NEXUS FUTURES Expert Working Paper

Climate Change Scenarios for Luxemburg – Andrew Ferrone, ASTA Luxemburg

NEXUS FUTURES
Nachhaltiger Umgang mit Wasser und Land

Current situation

In its Special Report on Global Warming of 1.5°C[1] (SR1.5) the Intergovernmental Panel on Climate Change[2] (IPCC) concluded: "Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C."

In Luxembourg City temperatures have been observed since 1838 and the average temperatures over the most recent 30-year period 1981-2010 are 1.3°C higher than the pre-industrial period (1861-1890). For precipitations, however no statistically significant trend could be observed, for accumulated precipitation on a yearly or seasonal basis. The climatological precipitation pattern for Luxembourg shows a strong gradient from the North-West to the South-east, with a maximum yearly precipitation sum over the period 1981-2010 in Arsdorf with 1055 mm an a minimum in Remich with 725 mm.

In Luxembourg City, an increase of the numbers of days with high precipitations (more than 11.7mm per day, which corresponds to the 95th preventative of the daily precipitation for the period 1981-2010) was observed. There was an average number of 15 days per year with high precipitation over the period 1951-1980, and this increased to 18 days per day for the period 1981-2010.

The temperature increases also lead to a stronger evapotranspiration. This implies that the upper soil layers dry out more quickly and that the agricultural production is impacted more quickly by drought situations in case of missing rain, in particular in summer.

Climate projections

In order to be able to project the climate and its changes to the future, we need to rely on socio-economic scenarios that allow to calculate possible time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover. The scenarios need to be representative, so that they cover a large part of the possible future evolutions.

To this end, a set of Representative Concentration pathways (RCPs; van Vuuren, 2011) was developed to serve the climate projections used by the IPCC. In practice general circulation model (GCMs), which are used to project the global climate and its changes in each of these RCPs, use four of the RCPs that are available:

- RCP2.6 One pathway where radiative forcing peaks at approximately 3 Wm^{-2} before 2100 and then declines;
- RCP4.5 and RCP6.0 Two intermediate stabilization pathways in which radiative forcing is stabilized at approximately 4.5 Wm^{-2} and 6.0 Wm^{-2} after 2100;

[1] Available here https://www.ipcc.ch/sr15
[2] For more information on the IPCC go to https://www.ipcc.ch

- RCP8.5 One high pathway for which radiative forcing reaches greater than 8.5 Wm^{-2} by 2100 and continues to rise for some amount of time.

The World Climate Research Program (WCRP)[3], coordinates, on a regular basis for each assessment report of IPCC, an Coupled Model Intercomparison Project (CIMP). The aim of CIMP is to coordinate major climate research centers worldwide, to produce intercomparable climate projections with different GCMs.

The latest fully available results come for the 5th Phase of CIMP[4] (CIMP5), which are used as a basis for the climate projections of the IPCC's 5th Assessment Report[5] (AR5).

Climate projections for Luxembourg

For this scenarios developed here, we use the results of CIMP5[6]. These are available on a regular grid with a resolution of 2.5 x 2.5°. We have chosen the grid cell, which covers the whole of the territory of Luxembourg, from 5.0 to 7.5° East and 47.5 to 50.0° North, and have evaluated all available realizations (multi model, multi ensemble) for three RCPs: RCP2.6: 65 realizations, RCP4.5: 105 realizations,RCP6.0: 47 realizations.

Based on these global climate projections a statistical evaluation of changes in temperatures and precipitation for the period 2021-2050 compared to 1981-2010 is done. Based on the different realization of the different RCPs, a median (best estimate) of the change as well as very likely range (90% -100%) of the change is indicated in parentheses. Also a significance of the likelihood that the change is different than zero is done and indicated by colors.

Table 1 indicates the changes in temperature (in °C) for Luxembourg for the period 2021-2050 compared to 1981-2010 on an annual and seasonal basis, with the significance of the change being different from zero as indicated in Table 3. Table 3 gives the same information for relative changes in precipitation (in %).

Scenario	DJF	MAM	JJA	SON	Year
RCP 2.6	0.9 (0.2-1.9)	0.8 (0.1-1.6)	1.4 (0.3-2.7)	1.2 (0.3-2.0)	1.1 (0.2-1.8)
RCP 4.5	1.0 (0.4-1.8)	1.1 (0.3-1.7)	1.3 (0.7-2.6)	1.2 (0.6-1.9)	1.2 (0.7-1.9)
RCP 6.0	0.8 (0.3-1.6)	0.9 (0.1-1.6)	1.2 (0.3-2.5)	0.9 (0.3-1.7)	0.9 (0.4-1.7)

Table 1: Temperature changes in °C for Luxembourg for the period 2021-2050 compared to 1981-2010, for the year and the four meteorological seasons (winter: December, January, February; spring: March, April, May; summer: June, July, August; autumn: September, October, November). The main figures indicate the median change of the evaluated realizations of the scenarios, whereas the figures in parenthesis indicate the very likely (90-100%) interquartile range. The colors indicate the significance level of the change signal, as given in Table 3.

[3] sponsored by the World Meteorological Organization (WMO), the International Science Council (ISC) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO, see https://www.wcrp-climate.org/

[4] https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip5

[5] https://www.ipcc.ch/assessment-report/ar5/

[6] Data was downloaded from https://climexp.knmi.nl

Scenario	DJF	MAM	JJA	SON	Year
RCP 2.6	+3 (-7 – +13)	+3 (-7 – +12)	-2 (-20 – +11)	+1 (-8 – +11)	+1 (-5 – +9)
RCP 4.5	+3 (-6 – +11)	+2 (-9 – +13)	-3 (-19 – +7)	+1 (-9 – +9)	0 (-4 – +6)
RCP 6.0	+4 (-3 – +19)	+1 (-6 – +8)	-3 (-18 – +12)	+2 (-9 – +11)	+1 (-3 – +9)

Table 3: Relative Precipitation changes in % for Luxembourg for the period 2021-2050 compared to 1981-2010, for the year and the four meteorological seasons (winter: December, January, February; spring: March, April, May; summer: June, July, August; autumn: September, October, November). The main figures indicate the median change of the evaluated realizations of the scenarios, whereas the figures in parenthesis indicate the very likely (90-100%) interquartile range. The colors indicate the significance level of the change signal, as given in Table 3.

Significance of change signal	Color
Virtually certain **(99%-100%)**	
Extremely likely **(95%-100%)**	
Very likely **(90-100%)**	
Not significant **(< 90%)**	

Table 3: Colors of significance of change

Interpretation of the results.

From Table 1, it is thus clear that temperatures in Luxembourg will continue to increase by around 1°C for the period 2021-2050, with a high level of confidence independent of the scenario chosen. This is in line with IPCC SR1.5, which highlights that temperature changes in scenarios with and without ambitious climate change mitigation only become visible after 2050. Table 1 also highlights, that increases in temperature will be slightly more pronounced in summer and autumn than in the other seasons.

For precipitation on the other side, the changes are not statistically significant, and median changes over the year are close to zero. The changes for the seasons are not significant either, however the median changes indicate a slight decrease in precipitations for summer and a slight increase of the other seasons, which is most pronounced for winter.

The coarse resolution of GCMs does not allow for a reliable reproduction of days with high precipitation events (e.g. Prein et al. 2015). However, as the increase of days with high precipitation events is directly linked to the increase of atmospheric and sea surface temperature, this trend is expected also to continue until 2050, as both drivers projected to rise over this period. (see IPCC Special Report on the Ocean and Cryosphere in a Changing Climate[7]).

With rising temperatures, evapotranspiration rates will also rise, thus worsening drought situations, in case of lower than average precipitation and leading to a drying out of agricultural soils.

References:

Prein AF, Langhans W, Fosser G, Ferrone A, Ban N, Goergen K, Keller M, Tölle M, Gutjahr O, Feser F, Brisson E, Kollet S, Schmidli J, van Lipzig NPM, Leung R (2015) A review on regional convection-

[7] See https://www.ipcc.ch/srocc/

permitting climate modeling: demonstrations, prospects, and challenges. Rev Geophys 53(2):323–361. https://doi.org/10.1002/2014RG000475

van Vuuren, D.P., Edmonds, J., Kainuma, M. et al. Climatic Change (2011) 109: 5. https://doi.org/10.1007/s10584-011-0148-z

Nexus Scenarios

Smarte Kreislaufwirtschaft

In this scenario, temperatures rise on annual average by 0.9°C compared to 1980-2010 (2.2°C compared to preindustrial), with an increase of 1.2°C in summer and 0.8°C in winter compared to 1980-2010.

The precipitations sums do not change over the summer months compared to 1980-2010 and show an increase of +5% in winter, and of +2% during the year. The number of days with strong precipitation raises to 21 per year on average and the increased evapotranspiration leads to strong drying of the upper level of the soil, which increases the drought situation in agriculture.

Ein Teil der Natur

In this scenario, temperatures rise on annual average by 1.2°C compared to 1980-2010 (2.5°C compared to preindustrial), with an increase of 1.3°C in summer and 1.0°C in winter compared to 1980-2010.

The precipitations sums decrease by −10% over the summer months compared to 1980-2010 and stay at similar level during the rest of the year, which leads to a decrease and of −3% during the year. The number of days with strong precipitation raises to 23 per year on average and the increased evapotranspiration in combination with the decrease of precipitation in summer leads to strong drying of agricultural soils over several years and corresponding strong losses in harvests.

Gemeinwohl und Wissen

In this scenario, temperatures rise on annual average by 1.1°C compared to 1980-2010 (2.4°C compared to preindustrial), with an increase of 1.4°C in summer and 0.9°C in winter compared to 1980-2010.

The precipitations sums over the year and the seasons remain similar to 1980-2010. The number of days with strong precipitation raises to 17 per year on average and the increased evapotranspiration continues to lead to a drying out of the upper soil levels.