Evaluation of greenhouse gas emissions avoided in the year 2019 attributable to the portfolio of wind energy and photovoltaic installations financed by Landwirtschaftliche Rentenbank

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Executive Summary

Within its loan programmes Landwirtschaftliche Rentenbank supports investment in installations for using renewable energy, notably bioenergy, wind energy and photovoltaic energy. Rentenbank commissioned ZSW to develop and apply a sound approach to estimate the amount of greenhouse gas emissions avoided in 2019 by photovoltaic and wind energy installations supported by the low-interest loans of Rentenbank.

To contribute to a transparent impact reporting, the present report describes the estimation approach and the data used alongside an assessment of the main sources of uncertainty involved. 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 31st December 2019, 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.

In the first step the installed electrical power is estimated from the residual debt of loans using specific investment cost values. In the second step the electricity production is calculated from the installed electrical power and average full-load hours in 2019. In the third step the electricity production is multiplied by emission reduction factors for electricity produced in German PV and wind energy plants.

In 2019 greenhouse gas emission savings of 799,000 tonnes of CO_2-equivalent (CO_{2eq}) can be attributed to PV installations supported by Rentenbank loans. For wind energy installations the corresponding value amounts to 4,160,000 tonnes of CO_{2eq}.

The comparison of the amount of CO_{2eq} avoided per invested Euro with values of similar RE loan programmes confirms the plausibility of the calculations, taking into account the composition of the portfolio with respect to the date of investment.

In conclusion the calculations represent estimates based on limited information. However, according to the current state of knowledge and under the assumptions made, the estimates provide a realistic indication of the actual savings in greenhouse gas emissions resulting from the operation of the PV and wind power installations supported by Rentenbank loans.

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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.
EEG	Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act)
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
UBA	German Federal Environment Agency (Umweltbundesamt)

1 Background

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.

Rentenbank commissioned ZSW to develop, based on the information available, a scientifically sound approach to estimate the amount of greenhouse gas emissions avoided by photovoltaic and wind energy installations supported by the low-interest loans of Rentenbank.

ZSW has a long track record in observing, documenting, and assessing the transition to renewables at national and international levels, as well as in the German federal states, regions, and municipalities. In particular, ZSW has assessed promotional loan programmes for renewable energy since the year 2009.

To contribute to a transparent impact reporting as recommended e.g. by the Green bond principles (see ICMA 2018), the following report describes the estimation approach, the data used, alongside with an assessment of the main sources of uncertainty involved.

2 Approach and Data

The following sections describe the calculation approach in general as well as the data used, the assumptions taken and possible sources of uncertainty in the estimation.

2.1 Calculation Approach

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 31st December 2019, 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 1 illustrates the calculation approach with light green arrows indicating input values and dark green arrows displaying calculation results.

In the first step to calculate the greenhouse gas emissions avoided, 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 per year of investment are used for both PV and wind installations.

In the next step the electricity production is calculated from the installed electrical power and average full-load hours in the year 2019. 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.

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.

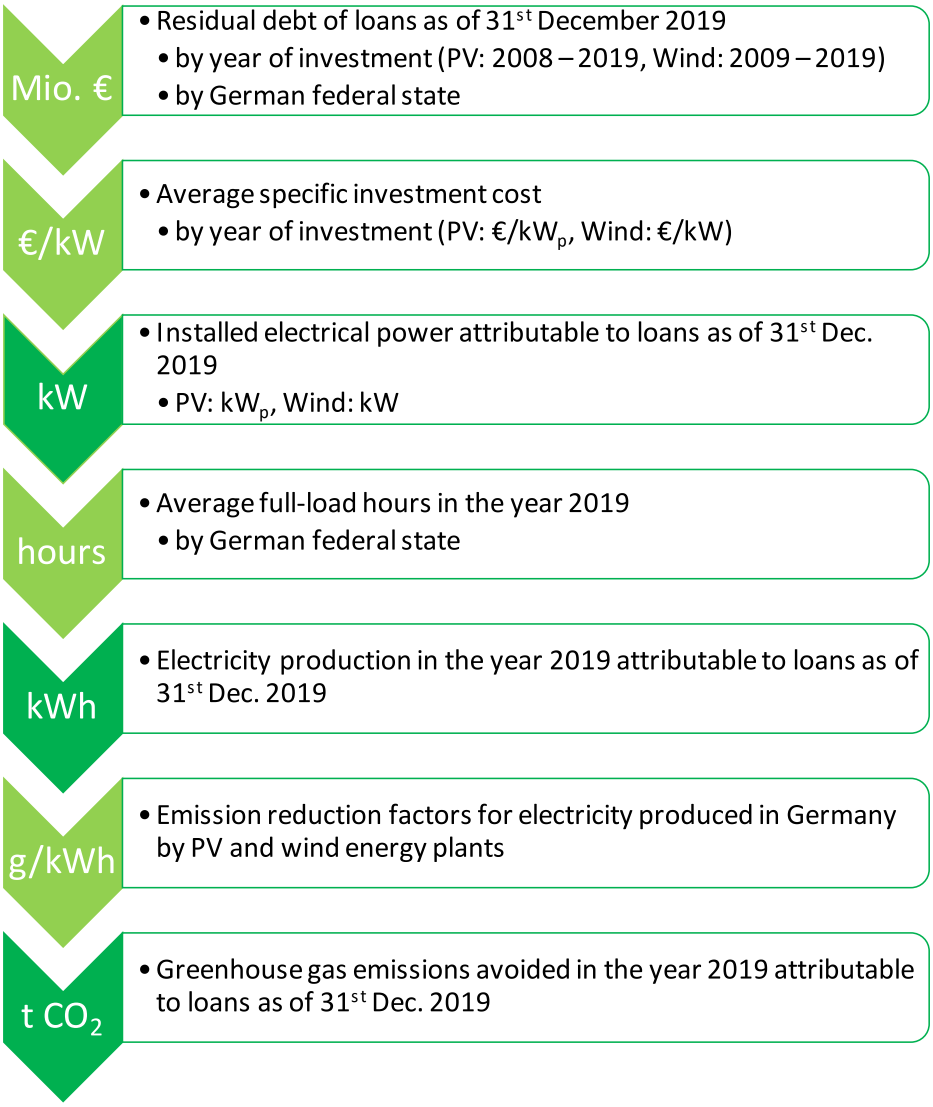

Figure 1: Overview of the calculation approach (light green arrows indicate input values, dark green arrows show calculation results).

2.2 Residual debt of loans

The residual debt of loans as of 31st December 2019, aggregated by year of investment and German federal state, was provided for the PV and wind energy plants supported by Rentenbank. The period of investment covers the years 2008 to 2019 for PV and 2009 to 2019 for wind energy. The total aggregated values are presented in Table 2 and Table 3.

It was assumed that the investment volume is fully covered by the loans and that the investment is exempt of value-added tax. If the investment volume were higher than the loan, the GHG emission savings would be underestimated.

In lack of specific information on the plants supported it was assumed that the year of investment corresponds to the year in which the facilities were put into operation. In case of a time gap of more than one year between investment and start of electricity production, the amount of GHG emissions avoided would be overestimated. This time delay tends to be greater for wind energy projects than for PV installations. However, this would affect only the most recent investment years (i.e. 2018 and 2019), because if the delay was longer, less installations would be in operation and thus less electricity would be produced.

2.3 Specific investment cost

The specific investment costs in € per kW installed varies with size of the installation and with the year of investment, both for PV and wind energy plants. Whereas the specific installation costs only decreased moderately for wind energy installations, they saw a drop of almost 80 percent between 2008 and 2019 for PV installations of all size classes.

For PV the investment costs comprise modules, inverters, costs of assembly, grid connection and other costs. Specific costs for each year were derived based on the work for the EEG progress reports (ZSW et al. 2019 and previous versions). As the specific costs differ significantly between size classes, following categories are distinguished: up to 10 kW_p, 10 to 100 kW_p, 100 to 1,000 kW_p as well as larger than 1,000 kW_p.

A plausibility check of the average electrical power of plants (calculated as mean residual debt per loan for the years 2017 to 2019 divided by size-specific investment costs) confirmed the assumption that most of the facilities supported lie in the category 100 to 1,000 kW_p, which are typical for agricultural installations.

For wind energy installations the investment costs comprise the main investment costs (wind turbine) plus ancillary investment costs (foundation, development, grid connection, compensation measures, planning and approval, internal park cabling, other costs). Specific values were derived based on Deutsche Windguard and ZSW (2019) and previous EEG progress reports. As no further information was available on the typical size of the installations, average cost values were used.

2.4 Full-load hours

Besides the efficiency of the plant itself, the full-load hours of a PV plant or a wind turbine varies with the solar radiation and average wind speed respectively. To reflect general differences in meteorological conditions between geographical locations, full-load hours were differentiated by German federal state.

For PV full-load hours were based on BDEW (2017), which reports values for the year 2015. These values were updated to the year 2019 based on annual solar radiation by federal state from Germany's National Meteorological Service (DWD – see DWD 2015 and DWD 2019).

Full-load hours for wind turbines were derived based on data by the German transmission system operators (Netztransparenz 2019) and Bundesnetzagentur (2019). As the most current year available is 2018, full-load hours were updated using yield index values by federal state reported in anemos (2019, 2020).

The initial commissioning dates of new plants are distributed over the months of the calender year, i.e. they produce electricity only for part of the first year of operation. This is reflected in the common assumption that only half of the full-load hours are taken into consideration for the first year of operation. In other words: the PV plants and wind turbines that were built in 2019 were assumed to generate half of the electricity than they would have with a start of operation on January 1st 2019.

According to Deutsche Windguard and ZSW (2019) the evaluation of the average number of full-load hours of wind turbines by the year of commissioning indicates that this number has increased the later the turbine was erected. This is due to increasing hub heights and continuous improvement of the turbines. On the other hand, studies show that the energy yield of wind turbines decreases with increasing age due to mechanical wear, blade contamination and other forms of wear. Both effects have led to a considerable increase in the number of full-load hours of newly commissioned wind turbines over the past years, which could not be adequately taken into account in the present calculation due to missing data.

In the PV sector, too, new systems are continuously being optimised and the efficiency of the systems tends to decline with increasing operating time. However, the differences in the average number of full-load hours are at a much lower level and are negligible for the purposes of this analysis in view of other uncertainties.

2.5 Emission reduction factors

Savings in greenhouse gas (CO_2, CH_4, N_2O) emissions due to renewable energy installations in Germany are calculated based on emission reduction factors provided by the German Umweltbundesamt (UBA – Federal Environment Agency). These factors reflect the specific fossil fuel mix that PV and wind energy replace. In other words: they take into account the shares of electricity from lignite, hard coal, natural gas and mineral oil that are replaced in Germany by electricity from renewables, where each technology (photovoltaics, wind energy, hydro power, solid biomass, biogas and geothermal energy) has its specific substitution pattern, determined mainly by the time structure of energy provision.

The emission reduction 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. All upstream process chains involved in the production and supply of the various energy sources and in installation construction and operation (but not dismantling) are also taken into account.

The emission reduction factors for a given year are usually only available in the autumn of the following year. For this reason, for the current calculations factors for 2018 (see Table 1) have to be applied. This appears to be acceptable with respect to the overall uncertainties of the calculations. For example, the emission reduction factors for wind turbines in 2018 and 2017 differed by around 2 % to 4 % from those of the previous year. For PV plants, the maximum difference from the previous year's figure was 2.4 %.

Table 1: Emission reduction factors for the year 2018.

g/kWh	CO_2	CO_{2eq}
Photovoltaic energy	570.37	627.43
Wind energy onshore	631.41	692.76

Source: UBA 2019.

3 Results

The greenhouse gas emission savings are presented in Figure 2 for PV installations and Figure 3 for wind energy installations. They amount to 799,000 tonnes of CO_2-equivalent (CO_{2eq}) and 4,160,000 tonnes of CO_{2eq} respectively.

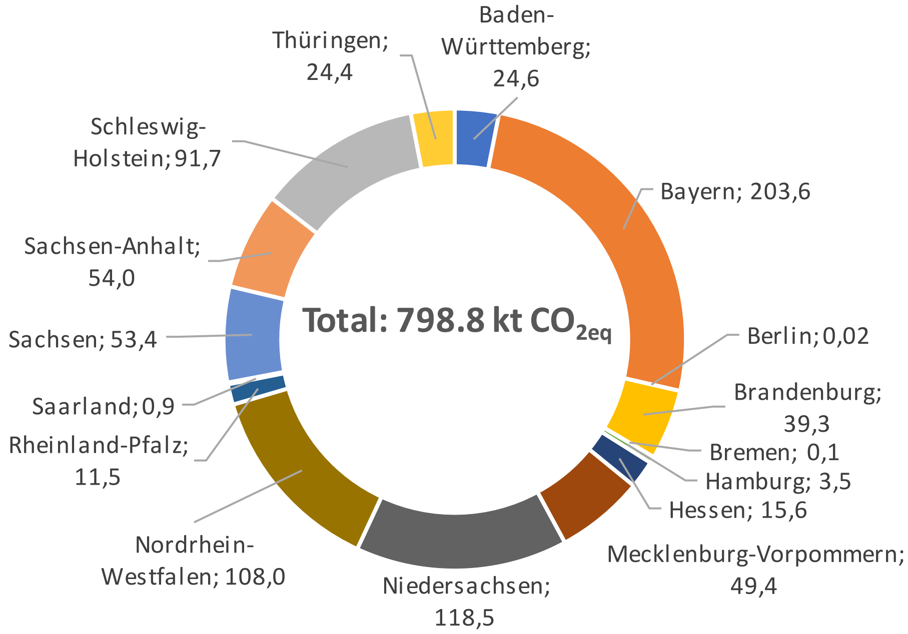

Figure 2: Greenhouse gas emission savings in the year 2019 attributable to photovoltaic installations supported by Rentenbank loans (kt = 1000 tonnes).

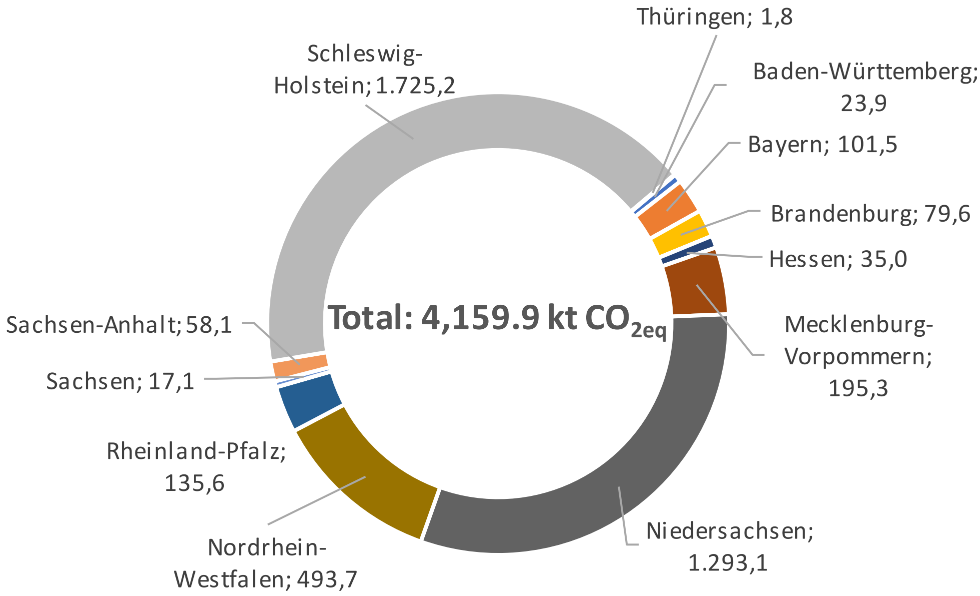

Figure 3: Greenhouse gas emission savings in the year 2019 attributable to wind energy installations supported by Rentenbank loans (kt = 1000 tonnes).

Table 2 and Table 3 present the results by federal state. It has to be borne in mind that the values are aggregated for 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 decline in specific investment cost, considerable variation can be observed between federal states according to different financing volumes over the course of time. High values result from early investment with higher specific costs. For wind energy installations the variation is comparably small as there was relatively little variation in specific costs.

Table 2: Loans for photovoltaic installations as of 31st Dec. 2019 and attributable effects in the year 2019 by German federal state.

	Loans		Average specific inv. cost	Attributable to loans as of 31st Dec. 2019			
	Count	Residual debt		Installed power	Electricity production	GHG emissions avoided	
		Million €	€/kW$_p$	MW$_p$	GWh	t CO_2	t CO_{2Eq}
Total	**21,558**	**-1,835.6**	**1,300**	**1,415.5**	**1,273.1**	**726,100**	**798,800**
Baden-Würt-temberg	880	-56.1	1,400	40.0	39.3	22,400	24,600
Bayern	5,561	-424.3	1,260	338.2	324.5	185,100	203,600
Berlin	1	-0.1	2,960	0.03	0.02	14	15
Brandenburg	138	-55.3	950	58.2	62.6	35,700	39,300
Bremen	6	-0.4	2,600	0.2	0.1	70	80
Hamburg	28	-7.8	920	8.5	5.7	3,200	3,500
Hessen	397	-36.0	1,240	29.1	24.9	14,200	15,600
Mecklenburg-Vorpommern	318	-93.3	1,040	89.5	78.8	44,900	49,400
Niedersach-sen	6,516	-355.6	1,540	231.5	188.9	107,700	118,500
Nordrhein-Westfalen	3,906	-262.5	1,300	202.5	172.2	98,200	108,000
Rheinland-Pfalz	527	-31.4	1,650	19.0	18.4	10,500	11,500
Saarland	12	-1.5	970	1.6	1.5	860	940
Sachsen	252	-88.3	1,040	85.0	85.2	48,600	53,400
Sachsen-An-halt	319	-90.3	1,030	87.8	86.1	49,100	54,000
Schleswig-Holstein	2,524	-285.3	1,560	182.6	146.1	83,300	91,700
Thüringen	173	-47.3	1,140	41.7	38.9	22,200	24,400

Totals may differ due to rounding.

Table 3: Loans for wind energy installations as of 31st Dec. 2019 and attributable effects in the year 2019 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	**2,780**	**-4,003.9**	**1,440**	**2,788.7**	**6,004.9**	**3,791,500**	**4,159,900**
Baden-Würt-temberg	9	-25.2	1,400	18.1	34.5	21,800	23,900
Bayern	221	-107.7	1,480	72.9	146.5	92,500	101,500
Brandenburg	21	-102.9	1,390	73.9	114.9	72,600	79,600
Hessen	19	-33.6	1,430	23.5	50.5	31,900	35,000
Mecklenburg-Vorpommern	71	-195.1	1,450	134.6	281.9	178,000	195,300
Niedersachsen	878	-1,283.3	1,420	903.4	1,866.6	1,178,600	1,293,100
Nordrhein-Westfalen	549	-506.8	1,440	352.5	712.6	449,900	493,700
Rheinland-Pfalz	29	-141.7	1,380	102.7	195.8	123,600	135,600
Sachsen	10	-18.6	1,370	13.5	24.6	15,500	17,100
Sachsen-An-halt	28	-65.0	1,440	45.1	83.9	53,000	58,100
Schleswig-Hol-stein	940	-1,522.0	1,450	1,047.1	2,490.4	1,572,400	1,725,200
Thüringen	5	-2.0	1,480	1.4	2.6	1,700	1,800

Totals may differ due to rounding.

Table 4 shows the comparison of the greenhouse gas emissions avoided per kWh of electricity production with the corresponding values calculated for the total 2019 electricity production from PV and wind onshore installations in Germany (see BMWi 2020). The values differ only little, the estimate for PV is about 2 % higher, the value for wind energy 2 % lower than the overall values. However, this agreement does not come as an undue surprise as the same calculation approach was used to derive GHG emission savings from the electricity production.

Table 4: GHG emissions avoided per kWh.

g CO_{2eq} / kWh	Rentenbank	BMWi (2020)	Relative Difference
Photovoltaic energy	627	614	-2.2 %
Wind energy onshore	693	706	1.8 %

To check the plausibility for the parts of the calculation which involve the highest uncertainty a further check is carried out. For this the amount of CO_{2eq} avoided per invested Euro is calculated and compared to the values that can be derived for the RE loan programmes for the year 2018 assessed in Bickel and Kelm (2019). Table 5 presents the results of the comparison. For wind energy there is good agreement between the values. In contrast, the value for PV is 23 % lower than the corresponding result for 2018. This however is due to the composition of the portfolio, which contains PV installations from 2008 to 2019 with high specific investment costs for the earlier years. The comparison with the value for the year 2012 (based on Bickel and Kelm 2013) confirms this correlation.

Table 5: GHG emissions avoided per €.

g CO_{2eq} / €	Rentenbank	Bickel and Kelm (2019, 2013)		Relative Difference	
year	2019	2018	2012	2018	2012
Photovoltaic energy	435	563	426	22.7 %	-2.2 %
Wind energy onshore	1,039	1,060	1,038	2.0 %	-0.1 %

4 Concluding remarks

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 greenhouse 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.

However, the missing technical information on the installations supported by the loans imply considerable uncertainties in the calculations. Therefore, the main and most important factor for improving the reliability of the estimates would be the provision of technical information on the facilities supported. In particular data on the electrical power installed would be essential. This would eliminate the uncertainty involved in the estimation of the electrical power based on specific investment costs.

A further important factor of uncertainty is the development of average full-load hours of wind energy installations by year of construction as described in section 2.4. Future estimates should include a more detailed analysis in this area.

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