# Evaluation of greenhouse gas emissions avoided in the year 2021 attributable to the portfolio of wind energy and photovoltaic installations financed by Landwirtschaftliche Rentenbank

**Study commissioned by Landwirtschaftliche Rentenbank**

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# Abbreviations and explanations

| | |
|---|---|
| $CO_2$ | Carbon dioxide |
| $CO_{2eq}$ | see $CO_2$-equivalent |
| $CO_2$-equivalent | Unit used for measuring the global warming potential (i.e. the potential contribution to the warming of near-surface layers of the atmosphere) of a greenhouse gas in relation to the effect of $CO_2$. It states the quantity of $CO_2$ that would have the same greenhouse effect as the gas in question over a period of 100 years. For instance, one kg of methane ($CH_4$) has the same effect as 25 kg of $CO_2$. |
| GHG | Greenhouse gas |
| GWh | Gigawatt hour(s); 1 GWh = 1 million kWh |
| kW | Kilowatt(s) |
| $kW_p$ | Kilowatts peak: peak power of PV facilities |
| kWh | Kilowatt hour(s) |
| kt | Kilo tonne (1,000 tonnes) |
| MW | Megawatt(s); 1 MW = 1,000 kW |
| PV | Photovoltaics |
| RE | Renewable energy |
| RES | Renewable energy sources |
| t | Tonne |

# 1 Introduction

The main focus of the promotional activities of Landwirtschaftliche Rentenbank (hereinafter referred to as “Rentenbank”) lies on loans for agriculture-related projects of all kinds, as well as for providing finance in rural areas. Within its loan programmes Rentenbank supports investment in installations for using renewable energy, notably in bioenergy, wind energy and photovoltaic energy (PV). On behalf of Rentenbank ZSW developed an approach to estimate the amount of greenhouse gas (GHG) emissions avoided by photovoltaic and wind energy installations supported by the low-interest loans (see Bickel 2020).

The present report describes the GHG emission savings attributable to the plant operation in the year 2021, based on the portfolio as of 31st December 2021. Figure 1 shows the installed power that can be attributed to the residual debt of loans by year of investment. An overview of the calculation approach is given in the annex.

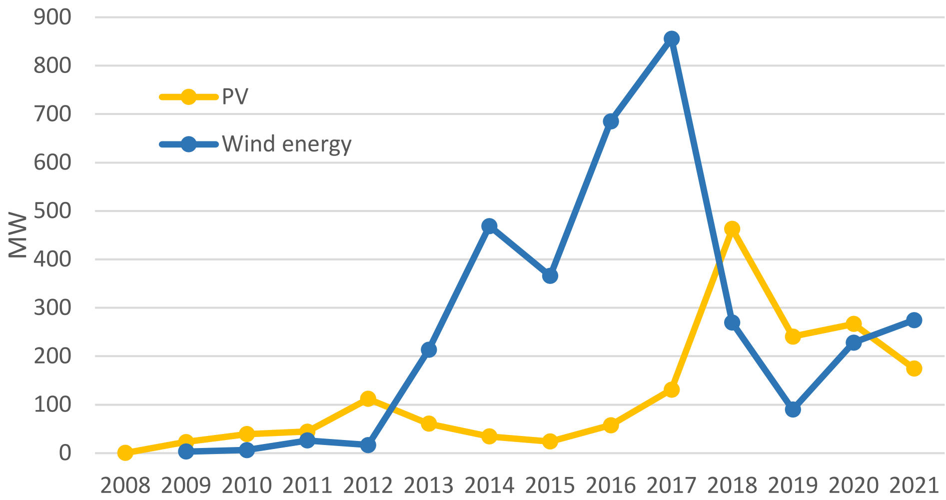


**Figure 1: Installed power attributable to residual debt of loans by year of investment (as of 31st December 2021).**

# 2 Emission savings

In contrast to the year 2020 with above-average sunny weather and very good wind conditions in Germany, meteorological conditions were less favourable for PV and in particular for wind energy in 2021. In conjunction with an increase in installed capacity, GHG emission savings attributable to the Rentenbank portfolio of PV installations still increased by 8 percent compared to 2020, amounting to 1,003,900 tonnes of $CO_2$-equivalent ($CO_{2eq}$) – see Figure 2. For the Rentenbank wind energy installations portfolio GHG emission savings decreased by 13 percent year-on-year to 4,820,700 tonnes of $CO_{2eq}$ (see Figure 3).

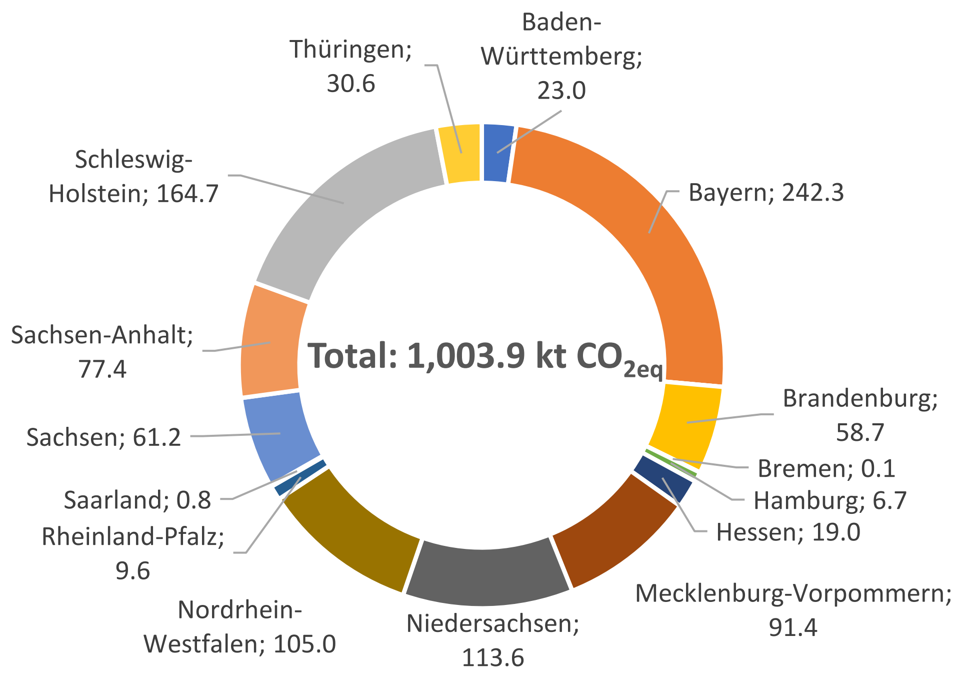


**Figure 2: Greenhouse gas emission savings 2021 attributable to photovoltaic installations supported by Rentenbank loans (kt = 1,000 tonnes).**

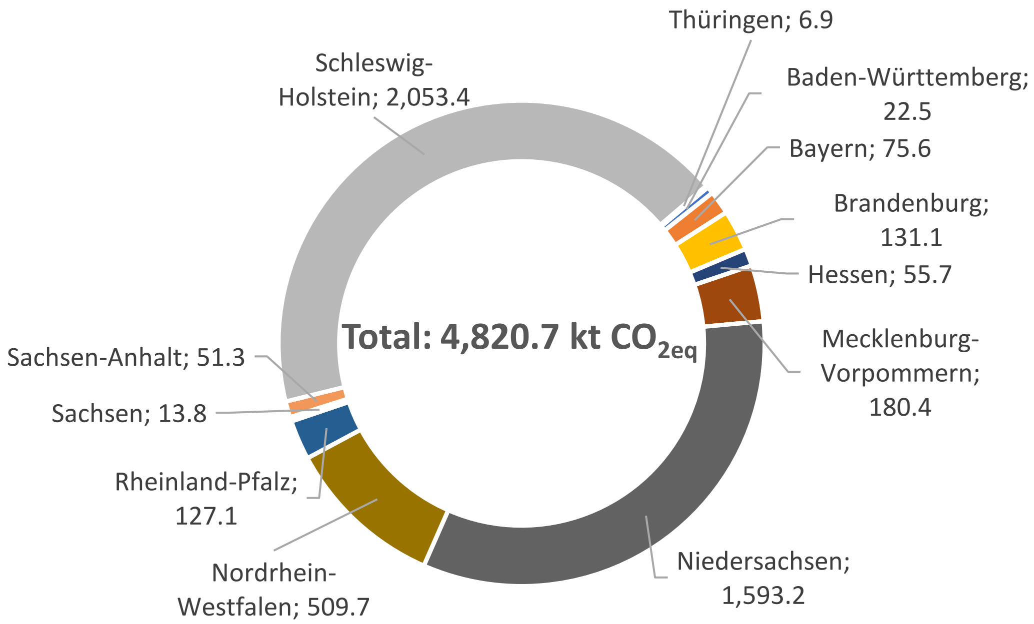


**Figure 3: Greenhouse gas emission savings 2021 attributable to wind energy installations supported by Rentenbank loans (kt = 1,000 tonnes).**

Table 1 and Table 2 present the results by federal state. It has to be noted that the values are aggregated over all years of investment. The average specific investment costs reflect the underlying time structure of investments in the portfolio. As PV installations saw a steep

**Table 1: Loans for photovoltaic installations as of 31st Dec. 2021 and attributable effects in the year 2021 by German federal state.**

| | Loans | | Average specific inv. cost | Attributable to loans | | | |
|---|---|---|---|---|---|---|---|
| | Count | Residual debt | | Installed power | Electricity production | GHG emissions avoided | |
| | | Million € | €/kW$_p$ | MW$_p$ | GWh | t $CO_2$ | t $CO_{2eq}$ |
| **Total** | **15,798** | **-1,739.8** | **1,040** | **1,670.8** | **1,464.7** | **947,400** | **1,003,900** |
| Baden-Württemberg | 561 | -38.9 | 1,080 | 35.9 | 33.6 | 21,700 | 23,000 |
| Bayern | 3,843 | -378.1 | 1,010 | 372.6 | 353.5 | 228,700 | 242,300 |
| Brandenburg | 148 | -74.6 | 890 | 83.4 | 85.6 | 55,400 | 58,700 |
| Bremen | 7 | -0.3 | 2,570 | 0.1 | 0.1 | 58 | 61 |
| Hamburg | 32 | -14.0 | 880 | 16.0 | 9.7 | 6,300 | 6,700 |
| Hessen | 279 | -31.9 | 1,000 | 31.8 | 27.7 | 17,900 | 19,000 |
| Mecklenburg-Vorpommern | 297 | -130.7 | 890 | 146.7 | 133.4 | 86,300 | 91,400 |
| Niedersachsen | 4,496 | -255.0 | 1,200 | 211.7 | 165.8 | 107,200 | 113,600 |
| Nordrhein-Westfalen | 3,017 | -199.5 | 1,090 | 183.0 | 153.2 | 99,100 | 105,000 |
| Rheinland-Pfalz | 374 | -19.9 | 1,290 | 15.4 | 14.0 | 9,100 | 9,600 |
| Saarland | 5 | -1.1 | 870 | 1.3 | 1.2 | 750 | 790 |
| Sachsen | 233 | -89.3 | 950 | 93.8 | 89.2 | 57,700 | 61,200 |
| Sachsen-Anhalt | 310 | -111.8 | 910 | 122.3 | 112.9 | 73,000 | 77,400 |
| Schleswig-Holstein | 2,022 | -343.8 | 1,130 | 305.2 | 240.3 | 155,400 | 164,700 |
| Thüringen | 174 | -50.6 | 990 | 51.4 | 44.6 | 28,800 | 30,600 |

Totals may differ due to rounding.

**Table 2: Loans for wind energy installations as of 31st Dec. 2021 and attributable effects in the year 2021 by German federal state.**

| | Loans | | Average specific inv. cost | Attributable to loans | | | |
|---|---|---|---|---|---|---|---|
| | Count | Residual debt | | Installed power | Electricity production | GHG emissions avoided | |
| | | Million € | €/kW | MW | GWh | t $CO_2$ | t $CO_{2eq}$ |
| **Total** | **3,263** | **-5,026.4** | **1,430** | **3,502.8** | **6,390.5** | **4,561,800** | **4,820,700** |
| Baden-Württemberg | 12 | -24.8 | 1,400 | 17.6 | 29.9 | 21,300 | 22,500 |
| Bayern | 195 | -92.9 | 1,480 | 62.9 | 100.3 | 71,600 | 75,600 |
| Brandenburg | 27 | -153.3 | 1,390 | 109.9 | 173.7 | 124,000 | 131,100 |
| Hessen | 31 | -63.5 | 1,450 | 43.8 | 73.8 | 52,700 | 55,700 |
| Mecklenburg-Vorpommern | 77 | -184.5 | 1,440 | 127.9 | 239.1 | 170,700 | 180,400 |
| Niedersachsen | 996 | -1,702.2 | 1,420 | 1,199.3 | 2,112.0 | 1,507,600 | 1,593,200 |
| Nordrhein-Westfalen | 655 | -569.3 | 1,430 | 397.0 | 675.7 | 482,300 | 509,700 |
| Rheinland-Pfalz | 35 | -149.6 | 1,390 | 107.9 | 168.5 | 120,300 | 127,100 |
| Sachsen | 10 | -16.0 | 1,370 | 11.7 | 18.3 | 13,000 | 13,800 |
| Sachsen-Anhalt | 33 | -61.6 | 1,450 | 42.6 | 68.0 | 48,600 | 51,300 |
| Schleswig-Holstein | 1,186 | -2,000.4 | 1,450 | 1,376.5 | 2,722.1 | 1,943,100 | 2,053,400 |
| Thüringen | 6 | -8.3 | 1,500 | 5.5 | 9.1 | 6,500 | 6,900 |

Totals may differ due to rounding.

decline in specific investment cost, considerable variation can be observed between federal states according to different financing volumes over time. High values result from early investments with higher specific costs. For wind energy installations the variation is comparably small as there was relatively little variation in specific costs between investment years.

Table 3 shows the comparison of the GHG emissions avoided per kWh of electricity produced with the corresponding values calculated for the total 2021 electricity production from PV and onshore wind installations in Germany reported in BMWK (2022). The specific GHG-avoidance factors show good agreement for both PV and wind energy.

**Table 3: GHG emissions avoided per kWh.**

| g $CO_{2eq}$ / kWh | Rentenbank | BMWK (2022) | Relative Difference |
|---|---|---|---|
| **Photovoltaic energy** | 685 | 687 | 0.3 % |
| **Wind energy onshore** | 754 | 756 | 0.2 % |

Table 4 illustrates the amount of $CO_{2eq}$ avoided per Euro invested. The values of the Rentenbank portfolio are compared with the latest availabe figures (year 2020) for the RE loan programmes assessed in Bickel and Kelm (2021) – even though this comparison is distorted due to the different meteorological conditions in the years 2021 and 2020 and the resulting electricity yields. The Rentenbank portfolio 2021 avoided less GHG emissions per invested Euro than the loan programmes 2020 for both PV and wind energy. Besides the differences in meteorology the composition of the portfolio is one of the main reasons for the lower specific avoidance of GHG emissions: The Rentenbank PV portfolio includes installations from 2008 to 2021 with high specific investment costs for the earlier years, resulting in comparably high average specific cost of investment (see Table 1) and thus finally to lower values regarding GHG emissions avoided per invested Euro. The comparison with the value for the year 2018 (based on Bickel and Kelm 2019), with underlying similar specific cost of investment and meteorological conditions, shows better agreement. For wind energy installations the differences between the Rentenbank portfolio 2021 and the comparative values of 2020 and 2018 largely correspond to the differences in meteorological conditions in the respective years.

**Table 4: GHG emissions avoided per €.**

| g $CO_{2eq}$ / € | Rentenbank | Bickel and Kelm (2021, 2019) | | Relative Difference | |
|---|---|---|---|---|---|
| year | 2021 | 2020 | 2018 | 2020 | 2018 |
| **Photovoltaic energy** | 577 | 831 | 563 | 30.6 % | -2.5 % |
| **Wind energy onshore** | 959 | 1,130 | 1,060 | 15.1 % | 9.6 % |

The calculations presented are estimates based on limited information and to the best of our knowledge. They do not represent exact calculations. However, according to the current state of knowledge and under the assumptions made, the estimates provide a realistic indication of the actual savings in GHG gas emissions resulting from the operation of the PV and wind power installations supported by Rentenbank loans. This is confirmed by the plausibility checks performed.

# References


| | |
|---|---|
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| UBA (2021) | Emissionsbilanz erneuerbarer Energieträger. Bestimmung der vermiedenen Emissionen im Jahr 2020. Umweltbundesamt Dessau-Roßlau (UBA), September 2021. |

# Annex: Calculation Approach

The following sections describe the calculation approach in general as well as the data used and the assumptions taken. A more detailed description of the approach can be found in Bickel (2020).

The only information available on the photovoltaic (PV) and wind energy plants built with the support of Rentenbank loan programmes is the residual debt of loans as of 31$^{st}$ December 2021, categorised by year of investment and German federal state. This can be interpreted as share of the installations and their operation that is attributable to the loan programmes and is the starting point of the calculation. Figure 4 illustrates the calculation approach with light green arrows indicating input values and dark green arrows displaying calculation results.

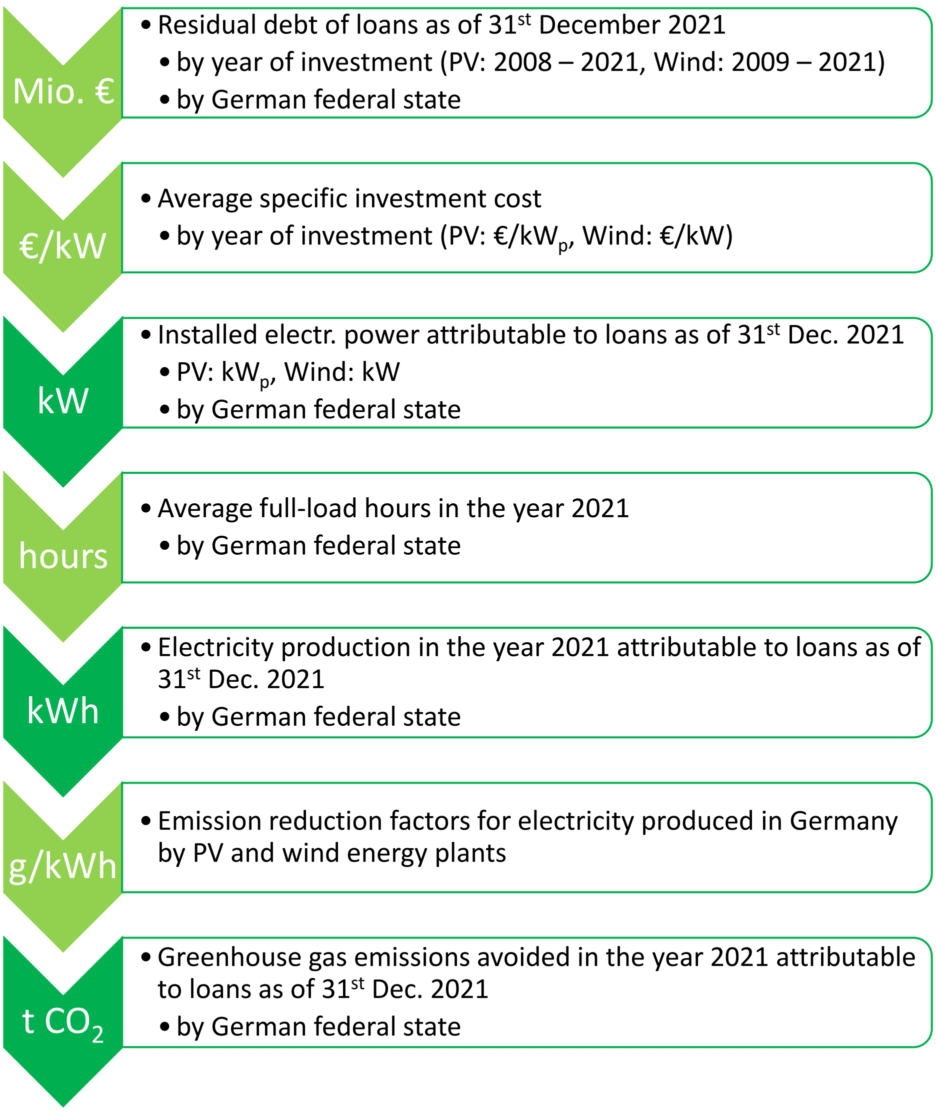


**Figure 4: Overview of the calculation approach (light green arrows indicate input values, dark green arrows show calculation results).**

In the first step the installed electrical power can be estimated from the residual debt of loans using specific investment cost values. As the cost per kW of electrical power installed has changed over the last years, average values differentiated by year of investment are used for both PV and wind installations. As for the previous years specific investment costs for the installation year 2021 were provided by ZSW.

In the next step the electricity production is calculated from the installed electrical power and average full-load hours in the year 2021. Full-load hours and thus the electricity produced by a PV or wind energy plant vary with geographical location within Germany. This is taken into account by using full-load hours differentiated by German federal state, which were derived based on data from DWD (2022) and Anemos (2022).

The final step is the multiplication of the electricity production by emission reduction factors for electricity produced in German PV and wind energy plants. These factors describe net emission savings, setting off the volume of emissions caused by the use of renewables (final energy supply) against the volume of gross emissions that are no longer being released due to fossil sources having been replaced with renewables. They are provided for emissions of $CO_2$ and $CO_2$-equivalents, both for PV and wind energy (as well as other renewable energy sources), by the German Umweltbundesamt. Table 5 shows the values for 2020, the most recent year available.

**Table 5: Emission reduction factors for the year 2020.**

| g/kWh | $CO_2$ | $CO_{2eq}$ |
|---|---|---|
| **Photovoltaic energy** | 647 | 685 |
| **Wind energy onshore** | 714 | 754 |

Source: UBA (2021), values rounded.