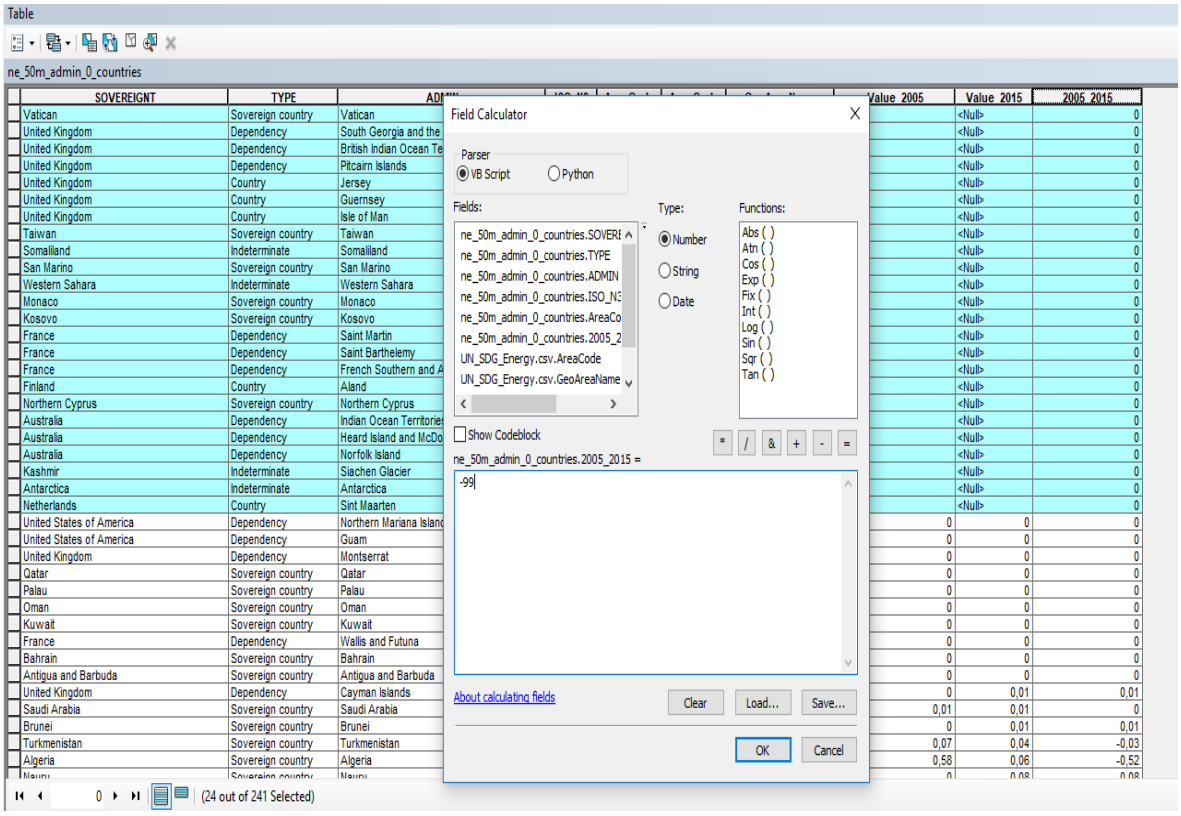
ne_50m_admin_0_countries

TYPE	ADMIN	ISO_N3	AreaCode	GeoAreaName	Value_2005	Value_2015
Sovereign country	São Tomé and Principe	678	678	Sao Tome and Principe	47,94	41,06
Sovereign country	San Marino	674	<Null>	<Null>	<Null>	<Null>
Sovereign country	Samoa	882	882	Samoa	45,13	34,32
Sovereign country	Saint Vincent and the Grenadines	670	670	Saint Vincent and the Grenadines	5,81	5,81
Sovereign country	Saint Lucia	662	662	Saint Lucia	2,5	2,13
Sovereign country	Saint Kitts and Nevis	659	659	Saint Kitts and Nevis	25,58	1,64
Sovereign country	Rwanda	646	646	Rwanda	89,24	86,66
Sovereign country	Russia	643	643	Russian Federation	3,62	3,3
Sovereign country	Romania	642	642	Romania	18,51	23,7
Sovereign country	Qatar	634	634	Qatar	0	0
Sovereign country	Portugal	620	620	Portugal	18,07	27,16
Sovereign country	Poland	616	616	Poland	7,21	11,91
Sovereign country	Philippines	608	608	Philippines	31,43	27,45
Sovereign country	Peru	604	604	Peru	32,73	25,5
Sovereign country	Paraguay	600	600	Paraguay	68,82	61,68
Sovereign country	Papua New Guinea	598	598	Papua New Guinea	58,56	52,5
Sovereign country	Panama	591	591	Panama	27,04	21,23
Sovereign country	Palau	585	585	Palau	0	0
Sovereign country	Pakistan	586	586	Pakistan	47,52	46,48
Sovereign country	Oman	512	512	Oman	0	0

Join result

The next step is to tackle the actual goal of presenting the trend in renewable energies from 2005 to 2015. To do this, you have to create a new field in the table in which the difference is to be stored. Open the table of the *Shapefile Layer* => *Table Options* => *Add Field*. Then choose a meaningful and short name for the difference (e.g. 2000_2016) and set the data type as Double, with precision 8 and scale 2. Right click on the new field => *Field Calculator*. In the Field Calculator, subtract the values for the year 2000 from the values for 2016.

Before we go to the visualization, let's take a closer look at the data. You can see that some countries have a <NULL> value. In contrast to the number 0, this indicates that no values are available here (in contrast to Palau, for example, which had a 0% share of renewable energies in 2000 and 0% in 2016 and consequently also had 0 percentage points growth). The <NULL> values were calculated in the Field Calculator as the number 0 and would therefore also be visualised and thus falsify the information content. Therefore you need to edit the table again (*Editor* => *Start Editing*). Arrange the data according to the 2000_2016 column (double-click on column header). Change the difference 2000_2016 of all zero-value lines by marking them with the *CTRL key* pressed and entering a unique value here via the calculator (Field Calculator), which otherwise does not appear in the data (e.g. -99). This value can then also be displayed separately in the visualization.



ne_50m_admin_0_countries

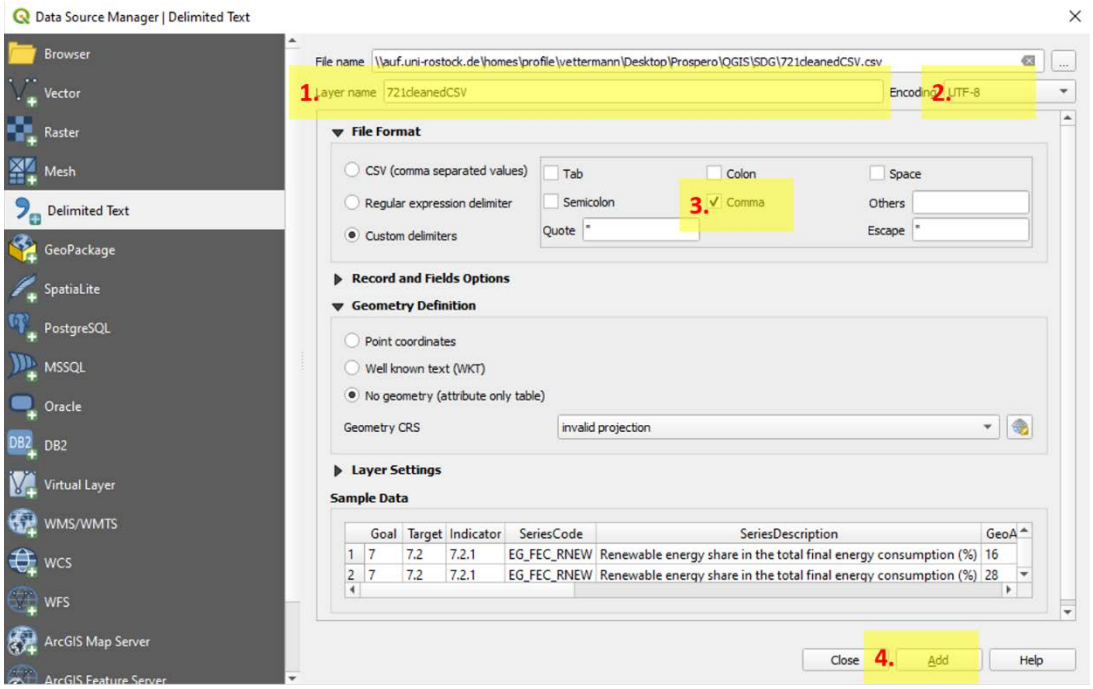
SOVEREIGNT	TYPE	ADMIN	ISO_N3	AreaCode	AreaCode	GeoAreaName	Value_2005	Value_2015	2005_2015
France	Dependency	French Southern and Antarctic Lands	260	260	<Null>	<Null>	<Null>	<Null>	-99
Finland	Country	Aland	248	248	<Null>	<Null>	<Null>	<Null>	-99
Northern Cyprus	Sovereign country	Northern Cyprus	-99	-99	<Null>	<Null>	<Null>	<Null>	-99
Australia	Dependency	Indian Ocean Territories	-99	-99	<Null>	<Null>	<Null>	<Null>	-99
Australia	Dependency	Heard Island and McDonald Islands	334	334	<Null>	<Null>	<Null>	<Null>	-99
Australia	Dependency	Norfolk Island	574	574	<Null>	<Null>	<Null>	<Null>	-99
Kashmir	Indeterminate	Siachen Glacier	-99	-99	<Null>	<Null>	<Null>	<Null>	-99
Antarctica	Indeterminate	Antarctica	10	10	<Null>	<Null>	<Null>	<Null>	-99
Netherlands	Country	Sint Maarten	534	534	<Null>	<Null>	<Null>	<Null>	-99
United States of America	Dependency	Northern Mariana Islands	580	580	580	Northern Mariana Island	0	0	0
United States of America	Dependency	Guam	316	316	316	Guam	0	0	0
United Kingdom	Dependency	Montserrat	500	500	500	Montserrat	0	0	0
Qatar	Sovereign country	Qatar	634	634	634	Qatar	0	0	0
Palau	Sovereign country	Palau	585	585	585	Palau	0	0	0
Oman	Sovereign country	Oman	512	512	512	Oman	0	0	0
Kuwait	Sovereign country	Kuwait	414	414	414	Kuwait	0	0	0
France	Dependency	Wallis and Futuna	876	876	876	Wallis and Futuna Islan	0	0	0
Bahrain	Sovereign country	Bahrain	48	48	48	Bahrain	0	0	0
Antigua and Barbuda	Sovereign country	Antigua and Barbuda	28	28	28	Antigua and Barbuda	0	0	0
United Kingdom	Dependency	Cayman Islands	136	136	136	Cayman Islands	0	0,01	0,01
Saudi Arabia	Sovereign country	Saudi Arabia	682	682	682	Saudi Arabia	0,01	0,01	0
Brunei	Sovereign country	Brunei	96	96	96	Brunei Darussalam	0	0,01	0,01
Turkmenistan	Sovereign country	Turkmenistan	795	795	795	Turkmenistan	0,07	0,04	-0,03
Algeria	Sovereign country	Algeria	12	12	12	Algeria	0,58	0,06	-0,52
Nauru	Sovereign country	Nauru	520	520	520	Nauru	0	0,08	0,08
United Kingdom	Dependency	Anguilla	660	660	660	Anguilla	0,14	0,11	-0,03
United Arab Emirates	Sovereign country	United Arab Emirates	784	784	784	United Arab Emirates	0,11	0,14	0,03
Trinidad and Tobago	Sovereign country	Trinidad and Tobago	780	780	780	Trinidad and Tobago	0,53	0,28	-0,25
Netherlands	Country	Curaçao	531	531	531	Curaçao	0,26	0,35	0,09
Syria	Sovereign country	Syria	760	760	760	Syrian Arab Republic	2,11	0,52	-1,59
United Kingdom	Dependency	Turks and Caicos Islands	796	796	796	Turks and Caicos Islan	0,54	0,57	0,03
Singapore	Sovereign country	Singapore	702	702	702	Singapore	0,54	0,71	0,17
Iraq	Sovereign country	Iraq	368	368	368	Iraq	2,3	0,8	-1,5

Replace NULL values with -99

with QGIS

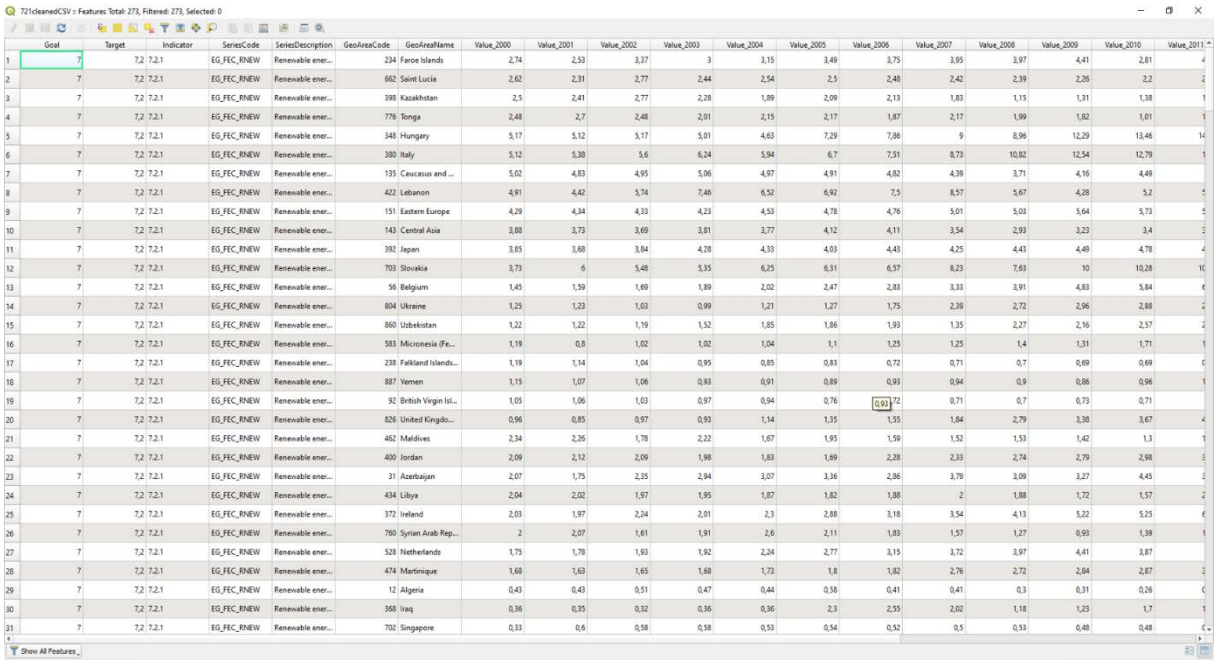
Import data

The next step is to add the UN dataset. You can do this via *Layer => Add Layer => Add Delimited Text Layer.* The new table is shown in the QGIS layer manager.



Add table in QGIS

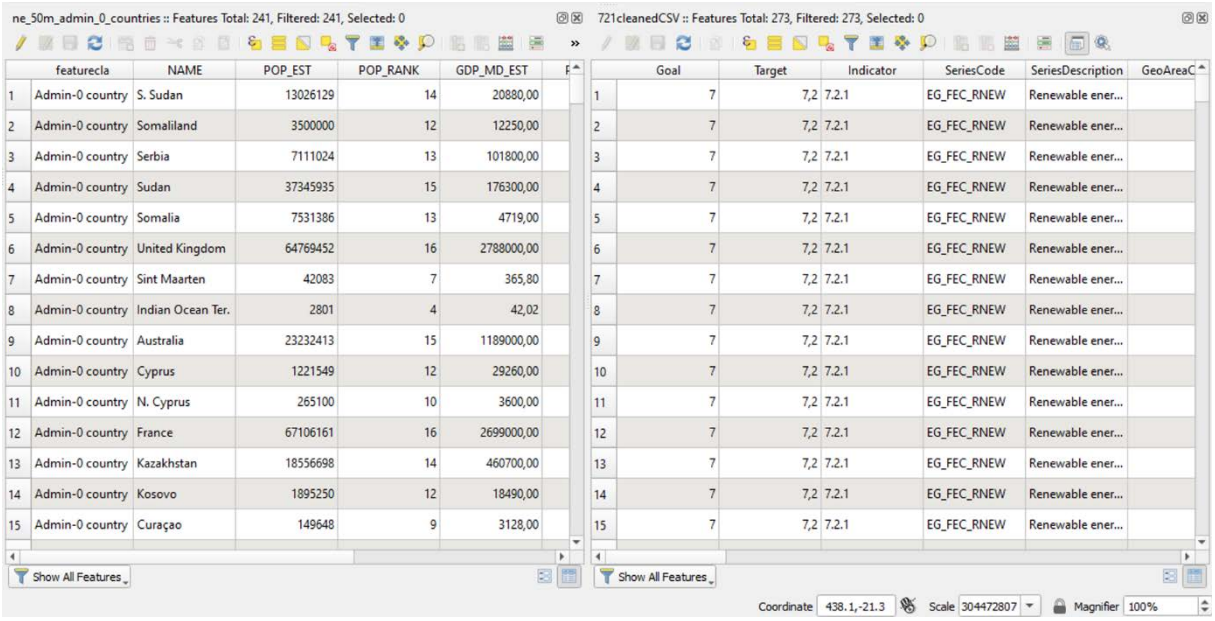
Click now with a right click at the table and select *Open*. The result should look like the following:



UN-SDG table

Data preparation

To view the UN SDG table as well as the attribute table from the countries, you can move them next to each other with *dock attribute table*.

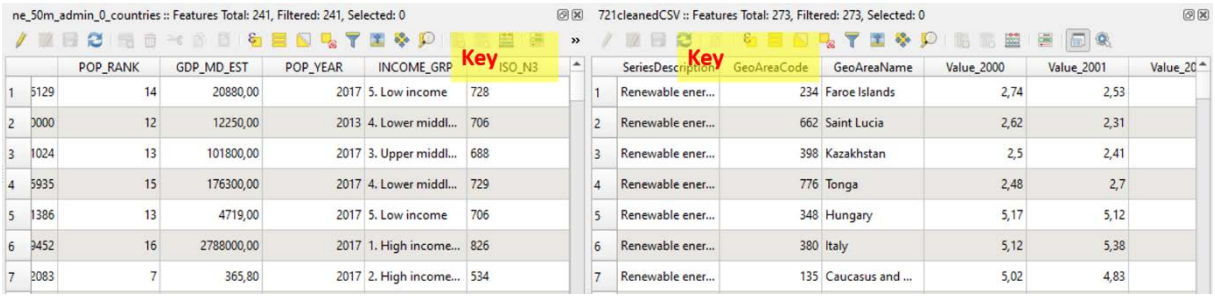


	featurecla	NAME	POP_EST	POP_RANK	GDP_MD_EST
1	Admin-0 country	S. Sudan	13026129	14	20880,00
2	Admin-0 country	Somaliland	3500000	12	12250,00
3	Admin-0 country	Serbia	7111024	13	101800,00
4	Admin-0 country	Sudan	37345935	15	176300,00
5	Admin-0 country	Somalia	7531386	13	4719,00
6	Admin-0 country	United Kingdom	64769452	16	2788000,00
7	Admin-0 country	Sint Maarten	42083	7	365,80
8	Admin-0 country	Indian Ocean Ter.	2801	4	42,02
9	Admin-0 country	Australia	23232413	15	1189000,00
10	Admin-0 country	Cyprus	1221549	12	29260,00
11	Admin-0 country	N. Cyprus	265100	10	3600,00
12	Admin-0 country	France	67106161	16	2699000,00
13	Admin-0 country	Kazakhstan	18556698	14	460700,00
14	Admin-0 country	Kosovo	1895250	12	18490,00
15	Admin-0 country	Curaçao	149648	9	3128,00

	Goal	Target	Indicator	SeriesCode	SeriesDescription	GeoAreaC
1	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
2	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
3	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
4	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
5	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
6	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
7	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
8	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
9	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
10	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
11	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
12	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
13	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
14	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	
15	7	7,2	7.2.1	EG_FEC_RNEW	Renewable ener...	

Docked attribute tables (left: country borders, right: UN data)

The next step is to prepare the join of the two tables. Therefore, you have to find a column with identical values for each of the countries. The names are not so well suited in this case, because they are written in a different manner (Viet Nam and Vietnam). To avoid this, the column with the ISO 3166-1 values is ideal. The column is named geoAreaCode (UN dataset) and ISO_N3 (countries).



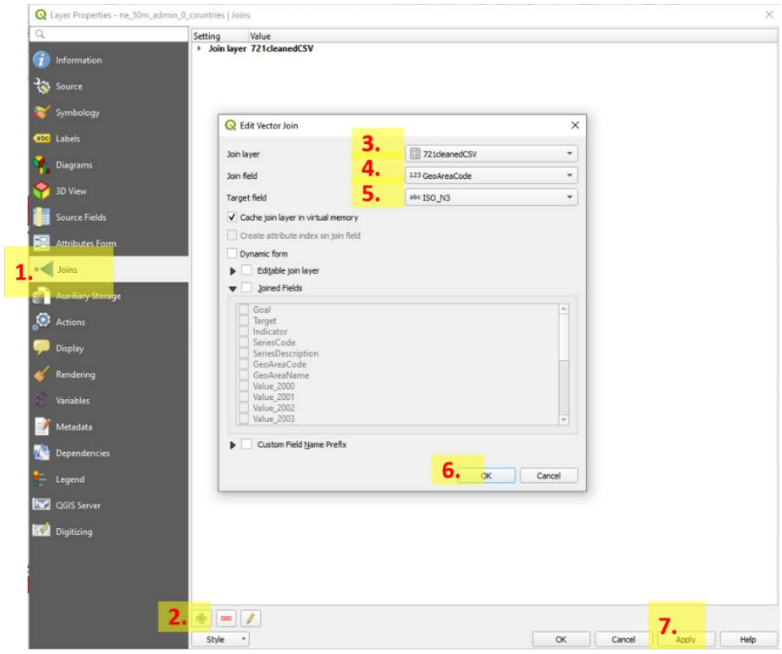
	POP_RANK	GDP_MD_EST	POP_YEAR	INCOME_GRP	ISO_N3
1	5129	14	20880,00	2017	5. Low income	728
2	0000	12	12250,00	2013	4. Lower middl...	706
3	1024	13	101800,00	2017	3. Upper middl...	688
4	5935	15	176300,00	2017	4. Lower middl...	729
5	1386	13	4719,00	2017	5. Low income	706
6	9452	16	2788000,00	2017	1. High income...	826
7	2083	7	365,80	2017	2. High income...	534

	SeriesDescription	GeoAreaCode	GeoAreaName	Value_2000	Value_2001	Value_20
1	Renewable ener...	234	Faroe Islands	2,74	2,53	
2	Renewable ener...	662	Saint Lucia	2,62	2,31	
3	Renewable ener...	398	Kazakhstan	2,5	2,41	
4	Renewable ener...	776	Tonga	2,48	2,7	
5	Renewable ener...	348	Hungary	5,17	5,12	
6	Renewable ener...	380	Italy	5,12	5,38	
7	Renewable ener...	135	Caucasus and ...	5,02	4,83	

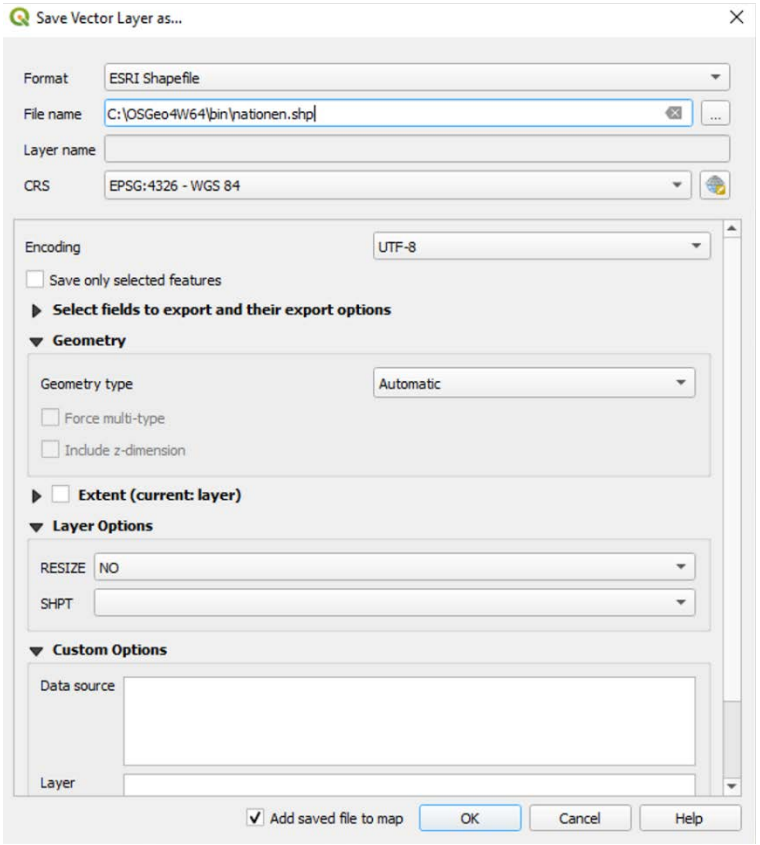
Common key: right geoAreaCode, left ISO_N3_L

Joining two tables

It is important to know that the code is formatted in a different datatype (Long vs String). But in comparison to ArcGIS, this is no problem in QGIS. You are able to join datasets also with a different datatype. To do so, you have to click with the right mouse button on the countries layer and select *Properties* => *Joins (1.)* => *+-Symbol (2.).* Then select the SDG dataset (3.), the join column (GeoAreaCode; 4.) and the right column from the countries (ISO_N3; 5.). After this click *OK* (6.) and apply (7.) the join.



Join

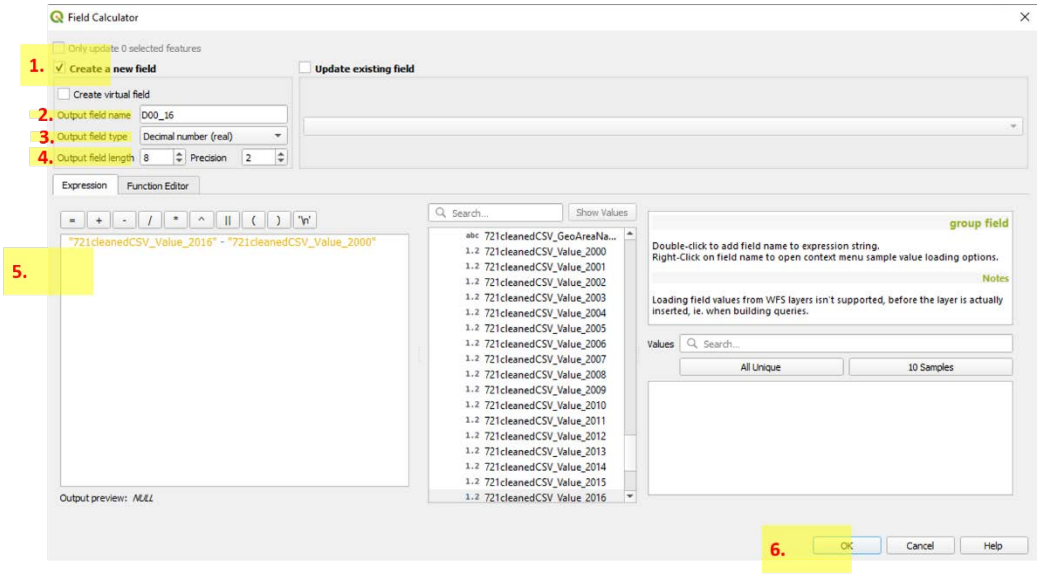


Make the join permanent

If you sort the resulting table the value_2000 field ascending, you can see that some fields are filled with <NULL>. These are the countries without any data.

Now we are creating a copy of the countries dataset to make the join permanent. To do so, right click on the layer, *Export => Save features as.* The name of the dataset should be “nations”. After the export, our copied layer is also visible in the layer manager.

Now we are able to calculate trends in the usage of renewable energy in the timeframe from 2000 to 2016. Therefore, we have to add a new field where the difference is calculated. First open the attribute table of our new nations layer and click *deselect all*. Then open the field calculator, insert a short name for the new field (D00_16), set decimal number (real) as datatype with precision 8 and scale 2. Now you can substract the values of 2000 from the values of 2016.



Calculate the difference

If you sort the new column ascending, the differences in the development of renewable energy get visible. Equatorial Guinea has in 2016 37% less, Liechtenstein 63% more energy share from renewable ressources. Many countries don’t have any big differences. We make a short discussion of the data later on.

Visualization

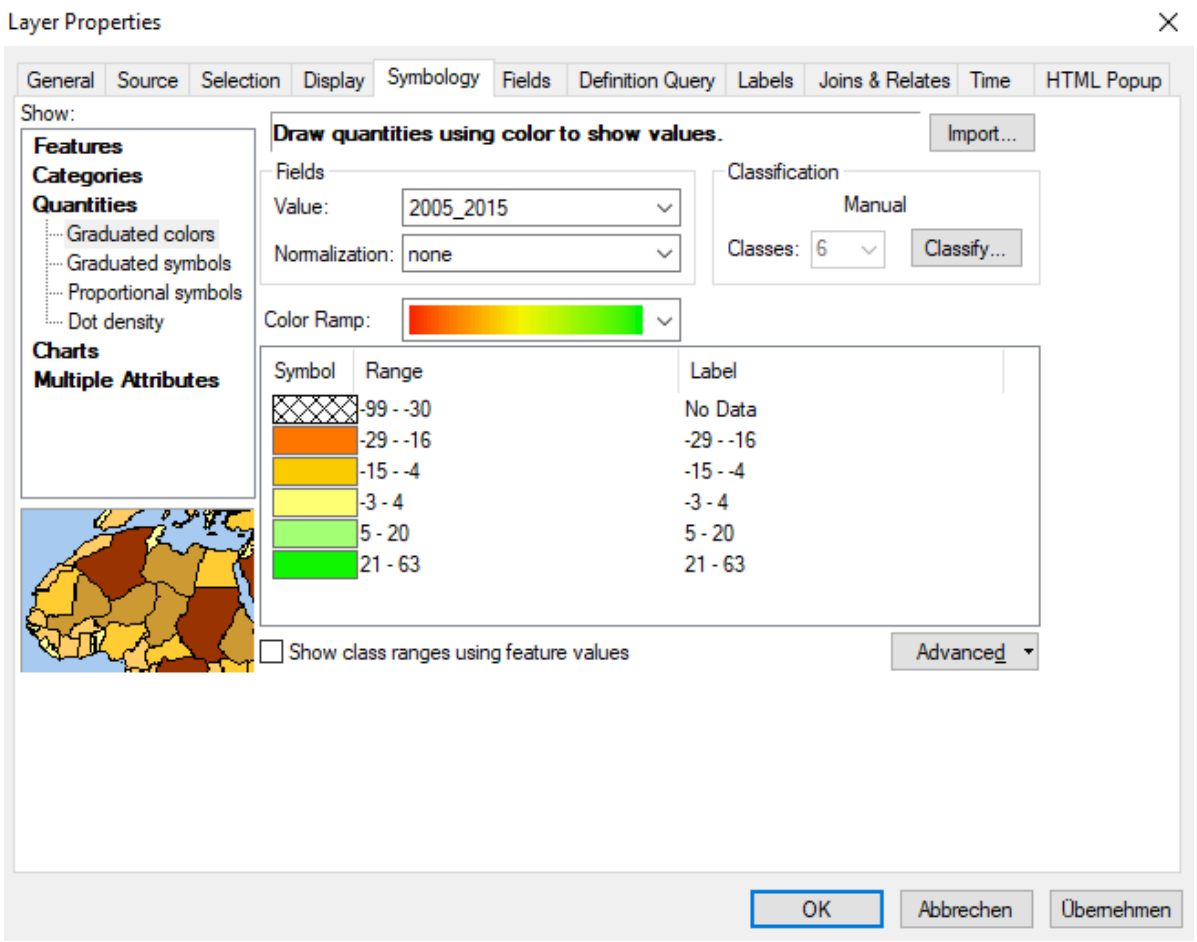
To create an attractive printable map for your final report that follows the rules of cartography, it is advisable to consult the tutorial on cartography[13] with common statements on maps. If you are not yet familiar with creating thematic maps, please read our tutorial on map design[14].

Again we will show you a solution with ArcGIS and one with QGIS.

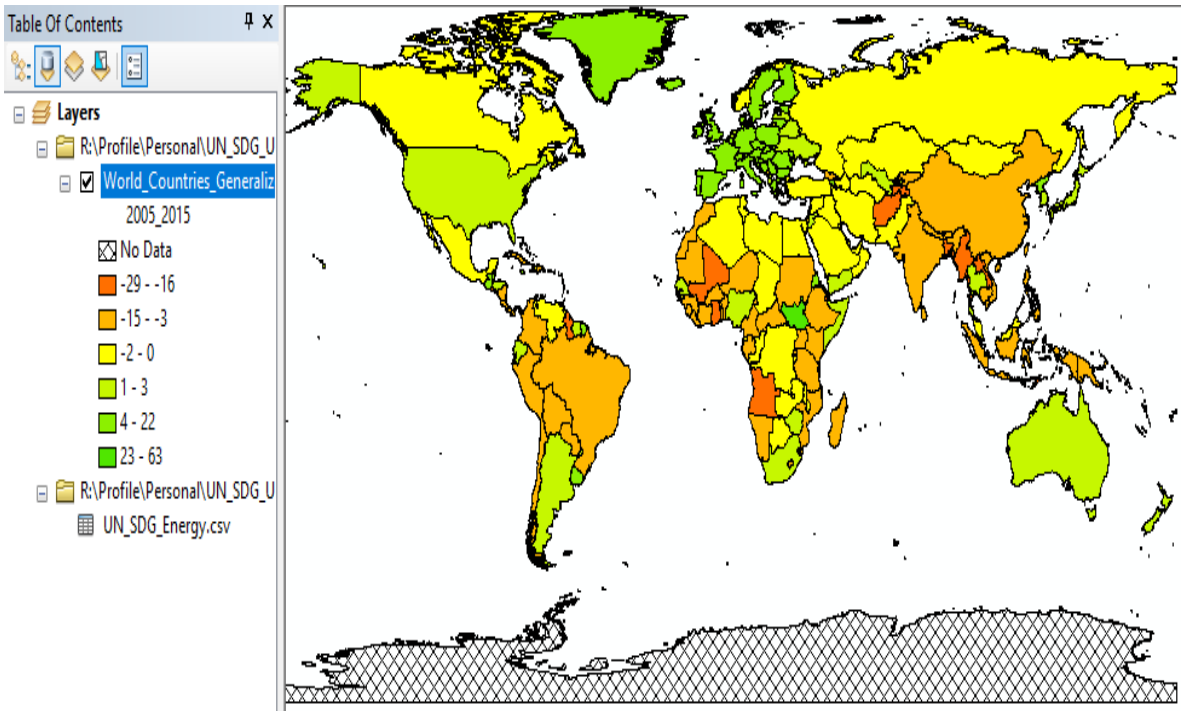
with ArcMap

The layer can now be categorized and colored again in symbology according to a meaningful scheme. For this we select a quantitative highlighting under *Properties* (*Symbology => Quantities => Graduated Colors*), take e.g. 6 classes (plus one class for the former <NULL>-values) and select a traffic light coloring for the representation. Red should represent a decrease, green an increase of renewable energies.

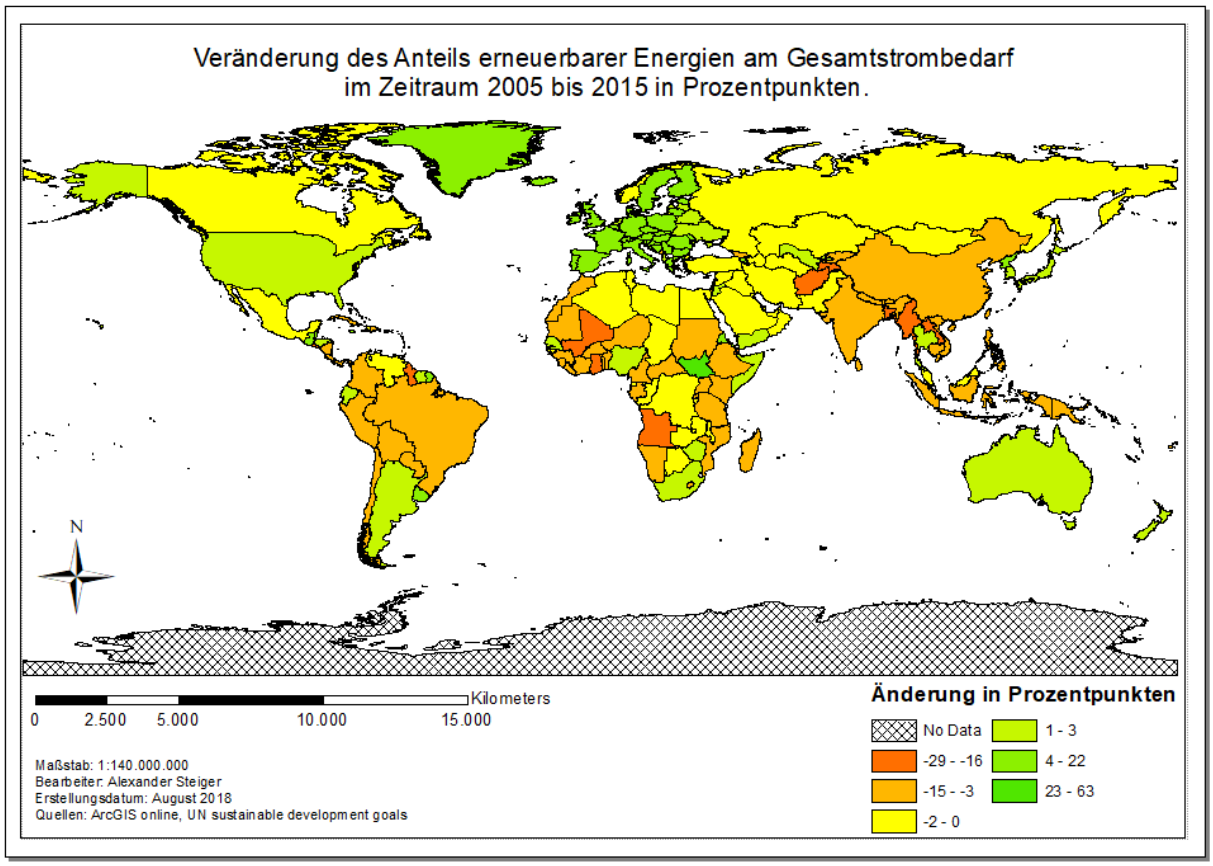
[13] https://learn.opengeoedu.de/tutorials#tutorial-kartographie
[14] https://learn.opengeoedu.de/tutorials/OGE-Tutorial_Kartengestaltung-en.pdf



Color coding



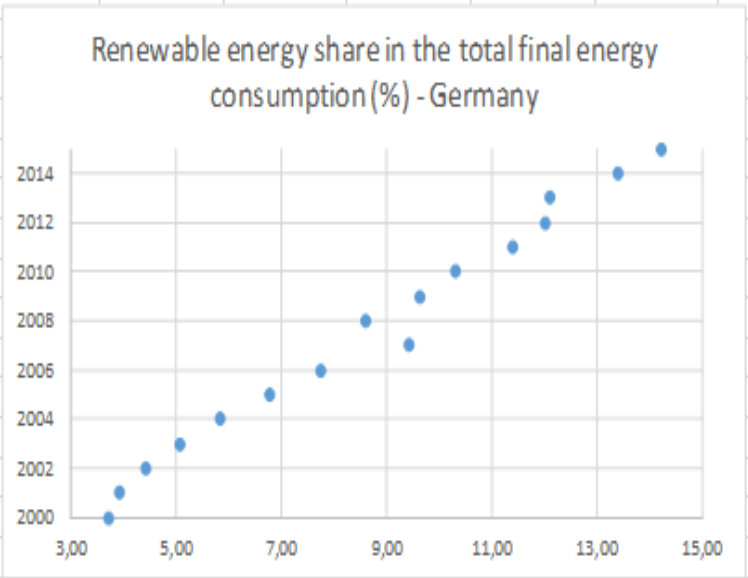
Visualization by countries



Map layout

To create a diagram for the development of renewable energies over time, select a country, copy the EG_FEC_RNEW value for the last 16 years and display it in a diagram (here with Excel) The result for Germany then looks something like this: A clear increase in renewable energies over the last 15 years.

Value	Year
3,70	2000
3,90	2001
4,41	2002
5,06	2003
5,83	2004
6,76	2005
7,75	2006
9,41	2007
8,59	2008
9,63	2009
10,29	2010
11,39	2011
12,02	2012
12,09	2013
13,38	2014
14,21	2015



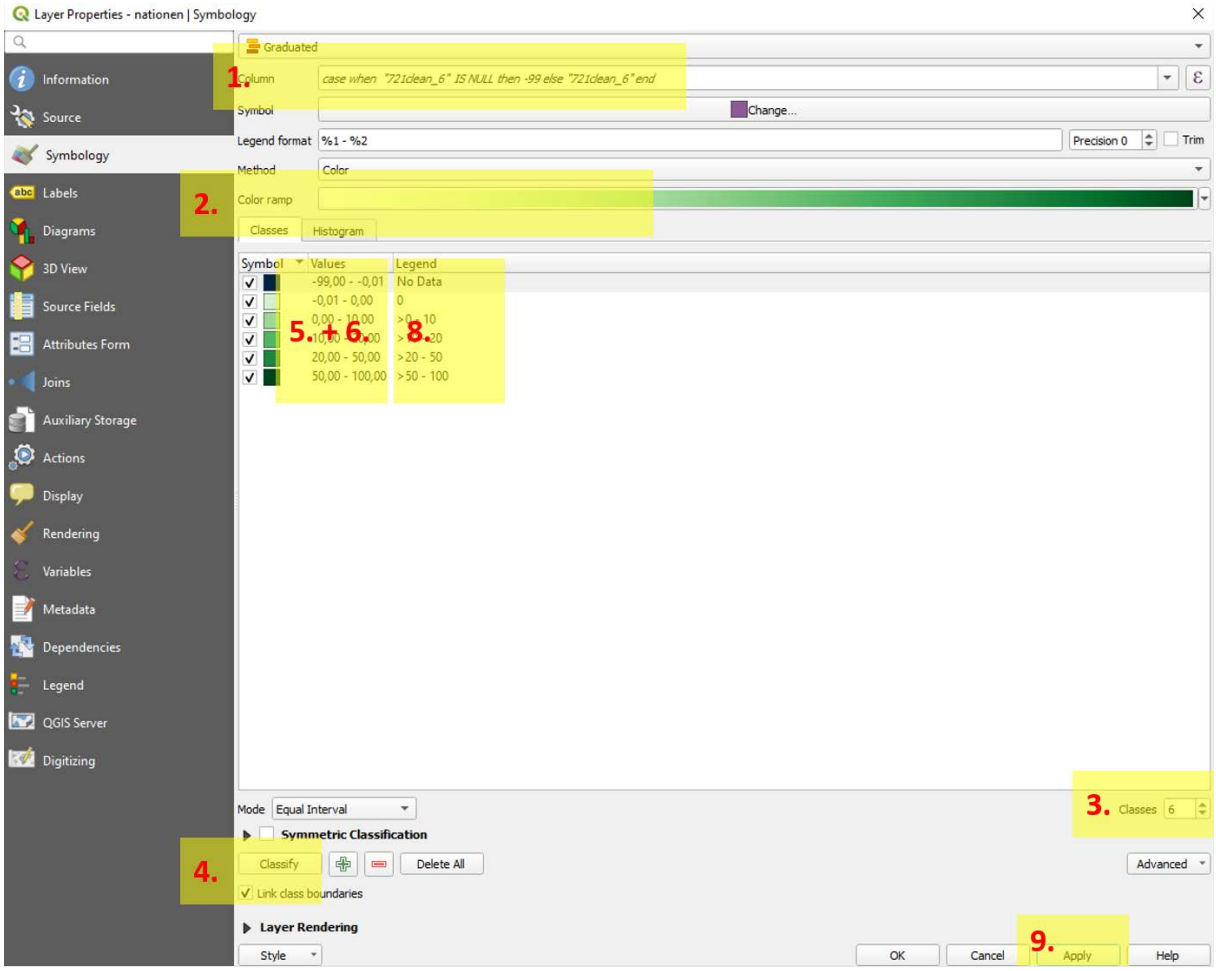
Time serie as chart

with QGIS

The layer can now be categorized and colored using the style management (*Layer Properties => Style*) according to a meaningful scheme. For this we select a quantitative highlighting under Properties (*Symbology => Quantities -= Graduated Colors*), take e.g. 5 classes (plus one class for the NULL values) and select a traffic light coloring for the representation. Red should represent a decrease, green an increase of renewable energies. The class boundaries as well as the entries for the legend can be changed manually by double-clicking on the respective values.

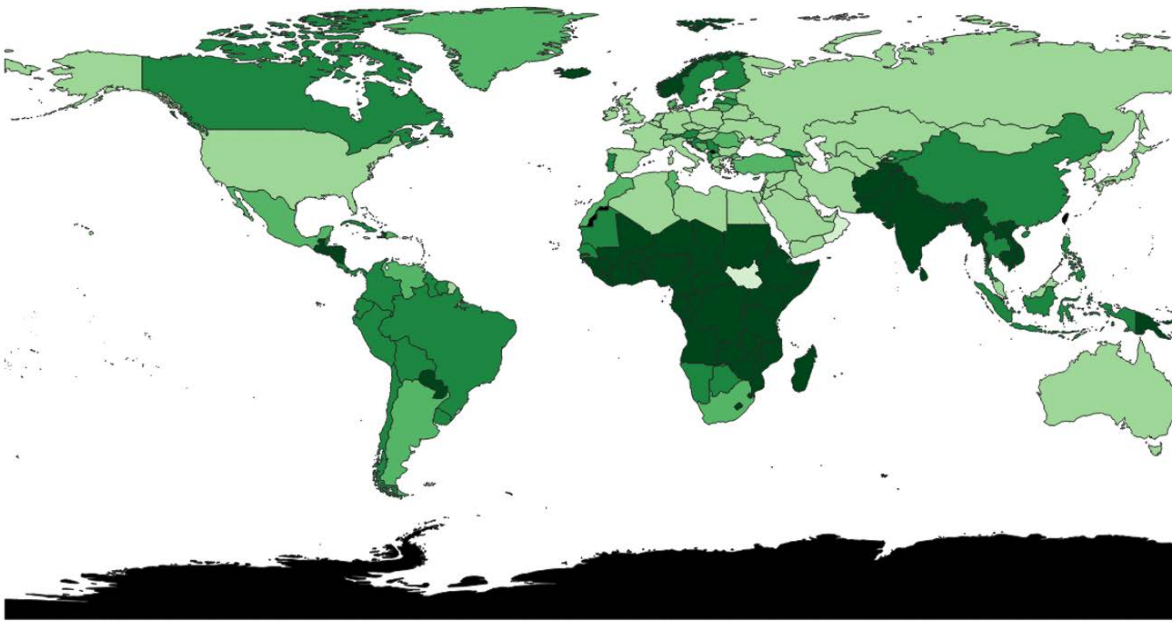
This will be demonstrated step by step using the year 2000. For the symbolisation, the column Value_2000 is selected using an expression (*case when "721clean_6" IS NULL then -99 else "721clean_6" end*) (1.). The expression sets all <NULL> values as -99 and thus recognizes them as data gaps.

They are then classified as a green gradient (2.) in 6 classes (3.) (4.). The class limits are defined manually (5.) by entering values (6.) (7.). The labels are adjusted (8.) and finally the selected setting is executed (9).



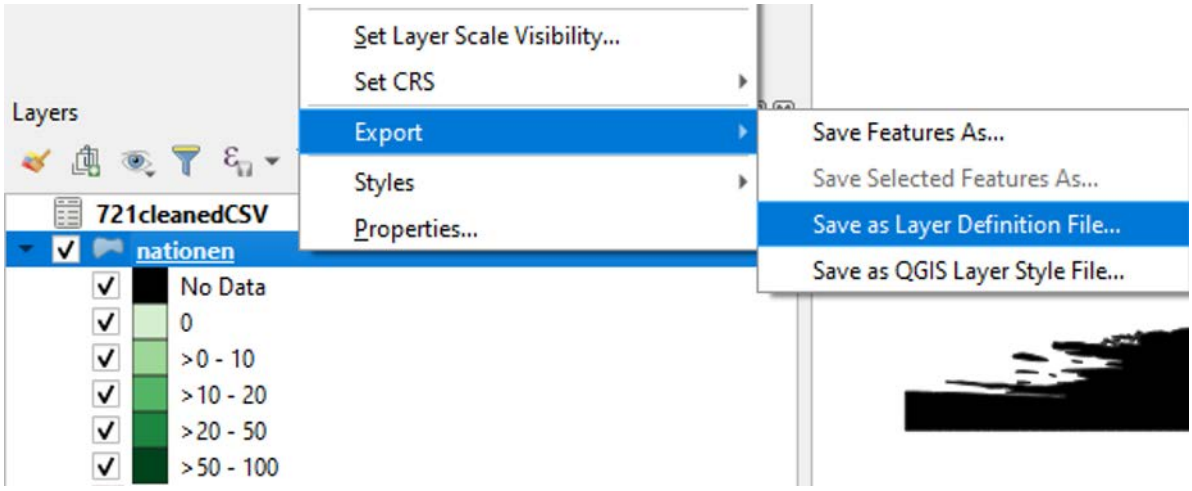
Color settings Value_2000

The result is the following view for the year 2000, in which on the one hand the countries without data (in black, from Antarctica to Taiwan) are well recognizable. On the other hand, the proportion of renewable energy used in 2000 can be differentiated to some extent on the basis of green tones.



View Value_2000

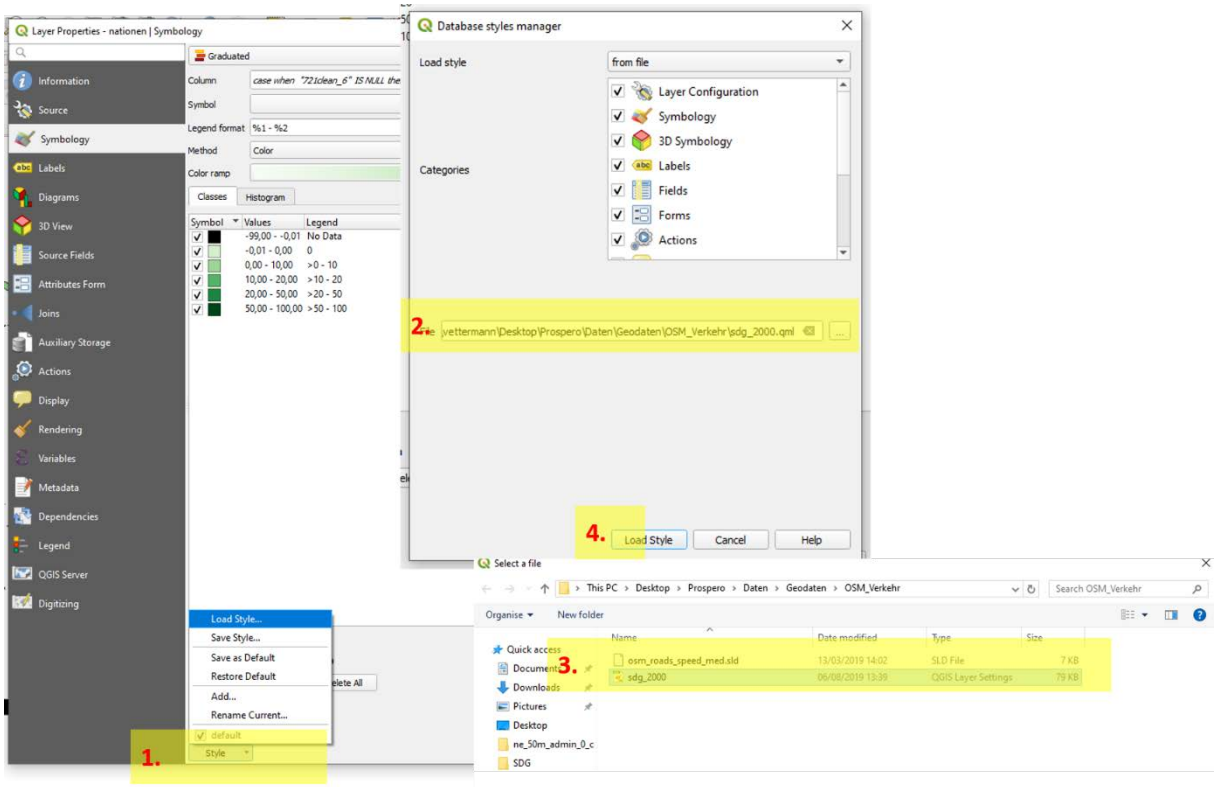
We save the selected color scheme by right-clicking on *Nations => Export => Save as QGIS Layer Style File* in the editing folder.



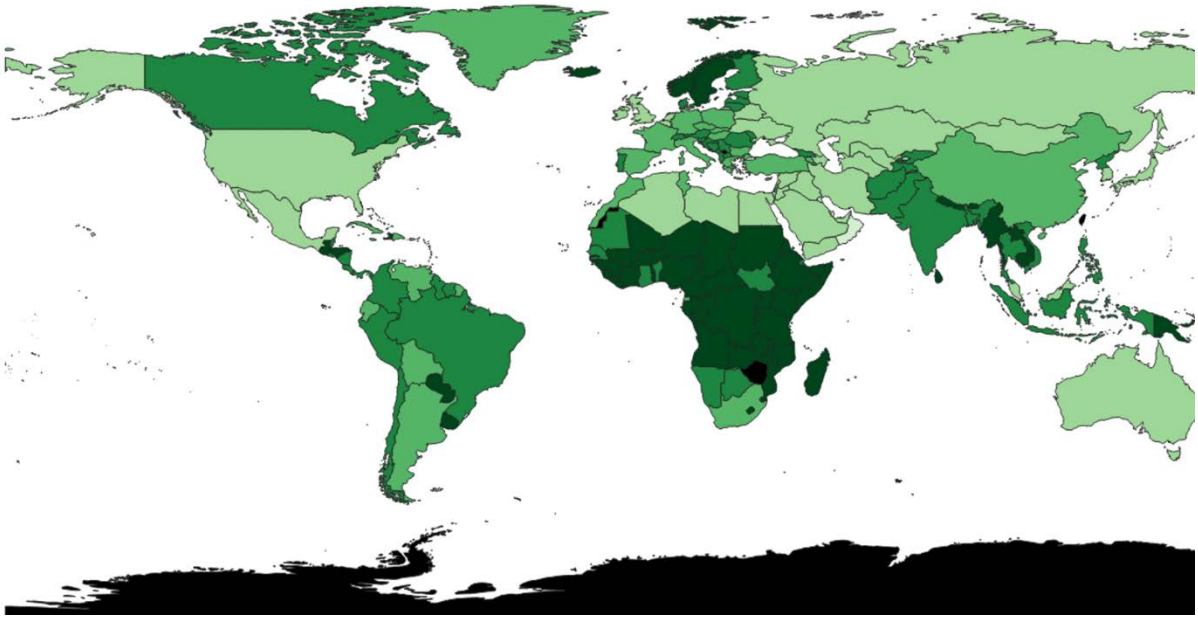
Save color settings

We then proceed in the same way for the values of 2016. However, in QGIS it is not possible to load the representation directly in the concrete case, since the select statement must be adapted accordingly (*case when "721clean22" IS NULL then -99 else "721clean22" end*).

In this case the classes are reset again. Consequently they have to be adjusted manually again. Nevertheless, styles can also be loaded and applied.



Apply color settings for other data set

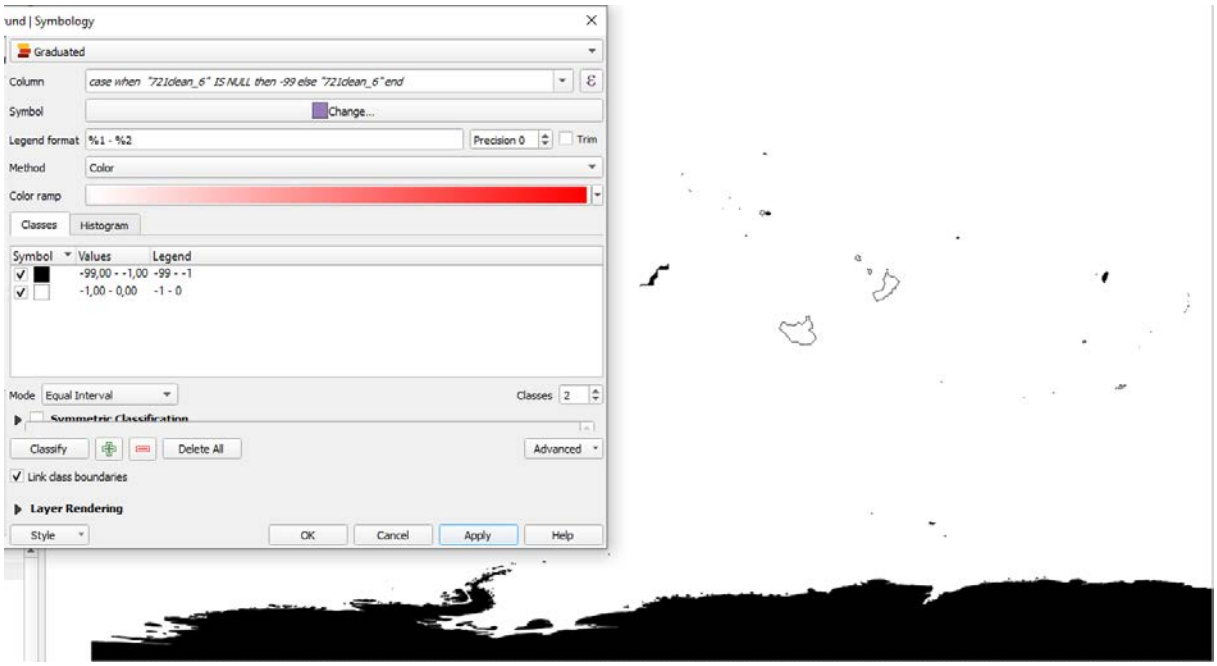


View Value_2016

In the year 2016, the darker shades of green in Europe in particular will indicate the higher use of renewable energies.

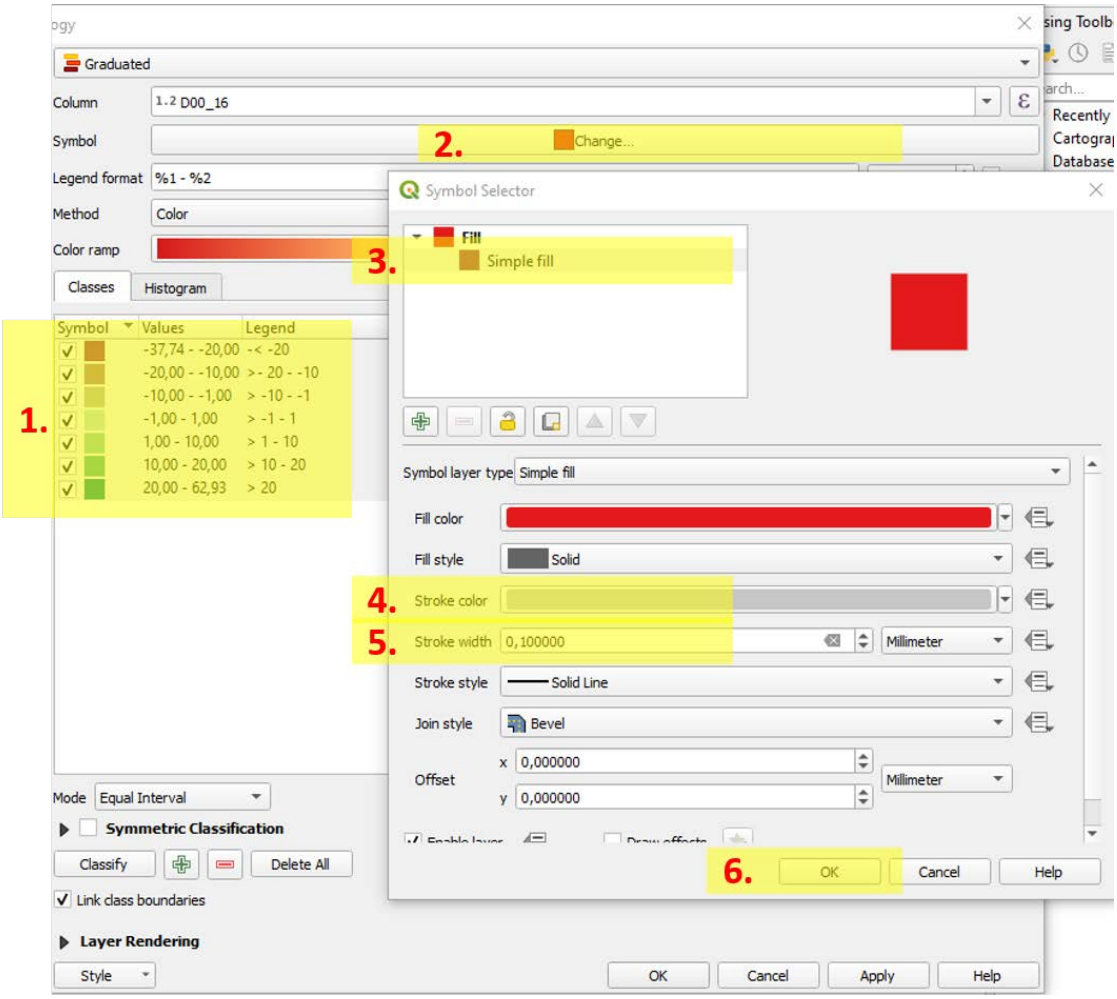
In order to emphasize this difference visually, we create a visualization in traffic light colors. Red should represent a decrease, green an increase of renewable energies. Since the difference between the countries without data would be 0 and therefore not distinguishable from countries with data that have not changed, we use a trick. We create a new copy of the shape file (see above) of the nation dataset, named NationBackground.shp. Now we color it so that all countries with -99 are colored black and all other countries are transparent. Now you can see the

Antarctica and other countries without data in black and unfilled countries like South Sudan or Oman, which have provided data only in the course of time.

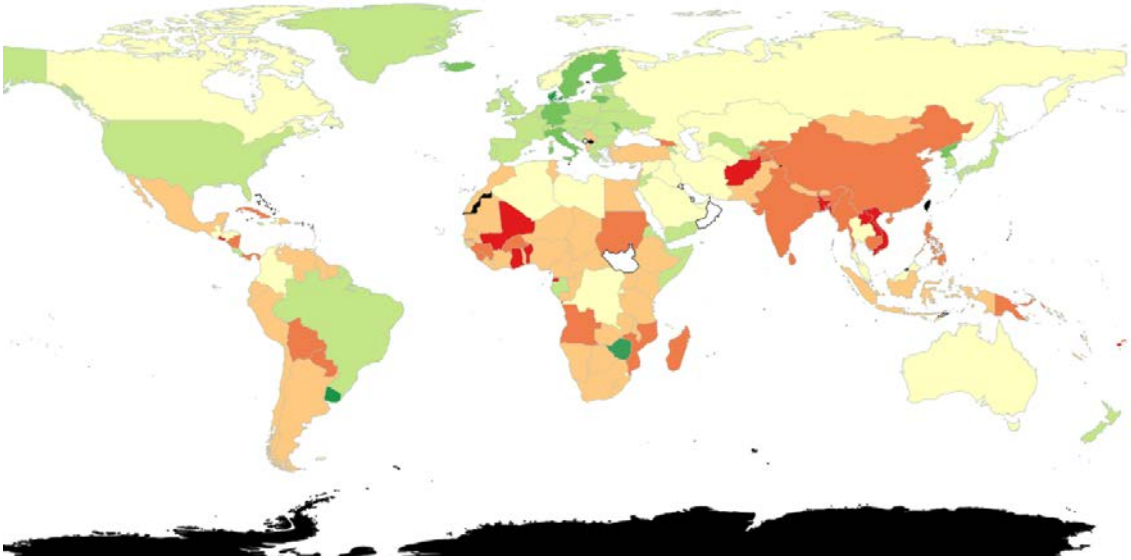


Background map

Now we go analogous to the single years to the coloring of the difference data and evaluate the field D00_16. The sequence corresponds to the previous one, only a color gradation from red to green in 7 classes is selected, the limits are set manually [<-20, -10, -1, 1, 10, 20, > 20]. It is essential that the borders of the fields are narrower and grayed out. To do this, all classes are marked and the border line is edited using the button *Symbol*. In addition, a meaningful description of the classes is necessary.



Edit colors settings



Difference 2016 to 2000 for all countries

The last step is to create a thematic map with QGIS. For a better understanding, you can read the online tutorials about Cartography and Thematic Mapping.

Thematic map production

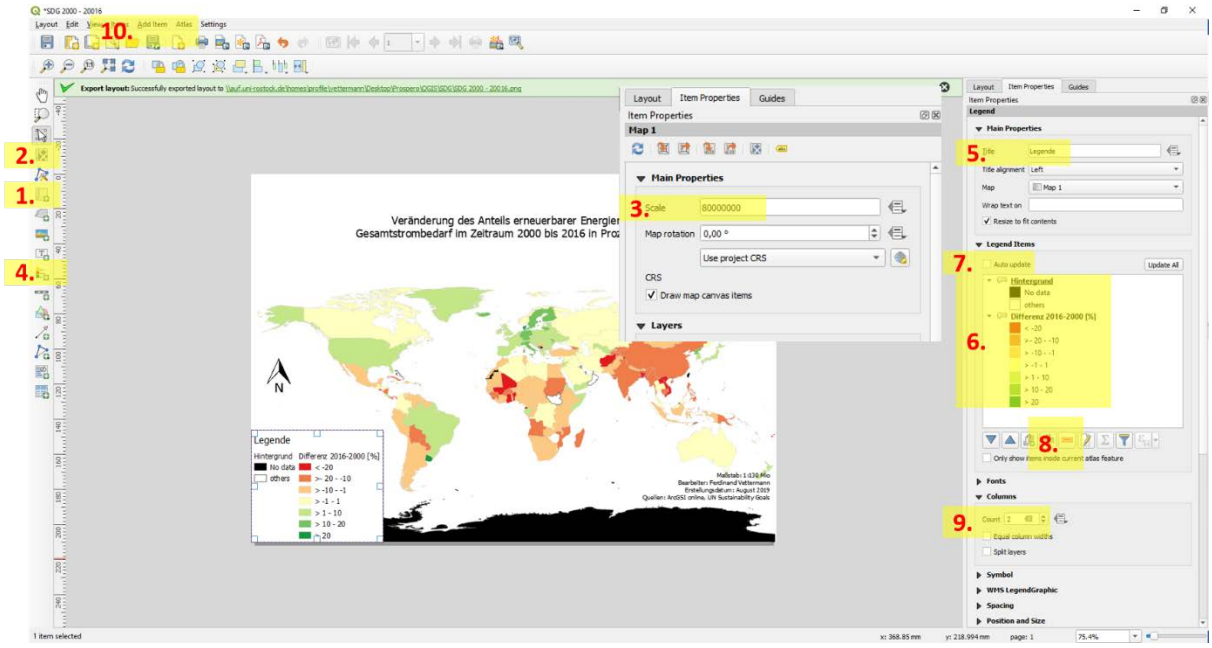
In order to create a sophisticated thematic map, a great deal of processing is usually required after the analysis in order to meet the demands of thematic cartography. We refer here again to the cartographic literature and our online tutorials on cartography and thematic cartography.

In QGIS, thematic maps are created using the print layout. This can be found under => Project => New print layout. We give the layout the name "SDG 2000 - 2016". Then the area for the map is drawn using the button Add new map to layout (1.). By clicking on Move content the map can now be moved to the desired position (2.). In the area Scale on the right side we enter 80.000.000, which corresponds to a scale of 1: 80.000.000, so that the map can be displayed full page (3.).

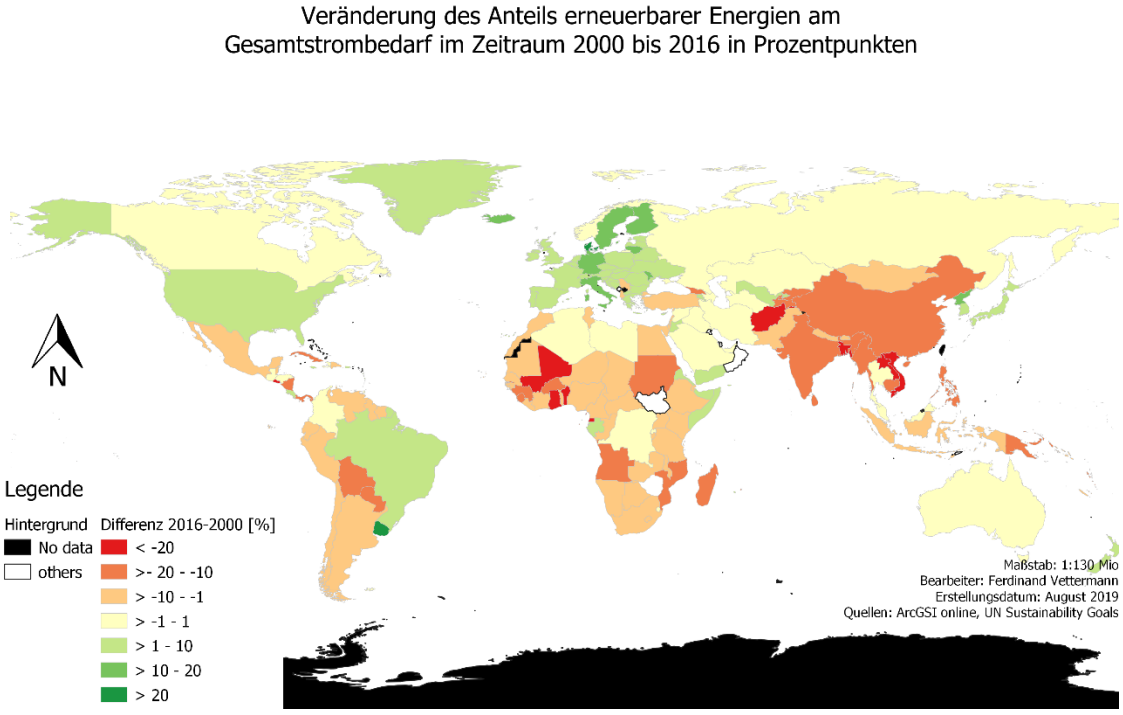
A legend window is then added (4.). On the right an area with the legends appears. The heading "Legend" can be assigned to the legend here (5.). Here you can rename the individual fields accordingly (6.). It is important that Automatic update is deactivated (7.). Furthermore, unneeded elements, such as the original data table, can be deleted using the minus button (8.). To display the legend in two columns, we increase the number of columns in the "Columns" area (9.).

Now we add the necessary map elements like title, scale bar (with kilometre indication), author, sources etc. via the Add element in the menu bar and get a quite acceptable map design (10.). A special feature is that the north arrow must be inserted as an image in QGIS.

Note: A scale bar cannot be added in QGIS for world maps because of their projection properties. You are only able to add a scale bar for maps with an aquidistant projection. In this case, the values of the scale bar screwed up so we don't draw it on the map.



QGIS print layout



Final map

Evaluation and visualization of time series

with Excel or LibreCalc

Now we return to the Excel or Libre Calc evaluation in order to analyse selected statistical measures as well as the temporal progressions. First we create a copy of the prepared data set, e.g. as a second table in the Excel file.

Measurements

First we eliminate all countries without data (-99) by sorting Value_2000 in ascending order and then manually deleting the rows with -99 completely (from the Aland Islands to Western Sahara). At the end of the table we add three new lines with the respective entries "Minimum worldwide", "Average worldwide" and "Maximum worldwide" to the place of the country names. We then calculate the values for Value_2000 at the respective position using the function "=Min(F2:F228)", "=MEDIUM VALUE(F2:F228)" and "=Max(F2:F228)". We then drag these functions in the row/column up to Value_2016. Then we format them as a number with 2 decimal places.

The interpretation of the very different results for the individual countries is done later.

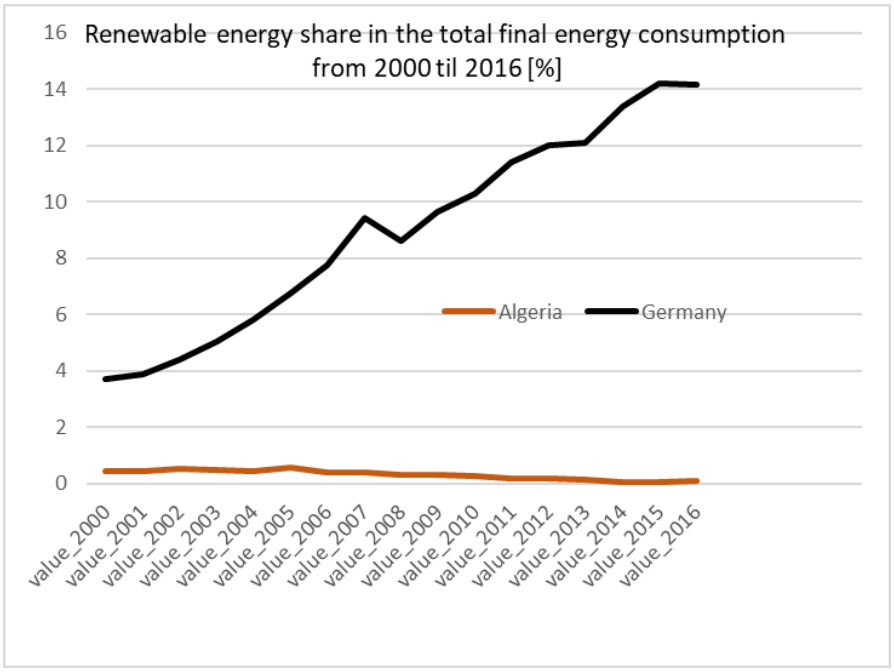
Time diagrams

To create a diagram for the development of renewable energy over time, we create another table, copy the headings of the old table and the rows of the calculated values Minimum, Average and Maximum as numerical values into the table. Then we search for the desired 6 countries (Algeria, Australia, Costa Rica, Ecuador, Germany and Viet Nam) and copy their data into the new table. Delete the first 4 columns (from goal to geoArea code) to make diagram evaluations easier. The result looks like this.

geoAreaName	value_2000	value_2001	value_2002	value_2003	value_2004	value_2005	value_2006	value_2007	value_2008	value_2009	value_2010	value_2011	value_2012	value_2013	value_2014	value_2015	value_2016
Minimum worldwide	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average worldwide	15,17	14,73	14,82	15,21	15,60	14,95	15,50	15,72	15,50	16,71	16,91	16,86	17,00	17,53	17,24	17,16	17,21
Maximum worldwide	93,91	96,23	96,16	97,02	97,27	97,29	96,86	96,89	96,85	96,92	95,28	93,80	93,89	94,39	94,58	94,44	94,67
Algeria	0,43	0,43	0,51	0,47	0,44	0,58	0,41	0,41	0,3	0,31	0,26	0,18	0,18	0,13	0,07	0,06	0,08
Australia	8,42	8,37	8,74	7,15	6,68	6,71	6,85	6,95	6,79	7,11	8,13	8,31	8,29	9,09	9,22	9,16	9,32
Costa Rica	32,95	32,11	32,65	33,66	39,5	42,06	42,27	42,84	43,13	42,27	42,31	40,5	38,62	38,29	38,05	38,93	37,16
Ecuador	20,03	18,43	18,06	17,97	15,97	12,16	12,97	12,81	15,09	13,3	12,11	13,65	13,38	12,94	12,48	14,13	15,18
Germany	3,7	3,9	4,41	5,06	5,83	6,76	7,75	9,41	8,59	9,63	10,29	11,39	12,01	12,09	13,38	14,21	14,17
Viet Nam	57,97	56,36	52,42	51,03	45,99	44,36	44,47	42,11	39,46	37,17	34,8	36,53	38,12	37,71	36,98	34,73	32,71

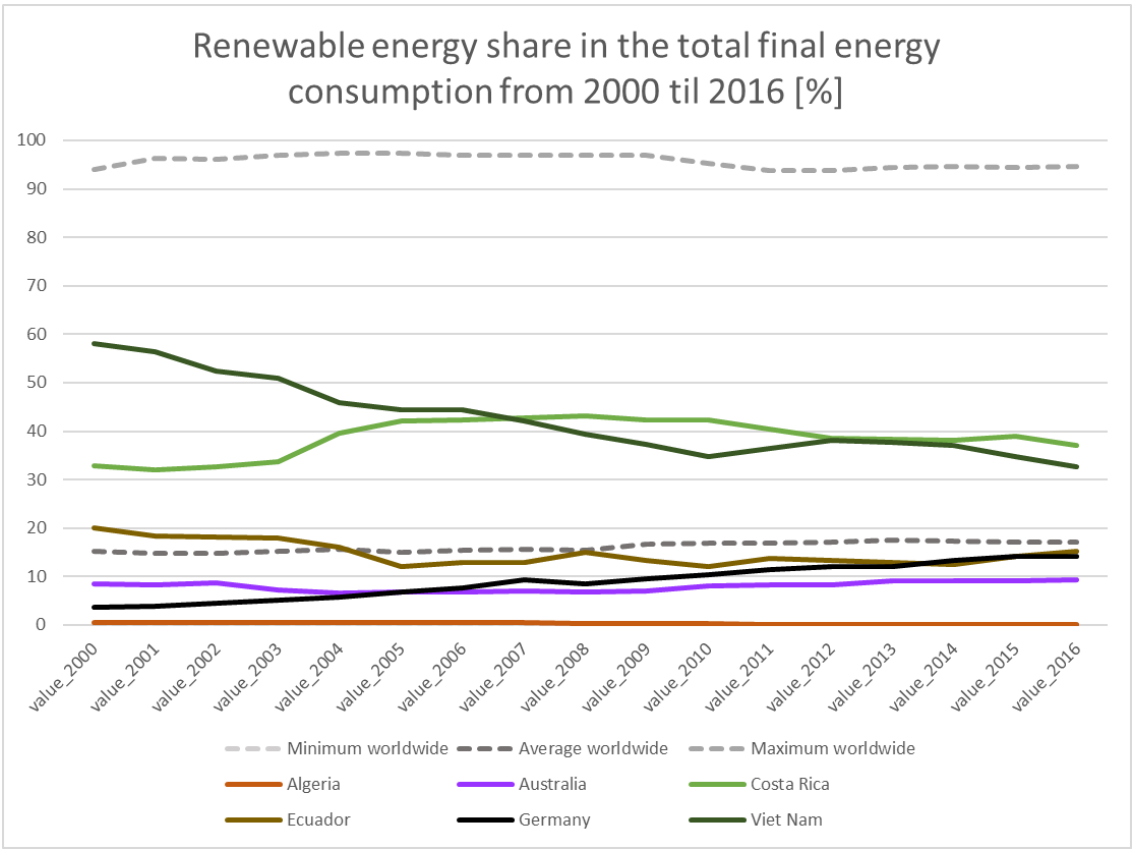
Country comparison

Select two countries (select line while pressing the CTRL key), here Algeria and Germany and create a line diagram.



Comparing Algeria and Germany

Similarly, we create a time diagram for all 6 countries considered in a worldwide comparison.



Six countries in comparison to the worldwide situation

Interpretation

To interpret your results, go back to the pages of the United Nations and read about the significance of the indicator you have chosen.

Interpretation of the example:

In the 7th objective for sustainable development, the UN calls (among other things) for a substantial increase in the share of renewable energies. According to the UN, the generation of energy from fossil fuels, which is still dominant today, accounts for 60% of all greenhouse gas emissions and is thus one of the main driving forces behind anthropogenic climate change. The fulfilment of this objective is therefore closely linked to objective 13 - climate change. On the other hand, renewable energies represent a great opportunity, especially for developing countries, to become independent of the import of energy (carriers) from abroad or to electrify remote areas in the first place. Against this background, this paper describes the extent to which the share of renewable energies in total energy consumption changed per country between 2000 and 2016. The indicator *7.2.1 - Renewable energy share in the total final energy consumption (%) (indicator EG_FEC_RNEW)* of the UN sustainable development goals was selected for this purpose. This is an estimated value based on national estimates.

European countries have developed almost exclusively positively (cf. the visualizations 2000 to 2016), as have most developed countries. In the period 2000 to 2016, Germany recorded an almost linear increase in the share of renewable energies (from 3.7% to 14.2%, see diagram), whereas Algeria recorded a regression.

The general trend in the developing and emerging countries in South America, Africa and Asia is a decline in the share of renewable energies. However, the development of absolute energy consumption remains unnoticed in this presentation. In China, for example, primary energy consumption almost doubled between 2005 and 2015 (from 1793 to 3010 million tonnes oil equivalent, i.e. enormous new capacities of renewable energies were built up during this period to "only" drop 6 percentage points).

Sources

Indicator 7.2.1.: https://unstats.un.org/sdgs/metadata/?Text=&Goal=7&Target=7.2=&Goal=7&Target=7.2

Statistical data: https://de.statista.com/statistik/daten/studie/42182/umfrage/primaerenergieverbrauch-von-china-in-oelaequivalent/

Country data: https://www.naturalearthdata.com/downloads/50m-cultural-vectors/